NONRESIDENT
TRAINING
COURSE

February 1993

Interior Communications Electrician, Volume 2

NAVEDTRA 14121

Although the words "he," "him," and "his" are used sparingly in this course to enhance communication, they are not intended to be gender driven or to affront or discriminate against anyone.

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ERRATA #2 28 Jul 1997

Specific Instructions and Errata for
Nonresident Training Course

INTERIOR COMMUNICATIONS ELECTRICIAN, VOLUME 2

1. This errata supersedes all previous erratas. No attempt has been made to issue corrections for errors in typing, punctuation, etc., that do not affect your ability to answer the question or questions.

2. To receive credit for deleted questions, show this errata to your local course administrator (ESO/scorer). The local course administrator is directed to correct the course and the answer key by indicating the question deleted.

3. Assignment Booklet

Delete the following questions, and leave the corresponding spaces blank on the answer sheets:

Questions	Questions
1-25	3-28
1-42	3-40
1-46	3-60
2-51	4-26
3-4	4-28

PREFACE

By enrolling in this self-study course, you have demonstrated a desire to improve yourself and the Navy. Remember, however, this self-study course is only one part of the total Navy training program. Practical experience, schools, selected reading, and your desire to succeed are also necessary to successfully round out a fully meaningful training program.

COURSE OVERVIEW: In completing this nonresident training course, you will demonstrate a knowledge of the subject matter by correctly answering questions on the following subjects: manual bus transfers, frequency regulators, and motor controllers; anemometer systems; the stabilized glide slope indicator (GSI) system; and technical administration.

THE COURSE: This self-study course is organized into subject matter areas, each containing learning objectives to help you determine what you should learn along with text and illustrations to help you understand the information. The subject matter reflects day-to-day requirements and experiences of personnel in the rating or skill area. It also reflects guidance provided by Enlisted Community Managers (ECMs) and other senior personnel, technical references, instructions, etc., and either the occupational or naval standards, which are listed in the *Manual of Navy Enlisted Manpower Personnel Classifications and Occupational Standards*, NAVPERS 18068.

THE QUESTIONS: The questions that appear in this course are designed to help you understand the material in the text.

VALUE: In completing this course, you will improve your military and professional knowledge. Importantly, it can also help you study for the Navy-wide advancement in rate examination. If you are studying and discover a reference in the text to another publication for further information, look it up.

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ICCS Bert A. Parker

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Sailor's Creed

"I am a United States Sailor.

I will support and defend the Constitution of the United States of America and I will obey the orders of those appointed over me.

I represent the fighting spirit of the Navy and those who have gone before me to defend freedom and democracy around the world.

I proudly serve my country's Navy combat team with honor, courage and commitment.

I am committed to excellence and the fair treatment of all."

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INSTRUCTIONS FOR TAKING THE COURSE

ASSIGNMENTS

The text pages that you are to study are listed at the beginning of each assignment. Study these pages carefully before attempting to answer the questions. Pay close attention to tables and illustrations and read the learning objectives. The learning objectives state what you should be able to do after studying the material. Answering the questions correctly helps you accomplish the objectives.

SELECTING YOUR ANSWERS

Read each question carefully, then select the BEST answer. You may refer freely to the text. The answers must be the result of your own work and decisions. You are prohibited from referring to or copying the answers of others and from giving answers to anyone else taking the course.

SUBMITTING YOUR ASSIGNMENTS

To have your assignments graded, you must be enrolled in the course with the Nonresident Training Course Administration Branch at the Naval Education and Training Professional Development and Technology Center (NETPDTC). Following enrollment, there are two ways of having your assignments graded: (1) use the Internet to submit your assignments as you complete them, or (2) send all the assignments at one time by mail to NETPDTC.

Grading on the Internet: Advantages to Internet grading are:

- you may submit your answers as soon as you complete an assignment, and
- you get your results faster; usually by the next working day (approximately 24 hours).

In addition to receiving grade results for each assignment, you will receive course completion confirmation once you have completed all the assignments. To submit your assignment answers via the Internet, go to:

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Grading by Mail: When you submit answer sheets by mail, send all of your assignments at one time. Do NOT submit individual answer sheets for grading. Mail all of your assignments in an envelope, which you either provide yourself or obtain from your nearest Educational Services Officer (ESO). Submit answer sheets to:

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Answer Sheets: All courses include one "scannable" answer sheet for each assignment. These answer sheets are preprinted with your SSN, name, assignment number, and course number. Explanations for completing the answer sheets are on the answer sheet.

