NONRESIDENT
TRAINING
COURSE

Interior Communications Electrician, Volume 1

NAVEDTRA 14120

IMPORTANT

Any future change to this course can be found at https://www.advancement.cnet.navy.mil, under Products.

You should routinely check this web site.

PREFACE

About this course:

This is a self-study course. By studying this course, you can improve your professional/military knowledge, as well as prepare for the Navywide advancement-in-rate examination. It contains subject matter about day-to-day occupational knowledge and skill requirements and includes text, tables, and illustrations to help you understand the information. An additional important feature of this course is its reference to useful information in other publications. The well-prepared Sailor will take the time to look up the additional information.

Training series information:

This is Module * of a series. For a listing and description of the entire series, see NAVEDTRA 12061, *Catalog of Nonresident Training Courses*, at https://www.advancement.cnet.navy.mil.

History of the course:

- *Sep1994: Original edition released. Authored by ICCS Bert A. Parker.*
- *Oct 2003: Administrative update released. Technical content was reviewed by ICC(SW) Curtis Fox. No change in technical content.*

Published by
NAVAL EDUCATION AND TRAINING
PROFESSIONAL DEVELOPMENT
AND TECHNOLOGY CENTER
https://www.cnet.navy.mil/netpdtc

POINTS OF CONTACT	ADDRESS
• E-mail: fleetservices@cnet.navy.mil • Phone: Toll free: (877) 264-8583 Comm: (850) 452-1511/1181/1859 DSN: 922-1511/1181/1859 FAX: (850) 452-1370	COMMANDING OFFICER NETPDTC N331 6490 SAUFLEY FIELD ROAD PENSACOLA FL 32559-5000
Technical content assistance. Contact a Subject Matter Expert at https://www.advancement.cnet.navy.mil/welcome.asp, under Exam Info, Contact Your Exam Writer.	

NAVSUP Logistics Tracking Number
0504-LP-022-3750

TABLE OF CONTENTS

ASSIGNMENT QUESTIONS follow Index.

CREDITS

The trade name "MICRO SWITCH" is included in this edition through the courtesy of Honeywell, Inc., and is gratefully acknowledged.

CHAPTER 1

ELECTRICAL AND GENERAL SAFETY PRECAUTIONS

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

- *Describe the basic safety requirements for working with electricity.*
- *Identify various sources of information regarding safety.*
- *Identify various warning tags, signs, and plates.*
- *Explain the purpose for equipment tag-out procedures.*
- *Describe the safety procedures to follow when working on or with various tools, equipment, and machinery.*
- *Describe basic first-aid procedures to use on electrical shock victims.*
- *Describe the Navy's Hearing Conservation and Noise Abatement Programs.*
- *Describe the Navy's Heat Stress Control Program.*

INTRODUCTION

It is Navy policy to provide a safe and healthy work place for all personnel. These conditions can be ensured through an aggressive and comprehensive occupational safety and health program fully endorsed by the Secretary of the Navy and implemented through the appropriate chain of command.

The material discussed in this chapter stresses the importance of electrical and general safety precautions. All electrical equipment is hazardous; therefore, all safety precautions must be strictly observed. The primary goals of an effective safety program are to protect personnel and material and to ensure that unsafe equipment operations do not occur. As a petty officer, you have the responsibility to recognize unsafe conditions and to take appropriate actions to correct any discrepancies. You must always observe safety precautions when working on equipment or operating machinery. You should also know and be able to perform the proper action when a mishap occurs.

In the interest of making Navy personnel aware of the dangers confronting them in their workplace environment and to outline means for avoiding mishaps, a number of safety precautions that are likely to concern IC Electricians at one time or another are listed in this chapter. You need to exercise caution in these areas. This chapter will further give you some facts so you can teach safety accurately and effectively. Finally, it will give the approved methods of action so you will be able to rehearse your actions and thus be ready in the event of a casualty.

Remember: Mishaps seldom just happen; they are caused. Another point to remember is to never let familiarity breed contempt. Hundreds of people have been injured by mishaps and many have died from injuries. Most mishaps could have been prevented had the individuals involved heeded the appropriate safety precautions. Preventing mishaps that are avoidable is one of your highest priorities.

SAFETY RESPONSIBILITIES

All individuals have the responsibility to understand and observe safety standards and regulations that are established for the prevention of injury to themselves and other people and damage to property and equipment. As an individual, you have a responsibility to yourself and to your shipmates to do your part in preventing mishaps. As a petty officer, you have the responsibility of setting a good example; you cannot ignore safety regulations and expect others to follow them.

Personnel should always observe the following safety practices:

- Observe all posted operating instructions and safety precautions.
- Report any unsafe condition or any equipment or material deficiency you think might be unsafe.
- Warn others of hazards and the consequences of their failing to observe safety precautions.
- Wear or use approved protective clothing or protective equipment.
- Report any injury or evidence of impaired health that occurs during your work or duty to your supervisor.
- Exercise reasonable caution as appropriate to the situation in the event of an emergency or other unforseen hazardous condition.
- Inspect equipment and associated attachments for damage before using the equipment. Be sure the equipment is suited for the job.

Safety must always be practiced by people working around electrical circuits and equipment to prevent injury from electrical shock and from short circuits caused by accidentally placing or dropping a conductor of electricity across an energized line. The arc and fire started by these short circuits, even where the voltage is relatively low, may cause extensive damage to equipment and serious injury to personnel.

No work will be done on electrical circuits or equipment without permission from the proper authority and until all safety precautions are taken.

PROMOTING SAFETY

Promoting safety will require you to become safety conscious to the point that you automatically consider safety in every job or operation. Providing safety reminders and setting the example allows you to pass this safety consciousness on to other personnel.

ENFORCING SAFETY

Safety precautions must be enforced. It is your duty to take appropriate action any time you see someone disregarding a safety precaution. You should ensure that all jobs are done according to applicable safety precautions.

Doing a job the safe way in some cases may take a little longer or be a little more inconvenient; however, there is no doubt as to the importance of doing it this way.

SOURCES OF SAFETY INFORMATION

To be an effective petty officer and supervisor, you should become familiar with the types of safety programs implemented throughout the Navy. You should also be familiar with all safety directives and precautions concerning your division. Safety instructions vary from command to command. This makes it impossible to give you a complete listing of manuals and instructions with which you should be familiar. Besides studying the information on safety described in this chapter and throughout this training manual, you should read and have knowledge of the safety information in the following references:

- *Standard Organization and Regulations of the U. S. Navy,* OPNAVINST 3120.32B, chapter 7—Outlines the safety program and the safety organization.
- *Navy Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat,* OPNAVINST 5100.19B—Provides general shipboard safety precautions and specific occupational health program guidance.
- *Navy Occupational Safety and Health (NAVOSH) Program Manual,* OPNAVINST 5100.23C—Encompasses all safety disciplines, such as systems safety, aviation safety, weapons/explosives safety, off-duty safety (recreation, public, and traffic), and occupational safety and occupational health.
- *Naval Ships' Technical Manual (NSTM),* chapter 074, volume 1—Provides general welding safety precautions.

- *General EIMB Handbook,* NAVSEA SE000-00-EIM-100, chapter 3—Provides general safety precautions and policies for electronic maintenance personnel.

Personnel are also advised and informed on mishap prevention through the following periodicals:

Fathom magazine, the afloat safety review, is published bimonthly for the professional benefit of all hands by the Naval Safety Center. *Fathom* presents the most accurate information currently available on the subject of shipboard mishap prevention.

Ships' Safety Bulletin is published monthly by the Naval Safety Center. This bulletin contains articles on shipboard safety problems, trends, mishap briefs, and statistics.

Deckplate magazine is published bimonthly by the Naval Sea Systems Command. This magazine contains information on the design, construction, conversion, operation, maintenance, and repair of naval vessels and their equipment. It also contains articles on safety hazards and their prevention.

Flash, a monthly mishap prevention bulletin, provides a summary of research from selected reports of submarine hazards to assist in the prevention program. It is intended to give advance coverage of safety-related information while reducing individual reading time.

These publications, as well as notices and instructions distributed by cognizant bureaus, make excellent reference materials. When these publications are available, you should read them and incorporate them into your training program.

Other sources of safety information that you will be dealing with on a day-to-day basis in your work as an IC Electrician are manufacturers' technical manuals and PMS maintenance requirement cards (MRCs).

These are not all of the safety resources that are available to you. However, these sources give you a good starting point from which you can expand your knowledge of safety procedures. The *Naval Safety Supervisor,* NAVEDTRA 12971, is also a very good resource for strengthening your awareness of safety procedures.

WARNING SIGNS, PLATES, POSTERS, TAGS, LABELS, AND MARKINGS

Warning signs, plates, and suitable guards/markings should be provided to prevent personnel from coming into accidental contact with dangerous voltages; for warning personnel of the possible presence of explosive vapors and radio frequency (RF) radiation; for warning personnel working aloft of poisonous effects of stack gases; and for warning personnel of other dangers that may cause injury to them. Equipment installations should not be considered complete until appropriate warning signs have been posted in full view of operating and maintenance personnel.

WARNING SIGNS

Warning signs (red/white) and caution signs (yellow/black) should be located in an area where known hazardous conditions exist or may exist. Some of the areas that are hazardous are wet, oily, or electrical spaces.

DANGER—High Voltage and DANGER— Shock Hazard warning signs are required near the entrance areas of compartments and walk-in enclosures that have equipment with voltages in excess of 30 volts. Signs are to be posted at eye level or above in full and clear view of entering personnel. Signs should also be located on or near equipment that is particularly dangerous or equipment having exposed conductors.

DANGER—Shock Hazard signs are to be used where voltages are between 30 and 500 volts. Where voltages are in excess of 500 volts and where voltages both below and above 500 volts are present, only the danger high voltage warning sign (fig. 1-1) will be

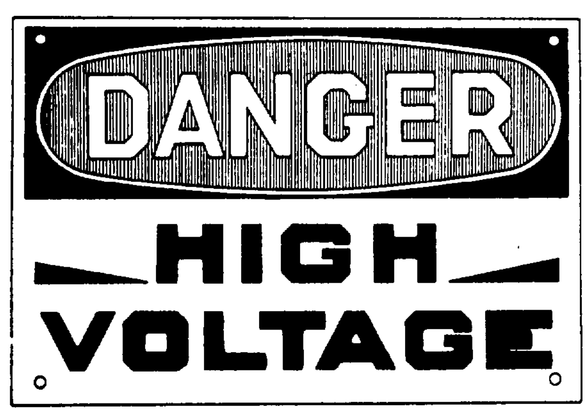


Figure 1-1.-High voltage warning sign.

used. Appropriate guards should also be installed at these locations.

Warning signs (fig. 1-2) are to be displayed at the bottom and top of all access ladders leading aloft to alert personnel working aloft of the presence of smoke pipe (stack) gases.

WARNING PLATES

Warning plates (fig. 1-3) for electronic equipment are installed in small craft to warn against the energizing of electronic equipment until ventilation blowers have been operating a minimum of 5 minutes to expel explosive vapors. This warning plate should also be displayed in all spaces where there is a possibility of the accumulation of explosive vapors.

SAFETY POSTERS

Safety posters (figs. 1-4, 1-5, and 1-6) are helpful both as safety reminders and in promoting safety. Safety posters should be changed or rotated regularly to different working areas to draw attention to them.

Figure 1-2.-Smoke pipe gases warning sign.

Figure 1-3.-Warning plate for electronic equipment installed in small crafts.

Posters put up and left in one area for months become part of the bulkhead and are ignored, written on, or covered with notices, schedules, or watch bills. The messages of these and other well-designed safety posters are clear and to the point. The left-hand poster of figure 1-6, for example, reminds personnel to think "safety"; the right-hand poster, to act promptly or suffer the consequences. Remember that the messages are aimed at YOU. It is your responsibility to "read and heed," and to remember your ABCs: Always Be Careful.

TAGS AND LABELS

Tags and labels are used in the Navy to identify a defective piece of equipment or instrument. Tags and labels are also used to ensure the safety of personnel and to prevent improper operation of equipment. They will be posted according to authorized procedures and must not be removed or violated without proper authorization and adequate knowledge of the consequences.

The use of tags and labels is not a substitute for other safety measures, such as locking valves or removing fuses from a fuse panel. Also, tags or labels associated with tag-out procedures must never be used for anything other than their intended purpose.

Remember, once a tag or label is used, it should only be removed by signed authorization of the authorizing officer. You should always follow your command's procedures for logging and recording tag-out actions.

MARKINGS

Markings consisting of paint or tape are used to designate safe traffic lanes, operator caution areas, operator working areas, and observer safe areas.

Safe traffic lanes are designated in workshops. These lanes start and stop at all exits and entrances for workshops and are marked by continuous white lines, 3 inches wide, painted on the deck.

Operator caution areas, operator working areas, and observer safe areas are designated for each equipment working area deemed hazardous. Operator caution areas are marked by a continuous yellow line, 3 inches wide outlining the caution area. Operator work areas are marked by painting the deck yellow in areas where it is safe for an operator of machinery or equipment. The outer perimeter of this area is designated by alternate black and yellow lines or

Figure 1-4.-Safety posters.

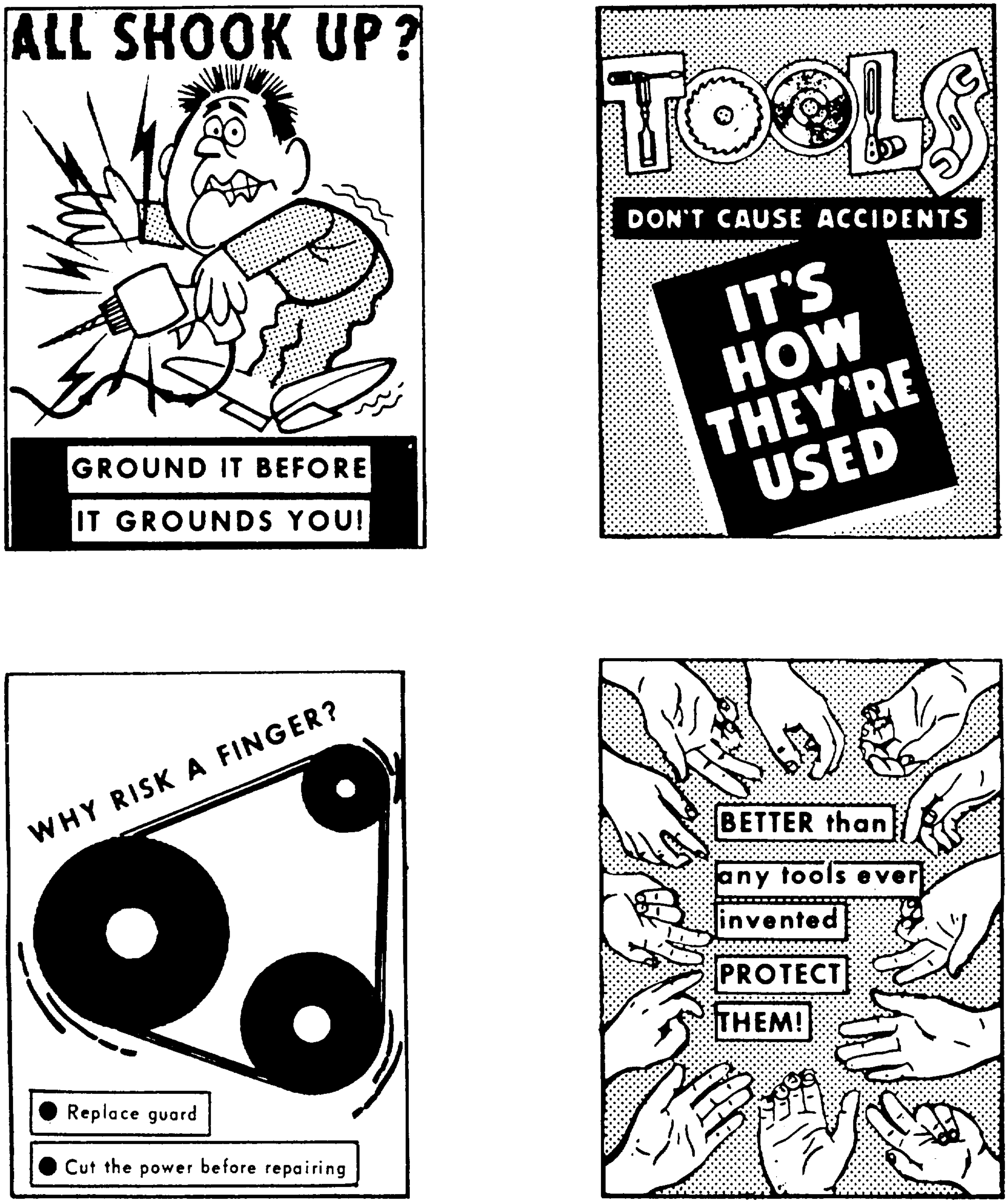


Figure 1-5.-Safety posters—Continued.

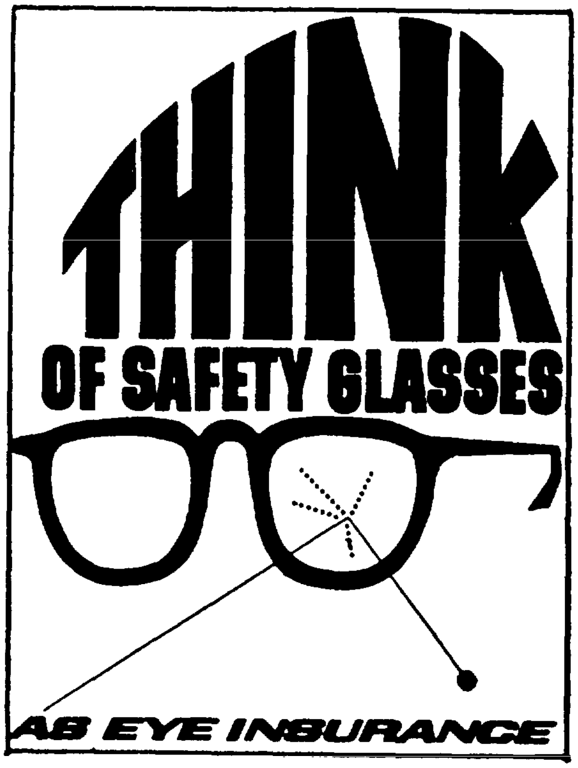


Figure 1-6.-Safety posters—Continued.

checkerboard pattern, 3 inches wide. Observer safe areas are designated as all areas outside of this perimeter and are the normal color of the deck within the space.

Eye hazardous areas are marked with a black and yellow checkerboard, or chevron, pattern and a label plate made up of black letters on a yellow background that reads: "CAUTION-EYE HAZARD."

EQUIPMENT TAG-OUT PROCEDURES

As an IC Electrician, you will be either directly or indirectly involved with tagging out equipment on a daily basis. The tag-out may be required to allow you to repair a piece of defective equipment, or it may be just to secure equipment to perform PMS maintenance requirements. A tag-out procedure is necessary in the Navy because of the complexity of modern ships and the cost, delays, and hazards to personnel that could result from improper operation of equipment. Tag-out procedures are mandatory and are governed by *Standard Organization and Regulations of the U.S. Navy,* OPNAVINST 3120.32, article 630.17.

TAGS

The purpose of using tags is to prevent the improper operation of a component, piece of equipment, system, or portion of a system when isolated or in an abnormal condition.

Equipment that you are intending to repair or perform PMS on must be de-energized and tagged out by use of a DANGER tag.

Caution Tag

A CAUTION tag, NAVSHIPS 9890/5 (fig. 1-7), is a yellow tag used as a precautionary measure to provide temporary special instructions or to indicate that unusual caution must be exercised to operate equipment. These instructions must state the specific reason that the tag is installed. Use of phrases such as DO NOT OPERATE WITHOUT EOOW PERMISSION is not appropriate since equipment or systems are not operated unless permission from the responsible supervisor has been obtained. A CAUTION tag cannot be used if personnel or equipment could be endangered while performing evolutions using normal operating procedures. A DANGER tag must be used in this case.

Danger Tag

The DANGER tag, NAVSHIPS 9890/8 (fig. 1-8), commonly called the red tag, is used to prevent the operation of equipment that could jeopardize the safety of personnel or endanger the equipment systems or components. When equipment is red tagged, under no circumstances will it be operated. When a major system is being repaired or when PMS is being performed by two or more repair groups, both parties will hang their own tags. This prevents one group from operating or testing circuits that could jeopardize the safety of personnel from the other group.

No work shall be done on energized or de-energized switchboards without approval of the commanding officer or in the CO's absence, the command duty officer. Various PM checks require additional approval from the engineer officer, and the electrical officer.

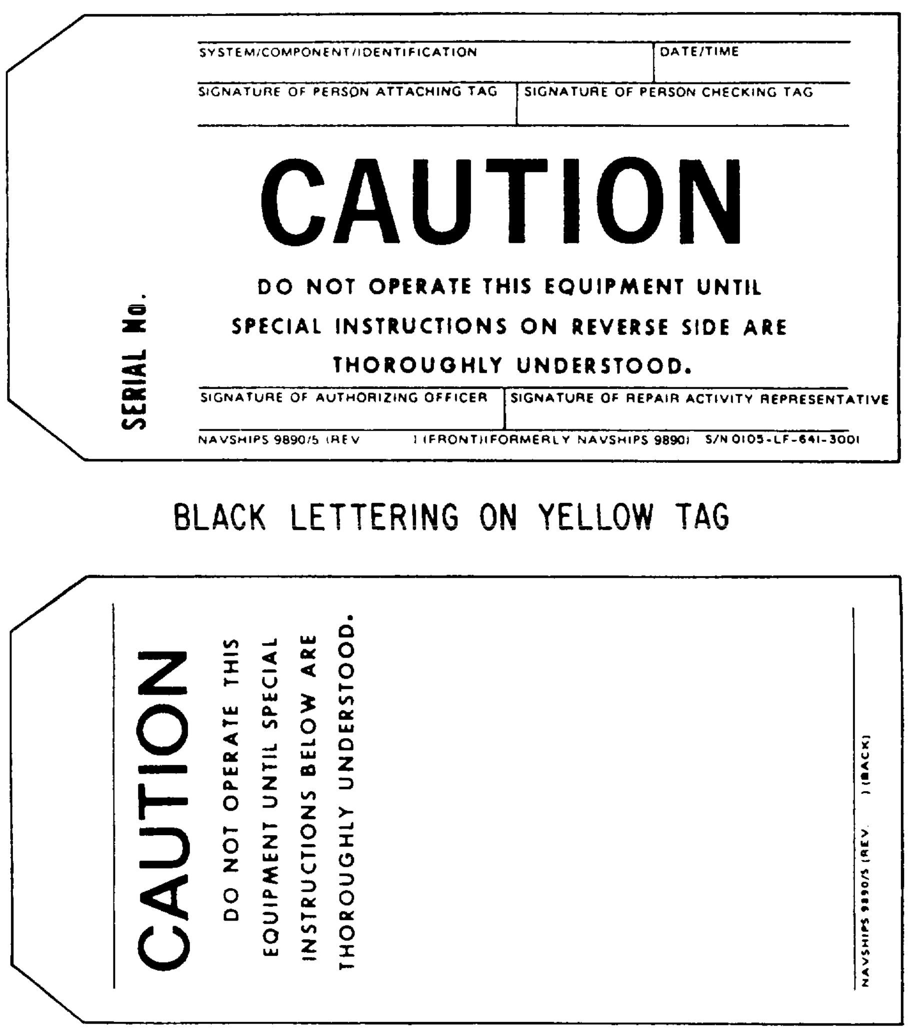


Figure 1-7.—CAUTION tag (colored YELLOW).

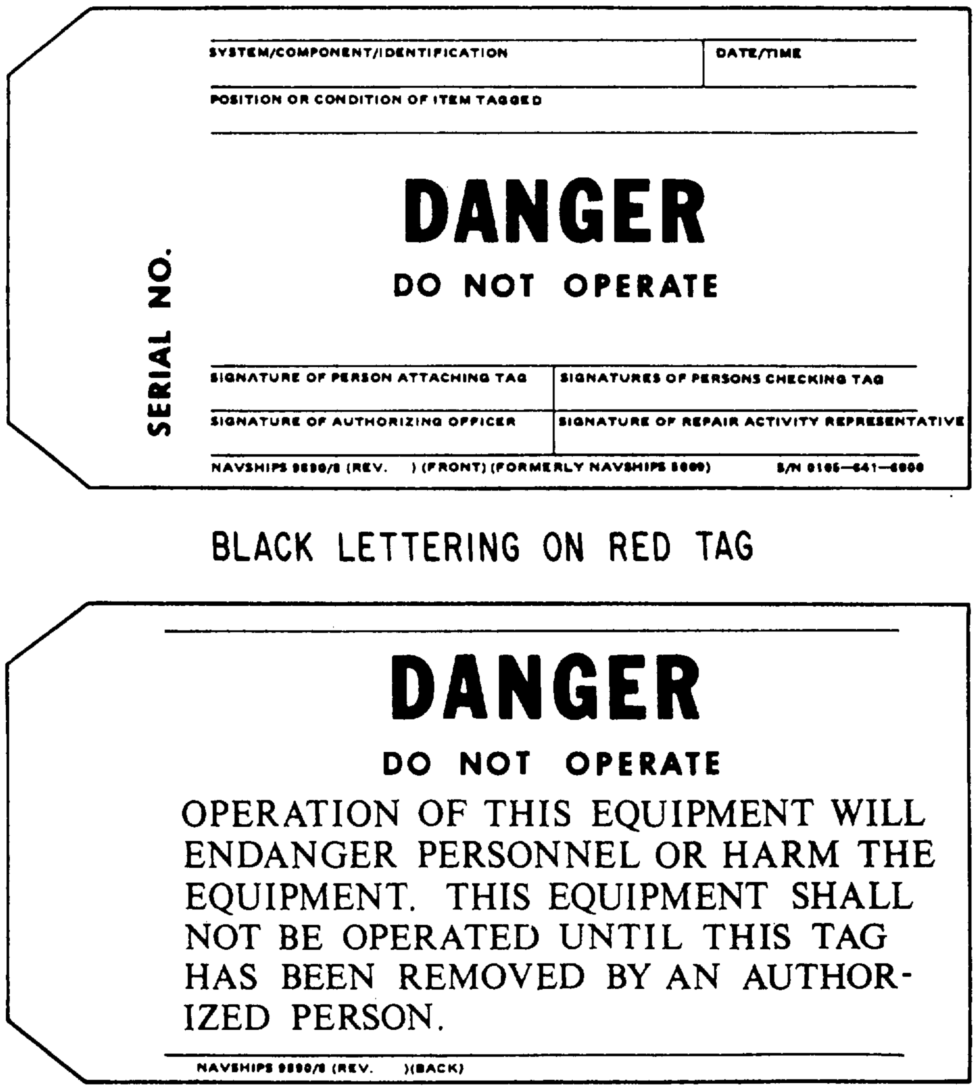


Figure 1-8.-DANGER tag (colored RED).

All supply switches or cutout switches from which power could be fed should be secured in the off or open (safety) position and red tagged. Circuit breakers should have a handle locking device installed as shown in figure 1-9. The proper use of red tags cannot be overstressed. When possible, double red tags should be used, such as tagging open the main power supply breaker and removing and tagging the removal of fuses of the same power supply.

LABELS

Labels are used to warn operating or maintenance personnel that an instrument is unreliable or is not in normal operating condition. There are two types of labels used on instruments, OUT-OF-CALIBRATION and OUT-OF-COMMISSION. The decision as to which label to use is made on a case-by-case basis.

Out of Calibration

OUT-OF-CALIBRATION labels (NAVSHIPS 9210/6) are orange labels (fig. 1-10) used to identify instruments that are out of calibration and will not give accurate measurements. In general, if the instrument error is small and consistent, an OUT-OF-CALIBRATION label may be used. This label indicates that the instrument may be used, but only with extreme caution.

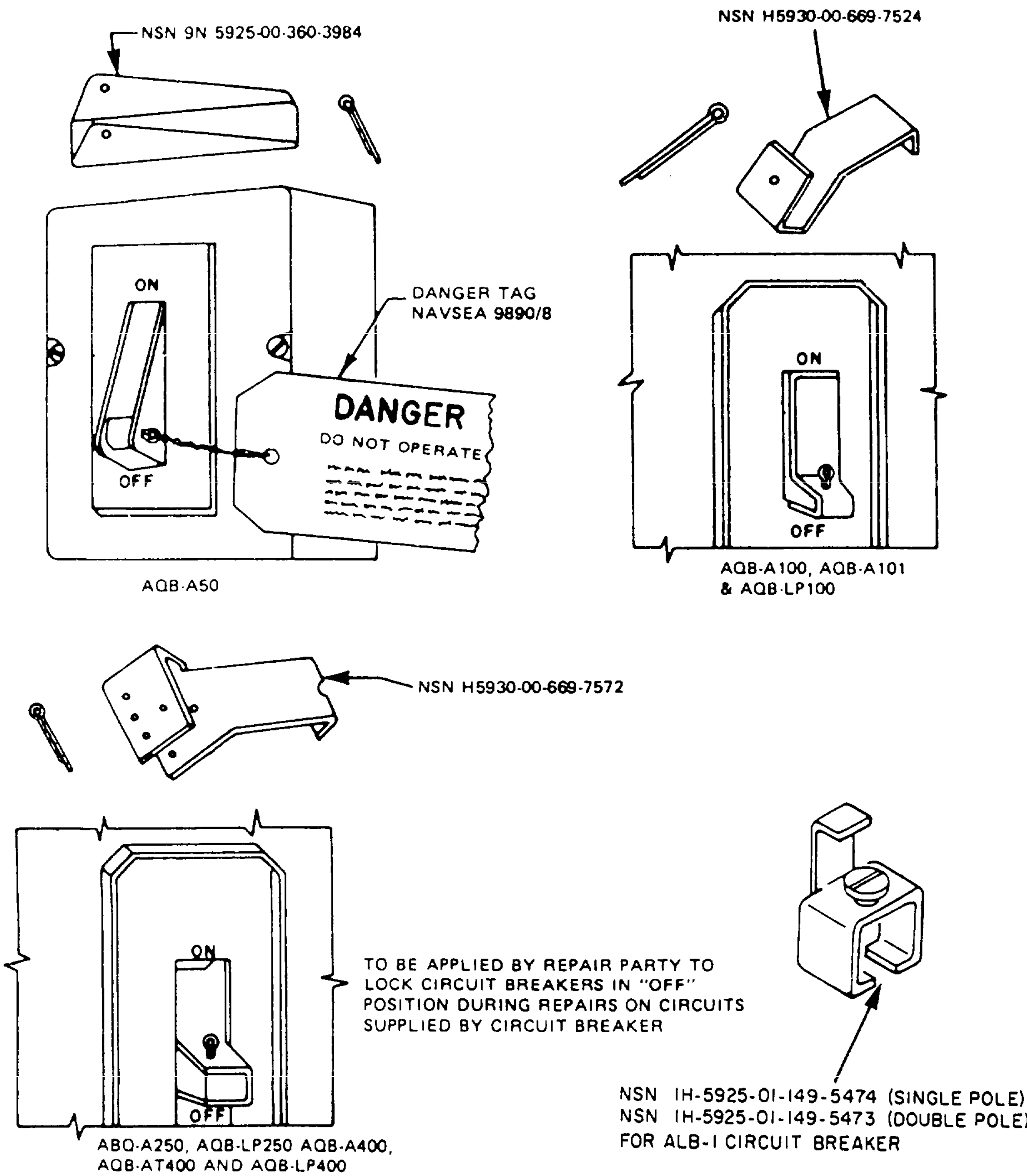


Figure 1-9.-Handle locking devices for circuit breakers.

Out of Commission

OUT-OF-COMMISSION labels (NAVSHIPS 9890/7) are red labels (fig. 1-11) used to identify instruments that will not indicate correct measurements because they are defective or isolated from the system. This label indicates that the instrument cannot be relied on and must be repaired and recalibrated or be reconnected to the system before it can be used properly.

SAFETY HAZARDS AND PRECAUTIONS

IC Electricians perform maintenance on equipment located throughout the ship. IC Electricians must be aware of the general and specific safety precautions involved in their work. The person who neglects to secure the power to the salinity system (circuit SB) when cleaning cells is as likely to be

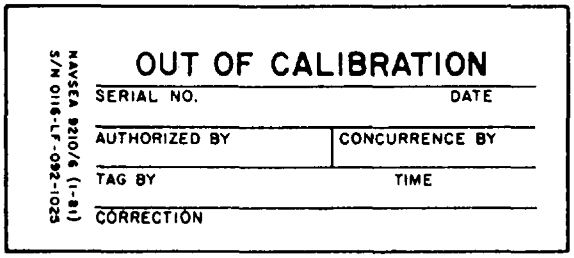


Figure 1-10.-Out-of-calibration label.

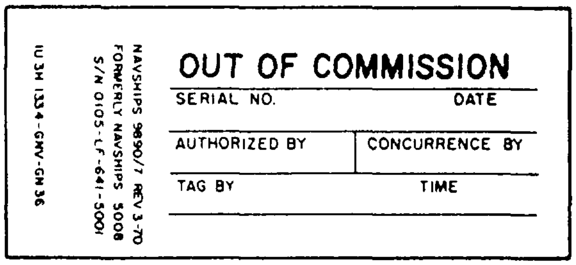


Figure 1-11.-Out-of-commission label.

injured or killed as the one who doesn't properly use a safety harness when going aloft to align the anemometer (circuits HD and HE).

CHECKING FOR ENERGIZED CIRCUITS

Be sure electrical equipment is de-energized before working on it. To check a de-energized circuit, first connect the leads of a test instrument (a voltmeter or a voltage tester) across the power source terminals of a known energized circuit to ensure that the test instrument is working properly. Then connect the leads of the test instrument across the power source terminals of the equipment under test to make sure it is de-energized. Recheck the test instrument on the known energized circuit to ensure that it is still working properly.

When checking to see whether circuits are de-energized, check metering and control circuits, as well as power circuits. In many cases, metering and control circuits are connected to the supply side of a circuit breaker or supplied from a separate source. A check of power circuits on the load side of a circuit breaker may show that they are dead after the circuit breaker is opened, but such a check gives no assurance that associated metering and control circuits are de-energized.

LIVE CIRCUITS

Safe practice in most electrical or electronic maintenance and repair work dictates that all power supplies must be de-energized. However, there are times when de-energizing the circuits is neither desirable nor possible, such as in an emergency (damage control) condition or when de-energizing one or more circuits would seriously affect the operation of vital equipment or jeopardize the safety of personnel.

No work may be done on energized circuits without the approval of the commanding officer. The only exceptions to this policy are in those cases in which approved instructions issued by higher authority permit opening or inspecting equipment in the course of performing preventive maintenance, routine testing, taking measurements, or making adjustments that require equipment to be energized. Testing for voltage with a voltage tester is not to be considered working on live circuits or equipment unless entry into energized panels is required.

When working on live or hot circuits, you must be supervised and aware of the danger involved. The precautions you must take to insulate yourself from ground and to ensure your safety include the following actions (these precautions do not apply to circuits and equipment with less than 30 volts):

- Provide insulating barriers between the work and the live metal parts.
- Provide ample lighting in the immediate area.
- Cover the surrounding grounded metal with a dry insulating material, such as wood, rubber matting, canvas, or phenolic. This material must be dry, free of holes and imbedded metal, and large enough to give you enough work room.
- Coat metallic hand tools with plastisol or cover them with two layers of rubber or vinyl plastic tape, half-lapped. Insulate the tool handle and other exposed parts as practical. Refer to *NSTM,* chapter 631, for instructions on the use of plastisol. If you do not have enough time to apply plastisol or tape, cover the tool handles and their exposed parts with cambric sleeving, synthetic resin flexible tubing, or suitable

insulation from scraps of electric cables; however, do this only in an emergency situation.

- Do not wear a wristwatch, rings, other metal objects, or loose clothing that could become caught in live circuits or metal parts.
- Wear dry shoes and clothing, and ALWAYS wear a face shield.
- Tighten the connections of removable test leads on portable meters. When checking live circuits, NEVER allow the adjacent end of an energized test lead to become unplugged from the meter.
- Be sure a person qualified to administer mouth-to-mouth ventilation and cardiac massage for electrical shock is in the immediate area.
- Be sure a person who is knowledgeable of the system is standing by to de-energize the equipment.
- Be sure a nonconducting safety line is tied around the worker's waist to pull the person free if he/she comes in contact with a live circuit.
- Where work permits, wear rubber gloves on both hands. If this is not possible, work with one hand and wear a rubber glove on the other hand.

LEAKAGE CURRENTS

The electrical distribution systems found on Navy ships are ungrounded. The reason for using an ungrounded system is to achieve maximum system reliability and continuity of electrical power under combat conditions. If one line of the distribution system is grounded, due to battle damage or deterioration of the system insulation resistance, the circuit protective devices (circuit breakers, fuses, and so on) will not de-energize the circuit having the ground, and electrical power will continue to be delivered to vital load equipment without further damage to the system.

Shipboard ungrounded electrical systems are capacitively grounded to the extent that lethal currents can flow through a person's body if a live conductor is touched while in contact with ship's ground. The capacitance that causes this electrical ground leakage current to flow is inherent in the design of equipment and cable, and cannot be eliminated by practical technical means.

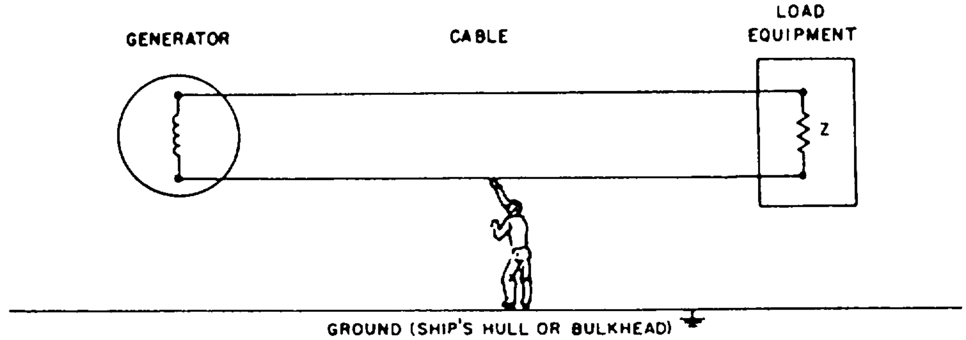
Many persons believe it is safe to touch one conductor since no electric current would flow. This is not true. It is NEVER safe to touch one conductor of the ungrounded shipboard system. This is because each conductor and the electrical equipment connected to the system have an effective capacitance to ground, which provides an electric current path between the conductors and the ship's hull. The higher the capacitance, the greater the current flow will be for your fixed body resistance. This situation occurs when one conductor of the ungrounded system is touched while your body is in contact with the ship's hull or other metal enclosures. When your body resistance is low due to wet or sweaty hands, for example, the inherent capacitance is sufficient to cause a FATAL electric current to pass through your body.

A perfect ungrounded system (fig. 1-12, view A) exists when the insulation is perfect on all cables, switchboards, circuit breakers, generators, and load equipment; no filter capacitors are connected between ground and the conductors; and none of the system equipment or cables have any inherent capacitance to ground. If all of these conditions were met, there would be no path for electrical current to flow from any of the system conductors to ground.

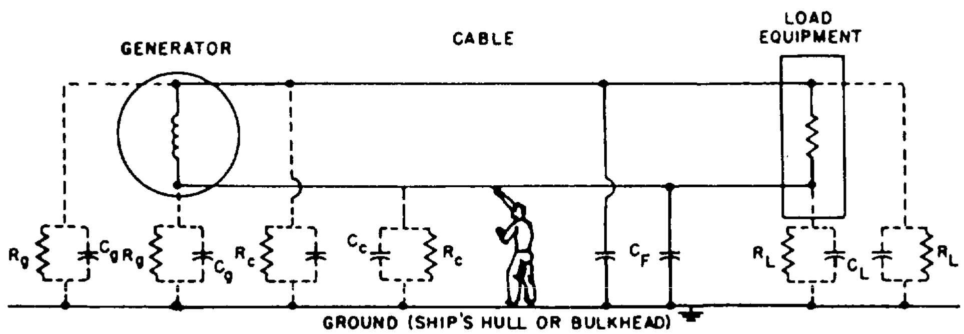
As shown in figure 1-12, view A, if a person touches a live conductor while standing on the deck, there would be no completed path for current to flow from the conductor through the person's body, and no electrical shock would occur. However, shipboard electrical power distribution systems DO NOT and CANNOT meet the above definition of a PERFECT ungrounded system.

In a shipboard real ungrounded system (fig. 1-12, view B) additional factors (resistances, R, and capacitances, C) must be considered, some of which are not visible.

The resistances, when combined in parallel, form the insulation resistance of the system, which is periodically measured with a 500-volt dc Megger. In figure 1-12, view B, there is a generator insulation resistance, an electric cable insulation resistance, and a load insulation resistance. The resistors cannot be seen as physical components, but are representative of small current paths through equipment and cable electrical insulation. The higher the resistance, the better the system is insulated; therefore, less current will flow between the conductor and ground.



A. CLOSED-CIRCUIT PERFECT UNGROUNDED SYSTEM.



B. CLOSED-CIRCUIT REAL UNGROUNDED SYSTEM.

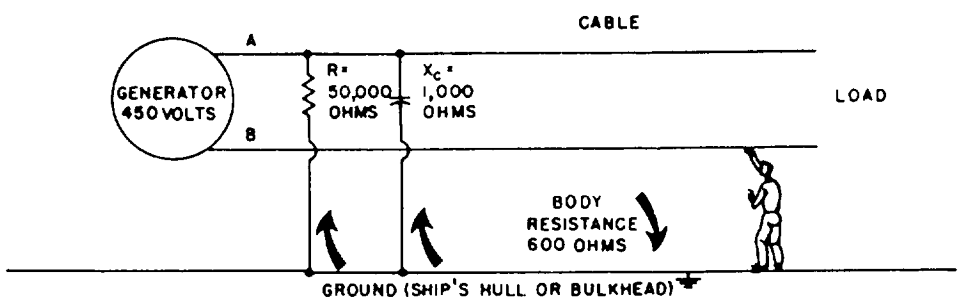


Figure 1-12.—DANGEROUS! BEWARE! Shipboard ungrounded electrical distribution systems are DEADLY.

Representative values of a large operating system can vary widely, depending on the size of the ship and the number of electrical circuits connected together.

Figure 1-12, view B, also shows the capacitance of the generator to ground, the capacitance of the distribution cable to ground, and the capacitance of the load equipment to ground. As stated before, these capacitances cannot be seen, since they are not actually physical components, but are inherent in the design of electrical equipment and cable.

The value of the capacitance generated between the conductor and ground is determined by the radius of the conductor, the distance between the conductor and the bulkhead, the dielectric constant of the material between the two, and the length of the cable. Similar capacitance exists between the generator winding and ground and between various load equipment and ground. Since capacitors ideally have an infinite impedance to direct current, their presence cannot be detected by a Megger or insulation resistance test. In addition to the nonvisible system capacitance, typical shipboard electrical systems contain radio frequency interference (RFI) filters that contain capacitors connected from the conductors to ground. These filters may be a part of the load equipment, or they maybe mounted separately. Filters are used to reduce interference to communications equipment.

If physical contact is made between cable B and ground (fig. 1-12, view C), current will flow from the generator through the person's body to ground and back through the system resistances and capacitances to cable A, thus completing the electrical circuit back to the generator. This presents a serious shock hazard. Suppose you check the system of figure 1-12, view C, for grounds with a Megger and get a reading of 50,000 ohms resistance. You can conclude that no low-resistance grounds exist. Don't assume that the system is a perfect ungrounded system without checking the circuit further. Do not forget the system capacitance that exists in parallel with the resistance.

It should be clear to you why you should NEVER touch a live conductor of an electrical system, grounded or ungrounded. Insulation resistance tests are made to ensure the system will operate properly, not to make the system safe. High insulation readings in a Megger test do not make the system safe—nothing does.

ISOLATED RECEPTACLE CIRCUITS

Isolated receptacle circuits are installed on all new construction ships. These receptacle circuits help reduce the inherent hazard of leakage currents where portable tools and appliances are plugged in and out, which is when personnel are more likely to get an electrical shock. These circuits are individually isolated from the main power distribution system by isolation transformers. Each circuit is limited to 1500 feet in length to reduce the capacitance to an acceptable level. This design is intended to limit ground leakage currents to 10 milliamperes, which would produce a nonlethal shock. To maintain a safe level of leakage currents, the isolated receptacle circuits must be free of all resistance grounds.

SHOCK-MOUNTED EQUIPMENT

Normally, on steel-hulled vessels, grounds are provided because the metal cases or frames of the equipment are in contact with one another and the vessel's hull. In some installations, grounds are not provided by the mounting arrangements, such as insulated shock mounts. In this case, a suitable ground connection must be provided.

CAUTION

Before disconnecting a ground strap on equipment supported by shock mounts, be sure the equipment is de-energized and a danger/red tag is installed.

When the grounding strap is broken and the equipment cannot be de-energized, use a voltmeter from the equipment to ground to ensure that no voltage is present.

Maintenance of grounding cables or straps consists of the following preventive procedures:

- Clean all strap-and-clamp connectors periodically to ensure that all direct metal-to-metal contacts are free from foreign matter.
- Replace any faulty, rusted, or otherwise unfit grounding straps, clamps, connections, or components between the equipment and the ship's hull.
- When replacing a grounding strap, clean the metallic contact surfaces and establish electrical continuity between the equipment and the ship's hull. Check continuity with an ohmmeter (the reading must be according to PMS).
- Recheck to be sure the connection is securely fastened with the correct mounting hardware.
- If a voltage is present, and the equipment cannot be de-energized, wear electrical rubber gloves and use a rubber mat while replacing the grounding strap.

SWITCHBOARDS, SWITCHGEARS, AND ENCLOSED EQUIPMENT

Switchboards and switchgears must have safety precautions, operating instructions, wiring diagrams, and artificial ventilation instructions posted in their vicinity. Switchboards, switchgears, and their access doors must also have DANGER HIGH VOLTAGE signs posted.

When removing or installing switchboard and control panel meters and instrument transformers, you must be extremely careful to avoid electrical shock to yourself and damage to the transformers and meters.

The secondary of a current transformer MUST be short-circuited before you disconnect the meter. An extremely high voltage buildup could be fatal to unwary maintenance personnel and it could damage the current transformer.

The primary of a potential transformer must be opened before you remove the meter to prevent damage to the primary circuit due to high circulating currents.

In most installations, potential transformer primaries are fused, and the transformer and associated meter cart be removed after you pull the fuses for the transformer concerned. When disconnecting the transformer and meter leads, you should avoid contact with nearby energized leads and terminals.

INTERLOCKS

Many modern electronic equipments are provided with various built-in safety devices, such as interlock switches, to prevent technical and maintenance personnel from coming into contact with electrical potentials in excess of 70 volts rms or dc. However, some of these protective devices are removed or destroyed by personnel who tamper with, block open, or otherwise "override" them. The foregoing practices must NOT be performed unless authorized by the commanding officer for operational reasons. Then the equipment must be properly tagged to notify personnel of this condition.

Interlocks and other safety devices must NOT be altered or disconnected, except for replacement, and must NOT be modified without specific authority from the cognizant systems command. Periodic tests and inspections must be made to ensure the devices are functioning properly.

SAFETY SHORTING PROBE

Before you start working on de-energized circuits that have capacitors installed, you must discharge them with a safety shorting probe. When using a safety shorting probe, first connect the test clip to a good ground to make contact. If necessary, scrape the paint off the metal surface. Then, hold the safety shorting probe by the handle and touch the probe end of the shorting rod to the points to be shorted. The probe end can be hooked over the part or terminal to provide for a constant connection to ground. Never touch any metal parts of the shorting probe while grounding circuits or components. It pays to be safe—use the safety shorting probe with care.

NOTE

Capacitors not electrically connected to the chassis ground must have their terminals shorted together to discharge than by the use of a shorting probe.

RUBBER GLOVES

There are four classes of rubber insulating gloves—class 0, class I, class II, and class III. The primary feature of each class is the wall thickness of the gloves and the maximum safe voltage. These features are identified by a color label on the glove sleeve. Only use rubber insulating gloves that are marked with a color label. Table 1-1 contains the

Table 1-1.—Rubber Gloves

CLASS	MAXIMUM SAFE VOLTAGE	LABEL COLOR
0	1,000 volts	Red
I	7,500 volts	White
II	17,000 volts	Yellow
III	26,500 volts	Green

maximum safe use voltage and label colors for insulating gloves approved for Navy use.

Before using rubber gloves, you should carefully inspect them for damage or deterioration. To inspect rubber gloves for tears, snags, punctures, or leaks that are not obvious, hold the glove downward, grasp the glove cuff, and flip the glove upward to trap air inside it. Roll or fold the cuff to seal the trapped air inside. Then, squeeze the inflated glove and inspect it for damage. For additional information on rubber gloves, refer to *NSTM,* chapter 300.

RUBBER FLOOR MATTING

You must use approved rubber floor matting in electrical and electronic spaces to eliminate electrical mishaps and afford maximum protection from electrical shock. Mishap investigations often show that the floors around electrical and electronic equipment had been covered with only general-purpose black rubber matting. The electrical characteristics of this type of matting do not provide adequate insulation to protect against electrical shock. There are various types of electrical grade mats or sheet coverings that conform to the requirements set forth in Military Specification (MILSPEC) MIL-M-15562.

To ensure the matting is completely safe, you must promptly remove from the matting surfaces all foreign substances that could contaminate or impair its dielectric properties. The dielectric properties of matting can be impaired or destroyed by oil, imbedded metal chips, cracks, holes, or other defects.

If the matting is defective for any reason, cover the affected area with a new piece of matting. Cementing the matting to the deck is not required, but is strongly recommended. This prevents removal of the mat for inspection and cleaning, which would leave the area unprotected. If the mat is not cemented, stencil an outline of the proposed mat on the deck. Inside the mat outline, stencil "ELECTRIC-GRADE MAT REQUIRED WITHIN MARKED LINES." Use 3/4 inch or larger letters.

Electrical insulating deck covering should be installed so there are no seams within 3 feet of an electrical hazard. Where this is not possible, thermoplastic deck coverings, such as vinyl sheet manufactured by Lonseal, Inc., should be fused chemically, heat welded, or heat fused with a special hot air gun. With rubber deck coverings, fusing with heat is not possible. A 3- or 4-inch wide strip of #51 Scotchrap 20-mil-thick polyvinyl chloride (PVC) tape (manufactured by Minnesota Mining and Manufacturing Company) should be installed beneath the seam. You may also use a 1-foot wide strip of electrical grade deck covering under rubber- or vinyl-type coverings instead of heat welding vinyl.

PORTABLE ELECTRIC-POWERED TOOLS

Safety is a very important factor in the use of portable power tools and cannot be overemphasized. The hazards associated with the use of portable power tools are electric shock, cuts, flying particles, explosions, and so on. You should ensure portable electric-powered tools are clean, properly oiled, and in good operating condition. Before you use any portable electrical equipment, you should visually examine the attached cable with plug (including extension cords, when used) to ensure it is in satisfactory condition. Replace promptly any cable that has tears, chafing, or exposed conductors, and any damaged plug. Use an approved tool tester or multimeter to test portable electrical equipment with its associated extension cord connected. When using the multimeter to check continuity of the ground conductor from the tool case to the dummy receptacle, be sure the meter reading is less than 1 ohm. With the multimeter still connected between the tool case and ground, bend or flex the cable to see if the meter resistance remains 1 ohm or less. If the resistance varies, you might have broken conductors in the cord or loose connections.

Other safe practices in the use of portable electric-powered tools include the following:

- Before you use a tool, inspect the tool cord and plug. Do not use the tool if the cord is frayed or its plug is damaged or broken. Never use spliced cables, except in an emergency.

- Before you use a tool, arrange the portable cables so you and others will not trip over them. The length of extension cords used with portable tools should not exceed 25 feet. Extension cords of 100 feet are authorized on flight and hangar decks. Extension cords of 100 feet are also found in damage control lockers, but are labeled FOR EMERGENCY USE ONLY.

- Do not use jury-rigged extension cords that have metal handy boxes on the receptacle ends of the cord. All extension cords must have nonconductive plugs and receptacle housings.

- When an extension cord is used with a portable electric tool, ALWAYS plug the tool into the extension cord before you insert the extension cord plug into a live receptacle.
- After using the tool, first unplug the extension cord from the live receptacle before you unplug the tool cord from the extension cord. Do not unplug the cords by yanking on them. ALWAYS remove the plug by grasping the plug body.
- When you use portable electric tools, always wear rubber gloves and eye protection.
- When defects are noted, return the tool to the ship's tool issue room (TIR).
- When tools produce hazardous noise levels, be sure personnel are wearing hearing protection.
- Never operate any portable power tools unless you are completely familiar with their controls and features.
- Make sure there is plenty of light in the work area. Never work with power tools in dark areas where you cannot see clearly.
- Before connecting power tools to a power source, be sure the tool switch is in the OFF position.
- When operating a power tool, give it your full and undivided attention.
- Do not distract or in any way disturb another person while they are operating a power tool.
- Never try to clear a jammed power tool until it is disconnected from the power source.
- After using a power tool, turn off the power, disconnect the power source, wait for all movement of the tool to stop, and then remove all waste and scraps from the work area. Store the tool in its proper place.
- Never plug the power cord of a portable electric tool into a power source before making sure that the source has the correct voltage and type of current called for on the nameplate of the tool.
- Do not allow power cords to come in contact with sharp objects (including watertight door knife edges), nor should they kink or come in contact with oil, grease, hot surfaces, or chemicals.
- Never use a damaged cord. Replace it immediately.
- Check electrical cables and cords frequently for overheating. Use only approved extension cords, if needed.
- See that all cables and cords are positioned carefully so they do not become tripping hazards.
- Treat electricity with respect. If water is present in the area of electrical tool operation, be extremely cautious and, if necessary, disconnect the power tool.

It is further suggested that, at the discretion of the commanding officer, a list be established of portable equipment requiring testing more or less often than once a month, depending on conditions in the ship. Where PMS is installed, tests should be conducted following the MRCs.

ELECTRIC SOLDERING IRONS

When using and handling an electric soldering iron, you can avoid burns or electrical shock by taking the following precautions:

- Grasp and hold the iron by its handle. Always assume a soldering iron is hot, whether it is plugged in or not. NEVER use an iron that has a frayed cord or damaged plug, or is missing a safety inspection tag.
- Hold small soldering workplaces with pliers or a suitable clamping device. NEVER hold the work in your hand.
- Always place the heated iron in its stand or on a metal surface to prevent fires or equipment damage.
- Clean the iron by wiping it across a piece of canvas placed on a suitable surface. DO NOT hold the cloth in your hand. DO NOT swing the iron to remove excess hot solder, as it could cause a fire in combustible materials or burn other personnel in the area.
- Before soldering electrical or electronic equipment, be sure it is disconnected from its power supply.

- After soldering, disconnect the iron from its power supply and let it cool before you store it.

TEST EQUIPMENT

Test equipment is precision equipment that must be handled with care if it is to perform its designed functions accurately.

Some hazards to avoid when using test equipment include rough handling, moisture, and dust. Bumping or dropping a test instrument may distort the calibration of the meter or short-circuit the elements of an electron tube within the instrument.

Moisture effects are minimized in some types of electronic test equipment, such as signal generators and oscilloscopes, by built-in heaters. These heaters should be operated for several minutes before high voltage is applied to the equipment.

Meters are the most delicate parts of test equipment. You should protect a meter by ensuring that the amplitude of the input signal being tested is within the range of the meter.

Since the moving coils of the meter in electronic test equipment are of the limited-current type, they can be permanently damaged by excessive current. To avoid such an occurence, you should observe the following safety precautions and procedures when using test equipment:

- Never place a meter near a strong magnetic field.
- Whenever possible, make the connections when the circuit is de-energized.
- When connecting an ammeter or the current coil of a wattmeter or other current-measuring device, always connect the coils in series with the load—NEVER ACROSS THE LINE.
- When voltmeters are used, they should always be connected in parallel with the line.
- Extend wires attached to an instrument over the back of the workbench or worktable on which the instrument is placed and away from observers—never over the front of the workbench.
- Place a mat or folded cloth under the test instrument when it is used in high-vibration areas.
- Remember that interlocks are not always provided and that they do not always work. Removal of the case or rear cover of an instrument not equipped with an interlock will allow access to circuits carrying voltages dangerous to human life.
- Do not change tubes or make adjustments inside equipment with the high-voltage supply energized.
- Under certain conditions, dangerous potentials may exist in circuits. With the power controls in the OFF position, capacitors can still retain their charge. Therefore, to avoid electrical shock, always de-energize the circuit, discharge the capacitors, and ground the circuit before working on it.
- Only authorized maintenance personnel with proper approval should be permitted to gain access to enclosures, connect test equipment, or test energized circuits or equipment.
- Circuits should be de-energized and checked for continuity or resistance, rather than energized and checked for voltage at various points.
- When a circuit or a piece of equipment is energized, NEVER service, adjust, or work on it without the assistance of another person.

HAND TOOLS

As an IC Electrician, you will be working with various hand tools on a daily basis. For your safety, you should take certain precautions when working with hand tools.

Keep your tools in good condition, and never use damaged tools. Tools having plastic or wooden handles that are cracked, chipped, splintered, or broken may result in injuries to personnel from cuts, bruises, particles striking the eye, and the like.

Use each tool only for the job for which it was designed. Be careful to avoid placing tools where they could fall into mechanical or electrical equipment.

Metallic tools used for working on electrical or electronic equipment must be covered with an electrical insulating material. The tools must be coated with platisol or covered with tape, If tape is used, two layers of rubber or vinyl plastic tape, half-lapped, is required. Cover the handle and as much of the shaft of the tool as practical.

For more information on hand tools refer to *Use and Care of Hand Tools and Measuring Tools,* NAVEDTRA 12085.

BATTERIES

Lead-acid storage batteries are used as an emergency power source for IC systems, such as gyrocompasses and automatic telephone exchanges. Alkaline storage batteries are used in bus failure alarms and dry-cell batteries are used in various pieces of test equipment. You must be careful when you use and maintain batteries, because of the electrical and chemical hazards involved. Chemical hazards include both the possibility of explosion and handling of hazardous chemicals. As an IC Electrician, you will care for and maintain these batteries. *NSTM,* chapter 313, gives extensive coverage of battery care, tests, and safety precautions.

Lead-Acid Storage Batteries

Lead-acid storage batteries are rechargeable and, when cared for properly, will last for 4 or more years, depending upon type and use. When a lead-acid storage battery is not fit for further use, it must be surveyed and disposed of according to *NSTM,* chapter 593. The safety precautions for lead-acid storage batteries are as follows:

- Keep flames and sparks of all kinds away from the vicinity of storage batteries. A battery on charge always gives off a certain amount of hydrogen gas, which is extremely explosive.
- Be sure battery compartments that have been sealed are well ventilated before entering the compartment, turning on any lights, making or breaking any electrical connections, or doing any work in the compartment.
- You must ensure that the battery compartment ventilation system is operating properly before starting to charge batteries.
- Stop the charge if ventilation is interrupted, except in an emergency, and do not resume the charge until ventilation has been restored.
- Charge a battery at the rate given on its nameplate.
- Never charge a battery at a higher finishing rate than that given on its nameplate.
- When charging more than one battery at a time, make sure that the voltage of the charging line exceeds the total voltage of the batteries being charged and that the charging rate, in amperes, does not exceed the maximum charging rate of the battery having the lowest ampere-hour capacity in the line.
- Lower the charging rate as soon as the battery begins to gas or the temperature of the battery reaches 125°F (52°C). If the battery is not allowed to cool off, it will be permanently damaged.
- Keep the temperature of the battery compartment below 96°F (36°C).
- Make no repairs to battery connections when current is flowing. Never connect or disconnect batteries on the charging line without first turning off the charging current; death or severe injury could result.
- When using tools around a battery, be careful not to short-circuit the battery terminals.
- Always pour acid slowly into water, and never water into acid. Guard skin and eyes against splashes of acid. Wear a rubber apron, rubber boots, rubber gloves, chemical splashproof goggles, and a full-face shield.
- Exercise proper care when handling acid.
- Do not add acid of greater specific gravity than 1.350 to a battery.
- Do not store sulphuric acid in places where freezing temperatures are possible.
- Keep the electrolyte level above the tops of separators.
- Add only pure distilled water to a battery.
- Do not, except in an emergency, discharge the battery below the given low-voltage limit.
- Never allow a battery to stand in a completely discharged condition for more than 24 hours.
- Do not operate the battery above 125°F (52°C).
- Avoid all sparks when removing or replacing batteries located in compartments that may contain gasoline vapors. Only tools with insulated handles should be used. Where batteries are used with one terminal grounded,

the grounded terminal of the battery should be disconnected first when removing the battery and connected last when replacing the battery.

- Never allow salt water to enter a battery cell, as chlorine gas, which is extremely toxic, will be generated. Also, salt water should never be used to wash out battery cases and jars.

- Make sure all terminal connections are tight to prevent sparks due to loose connections.

NSTM, chapter 313, also states that you should wear fire-retardant engineering coveralls to provide flash and fire protection when working with and around fire and explosive hazards created by batteries.

Alkaline Storage Batteries

Alkaline storage batteries are also rechargeable. They use potassium hydroxide for the electrolyte as opposed to sulfuric acid used in lead-acid storage batteries. Defective or unserviceable alkaline storage batteries should not be thrown overboard, as they are considered to be potential pollutants. Disposal methods are contained in OPNAVINST 5100.19B, chapter B3, and *NSTM,* chapter 593.

Use the same safety precautions for alkaline storage batteries that you do for lead-acid storage batteries.

Dry-Cell Batteries

Dry-cell batteries cannot be recharged after they are discharged. When these batteries are no longer usable, you simply replace them with new batteries. Do not throw the old batteries overboard, as they are also considered a potential pollutant. Disposal of dry-cell batteries should also be according to OPNAVINST 5100.19B, chapter B3, and *NSTM,* chapter 593. The safety precautions for dry-cell batteries are as follows:

- Dry-cell batteries should not be shipped or stored in the equipment with which they are to be used. They may become discharged, generating water in the cells, and the electrolyte may leak out and damage the equipment.

- When equipment operated by dry-cell batteries is to remain idle for more than 2 weeks, the batteries should be removed and then either scrapped or stored.

- When the batteries in a piece of equipment are no longer capable of operating it, they should be removed immediately to avoid damage to the equipment from electrolyte leakage.

- Never short-circuit the connections of a dry-cell battery as some types of dry-cell batteries will explode when shorted out.

RADIOACTIVE ELECTRON TUBES

Electron tubes containing radioactive material are now commonly used. Some of these tubes contain radioactive material that has intensity levels that are dangerous; they are so marked according to MILSPECs. The majority of these tubes contain radioactive cobalt (Co-60), radium (Ra-226), or carbon (C-14); several contain nickel (Ni-63); and a few contain cesium barium (CsBa-137).

No great hazard exists as long as the electron tube containing radioactive material remains intact. However, a potential hazard exists if the electron tube is broken and the radioactive material escapes. Normally, the concentration of radioactivity in a normal collection of electron tubes at a maintenance shop does not approach a dangerous level, and the dangers of injury from exposure are slight. However, at major supply points, the storage of large quantities of radioactive electron tubes in a relatively small area may create a hazard.

Be sure you are aware of your command's policy concerning decontamination procedures before working on equipment containing radioactive tubes. Some important instructions and precautions for the proper handling of radioactive tubes are as follows:

1. Radioactive tubes should not be removed from cartons until immediately before actual installation.

2. When a tube containing a radioactive material is removed from equipment, it should be placed immediately in an appropriate carton to prevent possible breakage.

3. A radioactive tube should never be carried in a manner in which breakage can occur.

4. If breakage does occur during handling or removing of a radioactive electron tube, notify the proper authority and obtain the services of qualified radiological controls personnel immediately.

5. Isolate the immediate area of exposure to protect other personnel from possible contamination and exposure.

6. Follow the established procedures set forth in the *Radiation, Health, and Protection Manual,* NAVMED P-5055.

7. Do not permit contaminated material to come in contact with any part of a person's body.

8. Take care to avoid breathing any vapor or dust that may be released by tube breakage.

9. Wear rubber or plastic gloves at all times during cleanup and decontamination procedures.

10. Use forceps for the removal of large fragments of a broken radioactive tube. The remaining small particles can be removed with a vacuum cleaner, using an approved disposal collection bag. If a vacuum cleaner is not available, use a wet cloth to wipe the affected area. In this case, be sure to make one stroke at a time. DO NOT use a back-and-forth motion. After each stroke, fold the cloth in half, always holding one clean side and using the other for the new stroke. Dispose of the cloth in the manner stated in item 14.

11. No food or drink should be brought into the contaminated area or near any radioactive material.

12. Immediately after leaving a contaminated area, personnel who have handled radioactive material in any way should remove any clothing found to be contaminated. They should also thoroughly wash their hands and arms with soap and water, and rinse them with clean water.

13. Notify a medical officer immediately if a wound is sustained from a sharp radioactive object. If a medical officer cannot reach the scene immediately, mild bleeding should be stimulated by pressure about the wound and by the use of suction bulbs. DO NOT USE THE MOUTH if the wound is of the puncture type. If the opening is small, make an incision to promote free bleeding and to facilitate cleaning and flushing of the wound.

14. When cleaning a contaminated area, all debris, cleaning cloths, and collection bags should be sealed in a container, such as a plastic bag, heavy wax paper, or glass jar, and placed in a steel can until disposed of according to existing instructions.

15. Decontaminate by use of soap and water all tools and implements used to remove a radioactive substance. Monitor the tools and implements for radiation with an authorized radiac set to ensure that they are not contaminated.

As you can see, the cleanup that results from breaking a radioactive tube is a long and complicated procedure. You can avoid this by simply ensuring that you <u>don't break the tube</u>.

CATHODE-RAY TUBES

Cathode-ray tubes (CRTs) should always be handled with extreme caution. The glass encloses a high vacuum and, because of its large surface area, it is subject to considerable force caused by atmospheric pressure. The total force on the surface of a 10-inch CRT may exceed 4,000 pounds, with over 1,000 pounds exerted on its face alone.

The chemical phosphor coating of the CRT internal face is extremely toxic. When disposing of a broken tube, be careful not to come in contact with this compound. Certain hazardous materials may be released if the glass envelope of a CRT is broken. If contact is made, seek medical aid immediately.

When handling a CRT, you should take the following precautions:

1. Avoid scratching or striking the surface of a CRT, particularly the rim.

2. Do not use excessive force when removing or replacing a CRT in its deflection yoke or its socket.

3. Do not try to remove an electromagnetic type of CRT from its yoke until the high voltage has been discharged from its anode connector (hole).

4. Never hold a CRT by its neck.

5. Always set a CRT with its face down on a thick piece of felt, rubber, or smooth cloth.

6. Always handle a CRT gently. Rough handling or a sharp blow on the service bench can displace the electrodes within the tube, causing faulty operation.

7. Safety glasses or goggles and protective gloves should always be worn when you are handling a CRT.

One additional procedure you should be aware of is the proper method of disposal of a CRT. When a CRT is replaced, the old CRT cannot be simply thrown over the side of the ship or placed in the nearest dumpster. When thrown over the side of a ship, a CRT will float; if it washes ashore, it is dangerous to persons who may come in contact with it. A CRT thrown in a dumpster represents a hidden booby trap. Therefore, always render the CRT harmless before disposing of it. Use the following simple procedure to render the CRT harmless:

- Place the CRT that is to be discarded face down in an empty carton and cover its side and back with protective material.
- Carefully break off the plastic locating pin from the base (fig. 1-13). This can be done by crushing the locating pin with a pair of pliers.
- Carefully break off the tip of the glass vacuum seal. This can be done with a small screwdriver or probe.

AEROSOL DISPENSERS

By deviating or ignoring procedures prescribed for selecting, applying, storing, or disposing of aerosol dispensers, personnel have been poisoned, burned, or have suffered other physical injury. It is difficult to compile a list of specific precautions and safe practices for handling aerosol dispensers due to the variety of industrial sprays that are available in this kind of container. However, users of aerosol dispensers can guard against poisoning, fire, explosion, pressure, and other hazards by regarding all aerosols as flammable. You can prevent an injury or hazard by following basic rules:

Poisoning—Adequately ventilate closed spaces where poisonous (toxic) substances are sprayed. Use exhaust fans or portable blowers to supply these spaces with fresh outside air. Where ventilation is inadequate, do not spray unless you wear an air respirator or a self-contained breathing apparatus.

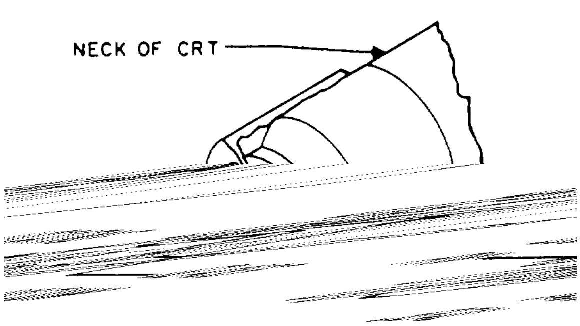


Figure 1-13.—Cathode-ray tube base structure.

Burns—Avoid spraying your hands, arms, face, or other exposed parts of the body. Some liquid sprays are strong enough to burn the skin, while milder sprays may cause rashes.

Fire—Keep aerosol dispensers away from direct sunlight, heaters, and other sources of heat. Do not store dispensers in an area where the temperature can exceed the limit printed on the container. Do not spray volatile substances on warm or energized equipment.

Explosion—Do not puncture an aerosol dispenser, Discard used dispensers in approved waste receptacles that will not be emptied into an incinerator.

CLEANING SOLVENTS

Exposure to chemical/solvent hazards may cause significant health problems. Solvents are capable of damaging your respiratory system in cases of prolonged inhalation. Chemicals and solvents come in the form of gas, vapor, mist, dust, or fumes. Materials ordinarily thought to be safe may be rendered hazardous under certain use conditions by the uninformed user.

Cleaning electrical and electronic equipment with water-based and nonvolatile solvents is an approved practice. These solvents do not vaporize readily. When it is not possible to clean with a water-based solvent, use inhibited methyl chloroform (1,1,1—trichloroethane). Methyl chloroform is a relatively safe effective cleaner when it is used in an adequately ventilated area. However, it should not be inhaled, and it should not be used on warm or hot equipment.

WARNING

Do NOT wear a gas mask when cleaning with methyl chloroform; its vapors displace oxygen in the air.

NEVER USE CARBON TETRACHLORIDE AS A CLEANING AGENT. It is a highly toxic (poisonous) compound that is a suspected carcinogen. Its threshold is 20 times lower than that of methyl chloroform, making it more dangerous. (Threshold is the point above which the concentration of vapor in the air becomes dangerous.)

NEVER clean with VOLATILE substances, such as gasoline, benzene, alcohol, or ether. Besides being fire hazards, they readily give off vapors that can injure the human respirator system if they are inhaled directly for a long time.

When using cleaning solvents in a nonventilated compartment, always supply air into the compartment, using a blower with a canvas wind chute (elephant trunk). Open all usable portholes, and place wind scoops in them. Keep a fire extinguisher (CO_2) close by, and NEVER WORK ALONE in a poorly ventilated compartment.

You should avoid coming in contact with cleaning solvents. Always wear gloves and chemical splashproof goggles, especially when you spray equipment. When spraying, hold the nozzle close to the equipment. DO NOT spray cleaning solvents on electrical windings or insulation.

Do not breathe directly over the vapor of any cleaning solvent for prolonged periods. Do not apply solvents to warm or hot equipment; this increases the toxicity hazard.

Following is a list of other safety precautions that you should observe when using and handling chemicals/solvents:

—Review the Material Safety Data Sheet (MSDS) for any chemical before using or handling it.

—Do not work alone in a poorly ventilated space.

—Never use a halocarbon-based solvent, such as freon, in the presence of any open flame.

—Place a fire extinguisher close by, ready for use.

—Dispose of solvent-soaked rags in a container designed for flammable disposal.

—Do not allow eating, drinking, smoking, open flames, or lights in the area where solvents are being used. Any chemicals or solvents should be handled with caution.

PAINTS AND VARNISHES

You must take special precautions when removing paint or repainting electrical equipment. In general, paint should not be removed from electrical equipment. Scraping or chipping tools may harm the insulation or damage relatively delicate parts. Paint dust, composed of abrasive and semiconducting materials, may also impair the insulation. Therefore, if paint is to be scraped, all electrical equipment, such as generators, switchboards, motors, and controllers, should be covered to prevent the entrance of the paint dust. After the paint is removed, the electrical equipment should be thoroughly cleaned, preferably with a vacuum cleaner. Sanding and grinding should not be the method of removal due to the potential of generating high levels of lead dust.

Electrical equipment should be repainted only when necessary to ward off corrosion. Painting should be confined only to the affected areas. General repainting of electrical equipment or enclosures for electrical equipment for the sole purpose of improving their appearance is not desirable. Insulating surfaces in electrical equipment should never be painted. NEVER PAINT OVER IDENTIFICATION PLATES.

Apply electrical insulating varnish to equipment only as necessary. Frequent applications of insulating varnish build up a heavy coating that may interfere with heat dissipation and develop surface cracks. Do not apply insulating varnish to dirty or moist insulation; the varnish will seal in the dirt and moisture and make future cleaning impossible.

Shellac and lacquer are forms of varnish, but MUST NOT be used for insulating purposes. The two types of insulating varnishes commonly used in the Navy are clear baking varnish (grade CB) and clear air-drying varnish (grade CA). Grade CB is the preferred grade; however, if it is not possible to bake the part to be insulated, grade CA may be used.

STEEL WOOL AND EMERY CLOTH/PAPER

Steel wool and emery cloth/paper are harmful to the normal operation of electrical and electronic equipment. The *NSTM* and other technical publications warn you against the use of steel wool and emery cloth/paper on or near equipment. When these items are used, they shed metal particles. These particles are scattered by ventilation currents and attracted by the magnetic devices in electrical equipment. This could cause short circuits, grounds, and excessive equipment wear. Therefore, emery cloth/paper and steel wool should NEVER be used for cleaning contacts. Clean the contacts with silver polish, sandpaper, or burnishing tools. After cleaning, use a vacuum to remove any remaining dust.

WORKING ALOFT

As an IC Electrician, you will have to go aloft to perform maintenance on various IC circuits, such as the wind direction and wind speed detectors. You should be familiar with the hazards and the safety precautions involved.

Personnel must obtain written permission from the officer of the deck (OOD) before going aloft. The OOD must ensure that all energized radio and radar transmitters have been placed in the STANDBY position, that the power has been secured to all radar antennas, and that their associated controls are tagged "SECURED: PERSONNEL ALOFT." The OOD must also notify the engineer officer that personnel will be working aloft to prevent the lifting of boiler safety valves or the blowing of boiler tubes or steam whistles while workers are aloft. The OOD will coordinate with the OODs of adjacent ships to ensure that equipment on their respective ships will not present a danger to personnel going aloft.

After permission has been obtained to go aloft, at least two workers will be assigned to the work area, along with a ship's Boatswain's Mate who is qualified in rigging. When you go aloft, you must always be equipped with a parachute-type safety harness, safety lanyard equipped with Dyna-Brake, working lanyard, and climber safety device (if a climber safety rail is installed). Before each use, you should inspect the safety harness and lanyards for defects. NEVER use defective equipment.

While working aloft, you should secure all tools and equipment with lanyards to prevent dropping them and injuring personnel below. Keep both hands free for climbing, and be sure you always have good footing and hand grasp. You should wear well-fitted clothing. Loose or baggy clothes may become caught or entangled and cause you to lose your balance. Your assistant should stand clear of danger from falling objects below the work area. Your assistant should also keep all personnel clear of the work area.

After the work has been completed, the OOD should be notified immediately.

PERSONAL EQUIPMENT

No personal electrical equipment, such as radios, television sets, record players, tape recorders, and hobby equipment, will be used aboard ship without having received an electrical safety inspection and having an approval sticker or tag attached. The shipboard electricians are responsible for inspecting personal electrical equipment.

Electric shavers that have a completely insulated housing and isolated cutting blades and that have no cracks in the housing or cord are authorized for use aboard ship. If in doubt whether your electric shaver complies, have it checked by the ship's electricians. If the shaver ever falls into a wash bowl of water, let it go. Unplug the cord from its receptacle, and take the shaver to the electricians for a safety check. Do not use it again without first having it checked.

No personally owned electrical appliances, such as heating pads, space heaters, lights, or fans, are allowed aboard ship.

ELECTRICAL FIRES AND FIRE EXTINGUISHERS

When at sea, fire aboard a Navy vessel can be more fatal and damaging to both personnel and the ship itself than damage from battle. The Navy requires that all hands be damage control qualified within 6 months after reporting aboard ship. You must learn the types of fire-fighting equipment and the location and operating procedures of the equipment.

The following general procedures are used for fighting an electrical fire:

1. Promptly de-energize the circuit or equipment affected. Shift the operation of the affected circuit or equipment to a standby circuit or equipment, if possible.

2. Sound an alarm according to station regulations or the ship's fire bill. When ashore, notify the fire department;

if afloat, notify the OOD. Give the location of the fire and state what is burning. If possible, report the extent of the fire; that is, what its effects are upon the surrounding area.

3. Secure all ventilation by closing compartment air vents or windows.

4. Attack the fire with portable CO_2 extinguishers (or a CO_2 hose reel system, if available) as follows:

- Remove the locking pin from the release valve.

- Grasp the horn handle by the insulated (thermal) grip; the grip is insulated against possible frostbite of the hand.

- Squeeze the release lever (or turn the wheel) to open the valve and release the carbon dioxide; at the same time, direct the discharge flow of the carbon dioxide toward the base of the fire.

- Aim and move the horn of the extinguisher slowly from side to side.

- Do not stop the discharge from the extinguisher too soon. When the fire has been extinguished, coat the critical surface areas involved with carbon dioxide "snow" to smother the fire by displacing oxygen,

- Do not lose positive control of the CO_2 bottle.

Table 1-2 is a list of the types of fire extinguishers that are normally available for use. Fire extinguishers of the proper type must be conveniently located near all equipment that is subject to fire danger, especially high-voltage equipment. You should be extremely careful when using fire-extinguishing agents around electrical circuits. A stream of salt water or foam directed against an energized circuit can conduct current. When water is broken into small particles, (nozzle fog patterns), there is little or no danger of it carrying electric current under normal conditions of fire fighting if the nozzlers are operated at least 4 feet from the energized source. Nozzles and Navy all-purpose (NAP) applicators, constitute a shock hazard to the fire fighter due to accidental shifting to a solid stream or by touching electrical equipment, particularly with the applicator. Even after current is shut off, a potential may remain until an effective ground is established in some electronic equipment. It is emphasized that the nozzle should not be advanced any nearer to the power source than 4 feet. Avoid prolonged exposure to high concentrations of carbon dioxide in confined spaces since there is danger of suffocation unless an oxygen breathing apparatus (OBA) is used.

Table 1-2.—Types of Fire Extinguishers

EXTINGUISHER	USE
CO_2 Gas	Effective on any type of fire, particularly electrical fires.
Potassium Bicarbonate (PKP)	Very effective on Class B fires. Not recommended for electrical fires because it causes corrosion of electrical and electronic components.
Soda-Acid	Effective only on Class A fires. Not recommended for electrical fires, as the compound is a good conductor of electricity. Not effective on burning compounds, such as oil and the like.
Foam	Very effective on buring compounds, such as oil and similar materials. Not satisfactory for electrical fires, as the compound is a good conductor of electricity.
Halon 1301	Effective on all classes of fire except Class D. It is a colorless, odorless gas that does not conduct electricity or leave a residue.

ELECTRICAL SHOCK

As an IC Electrician, you will be working in areas and on equipment that pose serious shock hazards. If you always follow the safety precautions outlined earlier, you can minimize the risk. However, you should remember that the possibility of electrical shock is always present. If you are at the scene of a mishap, you will be expected to help the victim as soon as possible.

When 60-Hz ac is passed through a human body and the current is gradually increased from zero, it could cause the following effects:

- 1 milliampere (0.001 ampere)—shock is perceptible.

- 10 milliamperes (0.01 ampere)—shock is of sufficient intensity to prevent the voluntary control of muscles. A person may not be able to release the circuit.

- 100 milliamperes (0.1 ampere)—shock is usually fatal if it is sustained for 1 second or more.

The danger of shock from 450-volt ac ship's service systems is well recognized by operating personnel as shown by the relatively few reports of serious shock received from this voltage. On the other hand, a number of shipboard fatalities have occured because of contact with 115-volt circuits. Despite a widespread but totally unfounded popular belief, low-voltage (115 volts and below) circuits are very dangerous and can cause death. Shipboard conditions contribute to the severity of shock because the body is likely to be in contact with the ship's metal structure and the body resistance may be low because of perspiration or damp clothing.

Keep your clothing, hands, and feet dry if at all possible. When you must work in a wet or damp location, use a dry, wooden platform to sit or stand on, and place a rubber mat or other nonconductive material between you and the wood surface. When you are required to work on exposed electrical equipment, use insulated tools and a nonmetallic flashlight.

RESCUE

When a victim is rendered unconscious by electrical shock, and the victim is no longer breathing, you should start artificial ventilation as soon as possible. You should also check the victim's pulse, since electrical shock may also cause the heart to stop.

The person nearest the victim should start artificial ventilation without delay and call or send others for assistance and medical aid. The only logical permissible delay is that time required to free the victim from contact with the electricity in the quickest, safest way. This step must be done with great care, otherwise there may be two victims instead of one. If contact is with a portable electric tool, light, appliance, equipment, or portable extension cord, turn off the bulkhead supply switch or remove the plug from its bulkhead receptacle. If the switch or bulkhead receptacle cannot be quickly located, the suspected electric device may be pulled free of the victim by grasping the insulated flexible cable to the device and carefully withdrawing it clear of its contact with the victim. Other persons arriving on the scene must be clearly warned not to touch the suspected equipment until it is unplugged. Aid should be enlisted to unplug the device as soon as possible.

Where a victim is in contact with stationary equipment, such as a bus bar or electrical connections, pull the victim free if the equipment cannot be quickly de-energized or if the ship's operations or survival prevent immediate securing of the circuits. To save time in pulling the victim free, improvise a protective insulation for the rescuer. For example, instead of hunting for a pair of rubber gloves to use in grasping the victim, you can safely pull the victim free (if conditions are dry) by grasping the victim's slack clothing, leather shoes, or by using your belt. Instead of trying to locate a rubber mat to stand on, use nonconducting materials, such as deck linoleum, a pillow, a blanket, a mattress, dry wood, or a coil of rope. At no time during the rescue should any part of your body directly touch the hull, metal structure, furniture, or victim's skin.

RESUSCITATION

Methods of resuscitating or reviving an electrical shock victim include artificial ventilation (to reestablish breathing) and cardiopulmonary resuscitation (to reestablish heartbeat and blood circulation).

Artificial Ventilation (Respiration)

A person who has stopped breathing is not necessarily dead, but is in immediate critical danger. Life depends on oxygen that is breathed into the lungs and then carried by the blood to every body cell. Since body cells cannot store oxygen, and since the blood can hold only a limited amount (and only for a short time), death will surely result from continued lack of breathing.

The heart may continue to beat and the blood may still be circulated to the body cells for some time after breathing has stopped. Since the blood will, for a short time, contain a small supply of oxygen, the body cells will not die immediately. Thus, for a very few minutes, there is some chance that the person's life may be saved. A person who has stopped breathing, but who is still alive, is said to be in a state of respiratory failure. The first-aid treatment for respiratory failure is called artificial ventilation/respiration.

The purpose of artificial ventilation is to provide a method of air exchange until natural breathing is reestablished. Artificial ventilation should be given only when natural breathing has stopped; it must NOT be given to any person who is still breathing. Do not assume that breathing has stopped merely because a person is unconscious or because a person has been rescued from an electrical shock. Remember, DO NOT GIVE ARTIFICIAL VENTILATION TO A PERSON WHO IS BREATHING NATURALLY. There are two methods of administering artificial ventilation: mouth-to-mouth and mouth-to-nose.

For additional information on performing artificial ventilation, refer to *Standard First Aid Training Course,* NAVEDTRA 10081-D.

Cardiopulmonary Resuscitation

When there is a complete stoppage of heart function, the victim has suffered a cardiac arrest. The signs include the absence of a pulse, because the heart is not beating, and the absence of breathing. In this situation, the immediate administration of cardiopulmonary resuscitation (CPR) by a rescuer using correct procedures greatly increases the chances of a victim's survival.

CPR consists of external heart compression and artificial ventilation. The compressions are performed by pressing the chest with the heel of your hands, and the lungs are ventilated either by mouth-to-mouth or mouth-to-nose techniques. To be effective, CPR must be started within 4 minutes of the onset of cardiac arrest.

CAUTION

CPR should NOT be attempted by a rescuer who has NOT been properly trained. Improperly done, CPR can cause serious damage to a victim. Therefore, CPR is NEVER practiced on a healthy individual. For training purposes, a training aid is used instead. To learn CPR, you should take an approved course from a qualified CPR instructor.

For additional information on administering CPR, refer to *Standard First Aid Training Course,* NAVEDTRA 10081-D.

WOUNDS

A wound, or breaking of the skin, is another problem that could be the result of an electrical shock. An IC Electrician could accidentally come in contact with an energized circuit, causing a loss of balance. This could result in a minor or serious injury. Because you could be in a critical situation to save someone's life, or even your own, you should know the basics of first aid.

Wounds are classified according to their general condition, size, location, how the skin or tissue is broken, and the agent that caused the wound.

When you consider the manner in which the skin or tissue is broken, there are four general kinds of wounds: abrasions, incisions, lacerations, and punctures.

Abrasions

Abrasions are made when the skin is rubbed or scraped off. Rope burns, floor burns, and skinned knees or elbows are common examples of abrasions. There is usually minimal bleeding or oozing of clear fluid.

Incisions

Incisions, commonly called cuts, are wounds made with a sharp instrument, such as a knife, razor, or broken glass. Incisions tend to bleed very freely because the blood vessels are cut straight across.

Lacerations

Lacerations are wounds that are torn, rather than cut. They have ragged, irregular edges and masses of torn tissue underneath. These wounds are usually made by blunt forces, rather than sharp objects. They are often complicated by crushing of the tissues as well.

Punctures

Punctures are caused by objects that penetrate some distance into the tissues while leaving a relatively small surface opening. As a rule, small punctures do not bleed freely; however, large puncture wounds may cause severe internal bleeding.

A puncture wound can be classified as penetrating or perforating. A perforation differs from a penetration in that it has an exit as well as an entrance site.

For additional information on the treatment of wounds refer to *Standard First Aid Training Course,* NAVEDTRA 10081-D.

BLEEDING

The first-aid methods that are used to stop serious bleeding depend upon the application of pressure. Pressure may be applied in three ways: (1) directly to the wound, (2) at key pressure points throughout the body, and (3) with a tourniquet.

Direct Pressure

You should try the direct-pressure method first to control bleeding. Place a sterile first-aid dressing, when available, directly over the wound. Tie the knot only tight enough to stop the bleeding, and firmly fasten it in position with a bandage. In the absence of sterile dressings, use a compress made with a clean rag, handkerchief, or towel to apply direct pressure to the wound, as in figure 1-14. If the bleeding does not stop, firmly secure another dressing over the first dressing, or apply direct pressure with your hand or fingers over the dressing. Under no circumstances is a dressing to be removed once it is applied.

Pressure Points

If the direct-pressure method does not stop the bleeding, use the pressure point nearest the wound, as shown in figure 1-15. Bleeding from a cut artery or vein may often be controlled by applying pressure to the appropriate pressure point. A pressure point is a place where the main artery to the injured part lies near the skin surface and over a bone. Pressure at such a point is applied with the fingers or with the hand; no first-aid materials are required. Pressure points should be used with caution, as they may cause damage to the limb as a result of an inadequate flow of blood. When the use of pressure points is necessary, do not substitute them for direct pressure; use both.

Use of a Tourniquet

A tourniquet is a constricting band that is used to cut off the supply of blood to an injured limb. It cannot be used to control bleeding from the head, neck, or body, since its use in these locations would result in greater injury or death. A tourniquet should be used on an injured limb only as a last resort for severe, life-threatening hemorrhaging that cannot be controlled by any other method. A tourniquet must be applied ABOVE the wound—that is, towards the trunk-and it must be applied as close to the wound as practicable.

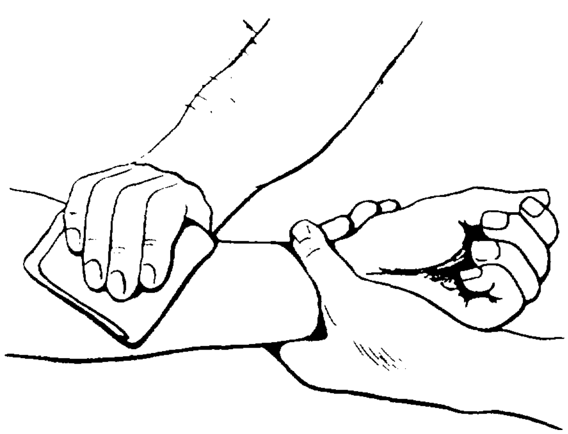


Figure 1-14.-Direct pressure.

Any long, flat material can be used as a band for a tourniquet—belts, stockings, flat strips of rubber, or a neckerchief. Only tighten the tourniquet enough to stop the flow of blood. Use a marker, skin pencil, crayon, or blood, and mark a large T on the victim's forehead.

WARNING

Remember, a tourniquet is ONLY used as a last resort to control bleeding that cannot be controlled by other means. Tourniquets should be removed as soon as possible by medical personnel only.

BURNS

The causes of burns are generally classified as thermal, electrical, chemical, or radiation. Whatever the cause, shock always results if the burns are extensive.

Thermal burns are caused by exposure to intense heat, such as that generated by fire, bomb flash, sunlight, hot liquids, hot solids, and hot gases. Their care depends upon the severity of the burn and the percentage of the body area involved.

Electrical burns are caused by electric current passing through tissues or the superficial wound caused by electrical flash. They may be far more serious than they first appear. The entrance wound may be small; but as electricity penetrates the skin, it burns a large area below the surface. Usually there are two external burn areas: one where the current enters the body, and another where it leaves.

Chemical burns for the most part are not caused by heat, but by direct chemical destruction of body tissues. When acids, alkalies, or other chemicals come in contact with the skin or other body membranes, they can cause injuries that are generally referred to as chemical burns. The areas most often affected are the extremities, mouth, and eyes. Alkali burns are usually more serious than acid burns, because they penetrate deeper and burn longer. When chemical burns occur, emergency

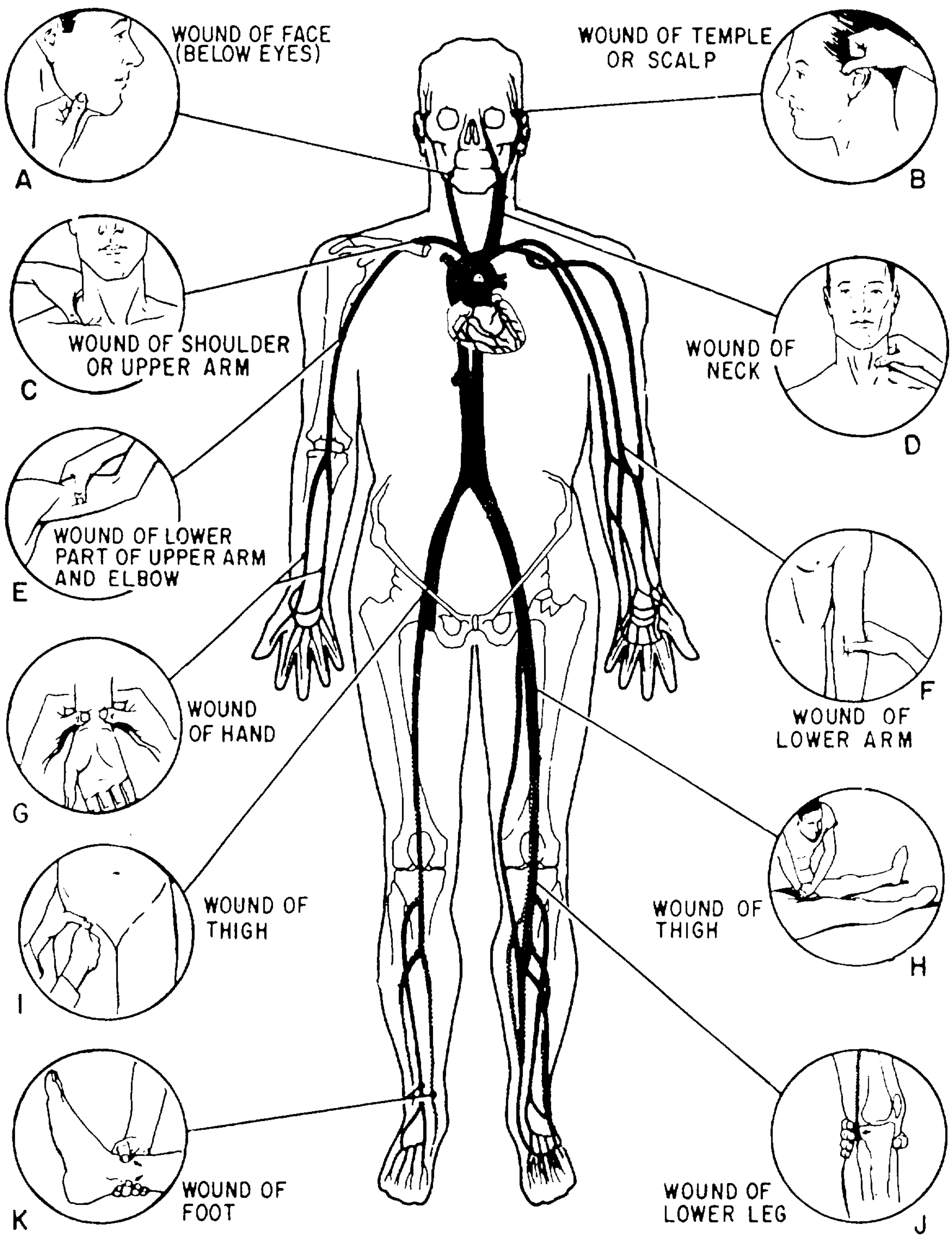


Figure 1-15.-Pressure points for control of bleeding.

measures must be carried out immediately. Do not wait for the arrival of medical personnel.

Radiation burns are the result of prolonged exposure to the ultraviolet radiation. First- and second-degree burns may develop. Treatment is essentially the same as that for thermal burns.

Classification of Burns

burns are classified in several ways: by the extent of the burned surface, by the depth of the burn, and by the cause of the burn. The extent of the body surface burned is the most important factor in determining the seriousness of the burn and plays the greatest role in the victim's chances of survival.

burns may also be classified as first, second, or third degree, based on the depth of skin damage (fig. 1-16). First-degree burns are mildest. Symptoms are reddening of the skin and mild pain. Second-degree burns are more serious. Symptoms include blistering of the skin, severe pain, some dehydration, and possible shock. Third-degree burns are worst of all. The skin is destroyed and possibly the muscle tissue and bone in severe cases. The skin may be charred or it may be white or lifeless. This is the most serious type of burn, as it produces a deeper state of shock and will cause more permanent damage. It is usually not as painful as a second-degree burn because the sensory nerve endings have been destroyed.

Emergency Treatment of Burns

The degree of the burn, as well as the skin area involved, determines the procedures used in the treatment of burns. Large skin areas require a different approach than small areas. To estimate the amount of skin area affected, the extent of burned surface, the "Rule of Nines" (fig. 1-17) is used. These figures aid in determining the correct treatment for the burned person.

As a guideline, consider that burns exceeding 15 percent of the body surface will cause shock; burns exceeding 20 percent of the body surface endanger life; and burns covering more than 30 percent of the body surface are usually fatal if adequate medical treatment is not received.

Minor burns, such as first-degree burns over less than 20 percent of the body area and small second-degree burns, do not usually require immediate medical attention unless they involve the facial area.

THERMAL BURNS.— When emergency treatment of the more serious thermal burns is required, first check the victim for respiratory distress. burns around the face or exposure to hot gases or smoke may cause the airway to swell shut. If facial burns are present, place the victim in a sitting position

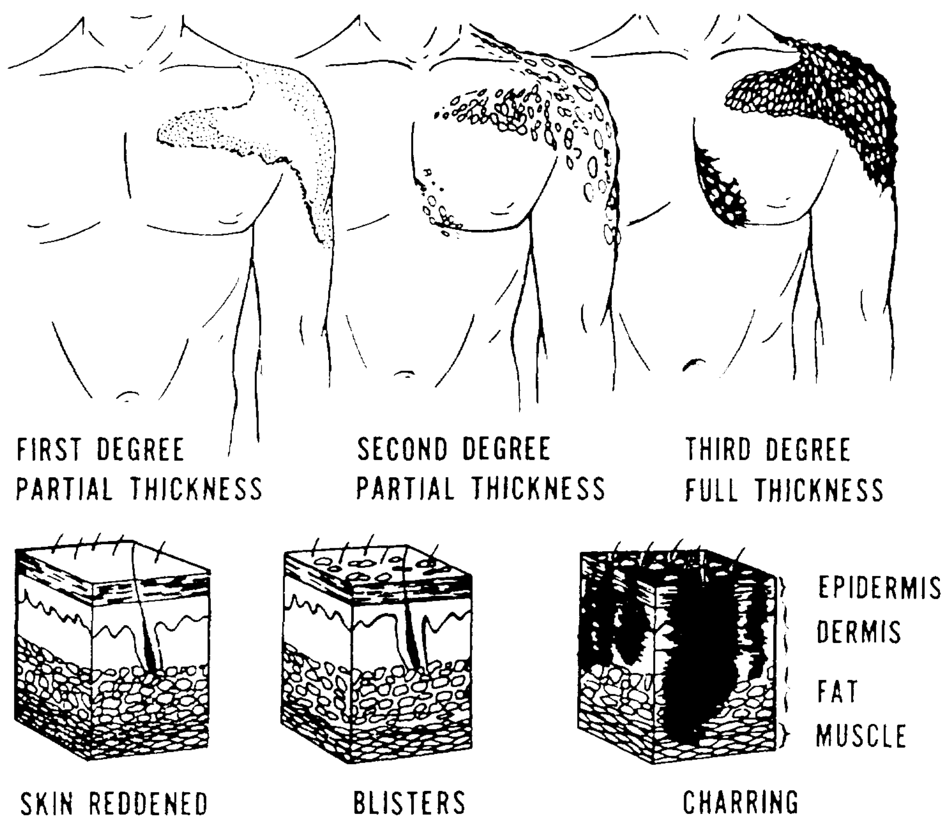


Figure 1-16.-First-, second-, and third-degree burns.

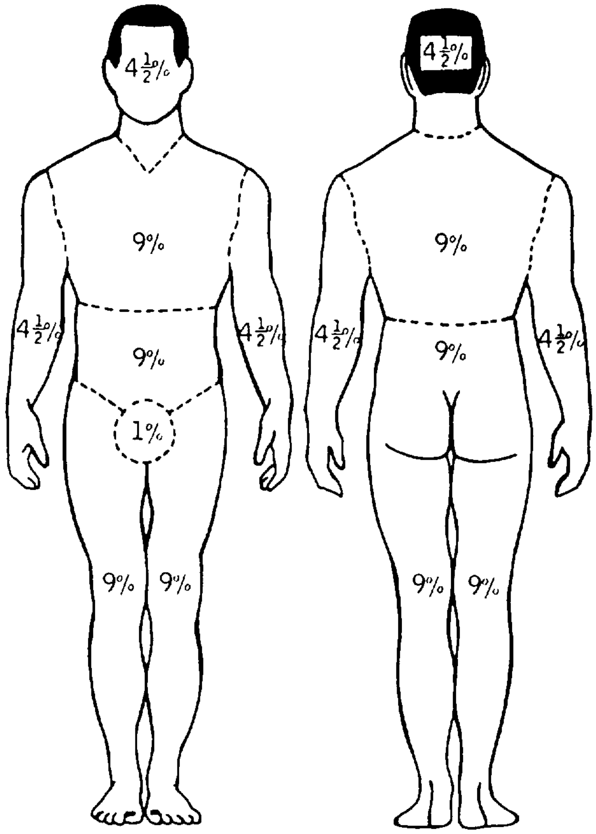


Figure 1-17.—Rule of Nines.

to further ease breathing. Transport the victim with facial burns to a medical facility as soon as possible.

Remove all jewelry and similar articles, even from unburned areas, since severe swelling may develop rapidly.

To relieve pain initially, apply cold compresses to the affected area or submerge it in cold water. Cold water not only minimizes pain, but also reduces the burning effects in the deep layers of the skin. Gently pat dry the area with a lint-free cloth or gauze.

Cover the burned area with a sterile dressing, clean sheet, or unused plastic bag. Coverings such as blankets or other materials with a rough texture should not be used because lint may contaminate and further irritate the injured tissue. When hands and feet are burned, dressings must be applied between the fingers and toes to prevent skin surfaces from sticking to each other.

Do not attempt to break blisters, and do not remove shreds of tissue or adhered particles of charred clothing. Never apply greasy substances (butter, lard, or petroleum jelly), antiseptic preparations, or ointments.

If the victim is conscious and not vomiting, prepare a weak solution of salt (1 teaspoon) and baking soda (1/2 teaspoon) in a quart of warm water. Allow the victim to sip the drink slowly. Aspirin is also effective for the relief of pain.

Treat for shock. Maintain the victim's body heat, but do not allow the victim to become overheated. If the victim's hands, feet, or legs are burned, elevate them higher than the heart.

ELECTRICAL BURNS.— In electrical shock cases, burns may have to be ignored temporarily while the patient is being revived. After the patient is revived, lightly cover the burn with a dry, preferably sterile, dressing, treat for shock, and transport the victim to a medical facility.

CHEMICAL BURNS.— To treat most chemical burns, you should begin flushing the area immediately with large amounts of water. Do not apply the water too forcefully. If necessary, remove the victim's clothing, including shoes and socks, while flushing.

Water should not be used for alkali burns caused by dry lime, unless large amounts of water are available for rapid and complete flushing. When water and lime are mixed they create a very corrosive substance. Dry lime should be brushed from the skin and clothing.

Isopropyl or rubbing alcohol should be used to treat acid burns caused by phenol (carbolic acid). Phenol is not water soluble; therefore, water should only be used after first washing with alcohol or if alcohol is not available.

For chemical burns of the eye, flush immediately with large amounts of fresh, clean water. Acid burns should be flushed at least 15 minutes, and alkali burns for as long as 20 minutes. If the victim cannot open the eyes, hold the eyelids apart so water can flow across the eyes. After thorough irrigation, loosely cover both eyes with a clean dressing.

The after care for all chemical burns is similar to that for thermal burns. Cover the affected area and get the victim to a medical facility as soon as possible.

RADIATION BURNS.— For first- and second-degree sunburns, treatment is essentially the same as for thermal burns. If the burn is not serious and the victim does not need medical attention, apply commercially prepared sunburn lotions and ointments.

For further information on the treatment of burns, refer to *Standard First Aid Training Course,* NAVEDTRA 10081-D.

HEARING CONSERVATION AND NOISE ABATEMENT

Historically, hearing loss has been recognized as an occupational hazard related to certain trades, such as blacksmithing and boilermaking. Modern technology has extended the risk to many other activities: using presses, forging hammers, grinders, saws, internal combustion engines, or similar high-speed, high-energy processes. Exposure to high-intensity noise occurs as a result of either impact noise, such as gunfire or rocket fire, or from continuous noise, such as jet or propeller aircraft, marine engines, and machinery.

Hearing loss has been and continues to be a source of concern within the Navy, both ashore and afloat. Hearing loss attributed to such occupational exposure to hazardous noise, the high cost of related compensation claims, and the resulting drop in productivity and efficiency have highlighted a significant problem that requires considerable attention. The goal of the Navy Hearing Conservation Program is to prevent occupational noise-related hearing loss among Navy personnel. The program includes the following elements:

- Work environments will be surveyed to identify potentially hazardous noise levels and personnel at risk.
- Environments that contain, or equipment that produces, potentially hazardous noise should be modified to reduce the noise to acceptable levels whenever technologically and economically feasible. When this is not feasible, administrative control and/or hearing protection devices should be used.
- Periodic hearing testing must be conducted to monitor the effectiveness of the program.
- Navy personnel must be educated on the Hearing Conservation Program to ensure the overall success of the program.

IDENTIFYING AND LABELING OF NOISE AREAS AND EQUIPMENT

Hazardous noise areas and equipment must be so designated and appropriately labeled. Areas and equipment that produce continuous and intermittent sound levels greater than 84 dB(A) or impact or impulse levels of 140 dB peak are considered hazardous.

An industrial hygienist with a noise level meter will identify the noise hazardous areas. Noise hazardous areas will be labeled using a hazardous noise warning decal, NAVMED 6260/2 (fig. 1-18). This decal will be posted at all accesses. Hazardous noise labels, NAVMED 6260/2A, are the approved labels for marking portable and installed equipment.

All personnel that are required to work in designated noise hazardous areas or with equipment that produces sound levels greater than 84 dB(A) or 140 dB sound/pressure levels are entered in the hearing conservation program.

You will find further information on hearing conservation in OPNAVINST 5100.23C, *Navy Occupational Safety and Health (NAVOSH) Program Manual* and OPNAVINST 5100.19B, *Navy Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat.*

Figure 1-18.-Hazardous noise warning decal.

MONITORING HEARING TESTS

All naval personnel receive an initial or reference audiogram shortly after entering the service. Thereafter, a hearing test will be conducted at least annually while you are assigned to a noise hazardous environment. Hearing tests will also be conducted when there are individual complaints of difficulties in understanding conversational speech or a sensation of ringing in the ears. The annual audiograms will be compared to the reference (baseline) to determine if a hearing threshold shift has occurred.

HEARING PROTECTIVE DEVICES

Hearing protective devices should be worn by all personnel when they must enter or work in an area where noise levels are greater than 84 dB(A). A combination of insert earplugs and circumaural muffs, which provides double protection, should be worn in all areas where noise levels exceed 104 dB(A). Personnel hearing protective devices should be issued to suit each situation.

HEAT STRESS CONTROL PROGRAM

Heat stress may occur in many work spaces throughout the Navy. Heat stress is any combination of air temperature, thermal radiation, humidity, airflow, and workload that may stress the human body as it attempts to regulate its temperature. Heat stress becomes excessive when your body's capability to adjust is exceeded. This results in an increase in body core temperature. This condition can readily produce fatigue, severe headaches, nausea, and poor physical and/or mental performance. Prolonged exposure to heat stress could cause heatstroke or heat exhaustion and severe impairment of the body's temperature-regulating ability. Heatstroke can be life-threatening if not immediately and properly treated. Recognizing personnel with heat stress symptoms and getting them prompt medical attention is an all-hands responsibility.

As a petty officer, your role in the command's Heat Stress Control Program involves adhering to the command's program and reporting heat stress conditions as they occur.

Primary causes that increase heat stress conditions are as follows:

- Excessive steam and water leaks
- Boiler air casing leaks
- Missing or deteriorated lagging on steam piping, valves, and machinery
- Clogged ventilation systems or an inoperative fan motor
- Operating in hot or humid climates

To determine heat stress conditions, permanently mounted dry-bulb thermometers are installed at key watch and work stations. Their readings should be recorded at least once a watch period. When a reading exceeds 100°F (38°C), a heat stress survey must be ordered to determine the safe stay time for personnel.

A heat stress survey is taken with a wet-bulb globe temperature (WBGT) meter. You should compare these readings to the physiological heat exposure limits (PHEL) chart. After comparing the readings with the PHEL chart, you will be able to determine the safe stay time for personnel.

As a petty officer, you should have a working knowledge of all aspects of the Heat Stress Program so you can recognize heat stress conditions if they occur and take the proper corrective actions.

Further information and guidance of the Navy Heat Stress Control Program is contained in OPNAVINST 5100.19B, *Navy Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat*.

SUMMARY

In this chapter, we have described your responsibilities regarding general and electrical safety, both as an individual and as a petty officer.

We have identified various sources of safety information that are available to you, and provided you with general and specific safety precautions to assist you in your day-to-day work as an IC Electrician.

We have discussed the danger of electrical shock, how to rescue a victim from electrical shock, and the procedures for giving first aid to the victim. We have also briefly discussed the Navy's Hearing Conservation, Noise Abatement, and Heat Stress Control programs.

Think safety! Always remain alert to possible danger.

CHAPTER 2

SWITCHES, PROTECTIVE DEVICES, AND CABLES

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

- *Describe the characteristics, construction features, applications, and maintenance procedures of the various types of switches, relays, and solenoids.*
- *Identify the characteristics, functions, and maintenance procedures of the various types of protective devices on IC equipment.*
- *Identify electrical cables by classification, type and size designation, ratings, and characteristics.*
- *Describe the proper procedures for installing and connecting cables.*
- *Identify the purpose and the installation and maintenance procedures of radio-frequency coaxial cable.*

INTRODUCTION

As an Interior Communications (IC) Electrician, you will be working with sophisticated circuitry consisting of complex equipment, multiconductor cables and connectors, and a variety of switching and protective devices. This chapter will give you a basic understanding of the hardware that is in general use with interior communications systems. You will be able to recognize installations and, with limited supervision, you will be able to install this hardware aboard ship. It should be understood that, due to the vast numbers of components used, not every component is discussed, but rather the common installations. For more detailed information concerning the operation and theory of circuit switching and protective devices, consult NEETS, Module 3, NAVEDTRA 172-03-00-85.

SWITCHES

A basic understanding of switches and their uses is a necessity for the IC Electrician. The Navy uses hundreds of different types of switches.

A switch is a device used for making, breaking, or changing connections in an electrical circuit. Switches are rated in amperes and volts; the rating refers to the maximum allowable voltage and current of the circuit in which the switch is to be used. Since it is placed in series, all the circuit current will pass through the switch; because it opens the circuit, the applied voltage will appear across the switch in the open circuit position. Switch contacts should be opened and closed quickly to minimize arcing; therefore, switches normally use a snap action.

TYPES OF SWITCHES

There are many types and classifications of switches. A common designation is by the number of poles, throws, and positions. The number of poles indicates the number of terminals at which current can enter the switch. The throw of a switch signifies the number of circuits each blade or contactor can complete through the switch. The number of positions indicates the number of places at which the operating device (toggle, plunger, and so on) will come to rest.

Another means of classifying switches is the method of actuation; that is, knife, toggle, push button, or rotary. Further classification includes a description of switch action, such as on-off, momentary on-off, and on-momentary off. Momentary contact switches hold a circuit closed or open only as long as the operator deflects the actuating control.

Knife Switches

Knife switches are basic power switches from which most modern switches have been developed. A single-pole, single-throw (SPST) knife switch consists of a single copper blade hinged at one end and designed to fit tightly between two copper jaws, or clips, at the other end. An insulated handle is fastened to the copper blade to open and close the switch. Terminals are provided for connecting the leads.

A double-pole, single-throw (DPST) knife switch (fig. 2-1, view A) has two blades with one set of clips for each blade and an insulated handle that operates both blades simultaneously. Double-throw switches (fig. 2-1, view B) have two sets of clips (one set at each end) so the blades can be thrown into either set of clips to shift from one circuit to another.

Toggle Switches

Representative examples of toggle switches are shown in figure 2-2, with the schematic symbols shown beneath each switch. View A of figure 2-2 shows a SPST toggle switch, rated at 20 volts and 20 amperes, and having two solder terminals. This type of switch opens and closes electric circuits.

View B of figure 2-2 shows a single-pole, double-throw (SPDT) switch, rated at 250 volts and 1 ampere, and having three screw terminals. One use of this switch is to turn a circuit on at one place and off at another place. It is sometimes called a 2-way switch.

View C of figure 2-2 shows a DPST switch, rated at 250 volts and 1 ampere, and having four solder terminals.

View D of figure 2-2 shows a double-pole, double-throw (DPDT) switch, rated at 125 volts and 3 amperes, and having six solder terminals.

The following types of switches are also used: 3-pole, single-throw (3PST); 3-pole, double throw (3PDT): 4-pole, single-throw (4PST); and 4-pole, double-throw (4PDT). The voltage ratings range from 20 volts to 600 volts, and the amperage ratings range from 1 ampere to 30 amperes.

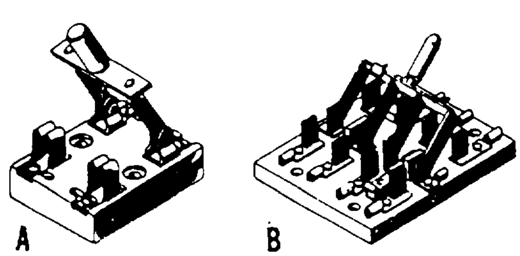


Figure 2-1.—Knife switches.

Push-Button Switches

The normal contact arrangement of a push-button switch is either make or break, as shown by the schematic symbols in figure 2-3, view A. View B of figure 2-3 is a picture of a push-button switch. The

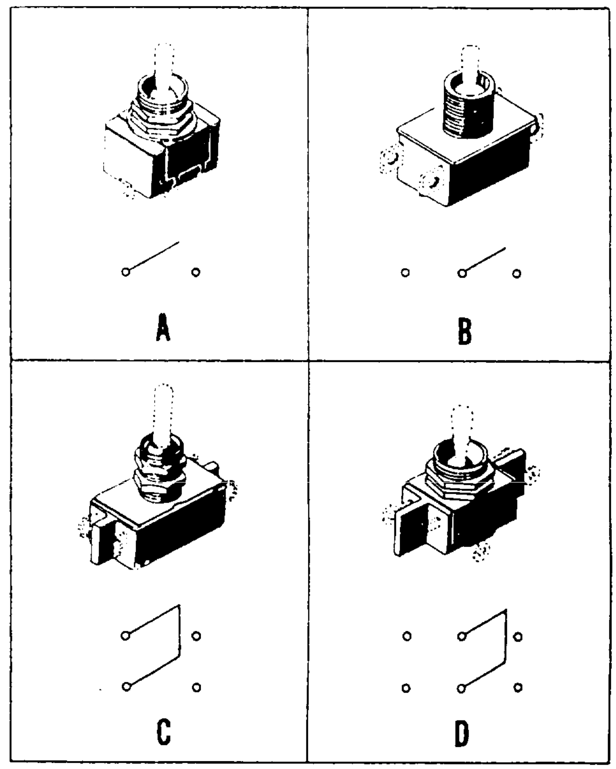


Figure 2-2.—Toggle switches.

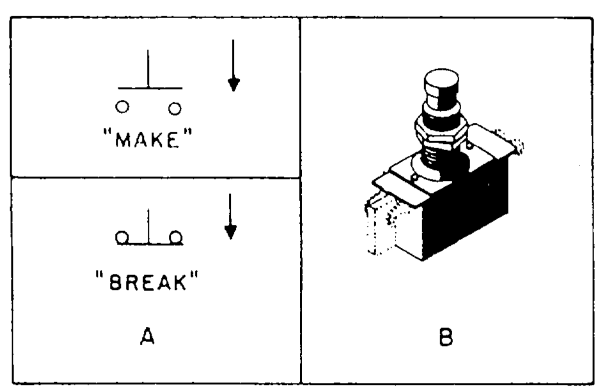


Figure 2-3.—Push-button switch.

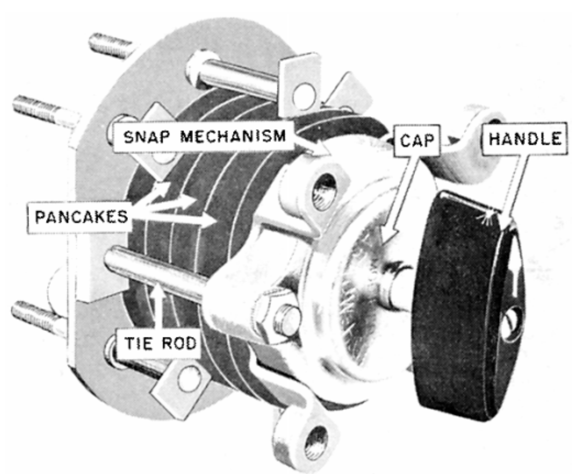
make type of switch is usually a start switch; the break type of switch is usually a stop switch. Either switch may be locking or nonlocking. There is also a break-make push-button switch (not shown).

Rotary Snap Switches

Rotary snap switches are devices that open or close circuits with a quick motion. A type SR rotary snap switch (fig. 2-4) consists of one or more sections, each of which has a rotor and a stationary member. Movable contacts are mounted on a bushing, and stationary contacts are mounted on insulated disks, which are arranged one beneath the other in pancake style along the switch shaft. This type of construction has the advantages of shockproofness, compactness, flexibility of circuit arrangements, and protection to the operator. The operator, by rotating the switch handle, triggers a spring and cam arrangement, which, in turn, operates the switch contacts. If the spring should break, further rotation of the handle will eventually cause a projection on the shaft of the handle to contact a projection on the operating shaft to operate the switch. However, the switch-driving shaft and handle will be misaligned from its normal position, and the characteristic snap action will not be apparent.

Snap switches are available in a wide variety of amperage ratings (from 10 to 200), poles, and mountings (bulkhead or panel mounting).

The switch type designation indicates its current rating (1SR is 10 amperes, 3SR is 30 amperes, and so on); number of poles (3SR3 is 30 amperes, 3 poles); switching action (1SR3A is single-throw; that is, on-off); mounting style (1SR3A1 is front-mounted,

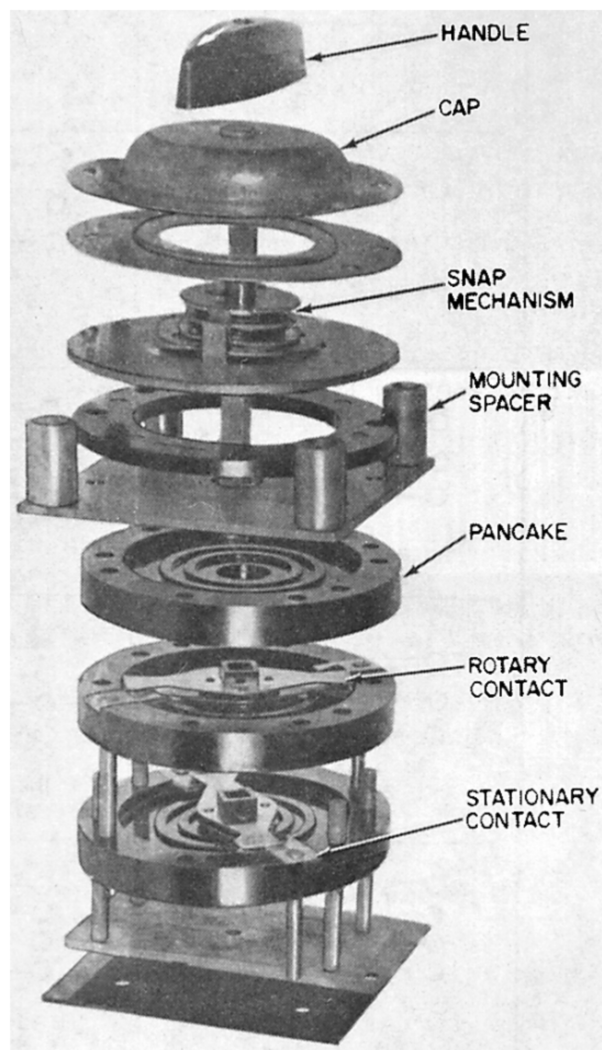


12.69

Figure 2-4.—Type SR rotary snap switch (1SR, 10 ampere size).

back-connected); and enclosure (3SR4B1-3 is watertight). (An exploded view of a type 6SR snap switch is illustrated in fig. 2-5.)

Most snap switches are suitable for 450-volt, 60-Hz ac and 250-volt dc operation. Present 10-ampere switches are suitable for 120-volt operation only, although the switches are sometimes used at higher voltages where the currents are very small. Care must be exercised in the application of multithrow (double-throw and triple-throw) switches. The movable blade, in some cases, is so wide that in moving from one stationary contact to a second, the two stationary contacts will be momentarily bridged by the arc and movable blade, causing a short circuit. Therefore, each time a multithrow switch is to be installed, a careful check should be made on both the switch and the intended circuit to make sure that a switch of the proper current and voltage ratings is used.



140.1

Figure 2-5.—Type 65R snap switch-exploded view.

Pile Switches

Pile switches are constructed so they open or close one or more electrical circuits. The contacts are arranged in leaf, or pileup, fashion and maybe actuated by a rotary, pushing, or sliding motion.

The various basic forms of the contact arrangements in pile switches are shown in figure 2-6, view A. These basic forms are used by themselves or in combination to makeup the contact assembly of a pile switch. View B of figure 2-6 shows a contact assembly made by combining two break-make contact arrangements to make form C. This switch is, therefore, designated 2C. When the armature is moved upward by the rotary motion of the cam lobe (fig. 2-6, view B), two circuits are opened and two are closed. This type of switch is commonly used in relays, key switches, and jacks in low-voltage signal circuits.

Rotary Selector Switches

Rotary selector switches may perform the functions of a number of switches. As the knob or handle of a rotary selector switch is rotated, it opens one circuit and closes another. In figure 2-7, the contact is from A to E. If the switch is rotated clockwise, as viewed, the circuit from A to E is opened and the circuit from A to D is completed. Some rotary switches have several layers of pancakes or wafers. With additional wafers, the switch can operate as several switches. Oscilloscope and voltmeter selector switches are typical examples of

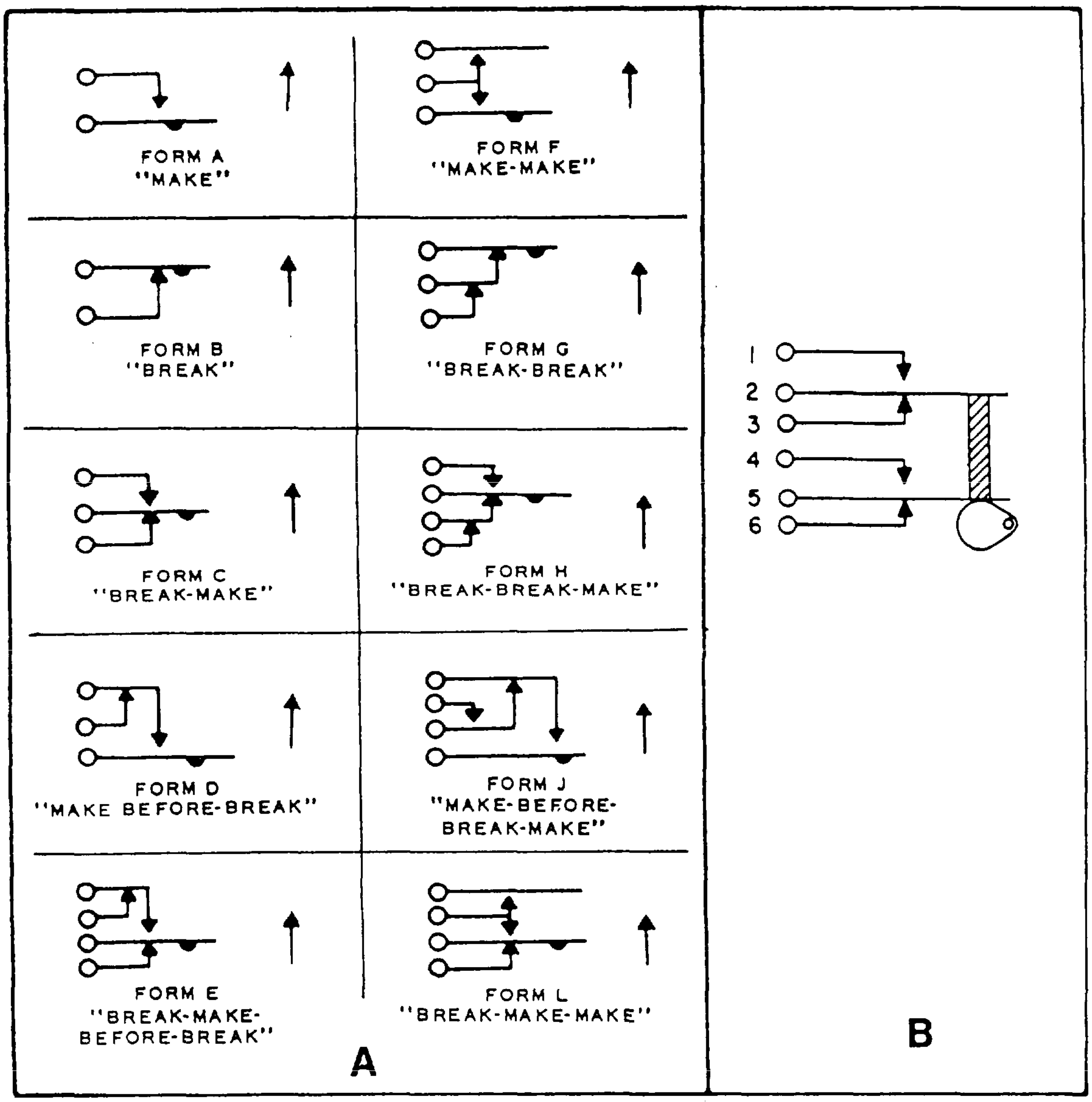


Figure 2-6.-Pile switches.

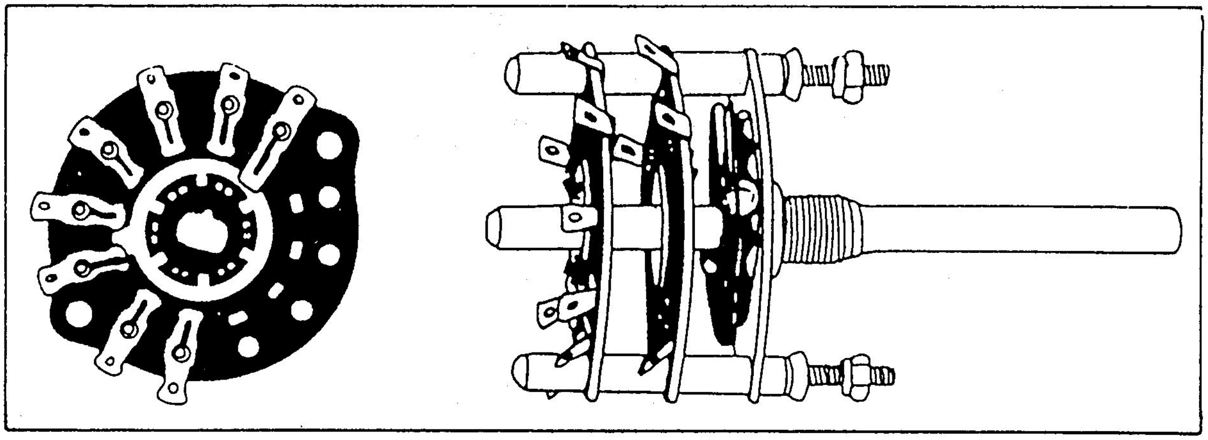


Figure 2-7.—Rotary selector switch.

this type. These switches are more common in civilian equipment than in military hardware.

TYPE J.— The type J multiple rotary selector switch (fig. 2-8) consists of an equal number of rotors and pancake sections. The number of sections required in the switch is determined by the individual application. A shaft with an operating handle extends through the center of the rotors. The movable contacts are mounted on the rotors, and the stationary contacts are mounted on the pancake sections. Each section consists of eight contacts, designated A to H, and a rotor with two insulated movable contacts spaced 180° apart. Each movable contact is arranged to bridge two adjacent stationary contacts. The switch has eight positions. A detent mechanism is provided for proper alignment of the contacts in each position of the operating handle. In one position, the rotor contacts bridge segments A-B and E-F, in the next position, the rotor contacts bridge segments B-C and F-G. Diagonally opposite pairs of contacts are subsequently bridged for the remaining positions.

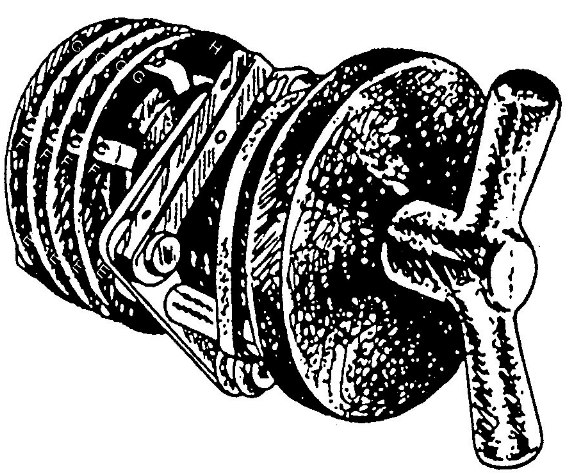
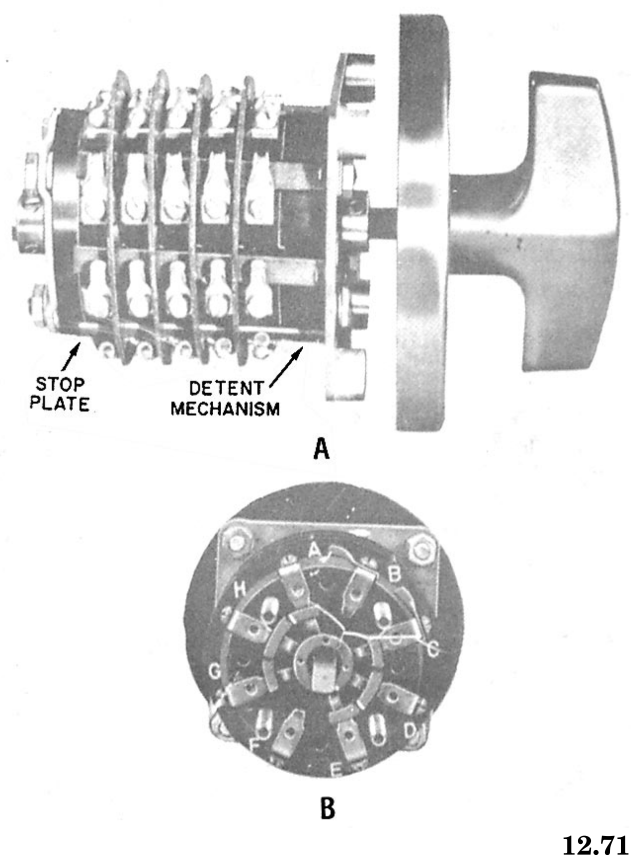


Figure 2-8.—Type J switch.

TYPE JR.— The type JR switch (fig. 2-9) is installed on recent IC switchboards. This switch is



12.71

Figure 2-9.—Type JR switch (4JR).

smaller than the J switch. This feature saves switchboard space. This feature also makes disassembly a lot easier. Remember, however, that a faulty switch should be repaired only when immediate replacement is not possible, and it should be replaced at the earliest opportunity. The JR switch is divided into four types: 1JR, 2JR, 3JR, and 4JR.

The 1JR switch has only one movable contact per section. This movable contact bridges two adjacent stationary contacts.

The 2JR switch has two movable contacts per section, 180° apart. Each movable contact bridges two adjacent stationary contacts.

The 3JR switch uses one of the stationary contacts as a common terminal. This stationary contact is connected, in turn, to each of the other stationary contacts of the section by a single-wiper contact. The 3JR switch is used for selecting one of several (up to seven) inputs.

The 4JR switch is designed as an either or both switch with two movable contacts per section. Each movable contact bridges three adjacent stationary contacts. This switch is used to select either or both of two indicators or synchros. The positions for energizing two indicators are as follows:

90° right—both indicators energized.

45° right—indicator 1 energized only.

0°—off.

45° left—indicator 2 energized only.

When the 4JR switch is in the OFF position, both indicators are connected together, but they are disconnected from the power supply.

The designations of JR switches are determined by the type of section (rotary and stationary contacts) followed by the number of sections in the switch. For example, a 2JR10 switch denotes a JR switch with ten 2JR sections.

The JR switch is stocked in multiples of five sections (up to 25 sections). In some cases, a switch with a number of sections (not a multiple of five) has been installed. If this switch must be replaced, a switch with the next largest number of sections that is a multiple of five should be installed, if space permits.

Type JR switches are rated at 120 volts, 60 Hz, 10 amperes. The switch should not be used on dc circuits because of the possibility of severely burned contacts when the switch is operated slowly (teased). The switch is the nonshorting type. Although the blade bridges two adjacent contacts simultaneously (for example, contacts 1 and 2 when the switch is operated), the blade breaks contact 1 before making the next alternate contact 3 (for example, in the 2JR switch, alternate terminals may be connected to an independent source of ac power without danger of short circuit during movement of the switch blade).

Barriers are also provided between sections to prevent terminals from turning and shorting to adjacent terminals.

If the sections are not uniform, the switch will be designated by JRSP followed by the number of sections.

The JR switch has a stop deck, which permits setting the switch to the number of positions desired. Pins or screws inserted in the stop deck immediately after the desired last position will limit the switch movement to the positions between these points.

TYPE JL.— The JL switch is identical to the JR, except in size, mounting facility, and electrical rating. The diameter of the JL deck is approximately 1 3/4 inches, whereas the diameter of the JR deck is approximately 2 1/4 inches. The rating of the JL switch is 120 volts, 60 Hz, 5 amperes. Standard types are available in three, five, and ten sections. The JL switch has a threaded bushing for single-hole mounting.

TYPE JA.— The JA switch (fig. 2-10) was developed primarily for circuit selection in sound-powered telephone applications. It provides a greater number of selections and is a smaller switch than the JR switch. The JA switch is furnished only with common rotor sections (as shown in fig. 2-11). Sixteen-position and 30-position JA switches permit selection of 16 and 30 circuits, respectively. With the JR switch, the maximum number of possible selections is seven.

The JA switch also provides lower contact resistance by using either silver or silver-overlay contacts. With brass or copper, an insulating film

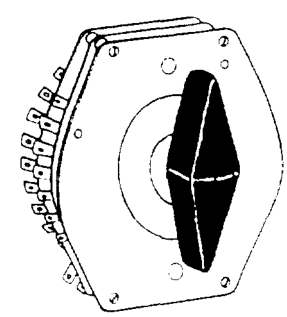


Figure 2-10.—Type JA switch.

forms over the contacts, which is only broken down if appreciable voltage and power are available in the circuit. However, in sound-powered telephone circuits, there is insufficient power to break down the film, and relatively high resistance results. The silver-to-silver contacts of the JA switch consist of pure silver welded to beryllium copper. Silver or silver-coated contacts are now being used for the latest type JA switches and other low-current switches. In larger switches, silver (unless alloyed with other metals) is unsatisfactory because it vaporizes too readily due to arcing.

The JA switch is available in two, six, and ten sections. An example of the switch designation is JA6C(16) for a 6-section, 16-position switch; here the first number designates the number of sections, the C indicates common rotor, and the number in parentheses indicates the number of positions.

TYPE JF.— The JF switch (fig. 2-12) was developed primarily to replace toggle switches in the 10- and 20-switch boxes for sound-powered telephone applications.

Because of the problems in making toggle switches watertight, it was necessary to provide a cover with a gasket for the 10- and 20-switch boxes, which contained the toggle switches. The cover had to be open when the switches were operated. Therefore, the switch box was not watertight, leading to possible malfunctioning of the switches. In addition, the lack of a strong contact wipe action in toggle switches and the low voltage and current in sound-powered circuits resulted in the formation of an insulating film on the contacts. This film resulted in open circuits or, if required, several operations of the toggle switch handle before the circuit was initially made.

The JF switch replacement uses silver-to-silver contact surfaces and provides a strong wiping action in moving between positions. Open circuit problems have been eliminated in this manner. The blade arrangement provides for a circuit between two adjacent contacts, such as in the 2JR switch previously discussed. The type 2JF has two such blade arrangements per switch deck. The standard switches have one, three, and five switching decks, which are indicated in the type designation by the number following JF.

The original production of the switches had a detent to limit the switching action to two positions. The present design has a 12-position detent arrangement with adjustable stops. The stops can be adjusted by removing the four screws on the back plate and arranging the stop arms mounted on the switch shaft to give the number of positions desired.

An O-ring on the switch shaft within the mounting bushing prevents water from entering the switch. An O-ring is also provided on the outside of the mounting bushing to give a watertight seal against the panel in which the switch is mounted. These features have eliminated the need for a watertight cover over the switch.

The JF switch is satisfactory for 120-volt ac applications up to 1 ampere. It is being used in sound-powered telephones, loudspeakers, microphone stations, and similar low-current equipment.

CAUTION

The switch decks are made of molded nylon material. Be careful in soldering the leads to the switch contacts. Too much heat passing back to the switch deck will destroy the switch deck or damage the insulation between adjacent contacts.

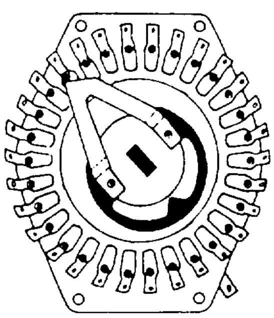


Figure 2-11.—Type JA switch.

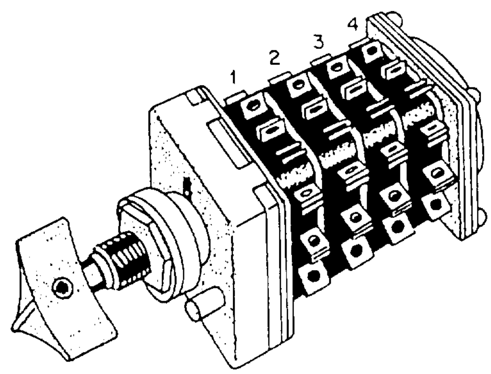


Figure 2-12.—Type JF switch.

Lever-Operated Switches

Many types of lever-operated switches are used in Navy alarm and warning systems to complete an electric circuit to various types of audible and visual alarm signals. The type depends upon the circuit in which it is installed.

Most lever-operated switches use JR interiors (fig. 2-13). These switches are operated by a lever with a suitable locking plate. In the interests of standardization, two types of interiors are available, each containing three 2JR sections. One type is the JRM-300, which has a spring return mechanism; and the other type is the JR-304, which has a positive detent mechanism. Through slightly different arrangements of pins, lever, and locking plate, various types of switches can be obtained.

Special switches are used where the standard switches cannot be used. For example, the diving alarm switch on the submarine bridge must be pressureproof. For submarine service, a distinctive shape is used for the operating lever knob or heads of alarm switches in the conning tower and the control room (where illumination is low) to avoid the possibility of confusion in operating the proper switch. A square-shaped knob is used for the diving alarm switch, a star-shaped head for the collision alarm switch, and a standard rounded head for the general alarm.

Lever-operated switches are available in 1-, 2-, and 3-ganged types. These switches are used in such systems as the fire room emergency signal, general alarm, chemical-attack alarm, steering emergency signal, whistle operation, lifebuoy-release, and flight-crash signal.

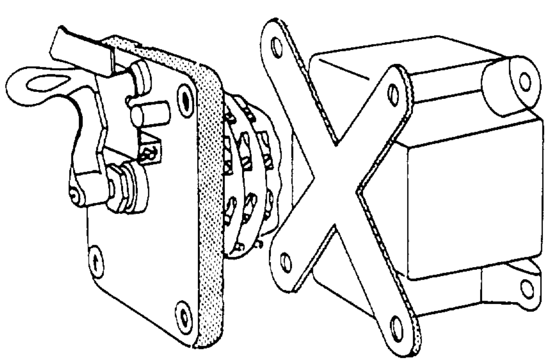


Figure 2-13.—Lever-operated switch.

IC/L Pressure Switches

Pressure-operated switches are normally SPST, quick-acting switches. Each contains either a bellows or a diaphragm that works against an adjustable spring. The spring causes the contacts to close automatically when the operating pressure falls below a specified value. The pressure at which the switches operate is adjustable within ranges, such as 0-15, 15-50, and 50-100. Make this adjustment at the screw marked HIGHER (fig. 2-14). These switches can be used also to indicate an increase in pressure above a predetermined point.

Pressure-operated switches are used with the lubricating oil, low-pressure alarm system; air-pressure alarm system; and booster-feed pressure alarm system.

IC/N Thermostatic Switches

Thermostatic, or temperature-operated, switches are usually SPST, quick-acting, normally open switches. Each switch contains a bellows that works against an adjustable spring, Y (fig. 2-15). The spring causes the contacts to close automatically when the operating temperature exceeds a specified value. The bellows motion is produced by a sealed-in liquid that expands with rising temperature. The sensitive element containing this liquid may be built into

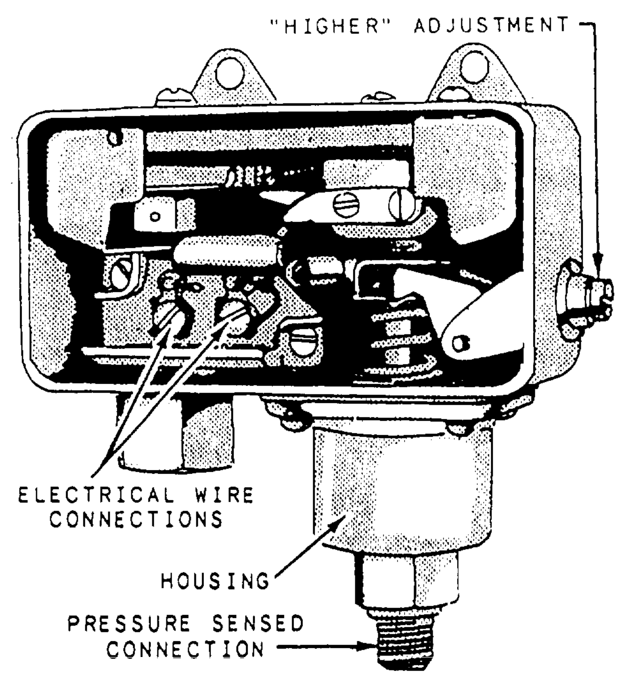


Figure 2-14.—Type IC/L pressure switch.

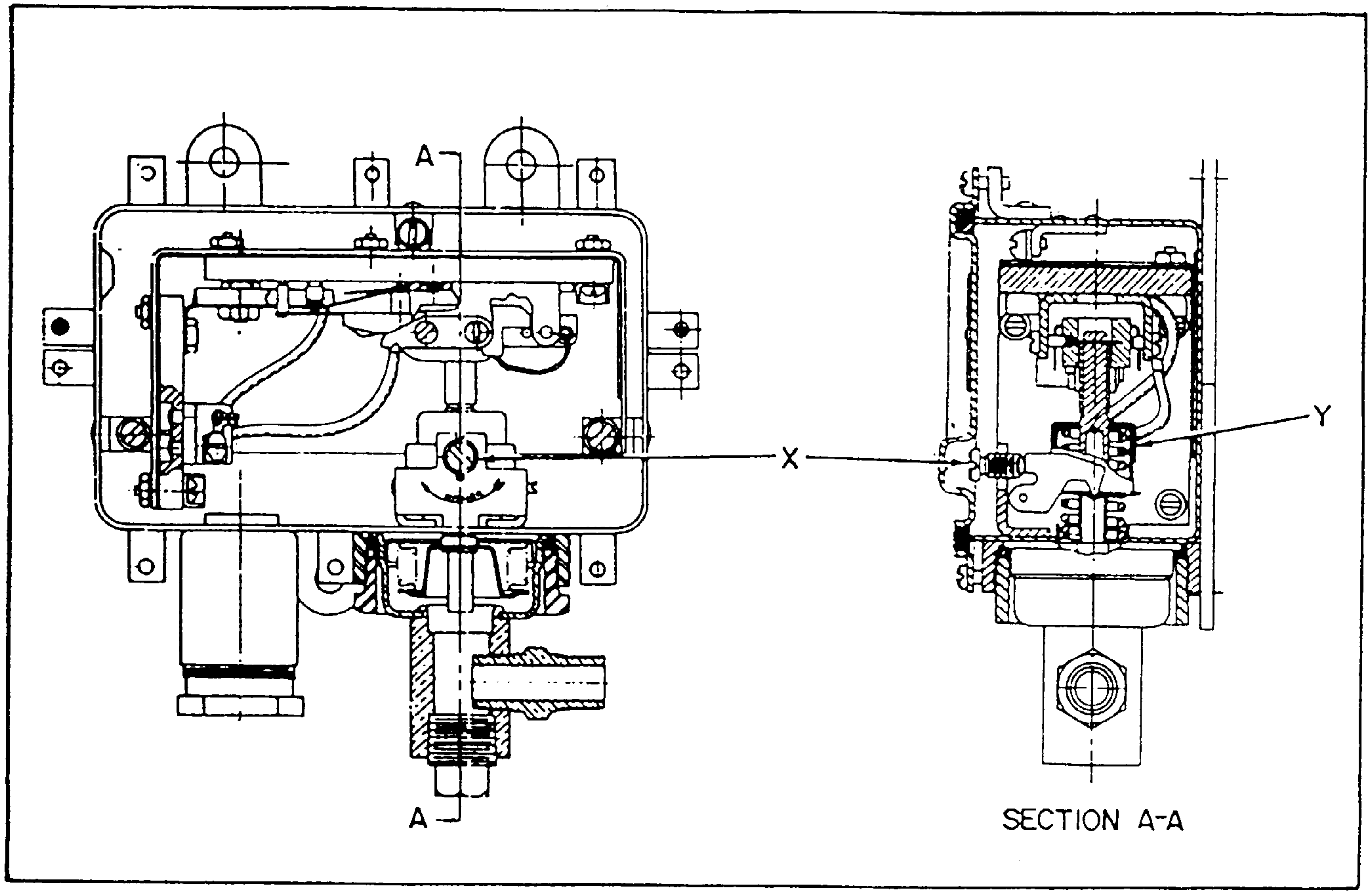


Figure 2-15.—Type IC/N pressure switch.

switch or located in a remote space and connected to the switch by a capillary tube. The temperature range at which the switches operate is adjustable at X (fig. 2-15).

Temperature-operated switches are used with the circulating-water, high-temperature alarm system; cruising-turbine exhaust alarm system; and generator-air, high-temperature alarm system.

Mechanical Switches

Mechanically operated switches are used in many types of installations, such as wrong-direction alarms and valve-position indicators.

Widely used because of their small size and excellent dependability, they are commonly called "micro switches, " or properly called sensitive switches. ("MICRO SWITCH" is a trademark of MICRO SWITCH Division, Honeywell Inc.)

These switches will open or close a circuit with a very small movement of the tripping device. They are usually of the push-button variety, and depend on one or more springs for their snap action. For example, the heat of the sensitive switch is a beryllium copper spring, heat-treated for long life and unfailing action. The simplicity of the one-piece spring contributes to the long life and dependability of this switch. The basic sensitive switch is shown in figure 2-16.

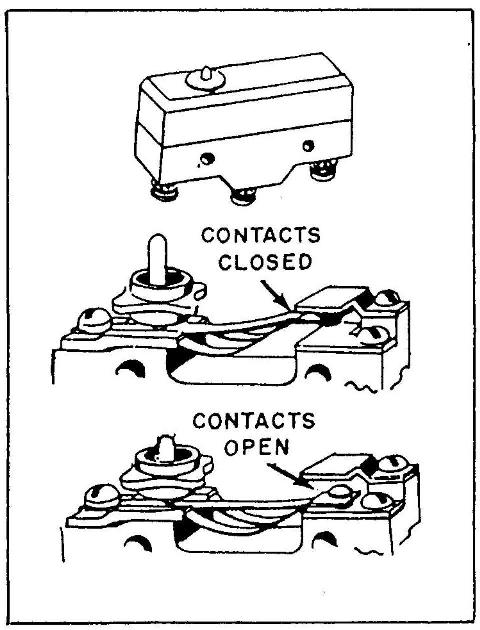


Figure 2-16.—Sensitive switch.

The types of mechanically operated switches are the push-action (type A-S) and the cam-action (types P and P41). The push-operated switch, provided for bulkhead mounting, is a single-throw or multiple-throw, momentary action, normally open push switch. The push-action mechanism uses a straight-line movement of the shaft to operate the electrical contacts. The cam-action switch consists of two SPDT sensitive switches operated by two adjustable cams mounted on the rotor shaft (fig. 2- 17).

The cam-action mechanism uses a rotary motion of the shaft to move cams, which in turn operate sensitive switches. The points of operation of the sensitive switches are varied by adjusting the angular positions of the cams with respect to the shaft on which they are mounted. Mechanical switches are used with the following systems:

QA Air-lock indicator

PW Clutch-position indicator

SP Shaft-position alarm

LS Submersible steering-gear alarm

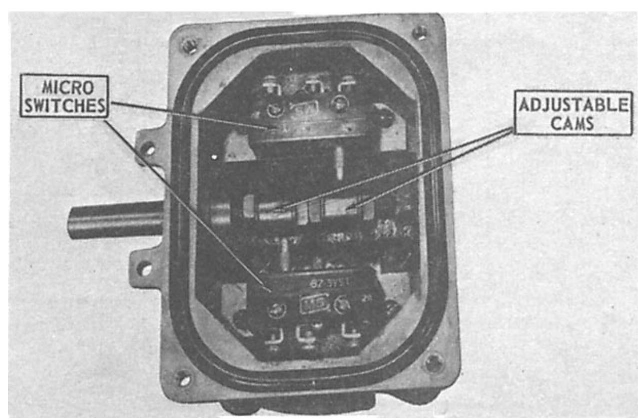
DW Wrong-direction alarm

TR Hull-opening indicator

VS Valve-position indicator

Water Switch

A water switch consists of a pair of terminals mounted in an insulated base within a cast fitting (fig. 2-18). There is a 7000-ohm, 5-watt resistor connected across the two terminals, which limits the current to the required value for the supervisory circuit when the



140.6

Figure 2-17.—Cam-action mechanical switch.

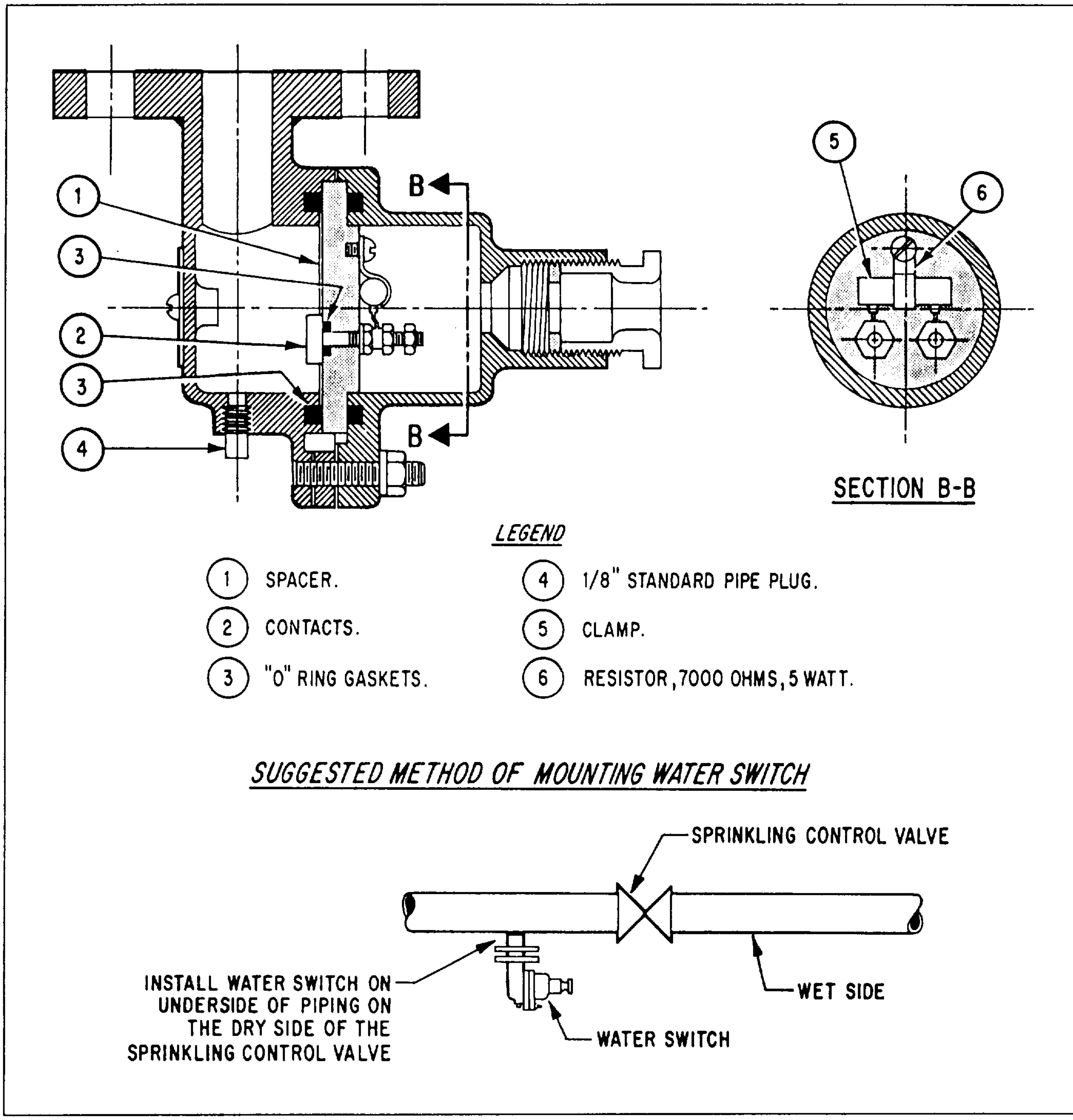


Figure 2-18.—Water switch.

switch casting is dry. The switch is mounted in the magazine flooding system, and a sprinkling control valve is installed between the switch and the firemain. When the sprinkling control valve is opened, water floods the switch casting and shorts out the 5-watt resistor. With the supervisory resistor shorted, a current of sufficient value to operate the alarm will flow in the circuit.

A water switch is used principally in sprinkling alarm systems (circuit FH).

Liquid-Level Float Switch

A relatively new development in indicating alarm and control functions, the liquid-level float switch (fig. 2-19), is replacing the float-and-switch combination found in tank- and bilge-level alarms. This float switch has a doughnut-shaped, floatable magnetic core operating over an encapsulated reed switch. The entire assembly can be mounted at any predetermined level, and the switch can be made normally open or closed by reversal of the core. Level conditions are indicated as normal, above normal, or below normal.

MAINTENANCE OF SWITCHES

Switches should be checked periodically to ensure that all electrical connections and mechanical fastenings are tight. Lockwashers must be in place. Avoid overtightening the packing and nut on watertight rotary switches, as excessive pressure on the switch shaft will cause improper positioning of the switch.

Remove dirt and grease from switch and relay contacts with a cloth moistened with an approved solvent. No lubricants of any kind should be applied

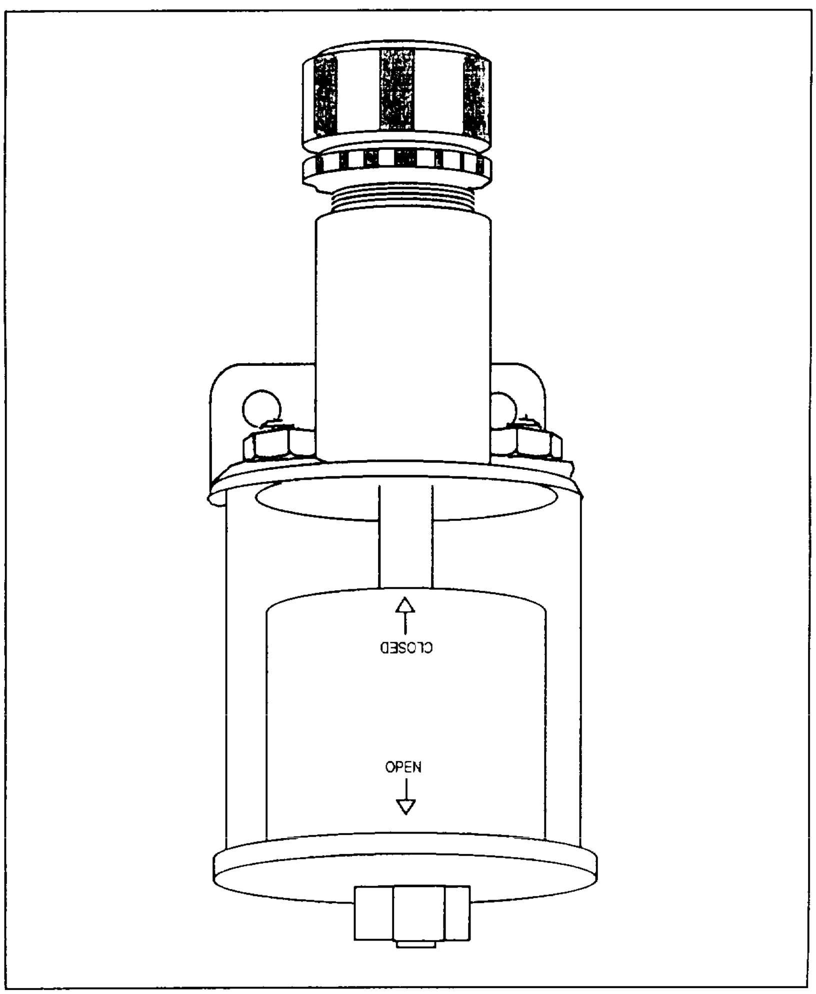


Figure 2-19.—Liquid-level float switch.

to the contacts. Use a burnishing tool for dressing small light contacts.

Clean burned copper contacts with fine sandpaper. Do not use emery cloth. Badly burned contacts should be replaced. Always replace contacts in pairs, rather than replacing a single contact.

Silver contacts require very little maintenance. Removal of the tarnish that forms on silver contacts due to arcing is no longer recommended, as this blackened condition improves the operation of the contacts.

When replacing a switch, take great care in tagging the leads to ensure proper replacement. Close supervision and proper checkout by an electrical petty officer can ensure against personal injury and equipment damage.

RELAYS

Relays are electrically operated switches. The operating coil can be connected in series with a supply line to the load or shunted across the line.

The coil design is influenced by the manner in which the relay is used. When the relay is designed for series connection, the coil is usually wound with a fairly small number of turns of large wire because the load current will be flowing through the winding. When the relay is designed for shunt connection, the coil is wound with a large number of turns of small wire, which will increase the resistance and thus lower the current through the coil.

Because the contacts of relays may open or close when energized, they can be used as protective devices or control devices or both simultaneously.

The basic difference between ac and dc relays lies in the armature and magnet core construction. The armature and magnet cores of an ac relay are made up of laminations, and those of a dc relay are of solid material. The use of laminations in an ac relay reduces the heating due to eddy currents. In addition, a copper strap or ring (called a shorted turn) is placed near the end of the pole piece of an ac relay to reduce chatter during operation. Because the ac is going through a peak, dropping to zero, going through a peak in the opposite direction, and then dropping to zero again during each complete cycle, the coil tends to release the armature each time the current drops to zero and attracts the armature each time it reaches a peak. The shorted turn acts as the secondary of a transformer, the primary of which is the relay operating coil. The current in the shorted turn is out of phase with the current of the operating coil because the copper ring has low-inductive reactance. Thus, when the operating coil flux is zero, the flux produced by the shorted coil is different from zero, and the tendency of the relay to chatter is reduced.

In general, a relay consists of a magnetic core and associated coil, contacts, springs, armature, and the mounting. Figure 2-20 illustrates the fundamental construction of a relay. When the coil is energized, the flow of current through the coil creates a strong magnetic field that pulls the armature downward to contact C1, completing the circuit from the common terminal to C1. At the same time the circuit to contact C2 is opened.

Relays are classified according to their use as control relays or power relays.

CONTROL RELAYS

Control relays are usually known simply as relays. They are frequently used in the control of low-power circuits or other relays, although they also have many other uses. Where multipole relays are used, several circuits may be controlled simultaneously. In automatic relaying circuits, a small electrical signal

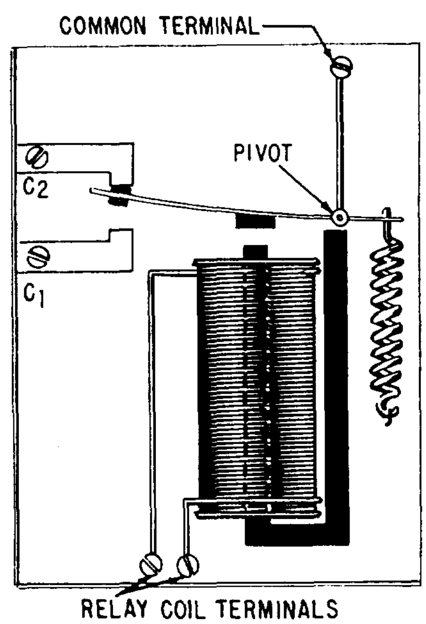


Figure 2-20.—Relay construction.

may set off a chain reaction of successively acting relays, which then perform various functions.

Control relays can also be used in so-called lockout action to prevent certain functions from occuring at the improper time. In some equipment, control relays are used to sense undervoltage and overvoltage, reversal of current, excessive currents, and so on.

Control relays are also classified as open, semisealed, or sealed. Figure 2-21 illustrates the various types of relays used today. Relays E, G, and H are examples of open relays. The mechanical motion

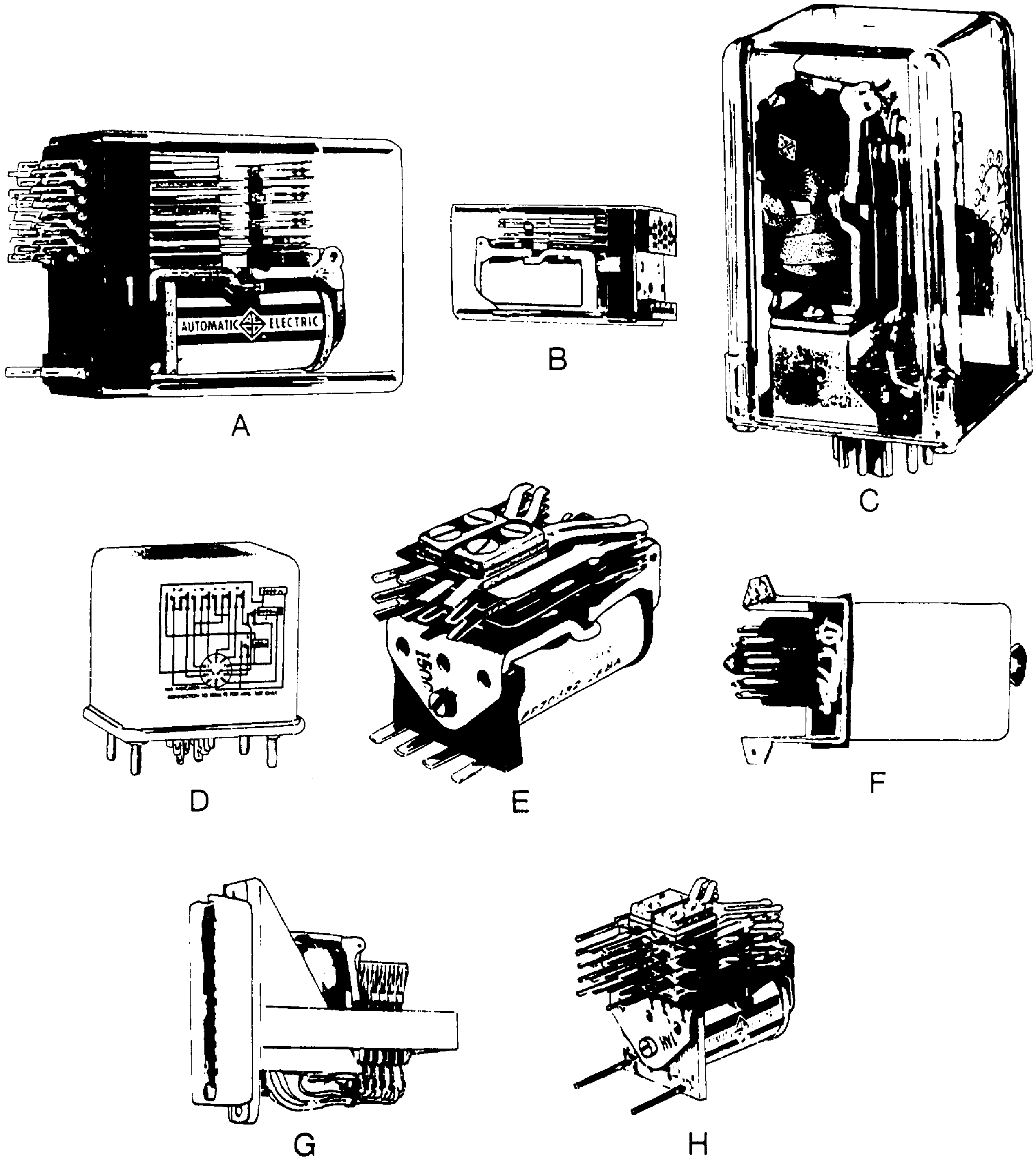


Figure 2-21.—Relay enclosures.

of the contacts can be observed and the relays are easily available for maintenance. Relays B, C, and F are semisealed relays. The covers provide protection from dust, moisture, and other foreign material, but can be removed for maintenance. Relays A and D are examples of hermetically sealed relays. These relays are protected from temperature or humidity changes as well as dust and other foreign material. The covers cannot be removed, thus making the relay tamper-proof.

Clapper Relay

The clapper relay (fig. 2-22) has multiple sets of contacts. As the circuit is energized, the clapper is pulled to the magnetic coil. Pulling the arm of the clapper forces the movable contact upward to move the pushrod and the upper movable contact. This action could be repeated for as many sets of contacts as required. Thus, it is possible to control many different circuits simultaneously. To the maintenance person, this type of relay can be a source of trouble. The motion of the clapper arm does not necessarily assure the tandem movement of all the movable contacts. If the pushrod was broken, the clapper arm would push the lower movable contact upward but would not move the upper moveable contact, thereby not completing the circuit.

Thermal Time Delay Relay

A thermal time delay relay (fig. 2-23) is constructed to produce a delayed action when energized. Its operation depends on a thermal action, such as that of a bimetallic element being heated. The element is made by welding together two strips of different metals having different thermal expansion rates. A heater is mounted around, or close to, the element, with the contacts mounted on the element itself. As the heat causes the element to bend (because of the different thermal expansion rates), the contacts close to operate a relay. The delay time of the bimetallic strips is usually from 1/2 to 1 1/2 minutes and is varied by using metals with different expansion rates or by increasing or decreasing the distance between the fixed and moving contacts.

One common form of time delay relay uses a lag coil, which is usually a large copper slug located at one end of the winding or a tubular sleeve located between the winding and the core. The lag coil (slug) acts as a short-circuited secondary for the relay coil. The counter magnetomotive force (mmf), due to the current induced in the coil by the changing coil current, delays the flux buildup or decay in the air gap and hence the closing or opening of the armature. A short slug near the armature end of the core has relatively more effect on the operating time, and one at the heel end has more effect on the release time.

Latch-In Relay

Another type of relay is the latch-in relay. This relay is designed to lock the contacts in the de-energized position until the relay is either manually or electrically reset. Two windings are used: the trip coil and the reset coil. When the trip coil is energized, it acts on a spring-loaded armature. The movable contacts of the relay are mounted on this armature. After the contacts open they are held in the open position by a mechanical latch. The mechanical latch is unlatched when the reset coil is energized, thus allowing the relay's contact to close again.

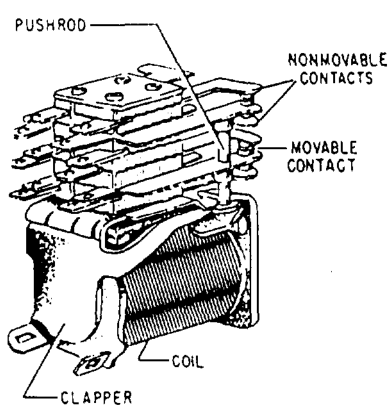


Figure 2-22.—Clapper relay.

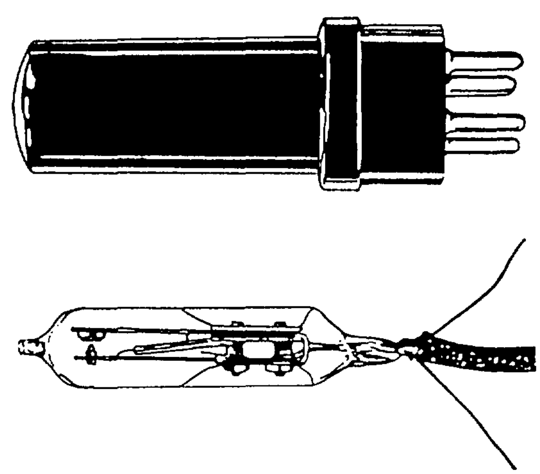


Figure 2-23.-Thermal time delay relay.

Ac Shunt Relay

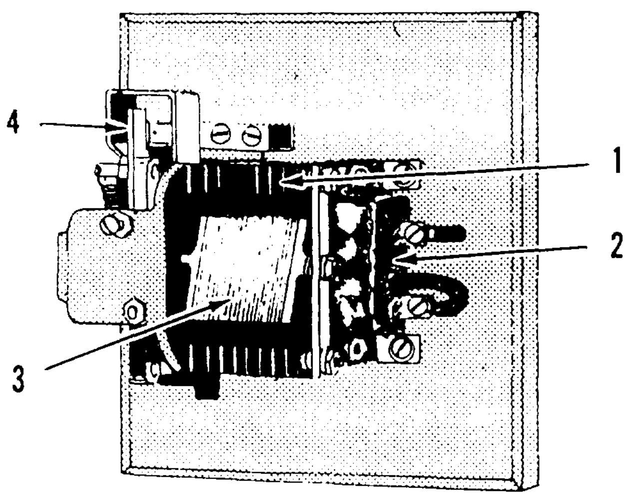
An ac shunt relay is illustrated in figure 2-24. The basic function of the relay is to make or break an electrical control circuit when the relay coil is energized. To do this, voltage is applied to the operating coil, 2 (connected across the line), which attracts the armature, 3. When the armature is pulled down, it closes the main contacts, 4.

The pull-in and dropout current values may be adjusted. In figure 2-25 the various adjustment points of the ac shunt-type relay are indicated. The spring, A, and the setscrew, E, control the pickup and dropout values. Before the relay is adjusted, the screw, F, should be set to clear the armature when the armature is in the closed position. The pull-in value can be raised by increasing the spring tension or by increasing the armature gap.

Series-Type Relays

The series-type relays are operated by circuit current flowing through the coil or coils. This feature makes it possible to use the relay as a field failure relay or for any application where the relay operation is in response to changes in circuit current flow.

There are two adjustments on the two-coil relay. One adjustment sets the difference between the opening and closing current values. The other adjustment sets the range of operating values. Usually, the operating adjustment is the only one required.



1. Magnetic frame
2. Operating coil
3. Armature
4. Main contacts

Figure 2-24.—Ac shunt relay.

POWER RELAYS

Power relays, also known as contractors, use a relatively small amount of electrical power to control the switching of a large amount of power. The relay permits you to control power at other locations in the equipment, and the heavy power cables need be run only through the power relay contacts.

Only lightweight control wires are connected from the control switches to the relay coil. Safety is also an important reason for using power relays, since high-power circuits can be switched remotely without danger to the operator.

MAINTENANCE OF RELAYS

Relays are some of the most dependable electromechanical devices in use; but like any other mechanical or electrical device, they occasionally wear out or become inoperative.

Relay contact surfaces must be kept clean and in good operating condition. Contact clearances or gap settings must be maintained according to the relay's operational specifications.

Under normal operating conditions, most relay contacts spark slightly; this will cause some minor burning and pitting of the contacts.

The buildup of film on the contact surfaces of a relay is another cause of relay trouble. Carbon buildup, which is caused by the burning of a grease film or other substance (during arcing), also can be troublesome. Carbon forms rings on the contact

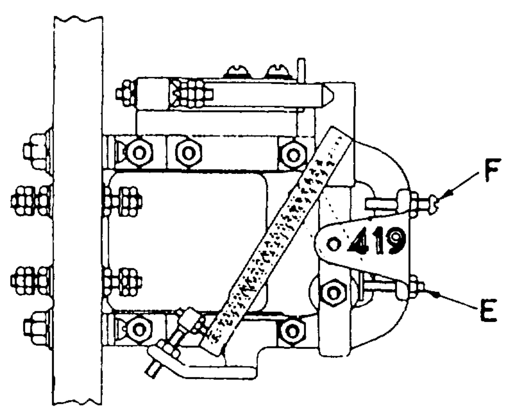


Figure 2-25.-Adjustment points of an ac shunt relay.

surfaces; and as the carbon rings build up, the relay contacts are held open.

When current flows in one direction through a relay, the contacts may be subjected to an effect called cone and crater. The crater is formed by the transfer of the metal of one contact to the other contact, the deposit being in the form of a cone. This condition is shown in figure 2-26, view A.

Some relays are equipped with ball-shaped contacts which, in many applications, are superior to the flat contacts. Dust or other substances do not collect as readily on a curved surface. In addition, a ball-shaped contact can penetrate film more easily than a flat contact. Figure 2-26, view B, shows a set of ball-shaped contacts.

When you clean or service ball-shaped relay contacts, be careful to avoid flattening or otherwise altering the rounded surfaces of the contacts. A burnishing tool should be used to clean relay contacts. Be sure you do not touch the surface of the tool that is used to clean the relay contacts. After the burnishing tool is used, clean it with alcohol. Never use sandpaper or emery cloth to clean relay contacts. Many relays have been damaged or ruined because the contact points were cleaned with sandpaper or emery cloth instead of a burnishing tool. The use of sandpaper or emery cloth may cause bending of the contact springs and other damage. Excessively burned and pitted contacts cannot be repaired by burnishing.

When a relay has bent contacts, you should use a point bender (fig. 2-27) to straighten the contacts. The use of any other tool could cause further damage, and the entire relay would then have to be replaced.

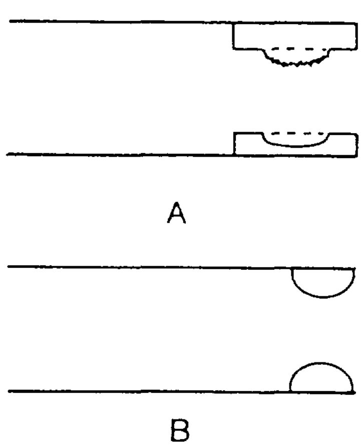


Figure 2-26.—Relay contacts.

Relays similar to the shunt relay (fig. 2-24) have replaceable contacts that should be maintained similar to switch contacts. See Maintenance of Switches at the beginning of this chapter for further information.

During preventive maintenance you should check for charred or burned insulation on the relay and for darkened or charred terminal leads. Both of these conditions indicate overheating, and further investigation should be made to determine the cause. One possible cause for overheating is loose power terminal connections, allowing arcing at the connection.

Covers should not be removed from semisealed relays in the field. Removal of a cover in the field, although it might give useful information to a trained eye, may result in entry of dust or other foreign material that may cause poor contact or an open circuit. Removal of the cover may also result in loss of or damage to the cover gasket. When the relay is installed in a position where there is a possibility of contact with explosive fumes, extra care should be taken with the cover gasket. Any damage to, or incorrect seating of, the gasket increases the possibility of igniting the vapors.

Should an inspection determine that a relay has exceeded its safe life, the relay should be removed immediately and replaced with another of the same type. The replacement relay must have the same characteristics or ratings, such as voltage, amperage, type of service, number of contacts, or continuous or intermittent duty.

Relay coils usually consist of a single coil. If a relay fails to operate, the coil should be tested for open circuit, short circuit, or short to ground. An open coil is a common cause of relay failure.

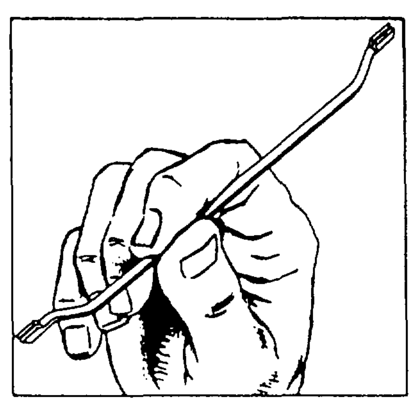


Figure 2-27.—Point bender.

SOLENOIDS

Solenoids are electromagnets formed by a conductor wound in a series of loops in the shape of a helix (spiral), Inserted within this spiral or coil is a soft-iron core and a movable plunger. The soft-iron core is pinned or held in position and therefore is not movable. The movable plunger (also soft iron) is held away from the core by a spring when the solenoid is de-energized (fig. 2-28).

When current flows through the conductor, a magnetic field is produced. This field acts in every respect like a permanent magnet having both a north and a south pole. The total magnetic flux density produced is the result of the generated mmf and the permeability of the medium through which the field passes.

In much the same way that electromotive force (emf) is responsible for current in a circuit, mmf is responsible for external magnetic effects. The mmf that produces the magnetic flux in a solenoid is the product of the number of turns of wire and the current through the coil. If the current is expressed in amperes, the mmf is expressed in ampere-turns.

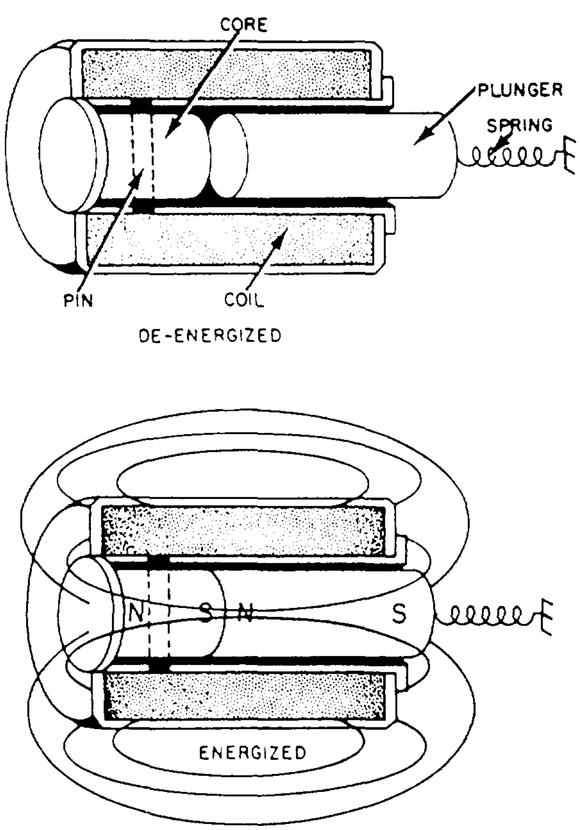


Figure 2-28.-Solenoid action.

From this it can be seen that a prescribed mmf can be produced by using either a few turns of large wire (high current) or many turns of small wire (low current).

The soft-iron core will also influence the strength of the magnetic flux produced by the coil. The strength of the field is greatly increased by the use of a soft-iron core due to the greater permeability of iron in respect to air. Consequently, by using an iron core, a greater flux density can be produced for a given number of ampere-turns.

The magnetic flux produced by the coil will result in establishing north and south poles in both the core and the plunger. These poles have such a relationship that the plunger is attracted along the lines of force to a position of equilibrium when the plunger is at the center of the coil. As shown in figure 2-28, the de-energized position of the plunger is partially out of the coil due to the action of the spring. When voltage is applied, the current through the coil produces a magnetic field that draws the plunger within the coil, thereby resulting in mechanical motion. When the coil is de-energized, the plunger returns to its normal position by the spring action. It is interesting to note that the effective strength of the magnetic field on the plunger varies with the distance between the two. For short distances, the strength of the field is strong; and as distances increase, the strength drops off quite rapidly.

USES OF SOLENOIDS

Solenoids are used for electrically operating hydraulic valve actuators, carbon pile voltage regulators, power relays, and mechanical clutches. They are also used for many other purposes where only small movements are required. One of the distinct advantages in the use of solenoids is that a mechanical movement can be accomplished at a considerable distance from the control. The only link necessary between the control and the solenoid is the electrical wiring for the coil current.

MAINTENANCE OF SOLENOIDS

The first step to be taken in checking an improperly operating solenoid is a good visual inspection. The connections should be checked for poor soldering, loose connections, or broken wires.

The plunger should be checked for cleanliness, binding, mechanical failure, and improper alignment adjustment. The mechanism that the solenoid is to actuate should also be checked for proper operation.

The second step should be to check the energizing voltage by use of a voltmeter. If this voltage is too low, the result would be less current flowing through the coil and thereby a weak magnetic field. A weak magnetic field can result in slow, ineffective operation. It could also possibly result in chatter or inoperation. If the energizing voltage is too high, it will in all probability damage the solenoid by either overheating or arcing. In either case, the voltage should be reset to the proper value so further damage or failure will not result.

The solenoid should then be checked for opens, shorts, grounds, and correct resistance with an ohmmeter. If when you check the resistance of the solenoid the ohmmeter indicates infinity, the solenoid is open-circuited and should be replaced. If the ohmmeter reads zero or less than the specified resistance, the coil is shorted and should be replaced. However, if the resistance of the coil is higher than specified (but not infinity), look for a poor contact or a damaged conductor. If the fault cannot be found or corrected, replace the solenoid. Another check possible with the ohmmeter is to determine if the coil is grounded. If the coil is grounded, reinsulate the solenoid.

PROTECTIVE DEVICES

Most protective devices are designed to interrupt the power to a circuit or unit under abnormal conditions, such as short circuits, overloads, high or low voltage, and excessive current. The most common types of protective devices are fuses, circuit breakers, and overload relays.

FUSES

A fuse is a protective device used to open an electric circuit when the current flow exceeds a safe value. Fuses are made in many styles and sizes for different voltages and currents, but they all operate on the same general principle. Each fuse contains a soft-metal link that melts and opens the circuit when overheated by excessive currents.

Plug Fuses

A plug fuse (fig. 2-29) has a piece of zinc-alloy wire mounted in a porcelain cup with a metal cover. A threaded contact base similar to a lamp socket is provided so that the fuse can be screwed into a socket in the fuse block. Plug fuses are used on small-capacity circuits ranging from 3 to 30 amperes at not more than 250 volts. Some plug fuses have small mica windows so the fusible link can be observed. Plug fuses are not normally used in naval vessels and are seldom used in commercial applications; however, they can be found in older buildings and houses.

Cartridge Fuses

A cartridge fuse (fig. 2-30) consists of a zinc-alloy link enclosed in a fiber, plastic, ceramic, or

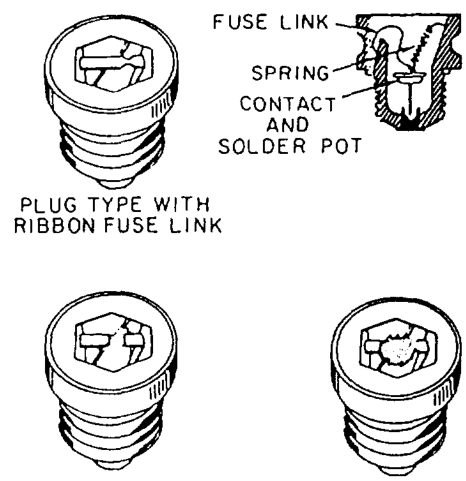


Figure 2-29.—Plug fuse.

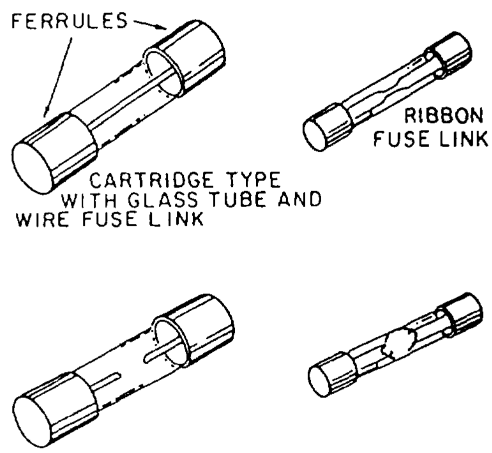


Figure 2-30.-Cartridge fuse.

glass cylinder. Some fiber and plastic fuse cylinders are filled with nonconducting powder. The smaller fuses are used in circuits up to 60 amperes and are made in the ferrule, or round-end cap, type. Large sizes with short flat blades attached to the end caps are rated from 65 to 200 amperes. These blades fit tightly into clips on the fuse block similar to knife-switch clips.

Cartridge fuses are made in capacities of 1 through 1000 amperes for voltages of 125, 250, 500, 600, and 1000 volts. Fuses intended for 600- and 1000-volt service are longer and do not fit the same fuse holders intended for lower volt service. Fuses of different ampere capacity are also designed for different sizes of holders. For example, fuses of 1 through 30 amperes fit one size of holder, and fuses with capacities of 35 through 60 amperes fit a different size holder.

Cartridge fuses in IC equipment are of various sizes, such as the miniature FO2 or FO3 (1 1/4- by 1/4-inch) fuse rated from 0.1 to 30 amperes at 125 volts and the midget FO9 (1 1/2- by 13/32-inch) fuse rated for 0.1 through 30 amperes at 125 volts. The standard 2- by 9/16-inch fuse is rated from 1 to 30 amperes, 500 volts for ac service and 250 volts for dc service. Fuses above 60-ampere capacity have knife-blade contacts and increase in diameter and length as the capacity increases.

Before fuses of greater than 10-ampere capacity are pulled, the switch for the circuit should be opened. Whenever possible, this precaution should be taken before any size fuse is pulled or replaced. Approved fuse pullers must be used for removing fuses. Fuses should never be short-circuited or replaced with fuses of larger current capacity.

Time-Delay Fuses

Time-delay fuses are used in motor supply circuits, for example, where overloads and motor-starting surges of short duration exist. A conventional fuse of much higher rating would be required to prevent blowing of the fuse during surges. Because of its high rating, this fuse could not provide necessary protection for the normal steady-state current of the circuit.

Time-delay fuses are rated as to their time lag characteristics with a minimum blowing time at some overload current. A typical rating is 12 seconds minimum blowing time at 200 percent rated current.

Selection of Proper Fuses

Individual fuses are provided on the IC switchboards for each associated circuit. A separate fuse in each line of each circuit has the effect of considerably increasing the maximum short-circuit current that the fuses can safely interrupt. It also provides greater protection to the remaining circuits energized from the same bus in case of a possible defect in one fuse.

In general, fuse ratings should be approximately 10 percent above the maximum continuous connected load. In circuits, such as call bell systems and alarm systems where only a small portion of the circuit is likely to be operated at any one time, the fuse rating should be 10 percent greater than the load of one associated group of signals operated, or 15 percent of the total connected load, whichever is greater. Where the circuit incorporates branch fuses, such as those associated with the fire-control (FC) switchboards, the rating of the fuses on the IC switchboard should be 20 percent above the maximum connected load to provide sufficient margin so branch fuses will always blow before the main fuses. In no case should the fuse rating be greater than 2 1/2 times the rated capacity of the smallest cable in the circuit. If too large a fuse were used, a fire hazard would exist.

Fuse Holders

The type EL-1 fuse holder consists of a base and a plug, as shown in figure 2-31. The base extends behind the panel, and the plug containing the fuse is screwed into the base. Behind a hole in the plug cap is a small neon lamp that serves as a blown-fuse indicator, lighting when the energized circuit through the holder is interrupted by the blowing of a fuse. Series resistors of different values are used with the lamp on 125- and 250-volt circuits, except for the midget holder, which is rated for 125 volts only.

The types FHL10U, FHL11U, and FHL12U (fig. 2-32) consist of a fuse holder body and a fuse carrier. The body is mounted on the panel, and the carrier with the fuse placed in the clips is inserted into the body in a manner similar to inserting a bayonet-type lamp into a socket. Removal of the fuse is accomplished by pushing and turning the fuse carrier in a counterclockwise direction, again similar to the removal of a bayonet-base lamp. The types FHL10G and FHL11G accommodate 1 1/4- by 1/4-inch fuses. The type FHL10G will hold two fuses and can therefore be used to fuse both sides of the line, or, in conjunction with a type FHL11G, will fuse a 3-phase line. Type FHL12G will accommodate 1 1/2- by 13/32-inch fuses. When these fuse holders are mounted in a dripproof enclosure, they maintain the dripproof integrity. They also possess the ruggedness and the vibration and high-impact shock resistance necessary for shipboard use.

The extensive use of low-voltage power supplies has required the use of incandescent lamps in place of neon glow lamps in some indicator light circuits. A modification of the FHL10U fuse holder provides a third terminal connected to a 28-volt incandescent lamp in the cap. By insertion of a suitable resistor between the load terminal and the added terminal, the lamp will be energized by a sufficient voltage to become visible when the fuse has blown. In some low-voltage fuse holders the resistor and lamp are included within the clear plastic cap. Low-voltage fuse holders should not be used in sensitive, low-current equipment. Where an overload condition occurs and the fuse blows, the low-resistance indicator circuit may pass sufficient current to damage the equipment.

Due to the design of certain fuses and in cases where space does not permit indicator-type fuse holders, separate indicator light circuits are mounted on a panel and connected in parallel with separately mounted fuses and fuse clips. In some cases an alarm circuit in the form of a bell or buzzer takes the place of the indicator light.

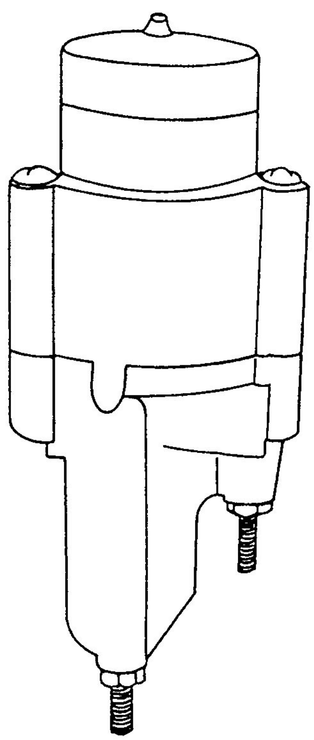


Figure 2-31.—Type EL-1 fuse holder.

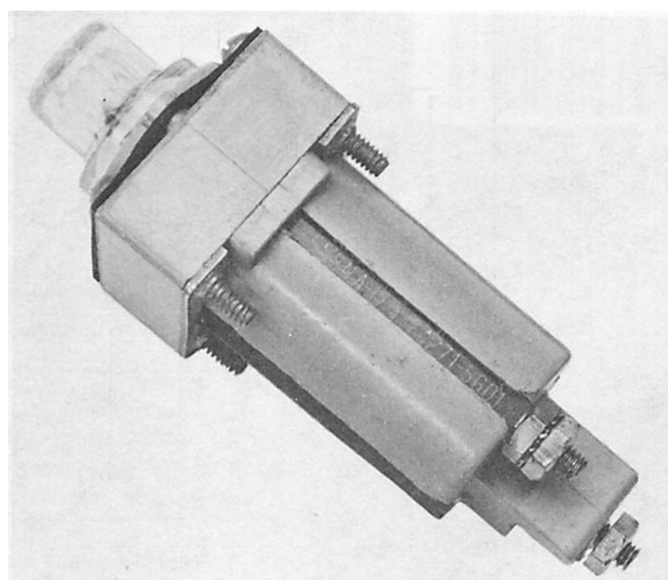
Troubleshooting Fuse Circuits

An electrical system may consist of a comparatively small number of circuits or, in the larger systems, the installation may be equal to that of a fair-sized city.

Regardless of the size of the installation, an electrical system consists of a source of power (generators or batteries) and a means of delivering this power from the source to the various loads (lights, motors, and other electrical equipments).

From the main power supply the total electrical load is divided into several feeder circuits, and each feeder circuit is further divided into several branch circuits. Each final branch circuit is fused to safely carry only its own load, while each feeder is safely fused to carry the total current of its several branches. This reduces the possibility of one circuit failure interrupting the power for the entire system. The feeder distribution boxes and the branch distribution boxes contain fuses to protect the various circuits.

The distribution wiring diagram showing the connections that might be used in a lighting system is



140.13

Figure 2-32.—Type FHL12U fuse holder.

illustrated in figure 2-33. An installation might have several feeder distribution boxes, each supplying six or more branch circuits through branch distribution boxes.

Fuses F1, F2, and F3 (fig. 2-33) protect the main feeder supply from heavy surges, such as short circuits or overloads on the feeder cable. Fuses **A-A₁** and **B-B₁** protect branch No. 1. If trouble develops and work is to be done on branch No. 1, switch S_1 may be opened to isolate this branch. Branches 2 and 3 are protected and isolated in the same manner by their respective fuses and switches.

VOLTAGE TESTER.— The most commonly used voltage tester now available to the fleet is the multifrequency type. This tester has electronic circuitry and glow lamps to indicate voltage, frequency, and polarity. One, two, or three lamps are used to indicate the ac or dc voltage. The other lamps identify the ac frequency (60 or 400 Hz) or whether the dc circuit being tested has negative polarity applied to either the red probe or the black probe. This tester is designed for operation of 28 to 550 volts ac or 28 to 600 volts dc.

Before being taken from the shop and used on a circuit, a voltage tester must be tested for proper operation on a known voltage source, such as the electric shop test panel.

If your voltage tester is inoperative, turn it in to your leading petty officer.

Never use a lamp in a "pigtail" lamp holder as a voltage tester. Lamps designed for use on low voltage (120 volts) may explode when connected across a higher voltage (440 volts). In addition, a lamp would only indicate the presence of voltage, not the amount of voltage. Learn to use and rely on standard test equipment.

BRANCH CIRCUIT TESTS.— Usually, receptacles for portable equipment and fans are on branch circuits separate from lighting branch circuits. Test

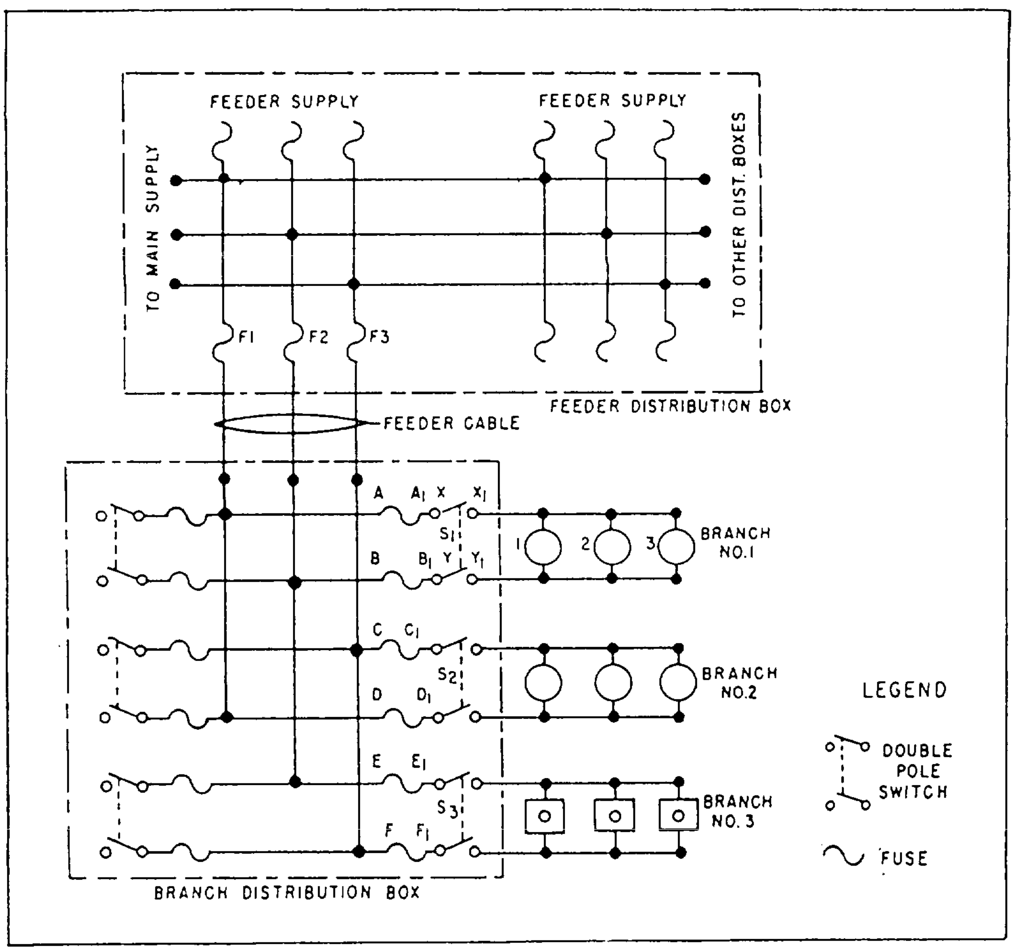


Figure 2-33.—Three-phase distribution wiring diagram.

procedures are the same for any branch circuit. Therefore, a description will be given on the steps necessary to (1) locate the defective circuit and (2) follow through on that circuit and find the trouble.

Assume that, for some reason, several of the lights are not working in a certain section. Because several lights are out, it will be reasonable to assume that the voltage supply has been interrupted on one of the branch circuits.

To verify this assumption, first locate the distribution box feeding the circuit that is inoperative. Then make sure that the inoperative circuit is not being supplied with voltage. Unless the circuits are identified in the distribution box, the voltage at the various circuit terminations will have to be measured. For the following procedures, use the circuits shown in figure 2-33 as an example.

To pin down the trouble, connect the voltage tester to the load side of each pair of fuses in the branch distribution box. No voltage between these terminals indicates a blown fuse or a failure in the supply to the distribution box. To find the defective fuse, make certain S_1 is closed, connect the voltage tester across A-A_1, and next across B-B_1 (fig. 2-33). The full-phase voltage will appear across an open fuse, provided circuit continuity exists across the branch circuit. However, if there is an open circuit at some other point in the branch circuit, this test is not conclusive. If the load side of a pair of fuses does not have the full-phase voltage across its terminals, place the tester leads on the supply side of the fuses. The full-phase voltage should be present. If the full-phase voltage is not present on the supply side of the fuses, the trouble is in the supply circuit from the feeder distribution box.

Assume that you are testing at terminals A-B (fig. 2-33) and that normal voltage is present. Move the test lead from A to A_1. Normal voltage between A_1 and B indicates that fuse A-A_1 is in good condition. To test fuse B-B_1, place the tester leads on A and B, and then move the lead from B to B_1. No voltage between these terminals indicates that fuse B-B_1 is open. Full-phase voltage between A and B_1 indicates that the fuse is good.

This method of locating blown fuses is preferred to the method in which the voltage tester leads are connected across the suspected fuse terminals, because the latter may give a false indication if there is an open circuit at any point between either fuse and the load in the branch circuit.

CIRCUIT BREAKERS

Circuit breakers have three fundamental purposes: to provide circuit protection, to perform normal switching operations, and to isolate a defective circuit while repairs are being made.

Circuit breakers are available in manually or electrically operated types that may or may not provide protective functions. Some types may be operated both ways, while others are restricted to one mode.

Types of Air Circuit Breakers

Air circuit breakers are used in switchboards, switch gear groups, and in distribution panels. The types installed on naval ships are ACB, AQB, AQB-A, AQB-LF, NQB-A, ALB, and NLB. They are called air circuit breakers because the main current-carrying contacts interrupt in air.

ACB CIRCUIT BREAKERS.— Figure 2-34 shows the exterior of a type ACB circuit breaker. This

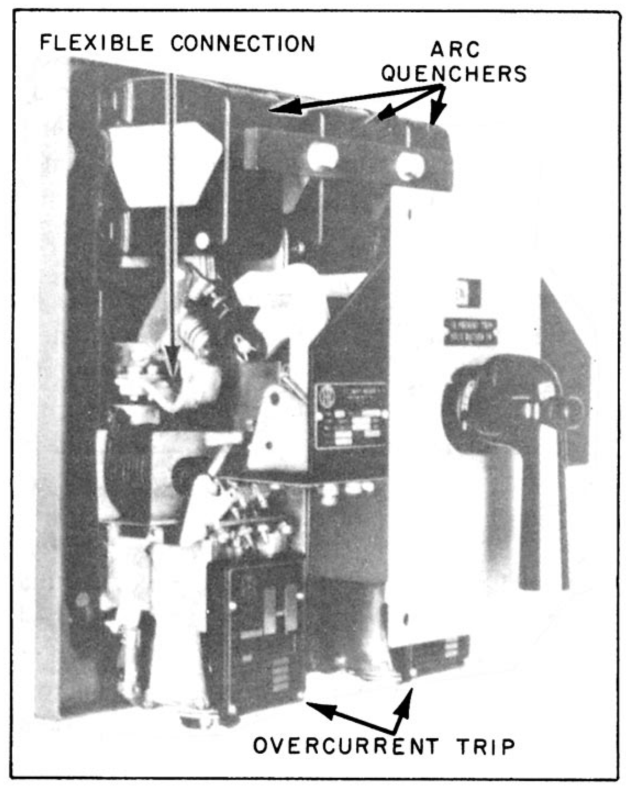


Figure 2-34.—Type ACB circuit breaker.

circuit breaker is designed for either manual local closing or electrical remote closing. It has an open metallic frame construction mounted on a drawout mechanism and is normally used to supply heavy loads and to protect the equipment from high short-circuit currents.

Type ACB circuit breakers are used to connect ship's service and emergency generators to the power distribution system. They are also used on bus ties and shore connection circuits, and on some feeder circuits from the ship's service switchboard. In these applications, they operate usually with a pilot device, such as a relay or a switch. An electrically operated circuit breaker has an electromagnet that acts as a solenoid to trip a release mechanism that causes the breaker contacts to open. The energy to open the breaker is derived from a coiled spring. The electromagnet is controlled by the contacts in the pilot device.

Circuit breakers designed for high currents have a double-contact arrangement. The complete contact assembly consists of the main bridging contacts and the arcing contacts. All current-carrying contacts are high-conductivity, arc-resisting silver or silver-alloy inserts.

Each contact assembly has a means of holding the arcing to a minimum and extinguishing the arc as soon as possible. The arc control section is called an arc chute or arc runner. The contacts are so arranged that when the circuit is closed, the arcing contacts close first. Proper pressure is maintained by springs to ensure that the arc contacts close first. The main contacts then close.

When the circuit opens, the main contacts open first. The current is then flowing through the arc contacts, which prevents burning of the main contacts. When the arc contacts open, they pass under the front of the arc runner, creating a magnetic field that blows the arc up into the arc quencher and quickly opens the circuit.

Type ACB circuit breakers are either manually (hand operated) or electrically operated. Electrically operated ACB breakers may be operated from a remote location, making it unnecessary for personnel to approach them in order to open or close the circuit.

AQB CIRCUIT BREAKERS.— Type AQB circuit breakers are mounted in supporting and enclosing housings of insulating material and have direct-acting automatic tripping devices. They are used to protect single-load circuits and all feeder circuits coming from a load center distribution panel.

Where the requirements are low enough, the type AQB may be used on generator switchboards. When it becomes necessary to replace one of the older type AQB circuit breakers, you should replace it with the newer AQB-A101, AQB-A250, AQB-A400, AQB-A600, or AQB-A800, as required.

AQB-A CIRCUIT BREAKERS.— The newer AQB type of circuit breakers, such as the AQB-A250 (fig. 2-35, views A, B, and C), have several advantages over the older types. They are designed for front or rear connections as required. They may be mounted so as to be removable from the front without removing the circuit breaker cover. The outside dimensions of these new breakers are the same for both the two-pole and three-pole circuit breakers.

The 250 part of the circuit breaker designation indicates the frame size of the circuit breaker. The current-carrying parts of a 250-ampere frame size circuit breaker have a continuous rating of 250 amperes. The voltage ratings of the AQB-A250 are 500 volts ac, 670 Hz or 250 volts dc.

Trip units for this breaker are available with current ratings of 125, 150, 175, and 250 amperes. The trip unit houses the electrical tripping mechanisms, the thermal element for tripping the circuit breaker on overload conditions, and the instantaneous trip for tripping on short-circuit conditions.

In addition, 100-, 160-, and 250-ampere rating trip units with a special calibration are available for use with generator circuit breakers. Regardless of the trip unit used, the breaker is still a 250-ampere frame sire. The automatic trip devices of the AQB-A250 circuit breaker are "trip free" of the operating handle; in other words, the circuit breaker cannot be held closed by the operating handle if an overload exists. When the circuit breaker has tripped due to overload or short circuit, the handle rests in a center position. To reclose the circuit breaker after automatic tripping, move the handle to the extreme OFF position. This resets the latch in the trip unit. Then move the handle to the ON position.

AQB-LF CIRCUIT BREAKER.— The AQB-LF type of circuit breaker, such as the

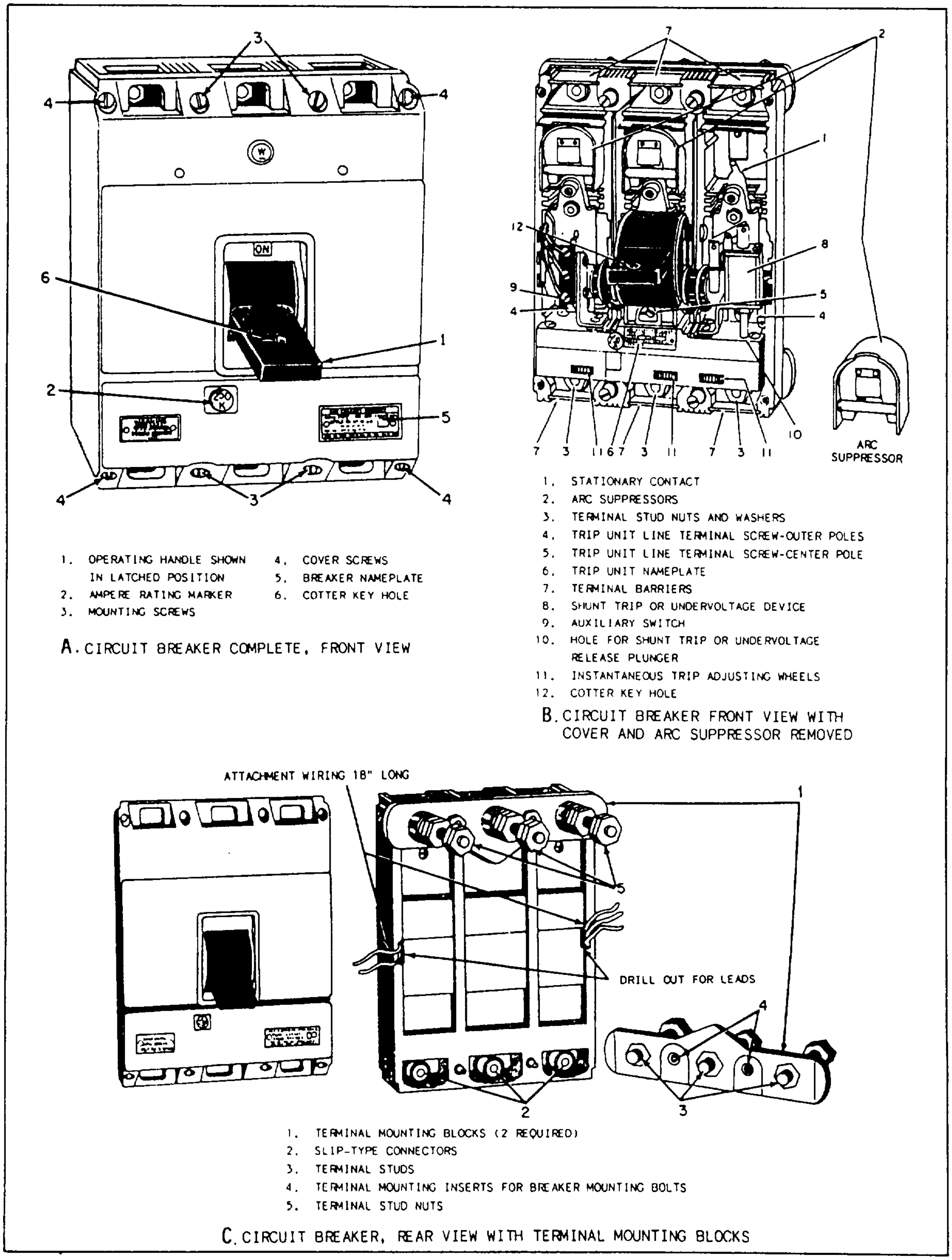
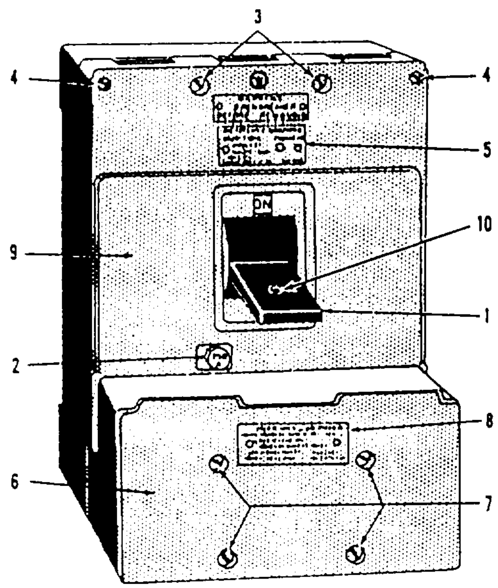


Figure 2-35.—Type AQB-A250 circuit breaker.



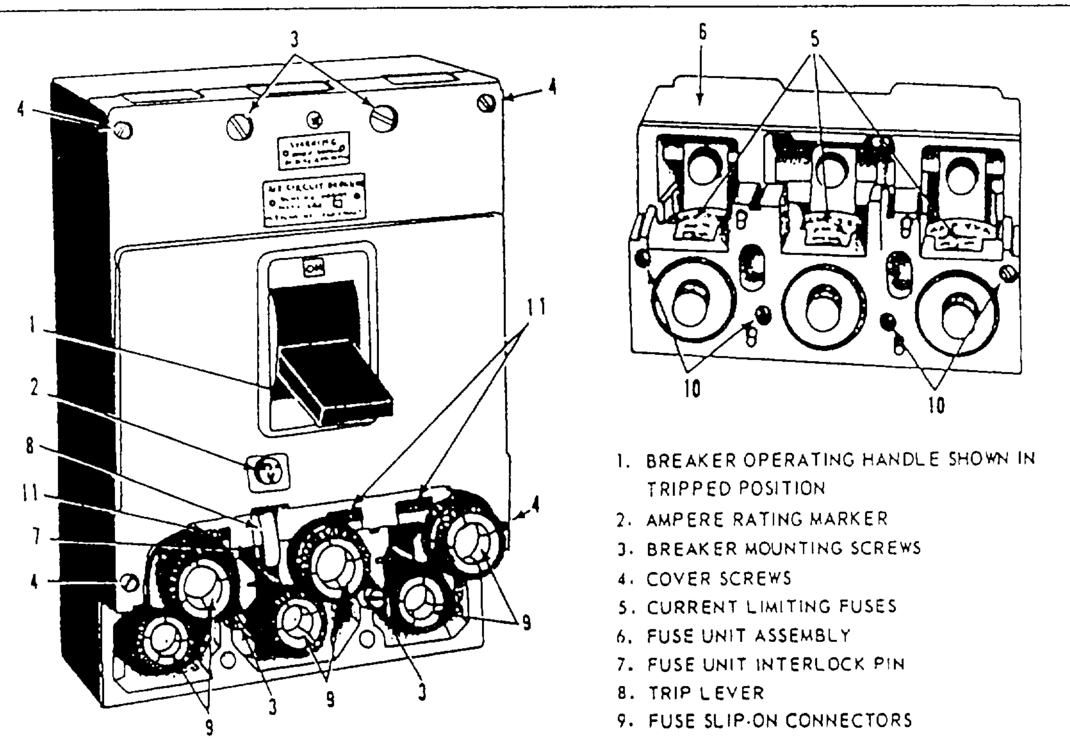
1. **Operating handle shown in latched position**
2. **Ampere rating marker**
3. **Breaker mounting screws**
4. **Cover screws**
5. **Breaker nameplate**
6. **Fuse unit assembly**
7. **Fuse unit mounting screws**
8. **Fuse unit nameplate**
9. **Breaker cover**
10. **Cotter key hole**

Figure 2-36.-Type AQB-LF250 complete circuit breaker, front view.

AQB-LF250 (fig. 2-36), combines the standard AQB circuit breaker and a current-limiting fuse unit. This fuse unit interrupts the circuit when the current is in excess of the interrupting rating of the breaker. Constructed as one compact unit, the AQB-LF circuit breaker incorporates the current-limiting fuses (fig. 2-37) as integral parts of the circuit breaker. The common trip features and trip units in this type of circuit breaker are identical to those in the AQB-A250 circuit breakers.

The current-limiting fuse unit is designed so that it trips the breaker and opens all poles if any current-limiting fuse (fig. 2-38) is blown. After a fuse has blown, the circuit breaker cannot be reclosed until the blown fuse is replaced. Any attempt to remove the fuse unit when the circuit breaker is in the closed position will automatically trip the breaker.

The AQB-LF250 circuit breaker is interchangeable with the AQB-250 circuit breaker, except a larger cutout is required in the switchboard front panel to accommodate the fuse unit of the AQB-LF250.



1. BREAKER OPERATING HANDLE SHOWN IN TRIPPED POSITION
2. AMPERE RATING MARKER
3. BREAKER MOUNTING SCREWS
4. COVER SCREWS
5. CURRENT LIMITING FUSES
6. FUSE UNIT ASSEMBLY
7. FUSE UNIT INTERLOCK PIN
8. TRIP LEVER
9. FUSE SLIP-ON CONNECTORS
10. FUSE RETAINING BLOCK SCREWS
11. INSTANTANEOUS TRIP ADJUSTING WHEELS

Figure 2-37.—Type AQB-LF250 complete circuit breaker, front view with fuse unit removed.

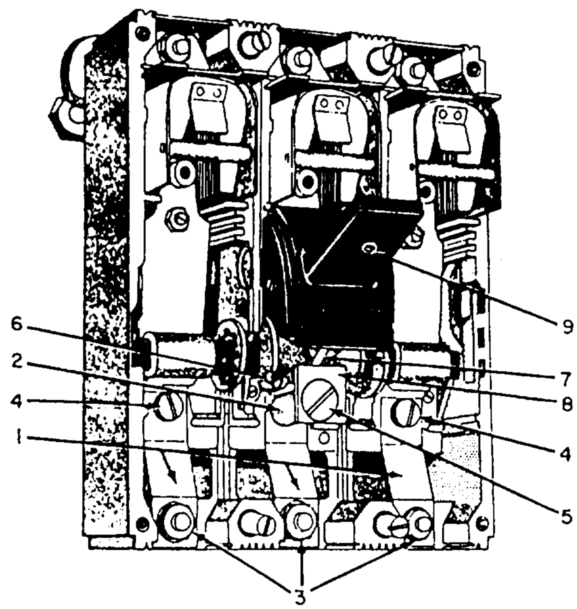
The AQB-LF250 circuit breaker is a 250-ampere frame size. However, the circuit breaker has an interrupting rate of 100,000 amperes at 500 volts ac. The AQB-A250 circuit breaker has an interrupting rating of 20,000 amperes at 500 volts ac.

While the AQB-A250 circuit breaker could be either front or back connected, the AQB-LF250 is designed for back (drawout type) connection only.

NQB CIRCUIT BREAKER.— The NQB type of circuit breaker, such as the NQB-A250 circuit breaker (fig. 2-39), is similar to the AQB-A250 circuit breaker, except the NQB-A250 has no automatic tripping devices. This type of circuit breaker is used for circuit isolation and manual transfer applications. The NQB-A250 is still a 250-ampere frame size as the current-carrying parts of the breaker are capable of carrying 250 amperes. Technically this circuit breaker is simply a large on-and-off switch. Some types of AQB and NQB breakers are provided with electrical operators mounted on the front of the breaker. These are geared motor devices for remote operation of the breaker handle.

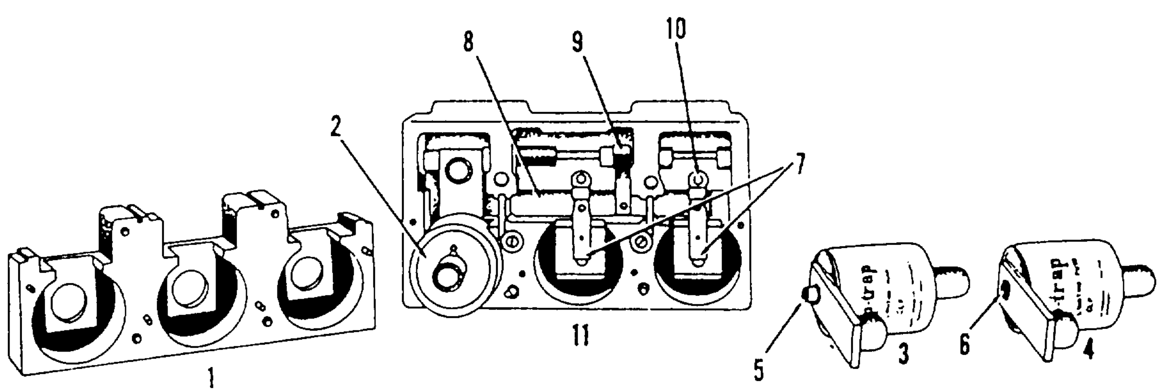
ALB CIRCUIT BREAKER.— The ALB circuit breaker is a designated low-voltage, automatic circuit breaker. The continuous duty rating ranges from 5 to 200 amperes at 120 volts ac or dc. The breaker is provided with a molded enclosure, drawout-type connectors, and nonremovable and nonadjustable thermal trip elements.

This circuit breaker is a quick-make, quick-break type. If the operating handle is in the tripped (midway between ON and OFF) position, indicating a short circuit or overload, the operating handle must be moved to the extreme off position. This automatically



1. Connector straps
2. Latch post
3. Terminal stud nuts and washers
4. Trip unit line terminal screws – outer poles
5. Latch mounting screws
6. Trip unit latch pin slot
7. Mechanism trigger
8. Mechanism trigger latch
9. Cotter key hole

Figure 2-39.-Type NQB-A250 circuit breaker, front view with cover removed.



1. Fuse retaining block
2.–4. Current-limiting fuses
5. Extended plunger of blown fuse
6. Retracted plunger of unblown fuse
7. Fuse plunger lever
8. Fuse unit tripper bar
9. Fuse unit tripper bar lever
10. Fuse interlock pin
11. Fuse unit housing

Figure 2-38.-Current-limiting fuse unit assembly for type AQB-LF250 circuit breaker.

resets the overload unit and the breaker can again be closed.

NLB CIRCUIT BREAKER.— The NLB circuit breaker is identical to the ALB circuit breaker, except it has no automatic tripping device. It is used only as an on-off switch.

Maintenance of Circuit Breakers

No circuit breaker, regardless of type, should be worked on without opening the circuit. Remember that certain terminals may have voltage applied to them even though the breaker is open. Aboard ship, power may be supplied to either end of the circuit breaker.

Circuit breakers require careful inspection and cleaning at least once a year (more frequently if subjected to unusually severe service conditions).

No work should be undertaken on circuit breakers without first obtaining approval of the electrical or engineer officer.

Before working on a circuit breaker, you should be aware of its time delay characteristics, such as short time, long time, or instantaneous trip. The adjustments for tripping the circuit breakers are made and sealed at the factory. No unauthorized changes should be made to their trip settings because these changes may completely disrupt their intended functions of protection. If improper tripping action is encountered in the contact assemblies, the fastest and easiest way to correct the problem is to replace the entire breaker assembly.

Before working on a circuit breaker, de-energize all control circuits to which it is connected; the procedure differs somewhat with the type of mounting that is employed. For example, before work is performed on drawout circuit breakers, they should be switched to the open position and removed. Before working on fixed-mounted circuit breakers, open the disconnecting switches ahead of the breakers. If disconnecting switches are not provided for isolating fixed-mounted circuit breakers, de-energize the supply bus to the circuit breaker, if practicable, before inspecting, adjusting, replacing parts, or doing any work on the circuit breaker.

Contacts are the small metal parts especially selected to resist deterioration and wear from the inherent arcing. The arcing occurs in a circuit breaker while its contacts are opening and carrying current at the same time. When firmly closed, the contacts must not arc.

Contact materials have been subjected to constant research, resulting in various products, ranging from pure carbon or copper to pure silver, each being used alone and also as alloys with other substances. Modern circuit breakers have contacts coated with silver, silver mixed with cadmium oxide, or silver and tungsten. The two latter silver alloys are extremely hard and resist being filed. Fortunately, such contacts made of silver or its alloys conduct current when discolored (blackened during arcing) with silver oxide. The blackened condition, therefore, requires no filing, polishing, or removal. As with a silver contact, silver oxide is formed during arcing; and it has been found that the addition of cadmium oxide greatly improves operation of the contact because it minimizes the tendency of one contact to weld to another, retards heavy transfer of one material to another, and inhibits erosion.

Usually, a contact containing silver is serviceable as long as the total thickness worn away does not exceed 0.030 inch.

Severe pitting or burning of a silver contact is another matter. It may require some filing (with a fine file or with fine sandpaper, No. 00) to remove raised places on surfaces that prevent intimate and overall closure of the contact surfaces. If necessary, use a CLEAN cloth moistened with INHIBITED methyl chloroform. Be very certain to provide ample ventilation to remove all DEADLY and TOXIC fumes of the solvent.

When cleaning and dressing copper contacts, maintain the original shape of each contact surface and remove as little copper metal as possible. Inspect and wipe the copper contact surfaces for removal of the black copper-oxide film; in extreme cases, dress and clean only with fine (No. 00) sandpaper to prevent scratching the surfaces. NEVER use emery cloth or emery paper. Because this copper-oxide film is a partial insulator, follow the sanding procedure by wiping with a CLEAN cloth moistened with INHIBITED methyl chloroform solvent. Provide VERY LIBERAL ventilation with exhaust fans or with portable blowers to entirely remove all traces of the deadly fumes of the solvent.

Calibration problems on circuit breakers should be handled according to *NSTM,* chapter 300.

The function of arcing contacts is not necessarily impaired by surface roughness. Remove excessively rough spots with a fine file. Replace arcing contacts when they have been burned severely and cannot be properly adjusted. Make a contact impression and check the spring pressure following the manufacturer's instructions. If information on the correct contact pressure is not available, compare the contact pressure with that of similar contacts. When the force is less than the designed value, the contacts either require replacing because they are worn down, or the contact springs should be replaced. Always replace contacts in sets, not singly; and replace contact screws at the same time. Do not use emery paper or emery cloth to clean contacts, and do not clean contacts when the equipment is energized.

Clean all surfaces of the circuit breaker mechanism, particularly the insulation surfaces, with a dry cloth or air hose. Before directing the air on the breaker, be certain that the water is blown out of the hose, that the air is dry, and that the pressure is not over 30 psi. Check the pins, bearings, latches, and all contact and mechanism springs for excessive wear or corrosion and evidence of overheating. Replace parts if necessary.

Slowly open and close circuit breakers manually a few times to be certain that trip shafts, toggle linkages, latches, and all other mechanical parts operate freely and without binding. Be certain that the arcing contacts make-before and break-after the main contacts. If poor alignment, sluggishness, or other abnormal conditions are noted, adjust the contacts following the manufacturer's instructions.

Before returning a circuit breaker to service, inspect all mechanical and electrical connections, including mounting bolts and screws, drawout disconnect devices, and control wiring. Tighten where necessary. Give the breaker a final cleaning with a cloth or compressed air. Operate manually to be certain that all moving parts function freely. Check the insulation resistance.

The sealing surfaces of circuit-breaker contactor and relay magnets should be kept clean and free from rust. Rust on the sealing surface decreases the contact force and may result in overheating of the contact tips. Loud humming or chattering will frequently warn of this condition. A light machine oil wiped sparingly on the sealing surfaces of the contactor magnet will aid in preventing rust.

Oil should always be used sparingly on circuit breakers, contractors, motor controllers, relays, and other control equipment. Oil should not be used at all unless called for in the manufacturer's instructions or unless oil holes are provided. If working surfaces or bearings show signs of rust, disassemble the device and carefully clean the rusted surfaces. Light oil can be wiped on sparingly to prevent further rusting. Oil has a tendency to accumulate dust and grit, which may cause unsatisfactory operation of the device, particularly if the device is delicately balanced.

Arc chutes or boxes should be cleaned by scraping them with a file if wiping with a cloth is not sufficient. Replace or provide new linings when they are broken or burned too deeply. Be certain that arc chutes are securely fastened and that there is sufficient clearance to ensure that no interference occurs when the switch or contact is opened or closed.

Shunts and flexible connectors, which are flexed by the motion of moving parts, should be replaced when worn, broken, or frayed.

Operating tests that consist of operating the circuit breakers in the manner in which they are intended to function in service should be conducted regularly. For manually operated circuit breakers, simply open and close the breaker to check the mechanical operation. To check both the mechanical operation and the control wiring, electrically operated circuit breakers should be tested by the operating switch or control. Exercise care not to disrupt any electrical power supply that is vital to the operation of the ship or to endanger personnel by inadvertently starting motors and energizing equipment under repair.

Metal locking devices are available that can be attached to the handles of type AQB circuit breakers to prevent accidental operation. All breaker handles are now provided with a 3/32-inch hole permitting fastening the locking device with a standard cotter pin. *NSTM,* chapter 300, lists the stock numbers for three different sizes of breaker handle locking devices.

OVERLOAD RELAYS

Overload relays are provided in motor controllers to protect the motor from excessive currents. Excessive motor current causes normally closed overload relay contacts to open, which break the circuit to the operating coil of the main contactor, and disconnects the motor from the line. Overload relays are of the thermal or magnetic type.

Thermal Overload Relay

The thermal type of overload relay is designed to open a circuit when excessive current causes the heater coils to reach the temperature at which the ratchet mechanism releases. The heater coils are rated so that normal circuit current will not produce enough heat to release the ratchet mechanism.

The thermal type of overload relay has a heat-sensitive element and an overload heater connected in series with the motor circuit (fig. 2-40). When the motor current is excessive, heat from the heater causes the heat-sensitive element to open the overload relay contacts. As it takes time for the heat-sensitive element to heat up, the thermal type of overload relay has an inherent time delay. Thermal overload relays may be of the solder-pot, bimetal, single-metal, or induction type.

SOLDER-POT TYPE.— The heat-sensitive element is a solder pot that consists of a cylinder inside a hollow tube. These are normally held together by a film of solder. In case of excessive motor current, the heater melts the solder, breaks the bond between the tube and cylinder, and releases the tripping device of the relay. After the relay trips, the solder cools and solidifies, and the relay is ready to be reset.

BIMETAL TYPE.— The heat-sensitive element is a strip or coil of two different metals fused together along one side. When heated, one metal expands more than the other, causing the strip or coil to bend or deflect and open the overload relay contacts.

SINGLE-METAL TYPE.— The heat-sensitive element is a metal tube around the heater. The tube lengthens when heated and opens the overload relay contacts.

INDUCTION TYPE.— The heat-sensitive element is usually a bimetal strip or coil. The heater consists of a coil in the motor circuit and a copper tube inside the coil. The copper tube acts as a short-circuited secondary of a transformer and is heated by the current induced in it. This type of overload relay is used only in ac controllers, whereas the previously described types of thermal overload relays may be used in ac or dc controllers.

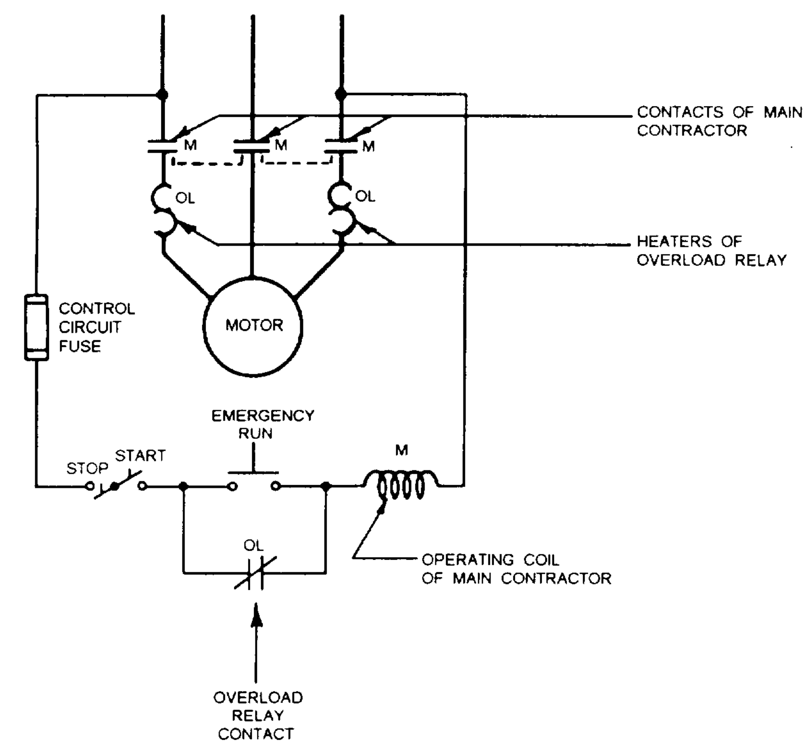


Figure 2-40.-Schematic diagram of motor controller with thermal type of overload relay.

Magnetic Overload Relay

The magnetic type of overload relay has a coil connected in series with the motor circuit and a tripping armature or plunger. When the motor current is excessive, the armature opens the overload relay contacts. Magnetic overload relays may be of the instantaneous or time-delay type.

INSTANTANEOUS TYPE.— This type operates instantaneously when the motor current becomes excessive. The relay must be set at a tripping current higher than the motor starting current to prevent tripping when the motor is started. This type of overload relay is used mostly for motors that are started on reduced voltage and then switched to full line voltage after the motor comes up to speed.

TIME-DELAY TYPE.— This type is essentially the same as the instantaneous type with the addition of a time-delay device. The time-delay device may be an oil dashpot with a piston attached to the tripping armature of the relay. This piston has a hole through which oil passes when the tripping armature is moved due to the excessive motor current. The size of the hole can be adjusted to change the speed at which the piston moves for a given pull on the armature. For a given size hole, the larger the current, the faster the operation. This allows the motor to carry a small overload current for a longer period of time than a large overload current.

ELECTRICAL CABLES

Shipboard electrical and electronic systems require a large variety of electrical cables. Some circuits require only a few conductors having a high current-carrying capacity; others require many conductors having a low current-carrying capacity; still others may require cables with a special type of insulation, the conductors may have to be shielded, or in some cases the conductors may have to be of a metal other than copper.

The proper installation and maintenance of the various electrical systems aboard ship are very important to the IC Electrician. The repair of battle damage, accomplishment of ship alterations, and some electrical repairs may require that changes or additions to the ship's cables be made by IC personnel. Additionally, during shipyard and tender availabilities, you may be required to inspect, test, and approve the new installations.

To perform these tasks you must first have a working knowledge of the various types, sizes, capacities, and uses of shipboard electrical cable. The IC Electrician must also be capable of selecting, installing, and maintaining cables in such a manner as to ensure their adequacy.

For many years most of the shipboard power and lighting cables for fixed installation had silicone-glass insulation, a polyvinyl chloride jacket, and aluminum armor and were of watertight construction. It was determined that cables with all these features were not necessary for many applications, especially within watertight compartments and noncritical areas above the watertightness level. Therefore, a new family of nonwatertight, lower-cost cable was designed. This new family of cables is electrically and dimensionally interchangeable with silicone-glass insulated cables of equivalent sizes. This cable is covered by Military Specification MIL-C-915.

Additionally, cables jacketed with polyvinyl chloride presented the dangers of toxic fumes and dense, impenetrable smoke when undergoing combustion. These hazards were noticed when an electrical fire smoldered through the cable ways aboard a naval ship. Due to the overwhelming amount of smoke and fumes, fire fighters were unable to effectively control the fire and a large amount of damage resulted. A new family of low-smoke, low-toxic cable was designed. This cable is constructed with a polyolefin jacket vice polyvinyl chloride jacket. This new design conforms to rigid toxic and smoke indexes to effectively reduce the hazards associated with the old design. This cable is covered by Military Specification MIL-C-24643.

A family of lightweight cables has also been introduced to aid in the elimination of excessive weight from the fleet. Considering the substantial amount of cable present on a ship or submarine, a reduction in cable weight will have a considerable impact on the overall load, thus improving performance and increasing efficiency. This new family of lightweight cables is constructed from cross-linked polyalkene and micapolymide insulation and a cross-linked polyolefin jacket. The lightweight cable is covered by Military Specification MIL-C-24640.

CLASSIFICATIONS OF CABLES

Because of the varied service conditions aboard ship, the cable must have the ability to withstand heat, cold, dampness, dryness, bending, crushing, vibration, twisting, and shock. No one type of cable has been designed to meet all of these requirements; therefore, a variety of types are employed in a shipboard cable installation.

Cables are classified as watertight or nonwatertight, watertight with circuit integrity construction or nonwatertight with circuit integrity construction, and armored or unarmored. They are also further classified for flexing or nonflexing service for power, lighting, control, electronic, and communication and instrumentation applications. Table 2-1 shows the various classifications for cable.

Watertight Cable

The term *watertight cable* indicates standard cable in which all spaces under the impervious sheath are filled with material. This eliminates voids and prevents the flow of water through the cable by hose action if an open end of cable is exposed to water under pressure.

Armored Cable

The term *armored cable* refers to a cable that has an outer shield of weaved braid. The braid is made of aluminum or steel and applied around the impervious sheath of the cable. This weaved braid helps prevent damage to the cable during installation.

Nonflexing Service

Nonflexing service cable designed for use aboard ship is intended for permanent installation and is commonly referred to as such. Cables for use with lighting and power circuits are intended for this nonflexing service. This nonflexing service can be further classified according to its application and is of two types-general use and special use.

GENERAL USE.— Nonflexing service cable is intended for use in nearly all portions of electric distribution systems, including the common telephone circuits and most propulsion circuits. Special cases occur in dc propulsion circuits for surface ships. In those cases where the impressed voltage is less than 1000 volts, an exception is permitted.

LSDSGA cable is one type usually found in this general use, nonflexing service. Also in this classification is the type LSMSCA cable. This cable is nothing more than watertight cable for use in interior communications, as well as in FC circuits.

SPECIAL USE.— There are many shipboard electrical circuits where special requirements of voltage, current, frequency, and service must be met in cable installation. There are also other circuits where general use, nonflexing service cable may meet the necessary requirements, yet be economically impracticable. For these reasons, there are many different types of nonflexing service cable for

Table 2-1.-Cable Classifications

MIL-C-24643
Watertight with circuit integrity nonflexing service
Power and Lighting
Control
Electronic, Communication, and Instrumentation
Watertight, nonflexing service
Power and Lighting
Electronic, Communication, and Instrumentation
Nonwatertight with circuit integrity, nonflexing service
Electronic, Communication, and Instrumentation
Nonwatertight, nonflexing service
Power and Lighting
Control
Electronic, Communication, and Instrumentation
Nonwatertight, flexing service
Power and Lighting
Control
Electronic, Communication, and Instrumentation
MIL-C-24640
Watertight with circuit integrity, nonflexing service
Power
Control
Electronic, Communication, and Instrumentation
Watertight, nonflexing service
Electronic, Communication, and Instrumentation
Nonwatertight, nonflexing service
Power
Electronic, Communication, and Instrumentation
MIL-C-915
Watertight, flexing service
Control
Electronic, Communication, and Instrumentation
Power
Nonwatertight, flexing service
Power and lighting
Electronic, Communication, and Instrumentation
Nonwatertight, nonflexing service
Electronic, Communication, and Instrumentation
Watertight, nonflexing service
Electronic, Communication, and Instrumentation

specialized use, such as degaussing, telephone, radio, and casualty power.

Type LSMDU is a multiconductor cable used in degaussing circuits. Type LSTCJA consists of one conductor of constantan (red) and one conductor of iron (gray), and is used for pyrometer base leads.

Flexing Service

Flexing service cable designed for use aboard ship is commonly referred to as being portable because it is principally used as leads to portable electric equipment. It is also of two types—general use and special use.

GENERAL USE.— Flexing service cable is used as leads to portable equipment and permanently installed equipment where cables are subjected to repeated bending, twisting, mechanical abrasion, oil, sunlight, or where maximum resistance to moisture is required.

SPECIAL USE.— There are many different types of flexing service cable designed for special requirements of certain installations, including type LSTTOP and casualty power cables. Type TRF is used for arc-welding circuits.

TYPES AND SIZE DESIGNATIONS OF CABLES

Shipboard electrical cables are identified according to type and size. Type designations consist of letters to indicate construction and/or use. Size designations consist of a number or numbers to indicate the size of the conductor(s) in circular mil area, number of conductors, or number of pairs of conductors, depending upon the type of cable.

In most cases, the number of conductors in a cable, up to and including four conductors, is indicated by the first type letter as follows: S—single conductor; D—double conductor; T—three conductor; and F—four conductor. For cables with more than four conductors, the number of conductors is usually indicated by a number following the type letters. In this latter case, the letter *M* is used to indicate multiple conductor, Examples of common shipboard cable designations are as follows:

LSDSGA-3— LOW smoke, double conductor, shipboard, general use, armored, conductor size approximately 3000 circular roils.

LSDCOP-2— LOW smoke, double conductor, oil resistant, portable, conductor size approximately 2000 circular mils.

LSMSCA-30— LOW smoke, multiple conductor, shipboard, control armored, with 30 conductors.

Most cables and cords contain a continuous, thin, moisture-resistant marker tape directly under the cable or cord binder tape or jacket at less than 1-foot intervals. This tape shows the name and location of the manufacturer; the year of manufacture; the military specification number of the cable; and the progressive serial number. The serial number is not necessarily a footage marker. A serial number is not repeated by a manufacturer in any one year for any one type and size of cable or cord.

RATINGS AND CHARACTERISTICS OF CABLES

Table 2-2 shows the ratings and characteristics of various cables that are included in Military Specification MIL-C-24643. Each cable is identified by the MILSPEC and specification sheet number, followed by the cable type designation, conductor size (AWG or MCM), number of conductors, conductor cross-sectional area (circular mils), overall diameter of the cable, cable weight per foot in approximate pounds, minimum radius of bend (which is approximately 8 times the overall diameter), conductor identification, rated voltage, ampacity (current-carrying capacity in amperes) of each conductor, and the national stock number (NSN).

The overall diameter is the overall measurement of the finished cable and is the determining dimension in selecting the proper deck or bulkhead stuffing tube size or multicable transit inserts. This diameter is also the determining dimension for stuffing tubes for equipment.

Electrical characteristics are given under columns headed Rated Voltage and Ampacity.

In the column headed CDR ID (conductor identification), the letters stand for the identification and the number stands for the method of applying the identification. There are four codes for identifying the conductors in a cable; they are STD (standard identification code), TEL (telephone identification code), SPL (special identification code), and LTR (letter identification code). Table 2-3 gives the standard identification color codes for identifying conductors in multiple-conductor

Table 2-2.—Cables for Watertight (With Circuit Integrity), Nonflexing Service, Power and Lighting

MIL-SPEC MIL-C-	CABLE TYPE DESIGNATION	CONDUCTOR SIZE: AWG OR MCM	NUMBER OF CONDUCTORS IN CABLE	AREA OF EACH CONDUCTOR (MCM)	CABLE OVERALL DIAMETER MAX. (INCH)	CABLE WEIGHT PER FT APPROX (LBS)	RADIUS OF BEND MIN. (INCH)	CDR ID	RATED VOLTAGE, MAX. (RMS)	AMPACITY, EACH CONDUCTOR (AMPS, MAX) DC OR 60 HZ 40° C AMBIENT	DC OR 60 HZ 50° C AMBIENT	400 HZ 40° C AMBIENT	400 HZ 50° C AMBIENT	NSN 6145-01
24643/19	LS6SGA- 100	0	6	105.600	1.650	2.919	13.0	LTR-5	1000	136	127	272	250	203-0370
	LS6SGA- 125	00	6	133.100	1.840	3.600	14.5	LTR-5	1000	160	147	299	275	201-9513
	LS6SGA- 150	000	6	167.800	2.010	4.468	16.0	LTR-5	1000	188	173	326	300	201-9514
	LS6SGA- 200	0000	6	211.600	2.250	5.613	18.0	LTR-5	1000	219	202	369	340	201-9515
24643/19	LS6SGU- 100	0	6	105.600	1.600	2.820	13.0	LTR-5	1000	136	127	272	250	201-9511
	LS6SGU- 125	00	6	133.100	1.790	3.490	14.5	LTR-5	1000	160	147	299	275	201-9512
	LS6SGU- 150	000	6	167.800	1.960	4.339	16.0	LTR-5	1000	188	173	326	300	203-2370
	LS6SGU- 200	0000	6	211.600	2.200	5.479	17.5	LTR-5	1000	219	202	369	340	203-0369
24643/26	LS7PS- 6	12	7	6.530	.775	.361	6.0	STD-4	600	35/20*	---	---	---	811-8376
24643/20	LS7SGA- 3	16	7	2.580	.595	.177	4.5	STD-1	1000	15/11	14/10*	15/11*	14/10*	201-9518
	LS7SGA- 4	14	7	4.110	.645	.231	5.0	STD-1	1000	26/14	24/13	26/14	24/13	201-9519
24643/20	LS7SGU- 3	16	7	2.580	.545	.152	4.5	STD-1	1000	15/11	14/10	15/11	14/10	201-9516
	LS7SGU- 4	14	7	4.110	.595	.198	5.0	STD-1	1000	26/14	24/13	26/14	24/13	201-9517
24643/26	LSDPS- 3	16	2	2.580	.455	.121	3.0	STD-4	600	10	---	10	---	156-9511
	LSDPS- 4	14	2	4.110	.489	.141	3.0	STD-4	600	20	---	20	---	977-6159
	LSDPS- 6	12	2	6.530	.585	.194	4.5	STD-4	600	28	---	28	---	158-2118
	LSDPS- 9	10	2	10.380	.628	.232	5.0	STD-4	600	41	---	41	---	542-6699
	LSDPS- 14	9	2	13.090	.730	.323	6.0	STD-4	600	54	---	54	---	154-4372
24643/15	LSDSGA- 3	16	2	2.580	.461	.109	3.5	STD-1	1000	13	12	13	12	202-9501
	LSDSGA- 4	14	2	4.110	.499	.133	4.0	STD-1	1000	22	20	22	20	203-0367
	LSDSGA- 9	10	2	10.380	.625	.230	5.0	STD-1	1000	44	41	44	41	202-9502
	LSDSGA- 14	9	2	13.090	.768	.297	6.0	STD-1	1000	60	55	60	55	202-9503
	LSDSGA- 23	7	2	20.820	.862	.410	7.0	STD-1^	1000	78	72	78	72	202-9504
	LSDSGA- 50	3	2	52.620	.969	.740	8.0	LTR-5	1000	126	116	126	116	204-4855
	LSDSGA- 75	1	2	83.690	1.184	1.086	9.5	LTR-5	1000	168	155	168	155	210-2343
	LSDSGA- 100	0	2	105.600	1.316	1.289	10.5	LTR-5	1000	199	183	199	183	204-4856
	LSDSGA- 200	000	2	211.600	1.719	2.458	14.0	LTR-5	1000	308	284	288	266	204-4857
	LSDSGA- 300	300	2	300.000	2.007	3.326	16.0	LTR-5	1000	413	380	347	319	204-4858
	LSDSGA- 400	400	2	413.600	2.253	4.408	18.0	LTR-5	1000	492	453	337	310	203-0368

* Ind/Avg indicates the maximum current per conductor (Ind), and the maximum current (Avg) per conductor when all conductors in the cable are used.

^ Maybe STD-1 or LTR-5, manufacturer's option

Table 2-3.-Standard Identification Code (STD)

Color, conductor or group No.	Background or base color	First tracer color	Second tracer color
1	Black	---	---
2	White	---	---
3	Red	---	---
4	Green	---	---
5	Orange	---	---
6	Blue	---	---
7	White	Black	---
8	Red	Black	---
9	Green	Black	---
10	Orange	Black	---
11	Blue	Black	---
12	Black	White	---
13	Red	White	---
14	Green	White	---
15	Blue	White	---
16	Black	Red	---
17	White	Red	---
18	Orange	Red	---
19	Blue	Red	---
20	Red	Green	---
21	Orange	Green	---
22	Black	White	Red
23	White	Black	Red
24	Red	Black	White
25	Green	Black	White
26	Orange	Black	White
27	Blue	Black	White
28	Black	Red	Green
29	White	Red	Green
30	Red	Black	Green
31	Green	Black	Orange
32	Orange	Black	Green
33	Blue	White	Orange
34	Black	White	Orange
35	White	Red	Orange
36	Orange	White	Blue
37	White	Red	Blue
38	Brown	---	---
39	Brown	Black	---
40	Brown	White	---
41	Brown	Red	---
42	Brown	Green	---
43	Brown	Orange	---
44	Brown	Blue	---
45	White	Black	Blue
46	Red	White	Blue
47	Green	Orange	Red
48	Orange	Red	Blue
49	Blue	Red	Orange
50	Black	Orange	Red
51	White	Black	Orange
52	Red	Orange	Black
53	Green	Red	Blue
54	Orange	Black	Blue
55	Blue	Black	Orange
56	Black	Orange	Green
57	White	Orange	Green
58	Red	Orange	Green
59	Green	Black	Blue
60	Orange	Green	Blue
61	Blue	Green	Orange
62	Black	Red	Blue
63	White	Orange	Blue
64	Red	Black	Blue
65	Green	Orange	Blue
66	Orange	White	Red
67	Blue	White	Red
68	Black	Green	Blue
69	White	Green	Blue
70	Red	Green	Blue
71	Green	White	Red
72	Orange	Red	Black
73	Blue	Red	Black
74	Black	Orange	Blue
75	Red	Orange	Blue
76	Green	Red	Black
77	Orange	White	Green
78	Blue	White	Green
79	Red	White	Orange
80	Green	White	Orange
81	Blue	Black	Green
82	Orange	White	---
83	Green	Red	---
84	Black	Green	---
85	White	Green	---
86	Blue	Green	---
87	Black	Orange	---
88	White	Orange	---
89	Red	Orange	---
90	Green	Orange	---
91	Blue	Orange	---
92	Black	Blue	---
93	White	Blue	---
94	Red	Blue	---
95	Green	Blue	---
96	Orange	Blue	---
97	Yellow	---	---
98	Yellow	Black	---
99	Yellow	White	---
100	Yellow	Red	---
101	Yellow	Green	---
102	Yellow	Orange	---
103	Yellow	Blue	---
104	Black	Yellow	---
105	White	Yellow	---
106	Red	Yellow	---
107	Green	Yellow	---
108	Orange	Yellow	---
109	Blue	Yellow	---
110	Black	Yellow	Red
111	White	Yellow	Red
112	Green	Yellow	Red
113	Orange	Yellow	Red
114	Blue	Yellow	Red
115	Black	Yellow	White
116	Red	Yellow	White
117	Green	Yellow	White
118	Orange	Yellow	White
119	Blue	Yellow	White
120	Black	Yellow	Green
121	White	Yellow	Green
122	Red	Yellow	Green
123	Orange	Yellow	Green
124	Blue	Yellow	Green
125	Black	Yellow	Blue
126	White	Yellow	Blue
127	Red	Yellow	Blue

cables. Table 2-4 gives the telephone identification color codes for telephone cables. Table 2-5 gives the special identification color codes for conductors and groups of conductors, such as pairs and triads. Letter identification codes consist of the letters *A, B, C,* and *D* printed in block type and with black, white, red, and green ink, respectively. There are six methods of applying identification to the conductors of a cable. They are as follows:

Method 1—calls for printing of the number and color designation on the outer surface of the insulation or jacket of each conductor.

Method 2—calls for the use of opaque white polyester tapes that have been printed with both the number and color designation prior to application.

Table 2-4.—Telephone Identification Code (TEL)

Conductor identification code for telephone cables is as follows:

Color or Conductor No.	Color	Color or Conductor No.	Color
1	Black	7	Brown
2	White	8	Gray
3	Red	9	Yellow
4	Green	10	Purple
5	Orange	11	Tan
6	Blue	12	Pink

The pairing of conductors for forming pairs shall be as follows:

No. 1 paired with Nos. 2 thru 12 for next 11 pairs
No. 2 paired with Nos. 3 thru 12 for next 10 pairs
No. 3 paired with Nos. 4 thru 12 for next 9 pairs
No. 4 paired with Nos. 5 thru 12 for next 8 pairs
No. 5 paired with Nos. 6 thru 12 for next 7 pairs
No. 6 paired with Nos. 7 thru 12 for next 6 pairs
No. 7 paired with Nos. 8 thru 12 for next 5 pairs
No. 8 paired with Nos. 9 thru 12 for next 4 pairs
No. 9 paired with Nos. 10 thru 12 for next 3 pairs
No. 10 paired with Nos. 11 thru 12 for next 2 pairs
No. 11 paired with No. 12

Method 3—calls for the use of solid colors or solid base colors with tracers as required.

Method 4—calls for the use of colored braids.

Method 5—calls for the use of the printed letter on the outermost insulating tape or the printed letter on a polyester binder tape over the insulating tape.

Method 6—calls for numerals to be printed in ink on the insulation of the conductor.

CABLE COMPARISON HANDBOOK

A new cable comparison handbook is being developed by NAVSEA and will contain information on the most current cables authorized for shipboard use. The new handbook will provide information to supply and installation activities on the use of electrical shipboard cable, particularly in the selection of suitable alternate or substitute cables for use in lieu of specified types and sizes that might not be immediately available, and for selecting a currently available item suitable for replacement of obsolete items. Cables will be listed in the handbook by general classifications as to application and design.

CABLE MARKING

Metal tags embossed with the cable designations are used to identify all permanently installed shipboard electrical cables. The tags (fig. 2-41), when properly applied, afford easy identification of cables for purposes of maintenance and repair of IC circuits.

Table 2-5.-Special Identification Code (SPL)

Color or Conductor No.	Color	Color or Conductor No.	Color
1	Black	7	Brown
2	White	8	Gray
3	Red	9	Yellow
4	Green	10	Purple
5	Orange	11	Tan
6	Blue	12	Pink

Twisted pair identification code. This code consists of numbers in sequence running from 1 through the number corresponding to the total quantity of twisted pairs in the cable. Both conductors in each pair shall be numbered the same, denoting the sequence number of the pair. Distinction between the two conductors is provided by different colored insulation. Conductors of a cable with a single pair need not be numbered.

Twisted triad identification code. This code consists of numbers in sequence running from 1 through the number corresponding to the total quantity of twisted triads in the cable. All three conductors shall be numbered the same, denoting the sequence number of the triad: Distinction between the three conductors is provided by different colored insulation. Conductors of a cable with a single triad need not be numbered.

These cable designations include (1) the service letter, (2) the circuit letter(s), and (3) the cable number. The SERVICE is denoted by the letter C, which is the designation for all cables and circuits that comprise the IC system in naval ships. Each circuit is distinguished by a single letter or double letters. These letters identify the cable as a part of one of the numerous IC circuits. If two or more circuits of the same system are contained in a single cable, the number preceding the circuit letter or letters is omitted. The cable number is the number of the cable of the particular circuit.

A typical IC cable designation is C-MB144. The letter *C* denotes the service (the IC system). The letters *MB* denote the circuit, engine-order system, which may actually include wires of circuits 1MB, 2MB, 3MB, and so on. The number 144 denotes cable number 144 of circuit MB.

Permanently installed ships' cables are tagged as close as practicable to each point of connection, on both sides of decks, bulkheads, and other barriers. Cables located within a single compartment in such a manner that they can be readily traced are not tagged.

TERMINAL MARKING

In single-letter circuits and dc supply circuits, the positive terminal is designated by a single letter, *M*. Similarly, an arbitrary polarity of single-phase ac circuits is designated by a single letter, *M* (assumed instantaneous positive). The other side (representing the opposite polarity of both dc and ac circuits is designated by double letters, *MM*.

Double-letter circuits have supply lead markings assigned as for single-letter circuits, except that the second letter of the negative is doubled; for example, positive MB, negative MBB.

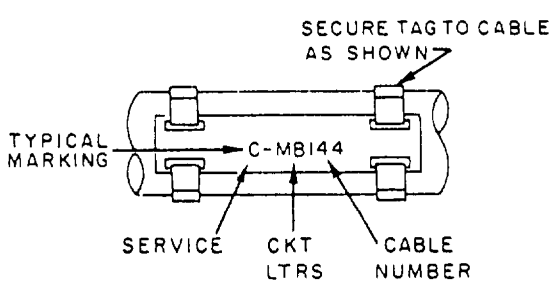


Figure 2-41.-Cable tags.

All IC terminals are identified by insulated sleeving that is stamped with the lead number and the cable number the lead belongs to.

The wire terminals 3EP and 3EPP (fig. 2-42), respectively, are the positive and negative supply terminals from cable C-E-52, which emanates from the IC switchboard and leaves from cable C-E-53.

The wire terminals 3EP3, 3EP5, 3EP6, and 3EP8 from cable C-E-52 are the positive terminals of push-button stations 3, 5, 6, and 8, respectively. The functions of these wires are found on the elementary and isometric drawings of the 3EP (protected E call) circuit for your ship.

Numbers following the circuit letter indicate a serial number assigned for the station, followed by the section wire number designating the function of the circuit. On systems containing synchros, the numerals 1, 2, and 3 are used for the connections to secondary windings. Where more than one synchro is employed in a single instrument, the numerals 4, 5, and 6 apply to the second synchro, and 7, 8, and 9 to the third synchro. For example, l-MB 14 should be interpreted as follows:

1—starboard circuit

MB—engine-order system

1—station number, such as pilot house

4—connection to secondary windings of the No. 2 synchro receiver in the instrument

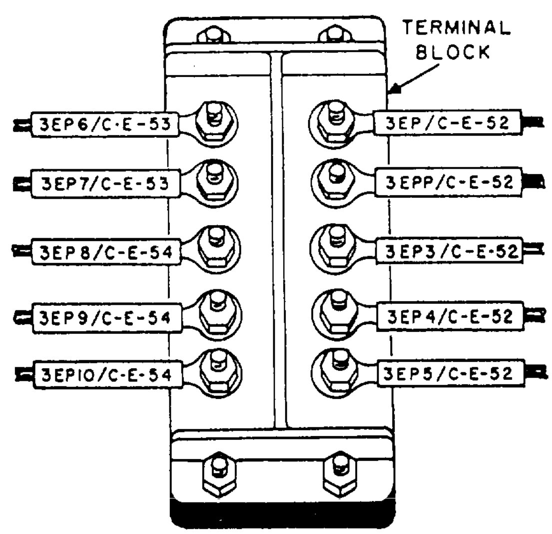


Figure 2-42.—Wire terminal markings.

If corresponding portions of a circuit are energized from the forward and aft IC switchboards, the suffix letters *F* and *A* are added to the ends of wire markings to indicate the switchboard from which the wire originated.

All terminals in a circuit that may be connected without a break (in the electrical sense) should be assigned the same wire marking. A fuse, switch, or instrument is considered a break in the circuit and requires a change in the wire marking.

Signal contacts should be connected to the positive (single-letter connection) in the instruments. The section-wire markings for bell or visual signal circuits should be assigned the next higher number after assignment of numbers to secondary windings of all synchro receivers in the instruments. For example, in an instrument containing two synchro receivers the signal circuits should be assigned section wires No. 7, 8, and so on.

MAINTENANCE OF CABLES

The purpose of cable maintenance is to keep the cable insulation resistance high. Cables should be kept clean and dry, and protected from mechanical damage, oil, and salt water.

The purpose of insulation on electrical cables and equipment is to (1) isolate current-carrying conductors from metallic and structural parts and (2) insulate points of unequal potential on conductors from each other. The resistance of such insulation should be sufficiently high to result in negligible current flow through or over its surface.

Factors Affecting Insulation Resistance

Factors that affect cable insulation resistance measurements are length, type, temperature, and the equipment connected in the circuit. Each of these factors must be evaluated to reliably determine the condition of the cable from the measurements obtained.

LENGTH OF CABLE.— The insulation resistance of a length of cable is the resultant of a number of small individual leakage paths or resistances between the conductor and the cable sheath. These leakage paths are distributed along the cable. Hence, the longer the cable, the greater the number of leakage paths and the lower the insulation resistance. For example, if one leakage path exists in each foot of cable, them will be 10 such paths for current to flow between the conductor and the sheath in 10 feet of cable, and the total amount of current flowing in all of them would be 10 times as great as that which would flow if the cable were only 1 foot long. Therefore, to establish a common unit of comparison, cable-insulation resistance should be expressed in megohms (or ohms) per foot of length. This is determined by multiplying the measured insulation resistance of the cable by its total length in feet.

When measured insulation resistance is converted to insulation resistance per foot, the total length of cable to be used is equal to the length of the cable sheath for single-conductor cable and for multiple-conductor cable in which each conductor is used in one leg of a circuit. For example, in an LSTSGA cable with a cable sheath of 100 feet in which the three conductors are phases A, B, and C of a 3-phase power circuit, the total length of the cable is 100 feet, not 300 feet. The reason for this is that each conductor is measured separately. If this cable is connected, either in series or parallel, to a similar cable that has a sheath length of 400 feet, the total length is 500 feet. As another example, 200 feet of type LSMSCA cable (7-conductor cable) connected to 200 feet of LSMSCA-24 cable (24-conductor cable) represents a total cable length of 400 feet.

TYPE OF CABLE.— Insulation resistance will vary considerably with the nature of the insulating materials employed and the construction of the cable. Therefore, it is possible to determine the condition of a cable by its insulation resistance measurements only when they are considered in relation to the typical characteristics of the particular type of cable. A Resistance Test Record Card, NAVSEA 531-1 (fig. 2-43), should be used to determine if the measured insulation resistance values are above the minimum acceptable values.

TEMPERATURE OF CABLE.— It is important to maintain the operating temperature of electrical equipment within their designed values to avoid premature failure of insulation. Temperatures only slightly in excess of designed values may produce gradual deterioration, which, though not immediately apparent, shortens the life of the insulation. Therefore, the temperature of the cable must be considered with the insulation resistance measurements. Consult *NSTM,* chapter 300, for the proper procedures for measuring the temperature of a cable.

EQUIPMENT CONNECTED.— When insulation resistance measurements are made with equipment connected, always record the exact equipment included and the type of tester used so accurate comparisons can be made with similar past or future measurements.

Testing Cables

Insulation resistance tests (ground tests) must be made periodically on IC cables to determine the condition of the cables. In addition, tests should be made when cables have been damaged, when cables have been disconnected for circuit or equipment changes, when there is evidence that a cable has been subjected to oil or salt water, and after shipboard overhauls.

Because of the variables in IC cables, such as cable length, type, or the temperature of the cable sheath, no single minimum insulation resistance reading for IC cabling can be given. For most IC cabling a reading of 0.2 megohm for each conductor is considered minimum. For the more extensive sound-powered

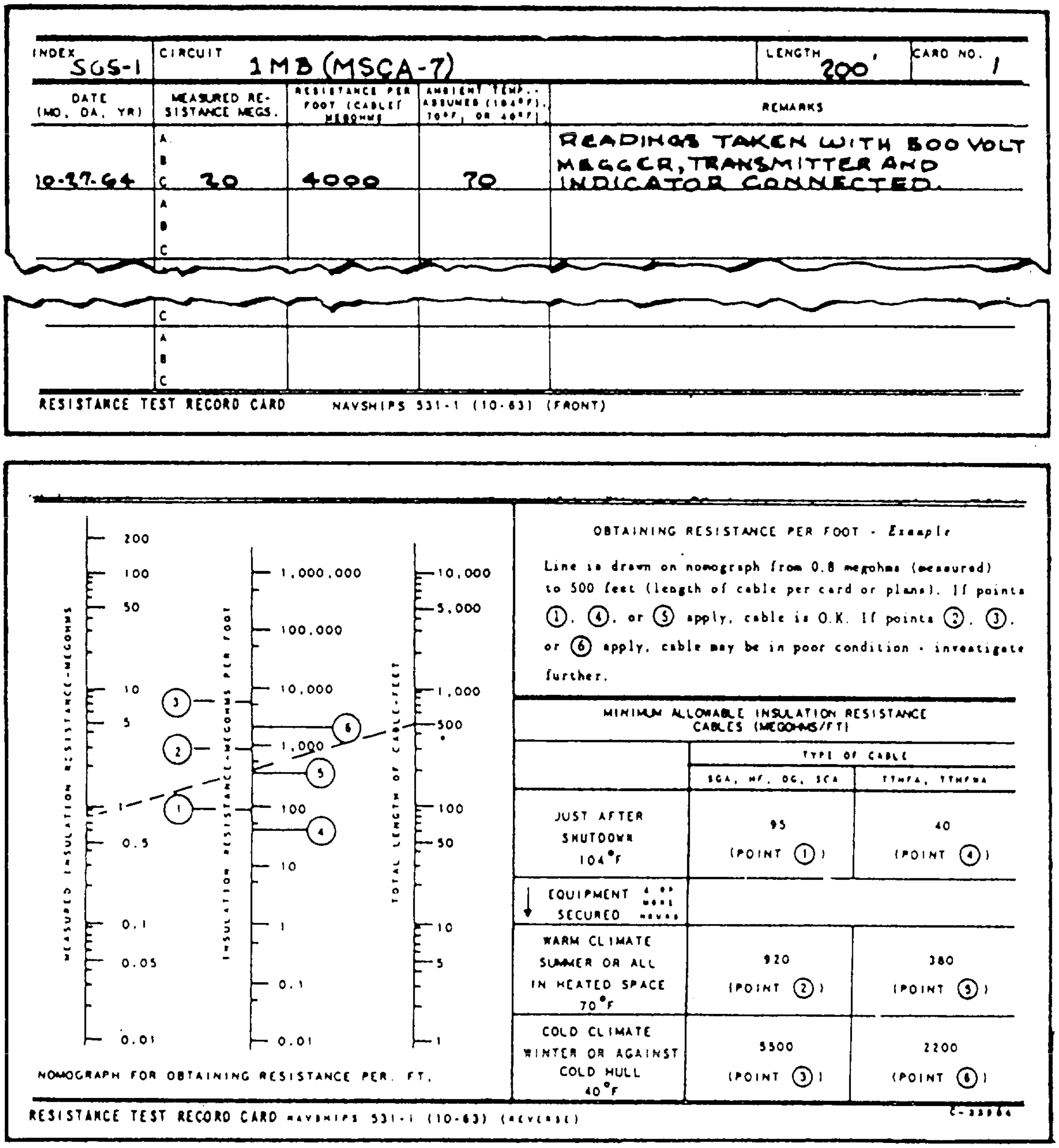


Figure 2-43.-Resistance Test Record Card, NAVSEA 531-1.

telephone circuits, insulation resistance readings of 50,000 ohms is the acceptable minimum. For short cable runs, minimum insulation resistance should be well above 50,000 ohms.

IC cables should be tested with an insulation resistance measuring instrument (Megger). If a Megger is not available, consult NSTM, chapter 300, for alternate methods of testing the insulation resistance.

To ground test a multiconductor IC cable with a Megger, proceed as follows:

1. Check to see that the cable armor is grounded by measuring between the cable armor and the metal structure of the ship; normally, grounding has been accomplished by cable straps. If a zero reading is not obtained, ground the cable armor.

2. Select one conductor to be tested, and connect all other conductors in the cable together. Ground them with temporary wires or jumpers.

3. Measure the resistance of the conductor being tested to ground. Apply test voltage until a constant reading is obtained. Crank hand-driven generator-type Meggers for at least 30 seconds to ensure a steady reading.

4. Repeat steps 2 and 3 as necessary to test each conductor to ground.

A reading equal to or above the accepted minimum for the cable concerned indicates that the conductor under test is satisfactory. A reading below the accepted minimum indicates that the insulation resistance of the conductor under test to ground or from one or more of the grounded conductors or both is low. The grounded conductors must then be disconnected from ground, and each conductor tested individually to isolate the low-reading conductor(s).

An alternate method of ground testing multi-conductor cables is to connect all conductors together and measure the insulation resistance from all conductors to ground simultaneously. If this reading is equal to or above the accepted minimum, no other reading need be taken. If the reading is below the accepted minimum, the conductors must be separated and tested individually to isolate the low-reading conductor(s).

When checking insulation resistance on circuits where semiconductor control devices are involved, the 500-volt dc Megger cannot be used. An electron tube megohmmeter is used on circuits and components where insulation resistance must be checked at a much lower potential. The megohmmeter operates on internal batteries. When circuits or components under test contain a large electrical capacity, the meg-ohmmeter READ button must be depressed for a sufficient time to allow its capacitor to charge before a steady reading is obtained. The test voltage applied by the megohmmeter to an unknown resistance is approximately 50 volts when resistances of approximately 10 megohms are measured and slightly greater than this when higher resistances are measured.

CABLE REPAIR

A cable repair is the restoration of the cable armor or the outermost sheath or both. Cable repair may be made by ship's force. However, cable repair should be according to NAVSEA standard methods drawing 803-5001027, unless standard methods cannot be applied.

CABLE SPLICING

A cable splice is the restoration on any part of a cable that cannot be restored by a cable repair. Cable splices should be according to NAVSEA standard methods drawing 803-5001027, unless standard methods cannot be applied. Cable splices should not be made by ship's force except in an emergency. When such splices are made, they should be replaced at the earliest opportunity by a continuous length of cable or by an approved splice installed by a repair activity.

CABLE INSTALLATION

The job of installing cable may be performed by IC personnel whenever necessary to repair damage or to accomplish authorized ship alterations (SHIPALTs). Before work is begun on a new cable installation, cableway plans should be available. If repairs to a damaged section of installed cable are to be effected, information on the original installation can be obtained from the plans of the ship's electrical system, which are normally on file in the engineering department office (legroom) aboard ship. If a SHIPALT is to be accomplished, applicable plans not already on board can be obtained from the naval shipyard listed on the authorization for the SHIPALT at the planning yard for the ship.

Selecting Cable

When selecting cable, use all reference data available. Electrical cables installed aboard Navy vessels must meet certain requirements determined by the Naval Sea Systems Command. These requirements, published in the General Specifications for Ships of the U.S. Navy, NAVSEA S9AA0-AA-SPN-010/ GEN.SPEC, are too numerous to cover in detail in this training manual; hence, only the more basic ones are included.

Installing Cable

Before installing new cable, survey the area to see if there are spare cables in existing wireways and spare stuffing tubes that can be used in the new installation. The cable run must be located so damage from battle will be minimized, physical and electrical interference with other equipment and cables will be avoided, and maximum dissipation of internally generated heat will occur. Do not run cables on the exterior of the deckhouse or similar structures above the main deck, except where necessary, because of the location of the equipment served or because of structural interferences or avoidance of hazardous conditions or locations. Where practicable, route vital cables along the inboard side of beams or other structural members to afford maximum protection against damage by flying splinters or machine-gun strafing.

Where practicable, avoid installing cable in locations subject to excessive heat. Never install cable adjacent to machinery, piping, or other hot surfaces having an exposed surface temperature greater than 150°F. In general, cables should not be installed where they may be subjected to excessive moisture.

Because attenuation (power loss) in a line increases with its length, cables should be kept as short as practicable.

Flexible cables are flexible only in the sense that they will assume a relatively long bend radius. They are not intended to be stretched, compressed, or twisted. Bends are made as large as practicable.

The numbers of connectors are generally kept to a minimum to reduce line losses and maintenance problems.

Fabricated straps are used for holding the cables. They are snug, but not too tight. Back straps (which keep the cable away from a surface) are used for cable runs along masts or in compartments that are subject to sweating. In more recent installations, semicontour straps and cable bands are used for certain applications.

The exact methods of installing cables can be found in the Electronics Installation and Maintenance Book, NAVSEA SE000-00-EIM- 110.

Cable Supports

Types of cable supports are the single cable strap, cable rack, and modular cable supports.

SINGLE CABLE STRAP.— The single cable strap is the simplest form of cable support. The cable strap is used to secure cables to bulkheads, decks, cable hangers, fixtures, and so on. The one-hole cable strap (fig. 2-44, view A) may be used for cables not exceeding five-eighths of an inch in diameter. The two-hole strap (fig. 2-44, view B) may be used for cables over five-eighths of an inch in diameter. The spacing of simple cable supports must not exceed 32 inches center to center.

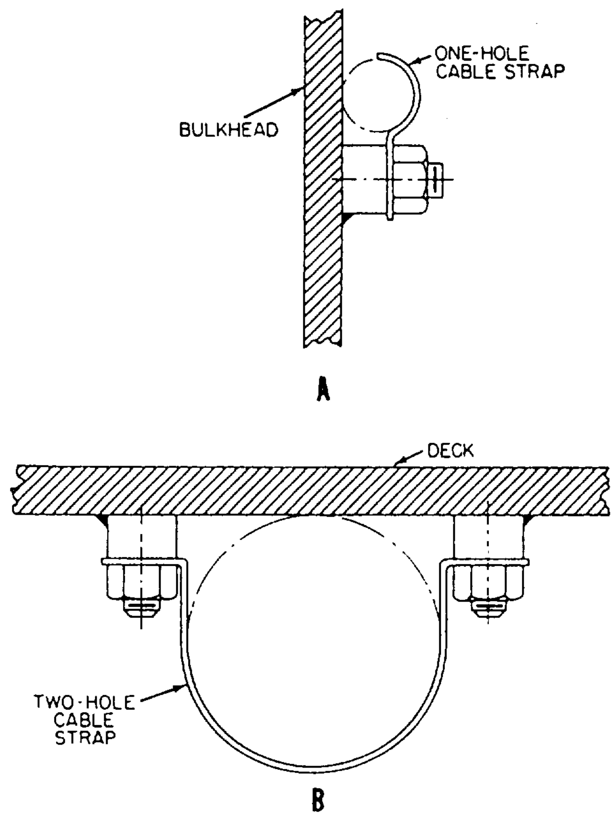


Figure 2-44.-Single cable strap applications.

CABLE RACK.— A more complex cable support is the cable rack, which consists of the cable hanger, cable strap, and hanger support (fig. 2-45).

Banding material is five-eighths of an inch wide and may be zinc-plated steel, corrosion-resistant steel, or aluminum, depending on the requirements of the installation. For weather-deck installations, use corrosion-resistant steel band with copper-armored cables; zinc-coated steel with steel armor; and aluminum with aluminum armor.

When applying banding material, apply one turn of banding for a single cable less than 1 inch in diameter. Apply two turns of banding for single cables of 1 inch or more in diameter and for a row of cables. Apply three turns of banding for partially loaded hangers where hanger width exceeds the width of a single cable or a single row of cable by more than one-half inch.

Cables must be supported so the sag between supports, when practicable, will not exceed 1 inch. Five rows of cables may be supported from an overhead in one cable rack; two rows of cables may be supported from a bulkhead in one cable rack. As many as 16 rows of cables may be supported in main cableways, in machinery spaces, and boiler rooms. Not more than one row of cable should be installed on a single hanger.

MODULAR CABLE SUPPORTS.— Modular cable supports (fig. 2-46) are installed on a number of naval ships. The modular method saves over 50 percent in cable-pulling time and labor. Groups of cables are now passed through wide opened frames instead of inserted individually in stuffing tubes. The frames are then welded into the metal bulkheads and decks for cable runs.

The modular method of supporting electrical cables from one compartment to another is designed to be fireproof, watertight, and airtight.

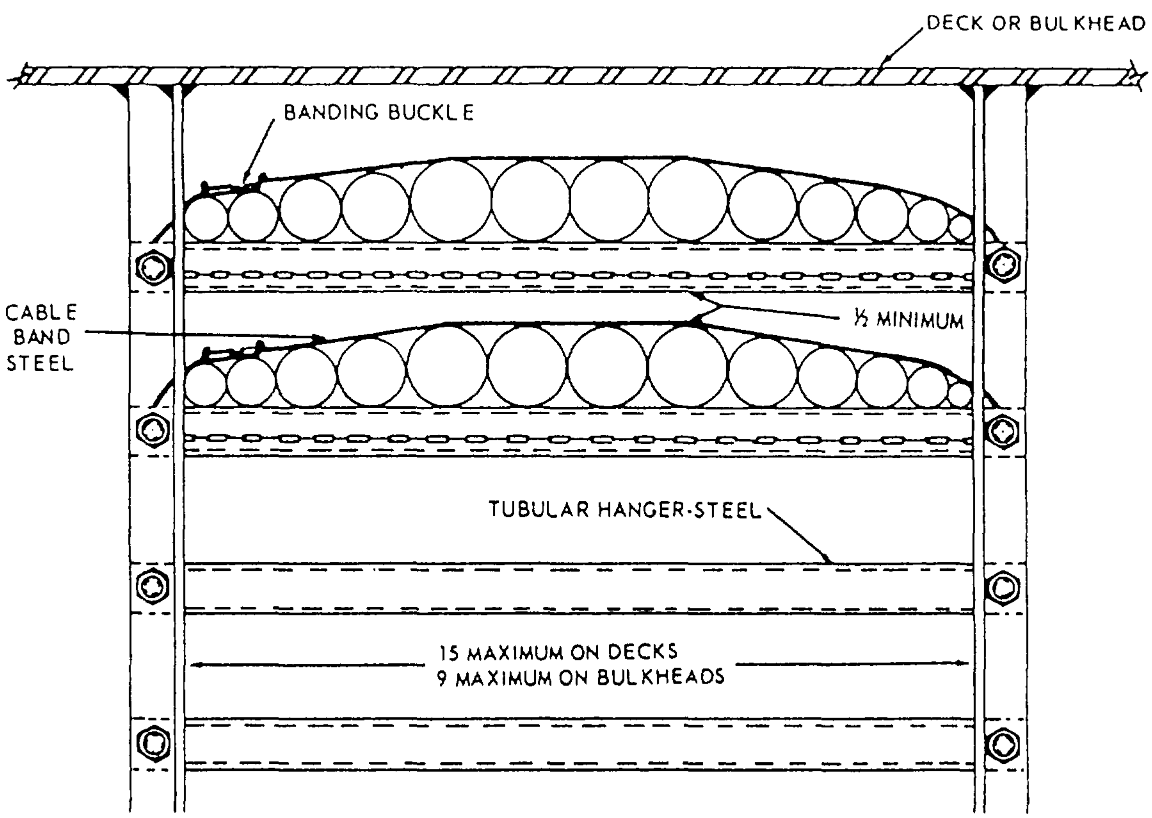


Figure 2-45.-Cables installed in a cable rack.

Modular insert semicircular grooved twin half-blocks are matched around each cable to form a single block. These grooved insert blocks, which hold the cables (along with the spare insert solid blocks), fill up a cable support frame.

During modular armored cable installation, a sealer is applied in the grooves of each block to seal the space between the armor and cable sheath. The sealer penetrates the braid and prevents air passage under the braid. A lubricant is used when the blocks are installed to allow the blocks to slide easily over each other when they are packed and compressed over the cable. Stay plates are normally inserted between every completed row to keep the blocks positioned and to help distribute compression evenly through-out the frame. When a frame has been built up, a compression plate is inserted and tightened until there is sufficient room to insert the end packing.

To complete the sealing of the blocks and cables, the two bolts in the end packing are tightened evenly until there is a slight roll of the insert material around the end packing metal washers. This indicates the insert blocks and cables are sufficiently compressed to form a complete seal. The compression bolt is then backed off about one-eighth of a turn.

When removing cable from modular supports, first tighten down the compression bolt. This pushes the compression plate further into the frame to free the split and packing. Then remove this end packing by loosening the two bolts that separate the metal washers and the end packing pieces. Back off the compression bolt, loosening the compression plate. Then remove this plate, permitting full access to the insert blocks and cables.

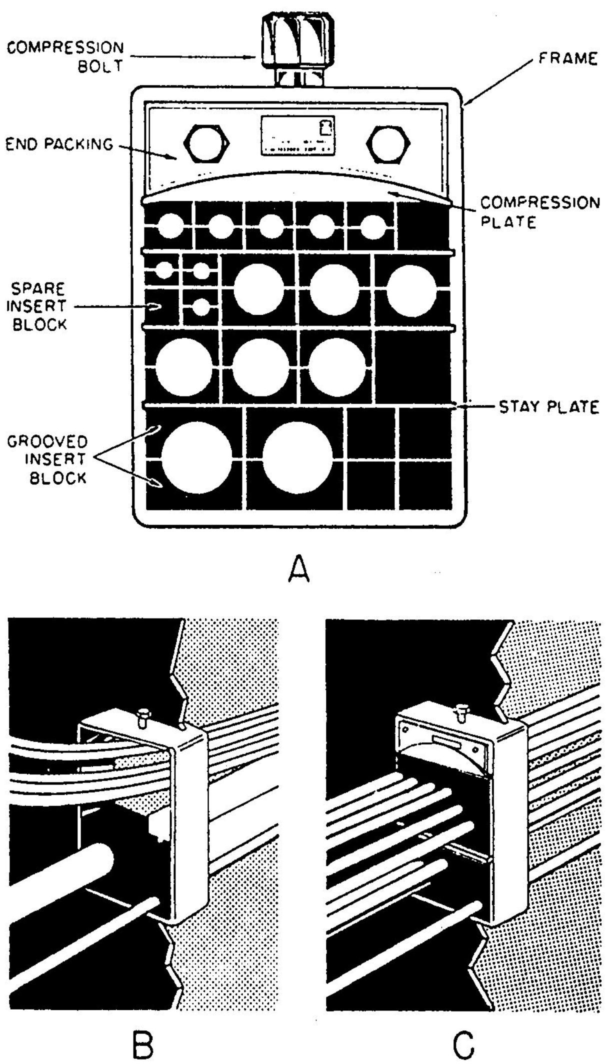


Figure 2-46.—Modular cable supports.

Stuffing Tubes

Stuffing tubes (fig. 2-47, views A, B, and C) are used to provide for the entry of electric cable into splashproof, spray tight, submersible, and explosion-proof equipment enclosures. Cable clamps,

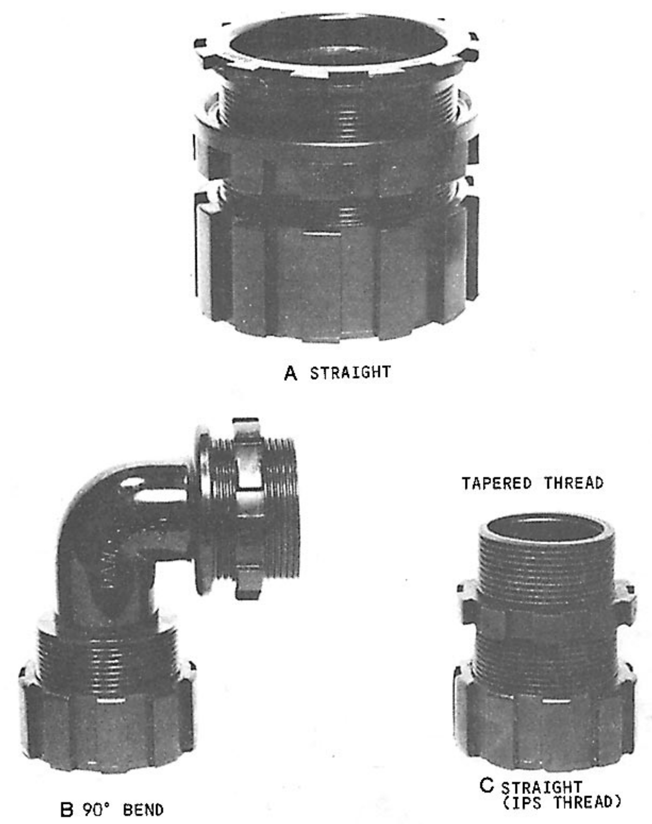


Figure 2-47.—Ny1on stuffing tubes.

commonly called box connectors (shown in fig. 2-48), may be used for cable entry into all other types of equipment enclosures. However, top entry into these enclosures should be made dripproof through stuffing tubes or cable clamps sealed with plastic sealer.

Below the main deck, stuffing tubes are used for cable penetrations of watertight decks, watertight bulkheads, and watertight portions of bulkheads that are watertight only to a certain height. Above the main deck, stuffing tubes are used for cable penetrations of (1) watertight or airtight boundaries; (2) bulkheads designed to withstand a waterhead; (3) that portion of bulkheads below the height of the sill or coaming of compartment accesses; (4) flametight or gastight or watertight bulkheads, decks, or wiring trunks within turrets or gun mounts; and (5) structures subject to sprinkling.

Stuffing tubes are made of nylon, steel, brass, or aluminum alloys. Nylon tubes have very nearly replaced metal tubes for cable entry to equipment enclosures.

The nylon stuffing tube is lightweight, positive-sealing, and noncorrosive. It requires only minimum maintenance for the preservation of watertight integrity. The watertight seal between the entrance to the enclosure and nylon body of the stuffing tube is made with a neoprene O-ring, which is compressed by a nylon locknut. A grommet-type neoprene packing is compressed by a nylon cap to accomplish a watertight seal between the body of the tube and the cable. Two slip washers act as compression washers on the grommet as the nylon cap of the stuffing tube is tightened. Grommets of the same external size, but with different sized holes for the cable, are available.

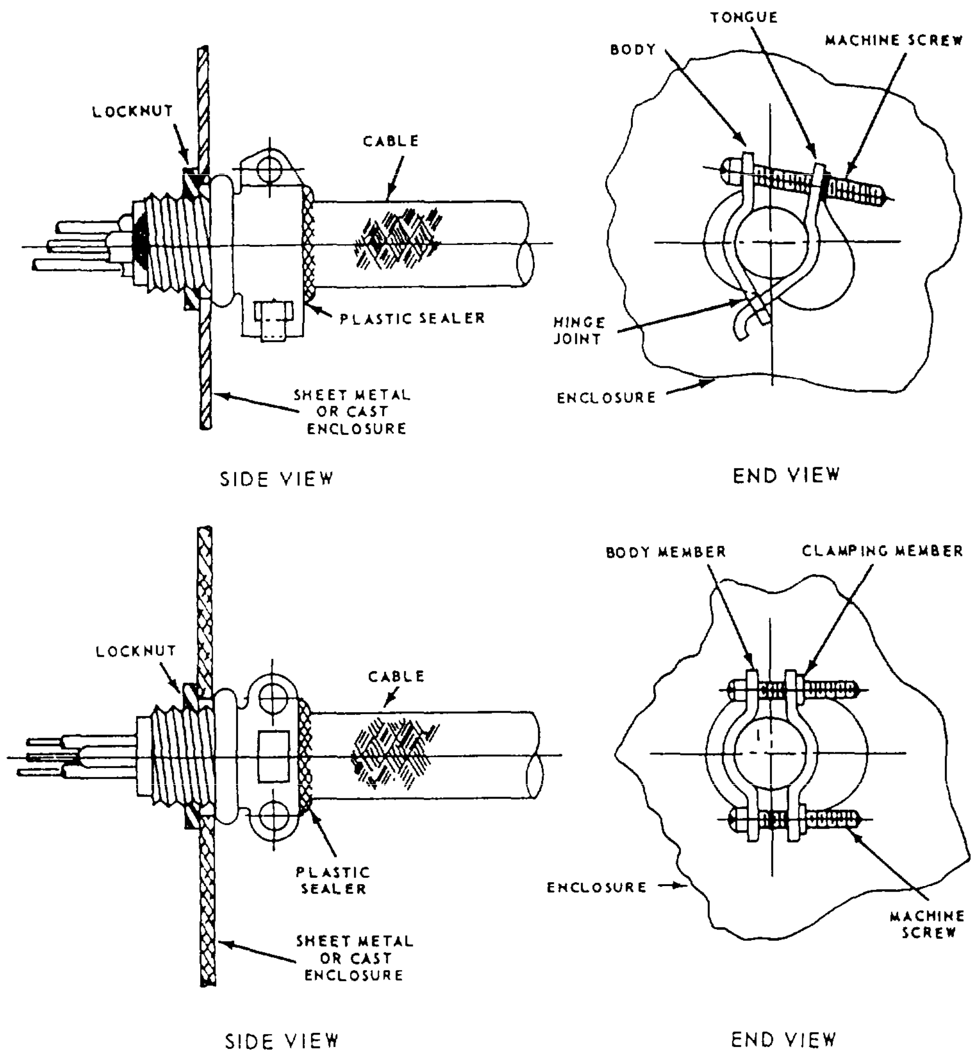


Figure 2-48.-Cable clamps.

This allows a single-size stuffing tube to be used for a variety of cable sizes, and makes it possible for 9 sizes of nylon tubes to replace 23 sizes of aluminum, steel, and brass tubes.

The nylon stuffing tube is available in two parts. The body, O-ring, locknut, and cap comprise the tube; and the rubber grommet, two slip washers, and one bottom washer comprise the packing kit.

A nylon stuffing tube that provides cable entry into an equipment enclosure is applicable to both watertight and nonwatertight enclosures (fig. 2-49, view A). Note that the tube body is inserted from inside the enclosure. The end of the cable armor, which will pass through the slip washers, is wrapped with friction tape to a maximum diameter. To ensure a watertight seal, one coat of neoprene cement is applied to the inner surface of the rubber grommet and to the cable sheath where it will contact the grommet. After the cement is applied, the grommet is immediately slipped onto the cable. The paint must be cleaned from the surface of the cable sheath before applying the cement.

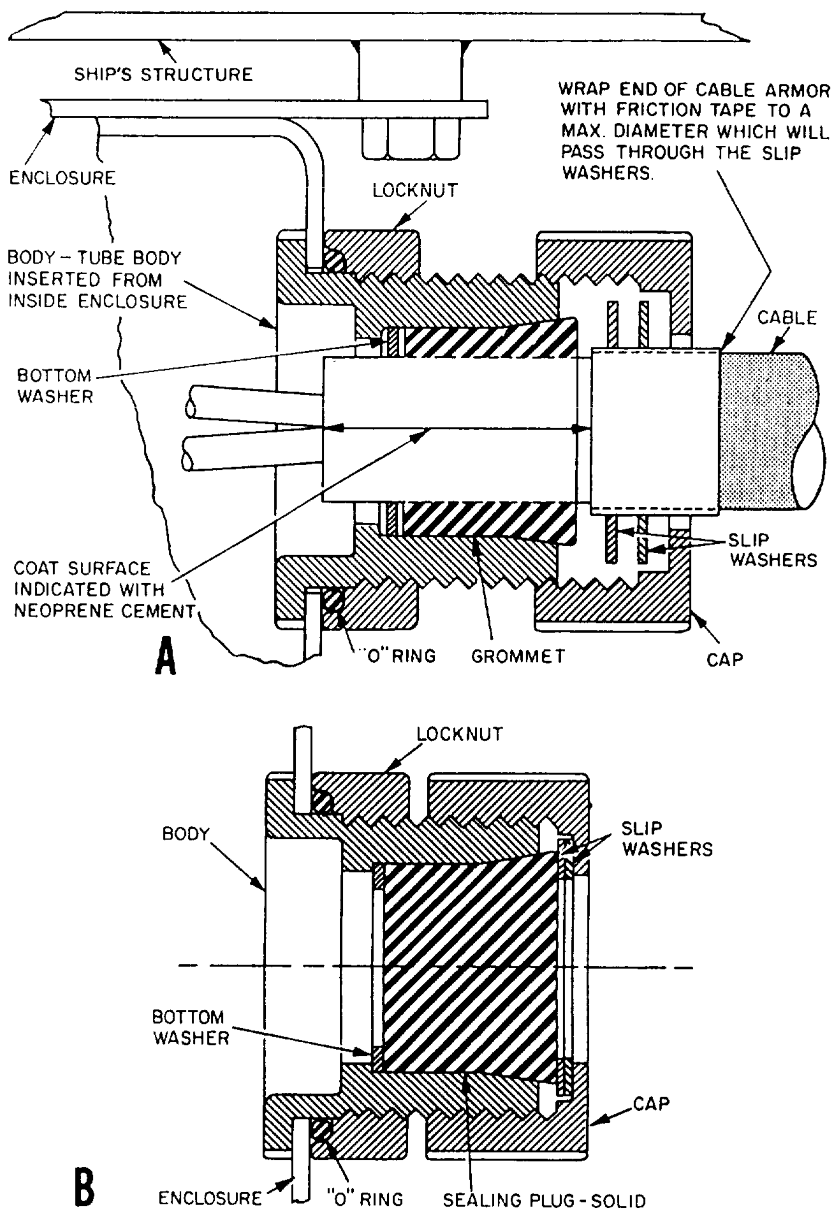


Figure 2-49.—Representative nylon stuffing tube installations.

Sealing plugs are available for sealing nylon stuffing tubes from which the cables have been removed. The solid plug is inserted in place of the grommet, but the slip washers are left in the tube (fig. 2-49, view B).

A grounded installation that provides for cable entry into an enclosure equipped with a nylon stuffing tube is shown in figure 2-50. This type of installation is required only when radio interference tests indicate

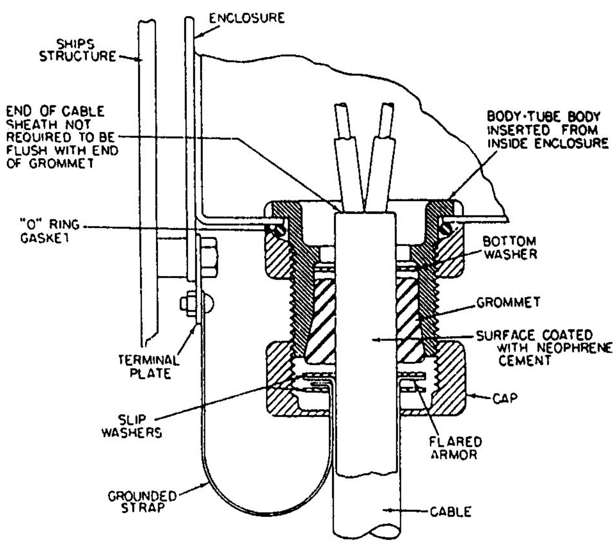


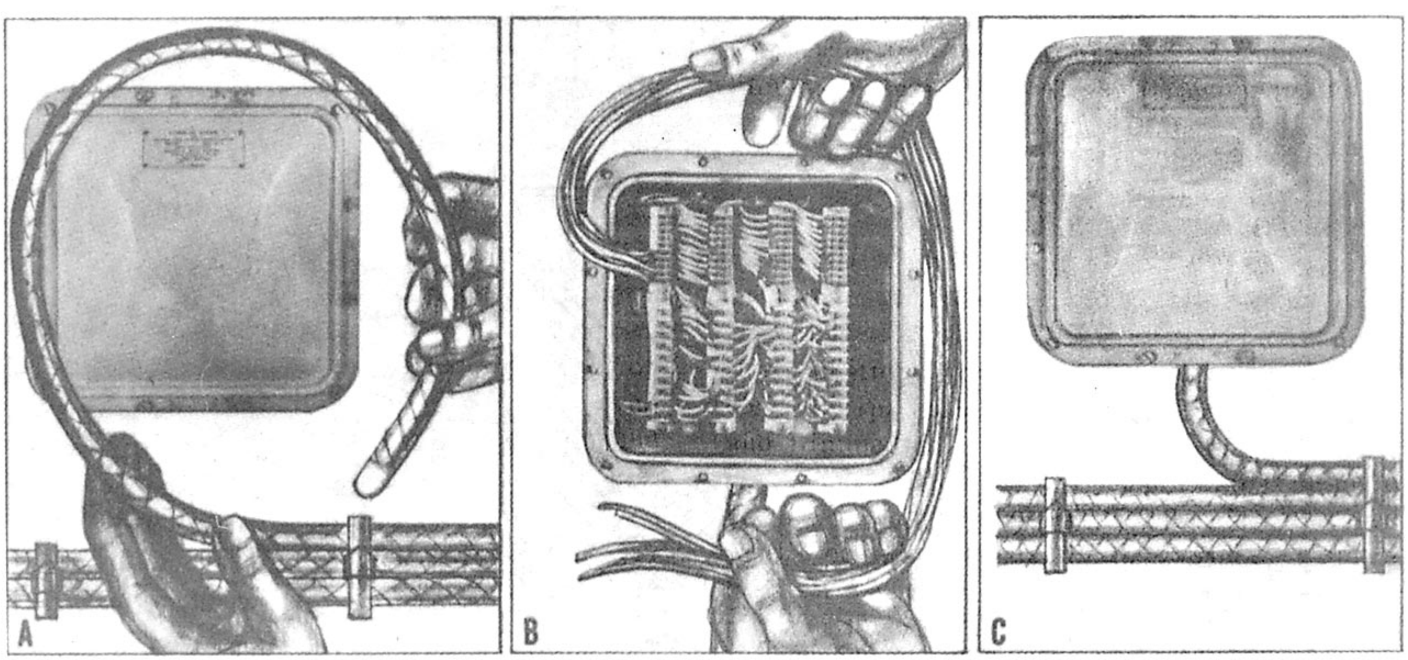
Figure 2-50.—Nylon stuffing tube grounded installation.

that additional grounding is necessary within electronic spaces. In this case, the cable armor is flared and trimmed to the outside diameter of the slip washers. One end of the ground strap is inserted through the cap; and one washer is flared and trimmed to the outside diameter of the washers. Contact between the armor and the strap is maintained by pressure of the cap on the slip washers and the rubber grommet.

Watertight integrity is vital aboard ship in peacetime or in combat. Just one improper cable installation could endanger the entire ship. For example, if a cable is replaced by a newer cable of a smaller size and the fittings passing through a watertight bulkhead are not changed to the proper size, the result could be two flooded spaces in the event of a collision or enemy hit.

Kickpipes and Deck Risers

Where one or two cables pass through a deck in a single group, kickpipes are provided to protect the cables against mechanical damage. Steel pipes are used with steel decks, and aluminum pipes with aluminum and wooden decks. When stuffing tubes and kickpipes are installed, care must be taken not to install two different metals together; an electrolytic action may be set up. Inside edges on the ends of the pipe and the inside wall of the pipe must be free of



140.15

Figure 2-51.—Connecting cable to a junction box.

burrs to prevent chafing of the cable. Kickpipes, including the stuffing tube, should have a minimum height of 9 inches and a maximum of 18 inches. If the height exceeds 12 inches, a brace is necessary to ensure rigid support. If the installation of kickpipes is required in nonwatertight decks, a conduit bushing may be used in place of the stuffing tube.

When three or more cables pass through a deck in a single group, riser boxes must be used to provide protection against mechanical damage. Stuffing tubes are mounted in the top of riser boxes required for topside weather-deck applications. For cable passage through watertight decks inside a vessel, the riser box may cover the stuffing tubes if it is fitted with an access plate of expanded metal or perforated sheet metal. Stuffing tubes are not required with riser boxes for cable passage through nonwatertight decks.

Connecting Cable

When connecting a newly installed cable to a junction box or unit of IC equipment, the length of the cable must be carefully estimated to ensure a neat installation (fig. 2-51). To do this, form the cable run from the last cable support to the equipment by hand. Allow sufficient slack and radius of bend to permit repairs without renewal of the cable. Carefully estimate where the armor on the cable will have to be cut to fit the stuffing tube (or connector), and mark the location with a piece of friction tape. In addition to serving as a marker, the tape will prevent unraveling and hold the armor in place during cutting operations.

Determine the length of the cable inside the equipment, using the friction tape as a starting point. Whether the conductors go directly to a connection or form a laced cable with breakoffs, carefully estimate the length of the longest conductor. Then add approximately 2 1/2 times its length, and mark this position with friction tape. The extra cable length will allow for mistakes in attaching terminal lugs and possible rerouting of the conductors inside the equipment. You now know the length of the cable and can cut it.

STRIPPING CABLE.— The cable armor maybe removed by using a cable stripper of the type shown in figure 2-52. Care must be taken not to cut or puncture the cable sheath where the sheath will contact the rubber grommet of the nylon stuffing tube.

Next, remove the impervious sheath, starting a distance of at least 1 1/4 inch (or as necessary to fit the requirements of the nylon stuffing tube) from where the armor terminates. Use the cable stripper for this job. Do not take a deep cut because the conductor insulation can be easily damaged. Flexing the cable will help separate the sheath after the cut has been made. Clean the paint from the surface of the remaining impervious sheath exposed by the removal of the armor. This paint is conducting. It is applied during manufacture of the cable and passes through the armor onto the sheath. Once the sheath has been removed, the cable filler can be trimmed with a pair of diagonal cutters.

CABLE ENDS.— When a cable is terminated in an enclosed equipment through a metal stuffing tube, the cable jacket must be tapered and any cavities filled with plastic sealer to prevent possible water transit in the event of flooding. The tapered section is then wrapped with synthetic resin tape, and the end of the tape served with treated glass cord.

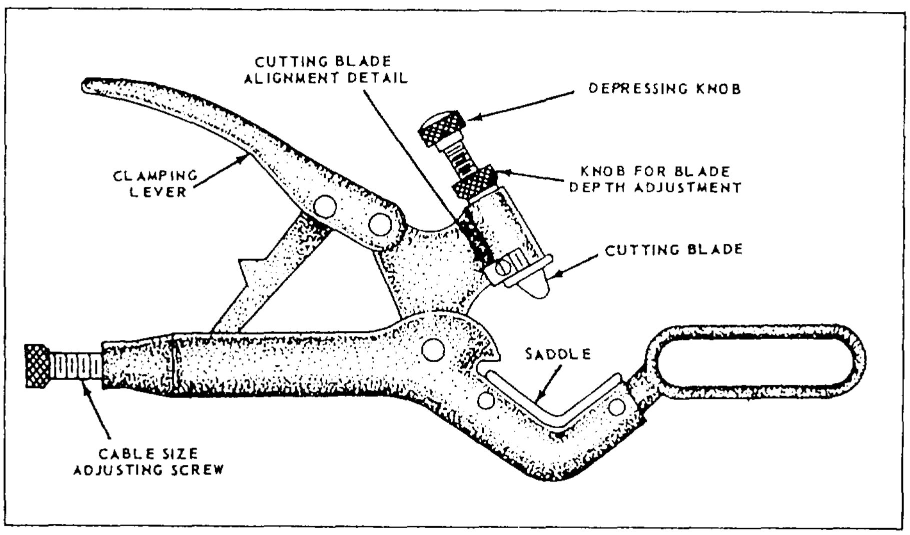


Figure 2-52.-Cable stripper.

When a cable is terminated in enclosed equipment through a nylon stuffing tube, the cable jacket is cut square and allowed to protrude through the grommet (fig. 2-49, view A).

When a connector is used for cable termination, the armor is cut back and taped, and the square cut jacket allowed to protrude through the connector about one-eighth inch.

The ends of cables terminating in open equipment are tapered, taped, served with cord, and varnished (fig. 2-53).

CONDUCTOR ENDS.— Hand wire strippers (fig. 2-54) are used to strip insulation from the conductors. Figure 2-55 shows the proper procedure for stripping conductor ends using the hand wire strippers. Care must be taken to avoid nicking the conductor while removing the insulation. Do not use side, or diagonal, cutters for stripping insulation from conductors.

Thoroughly clean conductor surfaces before applying terminals. After baring the conductor end for

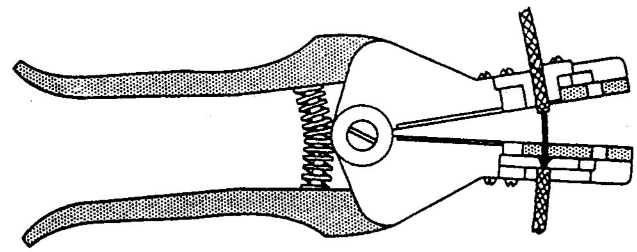
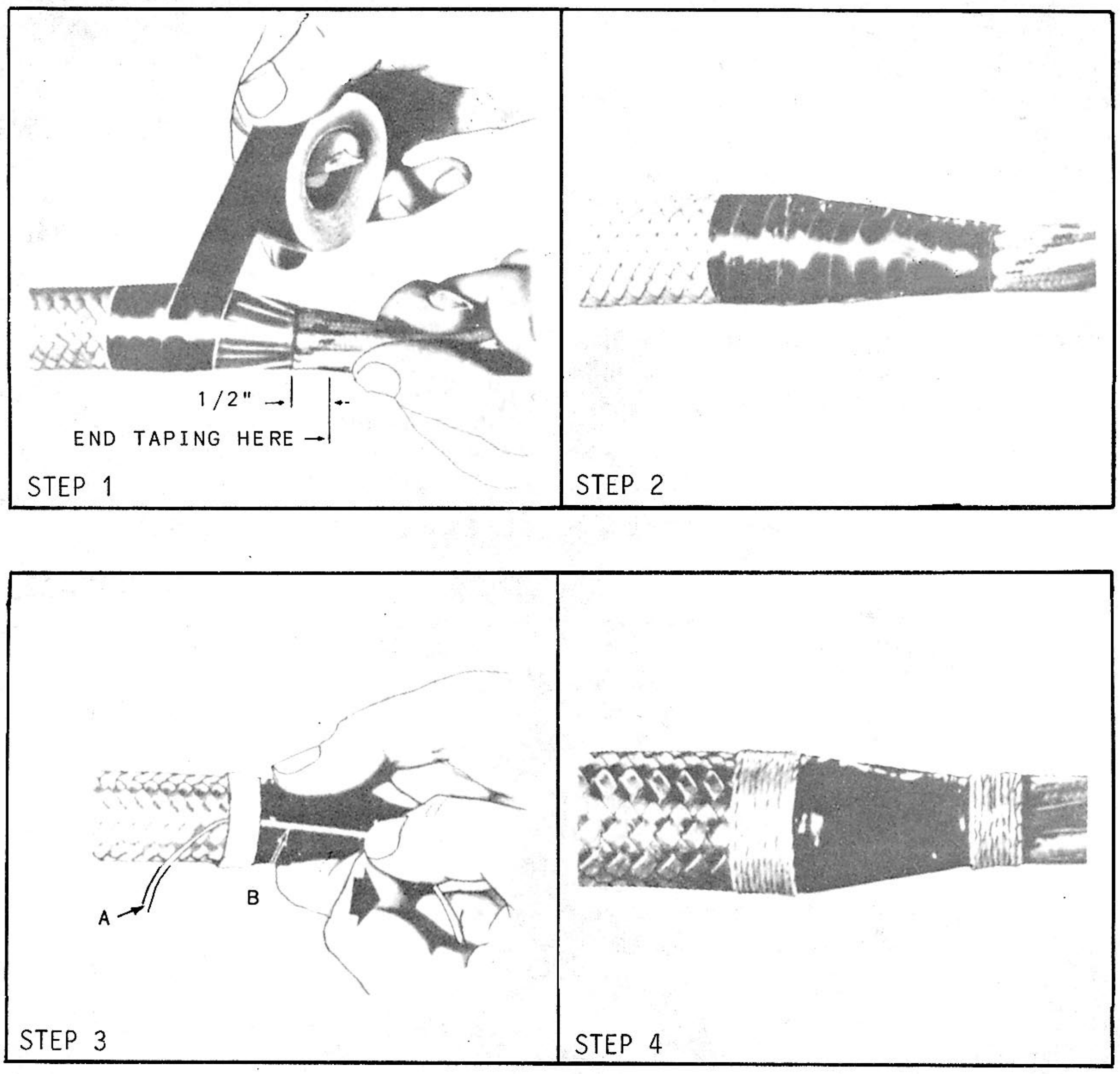


Figure 2-54.—Hand wire stripper.



29.226

Figure 2-53.—Preparing cable ends.

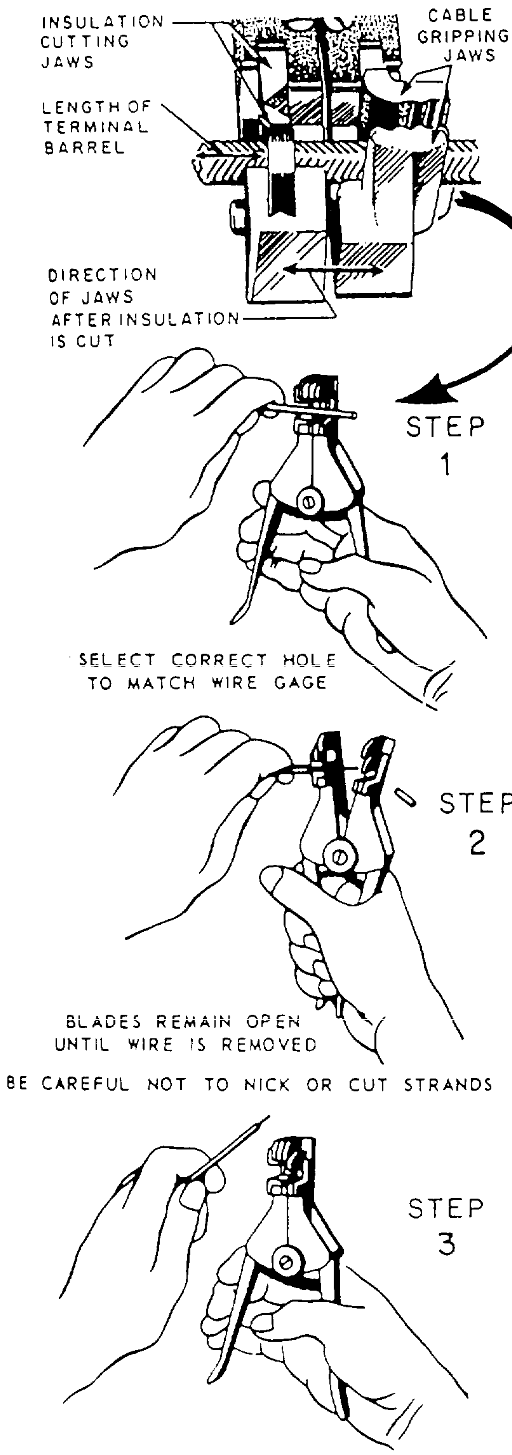


Figure 2-55.—Stripping wire with a hand stripper.

a length equal to the length of the terminal barrel, clean the individual strands thoroughly and twist them tightly together. Solder them to form a neat, solid terminal for fitting either approved clamp-type lugs or solder-type terminals. If the solder-type terminal is used, tin the terminal barrel and clamp it tightly over the prepared conductor (before soldering) to provide a solid mechanical joint. Conductor ends need not be soldered for use with solderless-type terminals applied with a crimping tool. Do not use a side, or diagonal, cutter for crimping solderless-type terminals. Refer to NEETS, module 4, for the proper procedures for soldering and crimping.

Solderless-type terminals may be used for all lighting, power, interior communications, and fire control applications. However, equipment provided with solder-type terminals by the manufacturer and wiring boxes or equipment in which electrical clearances would be reduced below minimum standards require solder-type terminals.

For connection under a screwhead where a standard terminal is not practicable, you can use an alternate method. Bare the conductor for the required distance and thoroughly clean the strands. Then twist the strands tightly together, bend them around a mandrel to form a suitable size loop (or hook where the screw is not removable), and dip the prepared end into solder. Remove the end, shake off the excess solder, and allow it to cool before connecting it.

After the wiring installation has been completed, measure the insulation resistance of the wiring circuit with a Megger or similar (0 to 100 megohm, 500 volts dc) insulation resistance measuring instrument. Do not energize a newly installed, repaired, or modified wiring circuit without first ascertaining (by insulation tests) that the circuit is free of short circuits and grounds.

Lacing Conductors

Conductors within equipment must be kept in place to present a neat appearance and to facilitate tracing of the conductors when alterations or repairs are required. When conductors are properly laced, they support each other and form a neat, single cable.

Use a narrow flat tape wherever possible for lacing and tying. This tape is not an adhesive type of tape. Round cord may also be used, but its use is not preferred because cord has a tendency to cut into wire insulation. Use cotton, linen, nylon, or glass fiber cord or tape, according to the temperature requirements.

Cotton or linen cord or tape must be prewaxed to make it moisture and fungus resistant. Nylon cord or tape may be waxed or unwaxed; glass fiber cord or tape is usually unwaxed.

The amount of flat tape or cord required to single lace a group of conductors is about 2 1/2 times the length of the longest conductor in the group. Twice this amount is required if the conductors are to be double laced.

Before lacing, lay the conductors out straight and parallel to each other. Do not twist them together. Twisting makes conductor lacing and tracing difficult.

A shuttle on which the cord can be wound will keep the cord from fouling during the lacing operations. A shuttle similar to the one shown in figure 2-56 may easily be fashioned from aluminum, brass, fiber, or plastic scrap. Smooth the rough edges of the material used for the shuttle to prevent injury to the operator and damage to the cord.

To fill the shuttle for single lace, measure the cord, cut it, and wind it on the shuttle. For double lace, proceed as before, except double the length of the cord before winding it on the shuttle, and start the ends on the shuttle to leave a loop for starting the lace.

Some installations, however, require the use of twisted wires. One example is the use of twisted pairs for the ac filament leads of certain electron tube amplifiers. This minimizes the effect of radiation of their magnetic field and helps to prevent annoying hums in the amplifier output. You should duplicate the original layout when replacing such twisted leads and when relating and wiring harness.

SINGLE LACE.— Single lace may be started with a square knot and at least two marling hitches drawn tight. Details of the square knot and the marling hitch are shown in figure 2-57. Do not confuse the marling hitch with a half hitch. In the marling hitch, the end is passed over and under the strand (step 1). After forming the marling hitches, draw them tight against the square knot (step 2). The lace consists of a

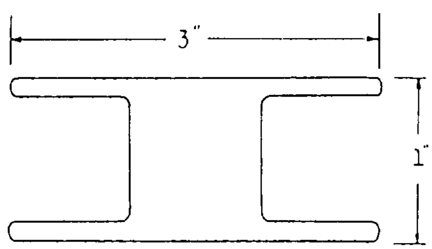


Figure 2-56.—Lacing shuttte.

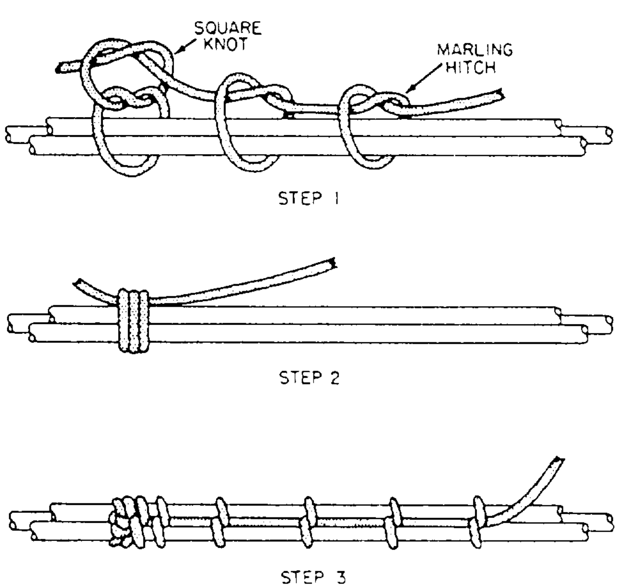


Figure 2-57.—Applying single lace.

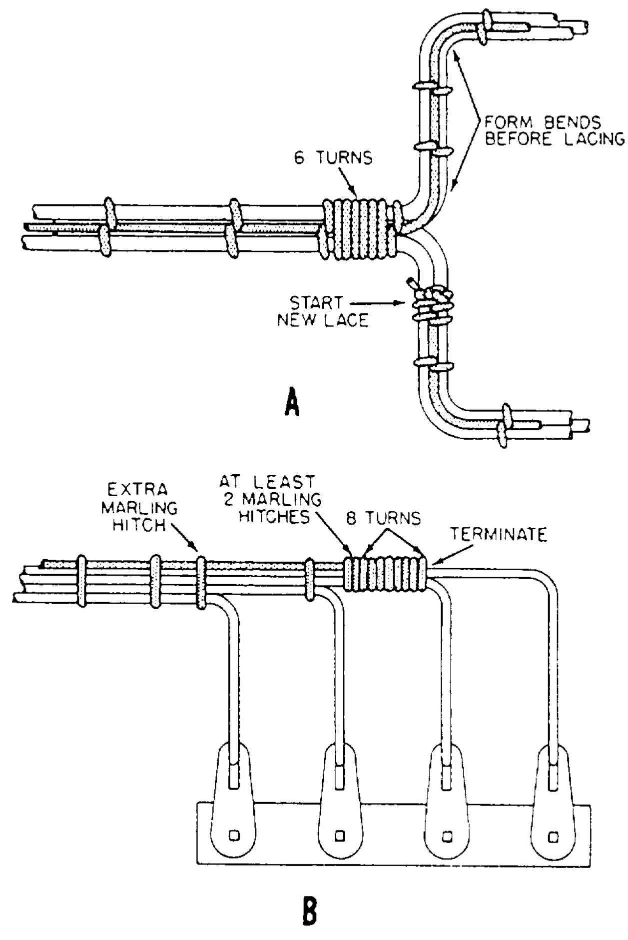


Figure 2-58.—Lacing branches and breakouts.

series of marling hitches evenly spaced at 1/2- to 1-inch intervals along the length of the group of conductors (step 3).

When dividing conductors to form two or more branches, follow the procedure illustrated in figure 2-58. Bind the conductors with at least six turns between two marling hitches, and continue the lacing along one of the branches (fig. 2-58, view A). Start a new lacing along the other branch. To keep the bends in place, form them in the conductors before lacing. Always add an extra marling hitch just before a breakout (fig. 2-58, view B).

DOUBLE LACE.— Double lace is applied in a manner similar to single lace. However, it is started with the telephone hitch and is double throughout the length of the lacing (fig. 2-59). You can terminate double, as well as single, lace by forming a loop from a separate length of cord and using it to pull the end of the lacing back underneath a serving of approximately eight turns (fig. 2-60).

An alternate method of ending the lacing is illustrated in figure 2-61. This method can also be used for either single- or double-cord lacing.

LACING MULTICONDUCTORS.— Lace the spare conductors of a muticonductor cable separately, and secure them to active conductors of the cable with a few telephone hitches. When two or more cables enter an enclosure, each cable group should be laced

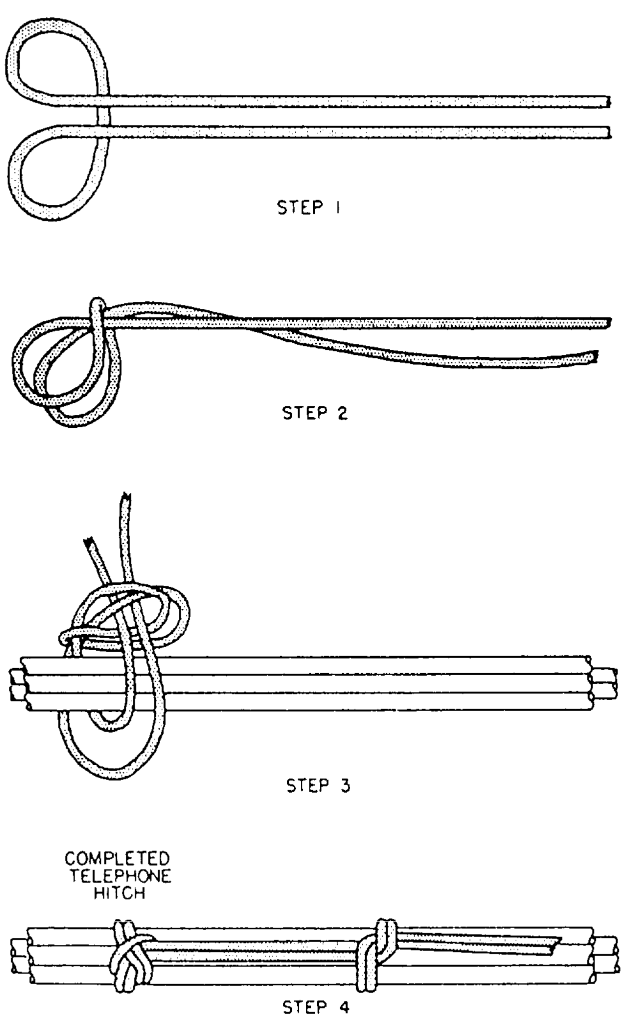


Figure 2-59.-Starting double lace with the telephone hitch.

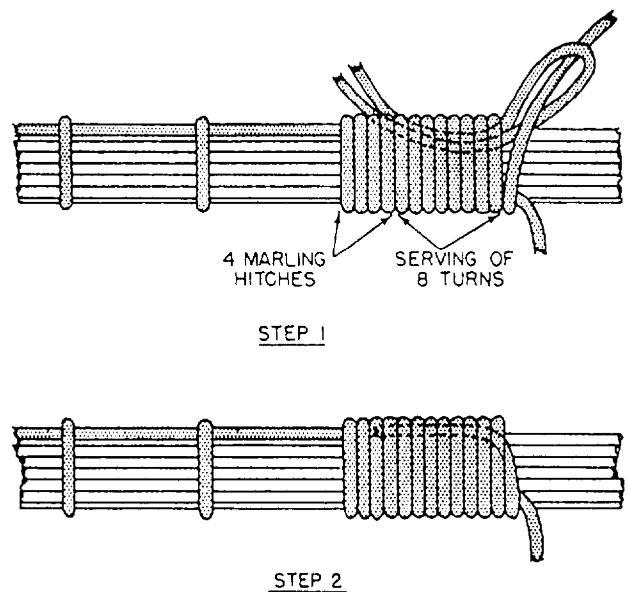


Figure 2-60.-The loop method of terminating the lace.

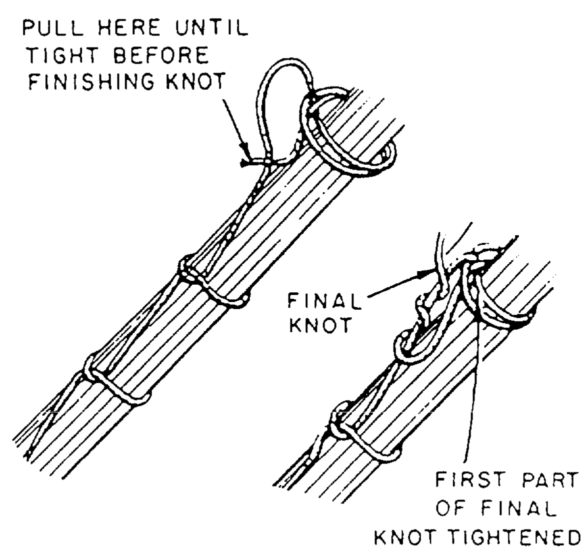


Figure 2-61.—Alternate method of terminating the lace.

separately. When groups parallel each other, they should be bound together at intervals with telephone hitches.

Conductor ends (3000 cm or larger) should be served with cord to prevent fraying of the insulation (fig. 2-62).

SPOT TYING.— When cable supports are used in equipment, as illustrated in figure 2-63, spot ties are used to secure the conductor groups if the supports are more than 12 inches apart. The spot ties are made by wrapping the cord around the group (fig. 2-64). To finish the tie, a clove hitch followed by a square knot with an extra loop is used. The free ends of the cord are then trimmed to a minimum of three-eighths of an inch.

SELF-CLINCHING CABLE STRAPS.— Self-clinching cable straps are adjustable, lightweight, flat nylon straps. They have molded ribs or serrations on the inside surface to grip the wire. They may be used instead of individual cord ties for securing wire groups or bundles quickly. The straps are of two types: a plain

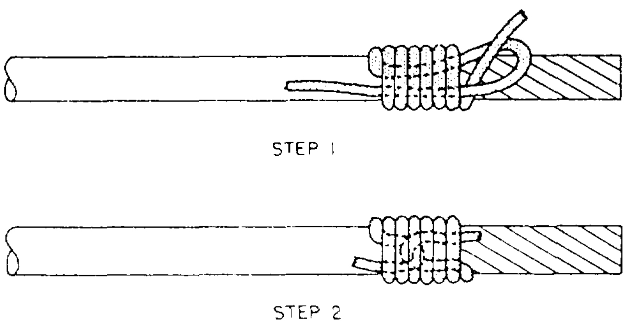


Figure 2-62.-Serving conductor ends.

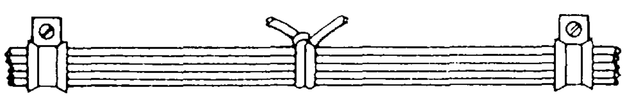


Figure 2-63.-Use of spot ties.

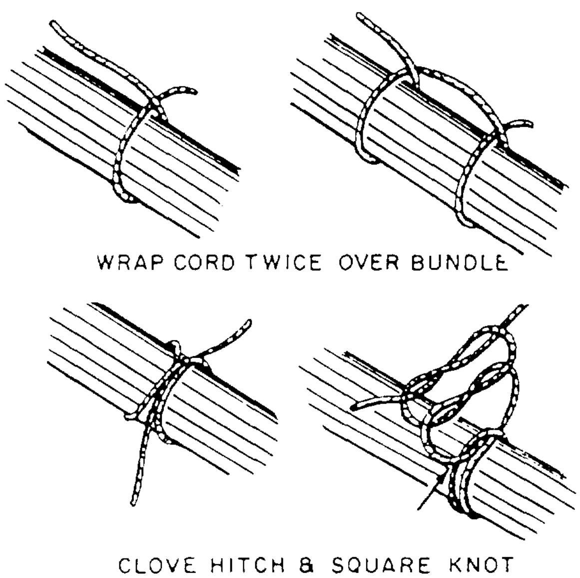


Figure 2-64.-Making spot ties.

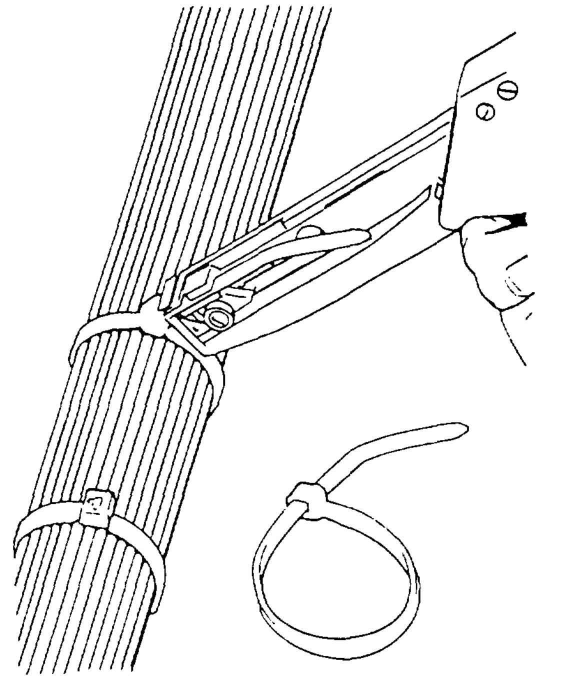


Figure 2-65.—Installing self-clinching cable straps.

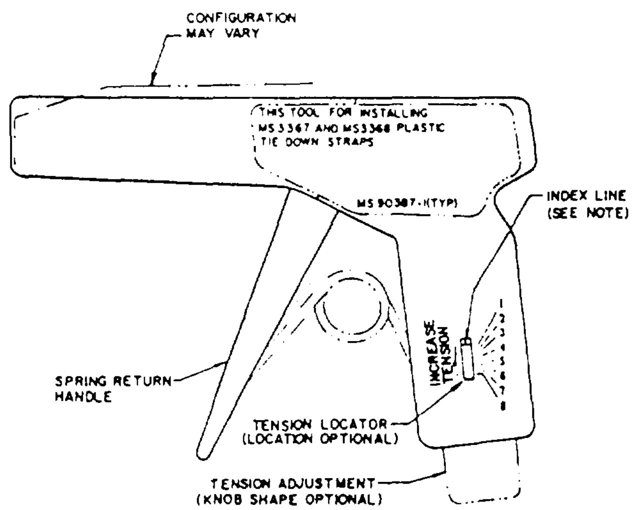


Figure 2-66.-Military standard tool for self-clinching cable straps.

cable strap and one that has a flat surface for identification of cables.

Installing self-clinching cable straps is done with a military standard hand tool (fig. 2-65). An illustration of the working parts of the tool is shown in figure 2-66. To use the tool, follow the manufacturer's instructions. Do not use nylon cable straps over wire bundles containing radio-frequency (RF) coaxial cable. Do not use nylon straps in areas where failure of the strap would allow the strap to fall into movable parts or in high-temperature areas (above 250°F).

HIGH-TEMPERATURE, PRESSURE-SENSITIVE TAPE LACING.— High-temperature, pressure-sensitive tape should be used to tie wire bundles in areas where the temperatures may go above 250°F. Install the tape as follows (see fig. 2-67):

1. Wrap tape around the wire bundle three times, with a two-thirds overlap for each turn.

2. Heat-seal the loose tape end with the side of a soldering iron tip.

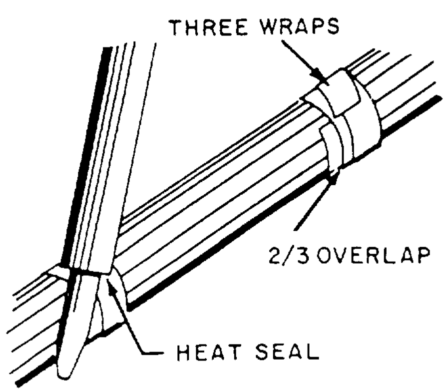


Figure 2-67.-Securing wire bundles in high temperature areas.

RADIO-FREQUENCY COAXIAL CABLES

RF cables may look like power cables, but they require special handling and careful installation. These cables are vital to the proper operation of all electronic equipment. They must be installed and maintained with the greatest care.

Flexible RF transmission lines (coax) are two-conductor cables. One conductor is concentrically contained within the other, as shown in figure 2-68. Both conductors are essential for efficient operation of the transmission line. The proper connectors and terminations are also necessary for efficient operation of the line.

The inner conductor may be either solid or stranded. It may be made of unplated copper, tinned copper, or silver-plated copper. Special alloys may be used for special cables.

The dielectric insulating material is usually polyethylene or Teflon. Polyethylene is a gray, translucent material. Although it is tough under general usage, it will flow when subjected to heavy pressure for a period of time. Teflon is a white opaque plastic material. This material will withstand high temperatures and will remain flexible at relatively low temperatures. It has a peculiar quality in that nothing will stick to it, and it is unaffected by the usual solvents.

Braided copper is usually used for the outer conductor; it maybe tinned, silver-plated, or bare. The outer conductor is chosen to give the best electrical qualities consistent with maximum flexibility.

The protective insulating jacket is usually a synthetic plastic material (vinyl resin). Neoprene rubber is generally used on pulse cable; silicone rubber jackets are used for high-temperature applications.

Armor is needed for protection. It may be braided aluminum, or sometimes galvanized steel, similar to that used on power cables.

SUMMARY

In this chapter, we have discussed some of the more common types of switches, relays, and solenoids used in the IC Electrician field. We have also discussed the use of fuses, circuit breakers, and overload relays in protecting IC equipment. Additionally, we have identified electrical cables used to supply power for IC equipment and the proper procedures for installing and connecting cable to the equipment.

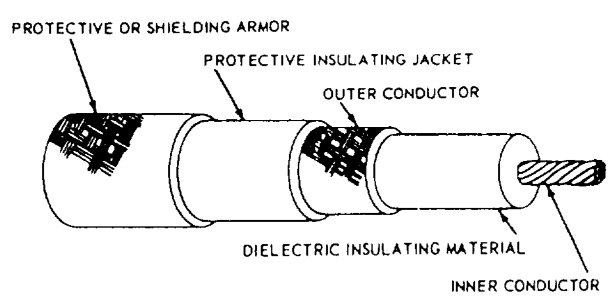


Figure 2-68.-Construction of flexible RF transmission line.

CHAPTER 3

POWER DISTRIBUTION, IC SWITCHBOARDS, AND CONTROLLERS

LEARNING OBJECTIVES

Upon completion of this chapter you will be able to do the following:

- *Describe the various electrical distribution systems installed on board Navy ships.*
- *Describe the characteristics, construction features, and functions of the various types of IC switchboards.*
- *Describe a typical IC power distribution system.*
- *Identify the various switchboard components used with IC switchboards.*
- *Identify IC circuits by their classification.*
- *Describe a typical IC test switchboard.*

INTRODUCTION

A ship's electrical equipment requires a constant uninterrupted supply of power to function properly. The ship's service power distribution system, the emergency power distribution system, and the casualty power distribution system provide power for the IC switchboards and other IC systems aboard ship. As an Interior Communications (IC) Electrician, you should become familiar with these different power sources. Your duties as an IC Electrician includes troubleshooting, repairing, and maintaining power distribution systems assigned to your division. This includes switchboards, power supplies, and motor controllers.

IC SYSTEMS CLASSIFICATION

IC systems are classified by importance, readiness, and designation.

IMPORTANCE

The importance classification defines the extent to which a system affects the fighting effectiveness of the ship. There are three classifications of importance: vital, semivital, and nonvital.

Vital Systems

An IC system classified as vital (V), if disabled, would seriously impair the fighting effectiveness and maneuverability of the ship.

Semivital Systems

An IC system classified as semivital (SV), if disabled, would impair the fighting effectiveness of the ship to a lesser extent than the loss of a vital system.

Nonvital Systems

An IC system classified as nonvital (NV), if disabled, would not impair the fighting effectiveness or maneuverability of the ship.

READINESS

IC systems are also classified according to the extent to which a system contributes to the operational readiness of the ship. There are four classes of readiness: class 1, class 2, class 3, and class 4. Readiness classification only switchboard plates is indicated by color on surface ships and by a specific symbol on submarines.

Class 1

Class 1 IC systems are systems that are essential to the safety of the ship and ship personnel. Class 1 IC systems are energized at all times. The switchboard plate is colored yellow on surface ships, and the symbol for submarines is a rectangle within a hexagon.

Class 2

Class 2 IC systems are systems that, together with class 1 systems, are essential to ship control. Class 2 systems are energized when the ship is preparing to get underway, standing by, underway, and anchoring, and until the ship is secured. The switchboard plate is colored black on surface ships, and the symbol for submarines is a rectangle.

Class 3

Class 3 IC systems are systems that, together with class 1 and class 2 systems, are essential to complete interior control and battle circuits. Class 3 systems are energized during condition watches and operations. The switchboard plate is colored red on surface ships, and the symbol for submarines is a circle.

Class 4

Class 4 IC systems are convenience circuits. These circuits are energized only when they are required. The switchboard plate is colored white on surface ships, and the symbol for submarines is a triangle.

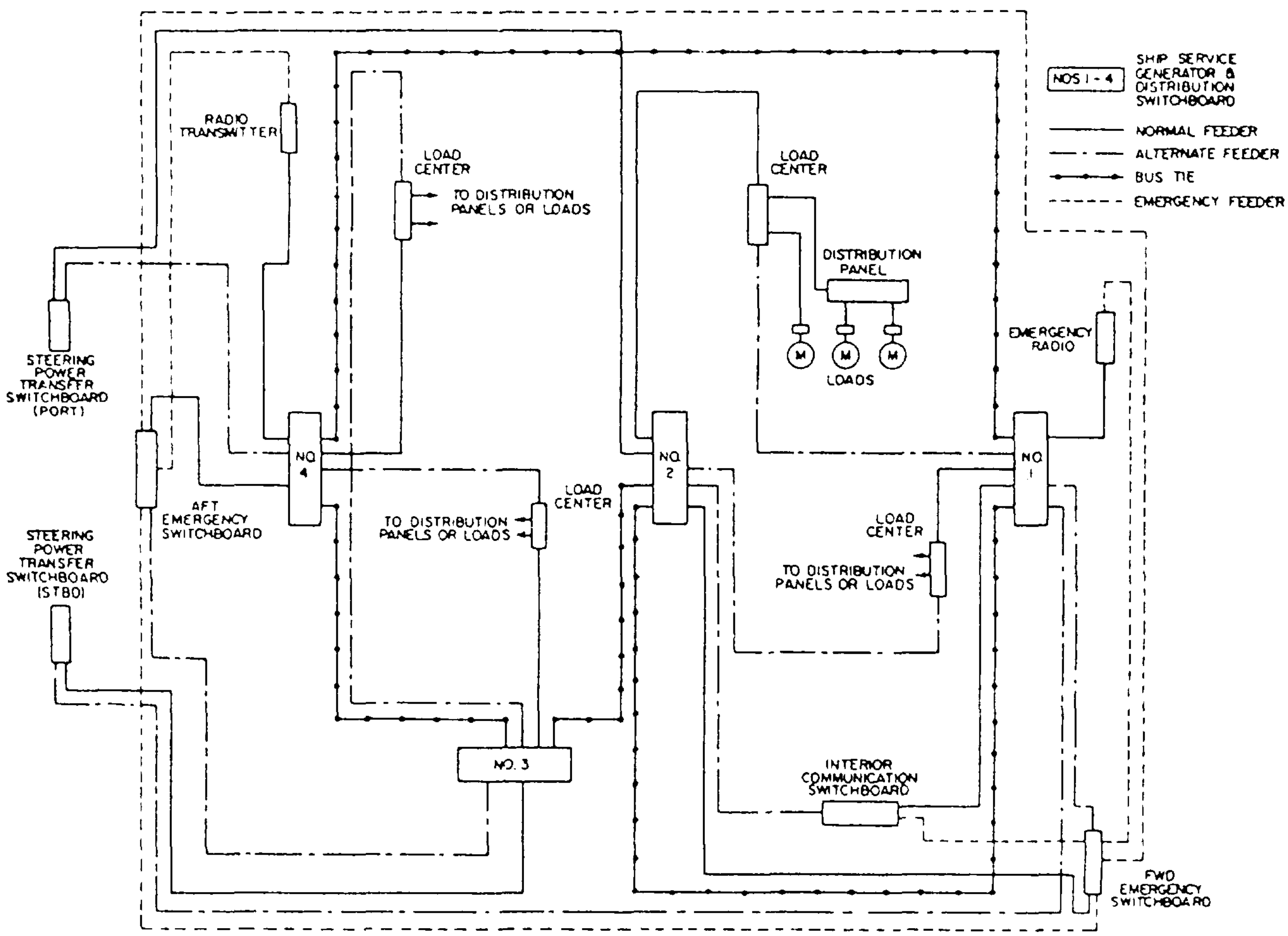


Figure 3-1.—Typical power distribution system found in a large combatant ship.

DESIGNATION

All IC systems are identified by circuit designations. Designations consist of single or double letters as previously described in chapter 2 under the heading Cable Marking.

SHIP'S SERVICE POWER DISTRIBUTION SYSTEM

The ship's service power distribution system is the electrical system that normally supplies power to the ship's equipment and machinery. The ship's service switchboards and associated generators are usually located in separate engineering spaces to minimize the possibility that a single hit will damage more than one switchboard.

The ship's service generator and distribution switchboards are interconnected by bus ties. This interconnection allows any distribution switchboard to feed power from its generators to one or more of the other switchboards, allowing the generator plants to be operated in parallel. The power distribution to loads can be directly from the generator and distribution switchboards. The power distribution can also be from distribution panels to small loads, or from load centers to larger loads. Figures 3-1 and 3-2 are examples of two typical power distribution systems found on some ships.

Most ac power distribution systems in naval vessels are 450-volt, 3-phase, 60-Hz, 3-wire ungrounded systems.

EMERGENCY POWER DISTRIBUTION SYSTEM

The emergency power distribution system supplies a limited amount of power for ship control and for the operation of vital equipment when the ship's service distribution system fails. An emergency power distribution system is installed on most combatant ships and some auxiliary ships.

This system is separate and distinct from the ship's service distribution generators and switchboards. Each emergency switchboard is supplied by its associated emergency diesel generator. The emergency feeders run from the emergency switchboards and terminate in manual or automatic bus transfer equipment at the distribution panels or at loads for which emergency power is required.

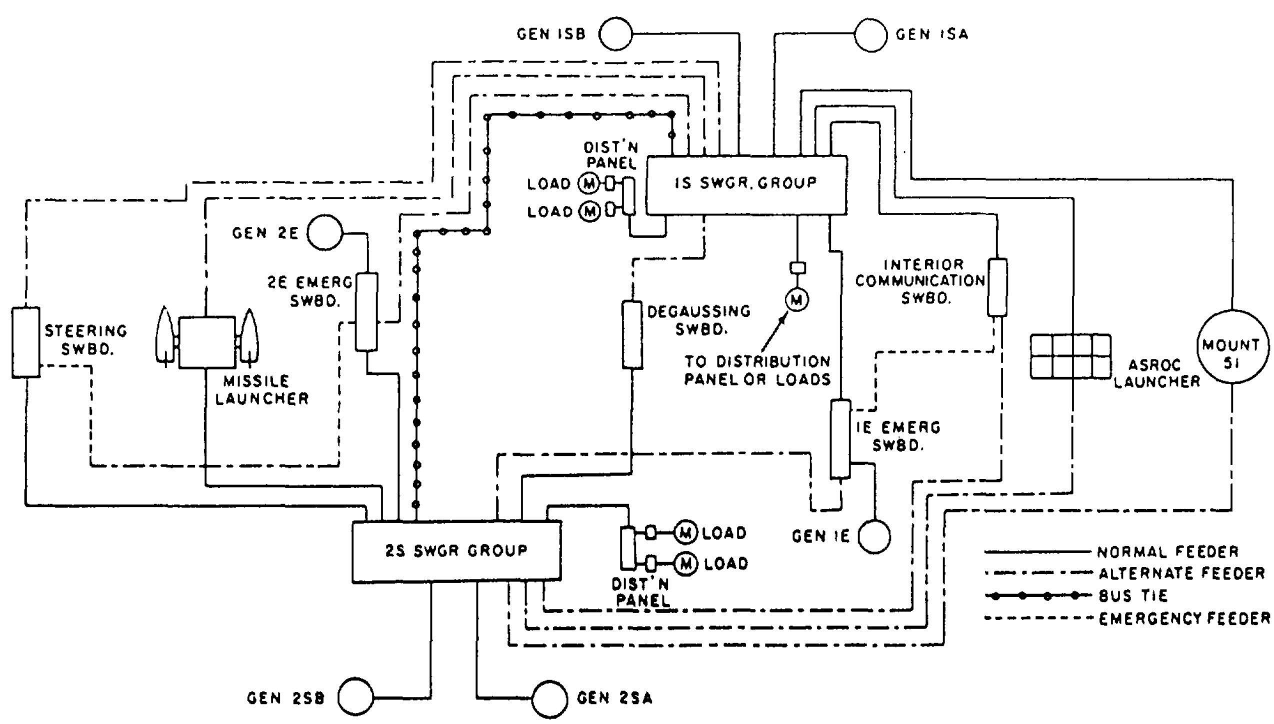


Figure 3.2-npicai power distribution system found In a guided missile destroyer.

The emergency switchboard is connected by feeders (fig. 3-3) to at least one and usually to two different ship's service switchboards. One of these ship's service switchboards is the preferred (normal) source of ship's service power for the emergency switchboard, and the other is the alternate source. The emergency switchboard and the distribution system are normally energized from the normal source of ship's service power. If this source of power should fail, bus transfer equipment automatically transfers the emergency switchboard to the alternate source of the ship's service power. If both the normal and alternate sources of power fail, the emergency generator will start automatically within 10 seconds and the emergency switchboard will automatically transfer to the emergency generator.

The emergency power distribution system is 450 volts, 3 phase, 60 Hz with transformer banks at the emergency distribution switchboards to provide 120-volt, 3-phase power for the emergency lighting system.

CASUALTY POWER DISTRIBUTION SYSTEM

A casualty power distribution system is installed on certain types of ships to provide the means for making temporary electrical connections if the permanently installed ship's service and emergency distribution systems cables are damaged. The system is limited to those facilities that are necessary to keep the ship afloat and to permit the ship to get out of a danger area. The system also supplies a limited amount of power to armament and directors to protect the ship when it is in a damaged condition.

If the ship's service and emergency circuits fail, temporary circuits can be rigged. Also, the casualty power distribution system can be used to supply power to vital auxiliaries if any of the ship's service or emergency generators can be operated.

Component parts of the casualty power distribution system include permanent and portable cables, bulkhead and switchboard terminals, risers, and portable switches.

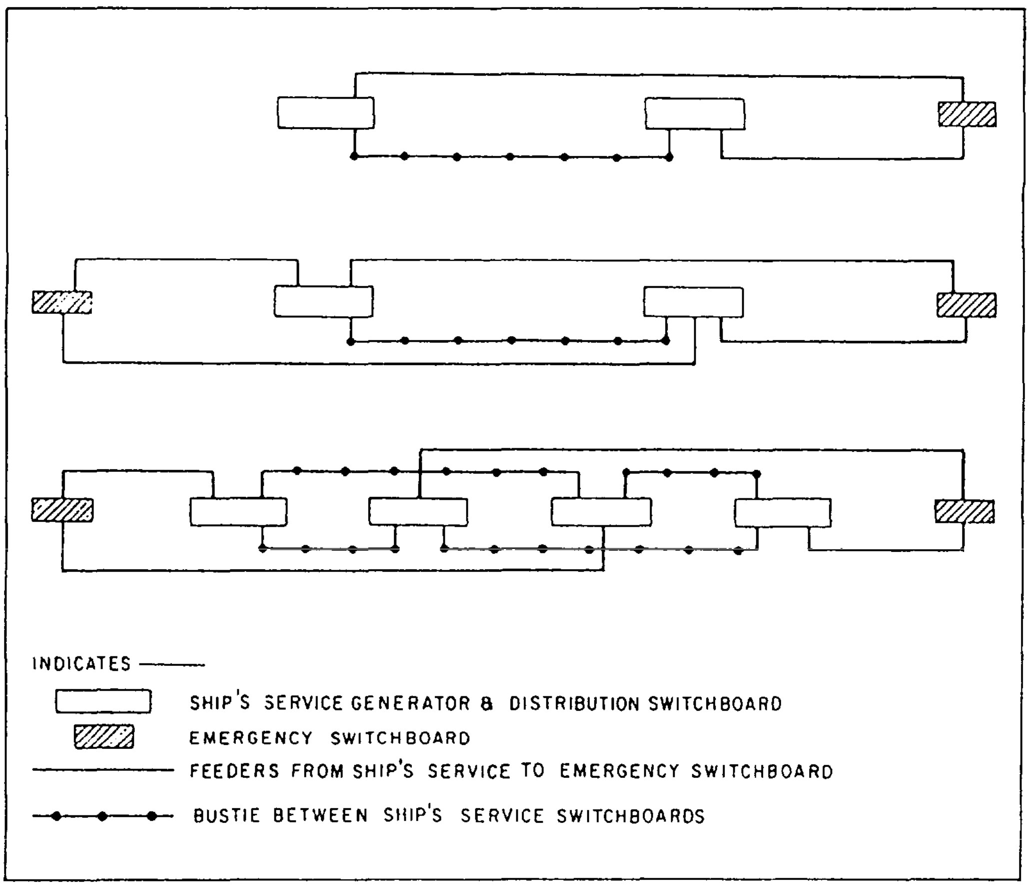


Figure 3-3.-Emergency and ship's service distribution system interconnections.

Suitable lengths of portable cable are stowed on racks throughout the ship close to locations where they may be needed.

Risers, consisting of a terminal at each end connected by permanently installed cable, provide connection points for 3-phase portable cables between decks. Bulkhead terminals are permanently installed in watertight bulkheads in chosen locations. Bulkhead terminals are used to connect the portable cables on opposite sides of bulkheads. This enables power to be transmitted through compartments without the loss of watertight integrity.

Casualty power switchboard terminals are provided at switchboards as well as at some distribution panels. Portable cables can be connected at these points to obtain power from, or supply power to, the bus bars. Casualty power circuit breakers are also installed at switchboards to de-energize terminals for connecting cables.

Portable switches are stowed in repair party lockers and can be used, when necessary, for connecting and disconnecting circuits.

Casualty power cables are to be rigged only when they are required for use or for practice in rigging the system.

Only qualified personnel should do the actual connecting; however, other personnel may lay out the portable cables. In rigging casualty power cables, make the connections from the load to the source to avoid handling energized cables. During practice sessions, do not make connections to any terminal that is not provided with a disconnect switch to de-energize the terminal until all power is disconnected and disconnects tagged according to safety instructions. For more detailed information on rigging and unrigging casualty power, consult *NSTM,* chapter 079, volume 3, "Damage Control Engineering Casualty Control."

IC AND ACO SWITCHBOARDS

Shipboard IC systems are defined as anything that causes an audible or visual signal to be transferred within or between the compartments of a ship. They provide a means of exercising command within a ship and include voice interior communications, alarm, warning, ship's control, entertainment, gyrocompass, and plotting systems.

IC systems receive their power from a variety of sources. The majority are energized from main IC switchboards. Some IC systems receive their power from a small local IC switchboard or a local lighting power panel.

The IC switchboard is the nerve center of the interior communications system. To obtain maximum protection, most IC switchboards are installed below the waterline and are energized from a normal, an alternate, and an emergency power supply to ensure continuous service. Since, in effect, all means of controlling the navigational systems on most ships depend upon proper functioning of the IC switchboards, their reliability is of the utmost importance. Many of the weapons and fire control (FC) circuits also receive their power from the IC switchboards; however, these systems are not part of the IC Electrician's responsibility.

In large combatant ships, there are normally two main IC switchboards. One switchboard is located in the forward IC room, and the other switchboard is located in the after IC room. This enables each system or equipment to receive its normal power supply from the nearest IC switchboard. Smaller ships may have only one main IC switchboard.

Local IC switchboards are installed in various spaces to provide local control of circuits vital to the operation of the space. These switchboards are usually found in engine rooms, central control stations, steering gear rooms, and other spaces if required.

Some of the newer ships also have a combat systems switchboard. On some ships this switchboard serves as an interface between certain IC and nonelectronic navigation systems and the ship's combat system. This switchboard also supplies power and action cutout (ACO) switching for certain IC systems. On other ships, this switchboard contains no distribution facilities. The switchboard is confined to ACO switching for the various instruments at navigational stations and inputs to the weapons control systems.

MAIN IC SWITCHBOARD

The latest type of main IC switchboard is the front-service switchboard. This switchboard is constructed so installation, operation, and maintenance can be accomplished entirely from the front of the switchboard. The switchboard can be mounted against a bulkhead because no access space is required in the rear of the board. This results in a saving of space, which is most important aboard ship.

The switchboard is a type 1, deck-mounted, front-serviced, enclosed, box-type structure. The structure is divided into panels, with each panel having a hinged door. Lightweight items, such as switches, meters, fuse holders of up to 60-ampere capacity, and other equipment, are mounted on the front of the hinged doors. The doors are hinged on the left-hand side and are provided with two "dog-type" latches on the right-hand side and a door stop assembly.

Terminal boards are mounted on the rear of each panel. Cables are terminated at the terminal boards on the inside of the panel. Wiring between the terminal boards and the door-mounted equipment is installed to ensure free-swinging of the doors without interference from, or damage to, the wiring harness.

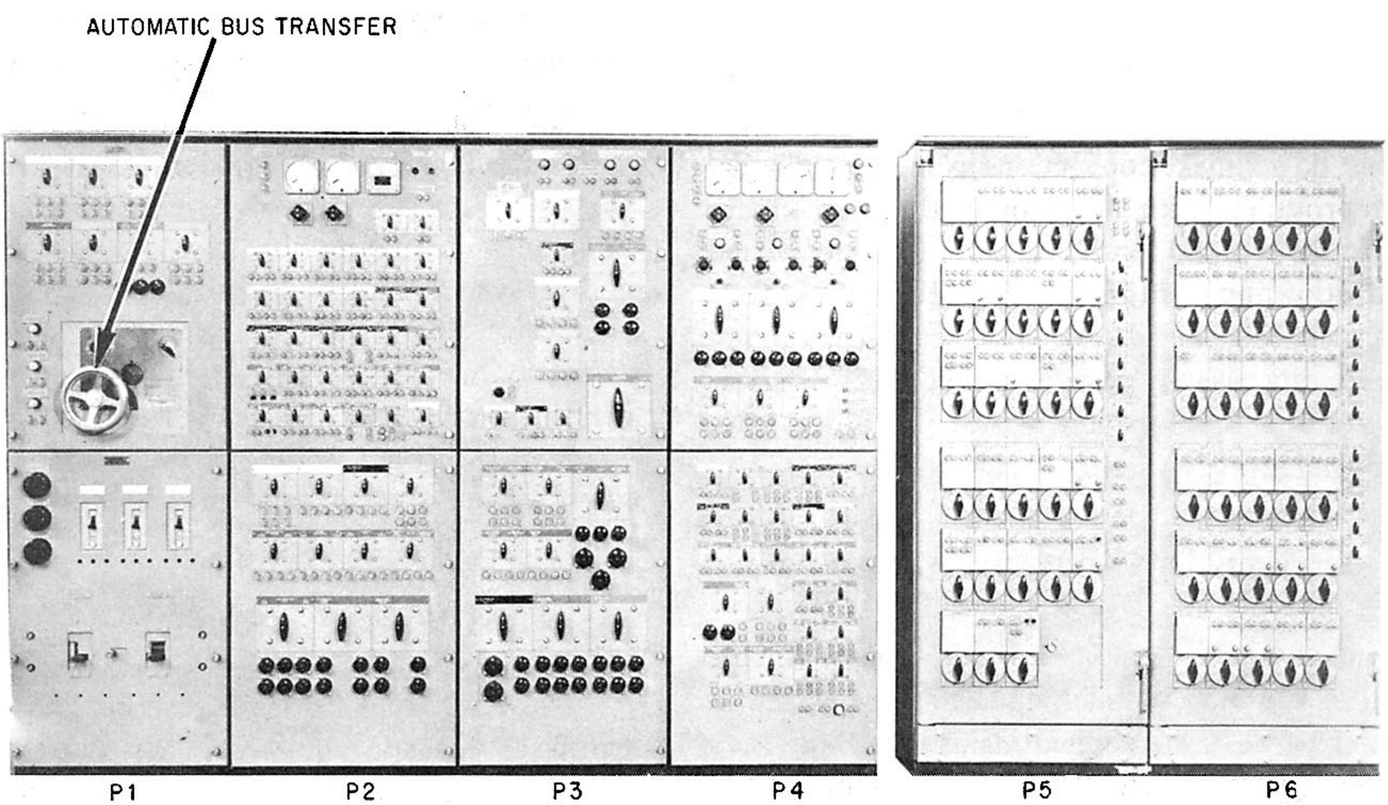
The switchboard consists of a power distribution section and an ACO section, The power distribution section may be subdivided into various buses, depending on the individual ship requirements. Figure 3-4 is an example of a front-service switchboard that is currently installed aboard some naval vessels. The distribution section consists of panels 1 through 4, while the ACO section consists of panels 5 and 6.

The following discussion describes the general principles of a forward main IC switchboard, such as the one illustrated in figure 3-4. For a detailed description of the main IC switchboard(s) and associated equipment installed on your ship, you should consult volume 5, part 1, of the *Ship Information Book* for your ship and any related technical manuals.

Power Distribution Section

The power distribution section of the switchboard (panels 1 through 4) is supplied with power from as many sources as possible. The power distribution section, in turn, supplies power from its various buses to several IC and FC circuits. Power distribution by the switchboard of a particular ship depends on the requirements of the IC and FC systems installed.

PANEL 1.— The 450-volt, 3-phase, 60-Hz bus located in panel 1 is energized from one of three power sources (normal, alternate, or emergency). Power becomes available through the use of two mechanically interlocked switches and an automatic bus transfer (ABT) device located in panel 1. An indication of the power available is provided through the use of indicator lights connected via transformers to each power source. On some of the newer ships in



27.270

Figure 3-4.—Front-service switchboard.

the fleet, the ABT is located separate from the switchboard itself.

The normal power supply is from the forward ship's service distribution switchboard. The alternate power supply comes from the after ship's service distribution switchboard. The emergency power supply comes from the forward emergency distribution switchboard. The bus may also be energized by a casualty power terminal installed on the board, which, in turn, receives its power via portable cable from a remotely located riser nearby.

PANEL 2.— The 120-volt, 3-phase, 60-Hz bus located in panel 2 receives its power from panel 1 via a bank of three 450/120-volt, 60-Hz, single-phase transformers located in panel 2. This panel disseminates both 120-volt, single-phase, 60-Hz, and 120-volt, 3-phase, 60-Hz power to various IC and FC systems as required. A voltmeter, an ammeter, and a megohmmeter are installed on the front of panel 2 for monitoring by watch standers and maintenance personnel.

PANEL 3.— Panel 3 is supplied with 120 volts dc from the 450-volt supply of panel 1 via two remotely located rectifiers. A switch on the front of panel 3 allows the operator to select either of the two rectifiers. Indicator lights on the panel indicate which of the two rectifiers is in operation.

Panel 3 is supplied with 250 volts dc from one of two 450-volt, 3-phase, 60-Hz motor generators. Two stop-start switches, power available indicator lights for each source, and a voltmeter are located on panel 3. The motor generators obtain their power from the 450-volt, 60-Hz, 3-phase bus.

PANEL 4.— The 450-volt, 400-Hz, 3-phase power for panel 4 is received from a motor generator or a static power supply. The 120-volt, 400-Hz, 3-phase power is received from a bank of transformers. A voltmeter, a frequency meter, and an ammeter are also installed on panel 4 for monitoring by watch standers and maintenance personnel.

ACO Section

The ACO section (panels 5 and 6) permits isolation of damaged portions of certain IC systems and, in addition, allows transfer control of certain systems from one station to another. Drawout switch units (fig. 3-5) are used, with each unit incorporating the associated JR switch, fuse holders, synchro overload transformers, and overload indicators.

The switches found on these panels are for the repeater and control circuits of the gyrocompass, wind indicating, propeller revolution, propeller order, engine order, and underwater log systems.

Through the proper manipulation of switches, either the main or the auxiliary gyrocompass may be

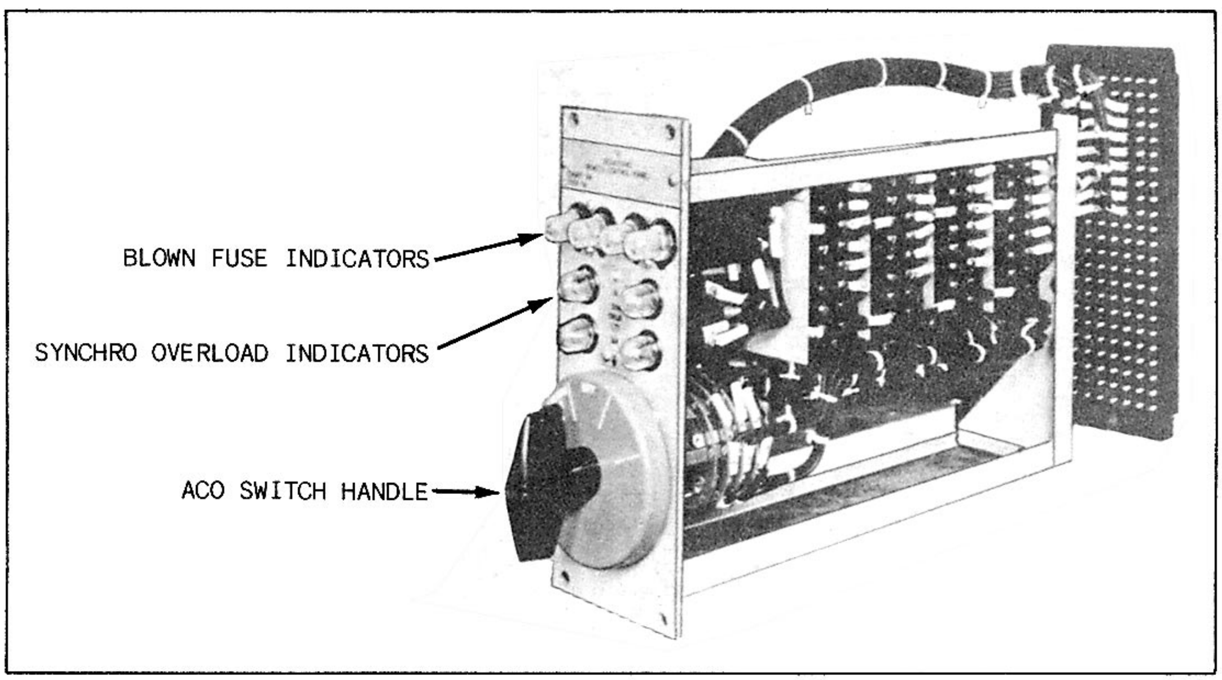


Figure 3-5.—ACO drawout switch unit.

selected as the information-sending device to the many gyrocompass repeaters of the system. In addition, each of the individual repeaters in the system may be cut in or out of the system without having any adverse effect on the operation of the system. The switches for the other systems may be used in the same manner as those for the gyrocompass.

A bank of SR switches is also located on the ACO section of some switchboards. These switches are used to isolate the various speaker groups and alarm contact makers of the general announcing system circuit 1MC.

Switchboard Components

There are several components used with the main IC switchboards. The need for these components range from providing a means of receiving and distributing power to the various IC systems to alerting watch standers of existing troubles within the systems. The components commonly used with main IC switchboards are ABT devices, switches, bus failure alarm units, fuses and fuse holders, lamps and lamp holders, synchro overload transformers and indicators, and power monitoring instruments,

ABT DEVICE.— The ABT device used with IC switchboards transfers the load from the preferred source of supply if it fails to an alternate source that remains energized. When the preferred source is restored, the load is then transferred back to the preferred source automatically by the ABT device. ABTs are designed for use in ac or dc, and 60- or 400-Hz systems.

ABTs may have either two or three bus transfer switch positions. Bus transfer switch positions indicate the number of power supplies the ABT is designed to handle. Two-way transfers indicate that the ABT is

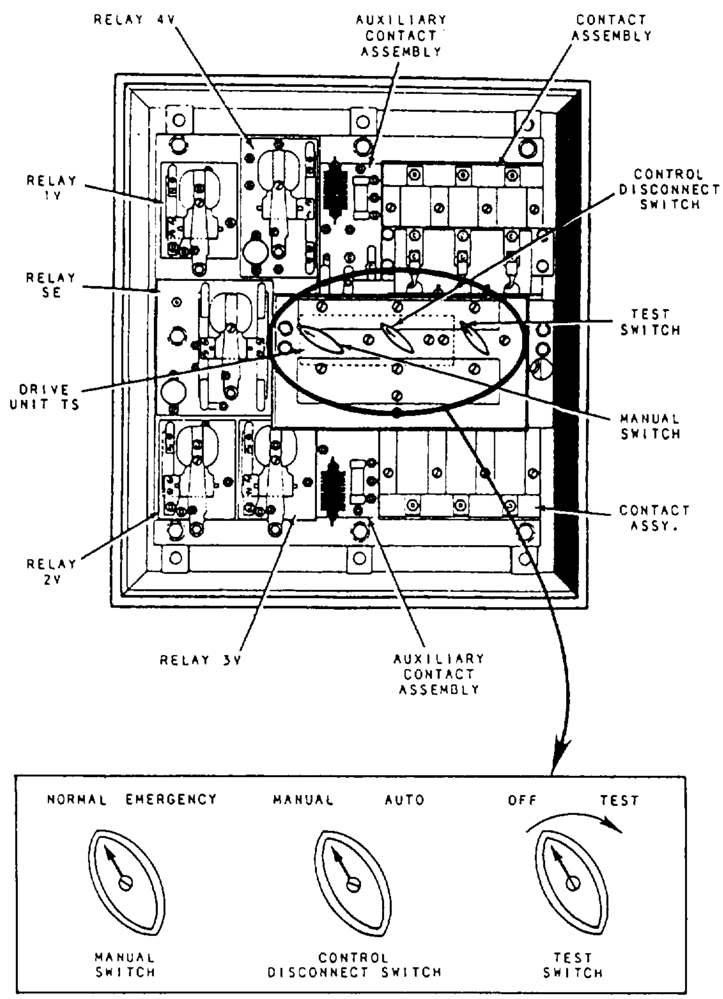


Figure 3-6.—Pictoral view of ABT-1A2.

capable of transferring the load between two sources of power available to the ABT. The two sources are identified as normal (ship's service) and alternate (ship's service) or normal (ship's service) and emer-gency (service).

Three-way transfers indicate that the ABT is capable of transferring the load between three sources of power available to the ABT. These three sources of power are identified as normal, alternate, and emergency. Either the normal or alternate source may be selected as the preferred source.

One of the more common ABTs used with IC switchboards is the ABT-1A2. This model operates on 120-volt, 60-Hz, single- or 3-phase systems.

The ABT-1A2 (fig. 3-6) has a control disconnect switch that allows the ABT to be operated in the manual or automatic mode. It also has a manual switch for selecting the normal or emergency power sources and a test switch.

For purposes of explanation, the 3-phase model will be discussed. The ABT-1A2 is designed to transfer automatically from normal to emergency supply upon a decrease in voltage to within the 81- to 69-volt range across any two of its three phases in a 120-volt system. Upon restoration of the voltage to the range of 98 to 109 volts, the unit is adjusted to retransfer to the normal source of supply. An intentional time delay of 0.3 to 0.5 seconds is included in the circuitry for both transfer and retransfer. This allows for surges in line voltage and short duration losses of power.

Automatic operation (refer to fig. 3-7) is accomplished when the normal supply voltage drops

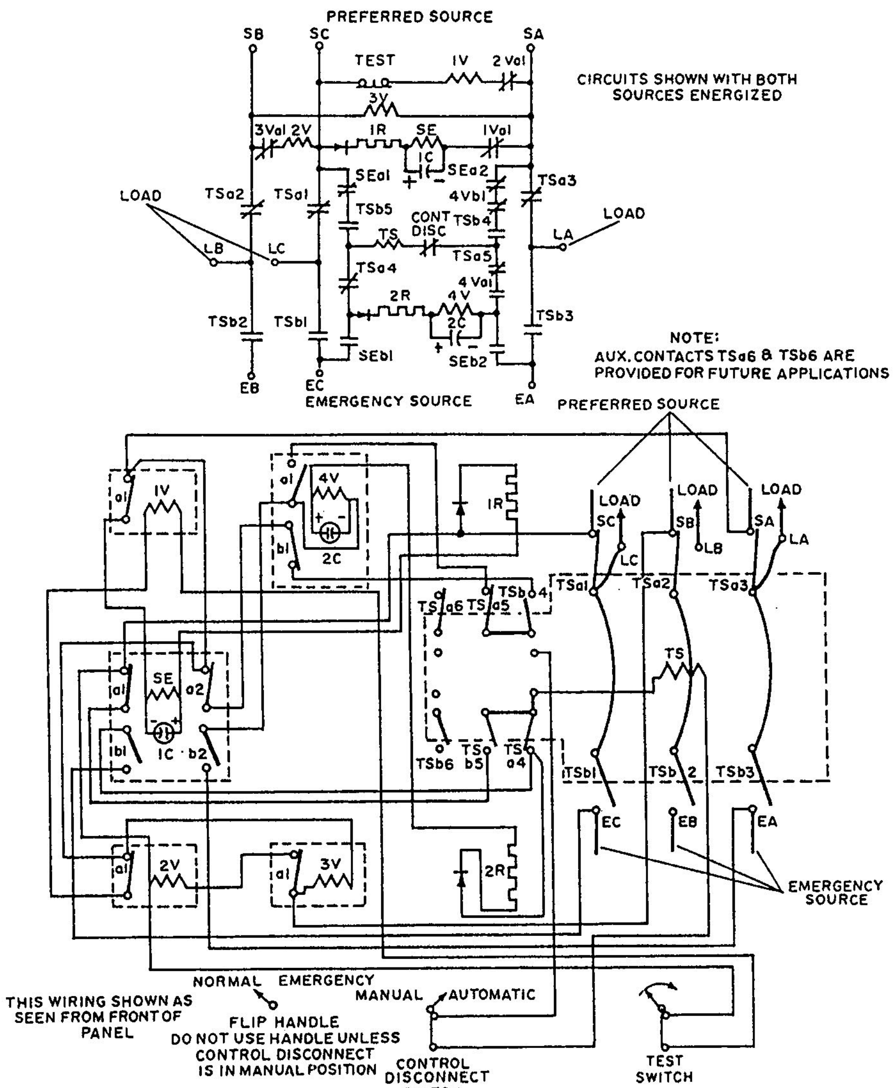


Figure 3-7.—Schematic and wiring diagram of ABT-1A2.

to the dropout range and relays 1V, 2V, and 3V drop out. Contact 1Val opens, disconnecting relay SE. After a time delay of 0.3 to 0.5 seconds, relay SE opens, closing its SEb1 and SEb2 contacts and energizing relay 4V from the emergency source. When contact 4Val closes, it connects the emergency source to coil TS of the transfer switch, which, in turn, operates, transferring the load to the emergency source.

After a short delay, contacts TSa4 and TSa5 open, disconnecting coil TS from its operating circuit. However, TS is now being held in the operated condition mechanically. This completes the transfer to the emergency supply.

Upon restoration of the normal power to the selected range, the retransfer is begun by the energizing of relays 1V, 2V, and 3V, which close, energizing relay SE. Contacts SEb1 and SEb2 now open, disconnecting relay 4V from the emergency source. After the time delay, relay 4V opens, closing its 4Vb1 contact and completing the normal supply circuit to the transfer switch coil, TS, which again operates, transferring the load back to the normal supply.

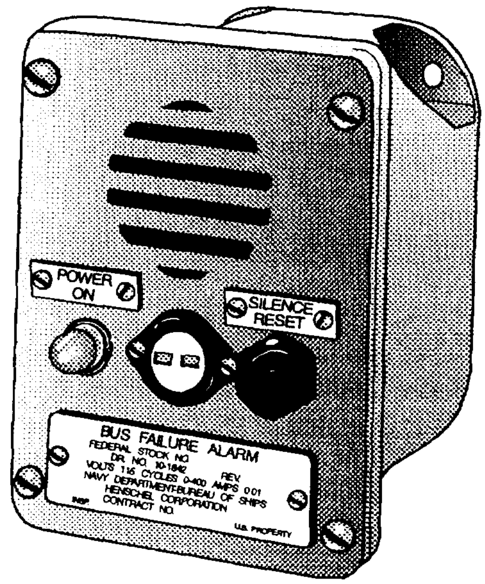
When you put the ABT in the manual mode, you no longer have the automatic transfer capability. You may select either the normal or emergency source of power by putting the manual switch in the position desired.

The test switch is used to test the ABT for its automatic transfer capability. The control disconnect switch must be in the AUTO position when using the test switch.

SWITCHES.— The types of switches usually found on IC switchboards are the JR, JL, toggle, and rotary snap switches. These switches were discussed in chapter 2 of this manual.

BUS FAILURE ALARM UNIT.— The type IC/E1D1 electronic signal unit (fig. 3-8) is designed as a bus failure alarm. The unit contains an electronic solid-state oscillator, which drives a 2-inch howler unit that provides an audible signal upon loss of power on the supervised bus. A red drop flag installed on the unit provides a visual signal upon loss of power.

A small nickel-cadmium battery provides power for the oscillator. The battery is maintained on a low charge when the supervised bus is energized. The unit will operate on 115 volts, dc or ac, and 60 or 400 hertz without modification.



27.302

Figure 3-8.—Type IC/E1D1 electronic signal unit.

The POWER ON light, a backlighted push button, tests the audible signal of the unit. The SILENCE RESET push button silences the alarm (the red flag will not reset until power is restored to the bus) and resets the unit when power is restored to the bus.

There is usually a bus failure alarm unit for each bus associated with the switchboard.

FUSES AND FUSE HOLDERS.— The basic type of fuse used in the IC switchboard is designated F03 plastic or ceramic with silver-plated ferrules.

The fuse holders used in IC switchboards are the dead-front blown fuse indicating type. The two basic types of fuse holders used with the F03 fuses are the FHL10U and the FHL11U.

LAMPS AND LAMP HOLDERS.— Both neon and incandescent lamps are used in the IC switchboard. Neon lamps are used as synchro overload and blown fuse indicators, and incandescent lamps are used for power indication.

Incandescent lamp holders are normally rated at 120 volts. These lamp holders use step-down transformers for ac applications or resistors for dc applications to permit use of a lower voltage rated lamp, Lamps that are rated at 120 volts are not suitable for the vibration and shock conditions encountered aboard ship.

SYNCHRO OVERLOAD TRANSFORMERS AND INDICATORS.— Synchro overload transformers and indicators are used in the ACO section of the IC switchboard to alert operating personnel of a casualty or overload in the associated circuit.

The transformers are wired in series with the secondary connections of selected synchro torque instruments. Type B and C transformers are used for 60-Hz and 400-Hz circuits, respectfully.

When the angular displacement of the synchro receiver is in excess of 17 ±3 degrees from the position of its associated transmitter, the indicator lamp connected to the transformer will glow. This displacement may be caused by an open or shorted rotor circuit, an open or shorted stator circuit, or lack of synchronism between transmitter and receiver caused by excessive bearing friction in the receiver.

When an overload indicator lamp is glowing, the cause of the malfunction should be investigated immediately and corrected as soon as possible. The switchboard operator can isolate the affected instrument from the circuit by operating the associated ACO switch. If the circuit malfunction cannot be determined, check the transformer setting. The indication may be the result of the overload transformer being set too low.

NOTE

Operation of an ACO transfer switch normally causes the associated overload indicator light to flash. This is due to a momentary displacement between the transmitter and receiver. The flash is normal and shows the system is operating properly.

POWER MONITORING INSTRUMENTS.— The power monitoring instrumentation consists of voltmeters, ammeters, and frequency meters. There are also phase selector switches for the voltmeters and the ammeters. These various meters are used to check the voltage, current, and frequency of each input power bus and the presence of grounds.

Watch Standing

When a ship is underway, the main IC switchboard should be manned 24 hours a day. On ships where there are two main IC switchboards, the forward main IC switchboard is usually the only one required to be manned. The IC Electrician on watch is responsible for recording hourly voltage, current, frequency, and ground readings of the various buses associated with the IC switchboard.

When checking for grounds, the watch stander should compare the readings being taken with previous readings. Unusual deviations should be investigated and the cause determined. Low voltage between any phase and ground, with high voltage between the other phases and ground, normally indicates a ground on the phase with the low-voltage reading.

The watch stander is also responsible for investigating all blown fuse indications, synchro overload indications, and bus failure alarms.

LOCAL IC SWITCHBOARDS

Local IC switchboards are type II, bulkhead-mounted, front-service, enclosed units. Terminal boards and an ABT are mounted inside the switchboard. Switches, fuse holders, and lamp holders are mounted on the door.

The number of local IC switchboards installed on a ship depends on the type and class of that ship. As stated earlier, local IC switchboards provide local control of circuits vital to the operation of a space. The local IC switchboards that will be discussed in this chapter are (1) engine room, (2) central control station, and (3) steering gear room. There may be other local IC switchboards installed aboard ships, depending on individual ship requirements.

Engine-room Local IC Switchboard

On some ships, a local IC switchboard is provided in each engine room to energize local IC alarm, warning, and indicating systems.

The engine-room switchboard operates on 120-volt, 60-Hz, single- or 3-phase ac power, There are two sources of power available: normal and emergency. The nearest main IC switchboard provides the normal power supply, The emergency power supply comes from a local emergency lighting circuit. The emergency power supply provides the switchboard with power if the normal supply is lost. The engine-room switchboard includes supply switches, an ABT device, and power available indicator lights.

Central Control Station Local IC Switchboard

On ships with a central control station, a local IC switchboard is provided to energize the machinery control IC systems.

The central control station switchboard receives its normal power supply (120-volt, 60-Hz, 3-phase) from one of the ship's power panels. One of the ship's lighting panels provides the emergency supply. The switchboard also includes an ABT device, power available indicator lights, and supply switches for the various machinery control systems.

Steering Gear Room Local IC Switchboard

A local IC switchboard is usually installed in each steering gear room to energize all circuits associated with steering-order and rudder-angle indicator systems.

The switchboard receives its 120-volt, 60-Hz, single- or 3-phase normal input from the steering-power transfer switchboard or one of the ship's power panels located in the steering gear room. A local emergency lighting circuit provides emergency power. This switchboard includes an ABT device, power available indicator lights, supply switches, and ACO switches.

IC TEST SWITCHBOARDS

Dead-front IC test switchboards are installed in the IC shops on most ships to provide a means of performing operational tests and for troubleshooting IC components.

The test switchboards are normally set up to provide the following test outputs:

120 volts, 60 Hz, single phase

0 to 230 volts, 60 Hz, single phase

120 volts, 400 Hz, single phase

80 volts, 20 Hz, single phase

120 volts dc

0 to 120 volts dc

The test switchboard may also contain ac and dc voltmeters, ammeters, test jacks, test leads, lamp test sockets, a multimeter, and a fuse tester. These capabilities permit comprehensive bench testing of all types of IC equipment.

SWITCHBOARD MAINTENANCE

Another of your duties as an IC Electrician is the maintenance of the power distribution systems assigned to your division. Normally, the required inspections and cleaning are outlined on maintenance requirement cards (MRCs). When the inspection and cleaning is due, you often think only of the main IC switchboard. The small local IC switchboards located in the engineering spaces and the remote sections of the ship are often forgotten. Auxiliary IC panels may have their own MRCs.

Switchboard preventive maintenance will be accomplished according to the applicable MRCs. Corrective maintenance and troubleshooting will usually consist of clearing grounds, repairing open circuits, tightening loose connections, and finding the cause for blown fuses and overloads.

INSPECTION AND CLEANING

Loose electrical connections or mechanical fastenings have caused numerous derangements of electrical equipment. Loose connections can be readily tightened, but it requires thorough inspection to detect them. Consequently, at least once a year and during each overhaul, each switchboard, propulsion control cubicle, distribution panel, and motor controller should be de-energized for a thorough inspection and cleaning of all bus equipment. Inspection of de-energized equipment should not be limited to visual examination but should include touching and shaking electrical connections and mechanical parts to make sure that the connections are tight and mechanical parts are free to function. Where space permits, a torque wrench should be used when tightening bolts. Overtightening can be detrimental as undertightening. Refer to *NSTM,* chapter 075, "Threaded Fasteners," for torquing procedures and precautions. Table 3-1 contains torque values for the more common bolt sizes used in switchboard construction. Torque values are minimum and should not be exceeded by more than 10 percent.

Be certain that no loose tools or other extraneous articles are left in or around switchboards and distribution panels. Check the supports of bus work to be certain the supports will prevent contact of bus bars of opposite polarity, or contact between bus bars and grounded parts during periods of mechanical shock. Clean the bus work and the creepage surfaces of insulating materials, and be certain that creepage distances are ample. If damaged, taped switchboard

Table 3-1.—Common Bolt Size Torque Values

Bolt Size (in)	Torque Requirements (ft/lb) Steel	Silicone Bronze	Copper
Bus Bar Bolts			
3/8	14	10	-
1/2	30	15	-
5/8	50	35	-
Circuit Breaker Studs			
3/8	-	-	7
1/2	-	-	15
5/8	50	-	-
3/4	-	-	25
1	130	-	-
1-1/8	-	-	40

bus bars should be retaped as necessary according to *NSTM,* chapter 320, "Electric Power Distribution Systems," Check the condition of control wiring and replace if necessary.

Bus bars and insulating materials can be cleaned with dry wiping cloths and a vacuum cleaner. Make sure the switchboard or distribution panel is completely de-energized and tagged out and remains so until the work is completed. Cleaning energized parts should be avoided because of the danger to personnel and equipment. Always observe electrical safety precautions when cleaning or working around switchboards.

Soap and water should not be used on the front panels of live front switchboards or on other panels of insulating material. Use a dry cloth.

The front panels of dead front switchboards may be cleaned without de-energizing the switchboard, These panels can usually be cleaned by wiping with a dry cloth. However, a damp, soapy cloth may be used to remove grease and fingerprints. Then, wipe the surface with a cloth dampened in clear water to remove all soap, and dry with a clean, dry cloth. The cloths used in cleaning must be wrung out thoroughly so that no water is left to squeeze out and run down the panel. Clean a small area at a time and wipe dry.

Rheostats and Resistors

Be certain that ventilation of rheostats and resistors is not obstructed. Replace broken or burned out resistors. Temporary repairs of rheostats can be made by bridging burned out sections when replacements are not available. Apply a light coat of petrolatum to the faceplate contacts of rheostats to reduce friction and wear. Make sure that no petrolatum is left in the spaces between the contact buttons as this may cause burning and arcing. Check all electrical connections for tightness, and wiring for frayed or broken leads. Service commutators and brushes for potentiometer-type rheostats according to instructions for the dc machines.

Instruments

The pointer of each switchboard instrument should read zero (except synchroscopes) when the instrument is disconnected from the circuit. The pointer may be brought to zero by external screwdriver adjustment.

CAUTION

This should not be done unless proper authorization is given.

The pointer should not stick at any point along the scale. Check instruments for accuracy whenever they have been subjected to severe shock. Repairs to switchboard instruments should be made only by the manufacturers, shore repair activities, or tenders. For detailed instructions on instruments, refer to *NSTM,* chapter 491, "Electrical Measuring and Test Instruments."

Fuses

Make sure that fuses are the right size and that they make firm contact with fuse clips. Ensure that lock-in devices (if provided) are properly fitted and that all fuse wiring connections are tight.

Control Circuits

Control circuits should be checked to ensure circuit continuity and proper relay, contactor, and indication lamp operation. Because of the many types of control circuits installed in naval ships, it is impractical to list any definite operating test procedures in this manual. In general, certain control circuits, such as those for the starting of motors or motor generator sets, or voltmeter switching circuits, are best tested by using the circuits as they are intended to operate. When testing such circuits, the precautions listed in *NSTM,* chapter 300, should be observed to guard against damage to the associated equipment.

Protective circuits, such as overcurrent or reverse current circuits, usually cannot be tested by actual operation because of the danger to the equipment involved. These circuits should be visually checked and, when possible, relays should be operated manually to make sure that the rest of the protective circuit performs its desired functions. Exercise extreme care not to disrupt vital power service or damage electrical equipment. Reverse power relays should be checked under actual operating conditions. With two generators operating in parallel, the generator whose reverse power relay is to be checked should be made to take power from the other generator. The reverse power relay should trip the generator circuit breaker in 10 seconds or less after the reverse power relay starts to operate. If the relay fails to function, the generator circuit breaker should be tripped manually to prevent damage to the prime mover. To make a generator act as a load, it is necessary to restrict the flow of steam or fuel. This can be accomplished by reducing the speed control setting slowly until the generator begins to absorb power and act as a motor.

Bus Transfer Equipment

Bus transfer equipment should be tested weekly. For manual bus transfer equipment, manually transfer a load from one power source to another, and check the mechanical operation and mechanical interlocks. For semiautomatic equipment, the test should also include operation by the control push buttons. For automatic equipment, check the operation with the control switches. The test should include operation initiated by cutting off power (opening a feeder circuit breaker) to see if an automatic transfer takes place. When testing bus transfer equipment, you should follow the same precautions given for testing circuit breakers. The tests and inspections are normally outlined on MRCs.

Overload Relays

During periodic inspections of motor controllers, or at least once a year, overload relays should be examined to determine that they are in good mechanical condition and that there are no loose or missing parts. The size of overload heaters installed should be checked to determine that they are of proper size as indicated by the motor nameplate current and heater rating table. Any questionable relays should be checked for proper tripping at the next availability and replaced. If necessary a description of the various types of overload relays can be found in *NSTM,* chapter 302, “Electric Motors and Controllers.”

Circuit Breakers, Contractors, and Relays

Circuit breakers should be carefully inspected and cleaned at least once a year and more frequently if subjected to unusually severe service conditions; that is, during ships overhaul period. A special inspection should be made after a circuit breaker has opened a heavy short circuit.

To test normally operated circuit breakers, simply open and close the breaker to check mechanical operation. For electrically operated circuit breakers, the test should be made with the operating switch or control to check both mechanical operation and control wiring. Care must be exercised during these operating tests not to disrupt any electric power supply vital to the operation of the ship, nor to endanger ship’s personnel by inadvertently starting or energizing equipment being repaired.

POWER REMOVAL.— Before working on a circuit breaker, control circuits to which it is connected should be de-energized. Drawout circuit breakers should be switched to the open position and removed before any work is done on them. Disconnecting switches ahead of fixed-mounted circuit breakers should be opened before any work is done on the circuit breaker. Where disconnecting switches are not provided to isolate fixed-mounted circuit breakers, the supply bus to the circuit breaker should be de-energized, if practical, before inspecting, adjusting, or replacing parts or doing any work on the circuit breaker. If the bus cannot be de-energized, observe the safety precautions of working on an energized circuit, These precautions can be found in *NSTM,* chapter 300.

CONTACT CLEANING.— Contacts in circuit breakers, contractors relays, and other switching equipment should be clean, free from severe pitting or burning, and properly aligned, Occasional opening and closing of contacts will aid cleaning and sealing. Remove surface dirt, dust, or grease with a clean cloth moistened, if required, with a small amount of inhibited methyl chloroform. Be sure that ample ventilation is provided if inhibited methyl chloroform is used. (Refer to *NSTM,* chapter 300, for information on the safety precautions to observe when inhibited methyl chloroform (1,1,1 trichloroethane) is used.) Remove all traces of residue left by inhibited methyl chloroform. Silver alloy contacts should not be filed or dressed unless sharp projections extend beyond the contact surface. Such projections should be filed or dressed only to the contact surface. When cleaning and dressing contacts, maintain the original shape of the contact surface and remove as little material as possible.

CONTACT SURFACE INSPECTION.— Inspect the silver alloy contact surface for heavy burning, erosion, or overheating. If any discrepancies are found, replace the contact. Slight burning, pitting, or erosion is acceptable. Carbon deposits should be removed using a dry, lint-free cloth. Loosen deposits according to the MRC. Do not use emery cloth, a file, or sandpaper. If the contacts have deep pitting that penetrates through the contact surface or 50 percent of the contact surface, replace the contact.

CLEANING BREAKER MECHANISM SURFACES.— Clean all circuit breaker mechanism surfaces, particularly insulation surfaces, with a dry cloth or air hose. Be sure that water is blown out of the air hose, that the air is dry, and that the pressure is not over 30 lb/in^2 before directing it on the breaker.

INSPECTION OF MOVING PARTS.— Inspect pins, bearings, latches, and contact and mechanism springs for excessive wear or corrosion and current-carrying parts for evidence of overheating. Bolt-on parts/attachments and subassemblies may be replaced by ship's force personnel. Replacement of parts that require major disassembly or subassembly teardown must be accomplished by an overhaul facility or shipyard with circuit breaker repair capability.

OPERATIONAL CHECK.— Slowly open and close circuit breakers a few times manually, See that trip shafts, toggle linkages, latches, and all other mechanical parts operate freely and without binding. Make sure that the arcing contacts meet before and break after the main contacts. If poor alignment, sluggishness, or other abnormal condition is noted, adjust according to the technical manual for the circuit breaker.

LUBRICATION.— Lubricate bearing points and bearing surfaces, including latches, with a drop or two of light machine oil. Wipe off excess oil.

FINAL INSPECTION AND INSULATION RESISTANCE CHECK..— Before returning a circuit breaker to service, inspect all mechanical and electrical connections, including mounting bolts and screws, drawout disconnect devices, and control wiring. Tighten where necessary. Give final cleaning with a cloth or compressed air. Operate manually to make sure that all moving parts function freely. Check insulation resistance .

SEALING SURFACE.— Sealing surfaces of circuit breaker, contactor, and relay magnets should be kept clean, and relay magnets should be kept clean and free from rust. Rust on the sealing surfaces decreases the contact force and may result in overheating of the contact tips. Loud humming or chattering will frequently warn of this condition. Light machine oil wiped sparingly on the sealing surfaces of the contactor magnet will aid in preventing rest.

USE OF OIL.— Oil should always be used sparingly on circuit breakers, contractors, motor controllers, relays, and other equipment, and should not be used at all unless there are specific instructions to do so or oil holes are provided. If working surfaces or bearings show signs of rust, the device should be disassembled and the rusted surface carefully cleaned. Light oil may be wiped on sparingly to prevent further rusting. Oil has a tendency to accumulate dust and grit, which may cause unsatisfactory operation of the device, particularly if the device is delicately balanced.

ARC CHUTE MAINTENANCE.— Arc chutes should be cleaned by scraping with a file if wiping with a cloth is not sufficient. Replace or provide new linings when they are broken or burned too deeply. See that arc chutes are securely fastened and that there is sufficient clearance to ensure that no interference occurs when the switch or contactor is opened or closed.

FLEXIBLE PARTS.— Shunts and flexible connectors that are flexed by the motion of moving parts should be replaced when worn, broken, or frayed.

Adjacent Installations

Inspections should not be confined to switchboard and distribution panels, but should also include adjacent installations, which may cause serious casualties. Rubber matting, located near switchboards, should be inspected for signs of deterioration, such as cracks in the material and separation at the seams. Ventilation opening located to permit water to discharge onto electrical equipment, insufficient insulation overhead to prevent sweating, need for dripproof covers and spray shields, and location of water piping and flanges where leakage could spray onto switchboards and other gear are examples of installations that could cause casualties. Action should be initiated to have unsatisfactory conditions corrected.

Distribution Boxes

Wiring distribution boxes (fused), with and without switches, that feed vital circuits should be checked annually. Tighten fuse clip barrel nuts and terminal connections. On anew ship and after a major overhaul, tighten and prick punch loose bus bar nuts on the backs of insulating bases.

The phosphor-bronze fuse clip and supplementary bent-wire fuse retainer have been superseded by a steel copper-clad silver-plated fuse clip. The steel fuse clips do not require fuse retainers to prevent dislodgement of fuses under shock and vibration. The wire fuse retainers impose a hazard of possible accidental dislodgement and falling into bus work to cause short circuits. To eliminate this hazard on both vital and nonvital circuits that require frequent removal of fuses, and where difficulties occur with loosening of existing phosphor-bronze fuse clips and wire fuse retainers, steel copper-clad silver-plated fuse clips should be used. Do not remove the wire retainers until the new steel fuse clips are on board for substitution. Tighten the fuse-clip barrel nut until the arch in bottom of the steel fuse clip is drawn flat.

Emergency Switchboards

Emergency switchboards should be tested regularly, according to the instructions on the switchboard, to check the operation of the ABT equipment and the automatic starting of the emergent y generator.

All other preventive maintenance should be performed according to the applicable PMS card. Remember, when you are conducting tests or troubleshooting equipment, the first thing you should do is consult your PMS schedule. By doing this, you will find information to assist you.

MOTOR CONTROLLERS

By definition, a motor controller is a device (or set of devices) that serves to govern, in some predetermined manner, the operation of the dc or ac motor to which it is connected. Preventive maintenance of motor controllers should be accomplished while consulting the applicable PMS card. Troubleshooting and corrective maintenance of motor controllers is discussed in depth in *Interior Communications Electrician,* volume 2, NAVEDTRA 12161.

MAINTENANCE AND REPAIR OF POWER SUPPLIES

Now that we have discussed the different types of power distribution systems and switchboards and the maintenance of switchboards, we will discuss the maintenance and repair of two of the most common power supplies: motor generators and static inverters.

MOTOR GENERATORS

Under normal conditions, the motor generator set and control equipment require inspection and cleaning as designated by the PMS MRCs. When the motor generator is inspected, cleanliness, brush operation, condition of brushes and commutator, bearing temperature, and vibration should be observed.

The acceptable methods of cleaning motors and generators involve the use of wiping rags or cloths, suction, low-pressure air, and solvents.

Wiping with a clean, lint-free, dry rag (such as cheesecloth) is effective for removing loose dust or foreign particles from accessible parts of a machine. When wiping, do not neglect the end windings, mica cone extensions at the commutator of dc machines, slip-ring insulation, connecting leads, and terminals.

The use of suction is preferred to the use of compressed air for removing abrasive dust and particles from inaccessible parts of a machine because it lessens the possibility of damage to insulation. If a vacuum cleaner is not available for this purpose, a flexible tube attached to the suction side of a portable blower will make a suitable vacuum cleaner. Always exhaust the blower to a suitable sump or overboard. Whenever possible, remove grit, iron dust, and copper particles by suction methods.

Clean, dry, compressed air is effective in removing dry, loose dust and foreign particles, particularly from inaccessible locations such as air vents in the armature. Use air pressure up to 30 pounds per square inch (psi) to blow out motors *or* generators of 50 horsepower (hp) or 50 kilowatts (kW) or less; use pressure up to 75 psi to blowout higher-rated machines. Where airlines carry higher pressure than is suitable for blowing out a machine, use a throttling valve to reduce the pressure. Always blow out any accumulation of water in the air lines before directing the airstream on the part or ma-chine to be cleaned. Be certain that the compressed air does not have any grit, oil, or moisture content in it. Compressed air should be used with caution, particularly if abrasive particles (carbon, and so on) are present, since these may be driven into the insulation or may be forced beneath insulating tapes or other possible trouble spots. If vibration exists, check for loose parts or mounting bolts.

Motors, generators, and other electrical equipment that have been wet with salt water should be flushed out with fresh water and dried. Never let the equipment dry before flushing with fresh water. For complete information on washing and drying procedures, refer to *NSTM,* chapter 300.

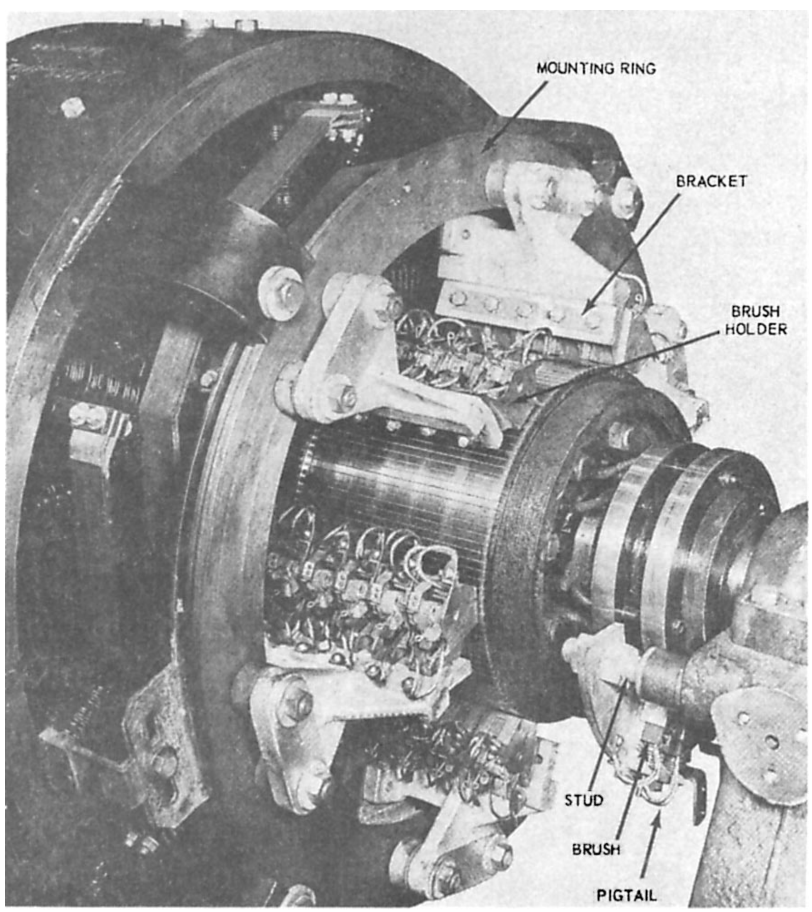
The key points in the maintenance of electric generators and motors are as follows:

- Keep insulation clean and dry.
- Keep electrical connections tight
- Keep machines in good mechanical condition.

The following paragraphs will discuss some of the procedures to follow when performing maintenance and repair on motor generators.

Brushes

Brushes used in electric motors and generators are constructed of one or more plates of carbon, riding on a commutator, or collector ring (slip ring), to provide a passage for electrical current to an internal or external circuit. The brushes are held in position by brush holders mounted on studs or brackets attached to the brush-mounting ring, or yoke. The brush holder studs, or brackets, and brush-mounting ring comprise the brush rigging. The brush rigging is insulated from, but attached to, the frame or one end bell of the machine. Flexible leads (pigtails) are used to connect the brushes to the terminals of the external circuit. An adjustable spring is generally provided to maintain proper pressure of the brush on the commutator to effect good commutation. Figure 3-9 shows a typical



77.70

Figure 3-9.—Brush holder and brush-rigging assembly.

dc generator brush holder and brush-rigging assembly.

Brushes are manufactured in different grades to meet the requirements of the varied types of service. The properties of resistance, ampere-carrying capacity, coefficient of friction, and hardness of the brush are determined by the maximum allowable speed and load of the machine.

CORRECT BRUSH TYPE.— The correct grade of brush and correct brush adjustment are necessary to avoid commutation trouble. For good commutation, use the grade of brush shown on the drawing or in the technical manual applicable to the machine, except where NAVSEA instructions issued after the date of the drawing or technical manual (such as the instruction for brushes to be used in electrical propulsion and magnetic minesweeping equipment) state otherwise. In such cases, follow the NAVSEA instructions. In the case of propulsion and magnetic minesweeping equipment, only one grade of each of two different brush manufacturers is permitted for any machine. This restriction on brush interchangeability is based on the vital nature of the machines involved and on the impracticability of factory testing these machines while operating them with several manufacturers' grades, which have been qualified under any one of the six military grades. Never mix different types or grades of brushes from the same manufacturer. Rapid brush wear could result from a mismatch of brushes.

CARE OF BRUSHES.— All brush shunts should be securely connected to the brushes and the brush holders. Brushes should move freely in their holders, but they should not be loose enough to vibrate in the holder. Before replacing a worn brush with a new one, clean all dirt and other foreign material from the brush holder.

Replace with new brushes, all brushes that

- are worn or chipped so they will not move properly in their holders;
- have damaged shunts, shunt connections, or hammer clips;
- have riveted connections or hammer clips and are worn to within one-eighth inch of the metallic part;
- have tamped connections without hammer clips and are worn to one-half or less of the original length of the brush; or
- have spring-enclosed shunts and are worn to 40 percent or less of the original length of the brush (not including the brush head, which fits into one end of the spring).

Where adjustable brush springs are of the positive gradient (torsion, tension, or compression) type, adjust them as the brushes wear to keep the brush pressure approximately constant. Springs of the coiled-band, constant-pressure type, and certain springs of the positive-gradient type are not adjustable except by changing springs. Adjust pressure following the manufacturer's technical manual. Pressures as low as 1 1/2 psi of contact area may be specified for large machines and as high as 8 psi of contact area may be specified for small machines. Where technical manuals are not available, a pressure of 2 to 2 1/2 psi of contact area is recommended for integral horsepower and integral kilowatt machines. About twice that pressure is recommended for fractional horsepower and fractional kilowatt machines. To measure the pressure of brushes operating in box-type brush holders, insert one end of a strip of paper between the brush and commutator; use a small brush tension gauge (such as the 0- to 5-pound indicating scale) to exert a pull on the brush in the direction of brush holder axis, as shown in figure 3-10. Note the reading of the gauge when the pull is just sufficient to release the strip of paper so that it can be pulled out

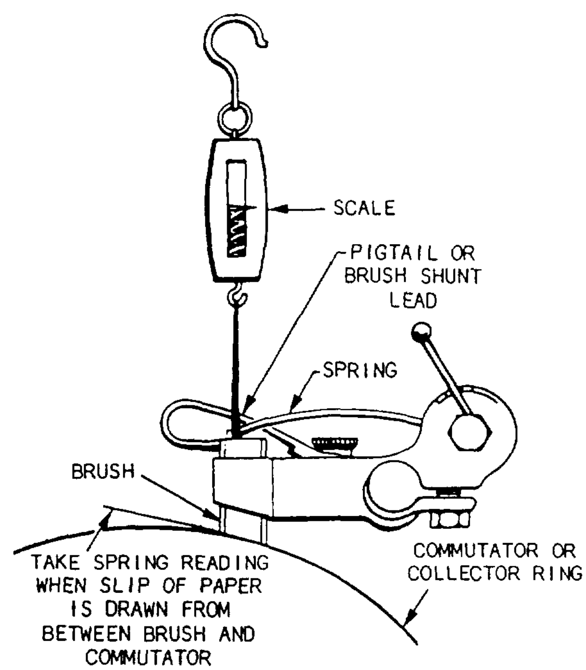


Figure 3-10.—Measuring brush tension.

from between the brush and commutator without offering resistance. This reading divided by the contact area may be considered to be the spring operating pressure.

The toes of all brushes of each brush stud should line up with each other and with the edge of one commutator segment.

The brushes should be evenly spaced around the commutator. To check brush spacing, wrap a strip of paper around the commutator and mark the paper where the paper laps. Remove the paper from the commutator, cut at the lap, and fold or mark the paper into as many equal parts as there are brush studs. Replace the paper on the commutator, and adjust the brush holders so that the toes of the brushes are at the creases or marks.

All brush holders should be the same distance from the commutator, not more than one-eighth inch, nor less than one-sixteenth inch. A brush holder must be free of all burrs that might interfere with the free movement of the brush in the holder. Burrs are easily removed with a fine file.

SEATING.— Accurate seating of the brushes must be ensured where their surfaces contact the commutator. Sandpaper and a brush seater are the best tools to accomplish a true seat.

Disconnect all power from the machine. Before using sandpaper to seat the brushes, you must take every precaution to ensure that the machine will not be inadvertently started.

Lift the brushes to be fitted, and insert (sand side up) a strip of fine sandpaper (No. 1), about the width of the commutator, between the brushes and the commutator. With the sandpaper held tightly against the commutator surface to conform with the curvature and the brushes held down by normal spring pressure, pull the sandpaper in the direction of the normal rotation of the machine (fig. 3-11), When returning the sandpaper for another pull, lift the brushes. Repeat this operation until the seat of the brush is accurate. Always finish with a finer grade of sandpaper (No. 0). You need a vacuum cleaner for removing dust while sanding. After sanding, thoroughly clean the commutator and windings to remove all carbon dust.

The use of a brush seater will further improve the fit obtained by sanding. A brush seater consists of a mildly abrasive material loosely bonded into a stick about 5 inches long. To use a brush seater to seat the brushes, install the brushes in the brush holders and start the machine. Press a brush securely against the commutator by using a stick of insulating material or by increasing the brush spring tension to its maximum value. Touch the brush seater lightly to the commutator, exactly at the heel of the brush (fig. 3-12), so that abrasive material worn from the brush seater will be carried under the brush. You must hold the brush seater behind each brush, applying the seater for a second or two, depending on brush size. Do not hold the seater steadily against the commutator because it will wear away too rapidly and produce too much dust. After seating one or two brushes, examine them to see if the seater is being applied long enough to give a full seat. After seating the brush, if white dust is plainly visible on the seat, you have applied insufficient pressure to the brush, or applied the brush seater too heavily or too far from the brush. Be careful not to remove the copper oxide film from the commutator surface. If you remove this film, you must restore it.

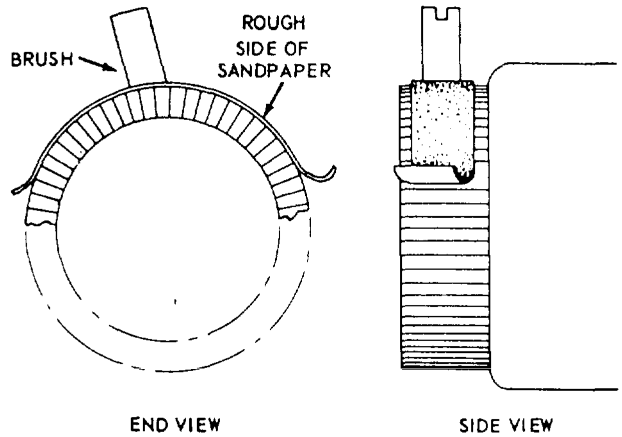


Figure 3-11.—Method of sanding brushes.

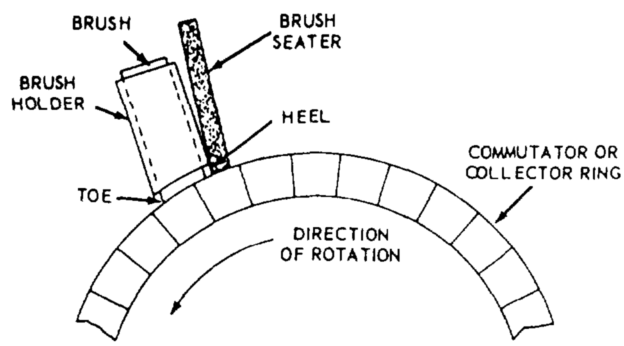


Figure 3-12.—Using the brush seater.

Use a vacuum cleaner during the seating operation to prevent dust from reaching the machine, the machine windings, and the bearings. After seating all the brushes, blow out the machine with a power blower or completely dry compressed air, or clean thoroughly with a vacuum cleaner.

For additional information on brushes, brush problems, and probable causes, refer to *NSTM,* chapter 300.

Commutator Care

After being used about 2 weeks, the commutator of a machine should develop a uniform, glazed, dark brown color on the places where the brushes ride. If a nonuniform or bluish-colored surface appears, improper commutation conditions are indicated. Periodic inspections and proper cleaning practices will keep commutator and collector-ring troubles to a minimum.

One of the most effective ways of cleaning the commutator or collector rings is to apply a canvas wiper while the machine is running. You can make the wiper by wrapping several layers of closely woven canvas over the end of a strong stick between one-fourth and three-eighths inch thick (fig. 3-13, view A). Secure the canvas with rivets, and wrap linen tape over the rivets to prevent the possibility of them coming in contact with the commutator. When the outer layer of canvas becomes worn or dirty, remove it to expose a clean layer. The wiper is most effective when it is used frequently. On ship's service generators, it may be desirable to use the wiper once each watch. When using the wiper, exercise care to keep from fouling moving parts of the machine. Figure 3-13, view B, shows the manner of applying the wiper to a commutator.

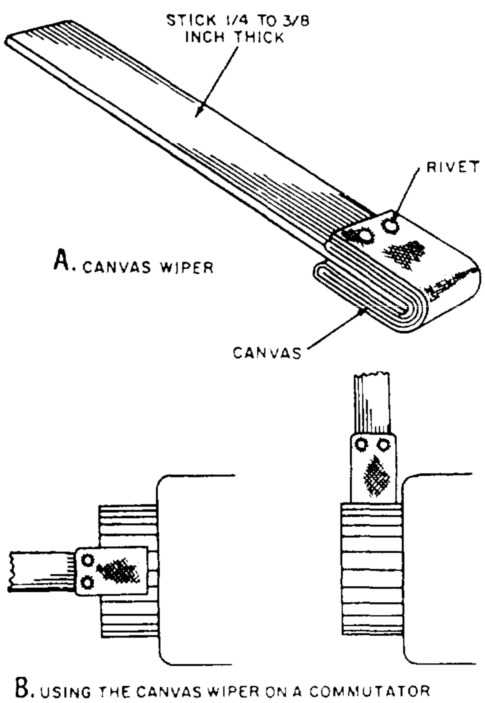


Figure 3-13.—Cleaning commutator or collector rings.

When the machines are secured, you can use a toothbrush to clean out the commutator slots. You can use a clean canvas or lint-free cloth for wiping the commutator and adjacent parts. Besides cleaning by wiping, periodically clean the commutator with a vacuum cleaner or blow it out with clean, dry air.

Do not sandpaper a commutator if it is operating well, even if long service has developed threading, grooving, pits, bum areas between bars, longitudinal irregularities, and so on, unless sparking is occurring or the brushes are wearing excessively. In sanding a commutator, use a fine grade of sandpaper (No. 0000 is preferred, but in no case coarser than No. 00). You can use sandpapering to make emergency reduction of high mica or to polish finish a commutator that has been stoned or turned. Attach the sandpaper to a wooden block shaped to fit the curvature of the commutator, and move the block slowly back and forth across the surface of the commutator while the machine is running at moderate speed. Rapid movement or the use of coarse sandpaper will cause scratches. Never use emery cloth, emery paper, or emery stone on a commutator or collector ring since the danger of causing electrical shorts exists.

Additional information on the care and cleaning of the commutator can be found in *NSTM,* chapter 300, "Electric Plant General."

Bearings

Bearings are designed to allow a rotating armature or rotor to turn freely within a motor or generator housing. The two common types of bearings found in motors and generators are antifriction bearings and friction bearings.

ANTIFRICTION BEARINGS.— There are two types of antifriction bearings—ball and roller. Basically, both types consist of two hardened steel rings, hardened steel rollers or balls, and separators. The annular, ring-shaped ball bearing is the type of roller bearing used most extensively in the construction of electric motors and generators used in the Navy. These bearings are further divided into three types dependent upon the load it is designed to bear—(1) radial, (2) angular contact, and (3) thrust. Figure 3-14 shows examples of these three bearings.

The ball bearings on a rotating shaft of an electric motor or generator may be subjected to radial thrust and/or angular forces. While every ball bearing is not subjected to all three forces, any combination of one or more may be found depending on the equipment design. Radial loads are the result of forces applied to the bearing perpendicular to the shaft; thrust loads are the result of forces applied to the bearing parallel to the shaft; and angular loads are the result of a combination of radial and thrust loads. The load carried by the bearings in electric motors and generators is almost entirely due to the weight of the rotating element. For this reason, the method of mounting the unit is a major factor in the selection of the type of bearing installed when they are constructed. In a vertically mounted unit, the thrust bearing is used, while the radial bearing is normally used in most horizontal units.

Wear of Bearings.— Normally it is not necessary to measure the air gap on machines with ball bearings because the construction of the machines ensures proper bearing alignment. Additionally, ball bearing wear of sufficient magnitude as to be readily detected by air-gap measurements would be more than enough to cause unsatisfactory operation of the machine.

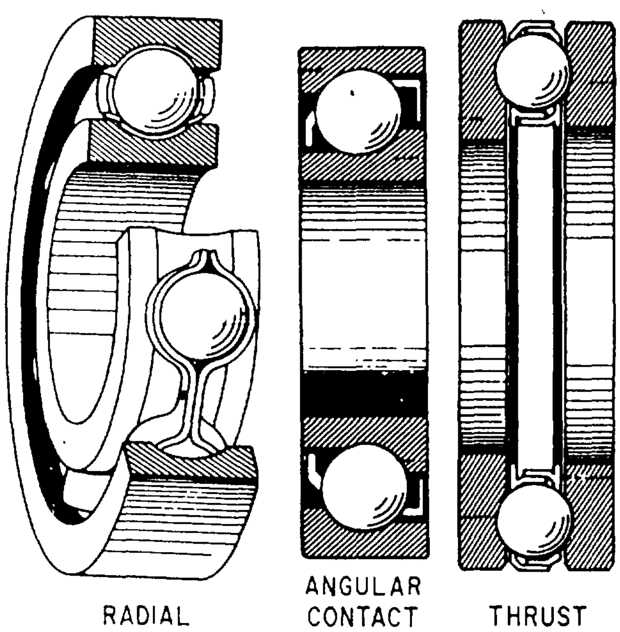


Figure 3-14.—Representative types of ball bearings.

The easiest way of determining the extent of wear in these bearings is to periodically feel the bearing housing while the machine is running to detect any signs of overheating or excessive vibration, and to listen to the bearing for the presence of unusual noises.

Rapid heating of a bearing may be an indication of danger. Bearing temperatures that feel uncomfortable to the touch could be a sign of dangerous overheating, but not necessarily. The bearing may be operating properly if it has taken an hour or more to reach that temperature; whereas, serious trouble can be expected if high temperatures are reached within the first 10 or 15 minutes of operation.

The test for excessive vibration relies to a great extent on the experience of the person conducting the test. The person should be thoroughly familiar with the normal vibration of the machines to be able to correctly detect, identify, and interpret any unusual vibrations. Vibration, like heat and sound, is easily telegraphed. A thorough search is generally required to locate the source and determine its cause.

Ball bearings are inherently more noisy in normal operation than sleeve bearings (discussed later). This fact must be kept in mind by personnel testing for the presence of abnormal bearing noise. A common method for sound testing is to place one end of a screwdriver against the bearing housing and the other end against the ear. If a loud, irregular grinding, clicking, or scraping noise is heard, trouble is indicated. As before, the degree of reliance in the results of this test depends on the experience of the person conducting the test.

Checking the movement of a motor or generator shaft can also give an indication of the amount of bearing wear. If the motor shaft has excessive vertical movement (fig. 3-15, view A), it indicates worn

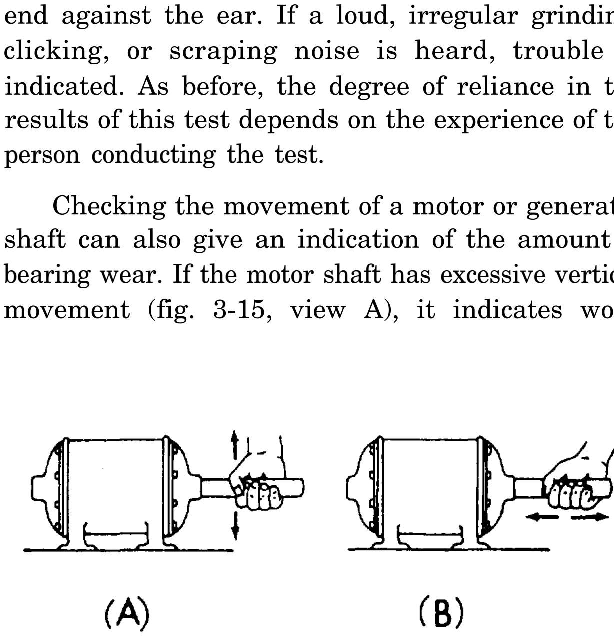


Figure 3-15.—Checking motor or generator shaft. (A) Vertical movement; (B) end-play movement.

bearings. Figure 3-15, view B, shows how to get a rough approximation of motor or generator end-play movement. You can correct excessive end-play, as described in the applicable technical manual, by adding bearing shims.

Lubrication

One cause of motor and generator failure is overlubrication. Forcing too much grease into the bearing housing seals and onto the stationary windings and rotating parts of the machine will cause overheating and deterioration of insulation, eventually resulting in electrical grounds and shorts. Overheating will also cause rapid deterioration of the grease and the eventual destruction of a bearing. To avoid overlubrication, add new lubricant only when necessary.

The frequency that new grease must be added depends on the service of the machine and the tightness of the housing seals, and the requirements should be determined for each machine by the engineer officer or PMS requirements. A large quantity of grease coming through the shaft extension end of the housing usually indicates excessive leakage inside the machine.

To prevent greasing by unauthorized personnel, remove the grease cups from motors and generators. Insert pipe plugs in place of the grease cups. Replace the pipe plugs temporarily with grease cups during lubrication (fig. 3-16). (Removable grease cups should remain in the custody of the responsible maintenance personnel.) Make sure the grease cups are clean. After the grease is added, clean the pipe plugs before replacing them.

The preferred method of adding grease calls for disassembly of the bearing housing. Although not recommended, renewing the bearing grease without at least partially disassembling the housing may be tried under certain conditions.

Oil-Lubricated Ball Bearings.— Lubrication charts or special instructions are generally furnished for electric motors and generators equipped with oil-lubricated ball bearings. The oil level inside the bearing housing should be maintained about even with the lowest point of the bearing inner ring. At this level, there will be enough oil to lubricate the bearing for its operating period, but not enough to cause churning or overheating.

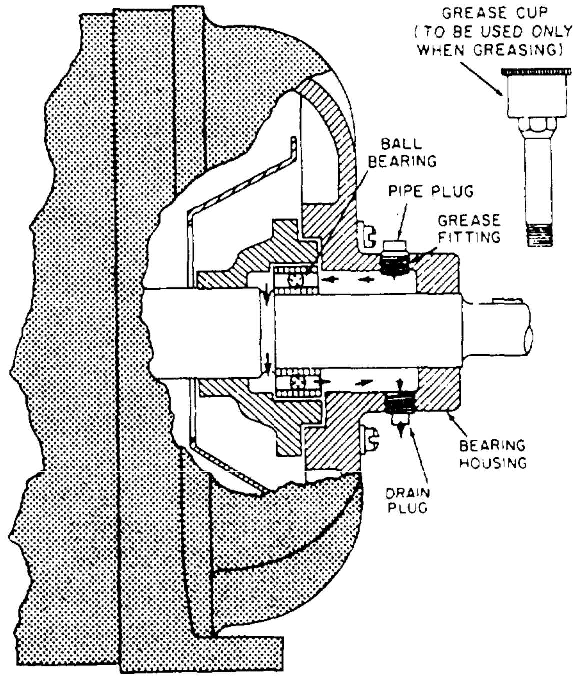


Figure 3-16.—Grease-lubricated ball bearings.

One common method by which the oil level is maintained in ball bearings is the wick-fed method. In this method, the oil is fed from an oil cup to the inside of the bearing housing through an absorbent wick. This wick also filters the oil and prevents leakage through the cup if momentary pressure is built up within the housing.

Grease-Lubricated Ball Bearings.— Preferred Navy bearing greases for shipboard auxiliary machinery are as follows:

1. Bearings operating below 110°C (230°F) in non-noise or noise-critical application should use DOD-G-24508 grease. It is available in a 1-pound can.

2. Bearings operating near water (for example, rudder stock bearings) should use MIL-G-24139 grease. It is available in a 5-pound can.

DOUBLE-SHIELDED OR DOUBLE-SEALED BALL BEARINGS SHOULD NEVER BE DISASSEMBLED OR CLEANED. These bearings are prelubricated. Cleaning will remove the lubricant from the bearings or can dilute the lubricant until it no longer possesses its original lubricating qualities.

Permanently lubricated ball bearings require no greasing. You can recognize equipment furnished with these bearings by the absence of grease fittings or the provision for attaching grease fittings. When permanently lubricated bearings become inoperative, replace them with bearings of the same kind. If not already provided, attach DO NOT LUBRICATE nameplates to the bearing housing of machines with sealed bearings.

Cleaning Ball Bearings

You can clean an open or a single-sealed ball bearing only in an emergency when a suitable replacement is not available. It is difficult to remove dirt from ball bearings. Unless the cleaning is carefully done, more dirt may get into the bearings than is removed.

In cleaning an open, single-shielded or single-sealed bearing, take the bearing off by applying a bearing puller to the inner race of the bearing. Figure 3-17, views A and B, shows two types of bearing pullers, both of which apply the pulling pressure to the inner race of the bearing. Removal of bearings by pulling on the outer race tends to make the balls dent the raceway even when the puller is used. If bearings are subjected to high temperatures, the race can be distorted. This can cause the race to shrink to the shaft more tightly. You should be careful not to damage the shaft when removing bearings. Use soft centers (shaft protectors), which are sometimes provided with a bearing removal kit. If not, the soft centers may be made of soft metal. such as zinc or brass.

After removal, thoroughly clean the bearing. The recommended cleaner is standard solvent or clean oil. Soak the bearing in cleaner for as long as necessary to dislodge dirt or caked grease from around the balls and separators. After the bearing is cleaned, wipe it carefully with a dry, lint-free cloth. If compressed air is used for drying, direct the airstream across the bearing so that the bearing does not spin. Because a dry bearing rusts quickly, protect the bearing at once by coating it with clean, low-viscosity lubricating oil.

Rotate the inner ring slowly by hand, and if the bearing feels rough, repeat the cleaning. After the second cleaning, if the bearing still feels rough when turned slowly by hand, renew it.

For additional information on the cleaning and lubrication of ball bearings, refer to *NSTM,* chapter 244.

FRICTION BEARINGS.— Friction bearings are of three types: right line (motion is parallel to the elements of a sliding surface), journal (two machine parts rotate relative to each other), and thrust (any force acting in the direction of the shaft axis is taken up). Turbine-driven, ship's service generators and propulsion generators and motors are equipped with journal bearings, commonly called sleeve bearings. The bearings may be made of bronze, babbitt, or steel-backed babbitt. Preventive maintenance of

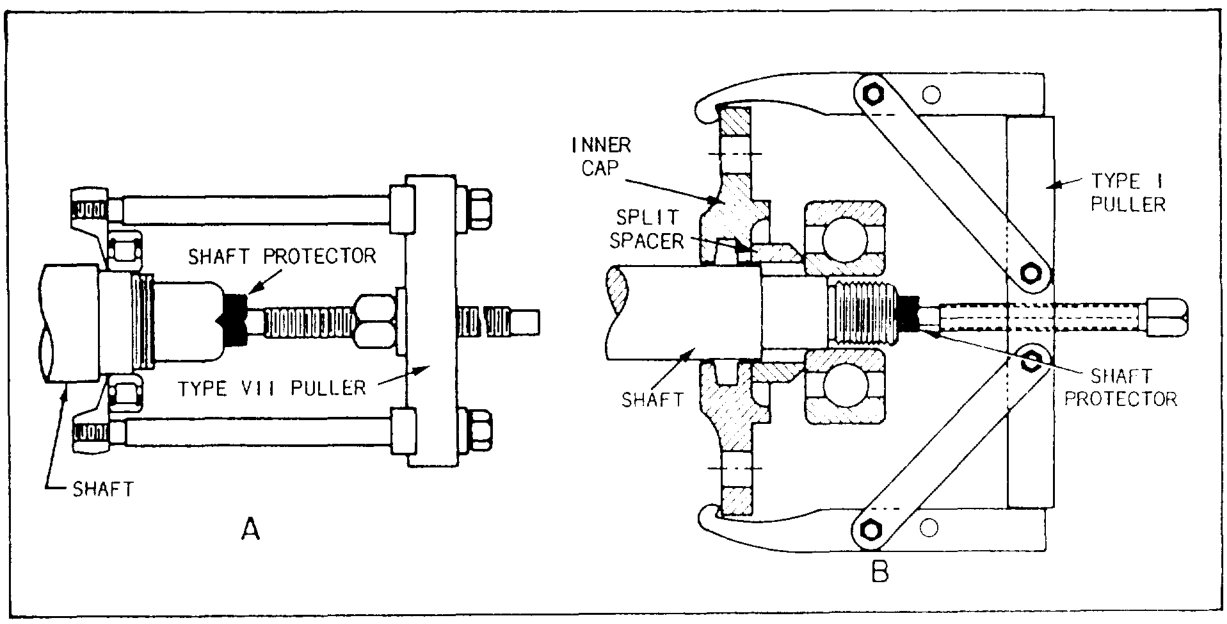


Figure 3-17.—Bearing pullers.

sleeve bearings requires periodic inspections of bearing wear and lubrication.

Wear of Bearings.— Propulsion generators, motors, and large ship's service generators are sometimes provided with a gauge for measuring bearing wear. You can obtain bearing wear on a sleeve-bearing machine not provided with a bearing by measuring the air gap at each end of the machine with a machinist's tapered feeler gauge. Use a blade long enough to reach into the air gap without removing the end brackets of the machine. Before making the measurements, clean the varnish from a spot on a pole or tooth of the rotor. A spot should also be cleaned at the same relative position on each field pole of a dc machine. For ac machines, clean at least three and preferably four or more spots spaced at equal intervals around the circumferences on the stator. Take the air gap measurement between a cleaned spot on the rotor and a cleaned spot on the stator, turning the rotor to bring the cleaned spot of the rotor in alignment with the cleaned spots on the stator. Compare these readings with the tolerance stated by the manufacturer's instruction book.

Oil Rings and Bearing Surfaces.— An opening is provided in the top of the bearing for you to check the condition of the oil rings and bearing surfaces (fig. 3-18). Periodic inspections are necessary to make certain that the oil ring is rotating freely when the machine is running and is not sticking. With the machine stopped, inspect the bearing surfaces for any signs of pitting or scoring.

Trouble Analysis.— The earliest indication of sleeve bearing malfunction normally is an increase in the operating temperature of the bearing. Thermometers are usually inserted in the lubricating oil discharge line from the bearing as a means of visually indicating the temperature of the oil as it leaves the bearing. Thermometer readings are taken hourly on running machinery by operating personnel. However, a large number of bearing casualties have occurred in which no temperature rise was detected in thermometer readings; in some cases, discharge oil temperature has actually decreased. Therefore, after checking the temperature at the thermometer, personnel should make a follow-up check by feeling the bearing housing whenever possible. Operating personnel must thoroughly familiarize themselves with the normal operating temperature of each bearing so they will be able to recognize any sudden or sharp changes in bearing oil temperature. Many large generators are provided with bearing temperature

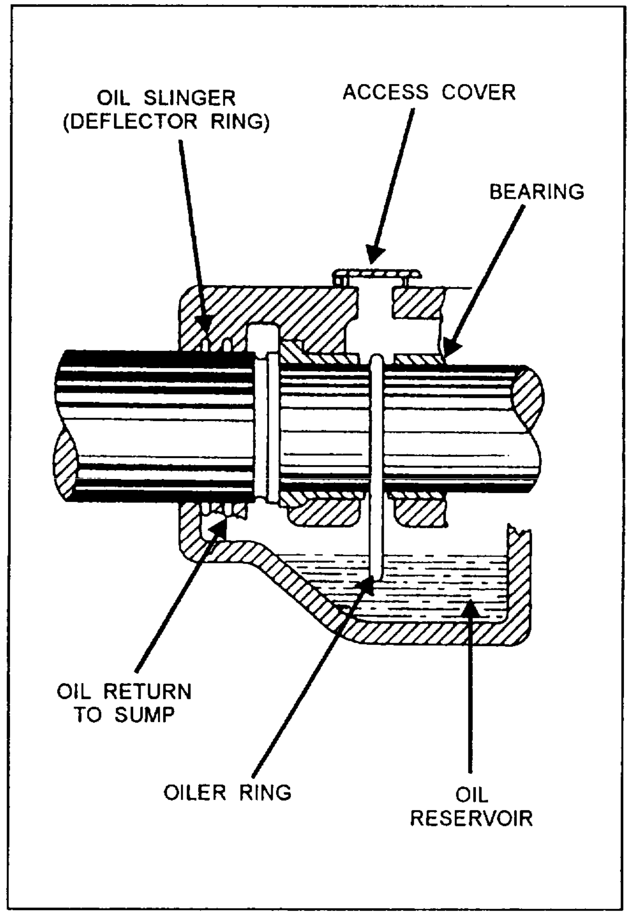


Figure 3-18.—Diagram of an oil-ring lubricated bearing.

alarm contractors, which are incorporated in the ship's alarm system. The contactor is preset to provide an alarm when the bearing temperature exceeds a value detrimental to bearing life. You should secure the affected machinery as soon as possible if a bearing malfunction is indicated. A motor with overheated sleeve bearings should be unloaded, if possible, without stopping the motor. If you stop it immediately, the bearing may seize. The best way to limit bearing damage is to keep the motor running at a light load and supply plenty of cool, clean oil until the bearing cools down.

Because the permissible operating temperature is often too high to be estimated by the sense of touch, temperature measurements should be taken to determine whether a bearing is overheated. A thermometer securely fastened to the bearing cover or housing will usually give satisfactory bearing temperature measurements on machines not equipped with bearing temperature measuring devices. Do not insert a thermometer into a bearing housing, as it may break and necessitate disassembly of the machinery to remove broken glass and mercury.

Any unusual noise in operating machinery may also indicate bearing malfunction. When a strange noise is heard in the vicinity of operating machinery, make a thorough inspection to determine its cause. Excessive vibration will occur in operating machinery with faulty bearings, and inspections should be made at frequent intervals to detect the problem as soon as possible.

Loose Metal and Solder

Keep all small pieces of iron, bolts, and tools away from the machines. Where it is necessary to do any soldering, make sure that no drops of solder get into the windings and that there is no excess of solder on soldered joints, which may later break off due to vibration and fall into the windings.

Bolts and Mechanical Fastenings

Care should be exercised not to disturb the commutator clamping bolts on dc machines. Interference with these may make it necessary to turn or grind the commutator to restore it to service. Other bolts and mechanical fastenings on both the stationary and rotating members should be tightened securely when the machine is erected, checked after the equipment has run for a short time, and thereafter checked at regular intervals to make sure that they are tight. Particular attention should be given to the bolts used to clamp any insulation.

Rotor Hardware

If an inspection of a rotor shows that there is a looseness of keys, bolts, or other fastenings, check for evidence of damage due to this looseness. Such looseness may result in worn dovetail keys, damaged windings, or broken dovetails on the end plates. Two or three drivings usually will ensure the tightness of the keys, but nevertheless they should be checked regularly.

Armature Banding

Check the banding wire on dc armatures at regular intervals to make sure that it is tight.

Electrical Connections

Inspect all electrical connections (particularly terminals and terminal board connections) at frequent intervals to ensure they are tight. Loose connections result in increased contact resistance and increased heating, which may result in breakdown. Use locknuts, lock washers, or other means to lock connections that tend to become loose because of vibration. Inspect soldered terminal lugs for looseness or loss of solder, and tighten solderless terminal lugs occasionally. When electrical connections are opened, clean all oil and dirt from contact surfaces before reconnecting. If the contact surfaces are uncoated copper, sandpaper and clean immediately before joining. If the contact surfaces are silver-plated, do not use sandpaper. Use silver polish or a cloth moistened slightly with an approved cleaning agent. Coat the finished joint with insulation varnish. Steel bolts for making electrical connections should be zinc plated. Make sure that exposed electrical connections are adequately insulated to protect against water and moisture and injury to personnel. This applies especially to exposed connections at terminal straps extending outside the frames of propulsion motors and generators, Motor connection box leads should be assembled as shown in figure 1B10 of DOD-STD-2003-1 (Navy).

Filter Cleaning and Equipment Inspection

Clean or replace permanent-type air filters quarterly. Machine temperatures should not be allowed to rise above the design rating, and filters should be changed as often as necessary to prevent the entrance of oil, water, metal shavings, abrasives from grinding, and dirt. Upon completion of overhaul and prior to operation without filters, ensure that all dirt, abrasives, chips, and so forth, are removed from pockets in the foundations in the vicinity of the foundations of electrical rotating machinery. After a machine has been cleaned, inspect the windings for visual evidence of mechanical damage to the insulation or damage caused by excessive action of any solvents used in cleaning.

Information on the repair and revarnishing of damaged insulation can be found in *NSTM,* chapter 300.

STATIC INVERTER

The need for a highly dependable, static, 400-Hz power supply led to the development of the 4345A static inverter.

The model 4345A static inverter delivers a closely regulated 400-Hz, 3-phase, 120-volt output from a 250-volt dc source. Two single-phase static inverters are operated with a controlled 90-degree phase difference. Pulse width modulation is used for control of the output voltage of each static inverter. The outputs of the two inverters are fed into two Scott "T"-connected transformers to provide a 3-phase output from a 2-phase input.

The 4345A static inverter is enclosed in an aluminum cabinet (fig. 3-19), divided into three sections. These are the meter panel assembly, the inverter module assembly, and the power stage assembly. A resistor subassembly is located on the back of the cabinet.

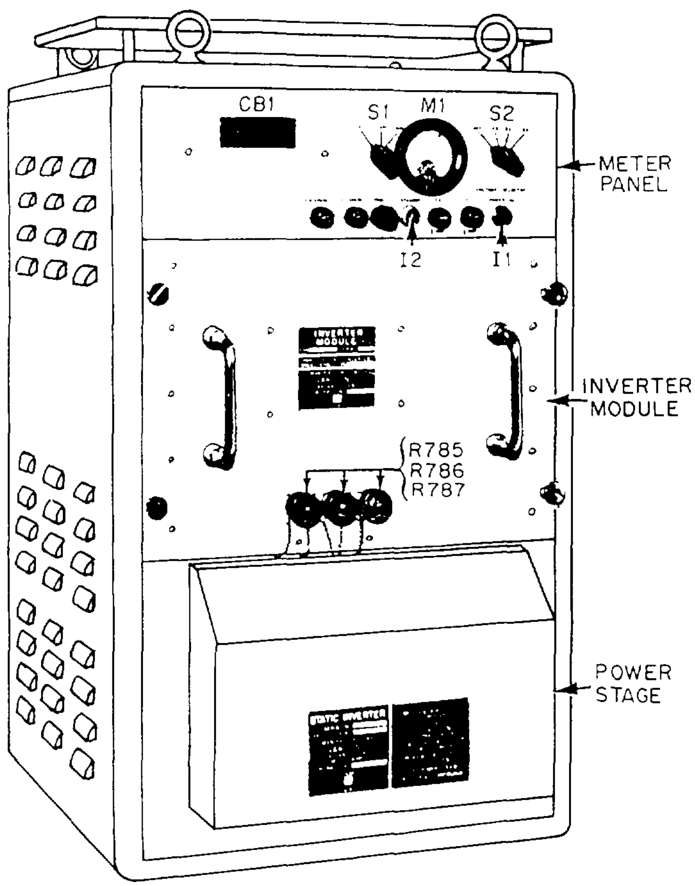


Figure 3-19.—Static inverter.

The meter panel assembly contains the instruments and controls necessary for the opration of the equipment.

The inverter module assembly contains a control circuit +30-volt dc power supply, a drive circuit +30-volt dc power supply, an input sensing circuit, a synchronizing subassembly, two variable pulse width generators, a frequency standard oscillator, a phase variable pulse width generator, two drive subassemblies, a step change adjustment circuit, and two silicon control rectifier power stages.

The power stage assembly contains capacitors, transformers, and filters associated with the power stage of the inverters.

Maintenance

Maintenance of the static inverter should normally be limited to simple replacement with a new or serviceable module. This will ensure rapid restoration of the inverter into service without risking dangers of handling high-test voltages,

Complete familiarization with the theory of operation must be obtained before troubleshooting is attempted. Then follow the step-by-step procedures outlined in the manufacturer's technical manual while using the specified test equipment.

SUMMARY

In this chapter, we have discussed the ship's service, emergency, and casualty PO wer distribution systems found on board Navy ships and their importance in supplying power to the IC switchboards and various IC systems.

We have discussed the main and local IC switchboards used to supply power to IC systems, the components associated with the switchboards, and switchboard maintenance. We have identified IC systems by their classification and described a typical IC test switchboard installed in IC shops for bench testing IC equipment.

Now that you have finished this chapter, you should have a better understanding of motor and generator repair and troubleshooting.

The information covered in this chapter does not include the necessary specifications or the specific procedures for repair and maintenance of each piece of equipment you will encounter. This information can only be obtained from the appropriate *NSTM* and the manufacturers' technical manuals.

CHAPTER 4

GYROCOMPASS SYSTEMS

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

- *Discuss basic gyroscopic and gyrocompass theory.*
- *Identify the major components of the Mk 23 gyrocompass systems, and explain the procedures for starting, standing watch on, and securing the Mk 23 gyrocompasses.*
- *Identify the major components of the Mk 27 gyrocompass system, and explain the procedures for starting, standing watch on, and securing the Mk 27 gyrocompass.*
- *Identify the major components of the Mk 19 Mod 3 gyrocompass systems, and explain the procedures for starting, standing watch on, and securing the Mk 19 Mod 3 gyrocompasses.*
- *Identify the major components of the AN/WSN-2 stabilized gyrocompass set, and explain the procedures for starting, standing watch on, and securing the AN/WSN-2 stabilized gyrocompass set.*
- *Explain the purpose of the synchro signal amplifier used with the various gyrocompass systems.*
- *Explain the purpose of the ship's course indicators used with the various gyrocompass systems.*
- *Describe the entries to be made in the engineering logs, and the deck and watch logs to be kept when standing watch on gyrocompass systems.*

INTRODUCTION

The ship's gyrocompass and its associated equipment is an important part of an IC Electrician's responsibility. Gyrocompass systems provide information that is used for remote indicators and various navigational, radar, sonar, and fire control systems throughout a ship. As an IC3, you will be responsible for starting, standing watch on, and securing the ship's gyrocompass.

To understand how a gyrocompass operates, you should be familiar with gyroscopic and gyrocompass theory. A variety of gyrocompasses are presently in use throughout the Navy. In this chapter, we will discuss basic gyroscopic principles, and then we will develop the basic gyroscope into a basic gyrocompass. We will then discuss the operation of some of the more common gyrocompass systems installed on board Navy ships today. We will also discuss the associated equipment used in conjunction with the gyrocompass systems. The topics include descriptions of the components and functions of the master compass, gyro control systems, follow-up systems, alarm systems, and starting control systems. In addition, we will also point out the significant differences among the various modifications of the Mk 19 Mod 3 installation, and provide procedures for operating the gyrocompass in normal and auxiliary modes.

THE FREE GYROSCOPE

A free gyroscope is a universal-mounted, spinning mass. In its simplest form, the universal mounting is a system that allows three degrees of freedom of movement. The spinning mass is provided by a heavy rotor. Figure 4-1 illustrates a free gyroscope. As you can see in the figure, the rotor axle is supported by two bearings in the horizontal ring,. This ring is supported by two studs mounted in two bearings in the larger vertical ring. These two rings are called the inner gimbal and outer gimbal, respectively. The outer gimbal is then mounted with two studs and bearings to a larger frame called the case.

The rotor and both gimbals are pivoted and balanced about their axes. The axes (marked X, Y, and Z) are perpendicular to each other, and they intersect at the center of gravity of the rotor. The bearings of the rotor and two gimbals are essentially frictionless and have negligible effect on the operation of the gyroscope.

THREE DEGREES OF FREEDOM

As you can see in figure 4-1, the mounting of the gimbals allows movement in three separate directions, or three degrees of freedom: (1) freedom to spin, (2) freedom to tilt, and (3) freedom to turn. The three degrees of freedom allow the rotor to assume any position within the case. The rotor is free to spin on its own axis, or the X axis, the first degree of freedom. The inner gimbal is free to tilt about the horizontal or Y axle, the second degree of freedom. The outer gimbal ring is free to turn about the vertical or Z axis, the third degree of freedom.

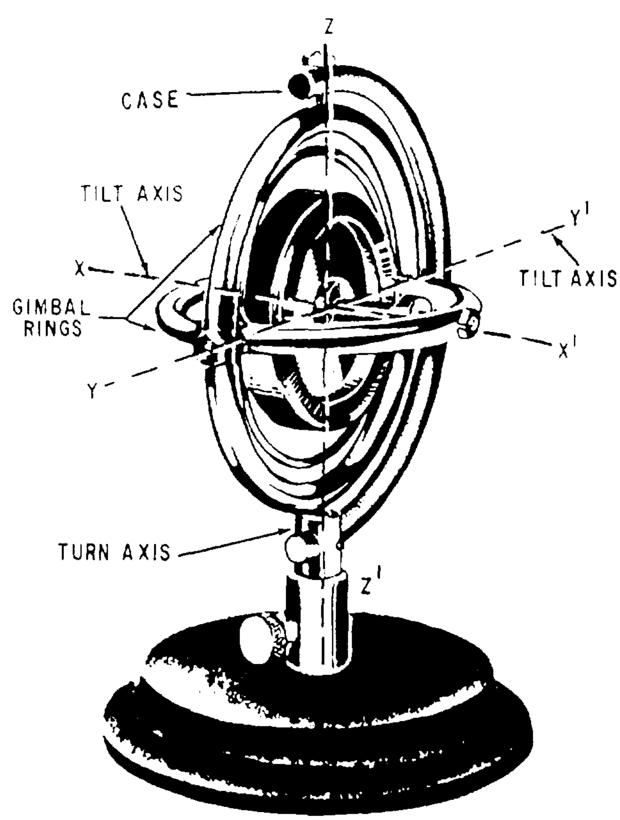


Figure 4-1.—The gyroscope.

GYROSCOPIC PROPERTIES

When a gyroscope rotor is spinning, it develops two characteristics, or properties, that it does not possess when at rest: rigidity of plane and precession. These two properties make it possible to convert a free gyroscope into a gyrocompass.

Rigidity of Plane

When the rotor of the gyroscope is set spinning with its axle pointed in one direction (fig. 4-2, view A), it will

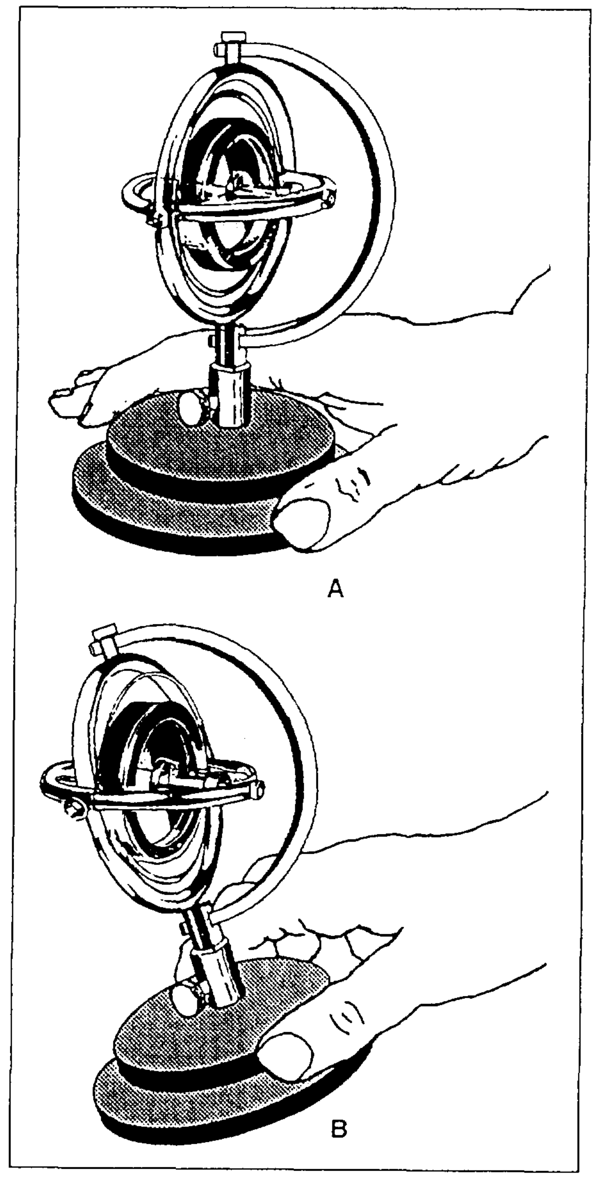


Figure 4-2.—Rigidity of plane of a spinning gyroscope.

continue to spin with its axle pointed in that direction, no matter how the case of the gyroscope is positioned (fig. 4-2, view B). As long as the bearings are frictionless and the rotor is spinning, the rotor axle will maintain its plane of spin with respect to a point in space. This property of a free gyroscope is termed *rigidity of plane.*

Newton's first law of motion states that a body in motion continues to move in a straight line at a constant speed unless acted on by an outside force. Any point in a spinning wheel tries to move in a straight line but, being a part of the wheel, must travel in an orbit around its axle. Although each part of the wheel is forced to travel in a circle, it still resists change. Any attempt to change the alignment or angle of the wheel is resisted by both the mass of the wheel and the velocity of that mass. This combination of mass and velocity is the kinetic energy of the wheel, and kinetic energy gives the rotor rigidity of plane. *Gyroscopic inertia* is another term that is frequently used interchangeably with rigidity of plane.

A gyroscope can be made more rigid by making its rotor heavier, by causing the rotor to spin faster, and by concentrating most of the rotor weight near its circumference. If two rotors with cross sections like those shown in figure 4-3 are of equal weight and rotate at the same speed, the rotor in figure 4-3, view B, will have more rigidity than the rotor in figure 4-3, view A. This condition exists because the weight of the rotor in figure 4-3, view B, is concentrated near the circumference. Both gyroscope and gyrocompass rotors are shaped like the rotors shown in figure 4-3, view B.

Precession

Precession describes how a gyro reacts to any force that attempts to tilt or turn it. Though vector diagrams can help explain why precession occurs, it is more important to know how precession affects gyro performance.

The rotor of a gyro has one plane of rotation as long as its axle is aligned with, or pointed at, one point in space. When the axle tilts, turns, or wobbles, the plane of rotation of the rotor changes. Plane of rotation means the direction that the axle is aligned or pointed.

Torque is a force that tends to produce rotation. Force acts in a straight line, at or on a point. Torque occurs within a plane and about an axle or axis of rotation. If the force acts directly on the point of an axis, no torque is produced.

Because of precession, a gyro will react to the application of torque by moving at right angles to the direction of the torque. If the torque is applied downward against the end of the axle of a gyro that is horizontal, the gyro will swing to the right or left in response. The direction in which it will swing depends on the direction the rotor is turning.

A simple way to predict the direction of precession is shown in figure 4-4. The force that tends to change the plane of rotation of the rotor is applied to point A at the top of the wheel. This point does not move in the direction of the applied force, but a point displaced 90° in the direction of rotation moves in the direction of the applied force. This results in the rotor turning left about the Z axis and is the direction of precession.

Any force that tends to change the plane of rotation causes a gyroscop to precess. Precession continues as long as there is a force acting to change the plane of rotation, and precession ceases immediately when the force is removed. When a force (torque) is applied, the

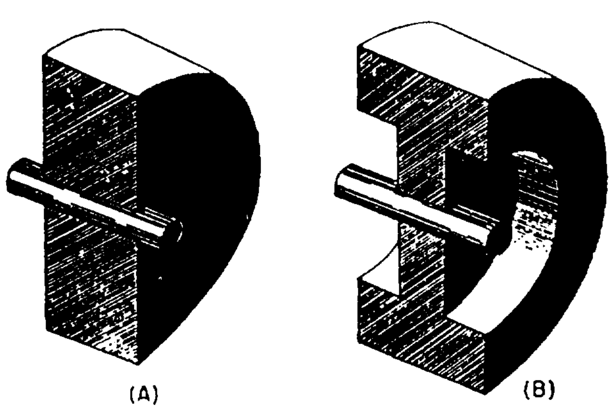


Figure 4-3.—Weight distribution in rotors.

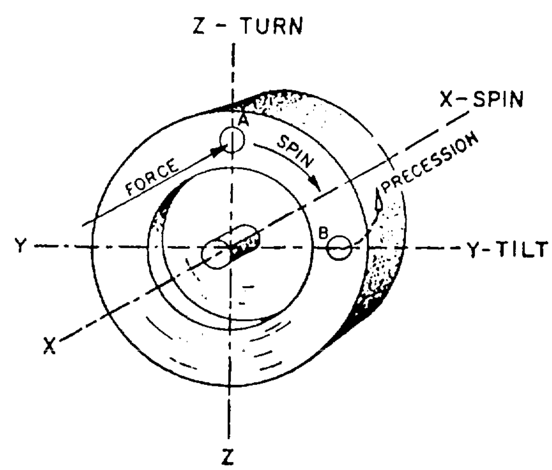


Figure 4-4.—Direction of precession.

gyroscope precesses until it is in the plane of the force. When this position is reached, the force is about the spinning axis and can cause no further precession.

If the plane in which the force acts moves at the same rate and in the same direction as the precession it causes, the precession will be continuous. This is illustrated by figure 4-5, in which the force attempting to change the plane of rotation is provided by a weight, W, suspended from the end of the spin axle, X. Although the weight is exerting a downward force, the torque is felt 90° away in the direction of rotation. If the wheel rotates clockwise, as seen from the weighted end, precession will occur in the direction of arrow P. As the gyroscope precesses, it carries the weight around with it so that forces F and F' continuously act at right angles to the plane of rotation, and precession continues indefinitely. In other words, the rotor will turn to the right and continue turning until the weight is removed.

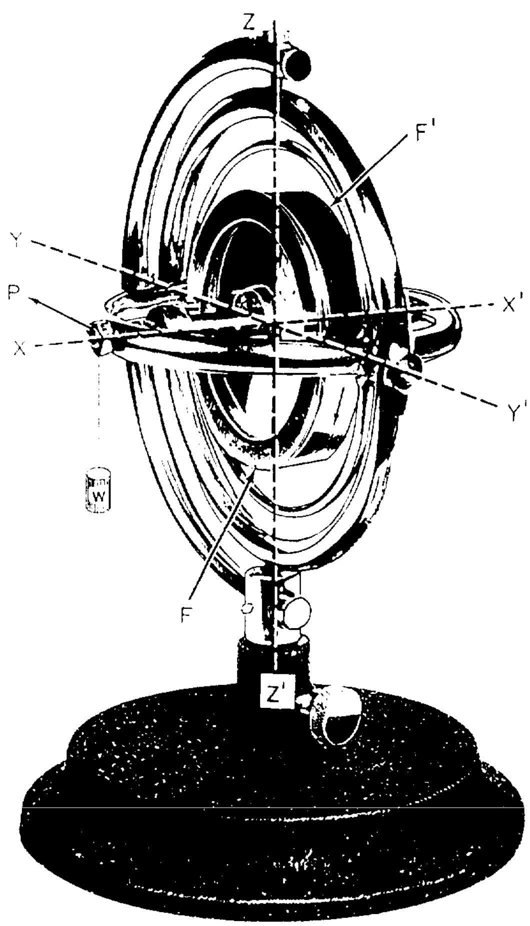


Figure 4-5.—Continuous precession.

FORCE OF TRANSLATION

Any force operating through the center of gravity of the gyroscope does not change the angle of the plane of rotation but moves the gyroscope as a unit without changing its position in space. Such a force operating through the center of gravity is known as a force of translation. Thus, the spinning gyroscope may be moved freely in space by means of its supporting frame, or case, without disturbing the plane of rotation of the rotor. This condition exists because the force that is applied through the supporting frame acts through the center of gravity of the rotor and is a force of translation. It produces no torque on the gyro rotor.

EFFECT OF EARTH'S ROTATION

As just explained, a free-spinning gyroscope can be moved in any direction without altering the angle of its plane of rotation. If this free-spinning gyroscope is placed on the earth'is surface at the equator, with its spinning axis horizontal and aligned east and west, an observer in space below the South Pole would note that the earth rotates clockwise from west to east and carries the gyroscope along. As the earth rotates, rigidity of plane keeps the gyroscope wheel fixed in space and rotating in the same plane at all times. Figure 4-6 shows how this gyroscope would appear. Assume that the gyroscope is set spinning at 0000 hours with its spinning axis aligned east and west and parallel to the earth's surface. At 0600, 6 hours after the gyroscope was started, the earth has rotated 90° and the axle of the gyroscope is aligned with the original starting position. At 1200 the earth has rotated 180°, while the gyroscope returns to its original position. The figure shows how the gyro completes a full cycle in a 24-hour period.

APPARENT ROTATION OF THE GYROSCOPE

An observer on the earth's surface does not see the operation of the gyro in the same way as an observer in space does. On the earth, the gyro appears to rotate, while the earth appears to stand still. As the earth rotates, the observer moves with it, so the gyroscope seems to rotate around its horizontal axis. The effect the observer sees on the earth is called apparent rotation and also is referred

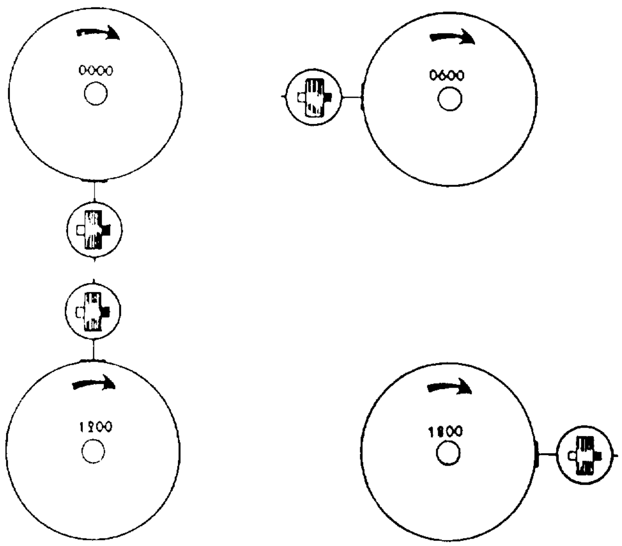


Figure 4-6.—Free gyroscope at the equator viewed from space.

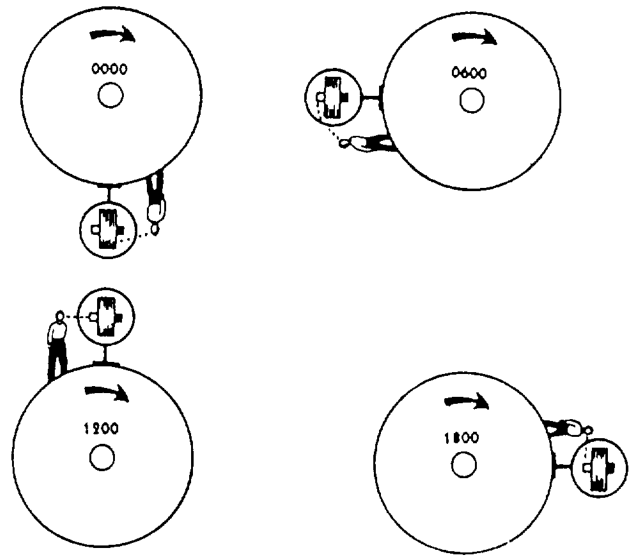


Figure 4-7.—Free gyroscope at the equator viewed from the earth's surface.

to as the horizontal earth rate effect. If the gyro were started with its axle vertical at one of the earth's poles, it would remain in that position and produce no apparent rotation around its horizontal axis. Figure 4-7 illustrates the effect of apparent rotation at the equator, as seen over a 24-hour period.

Now assume that the spinning gyroscope, with its spinning axis horizontal, is moved to the North Pole (fig. 4-8). To an observer on the earth's surface, the gyroscope appears to rotate about its vertical axis. To an observer in space, the gyroscope axle appears to remain fixed, and the earth appears to rotate under it. This apparent rotation about the vertical axis is referred to as vertical earth rate effect. It is maximum at the poles and zero at the equtator.

When the gyroscope axle is placed parallel to the earth's axis at any location on the earth's surface, the apparent rotation is about the axle of the gyroscope and cannot be observed. At any point between the equator and either pole, a gyroscope whose spinning axis is not parallel to the earth's spinning axis has an apparent rotation that is a combination of horizontal earth rate and vertical earth rate.

The combined earth rate effects at this point make the gyro appear to rotate partly about the horizontal axis and partly about the vertical axis. The horizontal earth rate causes the gyro to tilt, whereas the vertical earth rate causes it to turn in azimuth with respect to the earth. The magnitude of rotation depends on the latitude of the gyro.

Apparent rotation is illustrated by placing a spinning gyroscope with its axle on the meridian

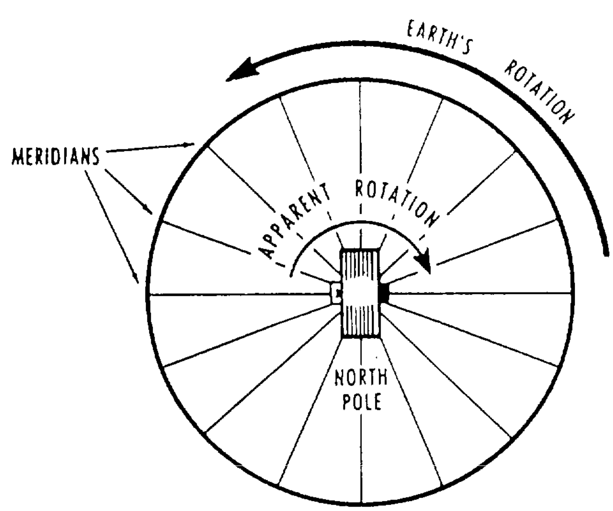


Figure 4-8.—Apparent rotation of a gyoscope at the North Pole.

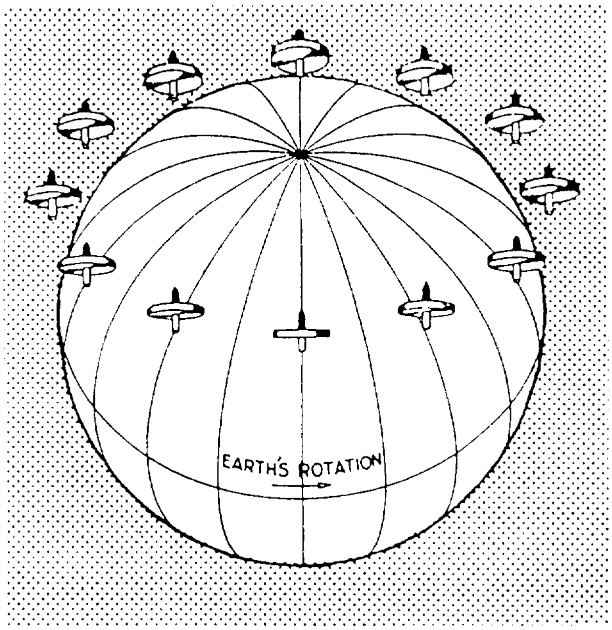


Figure 4-9.—Apparent rotation of a gyroscope at 45°N latitude.

(aligned north-south) and parallel to the earth's surface at 45° north latitude and 0° longitude (fig. 4-9).

A gyroscope, if set on any part of the earth's surface with the spinning axle not parallel to the earth's polar axis, appears to rotate, over a 24-hour period, about a line passing through the center of the gyroscope and parallel to the earth's axis. This apparent rotation is in a counterclockwise direction when viewed from south to north. The path that the north axle describes in space is indicated by the line EAWB back to E (fig. 4-10).

The effect of the earth's rotation causes the north end of the gyroscope axle to rise when east of the meridian and to fall when west of the meridian in any latitude. This tilling effect provides the means by which the gyroscope can be made into a north-seeking instrument.

MAKING THE GYROSCOPE INTO A GYROCOMPASS

Up to this point, we have discussed the basic properties of a free gyroscope. Now, we will discuss how we use these properties, rigidity of plane and precession, to make a gyroscope into a gyrocompass. The first step in changing the gyroscope to a gyrocompass is to make a change in the suspension system. The inner gimbal that holds the gyro rotor is modified by replacing it within a sphere or case (fig. 4-11, view A), a necessary feature that protects the rotor. A vacuum is formed inside the sphere to reduce air friction on the spinning rotor. The next step is to replace the simple gyroscopic hose with what is called a phantom ring (fig. 4-11, view A). The difference

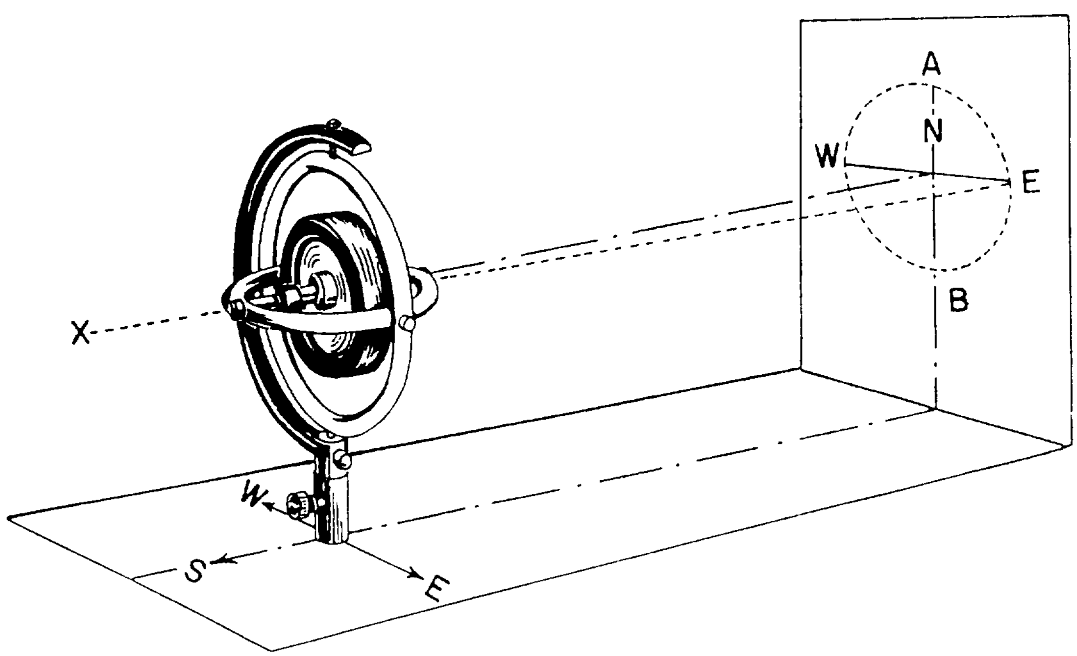


Figure 4-10.—Path of the spinning axis of a free gyroscope.