Do not use answer sheet reproductions: Use only the original answer sheets that we provide—reproductions will not work with our scanning equipment and cannot be processed.

Follow the instructions for marking your answers on the answer sheet. Be sure that blocks 1, 2, and 3 are filled in correctly. This information is necessary for your course to be properly processed and for you to receive credit for your work.

COMPLETION TIME

Courses must be completed within 12 months from the date of enrollment. This includes time required to resubmit failed assignments.

PASS/FAIL ASSIGNMENT PROCEDURES

If your overall course score is 3.2 or higher, you will pass the course and will not be required to resubmit assignments. Once your assignments have been graded you will receive course completion confirmation.

If you receive less than a 3.2 on any assignment and your overall course score is below 3.2, you will be given the opportunity to resubmit failed assignments. **You may resubmit failed assignments only once.** Internet students will receive notification when they have failed an assignment--they may then resubmit failed assignments on the web site. Internet students may view and print results for failed assignments from the web site. Students who submit by mail will receive a failing result letter and a new answer sheet for resubmission of each failed assignment.

COMPLETION CONFIRMATION

After successfully completing this course, you will receive a letter of completion.

ERRATA

Errata are used to correct minor errors or delete obsolete information in a course. Errata may also be used to provide instructions to the student. If a course has an errata, it will be included as the first page(s) after the front cover. Errata for all courses can be accessed and viewed/downloaded at:

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STUDENT FEEDBACK QUESTIONS

We value your suggestions, questions, and criticisms on our courses. If you would like to communicate with us regarding this course, we encourage you, if possible, to use e-mail. If you write or fax, please use a copy of the Student Comment form that follows this page.

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NAVAL RESERVE RETIREMENT CREDIT

If you are a member of the Naval Reserve, you may earn retirement points for successfully completing this course, if authorized under current directives governing retirement of Naval Reserve personnel. For Naval Reserve retirement, this course is evaluated at 6 points. (Refer to *Administrative Procedures for Naval Reservists on Inactive Duty,* BUPERSINST 1001.39, for more information about retirement points.)

Student Comments

Course Title: *Interior Communications Electrician, Volume 2*

NAVEDTRA: 14121 **Date**: ____________________

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Your comments, suggestions, etc.:

Privacy Act Statement: Under authority of Title 5, USC 301, information regarding your military status is requested in processing your comments and in preparing a reply. This information will not be divulged without written authorization to anyone other than those within DOD for official use in determining performance.

NETPDTC 1550/41 (Rev 4-00

CHAPTER 1

MANUAL BUS TRANSFERS, MOTOR CONTROLLERS, AND FREQUENCY REGULATORS

CHAPTER LEARNING OBJECTIVES

Upon completing this chapter, you should be able to do the following:

- *Describe the troubleshooting and maintenance procedures for manual bus transfer (MBT) switches.*
- *Identify the different types of electric controllers.*
- *Describe the principles of operation of various types of motor controllers.*
- *Describe the procedures for troubleshooting motor controllers.*
- *Describe the procedures to use when performing corrective maintenance on motor controllers.*
- *Describe the principles of operation of frequency regulators.*
- *Identify the components of motor generators and their principles of operation.*
- *Describe the procedures for troubleshooting and performing corrective maintenance on frequency regulators.*

This chapter discusses the troubleshooting and maintenance procedures for manual bus transfers (MBTs), motor controllers, and frequency regulators. To troubleshoot and maintain these components, you need to have an understanding of the characteristics, uses, and operating principles of the components. Because interior communications and weapons systems aboard modern Navy ships require closely regulated electric power for proper operation, you also need to have an understanding of closely regulated power supplies to troubleshoot and maintain frequency regulators. Because equipage in special power applications aboard ship is so diverse, little is said about troubleshooting or maintenance of MBT switches and frequency regulators. In studying this chapter, you should remember to refer to the manufacturer's technical manual when troubleshooting the equipment and to the applicable maintenance requirement card (MRC) for maintenance requirements.

MANUAL BUS TRANSFER SWITCHES

MBT switches are commonly used for nonvital equipment aboard ship. They consist of two make or break switches and a locking bar. To transfer from normal power to ship's emergency power, the locking bar must be manually loosened and moved before the positions of the switches can be changed. Troubleshooting should be done according to the technical manual associated with the equipment. Maintenance of the MBT switch should be done according to the applicable PMS cards.