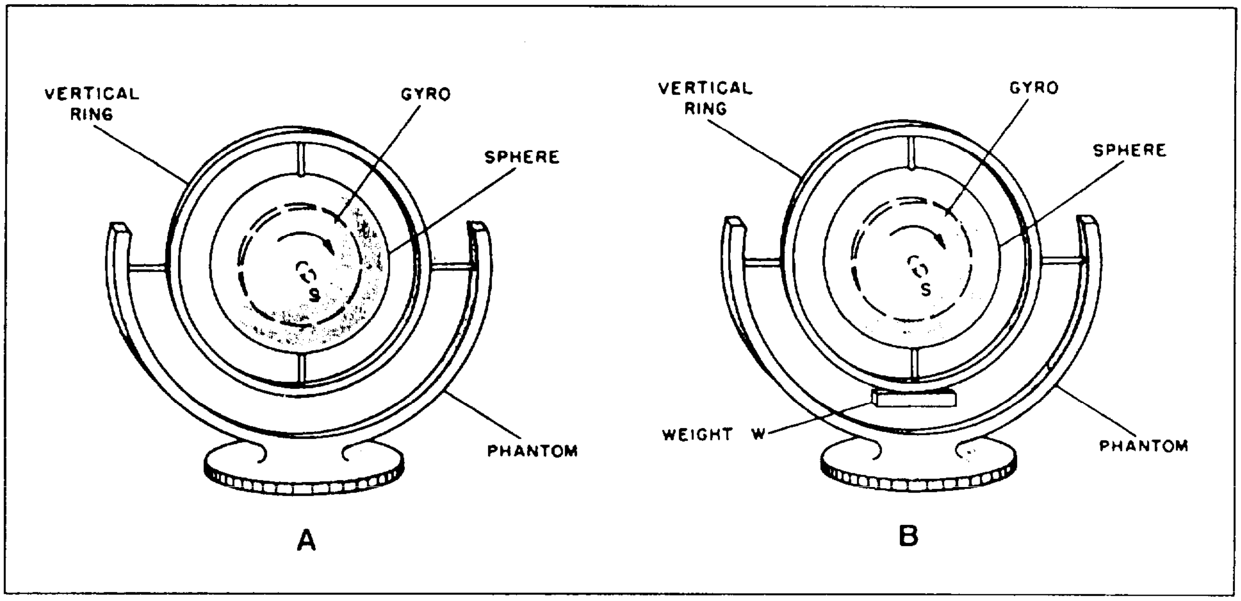


Figure 4-11.—A. Simple gyroscope. B. Modified gyroscope.

between the simple base and the phantom is that the phantom is turned by a servomechanism to follow the horizontal plane of the rotor's axle, while the simple base remains fixed in its position. The phantom ring allows the outer gimbal (vertical ring) (fig. 4-11, view A) the freedom to turn and to tilt. These modifications enable the gyroscope to maintain its plane of rotation as long as it spins and nothing touches it. We have modified the basic suspension system to enable us to convert the gyroscop to a gyrocompass. Now, we must make it seek out and point to true north.

For the purposes of this explanation, true north is the direction along the meridian from the point of observation to the North Pole.

To become a gyrocompass, a gyro must be modified so it can

1. align its axis on the meridian plane,
2. align its axis nearly horizontal, and
3. maintain its alignment both horizontally and on the meridian, once it is attained.

In figure 4-11, view B, a weight (pendulous weight) has been added to the bottom of the vertical ring, which makes it bottom heavy, or pendulous. The weight exerts a force on the gyro whenever the rotor is not level with the earth's surface.

In previous discussion, we talked about precession and vertical and horizontal earth rates. Now, we will see how we use the apparent rotation of the gyro rotor to make the modified gyroscope north-seeking. In figure 4-12, point A, the gyro axle is parallel to the earth's surface; however, as the earth rotates, the earth rate effect causes the gyro rotor axle to tilt in relation to the earth's surface, and the weight that we attached to the bottom of the vertical ring now applies a force to the bottom of the gyro. As we discussed earlier, precession occurs in the direction of rotation, but 90° away from the point of application; therefore, the weight applies a force to the bottom of the gyro but is felt about its horizontal axis, which causes the gyro to turn. As the gyro turns, the phantom follows the rotor axle. As you follow the gyro through one rotation on the earth's surface, you can see that the gyro rotor follows an elliptical path around the meridian. It actually points north twice in the ellipse; in other words, it has become north-seeking. The period of oscillation is actually much less than the 24 hours required of an unmodified gyro; the actual time is determined by the speed and weight of the rotor and the size of the pendulous weight. The next step, logically, is to make the north-seeking gyroscope north-indicating.

As you have seen, we made the gyroscope north-seeking by adding a pendulous weight, which caused the gyroscope to oscillate about north. To make it north-indicating, we must somehow dampen these oscillations. To do this, we must add another smaller weight, Wz, on the cast side of the rotor. Both weights,

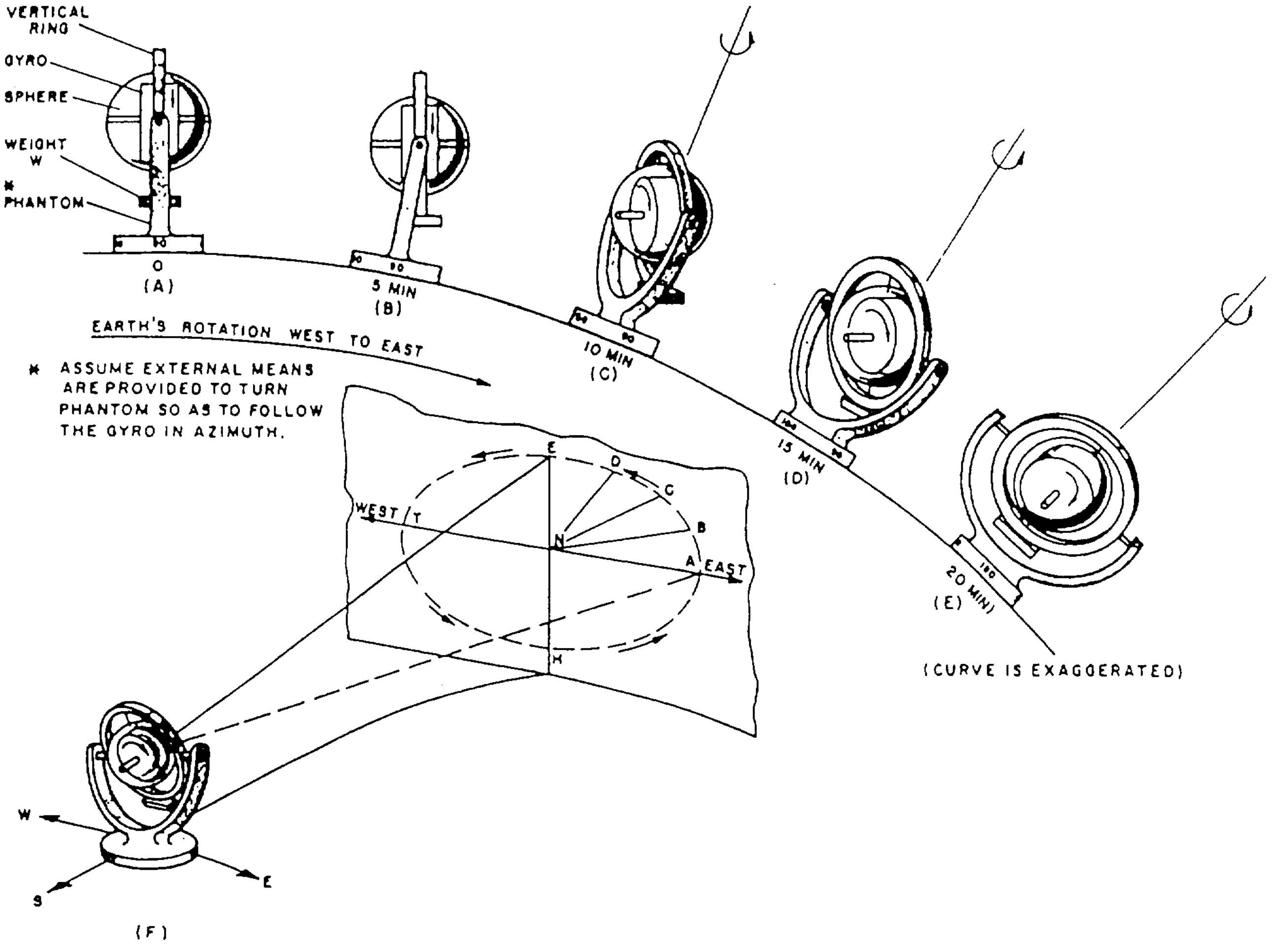


Figure 4-12.—Effect of weight and earth's rotation on the gyroscope.

W and W1, influence the gyro when it is not aligned with the meridian (fig. 4-13).

When the gyro is started while pointed away from the meridian, the effect of earth rate causes it to tilt. As soon as it tilts, weight W causes precession; however, now the smaller weight, W1, also causes the gyro to precess towards a more level position, which limits the effect of precession caused by weight W. The excursions from level continue, but the dampening effect of weight W1 causes each successive oscillation to be reduced; the path of the rotor axle then will be spiral shaped (fig. 4-14).

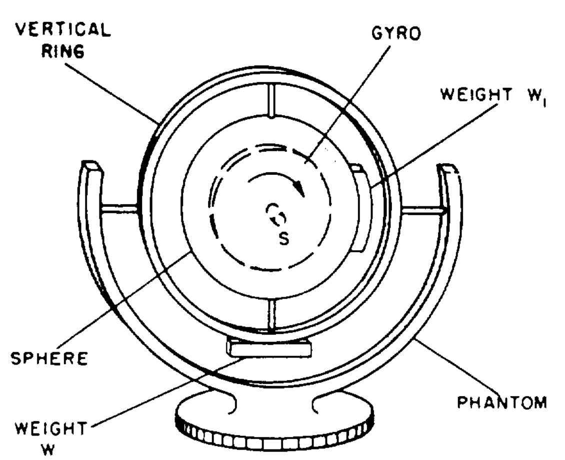


Figure 4-13.—Gyroscope with weights on the vertical ring and sphere.

As you can see, the only position of rest for the gyro axle is level and on the meridian. The free gyroscope has now become a gyrocompass, able to settle only on the meridian (pointing north) and level.

This is a very basic gyrocompass, and it really operates satisfactorily only on the equator and when mounted on a stable platform; however, the principles and basic concepts are the same for all gyrocompasses.

To make a basic gyrocompass function properly over a wide range of latitudes, we must stabilize it with respect to the earth's surface instead of with the earth's axis, and we must damp out the effects of the ship's

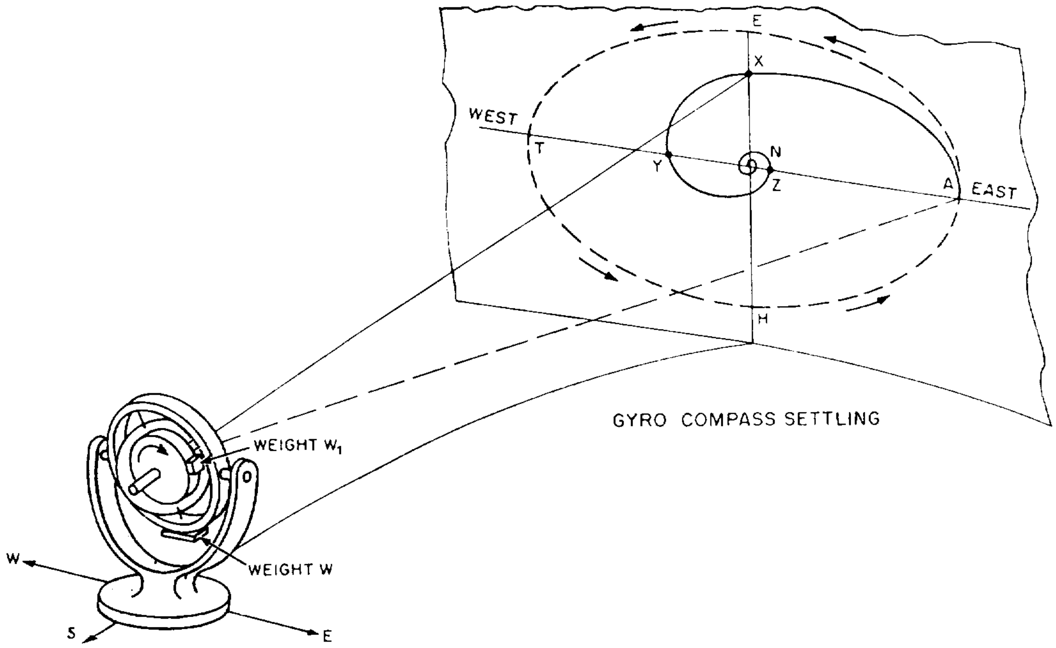


Figure 4-14.—Effect of weights on the gyroscope.

acceleration and deceleration. There are several methods used to do this. The method used depends on the type of gyrocompass. For further information on the method of damping used in the gyrocompasses installed on your ship, refer to the applicable manufacturer's technical manual.

GYROCOMPASS SYSTEMS

There are a wide variety of gyrocompass systems installed on Navy ships in the fleet today. Gyrocompasses are identified by the mark (Mk)–modification (Mod) system. The Mk number designates a major development of a compass. The Mod number indicates a change to the major development. The most common type of gyrocompasses found in the fleet today are the electrical gyrocompass systems, such as the Sperry Mk 23, Sperry Mk 27, and the Sperry Mk 19 Mod 3.

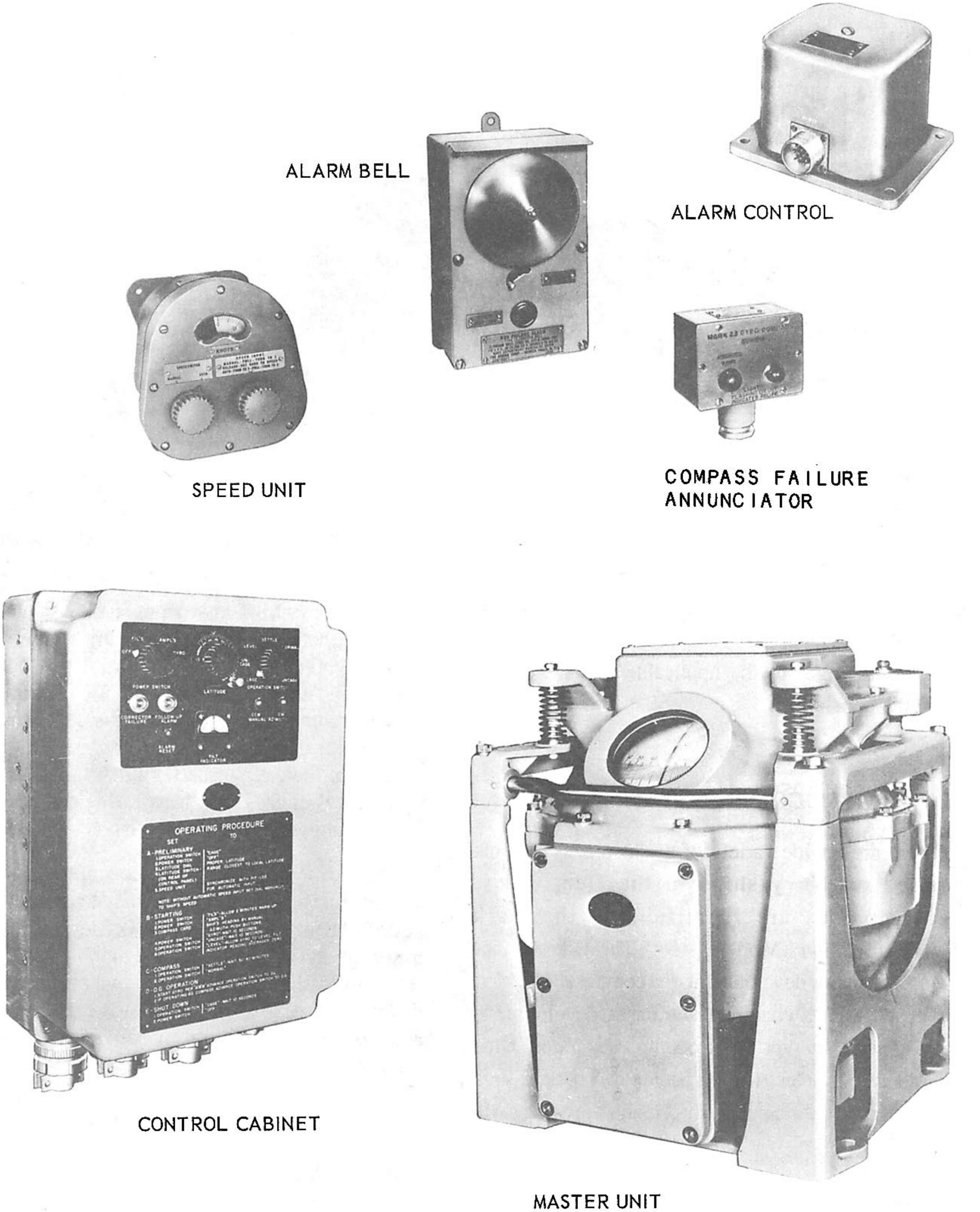
There are also two new gyrocompass systems currently being installed on Navy ships today. These are the Stabilized Gyrocompass Set AN/WSN-2 and the Inertial Navigation Set AN/WSN-5. Operation of the AN/WSN-5 is classified; therefore, only the ANAVSN-2 will be discussed in this training manual.

SPERRY MK 23 GYROCOMPASS SYSTEMS

The Sperry Mk 23 gyrocompass is a small electrical compass that is used aboard many naval vessels to furnish heading data. On many of the small combatant vessels and larger auxiliary vessels, it is used as the master compass. On some of the larger combatant vessels, it is used as a backup compass. The compass is capable of indicating true north accurately in latitudes up to 75°N or S. The compass also can be used as a directional gyro when nearer the poles.

Unlike the mechanical gyrocompass, which uses weights that are affected by gravity to cause the desired period of damping, the Sperry Mk 23 gyrocompass uses a special type of electrolytic bubble level (gravity reference), which generates a signal proportional to the tilt of the gyro axle. This signal is then amplified and applied to an electromagnet which applies torque about the vertical and/or horizontal axes to give the compass the desired period and damping. The gyrocompass is compensated for speed error, latitude error, unbalance, and supply voltage fluctuations. An electronic follow-up system furnishes accurate transmission of heading data to remote indicators.

The original Sperry Mk 23 gyrocompass (Mod O) has had several minor modifications and one major modification (Mod C-3). Only the Mk 23 Mod O and the Mk 23 Mod C-3 will be discussed in this training manual.



7.167

Figure 4-15.—Mk 23 Mod 0 gyrocompass equipment.

MK 23 MOD 0 GYROCOMPASS SYSTEM

The Mk 23 Mod 0 gyrocompass system (fig. 4-15) consists of the master unit, control cabinet, speed unit, alarm control unit, a compass failure annunciator, and an alarm belt.

Master Unit

The master unit consists of a shock-mounted, oil-filled binnacle and the gyrocompass element. The master unit is designed for deck mounting and weighs approximately 100 pounds. The compass element is the principle unit of the compass system and is gimballed in the binnacle to allow ±45° of freedom about the pitch and roll axes. Drain plugs are located in the lower bowl for draining the oil.

Control Cabinet

The control cabinet contains all the equipment required for operating and indicating the condition of the master compass except the visual alarm indicator and the alarm bell. The control cabinet houses the control panel, control amplifier, follow-up amplifier, and power supply.

Speed Unit

The speed unit contains the necessary components to produce an electrical signal proportional to ship's speed. Speed information is received from the ship's underwater log equipment or is set in manually by the ship's dummy log system. The speed range of the unit is 0 to 40 knots.

Alarm Control Unit

The alarm control unit contains the necessary relays and components to actuate the lamp on the visual alarm indicator or the bell alarm when certain portions of the system become inoperative.

Compass Failure Annunciator

The compass failure annunciator is a visual alarm indicator. It provides a visual indication of problems within the gyrocompass system. Under normal conditions, the lamp on the indicator is lighted continuously. When a failure occurs within the system, the lamp flashes or goes out. A test push button is provided on the annunciator. In some installations a type B-51 or B-52 alarm panel is used in place of the annunciator.

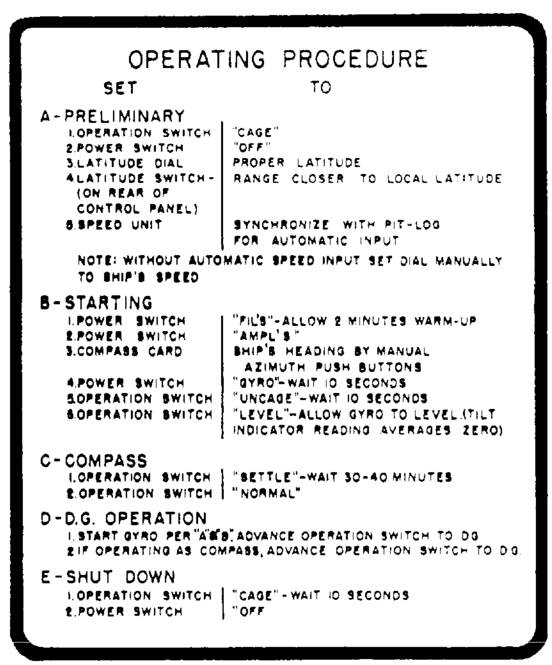
Alarm Bell

The alarm bell is used with the annunciator to provide an audible indication of problems within the gyrocompass system.

OPERATING THE MK 23 MOD 0 GYROCOMPASS

Instructions for starting and stopping (securing) the compass under normal conditions are on an instruction plate (fig. 4-16). This plate is located on the front of the control cabinet. There are two modes of operation, normal and directional gyro (DG). The normal mode of operation is used for latitudes up to 75°. The DG mode of operation is used for latitudes above 75°. Normally, the compass should be started at least 2 hours before it is needed for service. For additional information on starting the compass, refer to the manufacturer's technical manual.

If it becomes necessary to stop the compass in a heavy sea for any reason other than failure of the follow-up system, the following procedure should be used:


OPERATING PROCEDURE

SET	TO
A-PRELIMINARY	
1.OPERATION SWITCH	"CAGE"
2.POWER SWITCH	"OFF"
3.LATITUDE DIAL	PROPER LATITUDE
4.LATITUDE SWITCH-(ON REAR OF CONTROL PANEL)	RANGE CLOSER TO LOCAL LATITUDE
5.SPEED UNIT	SYNCHRONIZE WITH PIT-LOG FOR AUTOMATIC INPUT
NOTE: WITHOUT AUTOMATIC SPEED INPUT SET DIAL MANUALLY TO SHIP'S SPEED	
B-STARTING	
1.POWER SWITCH	"FIL'S"-ALLOW 2 MINUTES WARM-UP
2.POWER SWITCH	"AMPL'S"
3.COMPASS CARD	SHIP'S HEADING BY MANUAL AZIMUTH PUSH BUTTONS
4.POWER SWITCH	"GYRO"-WAIT 10 SECONDS
5.OPERATION SWITCH	"UNCAGE"-WAIT 10 SECONDS
6.OPERATION SWITCH	"LEVEL"-ALLOW GYRO TO LEVEL.(TILT INDICATOR READING AVERAGES ZERO)
C-COMPASS	
1.OPERATION SWITCH	"SETTLE"-WAIT 30-40 MINUTES
2.OPERATION SWITCH	"NORMAL"
D-D.G. OPERATION	
1.START GYRO PER "A"&"B", ADVANCE OPERATION SWITCH TO DG	
2.IF OPERATING AS COMPASS, ADVANCE OPERATION SWITCH TO D.G.	
E-SHUT DOWN	
1.OPERATION SWITCH	"CAGE"-WAIT 10 SECONDS
2.POWER SWITCH	"OFF

STARTING INSTRUCTION PLATE

Figure 4-16.—Operating procedures for the Sperry Mk 23 Mod 0 gyrocompass.

1. Place the power switch in the AMPL'S position.

2. Wait 30 minutes, and then place the operation switch in the CAGE position.

3. Place the power switch in the OFF position.

In case of follow-up system failure, place the operation switch in the CAGE position immediately and the power switch in the OFF position.

If power to the compass fails, place the power switch in the FIL'S position and the operation switch in the CAGE position. When the power is restored, restart the compass in the usual manner.

Setting Correction Devices

Correction device settings for the Mk 23 gyrocompass include the manual speed setting on the speed unit, the latitude control knob setting on the control panel, and the latitude switch setting on the rear of the control panel.

When you operate the speed unit manually, adjust the speed settings to correspond to the average ship's speed. Change the latitude control knob setting on the control panel when the ship's latitude changes as much as 2°, or as ordered by the ship's navigator. Throw the latitude switch on the rear of the control panel to the 65° position for normal operation when the ship's latitude is above 60°. The position of the latitude switch is immaterial for directional gyro operation.

Indications of Normal Operation

Normal operating conditions for the compass arc indicated by the following:

1. The follow-up failure and corrector failure lamps on the control panel should be dark.

2. The master unit should be lukewarm.

3. The speed dial should indicate the ship's speed for normal operation or zero for directional gyro operation.

4. The tilt indicator pointer should be oscillating evenly about the zero position.

WATCH STANDING

When you are assigned the gyrommpass watch, you will be required to maintain the gyrocompass log and to respond to any alarms associated with the gyrocompass system. The gyrocompass log contains hourly readings showing the conditions of the gyrocompass and the power sources available. During an alarm condition, the compass is no longer considered reliable.

MK 23 MOD C-3 GYROCOMPASS SYSTEM

The Mk 23 Mod C-3 gyrocompass system is identical to the Mk 23 Mod 0 system with the exception that the Mk 23 Mod C-3 system uses solid-state devices in place of vacuum tubes in the control cabinet. In addition, two more units are used in the C-3 system. These two additional units arc the power supply unit and the power supply control unit.

The power supply unit and the power supply control unit, together with a 120-volt dc battery, are used to form a standby power supply for the compass. This standby power supply provides uninterrupted 120-volt, 400-Hz, 3-phase power to the compass for a limited period of time if the normal ship's supply fails. If the normal ship's supply fails, a red light located on the power supply control unit will come on. When the compass is being supplied power from the standby power supply, power will be cut off to some of the remote repeaters.

The starting and stopping procedures for the compass are basically the same as for the Mk 23. Instructions for starting and stopping the compass under normal conditions are given on the instruction plate (fig. 4-17) located on the front of the control panel. Make sure the ON-OFF switch located in the power supply control unit is in the ON position before starting the compass. For additional information on starting and stopping the compass, refer to the manufacturer's technical manual.

Watch-standing procedures are basically the same as for the Mk 23 Mod 0 gyrocompass system.

SPERRY MK 27 GYROCOMPASS SYSTEM

The Sperry Mk 27 gyrocompass is a rugged, low-voltage electrical compass used as the master compass on small craft and as the auxiliary compass on larger ships.

The Mk 27 gyrocompass is designed to operate on 24-volt dc or 115-volt, 60- or 400-Hz, single-phase power.

A liquid ballistic filled with refined silicone oil provides the gravitational torque needed to make the compass north-seeking. The ballistic consists of two interconnected brass tanks and is mounted directly on the gyrosphere. Direction of rotation of the gyro axle is

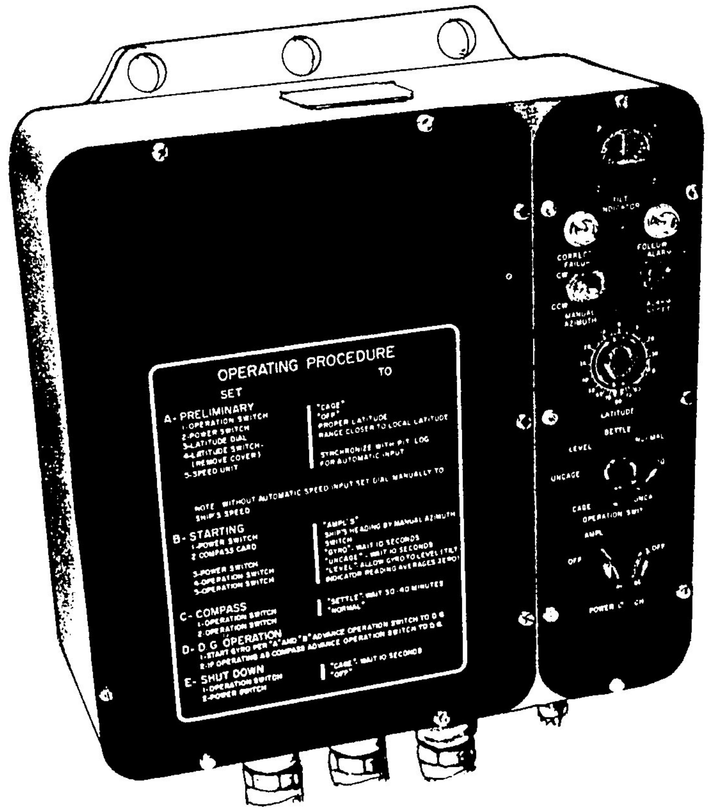


Figure 4-17.—Mk 23 Mod C-3 control cabinet.

reversed to counterclockwise as viewed from the south end of the gyro axle as it was in other ballistic compasses. The direction of the vertical torque is also reversed.

The Mk 27 gyrocompass system (fig. 4-18) consists of a master unit, an electronic control cabinet, and a power converter.

MASTER UNIT

The master unit contains the compass element and receives its electrical and electronic support from the electronic control cabinet. The master unit also contains a bellows assembly to allow for temperature variation, a card viewing window, a cager diaphragm, an electrical connector, and the fluid-filling nozzles.

ELECTRONIC CONTROL CABINET

The electronic control cabinet houses the control panel, power supply, servoamplifier, latitude compensation circuit, and alarm circuit. The electronic control unit has plug-in connectors, which are used to connect the unit to either a power converter or a 24-volt dc supply and to the master unit.

POWER CONVERTER

The power converter is used to convert 115-volt, 60- or 400-Hz, single-phase power to 24-volt dc when 24-volt dc is not available.

OPERATING THE MK 27 GYROCOMPASS

The control panel located on the electronic control cabinet contains all the operating controls necessary for operating the compass. Instructions for starting and securing the compass are listed on an instruction plate located near the electronic control cabinet. For additional information on starting and stopping the compass, refer to the manufacturer's technical manual.

WATCH STANDING

Watch-standing procedures for the Mk 27 gyrocompass are basically the same as for the Mk 23 gyrocompass. Indicator lamps for the power available

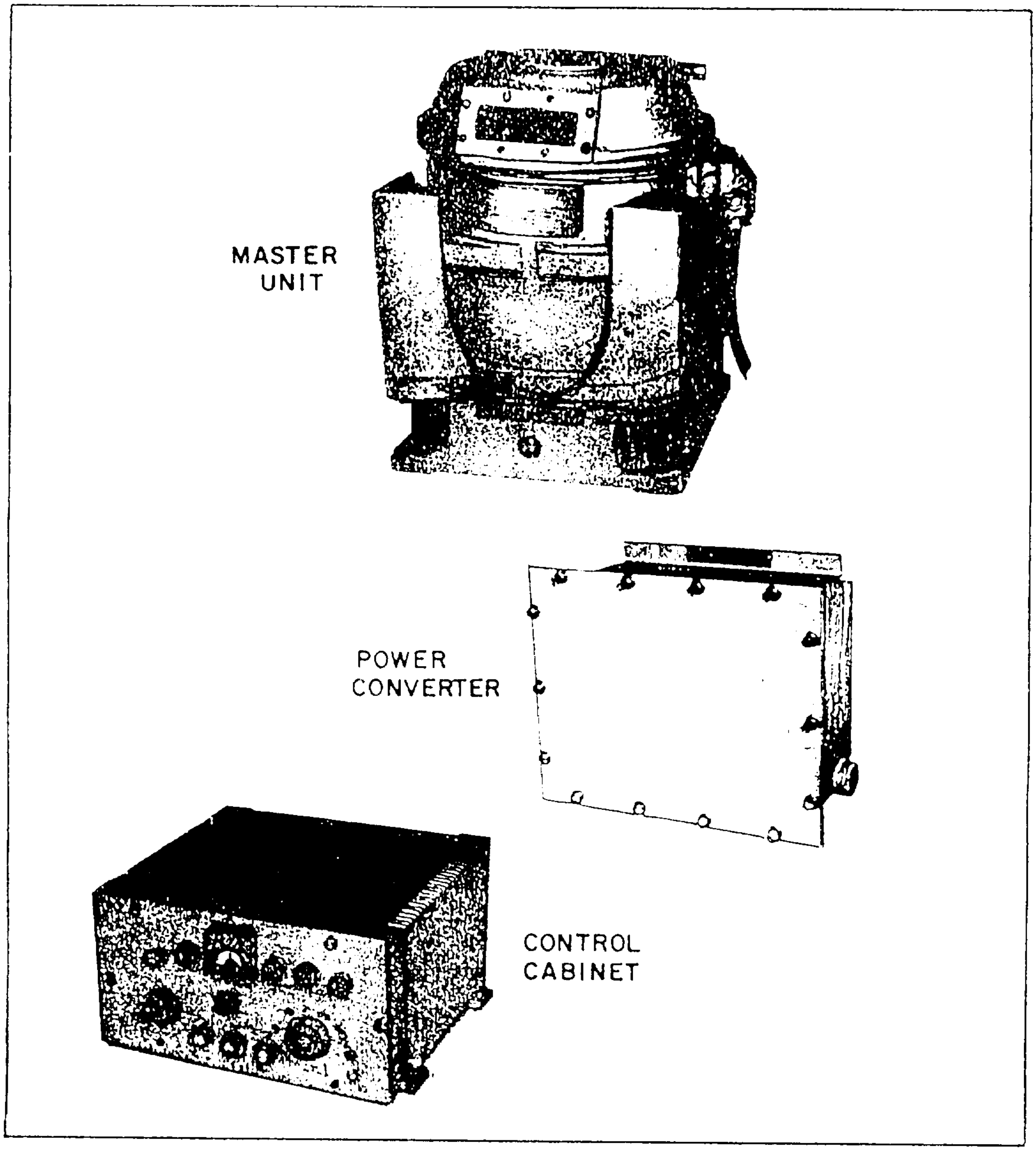


Figure 4- 18.—Mk 27 Mod O gyrocompass equipment.

and follow-up alarm are located on the control panel. When a power failure occurs, the power available lamp will go out. When a follow-up error occurs, the follow-up alarm lamp will light up and an audible alarm will sound.

SPERRY MK 19 MOD 3 GYROCOMPASS SYSTEMS

The Sperry Mk 19 Mod 3 gyrocompass systems furnish roll and pitch angle information as well as heading information. This roll and pitch angle information is used to stabilize gunmounts, missile launchers, and other equipment that must remain level with respect to the earth's surface for proper operation. The Mk 19 Mod 3 gyrocompasses are used as the master compass on Navy combatant ships. Some ships will have two Mk 19 compasses installed; one will be used as the master compass and the other as the backup compass. There have been five modifications to the original Sperry Mk 19 Mod 3 gyrocompass system since it was first introduced. These five modifications will be discussed in the following paragraphs.

MK 19 MOD 3A GYROCOMPASS SYSTEM

The Mk 19 Mod 3A gyrocompass is a navigational and fire control instrument with design features based on unusual requirements. The compass is designed to operate in latitudes up to 80° with an accuracy of 0.1° in azimuth at sea. In addition, it accurately measures and transmits angles of roll and pitch. These features distinguish the Mk 19 Mod 3A from all other shipboard gyrocompasses that preceded it.

Design of the compass is based on the principle that two properly controlled horizontal gyros can, together, furnish a stable reference for the measurement of ship's heading, roll, and pitch. Briefly, the basic unit consists of two gyros placed with their spin axes as shown by figure 4-19. The top gyro is a conventional gyrocompass and is referred to as the north-seeking, or meridian, gyro. Its spin axis is directed along a north-south line.

The lower gyro is a directional gyro with its spin axis slaved to the meridian gyro along an east-west line. It is referred to as the slave gyro and furnishes indications of roll on north-sowb courses and pitch on east-west courses.

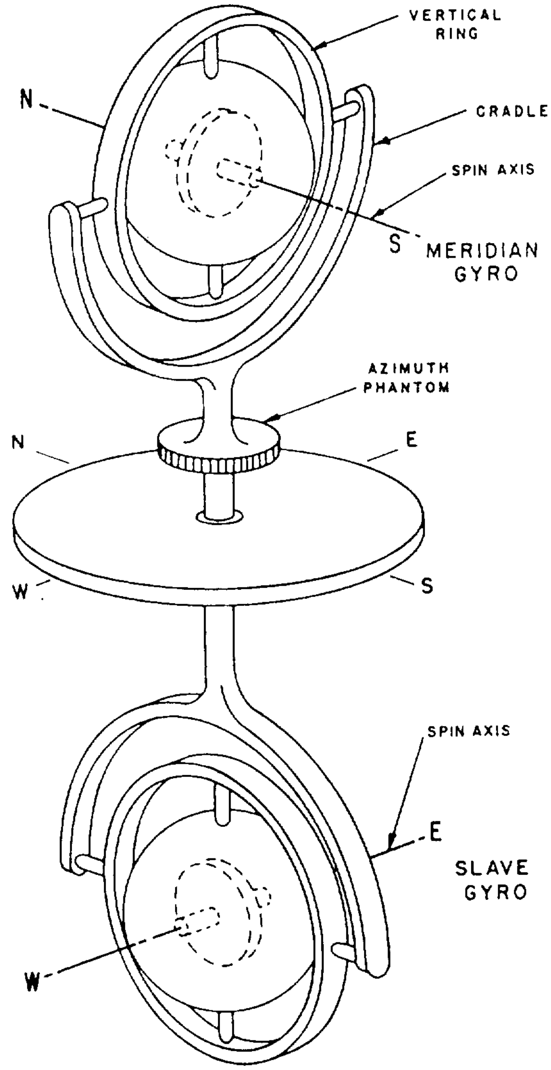


Figure 4-19.—Simplified diagram of the Mk 19 Mod 3A compass element.

An electric control system is used in the Mk 19 Mod 3A gyrocompass to make it seek and indicate true north as well as the zenith. A gravity reference system is employed for detecting gyro tilt, and torques are applied electromagnetically to give the meridian gyro the desired period and damping. Further, signals are generated by the compass, which are used to stabilize the entire sensitive element in roll and pitch, thereby furnishing an indication of the zenith in terms of roll and pitch data.

Both the meridian and slave gyros are enclosed in hermetically seated spheres and suspended in oil. The compass is compensated for northerly and easterly speed and acceleration, earth rate, constant torques, and follow-up errors. The system (fig. 4-20) consists of four major components: the master compass, the control cabinet, the compass failure annunciator, and the standby power supply.

Master Compass Assembly

The master compass assembly (fig. 4-21) is approximately 3 feet high and weighs about 685 pounds. Its two major components are the compass element and the supporting element.

COMPASS ELEMENT.— The compass element includes the sensitive element (meridian and slave gyros), the gimbal, and the phantom assembly. The phantom assembly includes the azimuth phantom, which indicates the meridian, and the roll and pitch phantom, which measures the angles from the horizontal. The compass element is gimballed in the binnacle to allow ±60° of freedom about the roll axis and ±40° of freedom about the pitch axis.

SUPPORTING ELEMENT.— The supporting element includes the frame and the binnacle. The compass elements are gimballed in the binnacle by a conventional gimballing system with 62° of freedom about the roll axis mechanically, 60° electrically; and 42° of freedom about the pitch axis mechanically, 40° electrically.

The meridian and slave gyros are similar in construction, with the exception that the slave gyro is inverted and minor changes in wiring are made. The two gyro assemblies are mounted on the inner ring of the

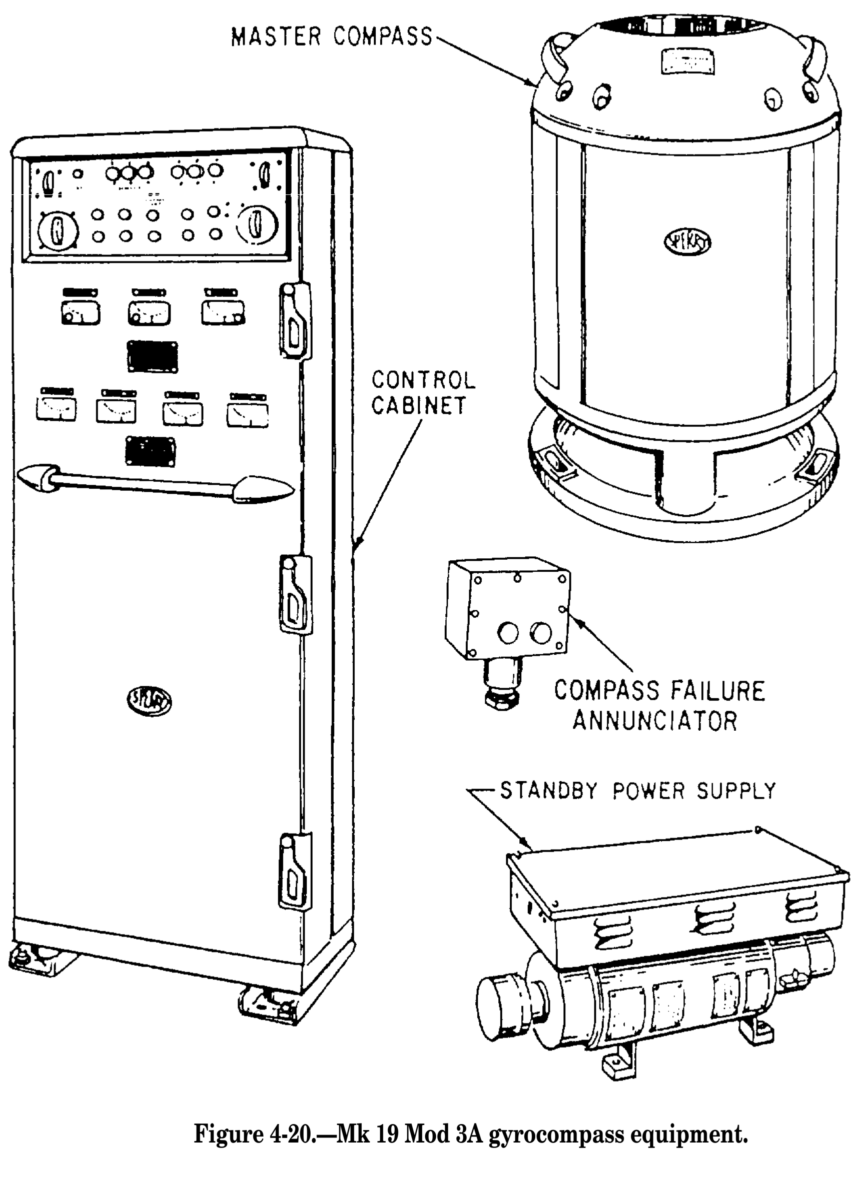


Figure 4-20.—Mk 19 Mod 3A gyrocompass equipment.

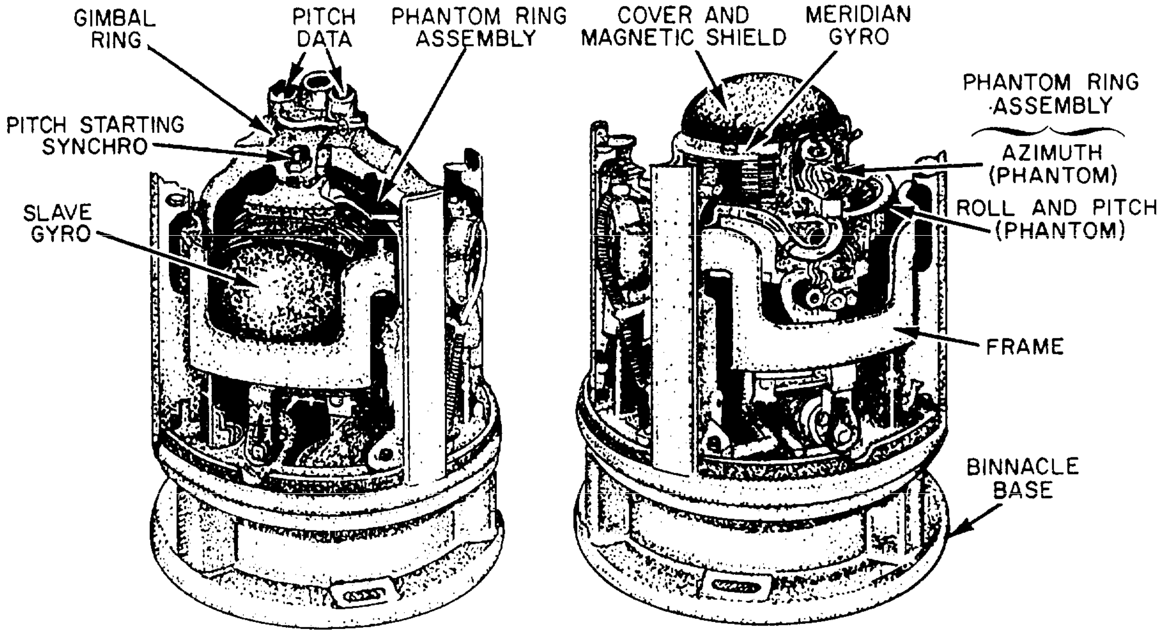


Figure 4-21.—Two views of master compass element and supporting element.

phantom assembly, the meridian gyro on top, and the slave gyro, upside down, on the underside. The gyro motors are 2-pole, 115-volt, 3-phase, 400-Hz squirrel cage induction motors. The meridian gyro rotates approximately 23,600 rpm clockwise viewed from the south, and the slave gyro rotates at the same speed counterclockwise viewed from the east.

The azimuth phantom is made to follow the azimuth motion of the meridian gyro and 1- and 36-speed heading data are transmitted by the azimuth servo and synchro assemblies mounted on the phantom assembly. The roll and pitch phantom is stabilized in roll and pitch, and 2- and 36-speed roll and pitch data are transmitted by the roll and pitch servo and synchro assemblies mounted on the frame and binnacle.

Control Cabinet

The control cabinet (fig. 4-20) contains the control panel, the computer indicator panel, a dc power supply, analog computers, amplifiers, and other assemblies required for operating and indicating the condition of the master compass.

CONTROL PANEL.— The control panel (fig. 4-22) contains all the switches, alarm lamps, and indicator fuses required for operating the system. Only the controls required for normal operation of the system are accessible when the control cabinet is closed. These controls are on a recessed panel to avoid injury to personnel, damage to the controls, or accidental change of setting.

COMPUTER INDICATOR PANEL.— Located below the control panel, and inside the cabinet, are seven computer assemblies for computing data for the systems. The computer indicator panel (fig. 4-23) consists of seven windows. A dial is visible behind each window to indicate the data being computed by its associated computer assembly. These assemblies are discussed later under the control system in which they are used.

COMPUTER CONTROL ASSEMBLY.— To minimize the number of amplifiers used in the system, two types of standard plug-in computer amplifiers are used in 13 applications. As the characteristics and the circuits in which the amplifiers are used vary, other components peculiar to a single circuit must also be used. For this reason, a T-shaped panel, known as the computer control assembly, is located inside the control cabinet. This panel provides a junction box into which the amplifiers may be plugged. This panel also serves as a chassis for the various components required to match the standard amplifiers to the particular circuits concerned. The computer control assembly houses 11 type 1, and 2 type 2 general-purpose computer amplifiers, and all the components required to operate the various computer and torque circuits, other than those contained in the mechanical assemblies or in the master compass.

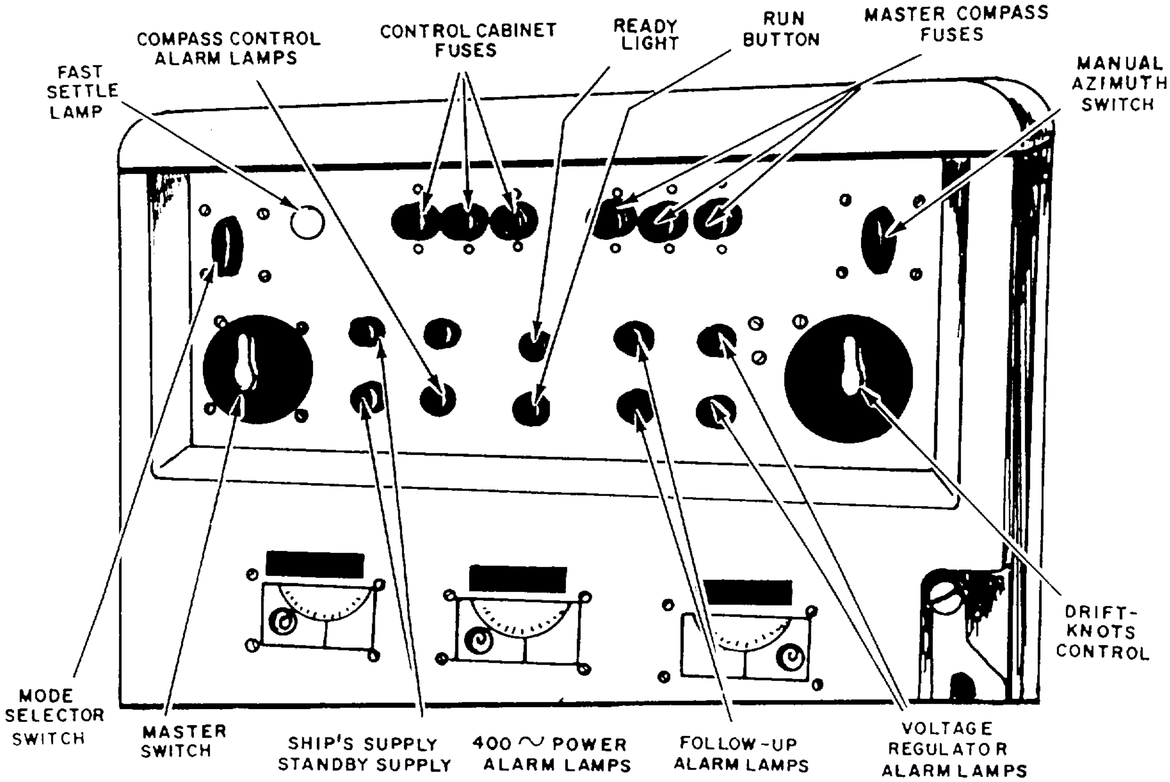


Figure 4-22.—Control panel.

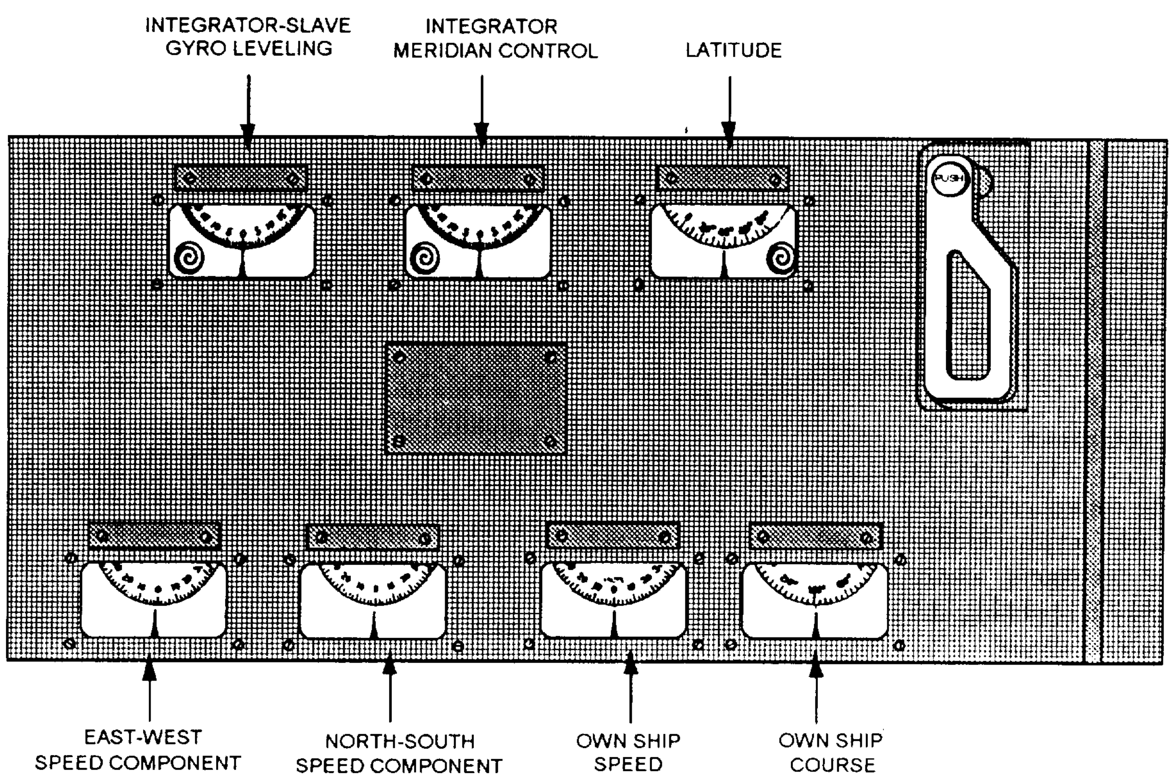


Figure 4-23.—Computer indicators.

SYSTEM CONTROL ASSEMBLY.— The system control assembly (fig. 4-24) is mounted at the top of the rear section of the control cabinet and includes switches, a time delay and circuits, and a stepping relay for cycling the events automatically. These components are required for starting and operating the compass system. They operate in conjunction with the switches, indicators, and relays on the control panel (fig. 4-22) and elsewhere in the system in performing starting and control functions.

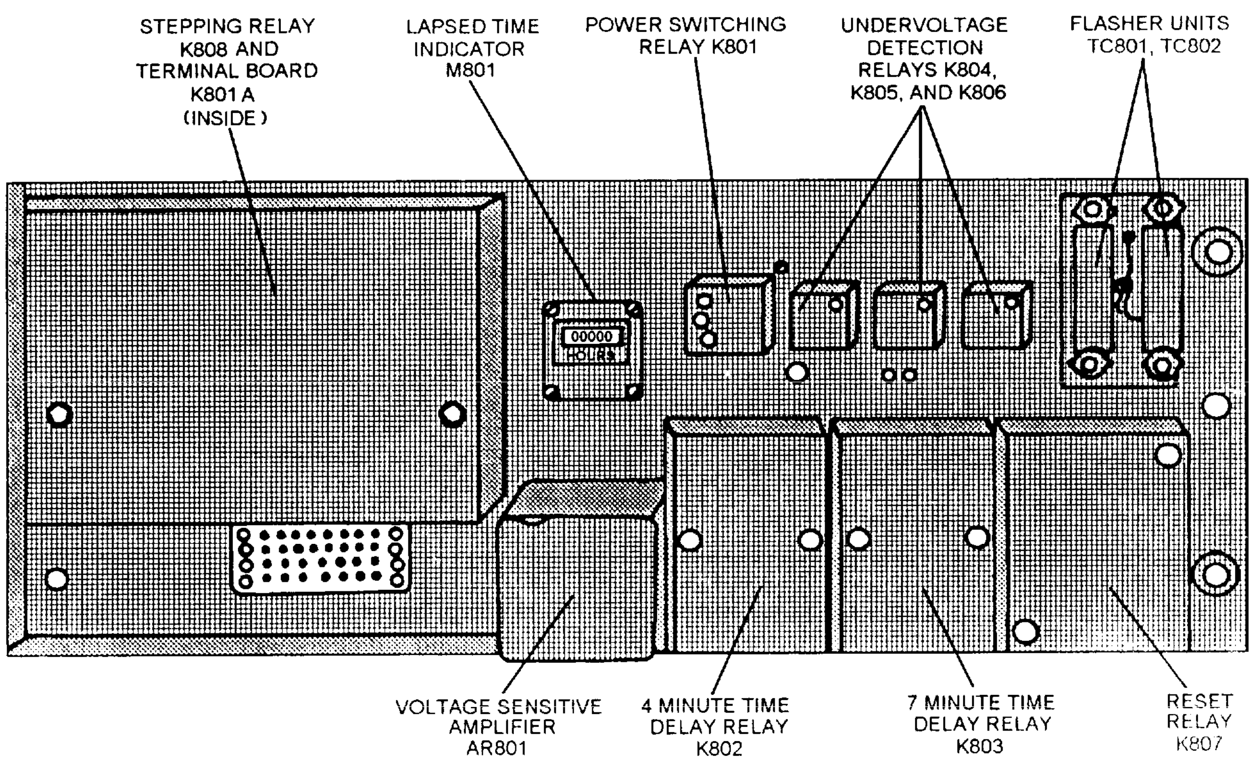
FOLLOW-UP AMPLIFIERS.— Mounted below the system control assembly are the roll, pitch, and azimuth follow-up amplifiers. The three follow-up amplifiers are identical and interchangeable.

DC POWER SUPPLY.— Below the follow-up amplifiers is the dc power supply unit (fig. 4-25, view A) containing the power supply component (metallic rectifiers, filters, and so forth), a monitoring meter, and an associated selector switch. The unit operates from the 115-volt, 4(X)-HZ, 3-phase supply and furnishes all dc voltages required for the operation of the various amplifiers and relays in the system.

VOLTAGE REGULATOR.— Because a supply voltage fluctuation even as low as 2 volts can cause compass errors, a voltage regulator was developed for the Mk 19 Mod 3A system. This regulator is designed to be installed in the bottom of the control cabinet and provides an output of 115 volts, 400 Hz ac regulated within ±0.75 volt for an input of 115 volts ±7 volts. The regulator unit (fig. 4-25, view B) is a single chassis containing a diode rectifier circuit, a dc reference circuit, a differential amplifier, and a corrector circuit. The corrector circuit includes a magnetic amplifier, a servomotor and gear train, a variable autotransformer, and a buck-boost transformer. The buck-boost transformer aids or opposes the line voltage with a voltage supplied from the autotransformer.

An alarm indicator tube is provided to indicate a tube failure and an out-of-tolerance input voltage. In addition, the unit contains a magnetic amplifier balance control, a nominal voltage adjustment control, an automanual switch, and an ac voltmeter to indicate the regulated output voltage.

ADDITIONAL COMPONENTS.— In addition to the components and assemblies previously mentioned,



Fignre 4-24.—System control assembly.

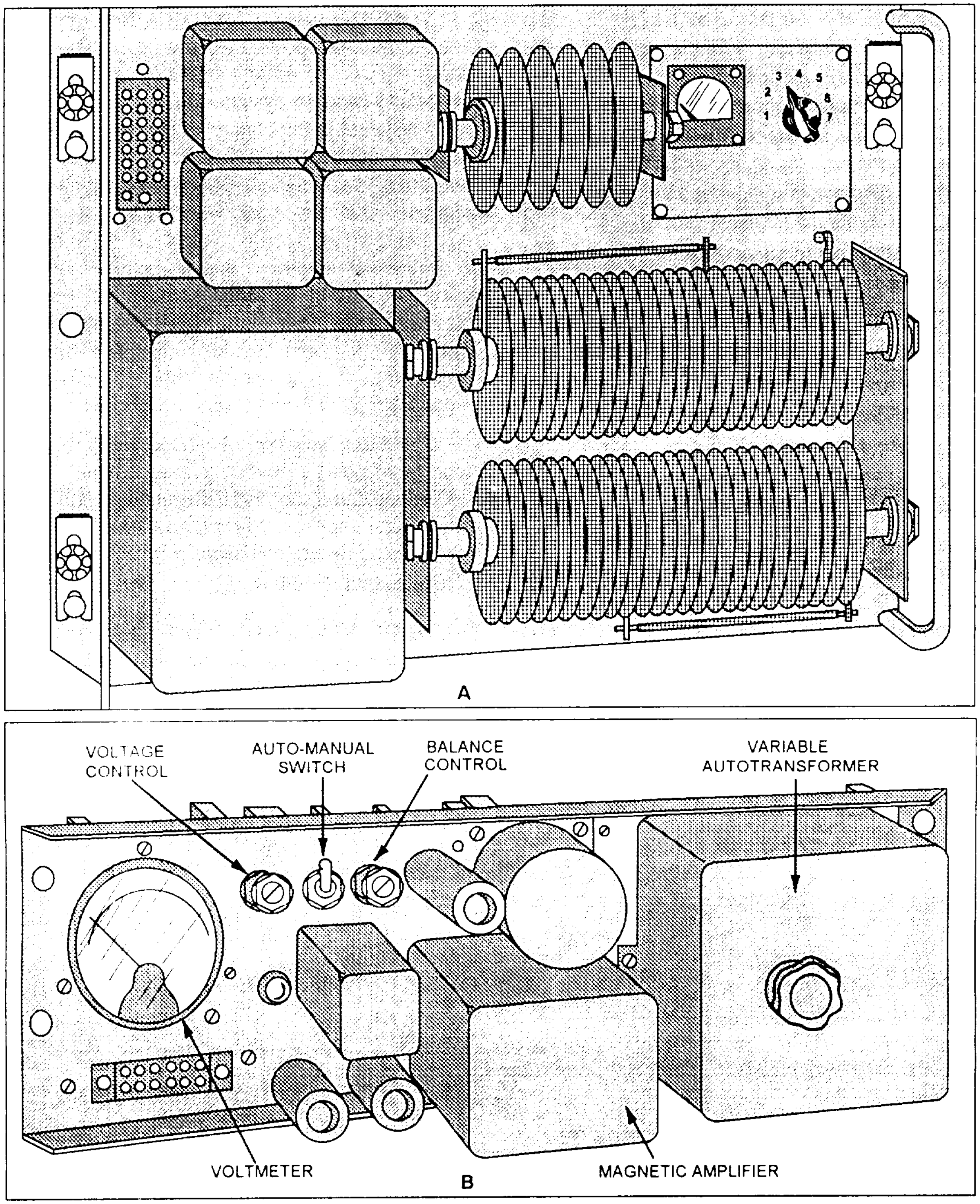


Figure 4-25.—A. Power supply. B. Mk 19 voltage regulator.

the control cabinet also includes an isolation transformer, a ventilating fan, and a spare amplifier.

The isolation transformer is located immediately below the top of the rear portion of the control cabinet and isolates the compass system from the rest of the components connected to the ship's 400-Hz power mains, thus eliminating line-to-ground ptentials in the gyro circuits from the ship's 400-Hz system.

The ventilating fan is located above the isolation transformer and provides ventilation for the interior of the cabinet.

On the bottom right-hand corner of the control cabinet is a spare type 1 computer amplifier.

Compass Failure Annunciator

The compass failure annunciator (fig. 4-20) is a remote visual indicator, of the same type used in the Mk 23 system. Associated with the annunciator is usually a Navy standard type IC/B5DSF4 alarm bell. The alarm bell and annunciator are actuated by the alarm control system to give both a visual and audible indication of system failure. The compass alarm system is discussed later in this chapter.

Standby Power Supply

The standby power supply (fig. 4-20) is a motor-generator set that provides emergency power for the compass system, for a short time, in case of failure of the ship's power supply. Under normal operation the ac section operates as a 115-volt, 400-Hz, 3-phase synchronous motor, driving a 120-volt compound-wound dc genemtor that charges a bank of 20 6-volt storage batteries. If the ship's 400-Hz supply fails, or falls below 105 volts, the ship's line is disconnected automatically and the 120-volt dc generator is driven as a motor by the storage batteries. The ac section now operates as a 115-volt, 4(X)-Hz, 3-phase generator supplying the compass system.

Mk19 Mod 3A Gyrocompass Controls

All controls for the Mk 19 Mod 3A gyrocompass system (fig. 4-26, views A and B) are contained in four

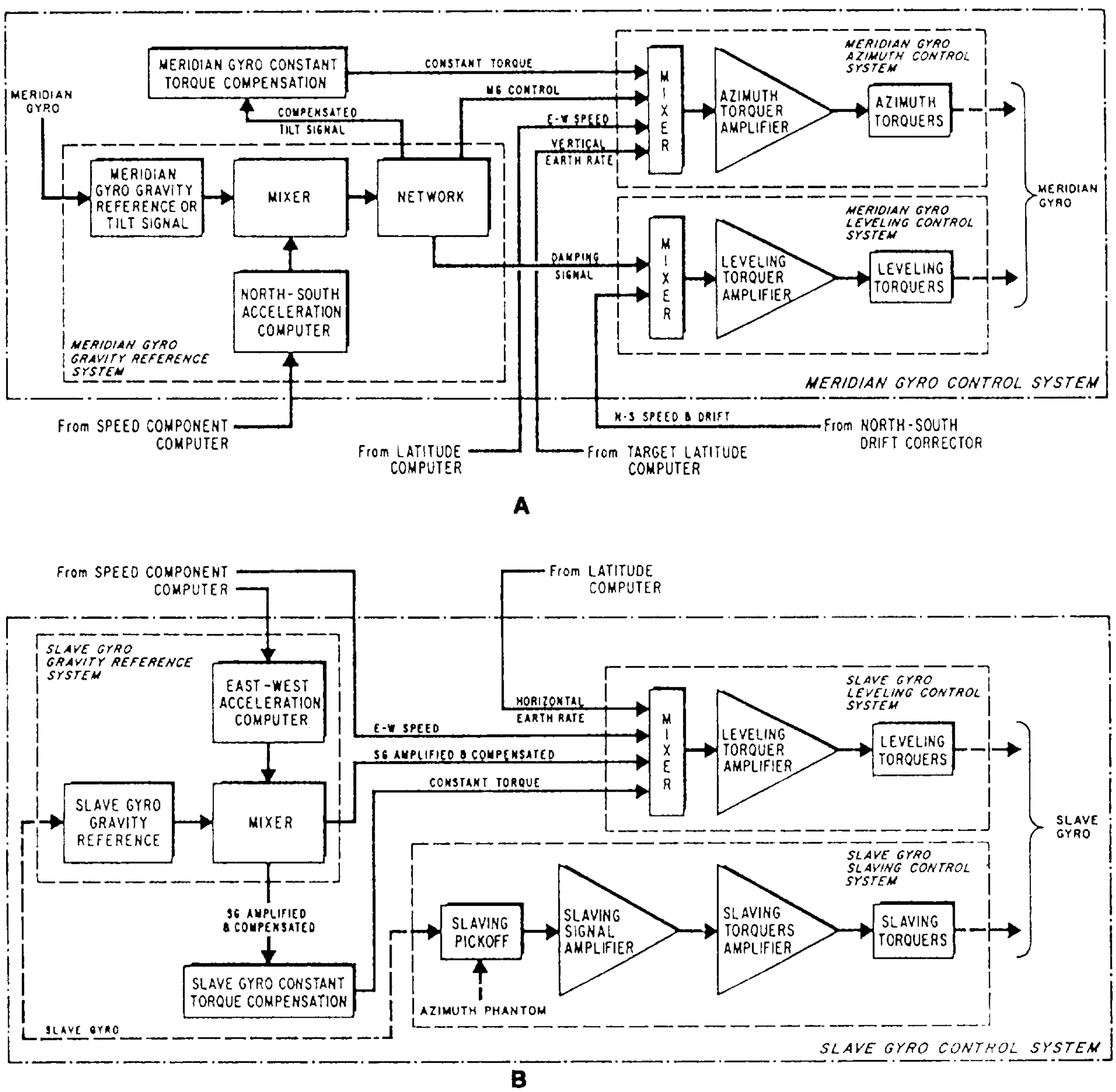


Figure 4-26.—A. Meridian gyro control system. B. Block diagram of a slave gyro control system.

major systems; the meridian gyro control system, the slave gyro control system, the azimuth follow-up system, and the roll and pitch follow-up system.

Meridian Gyro Control System

The meridian gyro control system includes the gravity reference system, the azimuth control system, and the leveling control system. These systems are similar to the Mk 23 compass control system, and they function to control the meridian gyro in the same manner. The compass compensation system is more elaborate, due to the high degree of accuracy required of the Mk 19 Mod 3A gyrocompass, and will be discussed separately.

MERIDIAN GYRO GRAVITY REFERENCE SYSTEM.— The gravity reference system (fig. 4-26, view A) consists of the meridian gyro gravity reference (the electrolytic bubble level and excitation tmnsformcr), the north-south acceleration computer, a mixer, and its associated network.

The tilt signal from the electrolytic bubble level is fed into the mixer. Here, the tilt signal is mixed with the north-south acceleration signal (a compensation signtil m be discussed later), and the compensated tilt signal is fed into a net work of resistors, potentiometers, and relay contacts. me network has three output signals: the meridian control signal to the azimuth control system, the damping signal to the leveling control system, and the compensated tilt signal to the meridian gyro constant torque compensation system.

MERIDIAN GYRO AZIMUTH CONTROL SYSTEM.— The azimuth control system consists of a mixer, an azimuth torque amplifier, and the azimuth torquers. (See fig, 4-26, view A.) The mixer input signals are the meridian control signal from the gravity refertnct system, an east-west speed signal from the tangent latitude computer, and a vertical earth rate compensation signal from the latitude computer. The azimuth torque amplifier output is fed to the control fields of the two azimuth torquers, which apply torque to precess the meridian gyro, toward the meridian, in the same manner as described in the Mk 23 system.

MERIDIAN GYRO LEVELING CONTROL. SYSTEM.— The meridian gyro leveling control system (fig. 4-26, view A) consists of a mixer, the leveling cent amplifier, and the leveling torque. The input signals to the mixer arc the dumping signal from the gravity reference system, and the north-south speed plus drift compensation signal. The amplifier output supplies the leveling torque control field, which produces the torque to level the meridian gyro.

Slave Gyro Control System

The slave gyro control system (fig. 4-26, view B) consists of the slave gyro gravity reference, leveling control, and slaving control systems, and the slave gyro constant torque compensation.

SLAVE GYRO GRAVITY REFERENCE SYSTEM.— The slave gyro gravity reference system is similar to the meridian gyro gravity reference system. It consists of a gravity reference, a mixer and its network and the east-west acceleration computer. The output of the system is the slave gyro compensated tilt signal, which is fed to the slave gyro leveling control system, and the slave gyro constant torque compensation system.

SLAVE GYRO LEVELING CONTROL SYSTEM.— The slave gyro leveling control system consists of a mixer, a leveling torque amplifier, and a leveling torque. The input signals to the mixer are the compensated tilt signal from the slave gyro gravity reference system, and the horizontal earth rate, the east-west speed, and the constant torque compensation signals. The leveling torque, amplifier and leveling torque arc duplicates of those used in the meridian gyro leveling control system. The output of the leveling torque amplifier is sent to the leveling torque control field.

SLAVE GYRO SLAVING CONTROL SYSTEM.— The slaving control system detects any misalignment between the azimuth phantom and the slave gyro, and slaves the gyro to its proper east-west position. The system consists of the slaving pickoff, the slaving signal amplifier, the slaving torque amplifier (STA), and two slaving torquers. The slaving pickoff is an E-core transformer mounted on the vertical ring. The armature of the pickoff is cemented to the gyrosphere. Thus, a misalignment signal between the azimuth phantom and the slave gyro is obtained from the pickoff in the same manner as described in the Mk 23 system. This signal is fed into the slaving signal amplifier. The output of the slaving signal amplifier is the slaving signal, and it is fed to the slaving torque amplifier. The output of the slaving torque amplifier is the slaving control signal, and it is fed to the slaving torque control fields.

The slaving torquers are duplicates of the azimuth torquers and operate in the same manner. They produce the torque about the slave gyro horizontal axis, which causes precession about the vertical axis to align the slave gyro with the azimuth phantom.

Compensation Signals

There are nine compensation signals in the Mk 19 Mod 3A gyrocompass system. These signals serve to counteract or compensate for certain effects that would otherwise produce azimuth or leveling errors in the master compass.

These effects may be classified as ship, earth, and constant torque effects. The ship effects include speed, course, and acceleration changes. The earth effects are from horizontal and vertical earth rate. Constant torque effects are caused by a mechanical unbalance of the master compass, or any other mechanical defects that would cause the compass to settle with a tilt.

Northerly or southerly ship speed produces a gyrocompass error due to gyro tilt as the ship follows the curvature of the earth. The rate of this gyro tilt is proportional to the product of ship's speed (S), and the cosine of own ship's course (C) and a constant of 0.0166. Easterly speed, however, produces an error equal to the product of ship's speed (S), and the sine of own ship's course (C). Easterly or westerly speed does not cause the meridian gyro to tilt; however, as the slave gyro is aligned east-west it is affected by easterly or westerly speed in the same manner as northerly or southerly speed affects the meridian gyro. Therefore, speed (any direction) causes tilt of one or both gyro elements. Tilt of the meridian gyro causes precession away from the meridian, causing azimuth, roll, and pitch errors. The tilt of the slave gyro causes only errors in roll and pitch. The slave gyro tilt signal is not applied to the azimuth servoloop. The slave gyro vertical ring is positioned by the azimuth servo follow-up motor. The slave gyro is made to follow the vertical ring by the slaving control system.

The Mk 19 compass is compensated for speed errors by applying a compensation signal (north-south speed and drift) to the meridian gyro leveling control system, and a signal (east-west speed) to the slave gyro leveling control system. (See fig. 4-27.) Thus, both gyros are maintained in a level position for any speed or course. These signals arc obtained from the own ship's speed repeater and speed component computer (shown in fig. 4-27).

The ship's heading may differ from the true course due to an error caused by the north-south drift of the ship. The north-south speed signal is compensated for drift by a manual corrector located on the front of the control cabinet. This drift setting is made by the compass operator after obtaining the necessary information from the ship's navigator.

Changes in the ship's speed will cause compass errors if not compensated. A tilt signal to compensate for errors from acceleration is produced by the electrolytic bubble level. When the ship accelerates in speed, the inertia will displace the electrolyte in the electrolytic bubble level. Deceleration will cause a displacement in the opposite direction. As a result, tilt signals will be produced even though there is no gyro tilt.

Acceleration compensation is obtained for the meridian gyro by the north-south acceleration computer and for the slave gyro by the east-west acceleration computer.

The east-west acceleration computer operates in the same manner as the north-south acceleration computer. Its input is east-west speed from the speed component computer, and its output is the east-west acceleration compensation signal to the slave gyro gravity reference system.

The effect of vertical earth rate on the meridian gyro is proportional to the product of earth rate at the equator and the sine of the ship's latitude. The effect of horizontal earth rate on the slave gyro is proportional to the product of the earth rate at the equator and the cosine of the ship's latitude. As the effect of vertical earth rate is caused by the speed of the earth's rotation about its north-south axis, a ship traveling in an easterly or westerly direction will either add to or subtract from the earth's rotation. This apparent change in the speed of the earth's rotation will, in effect, produce a comparable change in vertical earth rate. This change, which is the meridian gyro east-west speed error, is proportional to the product of the ship's east-west speed and the tangent of the ship's latitude.

To compensate for these effects on the meridian gyro, we need a compensating signal voltage proportional to the product of earth rate, at the equator and the sine of the ship's latitude, and a compensating signal voltage proportional to the product of east-west speed and the tangent of the ship's latitude.

To compensate the slave gyro for the effect of horizontal earth rate, we need a compensating signal voltage propottional to the product of earth rate and the cosine of the ship's latitude. These compensating signals are obtained from the latitude and tangent latitude computers (fig. 4-27).

If the sensitive elements were perfectly balanced, and there were no other factors that would cause a constant torque on either of the two gyros, the tilt signals from the electrolytic bubble level, over a period of time, would average out to zero. This is true because the gyro controls are designed to keep the gyro axles level at all times. As it is not possible to keep the gyros perfectly balanced at all times because of wear, a constant torque compensation system is provided for both the meridian and slave gyros.

If the magnitudes and durations of accelerations are excessive, during high-speed turns and maneuvers for example, it is desirable to cut out the tilt signal to the integrator. This is accomplished by the north-south

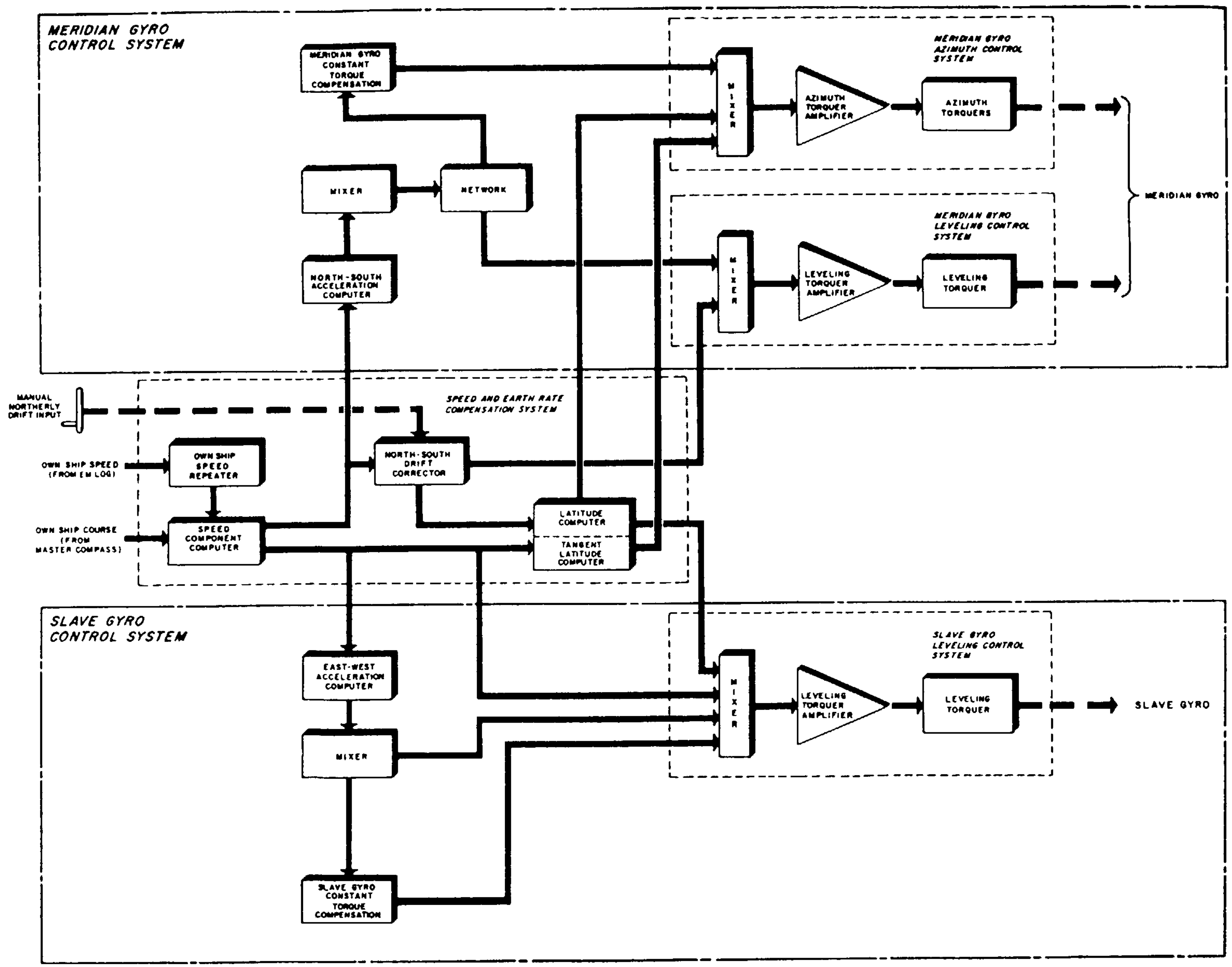


Figure 4-27.—Block diagram of compensation signals.

acceleration signal being fed to the meridian control integrator cutout, which operates a relay, cutting out the tilt signal during excessive accelerations.

For the tilt signal outputs from the electrolytic bubble level to average out to zero, the compass must be in perfect balance, and all compensating signals computed exactly. The constant torque compensation system will then compensate, within limits for errors in computation of other compensating signals.

The constant torque compensation system for the slave gyro is identical to the meridian gyro system.

Operation of Compensation Circuits

The own ship's speed repeater operates on 60-Hz data obtained from the ship's underwater log transmitter. The output of the repeater, however, is 400-Hz data. The repeater contains a 60-Hz servomotor (B1), a 60-Hz synchro control transformer (B2), a 400-Hz linear synchro and dial (B3), and a type 2 computer amplifier (A1). (See figs. 4-27 and 4-28.)

The linear synchro is an induction device like other synchros, but differs from other types in that it has one input rotor winding and one center-tapped output stator winding that produces an output voltage that is a linear function of its rotor position. The rotor winding is excited from the 400-Hz supply. When the rotor is in such a position that the axes of the two windings are separated by 90 electrical degrees, no voltage is induced in the output stator winding. If the rotor is displaced in one direction from this zero voltage position, a voltage is induced in the output winding that is proportional to the amount of rotor displacement. If the rotor is displaced in the opposite direction, a voltage of opposite phase is induced in the output winding that is also proportional to the amount of rotor displacement.

The 60-Hz servomotor is a 2-phase, 2-pole, induction motor, with a fixed field excited from the 60-Hz power line, and a control field connected to the type 2 computer amplifier output.

The input to the repeater is the own ship's speed from the underwater log to the control transformer (B2) (fig. 4-28). The output signal voltage from the control transformer, representing ship's speed, is fed to the input of the type 2 computer amplifier. The servomotor (B1) drives the control transformer rotor to its null position, and at the same time positions the linear synchro rotor (B3) to a position corresponding to the ship's speed. The linear synchro output, then, is a 400-Hz voltage proportional to own ship's speed. A dial is attached to the shaft of the linear synchro to provide a visual indication of own ship's speed.

The own ship's speed signal is applied to the input stage of a type 1 computer amplifier in the speed component computer. The speed computer (fig. 4-28) contains two type 1 computer amplifiers, a speed resolver and dial (B4), a synchro control transformer (B5), and a motor tachometer (B6).

The motor-tachometer (B6) is a 400-Hz servomotor tachometer generator built into the same housing. The motor is a 2-phase, 4-pole, induction motor with a fixed field and a control field. The tachometer generator section consists of a 2-phase, 2-pole stator and a copper shell rotor. One stator field (F1) is excited from the 115-volt, 400-Hz supply. The other stator field (F2) is not excited as long as the rotor is stationary (the axes of the two stator windings are 90° apart). When the shaft of the rotor is turned, a voltage is induced in the rotor and rotor current flow is proportional to rotor speed. This rotor current produces a magnetomotive force proportional to rotor current. This magnetomotive force is combined with the magnetomotive force of the reference winding to produce a resultant field, the axis of which is displaced in the direction of rotation of the rotor cup. The angle between the resultant field axis and the axis of the output winding varies with the speed. Hence, the coupling between the two stator windings varies with speed. Thus, the output voltage varies with the speed. Its frequency is 400 Hz, the same as that of the reference field, and the phase of the output voltage is dependent upon the direction of rotation of the rotor cup.

The own ship's speed signal is amplified and fed to the rotor winding of the speed resolver (B4). Heading data from the master compass is applied to the input of the control transformer (B5), and the output of the control transformer (B5) in series with a damping voltage obtained from the generator section of the motor-tachometer (B6) is fed to the input of the second type 1 computer amplifier. The damping signal voltage from the motor-tachometer is used to stabilize the computer servoloop and to introduce a small time lag in the computer. his time lag is required since the direction of motion of the ship's center of gravity differs from the ship's heading for a short interval after starting a course change. In other words, when rudder is first applied to turn the ship, the ship slides sidewise to some extent so that the original course is maintained for a short interval even though the ship's heading has changed.

The output of the second type 1 computer amplifier excites the control field of the motor section of the motor-tachometer (B6), which drives the tachometer

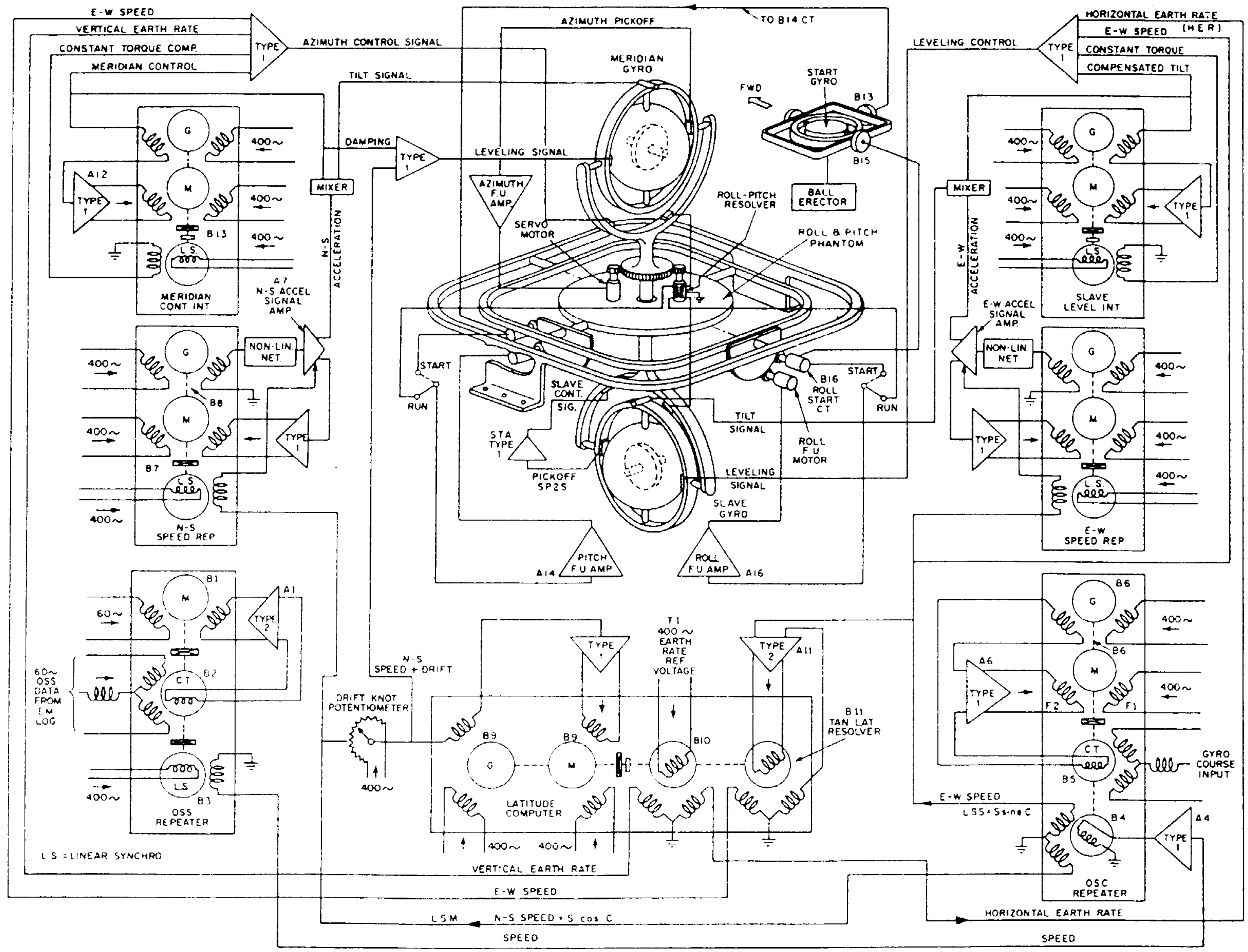


Figure 4-28.—Simplified schematic diagram of a complete compass control system.

generator section, furnishing the damping signal voltage, and at the same time the control transformer rotor of the resolver (B4) is positioned relative to the ship's heading. The resolver (B4) functions to resolve own ship's speed and course inputs into S cos C or north-south speed and S sin C or east-west speed. These are the speed compensation signals needed. A dial is coupled to the shaft of the resolver (B4), indicating own ship's course.

The north-south acceleration computer (fig. 4-28) contains a north-south speed repeater consisting of a linear synchro and dial (B7) and a motor-tachometer (B8). The computer also includes a limiting or nonlinear network, a north-south acceleration signal amplifier, and a type 1 computer amplifier.

The north-south speed signal voltage is fed to the stator of the linear synchro (B7) in series opposition with the stator voltage induced by the synchro rotor, The difference between these two voltages is applied in series with the north-south acceleration signal amplifier output to the input of the type 1 computer amplifier. The output of the type 1 computer amplifier drives the motor section of the motor-tachometer (B8) at a speed proportional to the rate of change of the ship's north-south speed, and positions the rotor of the linear synchro (B7) until the stator voltage due to rotor position equals the north-south speed signal voltage. A voltage proportional to the rate of change of the ship's north-south speed is obtained from the generator section of motor tachometer (B8) and applied through a limiting network to the input of the north-south acceleration signal amplifier, whose output is the north-south acceleration compensation signal to the meridian gyro gravity reference system, When the elcctrolytic bubble is displaced due to accelerations, it starts to return rapidly at first to its neutral position, then slows down. This is due to the viscosity of the electrolyte and the design of the level. By connecting the acceleration signal in series with the linear synchro before applying the voltage to the motor, of the motor-tachometer, the motor speed is made to vary nonlinearly. This nonlinear speed is designed to be proportional to the output of the electrolytic bubble level. In addition, the output signal voltage from the electrolytic bubble level is proportional to the displacement of the bubble over a limited range, beyond which it saturates. If the accelerations are of sufficient magnitude, the electrolytic bubble level will saturate. This factor is also compensated for by applying the output of the tachometer generator to a limiting network of rectifiers. The output of this network is amplified and used as the tachometer feedback voltage to the input of the type 1 computer amplifier.

A dial is attached to the shaft of the linear synchro (B7), indicating the north-south component of own ship's speed.

The latitude computer, which produces the horizontal and vertical earth rate compensation signals, consists of a type 1 computer amplifier, a motor-tachometer (B9), a resolver (B10), and an earth rate reference transformer (T1).

The tangent latitude computer, which produces the meridian gyro east- west compensation signal, consists of a type 2 computer amplifier and a resolver (B11). A dial attached to the shaft of the resolver (B11) indicates the ship's latitude.

The input to the latitude computer is the north-south speed plus drift signal, and the inputs to the tangent latitude computer are the east-west speed signal, and the initial, manual, ship's latitude setting. The latitude is set by the compass operator at the start of a voyage, and thereafter the latitude computer keeps the latitude up to date, automatically, wherever the ship may go.

The north-south speed plus drift signal is fed, in series opposing, with the output of the generator section of the motor tachometer (B9), which produces a damping voltage for stabilization of the servoloop, to the input of the type 1 computer amplifier. The type 1 computer amplifier output drives the motor section of the motor-tachometer (B9) at a speed corresponding to north-south speed plus drift. The motor shaft is geared down (240 million to 1) to position the rotor of the resolver (B10) so that it follows the changing ship's latitude. At any time, the position of the rotor of the resolver (B10) corresponds to the latitude position of the ship. With a reference voltage, representing earth rate, from the transformer (T1) impressed on the rotor of the resolver (B10), and the rotor set at the ship's latitude, the resolver (B10) functions to resolve its earth rate referencc voltage and latitude inputs into an output proportional to earth rate times the cosine of the latitude, or horizontal earth rate and earth rate times the sine of the local latitude or vertical earth rate.

The amplified east-west speed signal from the type 2 computer amplifier is fed to the rotor of the resolver (B11). With this voltage proportional to east-west speed on its rotor, and the rotor positioned to the ship's latitude, the outputs of the two resolver stator windings are proportional to cast-west speed times the sine and cosine of the ship's latitude. The output of the cosine stator winding representing the cosine of east-west speed and latitude, however, is fed back, inversely, to the input of the type 2 computer amplifier so that the resultant output of the amplifier represents the product of east-west

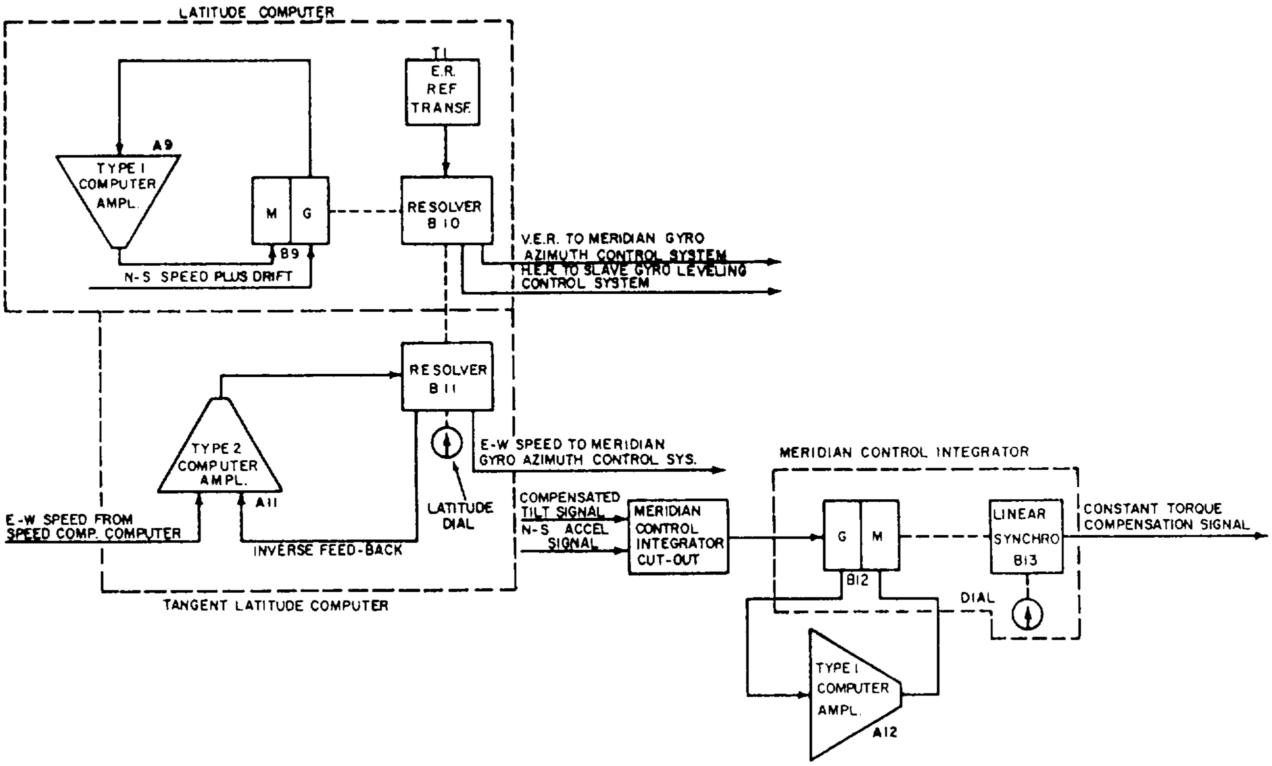


Figure 4-29.—Earth rate and constant torque compensation signals.

speed and the reciprocal of the cosine of the latitude. This output signal on the rotor of the resolver is multiplied by the sine of the ship's latitude in the sine stator winding, being proportional to the product of east-west speed and the tangent of the ship's latitude; the signal is the meridian gyro east-west speed compensation signal.

The meridian gyro constant torque compensation system (fig. 4-29) consists of a type 1 amplifier, an integrator cutout, and a meridian control integrator. The meridian control integrator includes a motor-tachometer (B12) and a linear synchro (B13). The dial provides visual indication of integrator operation.

The meridian gyro compensated tilt signal is fed through a relay in the integrator cutout, in series with the damping voltage output of the generator section of the motor-tachometer (B13) to the input of the type 1 computer amplifier.

The amplifier output drives the motor section of the motor-tachometer (B12), which is geared down (3 million to 1) to the linear synchro. Because of this high gear reduction, it takes a great number of motor revolutions over a period of time to appreciable y rot ate the rotor of the linear synchro (B 13). The linear synchro, therefore, for all practical purposes, does not respond to short-time signals, but responds to long-time signals or the sum of fluctuating and short-time signals. If the average signal from the electrolytic bubble level is not zero, and persists for a long period of time, such as mechanical unbalance of the compass would cause, the rotor of the linear synchro (B 13) will turn gradually at a constant rate. The output voltage, being of opposite phase to the

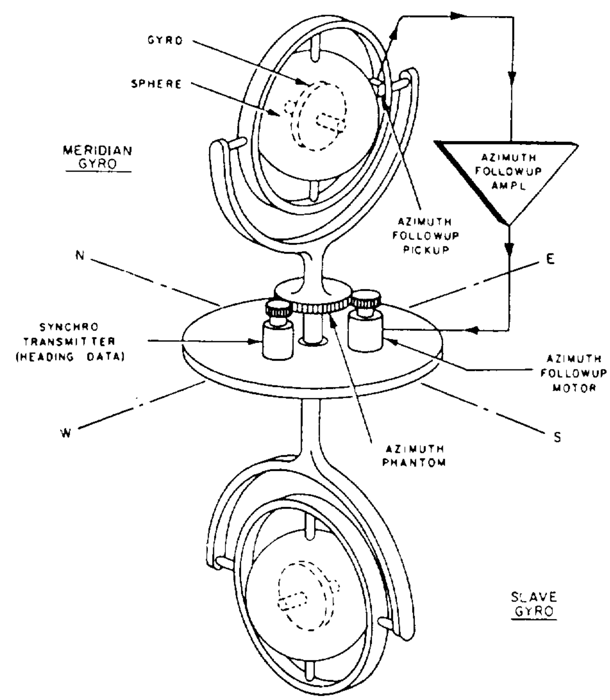


Figure 4-30.—Simplified diagram of the azimuth follow-up system.

tilt signal input, will tend to reduce the input slowly until the voltage output of the linear synchro exactly equals the tilt signal input caused by the unbalance.

The time constant, or rate of change, of the linear synchro output voltage for a given tilt signal is made slow enough so as not to affect the normal settling characteristics of the compass, and yet fast enough to compensate for any constant torque without appreciable delay.

Azimuth Follow-up System

The azimuth follow-up system (fig. 4-30) detects any misalignment between the vertical ring and the gyrosphere and functions to drive the azimuth phantom, and therefore the vertical ring, back into alignment with the gyrosphere.

An azimuth pickoff, consisting of an E-shaped core transformer mounted on the vertical ring and an armature cemented to the gyrosphere, furnishes the misalignment signal to the follow-up amplifier in the conventional manner. The follow-up motor, driven by the azimuth follow-up amplifier output, drives the azimuth phantom, restoring the azimuth pickoff to its neutral position and positioning, through gearing, the 1- and 36-speed heading data synchro transmitters. The follow-up motor also positions the rotor of the roll-pitch resolver (not shown in fig. 4-30) to a position corresponding to ship's heading.

The azimuth follow-up amplifier consists of a preamplifier stage, a demodulator stage with displacement and rate signal networks, and a magnetic amplifier output stage. Associated with the amplifier are two alarm circuits, which actuate the compass alarm in case of excessive pickoff signal or preamplifier tube failure.

Roll and Pitch Follow-up System

The roll and pitch follow-up system (fig. 4-31) detects and eliminates any misalignment between the

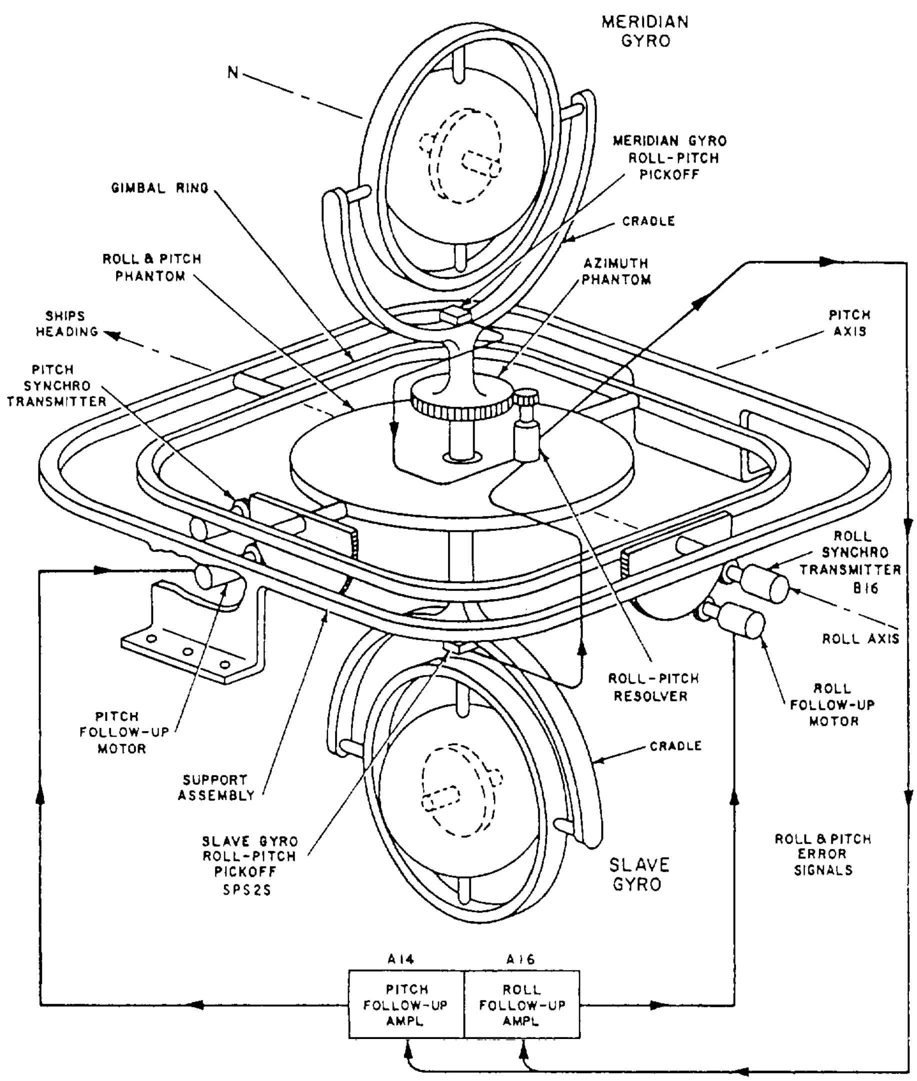


Figure 4-31.—Simplified diagram of the roll and pitch follow-up system.

roll-pitch phantom and the level position maintained by the two gyros. It also positions the roll and pitch synchro data transmitters. The system consists of two E-core pickoffs, two follow-up amplifiers, and two follow-up motors, all duplicates of the corresponding components in the azimuth follow-up system. In addition, the system includes a roll-pitch resolver.

The meridian gyro roll-pitch pickoff is mounted on the meridian gyro cradle and detects any misalignment between the cradle and the meridian gyro's vertical ring. This misalignment is about the meridian gyro's east-west horizontal axis. The roll-pitch phantom, being physically linked to the azimuth phantom, will be identically misaligned with the vertical rings of both gyros.

The slave gyro roll-pitch pickoff is mounted on the slave gyro cradle and detects any misalignment between the cradle and the slave gyro's vertical ring. This misalignment is about the slave gyro's north-south horizontal axis. Thus, any misalignment between the roll-pitch phantom and the vertical ring of either gyro produces a roll-pitch pickoff signal.

A pitch follow-up motor is mounted on the gimbal ring and meshed with the pitch gear on the roll-pitch phantom. It positions the roll-pitch phantom about the pitch axis. A roll follow-up motor is mounted on the support assembly and meshed with the roll gear on the gimbal ring. It positions the roll-pitch phantom about the roll axis, through the gimbal ring.

On a north-south course, the pickoff signal from the meridian gyro roll-pitch pickoff, if fed through the pitch follow-up amplifier to the pitch follow-up motor, would compensate for the effect of pitch. Similarly, if the pickoff signal from the slave gyro roll-pitch pickoff were fed through the roll follow-up amplifier to the roll follow-up motor, it would compensate for the effect of roll.

On an east-west course, however, the meridian gyro roll-pitch pickoff would have to be fed to the roll follow-up amplifier and motor, to compensate for roll, and the slave gyro roll-pitch pickoff would have to be fed to the pitch follow-up amplifier and motor, to compensate for pitch. It follows, therefore, that on any intermediate course, the roll-pitch motions of the ship will have components acting about both north-south and east-west axes, and both roll -pitch pickoffs will react to both roll and pitch. As a result, the two pickoff signals must be divided into proper proportions to each follow-up amplifier and motor to maintain the horizontal stability of the roll-pitch phantom. The own ship's course determines these proper proportions, and they are obtained from the roll-pitch resolver.

The roll-pitch resolver has its rotor positioned corresponding to own ship's course by the azimuth

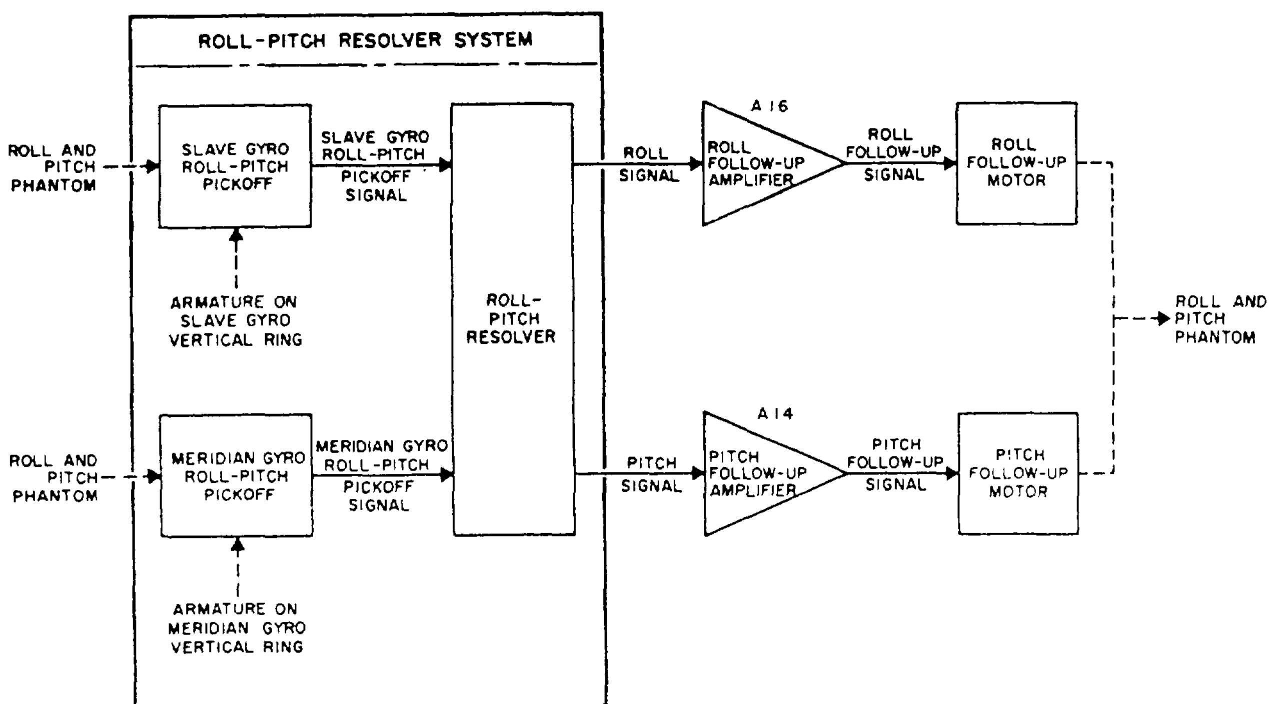


Figure 4-32.—Block diagram of the roll and pitch follow-up system.

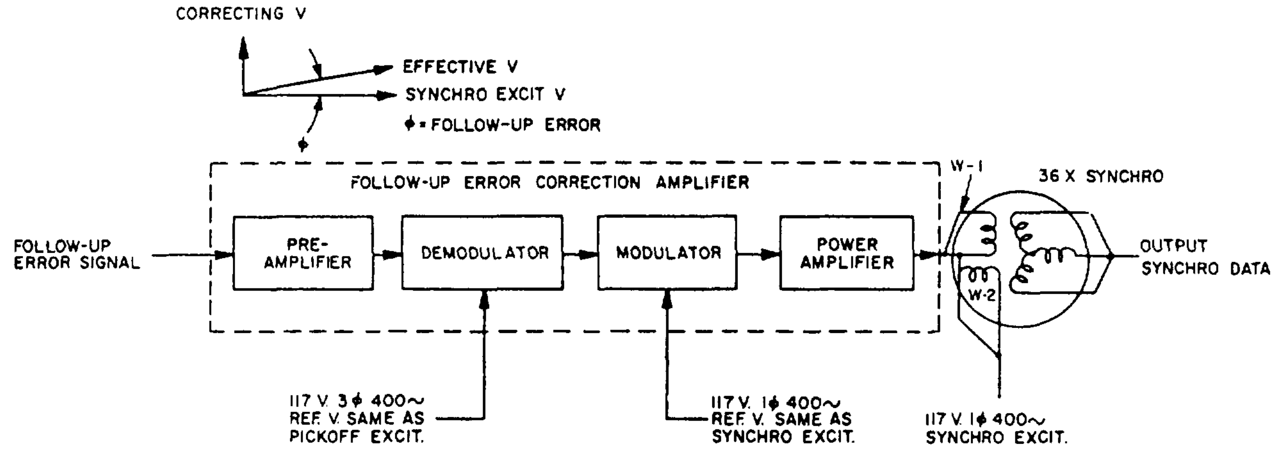


Figure 4-33.—Block diagram of the data correction system.

follow-up system, as mentioned previously. The meridian gyro roll-pitch pickoff signal is fed to one resolver rotor winding, and the slave gyro roll-pitch pickoff signal is fed to the other rotor winding. The resolver functions to resolve its own ship's course and roll-pitch pickoff input signals into output signals of proper proportions to the follow-up amplifiers. The follow-up motors position the roll-pitch phantom until the pickoffs are restored to their neutral position and, at the same time, position 2- and 36-speed roll and pitch synchro data transmitters. Figure 4-32 shows a block diagram of the roll-pitch follow-up sequence.

Due to backlash, spring in gearing, and other effects, follow-up motors may have errors up to 0.05°. These errors are compensated for in the Mk 19 gyrocompass by a data correction system (shown only in fig. 4-33). Three special type synchro transmitters are used with three transistor data correction amplifiers in transmitting the 36-speed heading, roll, and pitch data. Each 36-speed synchro transmitter has an additional rotor winding displaced 90 electrical degrees from the normal rotor winding. When this additional, or quadrature, rotor winding (W1) is excited by a variable voltage, the magnetic field produced reacts with the magnetic field of the normal rotor winding (W2), and thus produces a resultant rotor field that is displaced from the normal rotor winding field. The angle of this displacement is proportional to the magnitude and phase of the voltage applied to the additional rotor winding.

The three transistor data correction amplifiers are sealed and mounted in the bottom of the master compass. The input signals to the amplifier area portion of the azimuth follow-up signal, roll follow-up signal, and pitch follow-up signal. The signal is amplified and demodulated using the pickoff excitation voltage as a reference. The demodulator output (a dc voltage proportional to the pickoff signal) is modulated using the synchro excitation voltage as a reference (as shown in fig. 4-34). The output of the amplifier to the quadrature synchro rotor winding is a voltage proportional to the follow-up error; thus the transmitted data is corrected by an amount equal to the follow-up error. The transmitted data then indicates the true attitude of the gyros rather than the phantom ring assembly.

Alarm System

An alarm system is incorporated in the Mk 19 Mod 3A gyrocompass system to the extent that each loop in

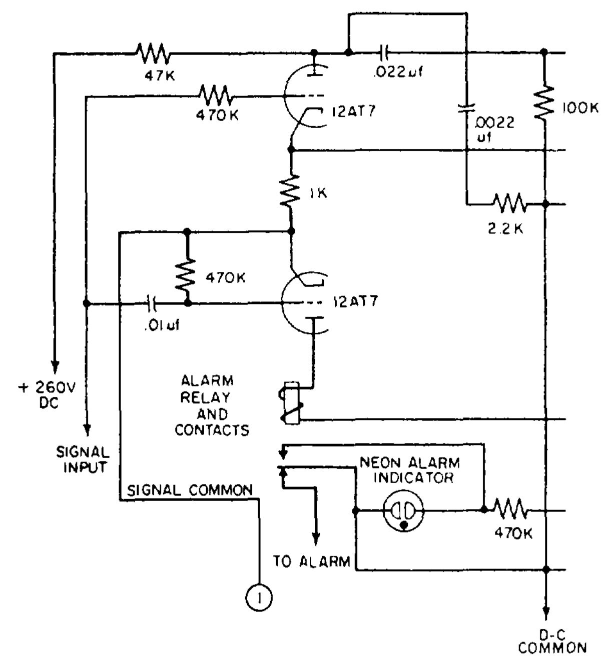


Figure 4-34.—Simplified schematic diagram of an amplifier alarm relay.

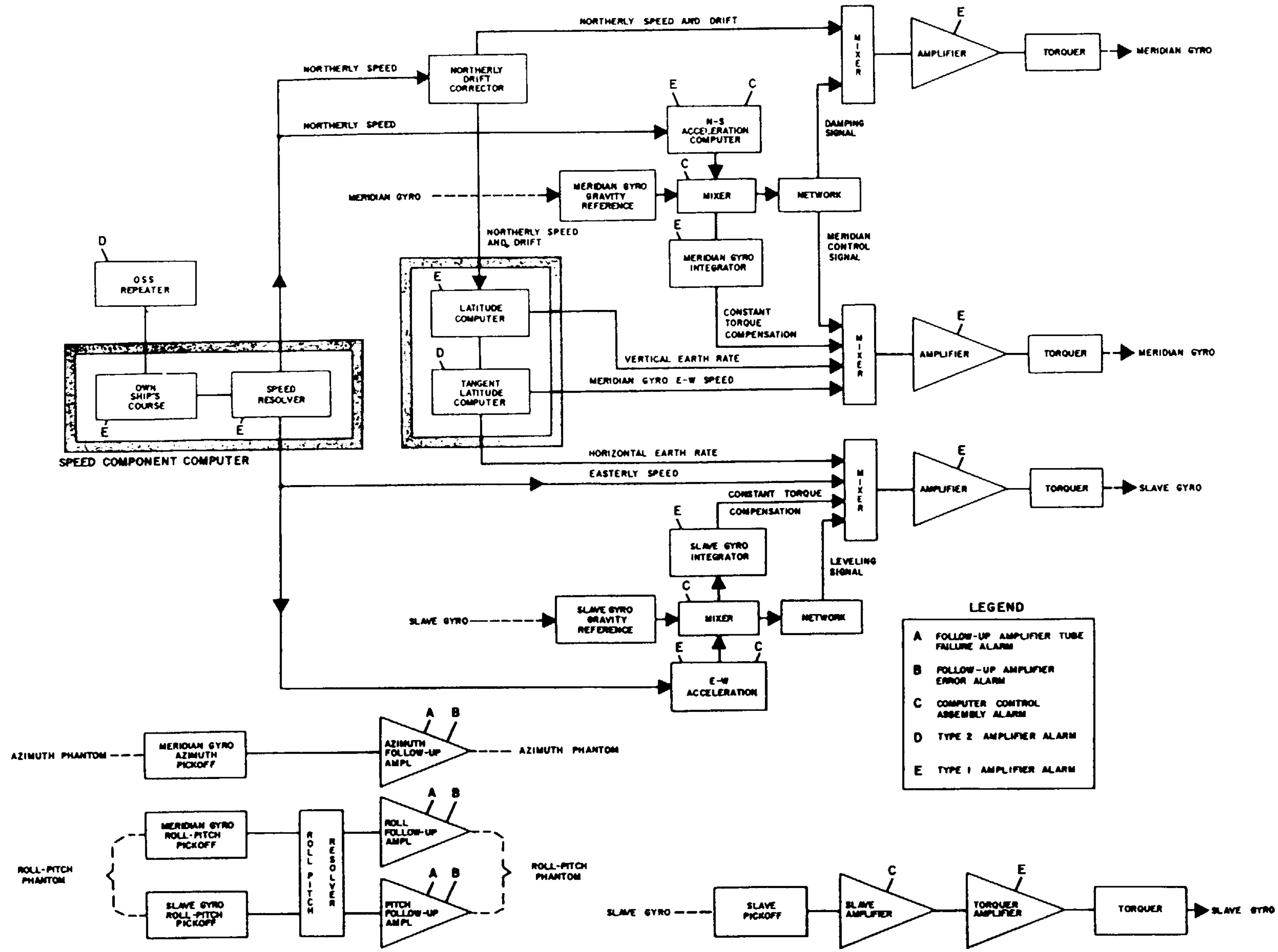


Figure 4-35.—Alarm points in compass control and follow-up circuits.

the system will give multiple alarm warnings when trouble develops in that loop. In addition, as trouble may also develop in the alarm circuits, the circuits are so arranged as to give alarm warnings when they themselves become defective. This is accomplished in each alarm circuit by using normal tube current to energize an alarm relay. (See fig. 4-34). Therefore, if trouble develops within that circuit to reduce tube current, the relay will de-energize and actuate the alarm.

Figure 4-35 shows in block form the points at which each loop in the system is alarmed. This figure does not show every alarm that will give warning, but merely the place in the loop where the initial alarm will occur. The complete alarm system may be divided into four separate systems: the follow-up alarm system, the compass control alarm system, the ship's 400-Hz supply alarm system, and the voltage regulator alarm system.

The follow-up alarm system consists of two alarm circuits in each follow-up amplifier. As the three follow-up amplifiers are identical, the alarms in each are identical. The alarm circuits are the preamplifier tube failure alarm and the follow-up error alarm. Two neon indicating lamps on each amplifier are provided to give a visual indication of the source of trouble when an alarm is actuated.

The compass control alarm system consists of nine computer loops and four torque loops. These 13 computer and torque loops have associated with them 11 type 1 and 2 type 2 computer amplifiers, with alarm circuits. Also, each of the compass control signals pass through the computer control assembly. An alarm circuit is employed that will actuate the compass alarm when any tube in the assembly becomes defective. A failure in any loop circuit will actuate the alarm and cause a neon indicating lamp to light on the associated computer amplifier, or amplifiers, and any tube failure in the computer control assembly will cause a similar indicating lamp to light on the computer control assembly panel.

The ship's 400-Hz supply alarm (not shown in fig. 4-35) is actuated in the event of failure of any phase of the ship's 3-phase, 400-Hz supply, or a drop supply voltage below 104 volts. Undervoltage detection circuits and associated relays in the system control assembly (fig. 4-24) actuate the alarm, disconnect the compass from the ship's supply line, and operate the standby supply as a generator. The ship's supply indicating light (green) on the control panel goes out and the standby supply light (red) comes on, showing that the ship's 400-cycle supply has failed and that the compass is operating on the standby supply.

The voltage regulator failure alarm gives a visual indication of a tube failure in the differential amplifier and for an out-of-tolerance input voltage. A voltage in excess of 122 volts or less than 108 volts will actuate the alarm.

Figure 4-36 shows a block diagram of the action of the complete alarm system. The flashing lamps in the compass failure annunciator are actuated by flasher units in the system control assembly (fig. 4-24).

Starting Control Systems

To aid in starting and operating the master compass, two auxiliary control systems are provided; the starting system and the fast-settling system.

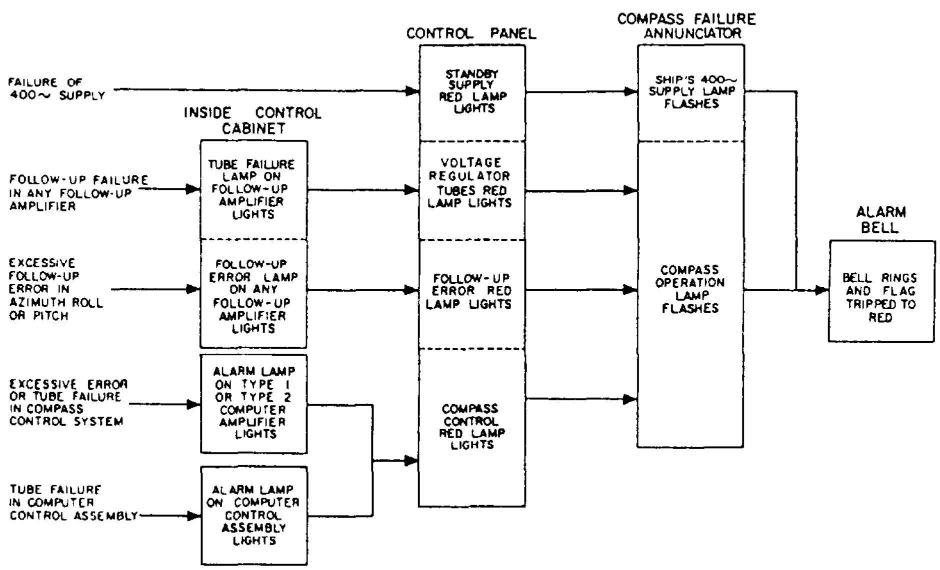


Figure 4-36.—Block diagram of the complete alarm system.

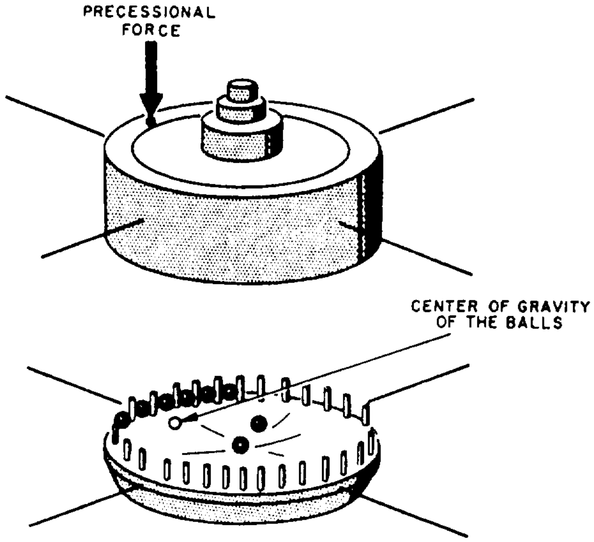


Figure 4-37.—Ball erector diagram.

The starting system functions to level the gyros and bring the meridian gyro to the meridian in as short a time as possible. The starting sequence is accomplished with a minimum number of manual operations by the compass operator. The system includes a fast erect system, a system control assembly, and part of the control panel.

When the compass is to be started, the roll-pitch phantom will be off its level position. A fast-erect system is employed, which greatly reduces the time required to bring the roll-pitch phantom (and therefore the gyros, as they are caged to their vertical rings and the azimuth phantom during starting) to a level position. This system uses a small stabilizer or start gyro mounted in its own gimbal, which, when started, comes very quickly to a vertical position, providing a fairly accurate level reference for the roll-pitch phantom.

The stabilizer gyro rotor is the squirrel cage portion of a 3-phase, 115-volt, 400-Hz induction motor, and spins within the stator at 22,500 rpm in ball bearings that are in the top and bottom of the gyro case. A ball erector mechanism (fig. 4-37) is employed for maintaining the gyro spin axis vertical. This mechanism consists of a flat cylindrical enclosure suspended from the gyro case by means of a ring that also serves as a bearing surface. It is geared to the rotor shaft and rotates at 22 rpm about an axis parallel to the gyro spin axis. When the gyro is vertical, eight small balls are massed in the center of the concave surface of a disk in the bottom cover. Eighteen holder pins are equally spaced near the edge of the concave disk. When the gyro tilts, the balls roll to the lower side of the disk, where they are held loosely by the holder pins and carried ahead, in the direction of rotation, toward the higher side. As each ball reaches a point where it can drop past the holder pin, it falls across the disk and resumes its cycle. The center of gravity of the balls, so displaced, is at a point 90° from the low point, in the direction of rotation. Thus, a torque is created that precesses the gyro in a clockwise direction viewed from above. The ball holder rotates in the same direction and is easily observed because of its slow speed.

Flat roll and pitch synchro transmitters are mounted on the stabilizer gyro (fig. 4-38). The output from the

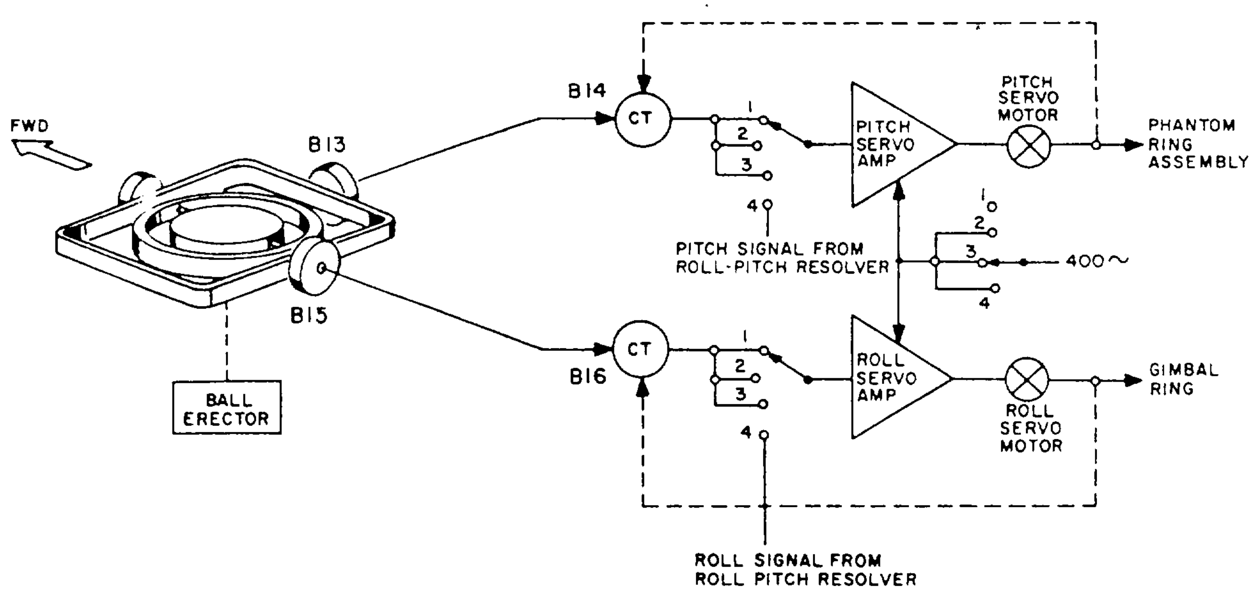


Figure 4-38.—Fast-erect system.

pitch transmitter is fed to a control transformer (B 14) mounted on the master compass and meshed with the pitch gear. The output signal from the control transformer (B14) represents the amount of pitch error in the roll-pitch phantom. This error signal is fed through the pitch follow-up or servoamplifier to the pitch follow-up motor, which positions the roll-pitch phantom until pitch error has been removed.

The output from the roll transmitter is fed to a second control transformer (B16), mounted on the compass frame and meshed with the roll gear. The roll follow-up motor positions the gimbal ring until roll error has been removed.

The roll-pitch signals from the control transformers (B14 and B16) are fed through the first three positions of a stepping relay, to the follow-up amplifiers. The stepping relay automatically disconnects these roll-pitch signals and connects the roll-pitch output signals from the roll-pitch resolver to the proper follow-up amplifier when the main gyros have attained sufficient gyroscopic rigidity to take over the stabilization of the roll-pitch phantom.

The stepping relay is an 11-deck, 5-position, electro-magnet-operated unit located in the system control assembly (fig. 4-24). This relay, with other time delay relays, serves to connect the various components automatically at the proper time during the starting sequence. Many operations are involved in starting the compass, and the steps must be performed in the proper sequence and at the proper time to bring the compass to a usable condition in an optimum amount of time.

STARTING SYSTEM.— The Mk 19 starting system is made as nearly automatic as possible. The only manual operations required of the compass operator are the master switch, the manual azimuth switch, the fast settle switch, and the run button, located on the compass control panel (fig. 4-22). The manual azimuth switch operates controls for slewing the compass in azimuth that are very similar to those described in the Mk 23 system.

To start the compass at latitudes below 75°, you should perform the following steps:

1. Turn the mode selector switch (fig. 4-22) to the FASTSETTLE mode.

2. Turn the master switch (fig. 4-22) to the FIL' S position, and wait about 30 seconds to allow the tube filaments to heat.

3. Turn the master switch to the ON position. The green ship's supply 400-Hz power green lamp should light at this time to indicate that power is available. The voltage regulator green lamp should also be lighted. The compass control and follow-up alarm lamps on the panel will be lighted either red or green. Now, wait for the blue ready lamp located on the control panel to light (approximately 11 minutes) before proceeding to the next step. When the blue ready lamp comes on, this indicates that the gyrocompass rotors have reached their operating speed of 23,600 rpm and all circuits are warmed up and ready to be placed in the RUN mode.

4. When the blue ready lamp comes on, check the OWN SHIP COURSE dial (fig. 4-23) to see if the compass is aligned with the ship's heading. If the dial does not indicate the ship's heading, you need to slew the compass until the dial is aligned within a maximum of 10°. To slew the compass, turn the manual azimuth switch either CW (clockwise) or CCW (counterclockwise) and hold in this position until the dial indicates the ship's heading as closely as possible. The nearer the OWN SHIP COURSE dial is set to the ship's heading, the quicker the compass will settle.

5. Press the RUN button that is located directly under the blue ready lamp (fig. 4-22), this uncages the compass, and the compass will now begin to settle.

6. Check the IATITUDE COMPUTER dial (fig. 4-23). If the latitude setting is more than 1° off the local latitude, you must adjust the dial to the correct setting. A screwdriver adjustment for adjusting the latitude is located in a hole behind the latitude computer nameplate. To gain access to this adjustment, you need to remove one of the nameplate screws and rotate the nameplate away from the hole.

7. At the end of 2 hours, the compass should be completely settled and transmitting the changes in the ship's actual position with respect to the earth's surface. Now, turn the mode selector switch (fig. 4-22) to the NORMAL mode. All alarm lamps should be lighted green, indicating that the compass is operating correctly. If any of the alarm lamps are lighted red at this time, notify the ship's gyrocompass technician.

FAST-SETTLING SYSTEM.— The fast-settling system's function is to reduce the compass period and increase the percent of damping during starting. This system reduces the time required for the gyros to assume a true level position and the meridian gyro to settle on the true meridian.

This system is actuated by placing the mode selector switch, located on the front of the compass control panel (fig. 4-22) to the FAST-SETTLE position. This switch completes the energizing circuit to the fast-settle relay, located in the computer control assembly.

When the fast-settle switch is closed, it energizes the 4-pole, double-throw, fast-settle relay. The operated fast-settle relay alters the resistance connections in the meridian gyro gravity reference system, which increases the damping signal output. It also allows the primary voltage of the meridian control step-up transformer to be taken directly from the cathode follower instead of from a potentiometer, thereby increasing the meridian control output signal. When operated, the relay's contacts short a potentiometer in the slave gyro gravity reference system, increasing the slave gyro leveling signal.

The fast-settle switch also disconnects the alarm circuit from the delay relay, rendering the compass failure alarms inoperative when the fast-settling system is in operation. A fast-settle lamp is lighted when the switch is closed, giving visual indication of fast-settle operation.

Operating the Mk 19 Mod 3A Gyrocompass

The Mk 19 Mod 3A gyro system maybe started by setting the fast-settle switch to either the OFF or the ON position. The settling time is much longer when the system is started in the OFF position. Therefore, it is recommended to always start it in the FAST-SETTLE position.

Because the alarm system is NOT in operation while it is in the FAST-SETTLE position, the switch should be reset to ON as soon as practical. The amount of time to settle is least when a ship is sailing at the equator and is greatest at the poles (90° latitude).

Two hours (120 minutes) is the normal period of oscillation at 40° latitude. With the fast-settle switch in the ON position, the period of oscillation is reduced to 50 minutes. These approximate periods are characteristic of all mods of the Mk 19 compass.

NORMAL OPERATION.— Normal operation of the Mk 19 Mod 3A compass is obtained after the fast-settle switch is moved to the OFF position, which is identified as the normal mode while the ship sails in latitudes (north or south) between the equator and 75°.

Auxiliary operating modes are described later for compass (chiefly submarine) uses between latitudes 75° and 90° near the poles. Operation in the normal mode is generally undesirable in these latitudes because horizontal earth rate (proportional to the cosine of the latitudes) results in the compass period becoming very high, causing slow settling and consequent poor azimuth accuracy.

EMERGENCY OPERATION.— If the ship's ac power line fails or drops below 105 volts, undervoltage relays open their normal contacts and switch to battery power that is applied to the dc generator so it serves as a motor. Speed of this dc temporary motor is controlled by a centrifugally operated speed regulating device. The ac section then operates as a synchronous generator (driven by the dc section) and, for a period of 15 minutes produces 0.75 kW, without excessive temperature rise.

When the ship's power line is restored above 112 volts ac, the relay automatically returns both units (motor and generator) to their normal functions. The dc section is then generating current and charging the storage batteries.

AUXILIARY OPERATING MODES.— The fast settle mode is auxiliary to the normal mode. It is used on all Mk 19 compass models for starting.

Two additional auxiliary modes are available on the Mod 3B, identified as high latitude mode and directional mode. Some converted Mod 3A gyros also have them. These two modes of operation will be explained later in this chapter when we discuss the starting procedures for the Mod 3B compass.

Securing the Gyrocompass

When your ship returns to port after an underway period, you must obtain permission before securing the compass. Permission to secure the compass is normally granted by the engineer officer.

To secure the gyrocompass, turn the master switch (fig. 4-22) to the OFF position. After the compass is secured, notify the engineer officer.

MK 19 MOD 3B GYROCOMPASS SYSTEM

The Mk 19 Mod 3B gyrocompass system is identical to the Mk 19 Mod 3A system with the exception of a few changes. The Mk 19 Mod 3B system uses a static standby power supply instead of a motor-generator standby supply. This standby power supply is considerably more reliable than the motor-generator type since the only moving parts are the three relays used in the sensing circuits.

Figure 4-39 is an open-door view of the 3B standby power supply. The unit supplies a highly reliable 3-phase, 400-Hz, 115-volt, line-to-line power from a 3-phase, 400-Hz, 115-volt or from a 120-volt dc source. For explanation, figure 4-40 is divided into two sections: a battery charger and an inverter. The battery charger will be discussed first.

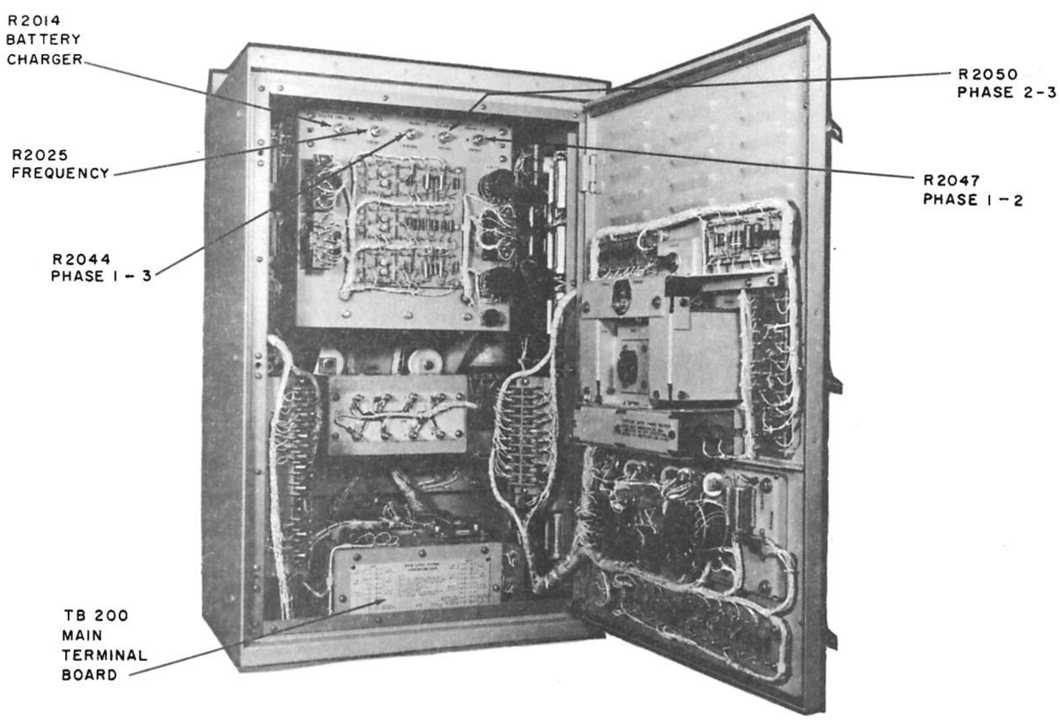
The input transformer is a delta-wye, 1 to 1 voltage ratio supplying approximately 110 volts ac line-to-line on the secondary and 64 volts ac line-to-neutral. The wye secondary is used to take advantage of the neutral.

The input transformer supplies a 3-phase, full-wave rectification circuit. The firing of the regulated rectifier is controlled with three silicon-controlled rectifiers. A dc filler is incorporated to smooth the output to the battery.

Two sensing circuits consisting of several resistors and a battery charging voltage potentiometer are also included in the charger. These components automatically sense charging current and voltage, and send a signal to the battery charging regulator.

The battery charging regulator receives its power from a second wye-wound secondary of the input transformer (a neutral is not used). The output of the transformer is rectified to 36 volts dc. In the battery-charging regulator, comparison is made between the sensing circuit output and the second transformer secondary output in the control windings of the reactor in the regulated rectifier. In this manner, the firing of the silicon-controlled rectifiers of the regulated rectifier are controlled. By controlling the tiring of the silicon-control rectifiers, the output of the regulated rectifier is controlled.

A relay is used to delay connection of the batteries to the charger until rated output is obtained.



40.125

Figure 4-39.—Standby power supply, door open.

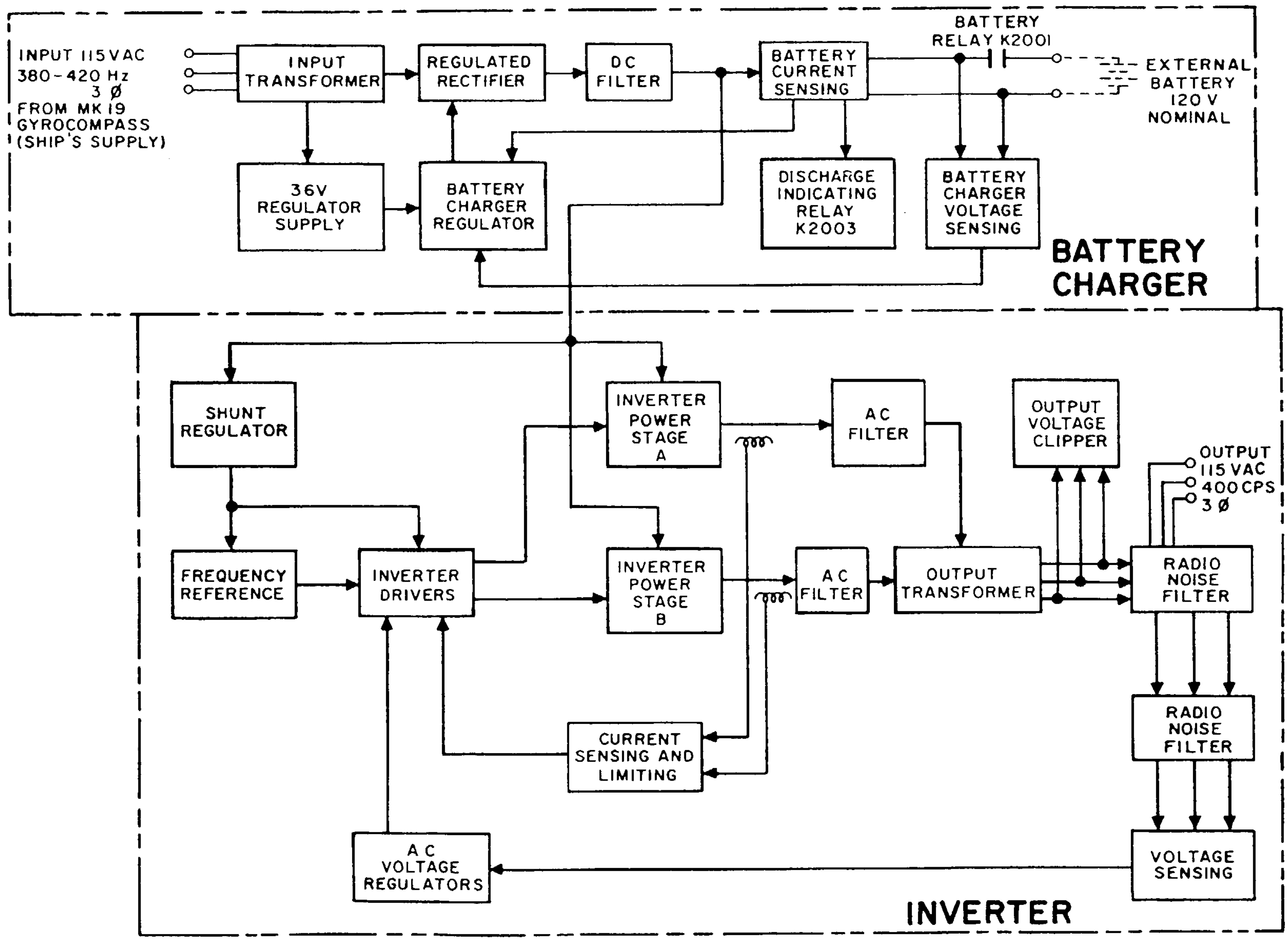


Figure 4-40.—Block diagram of standby power supply.

Working with the sensing circuit is a second relay. It operates to indicate when the batteries are being used as the supply.

In figure 4-40, the inverter portion depicts the components of the inverter that receive their power from the battery charger.

Input power to the shunt regulator is regulated to 6.8 volts, controlling a 36-volt output that is transmitted to the inverter drivers.

The frequency reference, containing its own separate power source, employs highly stable components to yield an 800-Hz output. In essence, it consists of a voltage regulator, a relaxation oscillator, and a pulse amplifier.

The 800-Hz output of the frequency reference circuit is used to control a master multivibrator (inverter). The action of the symmetrical multivibrator, while running at 400-Hz, is to control three slave multivibrators.

The four multivibrators are divided into two driver inverters (one master and one slave) and two power inverters (stage A and stage B). The yielded output is a 2-phase, approximately 86-volt, 400-Hz sine wave. Considerable filtering is employed, with both the amplitude and the phase being controlled. The 2-phase voltage is then sent to a Scott "T" transformer network from which it emerges as 3-phase, 115-volt, 400-Hz voltage to the output circuit.

Incorporated in the output circuitry is a radio noise filter and the primary of the voltage regulation control to the driver multi vibrators.

Further control is also exerted by a transformer in the power inverter output that reflects any overcurrent signal below the maximum capabilities of the individual multivibrators.

The large amount of energy stored in the output circuit filters requires a clipper circuit to be employed due to sudden quenching of voltage or removal of load.

There has also been some changes in components and circuitry to raise the ambient operating temperature of the system from 110°F to 149°F.

The Mk 19 Mod 3B system also has two additional modes of operation not found in the Mk 19 Mod 3A system. These two additional modes of operation, or auxiliary modes as they are called, are the high latitude mode and the directional gyro (DG) mode. These auxiliary modes of operation are used between latitudes 75° and 90° near the poles. In these latitudes, horizontal earth rate becomes very low and results in an excessive compass period and poor azimuth accuracy. In the high latitude mode of operation, damping is increased to a level just below the fast-settle mode of operation. The high latitude mode of operation is used between 75° and 86° latitudes and the directional gyro mode of operation is used when a ship is navigating above 86° latitude.

High latitude mode of compass operation should be used between 75° and 87° latitudes. Operation in normal mode is generally undesirable in these latitudes because horizontal earth rate (proportional to the cosine of latitude) becomes very low at high latitudes and results in an excessive compass period and poor azimuth accuracy. In this operation, a larger signal is applied to the gyro leveling torque amplifier and damping is increased to a level just below the fast-settle mode.

In the directional gyro mode, the compass takes on many of the characteristics of a free gyroscope.

It has been shown in previous sections how the degree of tilt of the meridian gyro controls azimuth accuracy of the Mk 19 Mod 3B gyrocompass equipment. (Tilt controls torque about the tilt axis that controls precession toward the meridian.) At very high latitudes the degree of tilt becomes very small because horizontal earth rate, which is proportional to the cosine of the latitude angle, becomes very small. The torque about the tilt axis that causes azimuth precession of the compass toward the meridian, therefore, is very small, resulting in weak azimuth control and consequently long periods and poor accuracy.

The torques required to correct the meridian gyro for east-west speeds are proportional to east-west speed in knots, multiplied by the tangent of the latitude angle. The tangent function is equal to zero at the equator (0°) and equal to infinity at the pole (90°). The torques required to correct for east-west speed at, or within 3° or 4° of, of pole approach infinity and are, therefore, impossibly high.

When Mk 19 Mod 3B gyrocompass equipment is operating in the directional gyro mode, it functions much the same as a simple gyroscope. The polar coordinate system used in the other three modes of operation cannot be used in the directional gyro mode because the compass, instead of pointing north, will point in a direction parallel to the meridian at point of entry into the directional gyro mode.

Table 4-1 shows the effect of the four modes of operation on vital compass parameters.

Starting the Mk 19 Mod 3B Gyrocompass

The procedure for starting the compass in the normal or fast-settle modes of operation is identical to that for the Mk 19 Mod 3A gyrocompass. The procedure for starting the compass in the high latitude and DC modes of operation will be discussed in the following paragraphs; refer to figures 4-22 and 4-23 while performing the steps.

HIGH LATITUDE MODE.— To start the compass when the ship is between 75° and 86° latitudes, perform the following steps:

1. Turn the mode selector switch to DC.

2. Turn the master switch to the FIL'S position, and wait about 30 seconds to allow the tube filaments to heat.

3. Turn the master switch to the ON position, and wait for the blue ready lamp to light (approximately 11 minutes) before proceeding to the next step.

4. When the blue ready lamp comes on, check the OWN SHIP COURSE dial to see if the compass is aligned with the ship's heading. If the dial does not indicate the ship's heading, you need to slew the compass until the dial is aligned within a maximum of 10°. The nearer the OWN SHIP COURSE dial is set to the ship's heading, the quicker the compass will settle to north when it is switched into the high latitude mode in step 7.

5. Press the RUN button.

6. Check the LATITUDE COMPUTER dial. If the latitude setting is more than 1° off the local latitude, you must adjust the dial to the correct setting.

7. At the end of 30 minutes, turn the mode selector switch to the HIGH LATITUDE mode. The compass will now settle to north in 2 hours or less, depending on how accurately the manual azimuth setting was made in step 4.

DIRECTIONAL GYRO MODE.— In the DC mode of operation, the compass functions much the same as a simple gyroscope. To start the compass when the ship is above 86° latitude, perform the following steps:

1. Turn (he mode selector switch to DG.

2. Turn the master switch to the FIL'S position, and wait about 30 seconds to allow the tube filaments to heat.

3. Turn the master switch to the ON position, and wait for the blue ready lamp to light (approximately 11 minutes) before proceeding to the next step.

4. When the blue ready lamp comes on, check the OWN SHIP COURSE dial to see if the compass is aligned with the ship's heading. If the dial does not indicate the ship's heading, you need to slew the compass until the dial is aligned within 1° or less, if possible.

5. Press the RUN button.

Changes In Operating Modes

When the gyrocompass is operating below 75° latitude and the ship is planning to navigate above 75° latitude, the mode of operation will have to be changed from the normal mode to the high latitude mode. If the ship plans to continue on and sail above 86°, the mode of operation will have to be changed from the high latitude mode to the DC mode. The procedure for changing operating modes will be discussed in the following parargraphs.

NORMAL MODE TO HIGH LATITUDE MODE.— To change from the normal mode of operation to the high latitude mode of operation, turn the mode selector switch to the high latitude mode at about 75° latitude.

HIGH LATITUDE MODE TO NORMAL MODE.— To change from the high latitude mode of operation to the normal mode of operation, turn the mode selector switch to the normal mode at about 75° latitude.

HIGH LATITUDE MODE TO DG MODE.— To change from the high latitude mode of operation to the DC mode of operation, turn the mode selector switch to the DC mode at about 86° latitude. Record the ship's longitude at the time the change is made. If the ship has been maneuvering, you should wait 2 hours after completion of the maneuvers before switching to the DC mode. This allows time for the transient error to settle out.

DG MODE TO HIGH LATITUDE MODE.— To change from the DC mode of operation to the high latitude mode of operation, the compass heading must be within 10° of true north; otherwise, the compass must be stopped and restarted.

Table 4-1.—Computer Loop Settings for the Four Modes of Operation

LOOP	NORMAL	FAST SETTLE	HIGH LATITUDE	DIRECTIONAL GYRO
Meridian Gyro Azimuth	Adjusted for 120-minute period at 40 degrees latitude	Increased to give approximately 50-minute period at 40 degrees latitude	Same as fast settle. This will cause 135-minute period at 80 degrees latitude	Tilt signal is completely removed. Torque for earth rate and constant torque compensation remains at value applied when switching to this mode of operation
Meridian Gyro Leveling	Adjusted for 65-percent damping with 120-minute period at 40 degrees latitude	Increased to give approxmiately 70-percent damping with 50-minute period at 40 degrees latitude	Adjusted to give about 85-percent damping with 135-minute period at 80 degrees latitude	Increased to maximum to keep gyro as level as possible
Slave Gyro Leveling	Set for good damping without excessive disturbance due to ship's motion	Increased to speed settling	Increased to speed settling	Increased to maximum to keep gyro as level as possible
Meridian Gyro East-West Speed Signal	Proportional to east-west speed times tangent of latitude	Same as normal	Same as normal	Signal removed to prevent gyro from changing direction with east-west speed
Meridian Control Integrator	Drives at speed proportional to tilt signal	Stopped to speed setting	Same as normal	Stopped any change of output will cause apparent change of drift rate
Latitude Computer	Continuously computes latitude by driving at speed proportional to ship's north-south speed	Same as normal	Same as normal	Stopped since Meridian Gyro is not necessarily on meridian, computer north-south speed is not necessarily correct and latitude computation would be incorrect

To change from the DG mode of operation to the high latitude mode of operation when the heading is within 10° true north, turn the mode selector switch to the high latitude mode at about 87° latitude.

To change from the DG mode of operation to the high latitude mode of operation when the heading is more than 10° from true north, perform the following steps:

1. Turn the master switch to the OFF position.

2. Leave the mode selector switch in the DG mode.

3. Turn the master switch to the FIL'S position, and wait about 30 seconds to allow the tube filaments to heat.

4. Turn the master switch to the ON position. Now wait for the blue ready lamp located on the control panel to light (approximately 11 minutes) before proceeding to the next step.

5. When the blue ready lamp comes on, check the OWN SHIP COURSE dial to see if the compass is aligned with the ship's heading. If the dial does not indicate the ship's heading, you need to slew the compass until the dial is aligned within a maximum of 10°. The nearer the OWN SHIP COURSE dial is set to the ship's heading, the quicker the compass will settle to north when it is switched into the high latitude mode in step 7.

6. Press the RUN button.

7. Reset the latitude computer to the correct latitude.

8. At the end of 30 minutes, turn the mode selector switch to the high-latitude mode. The compass will now settle to the north.

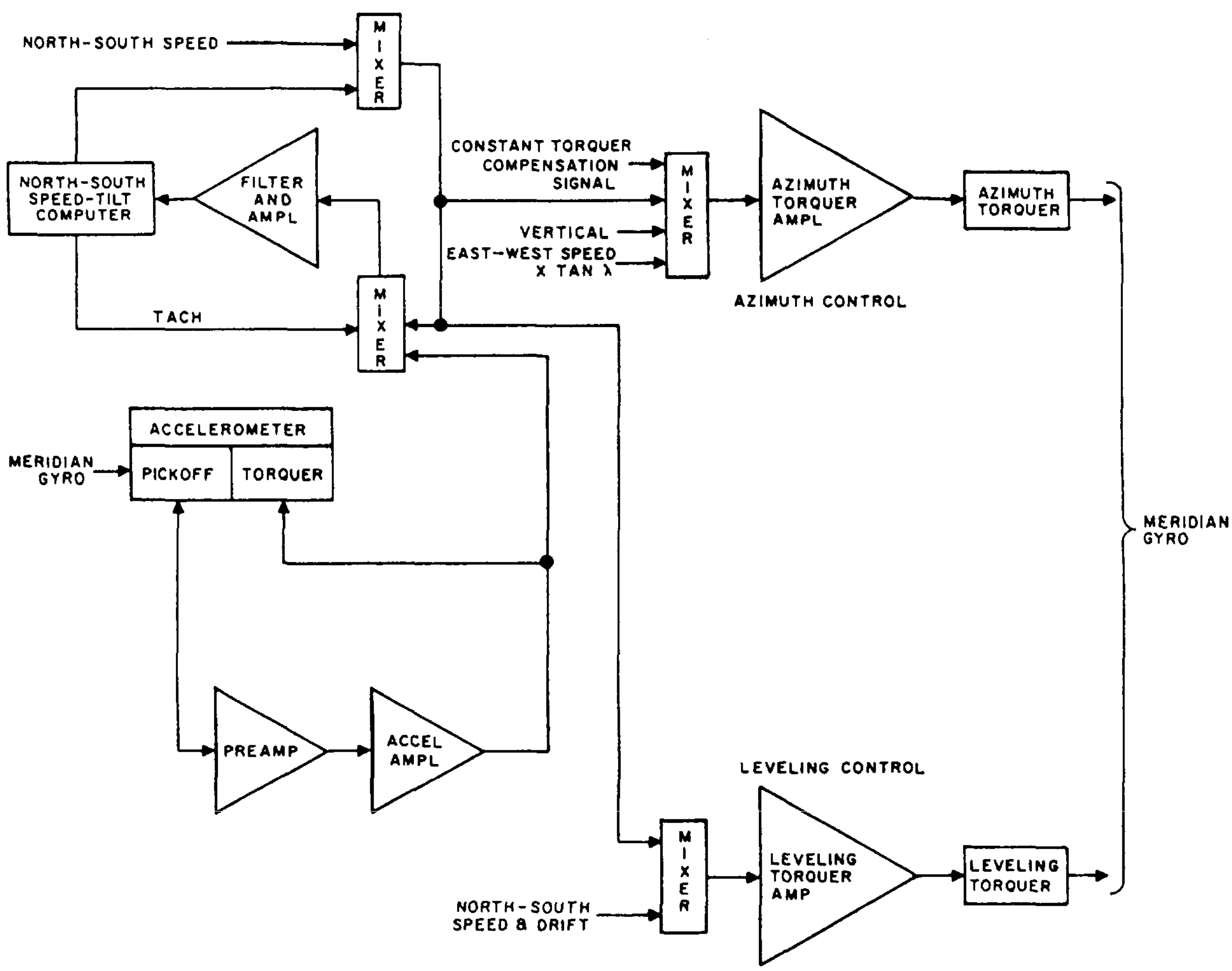


Figure 4-41.—Block diagram of a meridian gyro control system.

Securing the Mk 19 Mod 3B Gyrocompass

The procedures for securing the Mk 19 Mod 3B gyrocompass are the same as for the Mk 19 Mod 3A gyrocompass.

MK 19 MOD 3C GYROCOMPASS SYSTEM

The Mk 19 Mod 3C gyrocompass system uses a modified version of the static standby power supply used in the Mk 19 Mod 3B. This modified version, known as the static power supply, is used as the primary power supply as well as the standby supply for the compass. The static power supply receives 115-volt, 400-Hz power from the ship's supply and, in turn, supplies the compass with a highly reliable 3-phase, 115-volt, 400-Hz power. If the ship's supply fails or falls below 112 volts, the static power supply automatically receives its power from the storage batteries.

Another feature incorporated in the static power supply is a servicing switch on the inside of the panel door. When the servicing switch is in the OFF position, the incoming ship's supply and the battery supply are broken. When the servicing switch is in the READY position, the ship's supply and the battery supply circuits are lined up for normal operation.

An additional circuit called a fault protector has been added. This unit receives inputs from the current and voltage sensing circuits and sends an output or fault signal to the inverter drivers to expedite correction for overcurrent or other output faults.

Another major change in the Mk 19 Mod 3C compass is the replacement of the electrolytic level in the gravity reference system (Mk 19 Mod 3A and Mod 3B) with an accelerometer. The accelerometer is a more accurate detector than the electrolytic level.

The meridian gravity reference system of the 3A gyrocompass was discussed earlier in this chapter. In modification 3C, the system consists of two closed-loop systems: the accelerometer control loop and the speed-tilt computer loop (fig. 4-41). The system detects any horizontal deviation of the gyro spin axis and supplies a signal proportional to the amount of tilt to the meridian gyro azimuth and leveling control systems. The accelerometer senses any accelerations in the north-south plane as well as tilting of the gyro spin axis. The accelerometer control loop cannot distinguish between tilting and accelerations, and its output signal to the speed-tilt computer contains acceleration and tilt signals. The output signals would be basically the same for northerly accelerations as for a tilt of the spin axis

The speed-tilt computer accepts the output of the accelerometer control loop (fig. 4-42) and determines

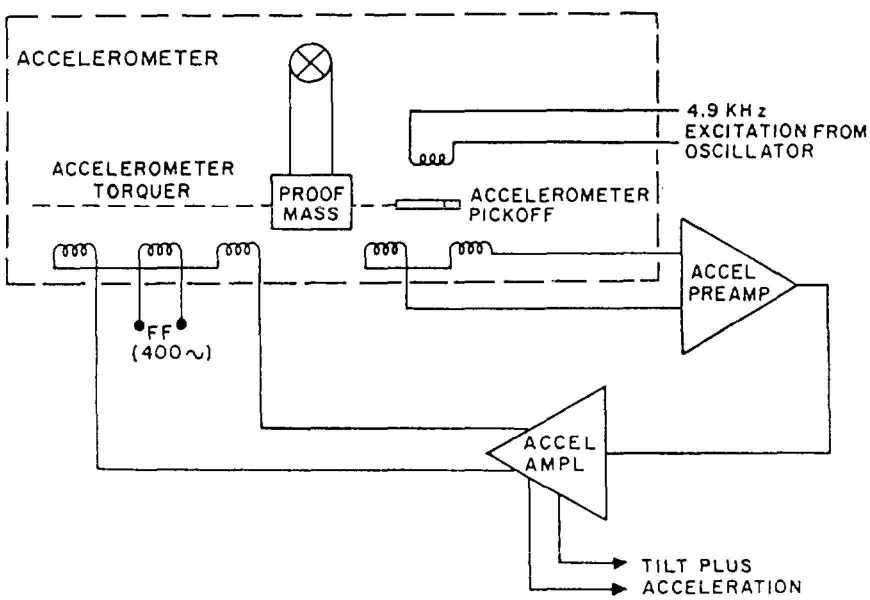


Figure 4-42.—Accelerometer control loop.

what portion of this signal is actual tilt of the spin axis. The signal from the accelerometer control loop, which consists of acceleration plus tilt signals, is integrated in the speed-tilt computer loop to obtain a velocity plus tilt signal. The velocity component of this signal is removed by subtracting north-south speed, which leaves only tilt.

The accelerometer (fig. 4-42) is a pendulous mass, force feedback instrument that mounts directly to the meridian gyro vertical ring. Its main components are the proof mass, torque and backup plate, and pickoff, all mounted to a common support.

The proof mass is a curved aluminum plate suspended by cross-spring pivots and is the element against which the torque acts. Attached to an extension of the proof mass is the iron pickoff core.

The torque is similar to the gyro torquers. It is a 2-phase induction type with the control field windings in series, opposing, and the fixed field winding excited from the A transformer wired in a Scott "T" arrangement. The torque is backed with a laminated iron piece to improve the torque capability. The torque and backup plate are encapsulated in plastic in such a manner so as to enclose the proof mass.

The pickoff is a moving iron inductive-type transducer that detects relative motion between the proof mass and the support. Excited with 4900 Hz to achieve frequency separation from the 400-Hz power frequency, the pickoff output has magnitude and phase sense proportional to displacement from a null or level position. This signal is amplified and converted to 400 Hz to drive the torque, which restores the proof mass to null.

The tilt plus acceleration output is the 400-Hz torque control field voltage. Because the accelerometer cannot distinguish between tilt and acceleration, the output contains both components. The acceleration component is withdrawn in the speed-tilt computer loop, leaving only the tilt component.

The range of the instrument is ±0.4 gram or a tilt of 23°35 minutes, and the scale factor is 75 volts per gram or approximately 23 millivolts per minute of tilt. The pickoff excitation is 0.5 volts, 4900 Hz, and the torque fixed field excitation is 100 volts, 400 Hz.

The accelerometer preamplifier amplifies the modulated 4900-Hz carrier output of the accelerometer before its transmission by cable to the compass control cabinet. By increasing the signal power level before transmission, crosstalk (or cross modulation) and spurious disturbances that would degrade the inherent accelerometer signal-to-noise ratio are prevented. Two such accelerometer preamplifiers are required per system—for the meridian and slave gyros—and each contains its own power supply.

MK 19 MOD 3D GYROCOMPASS SYSTEM

The Mk 19 Mod 3D gyrocompass system is identical to the Mk 19 Mod 3C system with the exception that solid-state devices are used in the follow-up amplifiers, switching, and control assemblies.

MK 19 MOD 3E GYROCOMPASS SYSTEM

The Mk 19 Mod 3E gyrocompass system is identical to the Mk 19 Mod 3D system with the exception that the compass has been modified to add an optical cube used for alignment. This optical cube permits precise alignment of the compass during compass installation.

In addition, the control cabinet has been modified and a velocity interface unit has been added to permit satellite interfacing with the compass.

MK 19 MOD 3R AND 3RC GYROCOMPASS SYSTEMS

The Mk 19 Mod 3R gyrocompass is a factory rebuilt Mk 19 Mod 3, rebuilt to Mod 3A specifications. The Mk 19 Mod 3RC gyrocompass is a factory rebuilt Mk 19 Mod 3, rebuilt to Mod 3C specifications.

WATCH STANDING

Watch-standing procedures for the Mk 19 Mod 3 gyrocompass systems are basically the same as for the Mk 23 Mod 0 and Mod C3 systems.

The alarm system for the Mk 19 Mod 3 is designed to give multiple alarm warnings when trouble develops in any circuit. The alarm circuits are also arranged to give indications when they become defective.

AN/WSN-2 STABILIZED GYROCOMPASS SET

The AN/WSN-2 stabilized gyrocompass set provides precision analog dual-speed roll, pitch, and heading signals to the ship's navigation and fire control systems. The set uses an accelerometer-controlled, three-axis, gyro-stabilized platform to produce vital heading synchro data and reference, nonvital heading synchro data, and both roll and pitch angle synchro data.

EQUIPMENT DESCRIPTION

The AN/WSN-2 stabilized gyrocompass set (fig. 4-43) consists of an electrical equipment cabinet and five

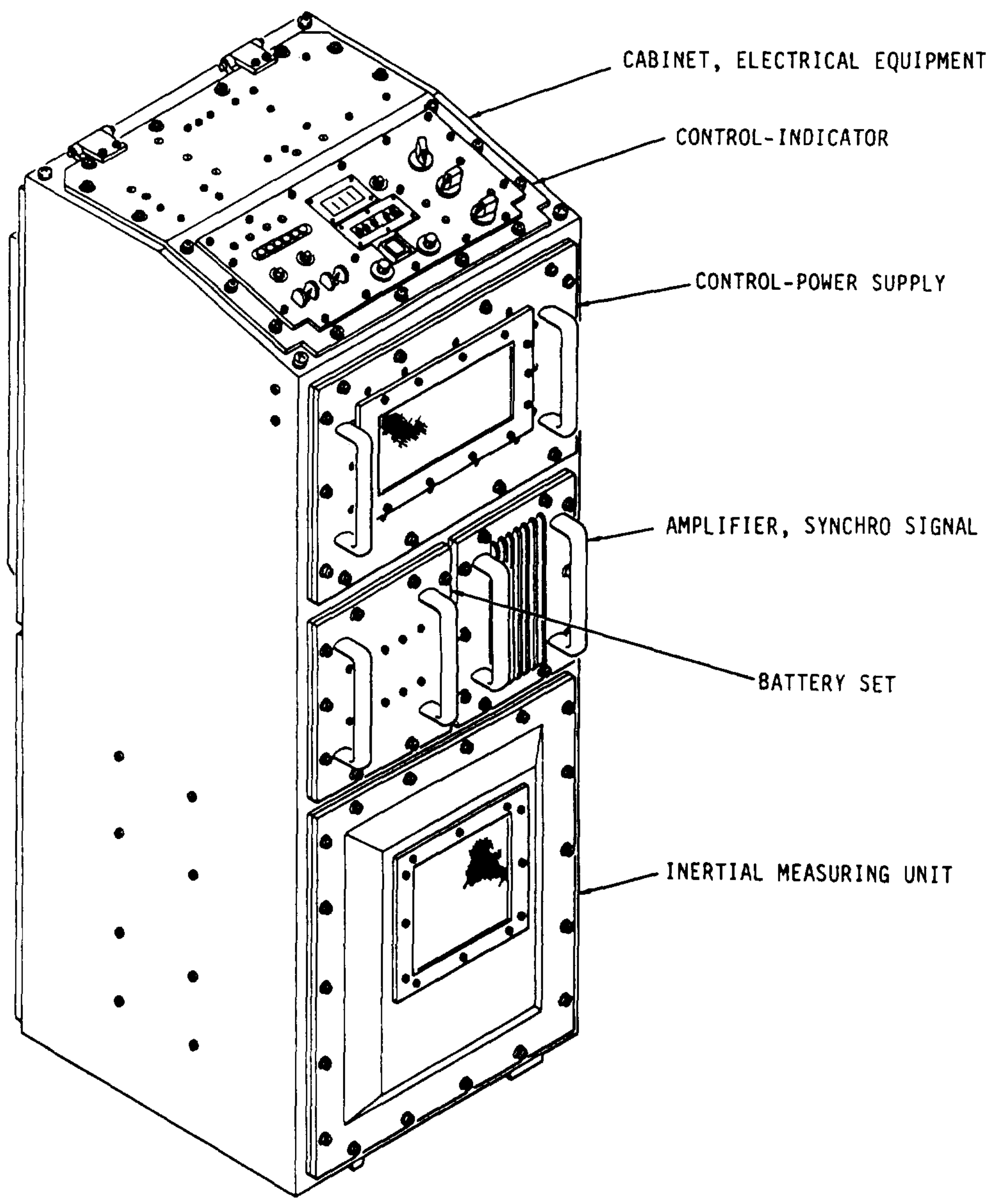


Figure 4-43.—Stabilized gyrocompass set, AN/WSN-2.

major assemblies. The five major assemblies are contained within the cabinet. These assemblies are the control indicator, control power supply, battery set, synchro signal amplifier, and inertial measuring unit (IMU).

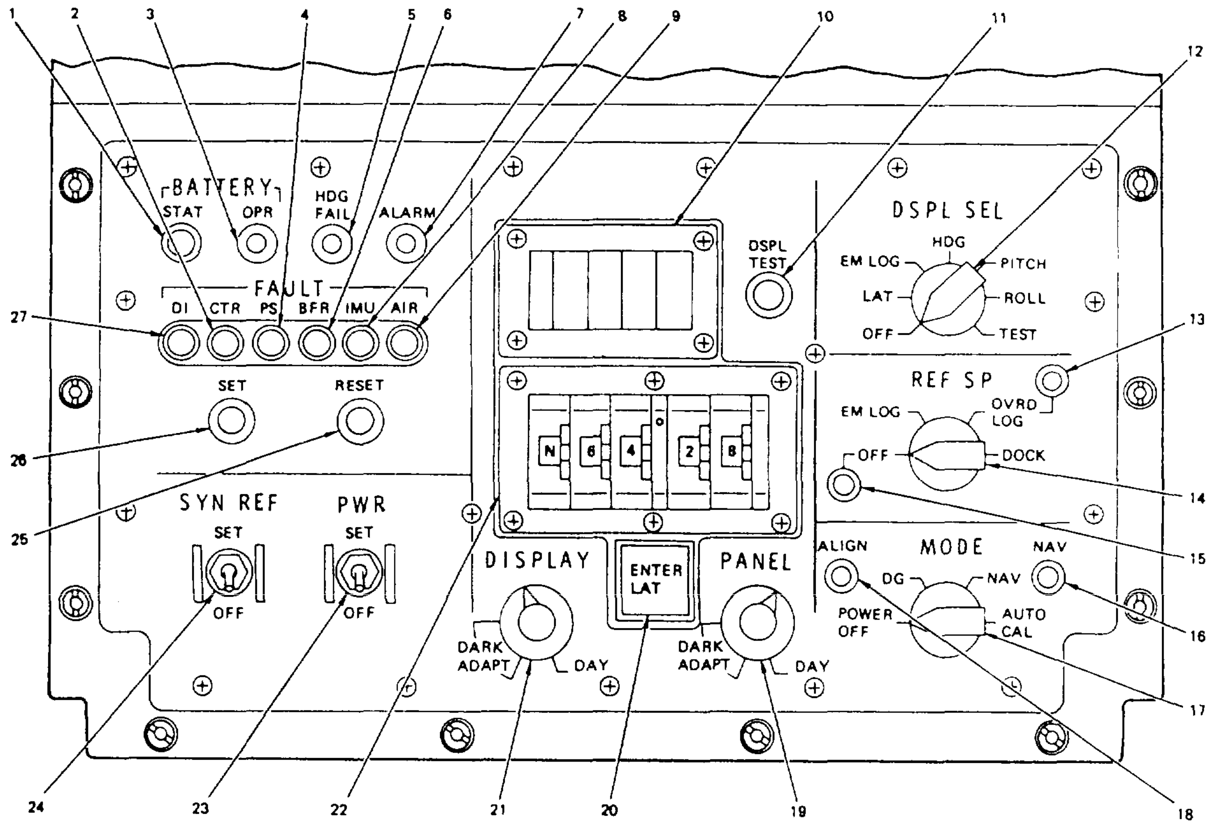
Electrical Equipment Cabinet

The electrical equipment cabinet (fig. 4-43) provides the mechanical and electrical interface for the five major assemblies. The cabinet also provides forced air cooling for the IMU.

The cabinet contains a wiring harness, alarm relays, power relays, electromagnetic interference (EMI) filters, an elapsed time meter, capacitor assemblies, a blower for IMU cooling, and the IMU rack. A connector panel located on the rear of the cabinet provides the electrical cable interconnections for cabling to external equipment, including primary power.

Control Indicator

The control indicator (fig. 4-44) is a hinged assembly located in the top of the electrical equipment



1. BATTERY, STAT indicator
2. FAULTY, CTR indicator
3. BATTERY, OPR indicator
4. FAULT, PS indicator
5. HDG FAIL indicator
6. FAULT, BFR indicator
7. ALARM indicator
8. FAULT, IMU indicator
9. FAULT, AIR indicator
10. Display
11. DSPL TEST push-button switch
12. DSPL SEL switch
13. REF SP, OVRD LOG indicator
14. REF SP switch
15. REF SP, OFF indicator
16. MODE, NAV indicator
17. MODE switch
18. MODE, ALIGN switch
19. PANEL potentiometer
20. ENTER LAT switch-indicator
21. DISPLAY potentiometer
22. Latitude thumbwheel switch
23. PWR circuit breaker
24. SYN REF circuit breaker
25. FAULT, RESET push-button switch
26. FAULT, SET push-button switch
27. FAULT, DI indicator

Figure 4-44.—Controts and indicators.

cabinet. It is secured to the cabinet with quick-release fasteners. The control indicator contains all the operator controls and indicators for the gyrocompass set. The control indicator also contains built-in test equipment (BITE) for the major assemblies and subassemblies. BITE circuits identify equipment faults and provide visual indications of the faulty assembly or subassembly.

CONTROL POWER SUPPLY

The control power supply (fig. 4-45) contains the control, computing, processing, analog/digital conversion, input/output interface, and power supply electronics for the gyrocompass set. The control power supply also contains capacitor assemblies, cooling blowers, BITE, and the battery charging electronics for charging the battery set.

BATTERY SET

The battery set is installed in the electrical equipment cabinet (fig. 4-43). It is secured in the cabinet by quick-release fasteners. The battery set consists of a battery, isolation diodes, fuses, and sensing circuits. The battery consists of 60 sealed lead-acid storage cells. They are connected in series-parallel, five parallel branches, consisting of 12 cells per branch, to provide a nominal 24-volt output for approximately 30 minutes during normal power failure. The battery set weighs 70 lbs and requires careful handling by two persons when moved. The battery is under a continuous charge, provided by electronics in the control power supply. The fuses provide overload protection in the battery charger input circuit and the battery output. The sensing circuits consist of a high-voltage sensing circuit, a low-voltage sensing circuit, and a temperature sensing circuit. The output of these sensing circuits go to BITE circuits in

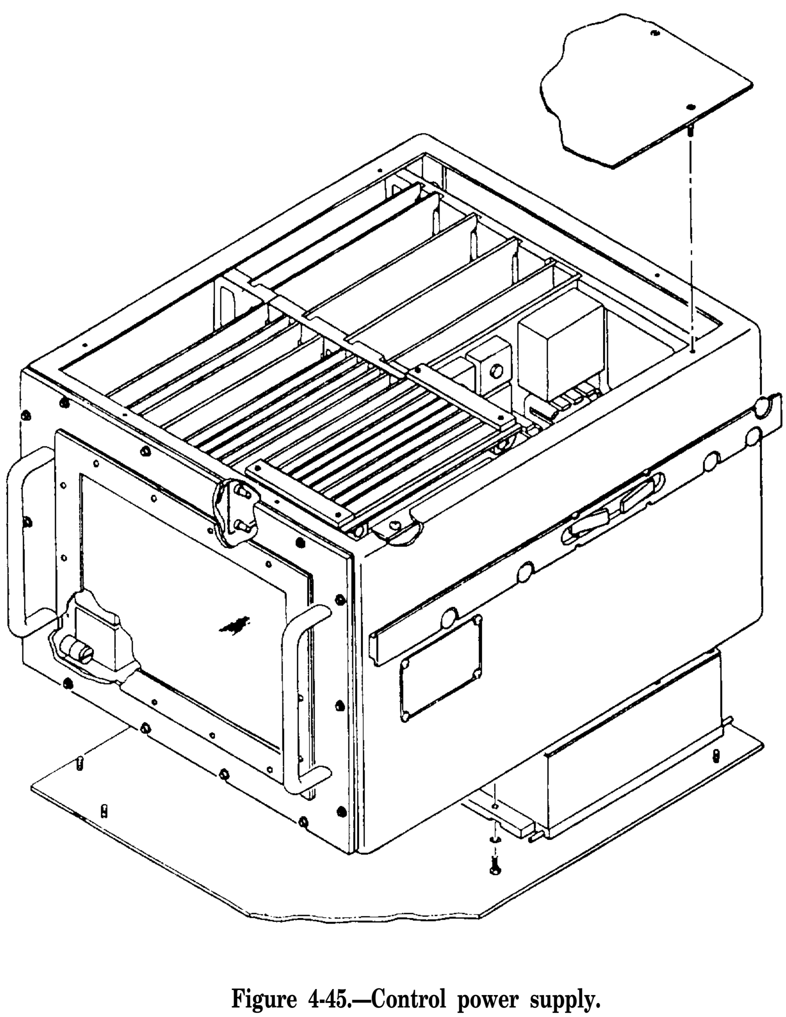


Figure 4-45.—Control power supply.

the control power supply and are routed to BITE indicators on the control indicator.

SYNCHRO SIGNAL AMPLIFIER

The synchro signal amplifier (fig. 4-46) is installed in the electrical equipment cabinet. It is held in the cabinet by quick-release fasteners. The synchro signal amplifier contains four synchro buffer amplifiers, an inverter power supply, cooling blower, and BITE.

The synchro buffer amplifiers provide the voltage and power levels for the gyrocompass heading, pitch, and roll synchro output signals.

The inverter power supply converts the battery output to 115-volt, 400-Hz power and converts this to the proper dc levels for the synchro signal amplifier. The inverter power supply also produces ac power for the equipment cooling fans and a vital heading reference output for the gyrocompass set when normal single-phase, 400-Hz power is lost. The inverter power supply also contains BITE summary logic for the synchro signal amplifier.

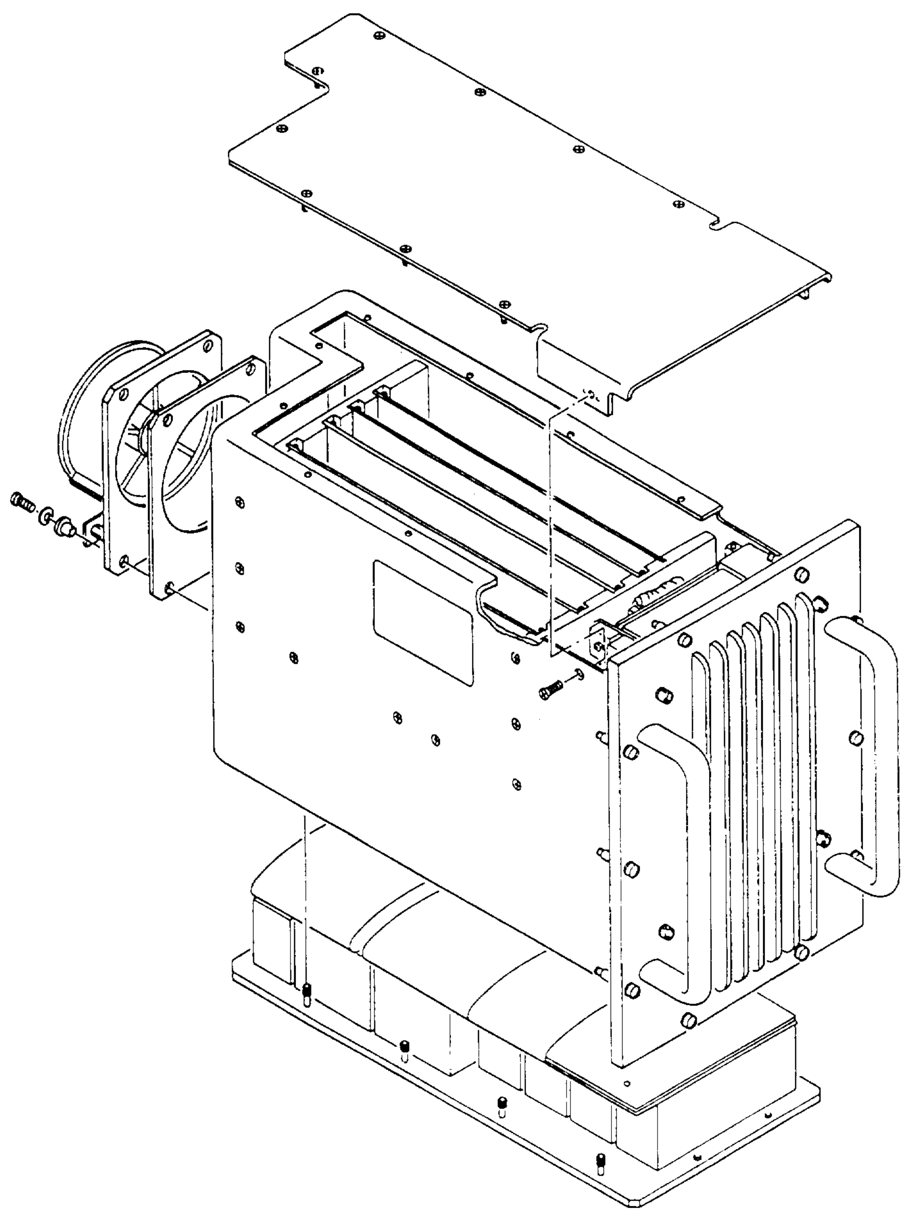


Figure 4-46.—Synchro signal amplifier, exploded view.

INERTIAL MEASURING UNIT

The IMU (fig. 4-47) is installed in a special precision IMU alignment rack located in the bottom of the electrical equipment cabinet, behind an access cover. Access to the IMU is gained by removing the access cover. The IMU contains the gimbal assembly, the electronics necessary to maintain the gimbal assembly, and associated electronics necessary to interface with the control, computing, and processing functions of the control power supply. The IMU also contains BITE circuitry and indicators and houses temperature controlling electronics.

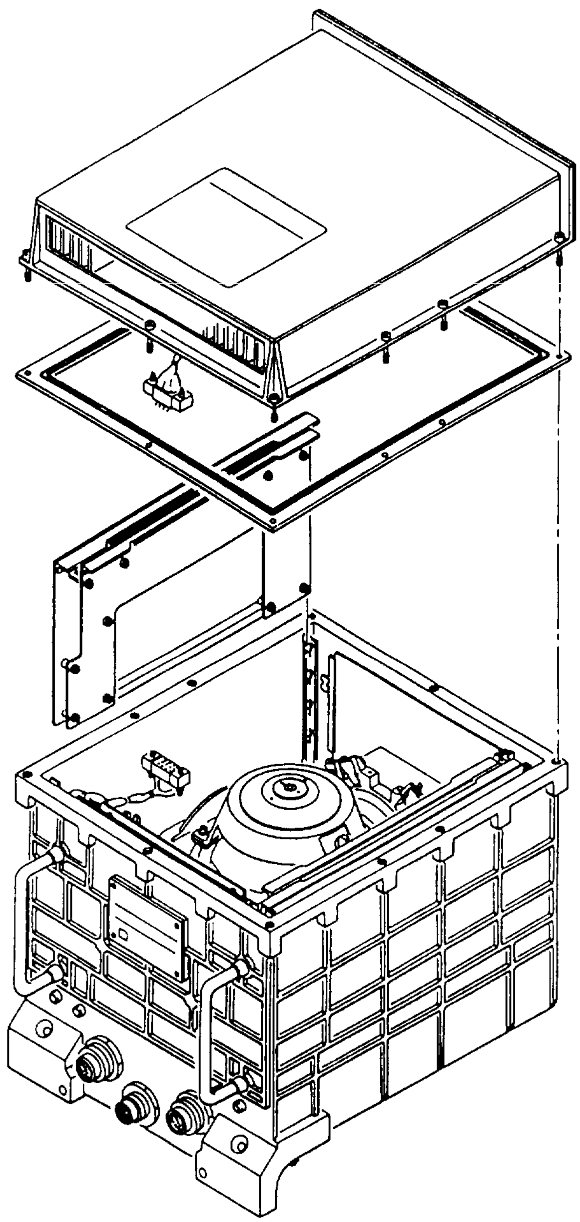


Figure 4-47.—Inertial measuring unit exploded view.

FUNCTIONAL DESCRIPTION

The primary function of the stabilized gyrocompass set is to produce precision analog dual-speed roll, pitch, and heading signals for use by the ship's equipment. The outputs are available in all modes during normal operation and battery backup. When operating on inverter produced single-phase power, only vital heading and its synchro reference are available.

For the stabilized gyrocompass to operate, it requires certain electrical inputs from the ship. These inputs are 115-volt ac, 400-Hz, single-phase synchro excitation; 115-volt ac, 400-Hz, 3-phase primary power; underwater log data with reference voltage; and 24-volts dc provided internally by the battery set and used during the loss of 3-phase input power.

SIGNAL DEVELOPMENT

The roll, pitch, and heading (in some publications referred to as azimuth) located in the IMU gimbal are excited by 26 volts, 4.8 kHz when the gimbal is caged, or by 26 volts, 400 Hz during normal operation. Both resolver excitation levels are provided by the servoamplifier. Each resolver has two outputs, which represent the sine and cosine of the angular displacement of its respective rotor shaft. These outputs are sent back to the servoamplifier when the gimbal is caged. When the gimbal is uncaged, during normal operation, the outputs are sent to the resolver preamplifier.

The roll and pitch sine and cosine signals from the resolver preamplifier are amplified, buffered, and converted to standard three-wire format by the synchro signal amplifier. The data leaves the synchro signal amplifier as S1, S2, and S3 synchro data.

The heading sine and cosine signals from the resolver preamplifier are converted to true heading sine and cosine signals in the 1X and 36X true heading converters before being sent to the synchro signal amplifier and the analog/digital (A/D) multiplexer. The true heading sine and cosine data, like the roll and pitch data, are amplified, buffered, and converted to standard three-wire synchro data in the synchro signal amplifier. True heading data is subsequently sent out as S1, S2, and S3 synchro data.

The roll, pitch, and heading sine and cosine signals from the resolver preamplifier and the true heading sine and cosine signals from the true heading converter are also sent to the A/D multiplexer. The A/D multiplexer sends these analog signals to the A/D converter, where each sine/cosine part is converted to the tangent of the respective angle, in digital format. The tangent values of the roll, pitch, and heading angles are sent to the processor for use in program computations and data updates.

MODES OF OPERATION

The stabilized gyrocompass set has three modes of operation: automatic calibration (AUTO CAL), navigate (NAV), and directional gyro (DG). At equipment turn-on, there is a leveling sequence that provides for equipment leveling and initial calibration.

Leveling Sequence

The stable element leveling sequence is initiated upon application of power to the equipment. This is accomplished by moving the MODE switch out of the POWER OFF position. The major elements of the leveling sequence are stable element caging, digital coarse leveling, tine leveling, gyrocompassing, and calibration.

STABLE ELEMENT CAGING.— Upon energizing and for 10 seconds thereafter, gyro spin power is inhibited by the software program and the stable element is caged. At the end of the delay, the gyros are energized with high spin power. The software program allows 60 seconds for the gyros to gain speed and then perform the gyro synchronization test. If the synchronization test is passed, the program examines the output of the X accelerometer (fig. 4-48) for minimum output, which indicates the platform is level. The software program then checks for proper temperature of the IMU. When the synchronization test, level check and temperature check are successfully completed, the stable element is uncaged and placed under gyro control. Gyro spin power is then set to normal low spin value.

DIGITAL COARSE LEVELING.— Upon completion of the caging sequence, all integrators and biases and the alpha (OC) angle (the alpha angle is the angular difference between the stable element's [north-south] axis and true north) are set to zero, and digital course leveling is initiated. Normally, digital coarse leveling requires 1 minute. This time, however, may be lengthened by loop settling delays. Completion

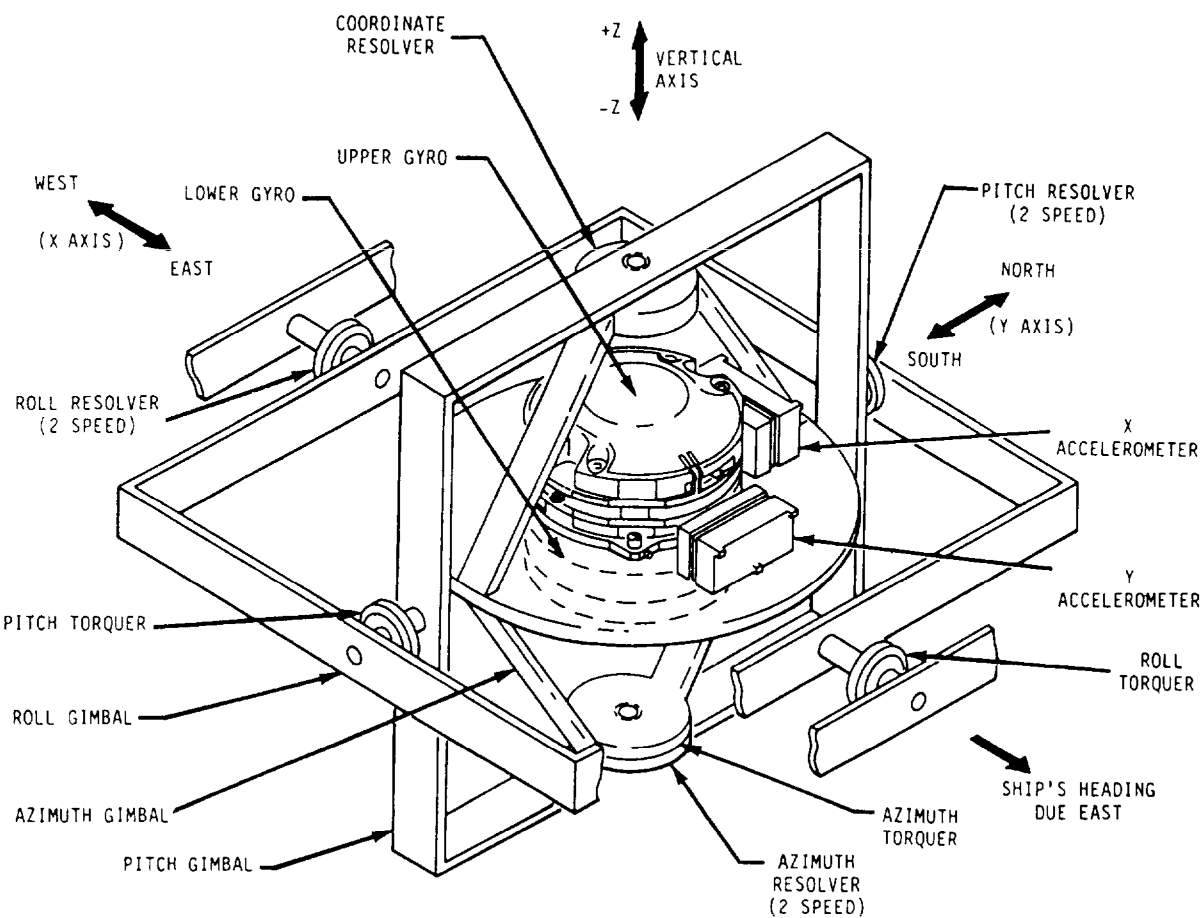


Figure 4-48.—Inertial measuring unit.

of digital coarse leveling is determined by the velocity error signal. When the absolute values of the velocity error signal represent less than 1/2 ft/sec, and 60 seconds have elapsed, digital coarse leveling is complete, and fine leveling is started.

FINE LEVELING.— At the start of fine leveling, as in digital coarse leveling, all integrators, biases, and the alpha angle signal are set to zero. Again, completion of the sequence is determined by the velocity error signals. When the absolute values of these signals represent less than 1/4 ft/sec and 6 minutes have elapsed, fine leveling is completed.

LEVELING COMPLETION.— At the end of the leveling sequence, the software program calculates the alpha angle, establishes an initial value for latitude, and initializes the two direction cosines (pitch and roll angles). If a latitude entry was made at the start or during the leveling sequence, that value will be the initial latitude; otherwise, latitude is set to zero degrees.

GYROCOMPASSING AND CALIBRATION.— A four-step, timed procedure accomplishes the gyrocompassing and calibration sequence. This sequence takes approximately 4 hours and must be completed before the gyrocompass is capable of providing full accuracy outputs. The software program estimates latitude if none was entered by the operator. In either case, latitude information will be updated at the end of the gyrocompassing and calibration sequence. At the completion of the sequence, the MODE NAV indicator light will come on, and the MODE ALIGN indicator light will go out, indicating the gyrocompassing and calibration sequence is completed. Table 4-2 details this sequence.

Auto Cal Mode

The AUTO CAL mode is used at latitudes below 85° north or south. The AUTO CAL mode is used at initial start-up and should be implemented at least every 90 days during continuous operation to ensure accuracy of

Table 4-2.—Gyrocompassing and Calibration Sequence

Step name	Mechanization functions	Calibration functions	Time
East Gyrocompass	Slew Y-Axis to -90°	None	0 - 6 minutes
	Settling Step	None	2 minutes
	Coarse Gyrocompass	Minibias X-axis	37 minutes
	Fine Gyrocompass	Minibias X- and Z-axis and estimate latitude if no entry	20 minutes
West Gyrocompass	Slew Y-Axis to +90°	Accelerometer bias data	6 minutes
	Slew Settle	Estimate Y-accelerometer bias and remove platform tilt	2 minutes
	Coarse Gyrocompass	Minibias X-axis	27 minutes
	Fine Gyrocompass	Minibias X-axis, minibias Z-axis, update latitude and compute X-axis bias	20 minutes
South Gyrocompass	Slew Y-Axis to 180°	None	3 minutes
	Slew Settle	None	2 minutes
	Coarse Gyrocompass	Minibias Y-axis	27 minutes
	Fine Gyrocompass	Minibias Y- and Z-axis	20 minutes
North Gyrocompass	Slew Y-Axis to 0°	Bias accelerometers	6 minutes
	Slew Settle	Remove platform tilt	2 minutes
	Coarse Gyrocompass	Minibias Y-axis	27 minutes
	Fine Gyrocompass	Minibias Y-axis, minibias Z-axis, update latitude and compute Y-axis bias	15 minutes

outputs. Automatic calibration requires 24 hours to complete but will continue as long as the mode switch is in this position.

Setting the MODE switch to AUTO CAL at anytime after completion of the leveling sequence places the equipment in the AUTO CAL mode. This mode starts an automatic recalibration sequence to determine new gyro biases, accelerometer biases, and latitude corrections. These new values are automatically averaged with old values to accomplish equipment recalibration.

All gyro functions and outputs are maintained in the AUTO CAL mode. The outputs from the IMU resolvers, representing pitch and roll angles, are applied directly to the synchro signal amplifier. The synchro signal amplifier amplifies the resolver input information and transmits dual-speed synchro information to the ship's equipment. Roll and pitch angle information is also sent to the A/D multiplexer.

In the AUTO CAL mode, heading is continuously slewed, completing 360° every 24 hours. The IMU heading signals are sent to the true heading converters. Also applied to the true heading converters is the alpha angle. In AUTO CAL it is set to a value representing 15° per hour. These two signals are combined in the true heading converter to develop true heading information. The output of the true heading converter is sent to the synchro signal amplifier for amplification and distribution to the ship's equipment and is sent to the A/D multiplexer for use by the processor.

The digital display indicator provides for local display of the quantities shown in table 4-3. Data for display is selected by the DSPL SEL switch.

Nav Mode

The NAV mode, the primary operating mode, is mechanized the same as the AUTO CAL mode. In the NAV mode, the heading is not slewed and the alpha angle is held at zero; thus, the equipment becomes a north-pointing gyrocompass.

The NAV mode is the normal mode of operation and is used between latitudes 85° north or south. If the NAV mode is initially selected as the mode of operation, the alignment sequence must be completed before the gyrocompass is capable of providing full accuracy outputs. This sequence takes approximately 4 hours. The alignment sequence is completed when the MODE ALIGN indicator goes off and the MODE NAV indicator comes on.

DG Mode

The DG mode is used at latitudes above 85° north or south. When the gyrocompass is operating in the DG mode, the stable element is dampened by velocity signals and allowed to wander in azimuth. Earth rate correction is made by torquing the stable element in

Table 4-3.—Data Display Parameters

DSPL SEL switch position	Data displayed	Range	Resolution	Remarks
LAT	Latitude	0 to 90°	1 minute	Sign of latitude is not displayed; degree and minute marks are displayed
EM LOG	LOG velocity	0 to 99.9 knots	0.1 knot	Leftmost digit is not used
HDG	True heading	0 to 359.9°	0.1°	
PITCH	Pitch	0 to ±99.9°	0.1°	Positive (bow down) sign is a blank
ROLL	Roll	0 to ±99.9°	0.1°	Positive (starboard up) sign is a blank
TEST	Test Pattern. The Program shall display all 0000's, 1111's through all 9999's. The pattern shall change approximately each second.			

azimuth. The alpha angle is held constant and grid heading, rather than true heading, is sent to the ship's equipment. Otherwise, the equipment's function is the same as for the AUTO CAL mode.

SUPPORTING FUNCTIONS

The major functions of the stabilized gyrocompass are supported by several supporting or subordinate functions. The supporting functions are described in the following paragraphs.

Latitude Set

The entry of latitude data maybe made during the leveling sequence (except during the north and south gyrocompassing phases) and at anytime the system is NAV ready. The gyrocompass is ready to receive a latitude entry when the ENTER LAT switch indicator (fig. 4-44) is on. The software program commands the ENTER LAT switch indicator on when power is applied and when the position of the MODE switch is changed. If the ENTER LAT switch-indicator is not on, entry can be accomplished by pressing the ENTER LAT switch indicator ONCE. The gyro compass will then be able to receive a latitude entry for 1 minute.

With the DSPL SEL switch set to LAT and the ENTER LAT switch indicator on (fig. 4-44), latitude entry is made by setting the desired latitude (hemisphere, degrees, and minutes) with the thumbwheel switch, then pressing and releasing the ENTER LAT switch indicator. The ENTER LAT switch indicator will go off and the selected latitude will be displayed on the digital display.

Data Display

Several pieces of data are available for display on the control indicator panel. The data available for display is latitude, electromagnetic (EM) log, ship's heading, pitch, roll, and test (table 4-3). The desired data is displayed by setting the DSPL SEL switch to the appropriate position. Also, under software control, but not selectable, are the MODE, ALIGN indicator, and the MODE, NAV indicator. When the alignment sequence is complete, the software program turns the MODE, NAV indicator on, and the MODE, ALIGN indicator off.

Reference Speed Selection

The software program controls the reference speed selection function. The REF SP switch is positioned by the operator to define to the software program the operational mode required. In the OVRD LOG position, the REF SP switch provides a ground via the dimming control circuit card to energize the OVRD LOG indicator. The REF SP OFF indicator is controlled by the processor.

The ship's EM log input is changed from synchro format to sine and cosine values by the Scott "T" transformers in the A/D multiplexer transformer. The EM log sine and cosine signals are selected by the A/D multiplexer and converted to a tangent value, in digital format, by the A/D converter. The EM log tangent signal is then applied to the processor. When the REF SP switch is set to OFF, the processor ignores the EM log inputs and the gyro operates in the free-inertial state. When the REF SP switch is set to EM LOG, the processor tells the software program to implement gyro operation, damped by the EM log velocity information.

The EM log velocity information is monitored for reasonableness by the software program. When it determines that the velocity information does not meet the reasonableness test, the processor will command the equipment to ignore the velocitly data and operate in the free-inertial state. The processor will also initiate a reference speed off signal, causing the REF SP, OFF indicator to light. The operator can override the reason- ableness test by setting the REF SP switch to OVRD LOG. In the OVRD LOG position, the processor disables the velocity monitor and commands the software program to use the EM log velocity information for damping purposes. The REF SP, OFF indicator will go off, and the OVRD LOG indicator will come on, indicating the equipment is operating in a damped state.

When the REF SP switch is set to DOCK, the processor tells the software program to use a zero reference velocity for damping instead of the EM log velocity input.

Illumination Control

Two circuits control the level of illumination of the control-indicator's panel lighting and indicators. These circuits are illustrated in block diagrams in figures 4-49 and 4-50.

PANEL LIGHTING.— The control indicator panel lighting is controlled by a potentiometer marked PANEL. The PANEL potentiometer is excited by ±15 volts dc. The potentiometer adjusts a biasing level applied to the illumination sensing circuit in the dimming control circuit card. The output of the sensing circuit drives the dimming control amplifier. The output of the dimming control amplifier is an aboveground variable voltage determined by the position of the PANEL potentiometer. Figure 4-49 identifies the lights controlled by the PANEL potentiometer.

STATUS INDICATOR AND DISPLAY LIGHTING.— The control indicator's status indicators and the digital display are controlled by the DISPLAY potentiometer. The potentiometer provides a triggering level input (0 volts to +5 volts) to a controlled-width blanking pulse circuit, located on the dimming control circuit card. The blanking pulse is applied to the indicator enabling logic, also on the dimming control circuit card. When the input to any indicator, controlled by the DISPLAY potentiometer, is determined to be correct by the display logic, the indicator is energized. The period of the blanking pulse, established by the DISPLAY potentiometer, determines the illumination level. Indicators on the control indicator that are controlled by the DISPLAY potentiometer are shown in figure 4-50.

Power Supplies

There are two power supplies to the AN/WSN-2 gyrocompass. These are the backup power supply and the normal power supply.

BACKUP POWER.— The backup power supply consists of the inverter and the inverter module, located in the synchro signal amplifier, for backup during loss of single-phase power, and the battery set and relays located on the transformer-rectifier assembly, for backup during loss of 3-phase power.

NORMAL POWER.— The normal power supply consists of the control monitor, battery charger, 5-volt regulator, 13-volt regulator, DC/DC module, and transformer rectifier. These are all located in the control power supply. Three-phase, 115-volt ac ship's power is routed through an EMI filter and power circuit breaker to the transformer rectifier for normal power. The transformer rectifier converts the 115 volts ac to 35 volts dc and unregulated 28 volts dc. The 35 volts dc goes to the battery charger and the unregulated 28 volts dc is sent to the 5-volt and 13-volt regulators.

The battery charger receives high- and low-voltage sensing signals and a temperature-sensing signal from the battery set. The battery charger uses the temperature-sensing signal to regulate the 35 volts dc to provide a charging voltage to the battery set. The

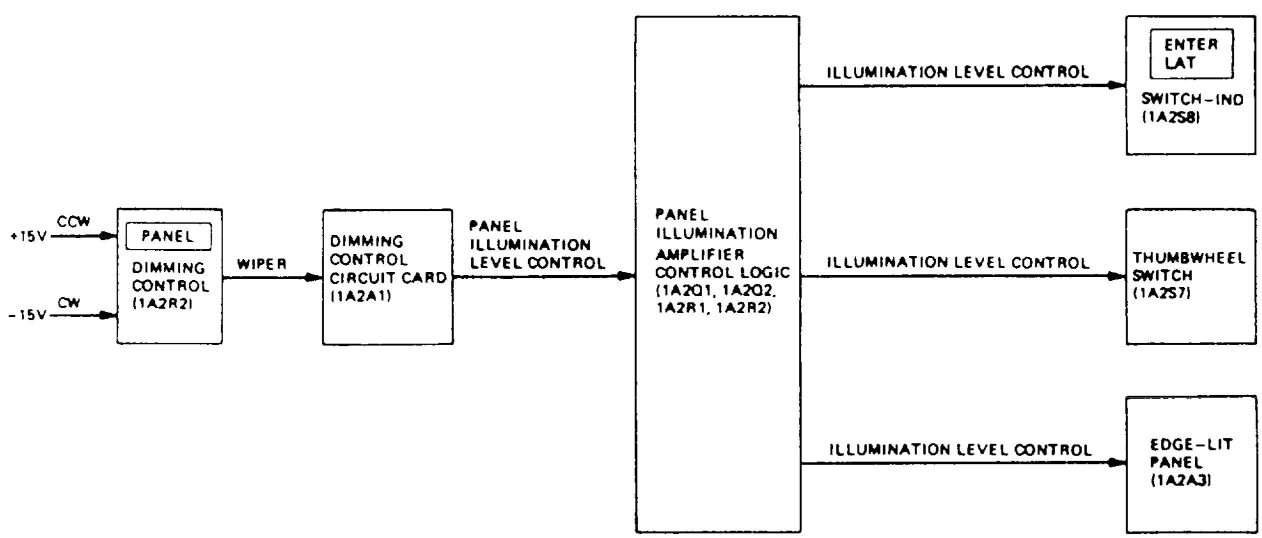


Figure 4-49.—Panel lighting dimming block diagram.

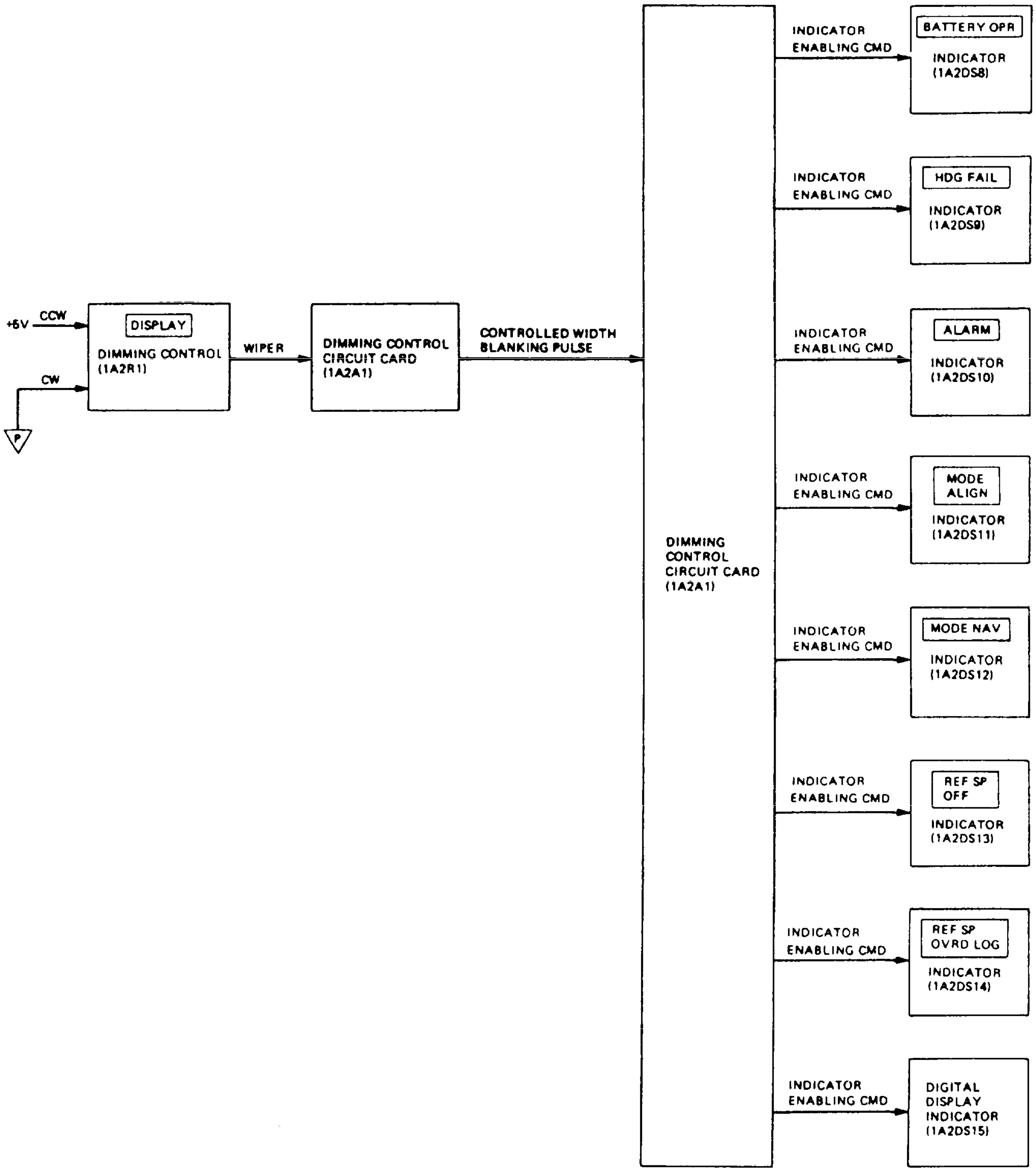


Figure 4-50.—Indicator and display lighting dimming block diagram.

charging voltage is present as long as the 3-phase, 115-volt ac ship's power is available and turned on.

The unregulated 28 volts dc is applied to the 5-volt and 13-volt regulators. The 5-volt regulator reduces the unregulated 28 volts dc to a regulated 5 volts dc, which is distributed to all using circuit cards and assemblies. The 13-volt regulator reduces the unregulated 28 volts dc to a regulated 13-volt dc level, which powers the DC/DC module. The 13-volt regulator is turned on before the 5-volt regulator to allow the DC/DC module and equipment to stabilize before the distribution of the 5 volts dc. The DC/DC module provides output voltages of +28 voks, -28 volts, +15 volts, -15 volts, +20 volts floating, +50 volts, and +50 volts floating. Floating indicates those voltages are isolated from power ground.

Single-phase, 115-volt ac ship's power is applied to the gyro by an EMI filter, a relay, and the SYN REF (synchro reference) circuit breaker. The single-phase, 115 volts ac provides power for the inverter magnetic module, internal resolver reference, and a vital heading reference output.

The gyrocompass will automatically switch to battery operation when the 3-phase or single-phase ship's power input is lost, loses a phase, or exceeds prescribed voltage or frequency tolerances. If the single-phase input is lost or exceeds tolerances, the system will shift to inverter backup.

The gyro is turned on and off by logic circuits in the control monitor, which is located in the control power supply.

Certain conditions will cause the control monitor to automatically turn the gyro off. These conditions are overtemperature, power supply fault, IMU fault, and battery under voltage when operating on the battery. When automatic shutdown occurs, the control monitor turns the gyro off as if the MODE switch were turned to the POWER OFF position, with one exception. Built-in test signals are applied to the control power supply to energize the proper fault indicators and alarms.

BITE circuits in the control monitor continuously check the 5-volt regulator, 13-volt regulator, DC/DC module, transformer rectifier, and inverter assembly outputs for over- and undervoltage conditions. hey also monitor the frequency and voltage of the 3-phase and single-phase, 115 volts ac and the power supply temperature.

Built-in Test Equipment

The BITE provides four types of built-in tests. These are hard-wired, software, software-initiated, and software-monitored built-in tests. The hard-wired BITE consists of test logic that is wired directly to the fault circuits. Fault signals that start the automatic shutdown sequence are hard wired. The software built-in tests are tests that are controlled by the processor, rather than by hard-wired logic circuits. The software-initiated BITE consists of hard-wired logic circuits that are activated by the processor. The software-monitored BITE circuits are not wired directly to fault circuits. Instead, the monitored parameters are compared to predetermined parameters known to the software. If the monitored parameters are determined to be wrong, the appropriate fault indicator is energized; and if the fault warrants, the gyro is shut down. When any fault is detected by the BITE, the ALARM indicator on the control indicator and the appropriate fault indicator are energized.

The fault indicators are located on the control indicator. They are labeled FAULT AIR, FAULT DI, FAULT CTR, FAULTPS, BATIERY STAT, BATTERY OPR, FAULT BFR, HDG FAIL, FAULT IMU, and ALARM. These indicators serve to lead the operator to the failed area of the system.

FAULT INDICATORS.— The FAULT AIR indicator is energized when an overtemperature condition occurs in the power supply section of the control power supply, synchro signal amplifier, or the IMU. When this condition exists, an overtemprature no-go signal is sent to the control monitor, which starts the automatic power shutdown sequence.

The processor monitors the control signals from the control indicator. When erroneous control output signals are detected, the processor sends out signals that energize the FAULT DI indicator and the ALARM indicator.

The circuit cards, in the control section of the control power supply, are monitored and tested by the processor. When a circuit card fails, the FAULT CTR and ALARM indicators on the control indicator are energized. A combination of the six indicators, located inside the control power supply, will be energized, indicating which circuit card is faulty.

BITE logic circuits in the control monitor continuously monitor the 5-volt regulator, 13-volt regulator, DC/DC module, battery charger, and battery set for overvoltage and undervoltage conditions. If an undervoltage condition in the battery charger occurs, the control monitor sends a battery status signal to the control indicator, setting the BATTERY STAT indicator. If an overvoltage condition occurs in the battery charger, 5-volt regulator, 13-volt regulator, or DC/DC module, the fault indicator on the faulty card will set, and the control monitor will send a signal to the control indicator, energizing the FAULT PS indicator. The control monitor will also turn off the 5-volt regulator, 13-volt regulator, and DC/DC module when an overvoltage condition occurs. The fault indicators will remain set after the power supply is turned off. A gyro overtemperature condition, failure of the servoamplifier or gyro spin supply will also initiate no-go commands to the control monitor, which will shut down the power supply.

The control monitor also senses the voltage and frequency of the 3-phase, 115-volt ac power and synchro reference inputs at the transformer rectifier. If the 3-phase input is lost or exceeds tolerances, the control monitor will switch the gyro to battery operation and send a signal to the control indicator, causing the BATTERY OPR indicator to come on. If the single-phase input is lost or exceeds tolerances, the control monitor will disconnect the ship's faultly input, switch on the inverter, sending a signal to the control indicator, causing the ALARM indicator to set.

Circuit cards and assemblies in the synchro signal amplifier we monitored by hard-wired BITE. The 1X heading amplifier, 36X heading amplifier, roll amplifier, pitch amplifier, and inverter in the synchro signal amplifier have fault indicators located on the individual circuit cards. The fault indicator on the inverter sets when the inverter or inverter magnetics module fails. A fault in any of these circuit cards or module will cause the fault indicator on the respective faulty circuit card to set and a BITE fail signal to be sent to the fault summary logic located in the inverter. The inverter then sends out a signal causing the FAULT BFR indicator on the control-indicator to set.

If either of the heading amplifiers fail, the inverter will send a heading fail signal to light the HDG FAIL indicator on the control-indicator. If the inverter or inverter magnetics module fail during inverter operation, the inverter sends a signal to the control monitor to command a power shutdown. A failure of either the servoamplifier or gyro spin supply, located in the IMU, causes a no-go signal to be sent to the control monitor. The control monitor initiates a power shutdown and the IMU fault indicator on the control indicator to set.

Circuit cards and assemblies in the IMU are tested by a combination of hard-wired and software-monitored BITE. When either the servoamplitier or gyro spin supply circuit card fails, a hard-wired BITE fail signal is sent to the control monitor, which was discussed in the preceding paragraph. The gyro spin supply circuit card is also tested under control of the processor. The remaining circuit cards and assemblies are tested by the processor. If the processor detects a fault, a signal is sent, causing the four indicators located on the front of the IMU to set in the proper combination to indicate the faulty card. The control indicator also receives a signal, setting the FAULT IMU indicator.

ALARM RELAYS.— A circuit card in the control power supply contains alarm summary logic for the BITE circuits. The alarm summary logic receives hard-wired BITE fault signals, alarm signals from faults detected by the processor, and alarm signals from the transformer rectifier via the control monitor. Any one or all of these signals will cause the alarm summary logic to send a signal to the control indicator, lighting the ALARM indicator, and an alarm relay on signal to the normally energized alarm relay. The alarm relay on signal causes the alarm relay to reenergize, completing the circuit for the malfunction summary alarm.

When the 3-phase power input is lost or exceeds tolerances, the control monitor switches the operation to battery power and sends out an alarm signal to the circuit card containing the alarm summary logic. The alarm summary logic sends a signal to the on-battery relay, which is normally de-energized. When this relay energizes, it completes the circuit for the on-battery alarm.

SECURING PROCEDURES

To secure the AN/WSN-2 compass under normal conditions, refer to figure 4-44 and perform the following steps:

1. Set the MODE control to the POWER OFF position.
2. Place the SYN REF switch to the OFF position.
3. Place the PWR switch to the OFF position.

To secure the compass under emergency conditions, refer to figure 4-44 and perform the following steps:

1. Place the PWR switch to the OFF position.
2. Place the SYN REF switch to the OFF position.
3. Set the MODE control to the POWER OFF position.

WATCH STANDING

The AN/WSN-2 operates unattended after a mode of operation has been selected and the automatic alignment sequence is completed. Audible and visual extension alarms will alert watch standers at various locations upon loss of normal power to the compass or if a malfunction exists within the compass.

SHIP'S COURSE INDICATORS (REPEATERS)

The trend to transistorized equipment has resulted in gyro installations being equipped with highly reliable transistorized ship's course indicators, or repeaters as they are commonly called. Ship's course indicators are used to visually display gyrocompass heading data for navigational purposes. They are installed at the helm, on the bridge wings, in the after steering room, and other remote locations aboard ship. Figure 4-51 is a breakdown of the various types of ship's course indicators used with gyrocompass systems.

The several variations of mounting dials, data transmission systems, and power requirements for ship's course indicators will be discussed in the following paragraphs.

Units may be designated as single-speed or 1 and 36 speed. Single-speed units contain one synchro control transformer in larger units and one synchro receiver in miniature units. The 1 and 36 speed units provide greater accuracy in reading and contain two control transformers. In the 1 and 36 speed, coarse control is 1 speed and fine control is 36 speed.

Units also may be divided by power requirements with some using 60 Hz and others using 400 Hz.

An additional feature is the low noise and normal (nonlow) noise characteristic of several repeaters. In the nonlow noise variety, the servo and dial assembly mount directly to the cast housing. In the low noise variety, the mounting is on vibration isolators similar to rubber shock mounts.

Figure 4-52 shows a type E repeater minus terminal block and cord. The inner dial is single speed and the blocked out outer dial is 36 speed. These repeaters are generally located in enclosed spaces, such as the OOD's repeater on the bridge.

The basic block diagrams of the various repeaters are shown in figure 4-53. View A shows the type L repeater synchro drive. View B displays the type A servo drive single speed. In view C, types B, E, and F are depicted, and view D shows the G and H course-to-steer repeaters.

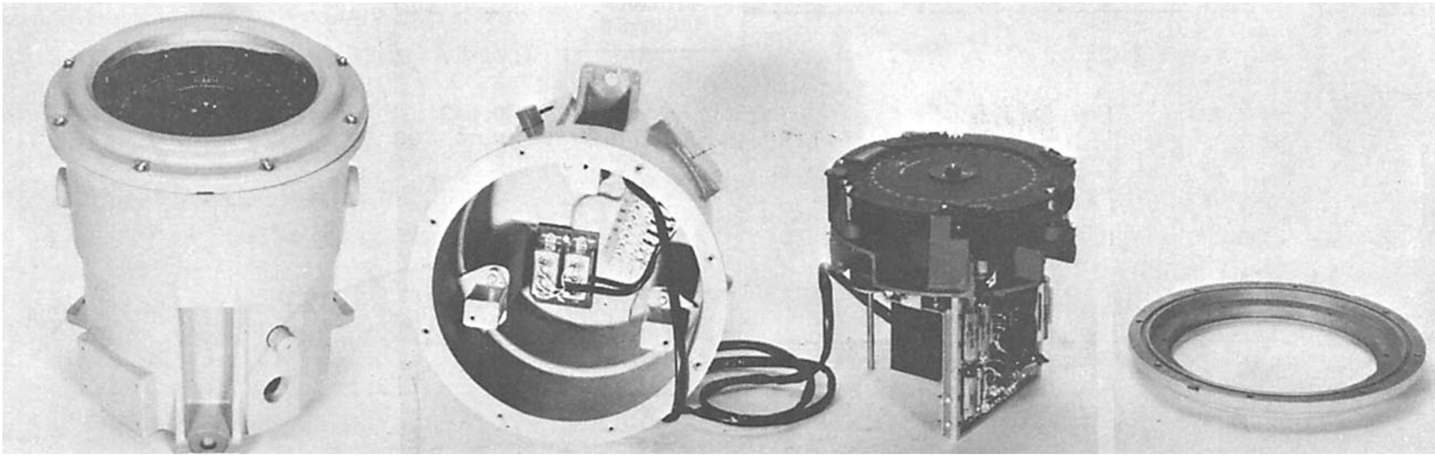
The operation of the components is standard; however, and explanation of the mixer and antistickoff voltage may be of assistance.

The 36X synchro control transformer determines the accuracy of the indicator, but because this synchro has 36 null positions for one revolution of the indicator dial, the 1X synchro sets the proper null. The two synchro rotors are connected in shunt through a mixing network consisting of pairs of diodes and two resistors. The mixing network performs three functions. First, it effectively opens the 1X synchro signal circuit whenever the indicator dial is within 2.5° of null. Second, it limits or attenuates the 36X synchro signal whenever the 36X synchro is more then ±2.5° from its null. Third, it keeps synchro loading to its minimum allowable level.

TYPE	FREQUENCY	SPEED	DRIVE	DIAL	MOUNT
A	400	1	Servo	Single	Bulkhead
B	400	1X + 36X	Servo	Single	Pelorus Bulkhead
E	400	1X + 36X	Servo	Dual	Bulkhead
F	400	1X±36X	Servo	Dual	Console
G*	60	1	Servo	Dual	Bulkhead
H*	60	1	Servo	Dual	Bulkhead
L	400	1	Synchro	Single	Console Bulkhead

*Used with a synchro driven course to steer inner dial input from sonar or other sources during specific tactical situations.

Figure 4-51.—Gyrocompass repeaters by letter designation.



40.129

Figure 4-52.—Type E ship's course indicator (designed for bulkhead mounting).

The use of the mixing network eliminates every false null except the one at the 180° point of the indicator dial. This null is eliminated by adding a 2.5-volt, 400-Hz, antistickoff voltage in series with the 1X synchro rotor voltage, and shifting the phase of the 1X synchro voltage by 2.5° to bring the indicator null back to a true reading. This procedure converts the 180° point to an unstable (or recentering) null. If the coarse (1X) and fine (36X) control transformers were installed (adjusted to the same electrical zero as the electrical zero position of the compass transmitters), there would be a position of the coarse control transformer shaft 180° out of correspondence with the compass transmitter, at which the rotor volt ages of both the coarse and fine control transformers would again both equal zero. Thus, the coarse synchro system provides two null points in a complete cycle. Regarding the coarse control transformer (1XCT), its null at the 180° point is an unstable null, because if the shaft were on either side of that point, by an infinitesimal angle, the servo would drive toward the correct null, 180° away. The fine synchro has 72 null positions or 36 times as many as the coarse synchro system. If only the fine control transformer (36XCT) were connected in the system, there would be 36 positions of the transmitter shaft that would produce a stable null error voltage. Only one of these 36 positions is desired, that position being the point where the 1XCT also provides a stable null.

The mixing network switches the fine error signal into the servoamplifier when the error is small (output of the coarse synchro is small) and introduces the coarse error signal to the amplifier when the error is large (output of the coarse synchro is large). The coarse error signal can be small enough at the 180° point to result in the tine error signal being fed into the servo, through the action of the mixing network. If only the 1X error voltage were applied at the 180° point, the servo would drive away from this false null; but, because the 36X voltage has control, it drives the servo toward this 180° point. The 36X error voltage (negative between 175° and 180°) tends to drive the servo to an increased angle (180°). The 36X voltage is positive between 180° and 185°, and tends to drive the servo to a decreased angle (180°), the same point. In other words, if this condition were tolerated, the servo would lock in at a false null.

To remove this condition (false null), an antistickoff voltage of 2.5 volts is obtained from a transformer in the amplifier unit and applied to the coarse error voltage. This voltage is applied either in phase or 180° out of phase with the 1X error voltage and is sufficient to shift the IX error signal null points 2.5°. The resultant voltage does not pass through the zero reference position of the 36XCT voltage. To restore the resultant voltage to the zero reference position, the 1XCT stator is shifted 2.5° in its housing. Thus, the resultant 1X error voltage is shifted a total of 5°, which corresponds to 180° rotation (36 x 1X) of the 36X synchro.

With antistickoff bias, the false null at the 180° point cannot be attained by virtue of the 36X or 1X error signal on either side of this point, both being of such polarity as to drive in the same direction to the real null at zero degrees. The 36X error signal drives 2.5° toward the correct null and then the mixing network switching to the 1X error signal, which drives to 2.5° of the zero degree null position.

As the 2.5° point is reached, the mixing circuit automatically shifts the amplifier input signal from the 1X synchro to the 36X synchro. This signal, with amplifier output and motor torque reacting accordingly, is reduced as the servo approaches null. The final null position is reached at the point of minimum 36X synchro

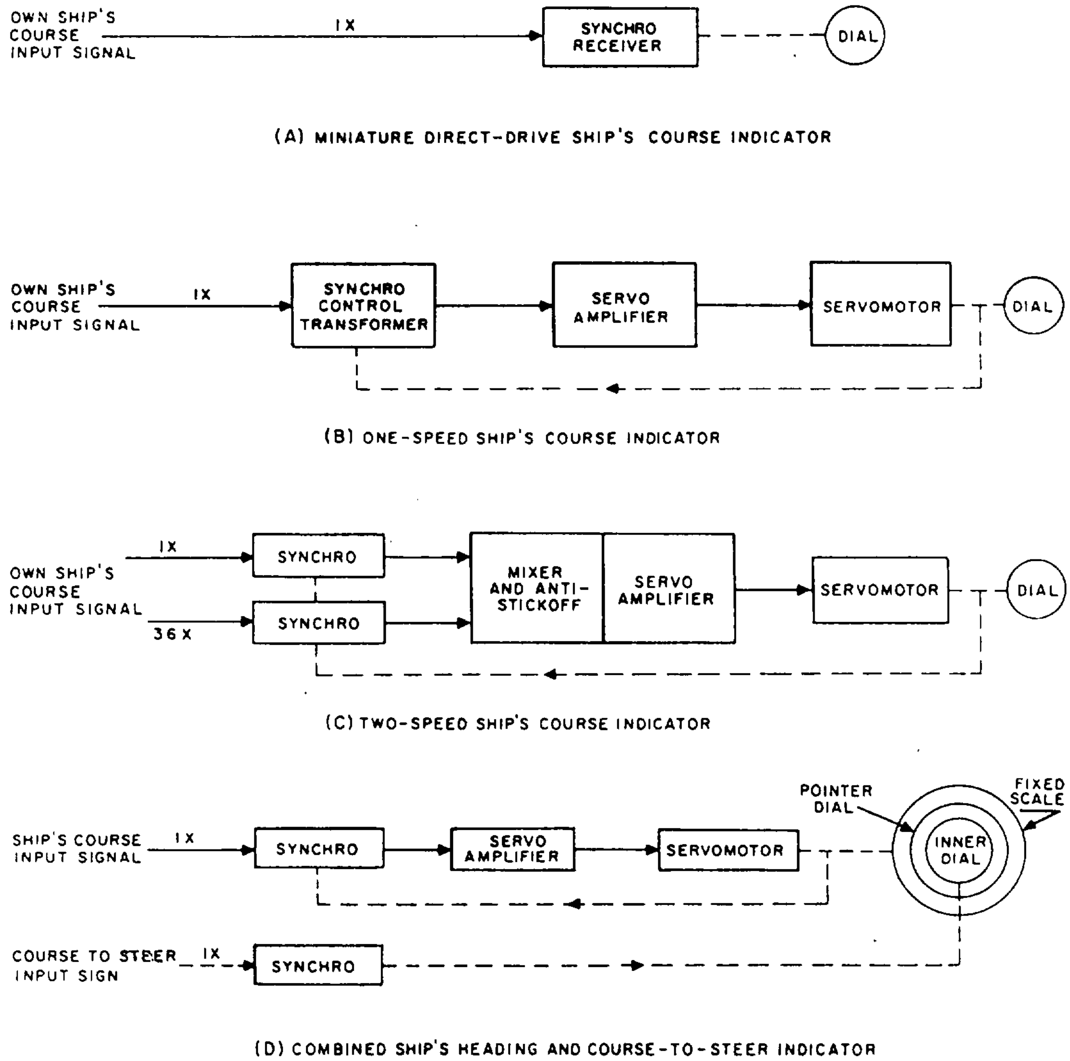


Figure 4-53.—Block diagram of ship's course indicators.

rotor voltage. Because thes synchro voltage is very low, the amplifier output and motor torque are reduced substantially to zero.

Mixing networks and antistickoff voltages are unnecessary in 1-speed systems. Although synchro voltage, and thus motor torque go to zero at the 180° point, this point is an unstable (decentering) null. If the servo approaches this false null with slight overshoot, the servo will not come to rest at the null. Instead, the servo will continue to rotate toward the true null, where it will come to final rest.

MAINTENANCE OF GYROCOMPASSES

Ships having the Planned Maintenance System (PMS) installed should perform gyrocompass maintenance requirements as indicated on the equipment maintenance requirement cards (MRCs). Such routine maintenance should not be recorded in the service record book. Repairs or replacement of parts resulting from such maintenance, however, should be recorded to aid those involved with future repairs to the gyrocompass.

The technical manual sent with the Mk 19 gyrocompass and the WSN-2 is laid out in such a manner as to greatly assist the troubleshooter. You should carefully study these technical manuals before starting any maintenance action.

Maintenance should not be undertaken by inexperienced personnel without close supervision of a qualified maintenance technician.

In the future, interior communications personnel can look forward to the use of lasers and fiber optic cables for navigation and communications.

RECORDS

The PMS of the 3-M Systems has cut the records and inspections of the gyrocompass to a minimum. *Naval Ships' Technical Manual,* chapter 252, no longer requires lengthy records to be kept on gyrocompass equipment; however, it specifically requires the record book that is sent with each compass to be scrupulously maintained.

The gyrocompass service record book is used to record important repair information (major part replacement, overhaul, and field change installation), providing a continuous repair history of each gyrocompass. Instructions for maintaining the record book are given in the front of the book.

The service record book remains with the master gyrocompass throughout its service life. Should the compass be removed from the ship, its service record book accompanies it.

SUMMARY

In this chapter, we have discussed basic gyroscopic principles and the making of the gyroscope into a gyrocompass. We have identified and discussed the major components of some of the most common gyrocompass systems installed on board Navy ships today and described the procedures for starting, standing watch on, and securing these gyrocompasses.

We have also described the purpose of the synchro signal amplifiers and ship's course indicators used with the various gyrocompass systems.

CHAPTER 5

SOUND-POWERED TELEPHONE SYSTEM

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

- *Describe the purpose of the sound-powered telephone system installed on Navy ships.*
- *Identify the sound-powered telephone circuits, as to type and classification.*
- *Describe the proper procedures for paralleling sound-powered telephone circuits.*
- *Describe the X40J casualty communication circuit.*
- *Describe the phone/distance and station-to-station lines used during replenishment at sea.*
- *Describe the preventive maintenance procedures for sound-powered telephone circuits.*
- *Identify the equipment* used with the *sound-powered telephone system, to include handsets, headset-chestsets, sound-powered amplifiers, amplifier control switches, circuit selector switches, soundproof booths, and the plotters transfer switchboard.*
- *Explain how to operate and maintain the equipment used with the sound-powered telephone system.*
- *Identify the call and signal circuits and associated equipment used with the sound-powered telephone system.*
- *Describe the AN/WTC-2(V) sound-powered telephone system, including identification and operation of the major units used with the system.*
- *Explain the purpose of voice tubes installed on Navy ships.*

INTRODUCTION

The sound-powered telephone system provides the most reliable means of voice communication within a ship. The sound-powered telephone system is used aboard ship for two-way voice communication between various sound-powered telephone stations. The system provides a rapid means of transmitting and receiving verbal orders and information. The system is easy to maintain and is not easily susceptible to damage during battle. The system includes sound-powered telephone circuits, sound-powered telephone equipment, and sound-powered call and signal circuits. As an IC Electrician third class, you will indoctrinate personnel in the uses and capabilities of the sound-powered telephone system. Ths chapter will be an aid in that indoctrination. Table 5-1 is a glossary of terms for the sound-powered telephone system. The *Sound-Powered Telephone Talkers Manual,* NAVEDTRA 14005-A, contains the proper operating procedures for sound-powered handsets and headset-chestsets.

Table 5-1.—Glossary of Terms

GLOSSARY OF TERMS

BUS—The common connection between a group of line cutout switches. It may be in a single section or divided; it maybe connected to a jack outlet or be free.

CIRCUIT—A quantity of telephone jackboxes connected by one or more lines, either directly or through switchboards and switchboxes, to provide a means of communication between personnel at various stations.

JACKBOX—A weatherproof enclosure mounted in any convenient location and connected to a sound-powered telephone line. Jackboxes can be single-gang, double-gang, or four-gang types. Gang is a term used for the number of jack outlets in the jackbox.

JACKPLUG—The plug connected to the end of the cable on a sound-powered telephone headset-chestset. When plugged into a jackbox, it connects the set to a sound-powered telephone circuit.

LINE—The smallest portion of a circuit that can be electrically isolated by operation of switches at a central point. For example, in the switchboard or switchbox types of circuits, a line is the pair of wires between the line cutout switch on a switchboard (or switchbox) and a telephone jackbox; in string circuits, a line is a pair of wires interconnecting the various jackboxes in the circuit.

PARALLELING—Cross connecting two or more sound-powered circuits.

STATION—The location of a jackbox where a sound-powered telephone operator mans a sound-powered telephone.

TIE LINE—A line between two switchboards, two switchboxes, or a switchboard and a switchbox. It connects two circuits and is terminated by a switch at each end.

TIE SWITCH—A switch at one end of a tie line, usually the end connected to an auxiliary circuit. It is normally open unless the ship's doctrine requires that it be closed.

TIE PLUS SWITCH—A normally closed switch at the opposite end of a tie line from the tie switch. It may be opened to clear a damaged circuit.

SOUND-POWERED TELEPHONE CIRCUITS

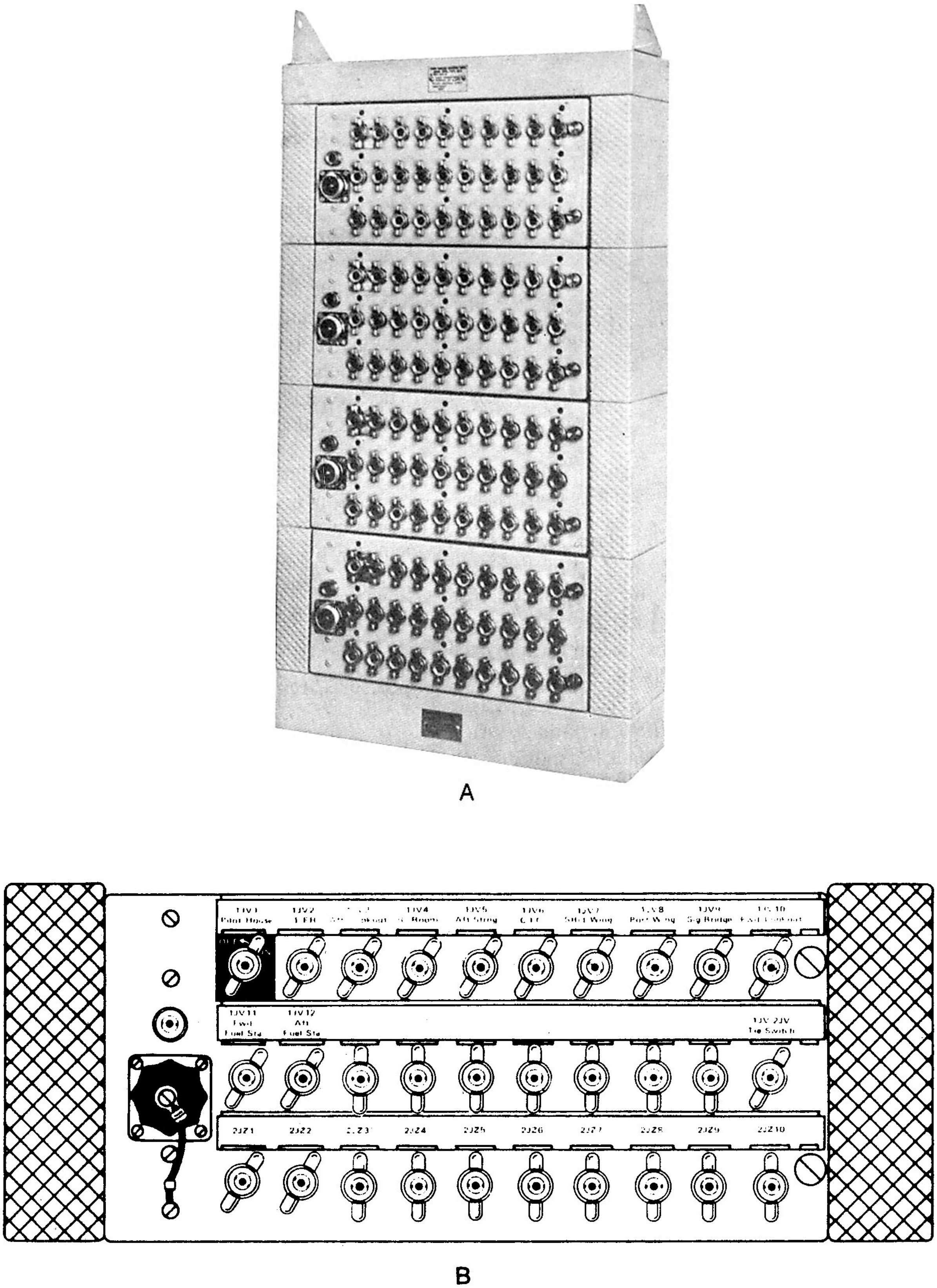
The sound-powered telephone system consists of individual sound-powered telephone circuits, each of which operates without any external source of electrical power. The number of particular circuits installed on each individual ship depends on the operational requirements of the ship.

TYPES OF CIRCUITS

There are three types of sound-powered telephone circuits: switchboard, switchbox, and string.

Switchboard Circuit

A switchboard circuit originates from a sound-powered telephone switchboard. Figure 5-1, view A, is an illustration of a type IC/A sound-powered telephone switchboard. Figure 5-1, view B, shows a



27.291.1

Figure 5-1.—Type IC/A sound-powered telephone switchboard.

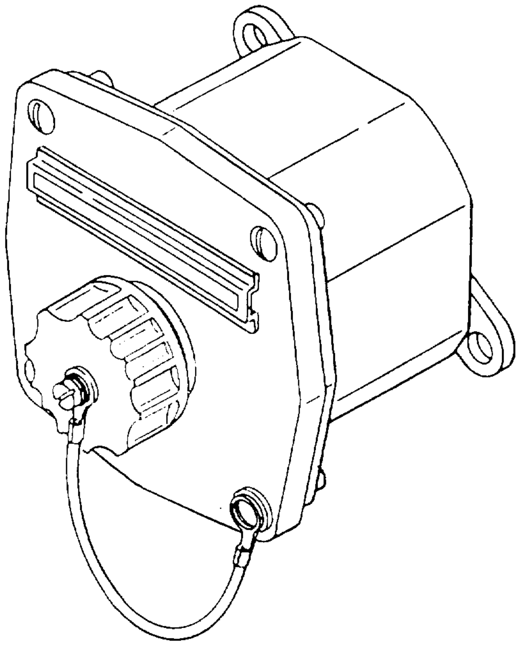


Figure 5-2.—Single-gang sound-powered telephone jackbox.

section from the sound-powered telephone switchboard. Each telephone station jackbox (fig. 5-2) in the circuit is connected to a switchjack on the switchboard. The switchjack (fig. 5-3) is a combination line cutout switch and telephone jack. The line cutout switch portion of the switchjack either connects or disconnects a telephone station jackbox from its circuit. The jack portion of the switchjack either parallels the telephone station associated with a particular switchjack to another circuit or parallels two entire circuits. This method of paralleling is accomplished by a patching cord. A patching cord is a short length of portable cord having a jackplug at each end. The lines and tie switches are also installed to allow paralleling with circuits on other switchboards or switchboxes.

Most large combatant ships have several sound-powered telephone switchboards installed in different centrally located and protected control stations. Each switchboard facilitates and controls several sound-powered telephone circuits.

Switchbox Circuit

A switchbox circuit originates from a sound-powered switchbox. Figure 5-4 is an illustration of a type A-17A sound-powered telephone switchbox. Each telephone station jackbox in the circuit connects to a line cutout switch in the switchbox. The line cutout switch either connects or disconnects an individual telephone station jackbox from its circuit. There are also tie lines and tie switches installed to allow paralleling with circuits in other switchboxes or switchboards.

Switchboxes contain either 10 or 20 switches and function primarily as small action cutout (ACO) switchboards. Switchboxes are normally located at the station having operational control over the circuit or circuits concerned. Usually, there is only one circuit in a switchbox.

String Circuit

A string circuit consists of a series of telephone station jackboxes connected in parallel to a common line. There are no line cutout switches provided for cutting out individual stations. However, some string circuits are connected to communication consoles, selector switches, and plotter transfer switchboards. These will be discussed later in this chapter.

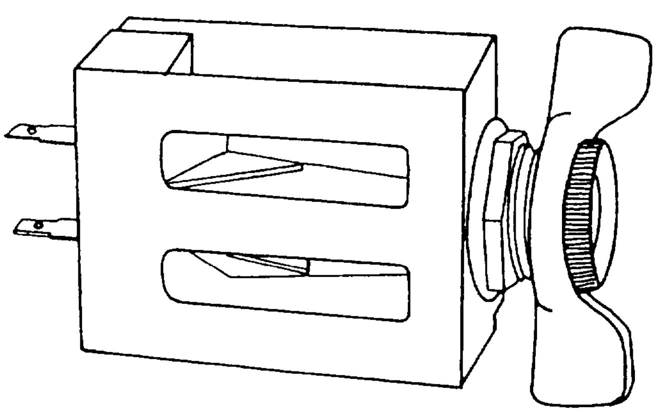


Figure 5-3.—A switchjack.

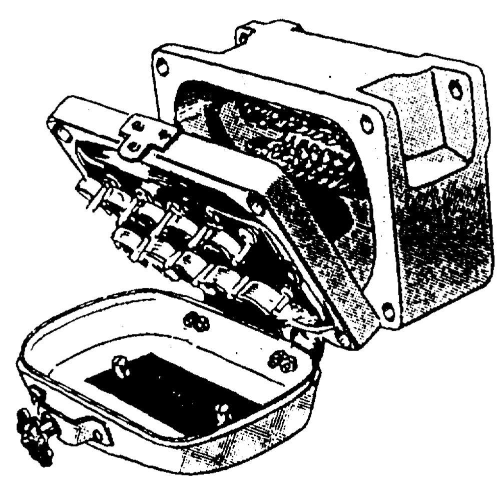


Figure 5-4—Sound-powered telephone switchbox.

CLASSIFICATION OF CIRCUITS

Sound-powered telephone circuits are classified to their usage. Circuits are classified as primary, auxiliary, or supplementary. Table 5-2 is a list of all sound-powered telephone circuits used on Navy ships.

Primary Circuits

Primary circuits provide communication for as primary control and operating functions associated with ship control, weapons control, aircraft control, engineering control, and damage control. Primary circuits are designated JA through JZ.

Table 5-2.—Sound-Powered Telephone Circuits

	Primary Circuits		Primary Circuits
Circuit	Title	Circuit	Title
JA	Captain' battle circuit	JR	Debarkation control circuit
JC	Weapon's control circuit	JS	Plotters' transfer switchboard circuit
10JC	Missile battery control circuit	1JS	CIC information circuit
JD	Target detectors circuit	2JS	NTDS coordinating circuit No. 1
JF	Flag officer's circuit	3JS	NTDS coordinating circuit No. 2
1JG	Aircraft control circuit	20JS1	Evaluated radar information circuit
2JG	Aircraft information circuit	20JS2	Evaluator's circuit
2JG1	Aircraft strike coordination circuit	20JS3	Radar control officer's circuit
2JG2	Aircraft strike requirement and reporting circuit	20JS4	Weapons liaison officer's circuit
2JG3	Aircraft information circuit CATTCC direct line	21JS	Surface search radar circuit
		22JS	Long range air search radar circuit
3JG	Aircraft service circuit	23JS	Medium range air search radar circuit
4JG1	Aviation fuel and vehicular control circuit	24JS	Range height finder radar circuit
4JG2	Aviation fueling circuit forward	25JS	AEW radar circuit
4JG3	Aviation fueling circuit aft	26JS	Radar information circuit
5JG1	Aviation ordnance circuit	31JS	Trank analyzer No. 1 air radar information check
5JG2	Aviation missile circuit		
6JG	Arresting gear and barricade control circuit	32JS	Trank analyzer No. 2 air radar information check
9JG	Aircraft handling circuit		
10JG	Airborne aircraft information	33JS	Trank analyzer No. 3 air radar information check
11JG	Optical landing system control circuit		
JH	Switchboard cross-connecting circuit	34JS	Trank analyzer No. 4 air radar information check
JL	Lookouts circuits		
JK	Double-purpose fuse circuit	35JS	Raid air radar information circuit
JM	Mine control circuit	36JS	Combat air patrol air radar information circuit
JN	Illumination control circuit	61JS	Sonar information circuit
JO	Switchboard operators' circuit	80JS	ECM plotter's circuit
2JP	Dual-purpose battery control circuit	81JS	EMC information circuit
4JP	Heavy machine gun control circuit	82JS	Supplementary radio circuit
5JP	Light machine gun control circuit	JT	Target designation control circuit
6JP	Torpedo control circuit	1JV	Maneuvering and docking circuit
8JP	ASW weapon control circuit	2JV	Engineer's circuit (engines)
9JP	Rocket battery control circuit	3JV	Engineer's circuit (boiler)
10JP	Guided missile launcher control circuit	4JV	Engineer's circuit (fuel and stability)
10JP1	Starboard launcher circuit	5JV	Engineer's circuit (electrical)
10JP2	Port launcher circuit	6JV	Ballast control circuit
11JP	FBM checkout and control circuit	11JV	Waste control circuit
JQ	Double-purpose sight setters circuit	JW	Ship control bearing circuit
		JX	Radio and signals circuit

Table 5-2.—Sound-Powered Telephone Circuits—Continued

Circuit	Title
	Primary Circuits—Continued
2JZ	Damage and stability control
3JZ	Main deck repair circuit
4JZ	Forward repair circuit
5JZ	After repair circuit
6JZ	Midship repair circuit
7JZ	Engineer's repair circuit
8JZ	Flight deck repair circuit
9JZ	Magazine sprinkling and ordnance repair circuit forward
10JZ	Magazine sprinkling and ordnance repair circuit aft
11JZ	Gallery deck and island repair circuit
	Auxiliary Circuits
XJA	Auxiliary captain's battle circuit
X1JG	Auxiliary aircraft control circuit
X1JV	Auxiliary maneuvering and docking circuit
XJX	Auxiliary radio and signal circuit
X2JZ	Auxiliary damage and stability control circuit
	Supplementary Circuits
X1J	Ship administration circuit
X2J	Leadsman and anchor control circuit
X3J	Engineer watch officer's circuit
X4J	Degaussing control circuit
X5J	Machinery room control circuit
X6J1	Electronic service circuit
X6J7	ECM service circuit
X7J	Radiosonde information circuit
X8J	Replenishment-at-sea circuit
X9J	Radar trainer circuit
	Supplementary Circuits—Continued
X10J	Cargo transfer control circuit
X10J1	Cargo transfer circuit–low decks
X10J10	Cargo transfer circuit–upper decks
X11J	Captain's and admiral's cruising circuit
X12J	Capstan control circuit
X13J	Aircraft crane control circuits
X14J	Missile handling and nuclear trunk crane circuit
X15J	SINS information circuit
X16J	Aircraft elevator circuit
X17J	5-inch ammunition hoist circuit
X18J	Machine gun ammunition hoist circuit
X19J	Missile component elevator circuit
X20J	Weapons elevator circuit
X21J	Catapult circuit
X22J	Catapult steam control circuit
X23J	Stores conveyor circuit
X24J	Cargo elevator circuit
X25J	Sonar service circuit
X26J	Jet engine test circuit
X28J	Dumbwaiter circuit
X29J	Timing and recording circuit
X34J	Alignment cart service circuit
X40J	Casualty communication circuit
X41J	Special weapons shop service circuit
X42J	Missile assembly and handling circuit
X43J	Weapons system service circuit
X44J	ASROC service circuit
X45J	Special weapons security circuit
X50J	Fog foam circuit
X61J	Nuclear support facilities operations and handling

Auxiliary Circuits

Auxiliary circuits duplicate certain principal primary circuits as an alternate means of communication in case of damage to the primary circuit. The wiring of the auxiliary circuits is separated as much as practicable from the wiring of the corresponding primary circuits to lessen the possibility of damage to both circuits. Auxiliary circuits are designated XJA through XJZ.

Supplementary Circuits

Supplementary circuits provide the means of communication for various subordinate control, operating, and service functions. Supplementary circuits are designated X1J through X61J and are normally string circuits.

PARALLELING OF CIRCUITS

When two or more circuits are tied together, the result is to parallel as many sound-powered telephones as there are manned stations.

All primary circuits are provided with a tie line between their respective switchboard or switchbox for cross-connection with their auxiliary circuits. The tie lines are fitted with a tie switch at one end and a tie + (tie plus) switch at the other end. The tie switch is normally open and is closed only to parallel two circuits. The tie + switch is normally closed and is opened only in the event of casualty, to disconnect the defective circuit or tie line.

When the patch cord method of paralleling is used, the following conditions may be obtained:

1. When the line cutout switches of both lines are open, the two lines will be connected together, but will not be tied in with any other station of either circuit. Figure 5-5 is an illustration of line cutout switches in the open and closed positions.

2. When the line cutout switch of only one line is closed, the two lines will be tied together and also connected to the other stations on the circuit of which the line cutout switch is closed.

3. When the line cutout switches of both lines are closed, all lines of the two circuits will be tied together.

Thus, by manipulating patch cords and individual line cutout switches, you can connect any pair of lines together and any line to any circuit or combination of circuits on the switchboard.

Circuits connected to switches on the communication consoles in the combat information center (CIC) may also be paralleled by the console operators. Since each circuit is routed to a number of plotter's positions, you must take care to avoid

In an extensive sound-powered telephone system, paralleling of circuits has both advantages and disadvantages. One advantage is that it allows a controlling station to extend supervision over several different stations, using fewer talkers. Another advantage is that if communications is lost to one of the

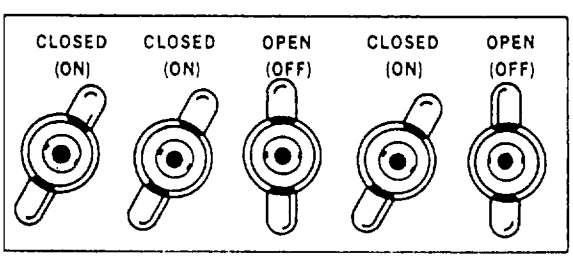


Figure 5-5.—Line cutout switches in the open and closed positions.

primary stations, the talker can easily reestablish communications with the control station by unplugging the headset from the primary jackbox and plugging it into the auxiliary jackbox.

One disadvantage of paralleling circuits is overloading transmitters. Each sound-powered telephone receiver unit consumes electrical energy when converting transmitted electrical signals to audible signals. As receiver units are added, the demand for electrical energy may exceed the capability of the transmitter unit, resulting in the transmitter becoming overloaded. An overload condition reduces the input electrical energy available to each receiver unit, with a corresponding reduction in receiver output volume. The reduced audio output may render the circuit ineffective. The number of receivers it takes to overload a circuit varies; therefore, the controlling station should be alert to garbled messages or frequent requests for repeats, indicating the circuit is overloaded.

A second disadvantage of paralleling circuits is that as the number of stations on a circuit increases, conversations may increase, resulting in confusion. This can be remedied by all stations exercising good circuit discipline.

Under normal operating conditions, circuits are usually paralleled to reduce the number of talkers required. As conditions of greater readiness are set, more talkers are assigned and fewer circuits are paralleled. Few, if any, primary circuits are paralleled under the highest condition of readiness.

CASUALTY COMMUNICATIONS

Circuit X40J is designated the casualty communication circuit. This supplementary string circuit provides a means of rigging emergency communication lines between vital stations after a casualty has occurred. This circuit applies to combatant ships and auxiliary ships, 200 feet and over in length, fitted with weapons.

Permanent vertical riser cables are installed between single telephone jackboxes located port and starboard in vital below-deck stations and corresponding four-gang jackboxes located port and starboard on the first weather deck directly above each below-deck station (hangar deck on aircraft carriers).

Each single jackbox installed in the below-deck stations contains a nameplate that indicates the circuit identification X40J. Below-deck stations include steering gear rooms, engine rooms, emergency generator rooms, central control stations, firerooms, auxiliary machinery rooms, and IC rooms.

The jackbox outlets in each four-gang jackbox are connected in parallel, and each box contains a nameplate that identifies the associated below-deck station and circuit identification X40J.

On aircraft carriers, four-gang jackboxes are installed port and starboard on the forward and after sides at each hangar division door. The respective forward and after jackboxes are permanently connected and are used to facilitate patching when the doors are closed.

Each repair party locker on the ship is equipped with four 200-foot lengths of type MRID-1 (commonly called salt and pepper) portable cable. Each cable has a telephone jackplug fitted at both ends and is stowed on a reel. Each repair locker also contains two sound-powered telephone headset-chestsets and eight double-gang jackboxes (with jackbox outlets connected in parallel).

Some ships have portable cables with jackbox outlets built into the cable ends. On these ships, the eight double-gang jackboxes are not provided in each repair locker.

If normal sound-powered telephone service is disrupted, the permanently installed jackboxes and risers, portable patching cables, jackboxes, and headset-chestsets maybe used to connect the casualty communication circuit over a wide variety of routes to suit any casualty condition that may occur.

PHONE/DISTANCE AND STATION-TO-STATION LINES

IC Electricians are responsible for maintaining the sound-powered telephone portion of the bridge-to-bridge phone/distance and station-to-station lines. The lines are made of 1 1/2-inch round, 3-strand, lightweight polypropylene. Each strand of the line has one electrical wire interwoven in it. Sound-powered telephone jackboxes are attached to both ends of each line; the boxes are labeled either BRIDGE-TO-BRIDGE or STA.-TO-STA.

The bridge-to-bridge phone/distance line is used between the delivery and receiving ships for ship-to-ship coordination during replenishment-at-sea operations. The line is made up and kept by the ship's deck division. Distance markers are attached to the line at 20-foot intervals. These markers consist of colored cloth squares for daytime use and red flashlights for nighttime use.

The station-to-station line is used for communications between the delivery and receiving cargo transfer stations on each ship. This line is also made up and kept by the ship's deck division. The line is identical to the bridge-to-bridge line, except it doesn't have any distance markers attached to it.

After the ship's deck division makes up a new line, the IC Electricians make the sound-powered telephone connections, which must be as secure as possible and watertight.

MAINTENANCE OF CIRCUITS

Preventive maintenance for sound-powered telephone circuits consists of routine tests, inspections, and cleaning, which should be conducted according to current PMS requirements. Cleanliness is essential to the proper operation of sound-powered equipment because of the low voltages and currents involved. Dirt and dust between closely spaced contacts in the sound-powered switchboards and switchboxes can cause cross talk.

When conducting insulation tests on sound-powered circuits, open all tie switches connected to the circuit. Close all line cutout switches on associated switchboards or switchboxes. Disconnect all sound-powered telephone headsets from the circuit. Be sure the push button on all handsets connected to the circuit are open. Remove all sound-powered telephone amplifiers associated with the circuit from their cases.

Insulation tests should be made using an approved megohmmeter. You should measure from each conductor to ground and between each pair of conductors. Each reading should be a minimum of 50,000 ohms of resistance; lower readings indicate a potential source of failure. Short cable runs should have a minimum resistance well above 50,000 ohms. A separate insulation test should be made for each circuit.

SOUND-POWERED TELEPHONE EQUIPMENT

In addition to switchboards, switchboxes, and jackboxes, sound-powered telephone equipment includes telephone handsets and headset-chestsets, telephone amplifiers, amplifier control switches, selector switches, soundproof booths, and a plotter's transfer switchboard.

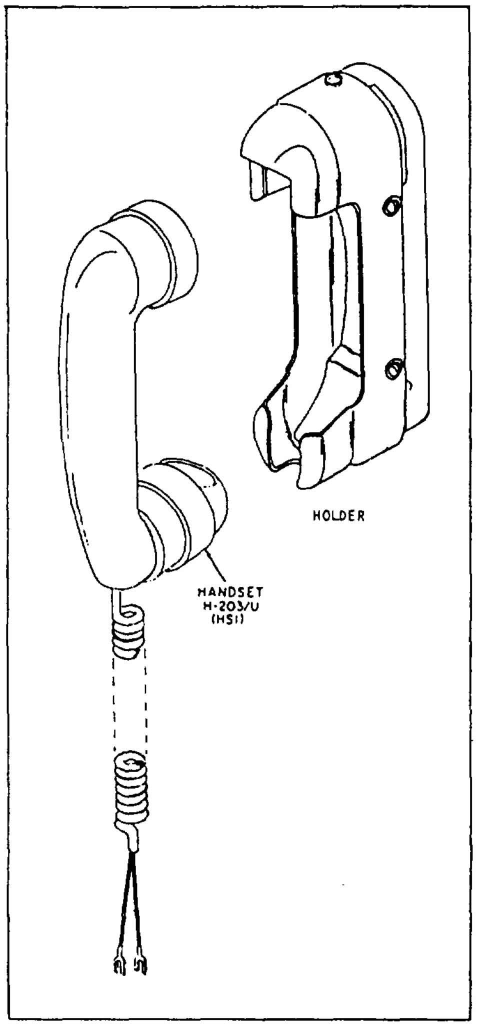


Figure 5-6.—The H-203/U sound-powered telephone handset and handset holder.

SOUND-POWERED TELEPHONE HANDSETS AND HEADSET-CHESTSETS

The sound-powered telephone system is comparatively reliable because external electrical power is not required. The sound waves produced by the transmitter's (talker's) voice is the only energy necessary for the reproduction of the voice at the receiver's telephone. The acoustic energy of the talker's voice is converted into electrical energy in the sound-powered telephone transmitter unit and transmitted, via connecting wires, to the receiving sound-powered telephone. The receiving sound-powered telephone receiver unit reconverts the electrical energy into acoustic energy. The types of sound-powered telephones used in the sound-powered system are the handset and the headset-chestset.

Sound-Powered Handsets

Sound-powered telephone handsets are designed for general use on a line with other handsets or headset-chestsets. Figure 5-6 is an illustration of a type H-203/U sound-powered telephone handset and handset holder. This type of handset has a nonkinking retractable cord. Another type of handset is the H-203/U (modified). This handset is identical to the type H-203/U except that the handset cord is straight and contains no less than two conductors in a single shield. The H-203/U (modified) is modified to meet security requirements of the ship's communication center.

Sound-powered handsets are hard-wired into sound-powered jackboxes, selector switches, and magneto call stations. For stowage of the handsets, handset holders are installed in enclosed spaces, and handset stowage cabinets are installed at stations exposed to the weather.

Figure 5-7 is a wiring diagram of a type H-203/U sound-powered telephone handset. The nonlocking, normally open, spring return, push switch, S1, disconnects the sound-powered transmitter and receiver units from the line in the open position, and connects the units to the line in the closed (depressed) position.

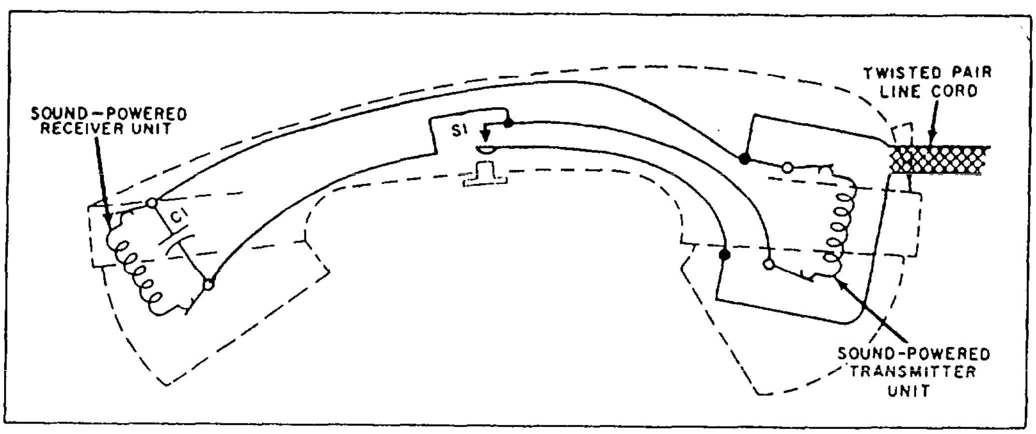


Figure 5-7.—Wiring diagram of the H-203/U sound-powered telephone handset.

Capacitor C1 is connected in parallel with the sound-powered units for tone compensation. When using the sound-powered handset, switch S1 must be depressed for both transmitting and receiving.

SOUND-POWERED UNITS.— The sound-powered transmitter (microphone) and receiver units in a sound-powered handset are identical and interchangeable. As illustrated in figure 5-8, views A, B, and C, a unit consists of two permanent magnets, two pole pieces, an armature, a driving rod, a diaphragm, and a coil. The armature is located between four pole tips, one pair at each end of the armature. The spacing between the pole tips at each end is such that an air space remains after the armature is inserted between them. This air space has an intense magnetic field, supplied by the two magnets that are held in contact with the pole tips.

The armature is clamped rigidly at one end near one of the pairs of poles and is connected to the other end to the diaphragm by the drive rod. Therefore, any movement of the diaphragm causes the free end of the armature to move toward one of the pole pieces. The armature passes through the exact center of a coil of wire that is placed between the pole pieces in the magnetic field.

Principles of Operation of the Transmitter Unit.— Sound waves are vibrations that cause compressions and rarefaction in the atmosphere in which they travel. In sound-powered telephones, the sound waves created by a speaker's voice cause the diaphragm in the transmitter unit to vibrate in unison with the sound wave vibrations. Figure 5-8, view A, shows the armature of a transmitter unit when there are no sound waves striking the diaphragm. Note that the armature is centered between the pole pieces with the magnetic lines of force passing from the north to the south pole and that there are no lines of force passing lengthwise through the armature.

Figure 5-8, views B and C, show sound waves striking the diaphragm and causing the diaphragm to vibrate. The vibrations are impressed upon the armature by the drive rod. During the compression part of the wave (fig. 5-8, view B) this action causes the armature to bend and reduce the air gap at the upper south pole. The reduction of the air gap decreases the reluctance between the upper south pole and the armature, while increasing the reluctance between the armature and the upper north pole. This action reduces the lines of force that travel between the two upper pole pieces. There is no large change in the reluctance at the lower poles; however, the armature has less reluctance than the lower air gap and a large number of magnetic lines of force will follow the armature to the upper south pole.

When the sound wave rarefaction reaches the diaphragm (fig. 5-8, view C), it recoils, causing the

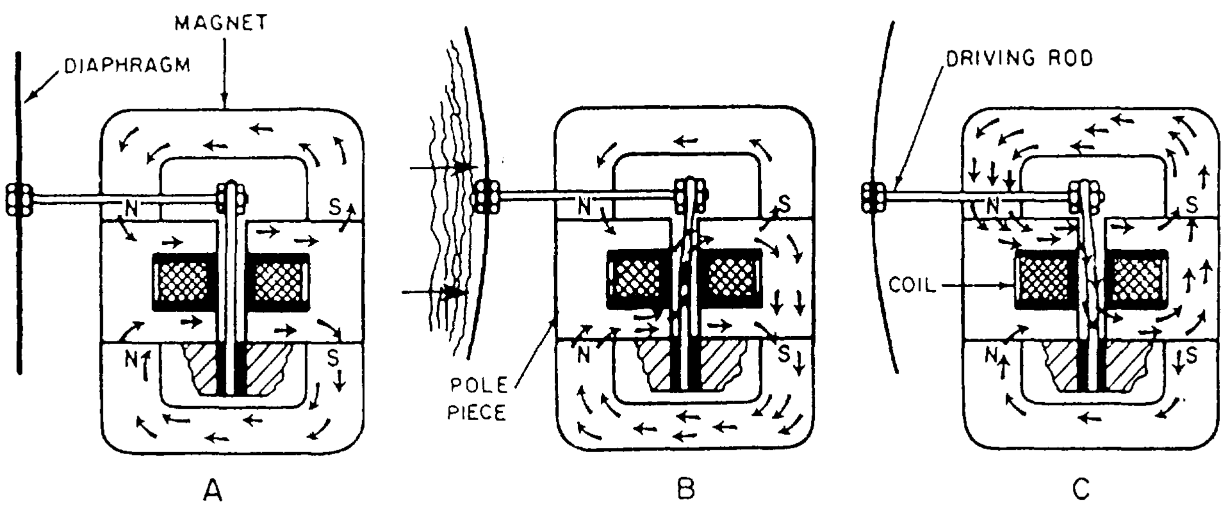


Figure 5-8.—Sound-powered transmitter receiver unit.

armature to bend in the opposite direction. This action reduces the air gap between the armature and the north pole. The reluctance between the armature and the upper north pole is decreased and the lines of force are reestablished through the armature, this time in the opposite direction.

As the sound waves strike the diaphragm, they cause the diaphragm to vibrate back and forth. The armature bends first to one side and then to the other, causing an alternating polarizing flux to pass through it, first in one direction and then the other. These lines of force passing through the armature will vary in strength and direction, depending upon the vibrations of the diaphragm. This action induces an electromotive force (emf) of varying direction and magnitude; that is, an alternating voltage in the coil. This alternating voltage has a frequency and waveform of the sound wave striking the diaphragm.

Principles of Operation of the Receiver Unit.— The sound-powered receiver unit reverses the transmission process. The alternating voltage generated in a transmitter unit is impressed upon the receiver coil, which surrounds the armature of the receiver unit. The resultant current through the coil magnetizes the armature with alternating polarity. An induced voltage in the coil of the transmitter unit (fig. 5-9, view A) causes a current to flow in the coil of the receiver unit (fig. 5-9, vie w B), magnetizing the free end of the armature arbitrarily with north polarity. The free end of the armature is repelled by the north pole and attracted by the south pole. As the direction of the current in the receiver reverses, the polarity of the armature reverses. The position of the armature in the air gap reverses, forcing the diaphragm inward. The diaphragm of the receiver unit vibrates in unison with the diaphragm of the transmitter unit and generates corresponding sound waves in the receiver unit.

LOADING HANDSET.— Handsets are designed to give maximum operating efficiency when used in a 1-to-1 ratio. The number of handsets operating in parallel should in no case exceed four. Where more than four are deemed necessary from an operational standpoint, the communication should be by sound-powered headset-chestsets. To maintain the overall efficiency of the circuit, handset buttons should not be taped down for convenience, as this may overload the lines. When using the handset, you should speak in a loud, clear voice. The power of the transmitter is generated by the voice, and while shouting is not necessary, the louder the speech, the louder the message is heard in the distant handset. When a handset is not in use, it should be stowed in its holder or stowage cabinet.

Sound-Powered Headset-ChestSets

Sound-powered headset-chestsets are designed for general use and for use with sound-powered telephone

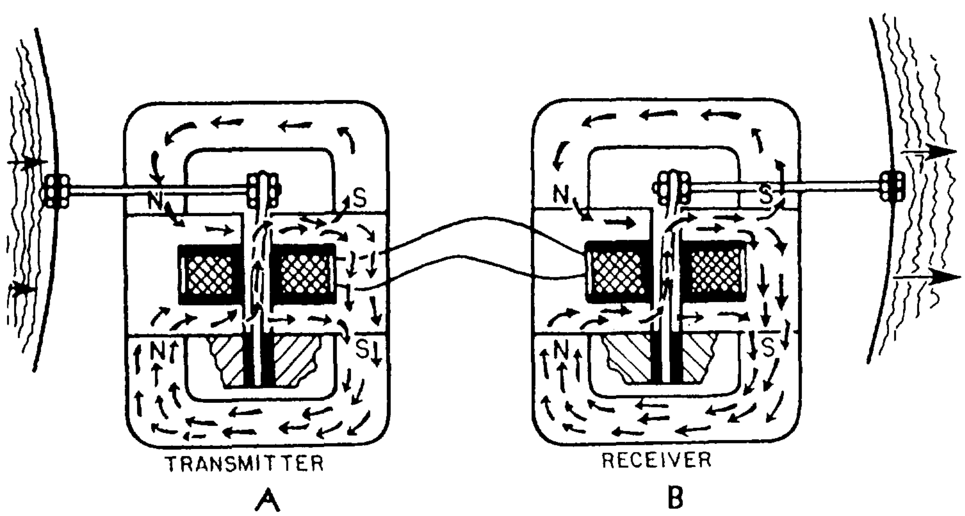


Figure 5-9.—Operation of sound-powered units.

amplifiers. Figure 5-10 is an illustration of a type H-200/U sound-powered telephone headset-chestset. This headset-chestset consists of two sound-powered receiver units with protective shells and ear cushions, one sound-powered transmitter unit with protective shell and a push switch, one mouthpiece, one chestplate assembly with junction box provided with capacitors and terminal facilities, one headband assembly and neck strap, and one cord assembly and plug. The receivers are mounted on the headband; the transmitter is mounted on the chestplate.

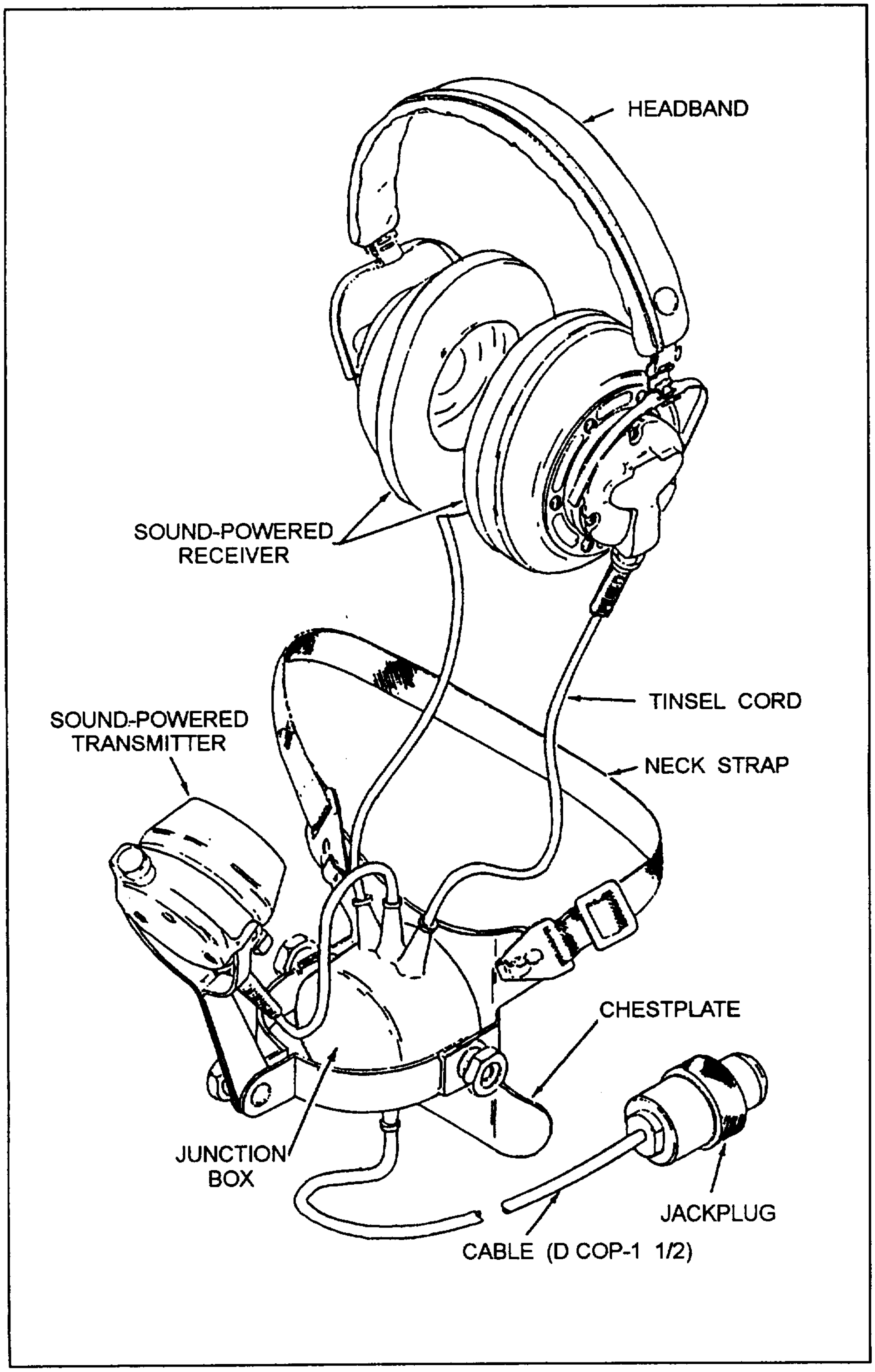


Figure 5-10.—The H-200/U sound-powered telephone headset-chestset.

Figure 5-11 is a wiring diagram of a type H-200/U sound-powered telephone headset-chestset. Closing the press-to-talk switch, S1, connects the sound-powered transmitter unit across the line. The receiver units are permanently connected across the line when the set is plugged in.

Capacitor C1 is in the circuit to prevent the flow of direct current through the receiver units when the set is used on the output side of a sound-powered telephone amplifier. When the set is used on the output side of the amplifier, a small dc voltage is placed across the set to form an amplifier squelching circuit to avoid acoustical feedback when the local set is transmitting. When the press-to-talk switch, S1, is depressed, direct current flows through the transmitter unit, causing a relay in the amplifier to operate and activate the squelching circuit.

Capacitor C2 provides for power-factor correction and improves the acoustical quality of the set.

The H-200/U can also be modified to meet security requirements for use in the ship's communication center. The headset-chestset cord must contain not less than two conductors in a single shield.

There are two other types of headset-chestsets used with the sound-powered telephone system. They are the H-201/U and the H-202/U.

The H-201/U is designed for use by plotters and console operators. This set features a transmitter suspended from the headband on an adjustable boom. The normally open, spring-loaded, press-to-talk switch, S1, is in a junction box clipped to the talker's belt.

The H-202/U is a specially designed set for use in high noise level areas. The receiver units are housed in noise-attenuating shells consisting of plastic caps lined with sound-absorbing material.

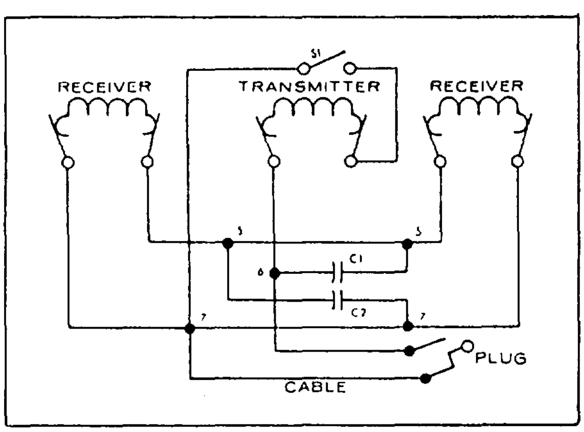


Figure 5-11.—Simplified sound-powered telephone headset-chestset schematic.

SOUND-POWERED UNITS.— The sound-powered transmitter and receiver units used in sound-powered telephone headset-chestsets are not interchangeable. The units differ physically; however, the principle of operation is the same for both.

Sound-powered telephone headset-chestset receiver units will transmit as well as receive. In the event the transmitter becomes defective, and the set cannot be repaired at once, communication can still be maintained. Remove either one of the receiving units from the headband and use it as a transmitter. Since the receivers are connected in parallel, either one can be used as the transmitter.

HANDLING HEADSET-CHESTSETS.— Sound-powered telephone headset-chestsets should be handled with care so they will be working properly in the event of an emergency. When not in use they should be correctly made up and stowed in their proper place.

The sets are made as waterproof as possible, but they should not be exposed unnecessarily to the weather. The cords should not be dragged over sharp edges, pulled too hard, or allowed to kink. When unplugging the cord from a jack, always pull on the body of the plug and never on the cord. If it becomes necessary to remove the set from the talker's head, hang the set by the headband and neck strap, and never by the connecting wires.

DONNING HEADSET-CHESTSETS.— When donning the headset-chestset, you should use the following procedure:

1. Remove the set from the stowage hook or stowage box.

2. Hold the set and coiled cord in one hand.

3. Unhook the neck strap and unwind the coiled cord. Do not allow the set to dangle by its connecting wires; this could cause open leads.

4. Put the neck strap around the neck and secure it to the chestplate.

5. Put on the receivers and adjust the ear cushions for maximum comfort and exclusion of noise.

6. Straighten out any kinks in the connecting wires.

7. Test the headset for satisfactory operation by blowing into the transmitter with S1 depressed. A hissing noise should be heard in both receivers.

8. Remove the jack cover and connect the plug to the jack.

LOADING HEADSET-CHESTSETS.— Sound-powered telephone headset-chestsets are designed to operate with 10 sets in parallel without any noticeable effect in response. However, it is possible to parallel up to 20 sets before overall line level response is considered critical. To maintain the overall efficiency of the circuit, do not tape down the transmitter button for convenience, as this may overload the circuit. When using the headset-chestset, hold the press-to-talk switch down firmly to ensure good contact, and talk directly into the transmitter. When listening, be sure to release the press-to-talk switch to eliminate the pickup of extraneous sounds and also the loss in receiver signal strength due to the low impedance transmitter shunted across the line.

REMOVING HEADSET-CHESTSETS.— When removing a sound-powered telephone headset-chestset, you should use the following proceedure:

1. Remove the headband and hang it over the yoke of the transmitter.

2. Remove the plug from the jackbox and replace the jack cover on the jackbox to keep out moisture and dirt.

3. Lay the cord out on the deck and remove any kinks.

4. Coil up the cord, starting from the end that attaches to the chestplate. Coil with the right hand, making the loops in a clockwise direction. The loops should be about 10 inches across.

5. After the cord is coiled, remove the headband from the transmitter yoke and hold the headband in the same hand with the cord.

6. Fold the transmitter yoke flat so that the mouthpiece lays flush against the chestplate connection box, using care not to pinch the transmitter cord.

7. Hold the headband and cord in the left hand and unhook one end of the neck strap from the chestplate.

8. Bring the top of the chestplate level with the headband and cord. Secure the chestplate in this position by winding the neck strap around the headband and coiled cord just enough times so that there will be a short end left over. Twist this end once and refasten it to the chestplate. The set is now made up and ready for stowing, Figure 5-12 shows a properly made up sound-powered telephone headset-chestset.

STOWING HEADSET-CHESTSETS.— In enclosed spaces, you should stow headset-chestsets on hooks. In machinery spaces and on weather decks, you should stow these sets in stowage boxes, which are designed for stowing one set or up to six sets.

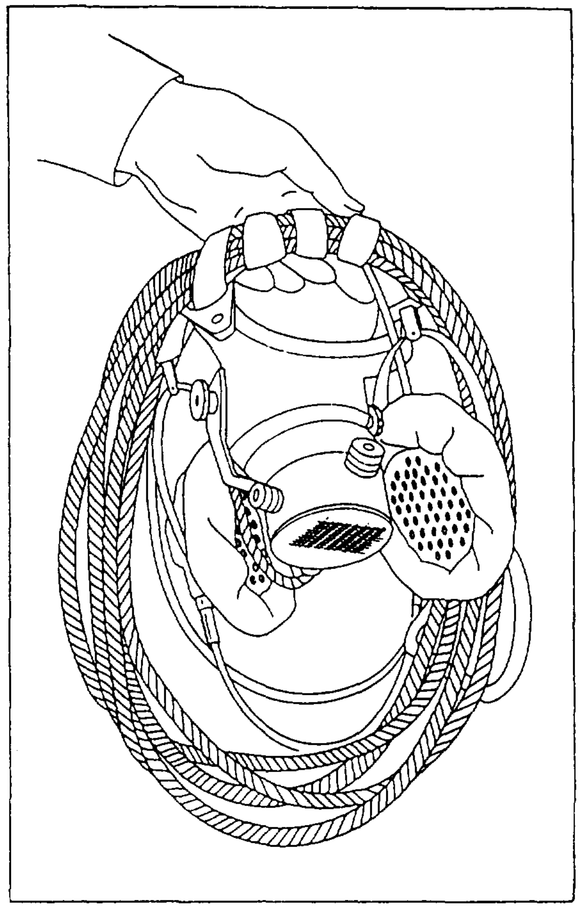


Figure 5-12.—A properly made-up sound-powered telephone headset-chestset.

A properly made-up set should fit into its stowage box without forcing. Never allow a loose cord to hang out of the box because it maybe damaged when the lid is closed. Never use the stowage box for storing cleaning gear or tools because rags give off moisture and soap powder gives off fumes that will cause the aluminum diaphragms to rapidly oxidize. Tools and other loose gear may damage the set(s) or may prevent you from getting a set out quickly in an emergency situation.

Sound-Powered Telephone Maintenance

As an IC Electrician, you will be required to service sound-powered telephones. Because a great deal of time is devoted to the repair of these sets, you should become thoroughly familiar with the proper methods of testing and repairing them. Many of the larger ships in the fleet have a telephone shop devoted entirely to the repair of sound-powered telephones.

Sound-powered handsets are usually repaired on location because they are permanently connected. When trouble develops in a sound-powered headset-chestset, the usual procedure is for the operator to bring it to the IC shop and exchange it for a good one. This procedure provides each station with properly operating sets at all times. The IC shop should maintain a log of all sets turned in; this will aid in locating faulty circuits or identifying operators who continually abuse their sets.

PRECAUTIONS.— When repairing sound-powered telephones, you should observe the following precautions:

- Do not repair telephones on a dirty workbench. The magnets in the units may attract iron filings, which are difficult to remove.
- Before disassembling a set, make a wiring diagram showing the color coding, polarity, or terminal numbers of the lead connections.
- Never alter the internal wiring of sets.
- Always replace parts exactly as they were before disassembly.

INSPECTION.— You should make a routine inspection of sets before you begin to repair the sets to determine whether you should replace physically defective parts. Many troubles may be located by inspecting the set for damaged cord or insulation; cord pulled out of units; loose units; defective or broken pushbuttons; and broken or damaged parts, such as unit covers, neck strap, chestplate, junction box, plug, and headband.

TRANSMITTER AND RECEIVER UNITS.— Transmitter and receiver units are not repairable. If these units become defective, they must be replaced. Both of these items are standard stock items.

OPEN AND SHORT CIRCUITS.— When testing the units for open and short circuits, you should use a low-voltage ohmmeter to avoid damage to the sound-powered transmitter and receiving units. Continuity tests may be made from the chestplate junction box on sound-powered headset-chestsets. Figure 5-13 is an illustration of the transmitter circuit of a sound-powered telephone headset-chestset. Figure 5-14 is an illustration of the receiver circuits. When testing the plug cable or tinsel cords of a sound-powered headset-chestset, you should disconnect them from the junction box. The normal dc resistances of the sound-powered transmitter and receiver units are 10 ohms and 62 ohms respectively. If the plug cable and tinsel cords test out satisfactorily, then you should check the capacitors.

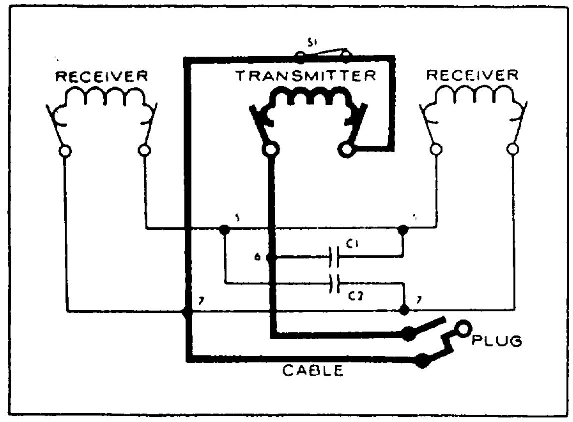


Figure 5-13.—Sound-powered telephone head set-chestset transmitter circuit.

A short circuit in a single sound-powered transmitter or receiver unit will render an entire circuit inoperative because all sound-powered telephones on the circuit are connected in parallel. Operation of

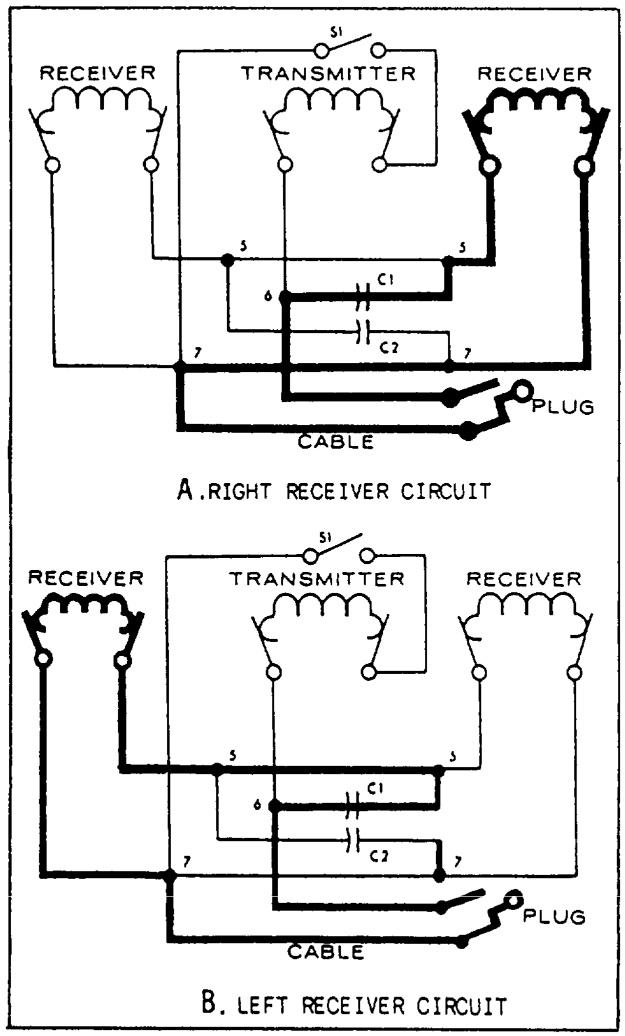


Figure 5-14.—Sound-powwed telephone headset-chestset recelver circuits.

switchboard or switchbox line cutout switches will allow isolation of a faulty unit. For string circuits, you should disconnect each set in sequence to isolate the faulty unit.

LOSS OF SENSITIVITY.— Loss of sensitivity, or weakening of the transmission sound, is a gradual process and seldom is reported until the set becomes practically inoperative. When a sound-powered telephone is in good condition electrically yet the sound is weak you should replace the transmitter unit. If this procedure does not remedy the trouble, then you should replace the receiver units.

To test a headset for loss of sensitivity, you should depress the talk switch and blow into the transmitter. If the set is operating properly, you will hear a hissing noise in the receiver units. You should listen to one receiver unit and then the other. In most cases, the loss in sensitivity is in the transmitter unit and might be caused by a displacement of the armature from the exact center of the air gap between the pole pieces.

To test a handset for loss of sensitivity, you should blow air into the transmitter. It is not necessary to press the talk switch because the transmitter and receiver are permanently connected in parallel. If no sound is heard, either the transmitter or the receiver is defective. The easiest method to determine which unit is defective is to have someone talk into another phone on the circuit while you listen to both the transmitter and receiver of the handset. If the talker's voice is heard on one of the units but not the other, you should replace the unit on which the voice is not heard because it is defective. If the talker's voice cannot be heard on either unit, and the telephone circuit being used is known to be good, the fault may be traced to the line cord, switch, or internal handset circuits.

REPLACING CORDS.— When replacing cords, you should always use prepared cords, if possible. Handset cords fitted with terminals at both ends are available through standard stock. Tinsel cord cut to the proper lengths and fitted with terminals for use with the various types of headset-chestset transmitter and receiver units are also standard stock items. DCOP 1 1/2 cord is used between the junction box and the plug on a sound-powered headset-chestset.

Replacing Handset Cords.— To replace the cord on a sound-powered handset, you should use the following procedure:

1. Remove the faulty cord by unscrewing the bushing and disconnecting the wires from the terminals.
2. Place the threaded bushing, washer, and grommet on the new cord.
3. Insert the cord into the handset and connect the wires to the terminals.
4. Screw the bushing into the handset tightly to secure the cable.
5. Test the set for proper operation.

Replacing Tinsel Cords.— To replace a tinsel cord on a sound-powered telephone headset-chestset, you should use the following procedure:

1. Open each unit connected to the cord that is to be replaced.
2. Before disconnecting the cord, make a diagram showing the color coding of the wires.
3. Disconnect both ends of the cord.
4. Remove the screw that holds the tie cord, or untie the cord if it is secured to an eyelet.
5. Unscrew the entrance bushing, if provided, and pull the cord through the port.
6. Place the threaded entrance bushing, metal washer, and rubber gasket on the new cord and insert the cord into the entrance port. The cord should be long enough to allow slack after it is connected.
7. Secure the tie cord so that it takes all the strain off the connections; otherwise the wires might be pulled from their terminals.
8. Connect the wires to the terminals.
9. Screw the entrance bushing on the entrance port, drawing the bushing up tightly to secure the cable and to seal the port.
10. Close the unit after all connections have been visually checked.
11. Test the set for proper operation.

If prepared cords are not available for repairing headset-chestsets, you can make them from bulk tinsel cord using the following procedure:

1. Strip about 2 inches of the outer layer of insulation from one end of the cord.

2. Remove about one-fourth of an inch of insulation from the ends of the conductors, exercising caution not to damage the tinsel wire.

3. Wind a single layer of 32-gauge tinned copper wire over the tinsel wire, and extend the tinned copper wire about one-eighth of an inch over the rubber insulation.

4. Dip these whipped conductors into melted solder and flatten them slightly when they are cool.

5. Solder the whipped conductor to a lug or cord tip, as required.

Replacing DCOP1 1/2 Cord.— To replace the cord between the junction box and the plug on a sound-powered headset-chestset, you should use the following procedure:

1. Prepare one end of the cord for use in the junction box.

2. Follow steps 1 through 10 for tinsel cord replacement for the junction box end of the cord.

3. Prepare the cord for use with the plug end.

4. Place the threaded bushing, washers, and rubber grommet on the plug end of the cord.

5. Insert the cord into the insulated sleeve and solder the wires to the connector strips.

6. Insert the insulated sleeve, grommet, and washers into the plug, and screw the bushing into the plug, drawing up tightly to secure the cable and to seal the plug.

7. Test the set for proper operation.

SOUND-POWERED TELEPHONE AMPLIFIERS

In high noise level areas it is often difficult, if not impossible, to hear conversations, even over the best maintained sound-powered telephone circuits. Thus, the sound-powered telephone amplifier was developed to assist communications in these vital areas. Sound-powered telephone amplifiers are installed in machinery rooms, gun mounts, missile checkout areas, flight and hangar decks, helicopter landing platforms, and other large noisy spaces. They are also installed in spaces where it is desirable to monitor incoming signals via a loudspeaker, without the use of a sound-powered telephone.

Sound-powered telephone amplifiers amplify one-way communications in a two-way sound-powered telephone system using existing sound-powered headset-chestsets; that is, amplify the voice to the high noise level area but not the voice from it. The amplifiers accept one incoming circuit for amplification and are capable of transmitting the amplified signal to as many as six headset-chest sets and two loudspeakers.

Sound-Powered Amplifier AM-2210/WTC

The transistorized AM-2210/WTC sound powered amplifier (fig. 5-15) is one of the most common types presently in wide use throughout the fleet and is the one that will be discussed in this training manual. Electrically, the unit consists of an audio amplifier, a switching circuit, and a power supply. The incorporation of transistors in the audio and switching circuits and silicon junction diodes in the power supply creates a highly reliable static condition.

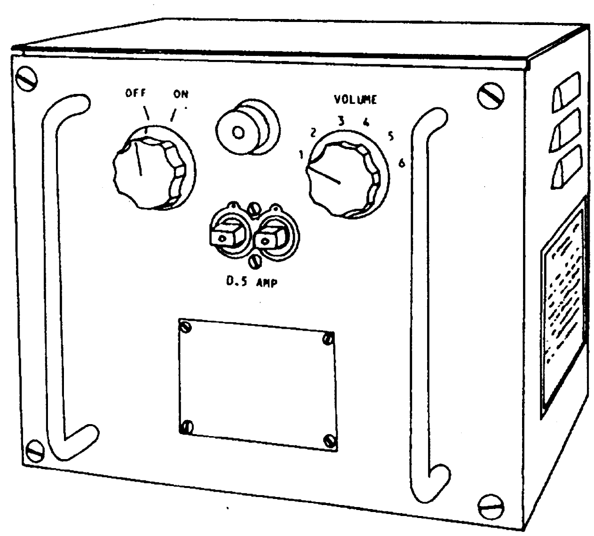


Figure 5-15.—AM-2210/WTC sound-powered telephone amplifier.

Figure 5-16 is a functional diagram of the AM-2210/WTC. One relay (K1) is used in the switching circuit.

AUDIO AMPLIFIER.— The audio amplifier (fig. 5-16) consists of a low-level, three-transistor amplifier (Q1 through Q3) and a power amplifier (Q4 and Q5), with negative feedback employed throughout. The output transformer (T3, not shown) has two secondaries: the first is used with the loudspeakers and the latter, a tapped winding, is used for as many as six sound-powered telephone outlets. The amplifier provides a 10-watt output.

SWITCHING CIRCUIT.— Figure 5-17 is a functional representation of the K1 switching circuit, showing K1 in an energized and operated condition. The receiver element of the local headset-chestset is in series with a dc blocking capacitor, thereby presenting a high resistance when the talk switch is open. Closing the talk switch connects the headset across the line, giving the headset a dc resistance of approximately 4.8 ohms. It is the function of the switching circuit to sense this change from high impedance to low resistance that takes place with the depression of one of the six headset-chestset talk switches.

The switching circuit is activated when the amplifier is energized. With power available and neither local nor remote talk switches closed, the relay (K1) is operated. When operated, the depression of a remote talk switch will have no effect upon K1; that is, it will remain operated. However, when one of the six local talk switches is depressed, the circuit to K1 is changed and K1 restores.

Resistor R31 provides a bias to the base of Q6, which normally holds Q6 in a saturated state, maintaining K1 in an operated condition. When the local talk switch is closed, the base of Q6 is connected to ground through the 4.8 ohms of the mouthpiece. Presently the voltage across Q6 from base to ground becomes less than the emitter bias voltage provided by voltage divider network R32 and R33; therefore, the transistor becomes reverse biased and Q6 becomes nonconductive, de-energizing and restoring K1.

The incoming and outgoing voice signals are coupled through capacitor C1 of the amplifier. CR1 is in the circuit to protect Q6 from surges while it is in the cutoff state.

The restoration of K1 will result in normal communications at sound-powered level between all

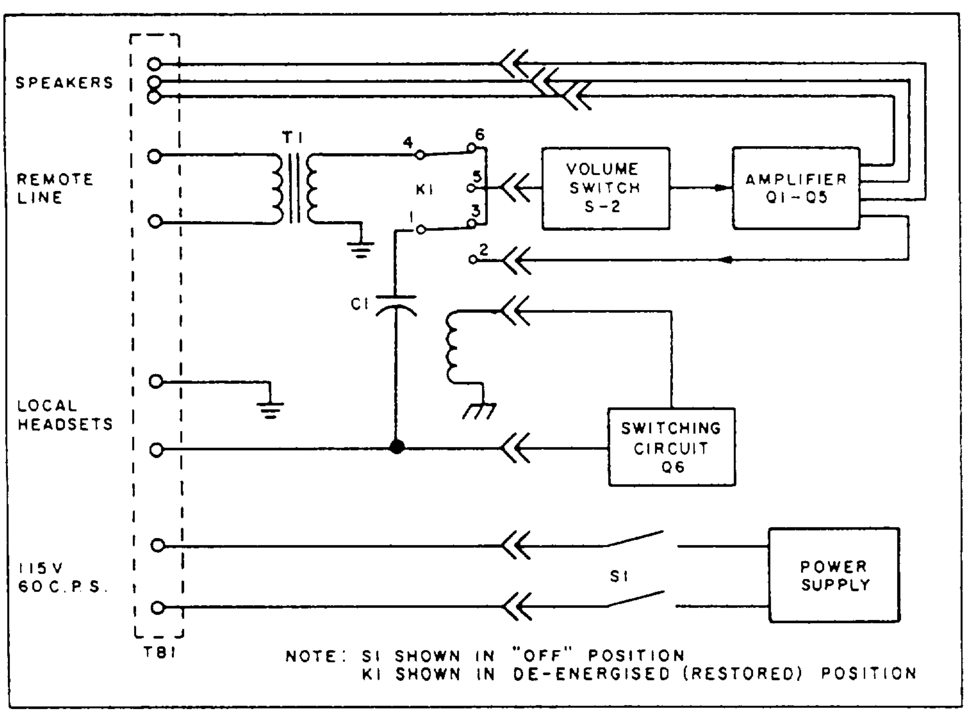


Figure 5-16.—Functional diagram of AM-2210/WTC.

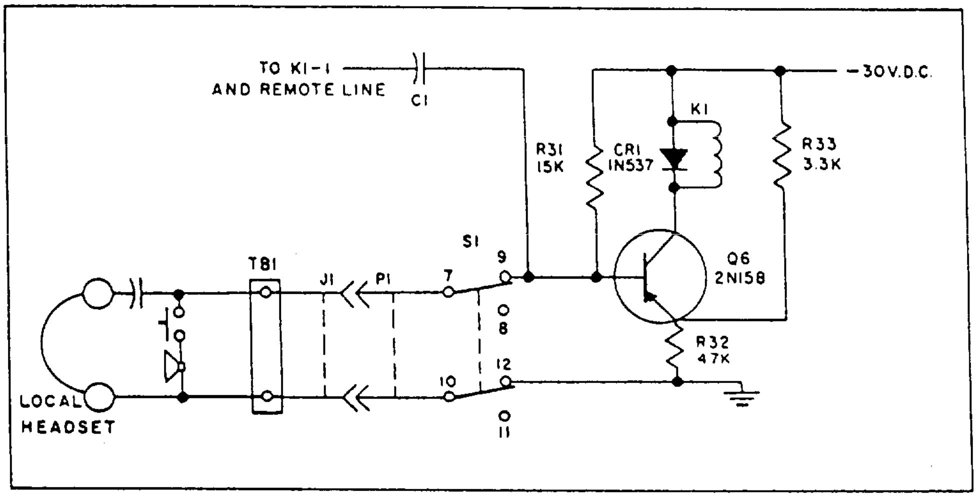


Figure 5-17.—Switchlng circuit of AM-2210/WTC.

stations. The amplifier is effectively bypassed. The advantage of this circuitry is that any casualty, such as loss of power, will allow normal sound-powered communications to continue.

POWER SUPPLY.— The power supply is basically a full-wave rectifier receiving its power through switch S1 (fig. 5-16) and the fuses on the face of the amplifier. A neon glow lamp and a volume control potentiometer are also located on the face of the amplifier. The amplifier operates on 115-volt, 60-Hz, single-phase power, which is normally supplied by the ship's local lighting panels.

AMPLIFIER OPERATION.— Incoming signals are amplified and delivered to local headset-chestsets and loudspeakers. The volume control knob located on the face of the amplifier is used to adjust the desired headset-chestset receiver output volume. The output volume for the associated loudspeakers is adjusted locally at the loudspeakers. The circuit associated with the telephone amplifier operates under the three following conditions:

1. When the amplifier is de-energized, direct two-way communication between local and remote stations takes place at the normal sound-powered level.

2. When the amplifier is energized, incoming signals from the remote line are amplified and transmitted to the local stations and associated loudspeakers.

3. When the amplifier is energized and the talk switch of any local station is closed, the amplifier is cut out and communications between any of the local and remote stations takes place at the normal sound-powered level.

Amplifier Maintenance

Although by no means trouble free, the AM-2210/WTC is a highly reliable piece of equipment. When trouble does occur, it is often caused by improper operating procedures or by a failure in external circuitry. Often personnel who operate the amplifier are not aware of its operational capabilities, and a brief indoctrination will clear up an apparent trouble.

One procedure that has caused some failures in the amplifier is the practice of taping closed the talk button of one of the local headset-chestsets. This violation of circuit integrity will result in K1 being continually restored, resulting in no amplification of incoming signals.

You should accomplish preventive maintenance using the applicable maintenance requirement cards (MRCs). You should accomplish corrective maintenance according to the applicable technical manual.

AMPLIFIER CONTROL SWITCHES

At stations where it is desired to maintain two-way communication for all circuits serving the station, an amplifier control switch is installed. This switch provides the operator with a means of selecting anyone of several circuits to be amplified while retaining two-way communications at normal sound-powered level for other circuits not selected to be amplified. These switches are multiple rotary-type S-3R and are provided with dial illumination for darkened-ship condition areas.

The incoming sound-powered telephone circuits are connected to the sound-powered telephone amplifier via this switch.

SELECTOR SWITCHES

Type A-26A sound-powered telephone selector switches (fig. 5-18) are located throughout the ship at control and operating stations served by more than one sound-powered telephone circuit. The selector switch enables the operator to connect the sound-powered telephone to any one of several circuits brought to the switch without having to change from one jackbox to another.

The selector switch is a multiple rotary switch designed for use in connection with sound-powered telephone systems. The switch is constructed with 2 sections and has 16 stationary contacts for incoming lines on each section. The rotor has a movable contact and is driven directly from the shaft attached to the handle, which has an indexing mechanism for selecting the desired circuit. The switch has a built-in jack outlet connected to the rotor contacts.

Most of the switches are installed with a sound-powered telephone handset permanently connected to the rotor contacts. Where a handset is not provided, the switch operator must insert a sound-powered telephone headset-chestset plug into the jack outlet. Switches located in normally darkened-ship condition areas are provided with dial illumination.

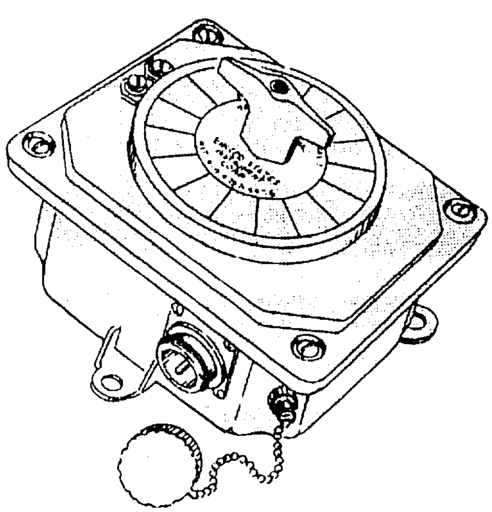


Figure 5-18.—Type A-26A selector switch.

At stations where only two circuits are involved, a double-throw lever or double-throw rotary snap-type selector switch is used rather than the larger rotary type.

SOUNDPROOF BOOTHS

In spaces where the ambient noise level at the handset location is 90 dB or more during any condition of operation, soundproof booths are installed for use with sound-powered telephone handsets. Wherever practicable, the telephone booths are installed so that the front faces away from the direction of maximum noise. The deck area under the booth will be solid or walkway grating. Only handset(s) with holder(s) and an illumination fixture are mounted inside the booth; all other associated sound-powered equipment is mounted on the outside of the booth.

PLOTTERS TRANSFER SWITCHBOARDS

Plotters transfer switchboards are found in areas aboard ship, such as the CIC, where the tactical situation governs the sound-powered circuit to which the plotters are to be connected. For instance, the situation may require that the CIC plotters connected to jackboxes JS1 through JS5 be connected to circuit 21JS, while the plotters connected to jackboxes JS6 through JS10 be connected to circuit 22JS. Another situation may call for an entirely different arrangement.

The switchboards consist of one or more SB-82/SRR panels (fig. 5-19, view A). Each panel consists of five vertical rows of 10 double-pole, single-throw switches. Each row on the panel is connected to a sound-powered circuit, and each switch on the panel is connected to a sound-powered jackbox. The switches are continuously rotatable in either direction. Several different sound-powered jackboxes and circuits are connected to these switchboards, thus permitting the plotters to be shifted from one circuit to another quickly and efficiently as the situation dictates and eliminates the necessity of installing multiple-circuit phone boxes at each station.

As shown in figure 5-19, view B, the closing of any one of the five switches associated with each jackbox permits the jackbox to be connected to one of the sound-powered circuits. In the figure, jackbox JS 1 is shown connected to sound-powered circuit 22JS, and jackbox JS2 is shown connected to sound-powered

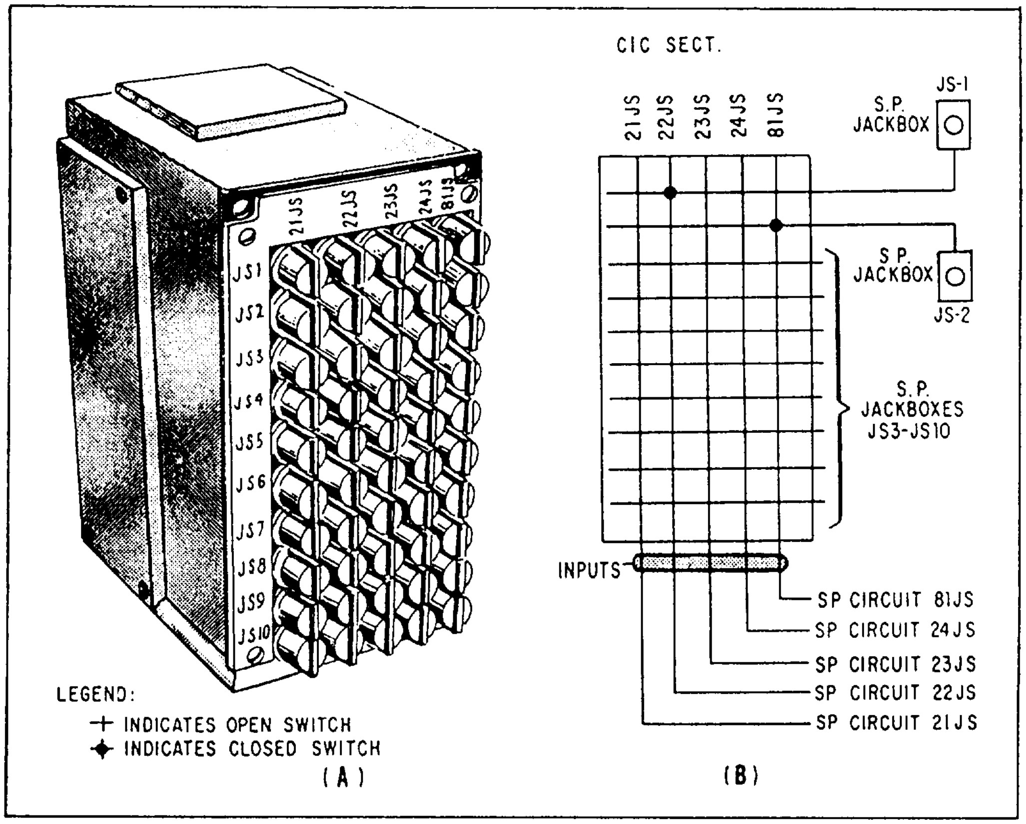


Figure 5-19.—Plotters transfer switchboard.

circuit 81JS. Any of the remaining jackboxes, JS3 through JS10, may be connected to one of the five sound-powered circuits by simply closing the associated switch.

CALL AND SIGNAL CIRCUITS

Call and signal circuits used in conjunction with a ship's sound-powered telephone system provide the means of calling and signaling between stations of the various sound-powered telephone circuits. The call and signal circuits are designated E, EM, and MJ.

CIRCUIT E - SOUND-POWERED TELEPHONE CALL CIRCUIT

Circuit E provides a means of signaling between sound-powered telephone stations, where not more than six stations are to be called by the calling station. The circuit operates on 120-volt, 60-Hz, single-phase power, which is usually supplied by the main IC switchboard. Watertight and nonwatertight push buttons and lever-operated spring return or spring return rotary switches are provided at all calling stations. Buzzers, horns, bells, and drop-type annunciators are installed at the associated called stations. Buzzers are used in low noise level spaces. Horns are used in high noise level spaces, and bells are used in other spaces. Annunciators are provided at all stations where two or more similar audible signals are required.

To use the circuit, the caller operates a switch at the calling station, which in turn energizes the audible and/or visual signal devices located at the called station.

Circuit E is divided into the following functional circuits:

1E-Cruising and miscellaneous

2E—Ship control

3E—Engineering

4E—Aircraft control

5E—Weapons control

A simplified call circuit is shown in figure 5-20. The upper branch circuit, with one bell and one push button in series with each other, is used to call a single station from one remote location.

The center branch circuit, with two push buttons in parallel with each other and in series with the bell, is used to call a single station from two remote locations.

The lower branch circuit, with two bells in parallel with each other and in series with one push button, is used to call two stations from one remote location.

Note that the bells or signaling devices are connected to the side of the lines bearing the negative designation EE. This arrangement is used on ac circuits that have no polarity, but in which one side of the line arbitrarily is designated as EE for convenience.

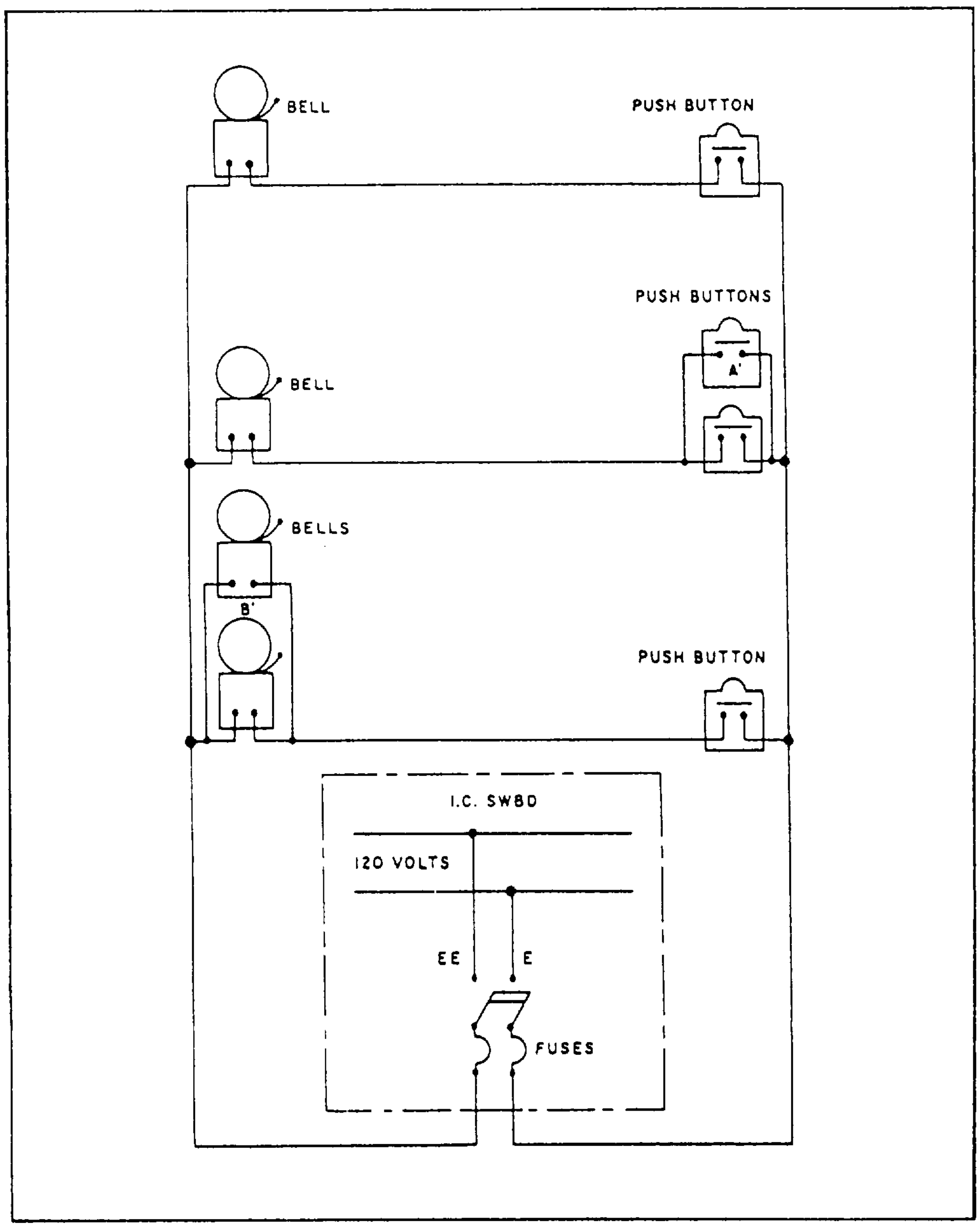


Figure 5-20.—Simple call-bell system.

Figure 5-21 is a simple diagram for a two-circuit, four-drop annunciator. Stations that have several sound-powered telephones, each on a different circuit, are provided with drop-type annunciators to identify the circuit of the station that originates the call. Each drop is embossed with the circuit letter and is held mechanically in the nonindicating (normal) position. There is also an audible signaling device provided with the annunciator.

One side of each drop and one side of an audible-signal relay are connected together. When the circuit is energized by operating a switch at the calling station, the current flows through the drop and the relay. The audible-signal relay closes its contacts to the audible signal and an electromagnet causes the proper drop to fall to the indicating position. The audible signal sounds only while the switch is operated. The drop is returned to its normal position by a hand-operated reset button.

The annunciator maybe equipped with one or more audible-signal relays as required by the number of associated circuits, but only one common audible signal device is used.

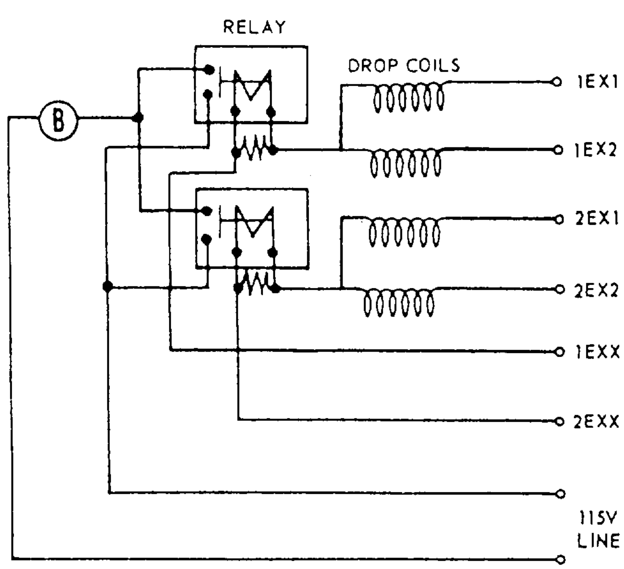


Figure 5-21.—Two-circuit, four-drop annunciator.

CIRCUIT EM - SOUND-POWERED TELEPHONE SIGNAL CIRCUIT

Circuit EM provides a means of signaling between sound-powered telephone stations, where more than six stations are to be called by the calling station. Circuit EM is divided into the same functional circuits as circuit E except that 1EM through 5EM is used. Circuit EM uses type IC/D call signal stations, which require no external power, and provides the operator with selective calling of up to 16 individual stations. The associated sound-powered telephone circuit is independent of the signal circuit and provides the voice communication facilities between stations. Each sound-powered telephone circuit can accommodate only one conversation over its facilities. The IC/D call signal station (fig. 5-22, views A and B), normally called a growler or a howler, uses a magneto generator to transmit a noninterrupted or interrupted signal to a selected station.

IC/D Noninterrupted Call Signal Station

The IC/D noninterrupted call signal station is made of cast aluminum, with all of the equipment mounted on the cover except for the terminal board and a sound-powered jack outlet. Equipment mounted on the cover include a 16-position rotary selector switch, an index plate, a hand-operated magneto generator, a howler unit, and an attenuator. The associated sound-powered telephone circuit may be either the string or the switchboard type.

To operate the station, you simply turn the rotary selector switch to the station to be called and crank the magneto generator handle. The howler (a modified sound-powered telephone receiver unit) at the selected station will produce a high distinctive howl. The howl will continue for as long as the calling station generator is cranked. The attenuator is used to control the volume of the individual howler at its respective station. Each EM circuit station is equipped with an IC/D call signal

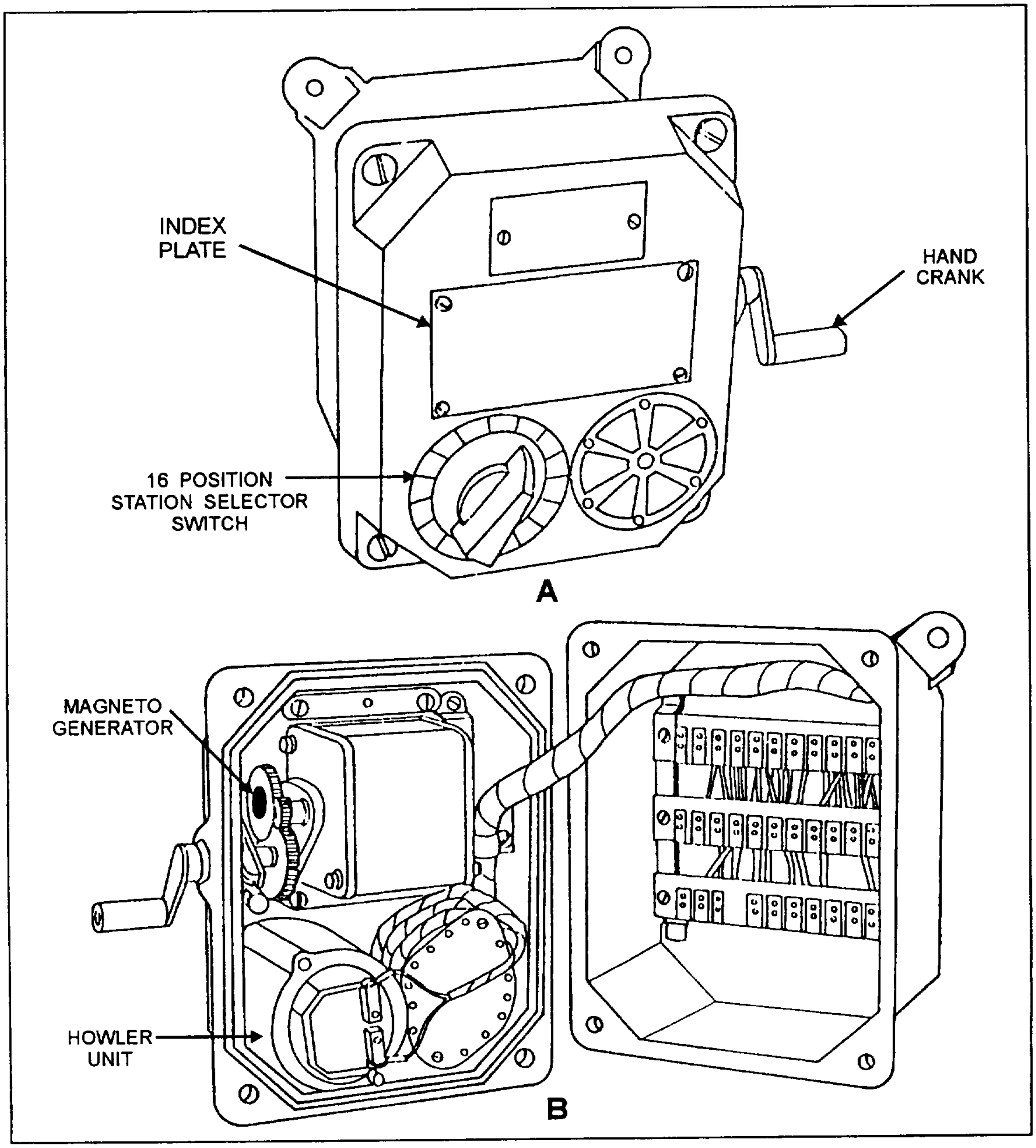


Figure 5-22.—IC/D call signal station. A. External view. B. Internal view.

station. Figure 5-23 is an elementary wiring diagram of the 2EM (ship control) circuit.

The call signal stations located in noisy spaces may include a visual indicator lamp to alert personnel of an incoming call. A relay box nippled to an indicator lamp is installed adjacent to each call signal station. The relay coil is connected to the howler circuit of the station. The relay contacts are connected to the nearest emergency lighting circuit. When the station howler is activated, the relay coil is energized and the relay contacts operate to complete the circuit from the lighting system to energize the indicator lamp.

IC/D Interrupted Call Signal Station

This station is identical to the noninterrupted station, except the hand-operated magneto generator has been modified to generate a pulsating voltage. When the generator handle is cranked, the pulsating voltage produced will provide an interrupted howl at the selected station.

This call signal station is used along with the noninterrupted call signal station in a space where two different circuits are required; thus providing different audible signals to alert personnel as to which station is being called.

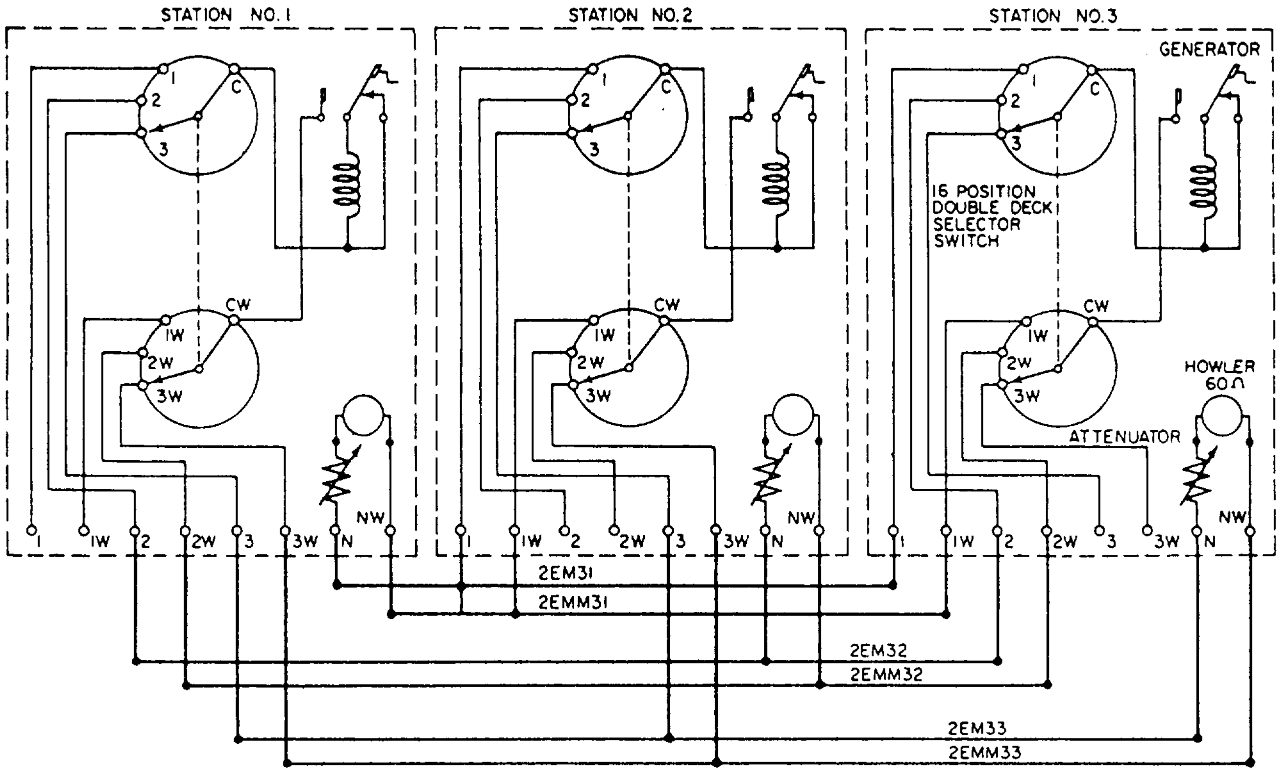


Figure 5-23.—Sound-powered magneto call circuit 2EM.

CIRCUIT MJ - MULTIPLE-TALKING AND SELECTIVE RINGING CIRCUIT

Circuit MJ provides a means of communication with more than one conversation on the circuit simultaneously, as well as providing selective ringing at each station. In addition, the sound-powered telephone and ringing circuits are combined to provide one common talking circuit between all stations. Up to eight separate conversations are possible at one time. The circuit may be used with any particular sound-powered circuit where its capabilities would be advantageous.

IC/D call signal stations are used with circuit MJ. The internal wiring of each call signal station is revised and a relay and diode assembly is mounted on the selector switch of each call signal station. When the relay is de-energized, its contacts complete the circuit to the local handsets at all call signal stations on the circuit. When a caller cranks the hand-operated magneto generator at the calling station, it energizes the coil of the relay at the called station. The contacts of the relay then close to complete the circuit to the howler at the called station. At some call signal stations on the circuit, extension handsets are provided for convenience in answering incoming calls. The extension handsets are connected to the "home station" circuit MJ wires to avoid the need of setting the station selector switch to the ANSWER position, which is required to use the local call signal station handset. Figure 5-24 is an elementary wiring diagram of an MJ circuit.

CALL AND SIGNAL CIRCUITS MAINTENANCE

You should accomplish preventive maintenance of call and signal circuits according to the applicable MRCs. Corrective maintenance will usually consist of isolating shorts, grounds, and opens in the circuits and repairing or replacing the audible and visual signal devices used with the circuits.

SOUND-POWERED TELEPHONE SYSTEM AN/WTC-2(V)

The AN/WTC-2(V) sound-powered telephone system is installed on some naval ships. This system replaces the existing EM and MJ call and signal circuits. The system is designed for interior shipboard use and, along with the sound-powered telephone circuits discussed earlier, provides two-way voice communication between shipboard terminal stations. You can signal and talk on the same cable. The system

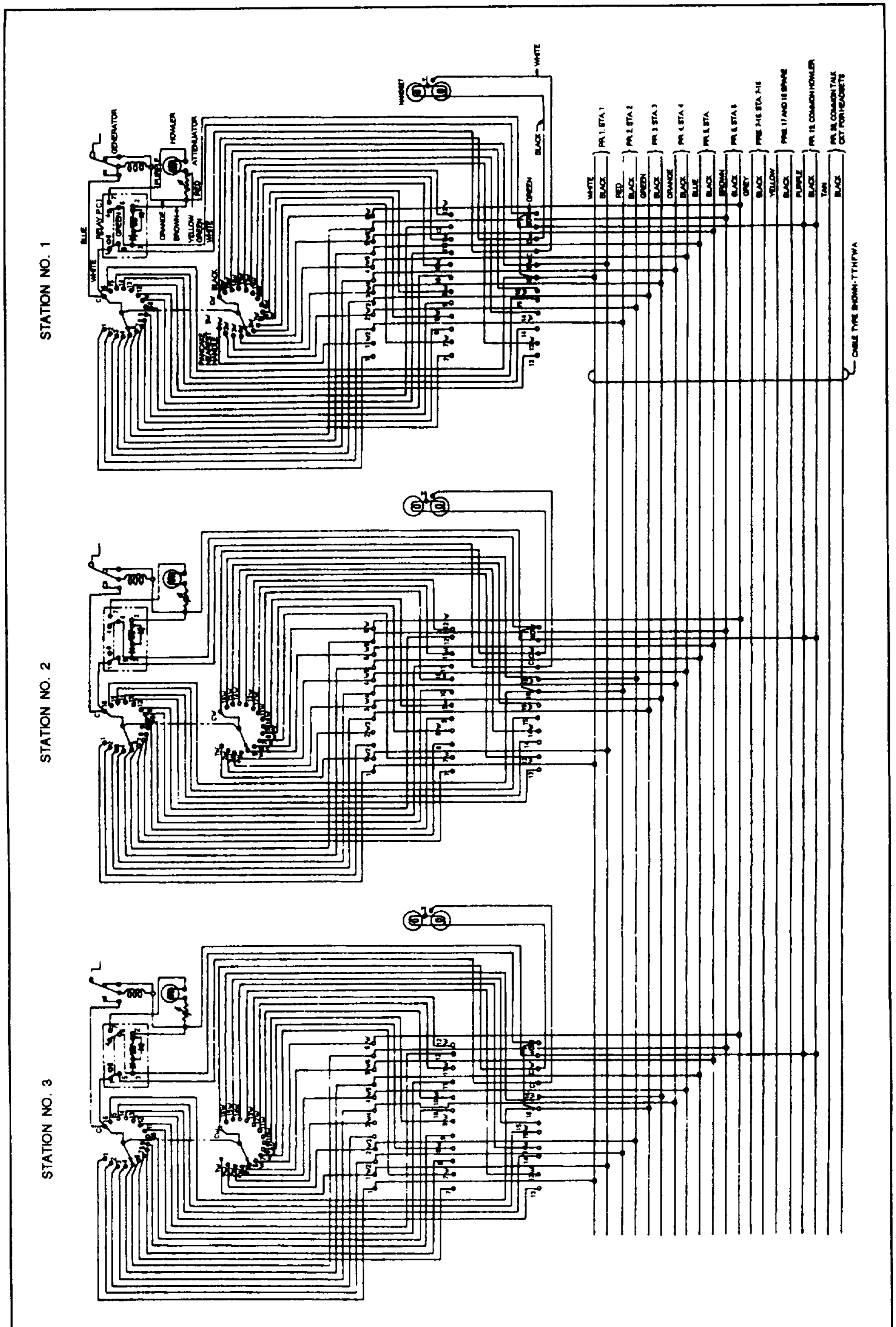


Figure 5-24.—Modification of IC/D call signal station, for multiple talking and selective ringing.

uses a variable number of 8 separate major units and may contain up to 144 terminal stations.

PHYSICAL DESCRIPTION AND PURPOSE OF UNITS

The eight major units of the AN/WTC-2(V) sound-powered telephone system are as follows:

1. Unit 1—TA-974/WTC-2(V) sound-powered telephone set
2. Unit 2—TA-975/WTC-2(V) sound-powered telephone set
3. Unit 3—TA-976/WTC-2(V) sound-powered telephone set
4. Unit 4—G-15/A sound-powered telephone jackbox
5. Unit 5—H-200/U headset-chestset
6. Unit 6—J-3523/WTC-2(V) distribution box
7. Unit 7—TS-3687/WTC-2(V) telephone test set
8. Unit 8—BZ-240/WTC-2(V) audible alarm

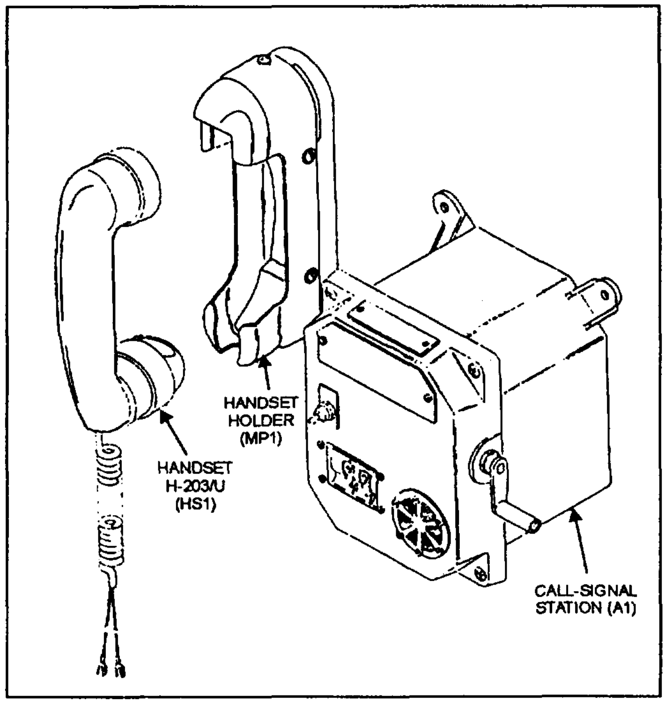


Figure 5-25.—The TA-974/WTC-2(V) sound-powered telephone set, unit 1.

Units 1,2, and 3

The terminal stations are units 1, 2, and 3. These terminal stations provide the means of selecting and calling other stations in the system.

UNIT 1.— Unit 1 (fig. 5-25) is a bulkhead-mounted terminal station consisting of three separate components: call-signal station A1, handset HS1, and handset holder MP1.

Call-signal station A1 consists of a cover assembly and a case assembly. The cover assembly (fig. 5-26) contains two single-pole, 12-position thumbwheel station selection switches, a PLACE CALL/ANSWER toggle switch, a side-crank dc hand-ringing generator with related electronics, and an attenuator to adjust the ring signal audio level. The case assembly is the housing for the cover assembly and contains the necessary terminal board and multipin connector to mate with the plug on the cover assembly. The case assembly also provides the means of connecting the handset.

Handset HS1 is a standard H-203/U sound-powered telephone handset.

Handset holder MP 1 is a standard holder for the H-203/U sound-powered telephone handset. The holder is mounted near call-signal station A1.

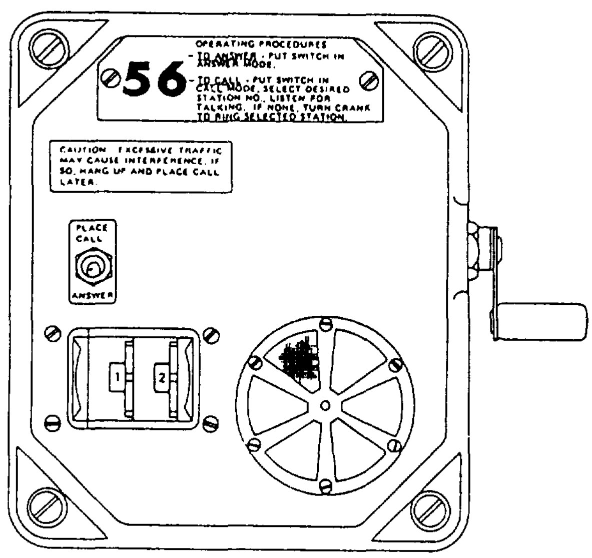


Figure 5-26.—Call signal station A-1.

UNIT 2.— Unit 2 (fig. 5-27) is similar to unit 1 except that the call-signal station has a front-crank hand ringing generator instead of a side-crank hand ringing generator.

UNIT 3.— Unit 3 (fig. 5-28) is a console-mounted terminal station consisting of four separate components: BCP console 3A1, hand-ringing generator 3A2, audible alarm BZ-240/WTC-2(V), and handset HS1. BCP console 3A1 and hand ringing generator 3A2 serve the same purpose as the cover assembly in unit 1. The audible alarm component houses an electrical horn for remote audible signaling.

Unit 4

Unit 4 is a standard sound-powered telephone single-gang jackbox.

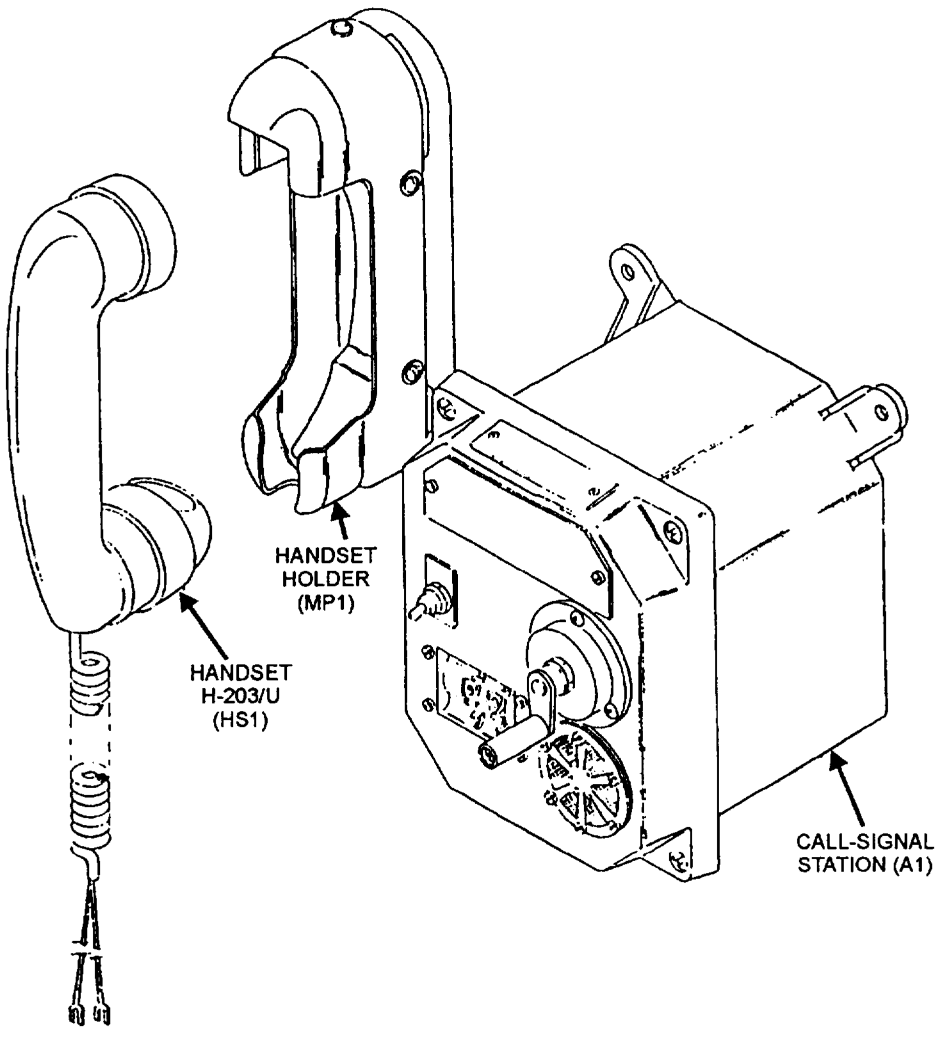


Figure 5-27.—The TA-975/WTC-2(V) sound-powered telephone set, unit 2.

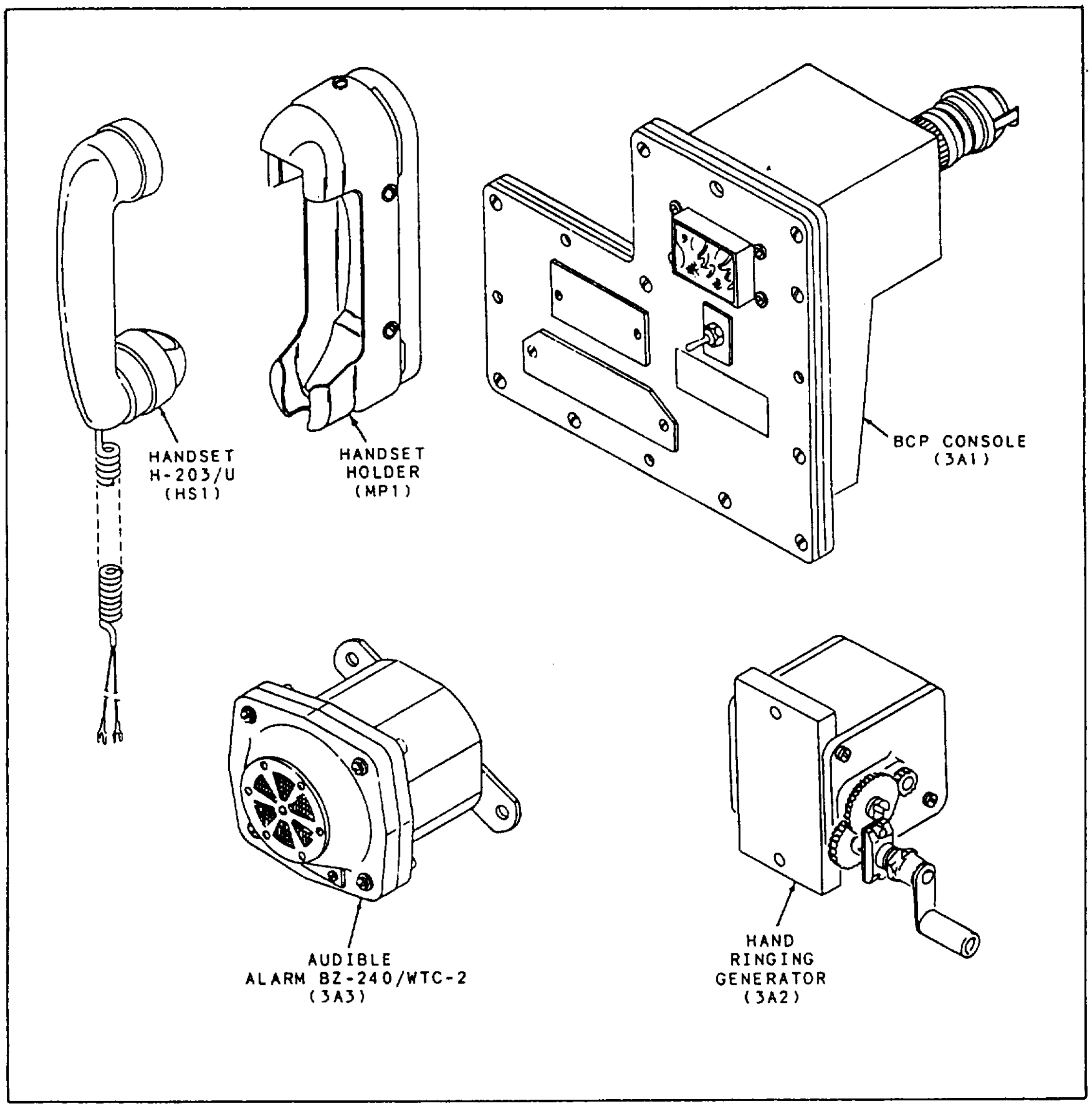


Figure 5-28.—The TA-975/WTC-2(V) sound-powered telephone set, unit 3.

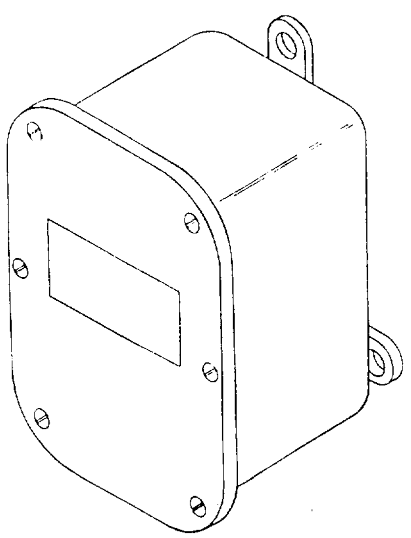


Figure 5-29.—The 6J-3523/WTC-2(V) distribution box, unit 6.

Unit 5

Unit 5 is a standard H-200/U sound-powered telephone headset-chestset. Unit 5 is used with unit 4 and may also be connected to a terminal station equipped with a jack.

Unit 6

Unit 6 (fig. 5-29) provides a means of connecting an extension visual signal device to ship's power in areas where such a device is required. Unit 6 is comprised of a relay assembly mounted inside an enclosure assembly. The dc voltage from a calling terminal station activates the relay, which connects the 115-volt power circuits to as many as three extension visual signal devices.

The extension visual signal device (fig. 5-30) provides a visual signal to a location remote from a terminal station when additional signaling is required due to high noise levels or physical barriers to sound near a station. The extension visual signal device uses a 50-watt incandescent lamp.

Unit 7

Unit 7 (fig. 5-31) is used to test the terminal stations, it has the capability of testing the continuity of the station selector switches and associated wiring of the terminal stations. The test set is a portable bench top unit that mainly consists of an ON/OFF toggle switch, a transformer, and 24 light emitting diodes to test the continuity of the two station selector switches on the terminal stations.

Unit 8

Unit 8 (fig. 5-32) provides an audible signal to a location remote from a terminal station when additional audible signaling is required due to high noise levels or physical barriers to sound near a terminal station. The audible alarm consists of an electrical horn mounted within the component. The audible alarm is also supplied as one of the components for unit 3.

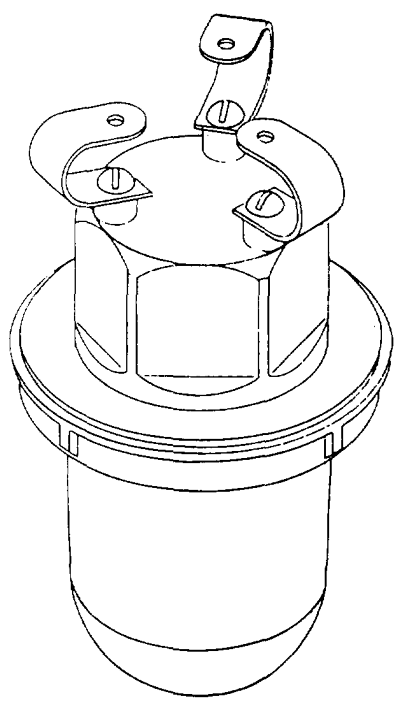


Figure 5-30.—Extension visual signal device.

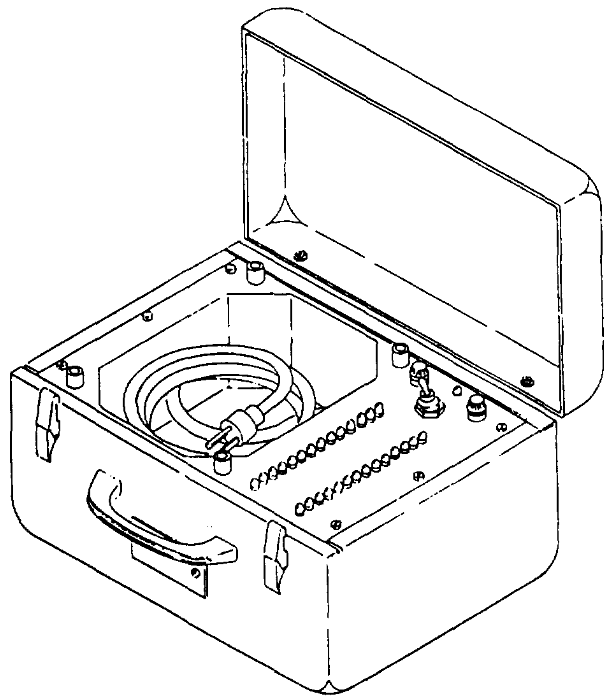


Figure 5-31.—The TS-3687/WTC-2(V) telephone test set, unit 7.

SYSTEM OPERATION

The system can be used to make point-to-point (station-to-station) calls and conference calls. The system also provides net access, call holding, and executive override functions.

Point-to-Point Calls

Point-to-point calls can be made from any terminal station to any other terminal station. To initiate a point-to-point call, you should perform the following procedures:

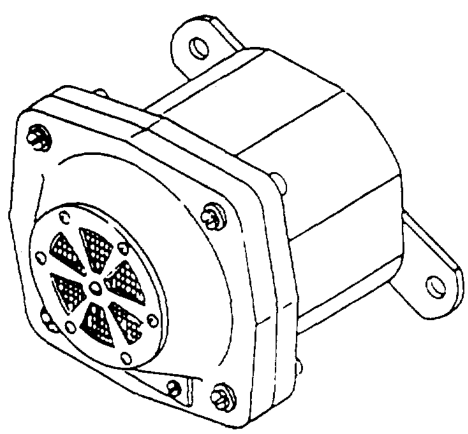


Figure 5-32.—The BZ-240/WTC-2 (V) audible alarm, unit 8.

1. Set the PLACE CALL/ANSWER switch to the PLACE CALL position.

2. Select the desired station number on the thumbwheel switches.

3. Remove the handset from its holder, depress the handset press-to-talk switch, and listen for talking on the line. If the line is clear, continue to step 4. If the line is not clear (busy), return the handset to its holder, and set the PLACE CALL/ANSWER switch in the ANSWER position.

4. Turn the crank several times to ring the desired station.

5. Talk to the desired station. After the call is completed, return the handset to its holder, and set the PLACE CALL/ANSWER switch to the ANSWER position.

To answer an incoming point-to-point call, you should perform the following procedure:

1. Set the PLACE CALL/ANSWER switch to the ANSWER position (the switch should already be in the ANSWER position).

2. Remove the handset from its holder and depress the handset press-to-talk switch and acknowledge the call.

3. When the call is completed, return the handset to its holder.

Conference Calls

A conference call involves the sharing of the same line among a number of terminal stations. The number of participants (stations) involved in a conference call should be limited to five, as each additional station will cause a drop in the audio-signal level. To initiate a conference call, you should perform the following procedure:

1. Place a point-to-point call to the first desired station.

2. Inform the called station that a conference call is being established, and give the called station your station number.

3. Repeat steps 1 and 2 for each terminal station you desire to participate in the conference call.

4. After each station has been contacted, rotate the thumbwheel switches to your own terminal station number and begin the conference.

5. When the conference call is completed, return the handset to its holder, and set the PLACE CALL/ANSWER switch to the ANSWER position.

To answer an incoming conference call, you should use the following procedure:

1. Answer the same as you would for a point-to-point call.

2. When the caller informs you that it is a conference call, set the thumbwheel switches to the caller's station number and wait for the conference to begin.

3. When the conference call is completed, return the handset to its holder.

Net Access

The AN/WTC-2(V) system is an integrated point-to-point and net communications system. when the system is installed aboard ship, certain interconnecting wire pairs and their associated station numbers are reserved for net (string circuits) use. A net consists of designated stations and their associated units, and only the stations in a net have access to that particular net. The system contains several nets so certain stations may operate as a string circuit during particular conditions, such as general quarters. Ringing is not possible in a net; stations must already be manned to accomplish the desired communications.

Net access can be obtained through the use of either the terminal station handset or a headset-chestset plugged into either the station jack or an associated jackbox. To access a net using the terminal station handset, you should perform the following procedure:

1. Select the predetermined net station number on the thumbwheel switches.

2. Set the PLACE CALL/ANSWER switch to the PLACE CALL position. Do not turn the crank.

3. Depress the press-to-talk switch on the handset to establish communications with the net.

4. When finished, return the handset to its holder and set the PLACE CALL/ANSWER switch to the ANSWER position.

To access a net using the headset-chestset, you should perform the following procedure:

1. Connect the headset-chestset to either the jack on the terminal station or to the associated jackbox.

2. Depress the press-to-talk switch to establish communications on the net.

3. When finished, disconnect the headset-chestset from the jack or jackbox and stow it.

Call Hold

The call hold function is used by a terminal station that has originated a call and desires to maintain communication with the called station while answering an incoming call. To perform the call hold function, you should use the following procedure:

1. Inform the called station that you have an incoming call, and tell the called station to stay on the line while you answer the call.

2. Answer the call according to normal procedures by setting the PLACE CALL/ANSWER switch to the ANSWER position.

3. When you have finished with the incoming call, set the PLACE CALL/ANSWER switch to the PLACE CALL position and continue with your original call.

Executive Override

When a station has received a call and is talking to the calling station at the time a second call is received, the second call is considered an override function. The call hold function cannot be used in this case.

COMMUNICATION INTERFERENCE

Communication interference while making point-to-point, conference calls, or both may occur due to cross talk and looping.

Cross talk

Cross talk is the effect created when an AC signal from one lead in a cable induces a small voltage into the adjacent lead. Crosstalk, while usually always present, is at a relatively low audio level and will be heard as a faint background conversation during a call.

Looping

Looping is an undesirable and unintentional formation of a complex series-parallel circuit among stations that are simultaneously busy. This is a result of a direct connection between terminal stations when an excessive number of simultaneous point-to-point calls are being made.

To create a loop, four or more point-to-point, conference calls, or both must be in progress at the same time and a particular and predictable relationship must exist among the station numbers of the called stations. The numbers of the calling stations are immaterial since the cable pairs carrying the calls are those assigned to the called terminal station. The called station is permanently connected to those pairs that carry the call, while the calling station connects itself in parallel to those pairs by the use of the station selector switch.

When a loop is formed, the operators of the affected stations will simultaneously hear all conversations among the stations involved in the loop. The conversations will be at relatively high audio levels, making normal communications among these stations impossible.

The only way to break a loop after it has formed is to end one of the calls. The press-to-talk switches on both handsets of the stations involved must be released to end the call. NEVER tape down the press-to-talk switch of a handset. A taped down switch will act as a continuous call even when a call is ended.

There is a caution label plate on the front cover of each terminal station to caution operating personnel against excessive traffic.

SYSTEM MAINTENANCE

Preventive and corrective maintenance for the system should be accomplished according to the applicable MRCs and associated technical manual(s) for the system.

VOICE TUBES

Voice tubes are installed aboard ship in addition to the sound-powered telephone system to provide another way for transmitting information between designated stations. The voice tube is used to transmit voice orders and information over short distances by nonelectrical means. Voice tubes are made of 3-inch brass, thin-walled tubing fitted with mouthpieces at each end. Voice tubes are installed between the following stations aboard ship as applicable:

– Surface Ships

From the pilothouse (helmsman's station) to the navigation bridge wings (port and starboard)

From the pilothouse (helmsman's station) to the exposed conning station (top of pilothouse)

From the pilothouse chart table to the navigation bridge wing peloruses (port and starboard)

From the chart room chart table to the navigation bridge wing peloruses (port and starboard)

From the flag plot chart table to the flag bridge wing peloruses (port and starboard)

From the pilothouse to the captain's sea cabin

– Submarines

From the engine room (upper level) to the engine room (lower level)

From the engine room (steam plant control panel) to the engine room (lower level) forward and aft

From the auxiliary machinery room (upper level) to the auxiliary machinery room (lower level)

Voice tubes used for ship control functions are fitted with a megaphone-type mouthpiece at interior stations and a hinged cover mouthpiece at weather stations. The voice tube between the pilothouse and the captain's sea cabin is fitted with an open mouthpiece in the pilothouse and a hinged cover mouthpiece in the sea cabin. Voice tubes between machinery stations are fitted with open mouthpieces. Drain plugs are provided in the lowest level of each voice tube so any water that may have entered the voice tube can be drained from it.

Voice tubes are provided with a call circuit to alert personnel to man the tube. Each call circuit is designated as circuit VT and assigned the same number as its associated voice tube. The VT circuit operates on 120-volt, 60-Hz, single-phase power, which is obtained from the nearest local lighting system supply. When alerted by the call signal, a person at the called station merely talks into the voice tube and is answered by a person at the calling station.

Switches and audible devices are installed adjacent to the ends of the voice tubes as follows:

– Surface ships

Push buttons are installed at the pilothouse chart table and chart room chart table and are connected to energize a bell installed at each navigation bridge pelorus (port and starboard).

Push buttons are installed at the flag plot and are connected to energize a bell installed at each flag bridge pelorus (port and starboard).

A push button and buzzer are installed in the pilothouse and captain's sea cabin, with each push button connected to energize its respective buzzer.

– Submarines

A push button is installed at one end of the tube and connected to energize a horn installed at the other end of the tube.

SUMMARY

In this chapter, we have discussed how the sound-powered telephone system is used to provide a reliable means of verbal communication aboard ship. We have identified the various sound-powered telephone circuits used with the system.

We have explained how to operate and maintain the equipment used with the sound-powered telephone system. We have identified the call and signal circuits used with the sound-powered telephone system. We also have explained how to operate and maintain the associated equipment used with the call and signal circuits.

We have discussed the operation of the AN/WTC-2(V) sound-powered telephone system and the use of voice tubes aboard ship.

CHAPTER 6

AUTOMATIC DIAL TELEPHONE SYSTEM

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

- *Describe the purpose of the automatic dial telephone system installed on Navy ships.*
- *Identify the two versions of the type G telephone sets used with the system.*
- *Describe how the two versions of the type G telephone sets operate and how the sets are maintained.*
- *Identify some of the more common troubles associated with the telephone sets.*
- *Describe some of the different types of telephone switchboards and how they are maintained.*
- *Describe the functions of the automatic dial telephone switchboards.*
- *Identify the automatic switching equipment used with the switchboard.*
- *Describe the function of the attendant's cabinet used with the switchboard.*
- *Describe the procedures for isolating and clearing the various alarms associated with the switchboard.*
- *Briefly describe some of the preventive maintenance procedures associated with the switchboard and the attendant's cabinet.*
- *Describe how shore lines are connected to the ship's automatic dial telephone system and other telephone sets on the ship.*

INTRODUCTION

The automatic dial telephone system (designated circuit J) is used on board ship primarily as an administrative circuit. It also supplements other communication facilities for ship control, fire control, and damage control on board ship. The automatic dial telephone system provides two-way telephone communications on a fully selective basis under the direct control of the calling stations. This includes two-way communications between telephone line stations throughout the ship and between ship and shore systems.

In an automatic telephone system, the connections between the telephones are completed by remotely controlled switching mechanisms. The switching mechanisms are controlled at the calling phone by a dial on the telephone instrument. When the dial is operated, it causes a series of interruptions, or impulses, in a current flowing in the line circuit. The number of impulses sent out by the dial corresponds to the digit dialed. These impulses cause the automatic switches to operate and to select the called telephone.

The automatic dial telephone system consists of (1) telephone line station equipment and (2) an automatic dial telephone switchboard that includes the switching mechanisms necessary to interconnect the line stations and accessory equipment used to interconnect the ship's system with shore systems when the ship is in port.

TELEPHONE LINE STATION EQUIPMENT

The telephone line station equipment consists of a telephone set connected to a set of line terminals of an automatic dial telephone switchboard and, in some cases, auxiliary equipment.

The auxiliary equipment consists of extension signal relays and extension signal devices (visual or audible) for use in high-noise areas. An extension signal relay is a relay in an enclosure mounted externally to a telephone set. The operating coil of the relay is connected in parallel with the ringer of the telephone set. The relay contacts are designed to open and close a ship's 120-volt power circuit to energize an extension signal. An extension signal is a visual or audible signal mounted externally to a telephone set. The signal is controlled by an extension signal relay.

The telephone set is a compact unit that transmits and receives speech, and signals the desired station. The telephone set is made up of a transmitter, receiver, dial, and ringer. The transmitter changes sounds into current variations that are sent over an electrical circuit. The receiver changes the current variations back into sound. The dial, when operated, causes a series of interruptions (impulses) in the current flowing in the line circuit. The ringer provides an audible signal when the station is called. The most common telephone sets installed aboard ship today are the type G sets.

There are two versions of the type G telephone set available for use in the automatic dial telephone system. Both versions are designed to provide shipboard, point-to-point communications over automatic dial telephone lines. Both versions can be used for either one- or two-party service. However, the physical makeup and circuitry of the two versions are different.

TYPE G TELEPHONE SET (VERSION 1)

There are four models of the type G (version 1) telephone set: the basic nonrestricted set, the restricted set, the portable set, and the modular set.

Basic Nonrestricted Set

The basic nonrestricted telephone set (fig. 6-1) is designed for nonrestricted communications. This set can be used in three different configurations to accommodate all ships' mounting requirements. Each configuration consists of the appropriate enclosure and basic telephone set as shown in figure 6-2.

Bulkhead-mounted telephone sets, both watertight and nonwatertight, are connected to the automatic dial telephone switchboard electrically by connecting the telephone line (ship's cable) to a screw-type terminal board mounted within the enclosure. Desk-mounted telephone sets are connected to the switchboard by an external connector block furnished with the sets.

The handset holder and handset retaining mechanism are mounted on the front of the stainless-steel cover. The remainder of the components are mounted either directly on the back side of the cover or on a steel baseplate (chassis), which is secured to the back side of the cover. There is a cutout in the cover to allow the dial to protrude through for dialing access. The cover can be mounted on any of the three enclosures. In addition, the set can be flush-mounted in a console panel or bulkhead cutout.

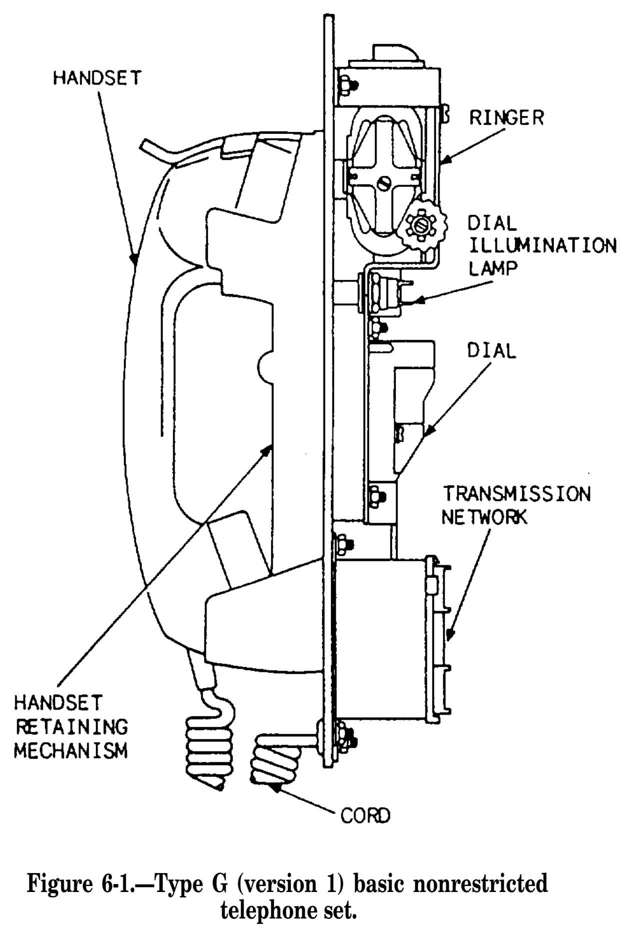


Figure 6-1.—Type G (version 1) basic nonrestricted telephone set.

HANDSET.— The handset (fig. 6-3) houses the transmitter, the transmitter mounting cup, and the receiver. The handset can be equipped with a standard transmitter or a noise-cancelling dynamic transmitter for use in high-noise areas. By connecting the handset cord terminals to a screw-type terminal board mounted within the telephone set, you can electrically connect the handset to the telephone set.

HANDSET RETAINER SLIDE.— The handset retainer slide is a mechanical control that secures the handset in the handset holder. When the handset is replaced in the handset holder, this control is activated automatically to lock the handset in place.

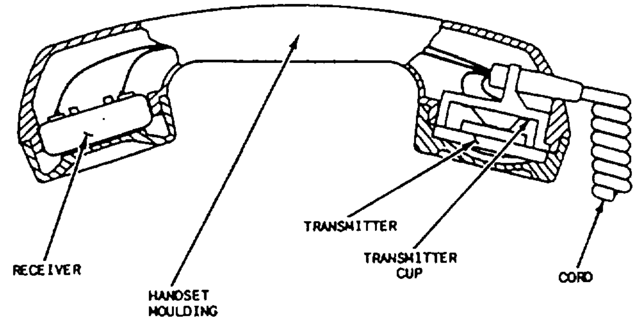


Figure 6-3.—Type G (version 1) telephone handset.

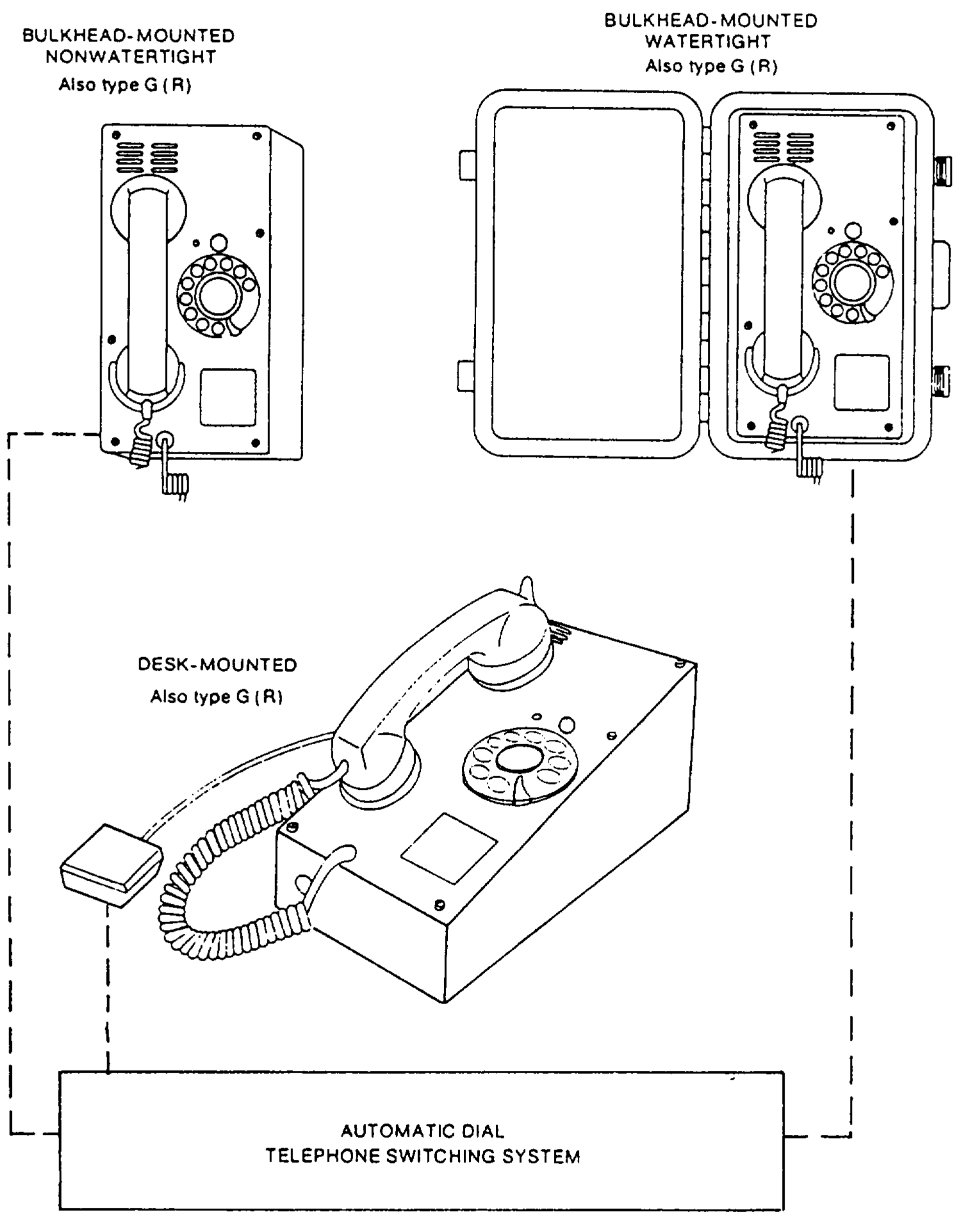


Figure 6-2.—Type G (version 1) telephone set configurations.

SLIDE ASSEMBLY RELEASE CONTROL.— The slide assembly release control is a mechanical control that consists of a button that must be depressed to unlock the handset retainer slide. When the handset retainer slide is unlocked, the handset can be removed from the handset holder.

TRANSMISSION NETWORK.— The transmission network is the control circuit for the telephone set. The transmitter output and all inputs to the receiver are extended to and from the associated automatic dial telephone switchboard under the control of this circuit. This circuit also produces and controls receiver sidetone (transmitter sounds reproduced in the receiver of the same handset).

Figure 6-4 is a simplified schematic diagram of the transmission network circuit. The handset transmitter and receiver, the hookswitch contacts, and the dial contacts are also shown to simplify the description of the circuit.

When the handset is removed from the handset holder, hookswitch contacts 1 and 2 close the dc loop between terminal 1 (L1) and terminal 2 (L2) by normally closed dial (impulse spring) contacts 1 and 2 and dc paths 1, 2, and 3.

Dc path 1 is through resistor R1 and varistor RV1. Resistor R1 limits the current through varistor RV1 to protect it from high line-voltage surges. Varistor RV1, with varistor RV2, acts as an automatic gain control to maintain a constant input and output level over the range of loop resistance encountered when used with any specific automatic dial telephone switchboard.

Dc path 2 is through inductor L1, the transmitter, resistor R2, and inductor L2. This path prepares the transmitter for audio excitation. Inductors L1 and L2 balance the line for varying levels of outgoing and incoming audio signals. Resistor R2 limits the current through the transmitter to protect it from high line-voltage surges.

Dc path 3 is through inductor L1, varistor RV2, and inductors L3 and L2. This is a balancing and gain control path, with varistor RV2 acting with varistor RV1 as described in path 1. Inductors L1 and L2 function as described in path 2. Inductor L3 aids in balancing the circuit and, by mutual inductance, couples audio signals from the transmitter circuit to

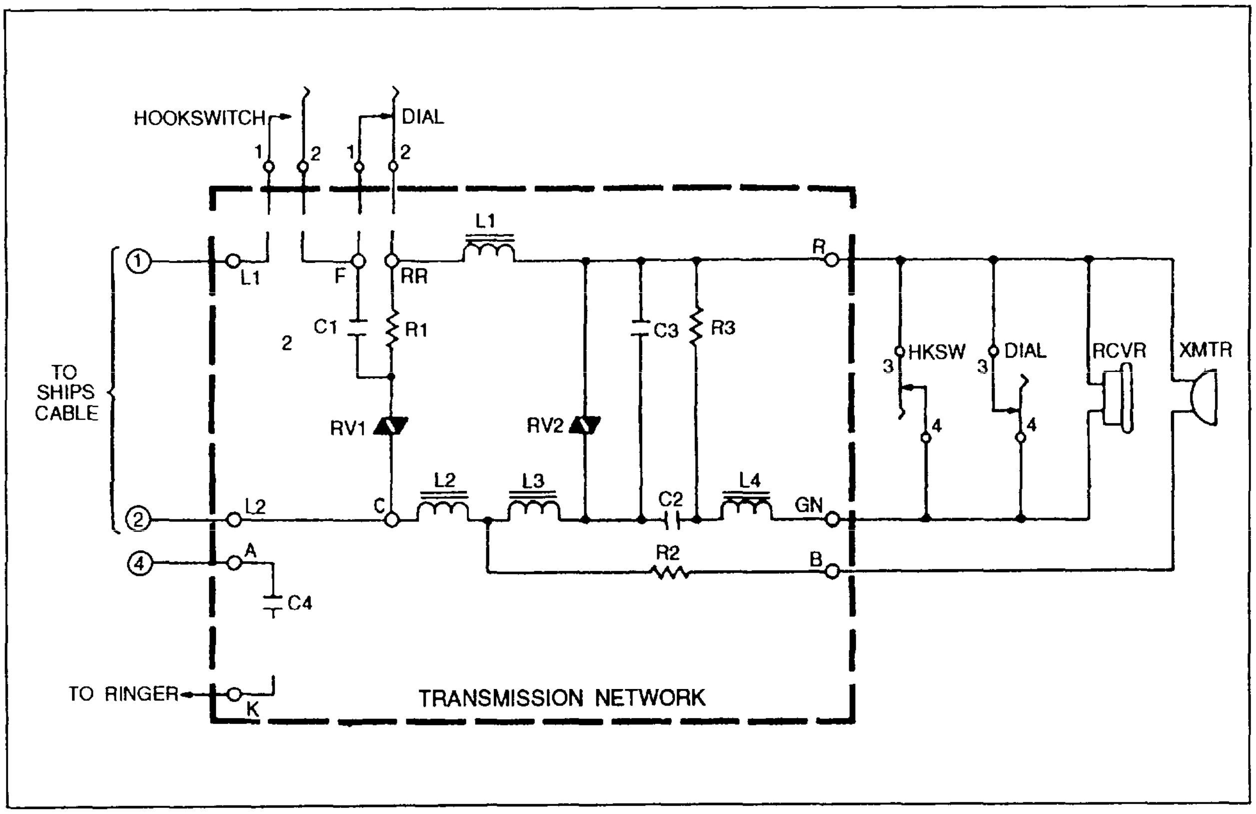


Figure 6-4.—Simplified schematic diagram of the transmission network.

inductor L4 in the receiver circuit. The coupling between inductors L3 and L4 results in the receiver producing a comfortable level of sidetone.

When contacts 1 and 2 close the dc loop, the automatic dial telephone switchboard produces dial tone for outgoing calls and cuts off ringing voltage on incoming calls.

At the same time that the dc loop is closed, the incoming and outgoing audio loops are also closed. The incoming audio loop is closed by hookswitch contacts 1 and 2, dial contacts 1 and 2, inductor L1, the receiver, inductor L4, capacitor C2, and inductors L2 and L3. Audio signals appearing at terminals 1 (L1) and 2 (L2) cause the receiver to reproduce the audio signals generated at the calling station (speech, busy tone, howler tone, and so on).

The outgoing audio loop is the same as that described in dc path 2. When speech or other audio patterns excite the transmitter, the direct current flowing through the transmitter varies around its nominal value at the audio source frequency. This variation extends to terminals 1 (L1) and 2 (L2) and, subsequently, to the distant end (receiving telephone) by the loop. The loop consists of hookswitch contacts 1 and 2, dial contacts 1 and 2, inductor L1, the transmitter, resistor R2, and inductor L2.

Capacitors C2 and C3 and resistor R3 function with varistors RV1 and RV2 as an impedance balancing network for line impedance. Capacitors C2 and C3 also compensate for the line capacitance. In addition, capacitor C2 prevents dc voltages from being extended to the receiver. Capacitor C4 is in the ringer circuit.

HOOKSWITCH.— The hookswitch automatically operates when the handset is removed from or replaced in the handset holder. When you remove the handset from the handset holder, the switch shifts to the off-hook position. When you replace the handset in the handset holder, the switch shifts to the on-hook position.

In the on-hook position, as shown in figure 6-4, hookswitch contacts 1 and 2 open to prevent any line currents from entering the transmission network circuit or the receiver and transmitter when the telephone set is not in use. Contacts 3 and 4 close, placing a short circuit across the receiver to bypass any internal flow of current around the receiver. This guards against demagnetizing the receiver.

In the off-hook position, hookswitch contacts 1 and 2 close to connect the telephone set to the line. Contacts 3 and 4 open to remove the short circuit from across the receiver, thereby preparing the receiver for response to audio inputs or sidetone.

When you remove the handset from its holder to place a call, the dial and transmission network assemblies send an off-hook supervisory signal to the automatic dial telephone switchboard. This signal informs the switchboard to extend dial tone (100 millivolts [mV] peak-to-peak, 600 Hz modulated with 120 Hz) to the telephone set when it is ready to accept dialing.

If you do not start dialing within 30 seconds, the supervisory signal informs the switchboard to extend the howler tone (600 Hz at 8 impulses per second) to the telephone set. To regain the dial tone, you must hang up.

DIAL.— The dial on the basic nonrestricted telephone set operates in the same manner as a rotary dial on commercial telephones.

When the dial is at rest (no digits being dialed), dial contacts 1 and 2 close and contacts 3 and 4 open. When the dial is rotated, dial contacts 3 and 4 close to short the receiver. Shorting the receiver prevents dial pulses from entering the receiver. If dial pulses enter the receiver, the receiver could become demagnetized. Contacts 3 and 4 remain closed as long as the dial is rotating.

When the dial is released, contacts 1 and 2 open and close according to the digit dialed. For example, if the digit dialed is a 4, contacts 1 and 2 will open the dc loop four times as the dial returns to the rest position. These four dc impulses inform the associated automatic dial telephone switchboard that digit 4 has been dialed. This process will be repeated for each digit dialed. Capacitor C1 and resistor R1 in the transmission network are bridged across dial contacts 1 and 2 to suppress contact arcing.

If the called number is busy or the automatic dial telephone switchboard is operating at full capacity, the switchboard will extend a busy tone (100 mV peak-to-peak, 600 Hz interrupted at 60 impulses per minute) to the telephone set.

DIAL ILLUMINATION LAMP AND LAMP DIMMER CONTROL.— When the handset is removed from the handset holder, a lamp mounted above the dial illuminates the dial. You can vary the brightness of the dial lamp with the lamp dimmer control, which is an adjusting screw. By using a screwdriver, you can access the dimmer control through a cutout provided in the cover. The lamp and lamp dimmer control circuit (fig. 6-5) is a basic dc circuit where dc voltage is applied to the telephone set terminal board on terminals 5 and 6. Terminals 4 and 6 will be connected to lead JJ9 of the ship's cable. The voltage is extended to the lamp and lamp dimmer control circuit through a pair of hookswitch contacts that close when the handset is removed from the handset holder.

RINGER.— A gong and clapper-type ringer is used in the telephone set to alert personnel of an incoming call. The ringer circuit (fig. 6-5) is a basic ac circuit where 75 to 110 volts ac, 20 Hz is applied to terminals 3 and 4 of the telephone set terminal board. Capacitor C4, located in the transmission network, tunes the ringer and blocks dc voltage.

The ringer can be connected to the telephone line for one-party (private-line) service or two-party (party-line) service (fig. 6-5). For one-party service,

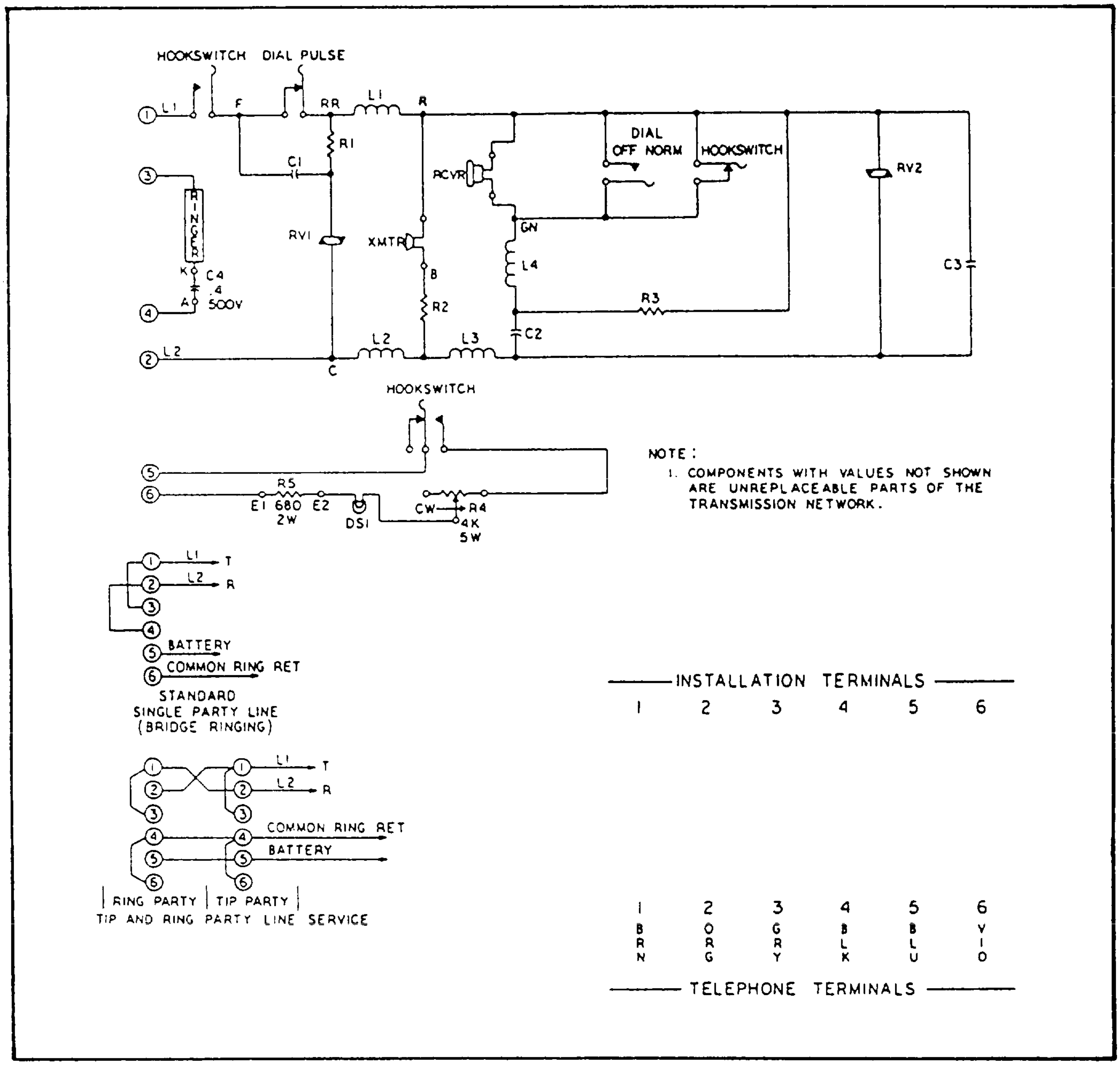


Figure 6-5.—Schematic diagram of the type G (version 1) telephone set

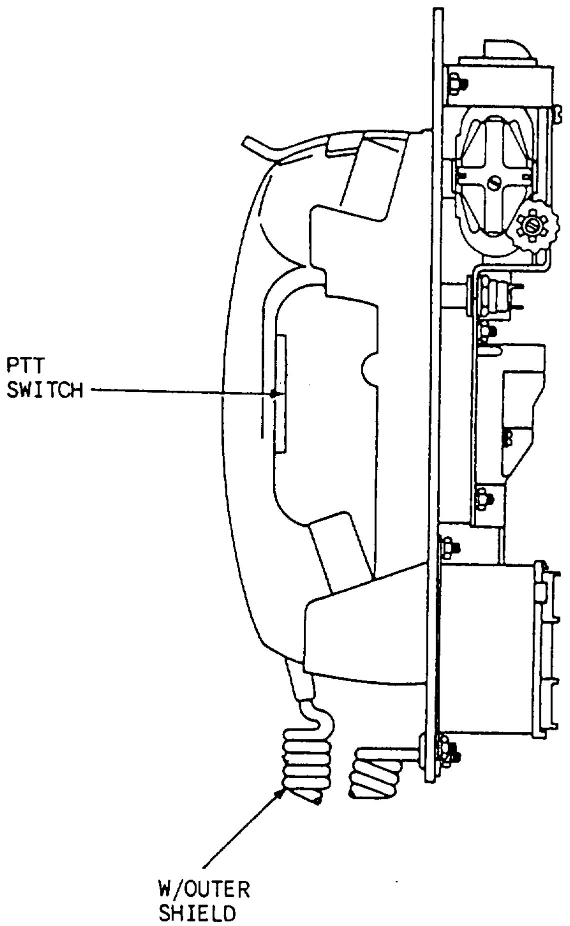


Figure 6-6.—Basic type G (R) restricted telephone set.

ringing voltage is applied to the telephone set terminal on the tip (1) and ring (2) terminals. It is then bridged to terminals 3 and 4.

For two-party service, a third wire (common ring return) is used and connected to terminal 4 of both telephone sets. Ringing voltage is then applied to one telephone set across tip terminal (1) and terminal 4 and to the other telephone set across ring terminal (2) and terminal 4.

Restricted Telephone Set

The type G (R) restricted telephone set is used in security areas where the chance of inductive coupling of signals to the telephone set might compromise the security established for that area. This telephone set is equipped with a noise-cancelling transmitter, shielded handset and deskset cords, and a push-to-talk (PTT) switch. This set has a distinctive identification plate to distinguish it from the nonrestricted set. The identification plate has "Restricted" as the first line and "(R)" after the type designation. The restricted telephone set is also adaptable for high-noise areas because of the PTT and noise-cancelling transmitter features.

Figure 6-6 illustrates a basic type G (R) telephone set. This set will fit the same enclosures as the basic type G nonrestricted set. Figure 6-7 illustrates a handset and cord assembly for the type G (R) set.

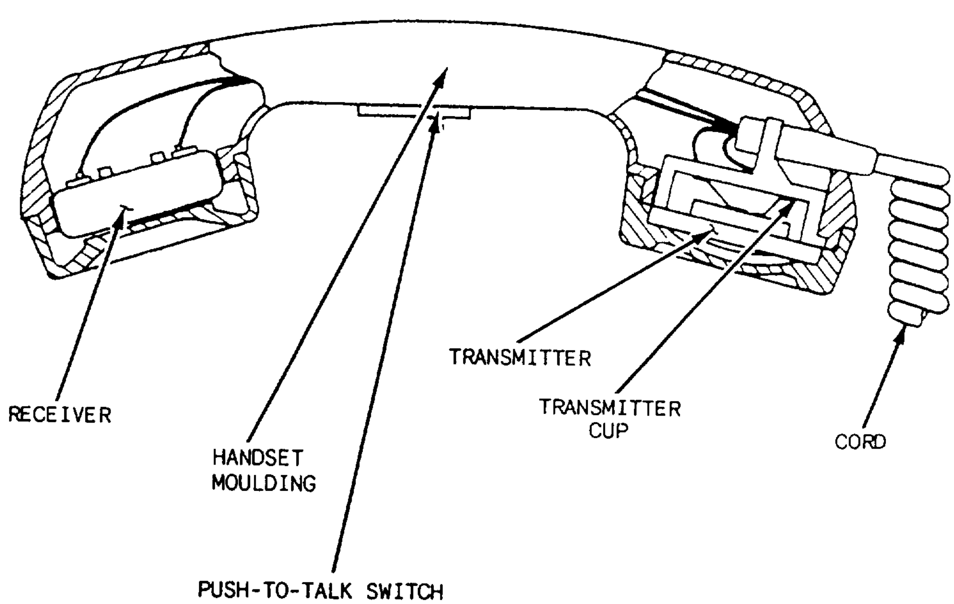


Figure 6-7.—Handset and cord assembly of the type G (R) set.

Figure 6-8 is a schematic diagram of the type G (R) set.

The components and component operation of the type G (R) telephone set are identical to the basic type G nonrestricted set, except for the PTT switch and the shielded cords. The type G (R) set is also maintained in the same manner as the basic type G nonrestricted set.

Portable Telephone Set

The type G portable telephone set is identical to the type G desk-mounted telephone set, except for mounting and electrical connections. The portable telephone set is provided with a cord and plug that connects to a jack in a telephone outlet box. The telephone outlet box is connected to the automatic dial telephone switchboard. The portable telephone set may be used at any location where a telephone outlet box is installed.

The telephone outlet box is a metal waterproof box designed for bulkhead mounting. A stuffing tube at the top of the box provides for electrical connections to the telephone switchboard. The box contains the telephone jack that accommodates the telephone set plug. The box also has a hinged cover to protect the jack when it is not being used.

Figure 6-9 is a wiring diagram of the type G portable telephone set. The set operates and is maintained in the same manner as the basic type G desk-mounted set.

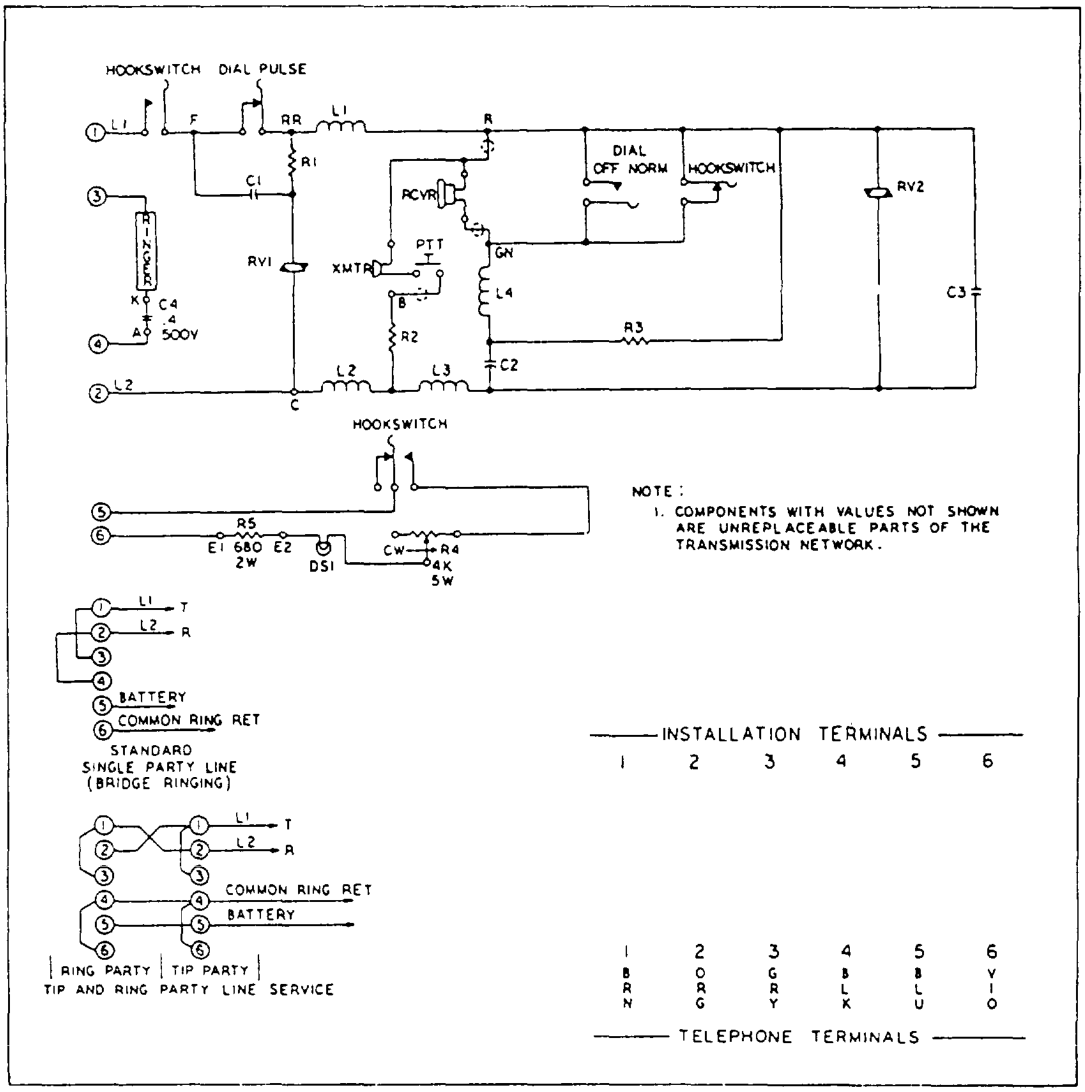


Figure 6-8.—Schematic diagram of the type G (R) set.

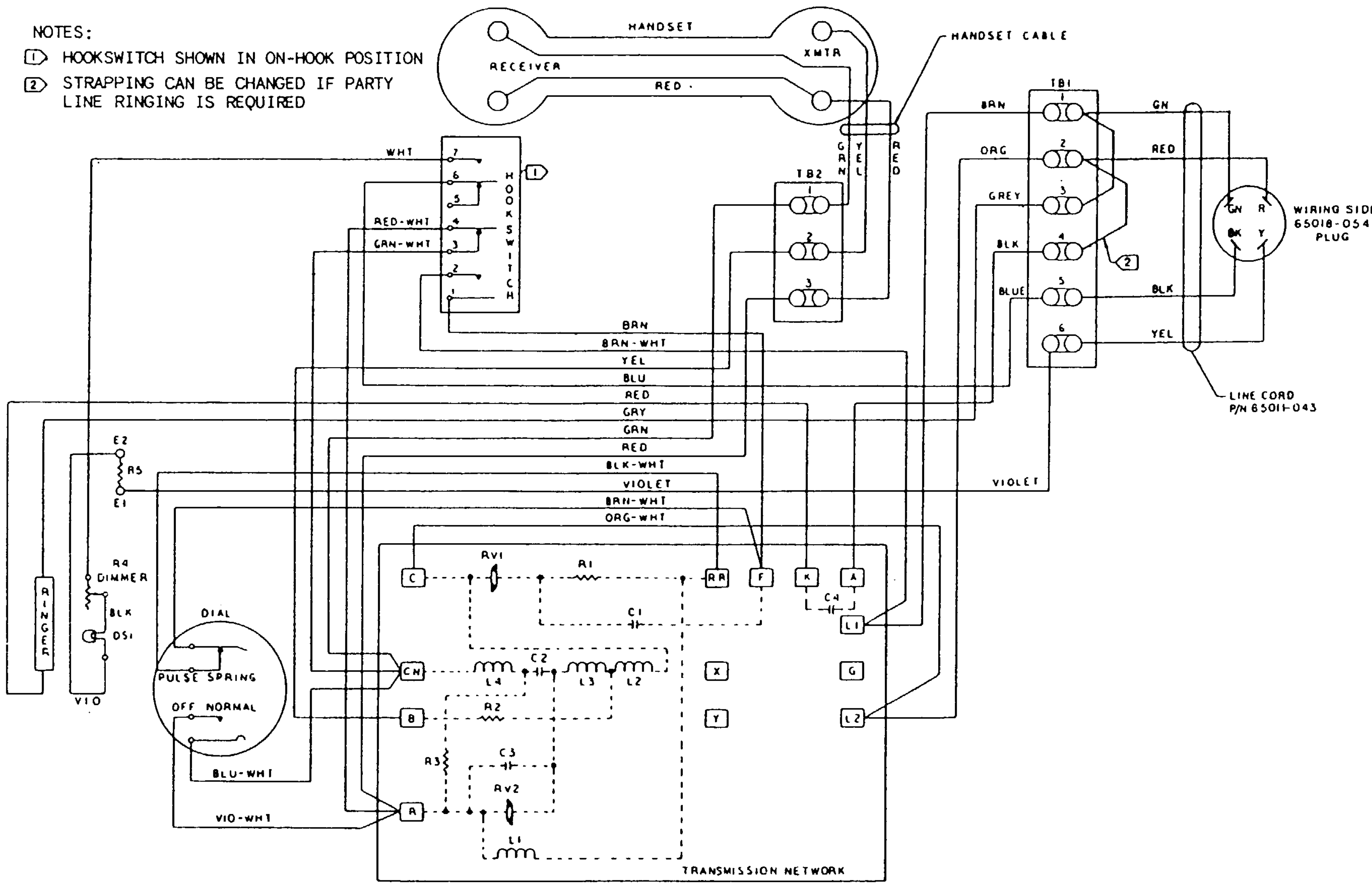


Figure 6-9.—Wiring diagram of the type G portable telephone set.

Modular Telephone Set

There are six models of the type G modular telephone set: a desk-mounted nonrestricted, a desk-mounted restricted, a bulkhead-mounted nonwatertight nonrestricted, two bulkhead-mounted nonwatertight restricted, and a bulkhead-mounted watertight nonrestricted. Each model is comprised of two units: the telephone set and its respective enclosure.

The components and operation of the type G modular sets are identical to the basic nonrestricted and restricted type G sets, except for the modular connectors. Each enclosure has a schematic diagram (fig. 6-10) pasted inside it for convenience in troubleshooting.

Preventive Maintenance

The type G (version 1) telephone set, due to its simple design, requires very little preventive maintenance. Most routine tests are performed during normal operation of initiating and answering calls.

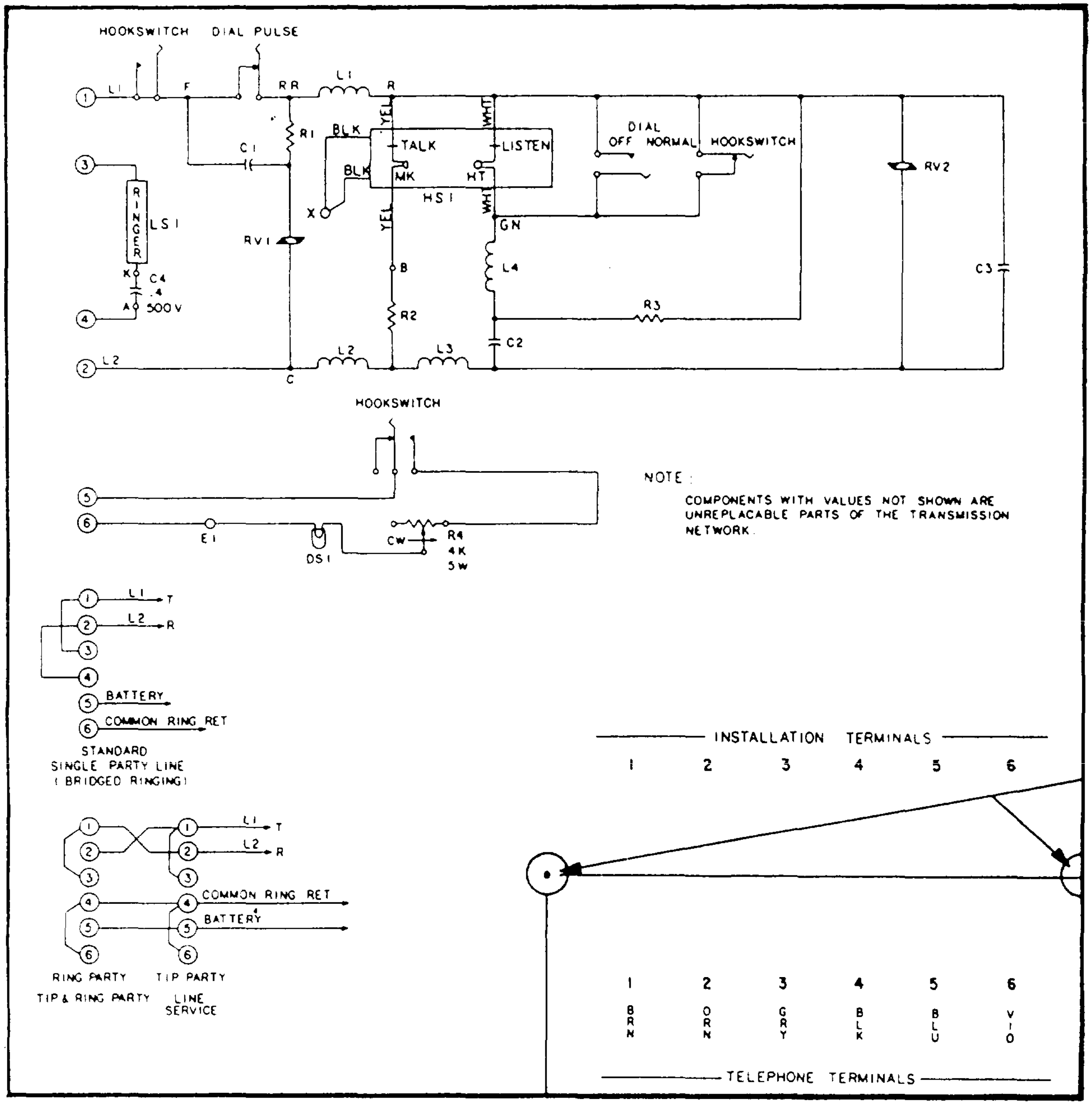


Figure 6-10.—Schematic diagram of the type G modular telephone set.

However, this type of set should be inspected and routine tests should be performed as described in the following paragraphs.

TELEPHONE SET INSPECTION.— The following operations should be performed during a routine inspection of the type G (version 1) telephone set:

1. Inspect the handset for broken or loose transmitter or receiver caps.
2. Check the handset cord for wear. Replace worn, frayed, or noisy cords. To check for a noisy cord, roll the cord back and forth between your hands while listening for a clicking or cracking noise in the receiver.
3. Inspect the handset holder for wear or chipping.
4. Check the handset retaining mechanism for positive action on release and lock functions.
5. Inspect the hookswitch lever for signs of wear. Depress the lever and check for positive outward movement of the lever on the release.

PERFORMANCE TEST.— The following operations should be performed when conducting performance tests of the type G (version 1) telephone set:

1. Remove the handset and check for the dial tone.
2. Check to see that the dial illumination lamp is lit, and rotate the dial dimmer control to see that lamp intensity varies.
3. Replace the handset in its holder to see if the illumination lamp goes out.
4. Remove the handset and wait 30 seconds for the howler tone.
5. Depress the hookswitch and release it to regain the dial tone.
6. Dial 0 and check to see if the dial returns to its normal position in approximately 1 second.
7. Listen for unwanted clicking (dial pulses) in the receiver unit.
8. Dial a number and listen for the ringback tone in the receiver unit.
9. Talk to a person at another station and determine if transmission and reception quality is satisfactory. Check that sidetone is reduced so as not to interfere with normal conversation.
10. Ask a person at another station to call you back so you can check the ringing level of the set and to see that ringing stops when the handset is removed from the handset holder.

When a preventive maintenance check reveals a malfunction in the telephone set, some form of corrective action is required.

Corrective Maintenance

Corrective maintenance of the type G (version 1) telephone set includes adjustments and replacement of failed components.

ADJUSTMENTS.— There are three adjustments on the type G (version 1) telephone set: the dial illumination lamp intensity adjustment, the ringer adjustment, and the dial speed adjustment.

Dial Illumination Lamp Intensity.— The brightness of this lamp is controlled by the dial illumination dimmer control. This control is accessed through a hole in the front panel and is adjusted with a screwdriver. You should rotate the control in a clockwise direction to brighten the lamp and in a counterclockwise direction to dim the lamp.

Ringer.— This adjustment can be made while the telephone set is on line or off line. For on-line adjustment, remove the set from its enclosure and have someone call the set number from another station. While the ringer is sounding, rotate the ringer adjustment control in the appropriate direction to obtain the desired ringing level.

For off-line adjustment, you will need two clip leads and a ringing voltage supply (75 volts at 20 Hz). Remove the telephone set from its enclosure and disconnect the terminal wires. Using the clip leads, connect the ringing voltage supply leads to the terminals of the grey and black leads. The ringer should sound. Rotate the ringer adjustment control in the appropriate direction to obtain the desired ringing level. Disconnect the ringing voltage supply from the terminals of the grey and black leads.

Dial Speed.— The bottom hook on the dial tension spring is attached to one of three tabs on the dial frame as shown in figure 6-11. To increase dial speed, use a pair of needle-nosed pliers to detach the tension spring hook from the tab being used. Then, attach the tension spring hook to the next tab in the clockwise direction. To decrease dial speed, attach the hook to the next tab in the counterclockwise direction.

REPLACEMENT OF COMPONENTS.— Most malfunctions of the type G (version 1) telephone set will be reported by those using the set. After verifying the malfunction, you should check all associated wiring for correct and secure connections before you attempt to troubleshoot the set for faulty components.

When working on the inside of the telephone set, you must follow high-voltage safety procedures. System line voltages can be as high as 54 volts dc and ringing voltages as high as 110 volts and can be dangerous. Always turn off and tag out the telephone station line switch at the automatic telephone switchboard before you begin working on the internal components of the telephone set.

When replacing the type G modular telephone sets, be sure you use the correct model set for the enclosure concerned.

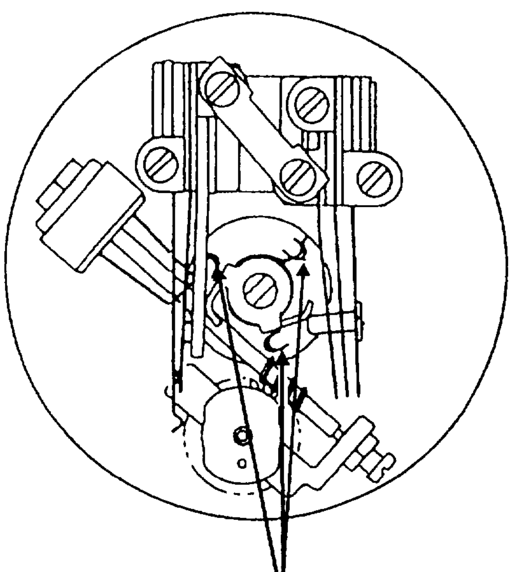


Figure 6-11.—Dial speed adjustment diagram.

The following paragraphs will discuss the procedures for replacing the components of the type G (version 1) telephone set.

Handset Transmitter and Receiver Units.— The transmitter and receiver units are not repairable and must be replaced if defective.

To replace a transmitter unit, unscrew the transmitter cap and lift the transmitter unit out of the transmitter mounting cup. Insert the new transmitter unit in the mounting cup and screw the transmitter cap onto the handset.

To replace a receiver unit, unscrew the receiver cap and lift the receiver unit out of the handset. Disconnect the handset cord red lead and green lead from the screw terminals of the receiver unit. Connect the red lead and green lead to the the screw terminals of the new receiver unit. Insert the new receiver unit into the handset and screw the receiver cap onto the handset.

Handset Cords.— Handset cords are standard stock items and can be readily replaced when the cord becomes worn, frayed, or defective. To replace a handset cord, remove the telephone set from its enclosure and disconnect the three handset cord terminal wires from the terminal board on the set. Remove the cord from the telephone set and the handset from its holder. Remove the receiver unit from the handset, and disconnect the cord terminal wires from the receiver unit. Remove the transmitter unit and the transmitter mounting cup. Disconnect the handset cord terminal wires from the mounting cup. Carefully pull the handset cord from the cord hole in the handset housing.

Insert new cord terminal wires into the housing cord hole. There is one long green wire and one red jumper wire for connection to the receiver. There is also one short red wire and one short yellow wire for connection to the transmitter mounting cup. The other end of the red jumper wire connects to the same terminal on the mounting cup as the short red wire. The cord is pressure-fitted in the handset housing and locked in place by two tabs on the transmitter mounting cup.

Connect the handset cord terminal wires to the mounting cup, and put the transmitter back in the handset. Connect the cord terminal wires to the receiver, and put the receiver back in the handset. Gently insert the handset cord through the cord hole in the chassis of the telephone set. Install the strain relief bushing in the cord hole, and connect the terminal wires to the terminal board.

Dial.— To replace a dial, remove the telephone set from its enclosure and disconnect the terminal wires from the terminal board. Remove the telephone set chassis from the telephone set cover. Remove the screws that hold the dial to the chassis, lift the dial out of the chassis, and remove the dial dust cover. Disconnect the four leads from the screw terminals of the dial.

Connect the four leads to the new dial, and secure the dust cover on the dial. Insert the new dial in the chassis, and secure the dial to the chassis. Secure the chassis on the telephone set cover, and reassemble the telephone set for normal operation.

Ringer.— To replace a ringer, remove the telephone set from its enclosure and disconnect the terminal wires from the terminal board. Remove the telephone set chassis from the telephone set cover. Unsolder the red lead and the green lead from the ringer terminals. Remove the screws that hold the ringer to the chassis and lift the ringer off the chassis.

Mount the new ringer on the chassis and secure the ringer to the chassis. Solder the red lead and the green lead to the ringer. Secure the chassis on the telephone set cover and reassemble the telephone set for normal operation.

Dial Illumination Lamp.— To replace the dial illumination lamp, remove the telephone set from its enclosure. Remove the screw that secures the lamp holder to the chassis. Lift the lamp holder up until the lamp is clear of the grommet, and then turn the lamp holder over. Remove the lamp from the lamp holder by pressing the lamp down gently and rotating it counterclockwise approximately one-quarter turn.

Install the new lamp in the lamp holder by pressing the lamp down gently and rotating it clockwise approximately one-quarter turn. Turn the lamp holder over and insert the new lamp in the grommet. Press down until the lamp holder is against the grommet. Secure the lamp holder to the chassis. Remove the handset from its holder and check to see that the lamp lights.

Transmission Network.— To replace the transmission network, remove the telephone set from its enclosure and disconnect the terminal wires from the terminal board. Remove the 17 lead terminals from the transmission network. Remove the two nuts and lockwashers that secure the transmission network to the cover. Lift the transmission network off the threaded studs. Position the new transmission network on the studs and secure it to the cover. Connect the 17 lead terminals to the network. Reconnect the terminal wires to the terminal board and secure the telephone set in its enclosure.

Common Telephone ‘lkoubles

Some of the more common telephone set troubles include (1) no dial tone, (2) dial impulses heard in the receiver while dialing, (3) poor transmission quality, (4) low reception, (5) can transmit but cannot receive, (6) can receive but cannot transmit, (7) ringer does not sound, (8) telephone set consistently dials the wrong number, (9) noisy connection, and (10) sidetone too loud. Procedures for analyzing these troubles and the corrective actions you should take if they occur are discussed briefly in the following paragraphs.

NO DIAL TONE.— If no dial tone is present, you must determine whether the telephone set, telephone line, or automatic dial telephone switchboard is the cause of the problem. To isolate the problem, connect a hand test telephone across the line. If a dial tone is present using the hand test telephone, then the problem is in the telephone set. If the problem is in the set, it could be in the hookswitch, the receiver, the handset or desk set cord, or the transmission network. Once you isolate the problem, replace the defective component.

If a dial tone is not present when checking the line with the hand test telephone, then the problem is either an open in the telephone line coming from the automatic dial telephone switchboard or in the switchboard itself. If the problem is found in the switchboard, you will need to refer to the switchboard technical manual.

DIAL PULSES HEARD WHILE DIALING.— Dial pulses heard in the receiver while you are dialing are usually the result of the hookswitch shunt spring contacts being out of adjustment. The contacts should make when dialing. If the hookswitch contacts are working properly, check the transmission network. If there is a problem with the transmission network, replace it. If the contacts are out of adjustment, adjust the contacts by bending them.

POOR TRANSMISSION QUALITY.— If a telephone transmits poorly, the fault is probably in the transmitter unit. One cause could be the carbon granules inside the transmitter clinging together. You can try and loosen the carbon granules in the transmitter by holding the handset in a horizontal position and shaking it, using a circular motion. If this does not work, then strike the transmitter end of the handset sharply with the palm of your hand. If the granules cannot be loosened, replace the transmitter.

Another cause could be loose connections or dirty contact springs in the transmitter cup. If replacing the transmitter or cleaning the transmitter cup contact springs does not correct the problem, check the transmission network. If there is a problem with the transmission network, replace it.

WEAK RECEPTION.— If a telephone has poor or weak reception, the trouble may be caused by a weak transmitter, a worn receiver cord, loose connections inside the handset, or a problem in the transmission network. If the problem is loose connections, tighten the connections. If the problem is a defective component, replace the component.

CAN TRANSMIT BUT CANNOT RECEIVE.— When a telephone can transmit but cannot receive, the problem is usually in the hookswitch or in the receiver unit. The fault could also be caused by a shorted transmitter unit or a shorted contact of the dial shunt springs. After you isolate the problem, replace the defective component.

CAN RECEIVE BUT CANNOT TRANSMIT.— When a telephone can receive but cannot transmit, check the transmitter unit as you would for poor transmission. If the transmitter is found to be defective, replace it. If the transmitter is not defective, replace the transmission network.

RINGER DOES NOT SOUND.— If the ringer at a called station does not ring, the fault could be caused by an open ringer coil or capacitor, or reversed or loose connections at the ringer terminals. Also, the ringer will not ring properly if the ringer is not properly adjusted, if the gongs have become loose, or if the position of the gongs has shifted with respect to the clapper. If the ringer does not sound at all, you should first check the connections and correct them if they are reversed or tighten them if they are loose. If the cause of the problem is a defective component, replace the component. If the ringer is ringing improperly, adjust the ringer as described earlier.

WRONG NUMBERS.— The most frequent cause of wrong numbers is the dial speed being too fast or too slow. If the dial speed is incorrect, adjust it as described earlier. If adjusting the speed does not correct the problem, replace the dial.

Another frequent cause of wrong numbers is jiggling the hookswitch before dialing. This can result in a series of pulses similar to those sent out by the dial. Also, keeping the dialing finger on the dial while it is returning to its normal position may result in wrong numbers.

NOISY CONNECTIONS.— Noisy connections are caused by worn handset or deskset cords, loose connections in the telephone set, partial shorts or grounds on the line, or noisy transmitter units. Check the telephone set cord as described earlier, and replace the cord as necessary. Tighten loose connections and clear any shorts or grounds on the line. If the problem is found to be in the transmitter unit, replace it.

SIDETONE TOO LOUD.— When you have a loud sidetone in the receiver of the handset, the problem is in the transmission network, which you should replace.

TYPE G TELEPHONE SET (VERSION 2)

The type G (version 2) telephone set is very similar in appearance and operation to the type G (version 1) set; however, slight differences do exist between them. The principle differences are component nomenclature, the handset holder and retaining mechanism, and the internal circuitry of the telephone set. The following paragraphs will only discuss the features of the version 2 set that are different from the version 1 set.

Component Nomenclature

The components of the type G (version 2) set are identified in figure 6-12, views A and B. Several components of the version 2 set serve the same function as components of the version 1 set, but are identified by different names. For example, the network assembly in the version 2 set serves the same purpose as the transmission network in the version 1 set.

Handset Holder and Retaining Mechanism

The handset for the version 2 set is equipped with an internal latching mechanism and a latch release button. The latching mechanism is used with the handset latch stud to retain the handset in its cradle. The latch release button is located on the side of the handset. If

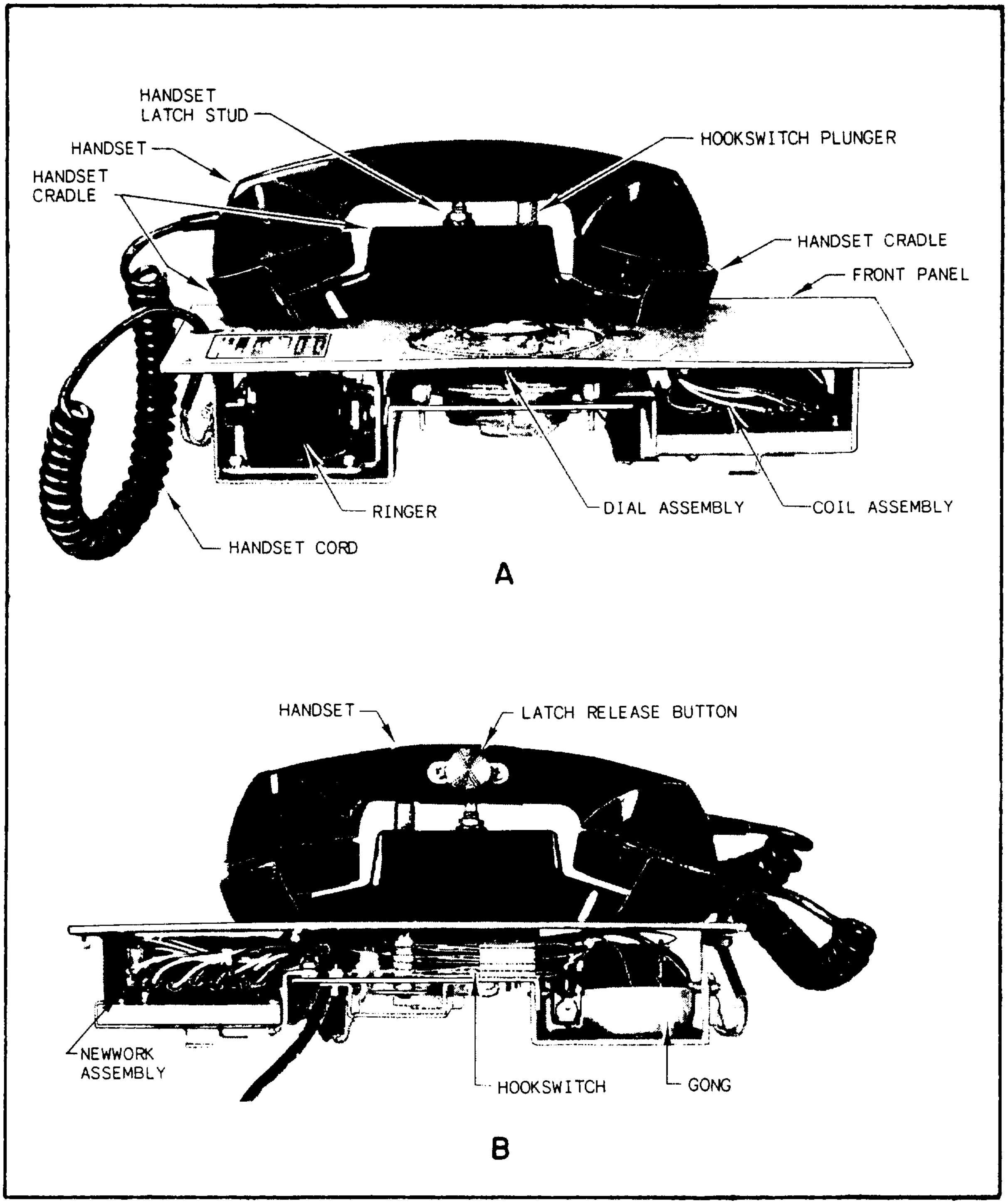


Figure 6-12.—Type G (version 2) telephone set.

you press this button, the handset will be released from its cradle.

Internal Circuitry

Figure 6-13 is a schematic diagram of the type G (version 2) telephone set. The circuit is designed and operates in a slightly different manner as that of the version 1 set. Circuit operation will be discussed in the following paragraphs.

NETWORK ASSEMBLY.— Figure 6-14 is a simplified schematic diagram of the network assembly circuit. This circuit serves the same function as the transmission network circuit in the version 1 set.

When you remove the handset from its cradle, three paths for dc are provided from terminal L1 to terminal L2. Dc path 1 is through resistor RI and varistor RV1. Dc path 2 is through inductor L1, resistor R2, and the transmitter. Dc path 3 is through inductors L1 and L2 and varistor RV2.

The mutual inductance of inductors L1, L2, and L3 and the value of resistor R_B(resistor, balance 68 ohms) is such that a comfortable level of sidetone is heard in the receiver when the transmitter is excited.

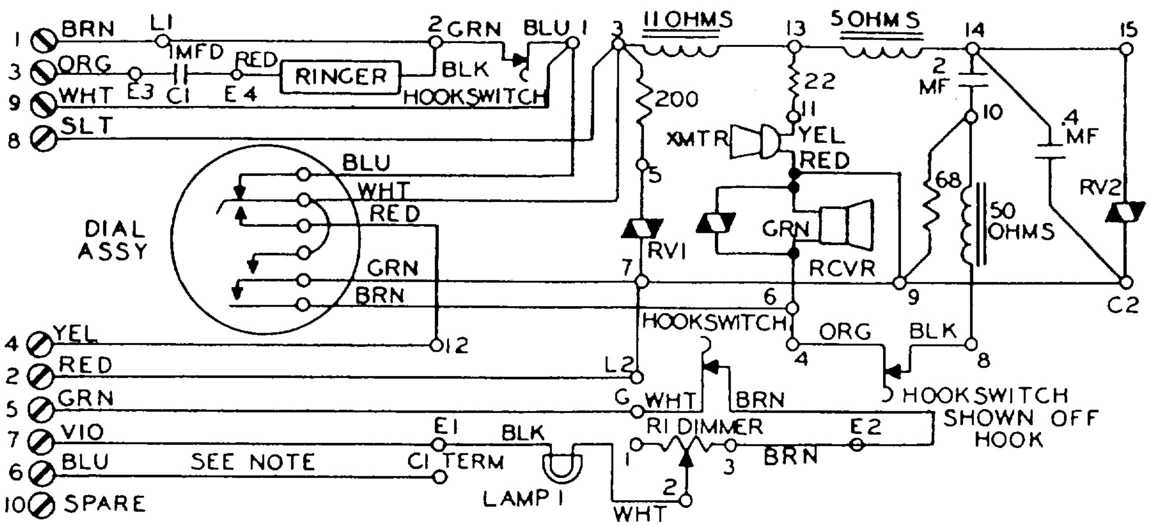


Figure 6-13.—Schematic diagram of the type G (version 2) telephone set.

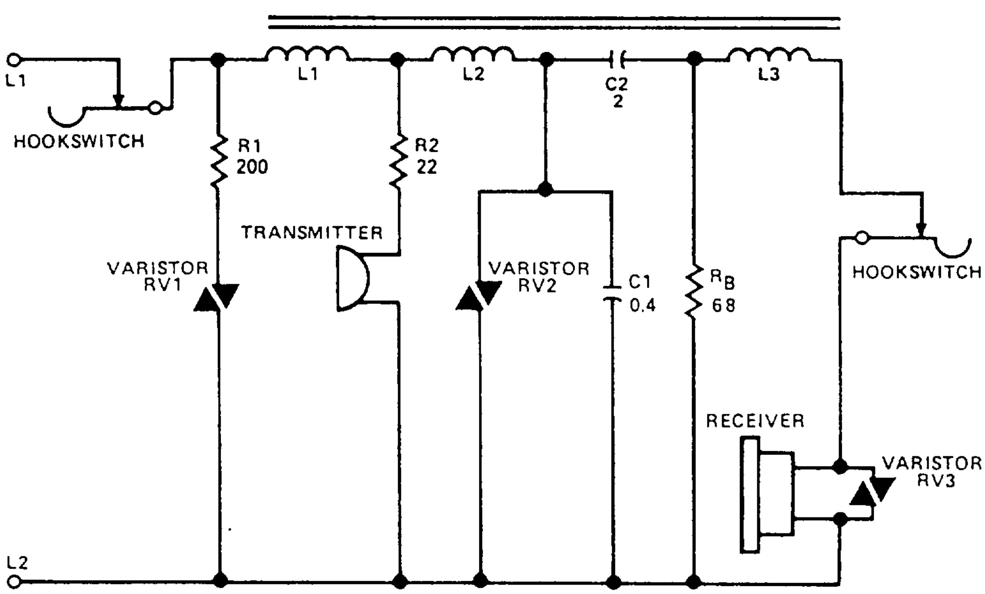


Figure 6-14.—Simplified schematic diagram of the network assembly circuit.

Capacitor C1, varistor RV1, and resistor R_B constitute an impedance balancing network for the line impedance. Capacitor C1 also compensates for the line capacitance. Capacitor C2 prevents dc voltages from being extended to the receiver.

Varistors RV1 and RV2 comprise a gain control to maintain a constant input and output level regardless of whether the telephone is connected to a long or a short loop. Resistor R1 is a current-limiting device to protect varistor RV1 from high line-voltage surges.

Varistor RV3 acts as a click suppressor and is almost a short circuit across the receiver when the voltage across RV3 reaches approximately 1 volt. This action also prevents demagnetization of the receiver.

SIDETONE CIRCUIT.— Figure 6-15 is a simplified schematic diagram of the receiver sidetone circuit. Because current will not flow through a balanced circuit, the turns ratio of inductors L1 and L2 is unbalanced by a predetermined amount and the value of resistor R_B is changed so as not to match the line impedance. This way, a controlled amount of signal can be induced into L3 to be used as receiver sidetone.

RINGER CIRCUIT.— The ringer can be connected to the telephone line for one- or two-party service. Figure 6-16, views A and B, illustrates how the telephone set is connected for the service desired. For two-party service, ringing is extended to the prime telephone set over the R (L2) lead and to the extension set over the T (L1) lead.

When a caller dials your number, the ringing generator located in the automatic dial telephone switchboard applies 75 to 100 volts ac at 20 Hz to the ringer of your telephone set through capacitor C1 (fig. 6-13), causing the bell to ring. When you pickup your receiver, you complete a dc circuit through the switchboard, which operates relays to disconnect the ringing generator and connect you to your calling party.

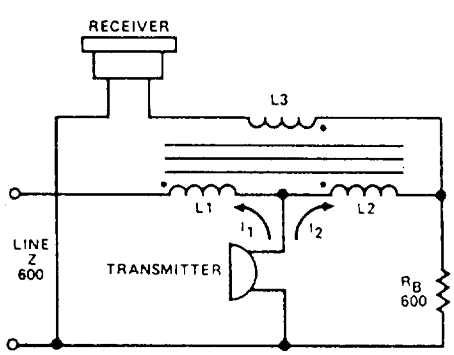


Figure 6-15.—Schematic diagram of the sidetone circuit.

Preventive Maintenance

Preventive maintenance for the version 2 set is the same as for the version 1 set.

Corrective Maintenance

Corrective maintenance of the version 2 set includes adjustments and replacement of failed components.

ADJUSTMENTS.— There are four adjustments on the type G (version 2) telephone set: the hookswitch contact springs adjustment, the ringer adjustment, the gong adjustment, and the dial illumination lamp intensity adjustment. Dial illumination lamp intensity on the version 2 set is adjusted in the same manner as the version 1 set. Dial speed on the version 2 set is not adjustable; therefore, if the dial speed is too slow or too fast, the dial must be replaced.

Hookswitch Contact Springs.— Figure 6-17 is an illustration of the hookswitch assembly. To adjust

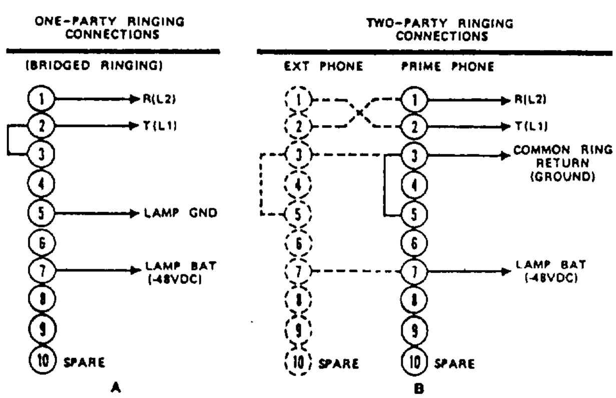


Figure 6-16.—Type G (version 2) ringer connectors.

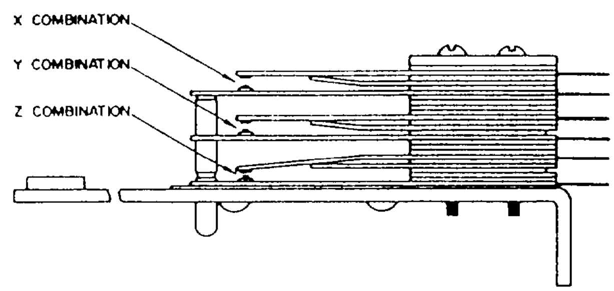


Figure 6-17.—Hookswitch assembly.

the hookswitch contact springs, bend the contact-spring stiffeners with a spring adjuster and measure the contact separations with a standard feeler gauge. With the hookswitch plunger fully operated on the hook, adjust the X and Z combinations for a contact separation of 0.025 to 0.035 inch and the Y contact combination for a contact separation of 0.045 to 0.055 inch.

After adjustment, check the follow (overtravel) of each contact combination. In going from on hook to off hook, the minimum follow must be 0.010 inch and the contact springs must not touch adjacent stiffeners.

Ringer.— To adjust the ringer, slightly loosen the three screws located on the bottom of the ringer. Be careful not to loosen the screws too much as the magnetic field could be broken and the ringer will need remagnetization. Next, insert a nonmagnetic feeler gauge of 0.025 inch thickness between the armature face and the pole face. Slide the coil and lamination assembly toward or away from the armature until a setting of 0.020 to 0.025 is obtained. Tighten the screws and remove the gauge.

Gong.— To adjust the gong, loosen the gong nut and have someone dial the number of the telephone set. While the telephone is ringing, rotate the gong until you get the desired ring level. Lift the handset to stop the ringing. Hold the gong so it does not move, and tighten the gong nut.

REPLACEMENT OF COMPONENTS.— As with the version 1 set, most malfunctions of this telephone set will be reported by those using the set. When replacing components in the version 2 set, use the same basic troubleshooting procedures and safety precautions as described earlier for the version 1 set.

The following paragraphs will discuss the procedures for replacing the components of the version 2 set. Only those components that are removed and replaced in a different manner than those described earlier for the version 1 set will be discussed.

Ringer.— To replace a ringer, remove the telephone set from its enclosure. If you are replacing the ringer on a bulkhead-mounted telephone set, you will need to disconnect the 9-lead line cord and take the set to a workbench.

Unsolder the red ringer wire connected to terminal E4. Disconnect the black ringer wire from terminal 2 of the network assembly. Remove the four nuts that hold the ringer to the panel and remove the ringer from the panel.

Secure a new ringer to the panel. Solder the red ringer wire to terminal E4. Connect the black ringer wire to terminal 2 of the network assembly. Reconnect the line cord, if required, and secure the telephone set to its enclosure.

To replace the ringer capacitor, remove the telephone set from its enclosure. Remove the capacitor retainer nut and unsolder the capacitor wires from the terminals. Remove the capacitor from the set. Solder the new capacitor to the terminals and secure the capacitor to the panel with the retainer nut. Secure the telephone set to its enclosure.

Network Assembly.— To replace the network assembly, remove the telephone set from its enclosure. Remove the three nuts holding the network assembly to the frame. Disconnect the wires from the assembly and remove the assembly from the frame. Connect the wires to the new network assembly and secure the assembly to the frame. Secure the telephone set to its enclosure.

Dial Illumination Lamp.— To replace the dial illumination lamp, remove the telephone set from its enclosure. Remove the locking nut holding the lamp socket. Lift out the lamp socket and remove the lamp. Insert a new lamp in the socket and secure the lamp socket to the frame. Secure the telephone set in its enclosure.

COMMON TELEPHONE TROUBLES.— Common troubles for the version 2 telephone set are basically the same as those for the version 1 set.

AUTOMATIC DIAL TELEPHONE SWITCHBOARD

The automatic dial telephone switchboard is the switching center of the dial telephone system. The switchboard is designed to perform the automatic switching functions necessary for shipboard point-to-point communications between telephone sets operating over automatic dial telephone lines. Some of the automatic dial telephone switchboards installed on board Navy ships include the Dynalec 100/150 line, the Marine Dialmaster, the Dynalec 200/500 line, and the Dimension 2000. The most common type of automatic dial telephone switchboard installed on board Navy ships today is the Dynalec 100/150 line.

DYNALEC 100/150-LINE SWITCHBOARD

The Dynalec 100/150-line switchboard (fig. 6-18) is a combination electrical/ectromechanical switching system. The equipment consists of a 100-line or a 150-line switchboard and an 8-line manually operated attendant's cabinet. The system is fully automatic except for shore access when the ship is in port, which requires the use of the attendant's cabinet. The switching mechanisms automatically perform the following functions:

- Locate a station desiring to make a call.
- Respond to dial pulses and extend the calling station to the called station.
- Ring the called station, selecting from among the stations on a party line, if necessary.
- Supply various tones, such as dial tone, busy tone, ring-back tone, and howler tone, as required.

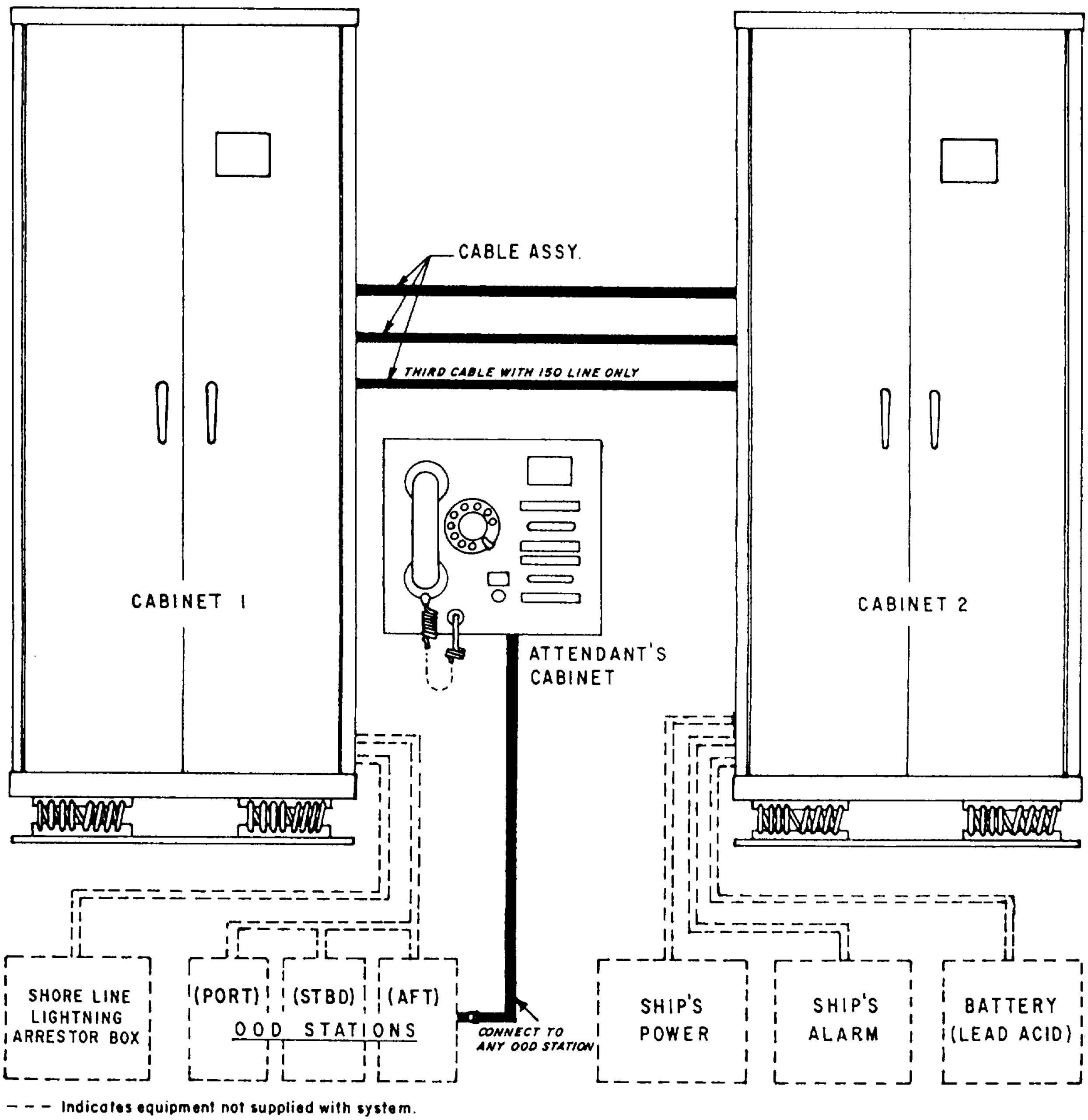


Figure 6-18.—Dynalec 100/150-line automatic dial telephone switchboard.

- Provide “hunt-the-not-busy-line” service where required.
- Provide “emergency cut-in” service to line stations as specified.
- Disconnect the calling and called stations at the completion of the conversation.

Any two-wire, dial telephone set using break-type dialing can be used with the system.

Switchboard Equipment Description

The automatic switching equipment is housed in two dripproof, steel, shock-mounted cabinets. Each cabinet has a front section and a rear section. The front section of cabinet 1 contains equipment gates and one crossbar switch. The front section of cabinet 2 contains equipment gates, the power supply, two ringing generators, and aground fault detection panel. The rear section of both cabinets contains the rest of the crossbar switches. For the 100-line switchboard, seven switches are mounted in the rear section of cabinet 1 and two switches are mounted in the rear section of cabinet 2. For the 150-line switchboard. seven switches are mounted in the rear section of each cabinet. The rear panel of each cabinet is removable to facilitate access to the rear section and the crossbar switches.

EQUIPMENT GATES.— There are two equipment gates in each switchboard cabinet. The upper gate in each cabinet mounts the switch and fuse panel for the respective cabinet. The lower gate mounts the circuit card cage. All the equipment gates swing out, providing access to the crossbar switches mounted in the rear of each cabinet in the event the rear panel cannot be removed. This swing-out feature also provides access

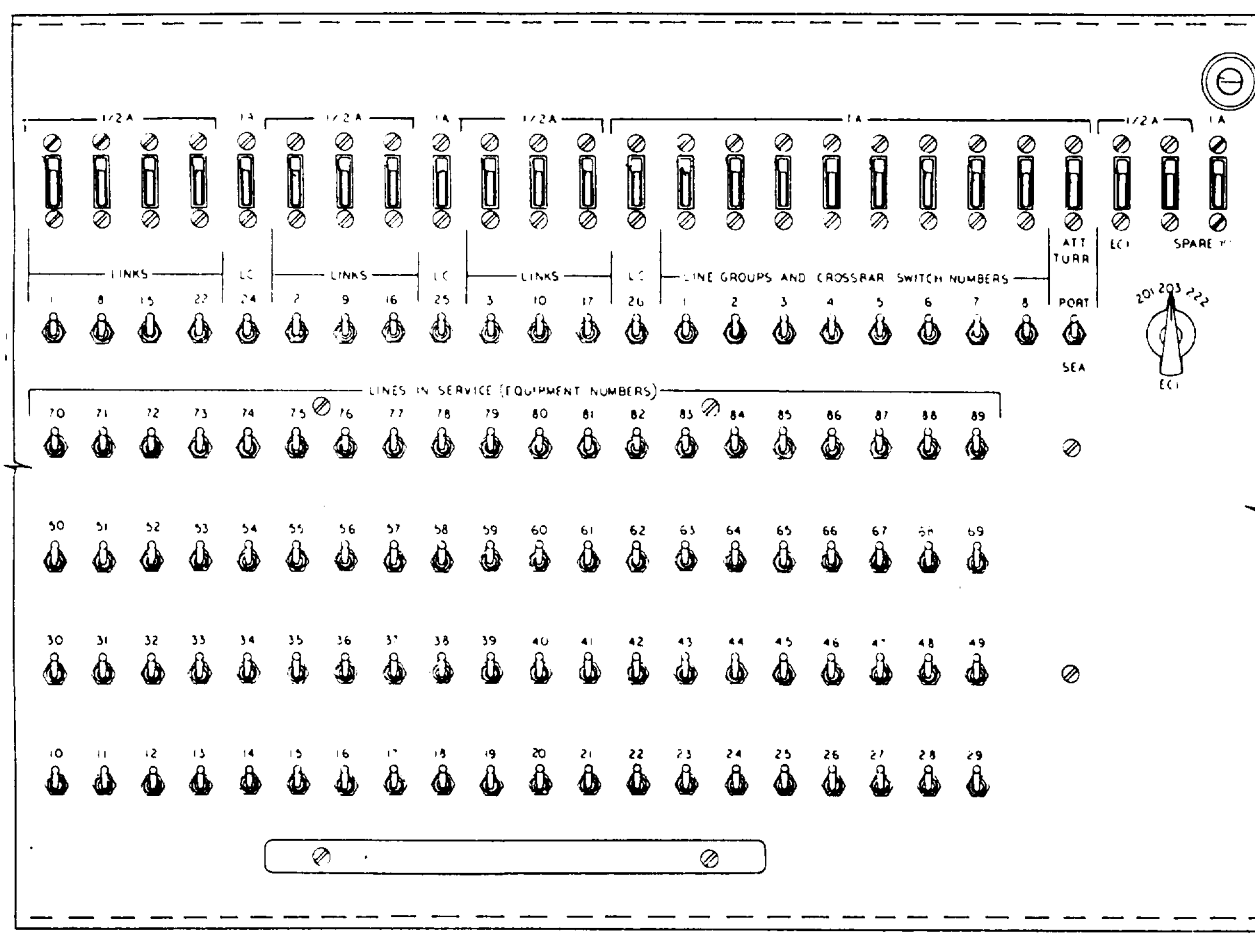


Figure 6-19.—Switch and fuse panel for the 100-line switchboard, cabinet 1.

to the terminal side of the plug-in modules for testing and troubleshooting.

Switch and Fuse Panels.— The switch and fuse panel in cabinet 1 contains alarm-type indicating fuses, equipment enable (in-service)/disable (out-of-service) switches, the attendant's cabinet enable switch, and the emergency cut-in selector switch. Figure 6-19 is an illustration of the switch and fuse panel for the 100-line switchboard located in cabinet 1.

The switch and fuse panel in cabinet 2 contains alarm-type indicating fuses, equipment enable/disable switches, ringing generator transfer switches, traffic and all trunks busy registers, and alarm indicator lamps. Figure 6-20 is an illustration of the switch and fuse panel for the 100-line switchboard located in cabinet 2.

The alarm-type indicating fuses located on the panels protect the various switchboard circuits and/or assemblies, as marked, from damage due to excessive current.

Tables 6-1, 6-2, and 6-3 describe the various operating controls (switches) and indicators located on the two switch and fuse panels.

Circuit Card Cages.— The circuit card cage in cabinet 1 of both the 100-line and 150-line switchboards contains six circuit card assembly shelves. The cage in cabinet 2 of the 100-line switchboard contains three circuit card assembly shelves, and the cage in cabinet 2 of the 150-line contains five assembly shelves. Each circuit card shelf accommodates 14 plug-in modules. The modules consist of integrated circuit (IC) packages mounted on circuit card assemblies.

CROSSBAR SWITCHES.— The standard coordinate-type crossbar switch is used as the basic switching unit in the switchboard. This

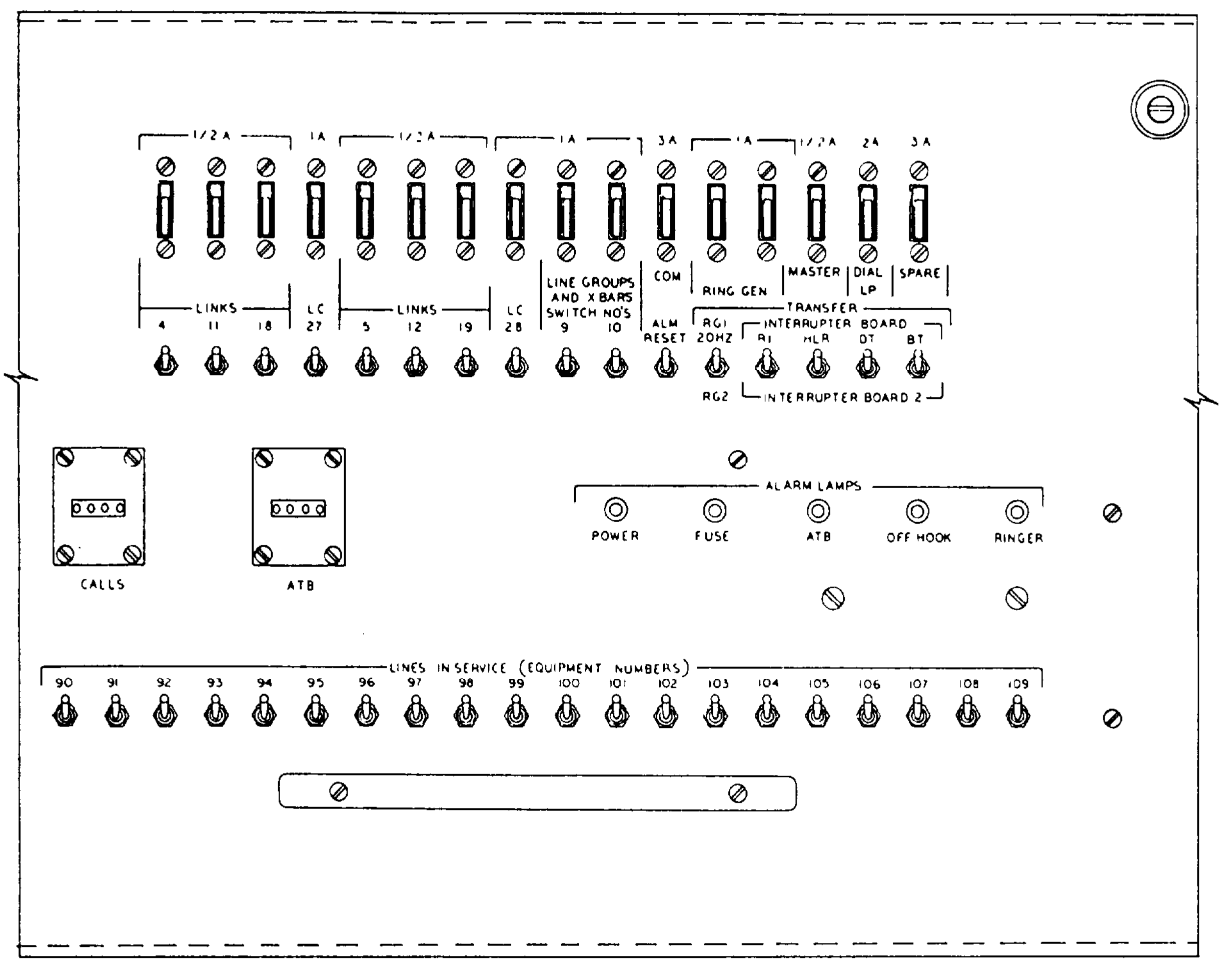


Figure 6-20.—Switch and fuse panel for the 100-line switchboard, cabinet 2.

Table 6-1.—Switch and Fuse Panel, Cabinets 1 and 2, Controls and Indicators

DESIGNATION	FUNCTION	POSITION/INDICATION
LINK Switches	Isolate link from switchboard to prevent seizing a link that is malfunctioning.	Up—link in service. Down—link out of service.
LC Switches	Isolate link control from switchboard to prevent seizing of link control or group of links that are malfunctioning. NOTE An LC switch set in the down position will also place the links, associated with that link control, out of service.	Up—link control in service. Down—link control out of service.
LINE GROUPS AND CROSSBAR SWITCH NUMBERS Switches	Isolate crossbar or group (10) of lines from switchboard to prevent seizing a crossbar switch or group of lines that are malfunctioning. CAUTION When a LINE GROUPS AND CROSSBAR SWITCH NUMBERS switch is set to the down position, all LINES IN SERVICE switches associated with that group must be set to the up position to prevent system failure.	Up—crossbar switch in service. Down—crossbar out of service.
LINES IN SERVICE Switches	Isolate line from switchboard due to: —Excessive howler time. —Telephone or ship's wiring fault. —No telephone connected.	Up—line in service. Down—line out of service,

Table 6-2.—Switch and Fuse Panel, Cabinet 1, Controls and Indicators

DESIGNATION	FUNCTION	POSITION/INDICATION
ATT TURR PORT/SEA Switch	Conditions attendant's cabinet for in-port (active) or at-sea (inactive) operation.	PORT (up)—PWR indicator on (attendant's cabinet). SEA (down)—PWR OFF indicator off (attendant's cabinet).
ECI Switch	Selects one of three stations to which the emergency cut-in feature will be assigned.	201—Quarter Deck. 203—Auxillary Quarter Deck. 222—Bridge.

Table 6-3.—Switch and Fuse Panel, Cabinet 2, Controts and Indicators

DESIGNATION	FUNCTION	POSITION/INDICATION
ALM RESET Switch	Silences audible alarm when momentarily operated in up position.	UP—silence audible alarm. Down—audible alarm (during alarm condition).
20 Hz RG1/ RG2 TRANSFER Switch	Manually enables ringing generator 1 or 2.	RG 1 (up)—ringing generator 1. RG2 (down)—ringing generator 2.
RI INTERRUPTER BOARD 1/2 TRANSFER Switch	Manually selects ring interrupt cycle from interrupter board 1 or 2.	Up—interrupter board 1, Down—interrupter board 2.
HLR INTERRUPTER BOARD 1/2 TRANSFER Switch	Manually selects howler from interrupter board 1 or 2.	Up—interrupter board 1, Down—interrupter board 2.
DT INTERRUPTER BOARD 1/2 TRANSFER Switch	Manually selects dial tone from interrupter board 1 or 2.	Up—interrupter board 1. Down—interrupter board 2.
BT INTERRUPTER BOARD 1/2 TRANSFER Switch	Manually selects busy tone from interrupter board 1 or 2.	Up—interrupter board 1, Down—interrupter board 2,
CALLS Meter	Registers number of completed calls.	
ATB Meter	Registers number of all trunks (links) busy conditions encountered.	
POWER ALARM Lamp	Indicates loss of primary ac power.	On—loss primary ac power. Extinguished—primary ac power available.
FUSE ALARM Lamp	Indicates flagged fuse on switch and fuse panel (cabinets 1 and 2).	On—flagged fuse. Extinguished—normal.
ATB ALARM	Indicates all trunks (links) in service are busy.	On—all trunks busy. Extinguished—normal.
OFF HOOK ALARM Lamp	Indicates off hook phone station has timed out without completing a call.	On—phone station off hook. Extinguished—normal
RINGER ALARM Lamp	Indicates loss of ring voltage.	On—loss of ring voltage. Extingusihed—normal.

switch (fig. 6-21) consists of a welded rectangular frame that houses 10 vertical (hold) units, 6 horizontal select bars, 12 select magnets, and 12 select off-normal spring pile-ups. Each switch can connect 10 sets of three conductors each to any of 30 sets of three conductors each. This means one switch can handle up to 10 connections at any given time. All paths are electrically isolated from each other.

POWER SUPPLY.— The switchboard power supply (fig. 6-22) receives a 115-volt, 60-Hz, single-phase input from the main IC switchboard. The power supply takes this input and internally develops 51.6-volt dc and +5 and +12 volt dc logic voltages. The 51.6-volt dc is used to trickle charge and equalize charge a 24-cell battery bank. The battery bank is used as an emergency input for the power supply when the input from the main IC switchboard fails. In the event there is a failure, the power supply automatically shifts to the battery input. The +5 and +12 dc logic voltages are used as inputs to the circuit card assemblies. Input line filters are also used in the power supply to prevent line voltage surges from affecting the output voltage of the power supply. Table 6-4 describes the operating controls, indicators, and indicator-type fuses located on the power supply,

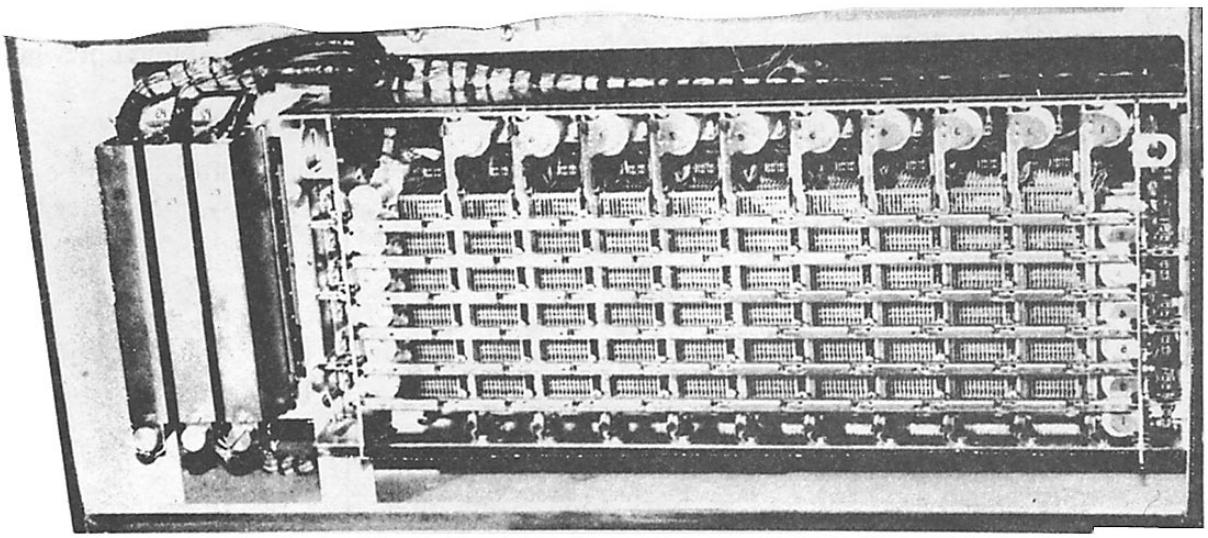


Figure 6-21.—Crossbar switch.

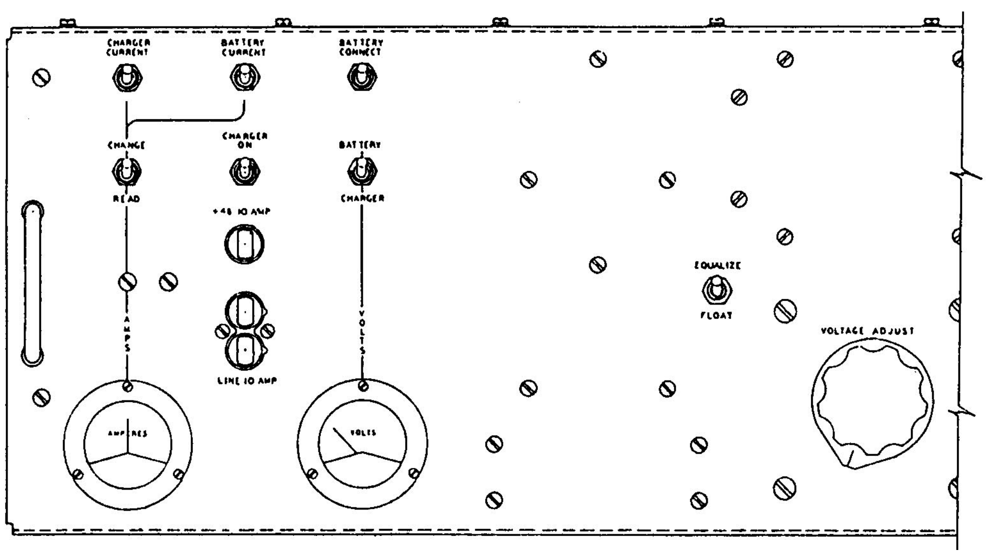


Figure 6-22.—Power supply.

Table 6-4.—Power Supply, Controls and Indicators

DESIGNATION	FUNCTION	POSITION/INDICATION
CHARGER CURRENT Switch	Conditions AMPS meter to measure charger current.	Up—charger current. Down—charger current not available to AMPS meter.
BATTERY CURRENT Switch	Conditions AMPS meter to read battery curreny.	Up—battery current. Down—battery current not available to AMPS meter.
CHANGE/ READ Switch	Allows changing of position of BATTERY CURRENT and CHARGER CURRENT positions. CAUTION When changing the positions of the CHARGER CURRENT and BATTERY CURRENT switches, the CHANGE/READ switch must be set to the CHANGE position to prevent the switch contacts from arcing,	CHANGE (up)—no AMPS meter indication. READ (down)—AMPS meter indication.
AMPS Meter	Indicates charger, battery or load current depending on switch conditions.	0—30 amperes.
CHARGER ON Switch	Energizes or de-energizes power supply via ac power input.	Up—at power applied to power supply. Down—at power removed from power supply.
+48 10 AMP Fuse	Protects power supply and switchboard from damage due to excessive current in (he 51.6 volt supply circuit.	On—fuse failed. Off—normal.
LINE 10 AMP Fuses	Protects power supply and primary ac power source from damage due to excessive line current.	On-fuse failed. Off—normal.
VOLTS Meter	Indicates battery or charger voltage depending on position of BATTERY/CHARGER switch.	0—100 volts.
BATTERY/ CHARGER Switch	Conditions VOLT meter to read battery voltage or power supply voltage.	BATTERY (up)—ship's battery voltage. CHARGER (down)—power supply voltage.
EQUALIZE/ FLOAT Switch	Selects float charge or quick charge for ship's battery.	EQUALIZE (up)—maximum charging current. FLOAT (down)—charging current determined by VOLTAGE ADJUST control.
BATTERY CONNECT Switch	Connects power supply output to ship's battery.	Up—power supply connected to ship's battery. Down—power supply disconnected from ship's battery.
VOLTAGE ADJUST CONTROL	Varies output voltage of power supply.	Set and locked for 51.6 volts dc at factory,

RINGING GENERATORS.— The switchboard has two ringing generators, which are mounted on a baseplate at the bottom of cabinet 2. The generators are transistorized units, which supply ringing current at 20 Hz, 75 to 110 volts to station telephones. The generators are wired so that one is active (on line) and the other is in a standby condition. Should the on-line generator fail, manual transfer to the standby generator is required. The manual transfer switch (RG1 20HZ/RG2) is located on the switch and fuse panel in cabinet 2. Figure 6-23 is an illustration of a ringing generator with the cover removed.

GROUND FAULT DETECTION PANEL.— The ground fault detection panel (fig. 6-24) detects shorts and/or leakage paths from the ship's wiring to the ship's hull. This panel is located in the lower right comer of cabinet 2. Table 6-5 describes the controls and indicators located on the ground fault detection panel.

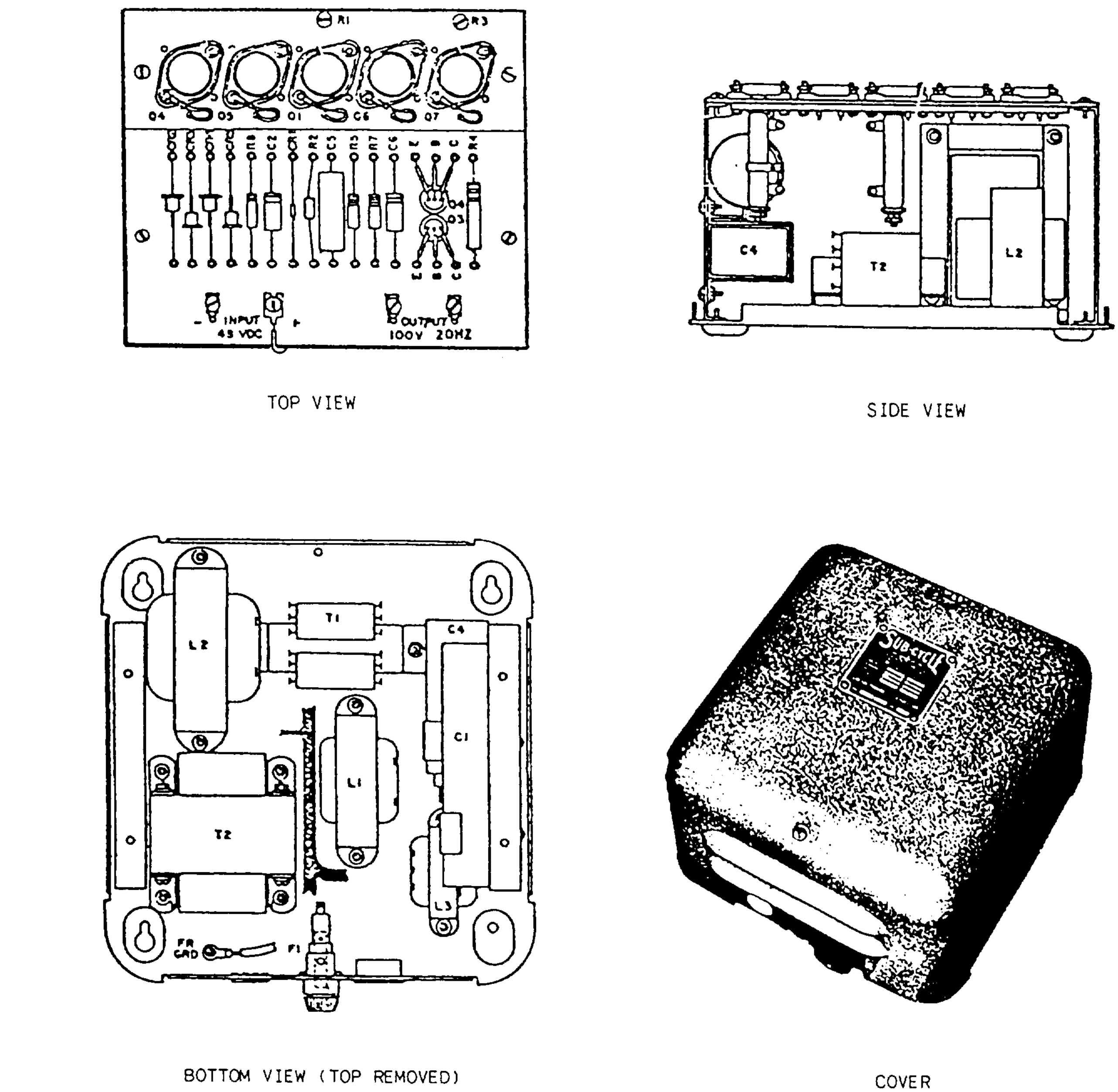


Figure 6-23.—Ringing generator, cover removed.