MOTOR CONTROLLERS

Controllers are commonly used for starting large motors aboard ship to reduce the amount of current they require when started. The starting current of huge motors is usually several times higher than the running current. If controllers are not used for starting, motors and the equipment they drive may be damaged, or the operation of other equipment in the same distribution system may be affected adversely. 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.

TYPES OF MOTOR CONTROLLERS

A motor controller protects a motor from damage, starts or stops it, increases or decreases its speed, or reverses its direction of rotation.

Manual

A manual (nonautomatic) controller is operated by hand directly through a mechanical system. The operator closes and opens the contacts that normally energize and de-energize the connected load.

Magnetic

In a magnetic controller, the contacts are closed or opened by electromechanical devices operated by local or remote master switches. Normally, all the functions of a semiautomatic magnetic controller are governed by one or more manual master switches; automatic controller functions are governed by one or more automatic master switches, after it has been initially energized by a manual master switch. Either controller can be operated in the semiautomatic or automatic mode, depending on the mode of operation selected.

Across-the-Line

An across-the-line controller throws the connected load directly across the main supply line. This motor controller may be either manual or magnetic, depending on the rated horsepower of the motor. Normally, across-the-line dc controllers are used for starting small (fractional horsepower) motors. However, they also may be used to start average-sized, squirrel-cage induction motors without any damage. This is because these motors can withstand the high starting currents due to starting with full-line voltage applied. Most squirrel-cage motors drive pumps, compressors, fans, lathes, and other auxiliaries. They can be started "across the line" without producing excessive line-voltage drop or mechanical shock to a motor or auxiliary.

Dc Resistor

In a dc resistor motor controller, a resistor in series with the armature circuit of the dc motor limits the amount of current during starts, thereby preventing motor damage and overloading the power system. In some resistor controllers, the same resistor also helps regulate the speed of the motor after it is started. Other dc controllers use a rheostat in the motor shunt field circuit for speed control.

Ac Primary Resistor

In an ac primary resistor controller, resistors are inserted in the primary circuit of an ac motor for both starting and speed control. Some of these controllers only limit the starting currents of large motors; others control the speed of small motors, as well as limit the starting current.

Ac Secondary Resistor

In an ac secondary resistor controller, resistors are inserted in the secondary circuit of a wound-rotor ac motor for starting or speed control. Although they are sometimes used to limit starting currents, secondary resistor controllers usually function to regulate the speeds of large ac motors.

Static Variable-Speed

A static variable-speed motor controller consists of solid-state and other devices that regulate motor speeds in indefinite increments through a predetermined range. Speed is controlled by either manual adjustment or actuation of a sensing device that converts a system parameter, such as temperature, into an electric signal. This signal sets the motor speed automatically.

Autotransformer

The autotransformer controller (or compensator) is an ac motor controller. It starts the motor at a reduced voltage through an autotransformer, and then it connects the motor to line voltage after the motor accelerates. There are two types of compensators: open transition and closed transition. The open-transition compensator cuts off power to the motor during the time (transition period) the motor connection is shifted from the autotransformer to the supply line. In this short transition period, it is possible for the motor to coast and slip out of phase with the power supply. After the motor is connected directly to the supply line, the resulting transition current may be high enough to cause circuit breakers to open. The closed-transition compensator keeps the motor connected to the supply line during the entire transition period. In this method, the motor cannot slip out of phase and no high transition current can develop.

Reactor

A reactor controller inserts a reactor in the primary circuit of an ac motor during starts, and later it short circuits the reactor to apply line voltage to the motor. The reactor controller is not widely used for starting large ac motors. It is smaller than the closed-transition compensator and does not have the high transition currents that develop in the open-transition compensator.

TYPES OF MASTER SWITCHES

A master switch is a device, such as a pressure or a thermostatic switch, that governs the electrical operation of a motor controller. The switch can be manually or automatically actuated. Drum, selector, and push-button switches are examples of a manual master switch. The automatic switch is actuated by a physical force, not an operator. Examples of automatic master switches include float, limit, or pressure switches.

Depending on where it is mounted, a master switch is either local or remote. A local switch is mounted in the controller enclosure; a remote switch is not.

Master switches may start a series of operations when their contacts are either closed or opened. In a momentary contact master switch, the contact is closed (or opened) momentarily; it then returns to its original condition. In the maintaining contact master switch, the cent act does not return to its original condition after closing (or opening) until it is again actuated. The position of a normally open or normally closed contact in a master switch is open or closed, respectively, when the switch is de-energized. The de-energized condition of a manual controller is considered to be in the off position.