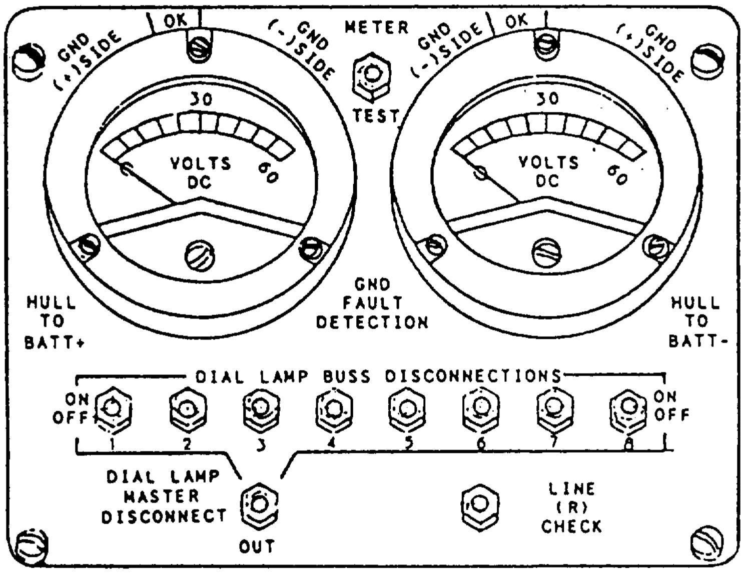


Figure 6.24.—Ground fault detection panel.

Table 6-5.—Ground Fault Detection Panel, Controls and Indicators

DESIGNATION	FUNCTION	POSITION/INDICATION
HULL TO BATT + Meter	Indicates voltage between system positive supply bus and ship's hull.	0—60 volts dc.
HULL TO BATT – Meter	Indicates voltage between system negative supply bus and ship's hull.	0—60 volts dc.
METER/TEST Switch	Disconnects ship's hull from circuit and places meter directly across power supply.	Test (down)—ship's hull in circuit. Meter (up)—ship's hull out of circuit, meters are across power supply.
DIAL LAMP BUS DISCON-NECTS Switches	Disconnects lamp buses from the power supply.	On (up)—lamp bus connected. Off (down)—lamp bus disconnected.
DIAL LAMP MASTER DIS-CONNECT Switch	Disconnects all lamp buses from phone station dial lamps.	Up—lamp buses connected. Out (down)—lamp buses disconnected.
LINE (R) CHECK Switch	Disconnects ATBT lead at oscillator board.	Up—ATBT lead disconnected. Down—ATBT lead connected.

Attendant's Cabinet

The attendant's cabinet (fig. 6-25) contains the manual switching equipment necessary for ship-to-shore interface. The equipment consists of a telephone set with push-button control of the ship-line and shore-line modules to seize and interconnect ship lines and shore lines. The attendant's cabinet is connected to the switching system electrically by a cable terminated in a 37-point male connector. The ship lines, shore lines, and all power, supervisory, and control leads are brought into the cabinet terminal boards by this connector and cable. The telephone set, phone jack, operating controls, and indicators are mounted on the front of the cabinet. Each OOD station is provided with a connection box for use with the attendant's cabinet. Table 6-6 describes the phone jack, operating controls, and indicators of the cabinet.

MARINE DIALMASTER SYSTEM

In response to the requirements for an expandable automatic dial telephone system that incorporated the features of flexibility, compactness, and reliability, the Marine Dialmaster Model (MDM) 200/700 telephone system was developed. The system is able to provide you with station-to-station communications via automatic dial telephone lines while at sea, and may interface with any commercial telephone network by way of the attendant's cabinet.

The main assemblies of the MDM 200/700 installation are one system cabinet and from two to seven identical switchboard cabinets. The line

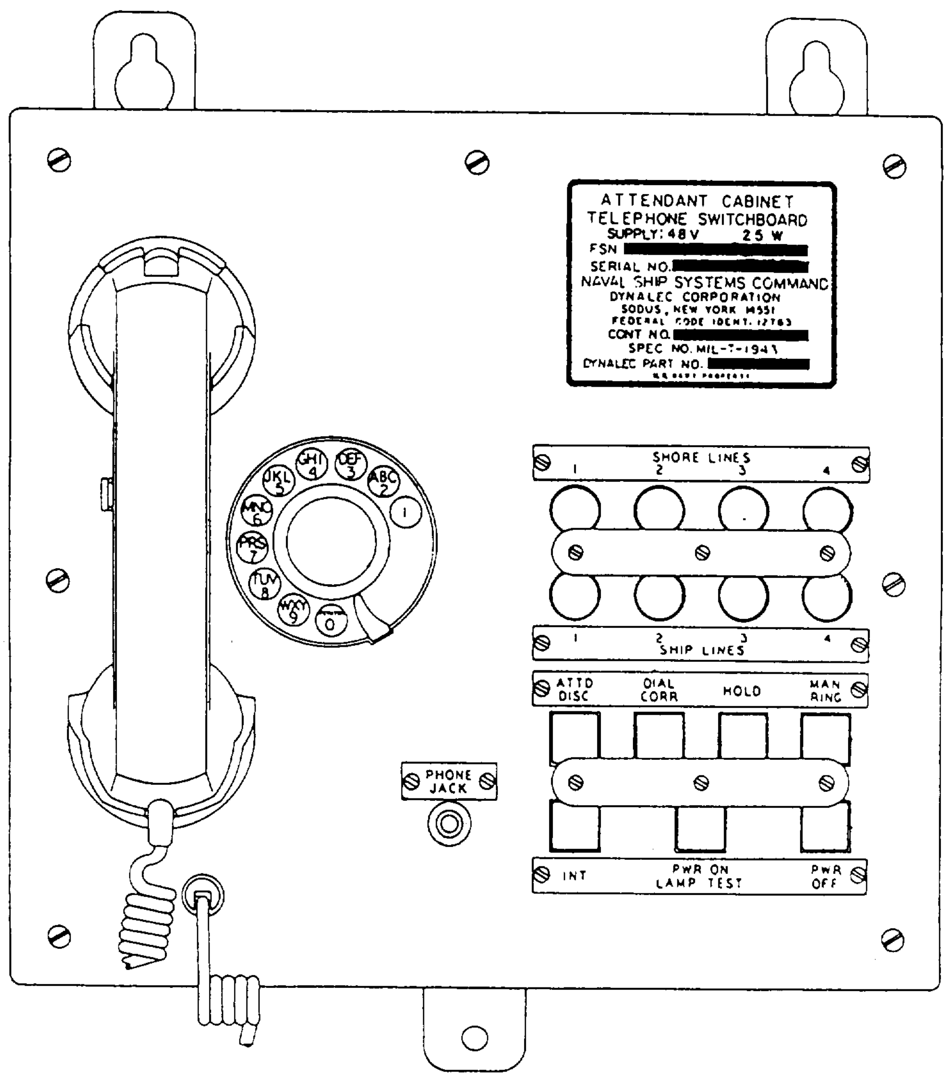


Figure 6-25.—Attendant's cabinet.

Table 6-6.—Attendant's Cabinet, Controls and Indicators

DESIGNATION	FUNCTION	POSITION/INDICATION
PWR OFF Switch/Indicator	Disconnects power from the internal circuitry. Indicates availability of power.	Momentarily pressed for power off. (See NOTE following PWR ON/ LAMP TEST Switch.)
PWR ON/LAMP TEST Switch/ Indicator	Connects power to the internal circuitry. Indicates power on-off condition. NOTE The indications of the above two power switches in conjunction show status of the attendant's cabinet. Both off power not available from switchboard. PWR OFF—on PWR ON/LAMP TEST—off; power available but not turned on. PWR OFF—off PWR ON/LAMP TEST—on; attendant's cabinet power on.	Momentarily pressed for power on.
SHORE LINES (1,2,3 and 4) Switch/Indicator	Connects the shore lines to the attendant's cabinet. Indicates line status.	Momentarily pressed for connect. Flashing bright/off—shore line calling attendant's cabinet. On (bright)—shore line connected to attendant. On (dim)—shore line connected to ship line. Flashing bright/dim—shore line on hold. Extinguished—idle.
SHIPS LINES (1 ,2, 3 and 4) Switch/Indicator	Connects the ship lines to the attendant's cabinet. Indicates line status.	Momentarily pressed for connect. Flashing bright/off—ship line calling attendant's cabinet. On (bright)—ship line connected to attendant. On (dim)—ship line connected to shore line. Flashing bright/dim—ship line on hold. Extinguished—idle.

Table 6-6.—Attendant's Cabinet, Controls and Indicators—Continued

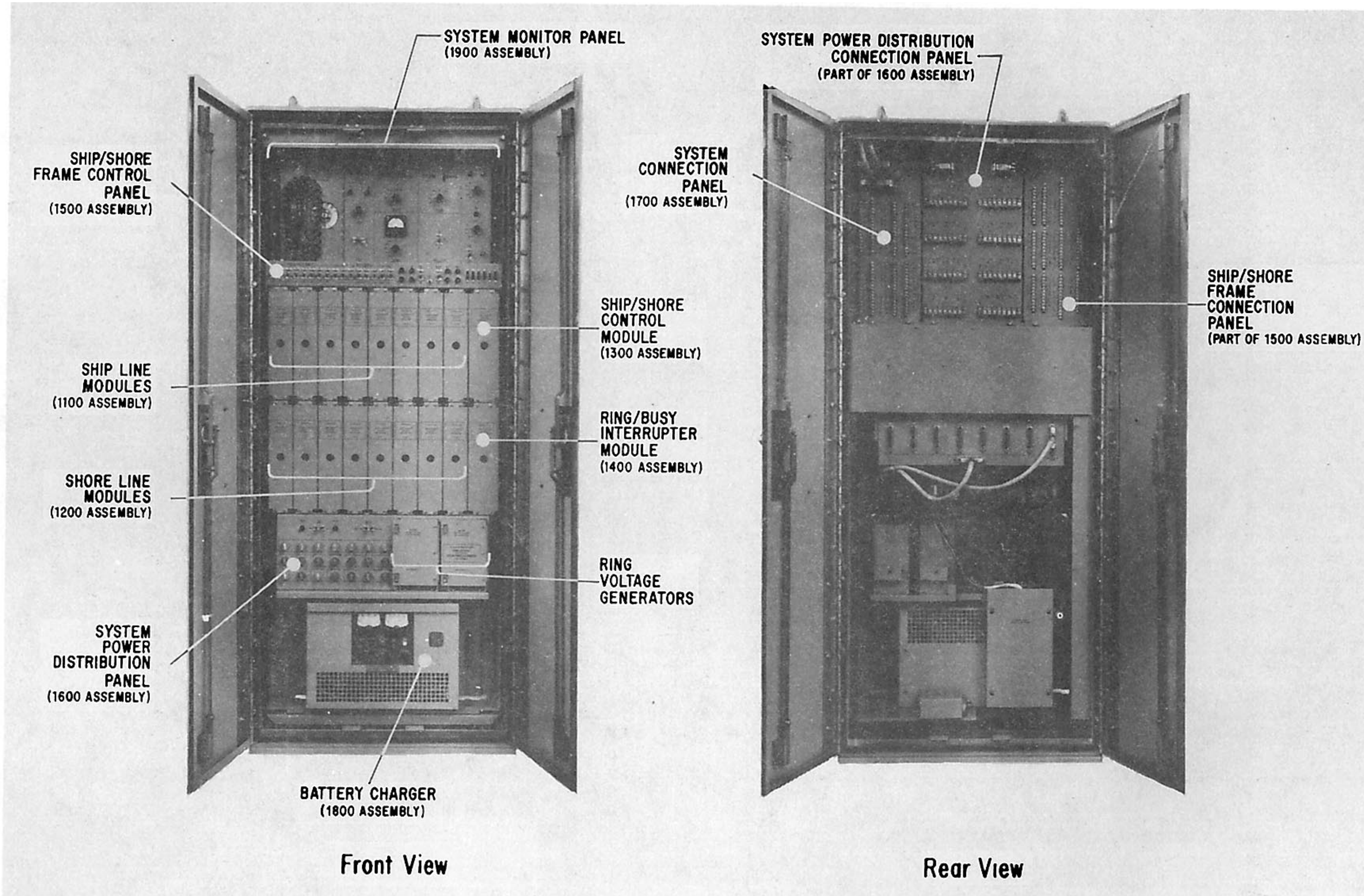
DESIGNATION	FUNCTION	POSITION/INDICATION
ATTD DISC Switch/Indicator	Disconnects attendant from a connection.	Momentarily pressed.
DIAL CORR Switch/Indicator	Re-access dial tone if error is made in dialing.	Momentarily pressed.
HOLD Switch/ Indicator	Places a connected ship or shore line on hold.	Momentarily pressed.
MAN RING Switch/Indicator	Manually extends ringing voltage to magneto-type shore exchanges.	Momentarily pressed.
[NT switch/ Indicator	NOT USED.	
HOOKSWITCH	Connects attendant's handset to the attendant's cabinet. Operates when handset is removed from handset holder.	Operated–ATTD DISC, DIAL CORR, HOLD, and MAN RING switch/ indicators on. Restored—ATTD DISC, DIAL CORR, HOLD, and MAN RING switch/ indicators extinguishes.
PHONE JACK Connector	A11ows connection of an external headset. (The permanently mounted handset and hookswitch are disabled when this connection is used.)	NOT APPLICABLE
Dial Switch	Enter dial pulses into a connected line.	Standard telephone dial,

capacity of the system can be increased from the basic number of 200 to 700 lines, in 100-line increments, simply by adding switchboard cabinets and associated cabling. Thus, a 200-line system initially installed can later be expanded to 300 lines, or to its maximum capability of 700 lines, without disrupting the initial installation. The number of simultaneous calls the system can handle is equivalent to 15 percent of the lines provided. As an example, a 200-line system is capable of handling 30 calls at any one time.

You can use the system with any two-wire telephone set, manufactured in the United States, which employs break-type dialing (a dial that interrupts the current flow). The compactness of the system is due to modular construction techniques. All electromechanical and solid-state switching circuits as well as all power equipment are mounted on a single equipment rack.

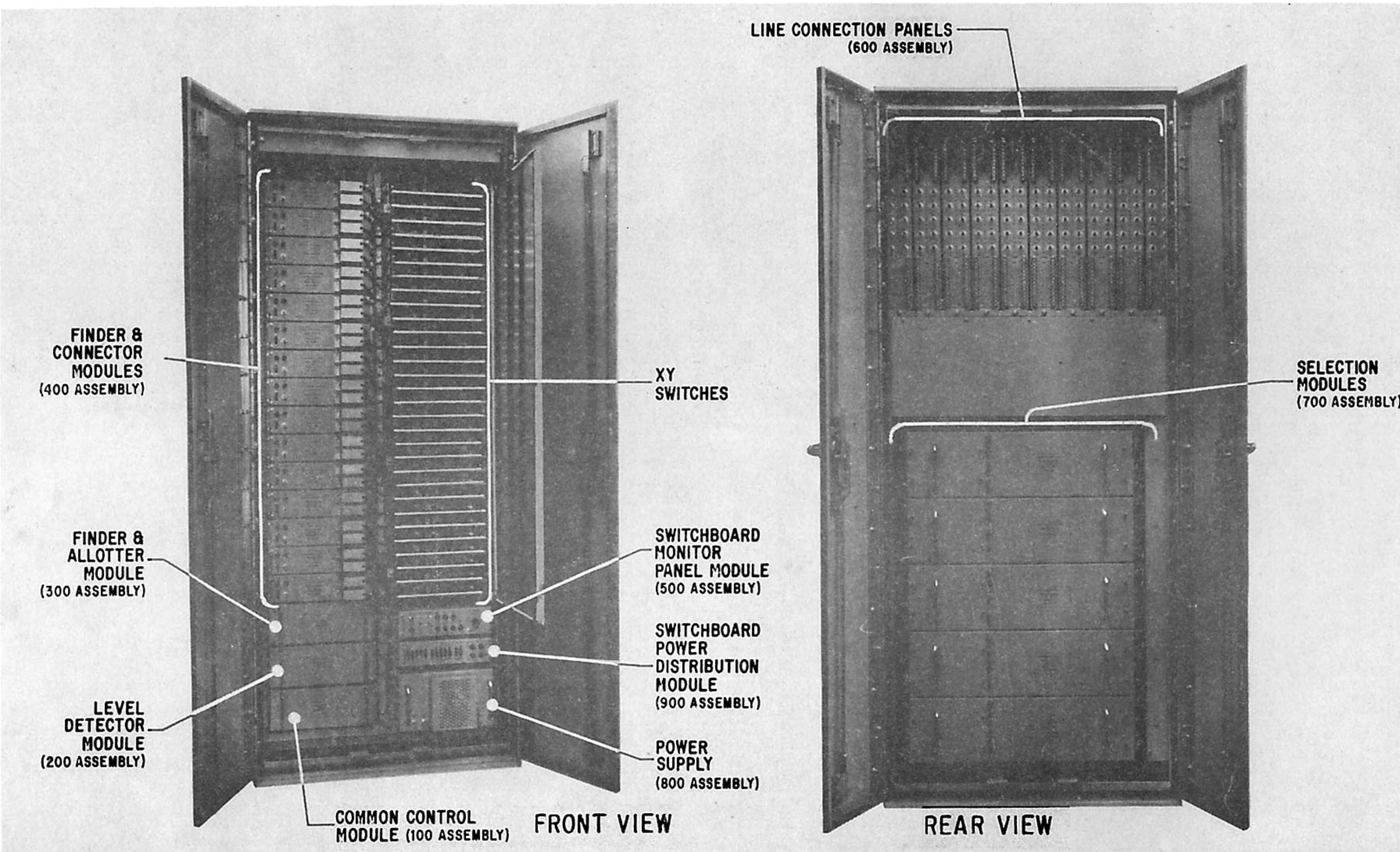
Description of Equipment

The MDM 200/700 system is a modular, electromechanical system that uses rotary stepping switches and XY universal switches as the basic switching components. The system is comprised of one system cabinet (fig. 6-26) and from two to seven



140.162

Figure 6-26.-System cabinet.



140.163

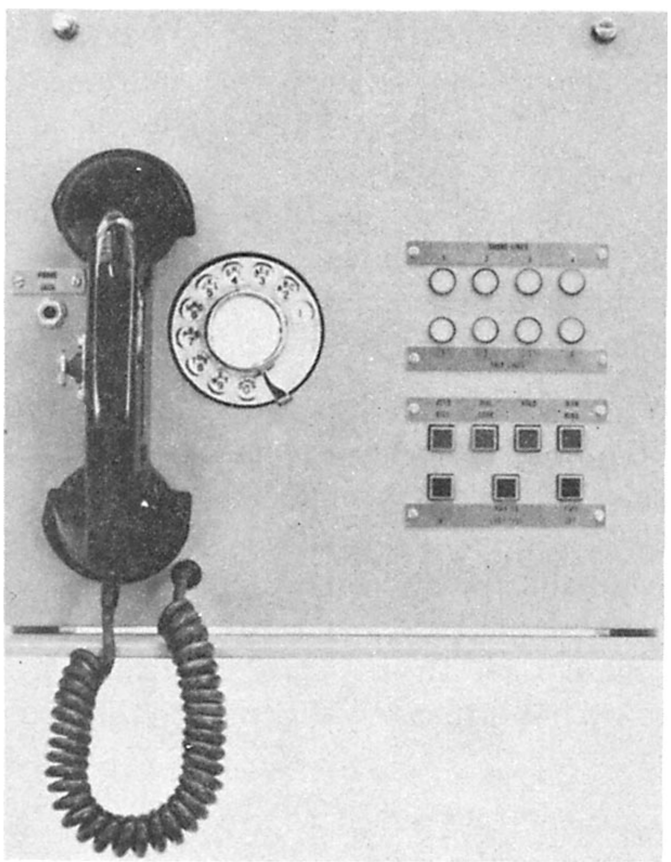
Figure 6-27.-Switchboard cabinet.

switchboard cabinets (fig. 6-27). An attendant's cabinet (fig. 6-28) provides an interface between ship lines and shore installations when the ship is in port, as shown in (fig. 6-26).

Each cabinet (system or switchboard) consists of one rack of equipment shock-mounted in a rigid cabinet assembly. The cabinet circuit modules, accessible through front and rear doors, plug into the framejack panel and contain all the switching circuits necessary for system operation. Two XY universal switches are associated with each of the 15 finder/connector circuit modules used in each switchboard cabinet. These switches mount in cells located on the front of the frame and plug into the associated finder/connector circuit modules. The line connection panels are mounted directly to the switchboard frame (fig. 6-27). These panels provide the means for connecting the switchboard to the ship's cables. Screw-type terminals are provided for all connections, allowing line-number changes to be readily accomplished.

Main Assemblies of the Switchboard Cabinet

There are nine main assemblies in the MDM 200/700 system. Each has both a name and a number designation.



140.164
Figure 6-28.—Attendant's console.

COMMON CONTROL PANEL (100 ASSEMBLY).— The common control assembly consists of six separate, though related, circuits. The main function of the 100 assembly is to provide timing for finder action requests and to extend finder request ground (positive signal voltage) to the finder allotter. This assembly also provides dial tone and busy tone for the system.

LEVEL DETECTOR AND ALARM CIRCUITRY (200 ASSEMBLY).— The level detector panel contains 10 identical level detection circuits, one for each system level, and a portion of the major and minor alarm circuits. The function of the level detector is to receive negative battery signal via a closed tip/ring loop of the line station requesting service; to operate the appropriate level relay; and to extend resistance battery to the sleeve wire bank and a finder request ground to initiate linefinding for that level (group).

FINDER ALLOTTER PANEL (300 ASSEMBLY).— The finder allotter panel, also referred to as the link allotter, contains 15 identical circuits, one for each finder circuit and a finder bypass relay for each finder. The circuit is used to select the next idle finder in the system. If the selected finder takes longer than 2 seconds to find the calling line, a finder bypass alarm is initiated.

FINDER/CONNECTOR PANEL (400 ASSEMBLY).— The finder/connector panel, also referred to as a link, is made up of two main sections: the finder circuit, where linefinding is accomplished by the finder XY switch; and the connector circuit where connection to the calling line is accomplished by the connector XY switch. The XY switch is external, but is part of the link. The transmission path is established in the assembly between the calling and the called telephones.

SWITCHBOARD MONITOR PANEL (500 ASSEMBLY).— The switchboard monitor panel contains three alarm signaling circuits that react to an off-hook alarm, a failure-to-restore alarm, and a finder bypass alarm. The link index switch determines the alarm condition. The panel also contains a line test jack, two functional lever switches, and eight indicator lamps. This panel activates audible as well as visual alarms.

LINE PANEL (600 ASSEMBLY).— There are 10 line panels in each switchboard cabinet. Each panel provides connections and switching facilities for one level (group) of 10 telephones. The line disconnect switches are located in this panel. This panel is also where a station can be wired for executive-right-of-way or become part of a line hunt group.

SELECTOR PANEL (700 ASSEMBLY).— There are five selector panels, each containing three identical selector circuits. The selector circuit provides the means by which a telephone station can call any other station in the system. Specifically, the selector performs the basic functions of busy testing available connectors, ringing, ring trip, extension of the line restriction feature, and call answer.

POWER SUPPLY (800 ASSEMBLY).— The power supply unit uses a single-phase, full-wave rectifier with choke input for regulation and diode surge current protection. A choke together with filter capacitors provide low ripple dc power. A two-position power selector switch is provided. Turn it to the 125V position if input ac power is greater than 120 volts, If input ac power is less than 120 volts, turn it to the 115V position. Each switchboard contains its own power supply unit.

POWER DISTRIBUTION PANEL (900 ASSEMBLY).— This assembly distributes dc power to equipment in the switchboard cabinet.

Main Assemblies of the System Cabinet

The system cabinet consists of nine main assemblies: 1100, 1200, and 1300 through 1900. Four of these (1100, 1200, 1300, and 1500) are associated with the operation of the attendant's console.

SHIP LINE MODULES (1100 ASSEMBLY).— There are eight identical ship line modules, one for each ship line connected to the attendant's console.

SHORE LINE MODULES (1200 ASSEMBLY).— There are eight identical shore line modules, one for each shore line associated with the attendant's console.

SHIP/SHORE CONTROL MODULE (1300 ASSEMBLY).— This module contains all the necessary circuitry to control the operation and interconnection of the ship and shore lines through the attendant's console.

RING/BUSY INTERRUPTER PANEL (1400 ASSEMBLY).— This panel consists of tone interrupter circuits and a ring timing circuit. It generates ground pulses that control ring voltage and busy tone interruptions used in the selector circuitry.

SHIP/SHORE FRAME PANEL (1500 ASSEMBLY).— This panel has the capability of connecting the eight ship lines to the shore lines. It is used to monitor the ring and busy interrupter circuits and to give visual indication that the attendant's console is energized. The panel also provides a direct audio path to the attendant's console for test purposes.

SYSTEM POWER DISTRIBUTION PANEL (1600 ASSEMBLY).— This assembly contains two solid-state ring generators, switches for controlling ring voltages, and four major power distribution buses and their associated terminal connectors.

SYSTEM CONNECTION PANEL (1700 ASSEMBLY).— Eight terminal blocks are mounted on this panel. They are used as connection points for various system functions.

BATTERY CHARGER (1800 ASSEMBLY).— The battery charger is a standard, alternating to direct current, solid-state unit. It can maintain a 23-, 24-, or 25-cell battery in a fully charged condition. The output voltage is adjustable from 48 volts to 56 volts dc at a maximum charging rate of 6 amperes.

In recent years, ships equipped with the MDM system have had, via authorized SHIPALT, the 1800 assembly remotely located. A switch panel has been installed in the 1800 assembly cavity that facilitates individual switchboard power-down for corrective and preventive maintenance actions.

SYSTEM MONITOR PANEL (1900 ASSEMBLY).— The system monitor panel is integrated in the MDM system. It monitors and tests all finder/selectors and connectors in the system. The panel contains call count indicators and all-trunks-busy indicators. Voltage monitoring and alarm locating circuits give the maintenance person a quick indication to the condition of any switchboard cabinet in the system.

ATTENDANT'S CONSOLE.— The MDM 200/700 installations are equipped with attendant's switching circuitry to provide for attendant-assisted ship-to-shore communications. This circuitry is mounted in the system cabinet (fig. 6-26), and consists of eight ship-line panels (one for each ship line) and one control panel. The attendant's switching circuit is controlled from a remotely located attendant's console (fig. 6-28).

Since all of the attendant's switching equipment is mounted in the system cabinet, each console (a maximum of three per system) is used only to perform the functions of a standard telephone with push-button control of switching modules to seize and interconnect ship lines and shore lines. The consoles are not much larger than standard type G telephone sets and can be mounted on a desk or bulkhead, or flush-mounted in a suitable panel.

System Operation

This section explains the fundamentals of XY switching as used in the MDM 200/700 system. It also describes the operation of the rotary switch that is used as a selector and the operation of the switchboard and control cabinets.

SWITCHING COMPONENTS AND LINE-FINDING.— The XY universal switch (fig. 6-29) is the heart of the MDM system. It provides the means for establishing connections throughout the system. The XY universal switch is a 100-point, two-motion, remote-control device. It may be operated by a dial or automatically pulsed from associated control circuitry. A 100-point, two-motion switch can make electrical contact with any of 100 sets of contacts, taking two motions to accomplish the connection. With the switch mounted in a horizontal plane, the switch carriage moves first in the X direction (left to right parallel to the wire bank), and then in the Y direction (into the wire bank). When mounted in the switchboard, the XY switch is located adjacent to a 42- by 10-wire matrix called a wire bank. This wire bank runs the length of the switchboard and serves as the contacts for the wipers of all the XY switches in the system.

THE XY SWITCH.— The main components of the XY switch (fig. 6-29) are an X-stepping magnet, a Y-stepping magnet, a release magnet, spring

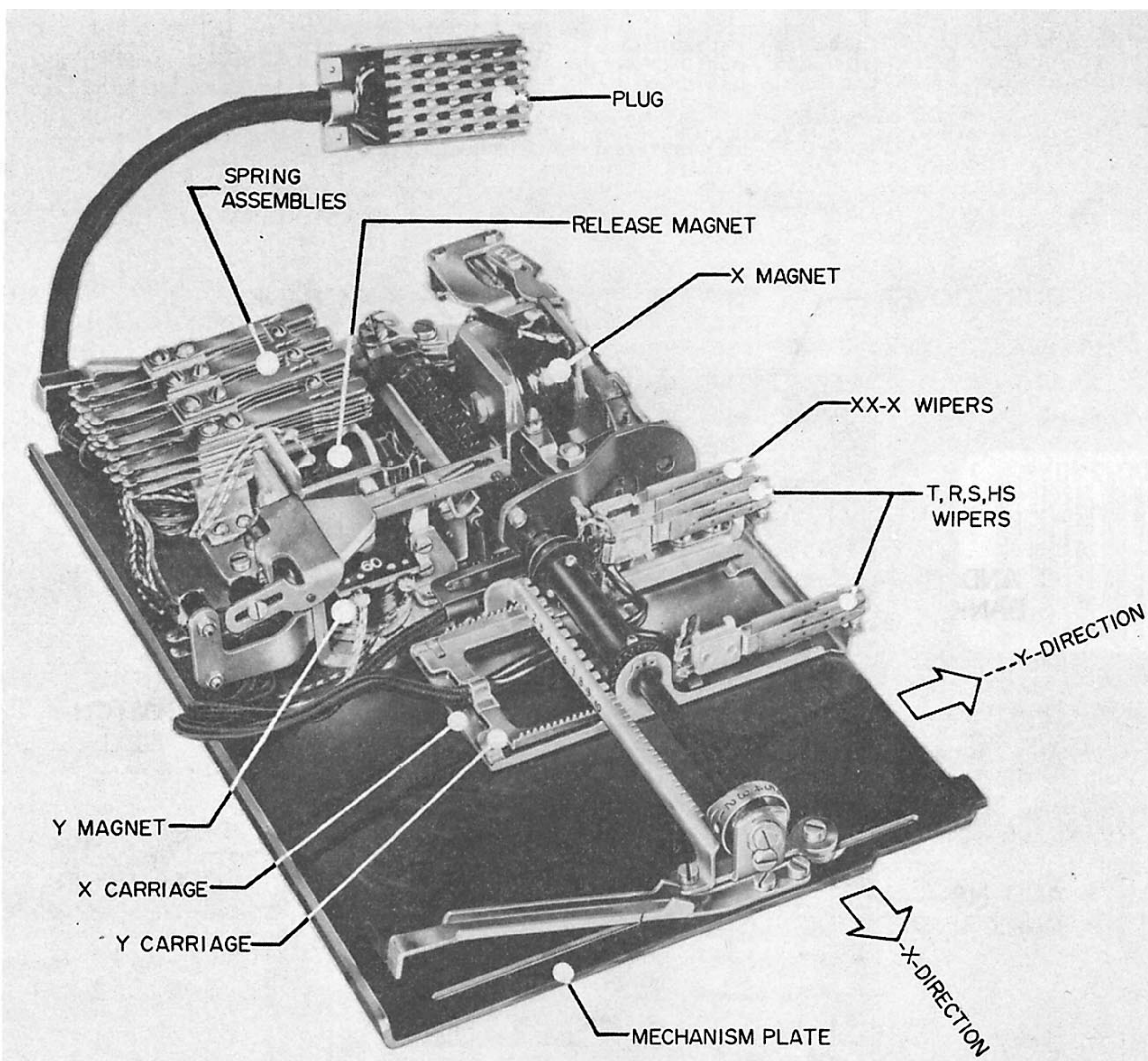


Figure 6-29.—XY switch.

assemblies, and associated mechanical drive hardware. A simplified schematic of the XY switch is shown in figure 6-30. The switch steps first in the X direction controlled by a series of ground (positive) pulses (periods of current flow) to the X-stepping magnet. Each time the magnet operates, the wipers advance one step in the X direction. The Y-stepping magnet operates in a similar manner to drive the wipers in the Y direction, which is into the wire bank.

The overflow, X-off normal, and Y-off normal spring pileups depend only on the position of the wipers for their operation. The spring position shown in figure 6-30 is the normal position. These springs are used by the associated circuitry to perform various

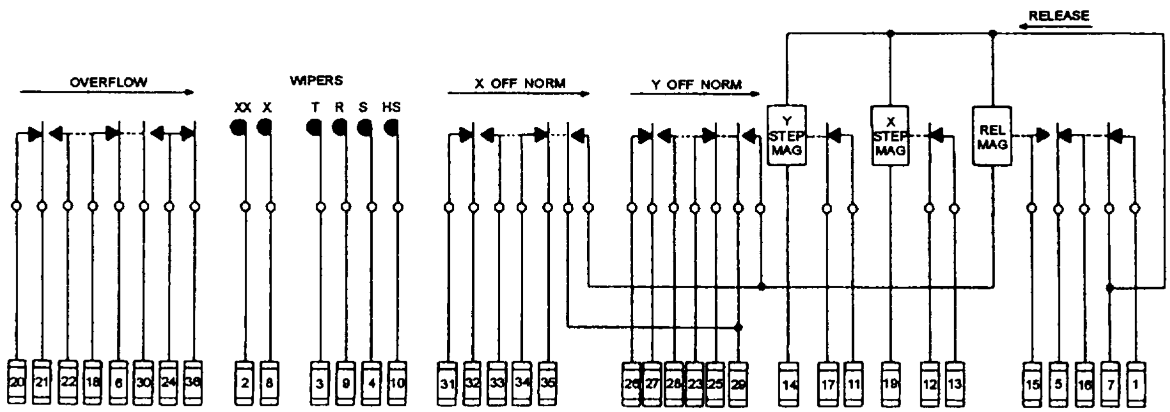


Figure 6-30.—XY universal switch, schematic diagram.

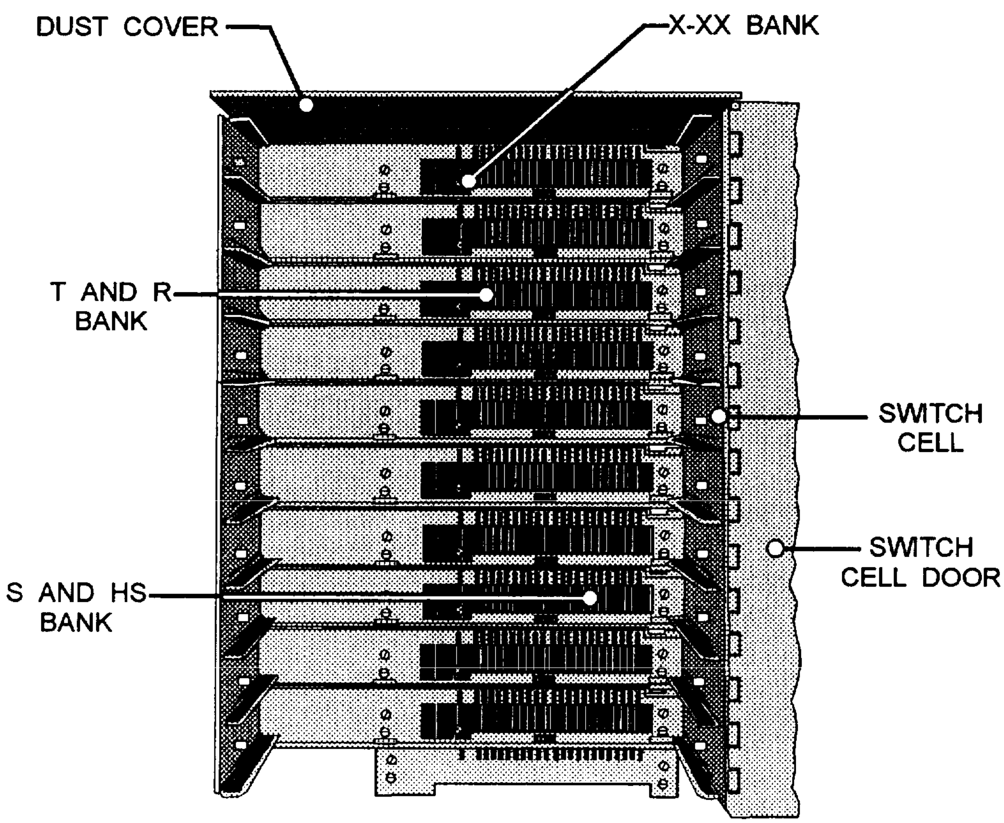


Figure 6-31.—XY switch and cell banks.

supervisory and control functions. When the wipers are stepped in the X direction, the X-off normal springs are operated; when stepped in the Y direction, the Y-off normal springs are operated. Only 10 steps are allowed in either direction. If these are exceeded, the overflow springs are operated. When the X-off normal or Y-off normal springs are operated, a path is competed to the release magnet. A ground (signal) can then be extended to pin 29 of the XY switch plug (fig. 6-30) to operate the release magnet, causing the wipers to return to the normal position. The release springs are operated to release the external control circuitry. The release magnet restores when both the X- and Y-off normal springs return to normal.

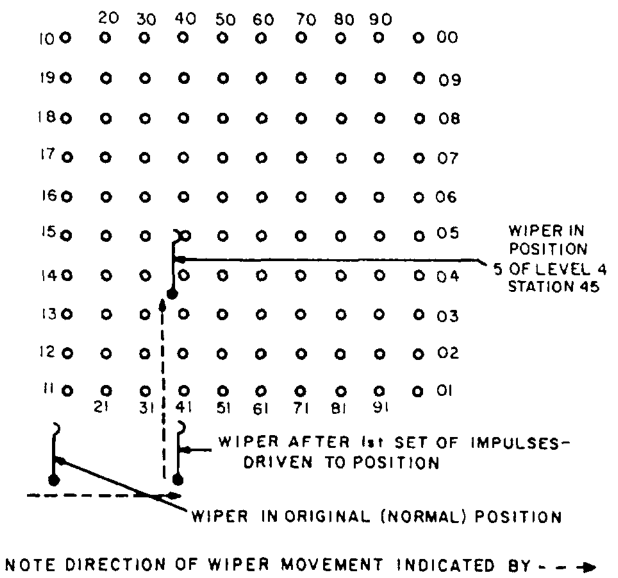


Figure 6-32.—Wire bank and associated XY switch wiper simplified schematic diagram.

THE WIRE BANK.— The 42- by 10-wire bank associated with the XY switch is actually made up of six smaller wire banks: four 10- by 10-wire banks and two 1- by 10-wire banks. The 10- by 10-wire banks are used with the four wires associated with each telephone line. These four wires are the tip (T) and ring (R) for transmission, and sleeve (S) and helping sleeve (HS) for supervisory and switching. The 1- and 10-wire banks (XX and X) are used to electrically indicate the X position of the wipers when the wipers are stepped in the X direction. Each of these banks is associated with its own particular wiper on the XY switch. The switch wipers are referred to as the T, R, S, HS, and XX-X wipers or banks (fig. 6-31). Figure 6-32 is a simplified diagram of one of the 10- by 10-wire banks (as seen from above) and the associated wiper.

This wire bank runs the length of the switchboard and is associated with the same wiper in all the other XY switches in the system (fig. 6-33). The X motion of the switch locates the wiper at a position (or bank) opposite the proper section of the wire bank referred to as the level. The Y motion of the switch positions the wiper into the bank to establish the connection at the proper point. The switch then remains in position indefinitely until it is released. A terminal block at the end of the wire bank provides the necessary

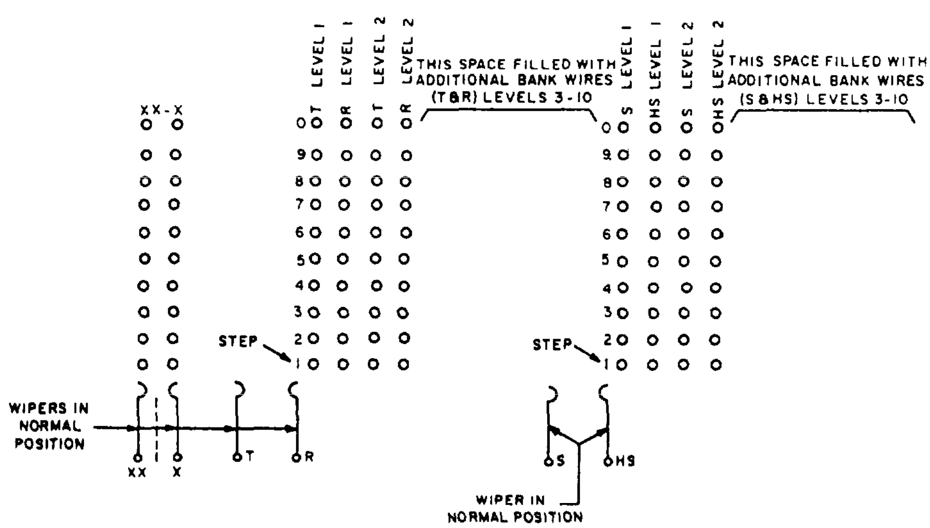


Figure 6-33.—Four wire banks and associated wipers shown in the normal position.

connections to the system circuitry. Figure 6-34 shows a simplified schematic diagram of the four 10- by 10-wire banks and the XX-X wire banks in the normal. When one wiper of the XY switch is in a given position in its 10- by 10-wire bank, the other three wipers are in the same position in their respective 10- by 10-wire banks. As the switch steps a certain number of steps in the X direction (fig. 6-35), the XX-X wipers advance the same number of steps into the XX-X wire banks. As the switch steps in the Y direction, the T, R, S, and HS wipers advance into the wire banks to the desired position (fig. 6-35).

Principles of Linefinding

Linefinding is actually the process used to connect one telephone line station to another. Since all the line stations will not be in use at the same time, it would be impractical to have a switch for each line station. Therefore, to reduce system complexity and

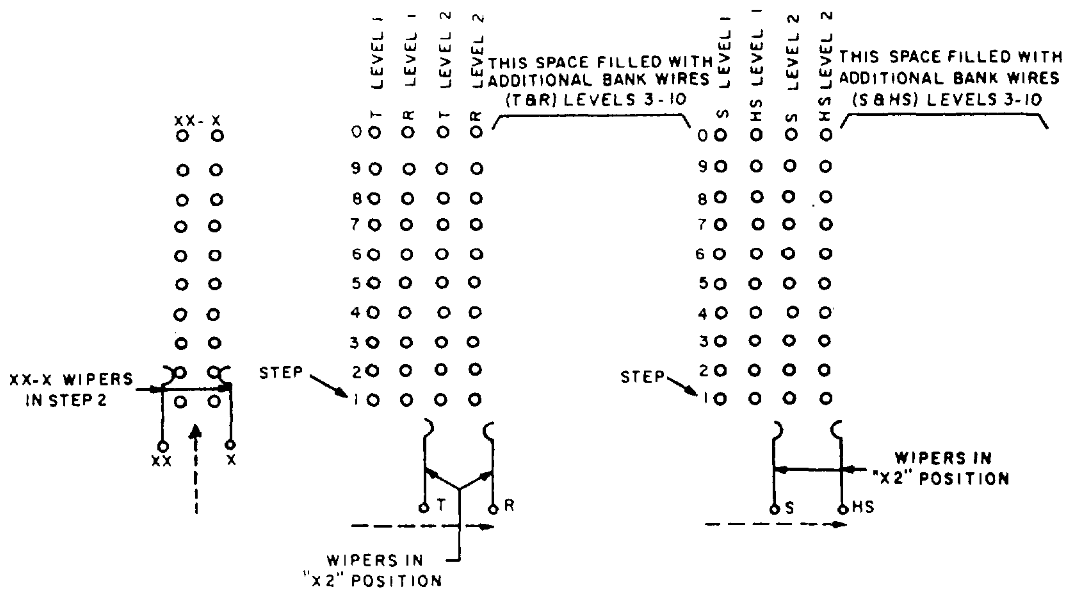


Figure 6-34.—Four wire banks and associated wipers shown in the X2 position.

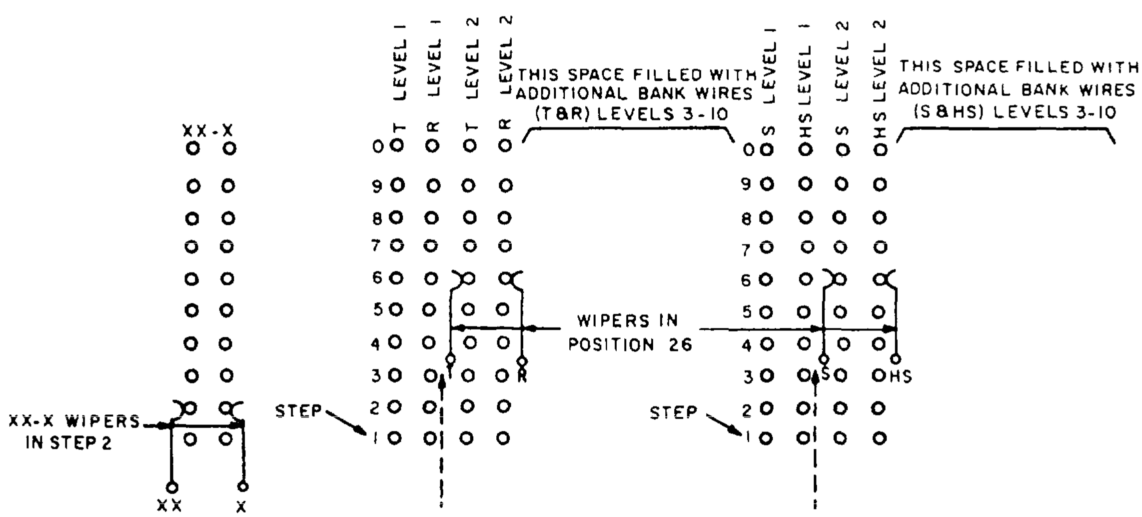


Figure 6-35.—Four wire banks and associated wipers shown in position 26.

save space, switching equipment is shared. The main pieces of equipment used in linefinding are the line circuit, the linefinder, and the allotter.

LINE CIRCUIT.— Since the shared equipment must be available to all line stations on an equal basis, there must be a method of indicating that a line station requires switching equipment. The line circuit performs this task by sending a signal to the switching equipment when a station wishes to originate a call (lifts the receiver from the cradle to operate the hook switch). There is one line circuit associated with each line station in the system, arranged so that on an incoming call to the station, the shared switching equipment is not connected to the station.

LINEFINDER.— Figure 6-36 illustrates the basic principles of linefinding. For the sake of simplicity, the allotter is not shown. When the calling party operates the hook switch by removing the handset from the cradle, the line circuit sends a linefinder start signal to the linefinder. This signal causes the XY switch to step automatically in the X direction, searching for the level in the wirebank where the calling line is located. The XX-X bank and wipers serve to indicate the tens level (level 4 would be the tens level for line 45) of the calling line. When the XY switch reaches this level, it stops and starts moving into the wire bank in the Y direction. When the proper line is located, it stops again and establishes the necessary connections so that the calling station may control the connector with the dial and complete the call. A dial tone then informs the calling party that the line has been found. The linefinder remains connected to the line during the entire call and is released when the calling party hangs up the handset.

Only one linefinder is shown in figure 6-36. When other calls are made simultaneously from other stations, additional linefinders must be available. The

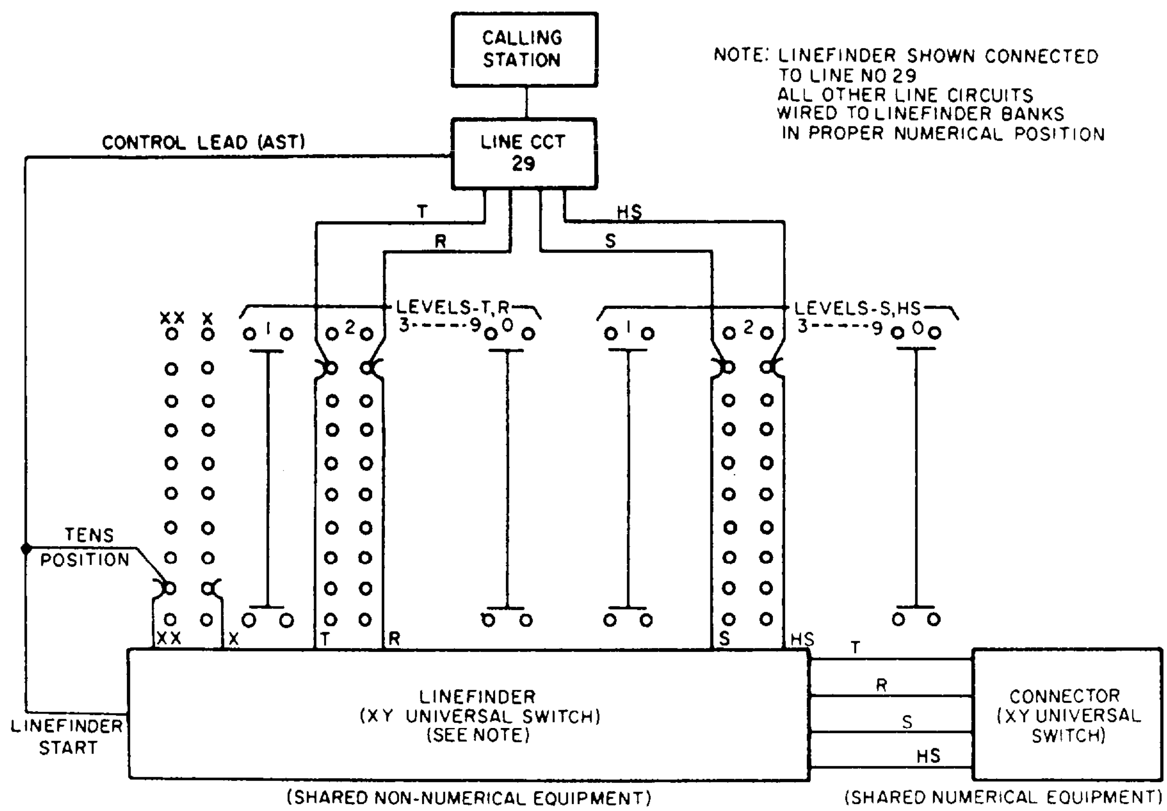


Figure 6-36.—Block diagram of linefinder operation.

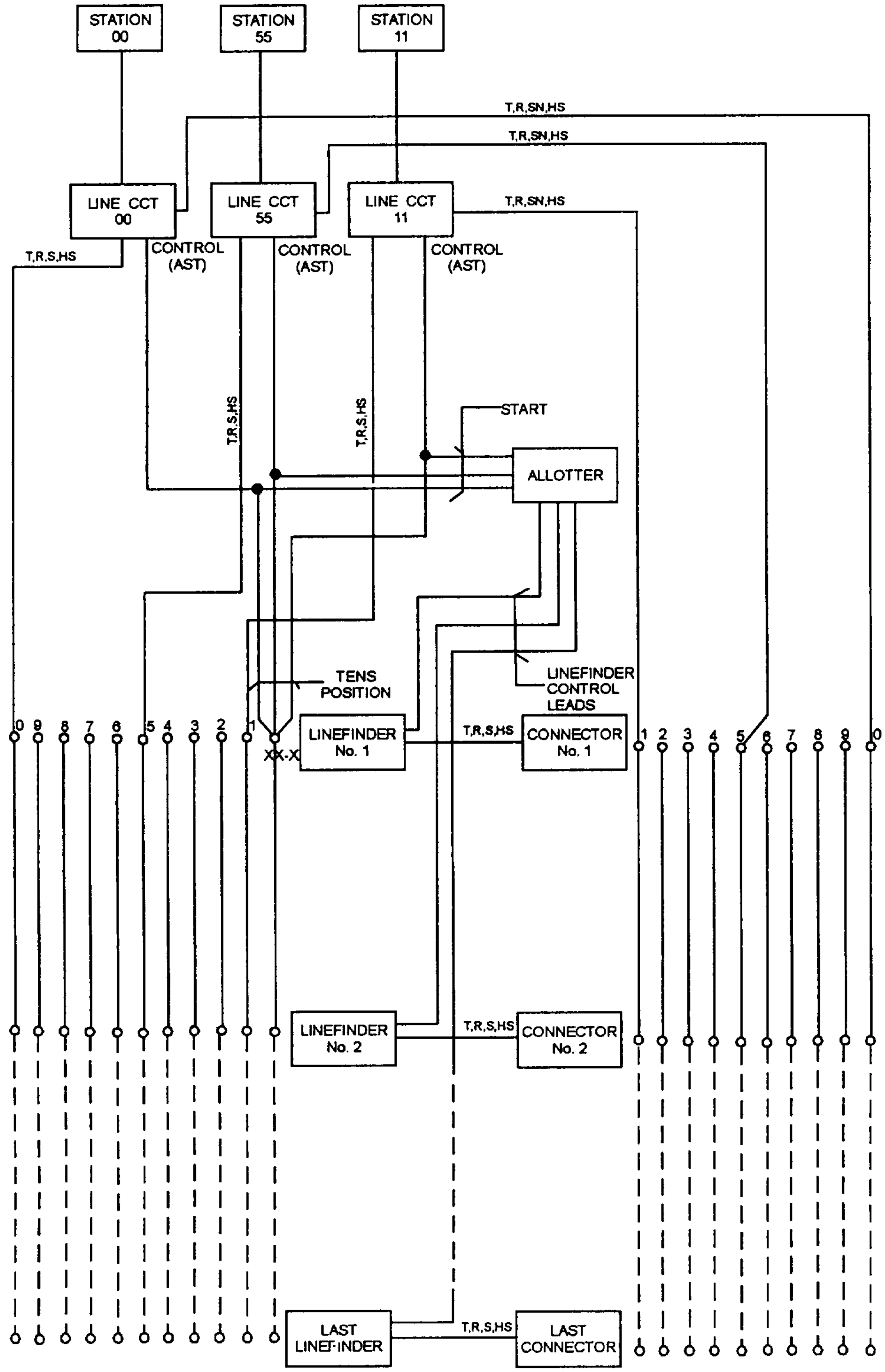


Figure 6-37.—100-line system using shared equipment.

function of the allotter (fig. 6-37) is to assign linefinders to any of the line circuits as required. When any line requests service, the allotter assigns a linefinder to the call, then preselects the next idle linefinder to be assigned to the next call. As busy linefinders become idle, they are made available for allotment to any subsequent calls. When one XY switch is connected to a given position in the wire bank, no other XY switch in the system may connect to that position. The S lead of the XY universal switch and the S wire bank are used to indicate the busy condition. For example, if station 55 calls station 21, a busy indicator, called a mark, is immediately extended to position 55 of the S wire bank from the station 55 line circuit. After the associated connector XY switch has been stepped to position 21 of the wire bank (under the control of dial pulses from station 55), a busy mark is applied to that position in the S wire bank from the connector. If any other station, say station 78, now tries to call station 55 or 21, the associated connector XY switch will encounter the busy mark and send a busy signal to the calling party (station 78).

SELECTOR.— The selector in the MDM 200/700 system is connected back to back with a finder (linefinder); that is, each finder has its own associated selectors witch. The selector locates an idle connector in the group of lines (switchboard) to which a call is being made.

The MDM 200/700 system uses a 20-point, 8-level, rotary switch as a selector (fig. 6-38). This switch may be stepped by pulses from the dial or be operated in an automatic hunt sequence by using interrupter spring contacts. The rotary switch wiper moves after it has been released electronically; that is, when the step magnet is operated, the wipers do not go into the next position until the step magnet is released. In a typical commercial XY installation, the rotary switch is used with the allotter circuits. However, in the MDM system, the rotary switch is used in the selector circuits.

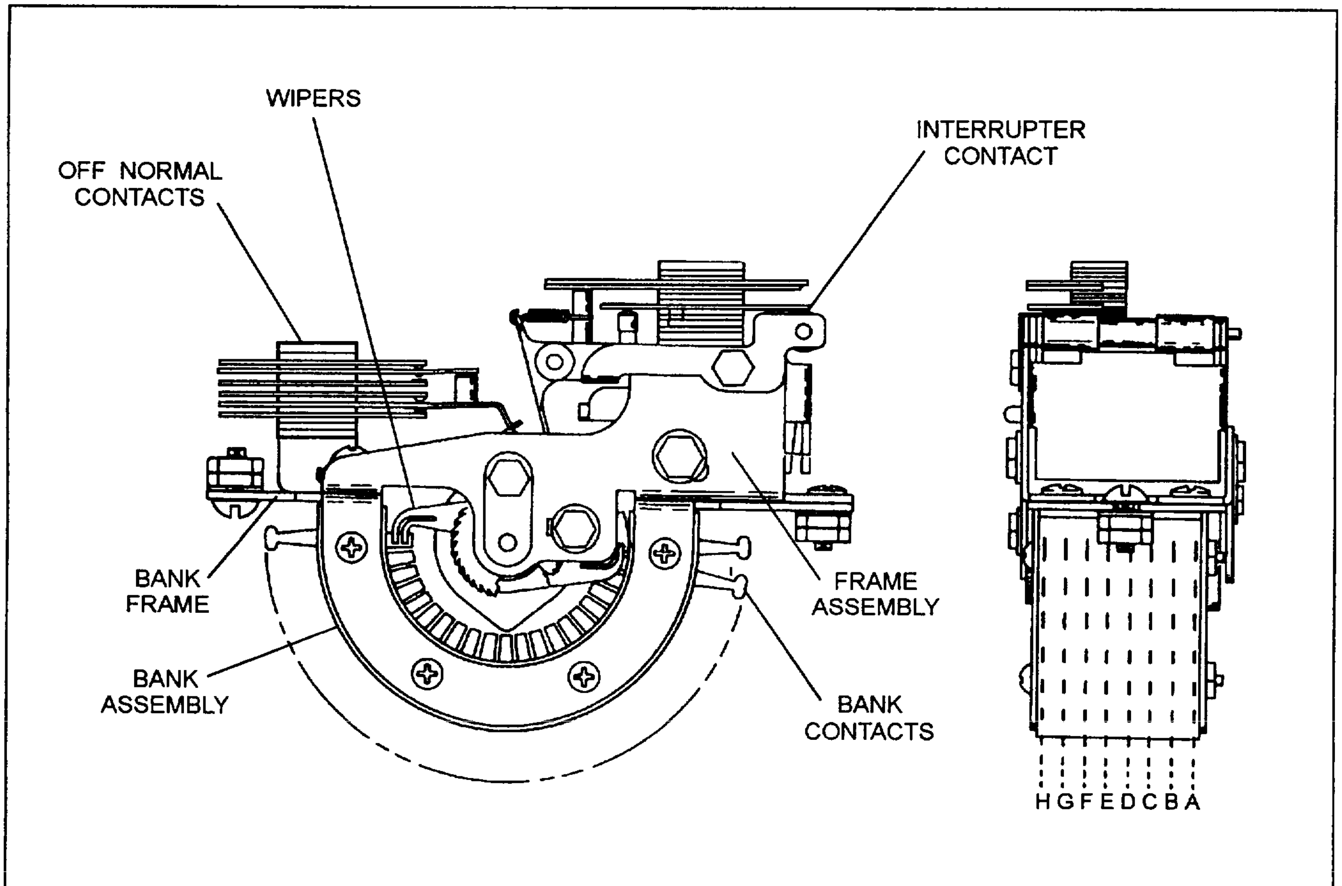


Figure 6-38.—Rotary stepping switch selector.

Figure 6-39 is a block diagram of a typical MDM system, having 300 telephone stations in three groups (switchboards) of 100 each. One finder/selector, one allotter, and one connector represent each switchboard. Each selector terminates into a connector circuit. The selector (using a rotary switch) is the link between the linefinder and the connector. Although the rotary switch has 20 positions, only 10 are shown (fig. 6-39).

Sample Call

Figure 6-40 is a simplified block diagram tracing a sample call from one station to another. As an aid toward understanding the actions involved in completing this call, keep in mind the following facts concerning the MDM system:

—Each telephone station has audio (tip and ring) leads that terminate in the wire bank of a switchboard cabinet.

—A calling station initiates finder action by removing the handset from the cradle, causing shared switching equipment to be placed under the control of the calling line by way of a connection in the wire bank.

—Dialing from the calling station extends the switching link to a wire bank position that terminates the audio leads of the called station.

The sample call diagramed in figure 6-40, view B, is between station 262 (the calling party) and station 474 (the called party). Assume that station 474 is not busy at the time of the call and that the idle connector is connector No. 13 in the switchboard of the called station.

The T and R leads for line 262 terminate in switchboard cabinet No. 1 and extend to wire bank position 62 by way of the line circuit serving level 6, line 2. When the calling party operates the hook switch, line circuit 262 extends two sources of battery

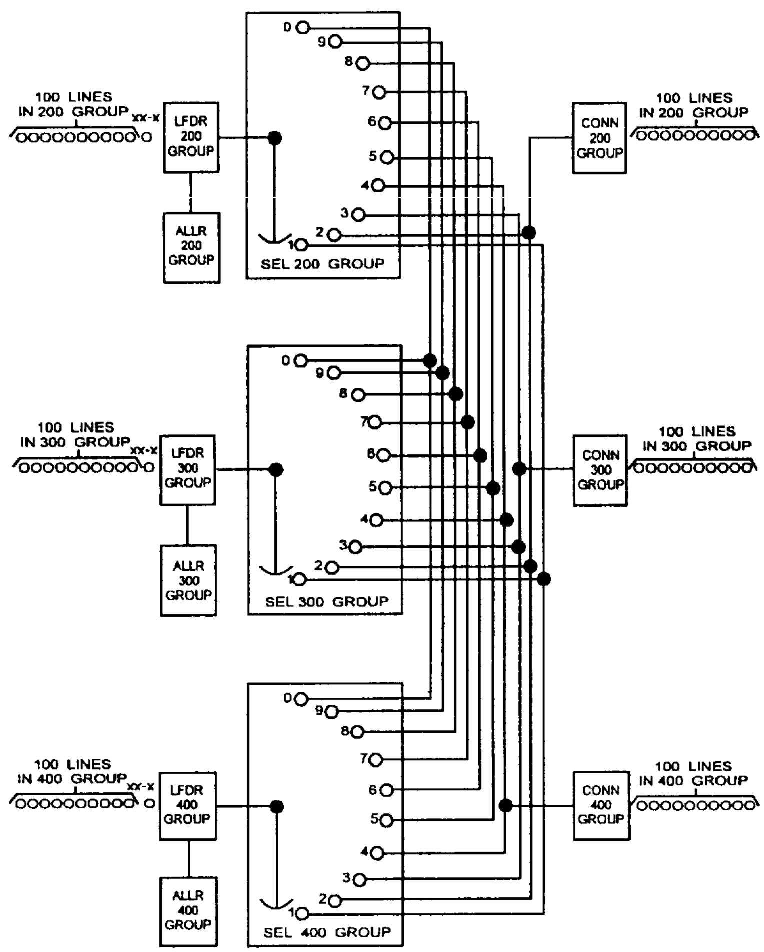


Figure 6-39.—The rotary switch in the selector, simplified block diagram.

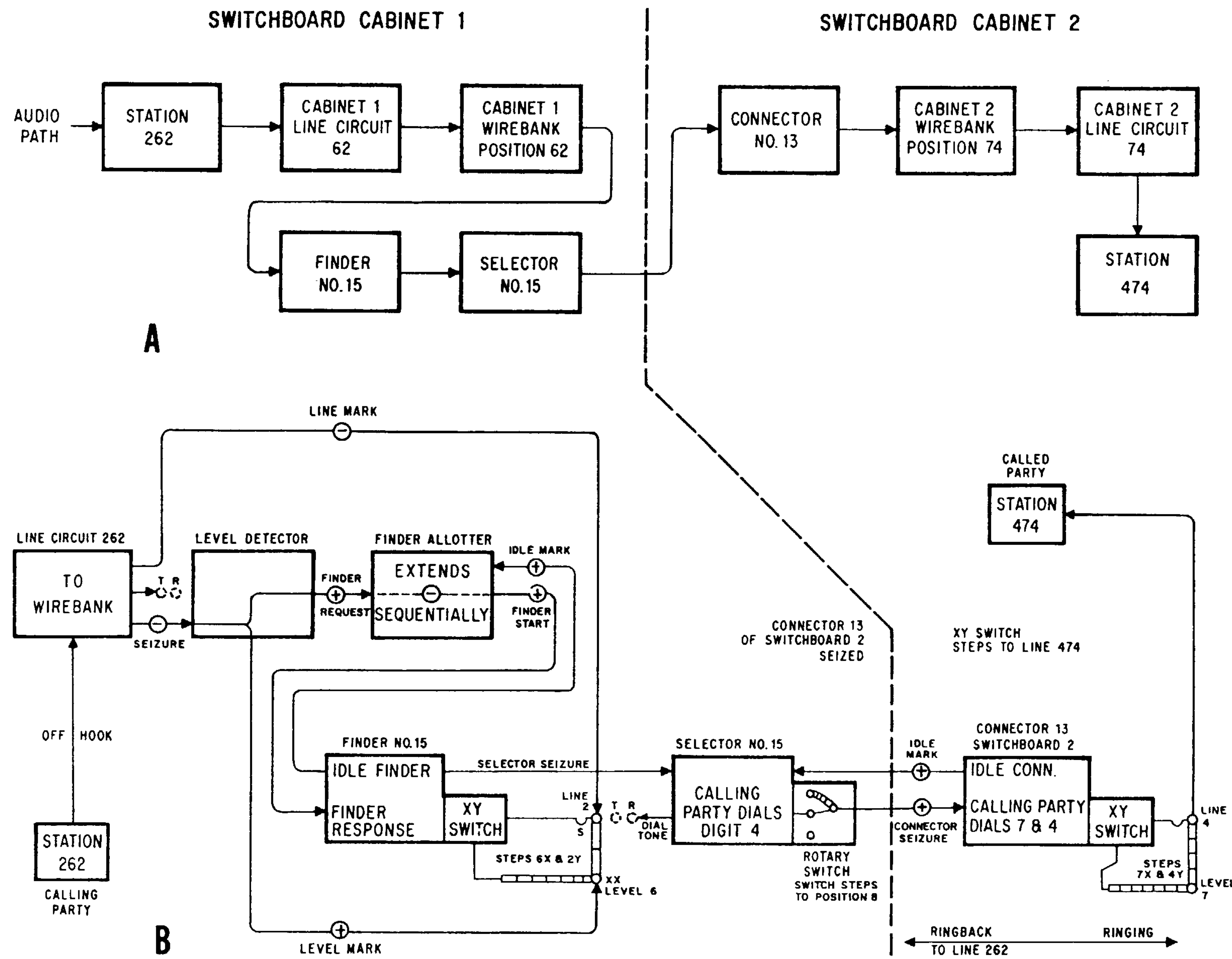


Figure 6-40.—Sample cell audio path and switch control path.

(negative signal voltage), one to the S wire position for line 62 for Y direction hunt stop, and the other to seize the level 6 section in the level detector. The level detector responds to level 6 seizure by extending level mark ground to mark position six of the XX wire bank for X direction hunt stop, and request ground to the find allotter.

The finder allotter, which serves to allot idle finders, routes the request ground to the next available finder in the allotter sequence. Assume that finder No. 15 is the next one available. This finder responds to automatically hunt for the calling line in the wire bank by stepping its associated XY switch in the X direction until the XX wiper encounters the level mark ground in the XX wire bank. The X direction hunting then stops and Y direction hunting automatically begins. After two steps, the S wiper encounters the line mark battery which halts the Y direction hunting. The finder XY switch wipers now rest in the wire bank position of the calling line 262.

As soon as line 262 is found, finder No. 15 seizes its associated selector (No. 15) and dial tone is returned to the calling station by way of the wire bank connection. The calling party now dials the initial digit 4 of the called station (474) and the rotary switch associated with selector No. 15 steps to seize the next idle connector in switchboard No. 2. The next idle connector in this case is connector No. 13. Selector No. 15 extends a seizure ground, which prepares the connector circuitry for the second and third digits to be dialed. When the calling party dials the digit 7, the wipers of the XY switch associated with connector No. 13 step seven times in the X direction, following the dial pulse. When the digit 4 is dialed, the wipers step four times in the Y direction. The XY switch wipers now rest on the wire bank position corresponding to called line 474. The connector extends ring voltage from the selector to the called line. When the called party answers, the switch-through is completed. The audio path for the call is shown in figure 6-40, view A.

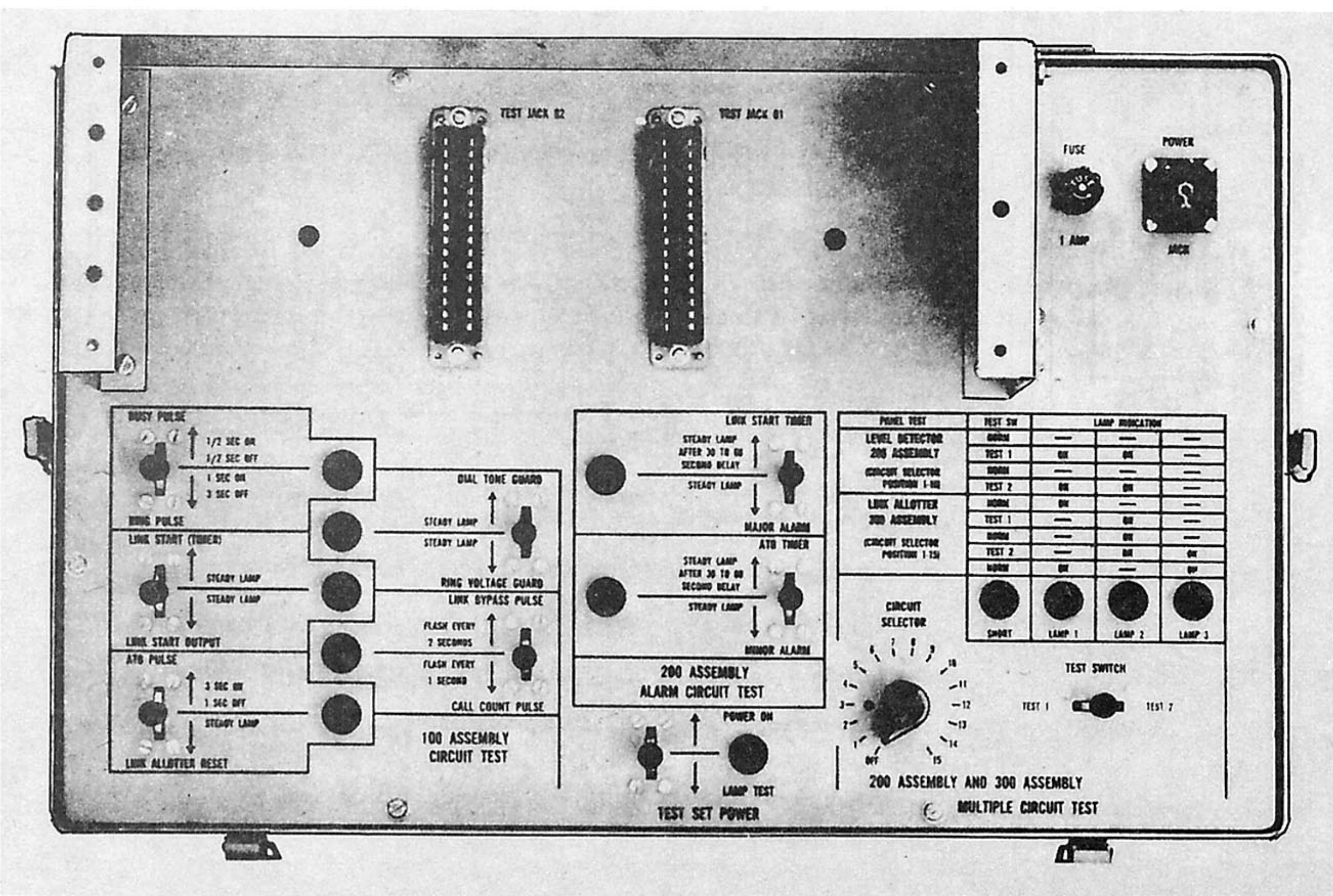


Figure 6-41.—Common panel test set.

Test Equipment

Preventive maintenance must be performed on the MDM system to keep it in good operating condition and to prevent interruptions in service. When corrective maintenance is required, special test equipment is needed to complete the work. In the following paragraphs the major special test equipment for the MDM system will be discussed.

COMMON PANEL TEST SET.— The common panel test set (fig. 6-41) is used to test the common control, link allotter, and level detector circuit modules of the MDM 50- and 100-line units out of the system. The purpose and function of the 50/100-line system and the 200/700-line system are the same. There are some physical characteristics that are different. The module to be tested is plugged into the jack receptacle located on the face of the test set. By operating the appropriate lever switches and the selector switch, various system conditions are simulated. The module response is indicated by the various test lamps located on the panel. The switches and lamps are connected so that the three modules tested use many common test set components. The test set requires an external source of ring voltage and dc power. These normally can be obtained from terminals located at the switchboard.

The description of controls and indicators listed in table 6-7 corresponds to the common panel test set in figure 6-41.

LINK PANEL TEST SET.— The link panel test set (fig. 6-42) is similar to the common panel test set. It is also used on the 50/100-line system. The one used for the 200/700-line system functions in the same way but has some physical differences. It is used to bench test the link circuit modules. To test the module, the

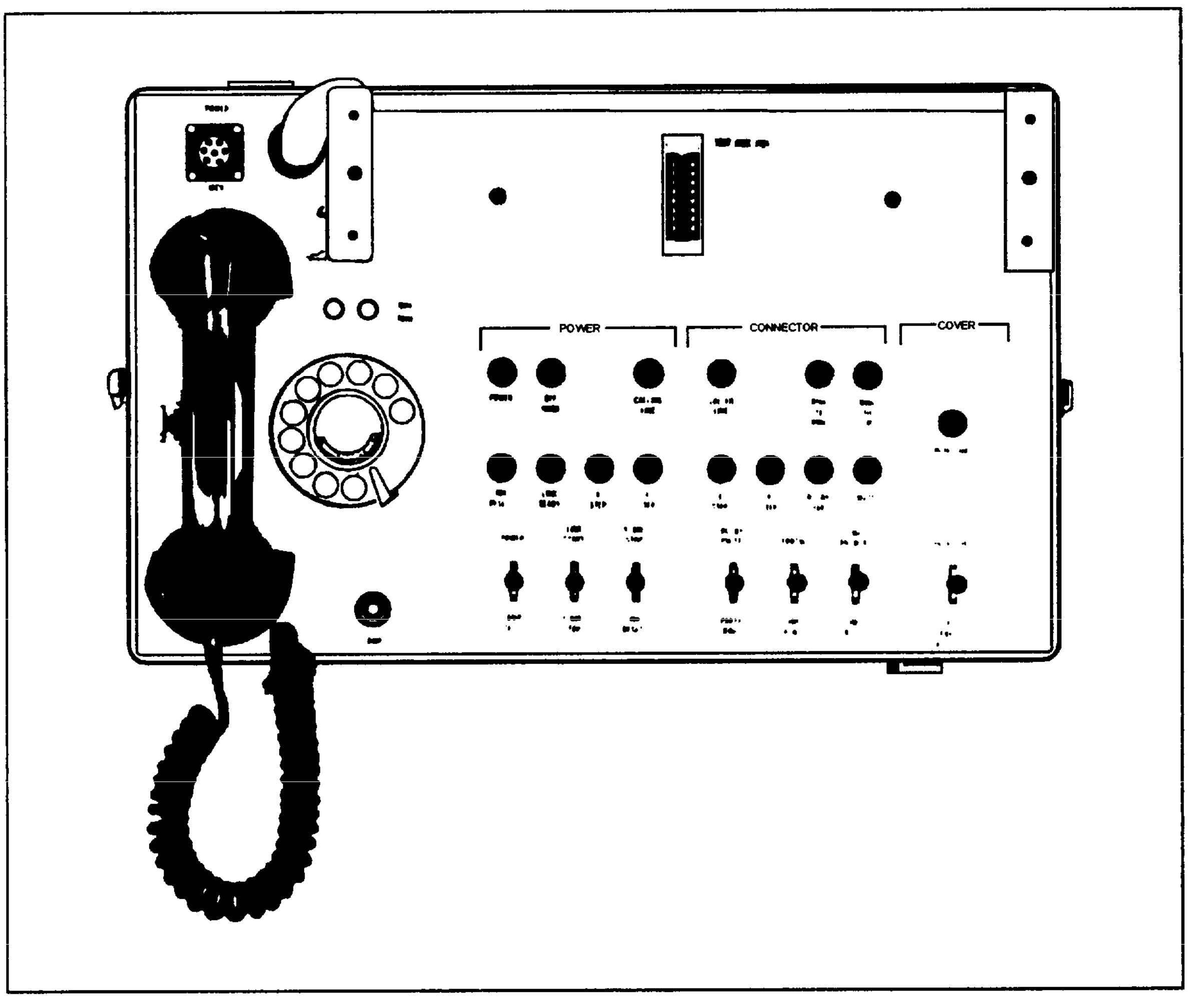


Figure 6-42.—Link panel test set.

Table 6-7.—Operation Procedures for the Common Panel Test Set

CONTROL OR INDICATOR	NORM POS	REF DESIG	DESCRIPTION	FUNCTION
COMMON CONTROL TEST 1:				
BUSY PULSE-RING PULSE and associated lamp	Center	S1 and DS1	Lever switch, two-position nonlocking; lamp, red lens cap	Used to test busy-pulse and ring-pulse relay interrupters in common control circuit module.
COMMON CONTROL TEST 2:				
LINK START TIMER-LINK START OUTPUT and associated lamp	Center	S2 and DS2	Lever switch, two-position nonlocking; lamp, red lens cap	Used to check "link start timer" and "link start" leads of common control circuit module.
COMMON CONTROL TEST 3:				
ATB PULSE-ALLOTTER RE-SET and associated lamp	Center	S3 and DS3	Lever switch, two-position nonlocking; lamp, red lens cap	Used to test ATB and link allotter reset circuitry in common control circuit module.
COMMON CONTROL TEST 4:				
DIAL TONE GUARD-RING VOLTAGE GUARD and associated lamp	Center	S4 and DS4	Lever switch, two-position nonlocking; lamp, red lens cap	Used to test dial tone and ringing monitor/alarm circuitry in common control circuit module.
COMMON CONTROL TEST 5:				
LINK BYPASS PULSE-CALL COUNT PULSE and associated lamp	Center	S5 and DS5	Lever switch, two-position nonlocking; lamp, red lens cap	Used to test link bypass and call count circuitry in common control circuit module.
LAMP TEST-POWER	Center	S10	Lever switch, two-position locking; lamp, red lens cap	Used to turn on test set power and to test all lamps on test set.
LEVEL DETECTOR TEST 1:				
LINK START TIMER-MAJOR ALARM and associated lamp	Center	S6 and DS6	Lever switch, two-position nonlocking; lamp, red lens cap	Used to test link-start 45-second timeout and major alarm circuitry in level detector circuit module.

Table 6-7.—Operation Procedures for the Common Panel Test Set—Continued

CONTROL OR INDICATOR	NORM POS	REF DESIG	DESCRIPTION	FUNCTION
LEVEL DETECTOR TESTS 2:				
ATB TIMER-MINOR ALARM and associated lamp	Center	S7 and DS7	Lever switch, two position nonlocking; lamp, red lens cap	Used to teat ATB 45-second time-out and minor alarm circuitry in level detector circuit module.
LEVEL DETECTOR AND LINK ALLOTTER MULTIPLE CIRCUIT TEST:				
LAMP 1, LAMP 2, and LAMP 3	. .	DS8, DS9, and DS10, resp.	Lamp, red lens cap	Used in conjunction with ROTARY SWITCH and TEST 1-NORM-TEST 2 switch to indicate proper responses of tested circuit modules.
ROTARY SWITCH:				
OFF and 1 through 15	OFF	S9	4-pole, 17-position rotary switch	Used in conjunction with TEST 1-NORM-TEST 2 switch to test level detector and link allotter circuit modules. Selects level or link-allotment circuits to be tested.
SHORT	--	DS11		Detects any shorts in 02 connector and link allotter circuit modules as ROTARY SWITCH is turned.
TEST 1-NORM-TEST 2	NORM	S8	Lever switch, two-position nonlocking	Used in conjunction with ROTARY SWITCH. Tests level relays and muting circuit in level detector circuit module; also tests link allotment and bypass relays in link allotter circuit module.

cover must be removed. It is tested after the chassis tests are completed.

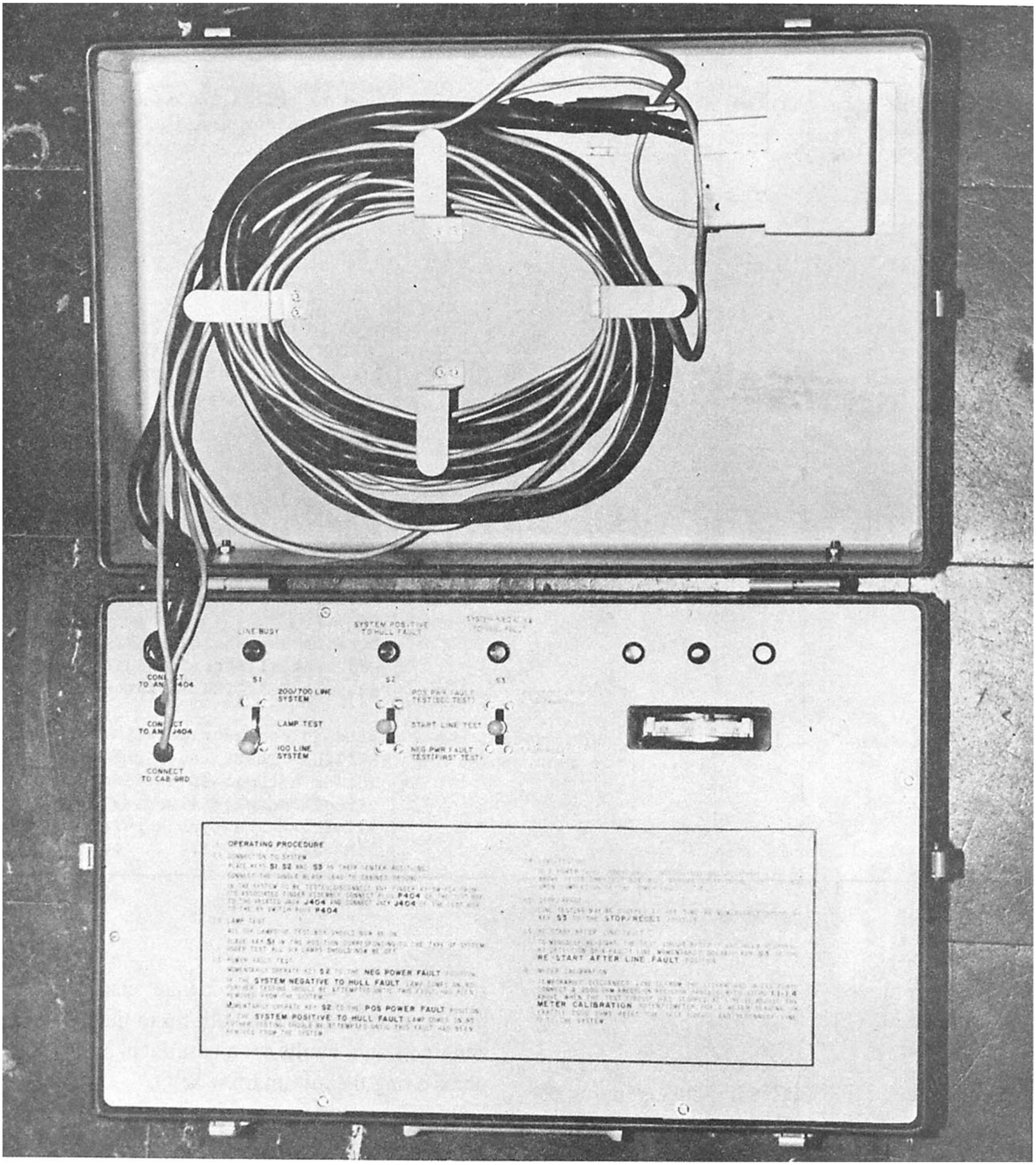
The test set uses the principle of simulating certain external circuit conditions, including the operation of the XY switch to check the module for proper response. Failure to respond is indicated by certain lights being either off or on.

The control and indicator descriptions shown in table 6-8 correspond to the link panel test set shown in figure 6-42.

LINE FAULT ROUTINER.— The line fault routiner (fig. 6-43) is used to test for line faults from the wire bank through internal cabinet wiring to the line panel (600 assembly) and out to the individual line stations. The faults tested for are system positive to hull, system negative to hull, tip to hull, ring to hull, and tip to ring. Faults are measured in ohms, with 50K ohms being the minimum.

The line fault routiner receives all power from the cabinet under test via interconnect cables, and may be used with the MDM 200/700 or MDM 50/100 system.

Once the unit is connected to the system, lever switches (keys) are used for starting and/or stopping various tests. Lamps are provided along with an ohmmeter for visual interpretation of test results. The routiner causes the XY switch to automatically sequence to level 1 (X direction) and sequence to each Y position until all 10 positions in the Y direction have



292.41

Figure 6-43.—Line fault routiner.

Table 6-8.—Operation Procedures for the Link Panel Test Set

CONTROL OR INDICATOR	NORM POS	REF DESIG	DESCRIPTION	FUNCTION
Switches				
3 DIGIT DIALING RG/BY PULSE	Center	S4	Lever switch, two-position locking-non-locking, respectively	Used to assign party ringing option to link (3 DIGIT DIALING position); also used to test ringing and busy tone.
DETECTOR TEST-LAST PARTY RELEASE	Center	S7	Lever switch, two-position nonlocking	Used to test level detector in link (DETECTOR TEST position) and to assign last party release option to link (LAST PARTY RELEASE position).
EROW-LINE HUNT	Center	S5	Lever switch, two-position nonlocking-locking, respectively	Used to test EROW entry (EROW position); also tests line hunting (LINE HUNT position).
LAMP TEST-POWER	Center	S1	Lever switch, two-position locking	Used to turn on test set power and to test all lamps on test set.
LINE BUSY-LINE ANSWER	Center	S6	Lever switch, two-position locking-non-locking, respectively	Used to simulate a busy called line (LINE BUSY position) or call answer by called party (LINE ANSWER position).
LINK START-X DIR STOP	Center	S2	Lever switch, two-position nonlocking	Used to seize link and test stepping in X direction (LINK START position); also tests stepping in Y direction (X DIR STOP position).
Y DIR (FINDER) STOP-LINK RESET	Center	S3	Lever switch, two-position nonlocking	Used to simulate calling line found (Y DIR (FINDER) STOP position); also simulates calling party release (LINK RESET position).
Indicators				
CALLING LINE	--	DS3	Lamp, red lens cap	Indicates link has found calling line and has set-up its circuitry for connector operations.
CALLED LINE	--	DS8	Lamp, red lens cap	Indicates link has performed ring trip after simulation of called-party answer.
DETECTOR	--	DS15	Lamp, red lens cap	Indicates level detector in link is operative
LINK READY	--	DS5	Lamp, red lens cap	Lights when link is seized; is extinguished when calling line has been found (simulation).

Table 6-8.—Operation Procedures for the Link Panel Test Set—Continued

CONTROL OR INDICATOR	NORM Pos	REF DESIG	DESCRIPTION	FUNCTION
LINK RESET	--	DS4	Lamp, red lens cap	Flashes to indicate link is reset after calling party or last party release.
MUTE	--	DS14	Lamp, red lens cap	Indicates muting circuit is operative for ring-on-tip.
OFF HOOK	--	DS2	Lamp, red lens cap	Indicates 45-second no-dialing timeout in link.
POWER	--	DS1	Lamp, red lens cap	Indicates power applied to test set circuitry.
RG/BY START	--	DS13	Lamp, red lens cap	Indicates dialed stepping in Y direction has occurred and link is prepared to extend ringing.
RING-R	--	DS9	Neon lamp NE2J	Indicates bridged ringing and ringing-on-ring.
RING-T	--	DS10	Neon lamp, NE2J	Indicates ring-on-tip.
X STEP (two lamps)	--	DS6 and DS11	Lamp, red lens cap	Indicates automatic and dialed stepping in X direction.
Y STEP (two lamps)	--	DS7 and DS12	Lamp, red lens cap	Indicates automatic and dialed stepping in Y direction.

been tested. The unit then resets and causes the XY switch to move to level 2, and the Y direction process is repeated. The sequence is repeated until all 100 lines have been tested. The process automatically stops if a fault is encountered. Table 6-9 shows the routiner operating procedure.

XY UNIVERSAL SWITCH TEST SET.— The XY switches and associated links are initially tested in place. This is done by the link cycle push-button switch located on the monitor and distribution panel. This switch causes the linefinder XY switch in each idle link to step to level 0 in the X direction and to overflow in the Y direction. A connector XY switch may be checked by interchanging it with a linefinder XY switch of the same link. If an XY switch is suspected of being faulty and further testing is required, the XY universal switch test set is used.

The XY universal switch test set (fig. 6-44) is an electrically operated, portable test set designed for bench testing the operation of the XY switch. The unit is mounted in a wooden carrying case; the XY switch to be tested is mounted on the panel of the unit and plugged into the associated jack. Power for the test set is from an external 48-volt dc source.

The purpose of the test set is to provide a way to test the stepping magnets of an XY switch under various conditions. The testing conditions are as follows:

1. Pulsing tests at the rate of 12 pulses per second with 34-percent make

2. Pulsing tests at the rate of 12 pulses per second with 84-percent make

3. Automatic stepping tests controlled by the interrupter springs of the XY universal switch under test

4. Stepping speed tests in the X or Y directions

Table 6-9.—Operating Procedures for the Line Fault Routiner

1 Operating Procedure

1.1 Connection to System

Place keys S1, S2 and S3 in their center positions. Connect the single black lead to cabinet ground.

In the system to be tested, disconnect any finder X-Y Switch from its associated finder assembly. Connect plug P404 of the test box to the vacated jack J404 and connect jack J404 of the test box to the X-Y Switch plug P404.

1.2 Lamp Test

All six lamps of the test box should now be on.

Place Key S1 in the position corresponding to the type of system under test. All six lamps should now be off.

1.3 Power Fault Test

Momentarily operate Key S2 to the Neg Power Fault position.

If the System Negative to Hull fault lamp comes on, no further testing should be attempted until this fault has been removed from the system.

Momentarily operate Key S2 to the Pos Power Fault position.

If the System Positive to Hull fault lamp comes on , no further testing should be attempted until this fault has been removed from the system.

1.4 Line Testing

If a power fault condition is not encountered in either of the above tests, the test box will automatically begin line testing.

1.5 Stop/Reset

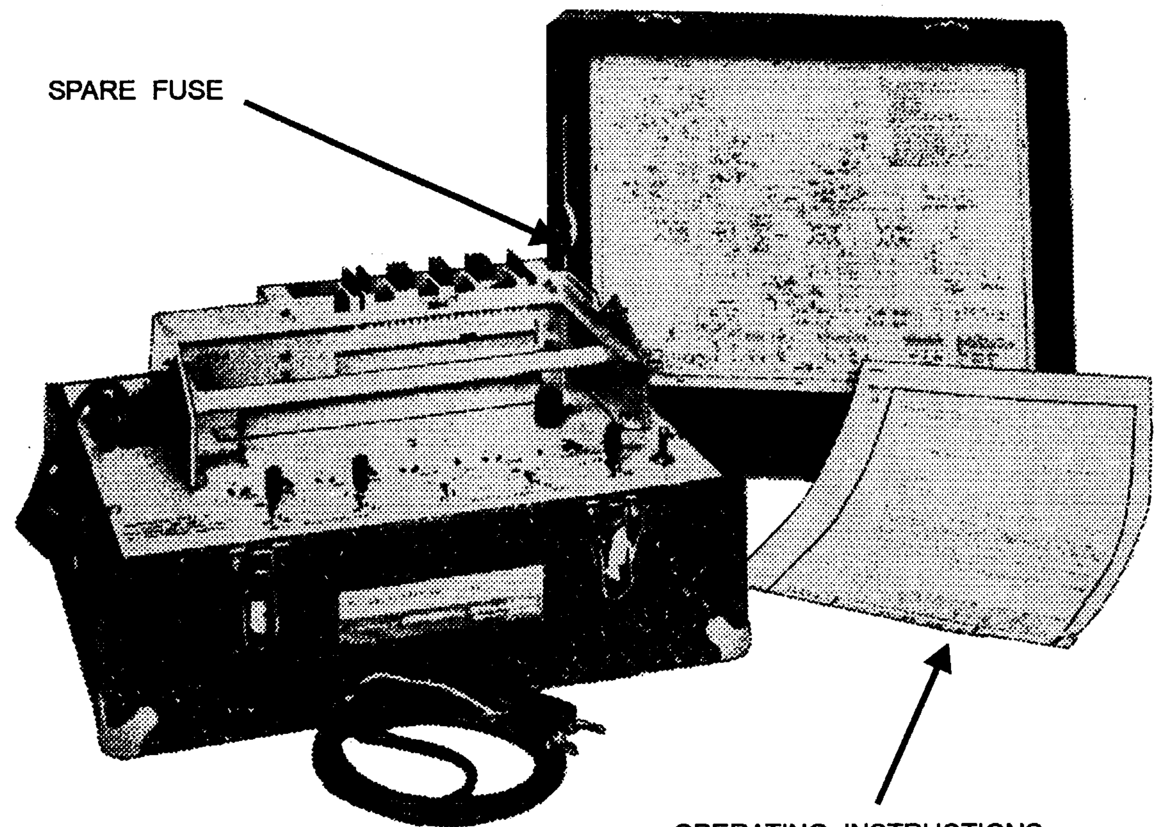
Line testing may be stopped at any the by momentarily operating Key S3 to the Stop/Reset position.

1.6 Re-Start after Line Fault

To manually re-start the test circuit after it has been stopped by the detection of a faulty line, momentarily operate Key S3 to the Re-Start After Line Fault position.

2. Meter Calibration

Temporarily disconnect line 11 from the system and in its place connect a 2000 ohm precision resistor. Proceed with steps 1.1 through 1.4 above. When the test circuit has stopped on line 11, adjust the meter calibration potentiometer for a meter reading of 2000 ohms exactly. Reset the test circuit and reconnect line 11 to the system.



292.42

Figure 6-44.—XY universal test set.

5. Spring assembly tests in the normal and operated positions

6. Release tests from the X- and Y-overflow positions

7. Supply of 24-volt test battery to the magnets for adjustment purposes

Table 6-10 explains what the switch and indicators do on the XY test set. The information in

Table 6-10.—XY Universal Switch Test Set Operation Procedures

LEVER SWITCH	FUNCTION
PULSING HIGH-LOW	Used in conjunction with PULSING X-XY-Y switch to test stepping action of XY Universal Switch (in the X, or Y, or the X and Y directions) under low or high percent make conditions. In LOW position -- supplies 12 pulses per second at 34-percent make (low pulse ratio). In HIGH position -- supplies 12 pulses per second at 84-percent make (high pulse ratio). In center position -- disconnects pulsing generator (XY Universal Switch in test cell will not step).
PULSING X-XY-Y	Used in conjunction with PULSING HIGH-LOW switch to select stepping direction of XY Universal Switch (X, or Y, or X and Y directions) when XY Universal Switch is being tested for Operation under low or high percent make conditions. In Y position -- causes XY Universal Switch in test cell to step in Y direction and recycle. In XY position -- causes XY Universal Switch in test cell to step in X then Y direction and recycle. In X position -- causes XY Universal Switch in test cell to step in X direction and recycle.
AUTO STEP STEP-SPEED	Used in conjunction with AUTO STEP X-XY-Y switch to test automatic stepping feature (self-interrupted stepping) of XY Universal Switch under test. In STEP position -- tests automatic stepping feature of XY Universal Switch in X, or Y, or X and Y direction (recycles). In SPEED position -- tests hunting speed of XY Universal Switch in X or Y direction (does not recycle). In center position -- disconnects automatic stepping source from XY Universal Switch.
AUTO STEP X-XY-Y	Used in conjunction with AUTO STEP STEP-SPEED switch to select stepping direction of XY Universal Switch (in X, or Y, or X and Y directions) when XY Universal Switch is being tested for operation under automatic stepping conditions or hunt-speed conditions. In Y position -- causes XY Universal Switch in test cell to step to Y overflow and recycle. In XY position -- causes XY Universal Switch in test cell to step in X then Y direction and recycle.

Table 6-10.—XY Universal Switch Test Set Operation Procedures—Continued

LEVER SWITCH	FUNCTION
AUTO STEP X-XY-Y (Continued)	In X position -- causes XY Universal Switch in test cell to step to X overflow and recycle.
24 V	Supplies 24-volt test battery to X magnet (if AUTO STEP X-XY-Y switch is in XY position) in Y magnet (if AUTO STEP X-XY-Y switch is in Y position) of XY Universal Switch in test cell.
CONTROL	**FUNCTION**
ON-OFF switch	In OFF position -- disconnects test set from negative battery supply. In ON position -- -connects test set to negative battery supply.
Test jack	Provides test point for measuring pulse speed and percent make of pulsing generator in the test set.
Battery-supply cord	Red lead provides means for connecting negative battery (49 ± 1/2 volts dc) to test set. Black lead provides means for connecting positive battery (ground) to test set.
Wire banks	Controls stepping of XY Universal Switch by means of various internal bank strapping arrangements. Provides wiper alignment fixture for XY Universal Switch.
Test-set plug	Provides means of connecting XY Universal Switch under test to test set.
LAMP	**FUNCTION**
X OFF-NORMAL (White)	Lights to indicate that break contacts of XON springs are closed. Goes out to indicate that break contacts of XON springs are open.
X OFF-NORMAL (red)	Lights to indicate that make contacts of XON springs are closed. Goes out to indicate that make contacts of XON springs are open.
Y OFF-NORMAL (White)	Lights to indicate that break contacts of YON springs are closed. Goes out to indicate that break contacts of YON springs are open.
Y OFF-NORNAL (Red)	Lights to indicate that make contacts of YON springs are closed . Goes out to indicate that make contacts of YON springs are open.

Table 6-10.—XY Universal Switch Test Set Operation Procedures—Continued

LAMP	FUNCTION
RELEASE (White)	Lights to indicate that break contacts of RLS springs are closed. Goes out to indicate that break contacts of RLS springs are open.
RELEASE (Red)	Lights to indicate that make contacts of RLS springs are closed. Goes out to indicate that make contacts of RLS springs are open.
OVERFLOW (White)	Lights to indicate that break contacts of X-Y overflow springs are closed. Goes out to indicate that break contacts of X-Y overflow springs are open.
OVERFLOW (Red)	Lights to indicate that make contacts of X-Y overflow springs are closed, Goes out to indicate that make contacts of X-Y overflow springs are open,
SPEED 25-32 (Green)	Lights to indicate that stepping speed of XY Universal Switch under tests is within range of 25-32 steps per second. Goes out to indicate that stepping speed of XY Universal Switch is outside range of 25 to 32 steps per second. Lights once and goes out to indicate that stepping speed of XY Universal Switch is below 25 steps per second,
SPEED 32-45 (Green)	Lights to indicate that stepping speed of Xf Universal Switch is above 32 but below 45 steps per second, Goes out to indicate that stepping speed of XY Universal Switch is outside range of 32 to 45 steps per second. Lights once and goes out to indicate that stepping speed of XY Universal Switch is below 32 steps per second.

table 6-10 corresponds to the XY test set in figure 6-45.

CURRENT FLOW TEST SET.— The current flow test set (fig. 6-46) is a portable, relay-adjusting test set. It is connected by its power cable to an external dc power source. The resistance circuits of the test set are connected to binding posts. The relay to be adjusted is connected to the binding posts by two test leads.

The purpose of the test set is to enable a maintenance person to readjust the relays in a telephone system. Four independent, continuously variable resistance circuits are provided in the test set. This allows the maintenance person to set up for operate, nonoperate, release, and hold or scale current requirements of a relay under adjustment. A three-range milliammeter allows the maintenance person to adjust to the correct current level. Table 6-11 lists the control and function of the current flow test set.

LIGHTNING ARRESTER AND SHORE-LINE CONNECTIONS BOXES.— Shore lines are provided to a connection box on the pier for use by ships, As an IC Electrician, you will be required to rig shore lines for your ship. The number of shore lines assigned will depend on the size of your ship; the bigger the ship, the more lines. Some of the shore lines will be connected to the attendant's cabinet for general use and others will be connected directly to telephone sets that are not part of the switchboard system. The direct shore lines are used by the commanding officer, the executive officer, department heads, and other designated personnel.

The ship's IC Electricians are responsible for maintaining a shore-line cable. When rigging shore lines, one end of the cable will be connected to the

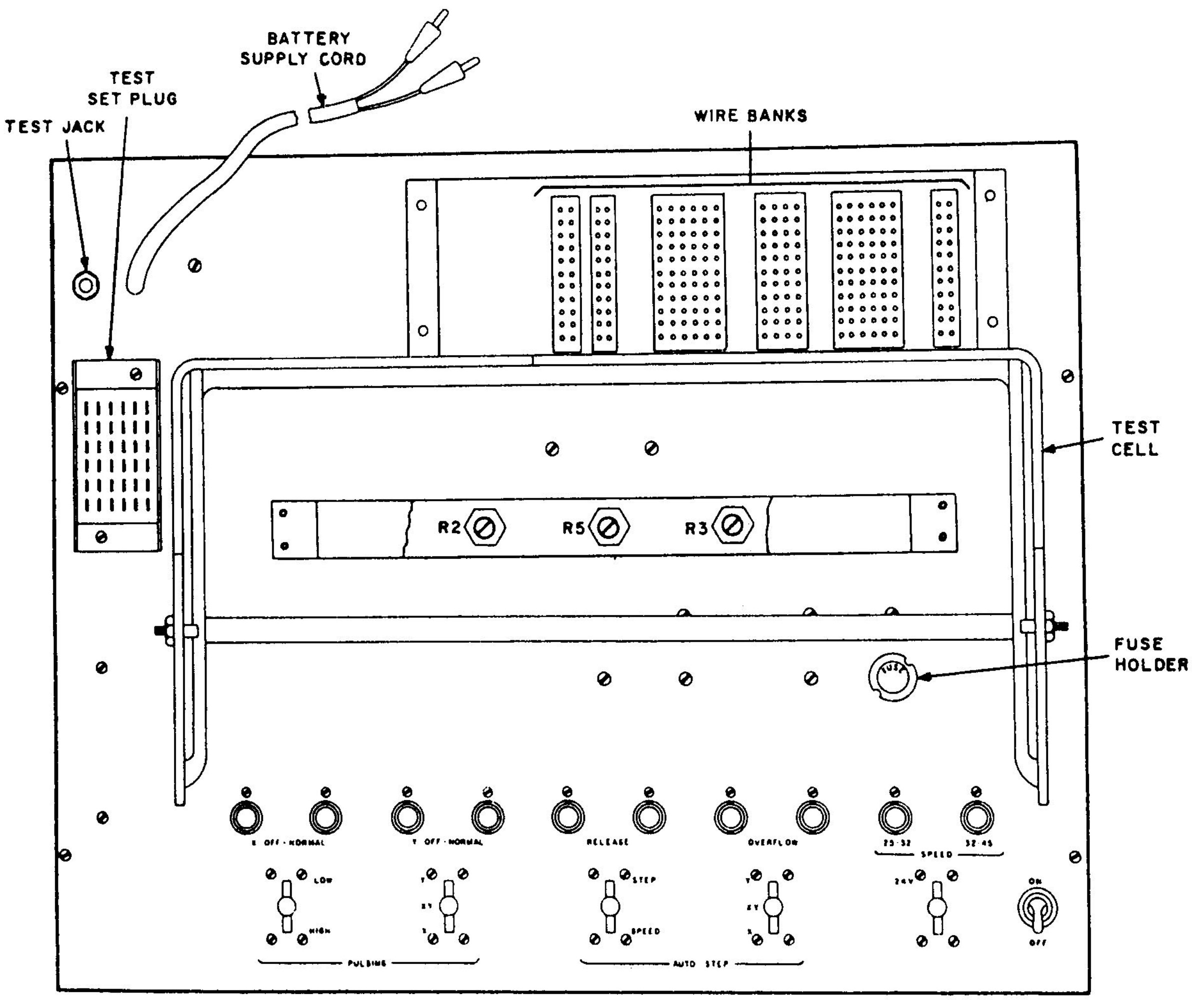


Figure 6-45.—XY universal switch test set controls.

shore-line connection box and the other end will be connected to the lightning arrester box on the ship.

Each set of shore-line telephone leads from the switchboard pass through a lightning arrester box and end in a shore-line connection box. The lightning arrester box protects the telephone operator and telephone equipment should lightning strike the incoming telephone lines.

The lightning arrester and shore-line connection boxes may be combined. The installations vary from ship to ship, and those mentioned here serve only as examples of the variety you may find in the fleet. On a large ship you are likely to find one arrestor box and one connection box on each side, port and starboard. Some small ships have only one lightning arrester box in the circuit ahead of the lines that branch off to the port and starboard shore-line connection boxes. Normally, standard electrical connection boxes are used where the incoming shore lines connect to the ship's lines. A practice that is gaining favor calls for the use of amphonel-type, multipin, jack-and-plug combinations. In such a case, the plug fits the shore-line connection box and the jack attaches to a portable cable that is run to the local shore-line connection box on the pier. The new boxes have a removable plug in the bottom of each box for inserting the cable.

Figure 6-47 shows the basic circuit arrangement for a typical lightning arrester box. Each lead of an incoming line has a 5-ampere fuse and a set of carbon contacts in the line. If lightning strikes the line, the fuse will blow to open the circuit to the switchboard equipment. The carbon contacts will fuse together to provide the incoming potential a path to ground. Most ships have a lightning arrester box on each side, port and starboard.

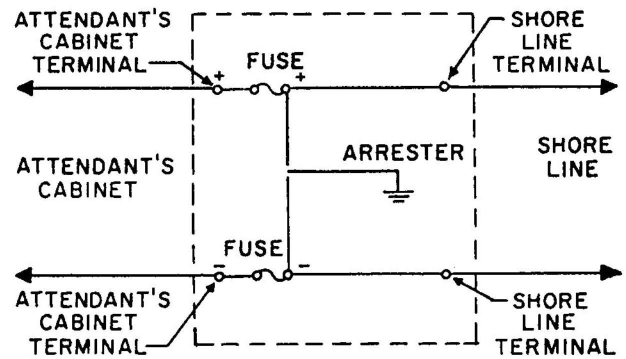


Figure 6-47.—Shore-tine connections.

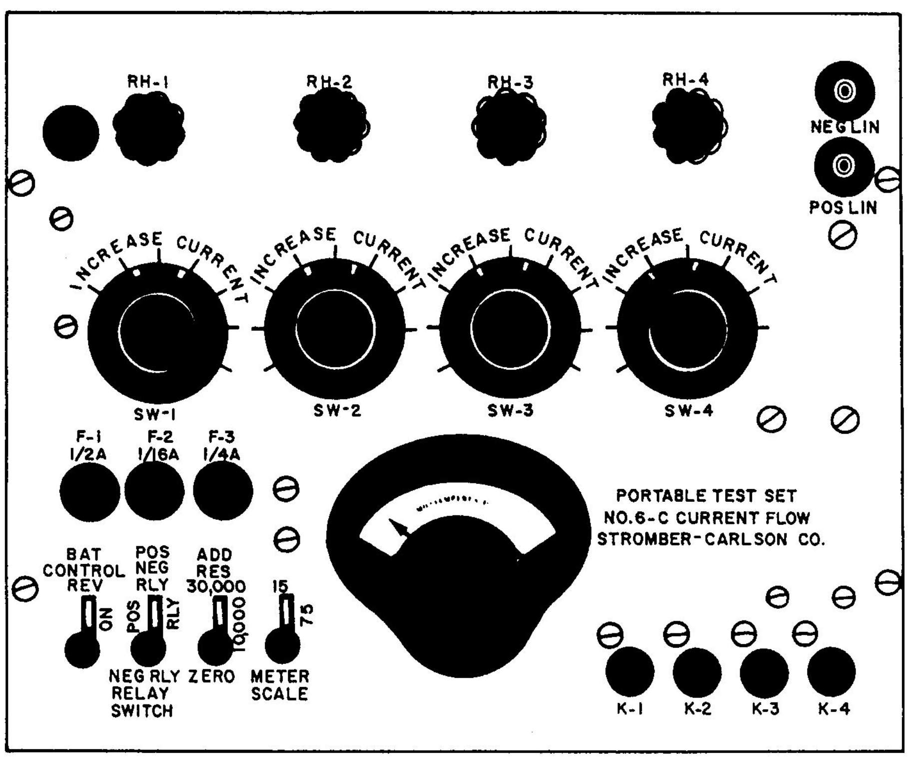


Figure 6-46.—Current flow test set controls and indicators.

Table 6-11.—Controls and Indicators for the Current Flow Test

CONTROL OR INDICATOR	FUNCTION
RH-1 through RH-4	Variable resistors; provide fine adjustment of current for each of the four resistance circuits.
SW-1 through SW-4	Selector switches; provide coarse control of current in each of the four resistance circuits.
K-1 through K-4	Push switches; complete the associated resistance circuits, which are associated as follows: K-1 - RH-1 and SW-1 K-2 - RH-2 and SW-2 K-3 - RH-3 and SW-3 K-4 - RH-4 and SW-4
BAT CONTROL	Lever switch; controls application of battery to binding posts. In OFF position - removes battery from binding posts. In ON position - applies battery to binding posts. In REV position - reverses polarity of battery to binding posts.
RELAY SWITCH	Lever switch; selects proper operate mode for type of relay winding condition. In NEG RLY position - for testing relays having either battery connected to one terminal or no potential present. In POS RLY position - for testing relays having external ground connected to one terminal. In POS NEG RLY position - for testing dual-coil relays, having external battery connected to terminal of one coil and external ground to terminal of other coil.

Table 6-11.—Controls and Indicators for the Current Flow Test—Continued

CONTROL OR INDICATOR	FUNCTION
ADD RES	Lever switch; provides additional resistance (less current) to all four resistance circuits. In ZERO position - provides no additional resistance. In 10,000 position - provides 10,000 ohms additional resistance. In 30,000 position - provides 30,000 ohms additional resistance.
METER SCALE	Lever switch; selects meter scale used. In 15 position - selects 15-milliampere scale. In 75 position - selects 75-milliampere scale. In 750 position - selects 750-milliampere scale.
NEG RLY	Binding post; used for connecting relays having external battery on one terminal.
POS RLY	Binding post; used for connecting relays having external ground or positive battery potential on one terminal,
BAT GRD	Power cord.
Milliammeter	Three-scale dc milliammeter; indicate current being applied to relay under test.

DYNALEC 200/500 CENTRALOFFICE TELEPHONE SYSTEM

The central office telephone system (figs. 6-48 and 6-49) provides point-to-point communication for ship's personnel in the same manner as commercial telephone systems. Special features provide capabilities that accommodate emergency conditions, protect secure compartments from compromise, allow command level people to obtained right-of-way, and increase the probability of call completion. All stations connected can be either private line service or two-party line service. These features are established at time of installation. If it is desired that the features to a station be changed, this is easily done. Contact the IC room supervisor.

Central Office Switchboard

The central office switchboard (fig. 6-48) is made up of from one to five switchboards and a power supply unit. The equipment is in modular form. Except for crossbar switches and dc converters, the modules are mounted on swing out gates. This gives easy access to the module terminals. Each unit is enclosed in a freestanding steel cabinet.

The central office switchboard houses the components that interconnect the calling telephone with the called telephone. The switching and control circuit components are the crossbar switches and circuit cards mounted in the card cage in a cabinet. Two dc-to-dc converter power supplies supply logic voltages for these circuits. The number of lines that can be connected within a system depends on the number of cabinets.

The central office switchboard's (fig. 6-49) primary job is to (1) interpret the dial pulse information from the calling telephone, (2) determine the called telephone, (3) choose a suitable path to interconnect the two telephones, and (4) connect the two telephones and ring the called party. Its secondary task is to notify a station, in an off-hook condition, to hang up the handset.

There are four arrangements of the central office system (200, 300, 400, 500 line). The system is expandable to a 700-line capacity; however, the manufacturer should be consulted should this need arise. The various configurations (line capacity) operate in the same way. The difference between the arrangements is the capability to interconnect more lines through more paths and links. Switching capacity (trunking) established by military specification is 16 percent of line capacity.

There are four areas not duplicated as the system expands. These are the power supply, ring generators, emergency cut-in, and manual switchboard. The power supply and ring generators are able to serve any arrangement. The emergency cut-in and manual switchboard are only required once. Although one power supply is required for any system configuration, a 50-amp unit is required for systems

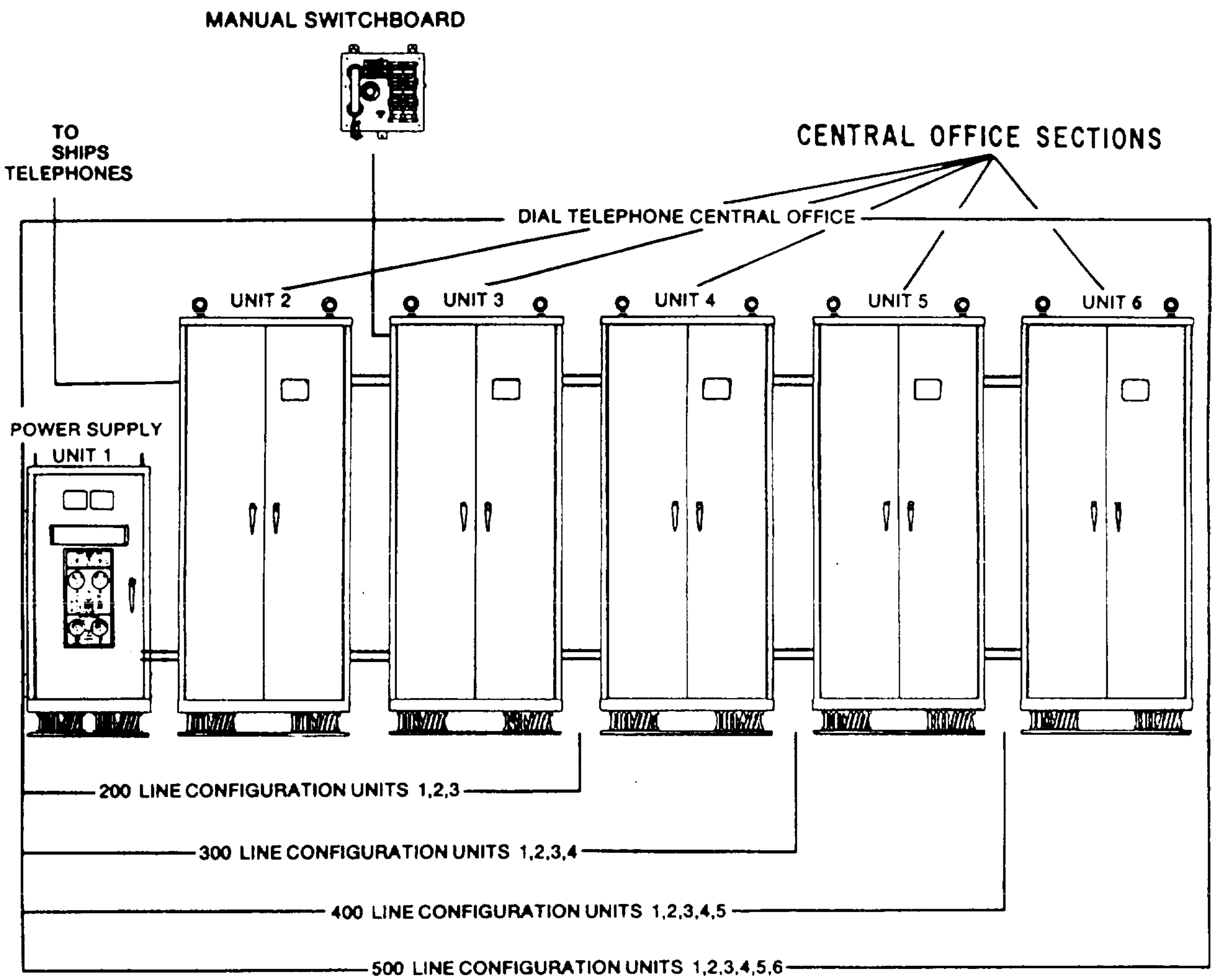


Figure 6-48.—Dial telephone central office.

of 400 lines or less. A 100-amp unit is required for systems of 500 lines or greater.

Digital logic and integrated circuit technology is used to interrupt, decode, determine path availability, and identify and notify a switch to operate. But, the actual voice circuit is completed through electromechanical switches. These switches are called crossbar switches.

The crossbar switches are able to switch 10 three-wire inputs to any of 30 three-wire outputs, or conversely 30 inputs to 10 outputs by using these switches in a series and parallel combination, the 1 to 999 capability (in the 500-line system) is achieved.

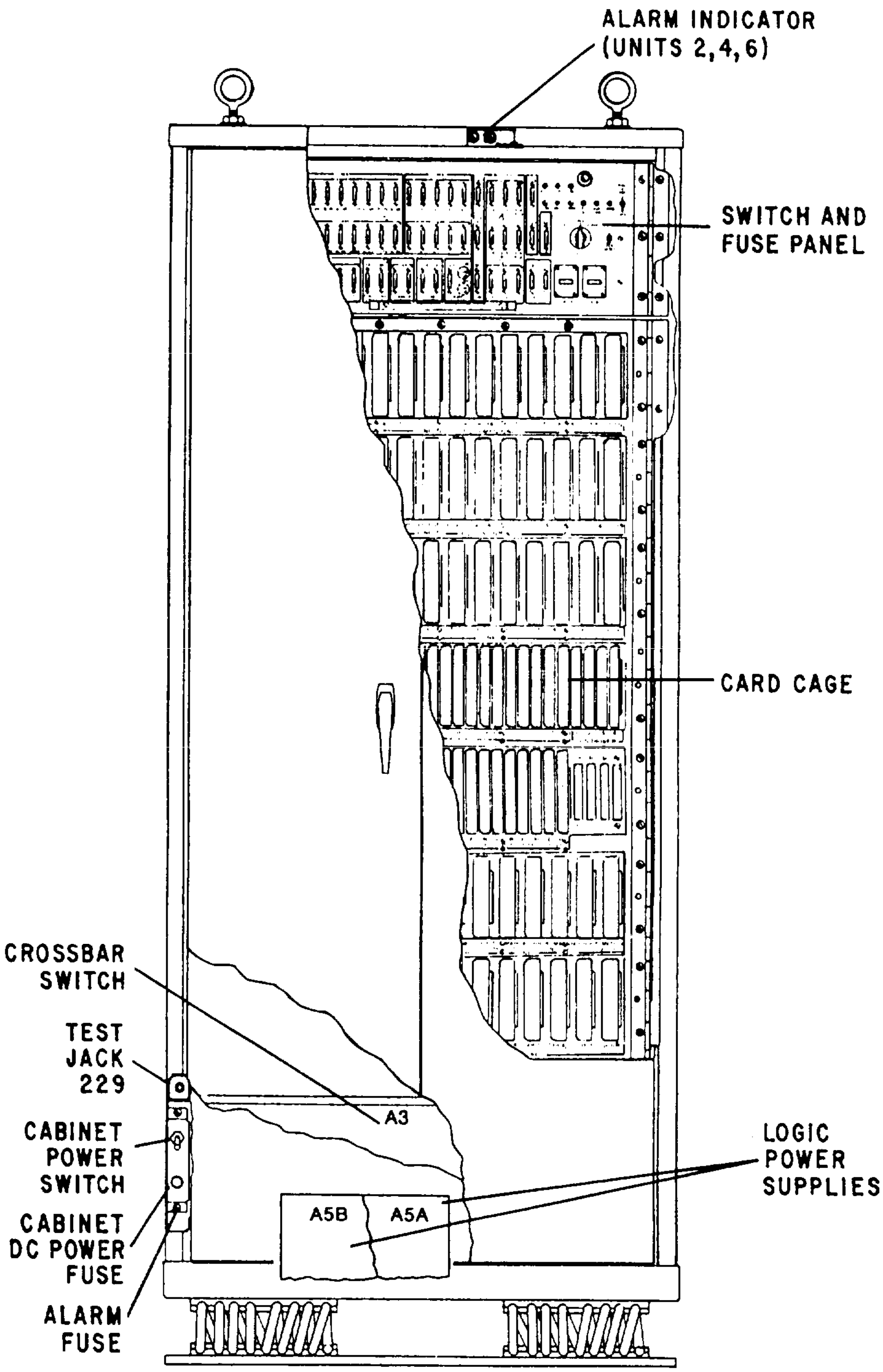


Figure 6-49.—Dial telephone central office section, cutaway.

The power supply (fig. 6-50) does two essential jobs in the system. It provides +48 volt dc and talk battery. Secondly, it provides the 90-volt ac 20-Hz ringing current for line station ringing. Included within the power supply is a battery charging network with all controls and indicators mounted on the door (fig. 6-50). Should a loss of ac power occur, switchover to battery source is automatic for uninterrupted service. Once normal power is restored, automatic switchback is again accomplished. Monitoring battery charging rate and voltage level, including battery maintenance, is essential in maintaining the Dynalec 200/500 central office system free of power-related faults.

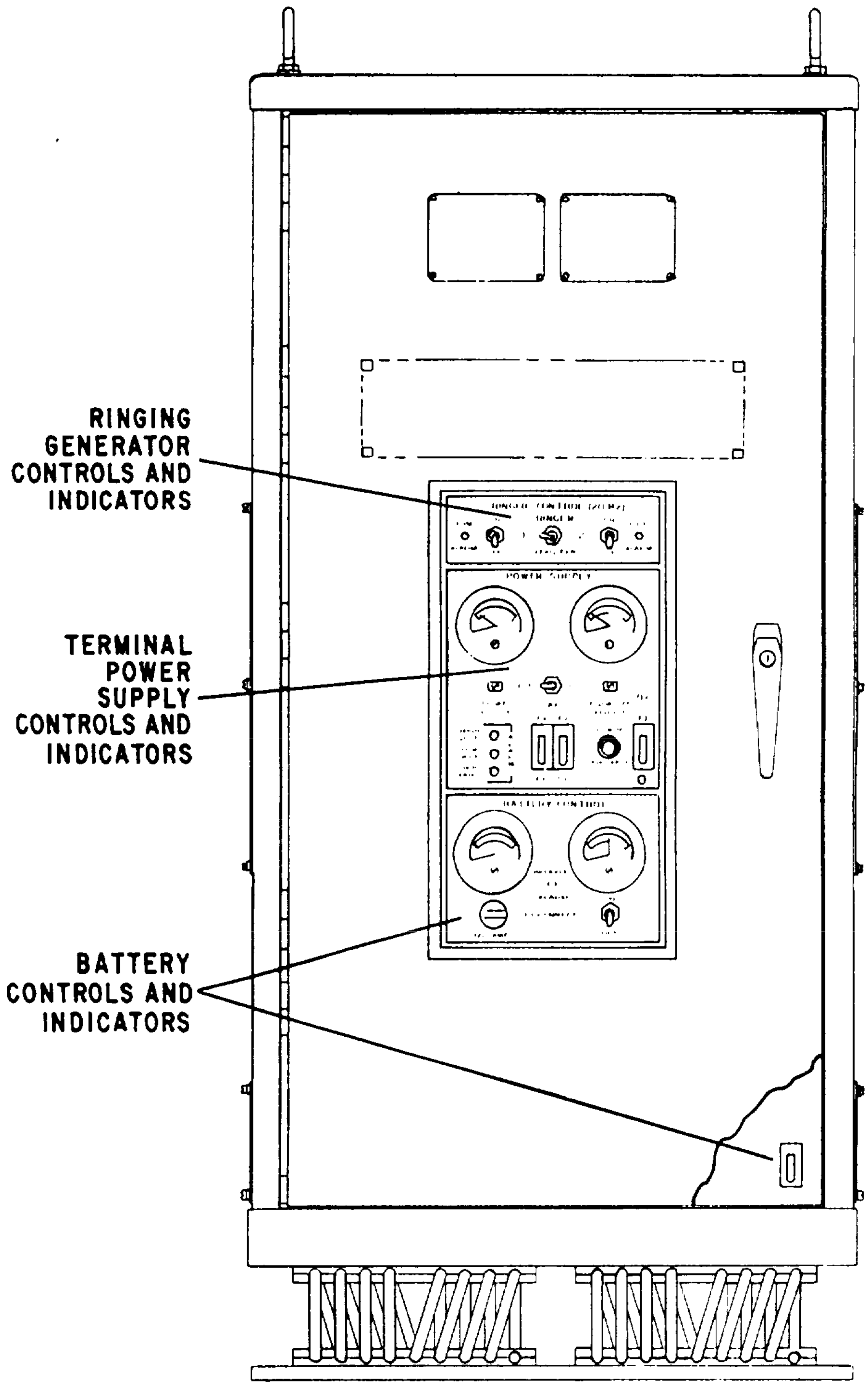


Figure 6-50.—Terminal power supply.

Manual Switchboard

The manual switchboard (fig. 6-51) is the link between the ship's dial telephone system and shore when the ship is docked. It allows the ship's unrestricted telephones to be connected to any shore line available to the ship. All ship-to-shore and shore-to-ship connections must be made through the manual switchboard by an attendant.

The manual switchboard is connected to the control office switchboard by a 37-pin connector. The ship's lines, shore lines, all power, and supervisory and central leads are brought into the manual switchboard through this connector.

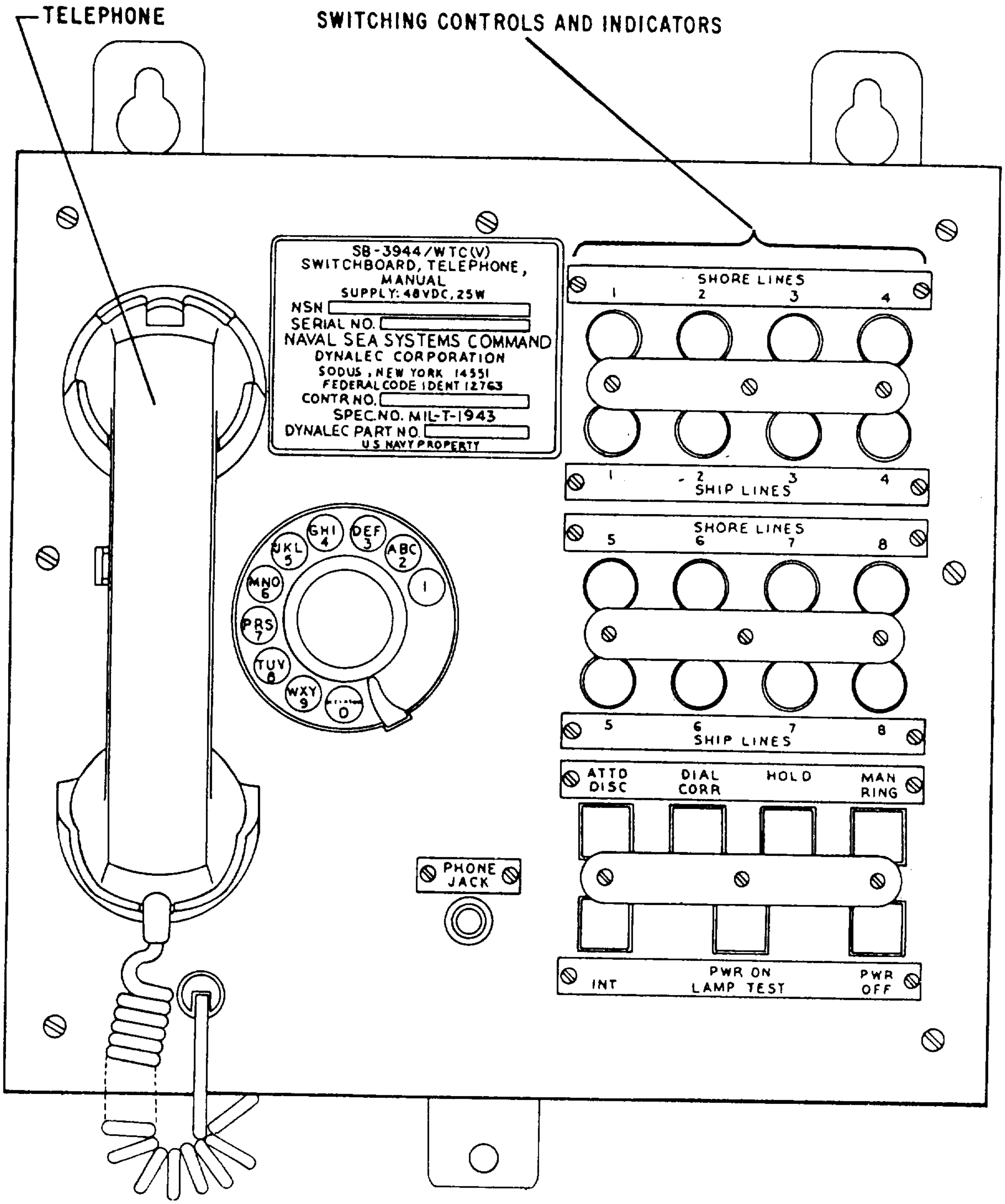


Figure 6-51.—Manual telephone switchboard.

The manual switchboard enables the attendant to do the following:

- Connect to any unrestricted ship line
- Connect to any shore line available to any ship
- Interconnect ship and shore lines
- Hold ship and shore lines accessed
- Correct dialing errors
- Enter and leave any ship-to-shore talking connection

Before operating the manual switchboard the attendant should become familiar with the use and indications of each control. Figure 6-52 illustrates and table 6-12 identifies the controls and indicators on the switchboard.

The lighted push buttons used to do the desired job have five states of illumination. The state of illumination indicates the status of a particular line or connection. The states of illumination for the individual indicators and status are given in table 6-13.

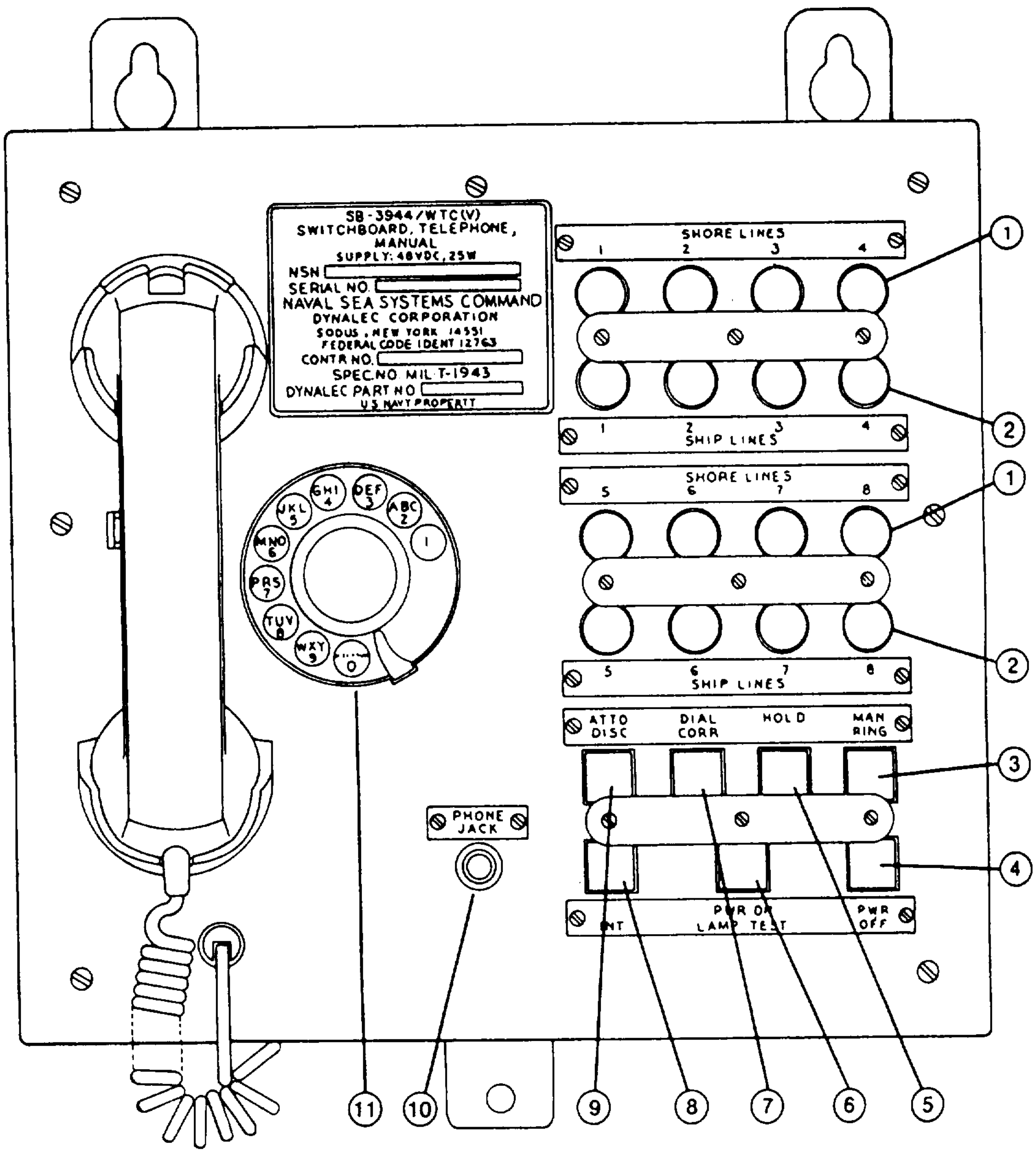


Figure 6-52.—Manual switchboard controls and indicators.

Table 6-12.—Manual Switchboard Controls and Indicators

FIGURE ITEM NO.	DESIGNATION	DESCRIPTION	CATEGORY	PURPOSE	POSITION/INDICATION
8-27(4)	PWR OFF	Switch/Indicator	I	Disconnects power from the internal circuitry. Indicates availability of power.	Momentarily depressed for power off. (See note following PWR ON/LAMP TEST switch).
8-27(6)	PWR ON LAMP TEST	Switch/Indicator	I	Connects power to the internal circuitry. Indicates power on-off condition.	Momentarily depressed for power on.
					NOTE: The indications of the above two power switches in conjunction show status of the switchboard. a). Both out- power not available from the Central Office. b). OFF on - ON off- power available but not turned on. c). OFF off - ON on- Manual Switchboard power on.
8-27(1)	SHORE LINES (8)	Switch/Indicator	I	Connects the shore lines to the Manual Switchboard. Indicates line status.	Momentarily depressed for connect (Refer to table 8-7).
8-27(2)	SHIP LINES (8)	Switch/Indicator	I	Connects the ships lines to the Manual Switchboard. Indicates line status.	Momentarily depressed for connect (Refer to table 8-7).

Table 6-12.—Manual Switchboard Controls and Indicators—Continued

FIGURE ITEM NO.	DESIGNATION	DESCRIPTION	CATEGORY	PURPOSE	POSITION/INDICATION
8-27(9)	ATTD DISC	Switch/Indicator	I	Disconnects attendants handset from a connection.	Momentarily depressed (Refer to table 8-7).
8-27(7)	DIAL CORR	Switch/Indicator	I	Re-access dial tone, if error made in dialing.	Momentarily depressed.
8-27(5)	HOLD	Switch/Indicator	I	Places a connected line on hold.	Momentarily depressed.
8-27(10)	PHONE JACK	Connector	I	Allows connection of an external handset. (The permanently mounted handset and hook switch are disabled when this connection is used.	Not applicable.
8-27(11)	Dial	Switch	I	Enter dial pulses into a connected line.	Standard telephone dial.
8-27(3)	MAN RING	NOT USED			
8-27(8)	INT	NOT USED			

Table 6-13.—Manual Switchboard Indicators State of Illumination

STATE OF ILLUMINATION	INDICATOR	STATUS
Steady Bright	PWR OFF	Power available to shipboard.
	PWR ON	Switchboard power on.
	SHORE LINES	Attendant connected to shore line.
	SHIP LINES	Attendant connected to ship line.
	ATTD DISC	Attendants handset off-hook.
	DIAL CORR	
	HOLD	
Flashing Bright-Off	SHORE LINES	A call coming into the switchboard from the shore.
	SHIP LINES	A call coming into the switchboard from within the ship.
Flashing Bright-Dim	SHORE LINES	A shore line on hold by the attendant.
	SHIP LINES	A ship line on hold by the attendant.
Dim	SHORE LINES	A shore line connected to a ship line.
	SHIP LINES	A ship line connected to a shore line.
Off	SHORE LINES	Shore line available.
	SHIP LINES	Ship line available.
	ATTD DISC	Attendants handset on-hook
	DIAL CORR	
	HOLD	
	PWR ON	Power off
	PWR OFF	PORT/SEA SWITCH in SEA position.

Operational Features

Any standard 600-ohm telephone can be used in the system. The type G telephone is normally used, but the other types are suitable.

All telephone numbers used in the system have three digits. They consist of a hundreds, a tens, and a units digit. They are preassigned during installation, but may be changed by a wiring change. Each station should be supplied with a copy of the ship's telephone directory. The directory is unique to a particular ship.

A person using the telephone system will hear four distinct tones from the receiver during normal operation. These tones give information to the status of a call. These tones are as follows:

- Dial Tone. 600 Hz interrupted 120 ips. The telephone is off-hook and the central office switchboard is ready to receive dial pulses.
- Busy Tone. 600 Hz interrupted 60 ips. The called station is off-hook or all trunks/links are busy.
- Ring-back Tone. 333 Hz modulated with 20 Hz interrupted at the same rate as the ringing period (1 1/4 seconds on, 2 3/4 seconds off). The ringing voltage is being sent to the called station.
- Howler Tone. 600 Hz interrupted at 8 ips. The howler tone is a loud, raucous sound intended to alert personnel across the compartment or in the next compartment of the situation. Therefore, it is uncomfortable if the receiver is held close to the ear. You should avoid the conditions that make the howler sound. These conditions are as follows:
  - — Telephone receiving dial tone and dialing is not started in 30 seconds.
  - — More than 30 seconds elapses between dialed digits.
  - — Busy tone is received for more than 30 seconds.

Hanging up the offending telephone will silence the howler and return the telephone to normal status. If the telephone is not hung up within 2 minutes, an alarm sounds in the central office switchboard.

Sometimes due to the number of calls in process at the same time, the dial tone may be delayed for a few seconds. This condition is not abnormal during periods of heavy traffic.

Within the ship, disconnect can only occur when both the calling and the called parties hang up. Ship-to-shore disconnect occurs when the ship's station hangs up, regardless of what the shore station does.

EMERGENCY.— Any telephone dialing 211 will automatically be connected to the predetermined emergency station for that time period. This cut-in happens even if the emergency station is busy. The emergency stations are 201 quarterdeck, 203 alternate quarterdeck, or 222 pilothouse. The station to receive emergency calls is determined by a three-position switch at the central office switchboard.

RESTRICTED LINE.— Telephone stations connected as restricted are prevented from accessing the manual switchboard; therefore, they are unable to connect to shore lines. This feature is established for a station at the central office switchboard. If a restricted station tries to call the manual switchboard, a busy tone will be returned. Additionally, if the manual switchboard attendant calls a restricted line, a busy tone will be returned.

EXECUTIVE CUT-IN.— Executive cut-in allows a station to complete a call even if the called station is busy. This feature is also known as executive right-of-way. The cut-in connection does not disconnect the original call, just joins it. To obtain cut-in, the user dials the digit 1 after getting a busy tone. This feature is established for a station at the central office switchboard.

HUNT-THE-NOT-BUSY.— A telephone dialing a number in a hunt-the-not-busy group will be connected to the next higher idle number in the group if the called number is busy. The numbers in the group must have consecutive units digits with common hundreds and tens digits. For purposes of this feature, the O is the highest number in the units digit group. If the search reaches the O, and it is busy, a busy tone is returned to the caller. This feature is established for a chosen group of numbers at the central office switchboard.

Test Equipment

The tools and test equipment required to trouble shoot and repair the central office telephone system are listed in table 6-14.

Table 6-14—Maintenance Equipment

CATEGORY	RECOMMENDED EQUIPMENT	ALTERNATE	EQUIPMENT TEST PARAMETERS	APPLICATION
Multimeter	Triplett Model 601		Continuity, resistance and voltage checks.	Troubleshooting, Corrective Maintenance, Installation.
Oscilloscope	Tektronics Type 7603		Voltage and signal level checks.	Troubleshooting, Corrective Maintenance.
Digital Voltmeter	Hewlett-Packard HP 3440 A with plug-in Units 3444 A and 1445 B.		Voltage checks.	Corrective Maintenance
Manual Wire Wrap Gun	Gardner-Denver part no. 14HP-1C		Installing wire on card cage.	Repair
24 Gauge Wire Wrap Bit	Gardner-Denver part no. 16263		Installing wire on card cage.	Repair
Sleeve Wire Wrap	Gardner-Denver part no. 18840		Installing wire on card cage.	Repair
24 Gauge Manual Unwrap Tool	Gardner-Denver part no. 504769		Removing wire from card cage.	Repair
Vacuum Cleaner			Cleaning parts and assemblies.	Scheduled Maintenance
Camelfs Hair Brush No. 6			Cleaning contacts and panels.	Scheduled Maintenance
Cleaning Compound		NONE	Removing corrosion and sticky deposits.	Scheduled Maintenance

Table 6-14—Maintenance Equipment—Continued

CATEGORY	RECOMMENDED EQUIPMENT	ALTERNATE	EQUIPMENT TEST PARAMETERS	APPLICATION
Sandpaper No. 000			Removing corrosion.	Scheduled Maintenance
Cotton Cloth			Removing dust and dirt parts.	Scheduled Maintenance
Soldering Iron			Disconnecting wires.	Corrective Maintenance

DIMENSION 2000

The Dimension 2000 PBX is a time-division switching system. It is designed to give up to 2000 lines and 353 trunks. Solid-state technology makes possible the use of time-division switching and stored program control. The stored program contains a wide variety of available features. Self-diagnostic maintenance routines reduce the time required to maintain the system. These features and routines are programmed on the system's memory tape. Features are added or modified by input to the memory tape and the necessary hardware to make the feature work.

The system has a battery pack for a backup power supply. It is capable of supplying the system for a minimum of 2 hours.

Switching System

Time-division switching is the name given to a new approach whereby calls travel over the same path but are separated from each other in time.

In this method the caller and the called party's telephone is connected to a common path by a transistorized switch that opens and closes synchronously at a rapid rate, During the brief closures, 1 microsecond out of every 100 microseconds, a series of pulses is transmitted from the sending connection.

Each pulse represents a portion of an electric wave from the calling party's telephone. The electric wave is reconstructed by the means of a filter, placed between the switch and the called party's telephone, which converts into a replica of the voice sound originated by the calling party.

Connections between other pairs of telephones are made over the common path in a similar manner, with each connection using time-division (microseconds) instants for switch closure that differs from that of any other connection.

The primary switching system consists of four basic cabinets. These are the common control cabinet, the module control cabinet, the line cabinet, and the auxiliary cabinet. The common control cabinet houses the processors, memories, and control equipment. The module control cabinet contains the network control circuits, trunk circuits, and line circuits. Additional line circuits are contained in the line and auxiliary cabinets.

Attendant's Console

The attendant's console is a desktop piece of equipment from which the attendant handles assistance calls. Keys are provided for each of the control functions. All calls made by the attendant to trunk lines or station lines are made using touch-tone dialing or the attendant direct station selection and trunk group selection feature.

The console is fully electronic. It is equipped with light emitting diode indicators, nonlocking push-button control keys, audible ring indicator with volume control, and touch-tone telephone pad for dial-up telephone service.

Maintenance

The Dimension 2000 PBX circuits are replaceable circuit cards. The circuit card components are not intended to be replaced in the field. The system is provided with automatic fault detection, fault reporting, and fault isolation aids.

The system's alarm panel displays failure alarms, halts the processor, overrides an emergency transfer condition, and initiates built-in processor diagnostic routines. Two alarms are generated by the system, a major alarm and a minor alarm. A major alarm usually indicates a failure that removes a large number of stations from service. A minor alarm is always indicated by a fault indicator light that helps isolate the fault. Both alarms have relay-operated circuits to a remote alarm panel.

The maintenance and administration panel executes the maintenance routines and displays the results. It also is used to modify the system's parameters and to monitor telephone traffic.

WATCH STANDING

One of your duties as the IC room watch stander will be to isolate and clear automatic telephone switchboard alarms. When a malfunction occurs during normal operation of the telephone switchboard, a remote audible alarm will sound. When this happens, you should open cabinet 2 of the switchboard and silence the audible alarm by momentarily operating the ALM RESET switch located on the switch and fuse panel to the up position. After you silence the audible alarm, check the alarm lamps (POWER, FUSE, ATB, OFF HOOK, RINGER) on the switch and fuse panel. The source of the malfunction will be indicated by one or more of the lamps being lit. The procedures for isolating and clearing the alarm condition(s) will be discussed in the following paragraphs.

POWER ALARM

A lighted POWER alarm lamp indicates a loss of primary ac power from the main IC switchboard. Check the circuit J switch on the main IC switchboard for a blown fuse. If a fuse has blown, replace it. If the new fuse blows, notify your supervisor.

FUSE ALARM

A lighted FUSE alarm lamp indicates failure of one of the fuses on the switch and fuse panel in either cabinet 1 or 2. Check both cabinets and look for a flagged fuse. When the open fuse is located, inspect the associated equipment and circuitry for broken wires or burn marks. If no obvious trouble is found, replace the fuse. If the new fuse fails, set the switch or switches for the equipment associated with the fuse to the down (out of service) position.

If the failed fuse is associated with the ringing generator or interrupter board, set the appropriate transfer switch to the down position and replace the fuse.

ATB ALARM

A lighted automatic transfer bus (ATB) alarm lamp indicates that all available links are being used. The only action that can be taken to satisfy this alarm is to place any links that may be manually switched out of service, for test purposes, back into service.

OFF HOOK ALARM

A lighted OFF HOOK alarm lamp indicates that at least one link circuit is being held by an off-hook condition for longer than 30 seconds with no valid connection being made. Check the links; the monitor lamp on the link serving the off-hook line will be flashing.

You can determine the number of the line causing the off-hook alarm by inspecting the crossbar switch contacts, the select level contacts, and the originating hold magnet. Find the contacts being held closed by the originating hold magnet corresponding to the link. The number of the line causing the alarm can be determined by observing the closed unit contacts and level selecting contacts. First move the switch for that line to the down (out of service) position. Then move the busy switch for the link in trouble to the down position. This clears the link, and the busy switch may be returned to the up position.

RINGER ALARM

A lighted RINGER alarm lamp indicates that the on-line ringing generator has failed. Set the RG1 20HZ/RG2 switch located on the switch and fuse panel in cabinet 2 to the appropriate position to select the standby ringing generator.

MAINTENANCE

As an IC Electrician third class, you will be required to perform routine preventive maintenance on the switchboard. Since corrective maintenance should be performed by a qualified technician specifically trained on this system, only preventive maintenance will be discussed.

Routine preventive maintenance of the switchboard consists of a systematic series of inspection, cleaning, and routine operational check procedures. The routine checks are designed to be performed without disturbing the equipment any more than necessary. Do not make any adjustments while performing preventive maintenance, and avoid moving equipment wiring when inspecting or cleaning the equipment. Preventive maintenance should be performed according to the maintenance requirement cards (MRCs) associated with the system. The following paragraphs will discuss some of the more common preventive maintenance checks.

GROUND FAULT DETECTION PANEL

This check should be accomplished daily using the following procedure:

1. Check the two meters on the panel; both meters should read in the OK region.

2. Momentarily operate the spring-loaded METER TEST switch. Both meters should read in the OK region.

3. If both the meters read in the OK region in steps 1 and 2, there are no ground faults and the check is completed. If either or both meters do not read in the OK region in step 2, notify your supervisor.

HINGES AND LOCKING MECHANISMS

The hinges and locking mechanisms of both cabinet doors and the four equipment gates should be cleaned and lubricated once a week.

CABINET INSPECTION

The two switchboard cabinets and the attendant's cabinet should be inspected once a month.

Switchboard Cabinets

Inspect the two switchboard cabinets using the following procedure:

1. Open the cabinet doors.

2. Check to see that the equipment gates are properly fastened.

3. Check to see that the circuit card assembly retaining bars are properly fastened.

4. Check for accumulations of dust, dirt, or grease in the cabinets. If the cabinets require cleaning, clean them according to the applicable MRC.

Attendant's Cabinet

Inspect the attendant's cabinet using the following procedure:

1. Check for accumulations of dust, dirt, or grease on the cabinet. If the cabinet requires cleaning, clean it according to the applicable MRC.

2. Check to see that the push-button switch retainer bars are in place and properly fastened.

3. Check the telephone set handset for worn or damaged components.

SUMMARY

In this chapter, we have discussed the purpose of the automatic dial telephone system. We have explained how the type G telephone sets used with the system operate and how they are maintained. We have also identified some of the more common troubles associated with the telephone sets and the procedures for correcting the troubles.

We have discussed the functions of the automatic dial telephone switchboards and identified the various switchboards and the automatic switching equipment used in the switchboards. We have described the function of the attendant's cabinet used with the switchboards. We have also discussed the various alarms associated with the switchboards and the procedures for isolating and clearing these alarms.

We have discussed some of the procedures used in performing preventive maintenance on the switchboard and the attendant's cabinet, and we have discussed shore lines and how they are connected to the system.

CHAPTER 7

AMPLIFIED VOICE SYSTEMS

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

- *Explain the purpose of amplified voice systems installed on Navy ships.*
- *Identify the various types of amplified voice systems.*
- *Identify the various announcing system circuits by their designations.*
- *Describe the types and characteristics of microphones and loudspeakers.*
- *Describe the components, operation, and maintenance procedures of a central amplifier system (one-way) and the additional sound equipment used with the system.*
- *Describe the components, operation, and maintenance procedures of a central amplifier system (two-way) and the additional sound equipment used with the system.*
- *Describe the components, operation, and maintenance procedures of the intercommunication systems and the additional sound equipment used with the systems.*
- *Briefly describe the integrated intercommunication system used on Navy submarines.*
- *Identify the types of public address sets and describe the components, operation, and maintenance procedures of the public address sets.*

INTRODUCTION

If you should look for the source of a sound, you will find that something had been set in vibratory motion. It may be that someone shouted or struck or dropped an object. In each case something vibrated and caused the sensation of sound. One sound that human beings produce is voice. Although air is the usual medium for carrying voice to your ears, any elastic material in the form of a solid, liquid, or gas can serve as well or better. Like any other sound, voice cannot travel in a vacuum.

In today's Navy, amplified voice systems amplify and transmit the voice so it can reach and be heard by the personnel aboard ship. With these systems, which are the heart of interior communications, the "word" is passed quickly and clearly.

Several types of amplified voice systems are installed in most ships. These types include the following:

- Central amplifier systems that provide one-way communications
- Central amplifier systems that provide two-way communications
- Intercommunication systems that provide two-way communications between selected stations
- Integrated intercommunication systems that provide both central amplifier and intercommunication systems
- Portable public address systems

Table 7-1.—Shipboard Announcing Systems

Circuit	System	Importance	Readiness Class
*IMC	General	V	1
*2MC	Propulsion plant	V	1
*3MC	Aviators'	V	1
4MC	Damage Control	V	1
*5MC	Flight Deck	SV	2
*6MC	Intership	SV	1
*7MC	Submarine Control	V	1
8MC	Troop administration and control	SV	2
*9MC	Underwater troop communication	SV	2
*10MC	Dock Control (obsolete)	SV	1
*11-16MC	Turret (obsolescent)	SV	3
*17MC	Double Purpose Battery (obsolescent)	SV	3
18MC	Bridge	NV	2
19MC	Aviation Control	SV	2
*20MC	Combat Information (obsolescent)	SV	1
21MC	Captain's Command	SV	1
22MC	Electronic Control	NV	1
23MC	Electrical control	SV	1
24MC	Flag Command	SV	1
25MC	Ward Room (obsolescent)	NV	4
26MC	Machinery Control	SV	1
27MC	Sonar and Radar Control	SV	1
*28MC	Squadron (obsolescent)	NV	4
*29MC	Sonar Control and Information	SV	2
30MC	Special Weapons	SV	2
31MC	Escape trunk	SV	2
32MC	Weapons control	SV	3
33MC	Gunnery Control (obsolescent)	SV	3
34MC	Lifeboat (obsolescent)	SV	1
35MC	Launcher Captains'	SV	1
36 MC	Cable Control (obsolete)	NV	4
37MC	Special Navigation (osbolete)	SV	2
38MC	Electrical (obsolete)	NV	1
39MC	Cargo Handling	NV	4
40MC	Flag Administrative	NV	1
41MC	Missile Control and Announce (obsolete)	SV	3
42MC	CIC Coordinating	SV	2
43MC	Unassigned		
44MC	Instrumentation Space	NV	1
45MC	Research operations	NV	1
*46MC	Aviation Ordnance and Missile Handling	SV	2
47MC	Torpedo Control	SV	2
48MC	Stores conveyor (obsolescent)	NV	1
49MC	Unassigned		
50MC	Integrated operational intelligence center	SV	2

Table 7-1.—Shipboard Announcing Systems—Continued

Circuit	System	Importance	Readiness Class
51MC	Aircraft Maintenance and handling control	SV	2
52MC	Unassigned		
53MC	Ship Administrative	NV	4
54MC	Repair officer's control	NV	4
55MC	Sonar Service	NV	4
56MC	Unassigned		
57MC	Unassigned		
58MC	Hanger Deck Damage Control	V	1
59MC	SAMID Alert	SV	3

* - Central amplifier systems.

Each installed announcing system aboard ship is assigned an IC circuit designation in the MC series. Table 7-1 lists the systems and their circuit designations and the importance and readiness classification for each circuit. These systems, however, are not all installed in any one ship.

In this chapter, we will discuss some of the more common systems that are installed on board ship today and the announcing equipment used with the systems.

ANNOUNCING EQUIPMENT

All amplified voice systems consist basically of an amplifier, a microphone, and a loudspeaker. The microphone converts the sound energy into electrical energy having the same waveform as the sound energy. The output from the microphone is applied as a signal voltage to the amplifier. The output power from the amplifier has the same waveform as the sound energy that is applied to the microphone. The loudspeaker reconverts the electrical energy from the amplifier into sound energy at a higher volume level than the original sound. In shipboard installations, many loudspeakers are operated from the same amplifier. Each loudspeaker produces sound having the same waveform as the original sound applied to the microphone.

MICROPHONES

A microphone is a device that converts sound energy into electrical energy. All types of microphones have a metal diaphragm that responds to the vibrations of the sound waves, and some means of changing this mechanical vibration into corresponding electrical signals. The most widely used microphones are the (1) magnetic, (2) dynamic, (3) crystal, and (4) carbon types.

Magnetic Microphone

The magnetic, or moving-armature, microphone (fig. 7-1) consists of a permanent magnet and a coil of wire, inside of which is a small armature. Sound waves impinging on the diaphragm cause the diaphragm to vibrate. This vibration is transmitted through the drive rod to the armature, which vibrates in a magnetic field, thus changing the magnetic flux through the armature.

When the armature is in its normal position, midway between the two poles, the magnetic flux is established across the air gap with no resultant flux in the armature.

When a compression wave strikes the diaphragm, the armature is deflected to the right. The flux path is directed from the north pole of the magnet across the reduced gap at the upper right, down through the armature, and round to the south pole of the magnet.

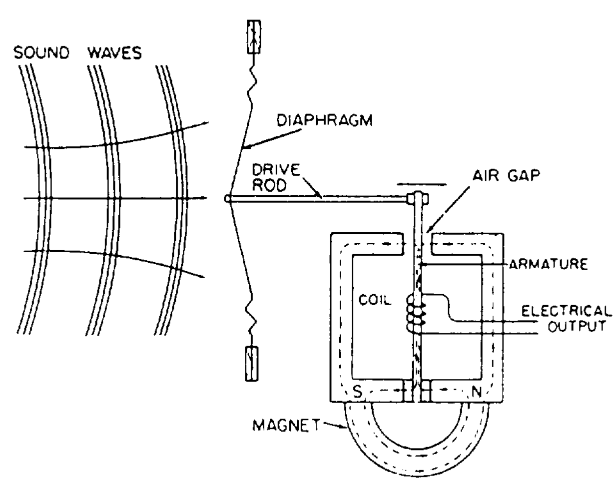


Figure 7-1.—Magnetic micropbone.

When a rarefaction wave strikes the diaphragm, the armature is deflected to the left. The flux path now is directed from the north pole of the magnet, up through the armature through the reduced gap at the upper left, and back to the south pole.

Thus, the vibrations of the diaphragm cause an alternating flux in the armature. The alternating flux cuts the stationary coil wound around the armature and induces an alternating voltage (approximately 10 millivolts at a 150-ohm load) in it. This voltage has the same waveform as the sound waves striking the diaphragm.

The magnetic microphone is the type most widely used in shipboard amounting and intercommunicating systems because it is more resistant to vibration, shock, and rough handling.

Dynamic Microphone

The dynamic, or moving-coil, microphone (fig. 7-2) consists of a coil of wire attached to a diaphragm, and a radial magnetic field in which the coil is free to vibrate. Sound waves impinging on the diaphragm cause the diaphragm to vibrate. This vibration moves the voice coil through the magnetic field so that the turns cut the lines of force in the field. This action generates a voltage in the coil that has the same waveform as the sound waves striking the diaphragm.

The dynamic microphone requires no external voltage source. It has good fidelity and produces an output volt age of about 0.05 volt when spoken into in a normal tone within a few inches of the diaphragm.

Crystal Microphone

The crystal microphone utilizes a property of certain crystals, such as quartz, Rochelle salt, sugar, or coal, known as the piezoelectric effect. The bending of the crystal resulting from the pressure of the sound wave produces an electromotive force (emf) across the faces of the crystal. This emf is applied to the input of an amplifier.

The crystal microphone (fig. 7-3) consists of a diaphragm that is cemented to one surface of the crystal. Metal plates, or electrodes, are attached to the other surface of the crystal. When sound waves strike the diaphragm, the vibration of the diaphragm produces a varying pressure on the surface of the crystal and induces an emf across the electrodes. The emf has the same waveform as the sound waves striking the diaphragm.

Rochelle salt is most commonly used in crystal microphones because of its relatively high-voltage output. The crystal microphone can produce an output voltage of from 0.01 to 0.03 volt into a load of 1 megohm or more, when subjected to a sound pressure of a normal tone within a few inches of the crystal. However, this crystal microphone is seldom used in naval announcing and intercommunicating systems because of the sensitivity of the crystal element to high temperature, humidity, and rough handling.

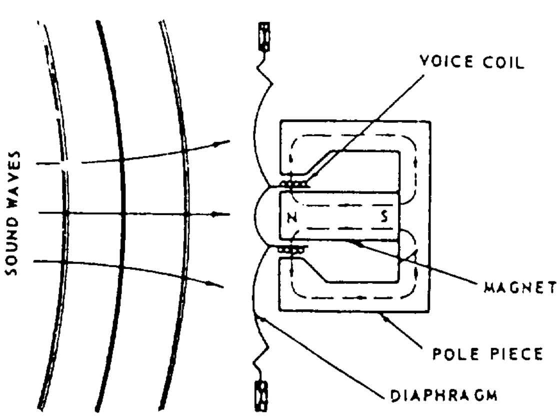


Figure 7-2.—Dynamic microphone.

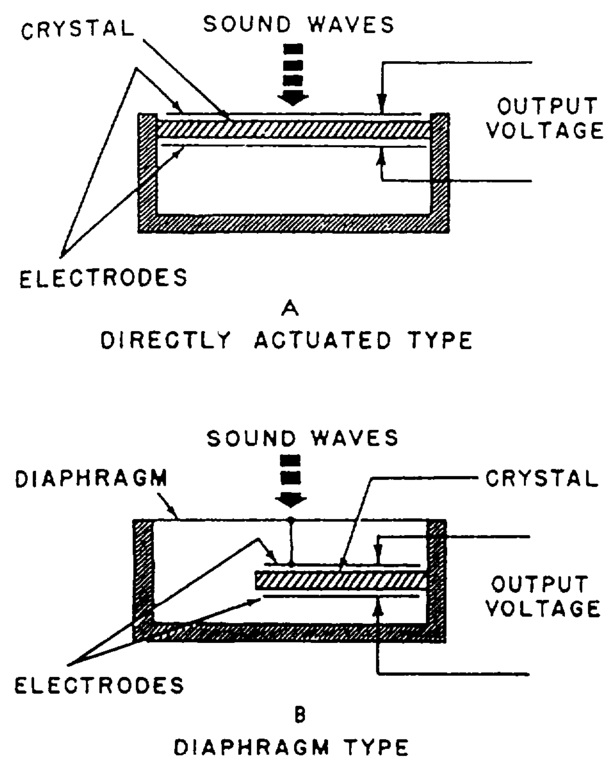


Figure 7-3.—Crystal microphone.

Carbon Microphone

The carbon microphone (fig. 7-4) operates on the principle that a changing pressure of a diaphragm applied to a small volume of carbon granules changes its electrical resistance according to the vibrations of the sound waves striking the diaphragm.

The carbon microphone consists of a diaphragm mounted against a mass of carbon granules that are contained in a small cup. To produce an output voltage, this microphone is connected in a series circuit containing a battery and the primary of a transformer.

When a direct current follows through the carbon granules, the varying resistance changes the amplitude of the current and produces an alternating voltage in the secondary of the transformer. This voltage has the same waveform as the sound waves striking the diaphragm. The current through this microphone may be as great as 0.1 ampere. The resistance may vary from about 50 to 90 ohms. The voltage developed across the secondary depends upon the ratio of the transformer primary and

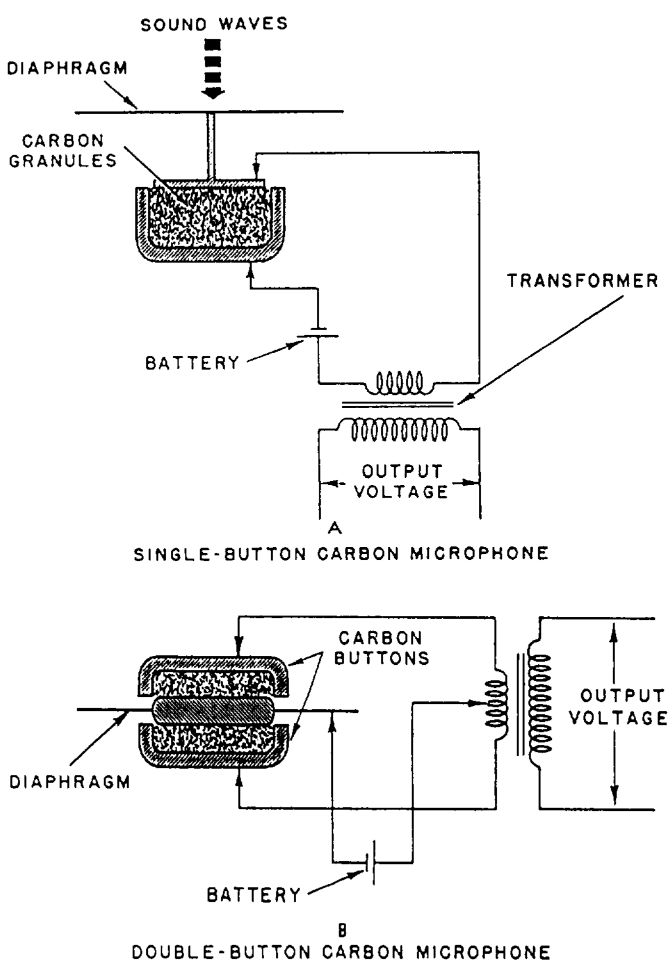


Figure 7-4.—Schematic diagram of a carbon microphone.

secondary turns and also upon the change in primary current. Normal output voltage of a typical circuit is from 3 to 10 volts peak at the secondary terminals.

The carbon microphone is not used in shipboard announcing equipment because it requires a polarizing current and has a tendency to amplify certain frequencies more than others.

Characteristics of Microphones

Microphones are rated according to their (1) frequency response, (2) impedance, and (3) sensitivity.

FREQUENCY RESPONSE.— Shipboard announcing and intercommunicating systems are designed to produce maximum speech intelligibility under conditions of high background noise. To achieve this objective, the overall frequency response characteristic of the system is altered by cutting off the system response at some lower limit, such as 500 Hz, and by employing an emphasized frequency response characteristic that rises with increasing frequency at a rate of approximately 6 dB per octave. The output sound pressure is doubled each time the frequency is doubled for a constant level input to the system. The emphasized speech tends to sound thin and sometimes harsh, but when the masking due to background noise is almost as high as the speech level, the speech appears to cut through the noise.

For good quality, a microphone must convert sound waves into electrical waves that have the same relative magnitude and frequency without introducing any new frequencies. The frequency range of the microphone must be at least as wide as the desired overall response limits of the system with which it is used.

Except in the case of the emphasized system in which it may be desirable for the microphone to have a rising frequency-response characteristic, the microphone response should be uniform or flat, within its frequency range, and free from sharp peaks or dips, such as those caused by mechanical resonances.

IMPEDANCE.— Crystal microphones have impedances of several hundred thousand ohms, whereas the magnetic and dynamic microphones have impedances that range from 20 to 600 ohms. The impedance of a microphone is usually measured between its terminals at some arbitrary frequency within the useful range, such as 1000 Hz.

The impedance of magnetic and dynamic microphones varies with frequency in much the same manner as that of any coil or inductance; that is, the impedance rises with increasing frequency. The actual impedance of the microphone in shipboard applications is of importance only as it relates to the input load impedance into which the microphone is designed to operate. If the microphone is mismatched with the input impedance, the microphone input is reduced and distortion occurs. All specifications and acceptability tests for naval microphones are based on the designed input load impedance.

SENSITIVITY.— The sensitivity or eficiency of a microphone is usually expressed in terms of the electrical power level that the microphone delivers to a terminating load, the impedance of which is equal to the rated impedance of the microphone, compared to the acoustical intensity level or pressure of the sound field that is being picked up.

Most systems rate the microphone in the electrical power level (in decibels below 1 milliwatt (mW) produced by an acoustical pressure of 1 dyne per square centimeter. For example, a crystal microphone rated at 80 dB means that for an input acoustical pressure of 1 dyne per square centimeter, the electrical output is 80 dB below 1 mW, or 10 mW. Other systems rate the microphone in terms of the voltage delivered to a specified terminating load impedance for an acoustical pressure input of 1 dyne per square centimeter.

It is important to have the sensitivity of the microphone as high as possible. High sensitivity means a high electrical power output level for a given input sound level. High microphone output levels require less gains in the amplifiers used with them and thus provide a greater margin over thermal noise, amplifier hum, and noise pickup in the line between the microphone and the amplifier.

When a microphone must be used in a noisy location, it should favor sounds coming from a nearby source over random sounds coming from a relatively greater distance. Microphones of this type cancel random sounds and pick up only those sounds originating a short distance away. When talking into this type of microphone, hold your lips as close as possible to the diaphragm. Directional characteristics that favor sound coming from one direction only also aid a microphone in discriminating against background noise.

LOUDSPEAKERS

A loudspeaker is a device that converts electrical energy into sound energy and radiates this energy into the air in the form of waves. The loudspeakers in general use in the Navy are (1) the direct radiator type, which radiates sound directly from a vibrating member into the air, and (2) the horn type, which consists of a driving unit combined with a horn to couple the unit to the air. All loudspeakers consist essentially of a driving mechanism.

Driving Mechanism

The driving mechanism changes electrical vibrations into mechanical vibrations that are transmitted to a diaphragm or other vibrating source. This vibrating source is coupled to the air, either directly or by a horn, and causes sound to be radiated. The dynamic, or moving-coil, driving mechanism is the basic type used in Navy loudspeakers. The design of this unit is similar to that of the dynamic microphone, but the principle of operation is the reverse of that of the dynamic microphone.

A coil of wire is attached to a diaphragm and rests in a magnetic field. When a varying electric current flows through the coil, a force is exerted on the coil, causing it to move back and forth in the magnetic field. The consequent motion of the diaphragm causes the radiation of sound waves that correspond to the variations in the electric current. The electrodynamics and the permanent-magnet types are the two variations in the dynamic loudspeaker. These types differ only in the method employed for obtaining the magnetic field.

In the electrodynamics loudspeaker, the magnetic field is established by passing a direct current through a field coil that is wound on an iron core. This type requires a source of filtered direct voltage and two additional conductors to carry the field current to the loudspeaker.

In the permanent-magnet dynamic loudspeaker, a permanent magnet establishes the magnetic field. All loudspeakers used by the Navy are of the permanent-magnet dynamic type.

Direct-Radiator Loudspeaker

The direct-radiator loudspeaker, sometimes called a cone loudspeaker, is the simplest form of loudspeaker. In this type of loudspeaker (fig. 7-5), the diaphragm acts directly on the medium, which is air. Both sides of the diaphragm are open to the air so sound radiates behind as well as in front of the loudspeaker. At the instant the diaphragm is moving in an outward direction, the front surface of the diaphragm produces a compression wave and the back surface produces a rarefaction wave.

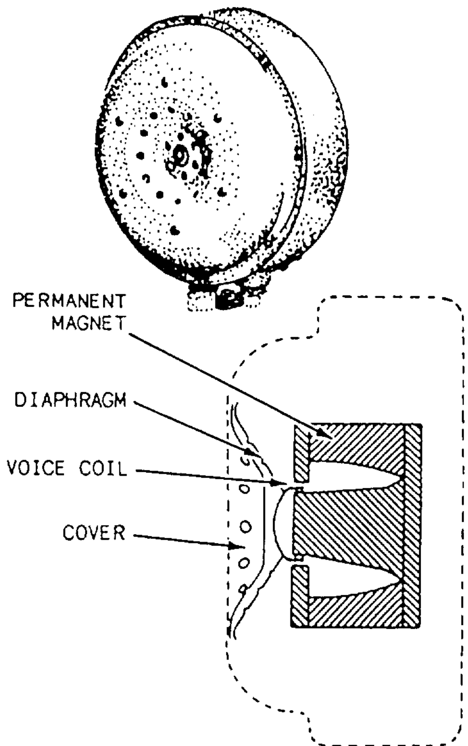


Figure 7-5.—Direct-radiator loudspeaker.

At low frequencies, where the wavelength is large compared with the dimensions of the loudspeaker, the rarefaction wave from the back of the diaphragm meets the compression wave from the front of the diaphragm and neutralizes it because the waves are in opposite phase relation. Thus, low frequencies are not reproduced from this type of direct radiator.

At higher frequencies, where the wavelength of the sound is small compared with the dimensions of the loudspeaker, the sound waves from the front of the diaphragm have time to travel an appreciable distance away from the loudspeaker (in terms of wavelength), and the phase of vibration of the diaphragm changes before the interfering wave from behind can traverse the distance around the diaphragm. Hence, a baffle is necessary only to reproduce low frequencies from a direct radiator. The purpose of the baffle is to delay the meeting of the front and back waves by artificially increasing the distance of the sound-wave path from the front to the back of the diaphragm.

The simplest form of baffle is a flat board with a hole in the center to accommodate the loudspeaker. This type of baffle is effective down to a frequency the wavelength of which is approximately four times the diameter of the baffle. If the loudspeaker is mounted in a wall or is completely enclosed, the baffle is called an infinite baffle. When a cabinet is used as a baffle, it is desirable to line the inside with a sound-absorbing material to minimize the effect of cabinet resonances produced by standing waves within the enclosure.

Horn Loudspeaker

The use of the direct radiator loudspeaker is limited because of its low radiation efficiency. When it is necessary to produce high sound intensities or to cover large areas with sound, the radiation efficiency of the loudspeaker must be increased to keep the size of the amplifier within reasonable limits. Horns with appropriate driver units provide a practical solution to the problem. A horn maybe considered as an impedance matching device for coupling a relatively heavy vibrating surface at the horn throat to a relatively light medium (the air) at the mouth of the horn. Figure 7-6 is an illustration of a straight-horn loudspeaker.

For a horn to operate effectively, the mouth must be sufficiently large in comparison with the longest wavelength (lowest frequency) of sound that is to be transmitted. Low-frequency horns often are considered to be useful at frequencies above that for which the mouth diameter is about one-third wavelength. The performance of a horn loudspeaker near the low-frequency cutoff point depends to a great extent upon the flare or shape of the horn. The function of the horn contour is to produce a smooth and continuous increase in cross-sectional area in progressing from the small throat to the large mouth. The shape most commonly employed is the exponential horn in which the diameter increases progressively by a fixed percentage for each equal-distance increment along the horn axis. For the horn to be of a practical size and shape,

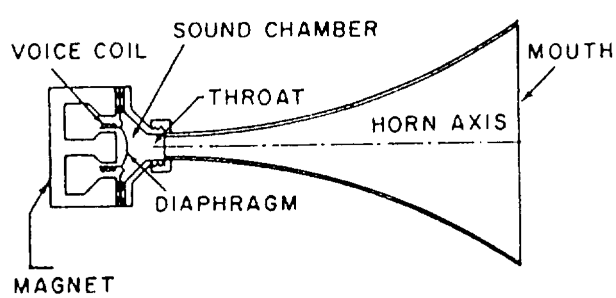


Figure 7-6.—Straight-horn loudspeaker.

a folded-horn loudspeaker (fig. 7-7) is employed in preference to a straight horn. There is a practical limit to the power that can be handled by a conventional driver unit. When extremely high sound intensities must be produced, multiunit loudspeakers are employed in which the units are coupled to individual horn sections that are combined mechanically into a common loudspeaker assembly.

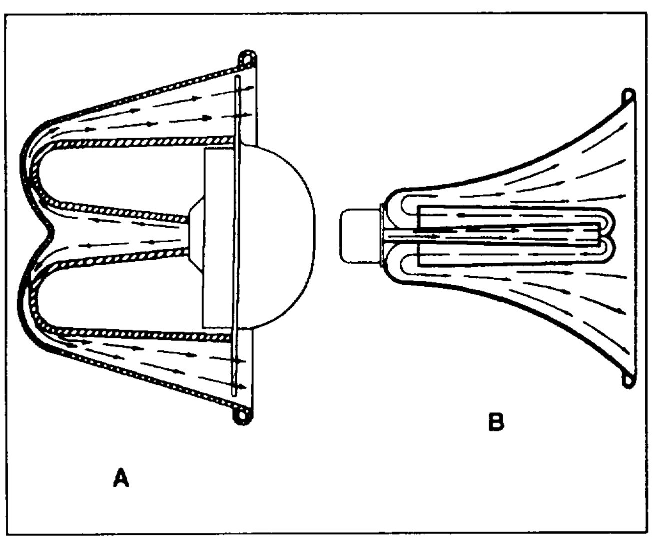


Figure 7-7.—Folded-horn loudspeaker.

Characteristics of Loudspeakers

Loudspeakers are rated according to their (1) frequency response, (2) directivity, (3) capacity, (4) efficiency, and (5) impedance.

FREQUENCY RESPONSE.— In the majority of cases, the frequency response of the loudspeaker is the limiting factor in the overall response of a sound system. For direct radiators, the low-frequency response is influenced by the (1) baffle or enclosure, (2) diameter of the cone, (3) ability of the cone and voice coil to execute large amplitudes of vibration, and (4) strength of the magnetic field in the air gap. The high-frequency response is limited by the mass of the voice coil and diaphragm.

For horn loudspeakers, the low-frequency response is influenced principal y by the (1) basic horn formula employed, (2) flare, and (3) mouth dimensions. The high-frequency response is limited by the (1) mass of the voice coil and the diaphragm, (2) phase effects caused by differences in path lengths due to bends, and (3) impedance irregularities caused by sudden changes in cross-sectional areas at folds or joints in the horn. Vibrations of the horn walls must be sufficiently damped to avoid introducing irregularities into the response, as well as transient effects.

DIRECTIVITY.— The directivity of a loudspeaker is an important factor in determining the efficiency of the sound radiation over the listening area. All practical forms of sound radiators exhibit some directional effects. If a radiator is placed in free space where the results are not affected by interfering reflections, the sound pressure at a given distance is not the same in all directions. The directivity of a loudspeaker is a function of both frequency and the size of the horn mouth of the loudspeaker. Thus, a loudspeaker becomes more directional with increasing frequency because of the shorter wavelength, and a direct radiator or horn mouth of large size is more directional than one of smaller size. These factors of frequency and size are interrelated in that the size becomes a factor relative to the wavelength of the sound being transmitted. Thus, the directional pattern of a small loudspeaker transmitting a high-frequency signal (short wavelength) is similar to that of a large loudspeaker transmitting a low-frequency signal (long wavelength). In general, a horn loudspeaker of a given mouth diameter is more directional than a direct radiator of the same diameter, particularly at the low frequencies.

The directivity of a horn loudspeaker is also dependent upon the rate of flare; that is, the directivity increases as the flare is made more gradual (longer horn). If a rectangular horn having a long narrow mouth (in terms of wavelength) is mounted with the long dimension of the mouth vertical, the radiation in the horizontal plane corresponds to that of a small radiator with a broad distribution pattern. The radiation in the vertical plane acts as a large radiator with a relatively narrow beam. In other words, the horn is made relatively much less directional in the horizontal plane than in the vertical plane, It is obvious that the reverse is true if the horn is turned so that the long dimension of the mouth is horizontal. Thus, the sound energy is flattened out in a plane at right angles to the long dimension of the loudspeaker mouth. This principle is used to obtain the required directional characteristics for efficient high-intensity reproduction on the flight decks of aircraft carriers.

CAPACITY.— The load-carrying capacity of a loudspeaker is usually expressed in terms of the maximum electrical power that should be applied to it. This power is limited by heating, mechanical strength, and the production of nonlinear distortion that is caused by excessive diaphragm amplitudes or excessive acoustical pressures in the sound passages. Excessive power causes the diaphragm to strike portions of the magnet or supporting frame and may produce buzzing or rattling.

EFFICIENCY.— The loudness of the sound obtainable from a loudspeaker at any particular listening point is not a factor of load-carrying capacity alone. Other important factors are the efficiency and the amount that the sound is spread out. The definition of absolute efficiency of a loudspeaker is not subject to simple practical interpretation, However, for specification purposes and for checking the performance of naval loudspeakers, a specified voltage is applied to the input terminals and the output sound pressure is measured at a given distance from the loudspeaker on the loudspeaker axis using various test frequency signals. These measurements are combined with off-axis sound pressure measurements to evaluate the relative loudspeaker efficiency.

When satisfactory frequency in a loudspeaker is limited to a small angle about the axis, the absolute efficiency at high frequencies is considerably lower than at low frequencies. The use of diffusing arrangements with these loudspeakers to spread out the high frequencies usually results in spreading out the small amounts of available high-frequency energy to such an extent that the response is unsatisfactory at all locations.

IMPEDANCE.— The impedance of a loudspeaker is usually measured between the voice coil terminals at some average frequency, such as 1000 Hz, in the usable range. This impedance varies with the frequency, rising with increasing frequency. The usual value of voice coil impedance varies from 3 to 15 ohms.

In shipboard announcing and public-address systems, a matching transformer is built into each loudspeaker to transform the low voice-coil impedance to a higher value suitable for connection to loudspeaker distribution lines. Because loudspeakers in a system are connected and operated in parallel, the combined impedance of a large number of low-impedance voice coils without matching transformers would be so low compared with the resistance of the connecting cables that an appreciable portion of the amplifier output power would be dissipated in the cables. Thus, matching transformers are provided to reduce this loss. These transformers have several taps to vary the loudspeaker impedance. Changing the loudspeaker impedance changes the power absorbed by the loudspeaker from the lines, and thus provides a means of varying the loudness of the loudspeaker.

CENTRAL AMPLIFIER SYSTEM (ONE-WAY)

The one-way central amplifier amounting system provides a means of transmitting general orders, information and, in some cases, alarm signals to various locations simultaneously by microphones and loudspeakers connected through a central amplifier. Two examples of the one-way central amplifier announcing system are the general announcing system, circuit 1MC, and the intership announcing system, circuit 6MC.

One of the more common types of central amplifiers installed on board ship today for use with circuits 1MC and 6MC is the AN/SIA-114B amplifier-oscillator group. The AN/SIA-114B, with other equipment, comprises a shipboard announcing system capable of both circuit 1MC and circuit 6MC operation. The major components of the system are the control rack and the power rack. The AN/SIA-114B contains two distinct amplifier channels, A and B. Each channel is made up of a preamplifier located in the control rack and a 500-watt power amplifier located in the power rack. There are two identical oscillator groups, 1 and 2, located in the control rack for generating alarm signals. There is also additional sound equipment used with the system and facilities available for muting and attenuating the ship's entertainment system. Figure 7-8 is a simplified block diagram of the circuits 1MC and 6MC using the AN/SIA-114B.

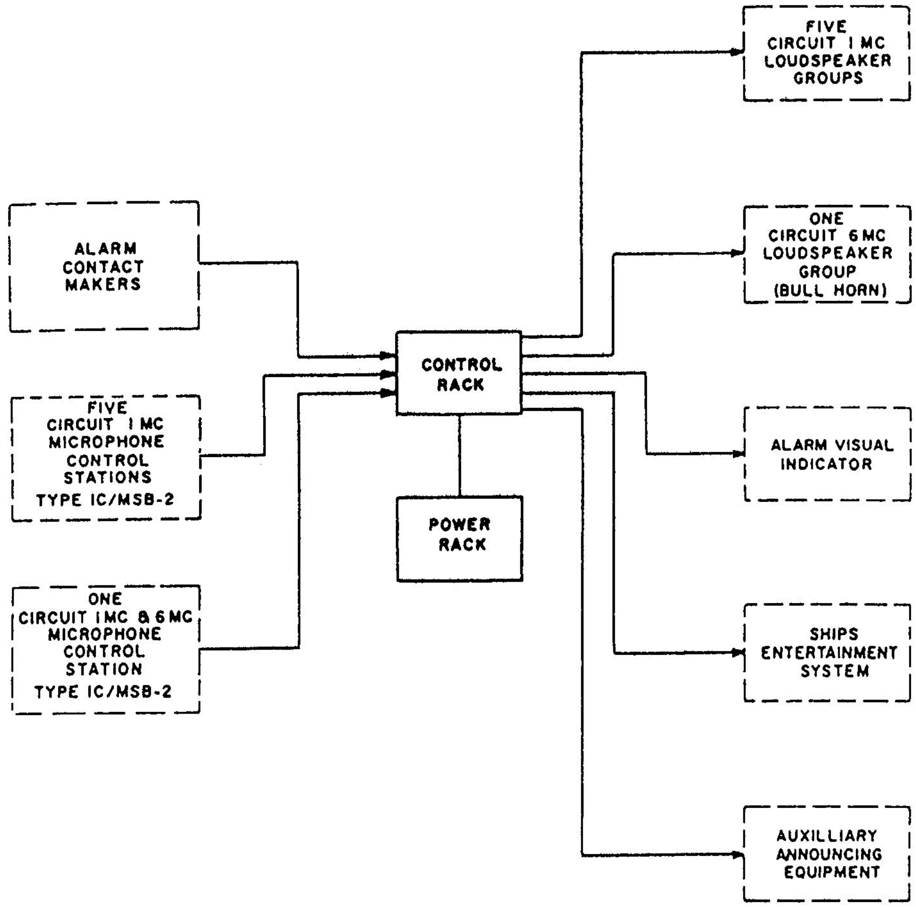
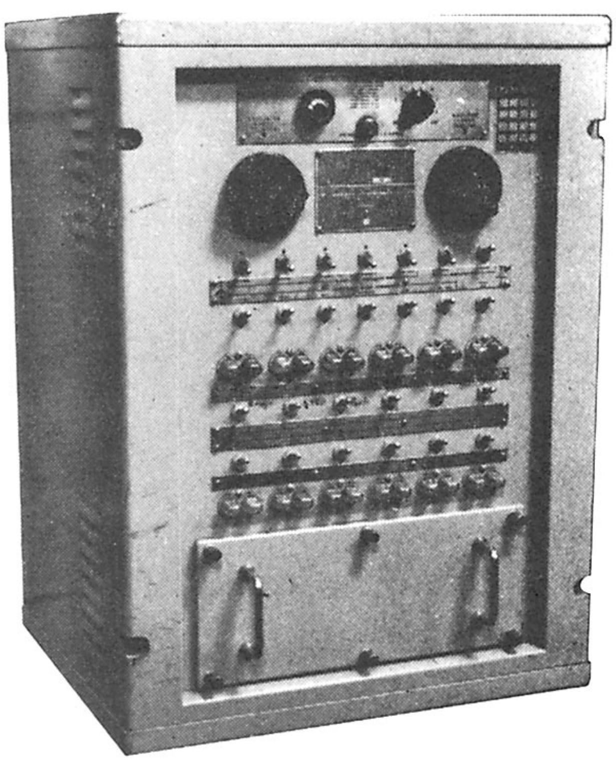


Figure 7-8.—Simplified block diagram of 1MC-6MC central amplifier announcing system.



7.176

Figure 7-9.—Control rack.

CONTROL RACK

The control rack (fig. 7-9) is a bulkhead-mounted enclosure containing the preamplifier modules, power supply modules, oscillator alarm modules, and the system switching and transferring controls and indicators. The rack also contains the control and power relays, the relay power supply, and the terminal boards for making connections to the ship's wiring.

The control rack preamplifier voice and alarm signals from the microphone control stations, routes them to the power rack for amplification, and then transmits them to the various loudspeaker groups.

Preamplifier Modules

Two preamplifier modules are located in the control rack one for each amplifier channel. Each preamplifier contains four transistor-amplifier stages for increasing the low-level microphone and alarm signals to drive their associated power amplifier to full output. Figure 7-10 is a block diagram of a preamplifier.

Power Supply Modules

Two power supply modules are located in the control rack. Each power supply is a regulated transistor unit that supplies -10 volt dc and -30 volt dc operating voltages to the alarm modules and preamplifier modules.

Alarm Modules

Ten alarm modules are located in the control rack, five for each oscillator group. Each alarm module, when actuated by an alarm contact maker, is capable of generating an audio-frequency alarm. When an alarm signal is actuated, all microphone control stations are automatically disconnected by priority relays. The audio-frequency oscillator ouput (alarm signal) is then connected to the alarm input of the microphone and oscillator amplifier of the channel selected for use on circuit 1MC. The output from the power rack is distributed to all circuit 1MC loudspeaker groups. Alarm signals are not transmitted over the circuit 6MC loudspeakers. The alarm modules in the order of their priorty are (1) collision, (2) chemical, (3) general, (4) unassigned A, and (5) flight crash.

The order of priority is controlled automatically by relays in the control rack. Any alarm takes priority over voice announcements.

COLLISION ALARM.— The collision alarm is a transistorized oscillator circuit that generates a signal composed of three 1000-Hz bursts. Each burst is 60 milliseconds duration. The first and second burst is followed by an off time of 60 milliseconds. The third burst is followed by an off time of 420 milliseconds. This cycle repeatedly continues as long as power is applied to the circuit.

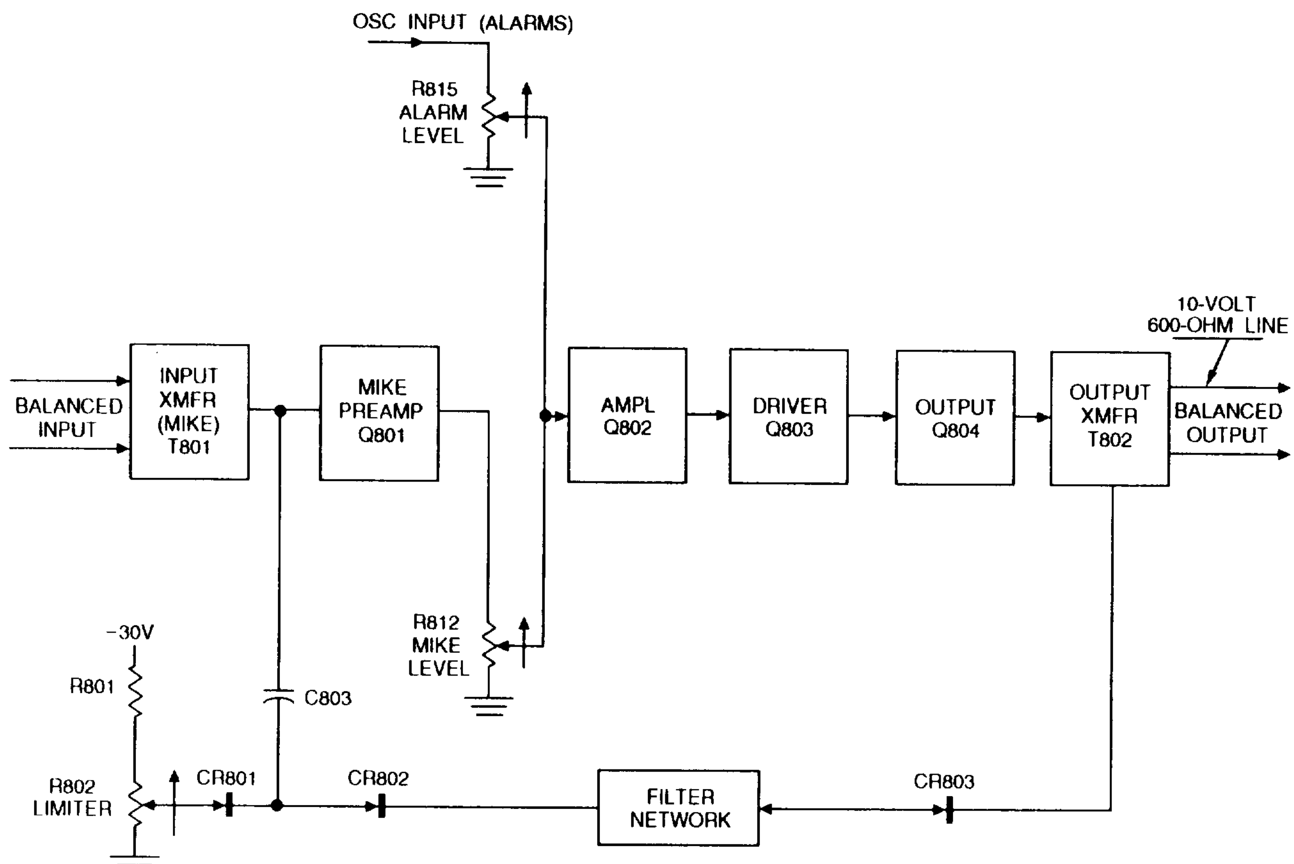


Figure 7-10.—Block diagram of a preamplifier.

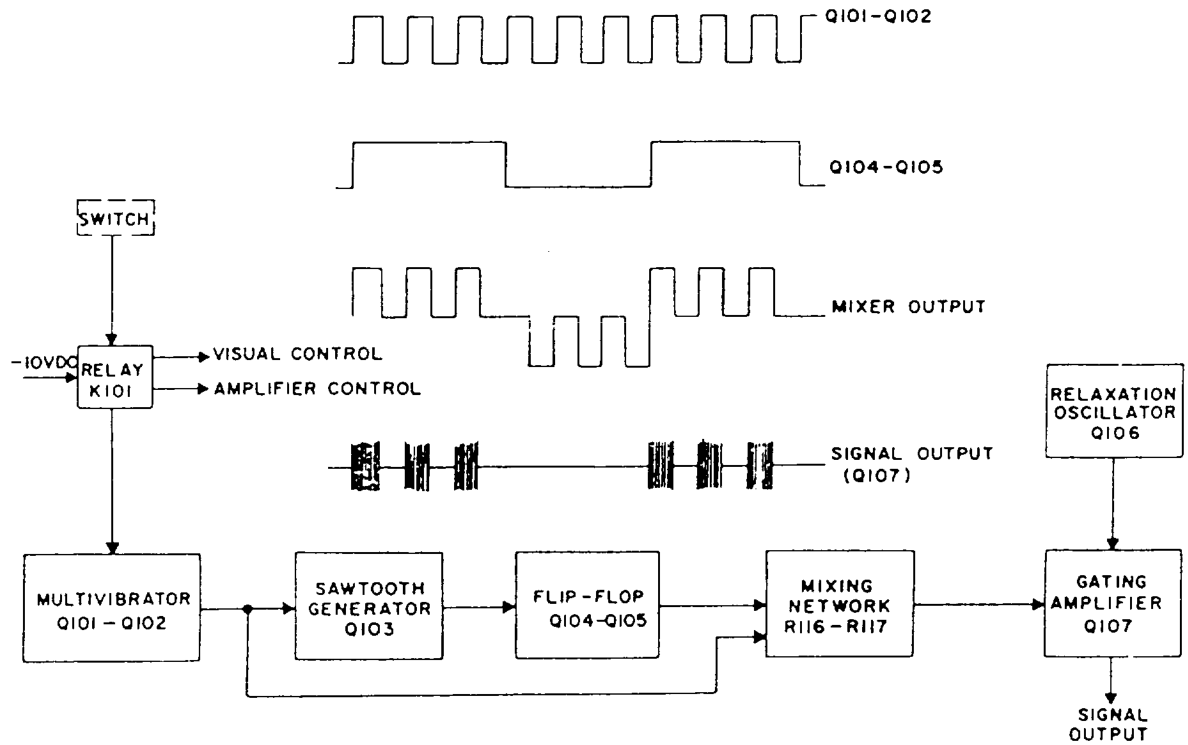


Figure 7-11.—Block diagram of the collision alarm module.

Figure 7-11 is a block diagram of a collision alarm module. Operation of the collision alarm contact maker will supply -10 volts dc to all stages in the circuit through relay K101. K101 will also apply control voltage to operate the visual signal circuit and the amplifier channel.

Resistor R107 (not shown) is a trimpot used in the circuit to adjust the number of pulses in a group. Clockwise rotation of the pot will decrease the number of pulses, while counterclockwise rotation will increase the number of pulses. Resistor R127 (not shown) is a trimpot used in the circuit to adjust the frequency to exactly 1000 Hz. Clockwise rotation of the pot will increase the frequency, while counterclockwise rotation will decrease the frequency.

CHEMICAL ALARM.— The chemical alarm is a transistorized oscillator circuit that generates a continuous 1000-Hz signal as long as power is applied to the circuit. This circuit consists of a square wave multi vibrator. Figure 7-12 is a block diagram of a chemical alarm module. Operation of the chemical alarm contact maker will supply -10 volts dc to the circuit through relay K201. Relay K201 will also apply control voltage to operate the visual signal circuit and the amplifier channel.

Resistor R203 (not shown) is used in the circuit to adjust the frequency to precisely 1000 Hz. Clockwise rotation of the pot will increase the frequency, while counterclockwise rotation will decrease the frequency.

There are also two other transistors in the chemical alarm circuit. These transistors are associated with the general alarm and will be discussed later.

GENERAL ALARM.— The general alarm consists of a 400-cycle per second rectangular wave oscillator coupled through a gated transformer. A striking multi vibrator supplies current to a diode across the gating winding of this transformer that produces the decaying characteristics of a gong. A timing multivibrator and relay holds the operating relay in the operating position for a period of 10 to 15 seconds after the alarm contact maker is released. Figure 7-13 is a block diagram of a general alarm module. Operation of

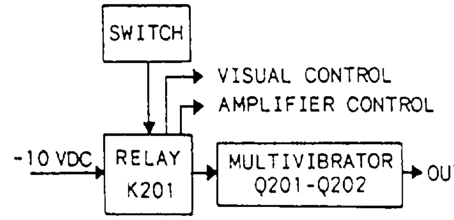


Figure 7-12.—Block diagram of the chemical alarm module.

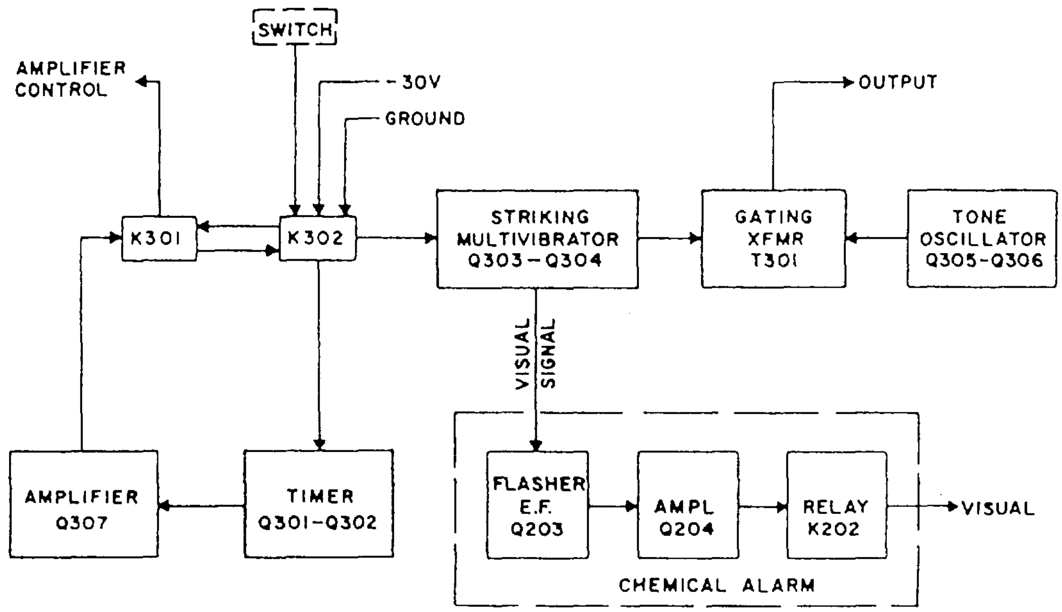


Figure 7-13.—Block diagram of the general alarm module.

the general alarm contact maker will energize relay K302, which will ground all stages fed with -10 volts dc. K302 also supplies -30 volts dc to transistor Q307 through relay K301, thus energizing K301, which holds K302 energized and supplies control voltage to the amplifier.

The striking multivibrator also supplies a signal to transistors Q203 and Q204 in the chemical alarm circuit, causing K202 in the chemical alarm circuit to operate every time the gong strikes at the rate of 100 times per minute, causing the visual signal to flash.

Resistor R311 (not shown) is a trimpot used in the circuit to adjust the rate at which the alarm strikes. Clockwise rotation speeds up striking, while counterclockwise rotation reduces it. Normal adjustment is for 100 strokes per minute. Resistor R302 (not shown) is a trimpot used in the circuit to adjust the amount of time the alarm will continue sounding after the alarm contact maker is released. Normal adjustment is for a 15-second hold.

UNASSIGNED A ALARM.— The unassigned A alarm contains transistorized oscillator and timer circuits that generate 500-Hz and 1500-Hz sine waves alternating at a rate of 1 1/2 Hz, producing a jump tone. Figure 7-14 is a block diagram of an unassigned A alarm module. Operation of the unassigned A alarm contact maker supplies -10 volts dc through relay K401 to all stages of the circuit.

Resistor R406 (not shown) is a trimpot used in the circuit to adjust the high-frequency tone. Resistor R408 (not shown) is a trimpot used in the circuit to adjust the low-frequency tone. If adjustment is required, you should always make the low-frequency adjustment first. The normal setting is 500 cycles per second for the low

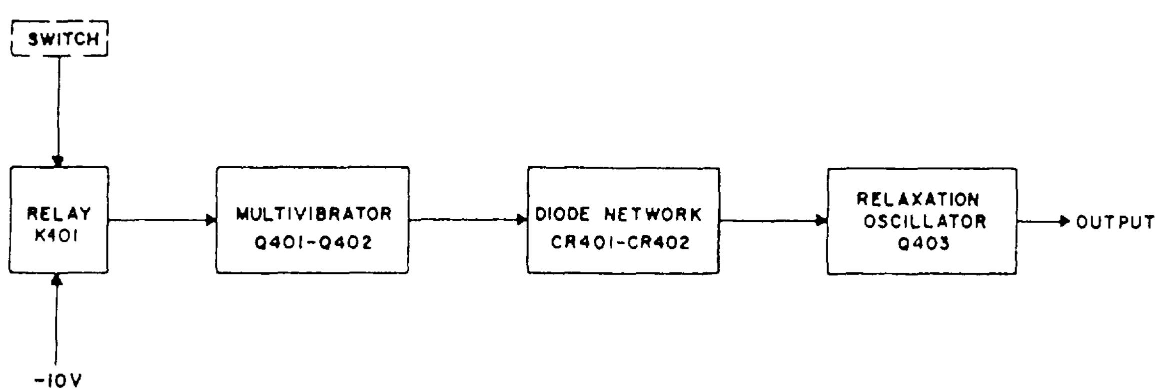


Figure 7-14.—Block diagram of the unassigned A alarm module.

frequency and 1500 cycles per second for the high frequency. In either case, clockwise rotation of the pots will increase frequency and counterclockwise rotation will decrease frequency.

FLIGHT CRASH ALARM.— The flight crash alarm consists of a phase shift oscillator that controls the frequency of a relaxation oscillator through a varistor network and an amplifier stage producing a siren tone. Figure 7-15 is a block diagram of a flight crash alarm module. Operation of the flight crash alarm contact maker supplies -30 volts dc through relay K501 to all stages of the circuit.

Resistor R7 (not shown) is a trimpot used in the circuit to adjust the frequency limits of the siren tone. Clockwise rotation of the pot will raise the frequency of Q503, while counterclockwise rotation will decrease it. The normal setting produces a frequency varying between 750 cycles per second and 1750 cycles per second.

Switching and Transfer Controls and Indicators

The switching and transfer controls on the front of the control rack consist of the amplifier oscillator power switches, the amplifier channel selector switch, the oscillator group selector switch, the microphone control station disconnect switches, the loudspeaker group disconnect switches, visual disc switch, and various test switches. Indicators on the front of the control rack consist of a power available lamp, blown-fuse indicators, and a test meter.

AMPLIFIER OSCILLATOR POWER SWITCHES.— These switches provide power to the two power supplies and relay power supply located in the control rack and the power amplifiers and blowers located in the power rack. During normal operation, these switches are in the ON position.

AMPLIFIER CHANNEL SELECTOR SWITCH.— Three choices of channel operation are available in this system: (1) 1MC-A/6MC-B, (2) 1MC-A/6MC-A, and (3) 1MC-B/6MC-B. Selection is accomplished by operation of the AMPLIFIER CHANNEL SELECTOR switch. Channel A is normally used for circuit 1MC operation, and channel B is normally used for circuit 6MC operation. Should one channel fail during operation, the switch can be positioned to the operational channel, thus putting both circuit 1MC and circuit 6MC on the same charnel. Under this condition, however, circuit 1MC has priority over circuit 6MC. Figure 7-16 is a simplified system switching diagram showing the AMPLIFIER CHANNEL SELECTOR switch in the 1MC-A/6MC-B position.

OSCILLATOR GROUP SELECTOR SWITCH.— Selection of either group of alarms is accomplished by operation of the OSCILLATOR GROUP SELECTOR switch. Should any alarm module within either oscillator group fail during operation, the switch can be positioned to the operational group. During normal operation, this switch is in the NO. 1 position.

MICROPHONE CONTROL STATION DISCONNECT SWITCHES.— There are six microphone control station disconnect switches, one for

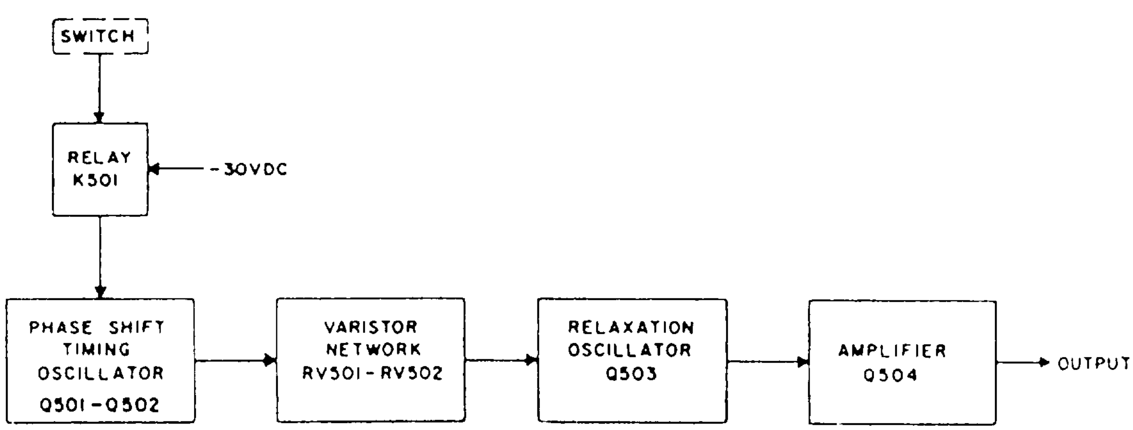


Figure 7-15.—Block diagram of the flight crash alarm module.

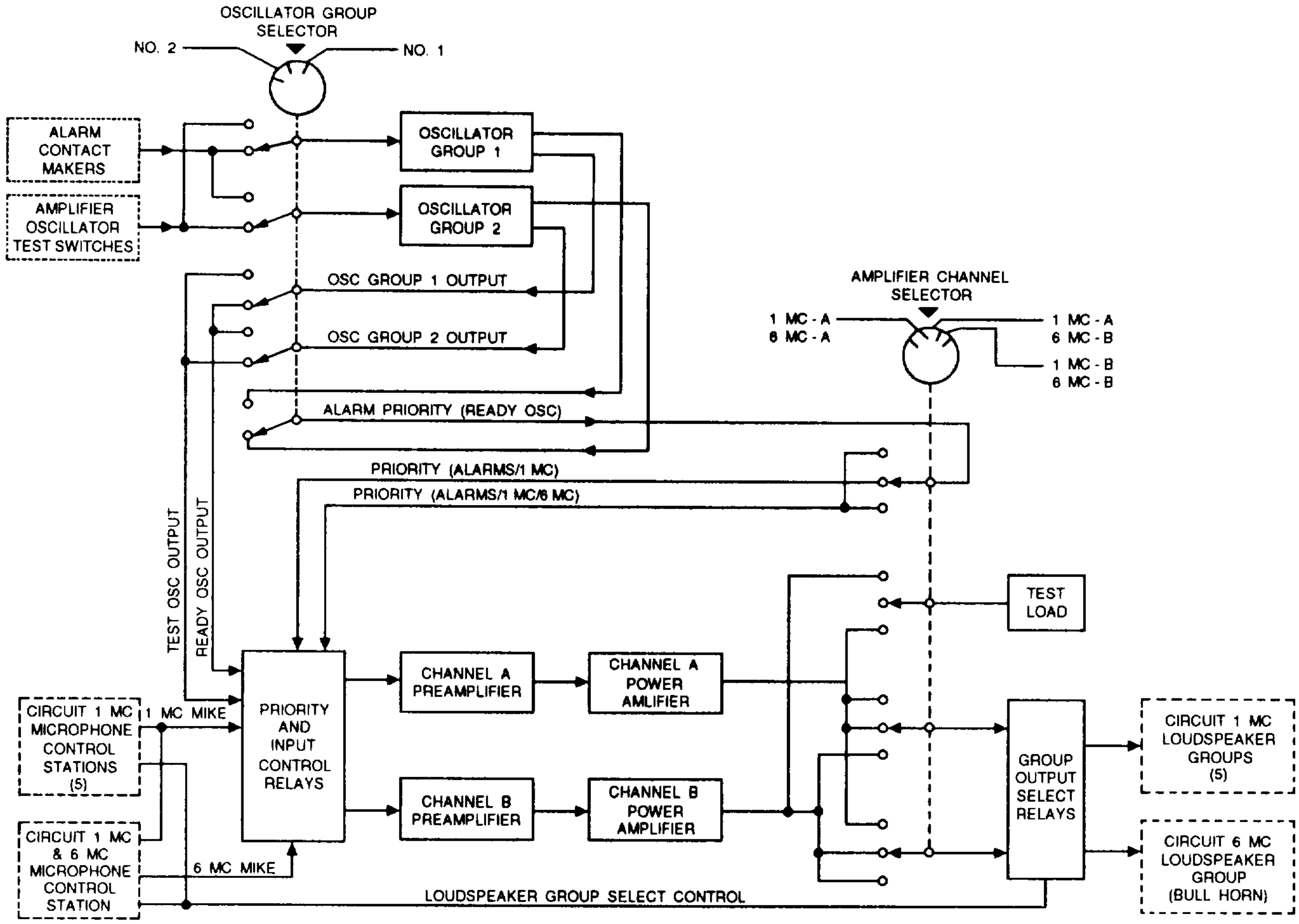


Figure 7-16.—Simplified system switching diagram.

each microphone control station. These switches control the relay power for each control station. They are also used to isolate the control stations during troubleshooting.

LOUDSPEAKER GROUP DISCONNECT SWITCHES.— There are six loudspeaker group disconnect switches, one for each loudspeaker group. These switches control system output power to each loudspeaker group. They are also used to isolate the loudspeaker groups during troubleshooting.

VISUAL DISC SWITCH.— This switch controls the output to the visual alarm indicators.

TEST SWITCHES.— The test switches consist of the amplifier test switches, the amplifier oscillator test switches, and a meter test switch. The amplifier test switches are used when making system level adjustments on the preamplifiers and the amplifiers. The amplifier oscillator test switches and the meter test switch are used to test the output of the power supplies and for silent and remote testing of the amplifier channels and oscillator groups.

POWER AVAILABLE LAMP.— This lamp, when lit, indicates that power is available to the control rack for operation of the system.

BLOWN-FUSE INDICATORS.— There are combination fuse holders and blown-fuse indicators for each amplifier oscillator power switch and for each microphone control station switch.

Primary power circuits are fused on both the high and low sides. The switch controlling power to the circuit, which a fuse protects, must be in the ON position for the blown-fuse indicator to give an indication of a fuse failure. For microphone control stations, the microphone press-to-talk switch at the station must be operated to give an indication of fuse failure.

TEST METER.— The test meter is used with the meter test switch for testing the output of the power supplies and for silent and remote testing of the amplifier channels and oscillator groups. Figure 7-17 is an illustration of the test meter.

POWER RACK

The power rack (fig. 7-18) is a deck-mounted enclosure that contains the two 500-watt, audio-frequency power amplifiers and two ventilation blowers. The power switch for these blowers is located on the control rack.

The power amplifiers amplify the voice and alarm signals received from their associated preamplifiers in the control rack and transmit the amplified signals back to the control rack for further transmission to the appropriate loudspeaker groups. The amplifiers maintain a relatively constant output signal that is independent of loudspeaker load. Therefore, impedance matching of the output is not critical, and adding or removing loudspeakers from the output of the amplifier will have little or no noticeable effect on the output level. Figure 7-19 is a block diagram of a power amplifier.

Each power amplifier consists of two separate chassis. Chassis 1 contains all the tubes and parts required for actual amplification of the audio signals. This chassis consists of an amplifier stage, a phase-inverter stage, two driver-amplifier stages, and a final power-amplifier stage. Two parallel-connected tubes comprise each stage except the final stage, which has six tubes in a push-pull parallel circuit. This parallel connection of twin-triode tubes permits normal circuit operation despite failure or removal of one tube per stage or two tubes in the final stage.

Chassis 2 contains all the parts required to furnish plate power to chassis 1. This chassis consists of a plate-power transformer, high-voltage rectifiers, low-voltage rectifers, and a filament transformer.

There are two eight-position selector switches and two meters mounted on the front of the power rack, one for each amplifier. These are used to check the operation of each stage of the amplifiers and the signal output of each amplifier. Normal operation of each stage will indicate a midscale reading (0±2 dB) on the meter.

Resistor R2101 is a potentiometer used to control the amplitude of the input signal being applied to V2103 and V2104. High-voltage switch S2101 is used to apply plate power to the amplifier.

ADDITIONAL SOUND EQUIPMENT

Additional sound equipment used with the system includes (1) microphone control stations, (2) loudspeakers, (3) alarm contact makers, and (4) visual alarm indicators.

Microphone Control Stations

The system has provisions for the connection of six type IC/MSB-2 microphone control stations. The microphone control stations are installed at various locations aboard ship. The stations provide a means of transmitting voice announcements over the 1MC or 6MC circuits and select the loudspeaker groups over which the announcements will be broadcast. All stations are capable of transmitting over circuit 1MC. Only station 1 is capable of transmitting over both circuit 1MC and circuit 6MC. Station 1 is normally located in the pilothouse/bridge and has operational priority over the other five stations. The other stations are normally located at the quarterdecks.

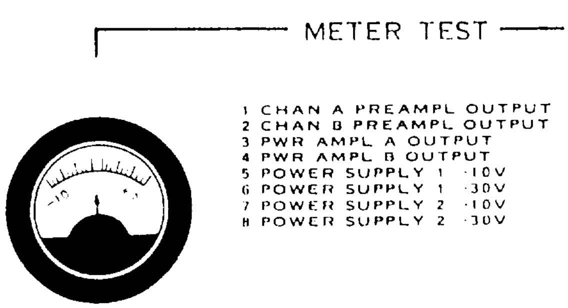


Figure 7-17.—Test meter.

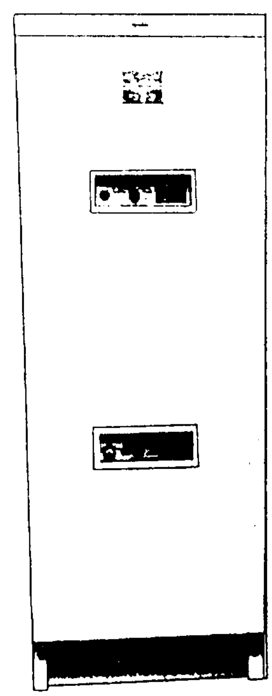


Figure 7-18.—Power rack.

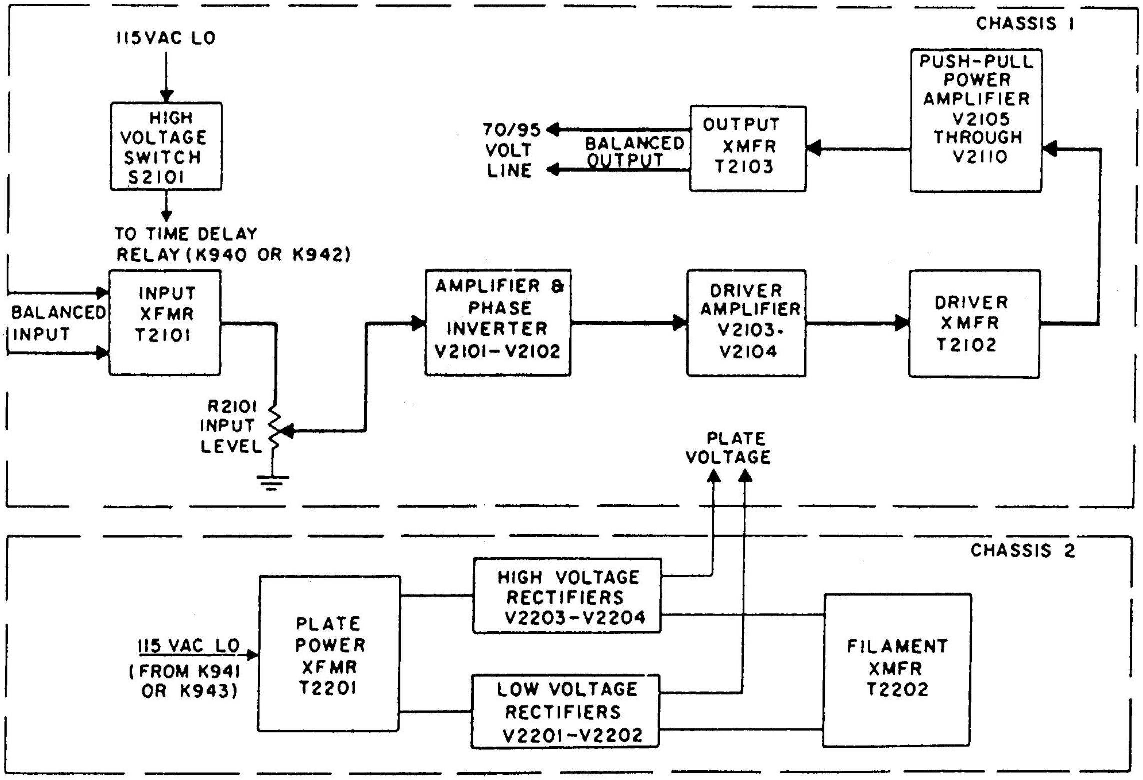


Figure 7-19.—Block diagram of a power amplifier.

Figure 7-20 is an illustration of an IC/MSB-2 microphone control station. Microphone control stations are self-contained, bulkhead-mounted units with a hinged cover guard. The stations consist of a detachable microphone with a press-to-talk switch, loudspeaker group control switches, busy indicator lights, and a volume indicator meter.

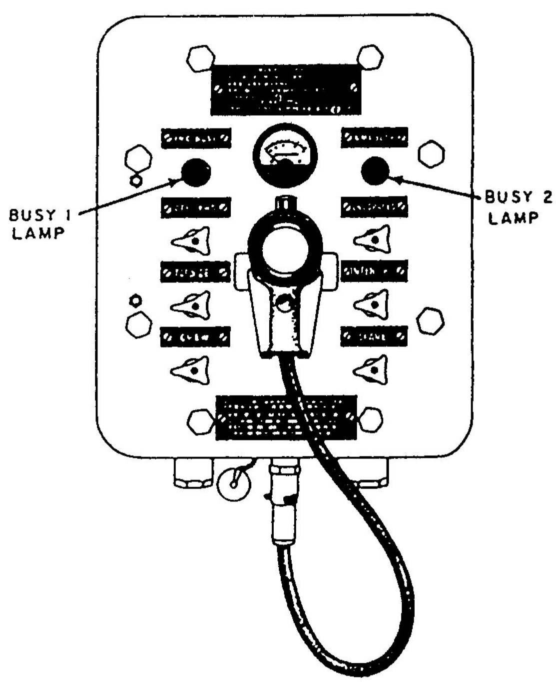


Figure 7-20.—IC/MSB-2 microphone control station.

MICROPHONE.— A magnetic type of microphone is used with the IC/MSB-2 microphone control station. This microphone is equipped with an 18-inch cable and a plug. The microphone plugs into a receptacle mounted in the bottom of the station. A tapered holder, mounted on the front panel of the station, holds the microphone. When using the microphone to transmit, you may remove it from its holder or leave it in the holder. To use the microphone, you must depress the press-to-talk switch located on the microphone to transmit. When talking into the microphone, you should hold the microphone one-half inch from your mouth and speak directly into it in a normal tone of voice.

LOUDSPEAKER GROUP CONTROL SWITCHES.— There are five circuit 1MC loudspeaker group control switches and one circuit 6MC loudspeaker group control switch mounted on the front of microphone control station 1. Stations 2 through 6 will contain circuit 1MC loudspeaker group control switches only. These switches are used to select which loudspeaker group(s) is/are to receive the announcement being transmitted from the microphone control station. When an announcement is made from any microphone control station, all loudspeakers selected at that station, except the loudspeaker in the immediate area of the station, will receive the anouncement.

The loudspeakers associated with circuit 1MC are normally divided into four groups. These loudspeaker groups are designated (1) officers, (2) topside, (3) crew, and (4) engineering. There is only one circuit 6MC loudspeaker group, with only one or two loudspeakers installed.

After making an announcement over circuit 1MC, make sure you place the loudspeaker group control switches selected in the OFF position. If any loudspeaker group control switch at any lMC microphone control station is left in the ON position, announcements made from any other control station will go out on those loudspeakers.

BUSY INDICATOR LIGHTS.— Two busy indicator lights are mounted on the front of the microphone control station, one for the 1MC (busy 1) and one for the 6MC (busy 2). These lights indicate if the associated circuit is in use, thereby avoiding the possiblity of initiating a call through that circuit. Before making an announcement, make sure the busy light for the desired circuit is not lighted.

Except in an emergency, do not attempt to use circuit 1MC when the busy indicator light is lighted. If another microphone control station has already selected a circuit 1MC loudspeaker group(s) and is initiating an announcement, the transmission will go out to all loudspeakers selected at both microphone control stations.

When the circuit 6MC busy indicator light is lighted, it will have no effect on circuit 1MC operation.

When both busy indicator lights are lighted, three possible conditions exist: (1) both circuit 1MC and circuit 6MC are in use, (2) both circuit 1MC and circuit 6MC are using the same amplifier channel, or (3) an alarm signal is being transmitted.

When both circuits are using the same amplifier channel, circuit 1MC takes priority over circuit 6MC. Therefore, if circuit 6MC is in use and a circuit 1MC loudspeaker group is selected from another microphone control station and a transmission is initiated, circuit 6MC will be cut off. The announcement will then go out to the circuit 1MC loudspeakers only.

VOLUME INDICATOR METER.— A volume indicator meter (fig. 7-21) is mounted on the front of the microphone control station. This meter indicates that the system is ready for use. his meter also indicates the amount of output volume when a transmission is made. This meter is calibrated in decibels from -10 dB through 0 dB to +6 dB. When the press-to-talk switch on the microphone is depressed, the meter needle should deflect. When an announcement is being transmitted, the meter needle should deflect to 0 dB on peaks for normal volume.

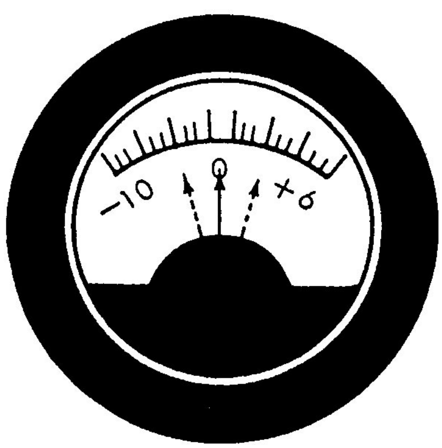


Figure 7-21.—Volume indicator meter.

Loudspeakers

Several different types of loudspeakers are used with circuit 1 MC to suit different needs. In areas with comparatively low noise levels, such as living spaces, low-power, radiator-type loudspeakers are used. On weather decks and in areas with high noise levels, such as engineering spaces, high-power, folded-horn loudspeakers are used.

Circuit 6MC requires the use of a multiunit straight-horn loudspeaker (fig. 7-22). This type of loudspeaker projects a narrow, powerful beam.

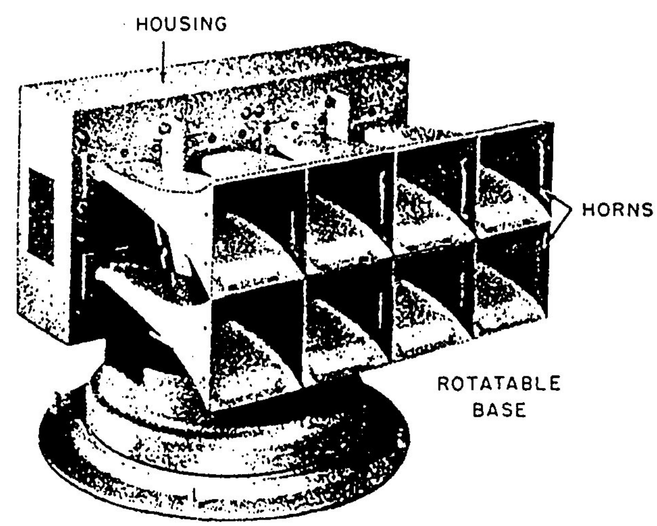


Figure 7-22.—Multiunit straight-horn loudspeaker.

Loudspeakers are usually provided with volume adjustments. The desired output level for each loudspeaker will depend on where it is located.

Alarm Contact Makers

Alarm contact makers are installed at various locations, such as the pilothouse/bridge and quarterdecks, where they are easily accessible to watch standers. The alarm contact makers are self-locking (in the OFF position), manual-release, lever-operated switches. Operation of any alarm contact maker will light both busy lights on all microphone control stations and transmit the alarm signal to all 1MC loudspeaker groups. Figure 7-23 is an illustration of a typical alarm contact maker arrangement. The alarm contact makers are color coded and prioritized according to their importance. The order of priority is controlled automatically by relays in the control rack. The alarm contact makers are color coded and prioritized as follows:

1. Collision (green)
2. Chemical attack (yellow)
3. General (red)
4. Unassigned A (gray)
5. Flight deck crash (red)

If a low-priority alarm is being sounded and the contact maker for a higher priority alarm is operated, the lower priority alarm will be silenced and the higher priority alarm will be transmitted over the 1 MC loudspeakers. Conversely, the operation of a low-priority alarm contact maker has no effect on a high-priority alarm that is being transmitted.

The nature and number of 1MC alarms installed aboard ship is dependent on the type and mission of the ship. As a rule, however, all 1MC systems aboard surface ships are capable of generating and broadcasting collision alarms, chemical attack alarms, and general alarms.

Visual Alarm Indicators

In areas where the noise level is high, such as in engineering spaces and on hangar decks, visual alarm indicators are installed to alert personnel when an alarm is being sounded. The visual alarm indicators consist of lighting fixtures with red lamps installed in them. The red lamp lights steady when the collision or chemical attack alarm is sounded and flashes when the general alarm is sounded.

OPERATIONAL SYSTEM TESTING

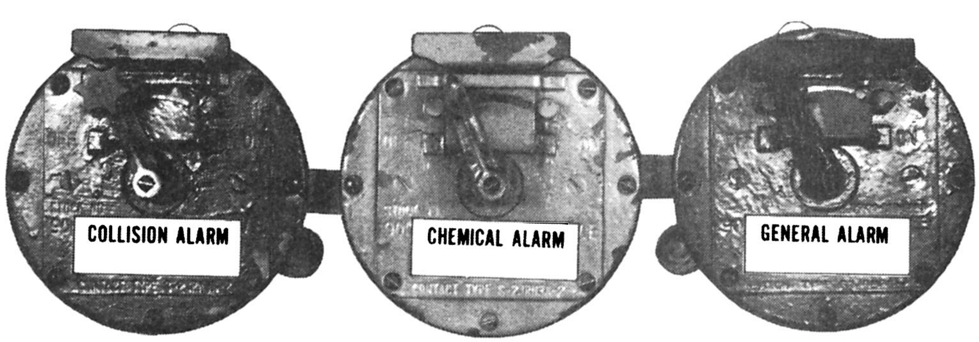
There are two methods for testing the system for proper operation: (1) silent testing and (2) remote testing.

Silent Testing

Since the system can operate on either channel A or B and oscillator group 1 or 2, one channel and one oscillator group can be on the line for ship's use while the other channel and group are available for silent testing.

To test channel A and oscillator group 1, proceed as follows:

1. Place the LOAD DISC switch in the OFF position.
2. Place the AMPLIFIER CHANNEL SELECTOR switch to the 1MC-B/6MC-B position, and turn the OSCILLATOR GROUP SELECTOR switch to the NO. 2 position. This puts channel B and oscillator group 2 on the line, and leaves channel A and oscillator group 1 available for testing.



7.344

Figure 7-23.—Alarm contact maker arrangement.

3. Turn the METER TEST switch to position 3 to test the power amplifier A output as the various alarm test switches are energized.

4. Hold the CHEMICAL test switch in the ON position. The meter reading should be 0æ2 dB. Release the switch.

5. Hold the COLLISION test switch in the ON position. The meter reading should fluctuate. Release the switch.

6. Operate the GENERAL test switch momentarily in the ON position. The meter reading should fluctuate for approximately 15 seconds. Release the switch.

7. Hold the UNASSIGNED test switch in the ON position. The meter reading should fluctuate. Release the switch,

8. Hold the FLIGHT CRASH test switch in the ON position. The meter reading should fluctuate. Release the switch.

This completes the testing of channel A and oscillator group 1. To test charnel B and oscillator group 2, turn the AMPLIFIER CHANNEL SELECTOR switch to the 1MC-A/6MC-A position and the OSCILLATOR GROUP SELECTOR switch to the NO. 1 position. Turn the METER TEST switch to position 4, and repeat steps 4 through 8.

Remote Testing

Remote testing consists of a test of the entire system. The test will include testing for proper operation of the system from the microphone control stations and the alarm contact makers. Figure 7-24 illustrates the proper switch positions on the control rack for remote testing.

MICROPHONE CONTROL STATION TEST.— When conducting a test of a microphone control station, you must monitor all the other microphone stations and at least one loudspeaker in each loudspeaker group. Make several test announcements over circuit 1 MC, selecting a different loudspeaker group for each transmission. The volume indicators should fluctuate at all stations, and the circuit 1 MC busy signal light should illuminate when each test announcement is made. Each test should be heard on the loudspeaker of the loudspeaker group selected and not on loudspeakers of any other loudspeaker group. Check the priority feature of microphone station 1 by depressing the press-to-talk switch at station 1 while making an announcement from another station. This should cut off the other station.

Conduct a test announcement from station 1 over circuit 6MC. The circuit 6MC busy signal light should illuminate at all stations, and the announcement should be heard over the 6MC loudspeaker(s) only.

ALARM CONTACT MAKER TEST.— When conducting a test of the alarm contact makers, you must monitor all the microphone stations and at least one loudspeaker in each loudspeaker group and any visual alarm indicators. Test the alarm contact makers in order, beginning with the lowest priority alarm first. The following procedure is for testing the general, chemical, and collision alarm contact makers only:

1. Operate the general alarm contact maker momentarily to the ON position. The alarm should sound for approximately 15 seconds.

2. While the general alarm is sounding, operate the chemical alarm contact maker to the ON position and hold it there. The chemical alarm should override the general alarm.

3. While the chemical alarm is sounding, operate the collision alarm contact maker to the ON position. The collision alarm should override the chemical alarm.

4. Return the chemical and collision alarm contact makers to the OFF position.

Operation of any alarm should light up the busy signal lights and all visual alarm indicators of circuit 1MC and circuit 6MC. As each alarm contact maker is operated, the corresponding alarm should be heard over all the circuit 1MC loudspeaker groups.

MAINTENANCE

Maintenance of the system consists of routine preventive maintenance and corrective maintenance.

Preventive Maintenance

Routine preventive maintenance of the system will be accomplished according to the maintenance requirement cards (MRCs) for the system, In most cases, this will consist of cleaning the interior and exterior of each rack, a visual inspection of equipment components and wiring, checking for loose connections, and testing the power amplifier tubes.

Corrective Maintenance

Corrective maintenance of the system consists of troubleshooting and actual replacement of defective parts. When performing corrective maintenance, you

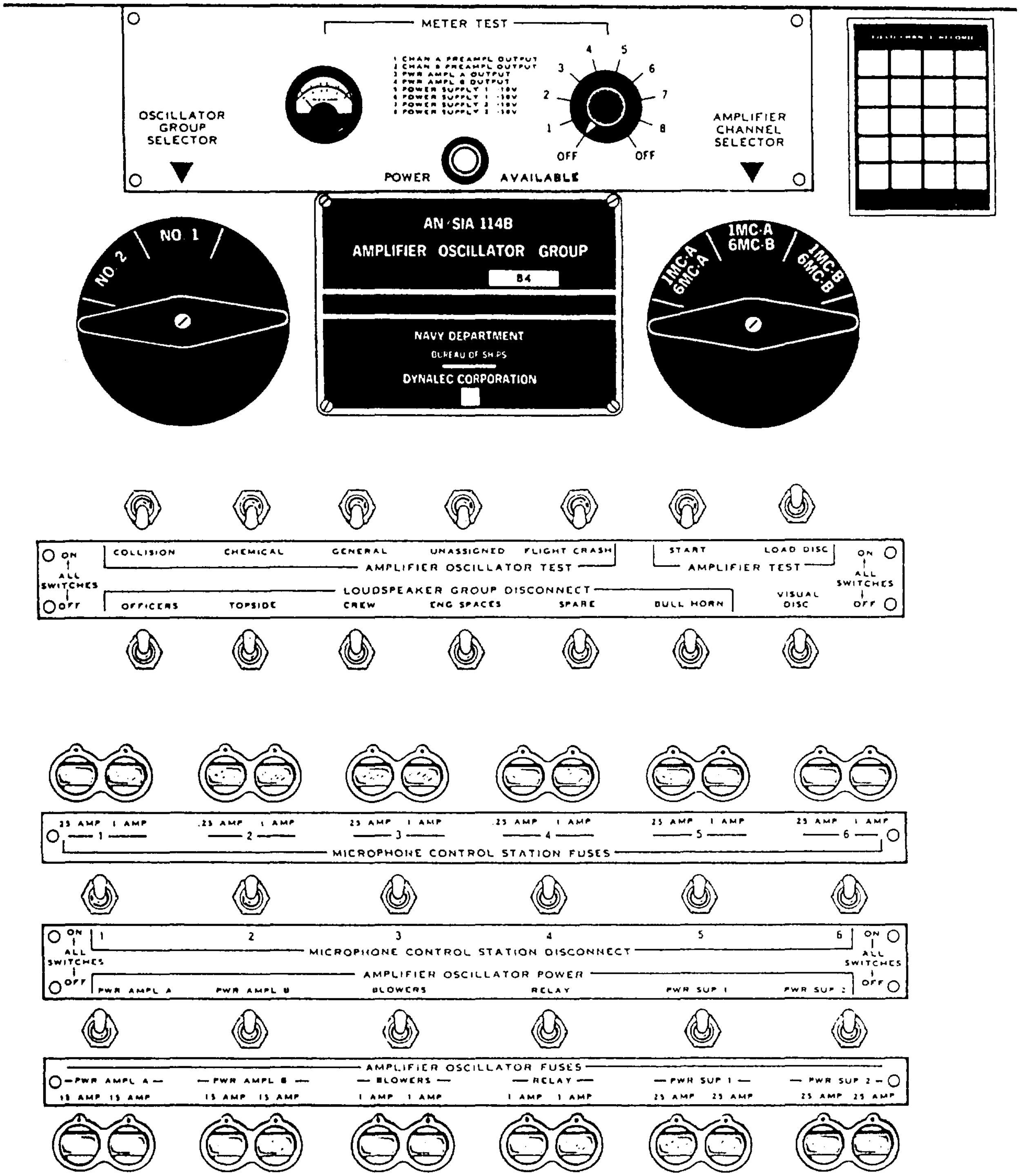


Figure 7-24.—Control rack with switches set for remote testing.

must observe all safety regulations and precautions at all times. There are no interlocks used on this equipment, and power to the control rack can be secured only by turning off the switch on the main IC switchboard. Operation of the system involves the use of high voltages, and you should not service or adjust this equipment alone. Under certain conditions, dangerous potentials may exist in circuits with the power amplifier in the OFF position, due to charges retained by capacitors and so on. Always use a safety shorting probe to discharge and ground circuits before touching them.

Localization of trouble in the system will be comparatively simple because of the test facilities included in the equipment. In most cases, a faulty assembly or even the faulty stage of an assembly can be localized by using the test meters and meter test switches included in the control and power racks. Also, the use of duplicate oscillator, preamplifier, and power amplifier assemblies permits the testing or repair of one assembly while the other assembly remains in active service, thereby avoiding the necessity for shutting down the system.

If the entire announcing system is inoperative, the trouble is probably in the ship's power supply or wiring from the ship's power supply. Check the power available indicator on the control rack. This indicator, unless it is defective, will be lighted when power is available to the rack. If power is not available, check the position of the supply switch on the main IC switchboard.

If power is available, check all fuses and switches associated with the system. If a fuse failure is indicated, replace the fuse. If the new fuse burns out immediately, do not replace it a second time until the cause has been corrected. A check of the switches on both the control rack and the microphone control stations may show that one or more are not in the proper position.

Tables 7-2, 7-3, and 7-4 are trouble charts for the system. These tables show some of the more common

Table 7-2.—Microphone Control Station Trouble Chart

SYMPTOM	PROBABLE DEFECTIVE COMPONENT						
	STATION NO. 1	STATION NO. 2	STATION NO. 3	STATION NO. 4	STATION NO. 5	STATION NO. 6	OTHER
Unable to select Officers Loudspeaker Group	K901 CR907	K910	K914	K918	K922	K926	K945
Unable to select Topside Loudspeaker Group	K901 CR908	K910	K914	K918	K922	K926	K946
Unable to select Crew Loudspeaker Group	K902 CR909	K911	K915	K919	K923	K927	K947
Unable to select Engineering Spaces Loudspeaker Group	K902 CR910	K911	K915	K919	K923	K927	K948
Unable to select Spare Loudspeaker Group	K903 CR911	K912	K916	K920	K924	K928	K949
Unable to select Bull Horn	K903	-	-	-	-	-	K950
Busy 1 lamps do not light and Amplifier channel does not switch to the Ready condition when a Microphone button is depressed for Circuit 1MC announcements	K906	CR912	CR913	CR914	CR915	CR916	K932
Busy lamps light but Amplifier Channel does not switch to the Ready condition	-	-	-	-	-	-	K941 K943
Busy 2 lamps do not light and Amplifier Channel does not switch to the Ready condition when the Circuit 6MC Microphone button is depressed.	-	-	-	-	-	-	K933
All stations except No. 1 inoperative	-	-	-	-	-	-	K953

Table 7-3.—Alarm Circuit Trouble Chart

SYMPTOM	PROBABLE DEFECTIVE ASSEMBLY OR COMPONENT
No System output when Collision Alarm Contact Maker is operated.	Collision Alarm, K101, S913 deck 1.
No System output when Chemical Alarm Contact Maker is operated.	Chemical Alarm, K201, S913 deck 2.
No System output when General Alarm Contact Maker is operated.	General Alarm, K302, S913 deck 3.
No System output when Unassigned "A" Alarm Contact Maker is operated.	Unassigned "A" Alarm, K401, S913 deck 4.
No System output when Flight Crash Alarm Contact Maker is operated.	Flight Crash Alarm, K501, S913 deck 5.
No System output when any contact maker is operated.	Relay power supply, Preamplifier, Power Supply, Power Amplifier, K930, S923 deck 4, K938 or K939, S913 deck 6 or 7, CR930 or CR931.

symptoms and probable defective assemblies or components.

DIODES.— If operation indicates that a diode is defective, disconnect one lead of the diode, being careful not to overheat the diode. Check the diode by measuring the front-to-back resistance ratio. The ratio should be at least 100 to 1.

RELAYS.— If operation indicates that a relay is defective, use the relay test facility located behind the front panel of the control rack to check the relay. The

Table 7-4.—Amplifier Circuit Trouble Chart

SYMPTOM	PROBABLE DEFECTIVE ASSEMBLY OR COMPONENT
No System output when any 1MC mike circuit is energized.	Preamplifier, Power Supply, Power Amplifier, K932, S923 deck 5, K934, CR926, K940 or K942, K941 or K943.
No System output when the 6 MC mike circuit is energized.	Preamplifier, Power Supply, Power Amplifier, K933, S923 deck 6, K935, CR927, K940 or K942, K941 or K943.
No System output when any 1 MC or 6 MC circuit is energized.	Relay power supply, K930.

relay test facility (fig. 7-25) consists of two relay test sockets, two indicating lamps, and a test switch. Test suspected defective relays by plugging into the proper socket and operating the test switch. When a crystal can-type relay is tested, both lamps should illuminate in both test switch positions. When a power-type relay is tested, both lamps should illuminate only in test switch position 2.

TUBES.— Defective or weak tubes cannot easily be detected when checking operation of the power amplifiers with the meter test switch and test meter. The system is designed to operate despite partial tube failures. The actual failure of one tube per stage will not noticeably affect the meter reading of that stage or the output signal if the remaining tube or tubes are good.

A tube with internally shorted electrodes may affect operation of its stage and give an abnormal meter reading, and a tube with an open filament will have no glow. Tubes that are suspected of being weak or defective will have to be checked with a tube tester.

RESISTORS.— You can use an ohmmeter to check the value of resistors in a circuit. Make sure the power is turned off and the circuit discharged before putting the meter across the resistor. If other components are in parallel with the resistor, one end of the resistor will have to be disconnected to get a correct reading.

Overloaded resistors will be discolored and give off a burnt odor and are often caused by shorted capacitors in the circuit. If you find an overloaded resistor in a circuit, check all the capacitors in the circuit as well.

CAPACITORS.— A shorted or leaking coupling capacitor or an open cathode bypass capacitor will cause an amplifier to hum and reduce amplification. An open coupling capacitor will block amplification and no sound will be produced by the amplifier.

You can use an ohmmeter to check for short-circuited or leaky capacitors with the power off. A good capacitor will give you an ohmmeter reading of very high resistance or infinity. However, the same is true for an open capacitor. Therefore, if you get a good reading and still suspect the capacitor of being faulty, shunt a new capacitor across it and note the effect.

TRANSFORMERS AND CHOKES.— In most cases, a shorted transformer or choke will cause the fuses in the supply circuit to blow. An ohmmeter can be used to check the dc resistance of transformers and chokes. A voltmeter can be used to check power transformers and chokes. To check a suspected transformer with a voltmeter, apply primary power to the input terminals; then use the voltmeter to read the output of the secondary windings. If one or more of the secondary windings show no voltage ouput, the transformer is defective.

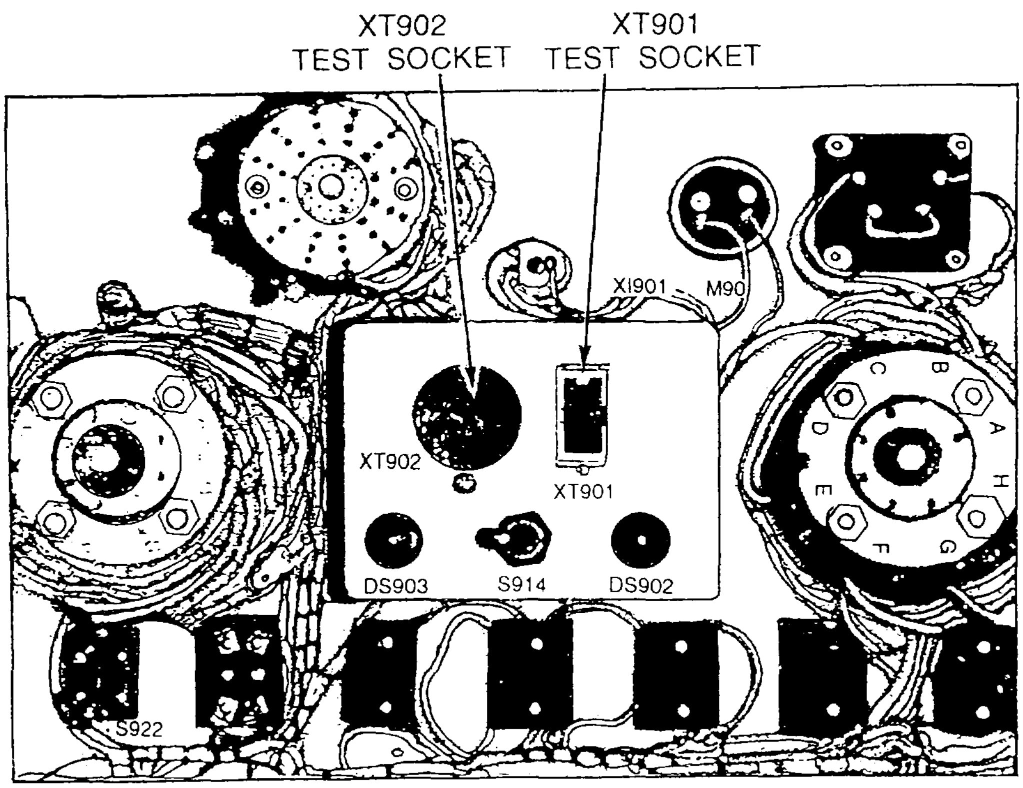


Figure 7-25.—Relay test facility.

To check a power-supply choke, use the voltmeter to read the output voltage of the choke. If the reading is excessively high, the choke has an internal short within the choke. If there is no output voltage, the choke has an open winding or a winding shorted to the case or core.

TRANSISTORS.— To check a suspected transistor, use an in or out of circuit transistor test set, or substitute the suspected transistor with a known good transistor.

SWITCHES.— An ohmmeter can be used to make continuity checks between switch terminals, or a voltmeter can be used to measure the voltages at the switch terminals.

INDICATOR LAMPS.— To check a suspected indicator lamp, you must replace it with a new lamp or one known to be good.

CENTRAL AMPLIFIER SYSTEM (TWO-WAY)

The two-way central amplifier announcing system provides two-way transmission of orders and information using central amplifiers. One example of a two-way central amplifier announcing system is the AN/SIA-120. The AN/SIA-120 comprises the circuit 29MC (sonar control and information amounting system) and provides two-way communications between the sonar control room and various remote stations. The sonar control room transmits to loudspeakers at the remote stations, and the remote stations transmit to the loudspeakers in the sonar control room.

The AN/SIA-120 operates on 115-volt, 60-cycle, single-phase ship's service power. The major components of the system are the control rack and the additional sound equipment used with the system.

CONTROL RACK

The control rack for the AN/SIA-120 (fig. 7-26) is a bulkhead-mounted enclosure containing two identical amplifier channels, A and B. Each channel uses one self-contained modular audio-frequency amplifier capable of 20-watt output power. The amplifiers are located in two compartments in the upper half of the rack The bottom half of the rack is a control panel. All the system's switching, testing controls, and indicators are located on the front of the control panel. The system control relays, relay power supply, and various other components are mounted on a bracket behind the control panel. Terminal boards, which are used for making connections to the ship's wiring, are located on the lower rear wall of the rack and are accessible by opening the control panel.

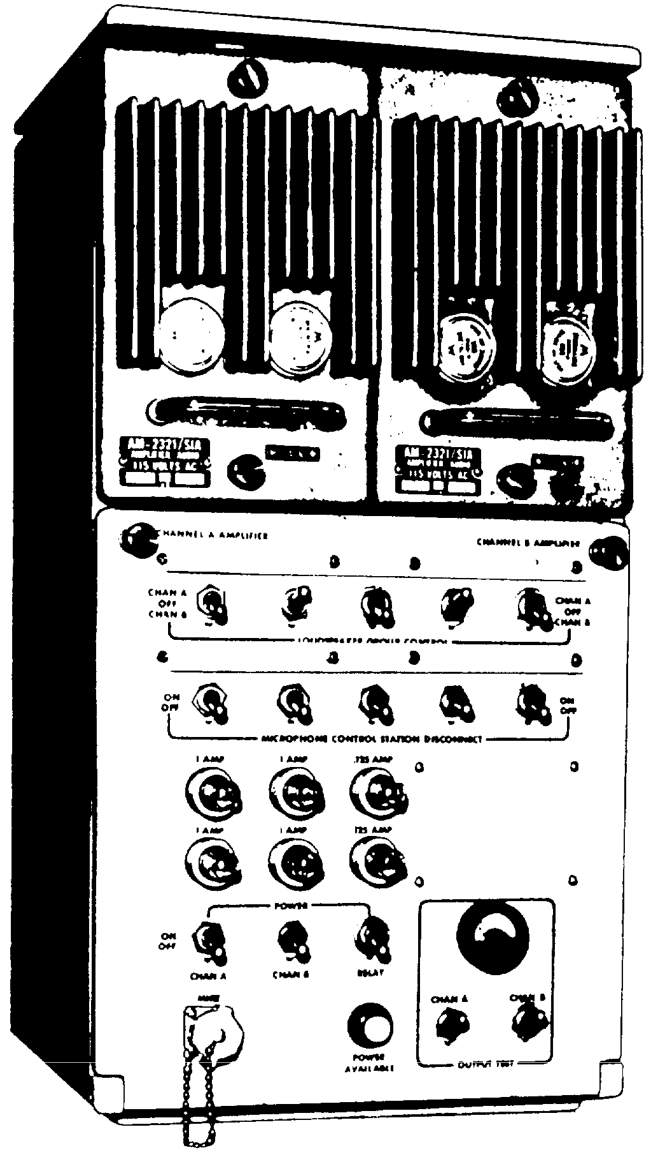


Figure 7-26.—Control rack.

The control rack has input facilities for one portable microphone and five microphone control stations. The control rack also has the facilities for connecting five individual loudspeaker groups to the outputs of the amplifiers. In addition, the rack has a circuit with an amplifier priority control feature, which will connect an alarm signal provided from an external source to the inputs of the amplifiers while inhibiting operation from the microphone control stations.

Audio-Frequency Amplifiers

The two amplifiers located in the upper half of the control rack are used for complete amplification of the microphone outputs. The inputs to the amplifiers are parallel connected. The output transistors are physically locatcd on the front of the panel. This design allows the use of the whole front panel as a heat sink, providing cooler operating temperatures than would otherwise be possible. Figure 7-27 is a blockdiagram of an amplifier.

Switches, Timing Controls, and Indicators

The microphone control station inputs to the amplifiers are controlled by five 2-position toggle switches located on the front of the control panel. In the ON position, the microphone control stations are connected to the amplifiers, and in the OFF position, they are disconnected.

The outputs of the amplifiers are individually connected to the loudspeaker groups by five 3-position toggle switches located on the front of the control panel. In the up position, the loudspeaker groups are connected to channel A; and in the down position, they are connected to channel B. Under normal operating conditions, the switches should be positioned so that the loudspeaker load is evenly divided between both amplifier channels. When the switches are in the center position, the loudspeaker groups are disconnected from the amplifier outputs. Separate connections provide for local speakers located adjacent to the associated microphone control stations, and muting features are accomplished in the control rack.

An output test meter and two toggle switches, designated CHAN A and CHAN B, are provided on the control panel for testing the output of each amplifier channel. A portable microphone jack is also provided. This jack can be used for local testing of the system or for talking.

Three toggle switches located on the front of the control panel provide power to the amplifiers and the relays.

A power available lamp and six blown-fuse indicators are also mounted on the front of the control panel.

ADDITIONAL SOUND EQUIPMENT

Additional sound equipment used with the system consists of (1) microphone control stations and (2) loudspeakers.

Microphone Control Stations

The microphone control stations located in the sonar control room consist of both microphones and foot-operated switches. A portable microphone and an associated jackbox is provided for the sonar control area supervisor, and a flexible microphone and foot-operated switch is provided for each sonar operator's position. The flexible microphones and foot-operated switches are wired in parallel to permit hands-free operation by the operators. The microphone inputs from the operators' positions connect to the control panel relay assembly in such a manner that only one microphone is connected to the amplifier input at a given time. This

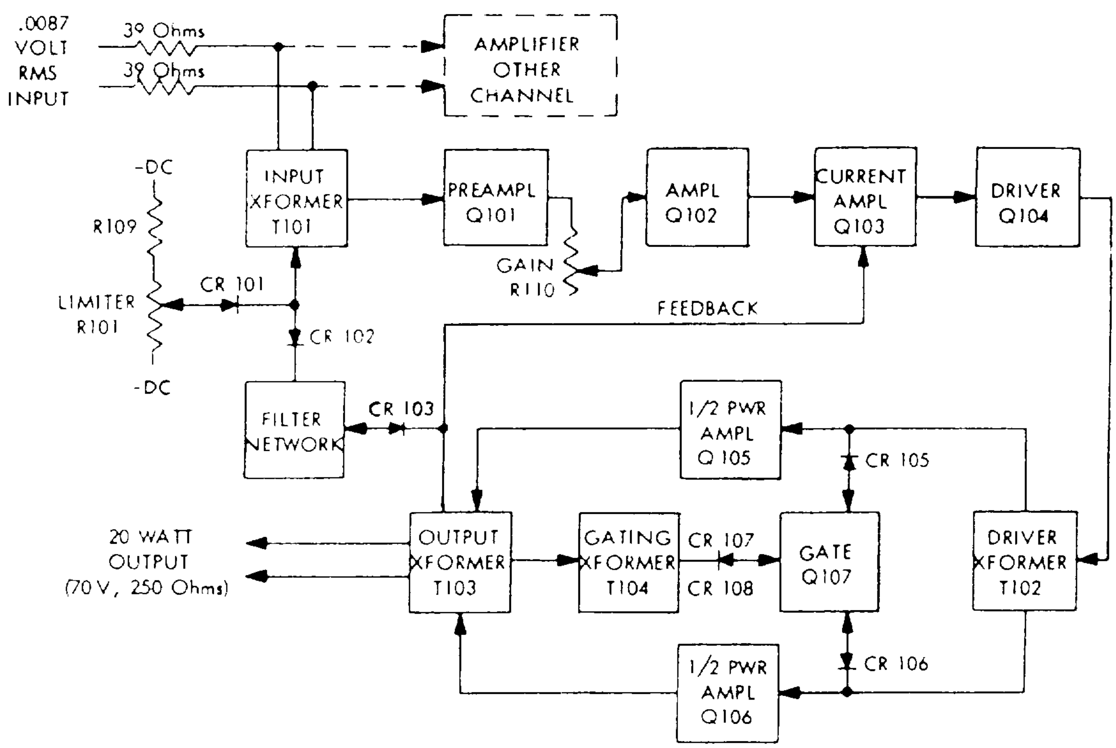


Figure 7-27.—Block diagram of an amplifier.

prevents multiple inputs to the amplifier, which could result in unintelligible transmissions to the remote loudspeakers.

The microphone control stations located at the remote stations consist of a flexible microphone and an associated microphone jackbox. These remote stations are connected to the amplifier as separate inputs.

Loudspeakers

Loudspeakers are located in the sonar control area and at each remote location. Loudspeakers located adjacent to control stations are wired so that they are disconnected from the amplifier when the adjacent control station is operated.

MAINTENANCE

Maintenance of the system consists of routine preventive maintenance and corrective maintenance. Maintenance for the two-way system is essentially the same as for the one-way system. Routine preventive maintenance consists of inspecting, cleaning, and testing. Corrective maintenance consists of troubleshooting and replacing parts.

As with the one-way system, operation of this equipment involves the use of high voltages with no interlocks provided. Therefore, all safety regulations and precautions must be observed at all times when you are performing corrective maintenance on this equipment.

Malfunctions can usually be localized by using the comparison method. A problem common to all microphone control stations usually indicates a failure within the circuits of the control rack. A problem peculiar to only one station indicates the fault could be located in the control rack the microphone control station, or the cables connecting the control station to the control rack.

If the entire system is inoperative, check the POWER AVAILABLE indicator lamp on the control rack. If the lamp is not lit, check the switch that provides power to the control rack. If the lamp is lit, check the position of the switches on the control panel. If all the control panel switches are in their proper positions, check for blown fuses. If there is no indication of a blown fuse(s), refer to the applicable technical manual and schematic diagram for the system.

The system's dual channel design, with switching controls, permits continued operation of the system when one channel fails. If there is a failure of the channel A amplifier, place all loudspeaker group control switches to channel B. If there is a failure of the channel B amplifier, place all loudspeaker group control switches to channel A. When operating under this condition, with all loudspeaker groups connected to one amplifier, be careful not to overload the amplifier. Use the OUTPUT TEST switch and meter to test the output of the channel in use. Proper output is indicated when the meter fluctuates with peaks occuring about midscale (0 dB).

INTERCOMMUNICATION SYSTEMS

Intercommunication (intercom) systems provide for two- way transmissions of orders and information between stations. Each intercom unit contains its own amplifier.

INTERCOMMUNICATING UNITS LS-433A/SIC AND LS-434A/SIC

Regardless of their construction, intercommunicating units on naval vessels are connected together electrically in a system. The electrical characteristics that must be identical to permit interconnection in a system are (1) audio-amplifier input and output requirements, (2) amplifier output impedance to the loudspeaker line transformer, (3) supply voltages and currents, (4) call and busy signal voltages, and (5) interconnection circuits.

One type of intercom unit, the LS-433A/SIC (fig. 7-28), can originate calls up to a maximum of 10 other

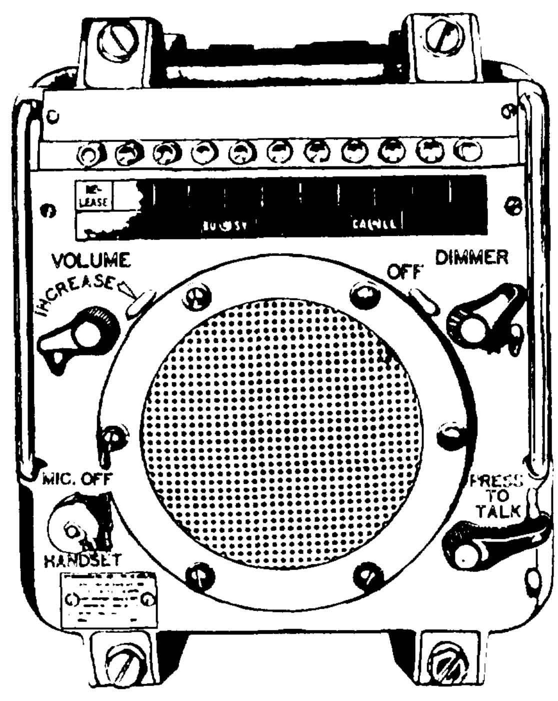


Figure 7-28.—Intercommunicating unit (LS-433A/SIC).

stations. Another type of intercom unit, the LS-434A/SIC, can originate calls up to a maximum of 20 other stations. There is, however, no operational difference between these two types of units.

Reproducer

The reproducer serves a dual function. When it is the transmitting station, it performs as a microphone; when it is the receiving station, it performs as a normal speaker; amplification occurs in the calling unit.

Controls and Indicators

The controls consist of the push-button assembly, talk switch, volume control, and dimmer control. The indicators consist of the busy light, call light, release light, and station designation lights.

PUSH-BUTTON ASSEMBLY.— The push-button assembly, or station selector switches, are located at the top of the front panel. The locations of the various units associated with the push button is engraved on the station designation plate immediately below the push button. When the button is depressed, it will lock into the operated position until the release push button is depressed to return them to the nonoperated position.

The 10-station unit (LS-433A/SIC) is provided with one bank of 10 selector switches. The 20-station unit (LS-434A/SIC) is provided with two banks of 10 selector switches each. During standby periods, the release push button is kept in the depressed, or operated, position. When any station selector switch is depressed, the release push button is restored to the nonoperated position and the release lamp under the push button will be lighted. At the conclusion of the conversation, the release push button should again be depressed, restoring the station selector switches to the nonoperated position and extinguishing the release lamp.

TALK SWITCH.— The talk switch serves to select the function of the reproducer. When the switch is depressed, the reproducer functions as a microphone and couples the reproducer (microphone) signal to the amplifier and from the amplifier to the receiving station. When the spring-loaded talk switch is released, the reproducer functions as a loudspeaker and is ready to receive information.

A handset can be used with the intercom unit in place of the reproducer. The operation is the same, except that the push button on the handset is used as the talk switch in place of the normal talk switch. Incoming calls will be heard in the handset and the reproducer simultaneously.

A portable microphone can also be used with this equipment. The operation is the same, except the push button on the portable microphone is used instead of the normal talk switch.

VOLUME CONTROL.— The volume control is associated with a variable impedance transformer inside the unit. As the knob is rotated, the electrical energy passing through the transformer to the loudspeaker is increased and the volume or sound output of the loudspeaker increases correspondingly. The volume control has no effect on the volume of the signal transmitted from the amplifier; thus, each unit in the system can control the incoming volume to the desired level.

DIMMER CONTROL.— The dimmer control controls all illumination of the unit. The signal lights (release, busy, and call) are off when the control knob is in the extreme counterclockwise position and are fully lighted for all other positions. The station designation lights are lighted for all positions of the control knob, and illumination increases as the knob is turned clockwise.

RELEASE LIGHT.— The release light is located under the release push button. When the release push button is in the depressed, or operated, position, the light will be out. When the release push button is in the nonoperated position, the light will be on.

BUSY LIGHT.— The busy light is lighted when a station selector switch is depressed and the station being called is busy. When the busy light is lighted, depress the release push button and restore the station selector switch and call later.

CALL LIGHT.— The call light is lighted when a station is being called by another station. The call light will remain lighted until the calling station releases the called station's push button.

DESIGNATION LIGHTS.— The designation lights are located at each end of the station designation plate. These lights remain lighted at all times and illuminate the various stations engraved on the designation plate.

Amplifier

The amplifier is a three-stage, push-pull amplifier that uses transformer input and output coupling. The amplifier uses an internal ac power supply provided by an unregulated dual diode. The primary advantages from push-pull amplifier arrangements are high gain and low distortion. Transformer coupling not only allows the amplifier to be isolated, but also provides impedance matching between the input and the output.

OPERATION

To call a particular station, depress the station selector push button for that station, depress the talk switch, and speak directly into the reproducer grille. Release the talk switch to listen. When the conversation is completed, depress the release push button to restore the selector switch.

To answer a call from another station, simply listen to the conversation, and answer by depressing the talk switch; it is not necessary to operate the station selector switch. The call light on your unit will be illuminated to indicate your station is being called by another station. If the call light remains illuminated at the completion of your conversation, depress the talk switch and remind the calling station to depress the release push button.

The audio circuit between two stations is illustrated by the simplified schematic diagram in figure 7-29. The talk switches at both stations are shown in the restored (listen) position. When talk switch S26 at either station is depressed, the voice coil leads of the loudspeaker are shifted from terminals 7 and 13 of the secondary of T2 to input transformer T1 of the amplifier. Thus, talk relay K1 is operated, which applies plate voltage to the amplifier at the talking station and places the amplifier in the ready condition. The voice signals are amplified and applied to terminals 14 and 15 of T2 at the listening station and appear across terminal 7 of T2 and the moving contact of volume control S25, and from there to the loudspeaker. The amplifier in the listening unit is in standby.

The operation of two intercom stations in parallel is illustrated by the simplified schematic diagram in figure 7-29. The incoming speech from a remote station will be heard at both stations 3 and 3A, and replies can be made from either station. Either station can call a third station, but both stations cannot call at the same time. When talk switch S26 at station 3 is depressed to transmit a message, talk relay K1 at station 3A is operated to open the circuit to the loudspeaker and prevent acoustic feedback (not shown).

Incoming speech lines 1 and 1C of station 3 are connected to terminals 15 and 14, respectively, on transformer T2.

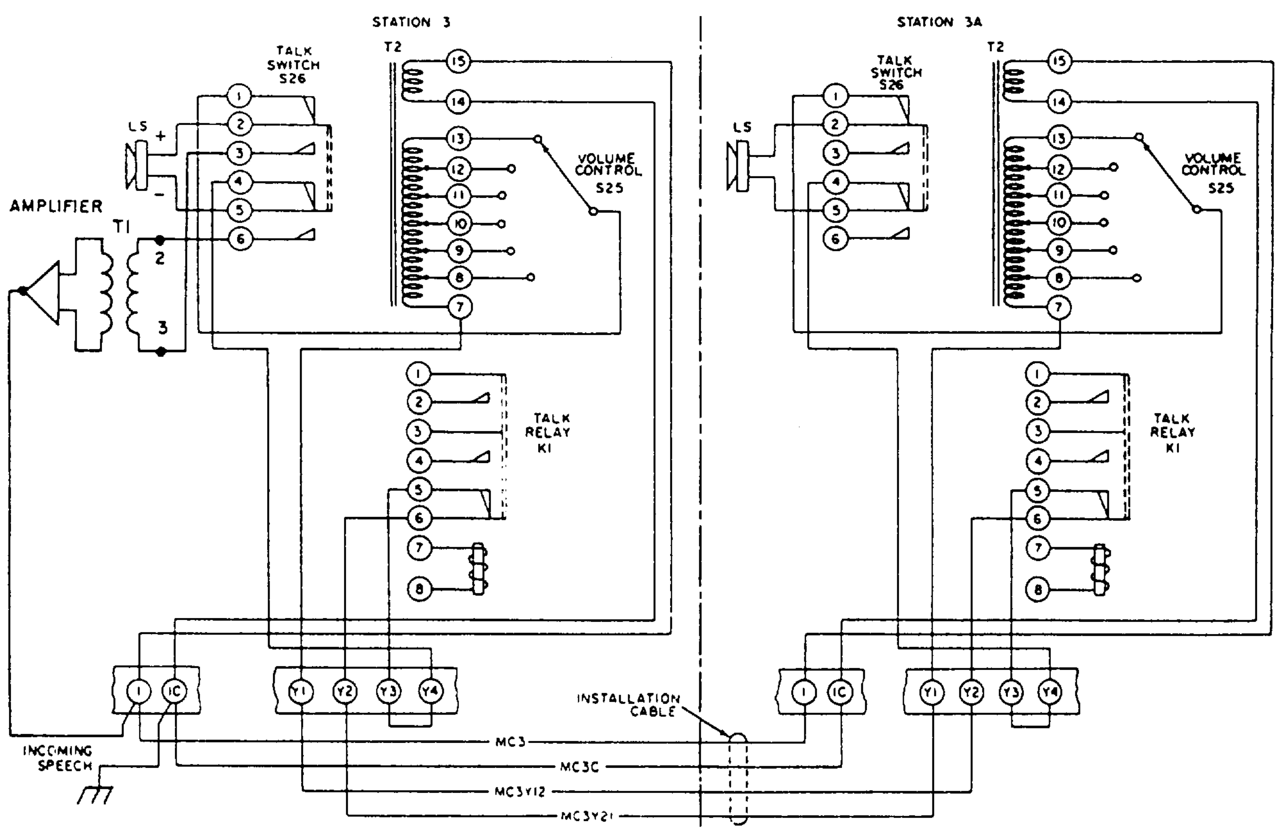


Figure 7-29.—Schematic diagram of two stations in parallel.

The 14-15 winding of T2 at both stations couples the incoming speech to the tapped windings of T2, which include volume controls S25. Thus, the incoming signals appear across terminal 7 of T2 and the moving contact of volume control S25 at both stations. These signal sources are connected in series addition through a closed loop containing both loudspeakers.

The circuit is from the arm of S25 at station 3, contact 1-2 of S26, the loudspeaker, contact 4-5 of S26, terminals Y4 and Y3, contact 5-6 of K1, terminal Y2 over line MC3Y21 to terminal Y1 of station 3A, terminal 7 of T2, the arm of S25, contact 1-2 of S26, the loudspeaker, contact 4-5 of S26, to terminals Y4-Y3, contact 5-6 of K1, terminal Y2, over line MC3Y12, terminal Y 1 in station 3, to complete the circuit at terminal 7 of T2.

The volume at both stations will be the same and can be controlled by either volume control S25. Both volume controls, however, should be kept at the same setting.

If talk relay K1 is operated at either station, the input to the audio circuit will be open for both stations.

MAINTENANCE

A test fixture is provided with the maintenance parts of the equipment to facilitate testing the intercom units. The test fixture is housed in a metal case and includes the necessary switches, resistors, and controls to perform all essential tests on a unit. It is provided with a line cord and plug for connection to the ship's 115-volt, 60-Hz power supply, and suitable female connectors for attaching it to the rear of the unit under test. The front cover contains 11 double-pole, double-throw (DPDT) test switches, S201 through S211, a single-pole, single-throw (SPST) call lamp test switch, S212, an SPST talk test switch, S213, a DPDT polarity test switch, S214, and an indicator lamp, I201. A wiring diagram of a test fixture is illustrated in figure 7-30.

To use the test fixture, remove the intercom unit to be tested from its case. Attach the test fixture to the rear of the unit by plugging it into the unit. Connect the line cord and plug to the ship's 115-volt, 60-Hz power. On the test fixture, operate talk switch S213 to the OFF position and the 11 test switches, S201 through S211, to the STANDBY position. On the unit under test, depress release push button S1, turn volume control S25 and dimmer control S27 to the extreme clockwise positions, and connect a microphone or handset into microphone jack J6.

Polarity Test

To test the polarity of the unit, operate polarity test switch S214 (fig. 7-30) to the OK WHEN LIT position (not shown). Indicator lamp 1210 should light with full intensity if the polarity is correct. Now operate polarity test switch S214 to the REVERSED position (not shown). The indicator lamp should go out if the polarity is not correct. The lamp may glow faintly, but it is not important. The polarity test checks the polarity of the line and signal voltage windings (terminals 10-11 and 8-9, respectively) of the power transformer, T3.

Call Lamp Test

To test the call lamp of the unit, operate call lamp test switch S212 on the test fixture. Call lamp 12 on the unit under test should be lighted.

Amplifier and Reproducer Test

To test the amplifier and reproducer, depress the talk switch microphone and talk into the microphone. The talker should hear his/her voice clearly through the reproducer. Rotate volume control knob S25 on the unit under test while talking into the microphone, and observe the effect on the output volume. Now place the microphone close to the reproducer. A microphone feedback should be observed when the volume control is in the full-volume position as well as at one step below full volume. This test provides a rough indication of the amplifier gain, power output, and the general performance of the entire unit, except for the signaling circuits.

Station Selector Circuit Test

On the test fixture (fig. 7-30), operate talk test switch S213 to the TALK position with the microphone reasonably close to the reproducer to produce a microphonics howl. Reduce the volume control to the minimum position at which the howl can still be obtained by moving the microphone as close to the reproducer as required. This position will produce the minimum objectionable howl during the subsequent station selector circuit tests.

When test switch S201 is in the TEST position, it places a short circuit across terminal 1 and 1C to interrupt the microphonics howl.

On the unit under test, depress station selector push button S2 (adjacent to release push button S1). On the test fixture, operate test switch S202 to the STANDBY

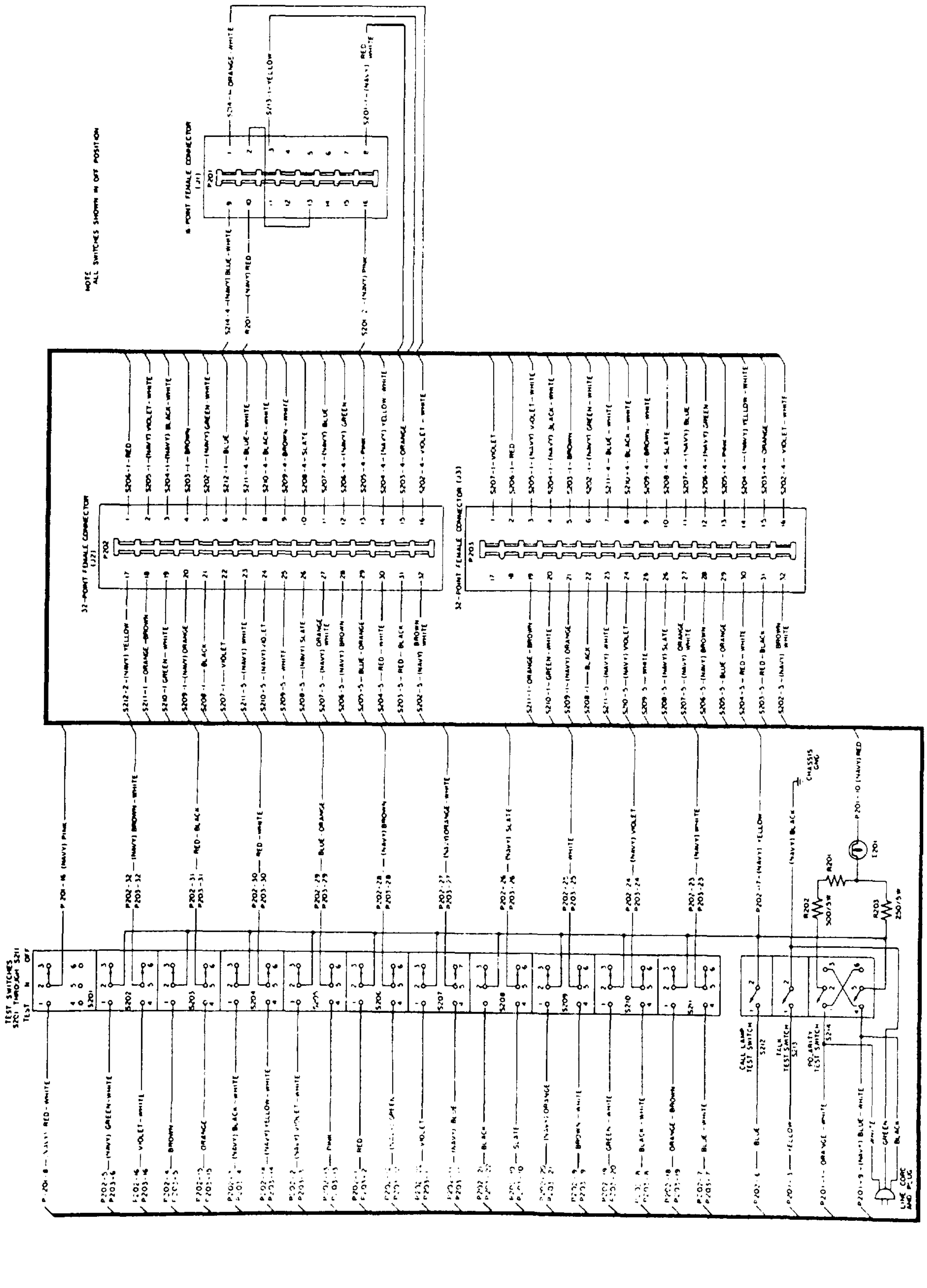


Figure 7-30.—Wiring diagram of test fixture for LS-433A/SIC.

position and depress release push button S 1 on the unit under test. This test checks the continuity between terminals 2 and 2C through switch S2U and busy relay K2 to the line winding terminals 14 and 15 of transformer T2.

Similarly, on the unit under test, depress the remaining station selector push buttons, S3 through S11, using the corresponding test switches, S203 through S211, on the test fixture for each test. This test checks the continuity of the various audio circuits. If the unit under test is provided with facilities for originating calls to 20 stations, repeat the foregoing tests, using the second row of station selector pushbuttons, S12 through S21.

Signal Circuit Test

On the test fixture (fig. 7-30), operate talk test switch S213 to the OFF position and the 11 test switches, S201 through S211, to the STANDBY position. On the unit under test, depress release push button S1 for the subsequent signal circuit tests.

On the test fixture, operate test switch S202 to the TEST position, and on the unit under test, depress station selector push button S2. Busy lamp I1 should light. On the unit under test, depress release pushbutton S1, and again depress station selector switch S2. Busy lamp I1 should go out and again light. Repeat this test several times in rapid succession. On the test fixture, restore test switch S201 to the STANDBY position, and on the unit under test, depress release push button S1.

When test switch S202 on the test fixture is operated to the TEST position, it makes station 2 busy by connecting terminal 2X to terminal XX. When station selector push button S2 on the unit under test is depressed to select station 2, it checks the busy circuit through lower switch assembly S2L, busy relay K2, latchbar switch S23, and associated wiring. It also checks the operation of upper switch assembly S2U and associated wiring.

Test the remaining push buttons by operating first the test switches, S204 through S211, to the TEST position on the test fixture, and then depressing the corresponding station selector push buttons, S4 through S11, on the unit under test. If the unit under test is a 20-station type, repeat the foregoing tests, using the second row of station selector pushbuttons, S12 through S21.

The manufacturer's technical manual furnished with the equipment installed in your ship contains more detailed information concerning the operation, repair, and maintenance of intercommunicating units.

INTERCOMMUNICATING UNITS LS-518/SIC AND LS-519/SIC

The N-518/SIC and LS-519/SIC intercoms (fig. 7-3 1) are 10-station and 20-station units, respectively. Both are fully transistorized intercoms that operate in much the same way as the older 433A and 434A types (refer to the overall functional diagram, fig. 7-32). The darkened solid line in this figure shows that the audio from the calling loudspeaker is amplified and transmitted via the station selector switches to the called station. The darkened broken line shows that the audio from the calling station goes into the speaker of the local

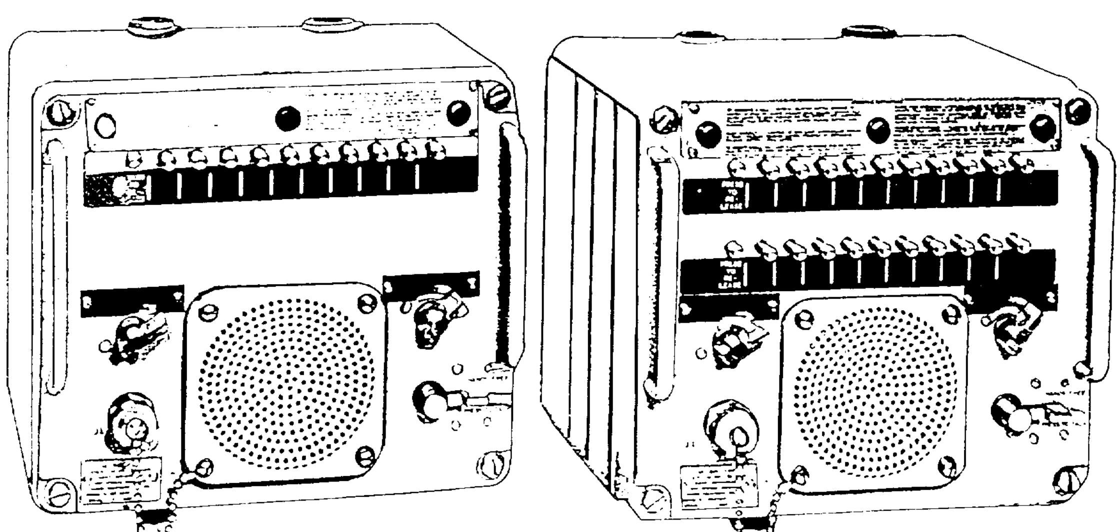


Figure 7-31.—Intercommunicating units, types LS-518/SIC and LS519/SIC.

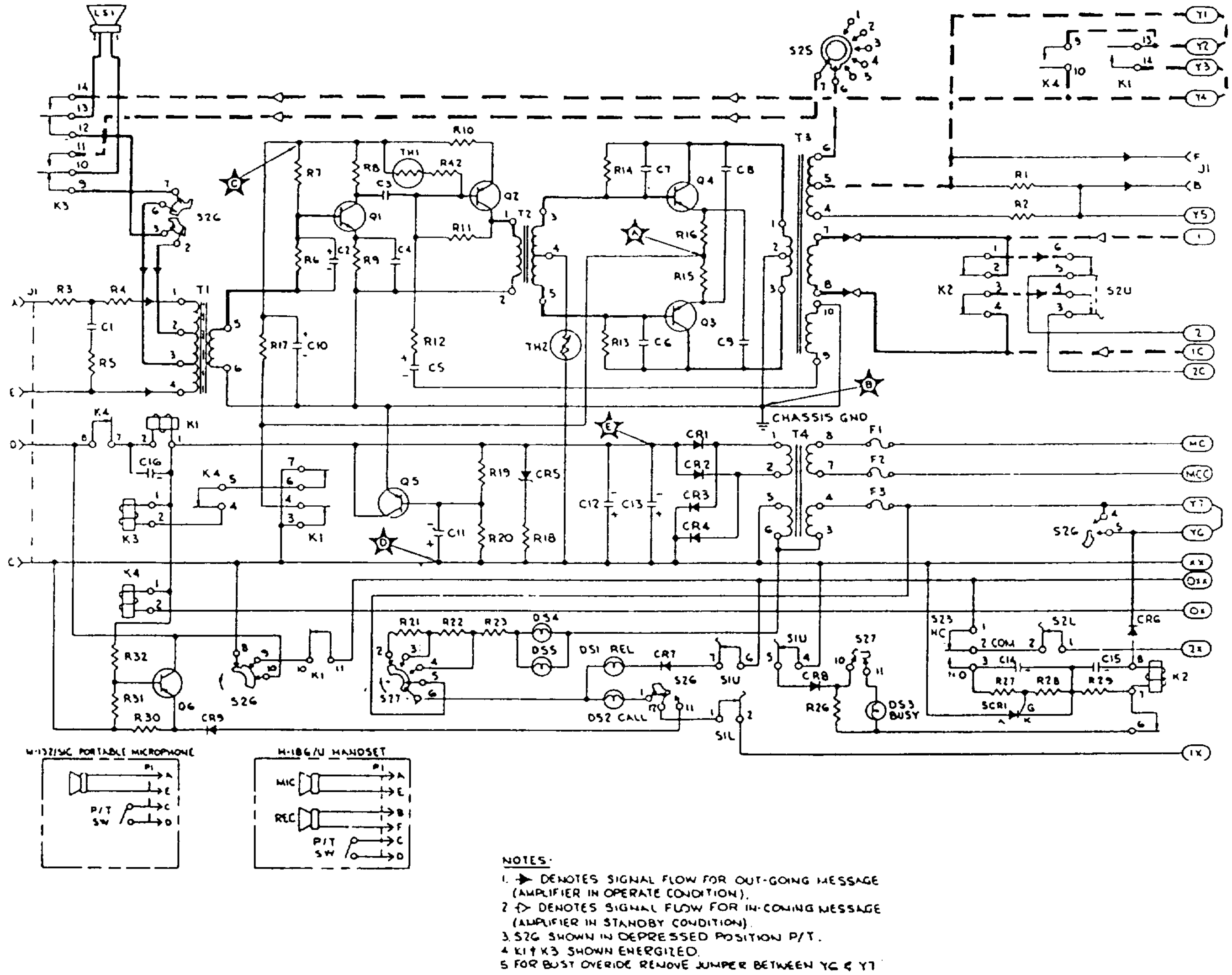


Figure 7-32.—Overall functional diagram.

called station, via output transformer T3, volume control S25, and relay contacts K1, K4, and K3.

The main differences between the older intercoms and the fully transistorized units concern the connection of a remote loudspeaker (model S-223) and the addition of a hands-free position to the press-to-talk switch. Connecting the loudspeaker calls for some minor wiring changes, such as cutting the leads on the switch assembly. Complete instructions for connecting the loudspeaker are contained in the manufacturer's technical manual. When the press-to-talk switch is in the hands-free position, the calling station controls the transmitting or receiving function; the receiving station need not press the switch to talk.

INTEGRATED INTERCOMMUNICATION SYSTEM

The integrated intercommunication announcing system is installed in submarines to provide the services of both central amplifiers and intercommunication systems. The system has the capablitiy for the transmission of orders, information, alarms, and selected station-to-station calls. The modes of operation it provides are as follows:

1. One-way broadcast of orders and information to select areas of the submarine or to the entire submarine.
2. Group announcing systems for intercommunication between stations performing common or related functions.

3. Two-way intercommunication between selected stations.
4. Alarm signals that may be broadcast over the general announcing system.
5. An emergency reporting system providing for the one-way communication of emergency reports from any compartment in the submarine to selected areas.
6. An escape trunk communication system that may be interconnected to selected stations; that, in an emergency, may be disconnected from the ship communication system and operating on its own auxiliary storage battery supply; and that may be used for communication between the escape trunk and adjacent compartments.
7. A system for use in the sonar control room that allows the sonar evaluator to break in on a sonar operator for communication purposes.
8. A portable loudspeaker control unit that maybe connected to the ship control unit extension cable for use in communicating from the deck watch to the control room when the ship is at anchor or in port. The portable unit may also be used on the general amounting system.

PUBLIC ADDRESS SETS

Public address sets are used at fleet landings and in amphibious operations to direct the movement of personnel, vehicles, and small boats; to communicate between ships and small boats; and to address personnel aboard ship where high noise levels are present or where the installed announcing system is inoperative or impractical. They are also used for entertainment and such functions as church services, wardroom and ready room briefings, change-of-command and other ceremonies, and personnel training. The two types of public address sets are the electronic megaphone type and the portable amplifier or lectern type.

PUBLIC ADDRESS SET AN/PIC-2

The AN/PIC-2 is an electronic megaphone-type public address set designed to perform under extremes of temperature and high humidity. The set consists of a loudspeaker horn, a microphone, a transistor amplifier assembly, a driver unit, eight D-size batteries, and a pistol-grip handle with a press-to-talk switch, battery selector switch, and external battery connector. All components are housed in one assembly (fig. 7-33). A 15-foot external power cable is provided for connecting

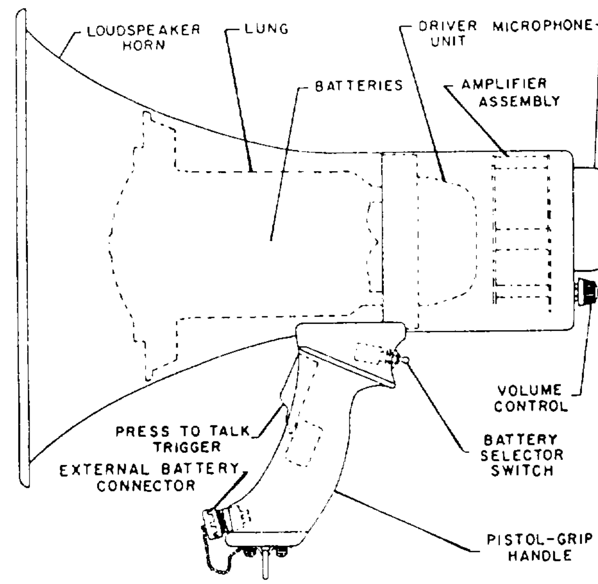


Figure 7-33.—AN/PIC-2 public address set.

the set to an external 12-volt battery when desired. The driver unit, microphone, amplifier enclosure, and battery enclosure are watertight.

To operate the set, put the battery selector switch to the INT. position (or to the EXT. position if operation is to be from an external battery). Grasp the pistol-grip handle with one hand, raise the unit so that the rubber microphone is almost touching the mouth, and direct the horn in the direction it is desired to communicate. Press the press-to-talk switch and speak directly into the microphone in a strong voice. Release the press-to-talk switch when the message is completed. The set is specially designed to eliminate acoustic feedback to the extent possible. Acoustic feedback may occur, however, if the horn is directed toward a reflecting surface, such as a deck or bulkhead. When using the set below decks, back the volume control knob off until feedback stops, and then advance it gradually to a point where maximum volume without feedback is obtained.

Amplifier Circuit

The transistor amplifier is a three-stage, transformer-coupled, push-pull type. It consists of volume control R1, input transistor Q1, interstage coupling transformer T2, push-pull power transistors Q3 and Q4, and output inductor L1.

DC Power Circuits

The 12-volt dc supply is selected from either the internal or external batteries by battery selector switch

S2. Press-to-talk switch S1 supplies dc power to the amplifier only while the switch is held closed.

The current drain is very small when S1 is closed and no signal is applied to the microphone. The current is maximum when the loudest signal is being amplified, as the collector current of the output stage varies with the strength of the amplified signal.

Microphone and Loudspeaker Assemblies

The Mk 1 magnetic microphone has an impedance of approximately 150 ohms. The microphone output is applied to transistor Q1 through volume control R1 and capacitor C1. A selected portion of the sound radiated to the rear by the loudspeaker horn acts on the back of the microphone diaphragm. This sound is phased so as to reduce acoustic feedback

Loudspeaker LS1 is a moving-coil, permanent-magnet type. Amplifier output signals actuate the voice coil and diaphragm, and the resulting sound waves are amplified and directed by the loudspeaker horn.

Maintenance

Preventive maintenance consists of replacing batteries, routine cleaning, and inspections. When the batteries are replaced, inspect the battery contact springs and clean them if necessary. If the springs are badly corroded, they should be replaced. Keep the external power cable free of dirt and corrosion. Clean the spring clips with sandpaper and apply a thin coat of petrolatum to reduce corrosion. Inspect the connector and clean it if necessary.

Periodically check the microphone housing. Keep the opening to the microphone free of dust, dirt, oil, grease, salt crystals, or other foreign matter. Salt crystals left by the evaporation of salt water and spray should be dissolved and rinsed away with fresh water, and then the parts should be dried with a soft cloth.

Check the inside of the pistol-grip handle occasionally. Remove the handle cover and inspect the switch contacts. Clean if necessary.

The manufacturer's technical manual contains detailed instructions for troubleshooting and repairing the set. All components are designed for easy replacement.

PUBLIC ADDRESS SET, LECTERN TYPE

Modern Navy ships are provided with the lectern-type public address set. This set (fig, 7-34) is a portable self-contained unit capable of reproducing sound for entertainment or dissemination of information. The set consists of an illuminated reading counter with a removable unidirectional dynamic microphone, a transistorized amplifier and controls, an extended range loudspeaker, a battery meter, and jacks for microphones, record player, tape recorder, and hvo external speakers. Power to operate the set is provided either by the self-contained dry battery, or an external 115-volt ac supply.

As an IC Electrician, you may be assigned the responsibility for setting up and checking out public address sets. To allow time for any minor adjustments or repairs that maybe required, always check the set or system well in advance of the time it is to be used.

SUMMARY

In this chapter, we have discussed how amplified voice systems are used to amplify and transmit both verbal announcements and alarm signals on board ship. We have identified the various announcing systems by their circuit designations.

We have explained how the various types of amplified voice systems operate and how to maintain the systems. Also, we have described the additional sound equipment used with the systems and the procedures for maintaining this equipment.

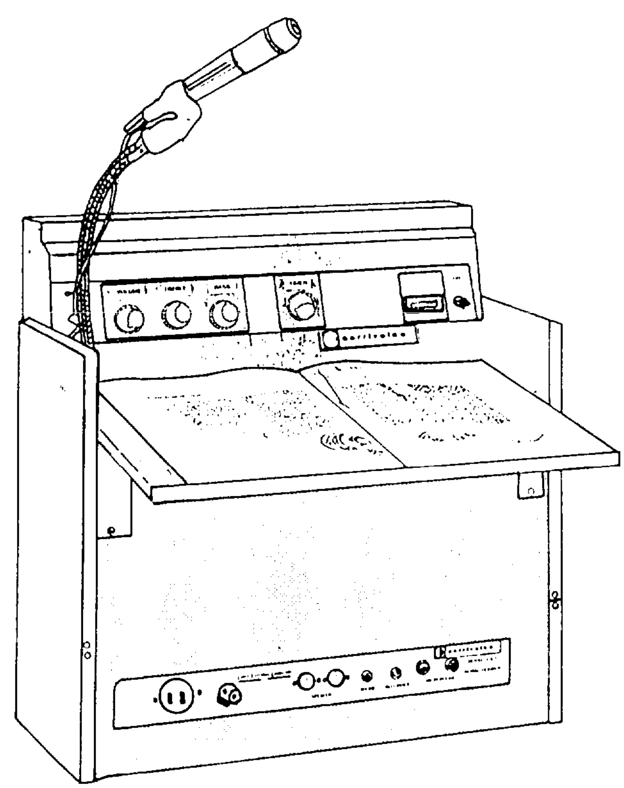


Figure 7-34.—Public address set, lecturn type.

CHAPTER 8

SHIP'S ENTERTAINMENT SYSTEMS

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

- *Describe the purpose of the various ship's entertainment systems installed on Navy ships.*
- *Describe a ship's entertainment loudspeaker*
- *Describe the AN/SIH-7 audio entertainment system.*
- *Describe the closed-circuit television system.*
- *Describe the television entertainment system.*
- *Describe the audiovisual entertainment system.*

INTRODUCTION

The entertainment systems used aboard Navy ships provide a wide variety of services to the crew. These services include entertainment and training. The ship's entertainment system also provides a medium whereby the commanding officer or commanding officer's representative can address the crew in an informal manner.

There are three entertainment systems used in the Navy today, They are (1) an audio entertainment system, (2) a television entertainment system, and (3) an audiovisual entertainment system.

AUDIO ENTERTAINMENT SYSTEM

An audio entertainment system provides a means of transmitting recorded and radio programs and voice announcements specifically for the entertainment of ship's personnel. A typical system is made up of tape recorders, record players, AM/FM radio receivers, microphones, amplifiers, and loudspeakers, A common audio entertainment system installed on board Navy ships is the AN/SIH-7.

AN/SIH-7

The AN/SIH-7 system is housed in a single cabinet and is designed for foredeck mounting against a bulkhead. The cabinet (fig. 8-1) contains two

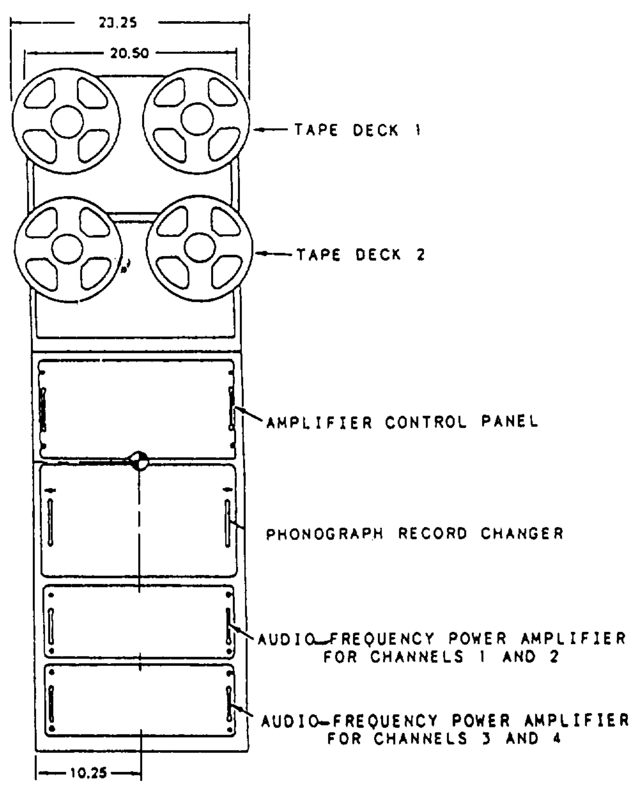


Figure 8-1.—AN/SIH-7.

magnetic tape recorder/reproducers, a phonograph record changer, an amplifier control panel, and two audio-frequency power amplifiers. The system distributes programs on four independent channels, which are selectable at all ship's entertainment loudspeakers. These programs are produced locally from the system and externally from remote sources.

Local program sources for the four channels are from the two tape recorders/reproducers and the phongraph changer. Remote program sources include two separate AM/FM radio transmitters and a remote microphone, permanently wired into the system. A microphone input jack, located on the front of the control panel, is also used as an input to the channels. This jack permits voice announcements to be made over any one of the four channels individually or over all four channels simultaneously. When this feature is used, it overrides any other signal or signals being distributed to the system.

Relays are installed in the system to provide for the muting of the system's loudspeakers when an alarm is transmitted over the general announcing system (circuit 1MC). These relays also provide for the attenuation of the system's loudspeakers during voice transmission over circuit 1MC.

The AN/SIH-7 system operates on 115-volt, 60-Hz, single-phase ac ship's service power.

Tape Recorders/Reproducers

The two magnetic tape recorders/reproducers contained in the control cabinet are identical in every respect. One tape recorder is designated TAPE 1 and is located at the top of the cabinet. The other tape recorder is designated TAPE 2 and is located directly below TAPE 1. TAPE 1 is a program source for channels 1 and 3. TAPE 2 is a program source for channels 2 and 4.

Each tape recorder is capable of playing and recording at two different speeds (7.5 and 3.75 inches per second [ips]), using either 7-inch or 10.5-inch standard tape reels, Each recorder can record quarter-track monaural in each tape direction and play back quarter-track and half-track monaural or commercial 4-track stereo tape recordings. Stereo playback is converted to monaural within the system. Each recorder contains all the mechanical components necessary for transporting tape and all the electronic components necessary for amplification equalization during recording and playback. Each tape recorder can record from any program source or from recorder to recorder, and will provide concurrent playback while recording.

The availability of two tape recorders/reproducers provides the ship's entertainment system operator with the capability for a variety of techniques. The operator can, for example, do the following:

- Duplicate(dub) from one tape to another
- Switch from one tape to another to maintain continuous recording
- Take material from one tape and put it on another tape while mixing microphone commentary into the program
- Edit a tape onto another by duplicating (dubbing) selected portions only
- Play a tape for ship's use while simultaneously duplicating the tape for the ship's library

NOTE: To use any of the exclusive rights of a copyright owner, without permission, is an infringement of the owner's copyright. These exclusive rights include copying, reproducing, printing, publishing, exhibiting, translating, and vending the copyrighted work or portions thereof and, in some instances, the oral delivery or performance of the work. In addition, the duplication of American Forces Radio and Television Services (AFRTS) or commercial reel-to-reel tapes is NOT authorized.

When a tape has been recorded, you can turn it over and record again in the other direction to double the amount of playing time. However, you should remember that when a tape has been recorded in both directions you cannot edit it by cutting and splicing one channel without disrupting material recorded in the other direction.

Amplifier Control Panel

The amplifier control panel (fig. 8-2) is located below TAPE 2. The panel contains the system power section, a mike control section, two record control sections, four channel control sections, a program monitor control section, and an output level monitor section.

SYSTEM POWER SECTION.— The system power section is located on the lower right side of the

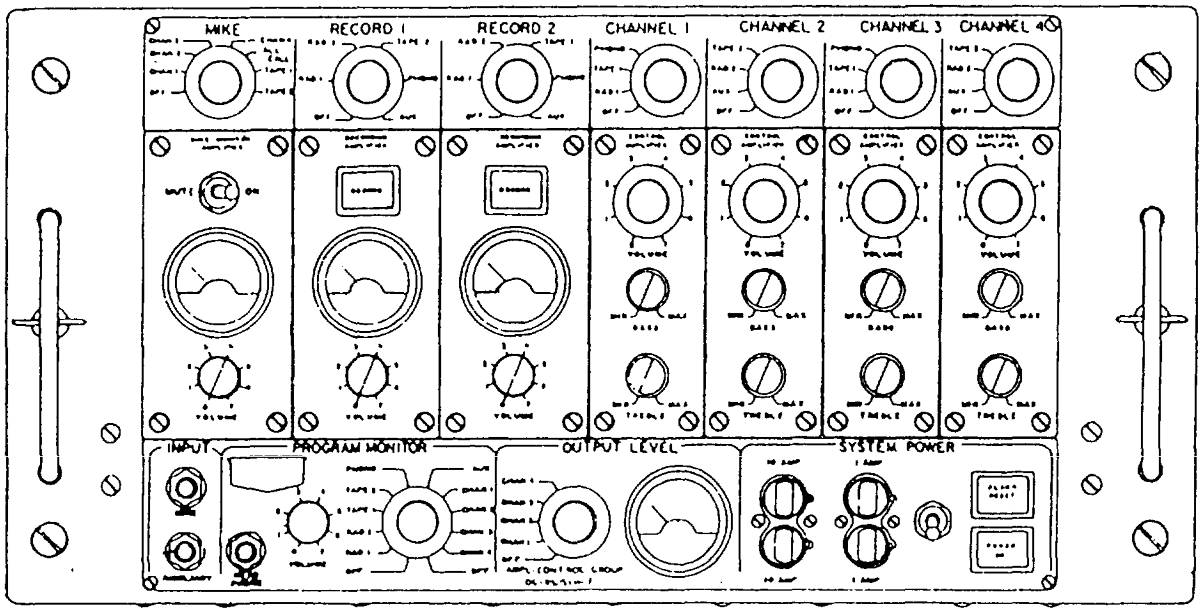


Figure 8-2.—Amplifier control panel.

panel. This section contains the switch for energizing the system, a power-on indicator lamp, an alarm reset indicator lamp, and four blown fuse indicators.

When the power-on switch is in the up position, the system will be energized and the power-on indicator lamp will be lighted.

When an alarm is transmitted over circuit 1MC, the alarm reset indicator lamp will light and will remain lighted after the alarm has ceased. The entire system will automatically be deactivated whenever an alarm condition exists. The alarm reset indicator lamp must be pressed to automatically reactivate the system following an alarm condition.

The two 10-amp fuses are main system power fuses, and the two 1-amp fuses are control power fuses.

MIKE CONTROL SECTION.— The mike control section is located on the left side of the panel. This section contains a microphone input jack, a selector switch to select routing of the microphone signal, a mute-on switch, a volume control, and a volume meter. Low- and medium-impedance microphones are used with the system. When using this feature, you should turn off all local loudspeakers and keep the surrounding noise to a minimum.

The mute-on switch disables the microphone signal when the microphone is not in use. This switch is also used to adjust the output volume of the microphone before using it. To adjust the output volume, speak into the mike and adjust the volume control until the signal just peaks into the red region of the volume meter.

To interrupt a program using a microphone, switch the microphone selector to that channel. Switch the channel program selector switch to an unused position and set the channel volume control to the minimum position. To add voice to a channel program, switch the mike selector to that channel, The voice signal will mix equally with the other program material. To fade out the normal program, turn the channel volume control down.

To add voice to a tape recording, set the microphone selector switch to the desired tape. Voice and program can now be mixed and faded together as described in channel operation.

The microphone ALL CALL selector position is a special function that interrupts all channels simultaneously and allows only microphone voice announcements to be made over the system.

RECORD CONTROL SECTIONS.— These two sections are located in the upper portion of the panel to the right of the mike control section. One section is for TAPE 1 and the other section is for TAPE 2. Each section contains a selector switch to select the program source for the recording, a record indicating button, a record volume level control, and a record volume level meter.

To set the correct recording volume level for the tape, press and hold the record indicating button down and rotate the record volume level control until the record volume level meter just peaks into the red region. Then, release the record button. The system is now ready to make a recording.

To record a program, set the selector switch to the program source desired, press the record button, and then turn on the tape recorder. During recording, you should monitor the tape output using the program monitor. By monitoring the tape, you will be able to quickly recognize a defective tape or recording process. You should also switch the monitor selector between the program source and tape output to see that sound level and quality are approximately equal. To stop recording, turn off the tape recorder and return the selector switch to the OFF position.

When recording a tape, you have a choice of two tape speeds: the 7.5 ips and the 3.75 ips. The 7.5 ips tape speed provides the best fidelity and is recommended when recording from high-quality program sources. However, the 3.75 ips speed provides very accurate fidelity for most purposes, and twice as much program can be recorded on any given reel of tape. After recording a tape, write the speed at which the recording was made on the tape reel box.

CHANNEL CONTROL SECTIONS.— There are four channel control sections, one for each channel. They are located on the upper right side of the panel. Each section contains a program selector switch, a volume control, a bass control, and a treble control. When a channel is being used, the output volume is set as described in the output level monitor section. The bass and treble control for each channel are normally set at the mid position.

PROGRAM MONITOR CONTROL SECTION.— The program monitor control section is located on the lower left side of the panel. This section is used to check any program source before switching it out to one of the channels and to monitor the output of each of the four channels. This section contains a program monitor selector switch, a volume control, and a headset jack.

To monitor a program source, plug a headphone into the headphone jack, set the monitor selector switch to the program source, and adjust the volume control for a comfortable listening level. The volume control in this section only affects headphone volume. Each program source should be checked for distortion, noise, and other signs of malfunction before being switched out to the ship's entertainment loudspeakers.

To monitor any one of the four channels in use, plug in the headphone and set the selector switch to the desired channel.

OUTPUT LEVEL MONITOR SECTION.— This section is located on the lower center part of the panel. This section is used to set the volume output of each channel and to monitor the output of any of the four channels while they are in use. The section contains an output selector switch and a volume meter.

To set the output volume of a channel, use the volume control for that channel and the output selector switch and volume meter for the output level monitor. The correct setting for most programs is where the signal just peaks into the red region of the meter.

Phonograph Record Changer

The record changer is located behind the door directly below the amplifier control panel. The phonograph record changer is a precision unit incorporating a dynamically balanced arm, a heavy turntable, and other features to promote maximum fidelity and record life. It plays all standard records manually or automatically. In the automatic mode, it is capable of playing up to 11 records. The record changer can be operated either on its slides or closed in its rack. When it is operated at sea, the closed position is preferred. The record changer is used as a program source for channels 1 and 3.

To gain access to the record changer, you must loosen the two quick-release fasteners on the door. Then swing the door down, release the record changer, and pull it out on its slides until it locks in place.

Audio-Frequency Amplifiers

The two audio-frequency (AF) amplifiers are located in drawers directly below the phonograph record changer. The upper amplifier is used for channels 1 and 2, and the lower amplifier is used for channels 3 and 4. A power switch is located on the front of each amplifier drawer.

OPERATING TIPS

When the ship's entertainment system is operating, the following procedures should be followed:

- Never permit a program to peak into the red area of the volume output meter unnecessarily.
- Monitor the output levels of all four channels frequently. An increase could overload the amplifier and cause damage. A decrease could be caused by a short circuit or an amplifier malfunction.
- Monitor each program source routinely for distortion.
- Never permit a tape to run out unexpectedly, a needle to stick in a record groove, or distorted sound to be broadcast.
- Keep tape recorder/reproducer tape heads and guides clean.
- Keep phonograph needle and stylus clean, and play only clean unscratched records.

SHIP'S ENTERTAINMENT LOUDSPEAKERS

The type of loudspeaker used with the ship's entertainment system are the permanent-magnet, direct-radiator type. Each loudspeaker contains a volume control switch and a channel selector switch.

CLOSED-CIRCUIT TELEVISION

Television is a rapidly advancing area where IC Electricians are used. Closed-circuit television (CCTV) is receiving wide use throughout the Navy. So broad are the applications of television that a special enlisted code is assigned to the IC Electricians who maintain these systems.

BLACK-AND-WHITE TV

In comparing CCTV with commercial television, you will notice how nearly alike they are in operation. The major difference is the methods of transmitting the picture and sound. In CCTV, several methods of transmission are used to bring the signals from the camera to the receiver/monitor. These units may be physically connected using telephone or coaxial cables for short distances. For greater distances, or when numerous receivers/monitors are involved, transmission is normally accomplished through the same media as commercial transmission. This may be accomplished by using a standard transmitter on specially assigned frequencies. When a receiver is used, the receiver is generally a standard television receiver. The monitor is basically the same as the television receiver except that the set does not use a tuner or associated circuits.

TELEVISED INFORMATION

To understand how a TV system works, you must know what information is passed from the camera to the receiver. There are four basic kinds of information required:

- Video signal—This signal is the actual moment-to-moment information that tells the receiving set how light or dark each little spot in the picture should be. Unlike movies, in which an entire picture is flashed upon the screen every 1/24th of a second, TV pictures are built up, line by line (525 horizontal lines per picture) and spot by spot within each line (approximately 426 spots per line). In TV, 30 complete pictures are produced every second.
- Blanking signals—These signals tell the camera and the receiving set when no video signal should be present (such as between the end of one line and the beginning of the next).
- Sync signals—Sync (synchronizing) signals are required to tell the receiving set exactly when to begin each picture (vertical sync) and when to begin each line within that picture (horizontal sync).
- Audio signals—The audio is the sound, or audible, portion of the total TV presentation.

A block diagram of a standard home television system is shown in figure 8-3. There are three main divisions in the diagram. The top division represents the video or picture section of the transmitter. The central division represents the audio or sound section of the transmitter. The lower division represents the television receiver.

SYSTEM COMPONENTS

A CCTV system consists of three basic units. These basic units are the camera(s), or pickup unit(s), the control unit, and the monitor(s) (fig. 8-4).

Pickup Unit

A pickup unit, generally referred to as the camera, starts the sequence of events that occurs in the CCTV system. A lens in the camera focuses an image on a photosensitive (light-sensitive) tube. The type of lens is determined by the size of the scene to be televised. It maybe a normal, wide-angle, or telephoto lens. The size of the camera unit varies from small palm size mobile units to large units mounted on special platforms. One or more cameras may be connected into the system to receive the desired picture (video) and route it as an electronic signal to a control unit (fig. 8-4).

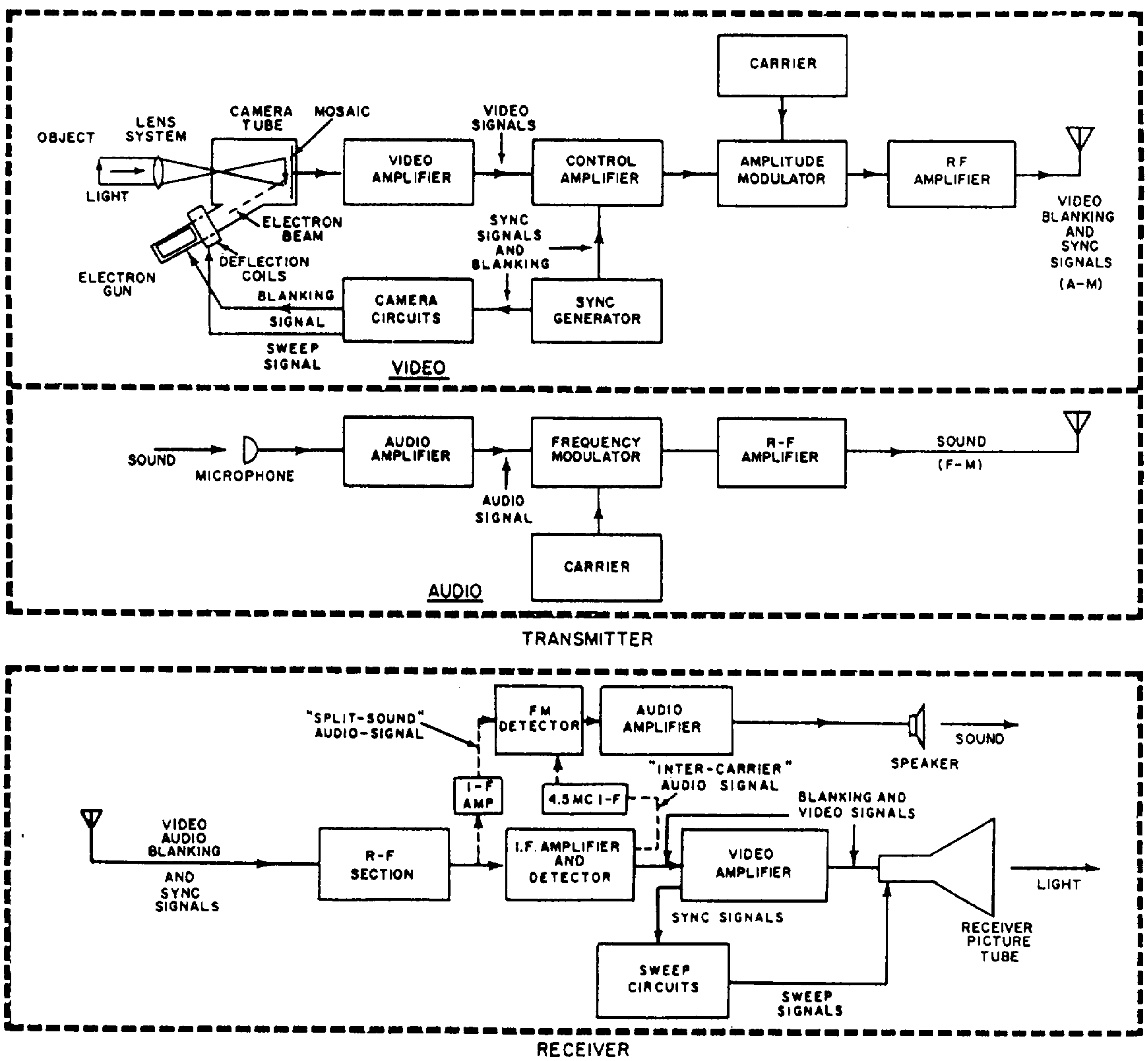


Figure 8-3.—Simplified block diagram of a commercial television.

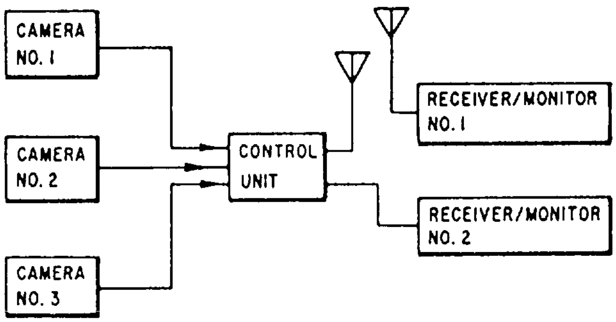


Figure 8-4.—CCTV simplified block diagram.

The camera tube provides a means of converting light, from an object on which the camera is focused, into electrical impulses. Light from the object is focused on the light-sensitive surface (called the mosaic or photoconductive material) in the camera tube by the lens system. The camera tube contains an electron gun, which generates and controls a stream of electrons. The gun directs the narrow stream of electrons in such a manner that it traverses (scans) the mosaic line by line. As the beam strikes a spot in the mosaic, it generates a small electrical impulse that corresponds to the lightness or darkness of that particular tiny portion of the image. The electrical impulses generated in this manner are sent to the video amplifier (fig. 8-3).

Control Unit

The control unit, as the name implies, is the heart of the system. This unit connects all the other units of the system together. Drive pulses are generated, and they develop the sweep and blanking signals required by the camera. Synchronizing and blanking pulses are supplied by the control unit to the receiver/monitor.

Video signals from the camera are amplified and distributed to the receiver/monitor. The output signals from the control unit contain vertical and horizontal blanking, sync, and video signals. The control unit consists of the following sections, shown in figure 8-3: video amplifier, control amplifier, carrier, amplitude modulator, radio-frequency (RF) amplifier, sync generator, and the audio controls.

Video amplifiers are designed to amplify a wide range of frequencies. The weak electrical impulses from the camera tube are built up by the video amplifier and fed to a control amplifier.

The control amplifier combines the video, sync, and blanking signals, all in proper sequence, into a single continuous output to the amplitude modulator.

Circuits in the sync generator produce synchronizing (sync) and blanking pulses. These pulses are applied to the control amplifier and become a part of the transmitted signal. Horizontal synchronization makes the horizontal scanning at the receiver occur at the same time as the horizontal scanning at the camera. Vertical synchronization makes the vertical scanning at the receiver keep in step with the vertical scanning at the camera.

Sync and blanking signals are also fed to the camera circuits, which develop the necessary control signals for the electron gun and the sweep voltages for the deflection coils (both horizontal and vertical).

In the carrier, the principal circuit is an oscillator designed to produce a steady, continuous RF signal. Its frequency is fixed and designated by appropriate civil authority for the TV station in which it is used.

In the amplitude modulator, the carrier signal is modulated by the video, sync, and blanking pulses. The composite (total) signal is then amplified by the R amplifier and fed to the antenna for radiation into space.

The sound portion of the television signal is transmitted by a frequency modulated R carrier. The sounds are picked up by a microphone, amplified by the audio amplifier, and fed to the frequency modulator section. The sound earner frequency is varied according to the frequency of the audio signal being picked up by the microphone. The frequency modulated signal is then amplified by an R power amplifier. Then it is fed to the antenna for radiation into space, or into a cable system installed throughout the ship.

Receiver/Monitor

The picture-producing unit is commonly referred to as the receiver/monitor unit. The receiver and the monitor (fig. 8-4) differ basically only in the circuits contained in each unit. The media of transmission between the receiver and monitor units are different. This difference requires the receiver to employ additional circuits. (The media employed for the receiver is radio waves, while the media for the monitor is normally cables.) The standard TV receiver contains the same circuits as the monitor, and, in addition, contains the antenna system, tuner, R amplifiers, and intermediate frequency (IF) amplifiers to receive the transmitted signals.

After the IF stage of amplification, the receiver and monitor units are basically the same. Power supplies provide the various voltages needed for the circuits. Audio amplification is basically the same as that used in standard radio receivers. Synchronization is accomplished through the use of a sync circuit with horizontal and vertical sync signals used to control the horizontal and vertical sweep circuits. Video amplification is accomplished through the various video circuits.

SCANNING

It is easily seen that a picture printed from a photo engraving is made up of a large number of dots. A good example of this is a halftone picture in a newspaper. The lightness or darkness of the picture is determined by the amount of separation between the individual dots. The dots are the elements that make up the picture.

A television picture is formed in a similar way. However, there is one very important difference. In the picture made from the photoengraving, all parts of the picture are seen at the same time. In a television picture, the elements are presented individually, one after the other. They are seen in such quick succession that the viewer sees the picture as a whole. To transmit images in this way, it is necessary to use a system of scanning. The image is swept by an electron beam in a systematic manner. During a set period of time all parts of the image are swept by the electron beam. Likewise, in the receiver, where the image is reconstructed, a similar system of scanning is used.

The principle of scanning can be illustrated by the following example. Assume that you have a flashlight that can produce a very narrow beam of light and that you wish to view a picture on the wall of a dark room. Obviously, because of the narrow beam, you must view a portion of the picture at a time. If you can manipulate the light very fast, you can view the picture in the same manner as the picture would be produced in television. To do this, you would start at the upper left-hand comer of the picture and move the beam rapidly to the right along the top of the picture. When the right-hand edge of the picture is reached, turn off the beam, and swing it rapidly to the left and one beam width lower. Turn the light on and again sweep it rapidly to the right. Each sweep of the light is a scan line. In commercial television there are 525 lines to a picture. Thus, when you reach the bottom right-hand comer of the picture, you have completed a frame. Turn the light off and move it to the upper left-hand corner of the picture to start the scanning process over again. The illuminated area scanned by the electron beam is called the RASTER. On the receiving TV tube, it is the area that becomes bright when the brilliance control is turned up with no signal.

In camera tubes and TV picture tubes, an electron beam of small diameter is formed and given the desired velocity by the electron gun, which is located in the neck of the tube. The electron gun in a picture tube or camera tube are the same and correspend to the movement of the flashlight. Deflection (sweeping) of the electron beam across the mosaic/photo-conductive material is accomplished by the deflection coils. These are positioned around the neck of the tube.

A simplified illustration of scanning is shown in figure 8-5. The beam begins its scan at the upper left-hand comer and moves horizontally along line 1 toward the right. The globules shown are exaggerated in size to simplify the illustration. All of the globules in line 1 are in the bright part. Therefore, they have lost the same number of electrons and accumulated uniform positive charges. The charges are neutralized as the beam sweeps across the globules. As this occurs, a relatively steady current flows from the metal coating of the plate down through a load resistor, which will be discussed later in this chapter. The same situation exists while line 2 is being scanned.

A part of the image is located in line 3, and there is not a steady flow of current through the load resistor as the beam traverses this line. The current flow is steady until the fourth globule is reached. From 4 through 13 the globules have been charged slightly. The discharge current through the load resistor is less when the beam sweeps across the black globules. Beginning with globule 14, the output current increases again. In line 4, the current through the load resistor is steady until the beam reaches globule 4. It then decreases until the beam reaches globule 5. The current through the load resistor then increases and remains steady until the beam reaches globule 13. The current then decreases while the beam is on globule 13 and increases when the beam strikes globule 14. The current through the load resistor then remains steady through the rest of line 4.

When the electron beam scans line 5, the current through the load resistor is steady while the beam scans globules 1, 2, and 3. It decreases for globule 4. It comes back to the steady value for globule 5, It

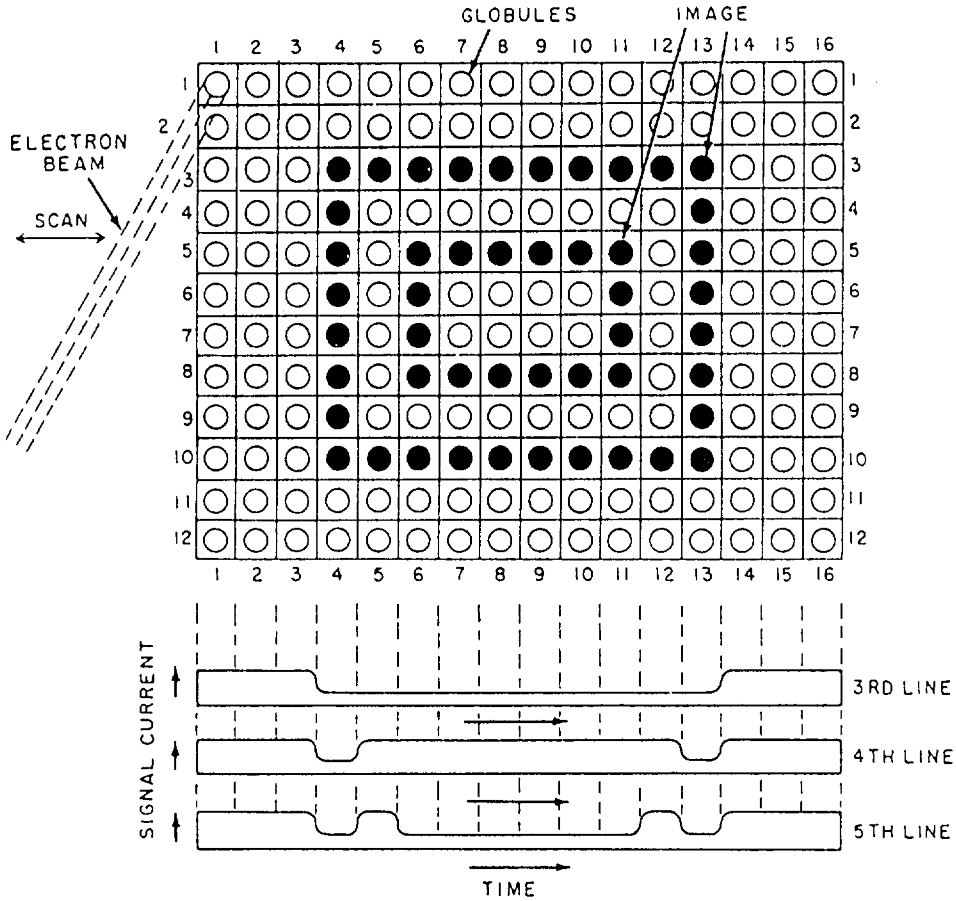


Figure 8-5.—Simplified illustration of scanning.

decreases again for globules 6 through 11. Then it goes to a steady value for globule 12. It decreases again for globule 13, and then it returns to the steady value for the rest of line 5. The relative strengths of the signal currents are shown at the bottom of fig. 8-5.

In a practical camera tube, the globules are extremely small and close together, so the picture will have great detail. Therefore, there must be many changes in current during the course of a single scan. The flow of the tiny pulses of current through a resistor develops signal voltages at the input of the video amplifier. For all of these signal voltages to be passed through the amplifier, the amplifier must be capable of passing a wide band of frequencies.

FLICKER

The eye retains an image for a fraction of a second (about 1/15 second) after the image is formed on the retina. This characteristic of the eye is used in motion pictures and television. Actually, it is because of this characteristic that it is possible to have motion pictures or television.

Motion-picture films are made up of a series of individual pictures (frames) that are shown on the screen in quick succession. The illusion of motion comes because the figures are displaced slightly in succeeding frames. If enough frames are shown per second, the figures appear to move because of the rapid sequence of the frames. At approximately 15 frames per second the motion appears continuous, but there is a pronounced flicker. At 24 frames per second, some flicker is present, but it is much less objectionable than at 15 frames per second. To further reduce the flicker, a special shutter arrangement is used. The shutter cuts off the light from the screen while a new frame is moved into position, It also cuts off the light from the screen once more while the picture frame is stationary. Thus, the shutter divides the presentation of every frame into two equal time intervals. This has essentially the same effect as increasing the frame frequency to 48 frames per second.

In television, similar problems are encountered. To keep flicker from becoming objectionable, 30 complete frames per second are shown. Flicker is further reduced by interlaced scanning. This has essentially the same effect as increasing the frame frequency to 60 frames per second. The horizontal scanning speed and bandpass requirements of the composite TV signal remain the same.

Interlaced scanning is illustrated in figure 8-6. Bandpass considerations, the problems of synchronization, and the necessity for detail lead to the choice of 525 horizontal scanning lines per frame. To reduce flicker by interlaced scanning, the electron beam scans the odd-numbered lines first and then the even-numbered lines. Thus, two scans (fields) are necessary to complete one frame. For example, as shown in figure 8-6, the sweep for the first field begins on the left side of line 1. The beam moves across the image plate at a slight downward angle (pulled downward by the vertical deflection coils). At the end of the line, the electron beam is blanked out during the retrace to the left side of line 3. This process is continued until the middle of line 525 is reached. Therefore, 262.5 lines are scanned in the first field. When the beam reaches the middle of the last line, it is blanked out and returned to the middle of line 2 where the trace for the second field starts. The even-numbered lines are scanned in sequence until the end of line 524 is reached. At that instant the beam is blanked out and

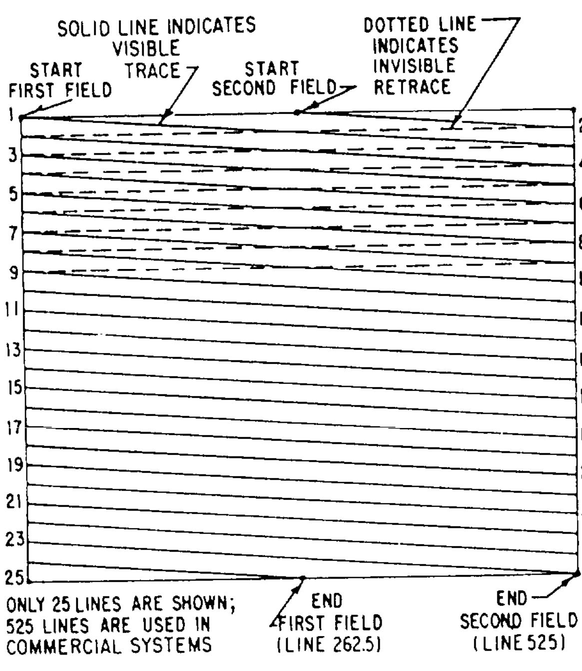


Figure 8-6.—Interlaced scanning.

returned to the beginning of line 1, and the whole process is repeated.

Synchronizing and blanking signals are transmitted by the transmitter to keep the movement of the electron beams in the camera and picture tube in step. These signals also blank out the signals from the picture tube during the horizontal and vertical retrace periods.

Sequential scanning differs from interlace scanning in the method of moving the electron beam down the screen. The sequential system can be compared to reading a page of print. Each line is read in turn instead of every other line as in interlace scanning.

If 60 complete frames are scanned per second, flicker does not exist. However, unless the system has a very broad bandpass, resolution would decrease due to the high video frequencies (extremely fast changing current levels through the load resistor) being produced. The horizontal scanning speed would have to be doubled and would introduce other problems with extremely high frequencies.

COMPOSITE SIGNAL

Blanking signals are used in both the camera tube and the picture tube control circuits. These signals cut off the electron beam at the end of a horizontal scan line so that the return trace does not produce picture signals at the transmitter or receiver picture tube. Blanking signals are also used to cut off the vertical return trace following the scan of each field.

Superimposed on the blanking signals are the synchronizing signals. These signals trigger the vertical sweep circuits and synchronize the horizontal sweep circuits of the receiver/monitor. The horizontal sync signals trigger the horizontal sweep at the correct instant 15,750 times per second (the horizontal sweep frequency). The vertical sync signals trigger the vertical sweep at the correct instant 60 times a second. Figure 8-7 shows the composite signal that produces the scanning illustrated in figure 8-6.

The vertical sync pulses have a special serrated form (see fig. 8-8) preceded and followed by equalizing pulses to produce interlaced scanning. This also keeps the horizontal sweep locked in step during the vertical retrace period.

All television receivers must perform basically the same functions. They must select the desired carrier frequency. They must amplify the required band of

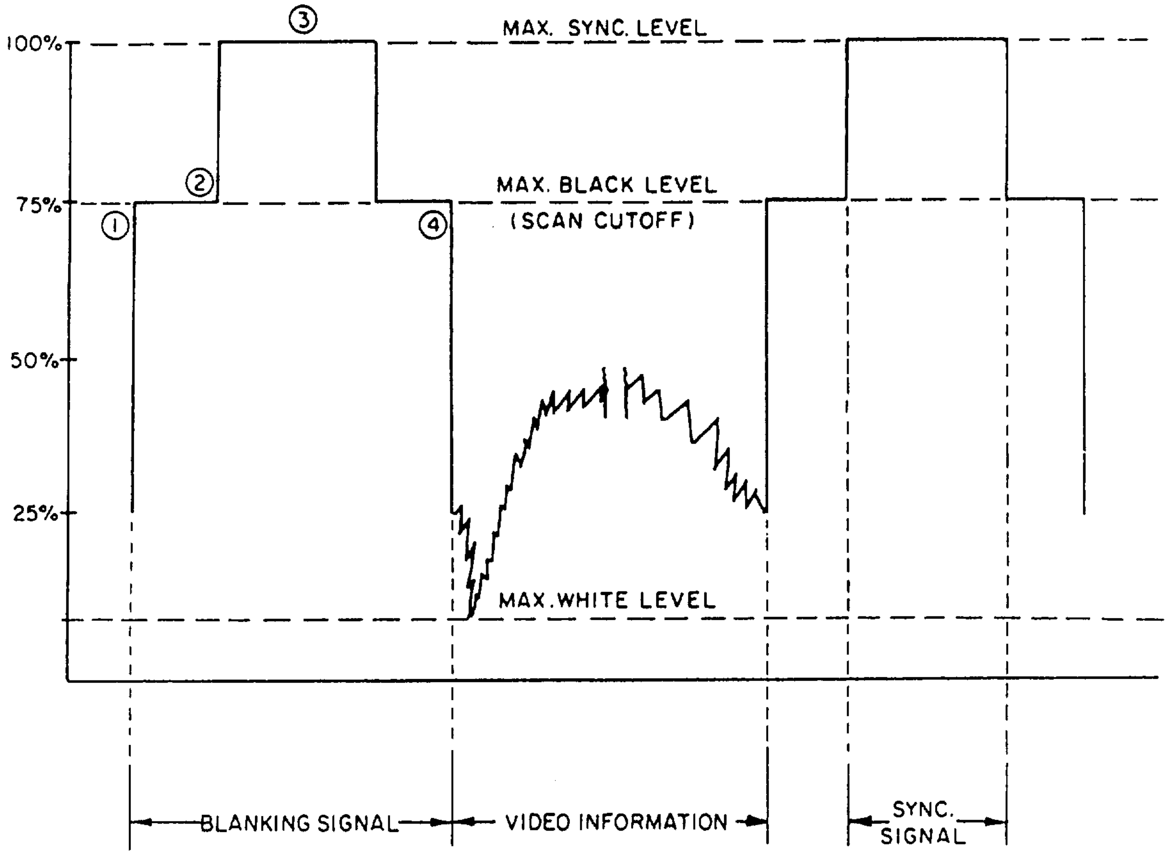


Figure 8-7.—Simplified synchronizing signal.

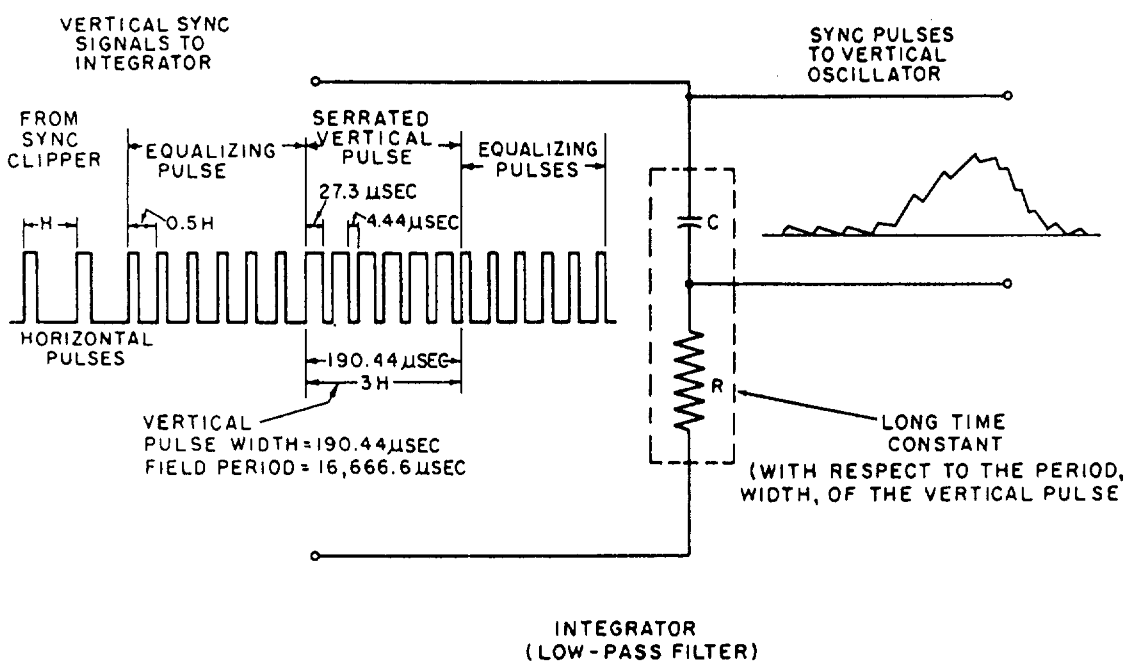


Figure 8-8.—Low-paas filter for vertical sync pulses.

frequencies and separate and demodulate the video and audio frequencies. They must be separated to use the sync pulses to reproduce the picture on the screen and sound at the speaker. How well each job is done depends largely on the design and quality of the TV receiver.

When the signal in CCTV is sent from the camera to the viewing unit by cables, there are no antenna problems. However, where the control unit contains a small oscillator, which furnishes an amplitude modulated video signal, the viewing unit must have a tunable receiver.

CAMERA TUBES

The objective of television camera tubes is to convert an image into a continuous electrical signal. The image can be a live scene, a series of motion-picture frames, or a still picture. The signal from the tube consists of a succession of voltages proportional to the light intensity of each individual element encountered in the scanning process.

The two types of camera tubes we will discuss in this chapter are the image orthicon and the vidicon.

Image Orthicon

The image orthicon tube (fig. 8-9) is an ultrasensitive camera tube used in modem television systems. This tube picks up a light image from the object that is focused on the light-sensitive face (photocathode) by the camera lens. Electrons are released from the photocathode in proportion to the intensity of the light striking it.

The released photoelectrons are directed on parallel courses from the photocathode through the target screen, to the two-sided target. This is done by an electrostatic field between the target screen and the photocathode. Electrons are released from the target by the impacting photoelectrons. This leaves a pattern of positive charges on the front of the target (fig. 8-9). The released electrons are collected by the target screen, which has a slightly positive charge relative to the target.

The back of the target is scanned by a beam from an electron gun in the base of the tube. The beam is slowed to a near zero velocity at the target by the decelerating ring. This is to avoid producing unwanted secondary electrons on the back side of the target. If the point on the target the beam approaches has a positive charge, it extracts enough electrons from the beam to become neutral. The remaining electrons in the beam travel back toward the aperture. The aperture is a good emitter of secondary electrons, thus providing amplification of the return beam. The secondary electrons are directed into the electron multipliers, where the signal is amplified, to a value great enough to be fed into a video amplifier. The focus, alignment, and deflection coils, along with special grids, keep the various streams in all parts of the tube under proper control.

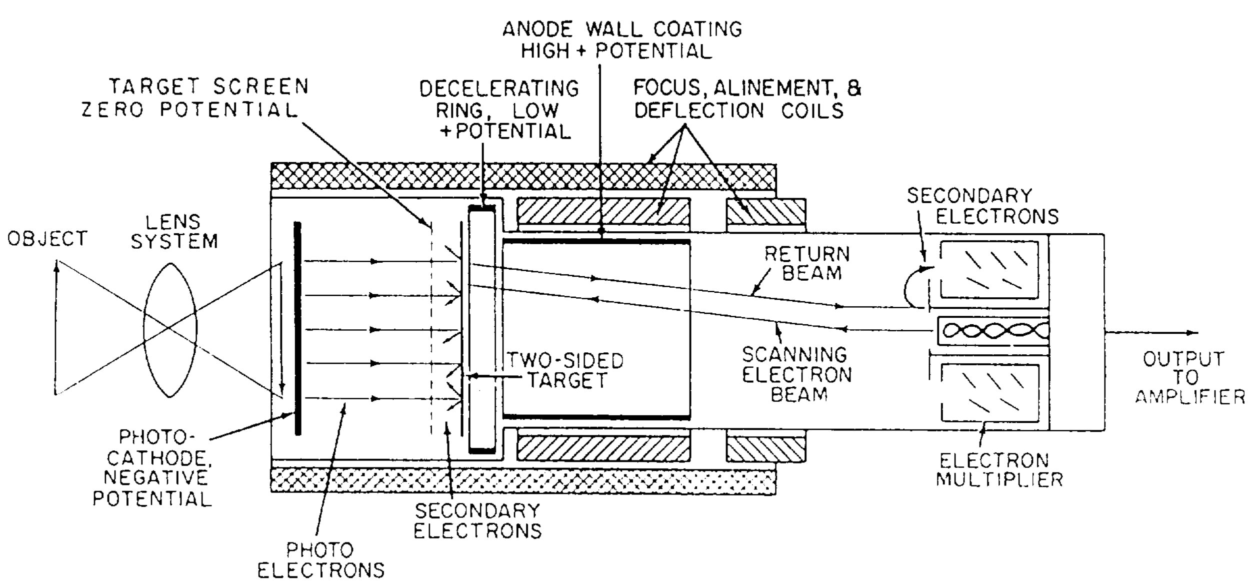


Figure 8-9.—Structure of image orthicon.

The image orthicon may be used for indoor or outdoor TV pickups. With this tube, scenes may be televised under light levels as low as 3 foot-candles illumination (ordinary room lighting). However, light levels of approximately 30 foot-candles provide broadcast quality results. This is important in some Navy applications.

Vidicon

The vidicon is a small television camera pickup tube. Its relative simplicity and small size permit its use in television cameras of very compact design. All vidicons are similar, differing primarily in specific size, sensitivity, and resolution.

The target area of the vidicon tube is made up of two layers. The outer layer is a transparent conducting film on the inner surface of the glass faceplate. The inner layer is a photoconductive material on the scanning side of the signal electrode. This is illustrated in figure 8-10. The low-velocity beam is focused at the target surface by the combined effects of the electromagnetic focus coil and the electrostatic focus field. A fine mesh screen is located near the photoconductive layer. This screen forms a uniform decelerating field with the photoconductive layer, which the beam passes through. This field causes the beam to land perpendicular upon the surface of the target. The electron beam is made to scan the photoconductive layer by the vertical and horizontal deflection coils.

Each small element of the photoconductive material acts as an insulator when the element is in the dark. When an image is formed on the target by the camera lens, each element becomes conductive in proportion to the amount of light falling upon it. Electrons flowing from the lowered resistance of the illuminated elements leave an electrical pattern on the scanning side of the photoconductive layer. The electrical pattern formed corresponds to the light areas of the optical image. The time required for the pattern to form is less than the time of one television frame.

As the electron beam scans the electrical pattern of the optical scene, electrons flow to the elements having the most positive charges. The small current generated in each element flows through the transparent conducting film, the signal electrode, and the load resistor to develop the video output signal. When the beam scans a dark area, each element in the dark area becomes negatively charged. When this occurs, most of the beam is turned back. When the entire surface is dark, a very small current flows to the load resistor and is called the dark current.

Vidicons should always be handled and shipped face up. Turning the tube face down could cause loose particles within the tube to spot the surface.

TYPES OF LENSES

The desired type of image or the size of camera coverage requires different types of lenses. The size of the lens (fig. 8-9) varies from small and short to large and long. The purpose of the various lenses varies from the wide-angle lens for large area coverage to the telephoto lens for narrow coverage at long distances.

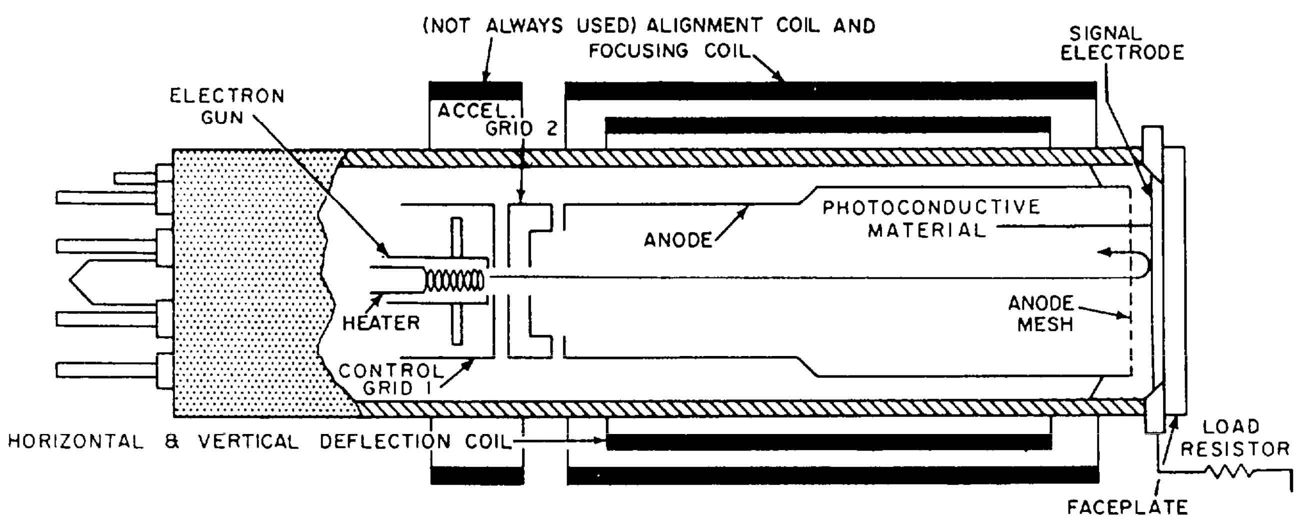


Figure 8-10.—Structure of the vidicon tube.

A special lens called the zoom lens is used for special effects. This lens can be varied from the normal visual coverage to distant closeups. In some installations the lens is manually adjusted, while in other TV cameras it is motor driven. The lens may be adjusted either manually or by an automatic motor-driven device.

COLOR TV

It is known that normal vision is in color. The human eye, in association with the brain, picks up the reflected light and imagines the scene in color. When you view a colored painting, the object appears as a solid section of color. But, upon close inspection, it is seen that what appeared as solid color is really individual brush lines. The same method is used in television to make color appear solid on the face of a picture tube. Small spots of color instead of brush lines make up each solid color.

PRINCIPLES OF COLOR

The principles of color presented in the following paragraphs apply specifically to the development of color television pictures.

The three primary colors (fig. 8-11) used in television are red, green, and blue. When two primary colors are combined, they produce another color.

Figure 8-11 shows three large circles that represent the three additive primary colors. In the center where all three overlap, the color white is formed. In sections where two primary colors overlap, another color is produced. Green and blue produce cyan (greenish blue). Blue and red produce magenta (bluish red). Red and green produce yellow.

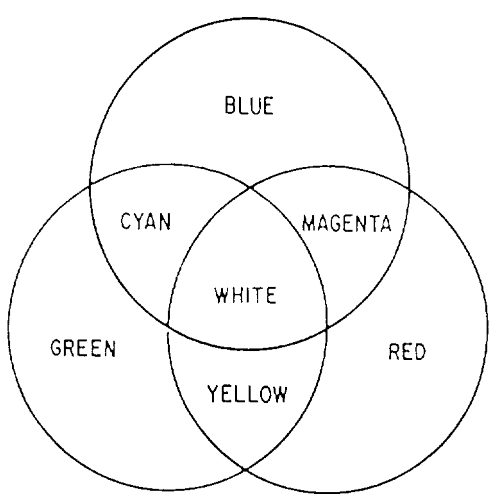


Figure 8-11.—The additive primaries.

The combining of two primary colors, in proportional amounts, produces the new color. However, when all three colors are combined as units and in percentage of color, the result is white. Note the following combination:

- One red unit represents 30 percent red
- One green unit represents 59 percent green
- One blue unit represents 11 percent blue

When one unit of green is combined with three units of red, the result is orange. By changing the proportions of red and green, a variety of colors between red and green can be produced. As the proportion of the primary color mixture changes, the resultant color also changes.

The color by itself is called the hue. Green leaves have a green hue. A red apple has a red hue. Different hues result from different wavelengths of light. Red has the longest wavelength; violet has the shortest.

The term *saturation* indicates how little a color is diluted by white light. The more a color differs from white, the greater its saturation. A weak blue color has little saturation, while vivid blue is highly saturated. Saturation is interchangeable with the terms *purity* and *chroma.*

The brightness of a color as perceived by the human eye is called luminance. The human eye sees brightness increase from blue to a peak at green and then decrease again to red. This apparent response curve is the standard CIE (International Commission of Illumination) luminosity (brightness) curve.

Color resolution is the full three-color reproduction of the red, green, and blue primaries. Monochrome (black-and-white) reproduction is used for the smallest details. For example, in the televised picture of an automobile, the entire body of the car would be in full color. Narrow vertical strips on the frame might be reproduced in two colors, while the outline of the car where it joins the background would be in black and white.

TRANSMISSION

The camera unit used for color pickup is similar to the black and white camera. However, the color camera unit (fig. 8-12) has three pickup tubes (one for

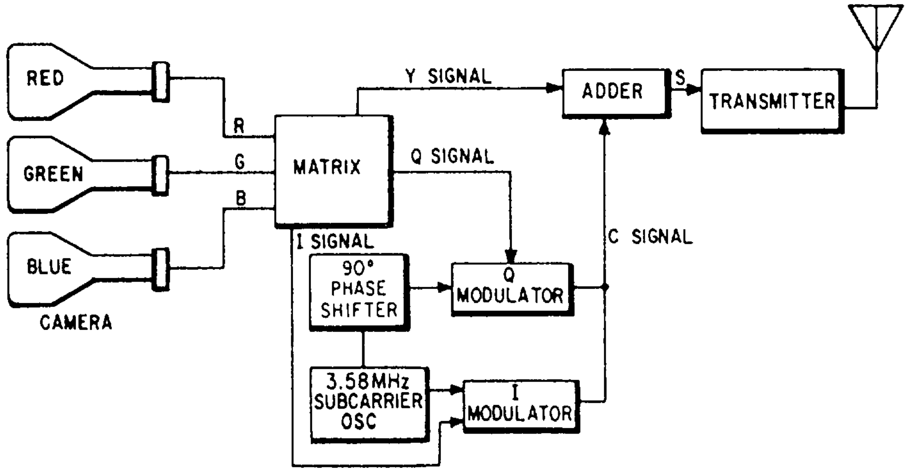


Figure 8-12.—The color camera unit.

each of the primary colors). Filters and mirrors are used to direct the right color of light to its respective pickup tube. The output of the camera unit provides a red, green, and blue video signal to the matrix system (a circuit that proportions the primary signals to produce the correct brightness and chrominance colors). The three primary colors are identified as R for red, G for green, and B for blue.

The matrix section is essentially a resistive voltage divider circuit that proportions the primary color signals to produce the brightness and chrominance signals. With the red, green, and blue color video voltages as inputs, the three video signal output combinations formed are the following:

- Luminance signal, designated the Y signal, which contains the brightness variations of the picture information.
- A color video signal, designated the Q signal, which corresponds to either green or purple picture information.
- A color video signal, designated the I signal, which corresponds to either orange or cyan picture information.

The I and Q signals together contain the color information for the chrominance (hue and saturation) signal.

The I and Q signals are transmitted to the receiver as the sidebands of a 3.58-MHz subcarrier wave (fig. 8-12). A subcarrier wave is a relatively low-frequency carrier wave that modulates the main carrier wave. The subcarrier frequency remains the same regardless of the channel frequency. Modulating the subcarrier makes it possible to broadcast the color information of the I and Q signals simultaneously without loss of identity. Each can be recovered as a separate signal with the proper timing of the transmitter and the receiver. The combined outputs are designated as the chrominance C signal and are routed to the adder (fig, 8-12).

The chrominance C signal (the color information) and the Y signal (the luminance information) are both coupled to the adder section, or colorplexer. The colorplexer combines the Y and C signals, forming the total video S signal which is sent to the transmitter.

RECEPTION

The received signals of video and sound enter the receiver/monitor just as they do in black-and-white reception. The same tuner and IF amplifiers are used (fig. 8-13). In the video amplifier the signals separate.

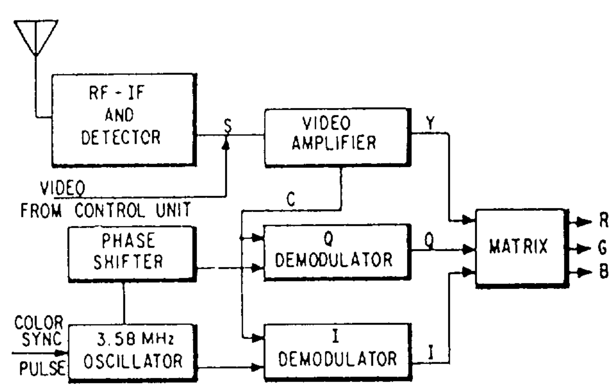


Figure 8-13.—Color TV receiver, block diagram.

The Y signal goes to the matrix and the C signal goes to the Q and I demodulator. The 3.58-MHz oscillator is synchronized by the color sync burst from the transmitter. The demodulator separates the chrominance C signal into the individual I and Q signals. The matrix circuit forms the original red, green, and blue signals.

The color picture tube is specially made for color reproduction. Three electron guns, one for each color, are used. The tube's screen consists of small, closely spaced phosphor dots of red, green, and blue. The dots are arranged so that a red, green, and blue dot form a small triangle. The shadow mask provides a centering hole in the middle of the triangle of dots. The convergence electrode causes the three separate electron beams to meet and cross at the hole in the shadow mask.

Each electron gun is electrostatically focused by a common grid voltage. In other words, each gun has its own electrode, but all three are connected together requiring only one grid voltage. The three electron beams scan the screen controlled by the deflection yoke mounted externally around the neck of the tube. As the three beams scan the phosphor screen in the standard scanning pattern, the dot trios are lighted according to the video input signals.

The purifying coil produces a magnetic field within the tube, which aligns the electron beams parallel to the neck of the tube. Rotating the purifying coil adjusts the electron beams so they strike their respective color dots without striking the neighboring dots. When this adjustment is made for the red dots, the other two electron beams are aligned as well.

The high-voltage anode is a metallic ring around the tube. The field neutralizing coil aids color purity at the outer edges of the picture tube. A metal shield, called a mu-metal shield, is placed around the bell of the tube to prevent stray magnetic fields from affecting the electron beams.

The color TV monitor/receiver has many adjustments in addition to those of a black-and-white unit. Consult the manufacturer's maintenance handbook before you make adjustments. A color television receiver, as shown in figure 8-14, contains many circuits that are different from the circuits used in monochrome (black-and-white) receivers. The differences are outlined in the following paragraphs.

The tuner and amplifier stage in color receivers are designed to pass a wider band of frequencies than conventional monochrome receivers. Wideband characteristics are necessary to assure uniform amplification of the high-frequency color subcarrier sidebands that carry chrominance information.

The video amplifier stage, which in monochrome receivers usually consists of one stage of amplification, usually has three stages of amplification. Additional stages are necessary because the luminance signal is used to drive the cathodes of all three electron guns in the color cathode-ray tube (CRT) as compared to the single gun in a monochrome CRT.

A video delay line is usually located between the video output stage and the CRT simultaneously. The fixed delay (fig. 8-14) is necessary because the chrominance signals pass through additional stages before being applied to the control grids of the CRT. Were it not for the delay of luminance information, the two signals would not arrive at the same time. A distorted video presentation would be the result.

The use of an aperture mask type of picture tube makes the brightness of a color receiver characteristically low. Therefore, higher voltage is necessary to maintain adequate brightness. The output voltage of the high-voltage supply is nominally 20 to 25 kV as compared with 15 to 18 kV for monochrome receivers.

All three electron guns must be sharply focused onto the screen to obtain good monochrome and color reproduction. The focus rectifier in color receivers provides a variable focus voltage (4 to 5 kV) that is applied to the electrostatic focus elements of the CRT. Another factor that requires design techniques much different than monochrome is the load of the high-voltage rectifier must be held fairly constant. Otherwise, severe blooming or shrinking of picture size will occur during the reception of signals with a varying brightness level. The voltage regulator circuit provides a fairly constant anode voltage regardless of the brightness level of incoming signals,

The color demodulator section is the "heart" of the color television receiver. In this section, the 3.58-MHz subcarrier sidebands are demodulated to produce color information signals. The color information signals are then applied to a matrix. In the matrix, color difference signals are produced by matrixing proportionate amounts of the demodulated signals. The color difference signals are amplified and applied to the control grids of the CRT in the proper proportions to reproduce the televised scene.

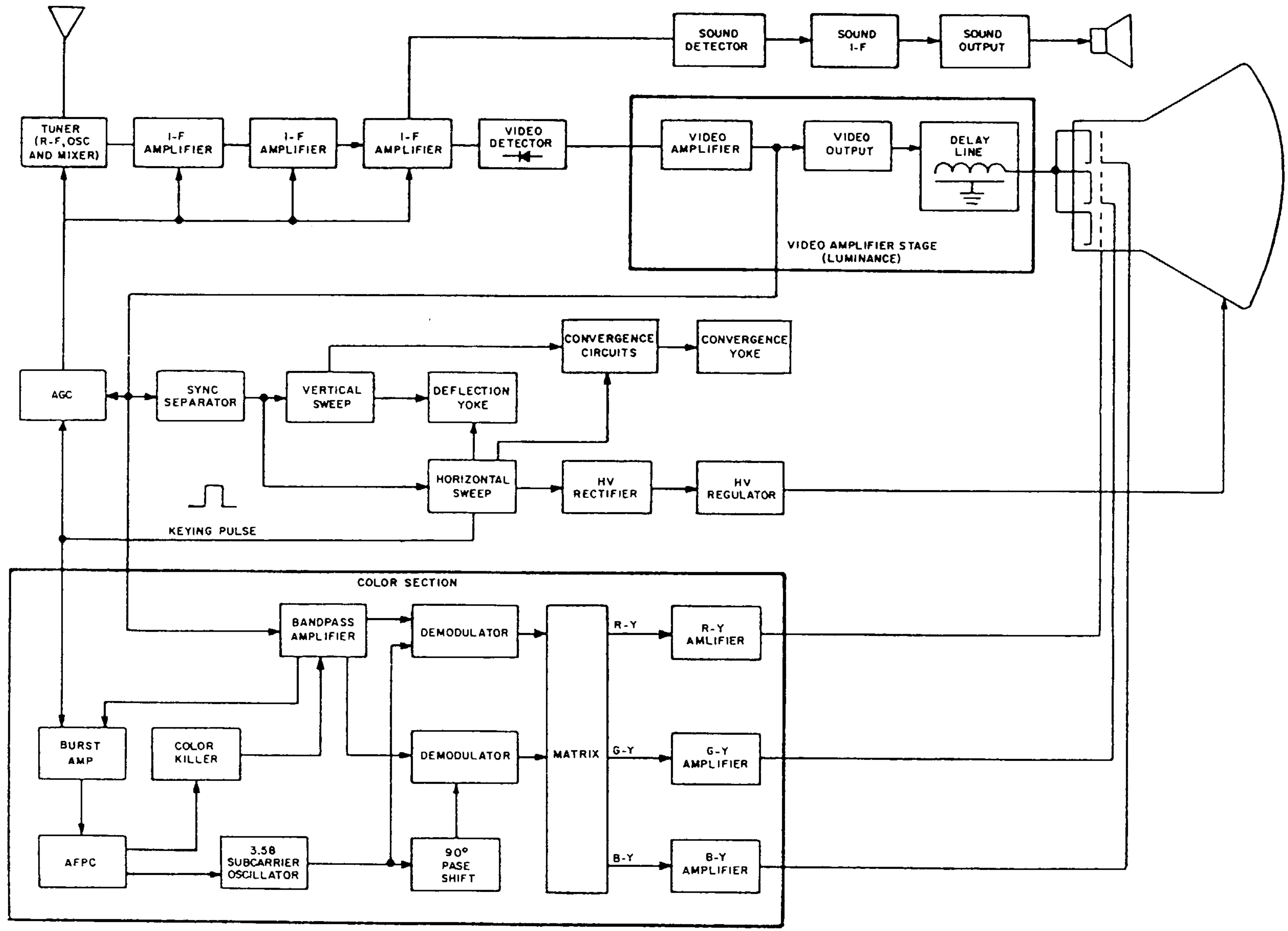


Figure 8-14.—Color television receiver, block diagram.

The color convergence circuits provide a secondary control over the electron beam of each gun. Convergence of the three electron beams to exact locations on the face of the three-gun CRT is necessary to produce good monochrome and color images.

Other differences, such as automatic color control, tuning indicators, and color reception indicators, serve to simplify the operation of front-panel controls.

Pincushioning

Modem color receiver design calls for the use of a wide-angle deflection yoke. Wider deflection angles allows the CRT to be shortened. This allows the cabinet to be made smaller. In an attempt to provide a larger viewing area, receivers are made with flat-surface rectangular CRTs. Unfortunately wide-angle deflection with flat-surfaced CRTs causes some problems. These are bowed scan lines and elongated corners at the edge of the raster. This distortion, referred to as "pincushioning," is caused by projecting the raster onto a flat surface and using wide deflection angles.

Figure 8-15 illustrates the effects of pincushioning when a cross-hatch pattern is projected onto the screen. Notice that the vertical and horizontal lines passing through the center of the raster are not noticeably distorted. As the scan goes away from the center, distortion occurs along the top, bottom, and both sides of the raster. In effect, the raster becomes "stretched" at the corners. This stretching is due to the greater distance the electron beams have to travel at the outer edges.

In monochrome receivers, where a single-gun CRT is used, geometric distortion can be corrected by "anti-pincushion" correction yokes. These yokes produce a somewhat distorted magnetic field that compensates for any pincushion error caused by a flat screen surface. Another method of correcting pincushion error in monochrome receivers is to place permanent magnets in the drift space between the deflection yoke and the screen. The magnetic field produced by each magnet "bucks" pincushion error, and an undistorted raster is obtained. Although these methods work well for single-gun CRTs, more sophisticated means are required to correct distortion in three-gun tubes. For example, the magnetic fields produced by the permanent magnets would not exert equal force on each gun, due to the triangular gun construction.

Modem color receivers use dynamic correction circuits to modify the height and width of the raster. Pincushioning along each side of the raster is corrected by subtracting from the horizontal deflection width at the beginning and end of the vertical scan (fig. 8-16, view A). In contrast, pincushion error is corrected at the top and bottom of the raster by adding to the vertical sweep. This addition occurs at the center of each line near the top and bottom of the raster. When the sweep pulses are modified in this manner, the pincushion error is corrected along both sides and the top and bottom of the raster (fig. 8-16, view B).

Although many circuits are presently used to provide dynamic pincushion correction, the end result is always the same; that is, predistortion of the sweep current waveform. Basically, this involves decreasing the change rate of the sweep current as it approaches its maximum values.

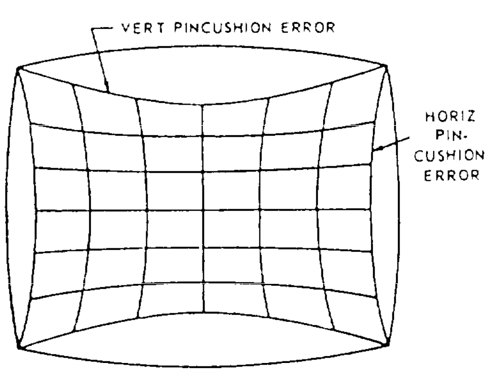


Figure 8-15.—The effect of pincushion distortion on a cross-hatch pattern.

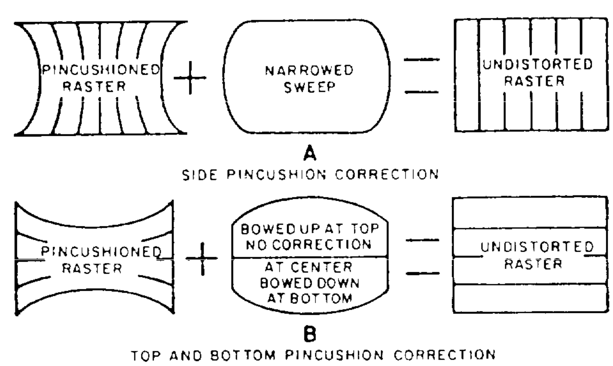


Figure 8-16.—Effects of dynamic pincushion corrections.

Automatic Degaussing

The metal aperture mask often becomes magnetized when the receiver is moved through the earth's magnetic field, Metal parts in and around the picture tube also become magnetized when a man-made magnetic field collapses or expands in close proximity to the receiver. If these stray fields are allowed to exist, the electron beam from each gun will strike the incorrect phosphor dots on the face of the screen, causing color impurities. Unless the parts have become permanently magnetized due to a prolonged exposure to a strong magnetic field, the magnetism can be canceled by the process of degaussing. During degaussing, a controlled magnetic field is developed by passing alternating current through coils of wire. The magnetic fields thus produced not only cancel the existing stray magnetic fields but also serve to prevent any future buildup.

In modem color receivers, the problem presented by stray magnetism is somewhat alleviated by automatic degaussing coils. These coils are an integral part of the color receiver and are usually activated each time the receiver is turned on. The coils, usually from two to four in number, are evenly spaced around the magnetic shield of the receiver picture tube (fig. 8- 17).

Of the many circuits designed to provide automatic degaussing, the voltage dependent resistor (VDR) thermistor circuit arrangement is the most popular method of obtaining trouble-free operation, The schematic diagram of such an arrangement is shown in figure 8-18. The circuit consists of a thermistor, a voltage dependent resistor, and the four degaussing coils.

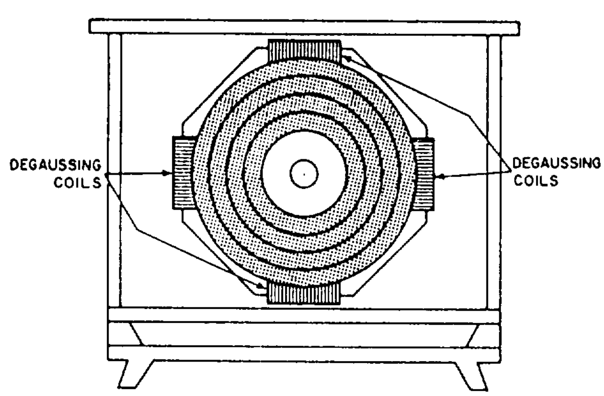


Figure 8-17.—Location of automatic degaussing coils.

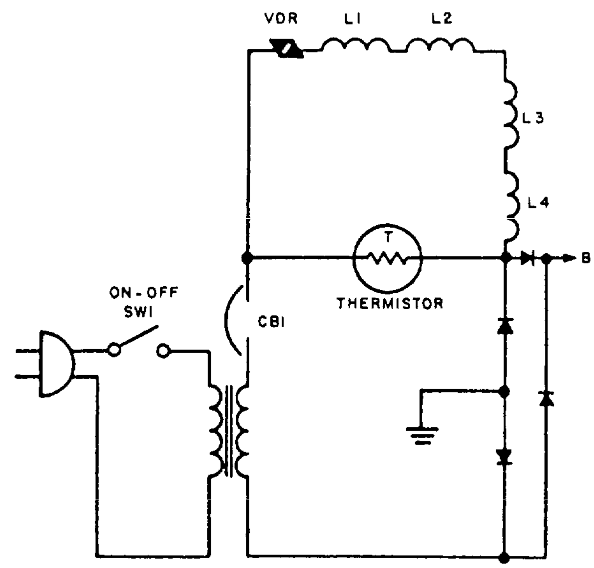


Figure 8-18.—VDR/thermistor automatic degaussing circuit, schematic diagram.

When the on-off switch is initially closed, the resistance of the thermistor is high and nearly all of the circuit current flows through the degaussing coils. After the first few seconds, degaussing is complete and it is necessary to remove the coils from the circuit. Coil isolation is completed by using the combined properties of the VDR and the thermistor. After the first few seconds of operation, the resistance of the thermistor begins to decrease due to the current flowing through the circuit. Simultaneously, the VDR begins to increase in resistance because less voltage is now applied. The combined action of the two special resistors results in the coils eventually being electrically removed from the circuit.

TELEVISION ENTERTAINMENT SYSTEM

The television entertainment system (circuit 15TV) receives VHF broadcast television signals and amplifies and broadcasts the signals to various locations throughout the ship. The system consists of an omnidirectional antenna, a lightning arrestor box, a signal amplifier, a signal splitter, line taps, TV signal/duplex power receptacle outlet boxes, impedance matching transformers, and standard commercial television receivers. The system is basically passive except for the amplifier, which requires 115-volt, 60-Hz, single-phase power.

The omnidirectional antenna is designed for marine use. The TV signals are picked up by the antenna and fed to the signal amplifier through the lightning arrestor box. The lightning arrestor box protects the system from damage in case lightning strikes the antenna. The signal amplifier raises the signals received to a level required to provide adequate signals to the distribution system. The signal splitter and line taps provide for multiple outlets for distribution of the signals. A signal/duplex outlet box is mounted wherever a television receiver is located. The outlet box contains a duplex 115-volt, 60-Hz, single-phase receptacle and a TV antenna outlet. The television receivers are standard commercial televisions. Impedance matching transformers are required for each receiver to match the impedance of the antenna distribution system with the input of the receivers. The transformers are usually installed in the line on the back of the receivers. The number of television receivers will vary depending on the size and class of the ship.

INTEGRATED LAUNCH AND RECOVERY TELEVISION SURVEILLANCE (ILARTS) SYSTEM

The ILARTS system is a replacement for the Mk 1 Mod 4 landing signal officer (LSO) pilot landing aid television (PLAT) system (fig. 8-19) currently in use aboard U.S. Navy aircraft earners. The PLAT system is becoming logistically unsupportable. The primary purpose of the ILARTS system, as with the PLAT system, remains the simultaneous monitoring and recording of aircraft recovery operations, both day and night, as a debriefing medium for pilots and for detailed accident analysis. In addition, programmed servo control equipment and additional camera control equipment required for a catapult launch surveillance system being developed can be accommodated within the equipment racks and control console and fully integrated into the video switching, recording, distribution, and display equipment provided.

SYSTEM DESCRIPTION

The ILARTS system is a closed television circuit to monitor aircraft landings aboard U.S. Navy aircraft carriers during both day and night operations, and is planned for expansion to include surveillance of launch operations. Three low-light level television (LLLTV) camera chains, each of which is comprised of a camera head unit (CHU), a camera control unit (CCU), and a remote control panel (RCP), are used in the present system. Two of the CHUs are located at selected positions along the angled deck centerline to provide glide slope and line-up data during the approach. Each of the two centerline CHUs is equipped with a 120mm fixed focal length lens, which provides approximately a 14-degree (horizontal) by 10-degree (vertical) field of view.

The centerline CHUs are mounted vertically (below and perpendicular to the flight deck) and view the flight deck through the deck fixture. The deck fixture contains the viewing aperture (window) and a mirror assembly, which provides a means of setting the optical axis (of the 120mm lens/CHU assembly) parallel to the optical glide slope of the incoming aircraft (fig. 8-19).

The remaining CHU is located above the flight deck level on the island structure, which provides an unobstructed view of the flight deck. This CHU is used to identify the aircraft and the arresting wire engaged. It is also used to monitor launch operations, accidents, and other flight deck activity. The island camera CHU is equipped with a motor-operated 10:1 zoom lens. The camera housing contains the operator's viewfinder (monitor) and zoom control. The island camera unit (CHU, zoom lens, and housing) is mounted on a pedestal equipped with a manually operated pan and tilt head (fig. 8-19). This, of course, requires that an operator be present in the island camera booth. The control of the CHU itself is accomplished in the same manner as the centerline CHUs. The CHUs are controlled from a centralized control room that contains equipment required for processing, control, and synchronization. The control room also contains equipment for switching, recording, and distribution of the video signals, as well as audio signals obtained from the LSO radio. Monitoring equipment consisting of a 9-inch or 17-inch monitor and 1-watt loudspeaker are located in each of the selected spaces throughout the ship.

SYSTEM INSTALLATION

The shipboard installation of the ILARTS system consists of two centerline camera installations; an island camera station; a centralized control room; and a remotely located monitor installed in the pilot house, each of the squadron ready rooms, and other designated spaces. The general arrangement of the system is shown in figure 8-19.

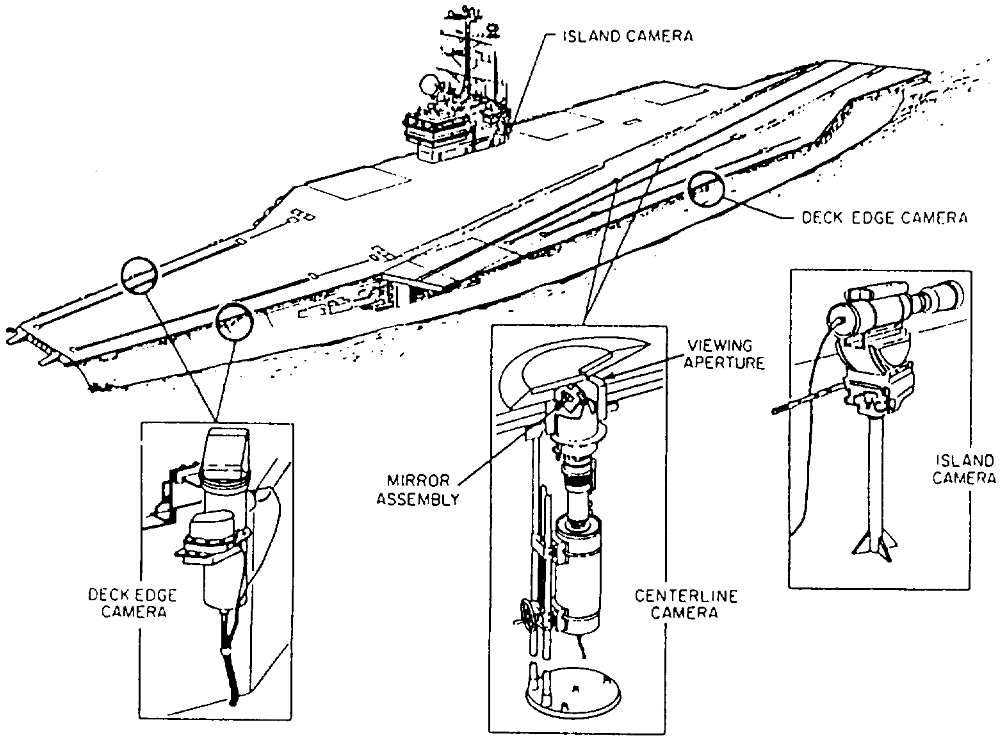


Figure 8-19.—ILARTS installation location.

Centerline Camera Installation

Two centerline camera installations, identified as Aft and Forward are required to accommodate the range of hook-to-eye values of the various aircraft, and the resultant vertical displacement of the optical glide path. Each of the centerline camera installations is enclosed in a compartment approximately 6-feet by 6-feet, The compartment is equipped with a locking access door; utility outlets at 115 volts, 60 Hz, single phase for operation of test equipment and portable power tools for maintenance purposes; a 125-psi air supply line with shut-off valves; piping connections to ship's drain; and a jackbox for connection of sound-powered telephone headset for audio communication to the ILARTS control room.

Island Camera Station

The island camera station is located on the ship's island structure approximately 40 feet above the flight deck. The island camera station is protected by an enclosure. The enclosure is equipped with 115-volt ac utility outlets for maintenance purposes; red and white lighting; space heaters or forced hot air to keep the enclosure dry when not in operation; drainage facilities for removal of water that may accumulate during operation; and a jackbox for connection of a sound-powered telephone headset to provide audio communication with the ILARTS control room. In addition, electrical power at 115 volts, 60 Hz, single phase, 10 amperes is required for operation of the viewfinder monitor and zoom lens control of the island camera housing.

Control Room

The ILARTS control room contains all equipment required for operation, control, switching, and distribution of video and audio signals. It is also used for shipboard intermediate level maintenance of the ILARTS equipment. The room should be air-conditioned. The heat dissipation of the ILARTS equipment is 10 kW. A sound-powered telephone circuit from the control room to the island camera station and each of the centerline camera compartments is required to provide audio communication during operation and maintenance of the system. A workbench, cabinets, and stowage space is required for intermediate level maintenance tools and test equipment.

Remote Monitors

Television monitors and loudspeakers are installed at various designated spaces.

System Interface Requirements

The ILARTS system interfaces with other shipboard equipment according to the following:

SHIPBOARD EQUIPMENT-SYSTEM	REFERENCE DESIGNATION
1. LSO Heads-Up Display (HUD)	
a. LSO Audio	Cable W47
b. ILARTS Video to LSO HUD Console	Cable W51
c. Manually Operated Visual Landing Aid System	Cable W55
2. Ships HD-HE Equipment, Synchro Signal for Wind Speed	Cable W19
3. AN/SPN-44 Radar, DC Analog Voltage for Aircraft Speed, Range, and Sink Rate	Cable W11
4. Fresnel Lens Optical Landing System Mk 5 Mod 2 for Wave-Off/Cut Signals	Cable W8
5. Ship's Gyro, Two-Speed Synchros for Pitch and Roll Stabilization Signals	Cable W4
6. Landing Area Signal System for Clear Deck-Foul Deck Signals	Cable W13
7. Sound-Powered Telephone Circuit	Cable W48

AUDIOVISUAL ENTERTAINMENT SYSTEM

An audiovisual entertainment system combines both audio entertainment and television entertainment into one system. The audiovisual entertainment system installed on board Navy ships today is the Shipboard Information, Training, and Entertainment (SITE) system.

The SITE system is a self-contained, CCTV system that uses video cameras, video cassette recorder/producers, film projectors, slide projectors, and television receivers.

An electronic switching system is used to modulate the audio and video signals to the applicable television frequencies, The signals are then distributed to television receivers located throughout the ship. The television receivers used with the SITE system are the same as those described earlier in this chapter.

SITE II is the second generation standardized CCTV system for Navy shipboard information, training, and entertainment. The system is engineered, assembled, and procured by the USA Television—Audio Support Activity (T-ASA). SITE II is the largest of the three systems being used in Navy ships. Smaller versions with limited capability, designated as MINI SITE and SUB SITE, are also being used in certain classes of Navy small surface ships and submarines. However, SUB SITE and MINI SITE will not be discussed in this chapter.

SITE II

The SITE II design is based on the experiences of the SITE 1/1A systems. It features a significant reduction in physical size, while maintaining operational capabilities. A technician, whether or not trained on SITE 1/1 A, will find SITE II to be more reliable and easier to maintain.

The service manuals are designed to keep all pertinent SITE II reference material under one cover. The technical manuals in the binders are the actual manufacturers' technical references for operation and maintenance of the equipment.

The program-originating equipment is housed in and on two dual bays (fig. 8-20).

Diplexer

Both bays are equipped with identical diplexers, which make up the film/slide chain input for the system. Each diplexer is shock-mounted on its respective dual bay and includes a Hitachi GP-7 color camera, a 16mm film projector, a two-position 70mm anamorphic lens, a 35mm slide projector, and a diplexing optical mirror assembly.

The 16mm film projectors are each equipped with a special 3-inch lens to match the optical characteristics of the camera. A gelatin neutral density

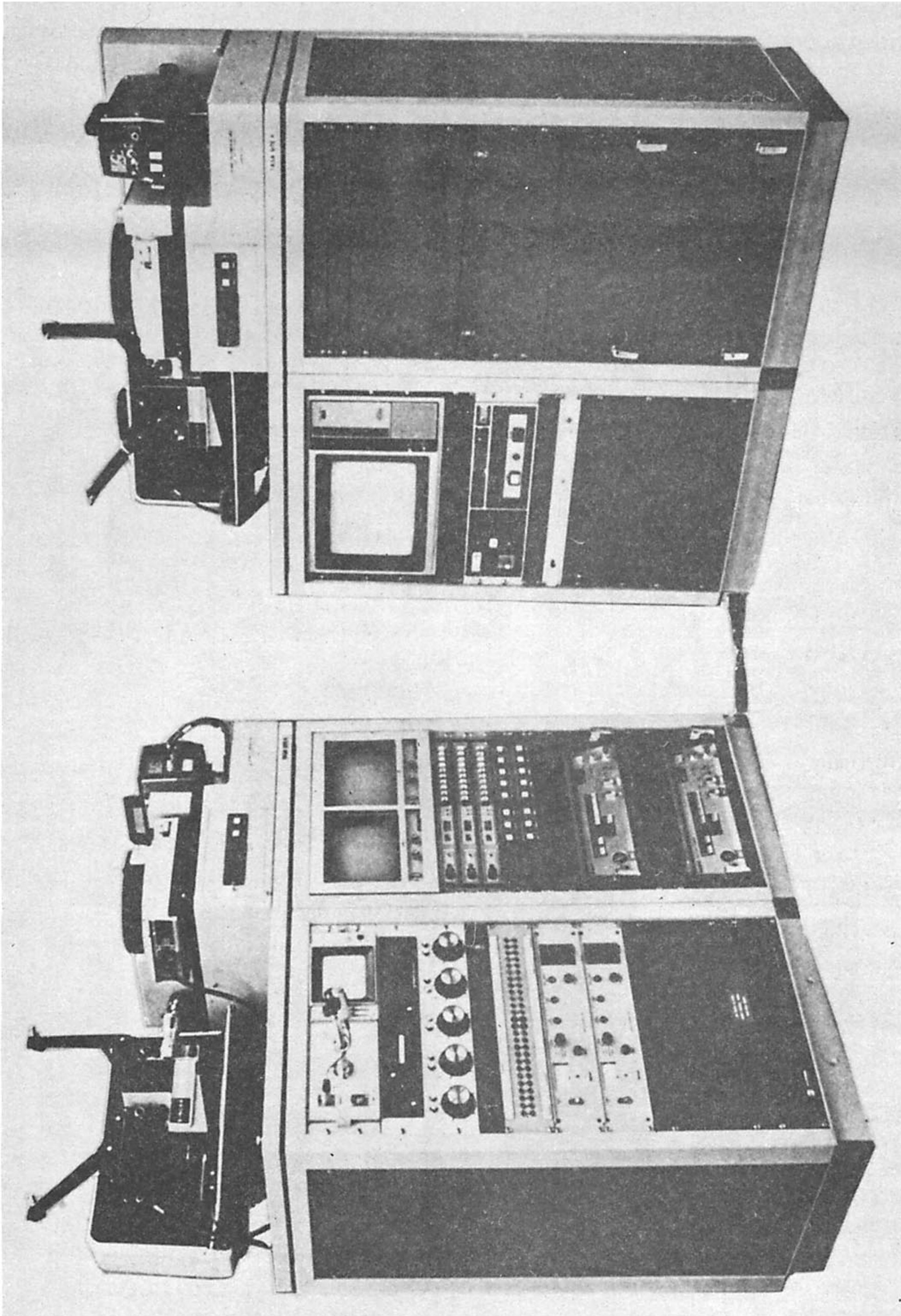
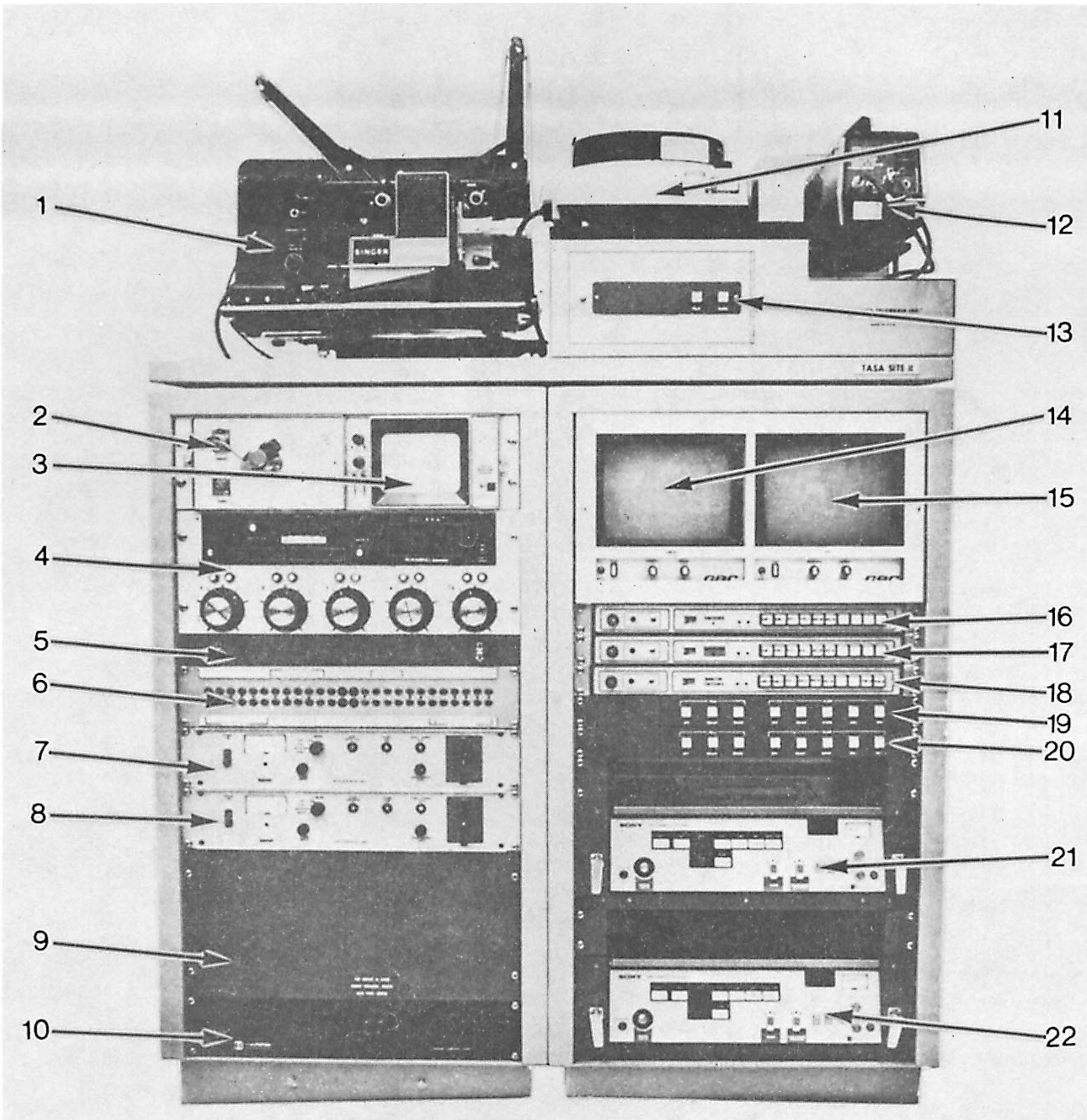


Figure 8-20.—SITE II, complete system.

filter should be attached to the lens to match the light intensity of the film projector with the slide projector.

The 35mm slide projector is a modified Kodak Ektagraphic, model E-E. The slide projector lens ismounted within the covered optical assembly and should have a filter attached to balance the light intensity striking the camera.

All color cameras in SITE II are Hitachi GP-7 single-tube cameras and are interchangeable. They are all equipped with internal encoders and internal sync.



1. 16mm Projector
2. Console Mike Panel
3. Waveform Monitor
4. Audio Mixer/Monitor
5. Shelf
6. Patch Panel
7. Modulator A
8. Modulator B
9. Blank Panel
10. Power Control Panel
11. Slide Projector
12. Color Camera #1
13. Diplexer Controls
14. Camera Monitor (B/W)
15. VCR Monitor (B/W)
16. PGM A Switcher
17. PGM B Switcher
18. Monitor Switcher
19. Remote Control Film 1
20. Remote Control Film 2
21. VCR 1
22. VCR 2

Figure 8-21.—SITE II, left side, dual bay.

Cameras mounted on the diplexer accept images from the slide or film projectors. This is determined by the position of the movable mirror located in the optical mirror assembly. The input image is processed through the camera electronics and emerges as a composite video signal. This video signal is then processed through the control bay and presented to the modulators and/or to one of the video cassette recorders (VCRs) for taping and to the control monitoring units.

Monitoring of cameras 1 and 2 is done by observing the display at the camera monitor. This is located at the upper left portion of the left dual bay (fig. 8-2 1). Selecting either camera 1 or 2 to monitor is done by a switch on the camera monitor panel.

Video Cassette Recorders

Two Sony SLO-320 color VCRs are mounted in the lower portion of the left dual bay (fig. 8-21). Video output from these VCRs may be monitored by positioning the toggle switch on the control panel of the VCR monitor to the correct position.

Patch Panel

All audio and video signals originated by the system or entering the system are connected directly to the patch panel. From there they are routed into the system on preestablished (normal) signal paths or alternate paths manually selected by patch cords.

The patch panel is an assembly of 52 audio and video jacks, 48 of which are dedicated. Designation strips above or below each jack identify the source equipment or the receiving equipment for each jack, Normally the jacks in the upper row receive signals to the equipment, In normal operation they act as in/out jacks; that is, a signal received through a jack on the top panel is connected to the jack immediately below it, Their normal connections are internal, and do not require looping plugs.

Occasionally it is desired to reroute a signal from its normal path. In this case a patch cord can be connected from a source jack to an input jack. Insertion of a patch-cord plug into an upper or lower jack breaks the normal through connection. The other end of the patch cord can then be connected to whatever jack will give the desired connection. Removing the patch cord from the jacks reestablishes the normal connection. Four video coaxial patch cords and six audio patch cords are supplied with the system. Effective use of the patch panel and patch cords increases system flexibility and simplifies trouble-shooting and maintenance of the SITE system.

The patch panel serves four principal purposes. Since all signals to and from the major pieces of equipment are routed through the panel, it provides convenient locations for testing signal levels and continuity. The patch panel can be used to bypass a defective unit so that operation can continue while repairs are being made. Also, the patch panel provides a means of introducing auxiliary inputs into the system. When programming requirements call for making an audio and/or video recording, the patch panel can be used to feed the signals to the proper recorder.

Audio Cartridge Recorder/Reproducer

The ITC RP-0001 recorder/reproducer is located in the right dual bay (fig. 8-22). The equipment is designed to operate exclusively for audio cartridge tape recording and reproducing. It has the capabilities of playback of prerecorded audio and recording audio for playback. Audio input and output cables are wired through the patch panel to the audio mixer/monitor. With proper use of the mixer/monitor and patch panel, any audio source can be recorded and played back.

Audio Mixer/Monitor

The Ramko audio mixer/monitor is located in the left dual bay (fig. 8-21). This device has the capability of monitoring and controlling all audio signals generated in the system. Monitoring is accomplished by the monitor select push buttons, built-in loud-speaker, and monitor volume control. Undesirable audio crisscrossing is possible. Care must be taken to depress the proper push buttons.

Color Monitor

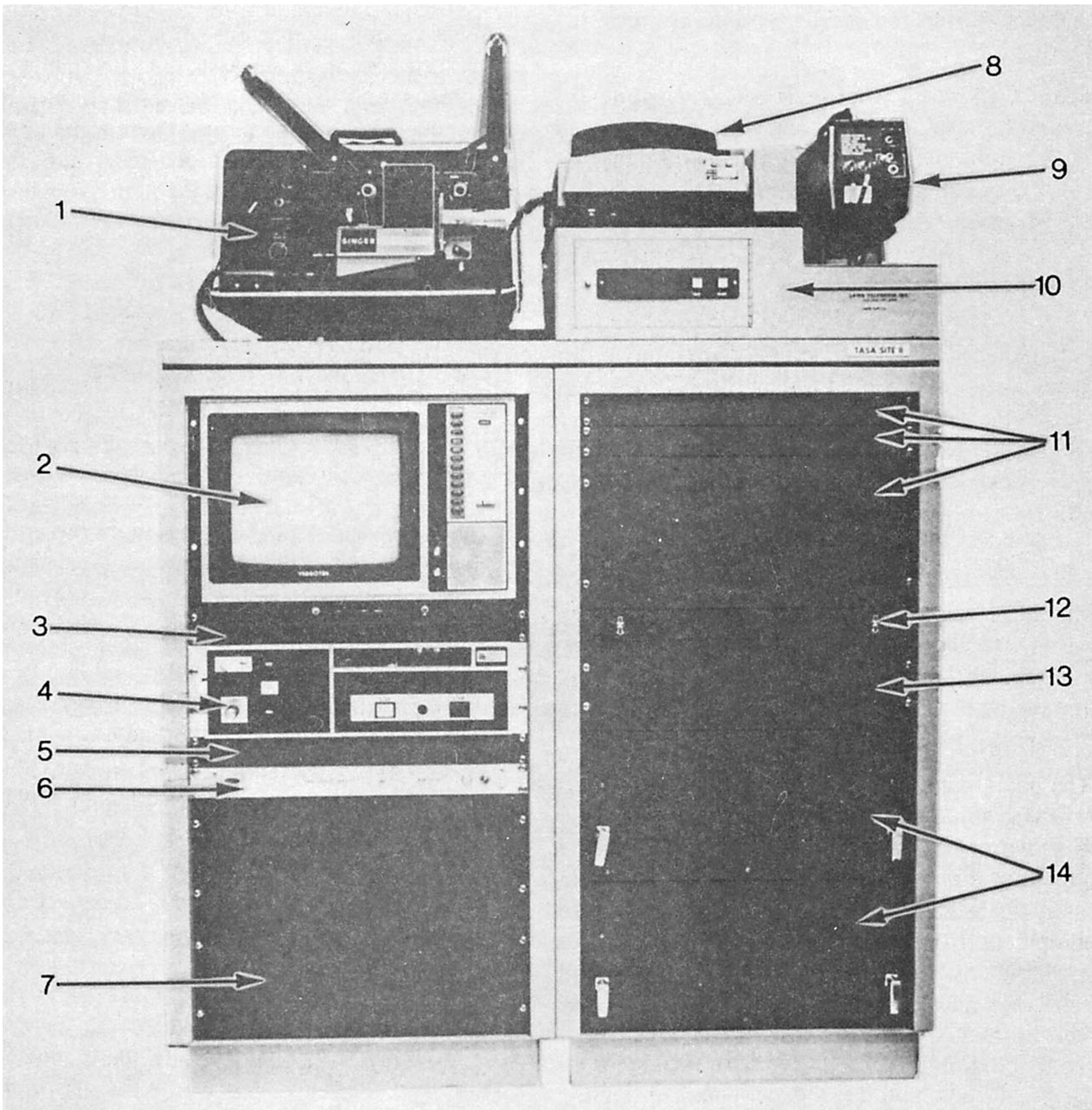
Mounted in the upper portion of the right dual bay is the 12-inch color monitor (fig, 8-22). The monitor displays the R output signal from the Telemet modulatators (which are discussed later) or the video output signal. The receiver/monitor toggle switch, located on the monitor control faceplate, switches from one display to the other.

Waveform Monitor

Directly associated with the input to the receiver/monitor is the waveform monitor. This is located in the upper part of the left dual bay (fig. 8-21). This display can be used during adjustments of video equipment requiring waveform examination. The video waveform of whichever video source is selected on the monitor will be displayed on the waveform monitor.

Modulators

Two Telemet modulators are mounted on the left dual bay (fig. 8-21). These modulators provide separate programs, one for channel A and the other for channel



1. **16mm Projector**
2. **Color Monitor**
3. **Blank Panel**
4. **Audio Cart Recorder**
5. **Blank Panel**
6. **Video DA**
7. **Blank Panel**
8. **Slide Projector**
9. **Color Camera #2**
10. **Diplexer Controls**
11. **Blank Panels**
12. **Shelf**
13. **Blank panel**
14. **Drawers**

Figure 8-22.—SITE II, right side, dual bay.

B. Two programs may be transmitted simultaneously, or one modulator maybe used as a backup for the other.

Each modulator accepts the composite audio and video signals routed to it. It converts those signals into a standard very high frequency (VHF) TV broadcast channel for transmission through the distribution system.

Power

Power for the system comes from a Topaz power line conditioner, which provides regulated, noise-free power. The conditioner is mounted at the bottom of the left dual bay (fig. 8-21). Power control is provided by the Harris power control panel located at the lower front of the left dual bay (fig. 8-21). All power is controlled by this main power switch, but individual components should also be turned off to prevent an initial power surge.

Associated with the power system is the Transtector transient suppressor. This provides additional protection against power surges and spikes.

Live and Remote Cameras

A third Hitachi GP-7 color camera is provided as a studio camera for live productions. This third camera may also be used in the portable mode. All necessary power packs, handles, supports, and viewfinders are supplied.

A black-and-white video camera is provided for remote use. All necessary accessories for remote operation are issued with the system.

COPYRIGHT INFRINGEMENT

To use any of the exclusive rights of a copyright owner without permission is an infringement of the owner's copyright. These exclusive rights include copying, reproducing, printing, reprinting, publishing, exhibiting, translating, and vending the copyrighted work or portions thereof and, in some instances, the oral delivery or performance of the work.

Where a copyright is infringed by or for the Government, with its authorization or consent, the exclusive remedy of the copyright owner is by suit against the United States in the Court of Claims. Government employees are no longer personally liable for copyright infringement occurring in the performance of their official duties. In cases involving Navy personnel, prior to the time suit is brought, claims of copyright infringement may be settled by the Secretary of the Navy or a duly authorized representative, the Chief of Naval Research, or a designate.

LOCALLY PREPARED BROADCASTS

Commanders may authorize American Forces Radio and Television (AFRT) outlets under their command to originate local programs, which are prepared, produced, or supervised by staff members of the outlet. Live or taped programs should reflect the highest standards of quality.

PROHIBITED BROADCASTS

No AFRT station may broadcast or rebroadcast any program sponsored by private or commercial interests or foreign governments, except those programs supplied or authorized by the AFRTS. The prohibition does not apply to live broadcasts of local sport and special events that are prepared initially for broadcast over AFRT, and are presented by, or are under the supervision of, staff members of those stations. In certain instances, events or ceremonies broadcast by a foreign government network or agency may be deemed of sufficient cultural or informational value to warrant rebroadcast by AFRT stations.

In addition to the foregoing policies, there are policies governing AFRTS program materials—video and audio tapes, films, slides, and transcriptions.

Use or reproduction of AFRTS program materials for private or commercial purposes is prohibited.

Use of recorded materials (for example, phonograph records, audio cartridges and cassettes, video cassettes, or films) secured directly from commercial sources, military exchanges, or private sources is prohibited on AFRT outlets.

Designated information transcriptions and films produced by DOD may be loaned to command information sections to support information programs.

SUMMARY

In this chapter, we have described the purpose of the ship's entertainment systems installed on Navy ships today and the various equipment used with each type of system. We have also identified the types of loudspeakers used with the ship's entertainment system and the operation and characteristics of the systems.

CHAPTER 9

ALARM, SAFETY, AND WARNING SYSTEMS

LEARNING OBJECTIVES

Upon completion of this chapter you will be able to do the following:

- *Explain the purpose of alarm, safety, and warning systems installed on Navy ships.*
- *ldentify the various sensing devices used with alarm, safety, and warning systems.*
- *Identify the various audible and visual devices used with alarm, safety, and warning systems.*
- *Describe the components and operation of a B-51 alarm panel.*
- *Describe the components and operation of an IC/SM alarm panel.*
- *Briefly describe some of the common troubles of alarm, safety, and warning systems and their effects on the systems.*

INTRODUCTION

Alarm, safety, and warning systems are installed in Navy ships for certain equipment and compartments. These systems provide audible and visual signals when abnormal or dangerous conditions occur. The principal components of the alarm, safety, and warning systems are sensing devices, audible and visual signals, alarm panels, and alarm switchboards. Circuit designations and classifications of some of the more common systems are listed in table 9-1.

Sources of possible trouble areas in many of the interior communication circuits are components that transmit information and the components that warn of malfunctions. Often, even though the detector and repeater parts of a system are aligned, an error is introduced by components that transmit or retransmit information.

This chapter discusses some of the devices that transmit information and warn of malfunctions. When you complete this chapter, you should have a basic understanding of transmission, alarm, and indicating systems, and be prepared to deal with malfunctions in such equipment.

SENSING DEVICES

Devices are used with alarm, safety, and warning systems to initiate alarms when there is a deviation in normal operation. A sensing device senses the deviation and, in turn, causes a switch or relay contact to close and energize the alarm signaling device. Sensing devices include switches, detectors, and relays.

SWITCHES

Switches used with the alarm, safety, and warning systems include lever-operated, pressure-operated, mechanical, water, liquid-level, and thermostatic switches. These switches were discussed in chapter 3 of this training manual. In addition, the alarm, safety, and warning systems use flow switches, relay switches, and mercury thermostats.

Flow Switches

Flow switches are installed in fluid lines to sense fluid flow. As the fluid flow rate increases or decreases, the contacts in the flow switch will close and initiate an alarm. Flow switches are available in various sizes to sense a variety of flow rates.

Table 9-1.—Alarm, Safety, and Warning Systems

Circuit	System	Importance	Readiness Class
BZ	Brig cell door alarm and lock operating	NV	4
BW	Catapult bridle arresterman safety ind.	NV	1
CX	Bacteriological lab. & pharmacy comb. refer failure	NV	1
DL	Secure communications space door position alarm	NV	1
DV	Wrong direction alarm	V	2
EA	Reactor compartment or fireroom emergency alarm	NV	1
IEC	Lubricating oil low pressure alarm-propulsion machinery	SV	2
2EC	Lubricating oil low pressue alarm-auxiliary machinery	SV	1
1ED	Generator high-temperature alarm	SV	1
2ED	Oxygen-nitrogen generator plant low temperature alarm	NV	1
EF	Generator bearing high-temperature alarm	SV	1
EG	Propeller pitch control, hydraulic oil system low-pressure alarm	SV	2
EH	Gas turbine exhaust high-temperature alarm	SV	1 (aux. machinery) 2 (prop. machinery)
EJ	Feed pressure alarm	SV	1
1EK	Pneumatic control air pressure alarm	NV	2
3EK	Catapult steam cutoff and alarm	NV	2
EL	Radar cooling lines temperature and flow alarm	NV	1
EP	Gas turbine lubricating oil high-temperature alarm	SV	1 (aux. machinery) 2 (prop. machinery)
1EQ	Desuperheater high temperature alarm	SV	1
2EQ	Catapult steam trough high-temperature alarm	SV	2

Table 9-1.—Alarm, Safety, and Warning Systems—Continued

Circuit	System	Importance	Readiness Class
3ES	Reactor fill alarm	V	1
ET	Boiler temperature alarm	NV	1
EV	Toxic vapor detector alarm	SV	1
1EW	Propulsion engines circulating water high temperature	SV	1
2EW	Auxiliary machinery circulating water high temperature	SV	1
EZ	Condenser vacuum alarm	SV	2
F	High temperature alarm	SV	1
4F	Combustion gas and smoke detector	SV	1
9F	High-temperature alarm system-ASROC launcher	SV	1
11F	FBM storage area temperature and humidity alarm	SV	1
12F	Gyro ovens temperature and power failure alarm	SV	1
FD	Flooding alarm	NV	1
FH	Sprinkling alarm	SV	1
FR	Carbon dioxide release alarm	NV	1
FS	Flight deck ready light signal system	NV	2
FZ	Security alarm (CLASSIFIED)	V	1
4FZ	Torpedeo alarm (CLASSIFIED)	V	1
HF	Air flow indicator and alarm	SV	1
LB	Steering emergency signal system	NV	2
IS	Submersible steering gear alarm	SV	2
MG	Gas turbine overspeed alarm	SV	1 (aux. machinery) 2 (prop. machinery)
NE	Nuclear facilities air particle detector alarm	NV	1

Table 9-1.—Alarm, Safety, and Warning Systems—Continued

Circuit	System	Importance	Readiness Class
NH	Navigation horn operating system	NV	2
QA	Air lock warning	NV	1
QD	Air filter and flame arrester pressure differential alarm, or gasoline compartment exhaust blower alarm	V	1
QX	Oxygen-nitrogen plant ventilation exhaust alarm	SV	1
RA	Turret emergency alarm	NV	1
RD	Safety observer warning	NV	2
RW	Rocket and torpedo warning	SV	3
4SN	Scavenging air blower high-temperature alarm	V	2
SP	Shaft position alarm	NV	2
TD	Liquid level alarm	NV	1
1TD	Boiler water level alarm	NV	1
2TD	Deaerating feed tank water level alarm	NV	1
5TD	Reactor compartment bilge tank alarm	SV	1
6TD	Primary shield tank, expansion tank level alarm	NV	1
7TD	Reactor plant fresh water cooling expansion tankd level alarm	NV	1
8TD	Reactor secondary shield tank level alarm	NV	1
9TD	Lubricating oil sump tank liquid level alarm	SV	1
11TD	Induction air sump alarm	SV	1
12TD	Diesel oil sea water compensating system tank liquid level alarm	SV	1
14TD	Auxiliary fresh water tank low-level alarm	NV	1
16TD	Pure water storage tank low-level alarm	SV	1
17TD	Reserve feed tank alarm	NV	1
18TD	Effluent tanks and contaminated laundry tank high level alarm	V	1

Relay Switches

Relay switches are used in critical circuits to sense power failure. Power failure causes the relay contacts to close and initiate an alarm.

Mercury Thermostats

Mercury thermostats are used with the high-temperature alarm system (circuit F) to detect the presence of fires or overheated conditions in important compartments or spaces,

A mercury thermostat (fig. 9-1) consists of a column of mercury in a glass tube. Three electrical contacts are sealed into the glass tube. A resistor is connected in parallel with the top and middle contacts. The theme contacts along with the resistor and the mercury form a path for current flow. A

Table 9-1.—Alarm, Safety, and Warning Systems—Continued

Circuit	System	Importance	Readiness Class
19TD	Seawater expansion tank low-level alarm	SV	1
20TD	Gasoline drain tank high-level alarm	Sv	1
21TD	Moisture separater drain cooler high-level alarm	NV	1
24TD	Reactor plant on board discharge tank level alarm	V	1
25TD	Crossover drains high-level alarm	SV	1
29TD	Sonar dome fill tank low-level alarm	SV	1
30TD	JP-5 fuel drain tank high-level alarm	SV	2
TW	Train warning system	NV	1
W	Whistle operating system	NV	2

Legend:

V-Vital SV-Semivital NV-Nonvital.
1-Continuously energized-supply switch color code yellow.
2-Energized when preparing to get underway, while underway, and until the ship is secured-supply switch color code black.
3-Energized during condition watches-supply switch color code red.
4-Energized only when required-supply switch color code white.
All electronic type alarm systems formerly designated as circuits CA, FC, FW, G, GD, GJ, GN, and FP are now classified as a portion of the respective announcing system with which they are associated.

mercury thermostat functions somewhat like a thermometer in that the column of mercury rises as temperature increases. Under normal conditions, a small amount of direct current flows from one side of the line through the resistor, the middle contact, the mercury, the bottom contact, and back to the other side of the line. An increase in temperature will cause the mercury to rise in the tube. When the mercury reaches the top contact, the resistor will be shunted from the circuit, and the current will increase, The increase in current will cause a relay contact to close and initiate an alarm.

Mercury thermostats are installed in the overhead of magazines, storerooms, paint lockers, and other

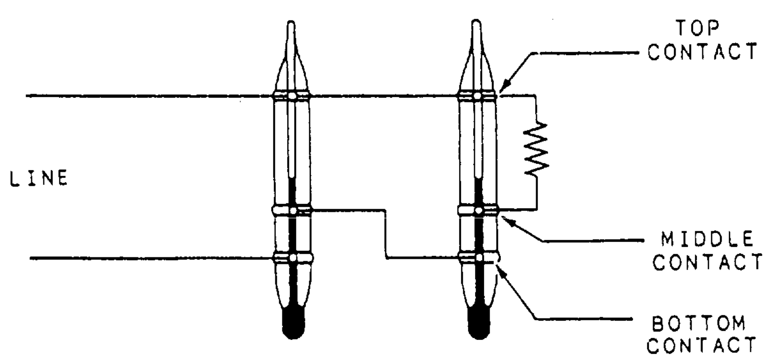


Figure 9.1.—Mercury thermostat.

spaces that house combustible stores. Figure 9-2 is an illustration of a mercury thermostat and its housing. The thermostats require a free circulation of air for proper operation. Barriers that obstruct the free circulation of air should never be placed around thermostats, and thermostats should not be installed in the path of supply ventilation. As many thermostats as needed for the prompt detection of high temperature can be connected to any one line. Figure 9-3 is an illustration of three thermostats connected in parallel on one line.

Mercury thermostats are available in three temperature ratings: 105°F, 125°F, and 150°F. The 105°F thermostat is normally installed in magazines, while the 125°F and 150°F thermostats are normally installed in storerooms and paint lockers. The thermostats are identical except for the differences in temperature ratings. When replacing a defective thermostat, you should always replace it with one having the same temperature rating.

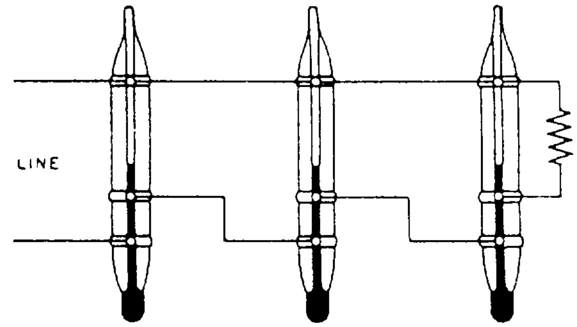


Figure 9-3.—Three mercury thermostats connected in parallel.

DETECTORS

Detectors used with the alarm, safety, and warning systems include ionization detectors and dual-purpose detectors.

Ionization Detectors

Ionization detectors are used with the combustible gas and smoke detector system (circuit 4F) to detect the presence of combustible gases and smoke. The combustion gas and smoke detector head (fig. 9-4, view A) is installed on the overhead in the compart- ment or space to be protected. A four-pin polarized plug fits into a socket base, allowing easy replacement (fig. 9-4, view B). The major units of the detector head are the inner and outer chambers and the cold cathode tube (fig. 9-4, view C). The detector compares the air in the inner chamber with the air in the outer chamber. When combustion gases and/or smoke are present in the air of the outer chamber, the cold cathode tube fires and supplies the current to initiate an alarm.

The air in the inner and outer chamber is made conductive by a small quantity of radium (fig. 9-4, view C). Alpha particles given off by the radium have the ability to ionize air into positive ions and negative electrons. If this ionized air is introduced into an electric

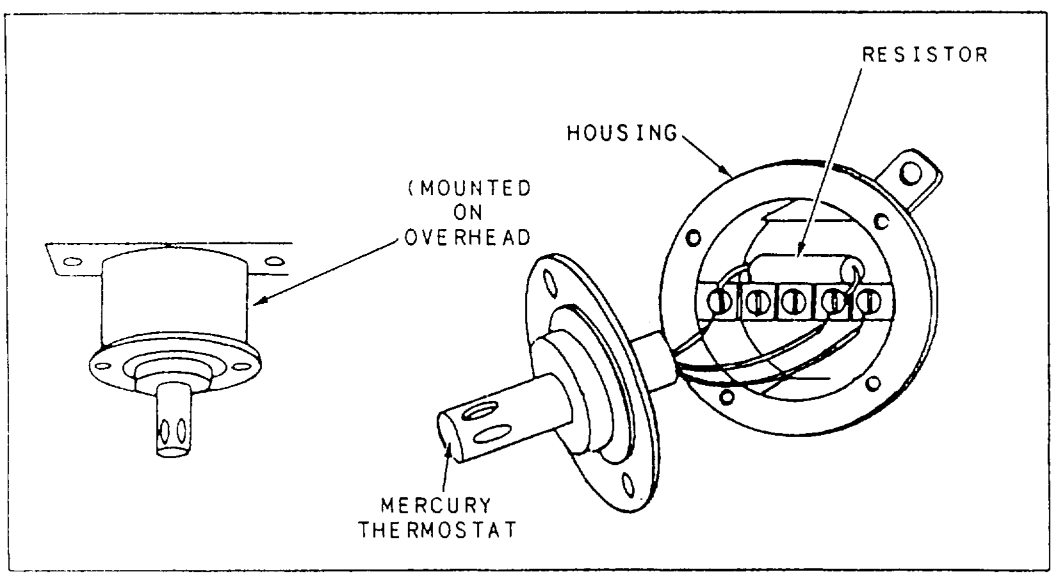
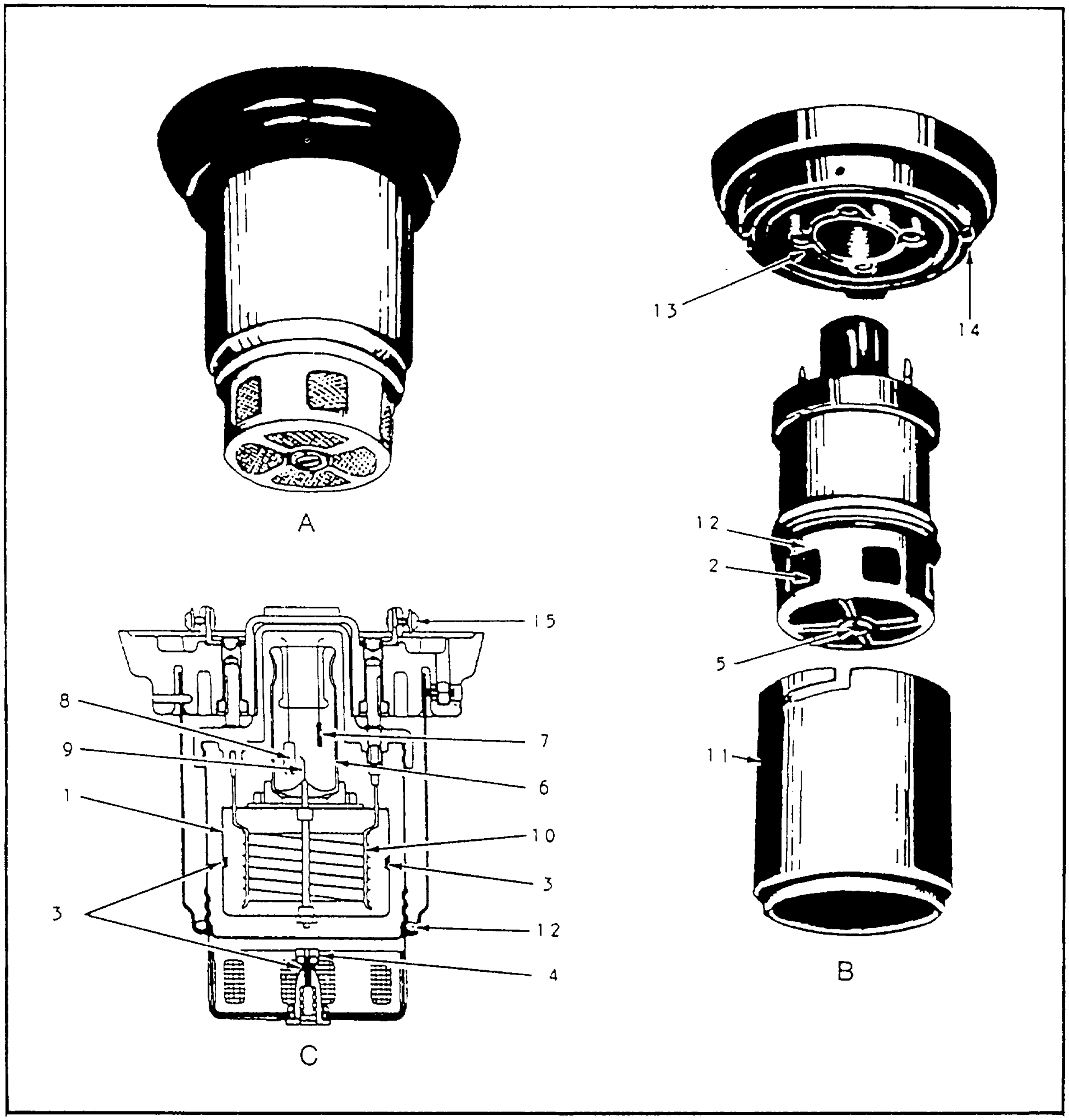


Figure 9-2.—Mercury thermostat and housing.



1. Inner or Reference Chamber
2. Outer or Detecting Chamber
3. Radium Sources
4. Sensitivity Adjustment Cap
5. Sensitivity Adjustment Screw
6. Gas Discharge (Cold Cathode Tube)
7. Anode
8. Cathode
9. Starter Electrode
10. Inner Wire Grid Electrode
11. Locking Shell
12. O-Ring
13. Socket Base
14. Locking Set Screw
15. Terminal Screws

Figure 9-4.—Combustion gas and smoke detector head.

field, a current will flow. Figure 9-5 illustrates this principle. A potential from battery B is applied to plates P_1 and P_2. The air between the plates is ionized by the radium. The charged particles move in the direction indicated by the arrows. A sensitive galvanometers measures the current, the value of which depends on the strength of the radium source, and part of the ions and electrons collide and neutralize each other. It is only when the potential reaches a certain limit that all of the ions formed reach the plates. This is known as the saturation point. Beyond this point, the current remains virtually constant regardless of the increase of potential. Only a change in the gas in the chamber will cause a change in the current flow when the unit is operating at the saturation point.

The presence of combustion gas or smoke particles between the plates will cause a sharp decrease in current flow through the galvanometers. This is true because the combustion gas and smoke particles are many times larger and heavier than the air molecules and require a stronger radioactive source to become ionized. Also, the ionized combustion gas and smoke particles are all neutralized by free electrons before reaching one of the plates.

Dual-Purpose Detectors

Dual-purpose detectors combine an ionization detector and a mercury thermostat in the same circuit in parallel.

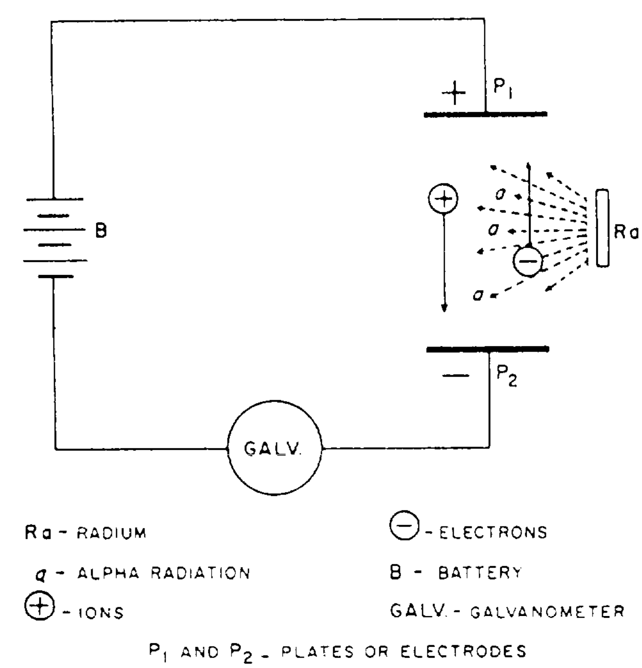


Figure 9-5.—Ionization principle.

RELAYS

Relays are used in alarm, safety, and warning systems to open and close circuits that may operate audible and/or visual signals. Relays were discussed earlier in chapter 3 of this training manual.

AUDIBLE AND VISUAL SIGNALS

Audible and visual signals are used with the alarm, safety, and warning systems to alert personnel that an alarm condition exists. The types of signals and their locations depend on the circuit they are used with. Audible and visual signals are also used with alarm panels and alarm switchboards, and as extension signals in remote spaces.

AUDIBLE SIGNALS

There are many types of audible signals in use on board Navy ships. The type of signal used depends upon the noise level of the location and the kind of sound desired. The principle types of audible signals are bells, buzzers, horns, sirens, and electronic signal units.

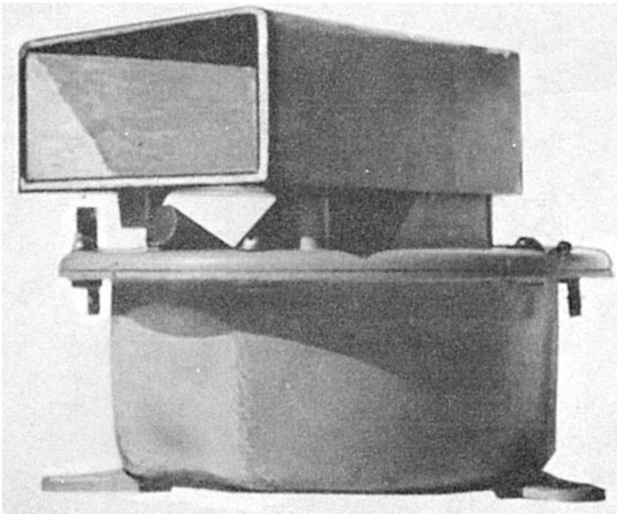
Bells

Bells used with alarm, safety, and warning systems are either ac or dc operated. Bells that are ac operated have four types of gongs: circular 3-inch diameter (type IC/B8S4), circular 4-inch diameter (types IC/B5DF4 and IC/B5S5), circular 8-inch diameter (types IC/B1S4 watertight and IC/B2S4 watertight explosion-proof), and cowbell (type IC/B3S4). Figure 9-6 is an illustration of a type IC/B3S4 bell.

Bells that are dc operated have three types of gongs: circular 2 1/2-inch diameter (type IC/B1D4), circular 8-inch diameter (type IC/B2D4), and cowbell (type IC/E13D4). Figure 9-7 is an illustration of a type IC/B2D4 bell.

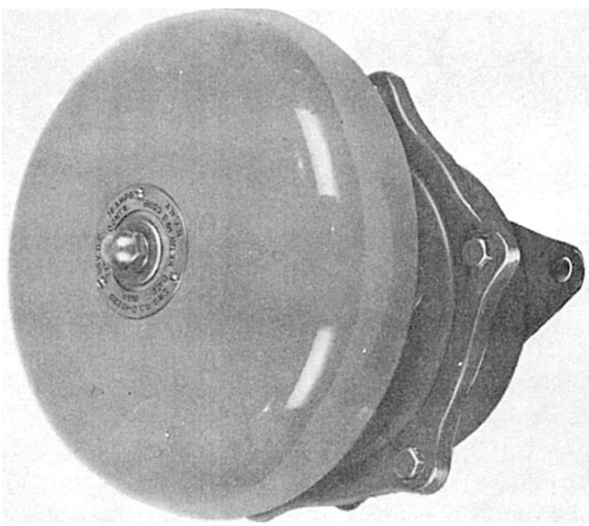
Buzzers

Buzzers are used only in relatively quiet spaces, There are two types of buzzers used with alarm, safety, and warning systems, Type IC/Z1D4 is dc operated and has make and break contacts. Type IC/Z1S4 is ac operated and has no contacts. Figure 9-8 is an illustration of a type IC/Z1D4 buzzer.



27.297

Figure 9-6.—IC/B3S4 bell.



27.298

Figure 9-7.—IC/B2D4 bell.

Horns

There are three types of horns used with the alarm, safety, and warning systems. They are (1) non-resonated horns, (2) resonated horns, and (3) motor-operated horns.

Nonresonated horns (types IC/H1D4, IC/H4D2, and IC/H4D3) use a diaphragm actuated by a vibrating armature to produce sound of the required intensity.

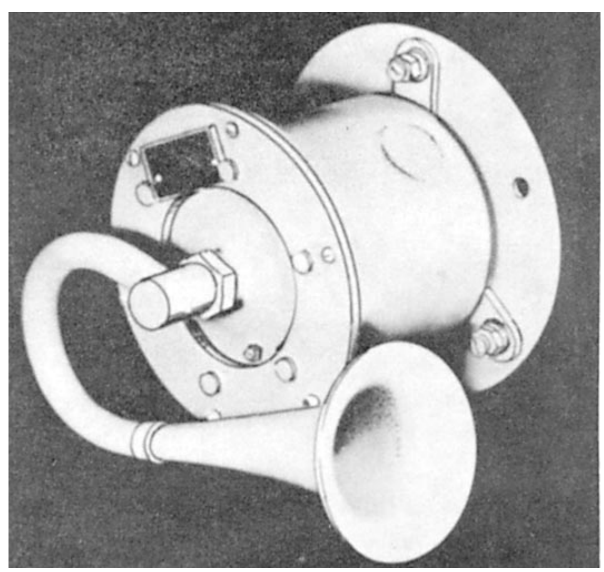
Resonated horns (types IC/H2S4 and IC/H2D4) also use diaphragms and, in addition, have

27.299

Figure 9-8.—IC/Z1D4 buzzer.

resonating projections to give the sound a distinctive frequency characteristic. The resonated horn is designed in a variety of types, differing as to intensity, frequency, or power supply. Figure 9-9 is an illustration of a resonated horn.

Motor-operated horns (types IC/H8D3, IC/H8D4, and IC/H8S3 use electric motors to actuate the



27.300

Figure 9-9.—Resonated horn.

sound-producing diaphragms. Figure 9-10 is an illustration of a motor-operated horn.

Sirens

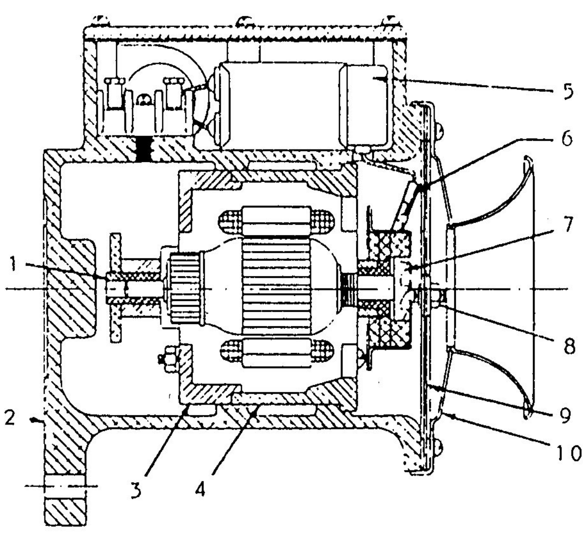
Sirens are used in very noisy spaces or to sound urgent alarms. The sound is produced by an electric motor driving a multiblade rotor past a series of ports or holes in the housing. The air being forced through the ports gives a siren sound, the frequency of which depends upon the number of ports, the number of rotor blades, and the motor speed. Figure 9-11 is an illustration of a siren.

Electronic Signal Units

The IC/E3D2 electronic signal unit (fig. 9-12) is designed for use with alarm switchboards. The unit consists of a solid-state oscillator and an amplifier. The unit is capable of generating three distinct tones: a wailing or siren tone, a steady tone, and a pulsating tone.

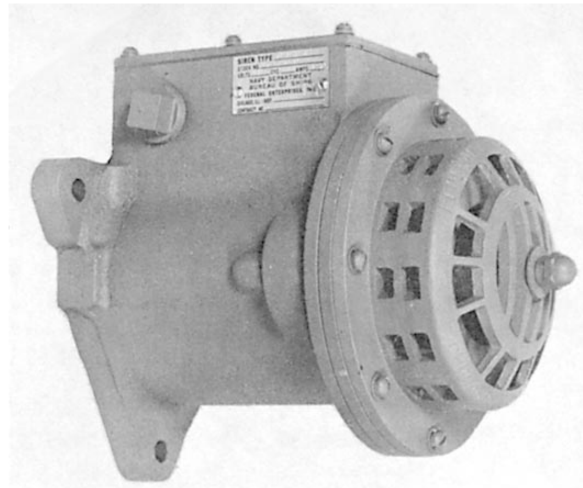
VISUAL SIGNALS

Visual signals are used with many alarm, safety, and warning systems to provide an additional means of identifying the alarm being sounded. Audible and visual signals are often used together. In noisy spaces, audible signals are supplemented by visual signals;



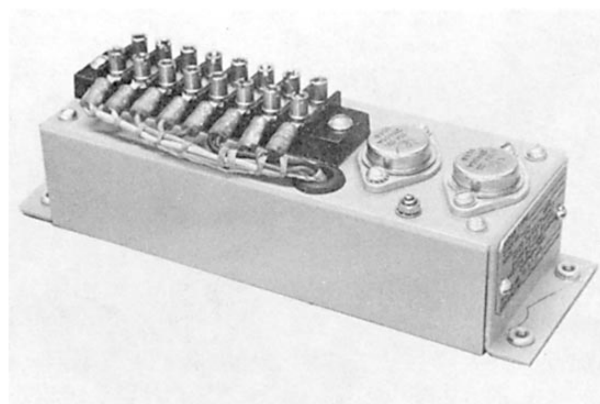
1. Bearing, Rear Oilite	6. Insulator
2. Motor Housing	7. Ratchet
3. Motor Support, Rear	8. Anvil
4. Motor Support, Front	9. Diaphragm
5. Filter	10. Front Cover Ass'y

Figure 9-10.—Motor-operated horn.



27.301

Figure 9-11.—Siren.



140.120

Figure 9-12.—Type IC/E3D2 electronic signal unit.

and in brightly lighted spaces, visual signals are supplemented by audible signals. In many instruments, the same audible device is used in combination with several visual signals. The principal type of visual signals are lamp indicators.

Standard watertight lamp indicators are designed as single-dial, two-dial, four-dial, and six-dial units. Two 115-volt lamps are connected in parallel and mounted behind each dial. The use of two lamps in parallel provides protection against the loss of illumination in case one lamp bums out. A colored-glass disk and sheet-brass target engraved with the alarm identification are illuminated from the rear by the two lamps. The 115-volt lamps are in parallel with the audible signal. When the audible signal sounds, the lamps illuminate the colored glass and brass target of the indicator and identify the alarm being sounded.

Standard watertight lamp indicators are also designed as two-dial variable-brilliancy, two-dial fixed-brilliancy, and four-dial variable-brilliancy units. Two 6-volt lamps are connected in parallel and mounted behind each dial. A colored jewel disk and sheet-brass target are illuminated from the rear by the two lamps.

Special lamp indicator panels are designed to give good visibility at all viewing angles. These panels contain rows of prism-shaped red and green jewels, Each indicator has two 6-volt lamps in parallel.

ALARM PANELS AND ALARM SWITCHBOARDS

Alarm panels and alarm switchboards are normally installed in spaces that are continuously manned both underway and in port. Alarm panels and alarm switchboards are capable of monitoring a number of circuits, depending on the type and size of the panel or switchboard used. All systems using alarm panels or alarm switchboards have a supervisory feature that indicates whether the system is operating in a normal mode. This supervisory feature usually consists of a 7000-ohm, 5-watt resistor connected across the terminals of the sensing device used in each system. When two or more sensing devices are used in the same line, the supervisory resistor will be connected across the terminals of the last sensing device in the line. The primary power source for alarm panels and alarm switchboards is 120-volt, 60-Hz ships' service power.

There are three basic conditions for each system being monitored. The first condition is the supervisory or normal condition. This condition exists when the system is functioning correctly. During this condition, a small continuous current flows in the circuit, which indicates that the circuit is in a normal condition.

The second condition is the alarm condition. This condition exists when there is an increase in current flow in the circuit.

The third condition is the trouble condition. This condition exists when an open in the circuit stops the flow of current in the circuit. Under this condition, an alarm condition cannot be detected.

ALARM PANELS

The alarm panel consists of a 3-inch alarm bell, a low-pitch trouble alarm buzzer, a three-position test switch, a test light, an alarm test light, a trouble test light a pilot light, negative and positive ground lamps, and four double-fuse holders (fig. 9-13).

The alarm bell, type IC/B1S4, is mounted in the upper left-hand comer of the alarm panel. The alarm bell sounds whenever an alarm condition exists,

The trouble buzzer, type IC/21S4, is mounted in the upper right-hand comer of the alarm panel. It is energized when there is a malfunction in the alarm circuit.

The test switch, type SR03, is a three-position, four-pole rotary switch, It is located in the center of the alarm panel. One section of the switch is not normally used, and can be used as a spare if another section malfunctions. The middle switch position is NORMAL, the left position is SILENT ALARM TEST, and the right position is SILENT TROUBLE TEST.

A TEST LIGHT is mounted between the bell and the buzzer. It is energized anytime the test switch is in any position other than NORMAL. When the TEST LIGHT is energized, it indicates the alarm bell or trouble buzzer have been disconnected from its circuit.

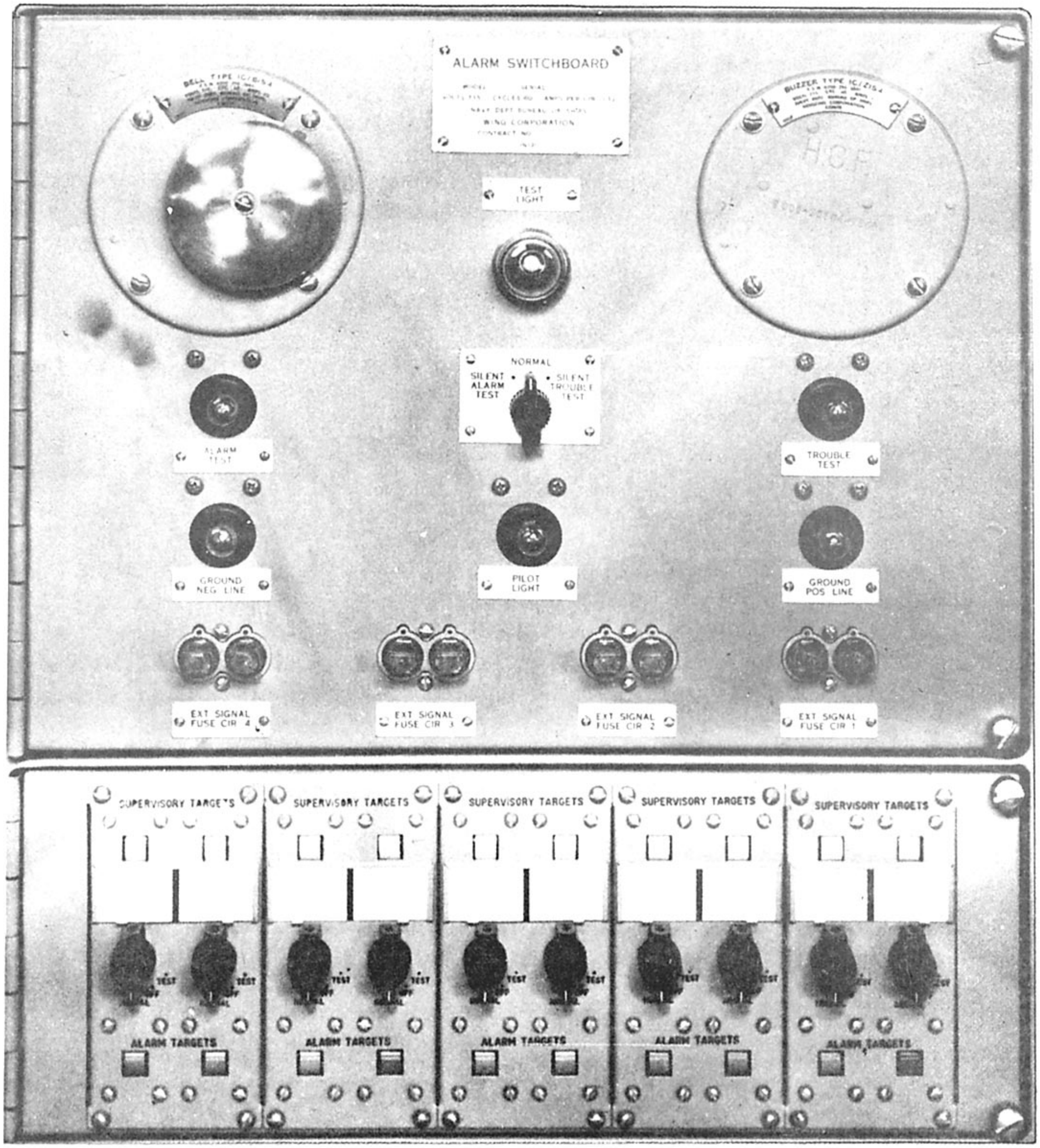
ALARM TEST and TROUBLE TEST lamps are mounted on the left and right of the test switch, respectively, The ALARM TEST light takes the place of the bell in the circuit when the test switch is put in the SILENT ALARM TEST position. The TROUBLE TEST light takes the place of the buzzer when the test switch is placed in the SILENT TROUBLE TEST position.

A PILOT LIGHT is located underneath the test switch. It is energized whenever power is available to the alarm switchboard.

Ground indicating lamps are located on either side of the PILOT LIGHT. The GROUND NEG LINE lamp is on the left and the GROUND POS LINE lamp is on the right side of the panel.

There are four double-fuse holders across the bottom of the alarm panel. These fuses are for remote alarms.

The most common types of alarm panels used with the alarm, safety, and warning systems are the B-51 and the B-52. The B-51 is a two-line panel, and the B-52 is a four-line panel. The only difference between these two panels is the number of lines. We will discuss the operation of the B-51 alarm panel in the following paragraphs.



292.31

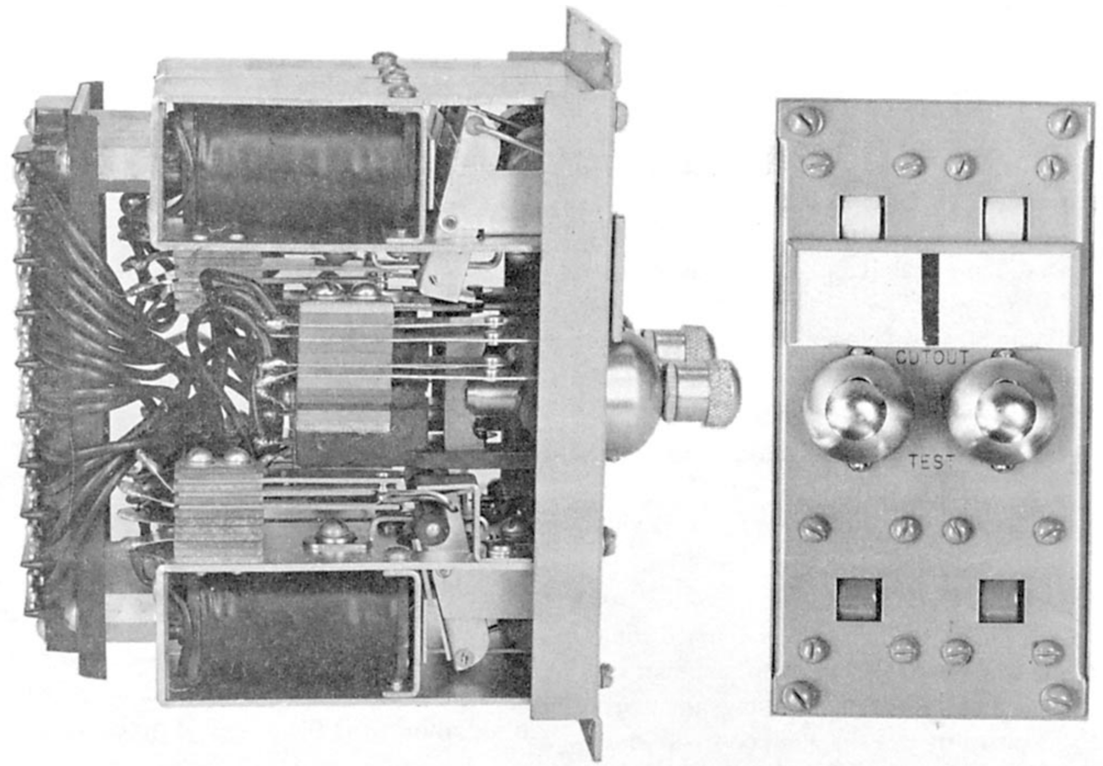
Figure 9-13.—Ten-line alarm switchboard.

The B-51 alarm panel, or two-line alarm unit (fig. 9-14), provides complete equipment for supervising two circuits or contact-maker lines. Five of these alarm units are mounted for each 10-line panel.

Each unit is secured to its case by four screws. This method of mounting permits the inspection of a unit by simply removing the four screws and pulling the unit out of its housing.

The equipment necessary for supervising a circuit or contact maker is comprised of an alarm-target relay, a supervisory-target relay, and a three-position rotary switch. Two sets of the equipment constitute a two-line alarm unit.

The two-line panel has two alarm relays mounted side by side at the rear and near the bottom of the unit panel. Each relay has an indicator drum that projects



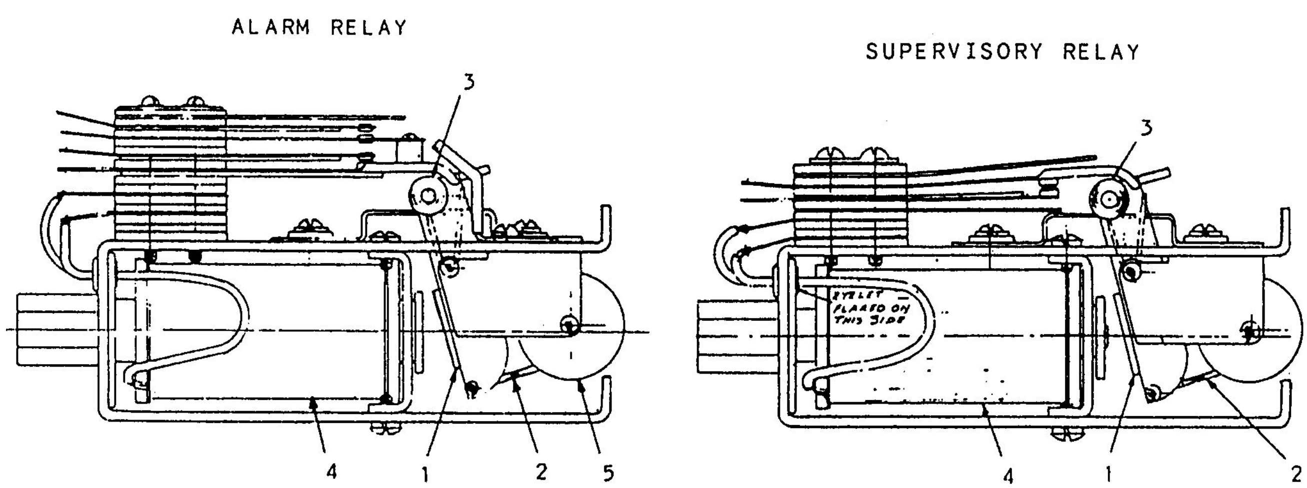
27.304

Figure 9-14.—B-51 alarm panel.

into square openings in the face of the panel. The two three-position rotary switches are mounted above the alarm relays. The two supervisory relays, with their indicator drums, are mounted above the switches. A bell and buzzer are connected in the relay circuits to provide audible alarms.

The alarm relay has a U-shaped frame. Inside the frame is a magnetic coil, an armature, and an indicator drum. On top of the frame, two pairs of contact springs are mounted (fig. 9-15).

The magnetic coil of the alarm relay is wound with 13,500 turns of wire to a resistance of 1325 ohms. The



1. Armature
2. Eccentric Arm
3. Roller
4. Coil
5. Target Drum

Figure 9-15.—Alarm and supervisory relays.

armature is located directly in front of the coil and is hinged between the side members of the frame. An insulated roller attached to the upper pm-t of the armature engages the contact spring. A helical coil spring maintains the armature in the open position when the coil is de-energized. The contacts are open when the coil is de-energized or in a normal condition, and closed when energized or in an alarm condition.

The indicator drum is located in front of the armature and is pivoted between the sides of the frame (fig. 9-15). The drum is connected to the armature by a short link, and rotates when the armature operates. The face of the drum protrudes slightly through the panel to be visible. The part of the drum visible when operated is painted red, the rest of the drum is grey.

The supervisory relay is similar in design and construction to the alarm relay. However, the number of turns on the coils and the contact arrangement are different. The supervisory relay is equipped with one pair of contacts. Note that when the armature (1) of the alarm relay operates, it rotates the target drum (5) through an eccentric, and closes the contacts for the audible alarms by moving the roller (3). However, the supervisory-target relay is designed to be normally operated; its alarm contact is closed when the relay is de-energized, and open when energized.

The magnetic coil of the supervisory relay is wound with 14,500 turns of wire and has a resistance of 1350 ohms.

The line unit test switch is a three-position, four-pole, rotary switch. The switch is not adjustable and should require no maintenance.

Normal Operation

The alarm drum has a red section that rolls into view when the alarm-target relay is operated. The supervisory drum shows a yellow section when it is de-energized. The two relays are in series with a sensing device.

When the circuit is in normal operation, the supervisory relay is energized. The supervisory resistor (a 7000-ohm, 5-watt resistor, connected across the terminals of the last sensor or detector) associated with the contact maker is in the circuit. While the alarm relay is also in the circuit, it is not sufficiently energized to operate the armature and close the contacts. When a contact maker closes, it short-circuits the supervisory resistor for that circuit, causing an increase in current. This increase in current increases the magnetic energy of the alarm relay to a point where it will operate its armature, closing the alarm relay contacts, energizing the alarm bell. When the alarm relay operates, it also rotates the target drum to red, indicating the circuit is in an alarm condition.

Since the normal operating current is just sufficient to hold the supervisory relay armature operated, an open circuit will cause the supervisory relay to drop out. This, in turn, closes the supervisory contacts, energizing a buzzer and rotating the supervisory target drum to yellow, indicating the circuit with a problem.

The current flowing under normal conditions (supervisory relay operated, supervisory resistor in the circuit, alarm relay not operated) is approximately 0.012 amperes. If a contact maker closes, shunting the supervisory resistor, the current flow will rise to approximately 0.043 amperes, which is sufficient to operate the alarm relay.

An extension signal relay is also in the alarm circuit (fig. 9-16). When the alarm relay contacts close, the alarm bell is energized by the extension

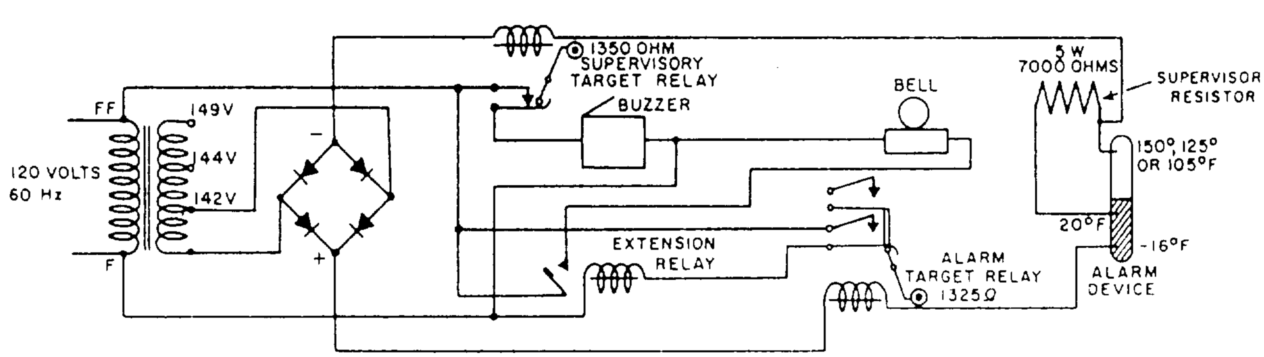


Figure 9-16.—High-temperature alarm circuit.

signal relay operating and closing its set of contacts. Figure 9-17 is a schematic of an alarm switchboard.

Test Operation

The supervisory alarm system is designed to require very little attention. Almost any trouble that may affect the system will give both an audible and a visual signal in the form of an alarm, or trouble alarm. However, the system is arranged so that periodic tests of all circuits may be made easily and quickly from the alarm switchboard. These procedures test only the panel and line units. External wiring must be checked at the panel for insulation resistance and continuity.

The silent test switch is centrally located at the top of the alarm switchboard. Keep this switch in the NORMAL position except when testing the switchboard circuits. For the silent alarm test, place the silent test switch in the SILENT ALARM TEST position. This disconnects the extension signal relay, that in **turn** controls the alarm bell and connects the ALARM TEST light into the circuit in place of the bell. When the silent test switch is placed in either test position, the TEST LIGHT on the panel will flash.

To test the capacity of each circuit to act as an alarm, place the silent test switch in the SILENT ALARM TEST position. Place the circuit test switch on the line unit in the TEST position. The ALARM TEST lamp will light and the target will show red on the circuit being tested, If the circuit is in proper condition to turn off the ALARM TEST light, return the station to NORMAL.

To perform the silent trouble test, place the silent test switch in the SILENT TROUBLE TEST position. Placing the switch in this position disconnects the trouble buzzer and places the silent test lamp in the circuit. As in the silent alarm test, the test lamp will also flash, Each supervisory circuit is tested by moving the line unit test switch slowly from NORMAL to OFF. The yellow target will show on the line unit directly above the line unit test switch, and the TROUBLE TEST lamp on the alarm panel will flash momentarily. The yellow target will show as long as the line unit test switch is in the OFF position. The TROUBLE TEST lamp will darken as soon as the line unit test switch is fully operated. If the yellow target does not show, the circuit is inoperative and should be repaired.

Upon completion of the silent alarm test and the silent trouble test, take care to see that all test switches are returned to normal.

ALARM SWITCHBOARDS

The alarm switchboard is an electrical system installed on board ship for the detection and warning of a variety of important functions or conditions that require continuous monitoring. It also gives warning when trouble or failure occurs in the alarm circuit and indicates which section of the equipment is involved. Alarm switchboards are normally used to monitor alarm, safety, and warning systems that have sensors located in a large number of spaces. The type IC/SM alarm switchboard is the latest type of switchboard installed on board ships today and is the only one we will discuss in this training manual.

The type IC/SM alarm switchboard uses individual line display alarm modules to present multiple steady and flashing visual displays together with multiple audible signals to indicate the state of the sensors associated with each individual line.

The type IC/SM alarm switchboard is available in many different sizes. Figure 9-18 is an illustration of an IC/SM-50 alarm switchboard. This switchboard is capable of monitoring 50 individual lines. Each switchboard contains a common alarm section and a line display section. The common alarm section includes all components located on the control panel, as well as the subassemblies common to any size alarm switchboard. The line display section contains the individual display modules, one for each circuit.

Common Alarm Section

The upper section of the switchboard is the common alarm section. The primary function of the common alarm section is to interpret commands from the line display alarm modules and, in turn, generate the appropriate audible signals. The audible signals produced are a wailing (or siren) tone, a pulsating tone, and a steady tone. Each of these signals represents a particular system condition. An alarm condition activates the wailing tone, the supervisory failure activates the steady tone, and a power failure activates the pulsating tone.

The secondary function of the common alarm section is to detect and indicate grounds in the switchboard itself or in any of the individual line circuits.

Mounted on the front of the common alarm section are two ground detection indicators, a visual-audible switch, an alarm silence indicator, a dimmer control, a speaker, and a fuse holder. Located inside the

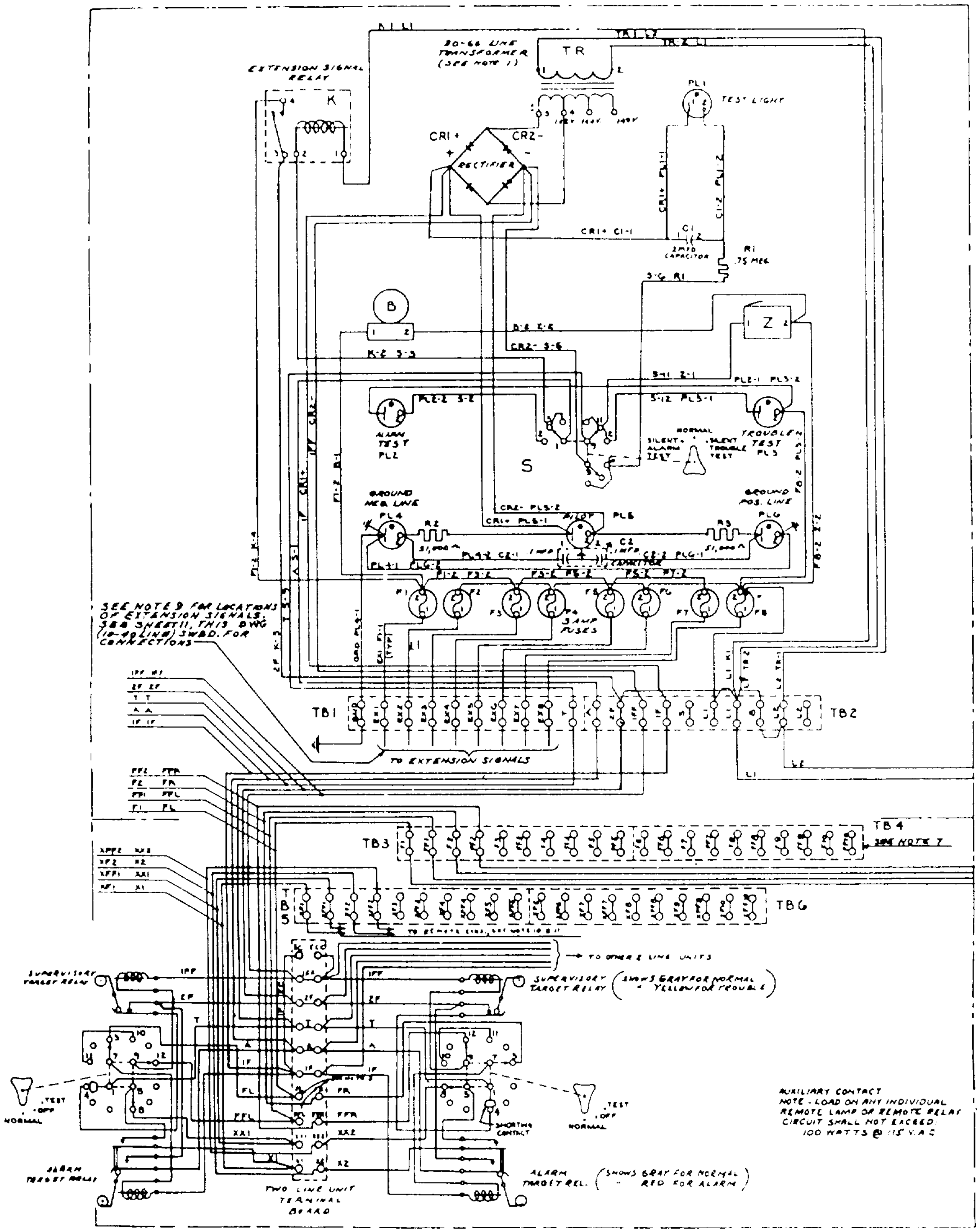


Figure 9-17.—Schematic of an alarm switchboard.

common alarm section are an audible volume control, a tone generator, a battery, a battery charger, the common board, and the power supply.

GROUND DETECTION INDICATORS.— The two ground detection indicators are provided to indicate when a positive or negative ground exists in the switchboard or in one of the lines. When a ground is sensed, one of the lamps will illuminate.

VISUAL-AUDIBLE SWITCH.— The visual-audible switch is a two-position switch. When it is placed in the VISUAL position, no audible alarm will be received, only the alarm silence indicator will

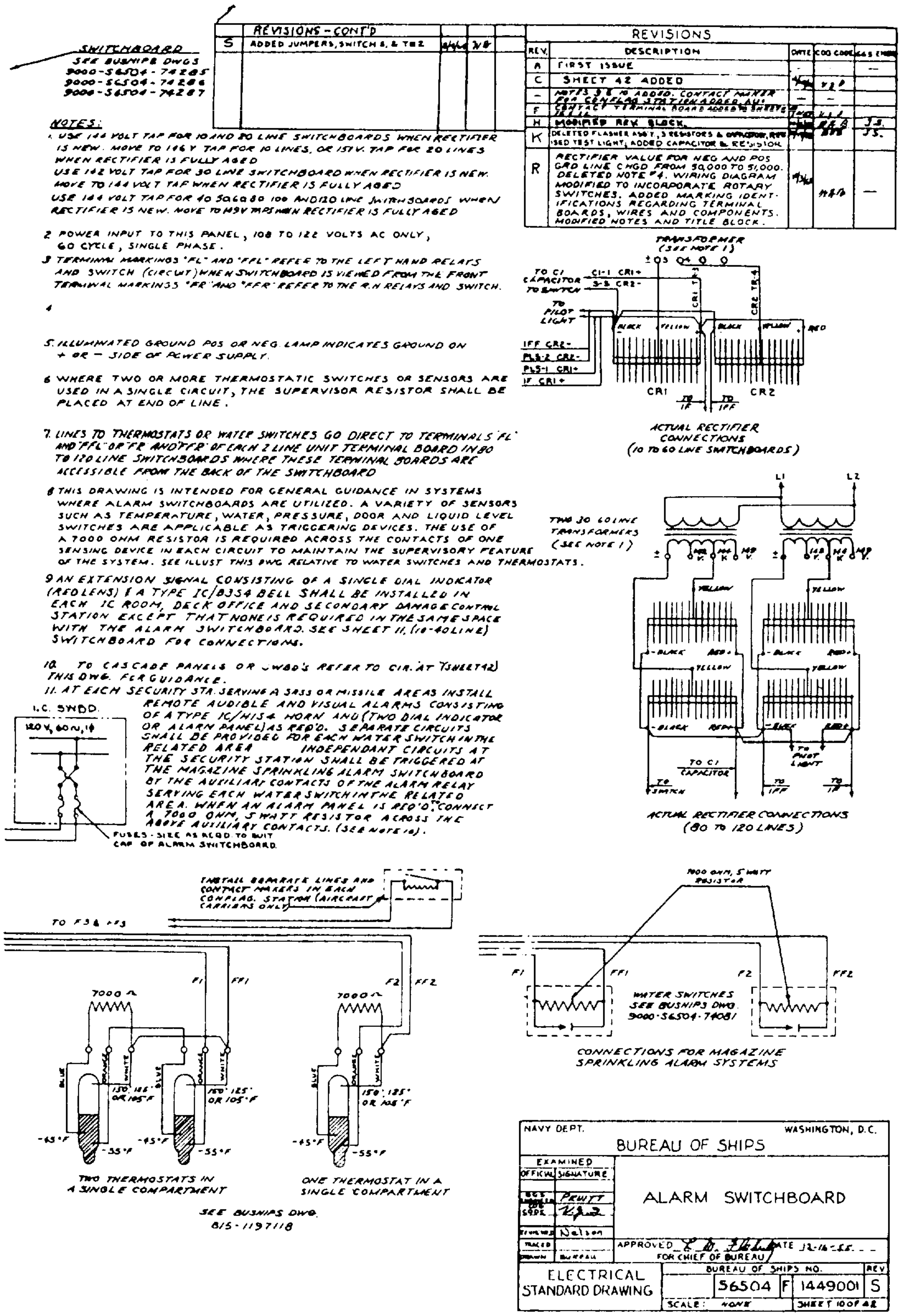


Figure 9-17.—Schematic of an alarm switchhoard—Continued.

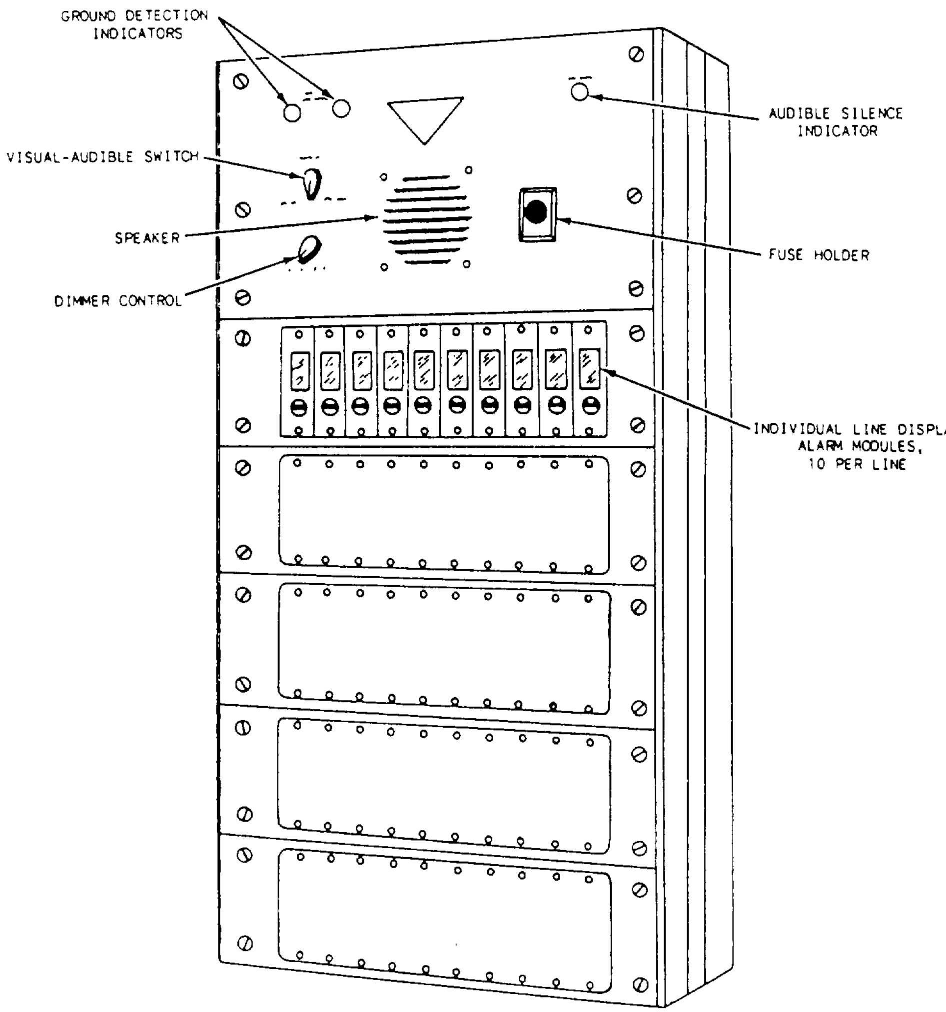


Figure 9-18.—IC/SM-50 alarm switchboard with 10 active modules in place.

indicate an existing alarm condition. This switch is normally left in the AUDIBLE position.