OVERLOAD RELAYS

Nearly all shipboard motor controllers provide overload protection when motor current is excessive. This protection is provided by either thermal or magnetic overload relays, which disconnect the motor from its power supply, thereby preventing the motor from overheating.

Overload relays in magnetic controllers have a normally closed contact that is opened by a mechanical device that is tripped by an overload current. The opening of the overload relay contact de-energizes the circuit through the operating coil of the main contactor, causing the main contactor to open, securing power to the motor.

Overload relays for naval shipboard use can usually be adjusted to trip at the correct current to protect the motor. If the rated tripping current of the relay does not fit the motor it is intended to protect, it can be reset after tripping so the motor can be operated again with overload protection. Some controllers feature an emergency-run button that enables the motor to be run without overload protection during an emergency.

Thermal Overload Relays

The thermal overload relay has a heat-sensitive element and an overload heater that is connected in series with the motor load circuit. When the motor current is excessive, heat from the heater causes the heat-sensitive clement to open the overload relay contact. This action breaks the circuit through the operating coil of the main contractor and disconnects the motor from the power supply. Since it takes time for the parts to heat up, the thermal overload relay has an inherent time delay, which allows the motor to draw excessive current at start without tripping the motor.

To make a coarse adjustment of the tripping current of thermal overload relays, change the heater element. Fine adjustment depends on the type of overload relay. To make a fine adjustment, change the distance between the heater and the heat-sensitive element. An increase in this distance increases the tripping current. You can make another form of adjustment by changing the distance the bimetal strip has to move before the overload relay contact is opened. Check the related technical manual for additional information and adjustments.

Thermal overload relays must be compensated; that is, constructed so the tripping current is unaffected by variations in the ambient (room) temperature. Different means are used for different types. Refer to the technical manual furnished with the equipment on which the controller is used for information on the particular form of compensation provided. There are four types of thermal overload relays: solder pot, bimetal, single metal, and induction.

SOLDER POT.– The heat-sensitive element of a solder-pot relay consists of a cylinder inside a hollow tube. The cylinder and tube are normally held together by a film of solder. In case of an overload, the heater melts the solder (thereby breaking the bond between the cylinder and tube) and releases the tripping device of the relay. After the relay trips, the solder cools and solidifies. The relay can then be reset.

BIMETAL.– In the bimetal relay, the heat-sensitive element is a strip or coil of two different metals fused together along one side. When heated, the strip or coil deflects because one metal expands more than the other. The deflection causes the overload relay contact to open.

SINGLE METAL.– The heat-sensitive element of the single-metal relay is a tube around the heater. The tube lengthens when heated and opens the overload relay contact.

INDUCTION.– The heater in the induction relay consists of a coil in the motor circuit and a copper tube inside the coil. The tube acts as the short-circuited secondary of a transformer and is heated by the current induced in it. The heat-sensitive element is usually a bimetal strip or coil. Unlike the other three types of thermal overload relays that may be used with either ac or dc, the induction type is manufactured for ac use only.

Magnetic Overload Relays

The magnetic overload relay has a coil connected in series with the motor circuit and a tripping armature or plunger. When the normal motor current exceeds the tripping current, the contacts open the overload relay. Though limited in application, one type of magnetic overload relay operates instantly when the motor current exceeds the tripping current. This type must be set at a higher tripping current than the motor-starting current because the relay would trip each time you start the motor. One use of the instantaneous magnetic overload relay is in motor controllers used for reduced voltage starting where the starting current peaks are less than the stalled rotor current.

The operation of a second type of magnetic overload relay is delayed a short time when the motor current exceeds the tripping current. This type of relay is essentially the same as the instantaneous relay except for the time-delay device. This is usually an oil dashpot with a piston attached to the tripping armature of the relay. Oil passes through a hole in the piston when the tripping armature is moved by an overload current. The size of the hole can be adjusted to change the speed at which the piston moves for a given pull on the tripping armature. For a given size hole, the larger the current, the faster the operation. The motor is thus allowed to carry a small overload current. The relay can be set to trip at a current well below the stalled rotor current because the time delay gives the motor time to accelerate to full speed before the relay operates. By this time, the current will have dropped to full-load current, which is well below the relay trip setting.

In either the instantaneous or time-delay magnetic overload relays, you can adjust the tripping currents by changing the distance between the series coil and the tripping armature. More current is needed to move the armature when the distance is increased. Compensation for changes in ambient temperature is not needed for magnetic relays because they are practically unaffected by changes in temperature.