ALARM SILENCE INDICATOR.— The alarm silence indicator illuminates when the visual-audible switch is in the VISUAL position.

DIMMER CONTROL.— The dimmer control dims the alarm module display lamps in all conditions except flashing.

SPEAKER.— The speaker sounds an audible alarm when the visual-audible switch is set in the AUDIBLE position.

FUSE HOLDER.— The fuse holder contains the two main power fuses for the switchboard. If either fuse blows, the fuse holder will illuminate to indicate that there is a blown fuse.

AUDIBLE VOLUME CONTROL.— The audible volume control is used to adjust the volume of the speaker.

TONE GENERATOR.— The tone generator is a type IC/E3D2 electronic signal unit. The tone generator receives inputs from the alarm relays located in the common board and, in turn, generates the appropriate audible signal over the speaker. A wailing tone is generated for an alarm condition. A steady tone is generated for a supervisory failure (trouble condition), and a pulsating tone is generated when there is a loss of power.

BATTERY.— The battery supplies power to the tone generator to generate the pulsating tone when primary power fails. The battery must be hooked up for the switchboard to operate under normal conditions. However, it does not supply emergency power to operate the switchboard. The battery also supplies power to operate the alarm silence indicator when the visual-audible switch is in the VISUAL position.

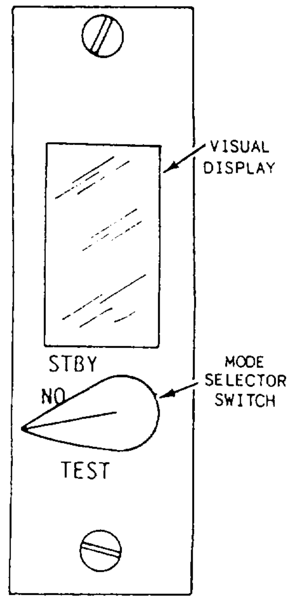


Figure 9-19.—Individual alarm display module.

BATTERY CHARGER.— The battery charger provides a floating charge to maintain the battery during normal switchboard operation. When the battery is charging, the battery voltage should be between 12 and 13.8 volts.

COMMON BOARD.— The common board contains the relays and circuitry to actuate all alarms. It also contains the circuitry for ground detection, dimming, and flashing lamp power.

POWER SUPPLY.— There is a power supply for each lo-line display alarm module. Each power supply consists of a transformer and a bridge rectifier. The output voltage of each power supply is approximately 6.3 volts.

Line Display Section

The lower section of the switchboard is called the line display section. This section contains all the individual line display alarm modules. Figure 9-19 is an illustration of an individual alarm display module.

Recognition of the state of the remote sensor is accomplished by the alarm module (fig. 9-19). One module is associated with each line circuit. Figure 9-20 illustrates an alarm module connected to a sensor circuit. A sensor circuit will be in one of three

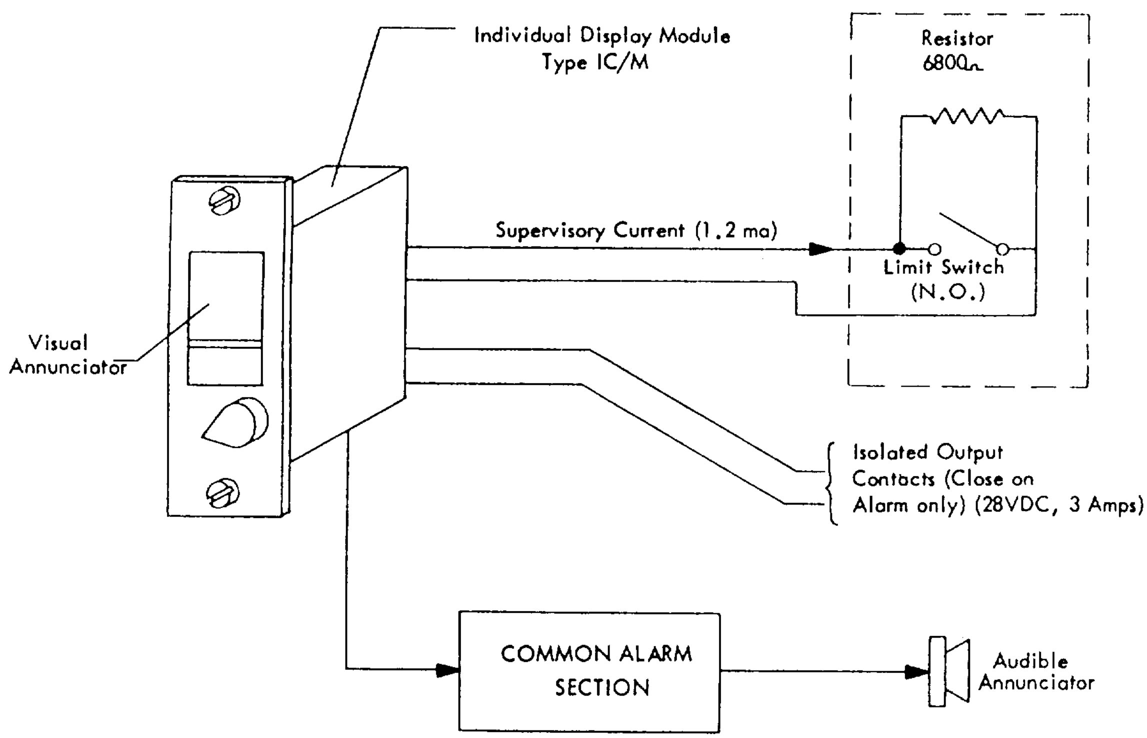


Figure 9-20.—Alarm module type IC/M, functional diagram.

conditions: normal, alarm condition, or supervisory failure. The upper rectangular portion on the module panel gives the visual display of the circuit condition.

Each module contains a horizontally centered, divided display that can present a steady or flashing red light or no light in either half of the display. All light modes can be dimmed except the flashing mode. The upper half of the display shows the circuit designation and the location of the sensor. The condition of a remote sensor by the alarm module is indicated by visual and audible signals. Figure 9-21 illustrates the visual and audible displays of an alarm module.

Each module also has a four-position mode selector switch. The mode selector switch is used to place the module in either the NORM (NORMAL), STBY (STANDBY), CUTOUT, or TEST mode.

NORMAL MODE.— The NORMAL mode is the normal operating position of the mode switch. In this mode, the upper display lamp is on (steady) and the lower display lamp is off (dark). There will be no audible signal. When the remote sensor contacts close, an alarm condition occurs. During an alarm condition, the upper display lamp flashes continuously and the lower display lamp remains off. The alarm module sends a command to the common alarm section. The tone generator in the common alarm section activates the alarm speaker, and a siren wail is heard.

During a trouble condition, such as an open circuit, with the mode switch in NORM, the alarm module will signal a supervisory failure. In this

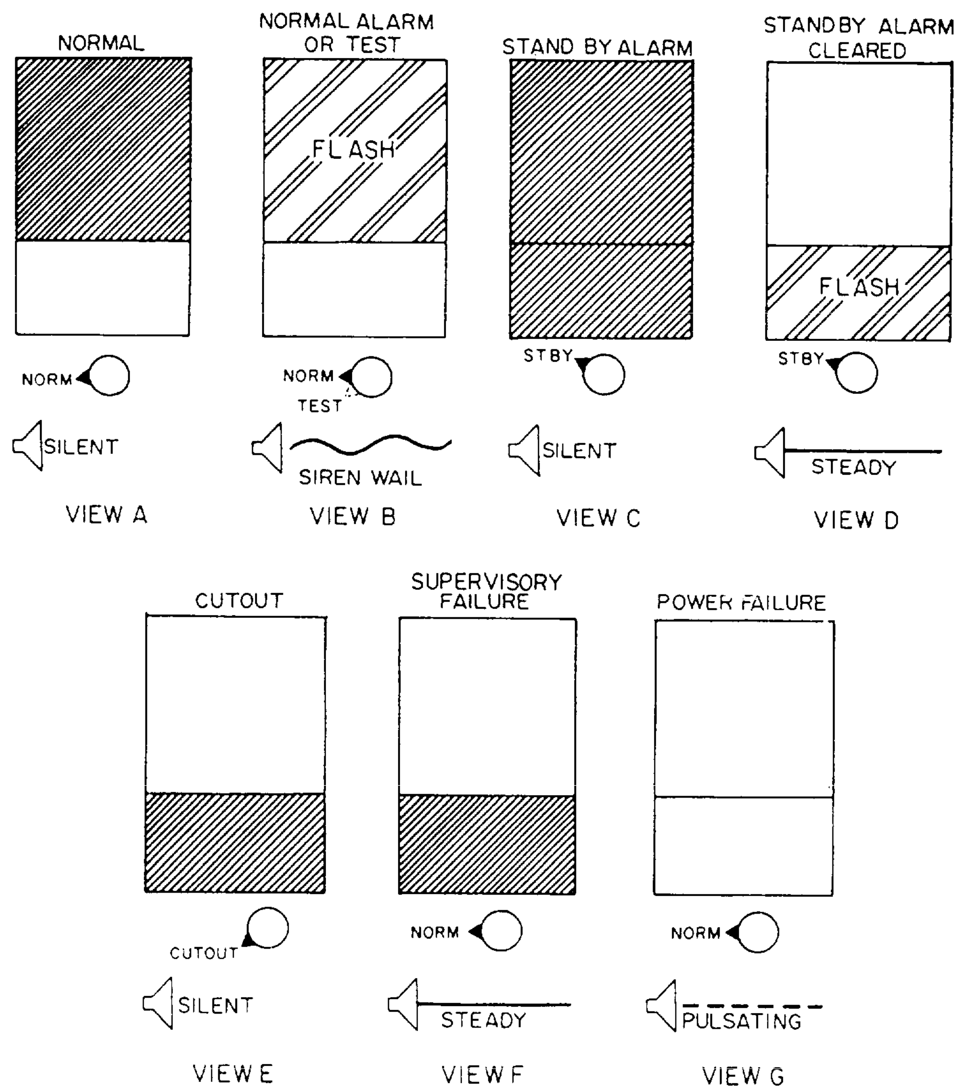


Figure 9-21.—Visual displays and audible outputs.

condition, the upper display lamp will go out, the lower display lamp will come on, and a steady alarm tone will sound.

STANDBY MODE.— The STANDBY mode is used to acknowledge an alarm. During an alarm condition, the mode switch is shifted to STANDBY to silence the audible alarm. The upper display lamp will stop flashing and remain on, and the lower display lamp will come on and remain on. When the alarm condition is cleared, the lower display lamp will begin flashing, and the upper display lamp will go out. The alarm module sends a signal to the tone generator and a steady tone will sound on the loudspeaker. The mode switch is then returned to the NORMAL mode to silence the alarm.

CUTOUT MODE.— The CUTOUT mode is used when maintenance needs to be performed on a line. In this mode, power is disconnected to the individual line, the upper display lamp will go off and remain off, and the lower display lamp will come on and stay on. There is no audible signal associated with this mode. The position of the mode switch disconnects power from the sensor circuit to allow maintenance to be performed.

TEST MODE.— The TEST mode is used to simulate an alarm condition. In this mode, the upper display lamp will flash continuously, a wailing tone will sound, and the lower display lamp will remain off.

Power supplies furnish operating power to the alarm modules, their sensors, and to a common circuit board in the common alarm section. The power supplies consist of one transformer and one bridge-type diode rectifier for each 10 alarm modules. The output voltage is approximately 6.3 volts rms.

A power failure alarm will sound if a primary power failure occurs. A battery in the alarm switchboard operates the power failure alarm upon loss of primary power. The battery is float charged by a taper charger while primary power is applied. The alarm switchboard is inoperative unless the battery is connected. A power failure is indicated when the upper and lower module lamps are out, and a pulsating tone is heard from the alarm speaker.

ELECTRICAL ALARM, SAFETY, AND WARNING SYSTEMS

The following sections will describe the various alarm and warning systems that you, as an IC Electrician, will be involved with. These interior communication systems provide audible and visible signaling devices to safeguard machinery and personnel.

HIGH-TEMPERATURE ALARM SYSTEM (CKT F)

Circuit F provides a means of detecting and warning of the presence of overtemperature or smoke in compartments requiring continual supervision; that is, ammunition spaces, flammable stowage areas, living spaces, or other spaces designated by ship's design. This system is classified as semivital readiness class 1.

Figure 9-16 illustrates a high-temperature alarm circuit using a mercury thermostat as the sensing device. This system is of the supervisory closed-circuit type, whereby each detector line and associated relay coils on the high-temperature alarm switchboard form a closed circuit, which is under continuous check for grounds, open circuits, low temperature, or the normal function of the system.

The presence of smoke or a rise in the temperature within the compartment to a predetermined temperature (105°F, 125°F, or 150°F) will create a bridge on the line that will actuate an alarm module in the high-temperature alarm switchboard. The nameplate on the alarm signal designates the compartment in which the alarm condition exists.

An extremely low temperature in a compartment or open circuit in the line will result in a failure of the supervisory current, causing a supervisory alarm on the switchboard.

GAS TURBINE AND DIESEL GENERATOR HIGH-TEMPERATURE ALARM AND FLAME DETECTION SYSTEM (CKT 1F)

Circuit IF provides a means for alarm signals to indicate high temperatures and detection of flame within the acoustical module enclosures for gas turbine and diesel generators. This system is classified as semivital readiness class 1.

To serve each gas turbine, two temperature switches are located in the acoustic cell and three flame detectors are located at critical points about the gas turbine. A manual push button is located adjacent to the enclosure access. In addition, door switches are installed at the enclosure access and vent fan control switches are provided at the local operating station and at the propulsion control console (PCC).

To monitor the diesel generators, a temperature switch with a supervisory resistor across its contacts is located in each acoustic cell and three flame detectors are located at critical points about each diesel generator.

At each gas turbine, the photoelectric cells in the flame detectors produce a signal when exposed to a flame condition. This signal operates a local contact closure. This closure is transmitted to the local operating station, where it energizes an alarm indicator mounted on the adjacent instrument panel. The signal is also transmitted to the PCC, where it energizes a second alarm indicator. This circuit is supplemented by a push button, mounted at the enclosure access, operation of which also energizes both of these alarms. Push buttons at the console and the local operating station provide a means for shutting down the engine room ventilation supply and exhaust fans. The status of the enclosure door is displayed at the console.

When the temperature in the acoustic cell reaches a predetermined level, the contacts of one or both temperature switches close and complete the circuit to a console alarm indicator.

At each diesel generator, photoelectric cells in the flame detectors produce a signal when exposed to a flame condition. This signal is transmitted to flame signal conditioner. The conditioner transmits the alarm signal to the electric plant control console.

When temperature in the acoustic cell reaches a predetermined limit, the contacts of the temperature switch close and complete the circuit to a module of the local alarm switchboard with an extension signal to a vent fan shutdown relay assembly. The energized relays disconnect power to the machinery room, supply, and exhaust fans.

Checkout procedures for the gas turbine high-temperature and flame detector circuit are contained in the *Electric Plant Control Console Technical Manual.* Checkout procedures for the diesel generator high-temperature alarm circuit are contained in the *Electric Plant Control Console Technical Manual.*

Power for all gas turbine circuits is taken from the PCC. Power supply for the diesel generator flame detector circuit is taken from a local 120 Vac distribution box, while the power supply for the diesel generator high-temperature circuit is taken from the alarm switchboard.

Maintenance should be accomplished according to the applicable technical manual and maintenance requirement cards (MRCs).

SPRINKLING ALARM SYSTEM (CKT FH)

Circuit FH is classified as semivital readiness class 1. This circuit provides a means of indicating leakage or flow of water in the sprinkling system lines for various protected spaces.

This system has four water switches and two pressure switches. Abnormal conditions are displayed on the circuit FH modules in the damage control area of the central control station (CCS).

Any leakage or flow of water in the lines to the small arms magazine, the trash disposal room, the torpedo magazine, or the 76mm ammunition magazine will actuate the switch and provide alarm indication on the associated module in the circuit F alarm switchboard in the damage control area of the CCS. The switches for the small arms magazine and trash disposal room are equipped with supervisory resistors. Since the torpedo magazine and the 76mm ammunition magazine use common alarm modules for circuits FD and FH, the water switches for the sprinkling system in these areas are not fitted with supervisory resistors since the resistors are in the level switches of circuit FD.

The sprinkling system for the Mk 13 Mod 4 guided missile launcher system (GMLS) magazine is provided with three separate alarms. Normally, the accumulator tank in the magazine is filled with water under pressure. A sensor in the magazine, on detecting a dangerous condition, releases the water in the tank, thus reducing the pressure; and its alarm switch closes, activating an alarm module on the circuit F alarm switchboard.

In the alarm system for the missile injection system compression tank, the alarm actuation is the same as for the Mk 13 Mod 4 GMLS magazine accumulator tank.

The supervisory resistors for the accumulator tank and the eductor valve Mk 13 magazine alarms are mounted in a common junction box No. C-17, located in the a/c machinery room on the first platform.

The supervisory resistor for the missile injection system compression tank is located in the pressure switch.

Individual extension alarms are provided via the supplemental relay of circuit F to the damage control console and common extension alarms to the alarm switchboard at the offtcer of the deck (OOD) station and to the alarm switchboard in the ship control console.

Circuitry of the alarm switchboards and associated connections may be verified by means of switchboard test procedures.

Power for each alarm circuit is provided from the alarm switchboard.

PROPULSION MACHINERY LUBRICATING OIL LOW-PRESSURE ALARM SYSTEM (CKT 1EC)

Circuit 1EC provides a means of indicating low oil pressure in the lubricating oil supply lines to the propulsion engines, reduction gear bearings, and associated equipment. This system is classified as semivital readiness class 2.

Pressure transducers of the pressure-to-current type are provided in the lubricating oil supply lines, the lubricating oil scavenge lines, the reduction gear bearing circuit, and the lubricating oil pump discharge lines. Pressure switches are provided in the coastdown circuit and the reduction gear bearing alarm circuit.

Each transducer transmits a signal, proportional to the lubricating oil pressure, to a signal conditioner at the local operating station for display at the local operating station, at the PCC, or as a digital readout at the console.

Each pressure switch transmits a signal to an alarm indicator at the local operating station or at the console.

The signal representing lubricating oil supply pressure is generated at the freestanding electronics enclosure. Pressure is displayed on meters at the local operating station and at the console alarm indicator. The transducer signal, representing lubricating oil scavenge pressure, is applied to the demand circuitry for a digital readout at the console. Internal circuitry generates both high- and low-pressure alarms at the console.

The pressure switch in the coastdown pump air supply is actuated when pressure drops to its low limit, and transmits a signal to a console alarm indicator. In addition, when the pump is operating, it provides a signal to a console pump running indicator.

The transducer signal, representing reduction gear bearing lubricating oil pressure, is transmitted to drive pressure meters at the local operating station and at the console. The associated pressure switch closes when pressure drops to its low limit, and transmits a signal to alarm indicators at the local operating station and at the console. In addition, when the pressure is established, it transmits a signal to a console GEAR LUBE OIL ON indicator.

The transducer signal, representing lubricating oil pump discharge pressure, is routed directly to the console where it is used as a demand digital checkout.

System checkout procedures for the lubricating oil pressure circuits can be found in the *Propulsion Control System Technical Manual.*

Power for the lubricating oil pressure circuits is taken from the PCC.

AUXILIARY MACHINERY LUBRICATING OIL LOW-PRESSURE ALARM SYSTEM (CKT 2EC)

Circuit 2EC is a semivital readiness class 1 circuit. This circuit provides a means of indicating low oil pressure in the lubricating oil lines to bearings of the ship's service diesel generators. This is done through the use of pressure transducers and pressure-type switches provided in the lubricating oil lines to the ship's service diesel generators.

A pressure transducer is installed in the lubricating oil supply line to each diesel generator. The transducer generates a signal proportional to supply line pressure that is applied to the console circuitry to drive a pressure meter and to generate an alarm signal when pressure drops to a predetermined low value.

A pressure switch is installed in the lubricating oil supply line to each diesel generator. Alarm modules on the IC/SM switchboards in each machinery room are actuated by these pressure switches to indicate a low-pressure condition at any of the supply lines.

Circuitry of the alarm switchboards and associated connections may be verified by test procedures previously described.

Checkout procedures for the console alarm circuit can be found in the *Electric Plant Control Console Technical Manual.*

Power supply for the circuits associated with the IC/SM alarm switchboard is from these switchboards.

The power for the console alarm circuits is taken from the console.

AUXILIARY MACHINERY CIRCULATING WATER TEMPERATURE INDICATING AND ALARM SYSTEM (CKT 2EW)

Circuit 2EW provides a means for indicating high temperatures in the ship's service diesel generators engine circulating water. This system is classified as semivital readiness class 1.

Sensors of the resistance-temperature-detector (RDT) type are installed in the circulating water line of each diesel generator. High-temperature switches, fitted with supervisory resistors across the contacts, are also provided in the circulating water line.

Each RTD in the circulating water line provides a signal to an RTD conditioner in the electric plant operating console. Temperature is displayed continuously on a temperature meter and as a demand digital display. If circulating water temperature rises to a predetermined limit, an alarm signal is generated that energizes visual and audible alarm indicators at the type IC/SM alarm panel associated with the generator.

Checkout procedures for this circuit can be found in the *Electric Plant Control Console Technical Manual.* Switchboards and associated connections can be checked out as described previously.

Power supply for the circulating water indicating and alarm circuits associated with the electric plant control console is taken from the console. Power for the alarm circuits associated with the alarm switchboards is taken from the switchboard.

GENERATOR AIR TEMPERATURE INDICATING AND ALARM SYSTEM (CKT 1ED)

Circuit 1ED provides a means of indicating high temperature of the cooling air exhaust of the ship's service diesel generators. This circuit is classified as semivital readiness class 1.

A sensor of the RTD type is installed in the cooling air exhaust of each diesel generator. In addition, a high-temperature switch is installed adjacent to the sensor.

The RTD in the cooling air exhaust provides a signal to an RTD conditioner in the electric plant control console. Temperature data is available at the demand digital display. In the event the temperature exceeds a predetermined value, an alarm indicator is energized.

The high-temperature switches in the cooling air exhaust, which operates when temperature reaches a predetermined limit, actuates visual and audible alarm indicators on the type IC/SM alarm panel associated with the generator.

Circuitry of the alarm switchboards and associated connections may be verified using the procedures previously described. Checkout procedures for the console circuits can be found in the *Electric Plant Control Console Technical Manual.*

Power for each alarm switchboard circuit is taken from the associated alarm switchboard. Power for the console circuits is taken from the console.

GENERATOR BEARING AND STATOR TEMPERATURE INDICATING AND ALARM SYSTEM (CKT EF)

Circuit EF provides a means for indicating high temperature in bearings and stators of ship's service diesel generators. This circuit is classified as semivital readiness class 1.

A sensor of the RDT type is installed so that it is in contact with the bearing or the stator, A high-temperature switch is also installed so that it is in contact with the bearing.

The RTD at a bearing sends a signal to an RTD conditioner in the electric plant control console. Temperature is displayed on a demand digital readout. In the event the temperature exceeds a predetermined value, visual and audible alarms are energized.

An increase in the temperature at the bearing to a predetermined temperature causes the temperature switch to operate, actuating a visual and audible indication at the type IC/SM alarm panel associated with the generator. Operation of the circuits of this switchboard has been previously described.

The RTDs at the generator stators provide signals to an RTD conditioner in the electric plant control console. Temperature for each phase is continuously available through a selector switch for display on a temperature meter.

Checkout procedures for the bearing and stator circuits can be found in the *Electric Plant Control Console Technical Manual.* Alarm switchboard circuitry may be verified with its test circuit, as previously described.

Power supplies for the bearing and stator indicating and alarm circuit associated with the electric plant control console are taken from the console. Power supply for the circuits associated with the IC/SM alarm switchboards is taken from these switchboards.

CARBON DIOXIDE AND HALON GAS RELEASE (CKT FR)

Circuit FR provides a means of indicating when carbon dioxide or Halon gas is released in compartments protected by a fixed-gas, fire-extinguishing system. This system is classified as nonvital readiness class 1.

Two dial lamp indicators with red lens or white lens are installed at the access to each compartment that is to be monitored and at the local actuating stations for machinery spaces and the gas turbine enclosures.

Single lamp-type indicators (red HALON RLSE lens) are installed at the local actuating station for all of the diesel enclosures, the flammable liquid storeroom, and the paint mixing and issue room.

Bells, types IC/B2S4 (EXP) and IC/B3S4 are installed in the protected spaces.

Rotary flashing red beacons are installed in the machinery spaces to supplement the bells, due to the high noise levels.

Alarm modules of the circuit F-type IC/SM switchboard in the damage control area of the CCS are assigned to this system.

Switches at the PCC activate the GT Halon system, Switches at the turbine enclosure energize a Halon ready indicator at the console.

A separate installation is provided for each compartment protected. The protected compartments are the Mk 13 Mod 4 GMLS magazine, auxiliary machinery rooms No. 1, 2, and 3, SS diesel generator enclosures No. 1, 2, 3, and 4, the engine room, the flammable liquids storeroom, the gas cylinder storeroom, and the paint mixing and issue room,

The configuration of the system and number of systems a compartment may have will depend on the size of the compartment, the equipment in the compartment, and the purpose of the compartment. For example, the Mk 13 Mod 4 GMLS magazine is a dual system, one for the magazine inner structure and one for the outer.

For each machinery space, auxiliary machinery room, and the engine room, a pressure switch (manual reset) is installed in the Halon actuating line at the remote actuating station in the CCS. This switch actuates the following:

- An alarm module on the circuit F alarm switchboard in the damage control area of the CCS, operation of which has been previously described
- Audible alarms, type IC/B3S4 bells, in the machinery space protected
- A rotating red beacon in the space protected
- A two-dial lamp-type indicator (red ALARM and white POWER-ON lenses) outside each access to the protected space

A rotary snap switch is installed at each local Halon actuating station that will silence the audible signals and maintain the red light at each access until reset.

Pressure switches, one each in the discharge lines of the primary and reserve banks of Halon cylinders, energize a two-dial lamp-type indicator (two red lenses—HALON RLS PRI and HALON RLS RSV) located at each local actuating station and on the damage control console in the CCS.

The installation for each ship's service diesel generator enclosure consists of a pressure-operated switch (manual reset) in the Halon actuating line in the CCS, which energizes the following when the gas is released:

- Alarm signals on the alarm switchboard for circuit Fin the damage control area of CCS
- A type IC/BS4(EXP) bell within the space
- A two-dial lamp-type indicator (red ALARM lens and white POWER-ON lens) installed outside of each access to the protected space

A rotary snap switch is installed at the local Halon actuating station to de-energize the audible alarm within the space while retaining the red light at the access.

A pressure switch in the discharge line of the Halon bank energizes a single dial (red HALON RLS lens) lamp-type indicator at the local Halon actuating station and an indicator on the damage control console.

The installation for each gas turbine module consists of a pressure-operated switch (manual reset) in the Halon actuating line in the CCS, which energizes the following when the gas is released:

- Alarm signals on the alarm switchboard specified for circuit F in the damage control area of CCS
- An explosion-proof bell, IC/B2S4(EXP), installed within the space
- A two-dial lamp-type (red ALARM lens and white POWER-ON lens) installed outside of each access to the protected spaces

A rotary snap switch in the discharge line of the Halon bank energizes a single-dial (red HALON RLS lens) lamp-type indicator at the local Halon actuating station and indicators on the damage control console.

Supervisory resistors are provided in all pressure switches used to actuate alarm modules on the circuit F alarm switchboard, which has been previously described.

Individual extension alarms are provided from all circuit FR alarm modules to the damage control console.

When the Halon flood switch at the PCC is set, the circuit is closed to a solenoid valve to actuate the Halon system within the gas turbine enclosure. A manual Halon inhibit switch at the enclosure in the open position closes the circuit to a console Halon ready indicator.

Circuitry for the alarm switchboard and related connections may be verified by switchboard test procedures.

The remaining circuits can only be tested by simulating an alarm condition at each pressure switch.

Power supply for each system can be verified by the white light at each access to each space.

Checkout procedures for the GT Halon Release System can be found in the *Propulsion Control System Technical Manual.*

BOILER WATER LEVEL ALARM SYSTEM (CKT 1TD)

Circuit 1TD provides a means of indicating alarm signals for each boiler when the steam drum water reaches the highest or lowest permissible operating level. The system consists of a drum water level indicator for each boiler, which energizes audible and visual alarm signals at the associated boiler operating station. Visual indications (red lights) will also be on the CCS indicating board. The water level indicator for each boiler will be provided with electrical contacts at the high- and low-level marks on the drum. Either set of contacts upon closing will energize the alarms.

Where only one alarm is required, the system consists of high- and low-water level contacts that energize a type IC/H8S4 horn through a cutout switch and a four-dial indicator (one lens blank) on the boiler gauge board. The four-dial indicator will have power on indication and red high- and low-water level indication.

For troubleshooting the system, refer to the appropriate technical manual, drawings, and PMS cards for the system applicable to your ship.

WRONG DIRECTION ALARM SYSTEM (CKT DW)

Circuit DW provides a means of warning personnel at the engine order system (EOS) area of the CCS when the operation of the propeller pitch control mechanism is in the opposite direction to an order acknowledged over the EOS. This circuit is classified as vital readiness class 2.

When actual operation of the EOS does not match the EOS acknowledgement of the ordered propulsion command, the contacts in the propulsion control unit and the EOS close in such combination to transmit a signal to the EOS WRONG DIRECTION indicator at the PCC.

When the propeller shaft watermills after a change in direction has been ordered, a reverse direction contact in the shaft revolution transmitter closes, energizing a relay that, in turn, closes a contact to actuate logic circuitry, which energized the shaft reverse rotation alarm indicator in the PCC.

For troubleshooting and repair of the wrong direction indicating system and the shaft reverse rotation system, refer to the *Propulsion Control System Technical Manual.*

FLOODING ALARM SYSTEM (CKT FD)

Circuit FD provides indication when the water level in the monitored compartments has reached a predetermined level. This circuit is classified as nonvital readiness class 1.

The system consists of magnetically operated liquid switches, which are installed in the lowest level of the monitored compartment. The alarm modules are in the alarm switchboard in the damage control area of the CCS.

The float-type switch in each space is fitted with a supervisory resistor to maintain the supervisory feature of the alarm module. In spaces fitted with more than one switch, the resistor is installed in the one at the end of the line.

Operation of any switch by a rising liquid level will short-circuit the line, initiating an alarm on the alarm switchboard as previously described.

Extension alarms are provided via the supple- mental relay of circuit F as follows except for the fire pump room, which has no extension:

— Individual extensions of all alarms to the damage control console except that the extensions for the sonar cooling equipment room and the sonar equipment room are paralleled to activate a common indication at the damage control console.

— Individual extensions of the alarms for engine room, a/c machinery room, auxiliary machinery rooms 1,2, and 3, eductor room, auxiliary propulsion machinery room, and steering gear room to the auxiliary control console.

— Common circuit FD alarms to the alarm switchboards at the OOD station No. 1 and in the pilothouse ship control console (SCC).

Troubleshooting and repair of the system can be accomplished by using the system checkout procedures for testing the circuitry of the alarm switchboards and associated connections by switch- board test procedures and by using applicable Planned Maintenance System (PMS) cards.

Power for each circuit is provided from the alarm switchboard.

PROPELLER PITCH CONTROL HYDRAULIC OIL INDICATING AND LOW PRESSURE AND ALARM SYSTEM (CKT 3EG)

Circuit 3EG provides means for indicating and alarming low pressure in the propeller hydraulic oil system at the EOS area of the CCS. This system is classified as semivital readiness class 2.

A pressure transducer of the pressure-to-current type is provided at the hydraulic oil power module. Differential pressure transducers of the pressure-to-current type are provided at the main and standby hydraulic pump suction strainers.

The transducer transmits a dc signal, proportional to pressure, to a signal conditioner located in the local operating station. Hydraulic oil pressure is displayed at the PCC on a pressure meter and on the digital demand display. This pressure is continuously monitored so that if, at any time, pressure drops below a predetermined value, visual and audible alarm indicators are energized at the PCC and at the local operating station.

Each differential pressure transducer transmits a signal proportional to the pressure drop in the pump suction strainers to a signal conditioner in the local operating station. The signal is transmitted to the PCC for conversion to a demand digital display. Internal circuitry provides the signal for visual/audible alarm indicators when differential pressure reaches a predetermined value.

Checkout procedures for this system can be found on the appropriate PMS cards and in the *Propulsion Control System Technical Manual.*

Power for the circuits is furnished by the PCC.

AIR PRESSURE INDICATING AND ALARM SYSTEM (CKT EK)

Circuit EK provides a means of indicating the pressure in the compressed air system and indicating when the air pressure drops below a predetermined value. It also provides an indication of emergency shutdown of the compressors. This circuit is classified as nonvital readiness class 1.

Pressure transducers and pressure switches are located in the piping for the system.

Each transducer is a pressure-to-current type that transmits a dc signal, proportional to the pressure, to a signal conditioner in the auxiliary control console. The HP and LP air receiver pressures are displayed on digital demand display. The HP range is 0 to 6000 psig and the LP range is 0 to 200 psig. These pressures are continuously monitored so that if, at any time, the pressure drops below a predetermined value, visual indicators and a bell in the auxiliary control console are energized.

The pressure at the starting air manifold is continuously displayed on an analog indicator on the auxiliary control console with a 0 to 150 psig range.

Each HP and LP compressor is fitted with a safety shutdown feature that closes a contact in its motor controller. This contact, in turn, energizes circuits in the auxiliary control console to display a visual alarm and sound a horn.

In addition to the alarms on the auxiliary control console associated with the air receiver pressures, there is a pressure switch fitted in the piping for each HP and LP air receiver. Alarm modules on the IC/SM switchboards in auxiliary machinery rooms No. 2 and No. 3 actuated by these pressure switches are used to indicate a low-pressure condition at any of the HP or LP air receivers. Alarms for HP and LP receiver No. 1 appear on alarm switchboard No. 2 in auxiliary machinery room No. 2. Alarms for HP and LP air receivers No. 2 appear on alarm switchboard No. 4 in auxiliary machinery room No. 3.

The engine turbocharger pressures are displayed on the digital demand display at the electric plant control console.

Low-pressured conditions, at the brake actuator and at the turbine brake actuator, operate pressure-sensitive switches, which transmit signals to alarm indicators at the PCC.

Transducer-controlled signals drive pressure meter displays at the local operating station for gas turbine starting air pressure. Alarm signals, taken from the meter circuitry, are transmitted to the PCC for energizing alarm indicators at the PCC.

The PCC computer calculates gas generator pressure ratios. The output signal is displayed on a console meter and is transmitted to the local operating station instrument panel for display on a second meter.

System checkout procedures for the HP and LP air indicating and alarm circuits can be found in the *Auxiliary Control Console Technical Manual.* The alarm circuitry may be verified with its test circuit as described in the appropriate PMS cards. Checkout procedures for the engine turbocharger indicating system can be found in the *Electric Plant Control Console Technical Manual.* Checkout procedures for the actuator alarm systems, the low starting air pressure alarms, and the gas generator pressure ratio indicating system can be found in the *Propulsion Control System Technical Manual.*

GAS TURBINE LUBRICATING OIL HIGH-TEMPERATURE ALARM SYSTEM (CKT EP)

Circuit EP provides a means for indicating high temperature for the lubricating oil supply to the gas turbine. This system is classified as semivital readiness class 1.

A signal, taken from circuit TM (temperature indicating and alarm system), is used as an input to an alarm control module at the local operating station when the lubricating oil reaches a predetermined temperature. An alarm signal is generated and transmitted from the local operating station to the PCC, where it energizes visual and audible alarm indicators.

Checkout procedures for this circuit can be found in the *Propulsion Control System Technical Manual.*

Power supply for this circuit is taken from the PCC.

STEERING EMERGENCY ALARM SYSTEM (CKT LB)

Circuit LB provides a means of signaling that a steering casualty has occurred. This system is classified as vital readiness class 2.

In the event of a casualty to the steering control system, the operator at the SCC operates the steering alarm switch on the console. One pole of this switch closes the circuit to the siren in the steering gear room. A plate installed at the siren reads "WHEN THIS SIREN SOUNDS, AFTER STEERING STATION TAKE CONTROL." The second pole of the switch on the SCC is bridged with a supervisory resistor and is connected to an alarm module of the alarm switchboard in the machinery control area of CCS. Thus, operation of the switch alerts CCS of the steering control casualty.

System checkout can be performed by operation of the switch on the SCC. Circuit checkout of the signal in CCS is available at the alarm switchboard.

POWER FAILURE ALARM SYSTEM (CKT PF)

Circuit PF provides an indication to a remote station when power input to the main IC switchboard has failed. This circuit is classified as semivital readiness class 1.

One 400-Hz and one 60-Hz relay is provided as integral units of the main IC switchboard. Two modules on the IC/SM alarm switchboard in the machinery control area of CCS function in this alarm circuit.

Each of the relays on the main IC switchboard is normally held energized by the bus voltage. Failure of the bus voltage permits the relay to assume the normal (de-energized) position, shorting the supervisory resistor by closing the alarm contacts to the associated module in the type IC/SM alarm switchboard in the machinery control area of CCS. Operation of the bus failure alarm signal at the main IC switchboard is also controlled by two bus relays and is described in the technical manual for the switchboards.

SECURITY ALARM SYSTEM (CKT FZ)

The purpose and use of the security alarm system is confidential. During normal ship operations, testing and maintenance of the system and its monitored areas should follow the two-man rule; that is, a minimum of two authorized personnel capable of detecting incorrect or unauthorized procedures with respect to the task to be performed and familiar with applicable safety and security procedures must be present. All keys to the switchboard door locks, terminal box padlocks, and so on, are to be handled as SECRET material, and should remain in the possession of designated ship's security personnel. If either a lock or its key is lost, both must be replaced immediately.

Refer to NAVSHIPS 401-4538943, Security *Alarm System Circuit FZ Elementary and Isometric Wiring Diagram (CONFIDENTIAL),* for equipment description, operation, and location. Because of the confidentiality involved, you will have to refer to the NAVSHIPS 401-4538943 and applicable PMS cards for procedures to troubleshoot and repair the system,

AIR FLOW INDICATOR AND ALARM PANEL (TYPE IC/APE)

The airflow indicator and alarm panel (circuit HO) is a remote panel installed in each compartment that needs a constant supply of fresh air, The meter can indicate a flow of air not exceeding 1000 feet per minute (fpm). An alarm sounds when the airflow from the exhaust ventilation decreases to a predetermined level, which is set by a second pointer on the meter face.

Under normal operating conditions, the sensor detects the airflow by rotation of its vanes. An interruption of contacts as the vanes turn produces the pulses that operate the meter.

The indicator is an electronic signal unit type IC/E102, a modification of the IC/EIDI. It serves as the alarm portion of the system and can be used with remote alarm units. A 12-volt battery inside the enclosure supplies power to the entire unit during normal and emergency operations.

SYSTEMS MAINTENANCE

Preventive maintenance of the systems should be done according to the MRCs associated with each system. Preventive maintenance consists of routine cleaning, visual inspection of components, and testing.

Corrective maintenance of the systems is relatively easy to perform. Almost any trouble that will affect system operation gives an audible and/or visual indication.

If an open occurs in one of the systems, an alarm condition cannot be detected. Therefore, the problem should be found and corrected as soon as possible, In some cases, such as open supervisory relay contacts, no indication will be received to indicate a trouble condition.

Shorted switch contacts or relay contacts in one of the systems could result in false alarm conditions or blown fuses. A short in an audible or visual signal will affect the operation of the system only during an alarm condition. The short will cause an increase in current flow and will result in blown fuses.

A ground in one of the systems could also result in false alarms or blown fuses. Grounds can be either single or multiple on the same side of the line or simultaneous on both sides of the line.

Mechanical problems, such as a weak spring on art alarm relay, will also result in a false alarm.

If a complete loss of power occurs in an alarm panel, check the fuses that supply primary power to the panel. If the fuses are good, open the panel and check the incoming line connections with a voltmeter. If power is not present, the problem is in the cable that supplies power to the panel. If power is present, check the power transformer and rectifier. For more information on troubleshooting alarm panels, refer to the applicable manufacturer's technical manual.

If a complete loss of power occurs in the IC/SM switchboard, check the two main power fuses located on the front of the common alarm. If the fuses are good, open the cabinet and check the incoming line connections of the fuse holder with a voltmeter. If input power is present, check the power transformers and bridge rectifiers. If power is not present, check the fuses that supply primary power to the switchboard. For more information on troubleshooting the IC/SM switchboard, refer to the applicable manufacturer's technical manual.

SUMMARY

In this chapter, we have discussed how the alarm, safety, and warning systems are used on board ship to alert personnel of dangerous or abnormal conditions. We have identified the principle components of the various alarm, safety, and warning systems and how they operate. We have also briefly described some of the common troubles associated with the systems and the effects they will have on the systems.

CHAPTER 10

SHIP'S ORDER INDICATING AND METERING SYSTEMS

LEARNING OBJECTIVES

Upon completion of this chapter you will be able to do the following:

- *Describe the purpose of the ship's order indicating and metering systems.*
- *Identify the various types of control consoles used with the ship's control order and indicating systems.*
- *Describe the operation of the ship's control order and indicating systems.*
- *Describe the operation of some of the various metering and indicating systems installed on Navy ships.*
- *Describe the function of gears.*
- *Identify the basic types of gears and their uses.*
- *Describe the operation of various gear mechanisms.*
- *Briefly describe the troubleshooting and maintenance procedures for various ship's order indicating and metering systems.*

INTRODUCTION

To operate a ship properly, watch personnel require vast quantities of information relative to conditions within and outside the ship. Ship's order indicating and metering systems are installed on ships to measure and transmit this information.

SHIP'S CONTROL ORDER AND INDICATING SYSTEMS

Ship's control order and indicating systems consist of the (1) propeller revolution order system (circuit M), (2) engine order system (circuit MB), (3) rudder angle indicator (circuit N), (4) rudder order (circuit L), and (5) steering emergency alarm signal (circuit LB). On the older ships, the equipment for these circuits is mounted in a ship's control console and a steering control console. On the newer gas turbine ships with automated propulsion systems, the ship's control and steering consoles are combined into one console using state of the art circuitry and equipment. Only the consoles installed on the older ships will be discussed in this training manual. For information on the consoles installed on the newer gas turbine ships, refer to the applicable Ship Information Book.

SHIP'S CONTROL CONSOLE

The ship's control console incorporates, in a single unit, the equipment required to transmit orders relative to the speed of the ship. Figure 10-1 is an illustration of a double engine order ship's control console. The order and indicator systems associated with the console are the propeller revolution order and the engine order. The ship's control console also contains circuits for control of the ship's speed lights. The speed light circuits are maintained by the Electrician's Mates.

Propeller Revolution Order System

The propeller revolution order system (circuit M) transmits the required propeller revolutions per minute (rpm) from the pilothouse to each propulsion

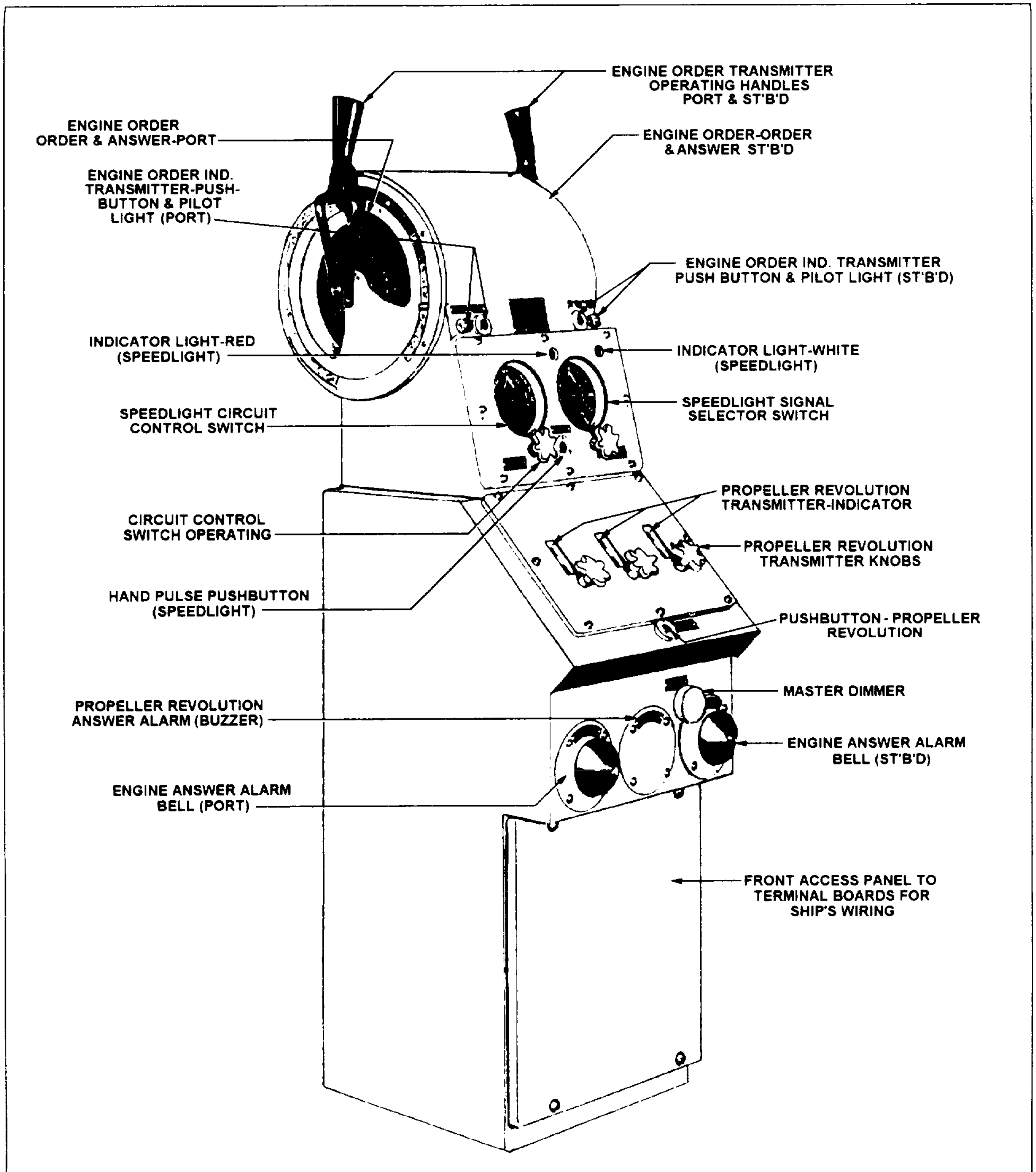


Figure 10-1.—Ship's control console.

gauge board. The control unit (propeller order indicator transmitter) for circuit M is mounted in the ship's control console. It is a self-synchronous control unit, containing three synchro transmitters and three synchro receivers, each of which is coupled to an indicating dial. The transmitters are further coupled to control knobs. The lee helmsman operates the indicator transmitter when a change in propeller revolutions is ordered by the OOD.

A second propeller order indicator-transmitter (fig. 10-2) is mounted on the main gauge board in engine room No. 1. When a change in propeller revolutions is transmitted from the ship's control

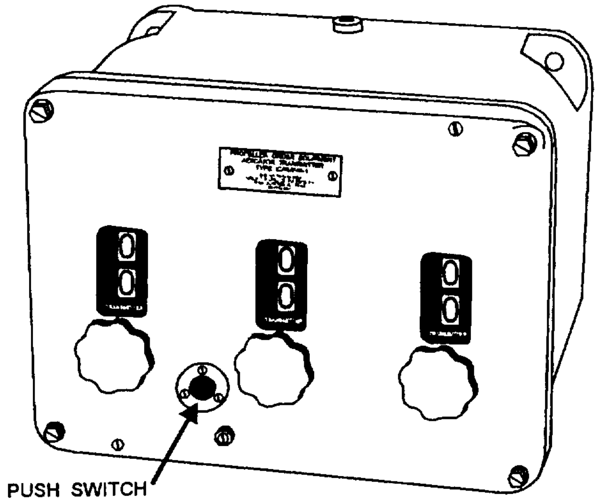


Figure 10-2.—Propeller order indicator-transmitter (circuit M).

console, it is received and indicated on this propeller order indicator-transmitter. The throttleman in engine room No, 1 acknowledges the change by transmitting the order back to the propeller order indicator-transmitter in the ship's control console. In the event of an engineering casualty or specific test, the throttleman in the engine room can reverse the procedure by requesting specific revolutions per minute.

A propeller order indicator (fig. 10-3) is mounted on the gauge board of engine room No. 2. This indicator is used to inform the watch in engine room No. 2 that a change in propeller revolutions has been ordered.

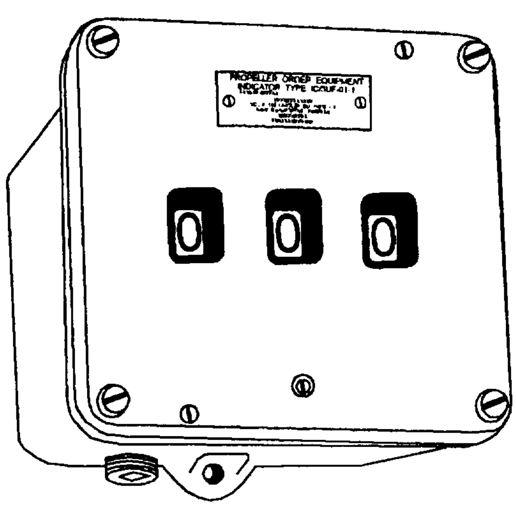


Figure 10-3.—Propeller order indicator (circuit M).

Engine Order System

The engine order system (circuit MB) transmits the required shaft direction orders (ahead/back) and the ordered speed of each shaft from the pilothouse to each propulsion gauge board.

An engine order indicator-transmitter for each shaft (1MB for starboard shaft and 2MB for port shaft) is mounted in the upper section of the ship's control console. An operating handle is attached to each indicator-transmitter, The lee helmsman operates the handles whenever a change in shaft direction or speed is ordered by the OOD. There is also a push button and a bell located on the console for each indicator-transmitter. The push buttons are used to alert the appropriate engine room of a change in orders. The bells alert the lee helmsman that the order has been acknowledged by the appropriate engine room.

Each engine room has one indicator-transmitter (fig. 10-4) for its associated shaft. After receiving an engine order, the throttleman acknowledges the order by turning the knob and matching its transmitter to the received order. A push button is located on the

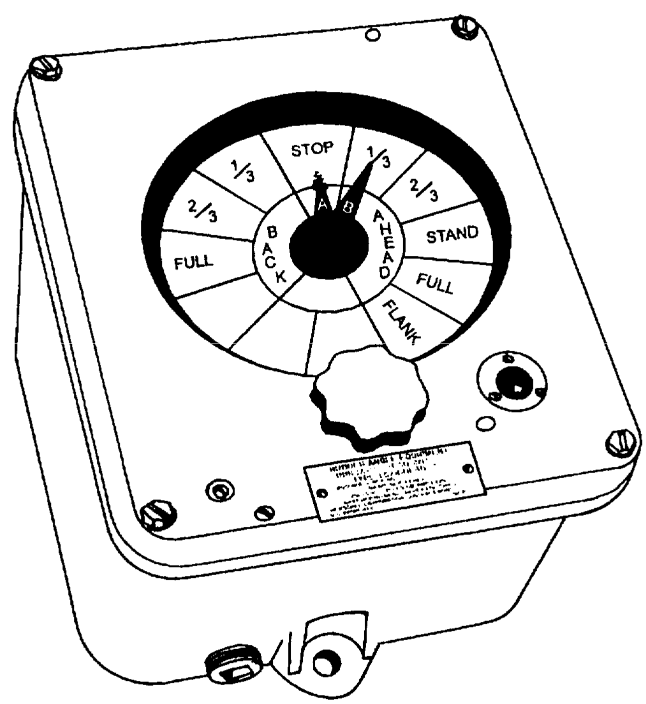
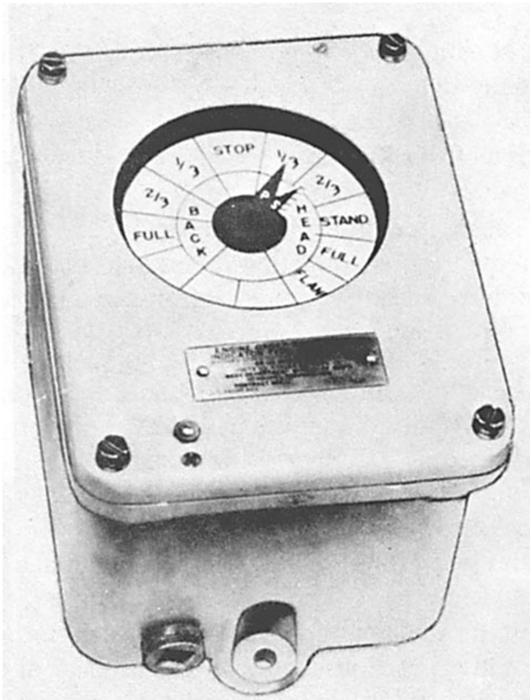


Figure 10-4.—Indicator-transmitter (circuit MB).



7.1264
Figure 10-5.—Double indicator (circuit MB).

7.1263
Figure 10-6.—Single engine order indicator (circuit MB).

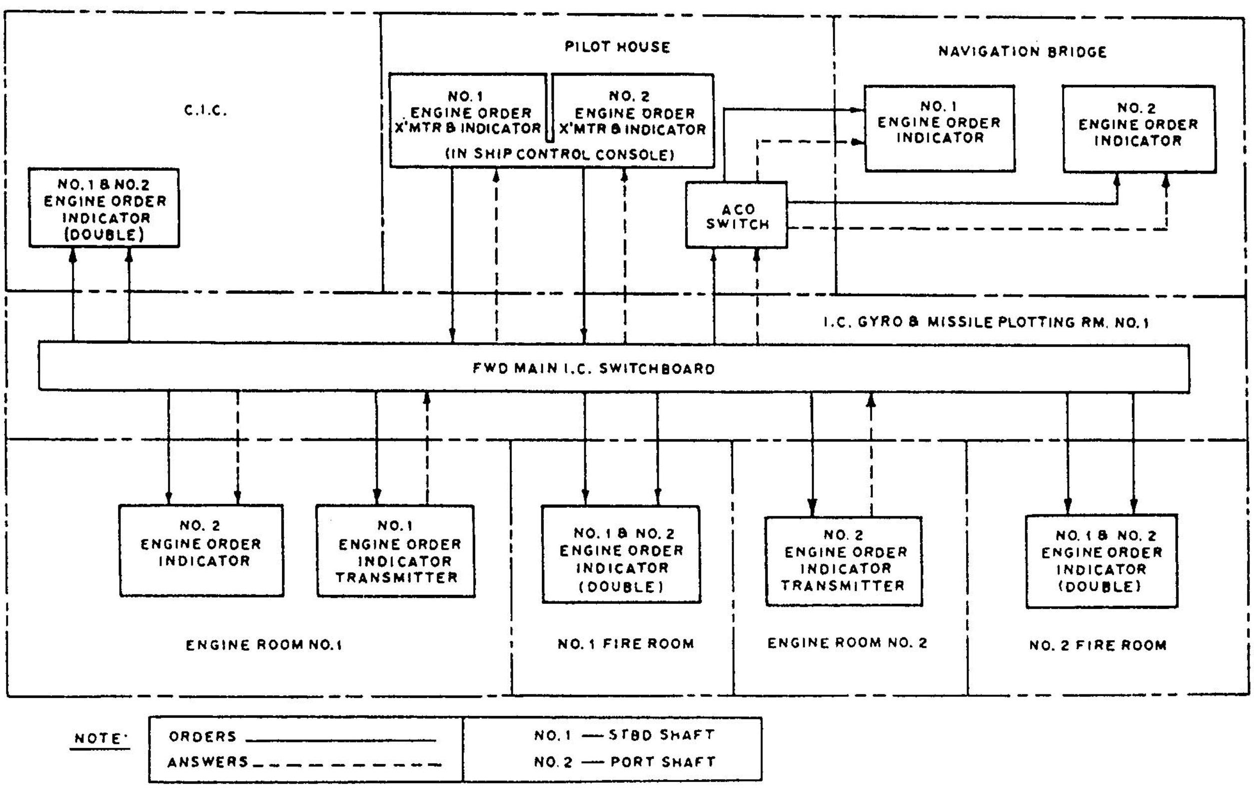


Figure 10-7.—Engine order system (circuit MB).

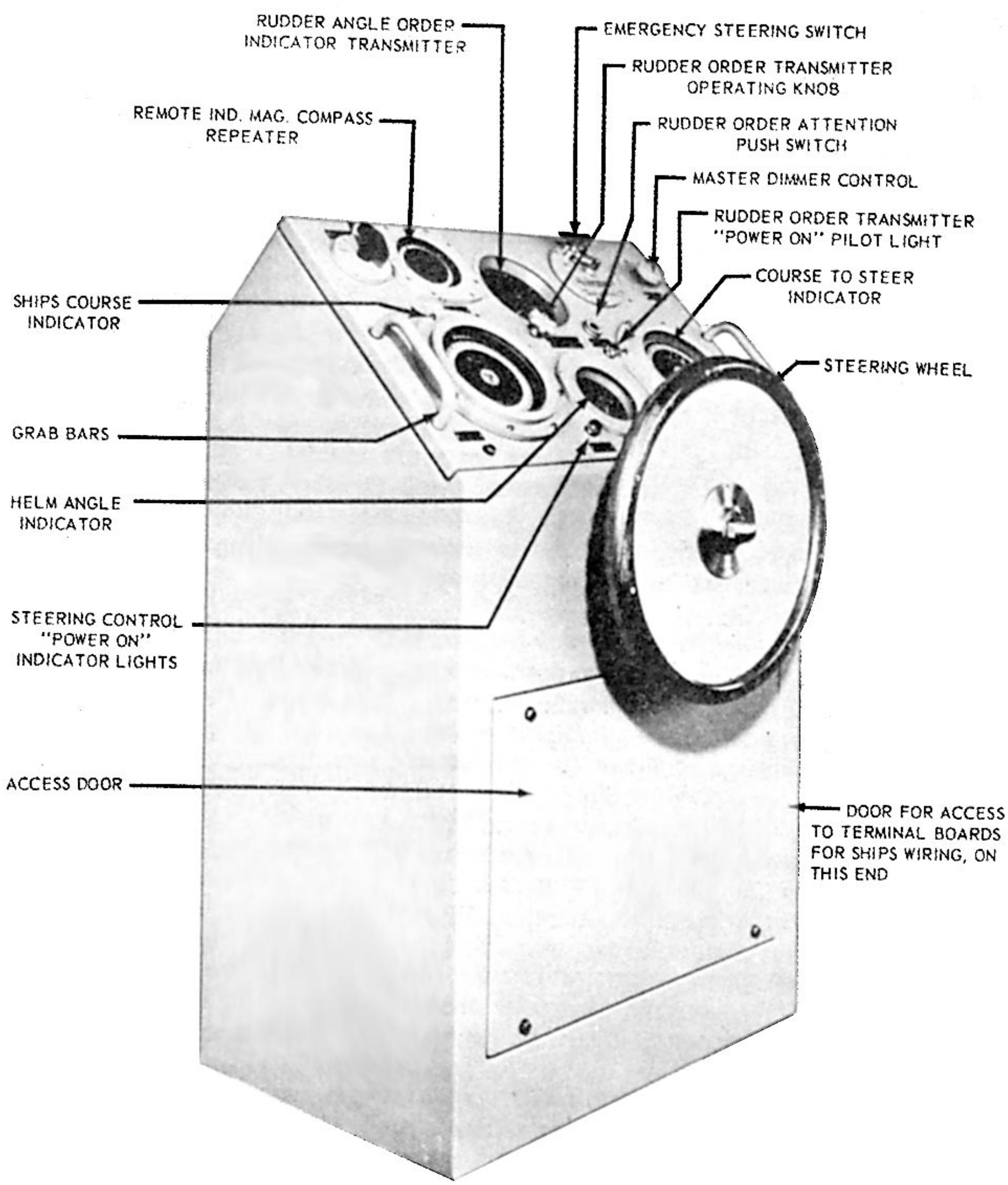
.indicator-transmitter to energize the appropriate bell on the ship's control console.

Each fireroom has a double engine order indicator (fig. 10-5) to alert the fireroom to changing steam requirements.

Engine order indicators are also located in other stations on the ship, such as the combat information center (CIC) and the navigation bridge. Figure 10-6 is an illustration of a single engine order indicator. Figure 10-7 is a block diagram of a typical engine order system, showing the various units and their locations for circuit MB. The associated remote indicator stations are also included in the diagram.

STEERING CONTROL CONSOLE

The steering control console (fig. 10-8) incorporates, in a single unit, the equipment required to navigate the ship from the pilothouse and to transmit



7.133

Figure 10-8.—Steering control console.

steering orders to the steering gear room. The order and indicating systems associated with this console are the rudder angle indicator, the rudder order, and the steering emergency alarm signal. The steering control console also contains ship's course indicators, a helm angle indicator, and a steering wheel (helm). Some steering control consoles also contain a magnesyn compass repeater.

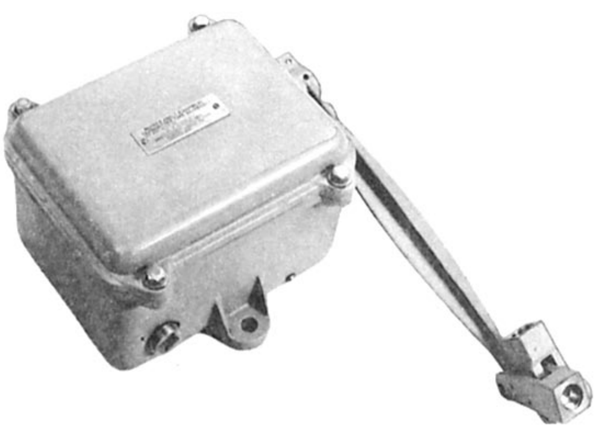
The helm angle indicator is a synchro receiver that is connected to a synchro transmitter attached to the steering gear. It indicates the mechanical position of the steering gear. The steering wheel (helm) is used to steer the ship. The magnesyn compass repeater is maintained by the ship's Quartermasters.

Rudder Angle Indicator

The rudder angle indicator system (circuit N) provides a means of electrically transmitting the angular position of the ship's rudder at the rudder head to designated stations throughout the ship.

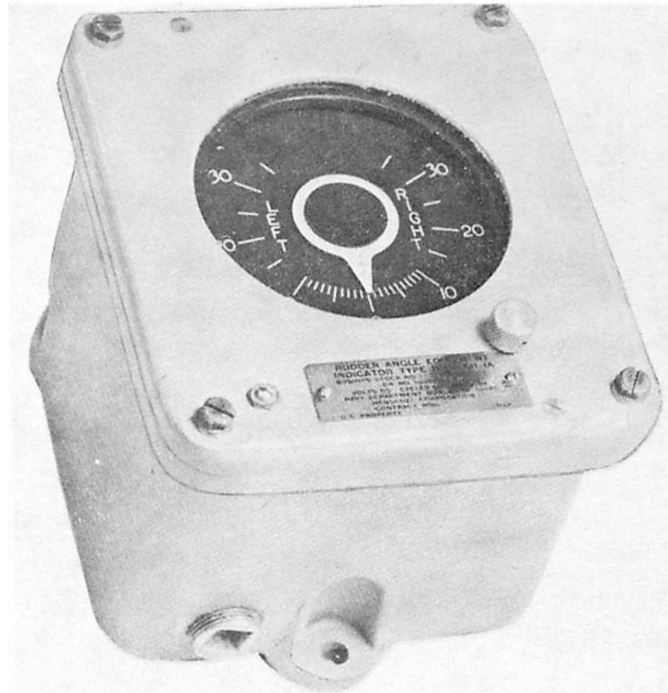
The rudder angle transmitter (fig. 10-9) is located at the rudder head and consists of a synchronous transmitter mechanically linked to the rudder stock in such a manner that its shaft follows the movement of the rudder. It transmits the angular position of the rudder angle to various ship's rudder angle indicators via the action cutout (ACO) section of the steering gear room IC switchboard.

The rudder angle indicator (fig. 10-10) consists of a fixed dial and pointer, which is mounted on the shaft of a synchro receiver. The receiver rotates the pointer



7.129

Figure 10-9.—Rudder angle transmitter.



7.126.6

Figure 10-10.—Rudder angle indicator (circuit N).

to the transmitted angular displacement on the dial face.

Figure 10-11 is a block diagram of the rudder angle order and rudder angle indicator systems, showing the various units and their locations.

A combination rudder angle order indicator (fig. 10-12) is located in the steering gear room in front of the steering gear room trick wheel. The trick wheel is used to steer the ship under emergency steering conditions.

Single rudder angle indicators are located in the engine rooms, bridge wings, CIC, pilothouse, and navigation bridge.

Rudder Order

The rudder order system (circuit L) provides a means of electrically transmitting rudder angle orders from the steering control console in the pilothouse to the steering gear room when the ship is being steered from the steering gear room.

The rudder angle order indicator transmitter is located in the steering control console. The helmsman operates the transmitter when a change in rudder angle is ordered by the OOD.

A push button is also provided on the console to ring a bell in the steering gear room so that the

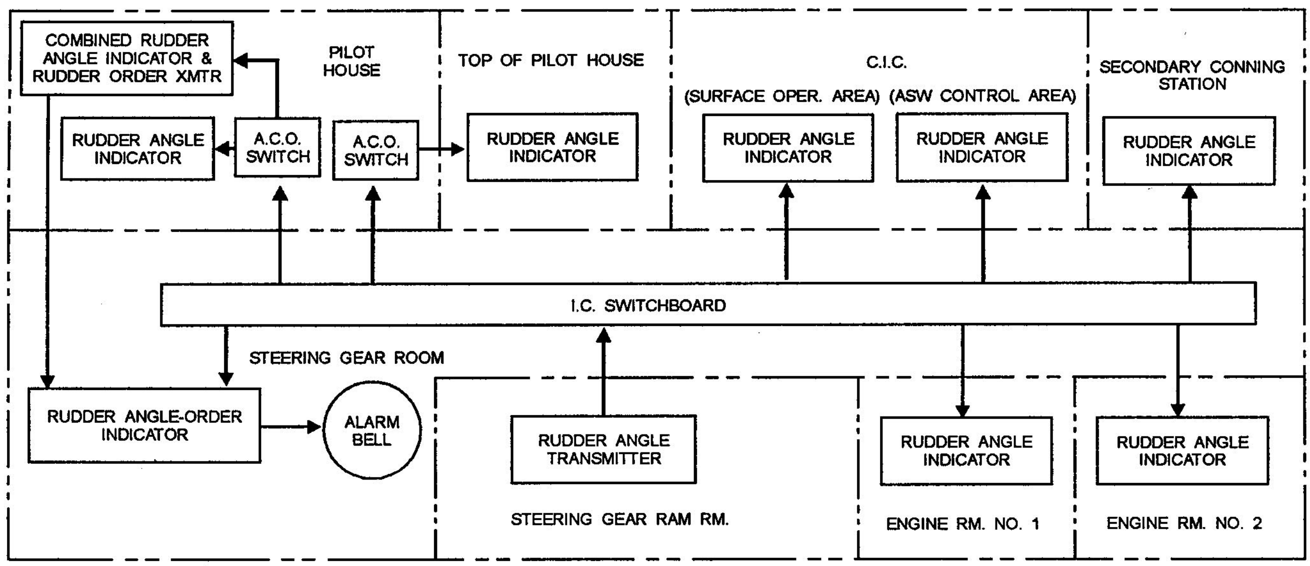


Figure 10-11.—Rudder angle indicator (circuit N) and rudder angle order (circuit L).

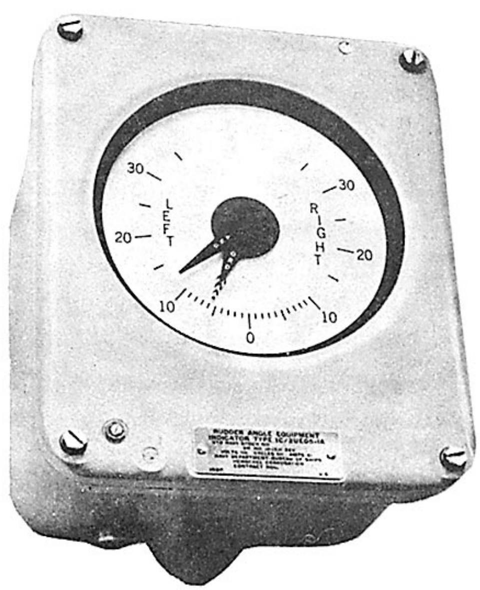


Figure 10-12.—Rudder angle order Indicator (circuits L and N).

steering gear room watch can anticipate a rudder angle order change. When operated, the transmitter sends the desired rudder angle in degrees left or right to the combination rudder angle order indicator in the steering gear room. The steering gear room watch then positions the trick wheel to cause the rudder angle order indicator to match the order.

STEERING EMERGENCY ALARM SIGNAL CIRCUIT

The steering emergency alarm signal circuit (circuit LB) provides a means by which the pilothouse can alert the steering gear room watch that a steering emergency has occurred and that the trick wheel must be used to steer the ship.

A spring return lever switch is located on the steering control console, and a siren is located in the steering gear room. The helmsman operates the switch to energize the siren when normal steering control is lost. When the siren sounds in the steering gear room, the steering gear room watch immediately engages the trick wheel and takes control of steering the ship.

GEARS

Since gears are used in most of the equipment that we are discussing in this chapter for changing the direction or speed of an input, or for converting an electrical input to a mechanical input and vice versa, it is essential that we discuss the different types of gears and their functions.

FUNCTIONS OF GEARS

Gears have three functions: they change the direction of motion; they change the speed of motion; and they change the force by changing the mechanical advantage.

A simple gear system that illustrates all of these functions is the eggbeater (fig. 10-13). There are 32 teeth on gear A, which mesh with 8 teeth on gear B. Notice the direction of rotation. Also notice that as gear B turns in one direction, its teeth mesh with gear C and cause C to revolve in the opposite direction. The rotation of the crank handle has been transmitted by gears A, B, and C to cause the beater blades to rotate.

Gears also can change the speed of the motion, as was stated previously. Since gear A has 32 teeth and gear B has only 8, one complete revolution of gear A causes four complete revolutions of gear B. Therefore, the ratio between A and B is 1:4. Since gear C also has 8 teeth, the ratio of B to C is 1:1. Therefore, the beater blades revolve four times as fast as the crank handle.

Gears also can change the force of the applied motion. Generally, any time a gear is used to increase the speed of motion, the force at the output of the gear is reduced. Conversely, when the speed is reduced by gears, the force at the output is increased.

TYPES OF GEARS

There are several types of gears used in mechanical assemblies. In the following paragraphs, we will discuss the spur, bevel, and worm gears.

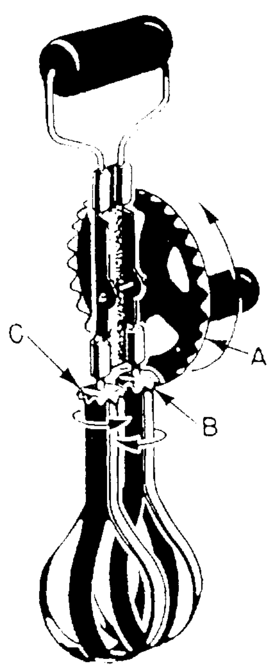


Figure 10-13.—A simple gear arrangement.

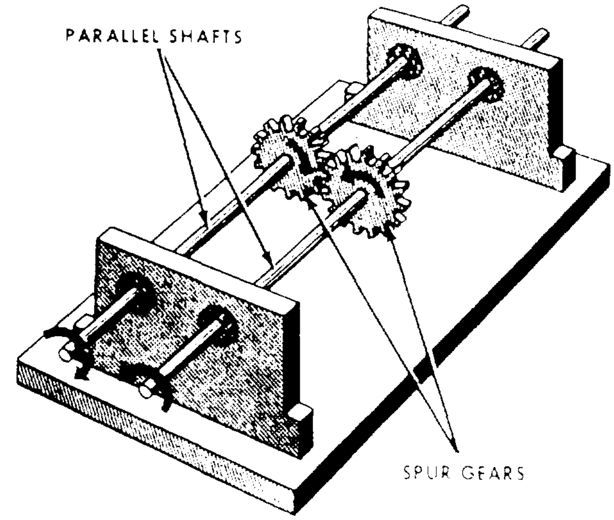


Figure 10-14.—Spur gears coupling two parallel shafts.

Spur Gears

When two shafts are not lying in the same straight line but are parallel, motion can be transmitted from one to the other by spur gears. This setup is shown in figure 10-14.

Spur gears are wheels with mating teeth cut in their surfaces so that one can turn the other without slippage. When the mating teeth are cut so that they are parallel to the axis of rotation (as shown in fig. 10-14), the gears are called straight spur gears.

When two gears of unequal size are meshed together, the smaller of the two is usually called a pinion. By unequal size, we mean an unequal number of teeth causing one gear to be of a larger diameter than the other. The teeth, themselves, must be of the same size in order to mesh properly.

The most commonly used type of spur gear is the straight spur gear, but quite often you will run across another type of spur gear called the helical spur gear.

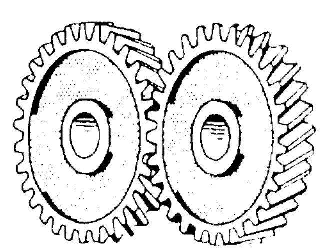


Figure 10-15.—Helical gears.

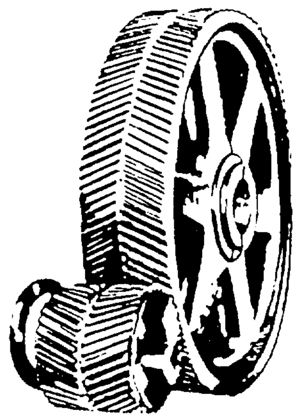


Figure 10-16.—Herringbone gears.

In helical gears, the teeth are cut slantwise across the face of the gear. One end of the tooth, therefore, lies ahead of the other. In other words, each tooth has a leading end and a trailing end. A look at these gears in figure 10-15 will show you how they are constructed.

In the straight spur gears, the whole width of the teeth comes in contact at the same time. But with helical (spiral) gears, contact between two teeth starts first at the leading ends and moves progressively across the gear faces until the trailing ends are in contact. This kind of meshing action keeps the gears in constant contact with one mother; therefore, less lost motion and smoother, quieter action is possible. One disadvantage of this helical spur gear is the tendency of each gear to thrust or push axially on its shaft. A special thrust bearing must be put at the end of the shaft to counteract this thrust.

Thrust bearings are not needed if herringbone gears like those shown in figure 10-16 are used. Since the teeth on each half of the gear are cut in opposite directions, each half of the gear develops a thrust that counterbalances that of the other half. You'll find herringbone gears used mostly on heavy machinery.

Figure 10-17 shows three other gear arrangements in common use.

The internal gear in figure 10-17, view A, has teeth on the inside of a ring, pointing inward toward the axis of rotation. An internal gear is always meshed with an external gear, or pinion, whose center is offset from the center of the internal gear. Either the internal or pinion gear can be the driver gear, and the gear ratio is calculated the same as for other gears-by counting teeth.

Often only a portion of a gear is needed where the motion of the pinion is limited. In this case, the sector gear (fig. 10-17, view B) is used to save space and

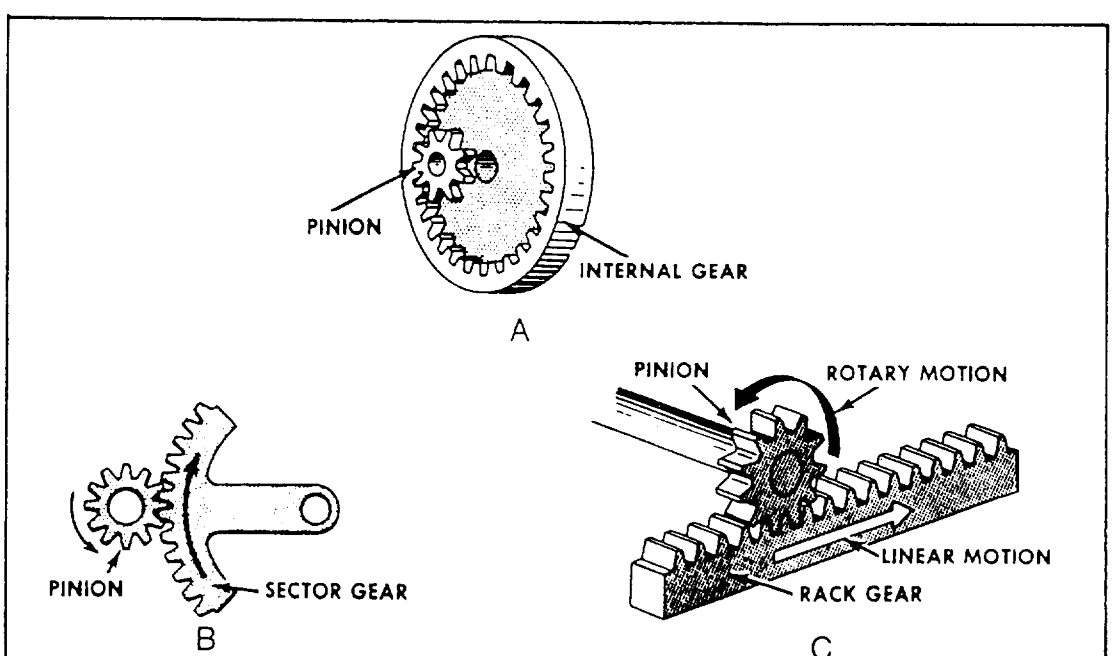


Figure 10-17.—Gear arrangements.

material. The rack and pinion in figure 10-17, view C, are both spur gears. The rack may be considered as a piece cut from a gear with an extremely large radius. The rack-and-pinion arrangement is useful in changing rotary motion into linear motion.

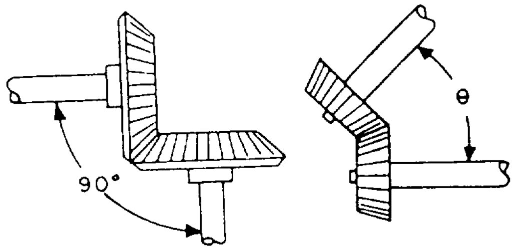


Figure 10-18.—Bevel gears.

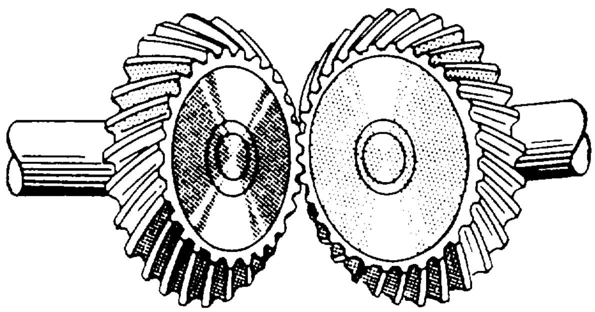


Figure 10-19.—Spiral bevel gears.

Bevel Gears

So far, most of the gears you have learned about transmit motion between parallel shafts. But when shafts are not parallel (at an angle), another type of gear is used—the bevel gear. This type of gear can connect shafts lying at any given angle because they can be beveled to suit the angle.

Figure 10-18, view A, shows a special case of the bevel gear-the miter gear. A pair of miter gears is used to connect shafts having a 90-degree angle, which means the gear faces are beveled at a 45-degree angle.

You can see in figure 10-18, view B, how bevel gears are designed to join shafts at any angle. Gears cut at any angle other than 45° are called just plain bevel gears.

The gears shown in figure 10-18 are called straight bevel gears because the whole width of each tooth comes in contact with the mating tooth at the same time. However, some spiral level gears have teeth cut so as to have advanced and trailing ends. Figure 10-19 is an illustration of spiral bevel gears. They have the same advantages as other spiral (helical) gears—less lost motion and smoother, quieter operation.

Worm Gears

Worm gears and worm gear-worm wheel combinations, like those in figure 10-20, have many

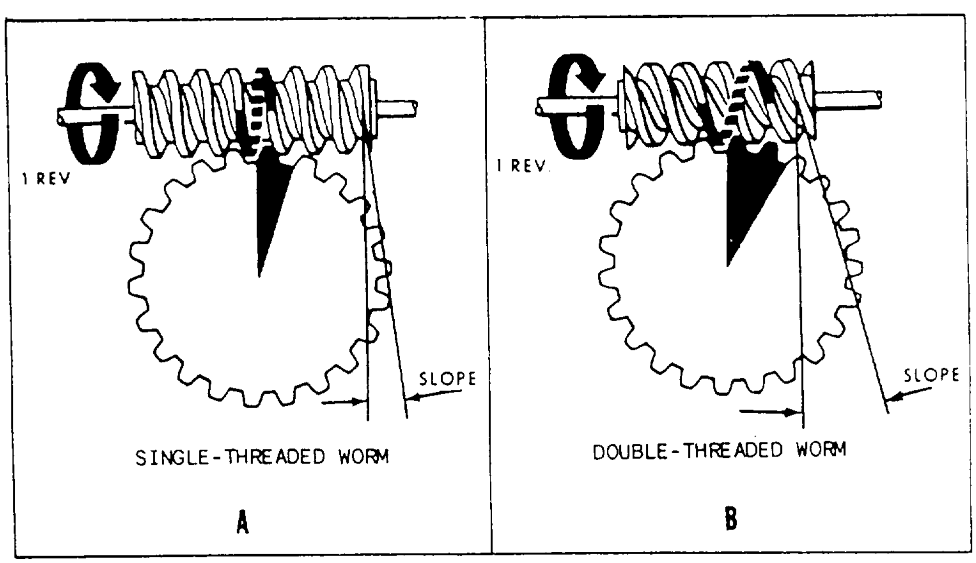


Figure 10-20.—Worm gears.

uses and advantages. But, it is better to understand their operating theory before learning of their uses and advantages.

Figure 10-20, view A, shows the action of a single-threaded worm gear. For each revolution of the worm gear, the worm wheel turns one tooth. Thus, if the worm wheel has 25 teeth, the gear ratio is 25:1.

Figure 10-20, view B, shows the action of a double-threaded worm. For each revolution of the worm gear in this case, the worm wheel turns two teeth. Thus, if the worm wheel has 25 teeth, the gear ratio is 25:2.

Likewise, a triple-threaded worm gear would turn the worm wheel three teeth per revolution of the worm gear.

A worm gear-worm wheel is really a combination of a screw and a spur gear. Tremendous mechanical advantages (M.A.) can be obtained with this arrangement. Worm drives can also be designed so that only the worm gear is the driver—the spur gear cannot drive the worm gear. On a hoist, for example, you can raise or lower the load by pulling on the chain that turns the worm gear. But, if you let go of the chain, the load cannot drive the spur gear and will let the load drop to the deck. This is a nonreversing worm drive.

CHANGING DIRECTION WITH GEARS

No doubt you know that the crankshaft in an automobile engine can turn in only one direction. If you want the car to go backwards, the effect of the engine's rotation must be reversed. This is done by a reversing gear in the transmission, not by reversing the direction in which the crankshaft turns.

A study of figure 10-21 will show you how gears are used to change the direction of motion. This is a schematic diagram of the sight mounts on a Navy gun. If you trunk the range-adjusting handle, A, in a clockwise direction, the gear, B, directly above it, is made to rotate in a counterclockwise direction. This motion causes the two pinions, C and D, on the shaft to turn in the same direction as gear B against the teeth cut in the bottom of the table. The table is tipped in the direction indicated by the arrow.

As you turn the deflection-adjusting handle, E, in a clockwise direction, gear F, directly above it, turns in the opposite direction. Since the two bevel gears, G and H, are fixed on the shaft with F, they also turn. These bevel gears, meshing with the horizontal bevel gears, I and J, cause I and J to swing the front ends of

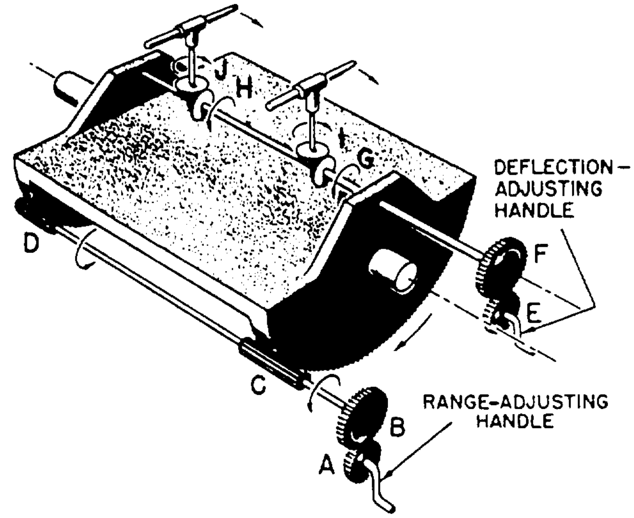


Figure 10-21.—Gears can change the direction of applied motion.

the telescopes to the right. Thus, with a simple system of gears, it is possible to keep the two telescopes pointed at a moving target. In this and many other practical applications, gears serve one purpose-they change the direction of motion.

CHANGING SPEED WITH GEARS

As you have already seen in the eggbeater, gears can be used to change the speed of motion. Another example of this use of gears is found in your clock or watch. The mainspring slowly unwinds and causes the hour hand to make one revolution in 12 hours. Through a series, or train, of gears, the minute hand makes one revolution each hour, while the second hand goes around once per minute.

Figure 10-22 will help you understand how speed changes are made possible. Wheel A has 10 teeth,

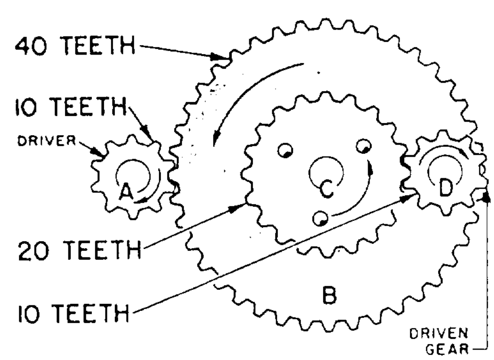


Figure 10-22.—Gears can change the speed of applied motion.

which mesh with the 40 teeth on wheel B. Wheel A will have to rotate four times to cause B to make one revolution. Wheel C is rigidly fixed on the same shaft with B. Thus, C makes the same number of revolutions as B. However, C has 20 teeth and meshes with wheel D, which has only 10 teeth. Hence, wheel D turns twice as fast as wheel C. Now, if you turn A at a speed of four revolutions per second, B will be rotated at one revolution per second. Wheel C also moves at one revolution per second and causes D to turn at two revolutions per second. You get out two revolutions per second after having put in four revolutions per second. Thus, the overall speed reduction is 2/4—or 1/2—which means that you got half the speed out of the last driven wheel that you put into the first driven wheel.

You can solve any gear speed-reduction problem with the following formula:

$$S_2 = S_1 \times \frac{T_1}{T_2}$$

Where

S_1 = speed of first shaft in train

S_2 = speed of last shaft in train

T_1 = product of teeth on all drivers

T_2 = product of teeth on all driven gears

Now use the formula on the gear train of figure 10-21.

$$S_2 = S_1 \times \frac{T_1}{T_2} = 4 \times \frac{10 \times 20}{40 \times 10} = \frac{800}{400} = 2 \text{ rps}$$

Almost any increase or decrease in speed can be obtained by choosing the correct gears for the job. For example, the turbines on a ship have to turn at high speeds—say 5800 rpm—if they are going to be efficient. But the propellers, or screws, must turn rather slowly—say 195 rpm—to push the ship ahead with maximum efficiency. So, a set of reduction gears is placed between the turbines and the propeller shaft.

When two external gears mesh, they rotate in opposite directions. Often you will want to avoid this. Put a third gear, called an idler, between the driver and the driven gear. But do not let this extra gear confuse you on speeds. Just neglect the idler entirely. It does not change the gear ratio at all, and the formula still applies. The idler merely makes the driver and its driven gear turn in the same direction. Figure 10-23 shows you how this works.

MAGNIFYING FORCE WITH GEARS

Gear trains are used to increase the M.A. In fact, wherever there is a speed reduction, the effect of the effort you apply is multiplied. Look at the cable winch in figure 10-24. The crank arm is 30 inches long, and the drum on which the cable is wound has a 15-inch radius. The small pinion gear has 10 teeth, which mesh with the 60 teeth on the internal spur gear. You will find it easier to figure the M.A. of this machine if you think of it as two machines.

First, figure out what the gear and pinion do for you. The theoretical M.A. of any arrangement of two

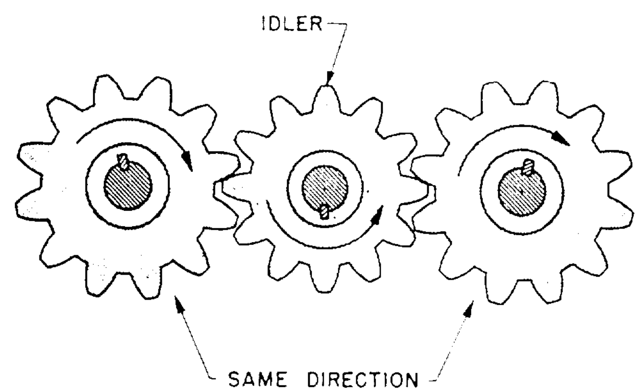


Figure 10-23.—An idler gear.

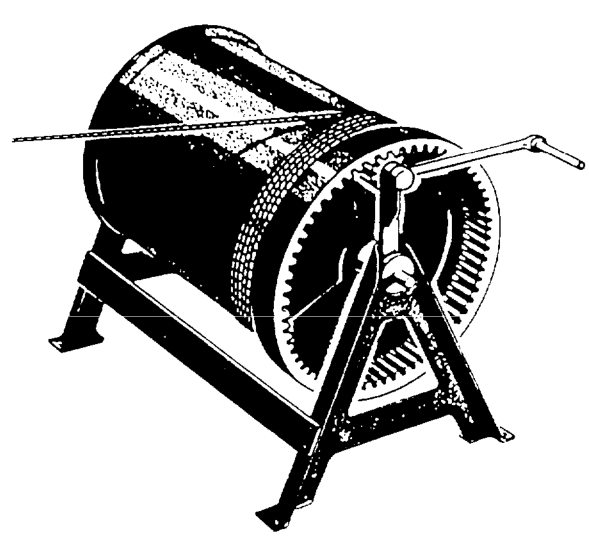


Figure 10-24.—Cable winch.

meshed gears can be found by using the following formula:

$$\text{M.A.(theoretical)} = \frac{T_o}{T_a}$$

In which,

T_o= number of teeth on driven gear
T_a= number of teeth on driver gear

In this case,

$$T_o = 60 \text{ and } T_a = 10$$

Then,

$$\text{M.A. (theoretical)} = \frac{T_o}{T_a} = \frac{60}{10} = 6$$

Now, the theoretical arrangement for the other part of the machine, which is a simple wheel-and-axle arrangement consisting of the crank arm and the drum, can be found by dividing the distance the effort moves—2R—in making one complete revolution, by the distance the cable is drawn up in one revolution of the drum—2r.

The total, or overall, theoretical M.A. of a compound machine is equal to the product of the M.A. of the several simple machines that make it up. In this case, you considered the winch as being two machines—one having an M.A. of 6 and the other an M.A. of 2. Therefore, the overall theoretical M.A. of the winch is 6 x 2, or 12. Since friction is always present, the actual M.A. may be only 7 or 8. Even so, by applying a force of 100 pounds on the handle, you could lift a load of 700 to 800 pounds.

THE GEAR DIFFERENTIAL

As you have seen, gears have a variety of functions, and as an IC Electrician, you will work with all types of gear trains. One type of gear train that is used extensively is the gear differential. It is capable of adding and subtracting mechanically. The gear differential adds the total revolutions of two shafts, or subtracts the total revolutions of one shaft from the total revolutions of another shaft, and delivers the answer by positioning a third shaft. The gear differential will add or subtract any number of revolutions, or small fractions of revolutions, continuously and accurately.

Figure 10-25 is a cutaway drawing of a bevel gear differential, showing all its parts and how they are related to each other. Grouped around the center of the mechanism are four bevel gears, meshed together. The two bevel gears on either side are called end gears. The

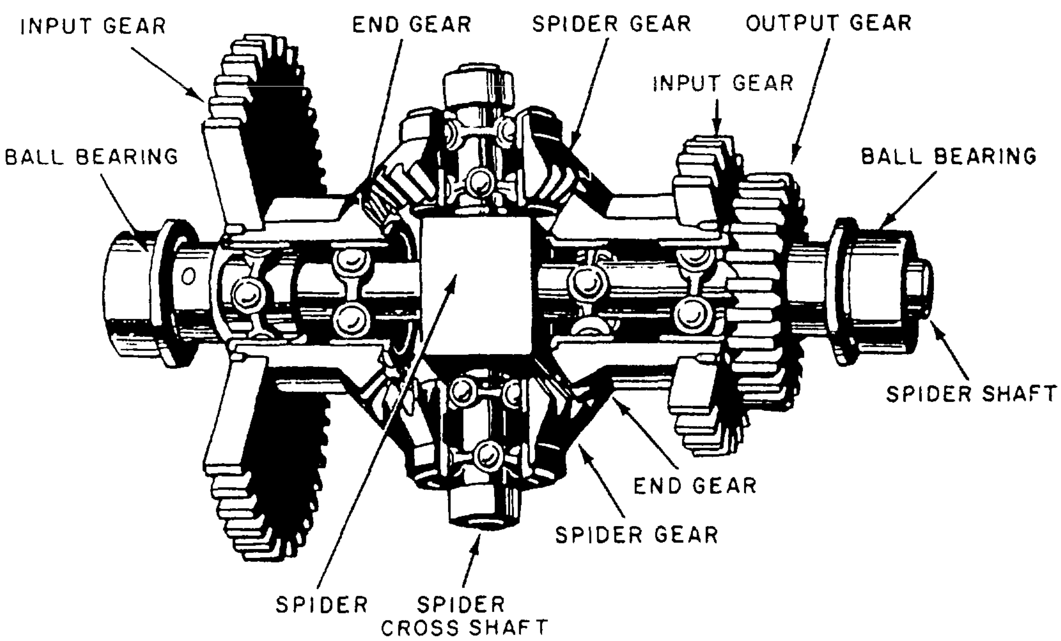


Figure 10-25.—Bevel gear differential.

two bevel gears above and below are called spider gears. The long shaft running through the end gears and the three spur gears is called the spider shaft. The short shaft running through the spider gears, together with the spider gears themselves, is called the spider.

Each of the spider gears and the end gears are bearing mounted on their shafts and are free to rotate. The spider shaft is rigidly connected with the spider cross shaft at the center block where they intersect. The ends of the spider shaft are secured in flanges or hangers, but they are bearing mounted and the shaft is free to rotate on its axis. It follows then that to rotate the spider shaft, the spider, consisting of the spider cross shaft and the spider gears, must tumble, or spin, on the axis of the spider shaft, inasmuch as the two shafts are rigidly connected.

The three spur gears shown in figure 10-25 connect the two end gears and the spider shaft to other mechanisms. They may be of any convenient size. Each of the two input spur gears is attached to an end gear. An input gear and an end gear together are called a side of a differential. The third gear is the output gear (as designated in fig. 10-25). This is the only gear that is pinned to the spider shaft. All of the other gears, both bevel and spur, in the differential are bearing mounted.

Figure 10-26 is an exploded view of a gear differential showing each of its individual parts, and figure 10-27 is a schematic sketch showing the relationship of the principle parts.

For the present, we will assume that the two sides are the inputs, and the gear on the spider shaft is the output. Later, it will be shown that any of these three gears can be either an input or an output. Now, look at figure 10-28. In this hookup, the two end gears are positioned by the input shafts, which represent the quantities to be added or subtracted. The spider gears do the actual adding and subtracting. They follow the rotation of the two end gears, turning the spider shaft a number of revolutions proportional to the sum, or difference, of the revolutions of the end gears.

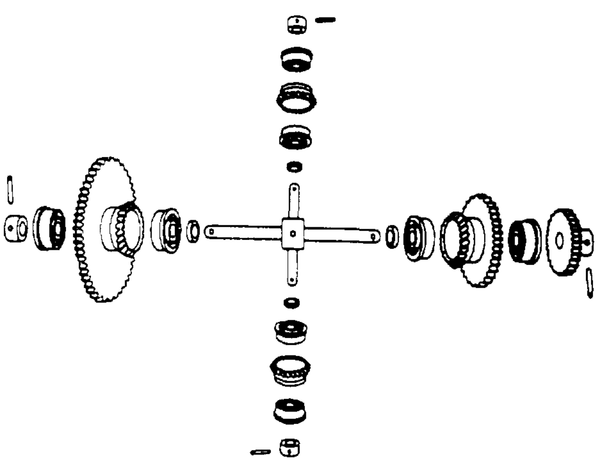


Figure 10-26.—Exploded view of a differential gear system.

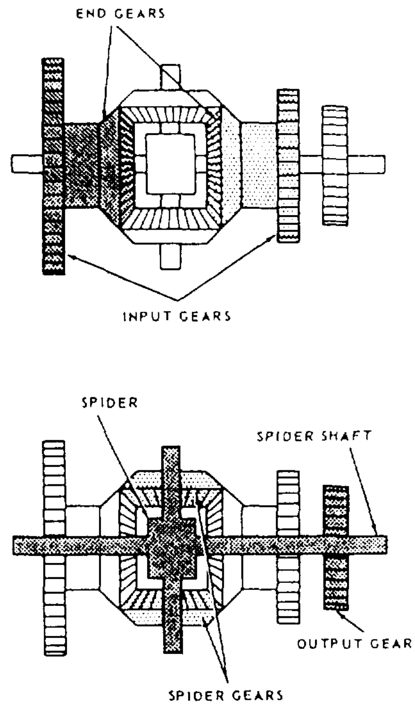


Figure 10-27.—End gears and spider arrangement of a differential.

Suppose the left side of the differential is rotated while the other remains stationary (as in block 2 of fig. 10-28). The moving end gear will drive the spider gears, making them roll on the stationary right end gear. This motion will turn the spider in the same direction as the input and, through the spider shaft and output gear, the output shaft. The output shaft will turn a number of revolutions proportional to the input.

If the right side is now rotated and the left side held stationary (as in block 3 of fig. 10-28), the same thing will happen. If both input sides of the differential are turned in the same direction at the same time, the spider will be turned by both at once (as in block 4 of fig. 10-28). The output will be proportional to the sum of the two inputs. Actually, the spider makes only half as many revolutions as the sum of the revolutions of the end gears, because the spider gears are free to roll between the end gears. To understand this better, look at figure 10-29. Here a cylindrical drinking glass is rolled along a table top by pushing a ruler across its upper side. The glass will roll only half as far as the ruler travels. The spider gears in the differential roll against the end gears in exactly the same way. Of course, the answer can be corrected by using a 2:1 gear ratio between the gear on the spider shaft and the gear for the output shaft. Very often, for design purposes, this gear ratio will be found to be different.

When the two sides of the differential move in opposite directions, the output of the spider shaft is proportional to the difference of the revolutions of the two inputs. This is because the spider gears are free to turn and are driven in opposite directions by the two inputs. If the two inputs are equal and opposite, the spider gears will turn, but there will be no movement of the spider shaft. If the two inputs turn in opposite directions for an unequal number of revolutions, the spider gears roll on the end gear that makes the lesser number of revolutions, rotating the spider in the direction of the input making the greater number of revolutions. The motion of the spider shaft will be equal to half the difference between the revolutions of the two inputs. A change in the gear ratio to the output shaft can then give us any proportional answer we wish.

We have thus far been describing a hookup wherein the two sides are inputs and the spider shaft the output, as long as it is recognized that the spider follows the end gears for half the sum, or difference, of their revolutions. However, it is not necessary to always use this type of hookup. The spider shaft may be used as one input and either of the sides used as the other. The other side will then become the output. This fact permits three different hookups for any given

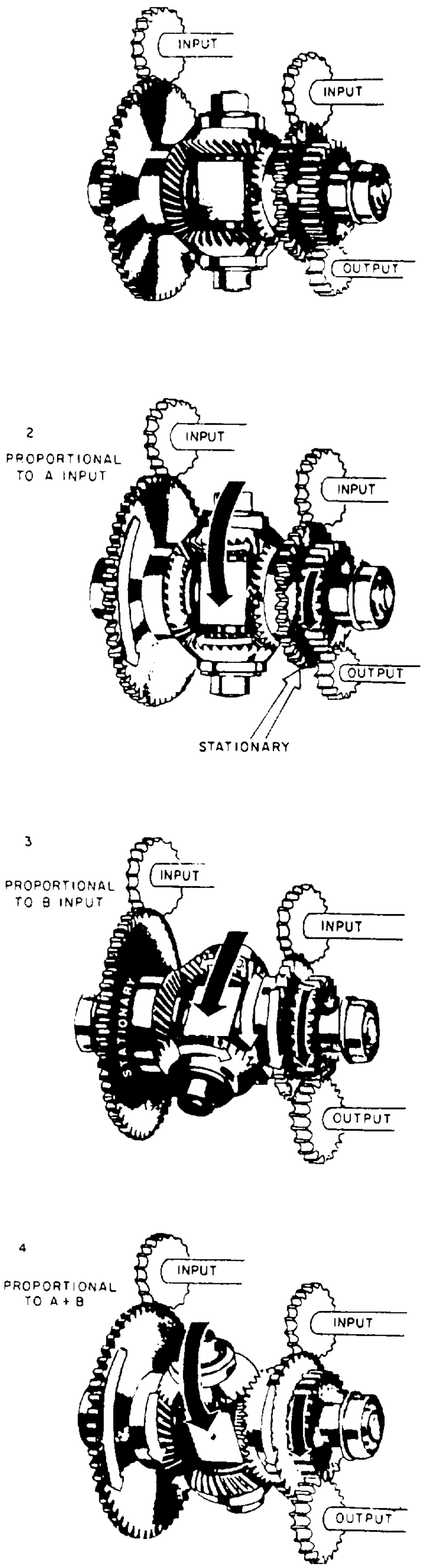


Figure 10-28.—How a differential works.

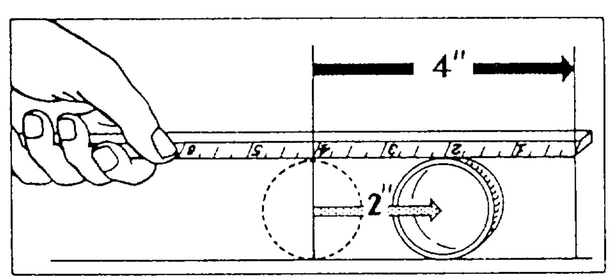


Figure 10-29.—The spider makes only half as many revolutions.

differential (as is illustrated in fig. 10-30). Whichever proves the most convenient mechanically may be used.

BASIC COMPUTER MECHANISMS

So far, we have discussed the various gears and what they can accomplish, and the gear differential, which is a simple analog computer. Next, we will discuss basic computer mechanisms. As in all complex machines, focus on the simple mechanisms that comprise the complex machine. An understanding of the simple mechanisms will enable you to understand how they enable the complex machine to perform its function.

The differentials used in analog computers are gear differentials similar to those we discussed previously, unlike the automotive differential, which receives two inputs and combines them to provide a single output. Most differentials used in computers are quite small, between 2 inches x 2 1/2 inches in size, and are designed for relatively light loads. Figure 10-31 illustrates the symbol used to indicate the differential in schematic drawings.

Figure 10-32 shows one of the many applications of the gear differential in a computer. In this case, the differential is being used as an integral part of a follow-up control. Computing mechanisms are not designed to drive heavy loads. The outputs from such mechanisms often merely control the action of servomotors. The motors do the actual driving of the loads to be handled. The device that makes it possible for the comparatively weak output from a computing mechanism to control the action of a servomotor is called a follow-up control. In this device, the differential is used to measure the difference, or error, in position between the input and the output. The input is geared to one side of the differential. The servo output is used to do two things: (1) to position whatever mechanism is being handled, and (2) to drive

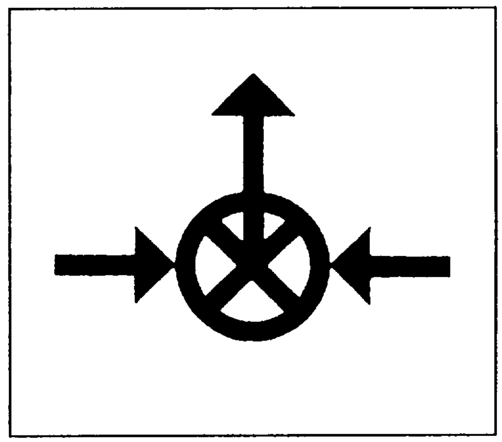


Figure 10-31.—Schematic drawing symbol for a differential.

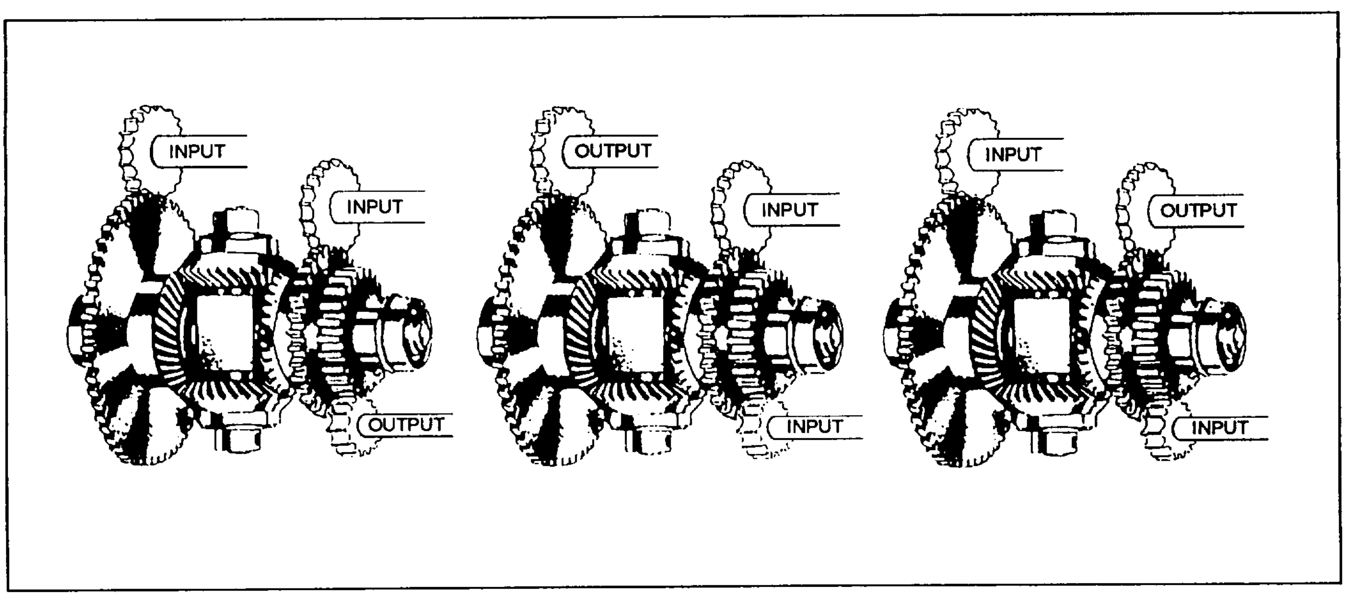


Figure 10-30.—Differential hookups.

the other side of the differential. This second operation is known as the servo response.

When there is a difference between the input and the output, the spider of the differential turns. As this happens, the spider shaft operates a set of controls which control the action of the servomotor in such a way that the motor drives its side of the differential in a direction opposite to that taken by the input. That is, the servo always drives to reduce the difference, or error, to zero.

While you may not work specifically with mechanical computers as an IC Electrician, you will see the various gears and linkages in many IC circuits. When working with mechanical gear trains, it will help to look for the simple machines within the equipment; this will help in the understanding of the whole complex machine and will enable you to more quickly isolate trouble areas.

METERING AND INDICATING SYSTEMS

Metering and indicating systems provide continuous information from remote sensors on the position, status, or condition of a particular system. The sensors used in metering and indicating systems include switches, salinity cells, mechanical linkages, synchros, pressure sensors, and various types of temperature sensors. Indicator panels used with the systems include meters, dials, lamps, and other indicators that provide a readout of the desired information. Some systems include alarms, which are actuated when predetermined conditions exist.

The operation of some of the various metering and indicating systems will be discussed in the following paragraphs.

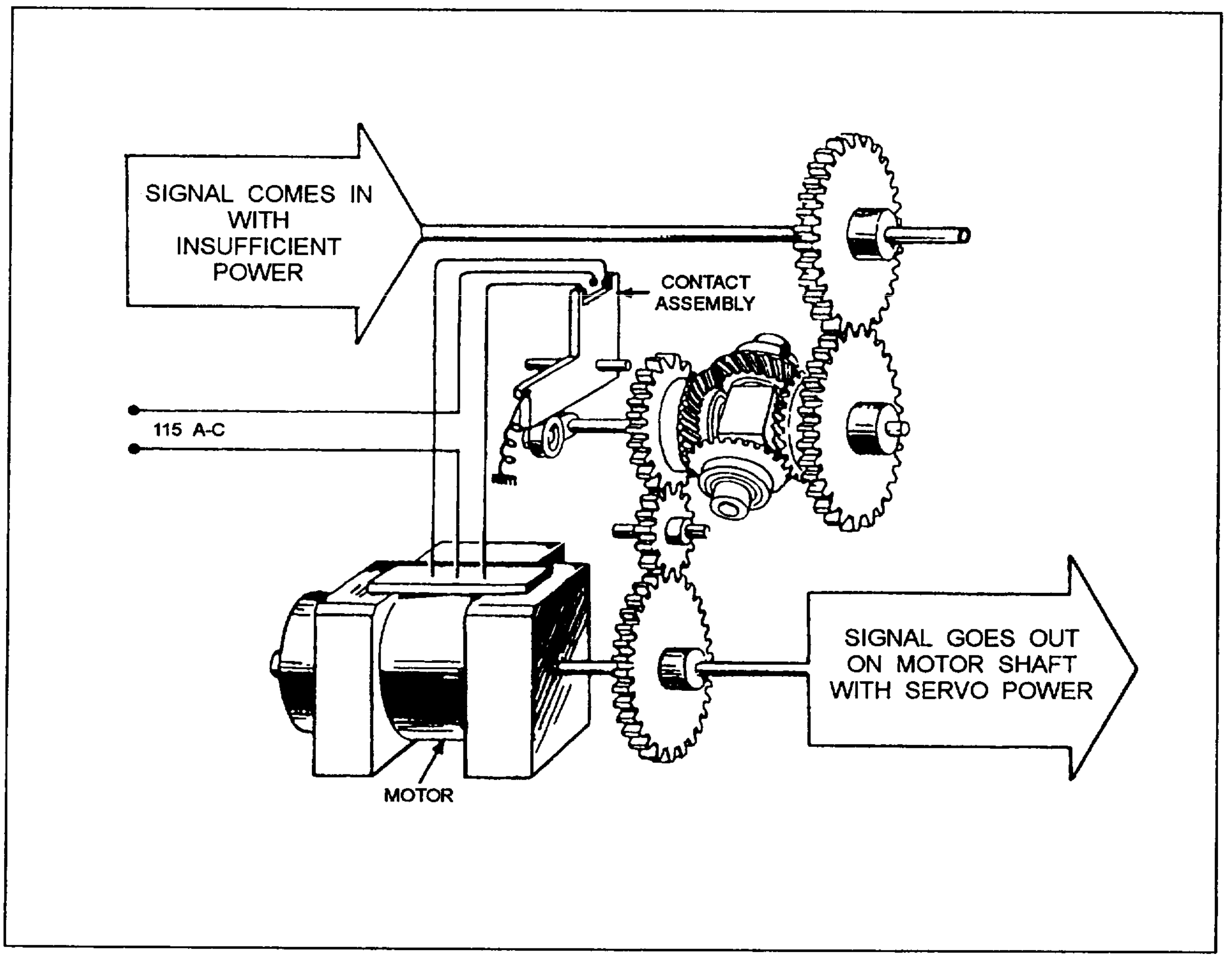


Figure 10-32.—Simplified sketch of a follow-up control showing application of a gear differential.

PROPELLER REVOLUTION INDICATOR SYSTEM

The propeller revolution indicator system (circuit K) is used to indicate instantaneously and continuously the revolutions per minute, direction of rotation, and total revolutions of the individual propeller shafts. The information is indicated in the engine rooms, pilothouse, and other required locations.

There are two types of propeller revolution indicator systems, the synchro system and the magneto-voltmeter system. The synchro system is installed in large combatant ships and in many newly constructed small ships. The magneto-voltmeter system is less complicated and is installed in small ships. Only the synchro system will be discussed in this training manual.

A representative synchro-type propeller revolution indicator system installed in a DDG is discussed in the following paragraphs. The system consists of transmitters, indicator-transmitters, and indicators.

Transmitters

The transmitters, one for each propeller shaft, indicate the revolutions of the propeller shaft. They also transmit the speed and direction of rotation of the propeller shaft to the associated indicator-transmitter. The transmitters are installed on the actual propeller shaft usually near the reduction gear. They are electrically connected to indicator-transmitters located in their respective throttle stations.

Figure 10-33 is the gearing diagram of a transmitter. The transmitter consists of a running synchro transmitter, revolution counter, and contact assembly. These components, which are actuated by suitable gearing, are mounted in a watertight housing. The transmitter is either gear driven from the propeller shaft or is directly coupled to the end of a stub shaft of the propulsion machinery, as required by the particular installation. The synchro transmitter is always driven at twice the propeller speed in a constant clockwise direction.

A drive worm, cut integral with shaft 56, meshes with worm gear 12, which is secured to shaft 14. The ratio is such that shaft 14 is driven at exactly one-tenth the propeller speed. Gear 25 is attached to shaft 14, and links 20 are free to swing on the shaft. The lower ends of links 20 support swinging shaft 31. Gear 26 is attached to shaft 31. Friction blocks 23 are held in contact with the hubs of gears 25 and 26 by spring 24. The friction blocks restrain the rotation of gears 25 and 26 and swing the links assembly, including shaft 31 and gear 26, in the direction of rotation of gear 25. This action engages gear 26 with one of the two gears 27, the selection depending on the direction of rotation of gear 25. Screws 80 limit the angular swing of the links assembly.

Gears 27 are secured to respective side shafts 35, which also carry gears 29 and 69. These gears are meshed and drive each other alternately, depending on which one of the two gears 27 is engaged with the swinging idler gear 26. Gears 29 and 69 do not reverse when the propeller shaft reverses because idler gear 26 reverses rotation each time it swings from side to side. The same is true for gears 28 and 57 because they are mounted on the hubs of gears 29 and 69, respectively. Gear 57 engages gear 58, which is mounted directly on the shaft of synchro transmitter 37. The overall gear ratio between transmitter shaft 56 and the shaft of the synchro transmitter is such that the synchro shaft is always driven at twice the propeller speed in a constant clockwise direction.

Revolution counter 38, which is driven at one-tenth the propeller speed, is driven through helical gears 28, 48, 47, and 30. The reading is directly in terms of propeller revolutions because each revolution of the counter shaft registers a count of 10. Brake shoes 50 prevent synchro transmitter 37 from driving counter 38 backward during brief periods of rapid speed reduction.

The contact assembly is actuated by small insulating block 22, attached to one of the swinging links 20. The block moves up and down as the link swings with reversals of driving rotation. This action moves center spring contact 44 from the bottom to the top stationary contact 42, and vice versa. The center contact and one of the stationary contacts energize the signal lights in the remote indicator when the propeller shaft rotates in the astern direction,

Indicator-Transmitters

The indicator-transmitter installed in each throttle station is used to convert the running speeds received from the associated shaft transmitters into angular synchro displacements, which are transmitted to the various indicators.

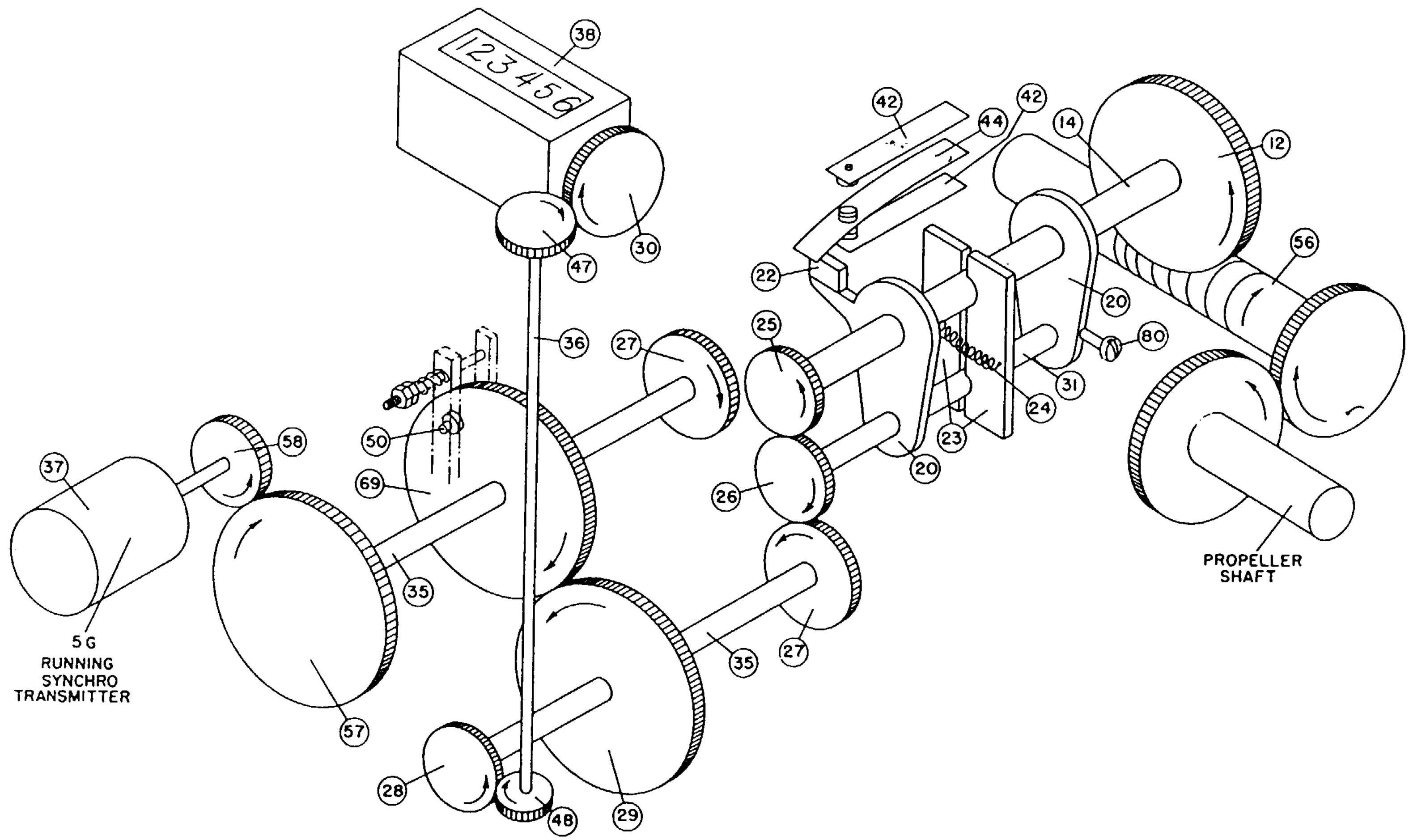
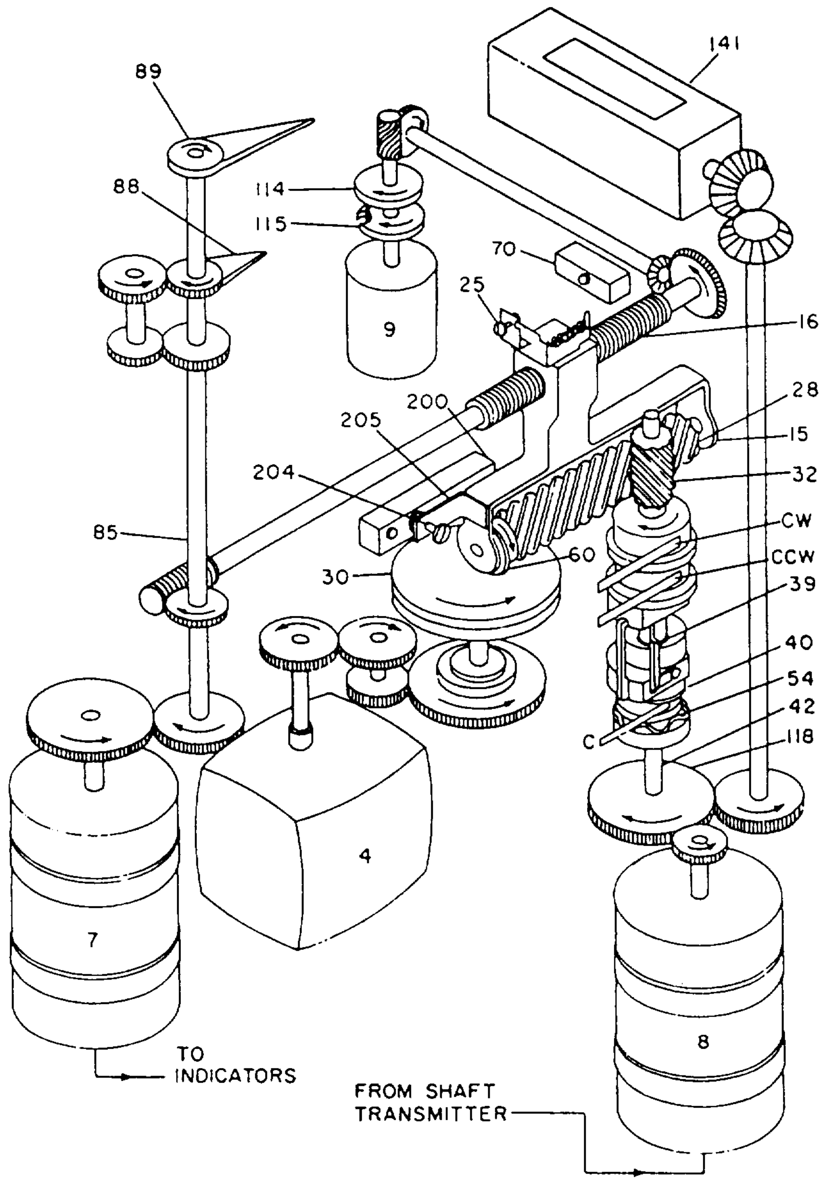


Figure 10-33.—Gearing diagram of a propeller revolution shaft transmitter.

Figure 10-34 is the gearing diagram of an indicator-transmitter. The indicator-transmitter consists of a running synchro receiver, a speed-measuring mechanism, a positioning synchro transmitter, a revolution counter, two pointers, a dial, and a backing signal.

The two concentric revolving pointers indicate on a dual-marked fixed dial the output in rpm of the speed-measuring mechanism. The inner scale, marked for each 100 rpm only, is indexed by short pointer 88. The outer scale, calibrated from zero to 100 rpm with numerals for each 5 rpm, is indexed by long pointer



4 – Synchronous Motor	28 – Helical Gear	60 – Friction Roller	115 – Drive Disk
7 – Positioning Synchro Transmitter	30 – Friction Disk	70 – Limit Switch	118 – Input Gear
8 – Running Synchro Receiver	32 – Helical Gear	85 – Pointer Shaft	141 – Mechanical Counter
9 – Followup Motor	39 – Slip Ring and Contact Assembly	88 – Inner Pointer	200 – Speed Signal Switch
15 – Traveling Yoke	40 – Hub Assembly	89 – Outer Pointer	204 – Actuator Screw
16 – Lead Screw	42 – Input Shaft	114 – Driven Disk	205 – Bracket
25 – Switch Operating Screw	54 – Spring Washer		

Figure 10-34.—Gearing diagram of an indicator-transmitter.

89. Positioning synchro transmitter 7 and pointers 88 and 89 are geared to friction roller 60 and follow-up motor 9. Long pointer 89 makes one complete revolution every 100 rpm, and short pointer 88 makes one complete revolution for full-scale indication. The relative direction of the speed is indicated by the backing signal indicator, which is lighted only when the propeller shaft rotates in the astern direction.

Running synchro receiver 8 is driven electrically by the associated shaft transmitter at a speed exactly one-tenth that of the propeller shaft. The running synchro drives the input shaft of the speed-measuring mechanism through gear 118. The speed-measuring mechanism converts the rotary motions into proportional angular displacements, Running synchro 8 also drives revolution counter 141 through gears at a speed exactly one-tenth that of the propeller speed. The revolution counter registers the total propeller revolutions directly, irrespective of the direction of rotation.

Positioning synchro transmitter 7 receives the angular displacement from the speed-measuring mechanism and transmits these displacements to the remotely located indicators.

The speed-measuring mechanism operates on the friction disk and roller assembly principle; that is, if a disk is driven by a synchronous motor supplied with a controlled frequency, the disk will run at a constant speed irrespective of fluctuations of the ship's supply frequency. A roller placed in the center of the rotating disk will not turn. However, if the roller is moved out from the center of the disk, the roller will turn at a speed that is proportional to the distance from the center of the disk. For example, if the roller is moved out one-half inch from the center of the disk, the roller runs at twice the speed at which it ran when moved one-fourth inch from the center of the disk. If the position of the roller on the disk is varied, the speed of the roller is varied in direct proportion to the distance the roller is positioned from the center of the constmt-speed disk.

The friction disk and roller assembly also operates on the principle of comparing an unknown speed with a known speed. The known speed in this case is provided by synchronous motor 4, which drives friction disk 30 through gears at a constant speed. The gearing is such that the disk speed is 16 2/3 rpm for 200 range units and 33 1/3 rpm for 400 range units. The friction disk is held in continuous contact with friction roller 60, which is integral with helical gear 28. The friction roller and helical gear are mounted on traveling yoke 15, which has a total longitudinal motion of approximately 1.10 inches along the radius of friction disk 30. The yoke is positioned along the disk radius by lead screw 16, which is driven by follow-up motor 9.

Friction roller 60, integral with helical gear 28, drives helical gear 32, which is mounted on, but free to turn through a limited range about, input shaft 42. Thus, the helical gear rotates at a speed proportional to the distance between the position of the roller on the disk and the center of the disk. The radius of contact at any given point will determine the drive ratio and speed at which roller 60, and gears 28 and 32 will rotate.

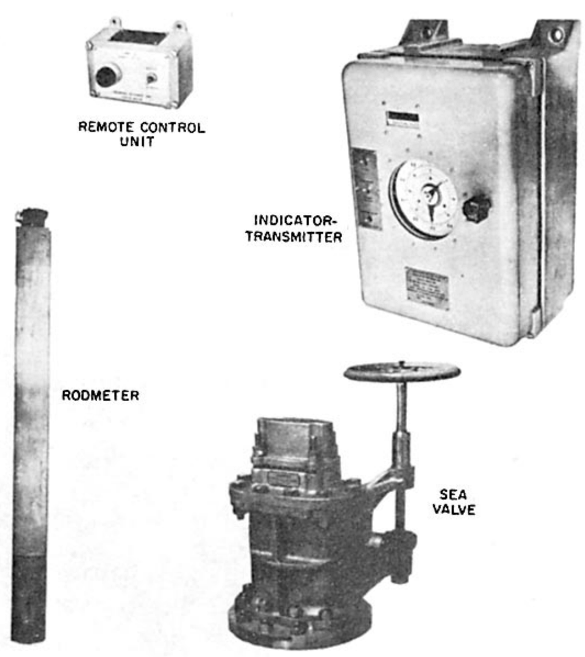
The speed of helical gear 32 is automatically adjusted to match the speed of running synchro driven gear 118 by the slip ring and contact assembly 39, the upper two slip rings of which are mounted on the hub of gear 32 and are free to turn through a limited range about input shaft 42. The assembly carries two outside brush contacts, CW and CCW, each of which slides on a slip ring. The center brush contact, C, slides on a slip ring, which is attached to hub 40 and is secured to input shaft 42 by friction thrust washer 54. The contact assembly can be turned in either direction so that one or the other of the outside contacts can mate with the center contact. This action energizes follow-up motor 9 and determines its direction of rotation.

When input gear 118 and helical gear 32 are running at exactly the same speed, the contacts are open, follow-up motor 9 is de-energized, and indicator pointers 88 and 89 are stationary. However, if the speed of gear 118 changes, follow-up motor 9 is energized and drives lead screw 16, which moves yoke 15, in or out, depending on the direction of rotation, If the speed of gear 118 is faster than the original balanced speed, the CW contacts close and, if the speed is lower, the CCW contacts close. The contacts will remain closed to energize the follow-up motor in a correcting direction until the radius of disk contact with roller 60 reaches a new value where the speed of gear 32 is again equal to that of gear 118. At this point, the contacts open to de-energize the follow-up motor.

At zero (rpm) input from running synchro receiver 8, gear 118 is stationary and the contacts of the slip ring assembly will cause follow-up motor 9 to move lead screw 16, forging friction roller 60 toward the center of friction disk 30. At the exact center, indicator pointers 88 and 89 should read zero rpm, and positioning synchro transmitter 7 should be on electrical zero. However, the pointers will not reach the exact scale zero because a limiting switch (not shown in fig. 10-34) de-energizes synchronous motor 4 at a pointer indicator of approximately 1 rpm.

The full-scale indication should occur when the point of roller contact is exactly 1 inch from the center of disk 30. The indicators provide for an overspeed indication of about 10 percent above full scale (1.10 inches disk radius) before limit switch 70 is actuated.

The indicator-transmitter can be provided with speed signal switch 200 to continuously energize a remote light or other signal at propeller speeds below a specified value. The signal setting is adjustable from about one-quarter of full speed down to about 5 rpm. As the speed of the propeller shaft decreases from higher value above the switch operating point, yoke 15, bracket 205, and actuator screw 204 are advanced along lead screw 16, until the roller and arm of stationary single-pole, double-throw (SPDT) switch 200 are lifted by actuator screw 204. The speed value at which the switch is operated is determined by the height of actuator screw 204, above bracket 205. The speed signal switch is adjusted by turning the actuator screw until the desired operating point is obtained. After the switch has been actuated in decreasing speed direction, it will remain actuated at lower speeds down to zero. Also, when the propeller speed increases, the OFF or release point of the switch will occur at a value slightly above the ON speed value in a decreasing direction because of the operating differential inherent in microswitch 200.



140.158
Figure 10-35.—Major components of an underwater log system.

Indicators

Indicators are installed in the pilothouse and engine rooms to indicate the rpm of the associated propeller shaft. An indicator consists of a positioning synchro receiver and a revolving pointer that indicates on a dial the rpm of the associated propeller shaft. The synchro receiver is driven by the positioning synchro transmitter in the associated indicator-transmitter unit. The indicator is also provided with a backing signal that is energized by the unidirectional mechanism in the shaft transmitter when the propeller shaft rotates in the reverse direction.

UNDERWATER LOG SYSTEM

The underwater log system (circuit Y) measures and indicates the speed of the ship in knots and the distance traveled through the water in nautical miles.

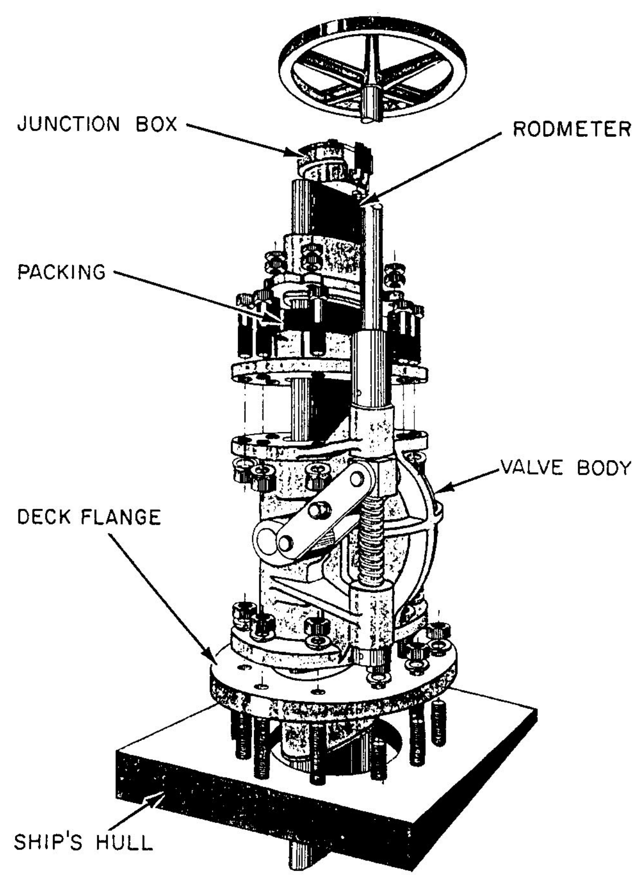


Figure 10-36.—Exploded view of the sea valve and packing assembly with the rodmeter installed.

There are two types of underwater log systems. One type uses a removable rodmeter and the other type uses a fixed rodmeter. The system we will discuss in this training manual is the type with the removable rodmeter. The major components of this system (fig. 10-35) are the sea valve, rodmeter, indicator-transmitter, and remote control unit.

Sea Valve

Mounted in the hull of the ship, the sea valve and packing assembly (fig. 10-36) provides a watertight support for the rodmeter. It also functions to seal the hull of the ship when the rodmeter is removed. The sea valve has no function relating to the production, transmission, flow, or conversion of data in the underwater log system.

Rodmeter

The rodmeter (fig. 10-37), or sword as it is commonly called, provides an ac signal that is proportional to the ship's speed. The sensing unit (fig. 10-38) of the rodmeter is contained in a boot at its lower end. The rodmeter operates on the principle of electromagnetic induction; that is, when a conductor is made to move in a magnetic field so that it cuts through the lines of flux, an electromotive force (emf) is induced in the conductor. In the case of the rodmeter, a 60-Hz current is supplied to a coil in the boot of the rodmeter. As the current flows through the coil, a magnetic field is produced that surrounds the rodmeter. The water, the conductor in this instance, flows around the rodmeter and cuts through the magnetic field. The induced voltage is felt at the contacts, or buttons, on either side of the rodmeter. The magnitude of the induced voltage is proportional to the speed of the water flowing through the magnetic field. Even when the ship is stationary, a current flowing around the rodmeter will cause a voltage to be induced.

Indicator-Transmitter

The indicator-transmitter displays the ship's speed on a dial and the distance on a counter and transmits

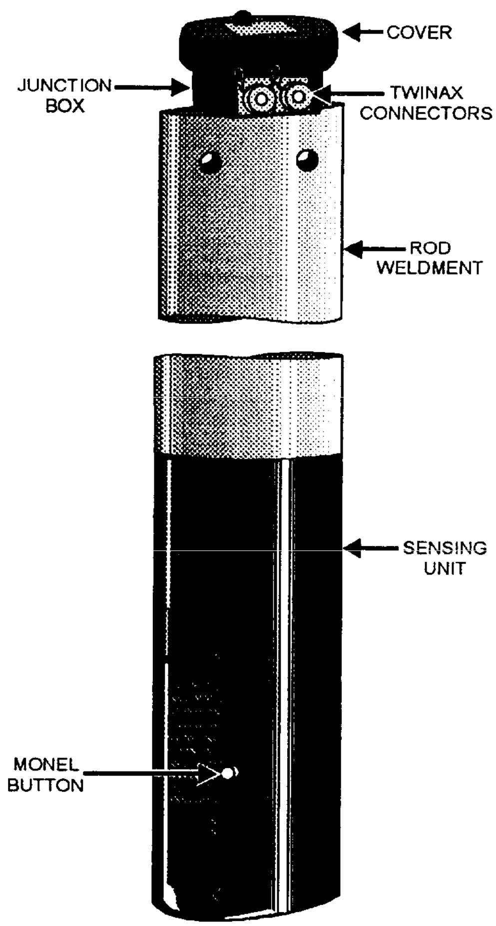


Figure 10-37.—Rodmeter.

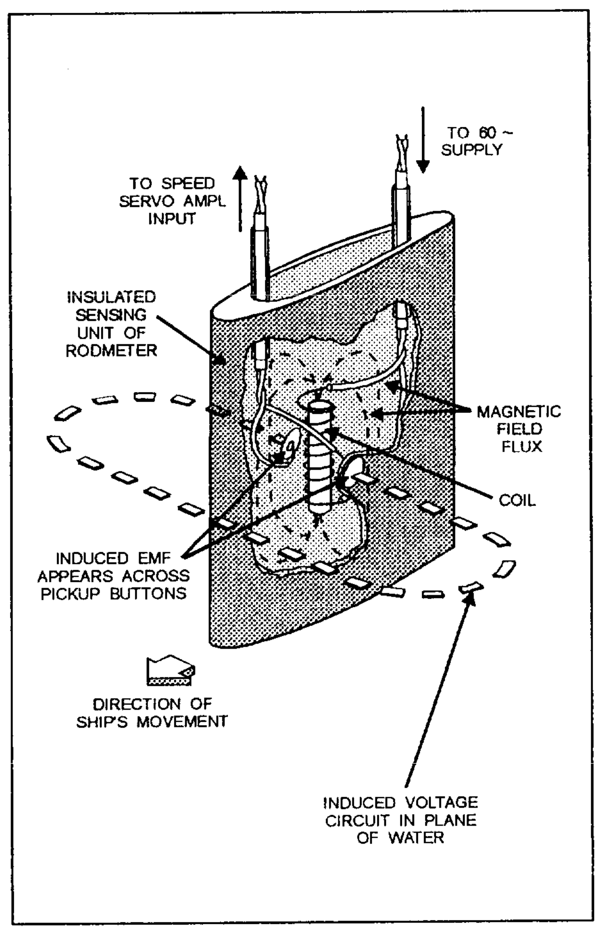


Figure 10-38.—Rodmeter sensing unit.

speed and distance information to various equipment and remote indicators throughout the ship.

The main internal components of the indicator-transmitter are the speed servo, the integrator, and the distance servo. The main external components of the indicator-transmitter are a distance motor, a speed dial, a distance counter, an electronic trim pot assembly, and a dummy signal unit used for calibration.

The ac signal voltage produced by the rodmeter is fed to the speed servo. The speed servo drives the synchro output transmitters, the dual-pointer dial, and the integrator. The integrator converts the speed input to a distance-traveled output, which drives a synchro output transmitter and a six-drum counter to display distance traveled.

Remote Control Unit

The remote control unit, or dummy log as it is commonly called, is used in place of the rodmeter when the ship is operating in shallow water, where lowering the rodmeter is impractical. The unit is normally located in the main propulsion control station. The unit has a spring-loaded, center-off, increase-decrease switch and is operated by the throttleman. The shaft rpm is used to determine approximate ship's speed.

VALVE POSITION INDICATOR SYSTEMS

Valve position indicator systems (circuit VS) provide personnel at remote stations of the positions (open or closed) of certain valves.

Sensitive switches, mounted on the valve housing and actuated by the valve, energize the indicators. On most installations, you will find two switches. One switch indicates that the valve is open and the other indicates that the valve is closed. They normally have a make contact arrangement. There are usually two lamps in each indicator; one lamp for the open position of a valve and the other for the closed position. The remote indicators may be found singly, but they are normally grouped into valve position indicator boards of from 5 to 15 indicators to indicate the positions of valves located in the same engineering space.

SALINITY INDICATOR SYSTEM

The salinity indicator system, described in this chapter, is a representative system. When working on the salinity system on your ship, you should consult the technical manual pertaining to your equipment for specific settings.

The salinity indicator system (circuit SB) measures the electrolytic impurities present in fresh water in equivalent parts per million (epm) or parts per million

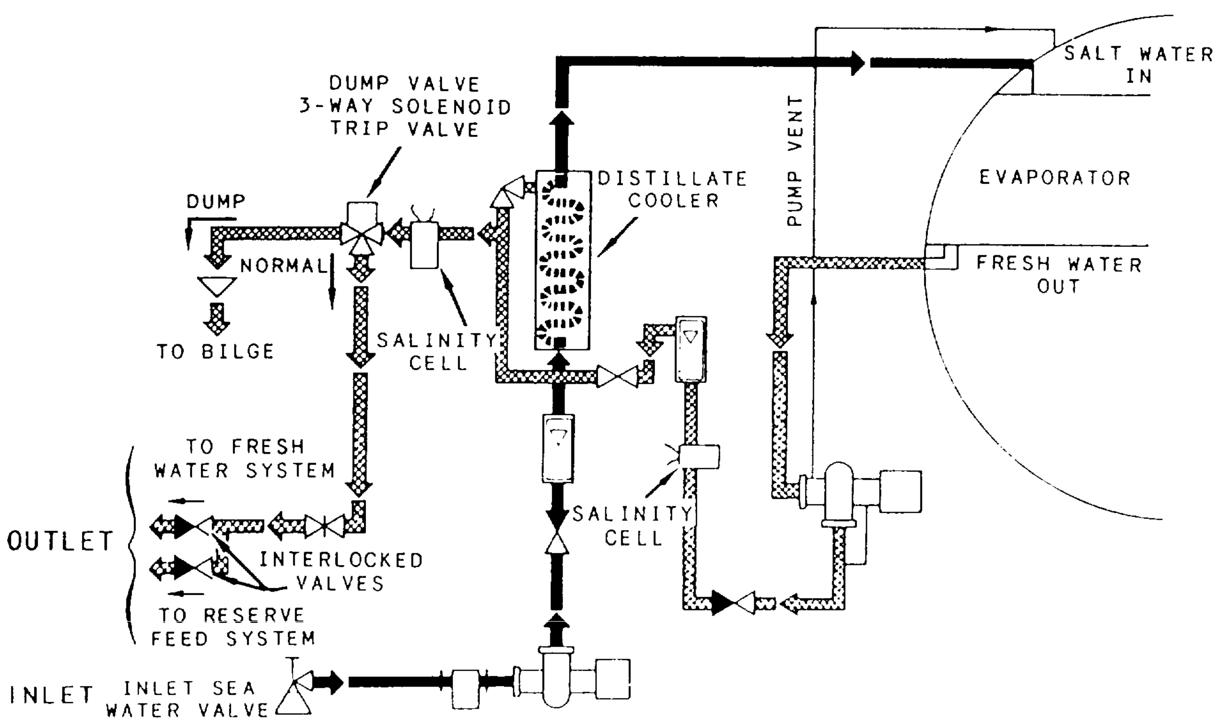


Figure 10-39.—Ships' water system diagram.

(ppm); the terms are interchangeable. For purposes of our discussion, we will use epm. The system is a necessity aboard ship because all fresh water, particularly when underway, is made from seawater. Excessive salinity in the boiler feedwater causes pitting of the tubes and rapid deterioration due to electrolysis. Salinity indicators are usually provided in the engine rooms and the firerooms for checking the condensate from the main and auxiliary condensers. They are also provided for the evaporator plants to indicate the degree of purity of the fresh water and condensate at various selected points in the distilling system.

The ship's water system (fig. 10-39) pumps water aboard the ship from the sea, sends it through the evaporator to remove the salt, and then stores the purified water in freshwater tanks. The fresh water is used for showers, drinking water, cooking, and, most importantly, it is used in the ship's boilers to generate the steam that drives the ship. The boiler feedwater must contain less than 0.065 epm or the boilers can be damaged or "salted up." The salinity system monitors the impurity content continuously; should the impurities reach alarm proportions, the salinity system de-energizes the dump valve solenoid and redirects the contaminated water to the ship's bilge or directly overboard.

The operation of the salinity indicator system is based on the principle that an increase of the electrolytic impurities (principally salt) in water increases the electrical conductivity of the water and, conversely, that a decrease in the impurities increases the electrical resistance of the water. If two electrodes are immersed in the water tested and a stable alternating voltage is applied across the electrodes, a stable alternating current will flow, provided the impurity content and the temperature of the water remain unchanged.

The amount of current flow is indicated on a meter, the scale of which is graduated in equivalent parts per million. If the saline content of the water increases because salt water leaks into the system or because the operation of the distilling plant becomes faulty, the conductivity between the electrodes increases and the meter reading increases an amount that is proportional to the increase in salinity.

The salinity system is composed of three major components: the salinity cell, the salinity indicator panel, and the dump valve and solenoid.

Salinity Cell

The salinity cell (fig. 10-40, views A and B) is the device that does the actual detecting of impurity. It

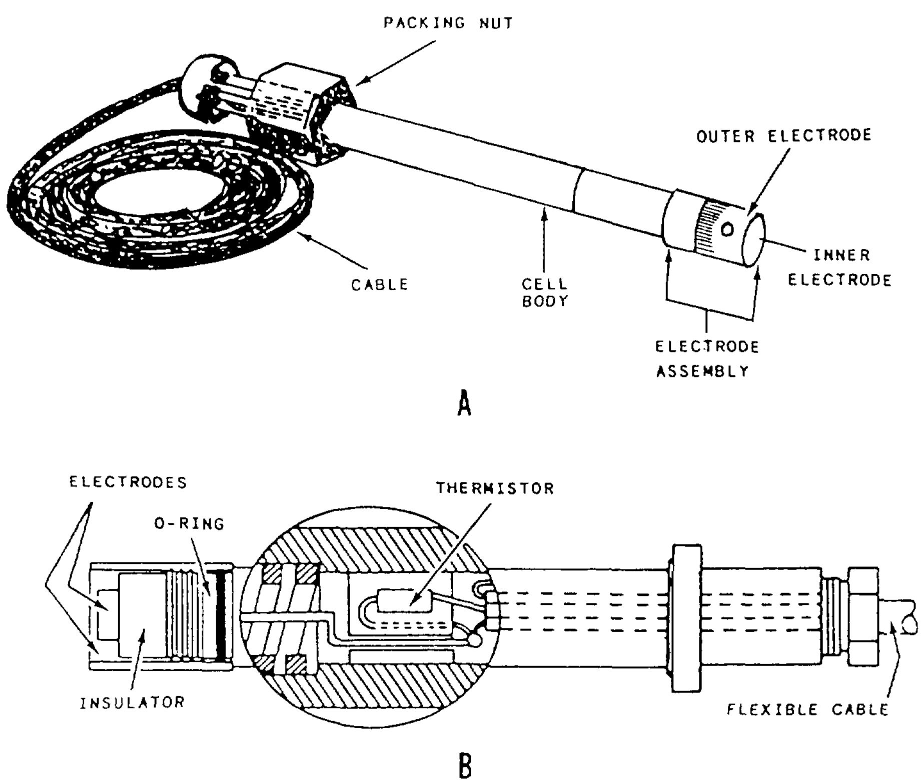
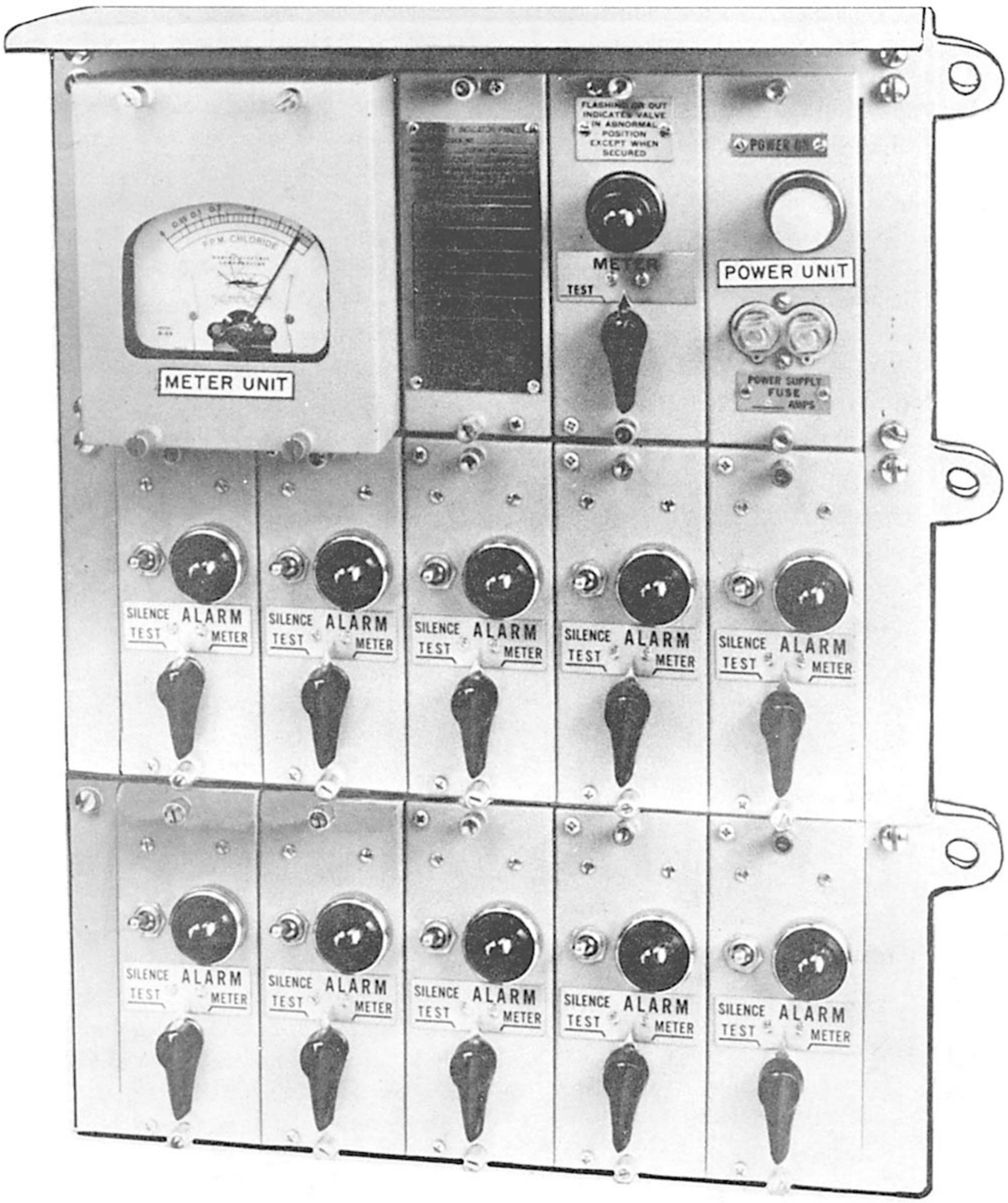


Figure 10-40.—Salinity cell.

operates on the principle that an increase in electrolytic impurities (salt) will increase the conductivity of the water. Therefore, the higher the impurities, the higher the current.

The salinity cell is a self-contained unit consisting of a nipple, packing nut, cell tube, and electrode assembly. The cell tube provides a means of extending the electrode assembly through the valve and is connected to the tee through the nipple and packing nut to form a watertight seal. The packing nut has a set screw that screws into a groove in the cell tube to prevent axial displacement of the tube by the hydrostatic pressure. A steel ring stop on the cell tube, between the packing nut and the nipple, locates the cell properly in the piping.

A 6-foot, three-conductor cable connects the cell to the salinity indicating panel and the ship's 115-volt,



140.201

Figure 10-41.—Salinity indicator panel.

60-Hz power. The cable is secured to the cell by means of a gland nut.

The electrode assembly comprises the inner electrode, adapter, automatic temperature compensator, and the outer electrode. The inner electrode is a hollow platinum-coated brass cylinder closed at the forward end. It is held in the adapter by means of a spring-loaded nut on the end of the inner electrode holder. A solder lug under this nut connects the white conductor of the incoming cable.

The outer electrode is a hollow brass cylinder, the inside of which is coated with a thin layer of platinum. This electrode screws onto the adapter, which in turn screws onto the cell tube. It is pierced with holes to vent the gases trapped in the space between the electrodes and to allow for free circulation of the water. The connection for the outer electrode is made by soldering the green conductor of the incoming cable into the hole provided in the cell tube.

The cell body (fig. 10-40, view A) has two platinum electrodes with a constant voltage applied to them. When they are exposed to air, no current flows. When they are immersed in water, the impurities in the water determine the amount of current flow. If the impurities in the water increase, the resistance of the water decreases, and this causes a corresponding increase in the current flow. If the current exceeds the alarm set point, an alarm (visual and/or audible) warns the ship's personnel of the condition.

A thermistor (fig. 10-40, view B) is located within the cell which automatically corrects for all temperature changes between 40°F and 250°F. The thermistor has a negative temperature coefficient of resistance, which means that as the temperature increases the resistance decreases. Therefore, the salinity circuit current is affected only by the impurities in the water and is unaffected by temperature changes.

Salinity Indicator Panel

The salinity indicator panel (fig. 10-41) indicates to the operator by meter indication the salinity level of the water at various points in the distillation process. The salinity indicator panel has switches and alarm indicating lamps for each salinity cell in its system, as well as an alarm lamp to indicate that the dump valve solenoid has "tripped" and water is being diverted from the potable water tanks. The meter indicating unit is calibrated in epm.

The salinity indicator panel is designed to function in a system having five salinity cells, external alarm bells, and two solenoid trip valves. The panel contains a power unit, a meter unit, five salinity cells, a valve position and meter test unit, and a relay unit, The units are of the plug-in type to facilitate removal for inspection and repairs.

POWER UNIT.— The ship's 115-volt, 60-Hz power is applied to the salinity indicator panel through the power unit (fig. 10-42). The power unit is not a plug-in type, but is wired directly onto the panel. It is provided with a white power-on indicator lamp, two fuse holders, and two blown-fuse indicators. The two fuses protect only the salinity cell and the alarm circuit wiring. The power circuits to the solenoid-operated control valves are not fused.

METER UNIT.— The meter unit (fig. 10-42) measures the specific electrical conductivity of the water. The conductivity values are then converted by meter scale calibration into equivalent concentrations of seawater. The meter is connected to the cell circuits by individual switches on each salinity cell. The specific electrical conductivity is measured by means of a bridge circuit that employs a special power-factor type of meter. The meter measures the ratio of currents in the two separate arms of the bridge. One arm of the bridge is the dilute solution of seawater to be measured. The other arm of the bridge is an automatic temperature compensating resistor that has the same resistance-temperature characteristics as dilute solutions of seawater.

The power-factor type of meter (fig. 10-42) employs a fixed coil and a movable coil. The movable coil consists of two windings, A and B, at right angles to each other. It is free to rotate within the fixed coil. The movable coil is energized from the secondary of the power transformer, T1. Hence, the currents in windings A and B are in phase with each other and the circuits are resistive because of the series limiting resistor, R6. The fixed coil is energized from the ship's 115-volt, 60-Hz power supply in series with the voltage dropping resistor, R12. The movable coil turns until its resultant field lines up with the field of the fixed coil. Therefore, the meter indication is directly dependent on the resultant field of the two movable windings, which, in turn, is dependent on the ratio of the currents in the two windings. The meter indication is independent of minor voltage and frequency changes of the power supply because there is no iron on the meter magnetic circuits and because the coil circuits are essentially resistive.

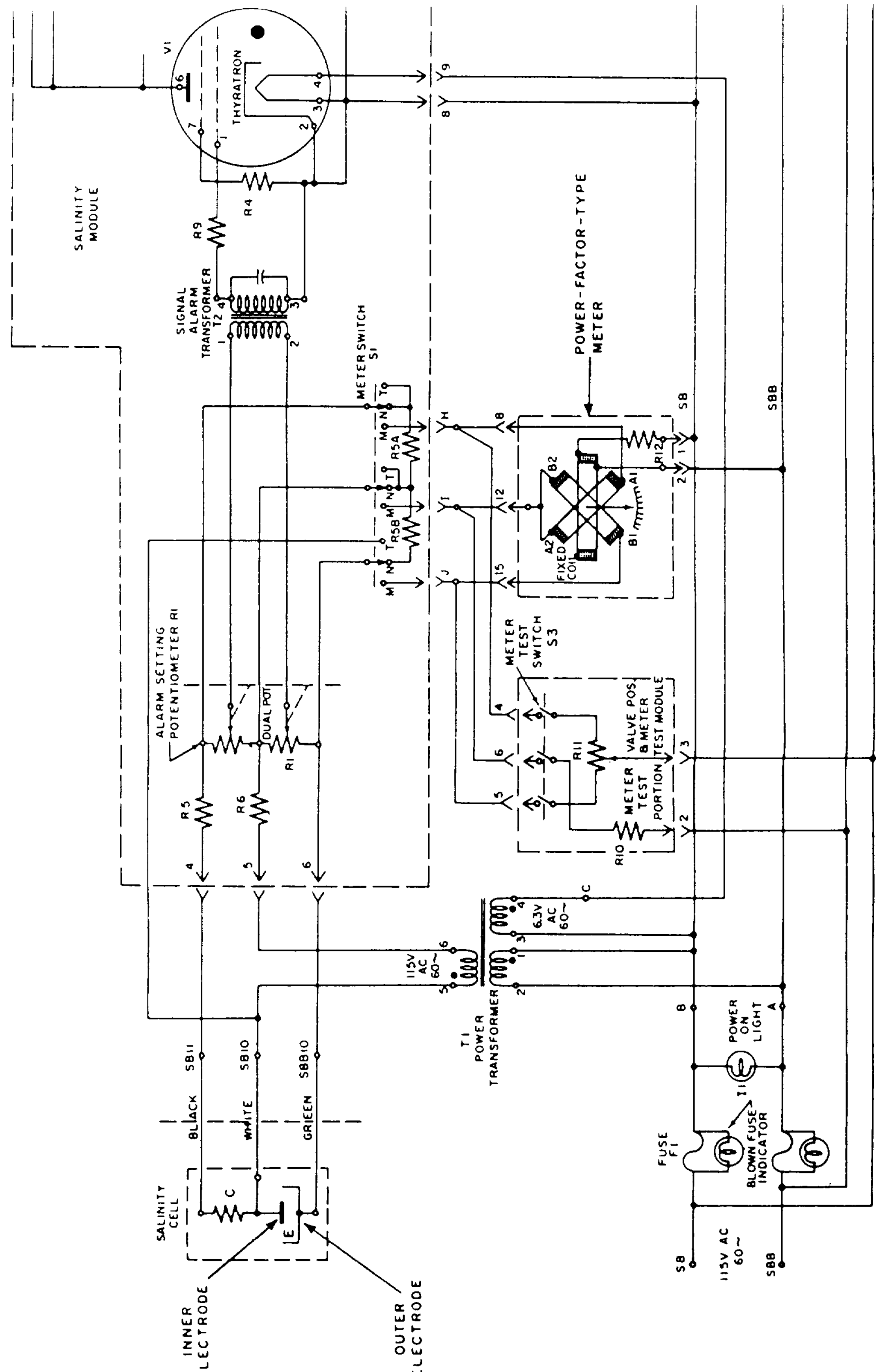


Figure 10-42.—Schematic diagram of the salinity indicator system.

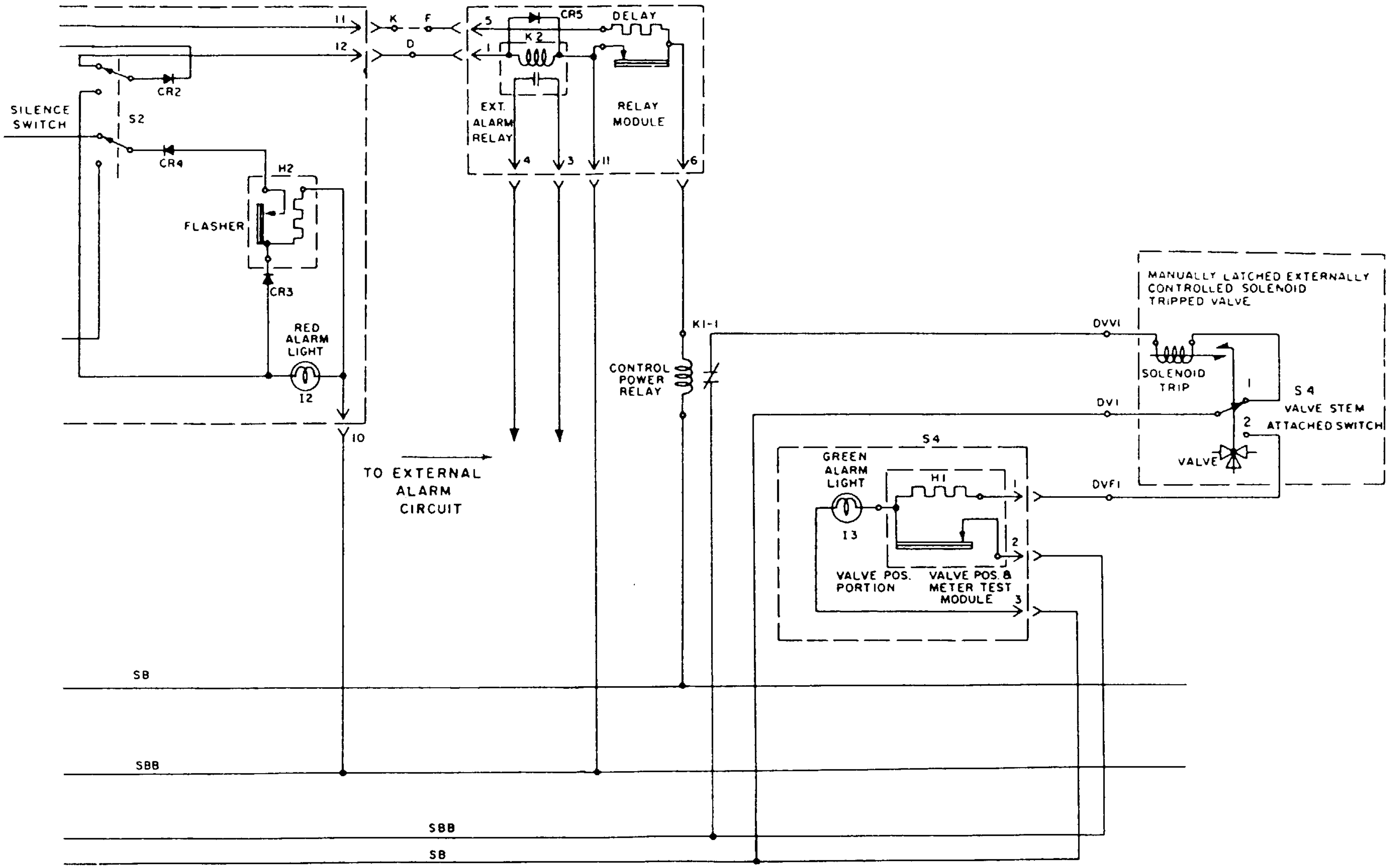


Figure 10-42.—Schematic diagram of the salinity indicator system—Continued.

The currents in the two windings of the movable coil are proportional to the two loads in the bridge circuit. As previously stated, the load in one leg of the bridge (movable winding A) is the automatic temperature compensator, C, located in the salinity cell, and in the other leg (movable winding B) is the resistance of the water being measured by the electrodes, E. The meter reading, which is determined by the ratio of the currents in the crossed windings, is therefore determined by the ratio of the cell resistance and the compensator resistance. At any given salinity and temperature there is only one possible meter reading. If the temperature is either raised or lowered from this point, the meter reading will remain unchanged because of the action of the compensator even though the water resistance may change appreciably. The temperature compensation occurs because any thermal change of the water being measured by the cell is immediately transferred to the automatic temperature compensator. The resistance of the compensator is inversely proportional to its temperature so that the thermal change transmitted to the compensator causes its resistance to change accordingly.

The resistance-temperature characteristics of the compensator are the same as those of dilute solutions of seawater. Therefore, the thermal change in the compensator, which is exactly the same as the thermal change of the seawater, causes sufficient resistive change in the compensator to compensate for the resistive change occurring in the cell. Although the absolute values of current in the windings have changed, their ratio has not changed and, consequently, the meter reading is unchanged. Because the temperature compensation is equally effective at all salinities, the only change that can vary the meter reading is a change in the current ratio caused by a change in salinity.

SALINITY CELL UNIT.— A salinity cell plug-in unit (salinity module, fig. 10-42) is provided for each salinity cell to continuously monitor the purity of the water of the cell. The unit consists of an alarm circuit that includes a dual potentiometer, R1, signal transformer, T2, thyratron tube, VI, flasher, H2, red alarm light, I2, and silence switch, S2. A three-position meter switch, S1, is also provided on the unit. The alarm point value is predetermined and set. A high salinity condition is indicated initially by flashing of the red alarm light and sounding of the external audible alarms.

The alarm circuit can be traced from the salinity cell electrodes and compensator through the dual potentiometer, R1, to the primary of the signal transformer, T2, the secondary of which is connected to the control grid and cathode of the thyratron, V1. The plate and cathode of V1 are connected across the 115-volt, 60-Hz power supply in series with the flasher, H2, and the red alarm light, I2.

There are two circuits from the secondary of the power transformer, T1, through the salinity cell, dual potentiometer, R1, and primary of the signal transformer, T2. One circuit is through the electrodes, the lower arm of R1, the primary of T2, the upper arm of R1, the primary of T2, the lower arm of R1, and resistor R6. The conductance values of the salinity cell electrodes and compensator, which are applied to the secondary of T1 and to the two arms of the potentiometer, R1, determine the grid to cathode voltage of V1. The current flow through the two arms is in opposite directions or 180° out of phase, and the resultant voltage is impressed across the primary of T2.

For thyratron V1 to conduct, the voltage between the control grid and the cathode (from the secondary of T2) must be in phase with the plate-to-cathode voltage.

When the salinity condition of the cell is higher than the alarm setting, the resistance across the two electrodes is decreased and more current flows through the lower arm of R1, the primary of T2, the upper arm of R 1, and resistor R6. The resultant voltage is impressed across the grid and the cathode of V1 through transformer T2. This voltage is of the proper phase to cause V1 to conduct during the half cycles when the grid and plate voltages of V1 are positive. The circuit is completed from one side of line SB through the cathode and plate of V1, silence switch S2, rectifier CR4, flasher H2, rectifier CR3, red alarm I2, to the other side of line SBB.

The silencing switch, S2, when placed in the SILENT (down) position, clears the external alarm circuit for other incoming alarms and causes the red alarm light to light steadily. When the high salinity condition is corrected, the red alarm light again flashes to remind the operator to place the switch, S2, in the NORMAL (up) position to extinguish the red alarm light and clear the unit for future alarm signals.

The meter switch, S1, is a three-position, spring-loaded switch having a NORMAL (center) position, a TEST position, and a METER position. The meter switch, S1, when placed in the TEST position, disconnects resistor R5B in the salinity cell circuit, resulting in an unbalanced condition that causes the cell to behave as though a high salinity condition exists. This action energizes the alarm circuit, causing the red alarm light to flash and the alarm relay to sound the external alarm. The meter switch, S1, when placed in the METER position, connects the meter unit in the circuit of the associated salinity cell and a salinity reading is indicated on the meter.

VALVE POSITION AND METER TEST UNIT.— The valve position and meter test module (fig. 10-42) is provided with a green valve position indicator lamp and a meter test switch. The dual purpose of the unit is to indicate when the control valve is in the NORMAL or ABNORMAL position and to provide a means of testing the meter unit.

When the solenoid trip valve is in the NORMAL position, as shown, the green indicator lamp is illuminated steadily; when the control valve is in the ABNORMAL position, the green alarm light flashes; and when the control valve is reset manually, the green alarm light is again lighted steadily.

The meter test switch, when placed in the TEST position, connects the meter unit in a circuit simulating a known salinity condition (1.7 ppm) to check the calibration of the meter.

The valve position portion of the unit consists of the green indicator lamp, I3, and the flasher, H1, interconnected with the solenoid-operated valve. During normal operating conditions, the solenoid is energized from the line terminal SSB through the contacts of the power control relay, K1-1, terminal 1 of the SPDT switch, S4 (on the control valve), to line terminal SB. The green indicator lamp, I3, is illuminated steadily during this condition from line terminal SB, the contact arm of flasher H1, to line terminal SBB.

When art abnormal condition occurs, the power control relay, K1-1, is de-energized and its contact opens the circuit to the solenoid coil, which actuates switch S4. This action connects the heater and contact arm flasher H1 from line terminal SB, through terminal 2 of switch S4, to line terminal SBB, causing the green indicator light to flash.

The meter test portion of the unit consists of meter test switch S3, resistor R10, and potentiometer R11. Normally, the meter unit is not connected to a salinity cell. The meter test switch, S3, is a two-position, spring-loaded rotary switch having a NORMAL (center) position and a TEST position. The rotary switch, s3, when placed in the TEST position, connects the movable windings, A and B, of the power-factor-type meter in a circuit comprising resistor R10 and potentiometer R11, the resistances of which duplicate the resistances of the electrodes and compensator. There are two circuits through the movable windings. One circuit is from line terminal SB, the right arm of potentiometer R11, terminal 4 of switch S3, resistor R10, to line terminal SBB. The other circuit is from line terminal SB, the left arm of potentiometer R11, terminal 6 of switch S3, resistor R10, to line terminal SBB. With the meter test switch in the TEST position, the meter should read 1.7 ppm.

RELAY UNIT.— The relay module (fig. 10-42) consists of an alarm relay, K2, and two 2-second delay flashers. (For simplicity, only one flasher is shown.) The flasher is used to delay the tripping time of the solenoid-operated valves. Normally, the current through the delay flasher contact circuit is not sufficient to open the flasher contacts. However, if terminal 5 of the relay unit is energized from an associated salinity cell, the flasher contact will open, de-energizing control power relay K1-1 and causing contacts K1-1 to open. This action de-energizes the valve control circuit, causing the valve to actuate.

The rectifier, CR2, allows a current to flow through the operating coil of alarm relay K2, from the plate of V1, through switch S2, in the NORMAL (up) position, and back to the other side of line SBB. Rectifier CR5, across the coil of K2, maintains the current flow through the coil during the non-conducting half cycles of V1, The contacts of relay K2 close to energize the external alarm circuit.

The silencing switch, S2, when placed in the SILENT (down) position, opens the circuit to the audible alarm and connects the plate of V1 to one side of the alarm light through CR2. As long as the salinity is higher than the alarm setting, CR2 allows a current to flow directly through the red alarm light, 12, which is lighted steadily. During this condition, CR3 prevents a large current flow through the heater of the flasher, H2, When the salinity decreases to a value at which V1 ceases to conduct, the flasher heater voltage causes the red indicator light to flash as a reminder for the operator to place the silencing switch, S2, in the NORMAL (up) position.

Normally, the current flows through the relay module from the line terminal, SBB, the bimetallic arm of the delay flasher, the coil of the power control relay, K1-1, to the line terminal, SB. This current maintains power relay K1-1, operated so that its contacts are closed. (For simplicity, only one solenoid-operated valve is shown.)

TANK LEVEL INDICATOR SYSTEMS

Tank level indicator systems provide an accurate measure of the fluid level within a tank, as well as sound an alarm, audible and/or visual, to indicate either a high or low fluid level. The fluid levels can be continuously indicated or in predetermined increments, depending on the type of equipment installed in the tank. This can be accomplished using various types of detection equipment, the most common of which is the magnetically operated reed switch. For the purposes of our discussion, we will talk about the magnetically operated reed switch.

The system consists of a level detector, which is installed in the tank, a receiver mounted outside the tank, and an alarm device. The types of alarm devices used varies depending on the system; however, they perform the same function.

The level detectors used in a tank level indicating system fall into two categories: level links and transmitters. Level links indicate the fluid level in increments. Transmitters provide continuous fluid level indications and are used in systems requiring greater accuracy.

The method of indication for level links and transmitters are the same. A permanent magnet, which moves with the fluid level, is enclosed in the float. When the permanent magnet becomes parallel to a switch, the switch closes. As it moves further on the stem, it will make the next switch before opening the former switch (make-before-break).

Transmitters and level links are sometimes used together. The actual combinations are determined by the size of the tank and its shape, as well as the desired type of level indication.

The electrical signals generated by the level links and transmitters are converted at the receivers and indicated on meters in gallons. Each meter is calibrated for a specific tank, and each tank is different in size and shape. The size and shape of the tank also accounts for the nonlinearity of the meter forces.

MAINTENANCE

Preventive maintenance for the ship's order indicating and metering systems consists of routine tests, inspections, cleaning, and lubrication. All preventive maintenance should be accomplished according to current applicable MRCs.

Corrective maintenance for the systems consists mainly of replacing burned out illumination lamps and zeroing synchros. For detailed information concerning the maintenance of synchro systems and the zeroing of synchros, refer to Navy Electricity and Electronics Training Series (NEETS), NAVEDTRA 172-15-00-85, Module 15.

SUMMARY

In this chapter, we have described the purpose of the ship's order indicating and metering systems. We have identified and discussed the operation of the ship's control order and indicating systems and the various control consoles used with the systems. We have identified and discussed the operation of some of the various metering and indicating systems installed on Navy ships. We have briefly discussed some of the preventive and corrective maintenance measures associated with the ship's order indicating and metering systems.

CHAPTER 11

AUXILIARY ELECTRICAL EQUIPMENT

LEARNING OBJECTIVES

Upon completion of this chapter you will be able to do the following:

- *Describe the operating and testing procedures of the ship's whistle.*
- *Explain the requirements for performing maintenance on the ship's whistle.*
- *Describe the components, operating procedures, and maintenance procedures of the microfiche reader-printer*
- *Describe the components, operating procedures, and maintenance procedures of the cathodic protection system.*
- *Describe the inspection, troubleshooting, and corrective maintenance procedures of auxiliary equipment.*

INTRODUCTION

IC Electricians are required to maintain various types of auxiliary equipment aboard ship. This chapter will describe the components, operating procedures, and troubleshooting and maintenance procedures of some of the auxiliary equipment that you will be involved with. This chapter will also introduce you to cathodic protection systems installed on naval ships.

SHIP'S WHISTLE

As an IC Electrician, you will be required to do preventive maintenance and repairs on the ship's whistle. This is a relatively simple system, but it is of the utmost importance. The ship's whistle is used to signal other vessels of the manuevers your ship may be doing. It is also used, in conditions such as heavy fog, to warn other ships of the location of your ship.

LOCATION OF WHISTLE

When a directional whistle is to be used as the only whistle on a ship, it is installed with its maximum intensity directed straight ahead. A whistle should be placed on a ship as high as practicable to reduce interception of the emitted sound by obstructions and to minimize risk of hearing damage to personnel. The sound pressure level of the ship's own signal at listening posts shall not exceed 110 dB(A), and so far as practicable should not exceed 100 dB(A).

FREQUENCIES AND RANGE

The fundamental frequency of the whistle signal lies between the 70- to 700-Hz range. The audibility range of the whistle signal is determined by those frequencies (which may include the fundamental and/or one or more higher frequencies) that lie within the 180 to 700 ($\pm$ 1 percent) range and that provide sound pressure levels specified in the following paragraph on intensity. The range of audibilty is for information, and is the approximate range at which a whistle may be heard on its forward axis (90 percent probability) in conditions of still air on board a ship having the average background noise level at the listening posts. This shall be assumed to be 68 dB in the octave band centered on 250 Hz and 63 dB in the octave band centered on 500 Hz. Values given can be regarded as typical, but under conditions of strong wind or high ambient noise level at the listening post, range may be reduced. In practice, the range at which a whistle may be heard is variable and depends on weather conditions.

To ensure a wide variety of whistle characteristics, the fundamental frequency of a whistle must be between the following defined limits:

- 250 to 700 Hz, for a ship less than 75 meters (240 feet) long
- 130 to 350 Hz, for a ship 75 to 200 meters (240 to 650 feet) long
- 70 to 200 Hz, for a ship more than 200 meters (650 feet) long

INTENSITY

A whistle shall provide in the direction of maximum whistle intensity and at a distance of 1 meter from the whistle, a sound pressure level in at least one 1/3-octave band within the range of 180 to 700 Hz (+ 1 percent) as listed in table 11-1.

MAINTENANCE

Maintenance should be accomplished according to the applicable technical manual. All preventive maintenance should be accomplished according to the preventive maintenance card for the system aboard the ship at the time.

MICROFICHE EQUIPMENT

There are many types and sizes of microfiche equipment in use today. Regardless of size and shape, they all accomplish the same job.

The microfiche reader-printer is a self-contained machine designed for reading and printing enlarged copies of microfiche images. There are normally two modes of operation: reading and printing. During the reading mode, an enlargement of the microfiche image appears on the translucent viewing screen. A print of the image may be made by pressing a PRINT button on the console of the machine. After an exposure and development cycle, the print emerges from a slot in the cabinet.

The microfiche reader-printer consists basically of six systems. These are the optical system, light source, paper feed system, developing system, paper cutter, and power distribution system. These systems are all housed in a cabinet and frame assembly.

OPTICAL AND LIGHT SYSTEMS

The purpose of the optical system is to project an image in sharp focus on the viewing screen. This is accomplished with a system of mirrors and lens. Figure 11-1 is an optical system from a 3-M 500 Reader-Printer. In this particular system, the reflector is adjustable to allow concentration of the light rays.

The lamp is the source of the light rays. Normally, the voltage of the lamp is adjustable. This allows the operator to select the proper exposure for the particular microfiche image.

Table 11-1.—Intensity Level and Audibility Range

SHIP LENGTH (METERS)	1/3 - OCTAVE BAND LEVEL AT ONE METER*	AUDIBILITY RANGE (NAUTICAL MILES)
200 OR MORE	143	2.0
75 TO 200	138	1.5
20 TO 75	130	1.0
LESS THAN 20	120	0.5

*dB REFERED TO 2 X 10^{-5} PASCALS.

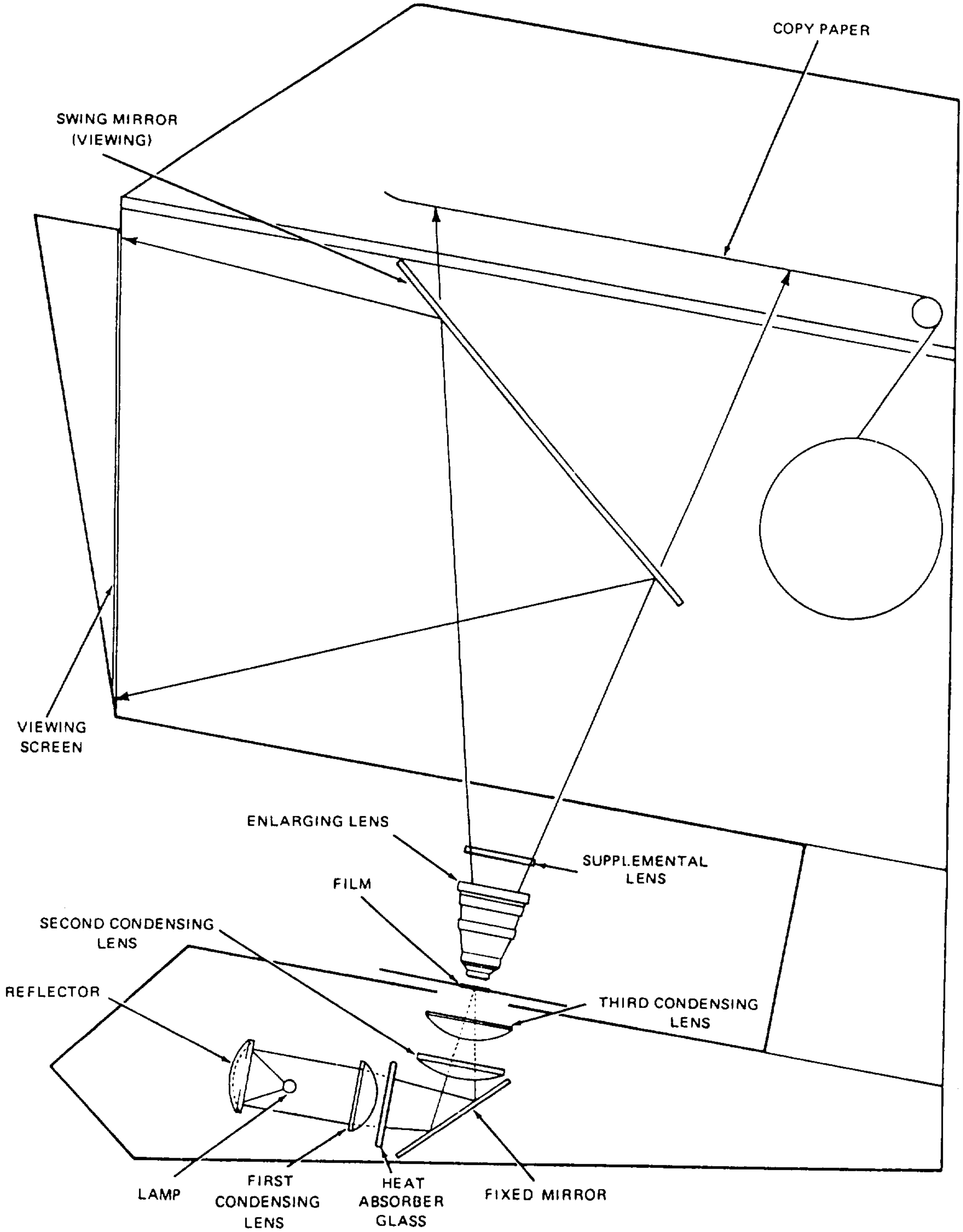


Figure 11-1.—Optical path.

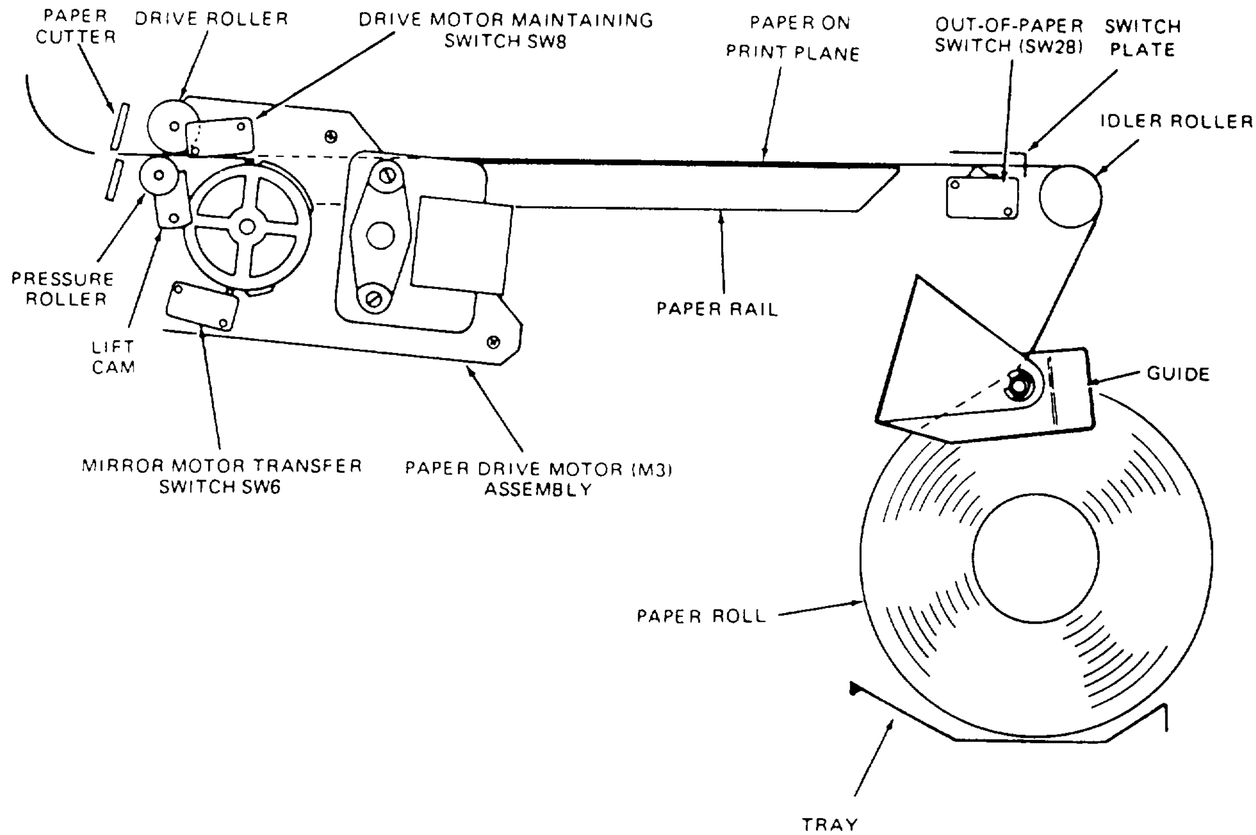


Figure 11-2.—Paper drive system.

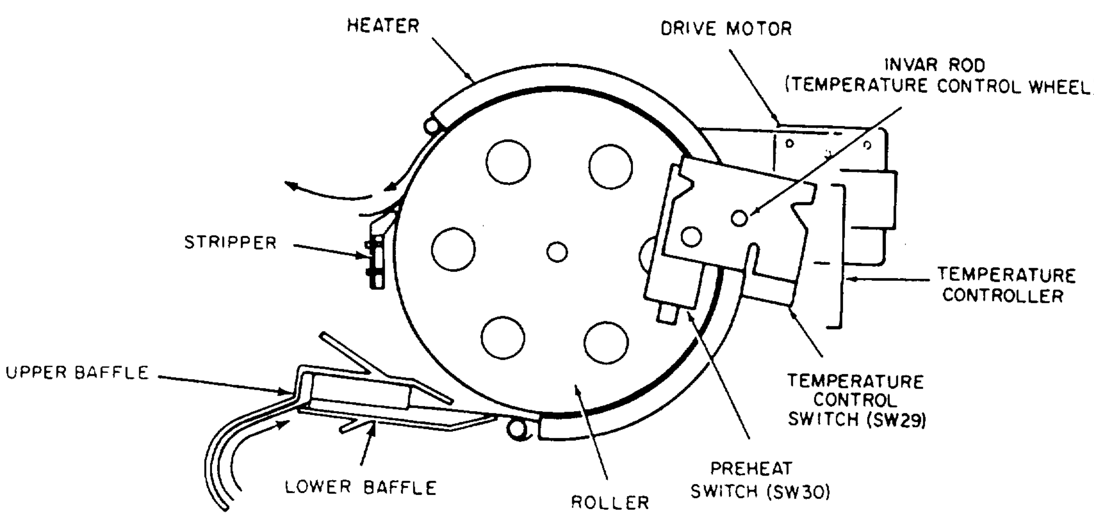


Figure 11-3.—Print developing system (dry).

PAPER FEED SYSTEM

The paper feed system drives the paper through the reader-printer. The paper roll is held in a paper supply holder. It is driven by the paper feed system through the developer and then to the paper cutter. Finally, the finished print is fed out a slot in the cabinet. Figure 11-2 is the paper feed system of the 3-M 500 Reader-Printer. Other models may have a slightly different system.

DEVELOPING AND PAPER CUTTING SYSTEMS

There are different types of developing systems used in reader-printers. Some are wet systems and some are dry. A wet system uses a developing fluid and special paper to make the print. The dry type uses a different paper and heat to make the print. Figure 11-3 is a diagram of a dry system, and figure 11-4 is a diagram of a wet developing system.

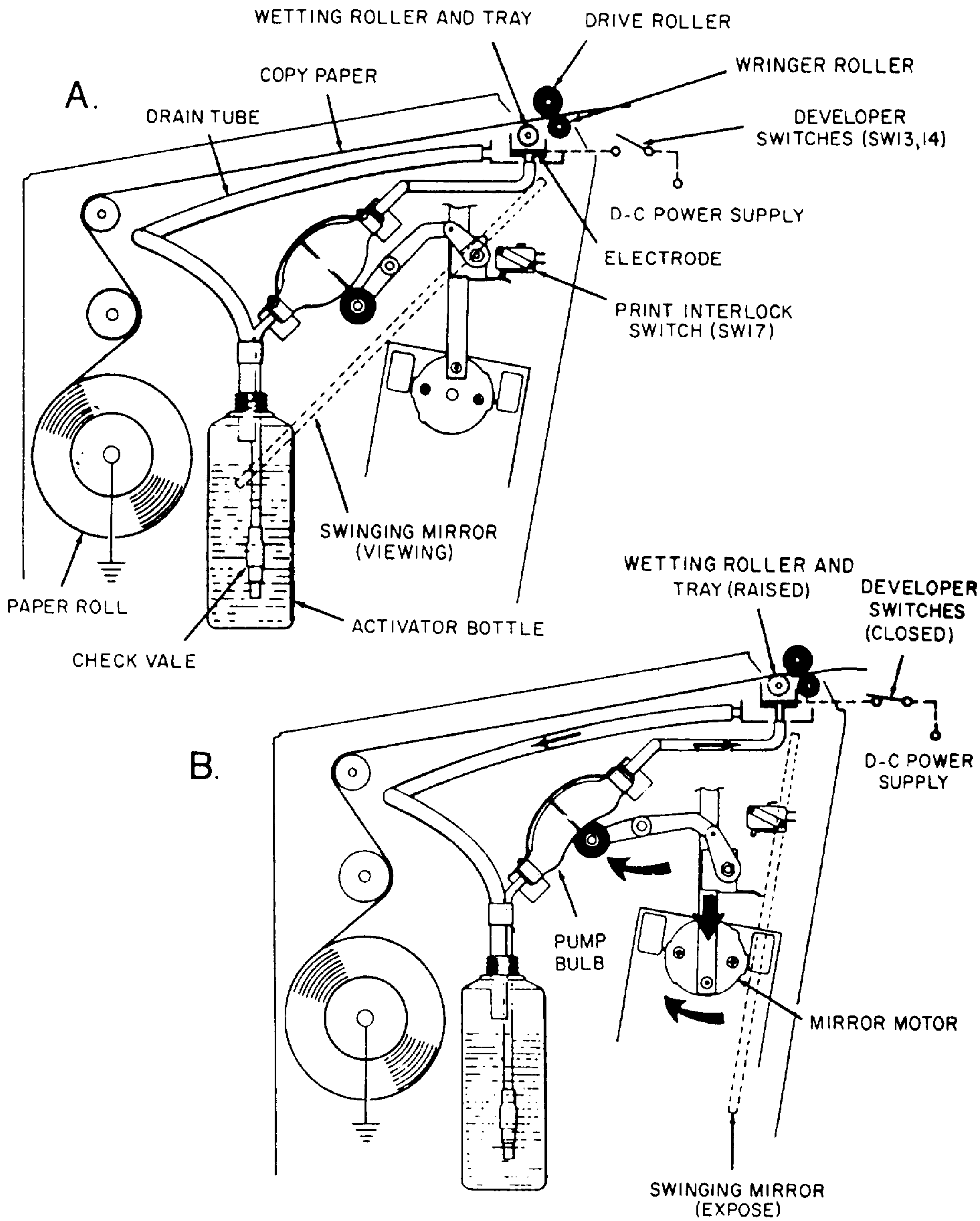


Figure 11-4.—Functional diagram of a developing system (wet).

After the print is developed, it is fed through the paper cutter (fig. 11-5), where it is cut off from the paper roll.

POWER DISTRIBUTION SYSTEM

Most reader-printers operate on 115 volts 60 Hz. The power distribution system supplies the power to operate the system in the reader-printer to produce a print. There are numerous motors, switches, and relays that operate the systems in the reader-printer. These are supplied by the power distribution system.

MAINTENANCE

Most maintenance, regardless of the type of reader-printer, is outlined on MRCs. The MRCs give detailed step-by-step instructions in performing needed maintenance on reader-printers.

CATHODIC PROTECTION SYSTEM

The next sections of this chapter will introduce you to cathodic protection systems installed on naval ships. There are two systems, the sacrificial anode and the impressed current. The two systems are different in both construction and operation.

Some technical terms used with this part of the chapter may be unfamiliar to you. These terms apply to cathodic protection systems, and are listed with their definitions in Apppendix I, Glossary.

CATHODIC PROTECTION

Cathodic protection reduces the corrosion or deterioration of metal caused by a reaction with its environment (ship's hull and seawater). The chemical action that is created is similar to the electrochemical action of a battery or cell. Figure 11-6 shows a dry-cell battery circuit. So that you may understand the electrochemical theory shown in figure 11-6, you need to use the conventional theory where current flows from positive to negative. The positive current is indicated by a positive deflection of the voltmeter needle when the positive terminal of the meter is connected to the cathode (positive terminal) of the cell. As the electrochemical action continues, the process will eventually corrode, or consume, the anode that is providing the current to light the lamp. This process is called electrochemical action.

ELECTROCHEMICAL ACTION

In a marine environment, corrosion is an electrochemical process caused when two dissimilar metals are immersed in seawater, with the seawater acting as the electrolyte. This process is shown in the electrochemical corrosion cell (fig. 11-7). You must understand that in an electrochemical cell a metal that is more corrosion prone always has a higher driving voltage

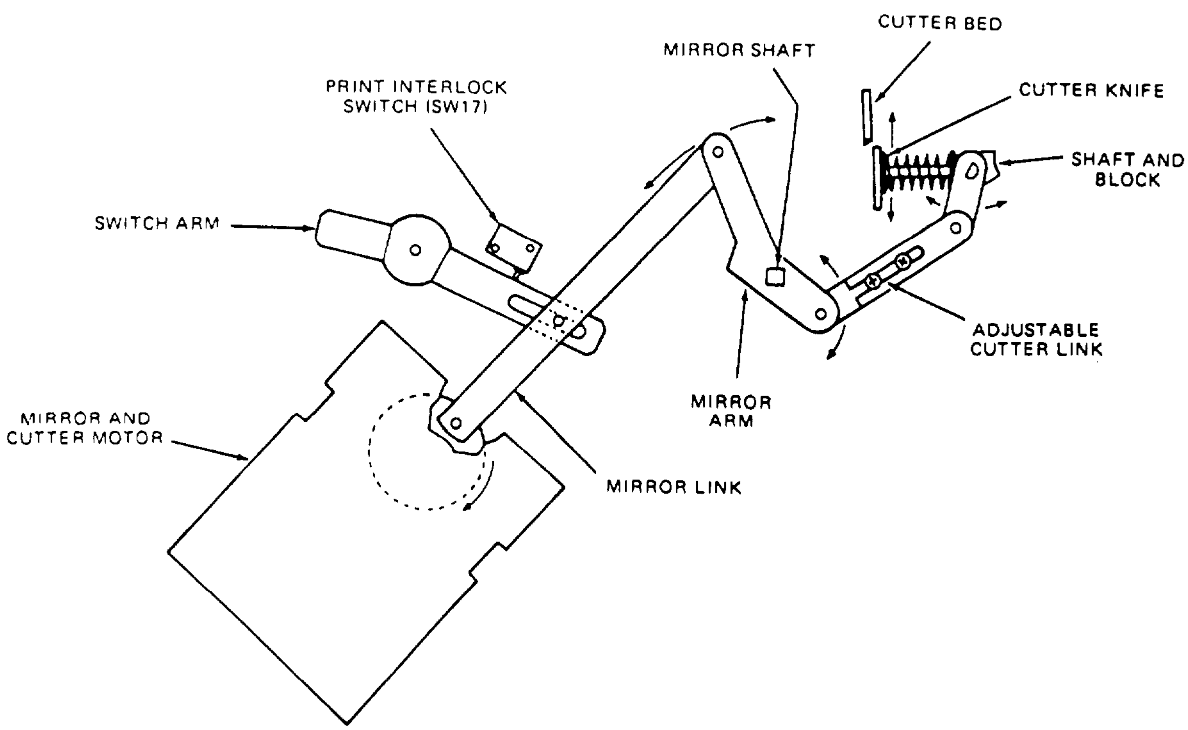


Figure 11-5.—Paper cutter system.

than the metal that is less corrosion prone. In cathodic protection, the more corrosion-prone metal is the anode (zinc) and the less corrosion-prone metal is the cathode (steel hull). The rate of corrosion is directly related to the magnitude of the potential difference and is referred to as the open- or half-cell potential of metals. Some of the factors affecting the amount of corrosion are stray currents, resistivity, and the temperature of the seawater.

Stray-current corrosion is caused by an external current leaving the hull of a vessel and entering the seawater. If the connection between the ship and

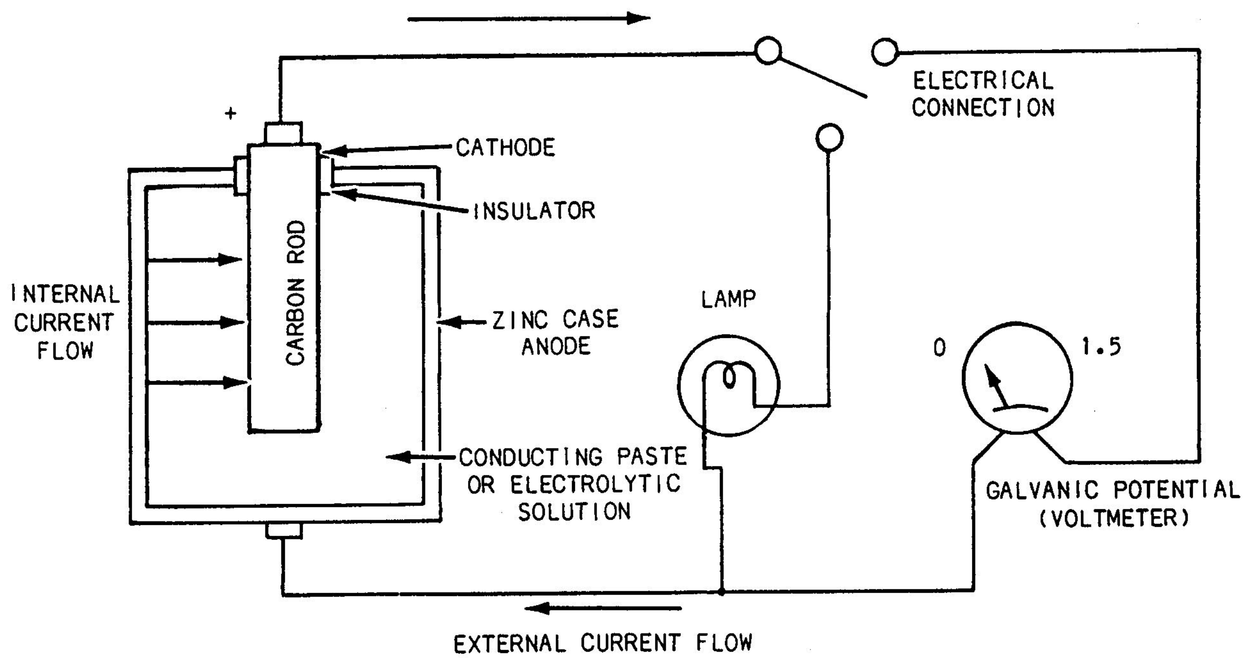


Figure 11-6.—Dry-cell battery circuit.

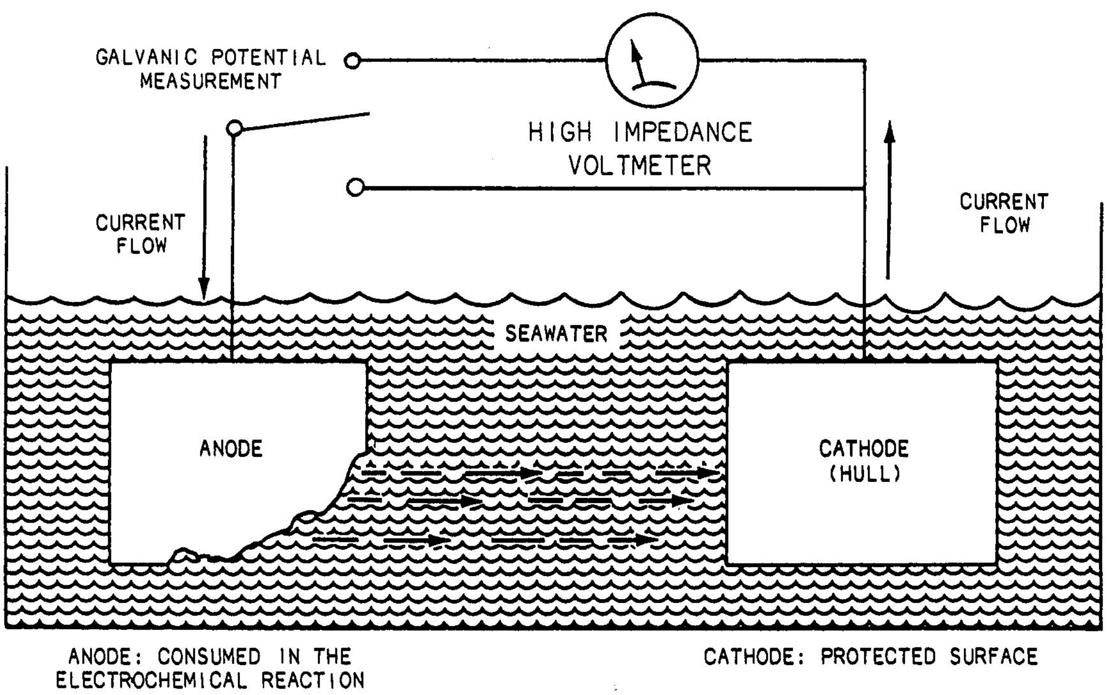


Figure 11-7.—Electrochemical corrosion cell.

welding machine is not correctly made (fig. 11-8) or no return lead to the welder is connected, you could have current flow between the ship's hull and the pier, causing corrosion to form on the hull.

Seawater resistivity is the concentration of ions in seawater, which acts as a resistance to current flow between two dissimilar metals. Normal seawater generally has a nominal resistivity of 20 to 22 ohms/cm at a temperature of 20°C (68°F). In brackish or fresh water this resistivity may vary.

TYPES OF CATHODIC PROTECTION

There are two types of cathodic protection systems, the sacrificial anode and the impressed current. Each system will be addressed separately.

Sacrificial Anode System

The sacrificial anode system is based on the principle that a more reactive metal, when installed near a less reactive metal and submerged in an electrolyte such as seawater, will generate a potential of a sufficient magnitude to protect the less reactive metal. In this process, the more reactive metal is sacrificed. Sacrificial anodes attached to a ship's hull slowly oxidize and generate a current (see the electrochemical corrosion cell in fig. 11-6 that protects the hull and its appendages). This system does not have an onboard control of protecting current, and depends on the limited current output of the anode. This type of system requires anode replacement on a fixed schedule (usually every 3 years on naval ships). The system is rugged and simple, requires little or no maintenance, and always protects the ship.

TYPES OF SACRIFICIAL ANODES.— The following is a list of sacrificial anodes:

- Zinc
- Aluminum
- Magnesium
- Iron
- Steel waster pieces

Zinc Anodes.— Zinc anodes are used for anodic polarization on steel or aluminum surfaces. They have a half-cell potential of a negative 1.04 volts. They can be either bolted or welded to the hull. Welding is the preferred method because the anodes will have a secure electrical and mechanical attachment.

Aluminum Anodes.— Aluminum anodes are currently being tested and evaluated by the Naval Sea Systems Command (NAVSEA). The use of aluminum anodes requires prior NAVSEA authorization and design review. It is also necessary to obtain guidance from NAVSEA before preparing a cathodic protection system design using aluminum anodes.

CAUTION

Do not use magnesium anodes on aluminum hulls. Production of an alkaline (basic corrosion product) may lead to serious corrosion of the aluminum metal structure. Aluminum is referred to as an amphoteric material because it is subject to deterioration by both acid and basic solutions.

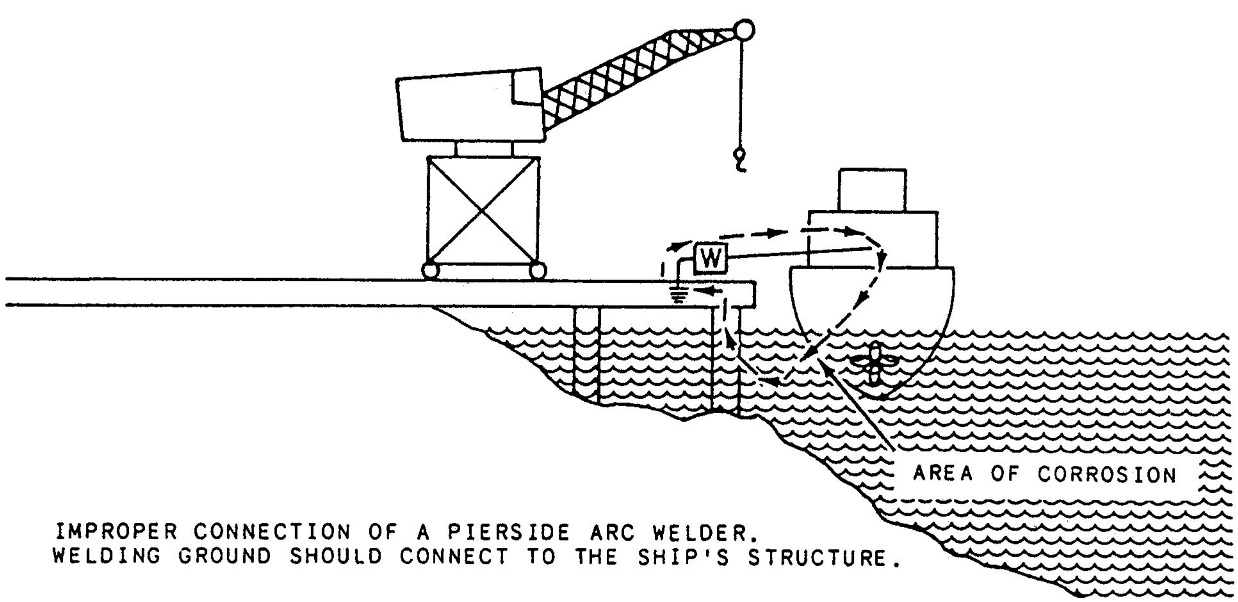


Figure 11-8.—Stray-current corrosion.

Magnesium Anodes.— Magnesium anodes have a half-cell potential of about negative 1.5 volts. They are not used in seawater applications because of rapid loss of the anode material and overprotection due to the high driving voltage. They are used in fresh or brackish water areas where the resistivity of the electrolyte is relatively high and a higher driving voltage is required to produce the proper amount of polarizing current.

Iron Anoes.— Iron anodes are installed to increase the presence of iron ions in the water. This strengthens the formation of the oxide film produced on copper alloy surfaces,

Steel Waster Pieces.— Steel waster pieces are sleeves of mild steel installed at nonferrous metal junctions to protect sea valves and sea chests.

USES OF SACRIFICIAL ANODES.— Sacrificial anodes are used in small boats, mothballed ships, and submarines. They may be installed in piping systems, bilge pumps, valves, ballast tanks, fuel tanks, sewage collection holding tanks (CHTs), sonar domes, voids, and stem tubes.

ADVANTAGES OF SACRIFICIAL ANODES.— The following is a list of the advantages of sacrificial anodes:

- No external electrical power is required.
- They are relatively foolproof and little maintenance is required.
- They are easy to install.
- Hull protection is provided at all times until the anode is completely consumed.

DISADVANTAGES OF SACRIFICIAL ANODES.— The following is a list of the disadvantages of sacrificial anodes:

The anode current is uncontrollable.

Water turbulence around the hull increases the noise level.

Frequent replacement is necessary when stray dc is present (especially when welding machines are used).

Fuel consumption is increased.

Replacement is usually necessary before scheduled overhaul (every 3 years).

Impressed Current Cathodic Protection System

The impressed current cathodic protection (ICCP) system (fig. 11-9) uses an external source of electrical power provided by a regulated dc power supply to provide the current necessary to polarize the hull. The protective current is distributed by specially designed inert anodes of platinum-coated tantalum. The principal advantage of an ICCP system is its automatic control feature, which continuously monitors and varies the current required for corrosion protection. If the system is secured, no corrosion protection is provided.

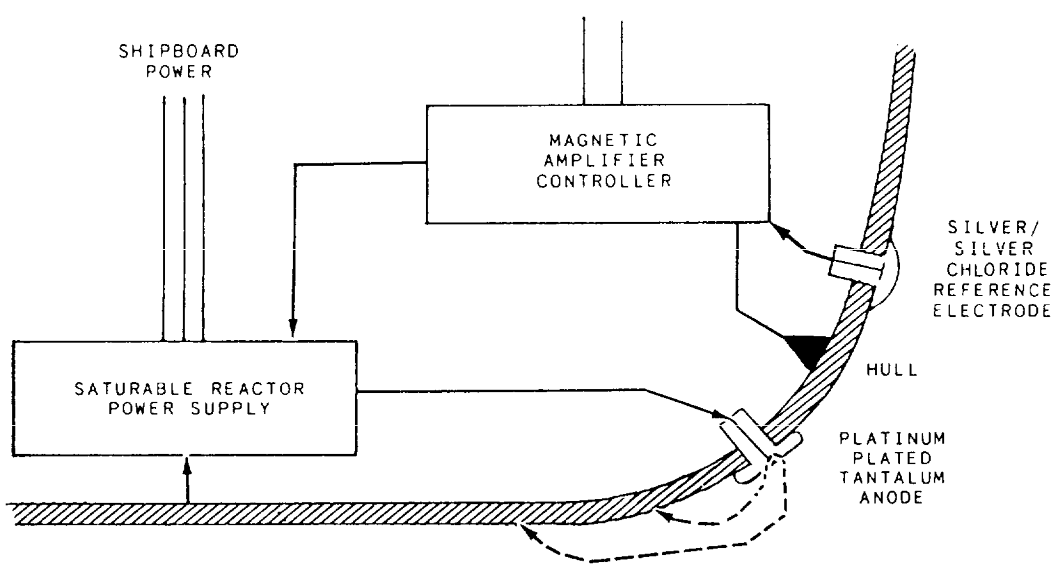


Figure 11-9.—Basic impressed current cathodic protection system.

COMPPENTS OF THE ICCP SYSTEM.— The following list of the components of the ICCP system:

- Power supply
- Controller
- Anodes
- Reference electrode
- Stuffing tube
- Shaft grounding assembly
- Rudder ground (including stabilizer if installed)
- Dielectric shield

Power Supply.— The power supply performs two functions. It converts available shipboard alternating current (at) to low-voltage direct current (dc) and provides a means of adjusting the value of current delivered to the anodes.

Controller.— The controller (fig. 11- 10) is used to monitor the control power supply outputs that maintain the hull at a preset potential versus the reference cell. The controller is a sensitive amplifier that creates an output signal proportional to the voltage difference between the reference (electrode-to-hull) voltage and the internally set voltage. The controller should be mounted in a readily accessible area.

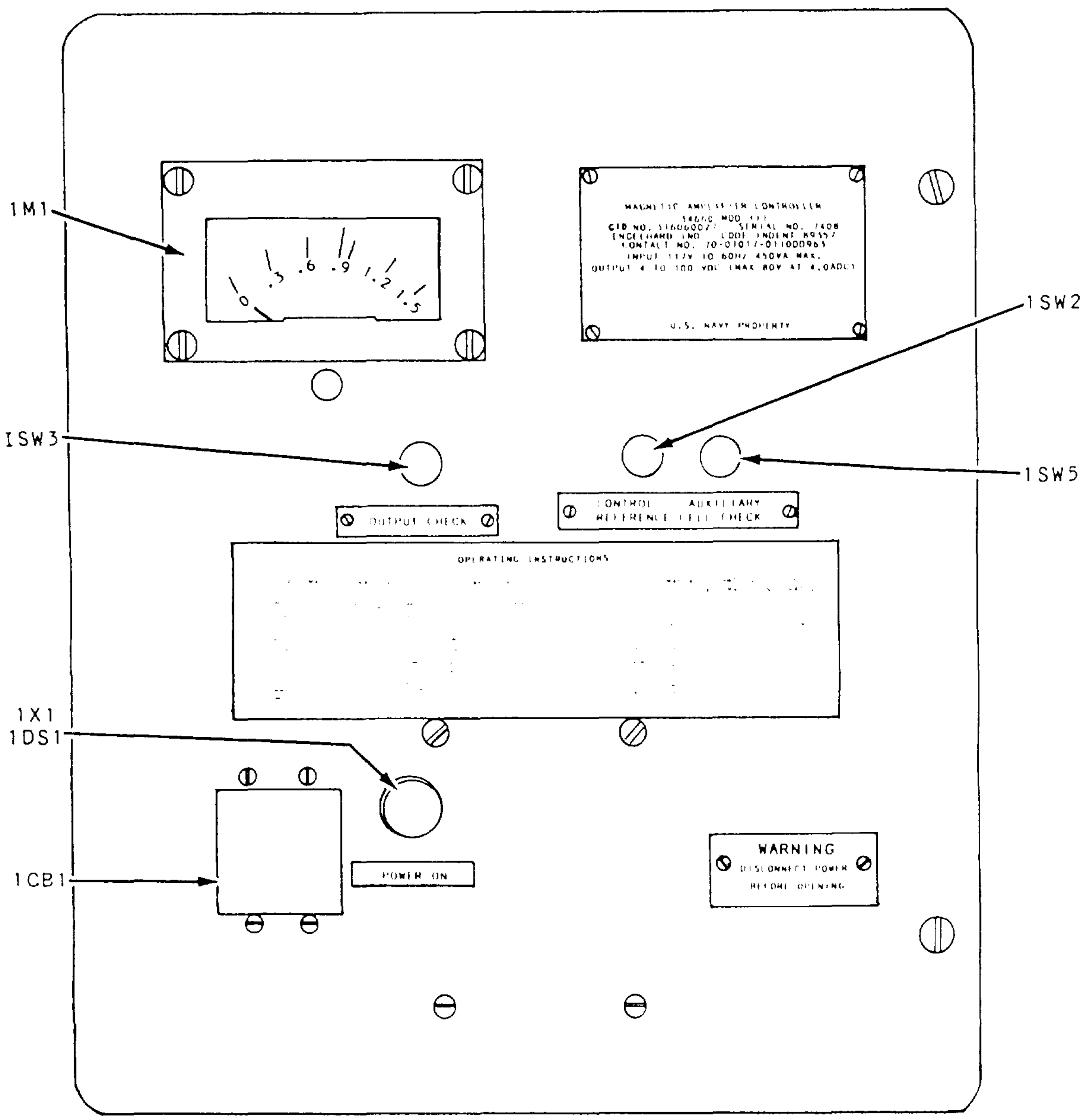
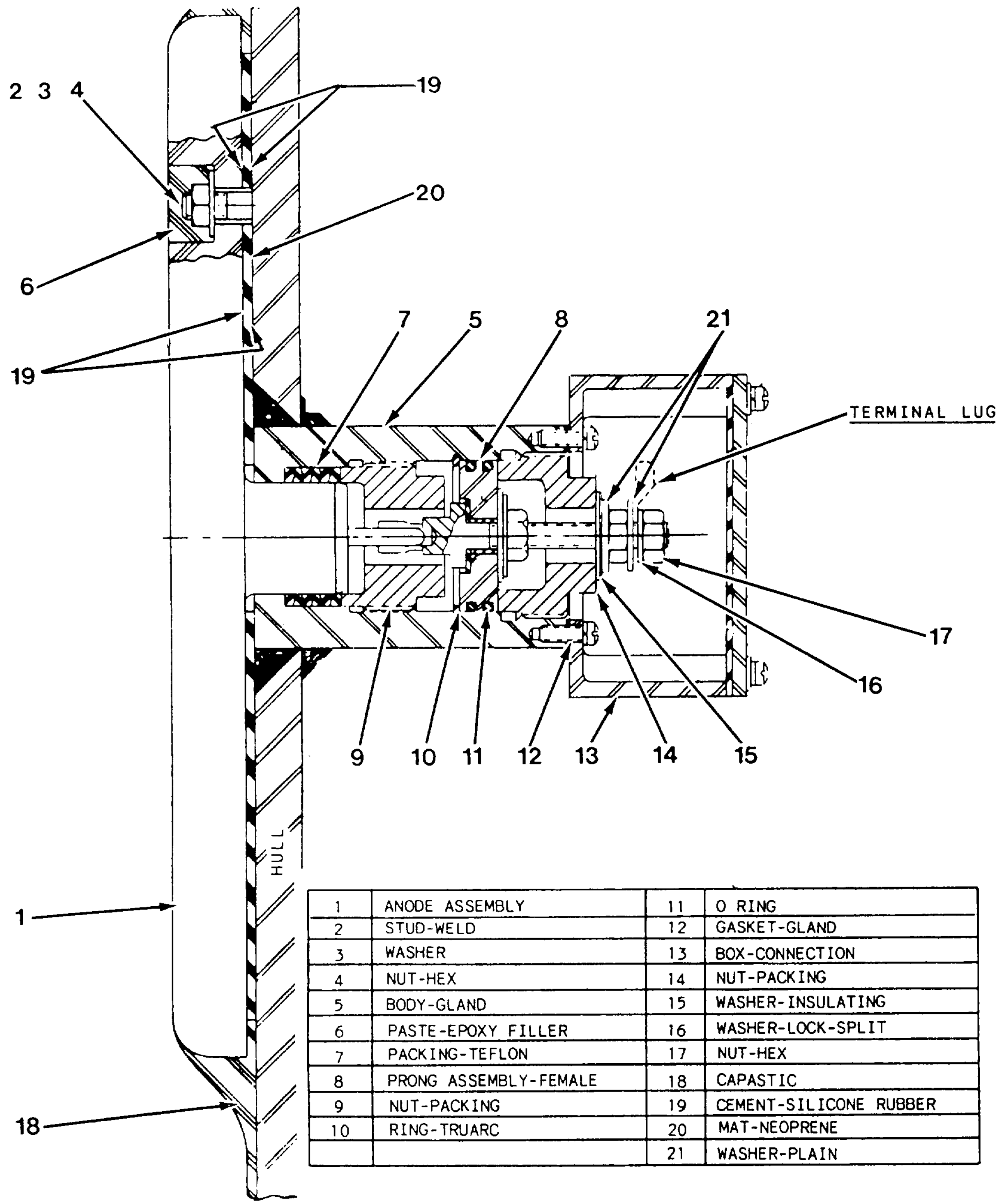


Figure 11-10.—Magnetic amplifier controller Mod III.

Anodes.— The anodes (fig. 11-11) are constructed of two platinum-coated tantalum rods mounted in an insulating glass-reinforced polyester holder. Anodes are bolted to the outside of the ship's hull. The direct current flows into the seawater through the platinum surface of the tantalum rods. The platinum surface of the anode corrodes very slowly. The replacement period for anodes is usually 10 years or longer. Anodes



1	ANODE ASSEMBLY	11	O RING
2	STUD-WELD	12	GASKET-GLAND
3	WASHER	13	BOX-CONNECTION
4	NUT-HEX	14	NUT-PACKING
5	BODY-GLAND	15	WASHER-INSULATING
6	PASTE-EPOXY FILLER	16	WASHER-LOCK-SPLIT
7	PACKING-TEFLON	17	NUT-HEX
8	PRONG ASSEMBLY-FEMALE	18	CAPASTIC
9	NUT-PACKING	19	CEMENT-SILICONE RUBBER
10	RING-TRUARC	20	MAT-NEOPRENE
		21	WASHER-PLAIN

Figure 11-11.—Anode assembly.

are available in the following three sizes: 2 feet (40 amperes), 4 feet (75 amperes), and 8 feet (150 amperes).

Installation of the anodes should be placed to maintain a uniform potential throughout the underwater hull. The following is a list of anode locations:

— Placement should be at least 5 feet below the light-load waterline.

— One- and two-screw ships will have one set of anodes located more than 10 feet, but less than 50 feet, forward of the propeller plane.

— Four-screw ships will have two anodes located between the forward and after propeller planes, one port and one starboard.

— Anodes should be mounted in an area that experiences minimum water turbulence and that is protected from mechanical damage.

Anode to anode, anode to electronic log equipment, and anode to reference cell separation should be a minimum of 40 feet.

Anodes should not be installed within 15 feet of a sea chest or pipe discharge.

Reference Electrode.— The reference electrode (fig. 11-12) is a silver/silver chloride type constructed of a silver mesh screen that has been treated with silver chloride. It is bolted to the exterior hull of the ship and is insulated from the ship by a polyvinyl chloride holder. A stuffing tube is used to pass the cable from the electrode through the hull to the controller. The controller measures the potential of the hull versus the reference electrode, and signals the power supply to increase or decrease current output as required. This is to reduce the potential difference between the hull potential and the preset desired potential. Two reference electrodes are installed for each controller. One reference electrode is selected for the primary control; the other reference electrode serves as an

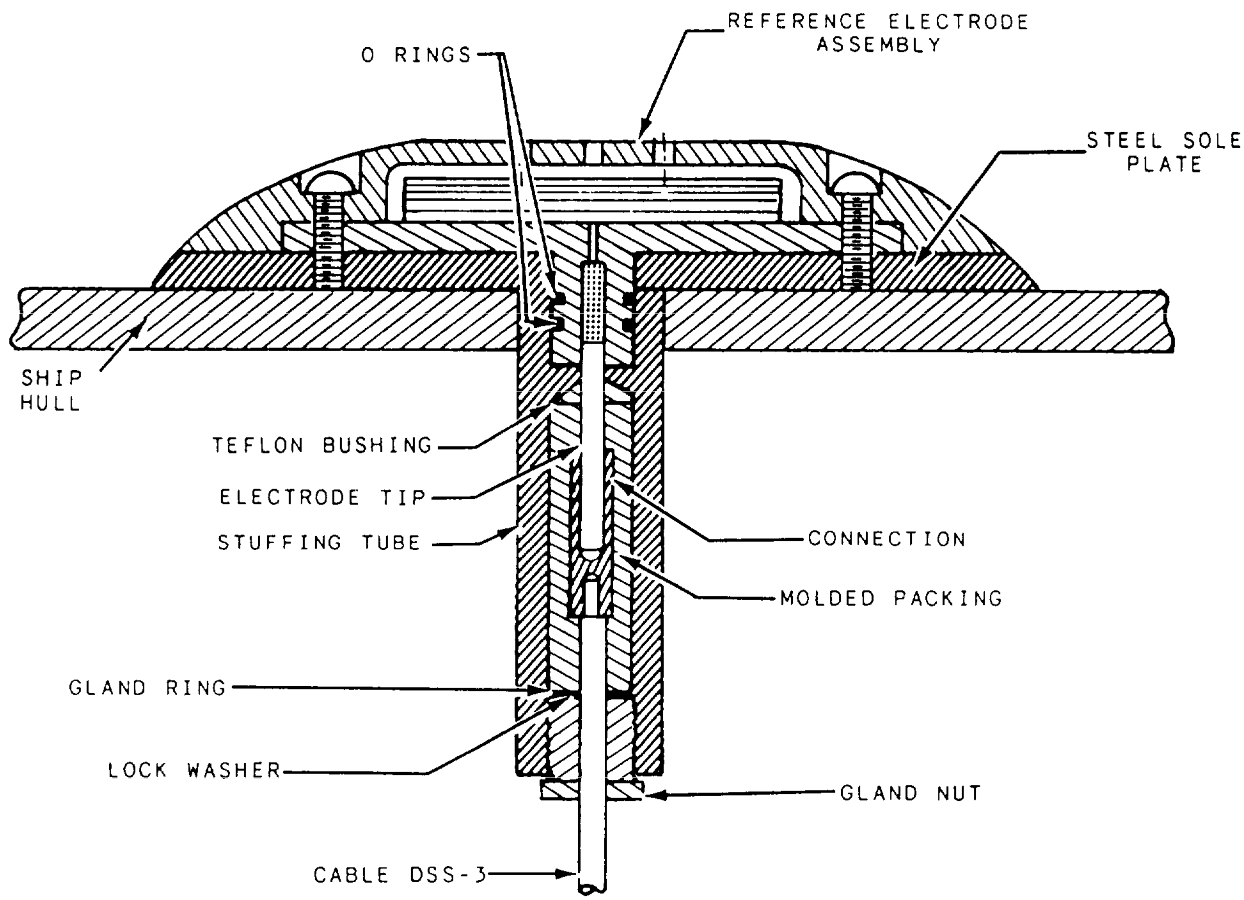


Figure 11-12.—Reference electrode assembly.

auxiliary to verif y operation of the controlling cell and serves as a backup if failure of the primary cell occurs. Reference electrodes are generally located on each side of the hull, about halfway between the anode sites. Reference electrodes are usually replaced approximately every 10 to 12 years.

Stuffing Tube.— Stuffing tubes are required to insulate the electrical wires that pass through the hull to anodes or reference electrodes.

Shaft Grounding Assembly.— The shaft grounding assembly (fig. 11-13) consists of a silver-alloy band, ring-fitted on the propeller shaft. It is electrically bonded to the shaft and is usually located in the shaft alley. Silver-graphite brushes ride on the hard silver surface of the bands, electrically connecting the rotating propeller shaft to the hull. This assembly is necessary to permit the anode current that flows through the water to enter the propeller blades and return to the hull. A shaft grounding assembly is provided for each shaft. Ships of earner size or larger are fitted with two brush assemblies on the silver-alloy ring.

Rudder Ground.— Rudders and stabilizers are grounded by brazing a braided, tinned-copper grounding strap, at least 1 1/2 inches wide, between the rudder stock and the hull. To permit full rotation of the rudder stock from port to starboard, a large loop is required in the ground strap.

Dielectric Shield.— The dielectric shield prevents shorting of the anode current to the hull and aids in wider current distribution. The dielectric shield is applied as a thick coating around each anode. It consists of a high-solids epoxy with a high-dielectric strength.

OPERATION.— The requirements for operating the ICCP system on ships is provided in the manufacturer's technical manual. The system should be operated at all times, except during diving operations, equipment repair, planned maintenance,

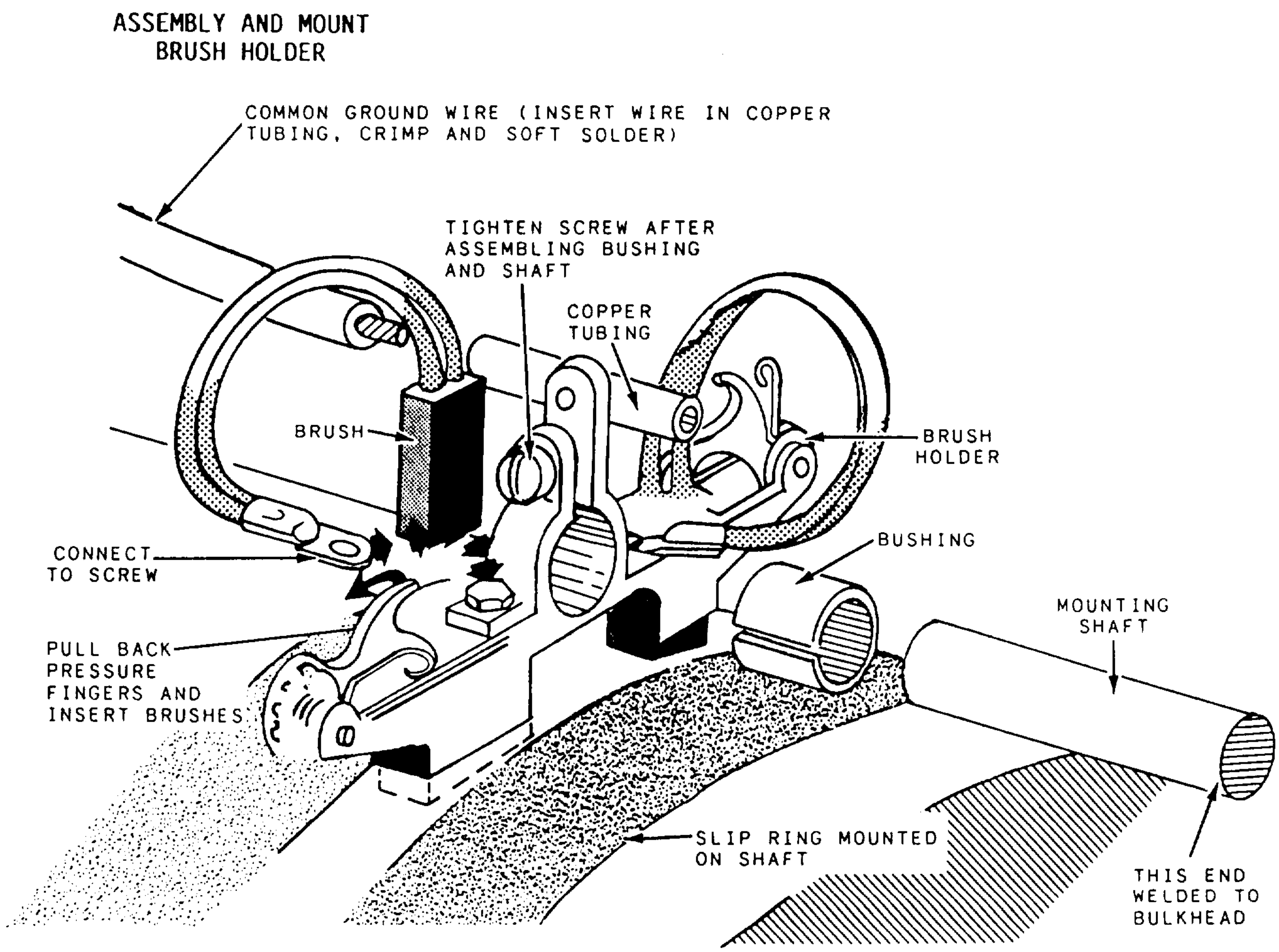


Figure 11-13.—Shaft grounding assembly.

or drydocking. The system must be reactivated within 2 hours after the activity is completed. You must NEVER energize the system if the ship is out of the water (drydocked).

Before the reference electrode is connected to the controller, check the voltage between the reference electrode and the steel hull; it should be approximately 0.6 volt dc. The hull will be negative (-) and the reference electrode will be positive (+). If the voltage is zero, the reference electrode has an open lead, or the lead or electrode is shorted to the hull. When the voltage is 0.6 volt or higher, the ship is receiving cathodic protection from an external source, which could be zinc anodes or an electrical leakage.

Inspect the controller and power supply wiring to ensure the unit is properly grounded. Before connecting the anode leads to the power supply, check for possible shorts. The voltage developed between a disconnected platinum anode and the steel hull will range from 1.0 to 2.0 volts dc. This can be read on a high-impedance voltmeter. The polarity of the anode is positive (+) and the polarity of the hull is negative (-). If this voltage is zero, you could have an open lead wire or a shorted anode. When the voltage reads between 2.0 to 5.0 volts, it indicates that the anode lead is immersed in seawater.

HULL POTENTIAL SETTING OF SHIPS IN SEAWATER.— The ICCP system is designed to operate automatically and requires a minimum amount of maintenance. The operator normally sets the hull potential at -0.85 volt. When the voltage between the hull and the reference electrode is more positive than the voltage set by the operator, the output of the controller increases. This causes an increase in the anode current output from the power supply until the voltage between the hull and the reference electrode approaches the set voltage. A voltage between the hull and the reference electrode that is negative to the set voltage causes a decrease in controller output, thereby decreasing the anode current output.

The optimum range of polarization or hull-to-reference electrode potential for a ship with an ordinary steel hull is from a -0.80 to a -0,90 volt to the silver/silver chloride reference electrode. Increased anode current will result in hull potentials more negative than the optimum amount. Increasing the negative potential does not provide more protection. If exceeded, this will result in hydrogen generation at the hull surface.

HULL POTENTIAL SETTING OF SHIPS ENTERING BRACKISH OR FRESH WATER.— As a ship enters a port or bay that is river-fed, the resistivity of the water will change as the salinity changes. Operation of the ICCP system will be affected by the changing water resistivity. The operator will notice the ICCP system operating at higher voltage outputs and lower current outputs. The lower current output is caused by the higher impedance of the water. A higher voltage output is required to drive the same current in the higher-resistivity electrolyte. The operator will record this condition on the ICCP log. Do not take action to correct this condition by equipment recalibration while the ship is in brackish water.

CATHODIC PROTECTION LOG.— Normal operating procedures require maintaining a Cathodic Protection Log of the ICCP system operation on NAVSEA Form 9633/1 (fig. 11-14, view A, and 11-14, view B). The readings will be recorded on these logs daily and submitted to NAVSEA monthly, Logs submitted to NAVSEA are analyzed to identify those systems that are not operating correctly. After analysis of the logs is complete, a response is sent to the ship or type command (TYCOM) indicating the operational status of the equipment as interpreted from the logs. This response will recommend corrective actions to be taken, if required.

Output Check.— A particularly significant value recorded on the log is the output check. The values recorded will range from practically zero to 1.0 volt, representing 100 percent current output. If the values range between 0.3 and 0.5 volt, the system is operating at 30 to 50 percent capacity.

Power Supply.—The daily current output is recorded for each power supply. Ampere values may vary, depending on the power supply, maximum output, and current demand. Two capacities of power supplies are used, 0 to 150 amperes and 0 to 300 amperes.

ICCP MAINTENANCE.— The ICCP maintenance will be performed according to the Planned Maintenance System (PMS). Take daily meter readings on the panel and record them on the log. A quarterly check must be performed on the shaft grounding assembly. Every 24 months the panel meters must be calibrated according to PMS requirements.

CATHODIC PROTECTION LOG

(NAVSEA S9086-VF-STM-000) *(Form cont'd on back)*

Refer to NAVSEA S9086-VF-STM-000, Chapter 633. Impressed Current Cathodic Protection (ICCP) system provides corrosion protection to underwater hull when maintained & operated properly

NAME OF SHIP	SHIP'S HULL NUMBER	SHIPS W/TWO CONTROLLERS *(Check One)* ☐ FORE ☐ AFT	MONTH	YEAR

DAILY (VOLTS)

AUTOMATIC CONTROL SETTING *(Fill In)* ☐ VOLTS

NORMAL OPERATION-AUTOMATIC MODE AT 086

POWER SUPPLY CURRENT (AMPERES)

TAG-OUT PERIODS

A. DIVING OPERATIONS*
B. EQUIPMENT MALFUNCTION*
C. MAINTENANCE*
D. DRYDOCK* E. OTHER *(Specify)**

DAY	SPEED ("X") IF PIERSIDE)	REF. CELL CHECK		OUTPUT CHECK	NUMBER				TIME		*REASON *(Specify "E")*				
		CONTROL	AUXILIARY		1	2	3	4	OFF	ON	A	B	C	D	E
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															
27															
28															
29															
30															
31															

SIGNATURE, ELECTRICAL OFFICER	SIGNATURE, CHIEF ENGINEER	SIGNATURE, COMMANDING OFFICER

NAVSEA 9633/1 (Rev. 7-84) S/N 0116-LF-096-3307 *(Previous edition obsolete, destroy stock)*

(FORM CONT'D ON BACK)

Figure 11-14, view A.—Cathodic Protection Log (front).

CATHODIC PROTECTION LOG - CONTINUATION

(NAVSEA S9086-VF-STM-000)

Refer to NAVSEA S9086-VF-STM-000, Chapter 633. Impressed Current Cathodic Protection (ICCP) system provides corrosion protection to underwater hull when maintained & operated properly

CONTROLLER

- ○ SHALL BE OPERATED IN AUTOMATIC HULL POTENTIAL CONTROL MODE AT ALL TIMES.
- ○ AUTOMATIC CONTROL SETTING FOR NORMAL OPERATION IS 0.85 VOLTS.
- ○ MANUAL CONTROLLER MODE IS A FIXED POWER SUPPLY CURRENT SETTING FOR PMS TEST OR OTHER SPECIAL CONDITIONS O N L Y
- ○ SENSITIVITY SWITCH IS (CHECK ONE) ....> ☐ LOW ☐ MEDIUM ☐ HIGH

POWER SUPPLY

- ○ SHALL BE OPERATED AT ALL TIMES EXCEPT DRYDOCK, DIVING OPERATIONS AND PMS

PMS

RECORD TEST INFORMATION FROM MRC 6332 (IC-38) IF CONTROLLER AND POWER SUPPLY PMS IS COMPLETED.

○ CONTROLLER

	VOLTS NO. 1	VOLTS NO. 2
MAX. AUTOMATIC SETTING - OUTPUT CHECK ....>		
MIN. AUTOMATIC SETTING - OUTPUT CHECK ....>		

○ POWER SUPPLIES

	AMPS NO 1	AMPS NO 2	AMPS NO 3	AMPS NO 4
FORWARD SYSTEM ....>				
AFTER SYSTEM ....>				

○ INDICATE IF ANY ANODE CIRCUIT BREAKERS TRIP ....>

NORMAL OPERATION RANGES (MIN. - MAX)

V O L T S		A M P E R E S	
REFERENCE CELL CHECK CONTROL AUXILIARY	OUTPUT CHECK	POWER SUPPLY CURRENT	
0.75-1.20	0.01-1.00	5-150 ± 10% 10-300 ± 10%	150A POWER SUPPLY 300A POWER SUPPLY

FORWARD LOGS QUARTERLY TO:

○ NAVAL SEA SYSTEMS COMMAND, SEA 06M1, WASHINGTON, DC 20362

○ REFER QUESTIONS CONCERNING OPERATION AND MAINTENANCE TO

(In Order Of Precedence)

1. NAVSEACENS (CODE 750)	2. NAVSSES (CODE 063)	3. NAVSEA (SEA 05M1)

COMMENTS (If applicable)

NAVSEA 9633/1 (Rev. 7-84) (BACK) S/N 0116-LF-096-3307

Figure 11-14, view B.—Cathodic Protection Log (back).

ELECTROHYDRAULIC STEERING GEAR

The steering gear is one of the most vital auxiliaries aboard ship. It must be thoroughly dependable and have sufficient capacity for maximum maneuverability. The types of steering gear listed in the sequence of their development are (1) steam, (2) electromechanical, and (3) electrohydraulic. Electrohydraulic steering gear was developed to meet the power requirements of naval vessels having large displacements and high speeds with attendant increase in rudder torques.

CONSTRUCTION

The majority of steering gear installations in new construction naval vessels are of the electrohydraulic type. The electrohydraulic steering system installed in one class of destroyer (fig. 11-15) consists essentially of (1) a ram unit, (2) a power unit, and (3) a remote control unit (not shown).

Ram Unit

The ram unit is mounted athwartship and consists of a single ram operated by opposed cylinders. The ram is connected by links to the tillers of the twin rudders. When oil pressure is applied to one end of the operating cylinder, the ram will move, causing each rudder to move along with it. Oil from the opposite end of the cylinder is returned to the suction side of the main hydraulic pump in the power unit.

The tie rods that connect the two cylinders also serve as guides for a sliding crosshead attached to the ram to prevent the ram from rotating. The crosshead also provides mechanical limits to the ram travel at 42° of rudder angle. At this position the crosshead contacts the copper facing on the stop collars and prevents further movement.

A rack is attached to the ram and engages two gears. The rotation of these gears is transmitted to the respective differential control boxes through the follow-up shaft.

Power Unit

The power unit has two independent pumping systems. These include two motor-driven pumps, two 4-way transfer valves with operating gear, a relief valve, two differential control boxes, two trick wheels, and a hand emergency gear all mounted on a bedplate. The bedplate is the top of an oil reservoir. Steering power is derived from either pumping system acting alone. The system not in use serves as a standby source in case of an emergency.

The two pumps (port and starboard) are identical in size and design and are of the variable delivery axial piston type. Each main pump unit includes a built-in vane-type servo pump, pressure control and replenishing valves, and two main relief valves. Each main pump is stroked through a rotary servo control.

Each pump is driven by a 20-hp, 1200-rpm, 440-volt, 3-phase, 60-Hz induction motor through reduction gears and a flexible coupling.

The pumps of the power unit are connected to the ram cylinders by a high-pressure piping system. The two 4-way transfer valves are interposed in this piping, and their positions determine which pump is connected to the cylinders in the ram unit. The hand lever, which moves both valves simultaneously, is located on the power unit between the trick wheels. It has three latched positions. The latched positions are marked P, N, and S, which denote port pump connected, neutral (ram locked), and starboard pump connected, respectively.

The transfer valves, which are of the ported piston type, are mounted on the power unit bedplate between the motors. When the valves are in the neutral (ram locked) position, the ports of the pipes to the ram cylinders are blocked, and the two pipes from each pump are connected through ported passages in their respective valves. If either or both pumps are started and put on stroke, oil will circulate through the valve and back to the pump. Movement of the transfer valves in either direction connects the selected pump to the ram cylinders, and the opposite pump remains bypassed.

The drain pipes from the ram cylinders lead to the reversible hand pump. It provides a means for emergency steering under limited rudder torques. The relief valve in the emergency steering system is set at 500 psi. The oil flow is through pilot-operated blocking valves that prevent the ram from overhauling the pump and kicking back the handles. When you move the ram with the hand pump, set the main transfer valves in the ram locked position and open the drain valves beneath the cylinders.

The mechanical differential control box serves to correlate the signal from the ram follow-up assembly

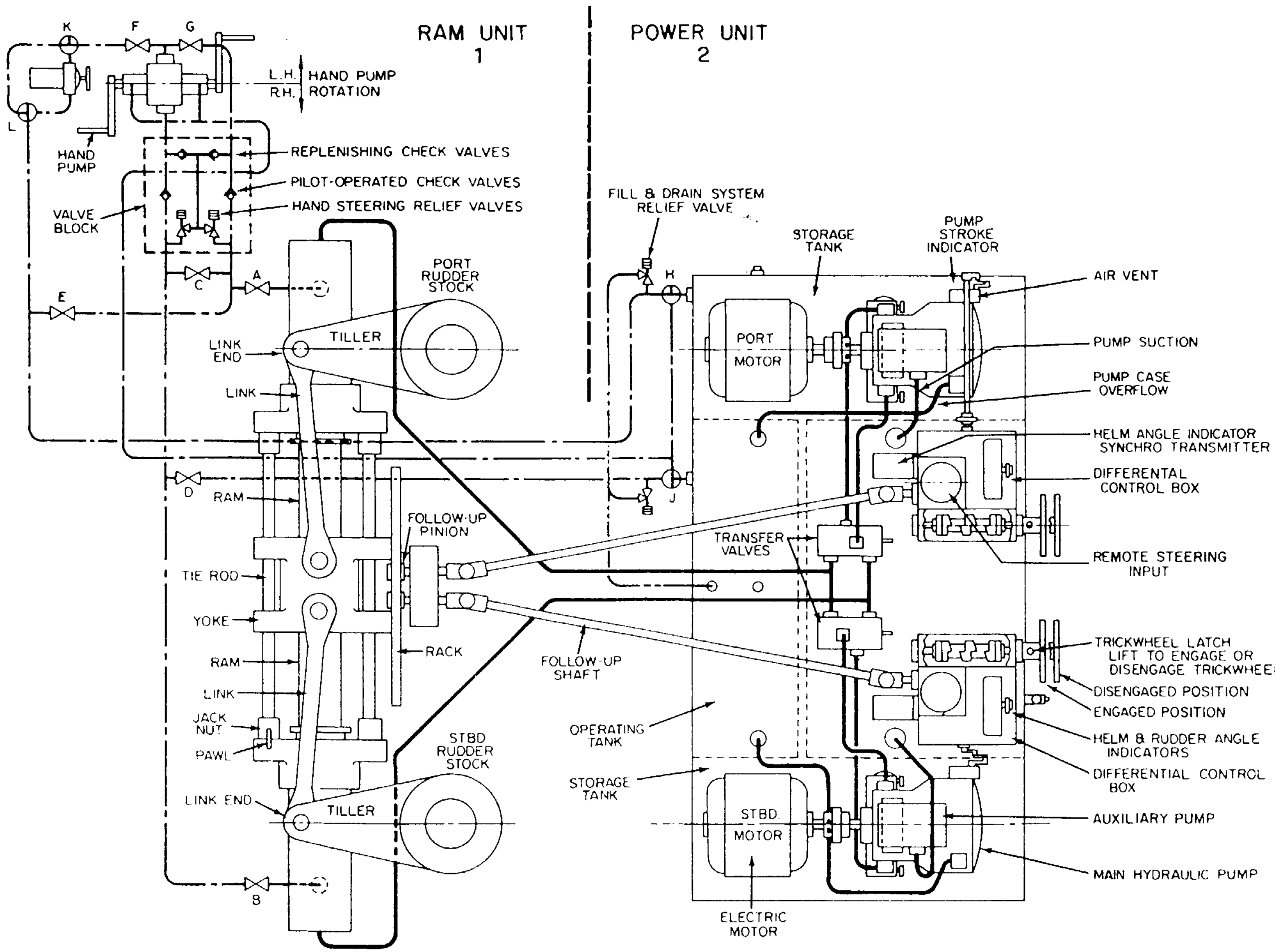


Figure 11-15.—Electrohydraulic steering

and the steering control system into one order to the hydraulic pump.

The stroking lever and output shaft on each differential control box actuate a rotary servo valve that controls the associated main pump on the power unit. In response to movements transmitted through the control box, the pump discharge is varied between zero and maximum, and in either direction of flow.

In normal steering from the pilothouse, a synchro transmitter is turned by the steering wheel. This synchro transmitter is electrically connected to a synchro receiver in the steering gear room. The synchro receiver is geared to the LOWER bevel gear in the differential control unit, and its rotation is transmitted through gearing to a cylindrical cam. A follower roller, which engages a groove in the cylindrical cam, is mounted on an arm keyed to the output shaft of the control box.

For example, assume that the rudder is amidships and it is desired to obtain 20° right rudder. The rotation of the lower bevel gear causes rotation of the cylindrical cam, which, in turn, imparts a motion to the servo control valve through the cam roller. This motion of the servo control valve puts the pump on stroke. Oil pressure is then applied in the port cylinder, forcing the ram to starboard to give right rudder.

A rack, attached to the ram, rotates the follow-up shaft, which is geared to the UPPER bevel gear in the differential control unit. The movement of the ram and rudders (in response to the stroking of the pump) causes the upper bevel gear to rotate in a direction opposite to that of the lower bevel gear. This action rotates the cylindrical cam in the opposite direction, tending to cancel the movement of the control input and bring the servo control valve back to the neutral position to return the pump stroke to neutral and stop the pumping of oil.

Thus, the rudders are at 20° right rudder, the cam is returned to neutral, and the pump is returned to zero stroke until further movement of the steering wheel causes repetition of the cycle. The same sequence occurs if the control is from the trick wheel in the steering compartment.

An engraved dial, graduated in rudder degrees, is mounted on top of the differential control box. Two concentric pointers (one geared to the control pump input and the other geared to the rudder follow-up) indicate the positions of the helm and rudders, respectively. A helm-angle synchro transmitter, also mounted on the differential control box, actuates a synchro receiver in the steering console in the pilothouse. This receiver positions a pointer to indicate to the helmsman the angle that is ordered rather than the actual rudder angle. The ordered angle is called the helm angle.

Remote Control System

The remote control system provides control from the pilothouse for normal steering. This system has a synchro transmitter mounted in the steering console and a synchro receiver mounted on each pump differential control box (port and starboard). A cable selector switch in the pilothouse and a similar switch in the steering compartment permit a choice between the port or starboard steering cables. The selection of the control cable is made by the operation of the cable selector switches in the pilothouse and in the steering gear room to the desired (port or starboard) position.

The synchro-receiver selector switch in the steering gear room is then set to connect the synchro receiver on the active power unit to the steering console synchro transmitter. The rotary motion of the synchro receiver is transmitted through gearing to the input of the differential control box (stroking mechanism previously described).

The helm-angle indicator synchro transmitters on the differential control boxes in the steering gear room are electrically connected to their associated steering-control synchro receivers. These transmitters, under all conditions of operation, actuate their associated helm-angle indicator synchro receivers in the pilothouse console through their associated cables.

The 120-volt, single-phase power for the remote control system is supplied to the steering power panel through a 450/120-volt transformer from the steering power transfer switchboard.

The 120-volt, single-phase power for the indicator synchro transmitters is supplied from the IC switchboard.

Magnetic Controller

The motor of each steering gear pump is provided with a nonreversing across-the-line starter and a maintained-contact master switch (fig. 11-16). The starter is supplied with 440-volt, 3-phase, 60-Hz power from the steering power transfer switchboard located in the steering gear room.

The pump motor on either power unit is started or stopped by operating the maintained-contact push button on the associated push-button station to the desired position. When the maintained-contact start push button is pressed, the circuit is completed to the contactor operating M coil of the line contactor. This action energizes the operating M coil and closes the contactor in the motor starter to connect the motor to the line. The motor will continue to run until the M coil is de-energized because of loss of voltage, tripping of the overload relay, or pressing of the stop push button.

The motor starter is provided with overload and low-voltage release (LVR) protection. The overload relays are of the thermal type, similar to those installed in the anchor windlass starter (discussed later in this chapter under the operation of the destroyer anchor windlass). The low-voltage release protection is provided by the maintained-contact master switch.

If the operating M coil is de-energized due to failure of the line voltage or tripping of an overload relay, the contactor will reclose and restart the motor when voltage is restored or when the overload relays are reset by the reset push button.

In an emergency you can run the motor (even though the overload relays have been tripped) by holding the EM-RUN push button closed with the START push button in the operated position. If the overload condition has not been corrected, the motor will operate only as long as the EM-RUN push button is held closed.

OPERATION AND MAINTENANCE

Operating instructions and system diagrams are normally posted near the steering gear. The diagrams describe the various procedures and lineups for operation of the steering gear.

Maintenance should be performed according to your ship's PMS requirements for steering gears.

SUMMARY

In this chapter, you were given information on auxiliary equipment, including the components, operating procedures, troubleshooting procedures, and maintenance procedures. You were also introduced to the fundamentals of cathodic protection systems, including their operation, logs, and maintenance.

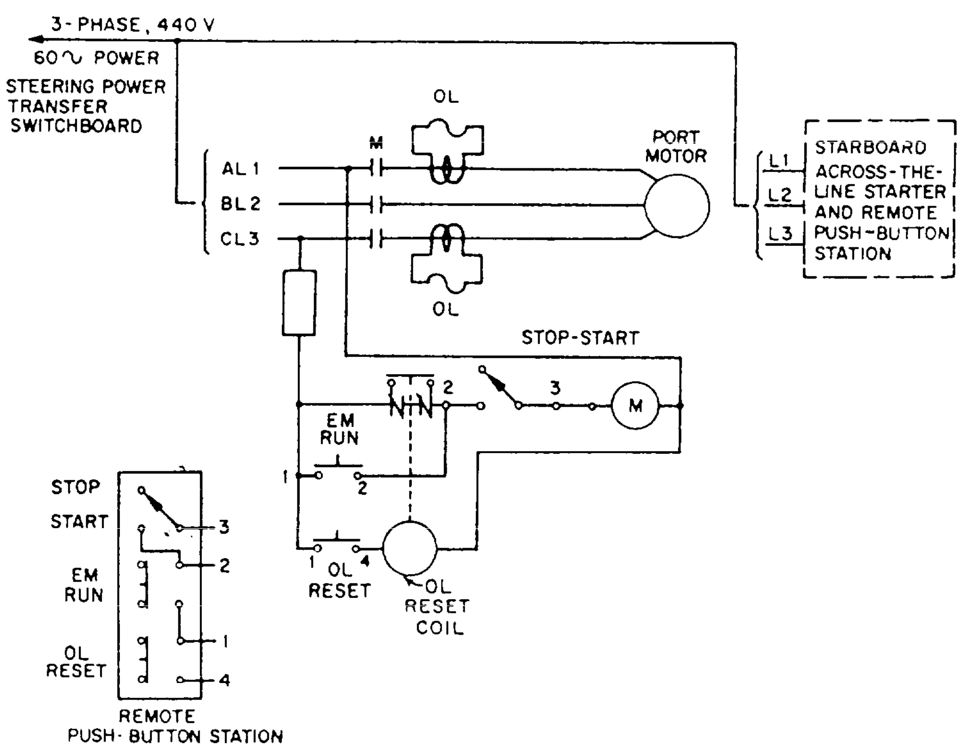


Figure 11-16.—Nonreversing across-the-line starter for steering gear pump motor.

APPENDIX I

GLOSSARY

ACID— A solution that contains an excess of hydrogen ions and exhibits a pH below the neutral value of 7.

ACTIVE— A state in which a metal tends to corrode (opposite to passive); freely corroding.

AIR-CORE TRANSFORMER— A transformer composed of two or more coils, which are wound around a nonmetallic core.

ALARM LOG— A record of quantities that are in an alarm condition only.

ALARM ACKNOWLEDGE— A push button that must be depressed to silence an alarm horn.

AMMETER— An instrument for measuring the amount of electron flow in amperes.

AMPERE— The basic unit of electrical current.

ANALOG DATA— Data represented in continuous form, as contrasted with digital data having discrete values.

ANNUNCIATOR— A device that gives an audible and a visual indication of an alarm condition.

ANODE— The positive electrode of an electrochemical device toward which the negative ions are drawn.

ANTIFOULING— The prevention of marine organism attachment or growth on a submerged metal surface through chemical toxicity. Achieved by the chemical composition of the metal, including toxins in the coating, or by some other means of distributing the toxin at the areas to be kept free of fouling.

APPARENT POWER— That power apparently available for use in an ac circuit containing a reactive element. It is the product of effective voltage times effective current expressed in voltamperes. It must be multiplied by the power factor to obtain the true power available.

AQUEOUS— A term pertaining to water; an aqueous solution is a water solution.

ARMATURE— In a relay, the movable portion of the relay.

AVERAGE VALUE OF AC— The average of all the instantaneous values of one-half cycle of alternating current.

BASE— A solution that contains an excess of hydroxyl ions and exhibits a pH above the neutral value of 7.

BATTERY— A device for converting chemical energy into electrical energy.

BATTERY CAPACITY— The amount of energy available from a battery. Battery capacity is expressed in ampere-hours.

BELL LOG— A printed record of changes in the ship's operative conditions, such as speed or point of control.

BINARY UNIT— One of the two possible alternatives, such as 1 or 0, YES or NO, ON or OFF.

BLOCK DIAGRAM— A drawing of a system using blocks for components to show the relationship of components.

BURNISHING TOOL— A tool used to clean and polish contacts on a relay.

CARD— *See* PRINTED CIRCUIT BOARD.

CASUALTY— An event or series of events in progress during which equipment damage and/or personnel injury has already occurred. The nature and speed of these events are such that proper and correct procedural steps will only serve to limit equipment damage and/or personnel injury.

CATHODE— The general name for any negative electrode.

CATHODIC CORROSION— Corrosion of a metal when it is a cathode. Occurs on metals, such as A1, Zn, Pb, when the water solution turns strongly alkaline as a result of the normal cathodic reactions. It is a secondary reaction between the alkali generated and the amphoteric metal.

CATHODIC POLARIZATION— The change of the electrode potential in the negative direction due to current flow.

CATHODIC PROTECTION— A technique or system used to reduce or eliminate the corrosion of a metal by making it the cathode of an electrochemical cell by means of an impressed direct current or attachment of sacrificial anodes such as zinc, magnesium, or aluminum.

CELL— A single unit that transforms chemical energy into electrical energy.

CHARGE— A term representing electrical energy. A material having an excess of electrons is said to have a negative charge. A material having an absence of electrons is said to have a positive charge.

CIRCUIT— The complete path of an electric current.

CIRCULAR MIL— An area equal to that of a circle with a diameter of 0.001 inch. It is used for measuring the cross-sectional area of wires.

CLOCK— An instrument for measuring and indicating time, such as a synchronous pulse generator.

COMPONENT PARTS— Individual units of a subassembly.

COMPONENTS— Any electrical device, such as a coil, resistor, or transistor.

CONDITION— The state of being of a device such as ON-OFF or GO-NO-GO.

CONDUCTANCE— The ability of a material to conduct or carry an electric current. It is the reciprocal of the resistance of the material and is expressed in mhos or siemans.

CONDUCTIVITY— The ease with which a substance transmits electricity.

CONDUCTOR— (1) A material with a large number of free electrons. (2) A material that easily permits electric current to flow.

CONTINUOUS DISPLAY— An electrical instrument giving a continuous indication of a measured quantity.

CONTROL MODE— The method of system control at a given time.

CONTROL POWER— The power used to control or operate a component.

CONTROL SIGNAL— The signal applied to a device that makes corrective changes in a controlled process.

CONVERTER— A device for changing one type of signal to another; for example, alternating current to direct current.

CORROSION— The reaction between a material and its environment that results in the loss of the material or its properties; for example, the transformation of a metal, used as a material of construction, from the metallic to the nonmetallic state.

CORROSION POTENTIAL— The potential that a corroding metal exhibits under specific conditions of concentration, time, temperature, aeration, or velocity in an electrolytic solution and measured relative to a reference electrode under open-circuit conditions.

CORROSION PRODUCT— A product resulting from corrosion. The term applies to solid compounds, gases, or ions resulting from a corrosion reaction.

CORROSION RATE— The speed at which corrosion progresses. Frequently expressed as a constant loss or penetration per unit time. Common units used are roils penetration per year (mpy), millimeters penetration per year (mm/y), micrometers penetration per year (um/y). 1 mil = 0,001 inch, 1 mm = 0.001 meter, 1 um = 0.000001 meter.

COULOMB— A measure of the quantity of electricity. One coulomb is equal to 6.28×10^{18} electrons.

COULOMB'S LAW— Also called the law of electric charges or the law of electrostatic attraction. Coulomb's law states that charged bodies attract or repel each other with a force that is directly proportional to the product of their individual charges and inversely proportional to the square of the distance between them.

COUPLE— A cell developed in an electrolytic solution resulting from electrical contact between two dissimilar metals; two dissimilar metals in electrical contact.

CPR— Cardiopulmonary resuscitation.

CROSS-SECTIONAL AREA— The area of a "slice" of an object. When applied to electrical conductors, it is usually expressed in circular roils.

CURRENT— The drift of electrons past a reference point. The passage of electrons through a conductor. Measured in amperes.

CURRENT CAPACITY— The hours of current that can be obtained from a unit weight of a galvanic anode metal. Usually expressed in ampere hours per pound (Ah/lb) or ampere hours per kilogram (Ah/kg).

CURRENT DENSITY— The current per unit area of surface of an electrode. Common units used are mA/ft^2 (milliamperes per square foot), mA/m^2 (milliamperes per square meter), A/ft^2 (amperes per square foot), and A/m^2 (amperes per square meter).

CURRENT EFFICIENCY— The ratio of the actual total current measured from a galvanic anode in a given time period and the total current calculated from the weight loss of the anode and the electrochemical equivalent of the anode metal, expressed as a percentage.

D'ARSONVAL METER MOVEMENT— A name used for the permanent-magnet moving-coil movement used in most meters.

DAMPING— The process of smoothing out oscillations. In a meter, damping is used to keep the pointer of the meter from overshooting the correct reading.

DEAD BAND— The range of values over which a measured variable can change without affecting the output of an amplifier or automatic control system.

DEMAND— To request a log printout or data display,

DIELECTRIC FIELD— The space between and around charged bodies in which their influence is felt. Also called electric field of force or an electrostatic field.

DIGITAL— A term pertaining to data in the form of digits.

DIGITAL CLOCK— A device for displaying time in digits.

DIRECT CURRENT— An electric current that flows in one direction only.

DOMAIN THEORY— A theory of magnetism based upon the electron-spin principle. Spinning electrons have a magnetic field. If more electrons spin in one direction than another, the atom is magnetized.

DRIFT— A slow change in some characteristics of a device, such as frequency, current, and direction.

DRY CELL— An electrical cell in which the electrolyte is not a liquid. In most dry cells, the electrolyte is in the form of a paste.

EDDY CURRENT— Induced circulating currents in a conducting material that are caused by a varying magnetic field.

EDDY CURRENT LOSS— Losses caused by random current flowing in the core of a transformer. Power is lost in the form of heat.

EFFICIENCY— The ratio of output power to input power, generally expressed as a percentage.

ELECTRIC CURRENT— The flow of electrons.

ELECTRICAL CHARGE (Q,q)— Electric energy stored on or in an object. The negative charge is caused by an excess of electrons; the positive charge is caused by a deficiency of electrons.

ELECTROCHEMICAL— The action of converting chemical energy into electrical energy.

ELECTROCHEMICAL CELL— (1) A system consisting of an anode and a cathode immersed in an electrolytic solution. The anode and cathode may be different metals or dissimilar areas on the same metal surface. (2) A cell in which chemical energy is converted into electrical energy under the condition of current flow between anode and cathode.

ELECTRODE— The terminal at which electricity passes from one medium into another, such as in an electrical cell where the current leaves or returns to the electrolyte.

ELECTRODE POTENTIAL— The difference in electrical potential between an electrode and the electrolytic solution with which it is in contact; measured relative to a reference electrode.

ELECTRODYNAMICS METER MOVEMENT— A meter movement using fixed field coils and a moving coil; usually used in wattmeters.

ELECTROLYSIS— The process of changing the chemical composition of a material by passing an electric current.

ELECTROLYTE— A solution of a substance that is capable of conducting electricity. An electrolyte may be in the form of either a liquid or a paste.

ELECTROLYTIC CELL— A system in which an anode and cathode are immersed in an electrolytic solution and electrical energy is used to bring about electrode reactions. The electrical energy is thus converted into chemical energy. **(NOTE:** The term *electrochemical cell* is frequently used to describe both the electrochemical cell and the electrolytic cell.)

ELECTROLYTIC SOLUTION— A solution that conducts electric current by the movement of ions.

ELECTROMAGNET— An electrically excited magnet capable of exerting mechanical force or of performing mechanical work.

ELECTROMAGNETIC— The term describing the relationship between electricity and magnetism; having both magnetic and electric properties.

ELECTROMAGNETIC INDUCTION— The production of a voltage in a coil due to a change in the number of magnetic lines of force (flux linkages) passing through the coil.

ELECTROMOTIVE FORCE (emf)— The force (voltage) that produces an electric current in a circuit. The force that causes electricity to flow between two points with different electrical charges or when there is a difference of potential between the two points. The unit of measurement is volts.

ELECTRON— The elementary negative charge that revolves around the nucleus of an atom.

ELECTRON SHELL— A group of electrons that have a common energy level that forms part of the outer structure (shell) of an atom.

ELECTROSTATIC— Pertaining to electricity at rest, such as charges on an object (static electricity).

ELECTROSTATIC METER MOVEMENT— A meter movement that used the electrostatic repulsion of two sets of charged plates (one fixed and the other movable). This meter movement reacts to voltage rather than to current and is used to measure high voltage.

ELEMENT— A substance, in chemistry, that cannot be divided into simpler substances by any means ordinarily available.

EMBRITTLEMENT— Severe loss of ductility of a metal or alloy.

EMERGENCY— An event or series of events in progress that will cause damage to equipment unless immediate, timely, and correct procedural steps are taken.

EXTERNAL CIRCUIT— Wires, connectors, measuring devices, current sources, and so forth, that are used to bring about or measure the desired electrical conditions within the test cell. Also known in corrosion parlance as that part of an electrochemical cell external to the solution.

FAIL— The loss of the control signal or power to a component. Also, the breakage or breakdown of a component or component part.

FAIL POSITION— The operating or physical position to which a device will go upon loss of its control signal.

FEEDBACK— A value derived from a controlled function and returned to the controlling function.

FERROMAGNETIC MATERIAL— A highly magnetic material, such as iron, cobalt, nickel, or alloys.

FIELD OF FORCE— A term used to describe the total force exerted by an action-at-a-distance phenomenon, such as gravity upon matter, electric charges acting upon electric charges, magnetic forces acting upon other magnets or magnetic materials.

FIXED RESISTOR— A resistor having a definite resistance value that cannot be adjusted.

FLUX— In electrical or electromagnetic devices, a general term used to designate collectively all the electric or magnetic lines of force in a region.

FLUX DENSITY— The number of magnetic lines of force passing through a given area.

FREQUENCY METER— A meter used to measure the frequency of an ac signal.

FUNCTION— To perform the normal or characteristic action of something, or a special duty or performance required of a person or thing in the course of work.

GALVANIC CORROSION— Corrosion of a metal because of electrical contact with a more noble metal or nonmetallic conductor in a corrosive environment. Often used to refer specifically to bimetallic corrosion; sometimes called couple action.

GALVANIC COUPLE— Two or more dissimilar conductors, commonly metals, in electrical contact in the same electrolytic solution.

GALVANIC SERIES— A list of metals and alloys arranged according to their relative corrosion potentials in a given environment. Note that this may not be the same order as in the electromotive force series.

GALVANOMETER— A meter used to measure small values of current by electromagnetic or electrodynamics means.

GROUND POTENTIAL— Zero potential with respect to the ground or earth.

HALF-CELL— One of the electrodes and its immediate environment in an electrochemical cell; an electrode and environment arranged for the passage of current to another electrode for the measurement of its electrode potential; when coupled with another half-cell, an overall cell potential develops that is the sum of both half-cell potentials.

HENRY (H)— The electromagnetic unit of inductance or mutual inductance. The inductance of a circuit is 1 henry when a current variation of 1 ampere per second induces 1 volt. It is the basic unit of inductance. In radio, smaller units are used, such as the millihenry (mH), which is one-thousandth of a henry (H), and the microhenry (μH), which is one-millionth of a henry.

HERTZ (Hz)— A unit of frequency equal to one cycle per second.

HORSEPOWER (hp)— The English unit of power, equal to work done at the rate of 550 foot-pounds per second. Equal to 746 watts of electrical power.

HOT WIRE METER MOVEMENT— A meter movement that uses the expansion of a heated wire to move the pointer of a meter; measures ac or dc.

HYDRAULIC ACTUATOR— A device that converts hydraulic pressure to mechanical movement.

HYDROGEN BLISTERING— The formation of blisterlike bulges on or below the surface of a ductile metal caused by excessive internal hydrogen pressure. Hydrogen may be formed during cleaning, plating, corrosion, or cathodic protection.

HYDROGEN EMBRITTLEMENT— Severe loss of ductility caused by the presence of hydrogen in the metal; for example, through pickling, cleaning, or cathodic protection.

HYDROMETER— An instrument used to measure specific gravity. In batteries, hydrometers are used to indicate the state of charge by the specific gravity of the electrolyte.

HYSTERESIS— The time lag of the magnetic flux in a magnetic material behind the magnetizing force producing it, caused by the molecular friction of the molecules trying to align themselves with the magnetic force applied to the material.

HYSTERESIS LOSS— The power loss in an iron-core transformer or other ac device as a result of magnetic hysteresis.

INDUCED CURRENT— Current due to the relative motion between a conductor and a magnetic field.

INDUCED ELECTROMOTIVE FORCE— The electromotive force induced in a conductor due to the relative motion between a conductor and a magnetic field. Also called induced voltage.

INDUCED REACTANCE (X_L)— The opposition to the flow of an alternating current caused by the inductance of a circuit, expressed in ohms.

INSULATION— (1) A material used to prevent the leakage of electricity from a conductor and to provide mechanical spacing or support to protect against accidental contact. (2) Use of material in which current flow is negligible to surround or separate a conductor to prevent loss of current.

INTERLOCK— A device that prevents an action from taking place at the desired time, but will allow the action when all required conditions are met.

ION— An electrically charged atom or group of atoms. Negative ions have an excess of electrons; positive ions have a deficiency of electrons.

JACKING GEAR— Electric motor-driven device that rotates the turbine shaft, reduction gears, and line shaft at a low speed.

KILO— A prefix meaning one thousand.

KINETIC ENERGY— Energy that a body possesses by virtue of its motion.

KIRCHHOFF'S LAWS— (1) The algebraic sum of the currents flowing toward any point in an electric network is zero. (2) The algebraic sum of the products of the current and resistance in each of the conductors in any closed path in a network is equal to the algebraic sum of the electromotive forces in the path.

LEAD-ACID CELL— A cell in an ordinary storage battery, in which electrodes are grids of lead containing an active material consisting of certain lead oxides that change in composition during charging and discharging. The electrodes or plates are immersed in an electrolyte of diluted sulfuric acid.

LINE OF FORCE— A line in an electric or magnetic field that shows the direction of the force.

LINEAR— Straight line relationship where changes in one function are directly proportional to changes in another function.

LOAD— (1) A device through which an electric current flows and which changes electrical energy into another form, (2) Power consumed by a device or circuit in performing its function.

LOGIC— A method for describing the existing condition of circuits and devices that can remain at only one of two opposite conditions at a particular time, such as ON or OFF, UP or DOWN, IN or OUT.

MAGNETIC FIELD— The space in which a magnetic force exists.

MAGNETIC POLES— The section of a magnet where the flux lines are concentrated; also where they enter and leave the magnet.

MAGNETISM— The property possessed by certain materials by which these materials can exert mechanical force on neighboring masses of magnetic materials and can cause currents to be induced in conducting bodies moving relative to the magnetized bodies.

MANUAL THROTTLE CLUTCH— Means of mechanically disconnecting the throttle handwheels, mounted on the engine-room console, from the reach rods that are connected to the throttle valves.

MEGA— A prefix meaning one million, also Meg.

MHO— Unit of conductance; the reciprocal of the ohm.

MICRO— A prefix meaning one-millionth.

MICROTESLA— Equal to one million teslas.

MILLI— A prefix meaning one-thousandth.

MODULE— Subassemblies mounted in a section.

MONITOR— One of the principal operating modes of a data logger that provides a constant check of plant conditions.

MONITORING POINT— The physical location at which any indicating device displays the value of a parameter at some control station.

MOVING-VANE METER MOVEMENT— A meter movement that uses the magnetic repulsion of the like poles created in two iron vanes by current through a coil of wire: most commonly used movement for ac meters.

MULTIMETER— A single meter combining the functions of an ammeter, a voltmeter, and an ohmmeter.

NEGATIVE TEMPERATURE COEFFICIENT— The temperature coefficient expressing the amount of reduction in the value of a quantity, such as resistance for each degree of increase in temperature.

NEUTRAL— In a normal condition, neither positive or negative. A neutral object has a normal number of electrons.

NO-BREAK POWER SUPPLY— A device that supplies temporary power to the console during failure of the normal power supply.

NOBLE— A state in which a metal tends not to be active; the positive direction of electrode potential.

NOBLE METAL— A metal that is not very reactive, such as silver, gold, or platinum, which may be found naturally in metallic form on earth.

NOBLE POTENTIAL— A potential toward the positive end of a scale of electrode potentials.

NONTRIP-FREE CIRCUIT BREAKER— A circuit breaker that can be held ON during an overcurrent condition.

NORMAL MODE— Operating condition at normal ahead speeds, differing from maneuvering, where certain functions, pumps, or valves are not required, while others are for proper operation of ship and machinery.

NULL POSITION— Condition where the output shaft is positioned to correspond to that which the input shaft has been set.

OCTAL CODE— Numeric system consisting of eight consecutive digits, 0 through 7.

OHM— The unit of electrical resistance. It is that value of electrical resistance through which a constant potential difference of 1 volt across the resistance will maintain a current flow of 1 ampere through the resistance.

OHM'S LAW— The current in an electric circuit is directly proportional to the electromotive force in the circuit. The most common form of the law is E= IR, where E is the electromotive force or voltage across the circuit, I is the current flowing in the circuit, and R is the resistance of the circuit.

OHMIC VALUE— Resistance in ohms.

ONE-LINE SCHEMATIC— A drawing of a system using only one line to show the tie-in of various components; for example, the three conductors needed to transmit three-phase power are represented by a single line.

ONE-LINE SKETCH— A drawing using one line to outline the general relationship of various components to each other.

OPEN-CIRCUIT POTENTIAL— The potential of an electrode measured with respect to a reference electrode when essentially no current flows to or from the electrode.

OPEN LOOP— A system having no feedback.

OPERATING CHARACTERISTICS— A combination of a parameter and its set point.

PARALLAX— The error in meter readings that results when you look at a meter from some position other than directly in line with the pointer and the meter face. A mirror mounted on the meter face aids in eliminating parallax error.

PARAMETER— A variable, such as temperature, pressure, flow rate, voltage, current, or frequency that may be indicated, monitored, checked, or sensed in any way during operation or testing.

PARALLEL CIRCUIT— Two or more electrical devices connected to the same pair of terminals so separate currents flow through each; electrons have more than one path to travel from the negative to the positive terminal.

PERIPHERAL— Existing on or near the boundary of a surface or area.

PERMEABILITY— The measure of the ability of a material to act as a path for magnetic lines of force.

pH— A logarithmic measure of the acidity or alkalinity of a solution. A value of 7 is neutral; low numbers are acid (1-6); large numbers are alkaline (8- 14). Each unit represents a tenfold change in concentration.

PHASE— The angular relationship between two alternating currents or voltages when the voltage or current is plotted as a function of time. When the two are in phase, the angle is zero, and both reach their peak simultaneously. When out of phase, one will lead or lag the other; at the instant when one is at its peak, the other will not be at peak value and (depending on the phase angle) may differ in polarity as well as magnitude.

PHASE ANGLE— The number of electrical degrees of lead or lag between the voltage and current waveforms in an ac circuit.

PHASE DIFFERENCE— The time in electrical degrees by which wave leads or lag another.

PHOTOELECTRIC VOLTAGE— A voltage produced by light.

PICO— A prefix adopted by the National Bureau of Standards meaning 10^{-12}.

PIEZOELECTRIC EFFECT— The effect of producing a voltage by placing a stress, either by compression, expansion, or twisting, on a crystal and, conversely, producing a stress in a crystal by applying a voltage to it.

PILOT MOTOR— The small dc motor that drives the input shaft of an actuator.

POLARITY— (1) The condition in an electrical circuit by which the direction of the flow of current can be determined. Usually applied to batteries and other direct voltage sources. (2) Two opposite charges, one positive and one negative. (3) A quality of having two opposite magnetic poles, one north and the other south.

POLARIZATION— The effect of hydrogen surrounding the anode of a cell that increases the internal resistance of the cell.

POTENTIAL ENERGY— Energy due to the position of one body with respect to another body or to the relative parts of the same body.

POTENTIOMETER— A three-terminal resistor with one or more sliding contacts, which functions as an adjustable voltage divider.

POWER— The rate of doing work or the rate of expending energy. The unit of electrical power is the watt.

POWER SUPPLY— The module that converts the 115-volt, 60-hertz incoming power to ac or dc power at a more suitable voltage level.

PRIMARY WINDING— The winding of a transformer connected to the electrical source.

PRINTED CIRCUIT BOARD— Devices usually plugged into receptacles that are mounted in modules.

PRIORITY— The order established by the relative importance of the function.

PROTECTIVE FEATURE— The feature of a component or component part designed to protect a component or system from damage.

PROTECTIVE POTENTIAL— A term used in cathodic protection to define the minimum potential required to mitigate or suppress corrosion. For steel in quiescent seawater, a value of -0.80 volt to Ag/AgCl reference electrode is generally used.

RECIPROCAL— The value obtained by dividing the number 1 by any quantity.

RECTIFIER— A device used to convert ac to pulsating dc.

REFERENCE ELECTRODE— A half-cell of reproducible potential by means of which an unknown electrode potential can be determined on some arbitrary scale (for example, Ag/AgCl, SCE, $Cu/CuSO_4$). A standard against which the potentials of other metal and nonmetallic conductor electrodes are measured and compared.

REFERENCE POINT— A point in a circuit to which all other points in the circuit are compared.

REFERENCE SIGNAL— The command signal that requests a specific final condition.

RELAY— An electromagnetic device with one or more sets of contacts that changes contact position by the magnetic attraction of a coil to an armature.

RELUCTANCE— A measure of the opposition that a material offers to magnetic lines of force.

REPULSION— The mechanical force tending to separate bodies having like electrical charges or like magnetic polarity.

RESIDUAL MAGNETISM— Magnetism remaining in a substance after removal of the magnetizing force.

RETENTIVITY— The ability of a material to retain its magnetism.

RHEOSTAT— (1) A resistor whose value can be varied. (2) A variable resistor that is used for the purpose of adjusting the current in a circuit.

RLC CIRCUIT— An electrical circuit that has the properties of resistance, inductance, and capacitance.

ROOT MEAN SQUARE (RMS)— The equivalent heating value of an alternating current or voltage, as compared to a direct current or voltage. It is 0.707 times the peak value of a sine wave.

ROTARY SWITCH— A multicontact switch with contacts arranged in a circular or semicircular manner.

RUSTING— Corrosion of iron or iron-base alloy to form a reddish-brown product known as rust, which is primarily hydrated iron oxide. A term properly applied only to ferrous alloys.

SCALING— Applying a factor of proportionality to data or signal levels.

SCHEMATIC CIRCUIT DIAGRAM— A circuit diagram in which component parts are represented by simple, easily drawn symbols. May be called schematic.

SCHEMATIC SYMBOLS— A letter, abbreviation, or design used to represent specific characteristics or components on a schematic diagram.

SECONDARY— The output coil of a transformer.

SELF-INDUCTANCE— The production of a counter electromotive force in a conductor when its own magnetic field collapses or expands with a change in current in the conductor.

SELSYN— Self-synchronizing device or synchro-motor.

SENSING POINT— A physical and/or functional point in a system at which a signal maybe detected or monitored in an automatic operation.

SENSITIVITY— (1) For an ammeter, the amount of current that will cause full-scale deflection of the meter. (2) For a voltmeter, the ratio of the voltmeter resistance divided by the full-scale reading of the meter, expressed in ohms-per-volt.

SENSOR— A device that is sensitive to temperature, pressure, position, level, or speed.

SERIES CIRCUIT— An arrangement where electrical devices are connected so that the total current must flow through all the devices; electrons have one path to travel from the negative terminal to the positive terminal.

SERIES-PARALLEL CIRCUIT— A circuit that consists of both series and parallel networks.

SET POINT— The numerical value of a parameter at which an alarm is actuated.

SHIELD— A nonconducting coating, paint, or sheet that is used to beneficially change the current on a cathode or anode; normally used with impressed current or other high-potential cathodic protection systems to distribute the current beyond the immediate vicinity of the electrode.

SILICON CONTROLLED RECTIFIER PACKAGE— A device that furnishes controlled dc power to a device.

SINE WAVE— The curve traced by the projection on a uniform time scale of the end of a rotating arm, or vector. Also known as a sinusoidal wave.

SOLENOID— An electromagnetic device that changes electrical energy into mechanical motion; based upon the attraction of a movable iron plunger to the core of an electromagnet.

SOLID STATE— A class of electronics components, such as transistors, diodes, integrated circuits, silicon controlled rectifiers, and so forth.

SPAN— The distance between two points.

SPECIAL FUNCTION— A unique service performed by a system; usually above and beyond the direct design intent of the system.

STANDARD PRINT— A standard drawing, schematic, or blueprint produced in the applicable technical manual or other official technical publication.

STATUS LOG— A record of the instantaneous values of important conditions having analog values.

STRAY-CURRENT CORROSION— Corrosion caused by current flow from a source (usually dc) through paths other than the intended circuit or by extraneous currents in the electrolytic solution.

SYSTEM— The major functional section of an installation.

SYSTEM INTERRELATION— Specific individual operations in one system affecting the operation in another system.

TACHOMETER GENERATOR— A device for converting rotational speed into an electrical quantity or signal,

TESLA— The tesla is a measurement of magnetic flux, equivalent to 1 weber per square meter. One tesla is equal to 10,000 gauss.

TEST POINT— A position in a circuit where instruments can be inserted for test purposes.

THERMAL-MAGNETIC TRIP ELEMENT— A single circuit breaker trip element that combines the action of a thermal and a magnetic trip element.

THERMOCOUPLE METER MOVEMENT— A meter movement that uses the current induced in a thermocouple by the heating of a resistive element to measure the current in a circuit; used to measure ac or dc.

THETA (θ)—The The greek letter used to represent phase angle.

THRESHOLD— The least value of current or voltage that produces the minimum detectable response.

TIME CONSTANT— (1) The time required to charge a capacitor to 63.2 percent of maximum voltage or discharge to 36.8 percent of its final voltage. (2) The time required for the current in an inductor to increase to 63.2 percent of maximum current of decay to 36.8 percent of its final current.

TOLERANCE— (1) The maximum error or variation from the standard permissible in a measuring instrument. (2) A maximum electrical or mechanical variation from specifications that can be tolerated without impairing the operation of a device.

TRACKING— One object or device moving with or following another object or device.

TRANSDUCER— A device that converts a mechanical input signal into an electrical output signal.

TRANSFORMER— A device composed of two or more coils, linked by magnetic lines of force, used to transfer energy from one circuit to another.

TRANSFORMER, STEP-DOWN— A transformer so constructed that the number of turns in the secondary winding is less than the number of turns in the primary winding. This construction will provide less voltage in the secondary circuit than in the primary circuit.

TRANSFORMER, STEP-UP— A transformer so constructed that the number of turns in the secondary winding is more than the number of turns in the primary winding. This construction will provide more voltage in the secondary circuit than in the primary circuit.

TRIP ELEMENT— The part of a circuit breaker that senses any overload condition and causes the circuit breaker to open the circuit.

TRIP-FREE CIRCUIT BREAKER— A circuit breaker that will open a circuit even if the operating mechanism is held in the ON position.

TRUE POWER— The power dissipated in the resistance of the circuit, or the power actually used in the circuit.

TURN— One complete loop of a conductor about a core.

TURNING GEAR— *See* JACKING GEAR.

TURNS RATIO— The ratio of the number of turns in the primary winding to the number of turns in the secondary winding of a transformer.

VOLT— The unit of electromotive force or electrical pressure. One volt is the pressure required to send 1 ampere of current through a resistance of 1 ohm.

VOLTAGE— (1) The term used to signify electrical pressure. Voltage is a force that causes current to flow through an electrical conductor. (2) The voltage of a circuit is the greatest effective difference of potential between any two conductors of the circuit.

VOLTAGE DIVIDER— A series circuit in which desired portions of the source voltage may be tapped off for use in equipment.

VOLTAGE DROP— The difference in voltage between two points. It is the result of the loss of electrical pressure as a current flows through a resistance.

WATCH STATION— Duties, assignments or responsibilities that an individual or group of individuals may be called upon to carry out; not necessarily a normally manned position with a "watch bill" assignment.

WATT— The practical unit of electrical power. It is the amount of power used when 1 ampere of dc flows through a resistance of 1 ohm.

WATT-HOUR— A practical unit of electrical energy equal to 1 watt of power for 1 hour.

WATTAGE RATING— A rating expressing the maximum power that a device can safely handle.

WEBER'S THEORY— A theory of magnetism that assumes that all magnetic material is composed of many tiny magnets. A piece of magnetic material that is magnetized has all of the tiny magnets aligned so that the north pole of each magnet points in one direction.

APPENDIX II

REFERENCES USED TO DEVELOP THIS NRTC

NOTE: Although the following references were current when this NRTC was published, their continued currency cannot be assured. When consulting these references, keep in mind that they may have been revised to reflect new technology or revised methods, practices, or procedures; therefore, you need to ensure that you are studying the latest references.

Chapter 1

Electrician's Mate 3 & 2, NAVEDTRA 10546-F, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1988.

General EIMB Handbook, NAVSEA SE000-00-EIM-100, Naval Sea Systems Command, Washington, D.C., April 1983.

Naval Safety Supervisor, NAVEDTRA 10808-2, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1988.

Naval Ships' Technical Manual (NSTM), NAVSEA S9086-KC-STM-000, Chapter 300, "Electrical Plant General," Naval Sea Systems Command, Washington, D.C., April 1979.

Naval Ships' Technical Manual (NSTM), NAVSEA S9086-KR-STM-000, Chapter 313, "Portable Storage and Dry Batteries," Naval Sea Systems Command, Washington, D.C., June 1976.

Navy Occupational Safety and Health (NAVOSH) Program Manual, OPNAVINST 5100.23B, Office of the Chief of Naval Operations, Washington, D.C., January 1987.

Navy Safety Precautions For Forces Afloat, OPNAVINST 5100.19A, Office of the Chief of Naval Operations, Washington, D.C., January 1983.

Shipboard Heat Stress Control and Personnel Protection, OPNAVINST 5100.20C, Office of the Chief of Naval Operations, Washington, D.C., March 1985.

Standard First Aid Training Course, NAVEDTRA 1208 1-D, Naval Education and Training Program Development Center, Pensacola, Fla., 1991.

Standard Organization and Regulations of the U.S. Navy, OPNAVINST 3120.32B, Office of the Chief of Naval Operations, Washington, D.C., September 1986.

Chapter 2

Electrician's Mate 3 & 2, NAVEDTRA 10546-F, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1988.

General Specifications for Ships of the United States Navy, NAVSEA S9AAO-AA-SPN-010, Naval Sea Systems Command, Washington, D,C., April 1987.

Military Specification, MIL-C-915F, *Cable and Cord, Electrical, for Shipboard Use, General Specification for,* Naval Sea Systems Command, Washington, D.C., June 1985.

Military Specification, MIL-C-24640, *Cable, Electrical, Lightweight for Shipboard Use, General Specification for,* Naval Sea Systems Command, Washington, D.C., August 1984.

Military Specification, MIL-C-24643, *Cables and Cords, Electrical, Low Smoke, for Shipboard Use, General Specification for,* Naval Sea Systems Command, Washington, D.C., September 1984.

Naval Ships' Technical Manual (NSTM), NAVSEA S9086-KC-STM-000, Chapter 300, "Electrical Plant General," Naval Sea Systems Command, Washington, D.C., April 1979.

Naval Ships' Technical Manual (NSTM), NAVSEA S9086-PA-STM-000, Chapter 430, "Interior Communication Installations," Naval Sea Systems Command, Washington, D.C., February 1980.

Navy Electricity and Electronics Training Series (NEETS), NAVEDTRA 172-03-00-85, Module 3, *Circuit Protection, Control, and Measurement,* Naval Education and Training Program Development Center, Pensacola, Fla., 1985.*

Navy Electricity and Electronics Training Series (NEETS), NAVEDTRA 172-04-00-92, Module 4, *Electrical Conductors, Wiring Techniques and Schematic Reading,* Naval Education and Training Program Development Center, Pensacola, Fla., 1992.

Chapter 3

General Specifications for Ships of the United States Navy, NAVSEA S9AA0-AA-SPN-010, Naval Sea Systems Command, Washington, D.C., April 1987.

IC Electrician 2 & 1, NAVEDTRA 10561, Naval Education and Training Program Development Center, Pensacola, Fla., 1985.*

Main and Local Interior Communications Switchboards, NAVSEA 0965-LP-096-9010, Naval Sea Systems Command, Washington, D.C., May 1978.

Military Specification, DOD-S-17773B(SH), *Switches, Bus Transfer Electric Power, Automatic and Manual (METRIC),* Naval Sea Systems Command, Washington, D.C., September 1983.

Naval Ships' Technical Manual (NSTM), NAVSEA S9086-CN-STM-030, Chapter 079, Volume 3, "Damage Control, Engineering Casualty Control," Naval Sea Systems Command, Washington, D.C., June 1987.

Naval Ships' Technical Manual (NSTM), NAVSEA S9086-KC-STM-000, Chapter 300, "Electric Plant General," Naval Sea Systems Command, Washington, D.C., April 1979.

Naval Ships' Technical Manual (NSTM), NAVSEA S9086-KN-STM-000, Chapter 310, "Electric Power Generators and Conversion Equipment," Naval Sea Systems Command, Washington, D.C., February 1976.

Naval Ships' Technical Manual (NSTM), NAVSEA S9086-KY-STM-000, Chapter 320, "Electric Power Distribution Systems," Naval Sea Command, Washington, D.C., March 1976.

Naval Ships' Technical Manual (NSTM), NAVSEA S9086-PA-STM-000, Chapter 430, "Interior Communication Installations," Naval Sea Systems Command, Washington, D.C., February 1980.

Ship Information Book, NAVSEA S9DDG-BF-SIB-051/(U) DDG-39, Volume 5, Chapter 1, “Interior Communication Systems,” Naval Sea Systems Command, Washington, D.C., September 1980.

Ship Information Book, NAVSEA S9DDO-6F-SIB-070/DD 963, Volume 5, Part 1, “Interior Communication Systems,” Naval Sea Systems Command, Washington, D.C., April 1987.

Chapter 4

General Specifications For Ships of the United States Navy, NAVSEA S9AAO-AA-SPN-010, Naval Sea Systems Command, Washington, D.C., April 1987.

Gyrocompass Set, Stabilized, AN/WSN-2, NAVSEA 0924-LP-066-8010, Naval Sea Systems Command, Washington, D.C., August 1978.

IC Electrician 2 & 1, NAVEDTRA 10561, Naval Education and Training Program Development Center, Pensacola, Fla., 1985.*

Mark 19 Mod 3B Gyrocompass Equipment, NAVSEA 0924-LP-063-3010, Naval Sea Systems Command, Washington, D.C., 1964

Mark 19 Mod 3D Gyrocompass Equipment, NAVSEA 0924-LP-038-2010, Naval Sea Systems Command, Washington, D.C., July 1974.

Mark 23 Mod C-3 Gyrocompass Equipment, NAVSEA 0924-LP-038-2010, Naval Sea Systems Command, Washington, D.C., October 1968.

Naval Ships' Technical Manual (NSTM), NAVSEA S9806-HW-STM-000, Chapter 252, “Ship Control Equipment,” Naval Sea Systems Command, Washington, D.C., September 1977.

Ship Information Book, NAVSEA S9FFG-AK-SIB-051/(U) FFG-10, Volume 5, Part 1, “Interior Communications Systems,” Naval Sea Systems Command, Washington, D.C., October 1981.

Chapter 5

General Specifications For Ships of the United States Navy, NAVSEA S9AA0-AA-SPN-010, Naval Sea Systems Command, Washington, D.C., April 1987.

Naval Ships' Technical Manual (NSTM), NAVSEA S9086-CN-STM-020, Chapter 079, Volume 2, “Damage Control, Practical Damage Control,” Naval Sea Systems Command, Washington, D.C., July 1977.

Naval Ships' Technical Manual (NSTM), NAVSEA S9086-PA-STM-000, Chapter 430, “Interior Communication Installations,” Naval Sea Systems Command, Washington, D.C., February 1980

Ship Information Book, NAVSEA S9FFG-AK-SIB-052/(U)FFG-10, Volume 5, Part 2, “Sound-Powered Telephone Systems and Voice Tubes,” Naval Sea Systems Command, Washington, D.C., October 1981.

Sound-Powered Telephone System AN/WTC-2(V), NAVSEA SE165-AD-MMA-010/WTC-2(V), Naval Sea Systems Command, Washington, D.C., June 1978.

Chapter 6

Central Office Telephone, Dial AN/WTC1(V), NAVSEA SE165-AC-MMO-020/ 200-500 Line, Naval Sea Systems Command, Washington, D.C., April 1979.

General Specifications For Ships of the United States Navy, NAVSEA S9AAO-AA-SPN-010, Naval Sea Systems Command, Washington, D.C., April 1987.

Naval Ships' Technical Manual (NSTM), NAVSEA S9086-PA-STM-000, Chapter 430, "Interior Communication Installations," Naval Sea Systems Command, Washington, D.C., February 1980.

100/150-Line Automatic Dial Telephone Switchboard, NAVSEA SE165-A4-MMO-010, Naval Sea Systems Command, Washington, D.C., October 1980.

Telephone Set, Type G, NAVSEA SE165-AR-MMO-000, Naval Sea Systems Command, Washington, D.C., October 1977.

Type G Telephone Set, NAVSEA 0965-LP-022-2010, Naval Sea Systems Command, Washington, D.C., March 1966.

Chapter 7

Amplifier-Control Group AN/SIA-120, NAVSEA 0365-LP-287-7000, Naval Sea Systems Command, Washington, D.C., November 1963.

Amplifier-Oscillator Group AN/SIA-114B, NAVSEA 0365-LP-287-9000, Naval Sea Systems Command, Washington, D.C., September 1963.

General Specifications For Ships of the United States Navy, NAVSEA S9AAO-AA-SPN-010, Naval Sea Systems Command, Washington, D.C., April 1987.

Intercommunication System AN/WIC-2B(V), NAVSEA 0965-LP-068-3010, Naval Sea Systems Command, Washington, D.C., June 1969.

Microphone Control Station IC/MSB-2 with Microphone, NAVSEA SE120-AE-MMA-010, Naval Sea Systems Command, Washington, D.C., June 1979.

Naval Ships' Technical Manual (NSTM), NAVSEA S9086-PA-STM-000, Chapter 430, "Interior Communication Installations," Naval Sea Systems Command, Washington, D.C., February 1980.

Chapter 8

General Specifications For Ships of the United States Navy, NAVSEA S9AAO-AA-SPN-010, Naval Sea Systems Command, Washington, D.C., April 1987.

Naval Ships' Technical Manual (NSTM), NAVSEA S9086-PA-STM-000, Chapter 430, "Interior Communication Installations," Naval Sea Systems Command, Washington, D.C., February 1980.

Public Address Set AN/SIH-7, NAVSEA 0965-LP-078-4010, Naval Sea Systems Command, Washington, D.C., December 1972.

Service Manual, *Shipboard Information Training and Entertainment (SITE II),* Volume 1, Television - Audio Support Activity (T-ASA), Sacramento Army Depot, Sacramento, Calif.

Chapter 10

General Specifications For Ships of the United States Navy, NAVSEA S9AAO-AA-SPN-010, Naval Sea Systems Command, Washington, D.C., April 1987.

Naval Ships' Technical Manual (NSTM), NAVSEA S9086-PA-STM-000, Chapter 430, "Interior Communication Installations," Naval Sea Systems Command, Washington, D.C., February 1980.

Chapter 11

Technical Manual, *Cathodic Protection System, Impressed Current,* NAVSEA S9633-AA-MMM-010/89357, Naval Sea Systems Command, Washington, D.C., February 1984.

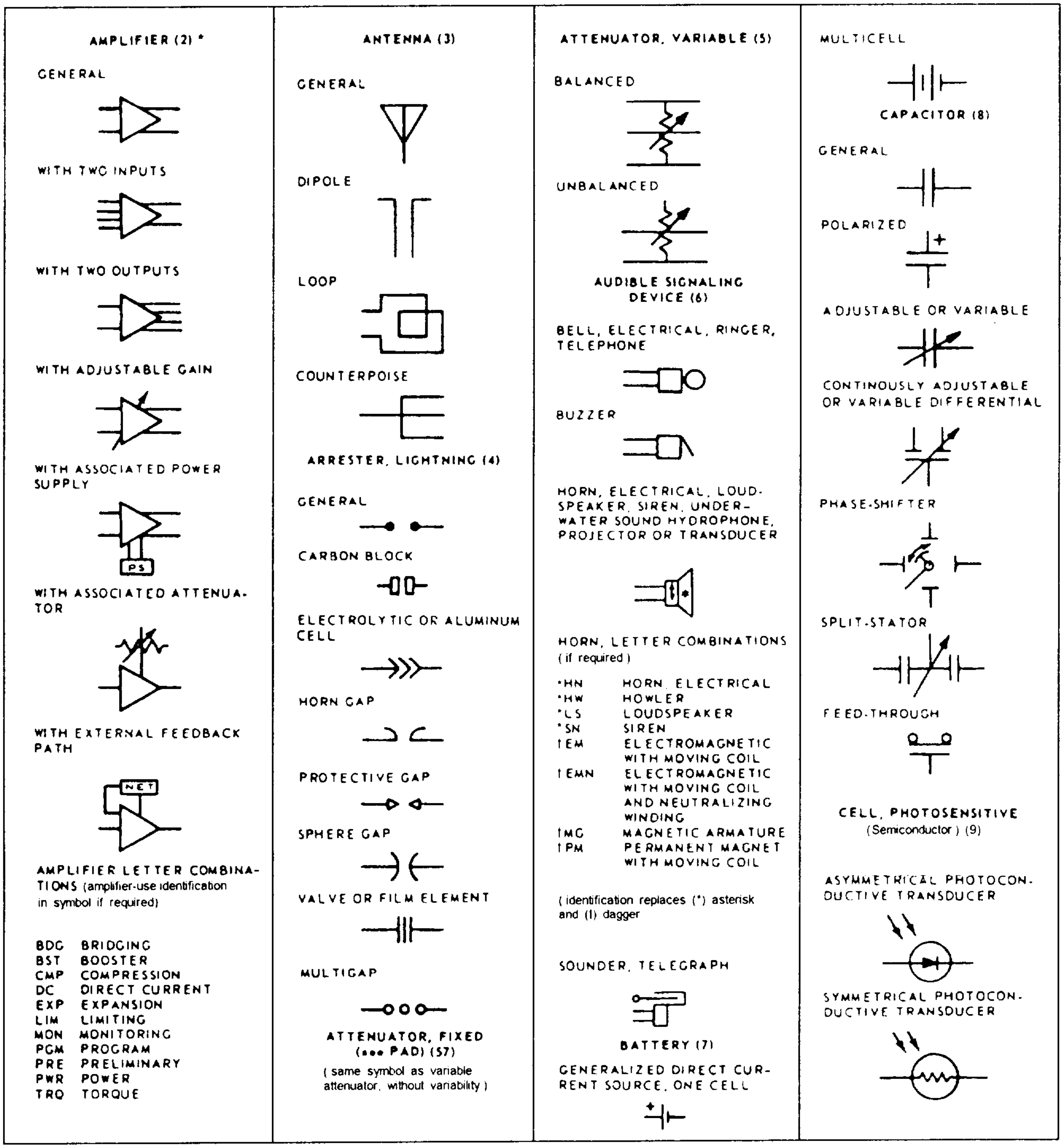
IC Electrician 2 & 1, NAVEDTRA 10561, Naval Education and Training program Development Center, Pensacola, Fla., 1985.*

Electrician's Mate 3 & 2, NAVEDTRA 10546-F, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1988.

Naval Ships' Technical Manual (NSTM), NAVSEA S9086-VF-STM-010, Chapter 633, "Cathodic Protection," Naval Sea Systems Command, Washington, D.C., October 1985.

* Effective 1 September 1986, the Naval Education and Training Program Development Center became the Naval Education and Training Program Management Support Activity.

ELECTRONIC SYMBOLS



* NUMBER IN PARENTHESES INDICATES LOCATION OF SYMBOL IN MIL-STD PUBLICATION

Figure AIII-1.—Electronic Symbols.

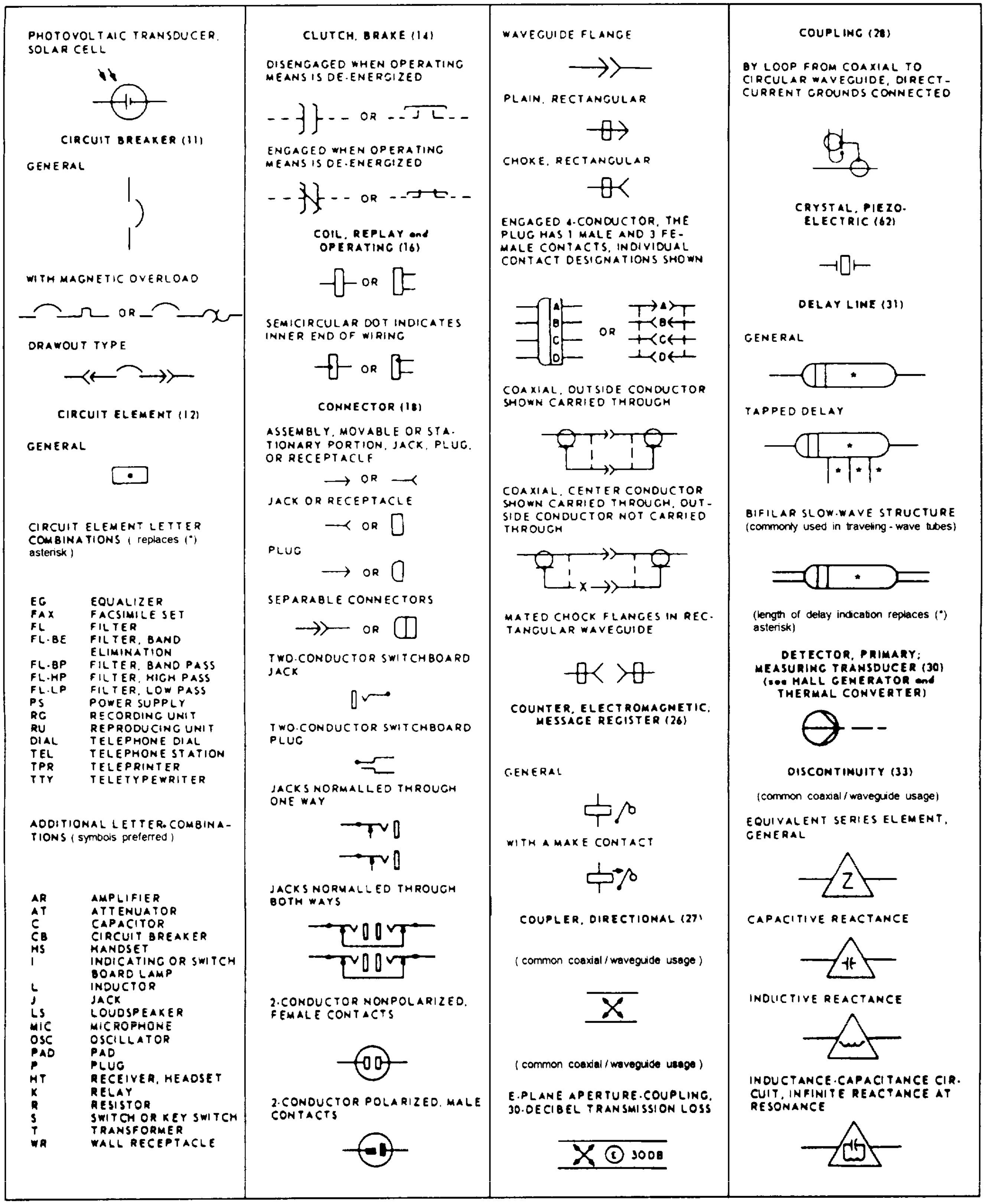


Figure AIII.1.—Electronic Symbols—Continued.

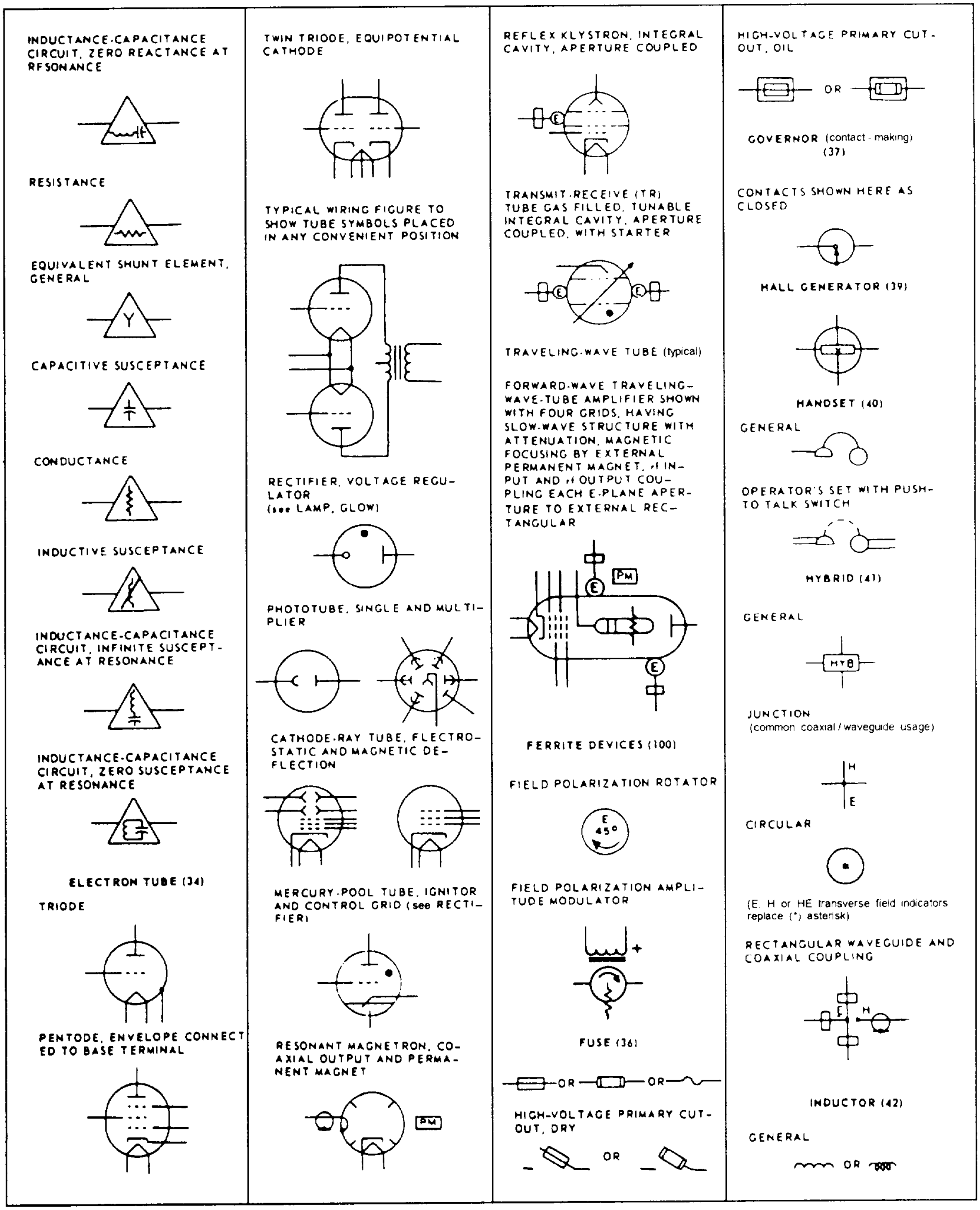


Figure AIII.1.—Electronic Symbols—Continued.

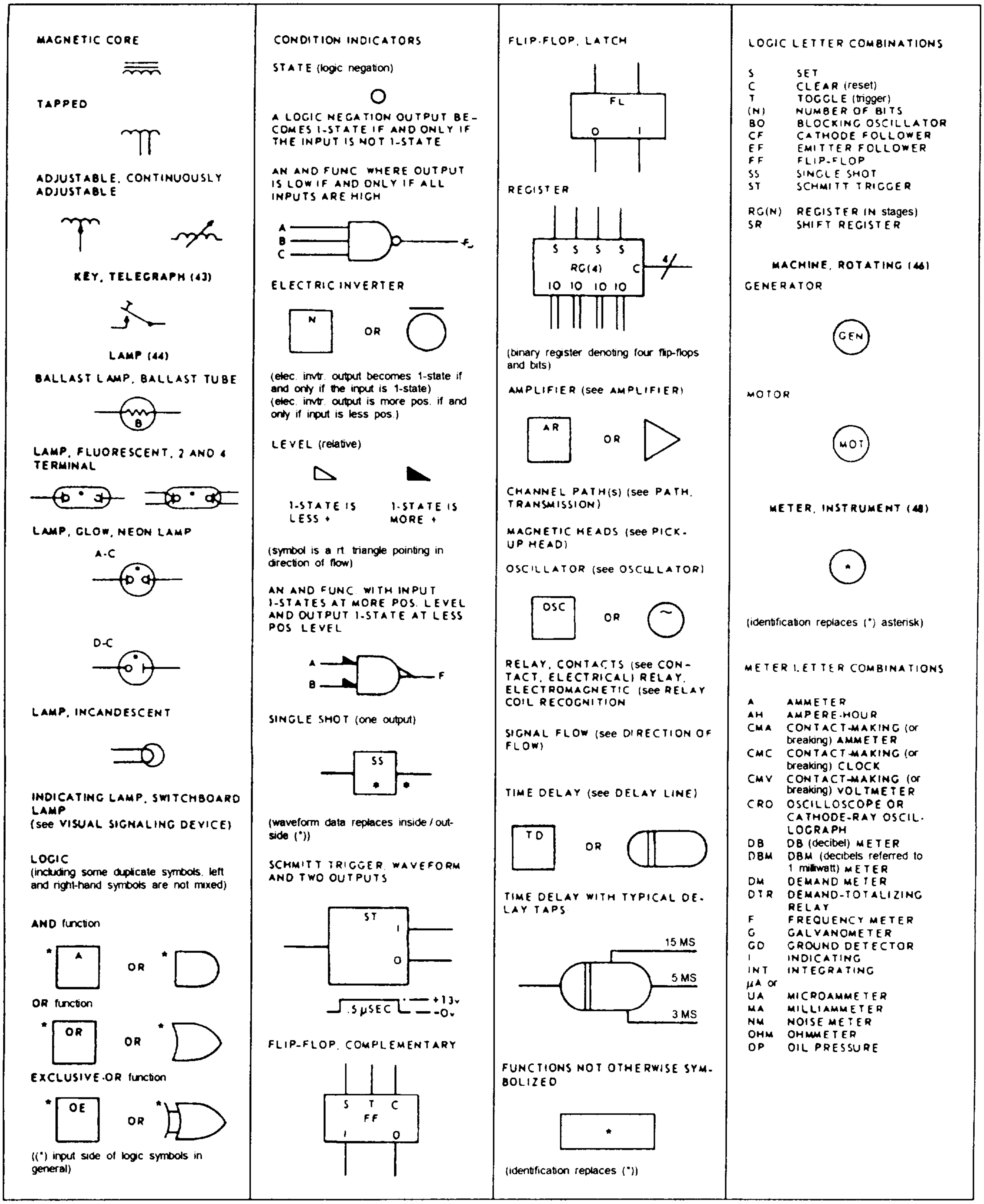


Figure AIII-1.—Electronic Symbols—Continued.

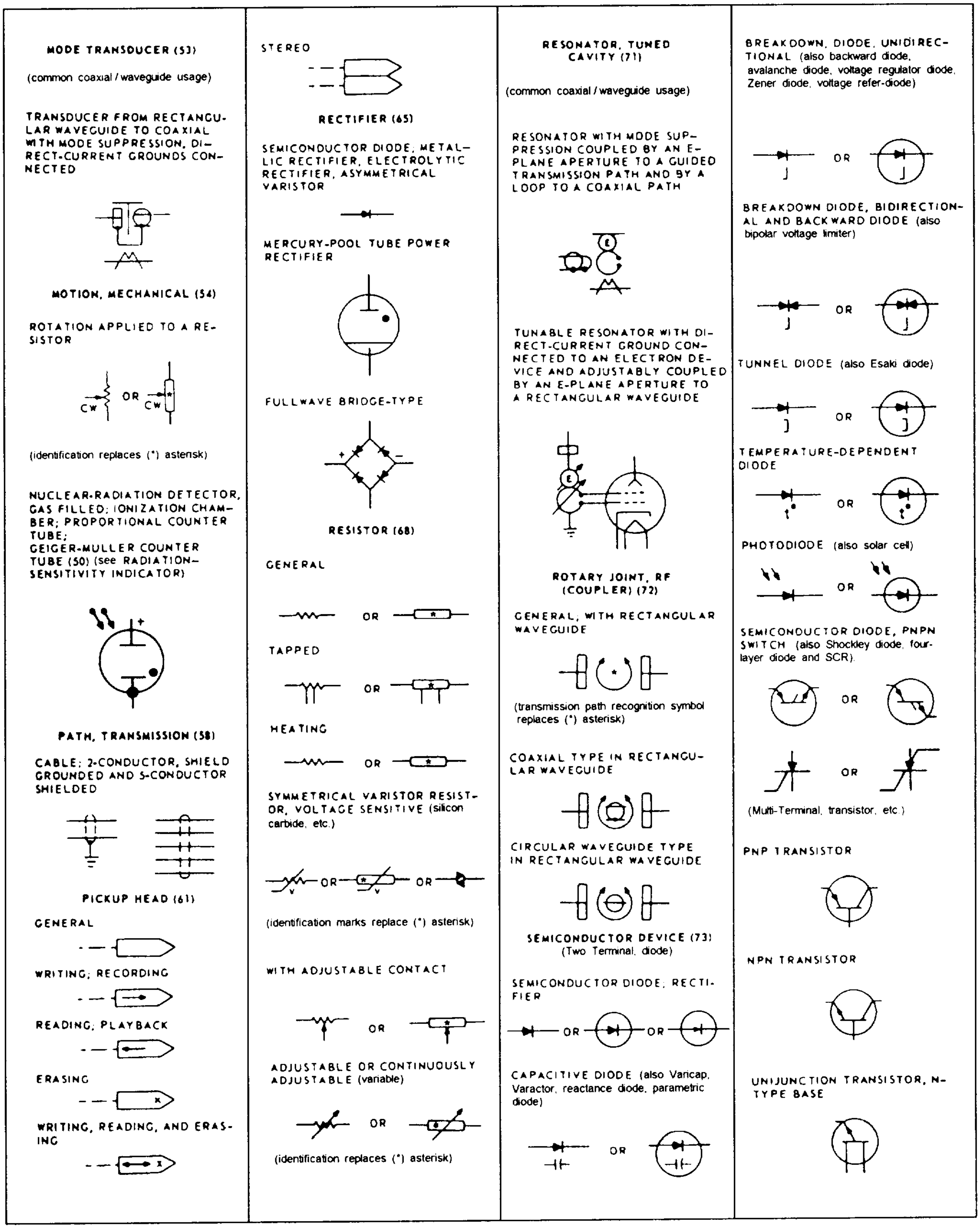


Figure AIII-1.—Electronic Symbols—Continued.

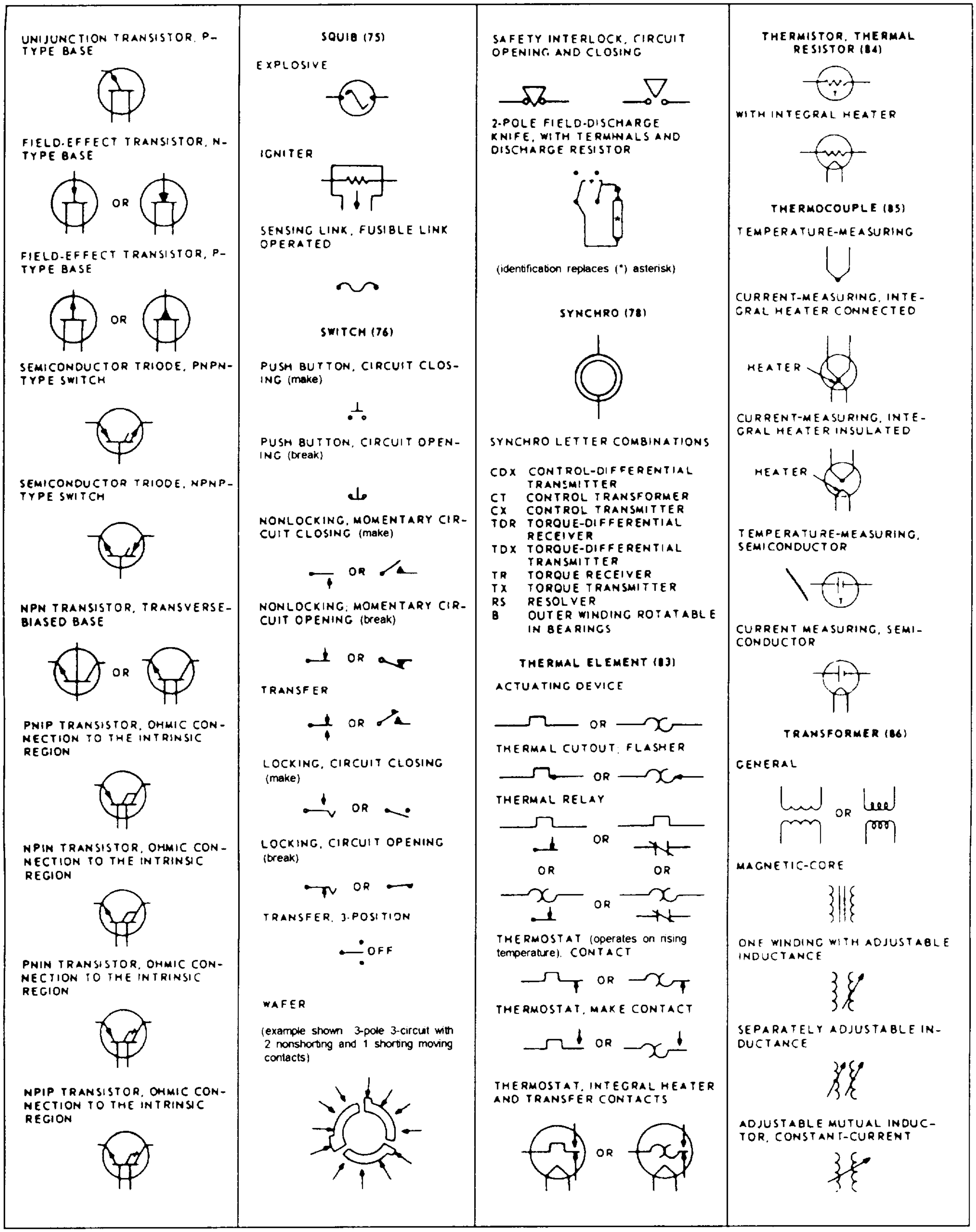


Figure AIII-1.—Electronic Symbols—Continued.

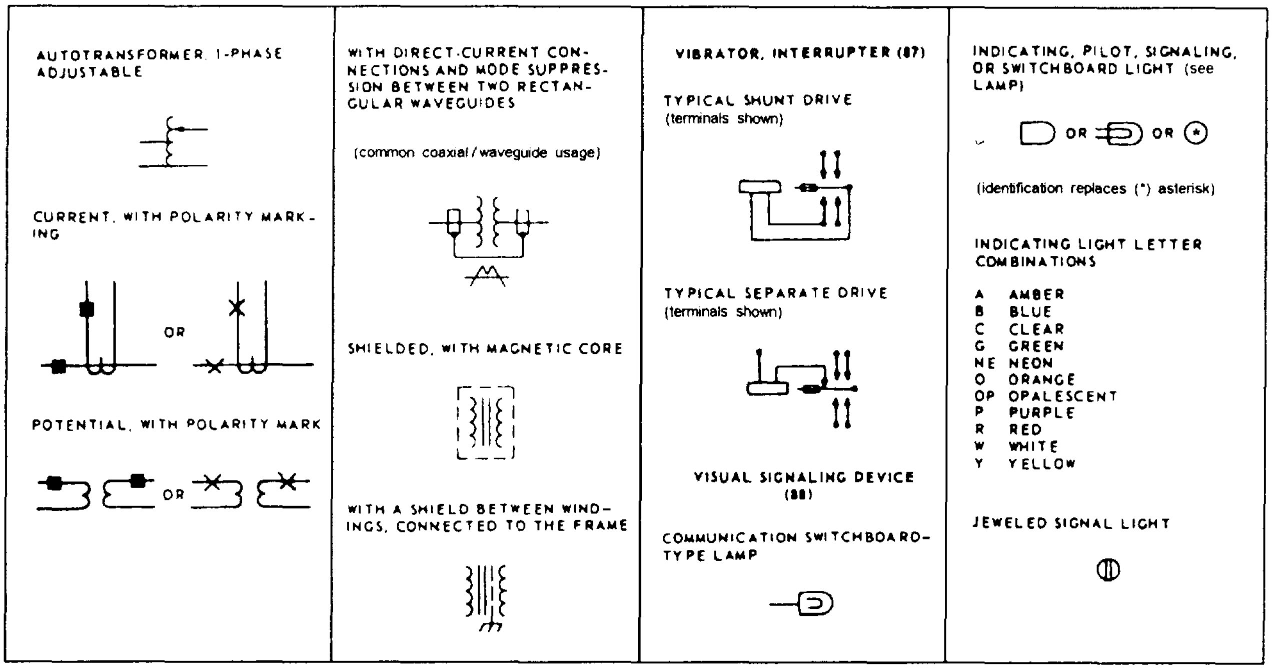


Figure AIII-1.—Electronic Symbols—Continued.

INDEX

S

T

V

W

ASSIGNMENT 1

Textbook Assignment: Chapter 1, “Electrical and General Safety Precautions,” pages 1-1 through 1-33.

1-1. Which of the following people is/are responsible for understanding and observing safety standards and regulations on board ship?

1. The commanding officer
2. The executive officer
3. All individuals
4. The chief engineer

1-2. Which of the following is a good safety practice?

1. Observe all posted operating instructions and safety precautions
2. Report any unsafe conditions or any equipment or material deficiency you think might be unsafe
3. Wear or use approved protective clothing or protective equipment
4. Each of the above

1-3. Which of the following statements concerning safety precautions is correct?

1. All applicable safety precautions should be committed to memory
2. A person should not worry about safety precautions because mishaps can and will happen
3. Safety precautions are designed primarily for persons who are unfamiliar with their equipment
4. It is important to understand the meanings of and reasons for safety standards

1-4. Which of the following publications specifically contains general shipboard safety precautions?

1. OPNAVINST 3120.32B
2. OPNAVINST 5100.19B
3. OPNAVINST 5100.23B
4. NAVEDTRA 10808-2

1-5. What color are (a) warning signs and (b) caution signs?

1. (a) Blue (b) green
2. (a) Green (b) blue
3. (a) Yellow (b) red
4. (a) Red (b) yellow

1-6. When are danger shock hazard signs used?

1. Where voltages are below 30 volts
2. Where voltages are between 30 and 100 volts only
3. Where voltages are between 30 and 500 volts
4. Where voltages are above 500 volts only

1-7. Warning plates are installed in small craft to warn personnel of what potential hazard?

1. Explosive vapors
2. High voltages
3. Wet decks
4. Oily decks

1-8. What color are (a) CAUTION tags and (b) DANGER tags?

1. (a) Red (b) yellow
2. (a) Yellow (b) red
3. (a) Red (b) orange
4. (a) Orange (b) yellow

1-9. When are CAUTION tags used?

1. When DANGER tags are not available
2. When equipment is secured for repairs
3. When temporary special instructions or unusual caution must be exercised to operate equipment
4. When operation of equipment could present a small danger to personnel

1-10. When are DANGER tags used?

1. When operation of equipment could injure personnel or damage equipment
2. When authorized by the commanding officer
3. When two or more repair groups are working on the same system
4. When repairing a major system

1-11. Which of the following statements is true concerning an instrument that is labeled OUT-OF-CALIBRATION?

1. It should be used with extreme caution
2. It should not be used
3. It should be repaired
4. It should be replaced

1-12. After a tag has been installed on a piece of equipment and the reason for the tag-out has been remedied, which of the following individuals may authorize the removal of the tag?

1. The division officer responsible for the equipment
2. The damage control assistant
3. The authorizing officer
4. The officer of the deck

1-13. Permission to work on an energized circuit must be approved by what person?

1. The engineering officer of the watch
2. The electrical officer
3. The engineer officer
4. The commanding officer

1-14. When you are working on energized equipment, which of the following safety precautions should you observe?

1. Be sure the equipment is grounded
2. Wear rubber boots
3. Make sure that a person qualified to administer mouth-to-mouth ventilation and cardiac massage is in the immediate area
4. Make sure that an insulated rope is tied around the worker's wrist

1-15. What type of electrical distribution systems are found on Navy ships?

1. Grounded
2. Ungrounded
3. Resistively grounded
4. Capacitively ungrounded

1-16. Isolated receptacle circuits are designed to limit ground leakage currents to how many milliamperes?

1. 1
2. 10
3. 100
4. 1000

1-17. When checking continuity between the equipment and the ship's hull on a piece of equipment that uses a ground strap, what reference should you use to determine the allowable resistance to ground?

1. OPNAVINST 3120.3B
2. Manufacturer's technical manual
3. PMS card
4. Fathom

1-18. Why must you short-circuit the secondary of a current transformer before you disconnect the meter?

1. To prevent damage to the primary circuit
2. To prevent blowing the meter fuses
3. To prevent overloading the circuit
4. To prevent an extremely high-voltage buildup

1-19. When, if ever, is it permissible to block open an interlock switch on a piece of equipment?

1. When performing PMS
2. When performing corrective maintenance
3. When authorized by the commanding officer for operational reasons
4. Never

1-20. To discharge capacitors in de-energized equipment, which, if any, of the following devices should you use?

1. A safety shorting probe
2. A ground strap
3. A screwdriver
4. None of the above

1-21. What class of rubber gloves should be selected if a person is to work around a piece of equipment rated at 5000 volts?

1. I
2. II
3. III
4. 0

1-22. When installing rubber floor matting, you should ensure there are no seams within what minimum distance of an electrical hazard?

1. 1 in.
2. 1 ft
3. 3 in.
4. 3 ft

1-23. Which of the following statements is correct?

1. Safety is unimportant in the use of power tools
2. Electrical power tools do not require cleaning or lubrication
3. Replace promptly any cable that has tears, chafing or exposed conductors, and any damaged plug
4. Metal electrical power tools do not require grounding

1-24. Why should a dummy outlet be installed near a workbench?

1. To test the grounding conductors on portable power tools
2. To serve as an extra test bench receptacle
3. To furnish power at frequencies other than the service frequencies of the ship
4. To furnish power at voltages other than the service voltages of the ship

1-25. What is an acceptable resistance reading for the ground connection between the ship's hull and metal frame of a portable electric drill?

1. Less than 1 ohm
2. 1 ohm or less
3. More than 1 ohm but less than 10 ohms
4. 10 ohms

1-26. Under normal usage, the maximum length of an extension cord used with portable tools should NOT exceed what total number of feet?

1. 25
2. 50
3. 75
4. 100

1-27. The current coil of a wattmeter or an ammeter must be connected in what way?

1. In parallel with the load
2. Across the power source terminals
3. In series with the load
4. In series with a shunt

1-28. In signal generators and oscilloscopes, how are the effects of moisture minimized?

1. By the storage box
2. By the cloth cover
3. Both 1 and 2 above
4. By the built-in heaters

1-29. Before being used on electronic equipment, metallic tools should be insulated by wrapping with what material?

1. Several layers of rubber or vinyl plastic tape
2. Two layers of rubber or vinyl plastic tape, half-lapped
3. Three layers of rubber or vinyl plastic tape, half-lapped
4. Four layers of rubber or vinyl plastic tape, half-lapped

1-30. To clean a soldering iron of excessive solder, which of the following procedures should you use?

1. Shake the soldering iron
2. Wipe the soldering iron across a piece of canvas
3. Wipe the soldering iron across a damp sponge
4. Use a brush

1-31. If cared for properly, lead-acid storage batteries should last for what maximum period of time?

1. Less than 1 year
2. 1 or 2 years
3. 3 years
4. 4 or more years

1-32. The charging rate of a lead-acid storage battery being charged should be lowered under which of the following circumstances?

1. If the battery begins to gas
2. If the temperature of the battery reaches 125°F (52°C)
3. Both 1 and 2 above
4. When the battery has finished charging

1-33. What is the proper procedure for mixing electrolyte?

1. Pour the acid slowly into the water
2. pour the acid quickly into the water
3. Pour the water slowly into the acid
4. Pour the water quickly into the acid

1-34. Where are alkaline storage batteries used?

1. Emergency supply for gyrocompasses
2. Emergency supply for automatic telephone exchanges
3. Bus failure alarms
4. Test equipment

1-35. Dry-cell batteries should be removed when the equipment they are used with is going to remain idle for what minimum length of time?

1. 1 wk
2. 2 wk
3. 1 mo
4. 2 yr

1-36. To remove large fragments of a broken radioactive tube, which, if any, of the following items should you use?

1. Forceps
2. Wet cloth
3. Vacuum cleaner
4. None of the above

1-37. Why should you always be extremely cautious when handling a CRT?

1. Because its glass envelope encloses a radioactive gas
2. Because its glass envelope encloses a compressed gas that may escape rapidly through the glass seal
3. Because its glass envelope encloses a high vacuum and may implode under atmospheric pressure
4. Because its glass envelope encloses a high pressure and may explode in direct sunlight

1-38. Before disposing of a CRT, you should break off the tip of the glass vacuum seal with what device?

1. Pliers
2. Screwdriver
3. Forceps
4. Hammer

1-39. What is the proper method for disposing of aerosol dispensers?

1. Puncture the dispenser
2. Burn in an incinerator
3. Break off the nozzle
4. Put in an approved waste receptacle

1-40. Which of the following solvents should NEVER be used for cleaning electrical equipment?

1. Water-based solvents
2. Inhibited methyl chloroform
3. 1, 1, 1-trichloroethane
4. Carbon tetrachloride

1-41. What is the preferred grade of insulating varnish used in the Navy?

1. CA
2. CB
3. CC
4. CD

1-42. Which of the following materials should NEVER be used to clean contacts?

1. Emery cloth/paper
2. Silver polish
3. Sandpaper
4. Burnishing tools

1-43. Before going aloft, personnel must obtain written permission from which of the following persons?

1. The electrical officer
2. The engineer officer
3. The officer of the deck
4. The ship's Boatswain's Mate

1-44. When working aloft aboard ship, you must always be equipped with which of the following items?

1. Special gloves
2. A sound-powered telephone
3. A safety harness and safety lanyard
4. A life preserver

1-45. Which of the following personal electrical equipment is authorized for use aboard ship?

1. Electric shavers
2. Electric heating pads
3. Electric fans
4. Electric tools

1-46. A fire breaks out in a piece of electrical equipment. What is the first thing you should do?

1. Sound an alarm
2. Secure all ventilation to the space
3. De-energize the piece of equipment
4. Attack the fire with the nearest extinguishing agent

1-47. What type of fire-extinguishing agent should be used on an electrical fire?

1. Potassium bicarbonate (PKP)
2. Soda acid
3. Carbon dioxide (CO_2)
4. Foam

1-48. Low-voltage (115 volts and below) circuits are NOT dangerous because they do not cause death.

1. True
2. False

1-49. The victim of electrical shock by a portable drill should be freed of contact with the drill as quickly as is safely possible for the rescuer. Which of the following is a quick and safe way to free the victim?

1. Turn the drill switch off
2. Cut the drill's power cable
3. Pull the fuses at the distribution box
4. Unplug the drill

1-50. A fireman suffers an electrical shock caused by contact with stationary equipment that CANNOT be de-energized quickly. In pulling the person free of contact with the equipment, under dry conditions, how should you take hold of the victim?

1. By one arm or one leg
2. By one arm and one leg
3. By both arms or both legs
4. With your own belt without the buckle

1-51. What is the purpose of artificial ventilation?

1. To restore the heart's function
2. To provide a method of air exchange
3. To clear an upper air passage obstruction
4. To clear a lower air passage obstruction

1-52. Artificial ventilation should be administered to which of the following persons?

1. One who has received an electrical shock and is breathing shallow
2. One who is knocked unconscious from an electrical shock and is bleeding
3. One who has been rescued from an electrical shock and has a fast pulse
4. One who has stopped breathing naturally due to an electrical shock

1-53. To be effective, cardiopulmonary resuscitation (CPR) must be started within what maximum length of time after a victim has suffered a cardiac arrest?

1. 5 minutes
2. 6 minutes
3. 3 minutes
4. 4 minutes

1-54. A wound that is often complicated by crushing of the tissues is classified as what type of wound?

1. A laceration
2. An incision
3. An abrasion
4. A puncture

1-55. When the direct-pressure method is used on a victim and fails to stop the bleeding, what action should you take?

1. Apply a tourniquet
2. Use the pressure point method only
3. Use both the direct-pressure method and the pressure-point method
4. Wait for trained medical personnel to arrive

1-56. What burns are for the most part NOT caused by heat?

1. Radiation
2. Chemical
3. Electrical
4. Thermal

1-57. What is the most important factor in determining the seriousness of a burn?

1. The extent of the body surface burned
2. The cause of the burn
3. The depth of the burn
4. The degree of the burn

1-58. Which of the following is a characteristic symptom of a second-degree burn?

1. Reddened skin
2. Blistered skin
3. Charred skin
4. Mild pain

1-59. Hazardous noise areas are areas that produce continuous and intermittent sound levels greater than what minimum level?

1. 54 dB(A)
2. 64 dB(A)
3. 74 dB(A)
4. 84 dB(A)

1-60. A worker should wear double hearing protection when working around noise sources above what minimum sound level?

1. 94 dB(A)
2. 100 dB(A)
3. 104 dB(A)
4. 140 dB(A)

1-61. Exposure of personnel to excessive heat, humidity, and thermal radiation while under a continued work load can result in which of the following conditions?

1. Heat stress
2. Heat stroke
3. Heat exhaustion
4. Each of the above

1-62. A heat stress survey must be ordered when the temperature in a space exceeds what minimum level?

1. 80°F
2. 90°F
3. 100°F
4. 110°F

ASSIGNMENT 2

Textbook Assignment: Chapter 2. "Switches, Protective Devices, and Cables," pages 2-1 through 2-53.

2-1. To what does the rating of a switch refer?

1. The numbers of poles and throws
2. The numbers of poles and positions
3. The minimum allowable voltage and current of the circuit in which the switch is to be used
4. The maximum allowable voltage and current of the circuit in which the switch is to be used

2-2. Switch contacts should be opened and closed slowly to minimize arcing.

1. True
2. False

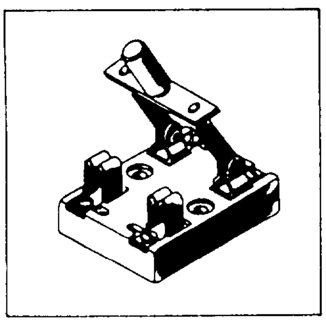


Figure 2A

IN ANSWERING QUESTION 2-3, REFER TO FIGURE 2A.

2-3. The single-throw switch has what total number of poles?

1. One
2. Two
3. Three
4. Four

2-4. What are the (a) voltage and (b) amperage ratings of the various types of toggle switches?

1. (a) 20 volts to 600 volts (b) 1 amp to 30 amps
2. (a) 10 volts to 500 volts (b) 10 amps to 50 amps
3. (a) 1 volt to 300 volts (b) 1 amp to 300 amps
4. (a) 5 volts to 400 volts (b) 20 amps to 600 amps

2-5. What is the normal contact arrangement of a push-button switch?

1. Make type
2. Break type
3. Either 1 or 2 above, depending on the type of switch
4. Make-break type

2-6. What does the first number in a rotary snap switch designation indicate?

1. The number of poles
2. The current rating
3. The switching action
4. The mounting style

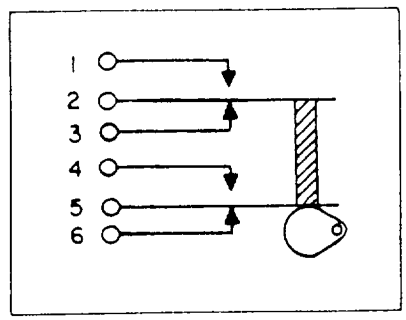


Figure 2B

IN ANSWERING QUESTION 2-7, REFER TO FIGURE 2B.

2-7. When the switch is operated, what terminals are connected together?

1. 2 and 3; 5 and 6
2. 1 and 3; 4 and 6
3. 1 and 2; 4 and 5
4. 1 and 2; 4 and 6

2-8. A type J multiple rotary switch with five sections has what total number of (a) stationary contacts and (b) movable contacts?

1. (a) 8 (b) 2
2. (a) 2 (b) 8
3. (a) 40 (b) 10
4. (a) 10 (b) 40

2-9. In the type 3JR switch, what total number of movable wiper contacts are there per section?

1. One
2. Two
3. Three
4. Four

2-10. What is the purpose of the stop deck of a JR switch?

1. It enables the switch to be installed with a nonuniform number of sections
2. It enables the switch to be connected to an independent source of ac power
3. It enables the switch to be set to a desired number of positions
4. It enables the switch to be used on dc circuits only

2-11. How does the JL switch compare to the JR switch?

1. The JR switch deck is smaller in diameter than the JL switch deck
2. The JL switch deck is larger in diameter than the JR switch deck
3. The JL switch is rated the same as the JR switch
4. The mounting of the JR switch is different than the JL switch

2-12. What kind of contacts are used in JA switches?

1. Silver-to-brass
2. Silver-to-bronze
3. Silver-to-copper
4. Silver-to-silver

2-13. The JF switch replaces what type of switch?

1. JR
2. Toggle
3. JA
4. Push-button

2-14. What type of interiors are used in most lever-operated switches?

1. J
2. JR
3. JA
4. JF

2-15. What means is used to distinguish the collision alarm switches on a submarine?

1. A round head
2. A square head
3. A star-shaped head
4. A triangle-shaped head

2-16. How is a typical pressure-operated switch similar to a typical temperature-operated switch?

1. Both are single-pole, single-throw, and quick-acting switches
2. Both contain a bellows or diaphragm that works against an adjustable spring
3. Both contain contacts that are closed automatically by an adjustable spring when a preset value of the operating condition is reached
4. Each of the above

2-17. How is the operating point of a cam-operated mechanical switch varied?

1. By adjusting the angular positions of the cams with respect to the shaft
2. By adjusting the position of the microswitch in relation to the cam
3. By adjusting the length of the lever arm
4. By adjusting the contact gap of the microswitch

2-18. How many pairs of terminals are used in water switches?

1. One
2. Two
3. Six
4. Four

2-19. How is the liquid-level float switch changed from normally open to normally closed?

1. By interchanging the connections
2. By replacing the encapsulated reed switch
3. By turning over the magnetic core
4. By turning over the encapsulated reed switch

2-20. Which of the following troubles is caused by excessive tightening of the packing gland nut on a watertight rotary switch?

1. Improper positioning of the switch
2. Warped seal
3. Scored shaft
4. Each of the above

2-21. When servicing a pair of copper contacts (one slightly burned, the other badly burned), which of the following procedures should you follow?

1. Replace both contacts
2. Clean both contacts with emery cloth
3. Replace the badly burned contact, and clean the other contact with fine sandpaper
4. Replace the badly burned contact, and clean the other contact with emery cloth

2-22. You should NOT attempt to remove the tarnish that forms on silver contacts for which of the following reasons?

1. Because you could damage the contacts
2. Because removal will cause the contacts to arc excessively
3. Because the tarnish improves the operation of the contacts
4. Because tarnished contacts should always be replaced not cleaned

2-23. What should you use to dress small light contacts?

1. A cloth moistened with an approved solvent
2. An approved lubricant
3. An emery cloth
4. A burnishing tool

2-24. How is the coil of a relay that is designed for shunt connection wound?

1. With a large number of turns of small wire
2. With a small number of turns of large wire
3. With a large number of turns of large wire
4. With a small number of turns of small wire

2-25. What is the purpose of the shorted turn used in ac relays?

1. To reduce heating
2. To reduce eddy currents
3. To reduce inductive reactance in the relay coil
4. To reduce chatter

2-26. How are control relays classified?

1. Open
2. Semisealed
3. Sealed
4. Each of the above

2-27. What causes the bimetallic strips of a thermal relay to bend when heat is applied?

1. Expansion of the restore spring
2. Magnetic induction
3. Difference in expansion rates of the strips
4. Lag coil or slug influencing their magnetic properties

2-28. What two windings are used in a latch-in relay?

1. Trip coil and the set coil
2. Set coil and the reset coil
3. Reset coil and the trip coil
4. Latch coil and the unlatch coil

2-29. To close the contacts of an ac shunt relay, a voltage must be applied to what component(s)?

1. The operating coil
2. The magnetic frame
3. The armature
4. The main contacts

2-30. What type of relay has multiple sets of contacts?

1. Clapper
2. Thermal time delay
3. Latch-in
4. Ac shunt

2-31. What total number of adjustments are there on a two-coil, series-type relay?

1. One
2. Two
3. Three
4. Four

2-32. What type of relays are also known as contractors?

1. Series
2. Shunt
3. Control
4. Power

2-33. The “cone and crater” effect that is associated with relay contacts is caused by what condition?

1. Current flowing in two directions through the relay
2. Dust collecting on the contacts
3. Current flowing in one direction through the relay
4. Rounding of flat contacts

2-34. When one of the contacts of a shunt relay is badly pitted, what action should you take?

1. Replace the relay
2. Replace the pitted contact
3. Replace the contacts
4. Dress the contacts

2-35. What should you use to clean relay contacts?

1. A burnishing tool
2. An emery cloth
3. Sandpaper
4. A file

2-36. When the relay contact springs are bent during cleaning, what action should you take?

1. Straighten the contact springs with long-nosed pliers
2. Straighten the contact with a point bender
3. Replace the contacts
4. Replace the relay

2-37. The magnetomotive force of a solenoid depends on which of the following factors?

1. The magnitude of current flowing through the coil
2. The number of turns of wire in the coil
3. The flux density of the core
4. Each of the above

2-38. Solenoids are used for which of the following reasons?

1. To convert electrical energy into mechanical motion
2. To convert mechanical motion into electrical energy
3. To replace relays
4. To replace switches

2-39. What is the second step in checking an improperly operating solenoid?

1. Check for opens
2. Check for grounds
3. Check the energizing voltage
4. Make a good visual inspection

2-40. Which of the following types of fuses is NOT normally used in naval vessels?

1. A plug fuse
2. A miniature cartridge fuse
3. A midget cartridge fuse
4. A knife-blade cartridge fuse

2-41. What is the maximum rating of a fuse that may be used on one associated group of an A-call circuit whose rated load is 9.1 amperes?

1. 5 amp
2. 10 amp
3. 15 amp
4. 20 amp

2-42. What type of fuse holder will hold two fuses?

1. EL-1
2. FHL10G
3. FHl11G
4. FHL12G

2-43. In replacing a blown fuse, which of the following procedures should you follow?

1. Short circuit the fuse
2. Open the switch to the circuit
3. Wear rubber gloves
4. Replace with a fuse of larger current capacity

IN ANSWERING QUESTION 2-44, REFER TO FIGURE 2-33 IN YOUR TEXTBOOK.

2-44. What is the purpose of fuses F1, F2, and F3?

1. To protect branch No. 1
2. To isolate branches No. 2 and No. 3
3. To protect the load
4. To protect the main feeder supply

2-45. The multifrequency-type voltage tester is designed to measure which of the following voltages?

1. 0 to 550 volts ac or 0 to 600 volts dc
2. 0 to 600 volts ac or 0 to 550 volts dc
3. 28 to 550 volts ac or 28 to 600 volts dc
4. 28 to 600 volts ac or 28 to 550 volts dc

2-46. What component supplies the energy that opens the contacts of an ACB circuit breaker?

1. A coil spring
2. A solenoid
3. A switch
4. A relay

IN ANSWERING QUESTION 2-47, REFER TO FIGURE 2-38 IN YOUR TEXTBOOK.

2-47. How is the instantaneous trip setting of the AQB-A250 circuit breaker adjusted?

1. By use of the trip coils
2. By use of the adjusting wheels
3. By use of the shunt trips
4. By use of the terminal studs

2-48. What type of circuit breaker must be manually operated to interrupt current flow?

1. Type ACB
2. Type AQB
3. Type NQB
4. Type ALB

2-49. What should you do to service severely burned silver contacts?

1. Wipe off the tarnish and apply a coating of oil
2. Wipe off the dirt and grease, then remove pits with emery cloth
3. Wipe off the dirt and grease, then remove the tarnish with emery cloth
4. File with a fine file or fine sandpaper

2-50. Which of the following problems is most likely to cause a circuit breaker relay magnet to chatter?

1. Rusty magnet sealing surfaces
2. Burned contacts
3. Shorted coils
4. Open coils

2-51. Under what conditions will a thermal-type overload relay open a circuit?

1. When the magnetic flux becomes great enough
2. When the magnetic flux becomes low enough
3. When the control shorts out
4. When the heater coil reaches a specific temperature

2-52. What type of thermal overload relay is used only in ac controllers?

1. Induction
2. Bimetal
3. Solder-pot
4. Single-metal

2-53. What type of overload relay uses an oil dashpot with a piston attached to the tripping armature of the relay?

1. Instantaneous
2. Time-delay
3. Bimetal
4. Single-metal

2-54. Low-smoke, low-toxic cable can be found in which of the following military specifications?

1. MIL-C-24643
2. MIL-C-24640
3. MIL-C-915
4. Each of the above

2-55. What type of cable is used aboard ship for permanent installation?

1. Watertight
2. Armored
3. Nonflexing
4. Flexing

2-56. Which of the following interpretations is applicable to a cable carrying the designation LSMSCA-30?

1. Low smoke, many conductors, shipboard, general use, conductor size 30 circular mils
2. Low smoke, multiple conductor, shipboard, control armored, 30 conductors
3. Low smoke, single conductor, armored, 30 ft
4. Low smoke, shipboard, casualty power, armored, 3000 circular mils

IN ANSWERING QUESTION 2-57, REFER TO TABLE 2-2 IN YOUR TEXTBOOK.

2-57. A cable designated LS7SGA-4 has what conductor identification code?

1. LTR-5
2. STD-4
3. LTR-4
4. STD-1

2-58. In a multiconductor cable, what is the color of the No. 5 conductor?

1. Green
2. White
3. Red
4. Orange

2-59. The No. 6 conductor in a telephone cable is what color?

1. Black
2. Blue
3. Purple
4. Pink

2-60. What total number of methods are there for applying identification to the conductors of a cable?

1. Six
2. Two
3. Eight
4. Four

2-61. What letter designation is used on cable tags to identify all cables and circuits for the IC systems in all naval ships?

1. C
2. I
3. IC
4. MB

2-62. Which of the following terminal markings is found on the negative terminal of a circuit designated EP?

1. EP
2. EEP
3. EPE
4. EPP

2-63. Which of the following is NOT a factor affecting cable insulation resistance?

1. Temperature of cable
2. Age of cable
3. Length of cable
4. Type of cable

2-64. What is the minimum acceptable insulation resistance reading for most IC cabling?

1. 0.20 megohm
2. 2.00 megohm
3. 0.22 megohm
4. 2.20 meghom

2-65. In measuring the circuit insulation resistance of a multiconductor cable, your first reading is taken between the cable armour and the metal bulkhead. It reads 0.8 megohm. What is your next step?

1. Check to see that the cable armor is grounded
2. Remove the ground from the cable
3. Check the accuracy of your test equipment
4. Connect all leads and measure the resistance to ground

2-66. One of the factors to consider when you are installing cable aboard ship include locating the cable in areas where which of the following conditions are satisfied?

1. Other equipment and cables cause no interference
2. Maximum dissipation of heat is provided
3. Damage from battle is minimized
4. All of the above

2-67. To remove cable from a modular support, what is the first thing you should do?

1. Loosen the compression bolt
2. Loosen the compression plate
3. Tighten down the compression bolt
4. Tighten the two bolts that separate the metal washers and the end packing

2-68. What type of stuffing tube uses a neoprene O-ring to ensure a watertight seal?

1. Nylon
2. Brass
3. Steel
4. Aluminum

2-69. Kickpipes, including stuffing tubes, should be what (a) minimum and (b) maximum height?

1. (a) 6 in. (b) 8 in.
2. (a) 8 in. (b) 12 in.
3. (a) 9 in. (b) 18 in.
4. (a) 12 in. (b) 24 in.

2-70. A riser box should be installed under which of the following conditions?

1. When passing cable through a watertight deck or bulkhead
2. When passing three or more cables through a deck in a single group
3. When passing cable through a nonwatertight deck
4. When passing cable into an electronic space that requires additional grounding

2-71. When connecting a newly installed cable, how much extra cable length should you allow in the enclosure for mistakes?

1. 1 1/4 times the length of the shortest conductor
2. 2 1/2 times the length of the longest conductor
3. 3 times the length of the shortest conductor
4. 2 times the length of the longest conductor

2-72. Solder-type terminals should be used for which of the following applications?

1. Lighting terminals
2. Interior communications
3. Wiring boxes with limited electrical clearances
4. Fire control circuits

2-73. You are about to single lace four conductors for a distance of 24 inches. If you use minimum spacing between hitches, approximately how many turns around the conductors are required to complete the lacing?

1. 24
2. 38
3. 44
4. 48

2-74. High-temperature, pressure-sensitive tape lacing should be used in areas where the temperature exceeds what minimum level?

1. 100°F
2. 150°F
3. 200°F
4. 250°F

2-75. The dialectic insulating material in radio-frequency coaxial cables is made of what type of material?

1. Silver-plated copper or braided copper
2. Braided aluminum or galvanized steel
3. Teflon or polyethylene
4. Neoprene rubber or silicone rubber

ASSIGNMENT 3

Textbook Assignment: Chapter 3, "Power Distribution, IC Switchboards, and Controllers," pages 3-1 through 3-26.

3-1. IC systems that are essential to the safety of the ship and ship personnel are assigned what readiness classification?

1. Class 1
2. Class 2
3. Class 3
4. Class 4

3-2. What is the importance classification of an IC system that, if disabled, would seriously impair the fighting effectiveness and maneuverability of the ship?

1. Unvital
2. Nonvital
3. Semivital
4. Vital

3-3. What are the three permanently installed power distribution systems aboard ship?

1. Ship's service, casualty, and lighting
2. Lighting, ship's service, and emergency
3. Casualty, emergency, and lighting
4. Emergency, casualty, and ship's service

3-4. Bus ties on ship's service distribution switchboards serve what function?

1. They allow power distribution direct from generator to load
2. They feed power to the dc generators
3. They allow generators to operate in series
4. They permit any switchboard to feed power to any other switchboard

3-5. The majority of ac power distribution systems in naval ships have which of the following characteristics?

1. 220 volts, single phase, 60 Hz
2. 220 volts, single phase, 400 Hz
3. 450 volts, 3 phase, 60 Hz
4. 450 volts, 3 phase, 400 Hz

3-6. When all electrical power is lost, the emergency generator is designed to start within what time period?

1. 1 sec
2. 10 sec
3. 1 min
4. 10 min

3-7. The emergency switchboard system is normally energized from what source?

1. The after emergency diesel
2. The forward emergency diesel
3. The alternate source of ship's service power
4. The preferred source of ship's service power

3-8. Casualty power bulkhead terminals are permanently installed on opposite sides of the bulkheads for what reason?

1. To permit selected equipment to receive casualty power
2. To permit transmission of power through compartments without the loss of watertight integrity
3. To permit transmission of power through decks
4. To permit phase checking for proper polarity

3-9. What is the main purpose of the casualty power system?

1. To make temporary connections to vital circuits
2. To make permanent connections to vital equipment
3. To make permanent connections to vital circuits
4. To make temporary connections to furnish power to ac generators

3-10. What is the proper procedure for rigging casualty power cables?

1. From source to load
2. From source to source
3. From load to source
4. From load to load

3-11. Most IC switchboards are normally energized by which of the following power supplies?

1. Normal and casualty power
2. Alternate and casualty power
3. Normal and emergency power only
4. Normal, alternate, and emergency power

3-12. Which of the following statements best describes a front-service main IC switchboard?

1. Terminal board inspection is accomplished through the rear access panel
2. Operation and maintenance are accomplished from the front of the switchboard
3. Maintenance is accomplished through the rear and side access panels
4. Operation and maintenance are accomplished from three sides of the switchboard

3-13. What panel in the power distribution section of the main IC switchboard supplies dc power to various IC circuits?

1. Panel 1
2. Panel 2
3. Panel 3
4. Panel 4

3-14. What are the functions of the ACO section of the main IC switchboard?

1. Isolation and transfer control of certain IC systems
2. Isolation and control of IC systems
3. Integration and operation of all IC systems
4. Integration and operation of special IC systems

3-15. When are ABTs used to transfer power supplies?

1. Upon loss of preferred power
2. Upon loss of emergency power
3. Upon loss or restoration of preferred power
4. Upon loss of alternate power

3-16. To test the automatic transfer capability of an ABT, the control disconnect switch must be in what position?

1. NORMAL
2. AUTO
3. MANUAL
4. EMERGENCY

3-17. Which of the following types of switches are usually found on IC switchboards?

1. Toggle and rotary
2. JL
3. JR
4. Each of the above

3-18. What is the power source for the type IC/E1D1 electronic signal unit?

1. A nickel-cadmium battery
2. 115 volts dc
3. 115 volts ac, 60 Hz
4. 115 volts ac, 400 Hz

3-19. When you operate an ACO transfer switch, what causes the overload indicator light to flash?

1. An open rotor circuit
2. A momentary displacement between the transmitter and receiver
3. A shorted rotor circuit
4. An open or shorted stator circuit

3-20. The engine-room local IC switchboard receives its emergency power supply from what source?

1. The nearest main IC switchboard
2. The nearest emergency switchboard
3. The nearest ship’s service switchboard
4. The local emergency lighting circuit

3-21. Inspection of de-energized equipment should be limited to visual examination only and should not include touching and shaking of electrical connections.

1. True
2. False

3-22. What should you use to clean the panels of live front switchboards?

1. A cloth dampened in soapy water
2. A cloth dampened in clear water
3. A dry cloth
4. A cloth dampened in a cleaning solution

3-23. When inspecting an IC switchboard, which of the following components should you inspect?

1. Rheostats
2. Meters
3. Fuses
4. All of the above

3-24. Bus transfer equipment should be tested a minimum of how often?

1. Daily
2. Weekly
3. Monthly
4. Yearly

3-25. Circuit breakers should be carefully inspected a minimum of how often?

1. Daily
2. Weekly
3. Monthly
4. Yearly

3-26. Silver-alloy contacts must be replaced if slight burning, pitting, or erosion is found.

1. True
2. False

3-27. Ship's force personnel may not make repairs on which of the following components?

1. Bolt-on parts
2. Attachments
3. Subassemblies
4. Meters

3-28. Under normal conditions, the motor generator set and control equipment should be inspected and cleaned according to what guidelines?

1. At least yearly
2. At least monthly
3. IAW the MRCs
4. IAW the technical manual

3-29. Suction cleaning of motors and generators is preferred to other methods because it lessens the possibility of damage to which of the following components?

1. Brushes
2. Insulation
3. Commutators
4. Soldered parts

3-30. You should use air pressure up to 30 psi to clean out motors and generators of what maximum rated (a) horsepower or (b) kilowatts?

1. (a) 50 (b) 50
2. (a) 25 (b) 30
3. (a) 60 (b) 70
4. (a) 90 (b) 100

3-31. Which of the following factors determines the grade of brush used in a motor or generator?

1. The time in service
2. The size of the motor or generator
3. The load and speed of the motor or generator
4. Each of the above

3-32. When should you install new brushes in a generator or motor?

1. When the brushes have enclosed shunts
2. When the brushes have a polished surface
3. When the brushes are worn to within 1/8 inch of the metallic parts
4. When the polarity of the brushes is reversed

3-33. To calculate brush pressure, you should use which of the following methods?

1. Subtract the spring pressure from the brush contact area
2. Subtract the brush contact area from the spring pressure
3. Divide the brush contact area by the spring pressure
4. Divide the spring pressure by the brush contact area

3-34. When seating a brush, you should use sandpaper and what other equipment?

1. An oil stone
2. A brush seater
3. Emery paper
4. A file

3-35. When seating a brush you should place the sandpaper between the brush and the commutator with the rough side toward (a) what component and (b) pull in what direction?

1. (a) The brush
   (b) direction of rotation
2. (a) The commutator
   (b) opposite the direction of rotation
3. (a) The commutator
   (b) direction of rotation
4. (a) The brush
   (b) opposite the direction of rotation

A.	Use No. 0 sandpaper
B.	Use the brush seater at the heel of the brush
C.	Use No. 1 sandpaper
D.	Vacuum the carbon dust from the commutator
E.	Vacuum the white powder from the brush holders and windings

Figure 3A

IN ANSWERING OUESTION 3-36, REFER TO THE PROCEDURAL STEPS FOR SEATING BRUSHES SHOWN IN FIGURE 3A.

3-36. Which of the following is the proper sequence for seating brushes?

1. A, C, D, B, E
2. C, B, A, D, E
3. A, C, B, D, E
4. C, A, D, B, E

3-37. To complete the job of seating the motor brushes, you should perform which of the following steps?

1. Pull a finer strip of sandpaper between the brush and the commutator once or twice, vacuum the dust that results, and clean the heel of the commutator
2. Turn the sandpaper over, sandpaper again, and touch the seater to the heel of the brush for a second or two
3. Touch the seater to the commutator for one or two seconds, vacuum the dust that results, and clean the commutator
4. Lift the brush, insert the seater between the brush and commutator for a second or two, and clean the commutator

3-38. The commutator of a machine should develop a uniform, glazed, dark brown color on places where the brush rides after being used for approximately what minimum length of time?

1. 1 week
2. 2 weeks
3. 3 weeks
4. 4 weeks

3-39. Which of the following types of roller bearings are generally used in the construction of motors and generators?

1. Radial
2. Angular contact
3. Thrust
4. All of the above

3-40. What type of bearing is designed to support loads resulting from forces that are applied perpendicularly to the shaft?

1. Thrust
2. Radial
3. Sleeve
4. Angular

3-41. In motor construction, what factor determines whether a thrust or radial bearing is installed?

1. If the bearing housing is or is not disassembled to renew bearing grease
2. If the drain holes on the bearing housing are accessible
3. If the motor is mounted vertically or horizontally
4. If the rotor has clockwise or counterclockwise rotation

3-42. In operating machinery, malfunctioning ball bearings may be indicated by which of the following symptoms?

1. Arcing brushes
2. A loss of speed
3. A high temperature
4. Each of the above

3-43. When a motor is started, serious trouble can be expected in a bearing if high temperatures are reached within what minimum length of time of operation?

1. 50 to 60 min
2. 30 to 40 min
3. 20 to 25 min
4. 10 to 15 min

3-44. Ball bearings are more noisy in normal operation than sleeve bearings.

1. True
2. False

3-45. Vertical movement of a motor shaft indicates that the bearings are in good condition.

1. True
2. False

3-46. When grease cups for a motor are not being used to grease bearings, where should they be kept?

1. In the custody of the responsible maintenance personnel
2. In the custody of the chief engineer
3. On a wire attached to the motor
4. On a wire attached to a pipe plug

3-47. In the absence of other instructions, at what level should you maintain the oil in an oil-lubricated, ball-bearing motor housing?

1. Level with the center of the bearing
2. Level with the top of the bearing
3. Almost level with the lowest point of the bearing inner ring
4. Almost level with the highest point of the bearing inner ring

3-48. You can clean a double-sealed ball bearing only in an emergency when a suitable replacement is not available.

1. True
2. False

3-49. To prevent damage to a bearing that you are pulling, you should place the bearing puller on the shaft and what other assembly?

1. The oiler ring
2. The outer race
3. The shield
4. The inner race

3-50. When the sleeve bearings of a motor overheat, what action should you take as a watch stander?

1. Stop the motor without securing the load
2. Stop the motor immediately after securing the load
3. Continue to run the motor at full load until the bearing cools
4. Continue to run the motor at a light load until the bearing cools

ASSIGNMENT 4

Textbook Assignment: Chapter 4, "Gyrocompass Systems," pages 4-1 through 4-61.

4-1. The supporting rings of a gyroscope are known as

1. gimbals
2. axles
3. bearings
4. rotors

4-2. How are the X, Y, and Z axes related to each other?

1. They are vertical to each other
2. They are parallel to each other
3. They are horizontal to each other
4. They are perpendicular to each other

4-3. A gyroscope rotor has how many degrees of freedom?

1. One
2. Two
3. Three
4. Four

4-4. What two properties make it possible to convert a free gyroscope into a gyrocompass?

1. Precession and rigidity of plane
2. Spin and tilt
3. Tilt and turn
4. Rigidity of plane and spin

4-5. If the case of a spinning gyroscope is tilted to the left, what, if anything, will happen to the rotor axle?

1. It will tilt to the left
2. It will tilt to the right
3. It will point in the same direction as the case
4. Nothing, it will not change direction

4-6. How can a gyroscope be made more rigid?

1. By concentrating most of the rotor weight away from the circumference
2. By making the rotor spin slower
3. By making the rotor lighter
4. By concentrating most of the rotor weight near the circumference

4-7. How does a gyro react to the application of torque?

1. It will move at left angles to the direction of torque
2. It will move at right angles to the direction of torque
3. It will spin faster
4. It will spin slower

4-8. If force is applied to the wheel of a spinning gyroscope, where will this force be felt?

1. At the point it is applied
2. At a point 45° away in the opposite direction of rotation
3. At a point 90° away in the direction of rotation
4. At a point 90° away in the opposite direction of rotation

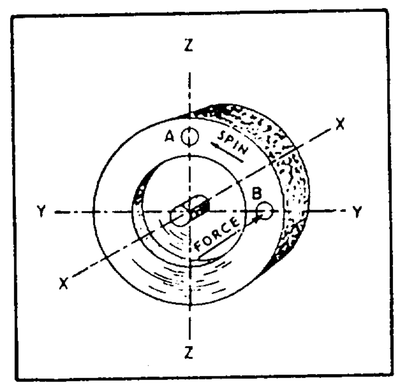


Figure 4A

IN ANSWERING QUESTION 4-9, REFER TO FIGURE 4A.

4-9. In the figure, in what direction will point A move?

1. About the Y axis in the direction of the applied force
2. About the Y axis opposite to the direction of the applied force
3. About the Z axis in the direction of the applied force
4. About the Z axis opposite to the direction of the applied force

4-10. Force of translation is best described by which of the following phrases?

1. Any force operating through the vertical axis
2. Any force caused by precession around the horizontal axis
3. Any force operating through the tilt axis
4. Any force operating through the center of gravity

4-11. A free-spinning gyroscope is located at a point on the equator during a 24-hour period. What will be the apparent effect of the earth's rotation on the gyroscope, as seen from the South Pole?

1. The gyroscope will make a complete clockwise revolution about its vertical axis
2. The gyroscope will make a complete clockwise revolution about a horizontal axis
3. The gyroscope will make a complete counterclockwise revolution about its vertical axis
4. The gyroscope will make a complete counterclockwise revolution about a horizontal axis

4-12. An observer is located in space above a free-spinning gyroscope located at the North Pole. What will be the apparent effect of the earth's rotation on the gyroscope during a 24-hour period of time?

1. The gyroscope will make a complete clockwise revolution about a horizontal axis
2. The gyroscope will make a complete counterclockwise revolution about a horizontal axis
3. The gyroscope will remain stable while the earth will appear to rotate under it
4. The gyroscope will make a complete counterclockwise revolution about its vertical axis

4-13. You are observing a free-spinning gyroscope with the spinning axis not parallel to the earth's axis. What is the effect of the earth's rotation during the part of the day that the north end of the gyroscope axle points to the east of the meridian?

1. The north end moves up
2. The south end moves up
3. The east end moves up
4. The west end moves up

4-14. To make a free gyroscope into a gyrocompass, what must you do?

1. Make the gyro axle point to the North Pole
2. Keep the gyro axle nearly horizontal
3. Both 1 and 2 above
4. Point the gyro axle to the east or west

4-15. How is the gyroscope made north-seeking?

1. By adding a nonpendulous weight to the bottom of the vertical ring
2. By adding a nonpendulous weight to the phantom ring
3. By adding a pendulous weight to the phantom ring
4. By adding a pendulous weight to the bottom of the vertical ring

4-16. How is the gyroscope made north-indicating?

1. By adding a smaller weight on the east side of the rotor
2. By adding a larger weight on the east side of the rotor
3. By adding a smaller weight on the west side of the rotor
4. By adding a larger weight on the west side of the rotor

4-17. How is the basic gyrocompass made to function properly over a wide range of latitudes?

1. By stabilizing it with respect to the earth's surface
2. By damping out the effects of ship's acceleration
3. By damping out the effects of ship's deceleration
4. All of the above

4-18. What does the mark (Mk) indicate in the designation of a gyrocompass?

1. A major development of a compass
2. A minor development of a compass
3. Change to a major development of a compass
4. Change to a minor development of a compass

4-19. The Mk 23 Mod 0 gyrocompass system uses a gravity reference which generates what kind of signal?

1. One that is inversely proportional to the speed of the gyro rotor
2. One that is inversely proportional to the tilt of the gyro axle
3. One that is directly proportional to the speed of the gyro rotor
4. One that is directly proportional to the tilt of the gyro axle

4-20. The Mk 23 Mod 0 gryocompass element has how many degrees of freedom about the pitch and roll axes?

1. ± 45°
2. ± 70°
3. ± 85°
4. ± 90°

4-21. Which of the following components is NOT found in the control cabinet?

1. The follow-up amplifier
2. The alarm control unit
3. The power supply
4. The control amplifier

4-22. What is the speed range of the speed unit?

1. 0 to 10 knots
2. 0 to 20 knots
3. 0 to 40 knots
4. 0 to 100 knots

4-23. Under normal conditions, what is the status of the lamp on the visual indicator?

1. It lights continuously
2. It flashes continuously
3. It is out
4. It flashes momentarily

4-24. In what location will you find the instruction plate that has a summary of the procedure for starting and securing the gyrocompass under normal conditions?

1. Top of the master unit
2. Front of the master unit
3. Top of the control cabinet
4. Front of the control cabinet

4-25. How many modes of gyrocompass operation are there?

1. One
2. Two
3. Three
4. Four

4-26. Before a compass is needed for service, as a minimum, how far ahead of time should you start it?

1. 30 min
2. 60 min
3. 75 min
4. 120 min

4-27. Before you start the compass, what should be the respective settings of the power and operation switches?

1. GYRO and UNCAGE
2. GYRO and LEVEL
3. OFF and SETTLE
4. OFF and CAGE

4-28. During the preliminary procedure for operating the gyrocompass, in what order do you set the latitude switch, latitude dial, and speed unit?

1. Latitude dial, latitude switch, and speed unit
2. Latitude dial, speed unit, and latitude switch
3. Latitude switch, latitude dial, and speed unit
4. Latitude switch, speed unit, and latitude dial

4-29. After you complete the preliminary procedure for operating the gyrocompass, what should be your first step in the starting procedure?

1. Position the power switch to AMPL'S
2. Position the power switch to FIL'S
3. Position the power switch to GYRO
4. Set the ship's heading on the compass card

4-30. Before you place the operation switch in the NORMAL position, it should be left in the SETTLE position for what length of time?

1. 10 to 20 min
2. 20 to 30 min
3. 30 to 40 min
4. 40 to 60 min

4-31. If the power to the compass fails, in what position should you place the (a) power switch and (b) operation switch?

1. (a) ON (b) CAGE
2. (a) OFF (b) UNCAGE
3. (a) FIL'S (b) UNCAGE
4. (a) FIL'S (b) CAGE

4-32. What is the normal procedure for shutting down the compass?

1. Set the power switch to OFF, wait 30 minutes, then place the operation switch to CAGE
2. Set the operation switch to CAGE, wait 10 seconds, then turn the power switch to OFF
3. Set the operation switch to UNSETTLE, wait 30 to 40 minutes, then turn the power switch to OFF
4. Set the power switch to OFF, then without waiting, turn the operation switch to UNCAGE

4-33. How much of a change in ship's latitude requires you to manually correct the setting on the latitude dial?

1. 1°
2. 2°
3. 1 1/2°
4. 1/2°

4-34. Which of the following is NOT a normal operating condition for the compass?

1. The master unit being lukewarm
2. The tilt indicator pointer oscillating evenly about the zero position
3. The corrector failure and follow-up failure lamps lighted
4. The speed dial indicating zero knots during directional gyro operation

4-35. What information is contained in the gyrocompass log?

1. Compass conditions and available power sources
2. Name and rate of the gyrocompass technician
3. Date the gyrocompass was installed on the ship
4. Recommendations for future reference

4-36. How many additional units, if any, are used with the Mk 23 Mod C-3 gyrocompass system that are NOT used with the Mk 23 Mod 0?

1. One
2. Two
3. Three
4. None

4-37. Prior to starting the Mk 23 Mod C-3 gyrocompass, the switch on the power supply control unit must be in what position?

1. START
2. STOP
3. ON
4. OFF

4-38. The Mk 27 gyrocompass is designed to operate on which of the following voltages?

1. 115 volts, 60 hertz, single phase
2. 115 volts, 400 hertz, single phase
3. 24 volts dc
4. Each of the above

4-39. What is used to make the compass north-seeking?

1. A liquid ballistic filled with mercury
2. A liquid ballistic filled with refined silicone oil
3. A liquid ballistic filled with lukewarm water
4. A liquid ballistic filled with special gases

4-40. Where is the instruction plate for starting and securing the compass located?

1. Near the electronic control cabinet
2. On the front of the electronic control cabinet
3. On the front of the power supply
4. On the top of the master unit

4-41. Which, if any, of the following devices is used in the master unit to allow for temperature variation?

1. A centrifugal fan
2. A small air conditioner
3. A bellows assembly
4. None of the above

4-42. The meridian gyro is the upper gyro element. It always provides heading information for the Mk 19 Mod 3A gyrocompass.

1. True
2. False

4-43. Which of the following statements best describes the relationship between the slave and meridian gyro elements of the Mk 19 Mod 3A gyrocompass?

1. Their planes of rotation are displaced by 180°
2. Their planes of rotation are displaced by 90°
3. Their planes of rotation are displaced by 45°
4. Their planes of rotation are not displaced

4-44. On a course of 270°, the slave element of the Mk 19 Mod 3A provides which of the following data?

1. Heading data
2. Roll data only
3. Pitch data only
4. Roll and pitch data

4-45. The Mk 19 Mod 3A gyrocompass has an accuracy of 0.1° in azimuth and roll and pitch up to what latitude?

1. 60°
2. 70°
3. 80°
4. 90°

4-46. The compass element of the Mk 19 Mod 3A gyrocompass has how many degrees of freedom about the roll axis?

1. ± 62°
2. ± 60°
3. ± 42°
4. ± 40°

4-47. The battery bank for the backup power supply of the Mk 19 Mod 3A gyrocompass consists of (a) what total number of batteries and (b) of what voltage each?

1. (a) 12 (b) 10 V
2. (a) 10 (b) 12 V
3. (a) 20 (b) 6 V
4. (a) 6 (b) 20 V

4-48. When normal power is lost to the ship, at what voltage will the standby power supply for the Mk 19 Mod 3A gyrocompass automatically connect?

1. 105 V
2. 112 V
3. 113 V
4. 120 V

4-49. What total number of major systems are there in the Mk 19 Mod 3A gyrocompass system?

1. One
2. Two
3. Three
4. Four

4-50. The meridian gyro control system includes the gravity reference system, the azimuth control system, and the leveling control system. These systems control the meridian gyro in the same manner as the Mk 23 compass control system.

1. True
2. False

4-51. What total number of compensation signals are there in the Mk 19 Mod 3A gyrocompass system?

1. Nine
2. Eight
3. Six
4. Four

4-52. Which of the following factors causes azimuth or leveling errors?

1. Ship effect
2. Earth effect
3. Constant torque effect
4. Each of the above

4-53. Changes in the ship's speed will cause compass errors if not compensated. How are errors caused by acceleration of the ship compensated?

1. By the manual corrector
2. By mercury ballistics
3. By the electrolytic bubble level
4. By the E-core transformer

4-54. When starting the Mk 19 Mod 3A gyrocompass, what maximum length of time does it take the blue ready lamp to light after the master switch is placed in the ON position?

1. 30 sec
2. 1 min
3. 5 min
4. 11 min

4-55. When starting the Mk 19 Mod 3A gyrocompass, the own ship's course dial can be misaligned from the ship's heading by what maximum number of degrees?

1. 1°
2. 5°
3. 10°
4. 100°

4-56. When starting the Mk 19 Mod 3A gyrocompass, the latitude computer dial is allowed to be how many degrees off local latitude?

1. 1°
2. 10°
3. 11°
4. 0°

4-57. When starting the Mk 19 Mod 3A gyrocompass, at what time do you press the RUN button?

1. After checking the latitude computer dial
2. After checking the own ship's course dial
3. Immediately after the blue ready light is lighted
4. After the compass is completely settled

4-58. After the MK 19 Mod 3A gyrocompass is completely settled and the mode selector switch has been placed in the NORMAL mode, what should be the color of the alarm lamps?

1. All alarm lamps should be red
2. The compass control alarm lamps should be red, and the follow-up alarm lamps should be green
3. The compass control alarm lamps should be green, and the follow-up alarm lamps should be red
4. All alarm lamps should be green

4-59. What person normally grants permission to secure the gyrocompass after the ship has returned to port?

1. The engineer officer
2. The navigator
3. The commanding officer
4. The ship's gyrocompass technician

4-60. The Mk 19 Mod 3B gyrocompass uses a motor-generator standby power supply instead of the static standby supply used with the Mk 19 Mod 3A.

1. True
2. False

4-61. What is the ambient operating temperature of the Mk 19 Mod 3B gyrocompass?

1. 100°F
2. 110°F
3 149°F
4. 249°F

4-62. When is the high latitude mode of operation used with the Mk 19 Mod 3B gyroscope?

1. Between 65° and 76° latitudes
2. Between 75° and 86° latitudes
3. Above 86° latitude
4. Above 90° latitude

4-63. When starting the Mk 19 Mod 3B gyrocompass in the high latitude mode of operation, what should be your first step?

1. Place the mode selector switch to HIGH LATITUDE
2. Place the mode selector switch to FIL'S
3. Turn the master switch to the ON position
4. Place the mode selector switch to DG

4-64. In the high latitude mode of operation, what maximum length of time should the Mk 19 Mod 3B gyrocompass take to settle?

1. 1 hr
2. 2 hr
3. 30 min
4. 4 hr

4-65. If the ship has been maneuvering, how long, if at all, should you wait before changing from the high latitude mode to the directional gyro mode of operation?

1. 11 min
2. 2 hr
3. 30 min
4. No waiting time is required

4-66. When the compass heading is within 10° of true north, what should you do to change from the directional gyro mode to the high latitude mode of operation?

1. Stop the compass and restart it
2. Turn the mode selector switch to HIGH LATITUDE
3. Turn the master switch to the OFF position
4. Turn the mode selector switch to the FIL'S position

4-67. The static power supply of the Mk 19 Mod 3C gyrocompass system is used as the primary power supply as well as the standby power supply.

1. True
2. False

4-68. What device(s) is/are used in the Mk 19 Mod 3C gyrocompass as the gravity reference system?

1. An electrolytic level
2. A liguid ballistic
3. Special weights
4. An accelerometer

4-69. The optical cube in the Mk 19 Mod 3E gyrocompass system serves what purpose?

1. It permits satellite interfacing
2. It permits precise alignment of the compass during compass installation
3. It permits the compass to settle faster during starting
4. It permits the compass to operate in higher latitudes

4-70. Which of the following statements best describes a Mk 19 Mod 3RC gyrocompass system?

1. It is a factory rebuilt Mod 3, rebuilt to Mod 3C specifications
2. It is a factory rebuilt Mod 3, rebuilt to Mod 3AC specifications
3. It is a factory rebuilt Mod 3R, rebuilt to Mod 3C specifications
4. It is a factory rebuilt Mod 3C, rebuilt to Mod 3RC specifications

4-71. The AN/WSN-2 stabilized gyrocompass set is comprised of what total number of major assemblies?

1. One
2. Two
3. Five
4. Six

4-72. During normal power failure, the battery set will provide power for approximately what maximum length of time?

1. 15 min
2. 30 min
3. 45 min
4. 60 min

4-73. To ensure accuracy of outputs of the set, as a minimum, how often should the AUTO CAL mode of operation be used during continuous operation?

1. Every 30 days
2. Every 60 days
3. Every 90 days
4. Every 120 days

4-74. During an emergency condition, what is the first step you should take in securing the compass?

1. Place the MODE control in the POWER OFF position
2. Place the PWR switch in the OFF position
3. Place the SYN REF switch in the OFF position
4. Place the MODE control in the EMERGENCY SHUT-OFF position

4-75. The 2.5-volt antistickoff voltage is obtained from what component(s)?

1. A transformer in the amplifier unit
2. The power supply transformer
3. S1 and S2 synchro terminals
4. R1 and R2 synchro terminals

ASSIGNMENT 5

Textbook Assignment: Chapter 5, "Sound-Powered Telephone System"; and Chapter 6, "Automatic Dial Telephone System,"; pages 5-1 through 6-10.

5-1. What is the purpose of the line cutout portion of a switchjack on a sound-powered telephone switchboard?

1. Only to connect a telephone station jackbox to a circuit
2. Only to disconnect a telephone station jackbox from its circuit
3. To connect or disconnect a telephone station jackbox from its circuit
4. To parallel a telephone station jackbox to another telephone station jackbox

5-2. String-type circuits usually fall under what classification?

1. Primary
2. Supplementary
3. Auxiliary
4. Emergency

5-3. What is the circuit designation of the flag officer's circuit?

1. JA
2. JC
3. JF
4. 1JG

5-4. What shipboard circuit is designated 3JZ?

1. Aircraft service
2. Mirror deck landing sight
3. Surface search radar
4. Main deck repair circuit

5-5. How do you parallel a primary circuit with an auxiliary circuit?

1. By use of a tie switch or a tie plus switch
2. By use of a patch cord or a jackbox
3. By use of a tie plus switch or a patch cord
4. By use of a tie switch or a patch cord

5-6. Which of the following is a disadvantage of paralleling sound-powered telephone circuits?

1. Several different stations can be controlled by one station
2. It requires the use of additional telephone talkers
3. Overloaded transmitters
4. Lost communications can be reestablished easily

5-7. Which of the following spaces does NOT have a permanently installed X40J jackbox?

1. Central control stations
2. Bridge
3. Engine rooms
4. Emergency generator rooms

5-8. Phone/distance and station-to-station lines are used under which of the following conditions?

1. During replenishment at sea
2. During general quarters
3. When all other sound-powered communications are lost
4. When primary circuit communications are lost

5-9. When you conduct insulation tests on sound-powered circuits, which of the following is a proper procedure to follow?

1. Disconnect all sound-powered telephone headsets from the circuit
2. Disconnect all sound-powered telephone handsets from the circuit
3. Close all tie switches connected to the circuit
4. Open all line cutout switches on associated switchboards or switchboxes

5-10. What is the source of power for sound-powered telephones?

1. A 24-volt battery
2. A 117-volt source
3. A 120-volt source
4. Sound waves produced by the talker's voice

5-11. When using the sound-powered telephone handset, you must depress switch S1 to perform which of the following functions?

1. For transmitting only
2. For receiving only
3. For transmitting and receiving
4. For tone compensation

5-12. The transmitter and receiver units in a sound-powered telephone handset are NOT interchangeable.

1. True
2. False

5-13. When sound waves strike the diaphragm of a sound-powered transmitter unit, what happens first?

1. A switch turns on the unit
2. The free end of the armature moves to a position exactly midway between the pole pieces
3. The diaphragm vibrates
4. The number of magnetic lines of force passing lengthwise through the armature is sharply reduced

5-14. What is the maximum number of sound-powered handsets you can connect in parallel and still maintain efficiency?

1. One
2. Two
3. Three
4. Four

5-15. What is the purpose of capacitor C1 in a sound-powered headset-chestset?

1. It is used for power-factor correction
2. It prevents the flow of dc through the receiver units when the set is used with a sound-powered telephone amplifier
3. It improves the acoustical quality of the set
4. It is used for tone compensation

5-16. Which of the following types of sound-powered headset-chestsets uses the press-to-talk switch in a junction box clipped to the talker's belt?

1. H-200/U
2. H-201/U
3. H-202/U
4. H-203/U

5-17. What maximum number of sound-powered telephone headset-chestsets can be connected in parallel before line level response is considered critical?

1. 10
2. 15
3. 20
4. 25

5-18. What part of a sound-powered telephone headset-chestset might be damaged if it were stowed with soap powder?

1. The cord
2. The switch
3. The diaphragm
4. The stowage box

5-19. When repairing sound-powered telephones, what main hazard exists, if you work on a dirty workbench?

1. Dust may get into the PRESS-TO-TALK switch and short-circuit it
2. Iron filings may come into contact with the magnets and be difficult to remove
3. Moisture may reach the coils and ruin the insulation
4. Dust may come into contact with the armature and drive rod and cause distortion of the signal

5-20. If an entire sound-powered telephone circuit is inoperative, what is the most probable cause?

1. A short circuit
2. An open circuit
3. A loss of sensitivity
4. A broken switch

5-21. What is the proper procedure for testing a sound-powered handset for loss of sensitivity?

1. Depress the PRESS-TO-TALK switch and blow into the transmitter
2. Depress the PRESS-TO-TALK switch and blow into the receiver
3. Plug the set into the test receptacle on the sound-powered telephone test set
4. Only blow into the transmitter

5-22. What material is used for whipping tinsel conductors that are being made from bulk supply for use with headsets?

1. Cotton thread
2. DCOP cord
3. 32-gauge steel wire
4. 32-gauge tinned copper wire

5-23. When replacing a tinsel cord on a sound-powered telephone headset-chestset, what must you do before disconnecting the cord?

1. Unscrew the entrance bushing
2. Make a diagram of the color coding
3. Secure the tie cord
4. Seal the port

5-24. When replacing the cord on a sound-powered handset, what must you do before disconnecting the cord?

1. Unscrew the entrance bushing
2. Make a diagram of the color coding
3. Secure the tie cord
4. Seal the port

5-25. Sound-powered telephone amplifiers are capable of transmitting the amplified signal to what total number of (a) headset-chestsets and (b) loudspeakers?

1. (a) Two (b) six
2. (a) Two (b) two
3. (a) Six (b) two
4. (a) Six (b) six

5-26. Sound-powered amplifiers operate on power supplied from which of the following sources?

1. A 115-volt, 60-Hz power supply
2. Sound waves from the sound-powered handset or headset-chestsets in the circuit
3. A 115-volt, 400-Hz power supply
4. Batteries in a central switchboard

5-27. When is relay K1 maintained in an operated condition?

1. When Q6 is in an unsaturated state
2. When Q6 is in a saturated state
3. When R32 and R33 emitter bias voltage is less than Q6 to ground
4. When C1, CR1, and Q6 sense a signal from an incoming voice

5-28. If power is lost to the amplifier, what will happen to sound-powered communications?

1. All sound-powered communications on the circuit will be lost
2. Remote stations will still be able to transmit but will not be able to receive
3. Local stations will still be able to transmit but will not be able to receive
4. Local and remote stations will still be able to communicate at the normal sound-powered level

5-29. What is the purpose of an amplifier control switch?

1. It allows for the connection of more than one amplifier to a sound-powered circuit
2. It allows any one of several circuits to be amplified while retaining normal sound-powered communications for other circuits
3. It allows for the connection of a sound-powered amplifier to a sound-powered switchboard
4. It allows an operator to control all sound-powered amplifiers from one central location

5-30. What total number of (a) sections and (b) stationary contacts can be found on a type A-26A sound-powered telephone selector switch?

1. (a) 2 (b) 16
2. (a) 16 (b) 2
3. (a) 32 (b) 2
4. (a) 2 (b) 32

5-31. Soundproof booths for sound-powered telephones are used in spaces where the ambient noise level is at what decibel level?

1. 20 dB or less
2. 45 dB to 60 dB
3. 65 dB to 80 dB
4. 90 dB or more

5-32. In which of the following spaces would you likely find a plotters transfer switchboard?

1. Combat information center
2. Damage control central
3. Quarterdeck
4. Bridge

5-33. What sound-powered telephone call circuit is used for engineering?

1. 1E
2. 3E
3. 5E
4. 7E

5-34. What total number of audible signaling devices is provided with a two-circuit, four-drop annunciator?

1. One
2. Two
3. Three
4. Four

5-35. Using a type IC/D call signal station, what total number of individual stations can be called?

1. 6
2. 12
3. 16
4. 32

5-36. Which of the following components are mounted on the cover of an IC/D call signal station?

1. Howler unit, SELECTOR switch, and attenuator
2. Howler unit, terminal board, and SELECTOR switch
3. Terminal board, sound-powered telephone jack outlet, and attenuator
4. Sound-powered telephone jack outlet, SELECTOR switch, and attenuator

5-37. When a station is being called, the howler at the selected station will howl for what maximum length of time?

1. 10 sec
2. 30 sec
3. Until the called station answers
4. Until the calling station stops cranking the generator

5-38. What total number of separate conversations are possible at one time on circuit MJ?

1. 1
2. 6
3. 8
4. 16

5-39. The AN/WTC-2(V) sound-powered telephone system may contain what maximum number of terminal stations?

1. 8
2. 16
3. 144
4. 288

5-40. The AN/WTC-2(V) sound-powered telephone system uses what total number of separate major units?

1. 6
2. 8
3. 16
4. 144

5-41. What is the difference between terminal stations unit 1 and unit 2?

1. Unit 1 has one station selection switch; unit 2 has two station selection switches
2. Unit 1 has a side-crank hand-ringing generator; unit 2 has a front-crank hand-ringing generator
3. Unit 1 has one attenuator; unit 2 has two attenuators
4. Unit 1 is bulkhead-mounted; unit 2 is console-mounted

5-42. What component is contained in unit 3 but NOT in units 1 and 2?

1. An audible alarm
2. A hand-ringing generator
3. A handset
4. An attenuator

5-43. Unit 4 of the AN/WTC-2(V) sound-powered telephone system is what type of jackbox?

1. Single-gang
2. Double-gang
3. Triple-gang
4. Four-gang

5-44. What type of sound-powered telephone headset-chestset is used with unit 4?

1. H-200/U
2. H-201/U
3. H-202/U
4. H-203/U

5-45. What maximum number of extension visual signal devices can be connected to unit 6?

1. One
2. Two
3. Three
4. As many as is required to cover a space

5-46. An extension visual signal device uses what size of incandescent lamp?

1. 15 watts
2. 30 watts
3. 50 watts
4. 100 watts

5-47. Unit 7 is used to test which of the following components?

1. Sound-powered telephone jackboxes
2. Sound-powered telephone headset-chestsets
3. Sound-powered telephone handsets
4. Terminal station selector switches and associated wiring

5-48. When additional audible signaling is required due to high noise levels, what device mounted within unit 8 provides this audible signal?

1. A siren
2. An electrical horn
3. A bell
4. A loudspeaker

5-49. If you want to initiate a point-to-point call, what is the first step you should take?

1. Select the desired station number on the thumbwheel switch
2. Remove the handset from its holder
3. Turn the crank several times to ring the desired station
4. Set the PLACE CALL/ANSWER switch to the PLACE CALL position

5-50. After you complete a point-to-point call, what is the last thing you should do?

1. Set the PLACE CALL/ANSWER switch to the ANSWER position
2. Return the handset to its holder
3. Return the thumbwheel switches to the 00 position
4. Turn the PRESS-TO-TALK switch off

5-51. What maximum number of stations can participate in a conference call without a noticeable drop in the audio-signal level?

1. Five
2. Six
3. Three
4. Eight

5-52. If you are the originator of a conference call, the thumbwheel switches should be in what position during the call?

1. 00
2. The first station number called
3. The last station number called
4. Your own terminal station number

5-53. At which of the following times would a net communications system be used?

1. When it is desirable to have all sound-powered circuits on a ship connected together
2. To communicate with stations on other ships
3. During general quarters
4. When the audio signal becomes weak during a conference call

5-54. Which of the following stations may use the call hold function?

1. A station that has originated a call
2. A station that has received a call
3. A station that is calling a busy station
4. Each of the above

5-55. Which of the following situations best describes an executive override condition?

1. When a station has originated a call and is talking to the called station when a call is received
2. When a station originating a call gets a busy signal and overrides the busy signal
3. When a station has received a call and is talking to the calling station when a second call is received
4. When one station takes control during a conference call

5-56. What situation describes looping?

1. When it is desirable to form a complex series-parallel circuit among circuits
2. When four or more point-to-point and/or conference calls are in progress at the same time and a particular relationship exists among the station numbers of the called stations
3. When more than four point-to-point and/or conference calls are in progress at the same time and a predictable relationship exists among the station numbers of the calling stations
4. When the press-to-talk switch is taped down on handsets of several stations

5-57. On a submarine, what audible device is installed at one end of a voice tube to alert personnel to man the tube?

1. A horn
2. A bell
3. A buzzer
4. A siren

5-58. What is the circuit designation of the automatic dial telephone system used on board ship?

1. J
2. JJ
3. T
4. TT

5-59. Auxiliary equipment used with telephone sets consist of which of the following items?

1. Visual signal devices
2. Audible signal devices
3. Extension signal relays
4. Each of the above

5-60. How many different configurations are there of the basic nonrestricted set?

1. One
2. Two
3. Three
4. Four

5-61. How are desk-mounted sets connected to the switchboard?

1. By an external connector block
2. By a screw-type terminal board mounted within the enclosure
3. By a screw-type terminal board mounted on the side of the enclosure
4. By an internal connector block

5-62. How many different types of transmitters can be used with the handset?

1. One
2. Two
3. Three
4. Four

5-63. The handset retainer slide is what type of control?

1. Electrical
2. Mechanical
3. Electrical/mechanical
4. Hydraulic

5-64. What device is used to unlock the handset retainer slide?

1. A button
2. A lever
3. A switch
4. A relay

5-65. In a telephone circuit, what is receiver sidetone?

1. Tingling of the ringer due to dial vibration
2. Dial impulses heard in the receiver
3. Sound transmitted and received by the same handset
4. Sound emitted by the transmitter diaphragm

5-66. What is resistor R2 used for in the transmission network?

1. Automatic gain control
2. Line balance control
3. Sidetone
4. Current limiter

5-67. In the dc transmission network, path 3 performs what function?

1. It protects the circuit from high line-voltage surges
2. It provides balance and gain control for the circuit
3. It prepares the transmitter for audio excitation
4. It balances the line for varying levels of outgoing and incoming audio signals

5-68. When the hookswitch is in the off-hook position, in what positions are (a) contacts 1 and 2 and (b) contacts 3 and 4?

1. (a) Open (b) closed
2. (a) Open (b) open
3. (a) Closed (b) open
4. (a) Closed (b) closed

5-69. After removing the handset from its holder, what maximum amount of time do you have to begin dialing before the howler tone begins?

1. 10 sec
2. 20 sec
3. 30 sec
4. 45 sec

5-70. What does the number dialed on a telephone determine?

1. The number of dc impulses
2. The intensity of the impulses
3. The duration of each impulse
4. The rate of the impulses

IN ANSWERING QUESTION 5-71, REFER TO FIGURE 6-5 IN YOUR TEXTBOOK.

5-71. For lamp and dimmer control, dc voltage is applied to which terminals?

1. 4 and 5
2. 2 and 6
3. 2 and 5
4. 5 and 6

5-72. In the ringer circuit, capacitor C4 is used for which of the following reasons?

1. To tune the ringer
2. To block dc voltage
3. Both 1 and 2 above
4. To suppress contact arcing

5-73. What characteristic distinguishes the type G (R) restricted telephone set from the nonrestricted set?

1. Color
2. Identification plate
3. Size
4. All of the above

5-74. How is the portable telephone set connected to the automatic dial telephone switchboard?

1. Through an outlet box
2. Through the antenna of the portable telephone set
3. Through any 120-volt ac receptacle
4. Through special dc receptacles

5-75. What total amount of bulkhead-mounted modular telephone set models are there?

1. Six
2. Two
3. Eight
4. Four

ASSIGNMENT 6

Textbook Assignment: Chapter 6, "Automatic Dial Telephone System (continued)," pages 6-11 through 6-71.

6-1. To check for a noisy handset cord, you should listen for a clicking or cracking noise in the receiver while performing which of the following actions?

1. Holding the cord with both hands and stretching it out completely
2. Rolling the cord back and forth between your hands
3. Twisting the cord in a back and forth motion
4. Holding the cord with one hand and pulling on it with the other

6-2. The dial should return to its normal position in approximately how much time after dialing 0?

1. 1 sec
2. 7 sec
3. 3 sec
4. 5 sec

6-3. How many adjustments are there on the telephone set?

1. One
2. Two
3. Three
4. Four

6-4. When adjusting the ringer, which leads of the telephone set do you connect to the ringing voltage supply?

1. The red and black leads
2. The black and grey leads
3. The grey and red leads
4. The red and green leads

6-5. How many tabs are there on the dial frame for dial speed adjustment?

1. 6
2. 9
3. 3
4. 12

6-6. High-voltage safety procedures should be followed whenever working on the inside of a telephone set.

1. True
2. False

6-7. Before replacing a defective telephone set transmitter and receiver units, you should attempt to repair them.

1. True
2. False

6-8. When replacing the cord on a handset, one end of the red jumper wire is connected to the receiver. Where is the other end connected?

1. On the same terminal of the transmitter mounting cup as the short red wire
2. On the same terminal of the mounting cup as the short yellow wire
3. On the same terminal of the transmitter as the long red wire
4. On the same terminal of the receiver as the green wire

6-9. When replacing the dial of a telephone set, after removing the telephone set chassis from the cover, what is the first step you should take?

1. Remove the dial dust cover
2. Remove the screws that hold the dial to the chassis
3. Disconnect the dial leads
4. Lift the dial out of the chassis

6-10. When replacing the ringer on a telephone set, which, if any, of the following leads should you unsolder?

1. The red lead only
2. The green lead only
3. The green and red leads
4. None of the above

6-11. What is the proper procedure for removing the dial illumination lamp from its holder?

1. Press down gently and rotate the lamp one-quarter turn counterclockwise
2. Press down hard and rotate the lamp one-quarter turn clockwise
3. Rotate the lamp one full turn counterclockwise
4. Gently pull the lamp straight out

6-12. When replacing the transmission network, what total number of lead terminals must you disconnect?

1. 5
2. 11
3. 17
4. 21

6-13. In checking a telephone set for no dial tone, you use the hand test telephone to isolate the problem and find that a dial tone is present. Where is the problem located?

1. In the telephone set
2. In the line coming from the automatic dial telephone switchboard
3. In the automatic dial telephone switchboard
4. In the main IC switchboard

6-14. What is the most common cause of dial pulses heard in the receiver while dialing?

1. The dial is out of adjustment
2. The receiver is defective
3. The telephone set cord is defective
4. The hookswitch shunt spring contacts are out of adjustment

6-15. To loosen the carbon granules that are clinging together in a handset transmitter unit, what should you do?

1. Strike the transmitter unit sharply with a hammer
2. Hold the handset in a horizontal position and shake it in a circular motion
3. Take the transmitter apart and use a nonmagnetic screwdriver to separate the granules
4. Hold the handset in a vertical position and shake it vigorously in a circular motion

6-16. If a telephone set has poor or weak reception, which of the following factors may be the cause?

1. Loose connections inside the handset
2. A worn receiver cord
3. A problem in the transmission network
4. Each of the above

6-17. All EXCEPT which of the following factors can cause a telephone to transmit but not receive?

1. A shorted transmitter unit
2. A shorted contact of the dial shunt springs
3. A defective receiver
4. An open transmitter unit

6-18. If the ringer on a telephone does not sound, what is the first component you should check?

1. The coil
2. The capacitor
3. The connections
4. The gong

6-19. Which of the following actions could result in a wrong number being dialed?

1. Keeping your finger on the dial while it is returning to its normal position
2. Jiggling the hookswitch before dialing
3. Incorrect dial speed
4. Each of the above

6-20. Where is the latch release button located on the type G (version 2) telephone set?

1. On the side of the handset
2. On the cover of the telephone set
3. On the front of the handset handle
4. On the back of the telephone set

6-21. What is capacitor C2 used for in the network assembly?

1. To protect the receiver from dc voltages
2. For gain control
3. To compensate for line capacitance
4. For mutual inductance

6-22. In the telephone set, what component is used to suppress clicks in the receiver?

1. Varistor RV1
2. Varistor RV2
3. Varistor RV3
4. Varistor RV4

6-23. When a caller dials your number, the automatic dial telephone switchboard applies how much voltage to the ringer of the telephone set?

1. 25 to 50 volts
2. 50 to 75 volts
3. 60 to 90 volts
4. 75 to 100 volts

6-24. What total number of adjustments are there on the type G (version 2) telephone set?

1. Six
2. Two
3. Eight
4. Four

6-25. If the dial speed on the type G (version 2) telephone set is too slow, which of the following actions should you take?

1. Replace the dial
2. Loosen the dial speed tension spring
3. Turn the dial speed adjust screw in a clockwise direction
4. Turn the dial speed adjust screw in a counterclockwise direction

6-26. When you adjust the hookswitch contact springs of the type G (version 2) telephone set, what is the correct contact separation for the Z combination?

1. 0.000 in. to 0.010 in.
2. 0.020 in. to 0.025 in.
3. 0.025 in. to 0.035 in.
4. 0.045 in. to 0.055 in.

6-27. When making an adjustment, what, if anything, will happen to the magnetic field of the ringer if you remove the three screws located on the bottom of the ringer?

1. It will decrease
2. It will increase
3. It will be broken and the ringer will need remagnetization
4. Nothing

6-28. When you replace the ringer on the type G (version 2) telephone set, what lead is connected to terminal 2 of the network assembly?

1. Red
2. Black
3. White
4. Green

6-29. What type of switching system is used in the Dynalec 100/150-line automatic dial telephone switchboard?

1. Electrical
2. Mechanical
3. Electrical/mechanical
4. Electrical/electromechanical

6-30. What type of telephone set is used with the Dynalec 100/150-line automatic dial telephone switchboard?

1. Type G (Version 1) only
2. Type G (version 2) only
3. Any two-wire dial telephone set
4. Any two-wire dial telephone set using break-type dialing only

6-31. How many crossbar switches are mounted in (a) cabinet 1 and (b) cabinet 2 of the Dynalec 100-line automatic dial telephone switchboard?

1. (a) Eight (b) two
2. (a) Seven (b) two
3. (a) Two (b) eight
4. (a) Two (b) seven

6-32. Where is the emergency cut-in selector switch located?

1. Switch and fuse panel, cabinet 1 upper gate
2. Switch and fuse panel, cabinet 1 lower gate
3. Switch and fuse panel, cabinet 2 lower gate
4. Switch and fuse panel, cabinet 2 upper gate

6-33. Which switches will you find on the switch and fuse panels located in both cabinet 1 and cabinet 2?

1. ALM RESET switches
2. LC switches
3. POWER ON switches
4. RG transfer switches

6-34. The ECI switch has what total number of positions?

1. One
2. Two
3. Three
4. Four

6-35. To silence an audible alarm, the ALM RESET switch should be placed in what position?

1. Up
2. Down
3. Center
4. Momentarily up

6-36. A circuit card assembly shelf can accommodate what maximum number of plug-in modules?

1. 5
2. 7
3. 3
4. 14

6-37. Each crossbar switch can house what maximum number of select off-normal spring pileups?

1. 6
2. 10
3. 12
4. 30

6-38. The switchboard power supply receives what type of input from the main IC switchboard?

1. 51.6 volts dc
2. 75 to 100 volts dc
3. 115 volts, 60 Hz, single phase
4. 115 volts, 60 Hz, three phase

6-39. What total number of 6-cell batteries do you need for the emergency power supply for the automatic dial telephone switchboard?

1. 6
2. 2
3. 24
4. 4

6-40. Before you change the position of the CHARGER CURRENT switch, what other switch must you operate?

1. CHANGE/READ switch
2. BATTERY CURRENT switch
3. AMPS METER switch
4. BATTERY CONNECT switch

6-41. The automatic dial telephone switchboard uses what total number of ringing generators?

1. 1
2. 2
3. 20
4. 75

6-42. Where is the ground fault detection panel located?

1. In the upper right corner of cabinet 1
2. In the lower right corner of cabinet 2
3. In the upper left corner of cabinet 1
4. In the lower left corner of cabinet 2

6-43. The attendant’s cabinet is capable of accommodating what maximum number of shore lines?

1. 8
2. 2
3. 24
4. 4

6-44. What are the main assemblies of the MDM 200/700 system

1. One system cabinet, one switchboard cabinet
2. Two identical system cabinets, two identical switchboards
3. One system cabinet, two to seven switchboard cabinets
4. Two identical system cabinets, three to nine identical switchboards

6-45. How many XY universal switches are associated with each 15 find connector circuit module used in a switchboard cabinet?

1. One
2. Two
3. Three
4. Four

6-46. Which cabinet assemblies are associated with the operation of the attendant’s cabinet?

1. 1100, 1200, 1300, 1400
2. 1200, 1300, 1400, 1500
3. 1100, 1200, 1300, 1500
4. 1300, 1500, 1700, 1900

6-47. What is the function of the 1400 assembly of the system cabinet?

1. To monitor the ring and busy interrupter circuits
2. To indicate whether or not the attendant’s console is energized
3. To generate ground pulses for busy tone interruptions
4. To connect the ship lines to the shore lines

6-48. Which circuits indicate quickly the condition of a switchboard cabinet in the MDM system?

1. Finder and connector circuits in the 400 assembly
2. Alarm signaling circuits in the 500 assembly
3. voltage monitoring and alarm locating circuits in the 1900 assembly
4. Tone interrupter and ring timing circuits in the 1400 assembly

6-49. What is the function of an attendant’s console?

1. To seize and interconnect ship and shore lines
2. To monitor its finder-selectors and connectors
3. To establish a transmission path between telephones
4. To select the idle finders

6-50. Under what condition will the overflow springs of the XY switch operate?

1. When the wipers advance 5 steps in the X direction only
2. When the wipers advance 5 steps in the Y direction only
3. When the wipers advance 5 steps in either the X or Y direction
4. When the wipers advance more than 10 steps in either the X or Y direction

6-51. Which of the following is NOT a main piece of equipment associated with the line finding operation in the MDM 200/700?

1. Allotter
2. Connector
3. Line circuit
4. Linefinder

6-52. Suppose line 36 originates a call. What total number of steps in the (a) X and (b) Y directions does the assigned XY switch make to locate line 36’s line in the wire bank?

1. (a) Six (b) three
2. (a) Three (b) six
3. (a) Six (b) six
4. (a) Three (b) three

6-53. To which wire in the wire bank does the connector apply the busy mark?

1. T
2. R
3. S
4. HS

6-54. What type of switch is used as the selector in the MDM 200/700 system

1. 100-point, 2-motion, XY switch
2. 20-point, 8-level, XY switch
3. 100-point, 2-motion, rotary switch
4. 20-point, 8-level, rotary switch

● For question 6-55 assume that station 336 dials station 878, that 878 is not busy at the time of the call, and that the idle connector is connector NO. 12 in the switchboard of the called station.

6-55. The level detector extends a level mark ground to (a) what level and (b) which wire in the wire bank?

1. (a) Position three
   (b) the X-wire bank
2. (a) Position six
   (b) the X-wire bank
3. (a) Position three
   (b) the XX-wire bank
4. (a) Position six
   (b) the XX-wire bank

6-56. Which of the following circuit modules is NOT tested out of the system by the common panel test set?

1. Finder connector
2. Common control
3. Link allotter
4. Level detector

6-57. The link panel test set is used to bench test what component(s)?

1. Link circuit module without the cover only
2. Link circuit cover only
3. Link circuit module without the cover and the link circuit module cover separately
4. Link circuit module with the cover installed

6-58. What is the purpose of the current-flow test set?

1. To serve as a resistance box
2. To enable a maintenance person to readjust the relays in a telephone system
3. To serve as a milliammeter
4. To provide a “saturate” current to the relay that is to be tested

6-59. What happens when a heavy surge of potential hits the lightning arrester box illustrated in textbook figure 6-46?

1. A fuse blows, opening the circuit to the automatic equipment
2. The carbon contacts fuse together, providing the potential with a path to ground
3. Both 1 and 2 above
4. The potential decreases, preventing the fuses from blowing

6-60. The central office switchboard is made up of what components?

1. Two to six switchboards only
2. Two to six switchboards and a power supply unit
3. One to five switchboards only
4. One to five switchboards and a power supply unit

6-61. Which of the following is the primary purpose of the central office switchboard?

1. To interpret the dial pulse information from the calling telephone
2. To determine the telephone being called and to choose a suitable path to interconnect the two telephones
3. To connect the two telephones and ring the called party
4. All of the above

6-62. Which of the following functions is NOT accomplished by the manual switchboard?

1. Indication of central office switchboard malfunction
2. Correction of dialing errors
3. Holding ship and shore lines accessed
4. Interconnection of ship-shore lines

6-63. The howler will sound under all EXCEPT which of the following conditions?

1. When more than 30 seconds elapses between dialed digits
2. When a telephone is in use over 5 minutes
3. When a busy tone is received for more than 30 seconds
4. When a telephone receives a dial tone and dialing is not started in 30 seconds

6-64. What telephone number will automatically connect you to the predetermined emergency station for that time period?

1. 203
2. 201
3. 211
4. 222

6-65. The common control cabinet houses which of the following components?

1. Additional line circuits
2. Control circuits
3. Processors, memories, and control equipment
4. Network control circuits

6-66. If you are on watch in the IC room and the automatic dial telephone switchboard audible alarm sounds, what is the first action you should take?

1. Call your supervisor
2. Turn off the power to the switchboard
3. Check the fuses on the IC switchboard
4. Silence the audible alarm

6-67. What minimum length of time does a handset have to be left off-hook before it will cause an off-hook alarm condition?

1. 10 sec
2. 15 sec
3. 30 sec
4. 45 sec

6-68. To determine the number of the line causing an off-hook alarm condition, which of the following components should you inspect?

1. The originating hold magnet
2. The select level contacts
3. The crossbar switch contacts
4. All of the above

6-69. As a minimum, how often should you check the automatic dial telephone system for ground faults?

1. Daily
2. Weekly
3. Monthly
4. Each watch

6-70. As a minimum, how often should you check the hinges and locking mechanisms of both cabinet doors?

1. Daily
2. Weekly
3. Monthly
4. Each watch

6-71. As a minimum, the switchboard cabinets and the attendant's cabinet should be inspected how often?

1. Daily
2. Weekly
3. Monthly
4. Each watch

6-72. When you perform preventive maintenance on the switchboard cabinet, which of the following procedures should you follow?

1. Check for accumulations of dust
2. Check to see that the equipment gates are properly fastened
3. Clean the cabinets, if required
4. All of the above

ASSIGNMENT 7

Textbook Assignment: Chapter 7, "Amplified Voice Systems," pages 7-1 through 7-35.

7-1. What is the circuit designation for the general announcing system used aboard ship?

1. 1MC
2. 5MC
3. 40MC
4. 51MC

7-2. The circuit designation 21MC is used for which of the following shipboard announcing systems?

1. Flag administrative
2. Captain's command
3. Bridge
4. Flag command

7-3. What is the importance classification of the 4MC?

1. Nonvital
2. Semivital
3. Vital
4. Not vital

7-4. What is the readiness classification of the 32MC?

1. One
2. Two
3. Three
4. Four

7-5. What do all microphones have in common?

1. They all convert electrical energy into sound energy
2. They all require an external voltage source
3. They are all rated the same
4. They all have a metal diaphragm

7-6. When a compression wave strikes the diaphragm of a magnetic microphone, in what direction does the (a) armature and (b) flux path move?

1. (a) Left (b) south
2. (a) Right (b) north
3. (a) Left (b) north
4. (a) Right (b) south

7-7. The magnetic microphone is preferred to the other types of microphones for use in shipboard announcing systems because of which of the following reasons?

1. Its resistance to shock
2. Its wide-frequency range
3. Its high-voltage output
4. Its high impedance

7-8. Rochelle salt is most commonly used in crystal microphones for which of the following reasons?

1. Its low-voltage output
2. Its low-current output
3. Its high-current output
4. Its high-voltage output

7-9. In the carbon microphone, the voltage developed across the secondary depends on which of the following factors?

1. Ratio of primary and secondary turns
2. Change in primary current
3. Both 1 and 2 above
4. The number of carbon granules

7-10. Why do shipboard announcing systems distort the frequency response of the system by attenuating the lower frequencies and boosting the higher frequencies?

1. To increase the gain of the system
2. To impart a pleasant quality to the sound
3. To improve the radiation efficiency of the loudspeaker
4. To make announcements easier to understand in noisy locations

7-11. Why is it important to have the sensitivity of a microphone as high as possible?

1. Because less gain is required in the amplifier
2. Because it eliminates all background noise
3. Because it provides for a low electrical power output level
4. Because it allows the speaker to hold the microphone at a greater distance from his or her mouth

7-12. What device in an announcing system converts electrical energy into sound energy?

1. A microphone
2. A loudspeaker
3. An amplifier
4. A transmission line

7-13. What is the basic type of driving mechanism used in Navy loudspeakers?

1. Moving-armature
2. Moving-coil
3. Magnetic
4. Carbon

7-14. Which of the following components must be used in a direct-radiator loudspeaker to reproduce low frequencies?

1. A baffle
2. A large diaphragm
3. A small diaphragm
4. Electrodynamics speaker coils

7-15. What factor(s) determine(s) if the use of a folded-horn loudspeaker would be practical?

1. The size and the amplitude of the sound to be reproduced
2. The amplitude of the sound to be produced and the distance from the loudspeaker to the listener
3. The distance from the loudspeaker to the listener only
4. The shape and the size

7-16. Which of the following factors does NOT principally influence the low-frequency response in a horn loudspeaker?

1. Mouth dimensions
2. Flare
3. Diameter of the cone
4. Basic horn formula employed

7-17. What relationship exists between the directional patterns of a small loudspeaker transmitting a high-frequency signal and a large loudspeaker transmitting a low-frequency signal?

1. They are inversely proportional
2. They are opposite
3. They are directly proportional
4. They are the same

7-18. A loudspeaker that is buzzing may normally have this fault corrected by which of the following actions?

1. By reducing the power applied
2. By lengthening the cone
3. By replacing the driver
4. By decreasing the flare of the cone

7-19. What is the usual range of voice coil impedance?

1. 20 to 60 ohms
2. 15 to 30 ohms
3. 3 to 15 ohms
4. 40 to 75 ohms

7-20. What is the purpose of the transformer used in shipboard loudspeakers?

1. To provide a means of varying the speaker volume
2. To match the voice coil to the line
3. To improve speaker frequency response
4. To reduce reverberation

7-21. In addition to the power rack, what is the other major component of the AN/SIA-114B amplifier-oscillator group?

1. Oscillator rack
2. Amplifier rack
3. Control rack
4. Speaker rack

7-22. To increase the low-level microphone and alarm signals, what total number of transistor-amplifier stages is contained in each preamplifier?

1. One
2. Six
3. Eight
4. Four

7-23. The power supply modules supply what operating voltages to the alarm modules and preamplifier modules?

1. -1 Vdc and -10 Vdc
2. -10 Vdc and -30 Vdc
3. -20 Vdc and -40 Vdc
4. -40 Vdc and -50 Vdc

7-24. What total number of alarm modules is in each oscillator group?

1. 5
2. 10
3. 15
4. 20

7-25. Which of the following alarm modules takes priority over the other?

1. Flight crash over general
2. Chemical attack over collision
3. General over collision
4. Chemical attack over general

7-26. What component in the collision alarm module is used to adjust the number of pulses in a group?

1. Resistor R107
2. Relay K101
3. Resistor R117
4. Resistor R127

7-27. After the alarm contact maker is released, the general alarm will sound for approximately what maximum length of time?

1. 5 sec
2. 15 sec
3. 30 sec
4. 1 min

7-28. What generates the alarm signal in the chemical alarm module?

1. Striking multivibrator
2. Phase shift oscillator
3. Relaxation oscillator
4. Square wave multivibrator

7-29. Transistor Q503 in the flight crash alarm module is normally set to produce what varying frequency?

1. 550 to 700 cycles per second
2. 700 to 1750 cycles per second
3. 750 to 1750 cycles per second
4. 1700 to 2750 cycles per second

7-30. What alarm module produces a jump tone?

1. Unassigned A
2. Flight crash
3. Chemical
4. General

7-31. Which amplifier channel is normally used for (a) 1MC operation and (b) 6MC operation?

1. (a) A (b) B
2. (a) B (b) A
3. (a) A (b) A
4. (a) B (b) B

7-32. What is the normal position for the oscillator group selector switch?

1. 1
2. 2
3. A
4. B

7-33. The amplifier oscillator power switches supply power to which of the following components?

1. The power amplifiers located in the control rack
2. The relay power supply located in the control rack
3. The power supplies located in the power rack
4. The blowers located in the control rack

7-34. What total number of (a) microphone control station disconnect switches and (b) loudspeaker group disconnect switches are located on the front of the control rack?

1. (a) Three (b) five
2. (a) Five (b) five
3. (a) Five (b) six
4. (a) Six (b) six

7-35. What total number of (a) selector switches and (b) meters are mounted on the front of the power rack?

1. (a) Two (b) two
2. (a) Eight (b) two
3. (a) Two (b) eight
4. (a) Eight (b) eight

7-36. Which of the following microphone control stations is the only one capable of transmitting over both circuit 1MC and circuit 6MC?

1. Main control
2. Quarterdeck
3. Forward IC
4. Bridge

7-37. Which of the following loudspeaker groups is associated with circuit 1MC?

1. Topside
2. Fantail
3. Flight deck
4. Each of the above

7-38. To transmit over the 1MC when the busy 2 indicator light is lighted, what should you do?

1. Wait until the light goes off before attempting to use the 1MC system
2. Switch to channel B and make your transmission
3. Make your transmission over the 1MC at any time
4. Disregard the light and use the 6MC system for your transmission

7-39. In the one-way central announcing system, when both busy indicator lights are lighted, which of the following conditions exists?

1. An alarm signal is being transmitted
2. Both the 1MC and 6MC are in use
3. Both the 1MC and 6MC are using the same amplifier channel
4. Each of the above

7-40. In the one-way central announcing system, under normal conditions, a transmission will result in a meter reading of how many decibels?

1. 0 dB
2. 5 dB
3. 10 dB
4. 20 dB

7-41. Which of the following types of loudspeakers is used with circuit 6MC?

1. Multiunit direct-radiator
2. Multiunit straight-horn
3. Multiunit folded-horn
4. Each of the above

7-42. What is the color of the general alarm contact maker?

1. Green
2. Yellow
3. Red
4. Gray

7-43. In which of the following spaces is a visual alarm indicator installed?

1. On the bridge
2. In the engine room
3. On the quarterdeck
4. In the galley

7-44. When conducting a remote alarm contact maker test, which of the following alarm contact makers should you operate first?

1. Chemical attack
2. Collision
3. General
4. Engineering

7-45. If microphone station No. 1 was the only station operative, which of the following relays would probably be defective?

1. K973
2. K948
3. K933
4. K919

7-46. If there is no output when the general alarm contact maker is operated, which of the following relays is probably defective?

1. K101
2. K201
3. K302
4. K402

7-47. If there is no output when any lMC mike circuit is energized, which of the following relays is probably defective?

1. K941
2. K942
3. K943
4. Each of the above

7-48. When testing a crystal can-type relay using the relay test facility, which, if any, of the following conditions indicates that the relay is defective?

1. Lamps light in test position 1 only
2. Lamps light in test position 2 only
3. Lamps light in both test positions
4. None of the above

7-49. Which of the following conditions indicates that a tube filament is open?

1. Filament not glowing
2. Low volume output
3. A lower than normal meter reading
4. A higher than normal meter reading

7-50. Which of the following is an indication that a resistor in a circuit is overloaded?

1. A burnt odor
2. Discoloration
3. Both 1 and 2 above
4. A loud crackling noise

7-51. Which of the following components will cause an amplifier to lose its output?

1. Open cathode bypass capacitor
2. Shorted coupling capacitor
3. Leaking coupling capacitor
4. Open coupling capacitor

7-52. Which of the following conditions could cause an excessive output voltage of a power-supply choke?

1. An internal short within the choke
2. A winding shorted to the case
3. A winding shorted to the core
4. An open winding

7-53. To check a suspected defective transistor, which of the following steps should you take?

1. Substitute with a known good transistor
2. Test with an out-of-circuit transistor test set
3. Test with an in-circuit transistor test set
4. Each of the above

7-54. The AN/SIA 120 is used with which of the following amplified voice circuits?

1. 5MC
2. 19MC
3. 29MC
4. 59MC

7-55. What total number of individual loudspeaker groups can be connected to the outputs of the AN/SIA-120 amplifiers?

1. One
2. Five
3. Seven
4. Nine

7-56. Where are the output transistors for the AN/SIA-120 physically located?

1. On the front of the control panel
2. On a bracket behind the control panel
3. Lower rear wall of the control rack
4. Upper rear wall of the control rack

7-57. Under normal operating conditions, the loudspeaker group toggle switches should be in what position?

1. Up position for channel A operation
2. Down position for channel B operation
3. Center position for split channel operation
4. Half in up position, half in down position

7-58. To permit hands-free operation by the operators, how are the foot-operated switches and the flexible microphones wired?

1. In series
2. In parallel
3. In series-parallel
4. Separately

7-59. If the entire system is inoperative and the power available indicator lamp on the control rack is lighted, what should you check first?

1. The control panel for blown fuses
2. The equipment technical manual
3. The position of the switches on the control panel
4. The switch that provides power to the control panel

7-60. What is the maximum number of calls that can be originated from the LS-433A/SIC intercommunicating unit?

1. 5
2. 10
3. 20
4. 25

7-61. The reproducer in an intercommunicating unit serves what function?

1. It performs as an amplifier
2. It performs as a microphone
3. It performs as a speaker
4. Both 2 and 3 above

7-62. How many banks of selector switches are provided with the 20-station LS-434A/SIC?

1. One
2. Two
3. Three
4. Four

7-63. When using a handset with an intercommunicating unit, where will the incoming calls be heard?

1. The handset
2. The reproducer
3. Both 1 and 2 above
4. A local loudspeaker

7-64. When the dimmer control knob is in the OFF position, what lights, if any, are lighted?

1. Release
2. Call
3. Station designation
4. None

7-65. In an intercommunicating unit, what type of coupling is used for (a) input and (b) output of the amplifier?

1. (a) RC
   (b) transformer
2. (a) Direct
   (b) transformer
3. (a) Transformer
   (b) transformer
4. (a) Direct
   (b) RC

7-66. To answer a call from another station, you should take which of the following actions?

1. Listen, then depress the talk switch to talk
2. Depress the calling station selector button, then talk
3. Check for a busy signal, then talk
4. Depress the calling station selector button and listen, then depress the talk switch to talk

7-67. When using the test fixture, which of the following characteristics is NOT tested by the amplifier and reproducer test?

1. Signaling circuits
2. General performance of the entire unit
3. Amplifier gain
4. Power output

7-68. To interrupt microphonics howls, test switch S201 on the test fixture provides a short circuit across what terminal?

1. 1 and 2
2. 1 and 1C
3. 2 and 3
4. 2 and 2C

7-69. When you are performing a signal circuit test with the test fixture, in what position should you initially place the 11 test switches?

1. OFF
2. RELEASE
3. ON
4. STANDBY

7-70. What is/are the main difference(s) between the new LS-518/SIC and LS-519/SIS intercommunicating units and the older LS-433A/SIC and LS-434A/SIC intercommunicating units?

1. The new units have the capability of using a remote loudspeaker
2. The new units have the capability of hands-free operation
3. Both 1 and 2 above
4. The new units are 20 and 40 station units

7-71. What mode of operation of the integrated intercommunication system has its own auxiliary storage battery supply?

1. Alarm signals
2. Portable loudspeaker
3. Sonar control room
4. Escape trunk

7-72. In the AN/PIC-2, what types of transistors are (a) Q1 and (b) Q3 and Q4?

1. (a) Input
   (b) push-pull power
2. (a) Push-pull power
   (b) input
3. (a) Input
   (b) output
4. (a) Output
   (b) input

7-73. When operating the AN/PIC-2, when is there maximum current drain?

1. Whenever switch S1 is depressed
2. When amplifying the loudest signal
3. When operating on external batteries
4. When operating on internal batteries

7-74. What should you use to clean salt crystals off the opening to the microphone housing?

1. Petrolatum
2. Fresh water
3. Sandpaper
4. Oil

7-75. What are the power requirements for the lectern-type public address system?

1. 115-volt ac or 220-volt ac
2. A self-contained dry battery or 115-volt ac
3. A self-contained dry battery or 220-volt ac
4. 115-volt dc or 115-volt ac

ASSIGNMENT 8

Textbook Assignment: Chapter 8, “Ship’s Entertainment System;” pages 8-1 through 8-25.

8-1. The entertainment systems on board ship are used for which of the following reasons?

1. For training
2. As entertainment for the crew
3. As a medium for the CO to address the crew in an informal manner
4. Each of the above

8-2. The AN/SIH-7 audio entertainment system distributes programs on what total number of channels?

1. 8
2. 2
3. 12
4. 4

8-3. The AN/SIH-7 audio entertainment system contains what total number of magnetic tape recorder/reproducers?

1. One
2. Two
3. Three
4. Four

8-4. When an announcement is being made over the lMC circuit, what, if anything, will happen to the audio entertainment system?

1. The system’s loudspeakers will be reduced in amplitude
2. The system’s loudspeakers will be muted
3. The system’s amplifiers will stop amplifying
4. Nothing, there will be no effect on the system

8-5. The tape recorder/reproducers are capable of recording and playing tapes at what speeds?

1. 3.57 and 5.70 inches per second
2. 3.50 and 7.75 inches per second
3. 3.75 and 7.50 inches per second
4. 3.70 and 5.75 inches per second

8-6. The reproduction of AFRTS or commercial reel-to-reel tapes is not authorized.

1. True
2. False

8-7. When a tape has been recorded, you can turn it over and record again in the same direction to double the amount of playing time.

1. True
2. False

8-8. After an alarm is transmitted over the 1MC circuit, what, if anything, must you do to reactivate the ship’s entertainment system?

1. Press the POWER ON switch to the off position and then back to the on position
2. Change the two main system power fuses
3. Press the alarm reset indicator lamp
4. Nothing, the system will reactivate automatically

8-9. What type of microphones are used with the AN/SIH-7 audio entertainment system?

1. Low impedance
2. Medium impedance
3. Both 1 and 2 above
4. High impedance

8-10. When you set the recording volume level for a tape, where should the needle peak on the record volume meter?

1. Midscale
2. Into the red region
3. Into the green region
4. 0 dB

8-11. Which tape speed allows for twice as much program to be recorded on any given reel of tape?

1. 3.75 inch per second
2. 5.75 inch per second
3. 7.50 inch per second
4. 7.75 inch per second

8-12. When a channel is in use, what is the normal setting for the bass and treble controls?

1. Minimum position
2. Maximum position
3. Mid position
4. Halfway between the mid and maximum positions

8-13. Which of the following components is NOT found in the program monitor control section?

1. A volume meter
2. A volume control
3. A headset jack
4. A program monitor selector switch

8-14. Where is the output level monitor section located in the amplifier control panel?

1. On the lower right side of the panel
2. On the lower left side of the panel
3. On the upper portion of the panel to the right of the mike control section
4. On the lower center part of the panel

8-15. In the automatic mode, what maximum number of records is the phonograph record changer capable of playing?

1. 7
2. 11
3. 15
4. 21

8-16. The lower audio-frequency amplifier is used for what channels?

1. 1 and 2
2. 2 and 3
3. 3 and 4
4. 4 and 1

8-17. Which of the following is a valid operating procedure to follow when operating the ship's audio entertainment system?

1. Never allow distorted sound to be broadcast
2. Never permit a needle to stick in a record groove
3. Never permit a tape to run out unexpectedly
4. Each of the above

8-18. What type of loudspeaker is used with the ship's audio entertainment system?

1. Permanent-magnet, dynamic-radiator
2. Permanent-magnet, electro-dynamics
3. Permanent-magnet, direct-radiator
4. Permanent-magnet, indirect-radiator

8-19. What is the main difference between a closed circuit TV system and a commercial home TV system?

1. The methods used to transmit the signal
2. The type of picture tube used
3. The size of wire used to carry the signal
4. The intensity of the signal sent from the camera to the receiver

8-20. What signals tell the camera and the receiving set when no video signal should be present?

1. Video
2. Sync
3. Blanking
4. Audio

8-21. Which of the following signals are ouputs from the control unit?

1. Vertical and horizontal blanking
2. Sync
3. Video
4. Each of the above

8-22. The weak electrical impulses from the camera tube are built up by (a) what amplifier and fed to (b) what amplifer?

1. (a) Sync (b) video
2. (a) Control (b) sync
3. (a) Video (b) control
4. (a) Video (b) sync

8-23. What system of modulation is used for transmitting television pictures through space?

1. Amplitude modulation
2. Frequency modulation
3. Phase modulation
4. Control modulation

8-24. Considering the method of TV picture presentation, how is it possible for the viewer to see an entire picture?

1. Each element constitutes an entire picture
2. The elements are presented in such rapid succession that they appear to be an entire picture
3. The video portion of the signal is presented as a whole, while the synchronizing portions of the signal result from the scanning process
4. Each time the electron beam scans from one side of the lamp to the other all the picture elements are scanned and presented as a whole

8-25. The scanning pattern that is evident when there is no picture signal is known by what term?

1. Composite video signal
2. Picture element
3. Raster
4. Synchronizing signal

8-26. In motion pictures, at what frame speed does motion appear continuous but with a pronounced flicker?

1. 5 frames per sec
2. 10 frames per sec
3. 15 frames per sec
4. 24 frames per sec

8-27. Interlaced scanning is commonly employed in television systems for which of the following reasons?

1. To decrease bandwidth requirements
2. To improve horizontal detail
3. To increase picture contrast
4. To reduce flicker

8-28. In a closed TV circuit, blanking signals are used to eliminate which of the following signals?

1. Horizontal sweep signals only
2. Vertical return traces only
3. Vertical and horizontal return traces
4. Vertical and horizontal sweeps

8-29. The horizontal sync signals trigger the horizontal sweep how many times per second?

1. 20,000
2. 15,750
3. 525
4. 60

8-30. What is the objective of a television camera tube?

1. To convert an image into a continuous electrical signal
2. To convert an image into a series of motion picture frames
3. To convert a continuous electrical signal into an image
4. Each of the above

8-31. What happens to the positive charges of the target in an image orthicon when the beam from the electron gun strikes the target?

1. Most of them are partially neutralized
2. Most of them are neutralized completely
3. All of them are partially neutralized
4. All of them are neutralized completely

8-32. All vidicon camera tubes are similar, but they differ primarily in which of the following factors?

1. Specific size
2. Sensitivity
3. Resolution
4. Each of the above

8-33. What happens to the resistivity of the photoconductive material of a vidicon tube when the illumination on the faceplate is increased?

1. It increases
2. It decreases
3. It remains high
4. It remains low

8-34. When the entire scanned surface is dark, a very small current flows to the load resistor. What is this current called?

1. Blanking current
2. Dark current
3. Load current
4. No image current

8-35. What are the three primary colors used in color television

1. Red, yellow, blue
2. Green, yellow, blue
3. Red, green, blue
4. Red, yellow, green

8-36. In the American flag, color saturation is exhibited by which of the following color or colors?

1. White
2. Red and blue
3. Red and white
4. White and blue

8-37. How do the three pickup tubes of a color camera select their assigned colors from a multicolor scene?

1. The scene's colors are filtered and reflected to the proper tube
2. Each tube is covered by a filter of the color its signal represents
3. Each tube contains a mosaic of globules of the color its signal represents
4. Phase shifting and reflection seperate the colors and route them to the proper tube

8-38. What video signal contains the brightness variation of the picture information?

1. Y
2. O
3. I
4. C

8-39 Where does the convergence electrode cause the three electon beams to meet and cross?

1. At the red dot
2. At the green dot
3. At the blue dot
4. At the centering hole in the middle of the triangle of dots

8-40 What coil produces a magnetic field within the picture tube which aligns the electron beams parallel to the neck of the tube?

1. Deflection
2. Neutralizing
3. Purifying
4. Degaussing

8-41. Which part of the TV circuitry delays the luminance signal for a fixed period of time so that the luminance and chrominance information arrive at the CRT simultaneously?

1. The degaussing circuit
2. The video delay line
3. The color demodulator
4. The high-voltage supply

8-42. Which section of a color receiver is the "heart" of the receiver?

1. The picture tube
2. The color demodulator
3. The high-voltage supply
4. The video amplifier

8-43. Which of the following components can cause problems in the reproduction of a video signal?

1. Short-necked CRTs
2. Wide-angle deflection yokes
3. Flat surface CRTs
4. Each of the above

8-44. To correct pincushion error in a monochrome receiver, which of the following methods should you use?

1. Produce wider deflection angles
2. Use a shorter necked CRT
3. Install a coil around the CRT
4. Put permanent magnets between the yoke and the CRT screen

8-45. Modern color receivers use what type of corrective circuits to correct pincushion error?

1. Dynamic
2. Static
3. Magnetic
4. Aperture

8-46. Degaussing circuits are installed in color TV receivers to accomplish which of the following objectives?

1. Ensure that each electron beam strikes the proper dots on the CRTs
2. Magnetize the picture tubes
3. Focus the electron beams on the CRT faces
4. Both 2 and 3 above

8-47. When does degaussing of a TV receiver take place?

1. While it is idle
2. After it has warmed up
3. While it warms up
4. From time to time during each hour it operates

8-48. What type of antenna is used with the television entertainment system installed on board ship?

1. Omnidirectional
2. Multidirectional
3. Unidirectional
4. Directional

8-49. Which of the following is/are the primary purpose(s) of the ILARTS system?

1. To provide for monitoring of flight deck operations by the "air boss" and the commanding officer
2. To provide for monitoring of the flight deck status by the air operations officer and the commanding officer
3. To provide simultaneous monitoring and recording of aircraft recovery operations
4. All of the above

8-50. The ILARTS system consists of which of the following components?

1. Camera control unit
2. Camera head unit
3. Remote control unit
4. All of the above

8-51. How are the centerline cameras mounted?

1. Above and parallel to the flight deck
2. Below and parallel to the flight deck
3. Below and perpendicular to the flight deck
4. Above and perpendicular to the flight deck

8-52. Aboard ship, intermediate level maintenance of the ILARTS equipment is performed in what location?

1. In the ILARTS control room
2. In the ILARTS repair and calibration lab
3. In the electronics maintenance shop
4. In the ILARTS maintenance shop

8-53. SITE II is the largest of the three systems being used on Navy ships.

1. True
2. False

8-54. SITE II design is based on the experiences of the SITE 1/1A systems and features a significant reduction in physical size, while maintaining operational capabilities.

1. True
2. False

8-55. In the diplexer, what component is used to match the light intensity of the film projector with the slide projector?

1. A neutral density lens
2. A neutral density mirror
3. A gelatin lens
4. A gelatin neutral density filter

8-56. Of the 52 audio and video jacks in the patch panel, what total number of them is dedicated?

1. 40
2. 44
3. 48
4. 52

ASSIGNMENT 9

Textbook Assignment: Chapter 9, "Alarm, Safety, and Warning System"; pages 9-1 through 9-30.

9-1. What is the circuit designation for the flooding alarm system?

1. F
2. FD
3. FH
4. FR

9-2. What is the readiness classification of the wrong direction alarm system?

1. 1
2. 2
3. Vital
4. Semivital

9-3. What is the importance classification of the boiler water alarm system?

1. 1
2. 2
3. Vital
4. Nonvital

9-4. The contacts in a flow switch will open and initiate an alarm whenever the fluid flow rate increases.

1. True
2. False

9-5. The contacts in a relay will open and initiate an alarm whenever there is a loss of power.

1. True
2. False

9-6. What total number of contacts are sealed into the glass tube of a mercury thermostat?

1. Six
2. Two
3. Three
4. Five

9-7. What maximum number of mercury thermostats may be connected in parallel on any one line?

1. Six
2. Two
3. Three
4. As many as needed

9-8. The thermostat that is normally installed in a ship's magazines will activate the alarm system at what minimum temperature?

1. 105°F
2. 115°F
3. 125°F
4. 150°F

9-9. Where are combustion gas and smoke detector heads located?

1. On the overhead in the compartment to be protected
2. On the bulkhead of the compartment at shoulder level
3. On the baseboard of the compartment bulkhead
4. On the front of the upper section of an alarm switchboard

9-10. To initiate an alarm in the combustible gas and smoke detector system, combustion gases or smoke has to be present in which of the following locations?

1. In the cold cathode tube
2. In the inner chamber of the detector head
3. In the compartment where the detector is located
4. In the outer chamber of the detector head

9-11. In a combustion gas and smoke detector head, the saturation point is reached when which of the following conditions occur?

1. When all ionized particles are of sufficient potential to reach the plates
2. When the gas molecules being ionized contain heavy particles of combustion products
3. When the ionized radium is working at full strength
4. When the battery is fully charged

9-12. Why will the presence of combustible gas or smoke in the detector head initiate an alarm?

1. Because the gas molecules are large and carry a greater electric charge
2. Because the saturation point of the galvanometers is reached quicker because of the more slowly moving ions
3. Because the large size of the gas and smoke particles causes the current flow in the detector head to decrease
4. Because the potential across the detector plates is reduced due to the absorption of gamma rays

9-13. What are dual-purpose detectors?

1. A combination mercury thermostat and an ionization detector connected in parallel in the same circuit
2. Two ionization detector heads connected together
3. A combination ionization detector and mercury thermostat connected in series in the same circuit
4. Two mercury thermostats connected in series in the same circuit

9-14. What type of bell has a circular 8-inch diameter watertight gong?

1. IC/B5S5
2. IC/B1S4
3. IC/B8S4
4. IC/B1S8

9-15. How is the type IC/B3D4 bell operated?

1. Battery operated
2. Ac operated
3. Dc operated
4. Both 2 and 3 above

9-16. The IC/Z1D4 de-operated buzzer has which of the following features?

1. A resonated bar
2. A resonated transducer
3. Make-and-break contacts
4. No contacts

9-17. Which of the following types of horns uses a diaphragm and produces a sound with a distinctive frequency characteristic?

1. IC/H2D4
2. IC/H8S3
3. IC/H4D3
4. IC/H8D4

9-18. Which of the following factors determines the frequency of the sound produced by a siren?

1. The number of holes in the siren housing
2. The motor speed
3. The number of rotor blades
4. Each of the above

9-19. The IC/E3D2 electronic signal unit is capable of generating what total number of distinct tones?

1. One
2. Two
3. Three
4. Four

9-20. Why are two 115-volt lamps connected in parallel and mounted behind each dial of a standard watertight lamp indicator?

1. To obtain greater brilliancy
2. To provide two separate signals
3. To provide an even heat inside the indicator
4. To prevent loss of illumination if one lamp burns out

9-21. A four-dial, variable-brilliancy standard watertight lamp indicator uses what total number of 6-volt lamps?

1. 16
2. 2
3. 8
4. 4

9-22. The prism-shaped jewels used in the special lamp indicator panels are what colors?

1. Green and red
2. Red and blue
3. Blue and green
4. Yellow and brass

9-23. The supervisory feature for systems using alarm panels and alarm switchboards consists of what size resistor?

1. 5,000-ohm, 7-watt
2. 7,000-ohm, 7-watt
3. 5,000-ohm, 5-watt
4. 7,000-ohm, 5-watt

9-24. A system is in what condition when there is no current flowing in the circuit?

1. Alarm
2. Supervisory
3. Trouble
4. Normal

9-25. What total number of supervisory resistors is needed for a circuit containing four sensing devices?

1. One
2. Two
3. Three
4. Four

9-26. When is the test light of the IC/S alarm panel energized?

1. When the test switch is in the normal position
2. When the test switch is in the silent alarm test position
3. When the test switch is in the silent trouble test position
4. Both 2 and 3 above

9-27. What total number of 2-line alarm units (B-51 alarm panels) are used for each 10-line panel?

1. 5
2. 10
3. 15
4. 20

9-28. Which of the following statements correctly describes the components of a B-51 alarm panel?

1. Two relays and a two-position rotary test switch
2. Three relays and a four-position rotary test switch
3. Three relays and two three-position rotary test switches
4. Four relays and two three-position rotary test switches

9-29. What is the resistance of the magnetic coil of the (a) alarm relay and (b) supervisory relay?

1. (a) 1,325 ohms (b) 1,325 ohms
2. (a) 1,325 ohms (b) 1,350 ohms
3. (a) 1,350 ohms (b) 1,325 ohms
4. (a) 1,350 ohms (b) 1,350 ohms

9-30. On the B-51 alarm panel, when the alarm-target relay is operated, what color does the alarm drum show?

1. Yellow
2. White
3. Black
4. Red

9-31. In the two-line alarm unit, what is the resistance value of the supervisory resistor?

1. 5,000 ohms
2. 7,000 ohms
3. 9,000 ohms
4. 11,000 ohms

9-32. What audible device is normally used with the visual signal of the B-51 alarm switchboard to alert personnel of a trouble condition in a circuit?

1. A bell
2. A buzzer
3. A siren
4. A horn

9-33. What is the least amount of current needed to operate the alarm relay?

1. 0.012 amp
2. 0.024 amp
3. 0.043 amp
4. 0.049 amp

9-34. With the test switch in the silent alarm test position and the line unit switch in the test position, what will be the color of the alarm relay drum if the system is operating correctly?

1. Gray
2. Yellow
3. White
4. Red

9-35. The line display section of the type IC/SM alarm panel contains which of the following components?

1. Subassemblies common to any size alarm panel
2. Ground detector lamps
3. Individual display modules
4. Battery back-up power supply

9-36. What component(s) is/are used to recognize the state of the remote sensors?

1. The alarm modules
2. The control panel
3. The alarm panel
4. The common alarm

9-37. The IC/SM-50 alarm switchboard is capable of monitoring what total number of individual lines?

1. 5
2. 10
3. 50
4. 100

9-38. Which of the following components is NOT mounted on the front of the common alarm section of the IC/SM-50 alarm switchboard?

1. An audible volume control
2. A ground detection indicator
3. A dimmer control
4. A visual-audible switch

9-39. The dimmer control dims the alarm module display lamps on the IC/SM-50 alarm switchboard in all EXCEPT which of the following conditions?

1. Steady
2. Normal
3. Alarm
4. Flashing

9-40. Which audible signal is generated by the IC/SM-50 alarm switchboard during an alarm condition?

1. Wailing
2. Pulsating
3. Steady
4. Siren

9-41. The battery in the IC/SM-50 alarm switchboard is used for which of the following reasons?

1. It supplies power to the alarm silence indicator when the visual-audible switch is in the visual position
2. It supplies power to the tone generator during a loss of primary power
3. Both 1 and 2 above
4. It supplies emergency power to operate the switchboard during a loss of primary power

9-42 During normal switchboard operation, the battery voltage should be between what range?

1. 6.3 volts and 12.0 volts
2. 6.3 volts and 13.8 volts
3. 12.0 volts and 13.8 volts
4. 0 volts and 6.3 volts

9-43 The line display alarm modules in the IC/SM-50 alarm switchboard have how many power supplies?

1. 1
2. 5
3. 10
4. 50

9-44 What section of the IC/SM-50 alarm switchboard is the line display section?

1. Lower
2. Middle
3. Upper
4. Top

9-45. On the IC/SM-50 alarm switchboard, which half of a line display alarm module shows the location of the circuit sensor?

1. Left
2. Right
3. Lower
4. Upper

9-46. During an alarm condition, what will be the status of the (a) upper display lamp and (b) lower display lamp on the line display alarm module of the IC/SM-50 alarm switchboard?

1. (a) On steady (b) flashing
2. (a) Flashing (b) off
3. (a) Off (b) flashing
4. (a) Flashing (b) on steady

9-47. There is no audible signal when the mode selector switch is placed in which position?

1. Normal
2. Standby
3. Cutout
4. Test

9-48. An alarm cannot be detected in a circuit during which, if any, of the following conditions?

1. Supervisory
2. Trouble
3. Normal
4. None of the above

9-49. When the mode switch is in the CUTOUT position, what is the state of the (a) upper and (b) lower lamps of the alarm module?

1. (a) Steady (b) flashing
2. (a) Dark (b) steady
3. (a) Steady (b) steady
4. (a) Flashing (b) flashing

9-50. What is the circuit designation of the high-temperature alarm system?

1. F
2. FH
3. E
4. EC

9-51. Where are pressure transducers of the pressure-to-current type located?

1. In the lubricating oil supply lines
2. In the lubricating oil scavenge lines
3. In the lubricating oil discharge lines
4. All of the above

9-52. What is the circuit designation of the auxiliary machinery lubricating oil low-pressure alarm system?

1. 1EC
2. 3EC
3. 2EC
4. 4EC

9-53. What is the circuit designation of the generator bearing and stator temperature indicating and alarm system?

1. 1ED
2. 2EW
3. EF
4. F

9-54. What circuit provides a means of indicating when carbon dioxide and Halon gas are released in compartments?

1. F
2. FH
3. FD
4. FR

9-55. What circuit provides a means of indicating the pressure in the compressed air system?

1. FH
2. F
3. EL
4. EK

9-56. When testing and maintaining the security alarm system, what minimum number of authorized personnel must be present?

1. One
2. Two
3. Three
4. Four

9-57. Which of the following conditions could cause an alarm panel or alarm switchboard alarm to sound a false alarm?

1. Shorted relay contacts
2. Weak alarm relay spring
3. Grounds
4. Each of the above

9-58. If a complete loss of power occurs in an IC/SM-50 alarm switchboard, what components should you check first?

1. The power transformers located inside the switchboard
2. The fuses that supply primary power to the switchboard
3. The fuses located on the front of the common alarm section
4. The fuses located on the front of the line display section

ASSIGNMENT 10

Textbook Assignment: Chapter 10, "Ship's Order Indicating and Metering Systems;" pages 10-1 through 10-32, and chapter 11, "Auxiliary Electrical Equipment;" pages 11-1 through 11-20.

10-1. Which of the following circuits are associated with the ship's control console?

1. M and MB
2. M and LB
3. MB and LB
4. LB and N

10-2. In the propeller revolution order system, the throttleman who acknowledges orders transmitted from the pilothouse is located in which engine room?

1. No. 1
2. No. 2
3. No. 3
4. Whichever engine room receives the order

10-3. The propeller order indicator transmitter contains what total number of synchro transmitters?

1. Six
2. Two
3. Three
4. Four

10-4. What is the circuit designation for the engine order system?

1. M
2. MB
3. L
4. N

10-5. What is the function of the engine order system?

1. It transmits and acknowledges required shaft speed changes
2. It transmits and acknowledges required shaft direction changes
3. Both 1 and 2 above
4. It transmits required propeller revolution changes

10-6. What person operates the engine order indicator-transmitters in the ship control console?

1. The OOD
2. The lee helmsman
3. The throttleman
4. The duty IC man

10-7. Where is the transmitter for the rudder angle indicator system located?

1. At the ship control console
2. In the steering control console
3. At the rudder head
4. In the No. 1 engine room

10-8. The rudder order system should be used in which of the following situations?

1. Whenever the steering gear room watch is steering the ship
2. Whenever the ship is underway
3. Whenever the ship is entering port
4. Whenever the OOD orders a change in rudder angle

10-9. The circuit designation LB is used for what system?

1. Propeller revolution order system
2. Steering emergency alarm system
3. Rudder angle indicator system
4. Rudder order system

10-10. What device is used in the steering gear room to alert the watch stander that a steering emergency has occured?

1. A bell
2. A trick wheel
3. A combination rudder angle order indicator
4. A siren

10-11. Which of the following is NOT a purpose of gears?

1. To increase or decrease the speed of the applied motion
2. To change the direction of mot ion
3. To increase or decrease the applied force
4. To eliminate frictional losses

10-12. When gears are used to reduce speed, what, if anything, will happen to the force at the output of the gear?

1. It will be increased
2. It will be decreased
3. It will double
4. Nothing

10-13. Which condition must hold true if two spur gears are to mesh properly?

1. The teeth of both gears must be the same size
2. Both gears must have the same diameter
3. The teeth of both gears must be the same distance apart
4. The gears must turn on parallel shafts

10-14. Which type of spur gear uses teeth with a leading end and a trailing end?

1. Straight
2. Thrust
3. Helical
4. Herringbone

10-15. Which type of spur gear is used mostly on heavy machinery?

1. Pinion
2. Straight
3. Rack
4. Herringbone

10-16. Which of the following is the most commonly used type of spur gear?

1. Spiral
2. Helical
3. Straight
4. Sector

10-17. What type of gear is used in a rack and pinon arrangement to save space and material?

1. Pinion
2. Herringbone
3. Driver
4. Sector

10-18. If you should find it necessary to transmit circular motion from one shaft to a second shaft which is at right angles to the first shaft, which of the following gear arrangements should you use?

1. Rack and pinion gears
2. Miter gears
3. Helical gears and a thrust bearing
4. Internal and external pinion gears

10-19. The whole width of each tooth does not come in contact with the mating tooth at the same time. Which type of bevel gear is described in this statement?

1. Straight
2. Miter
3. Angle
4. Spiral

10-20. In a worm gear-worm wheel combination, the worm gear is double threaded and the worm wheel has 50 teeth. To turn the worm wheel one complete revolution, the worm gear must be given what total number of complete turns?

1. 25
2. 2
3. 50
4. 100

10-21. To back up an automobile, it is necessary to reverse the direction of the crankshaft.

1. True
2. False

10-22. You have a pinion gear with 14 teeth driving a spur gear with 42 teeth. If the pinion gear turns at 420 rpm, what will be the speed of the spur gear?

1. 42 rpm
2. 140 rpm
3. 160 rpm
4. 278 rpm

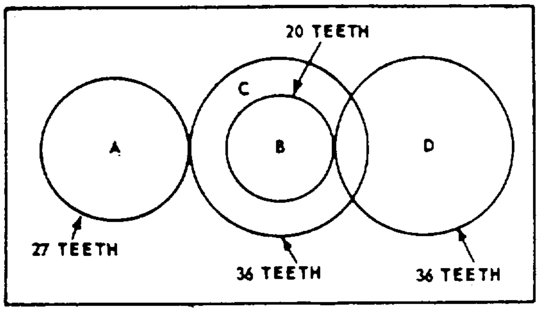


Figure 10A

IN ANSWERING QUESTION 10-13, REFER TO FIGURE 10A.

10-23. Gears B and C in the gear arrangement are rigidly fixed together. If gear A is turned counterclockwise at a rate of 120 rpm, (a) in what direction and (b) at what speed will gear D turn?

1. (a) Clockwise
   (b) 20 rpm
2. (a) Clockwise
   (b) 50 rpm
3. (a) Counterclockwise
   (b) 50 rpm
4. (a) Counterclockwise
   (b) 100 rpm

10-24. The product of all the driving teeth of a turbine reduction gearing is 400 and the product of all the driven teeth is 4,000. When the propeller shaft turns at 200 rpm, at what speed is the turbine turning?

1. 200 rpm
2. 400 rpm
3. 2,000 rpm
4. 4,000 rpm

10-25. What is the purpose of an idler gear?

1. To increase speed ratio
2. To decrease speed ratio
3. To take up lost motion
4. To allow the driven gear to turn in the same direction as the driver gear

10-26. What is the theoretical mechanical advantage if the number of teeth on a driven gear is 32 and the T_a is 4?

1. 128
2. 64
3. 8
4. 4

10-27. What is the total theoretical mechanical advantage of a compound machine made up of two simple machines if the M.A. of one machine is 10 and the M.A. of the other machine is 5?

1. 50
2. 25
3. 15
4. 5

IN ANSWERING QUESTIONS 10-28 THROUGH 10-30, REFER TO FIGURE 10-25 IN YOUR TEXTBOOK.

10-28. The two bevel gears located above and below the center of the mechanism are called what type of gears?

1. End gears
2. Input gears
3. Output gears
4. Spider gears

10-29. What gears are used to connect the end gears and spider shaft to another mechanism?

1. Two output gears and one input gear
2. Two input gears and one output gear
3. One output gear and one input gear
4. Two output gears and two input gears

10-30. Which type of gear is NOT bearing mounted?

1. Spider gear
2. End gear
3. Output gear
4. Input gear

10-31. Which of the following statements is true of a gear differential regardless of the type of hookup used?

1. The spider will follow the end gears for half the sum or difference of their revolutions
2. The two side gears are the inputs and the gear on the spider shaft is the output
3. The spider shaft is one input, one of the sides is the other input, and the other side is the output
4. If the two inputs are equal and opposite, the spider shaft will move in either direction

10-32. The outputs of computing mechanisms are used to do which of the following tasks?

1. Drive heavy loads
2. Control servomotors
3. Position the output mechanism
4. Each of the above

10-33. What is the propeller revolution indicator system used to indicate?

1. Total revolutions of each propeller shaft
2. Direction of rotation of each propeller shaft
3. Rpms of each propeller shaft
4. Each of the above

10-34. The synchro transmitters for the propeller revolution indicator system transmitters are driven (a) at what speed and (b) in what direction?

1. (a) Same speed as their respective shaft
   (b) clockwise
2. (a) Same speed as their respective shaft
   (b) counterclockwise
3. (a) Twice their respective shaft speed
   (b) clockwise
4. (a) One-half their respective shaft speed
   (b) counterclockwise

10-35. Where are the transmitters for the propeller revolution indicator system located?

1. In the pilothouse
2. On their respective propeller shaft
3. On the reduction gear for their respective propeller shaft
4. In the throttle station for their respective propeller shaft

10-36. At what speed is the revolution counter in the transmitter driven?

1. One-half the speed of the shaft
2. Twice the speed of the shaft
3. The same speed as the shaft
4. One-tenth the speed of the shaft

10-37. The remote indicator signal lights are energized by what component(s) in the transmitter?

1. The center contact and two of the movable contacts
2. The center contact and one of the stationary contacts
3. The swinging links
4. The small insulating block

10-38. The synchro transmitter is prevented from driving the counter backward during brief periods of rapid speed reduction by what component(s) in the transmitter?

1. The brake shoes
2. The contact assembly
3. The helical gears
4. The idler gear

10-39. How are the transmitters connected to their respective indicator-transmitters?

1. Through gears
2. Electrically
3. By a stub shaft
4. Directly coupled

10-40. Which of the following components is NOT a part of an indicator-transmitter?

1. A dial
2. A speed-measuring mechanism
3. A ruining synchro transmitter
4. A positioning synchro transmitter

10-41. The speed-measuring mechanism in the indicator-transmitter operates by what principle?

1. Vector gear
2. Differential gear
3. Accelerometer assembly
4. Friction disk and roller assembly

10-42. How is the outer dial of the indicator-transmitter numbered?

1. For each 5 rpm
2. For each 25 rpm
3. For each 50 rpm
4. For each 100 rpm

10-43. What total number of complete revolutions does the short pointer on the indicator-transmitter make for full-scale indication?

1. 1
2. 10
3. 100
4. 1000

10-44. As the roller is moved toward the center of the friction disk in the indicator-transmitter, what will happen to its speed?

1. It will increase inversely with the distance traveled
2. It will increase in direct proportion with the distance traveled
3. It will decrease inversely with the distance traveled
4. It will decrease in direct proportion to the distance traveled

10-45. What is the friction disk speed for an indicator-transmitter with a range of 400?

1. 16 2/3 rpm
2. 33 1/3 rpm
3. 45 rpm
4. 78 rpm

10-46. What component determines the direction of rotation of the follow-up motor in an indicator-transmitter?

1. A synchronous motor
2. A friction roller and helical gear
3. A slip ring and contact assembly
4. A running synchro transmitter

10-47. When the roller is at the exact center of the friction disk, what will be the position of the long pointer?

1. 1 rpm
2. 0 rpm
3. 100 rpm
4. Full scale indication

10-48. On an indicator-transmitter with a speed signal switch, what is the range of the signal setting?

1. 0 rpm to 1/4 full speed
2. 1/4 full speed to 5 rpm
3. 1/4 full speed to 0 rpm
4. 5 rpm to 1/4 full speed

10-49. When, if at all, is the dummy log in the underwater log system used in place of the rodmeter?

1. When the ship is operating in shallow water
2. When the ship is operating in deep water
3. When the propeller shafts are not turning
4. Never

10-50. The output of the rodmeter is fed directly to which of the following components of the indicator-transmitter?

1. The integrator
2. The speed dial
3. The speed servo
4. The synchro output transmitter

10-51. What is the purpose of the valve position indicator system?

1. To enable personnel to open certain valves remotely
2. To enable personnel to close certain valves remotely
3. Both 1 and 2 above
4. To enable personnel at remote stations to see if certain valves are opened or closed

10-52. The sensitive switches used in the valve position indicator system normally have what type of contact arrangement?

1. Make
2. Break
3. Make before break
4. Break before make

10-53. The salinity indicator system measures which of the following conditions?

1. Electrolytic impurities of dirty water
2. Electrolytic impurities of seawater
3. Electrolytic impurities of fresh water
4. Electrolytic impurities of salt water

10-54. To prevent damage to the ship's boilers, boiler feedwater should be kept below what maximum emp?

1. 0.656
2. 0.650
3. 0.560
4. 0.065

10-55. What, if anything, will happen to current flow in a salinity cell if the impurities in the water decrease?

1. Current flow will increase
2. Current flow will decrease
3. Current flow will stop
4. Nothing, current flow will remain the same

10-56. The automatic temperature compensator in a salinity cell is made from a material having what kind of temperature coefficient?

1. Negative
2. Positive
3. Resistive
4. Capacitive

10-57. What type of electrodes are used in a salinity cell to detect impurities?

1. Gold
2. Silver
3. Copper
4. Platinum

10-58. The meter unit in a salinity panel is calibrated in which of the following measurements?

1. Gallons
2. Volts
3. Ohms
4. Epm

10-59. What valve is used in the salinity indicator system to stop contaminated water from reaching the potable water tanks?

1. Dump
2. Ball
3. Gate
4. Redirect

10-60. What category of level detectors is used to detect fluid levels in systems with a need for greater accuracy?

1. Transmitter
2. Level link
3. Magnetic
4. Reed

10-61. To ensure a wide variety of whistle characteristics, the fundamental frequency of a whistle must be between which of the following defined limits?

1. 200 to 500 Hz, for a ship less than 75 meters (240 feet) long
2. 100 to 300 Hz, for a ship 75 to 200 meters (240 to 650 feet) long
3. 130 to 600 Hz, for a ship more than 200 meters (650 feet) long
4. 130 to 350 Hz, for a ship 75 to 200 meters (240 feet to 650 feet) long

10-62. The microfiche reader printer is a self-contained machine designed for reading and printing enlarged copies of microfiche images.

1. True
2. False

10-63. To reduce the corrosion or deterioration of the ship's hull in seawater, which of the following protection systems is installed?

1. Armament
2. Cathodic
3. Resistive
4. Degaussing

10-64. Which of the following elements acts as the electrolyte for the cathodic protection system?

1. Tricarboxylic acid
2. Sulfuric acid
3. Sal ammoniac
4. Seawater

10-65. The amount of corrosion on a hull is determined by all EXCEPT which of the following factors?

1. The depth of the seawater
2. The resistivity of the seawater
3. The temperature of the seawater
4. Stray electrical currents

10-66. Sacrificial anodes should be replaced a minimum of how often?

1. 1 yr
2. 2 yr
3. 3 yr
4. 4 yr

10-67. To protect valves and sea chests at nonferrous metal junctions, which of the following components are installed?

1. Iron anodes
2. Aluminum anodes
3. Steel waster pieces
4. Magnesium waster pieces

10-68. The sacrificial anodes have all EXCEPT which of the following advantages?

1. Hull protection is provided at all times
2. They are easy to install
3. They require little maintenance
4. They reduce the noise level around the hull

10-69. The impressed current cathodic protection system anodes are made of which of the following materials?

1. A carbon-coated rod
2. A silver-chloride-coated rod
3. A platinum-coated tantalum rod
4. A zinc-coated rod

10-70. A 4-foot anode has what maximum current rating?

1. 75 amp
2. 100 amp
3. 125 amp
4. 150 amp

10-71. The shaft grounding assembly used with cathodic protection systems grounds which of the following components?

1. The electrical motor shafts
2. The propeller shafts
3. The generator shafts
4. The air compressor shafts

10-72. The large loop that is placed in a rudder grounding strap serves what function?

1. It reduces stray currents
2. It grounds the rudder crosshead
3. It permits full rotation of the rudder stock
4. It ensures that the strap does not get fouled on deck as the rudder rotates

10-73. What is the voltage range developed between a disconnected platinum anode and the hull?

1. 1.0 to 2.0 volts dc
2. 1.9 to 2.5 volts ac
3. 2.5 to 3.5 volts ac
4. 3.0 to 5.0 volts dc

10-74. The optimum polarization range of the ship’s hull-to-reference electrode potential is which of the following voltages?

1. +1.00 to +2.00 volts dc
2. +0.80 to +0.90 volts dc
3. -0.80 to -0.90 volts dc
4. -1.00 to -2.00 volts dc

10-75. The majority of steering gear installations in new construction naval vessels are of the electrohydraulic type.

1. True
2. False