Overload Relay Resets

After an overload relay has operated to stop a motor, it must be reset before the motor can be started again. Magnetic overload relays can be reset immediately after tripping. Thermal overload relays must cool a minute or longer before they can be reset. The type of overload reset may be manual, automatic, or electric.

The manual, or hand, reset is usually located in the controller enclosure, which contains the overload relay. This type of reset usually has a hand-operated rod, lever, or button that returns the relay tripping mechanism to its original position, resetting interlocks as well, so the motor can be run again with overload protection. (An interlock is a mechanical or electrical device in which the operation of one part or mechanism automatically brings about or prevents the operation of another.)

The automatic type of reset usually has a spring- or gravity-operated device, resetting the overload relay without the help of an operator. The electric reset is actuated by an electromagnet controlled by a push button. This form of overload reset is used when it is desired to reset an overload relay from a remote operating point.

Overload Relay–Emergency Run

Motor controllers having emergency-run features are used with auxiliaries that cannot be stopped safely in the midst of an operating cycle. This type of feature allows the operator of the equipment to keep it running with the motor overloaded until a standby unit can take over, the operating cycle is completed, or the emergency passes.

NOTE: Use this feature in an emergency only. Do not use it otherwise.

Three methods of providing emergency run in magnetic controllers are an emergency run pushbutton, a reset-emergency run lever, or a start-emergency run push button. In each case, the lever or push button must be held closed manually during the entire emergency.

Figure 1-1 is a schematic diagram of a controller showing a separate EMERGENCY RUN push button with normally open contacts in parallel with the normally closed contact of the overload relay. For

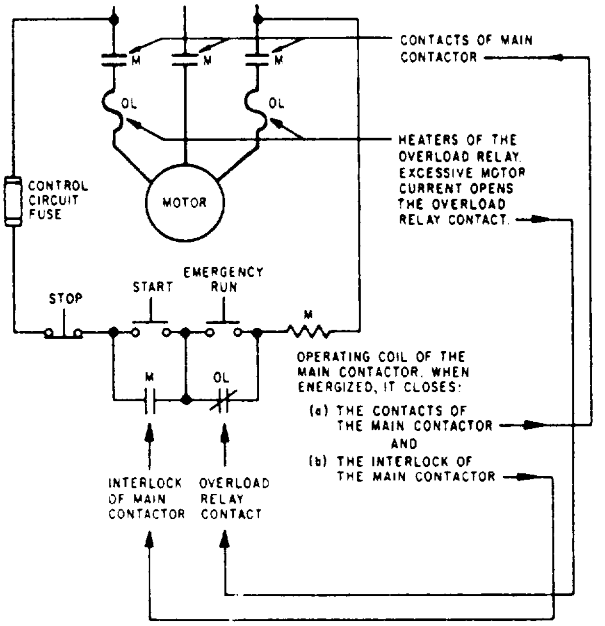


Figure 1-1.-Schematic of controller with emergency run push button.

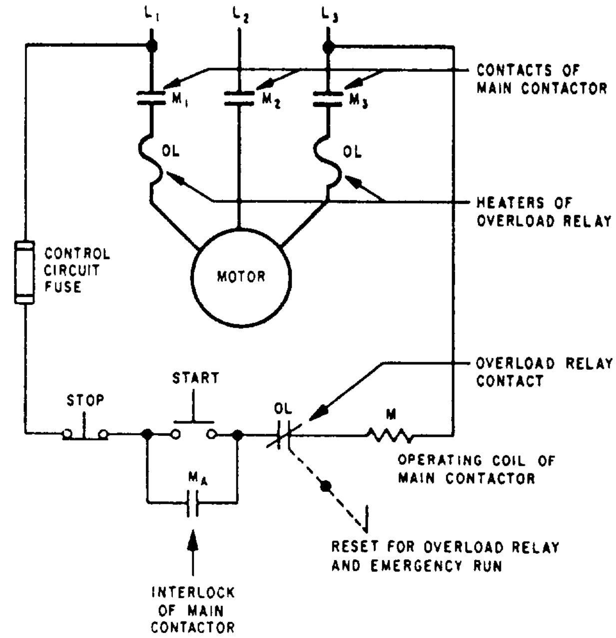


Figure 1-2.-Schematic of controller with reset-emergency run lever or rod.

emergency run operation, the operator must hold down this push button and press the START button to start the motor. While the emergency run push button is depressed, the motor cannot be stopped by opening the overload relay contact.

A REST-EMERGENCY RUN lever is shown in figure 1-2. As long as the lever or rod is held down, the overload relay contact is closed. The start button must be momentarily closed to start the motor. Figure 1-3 shows a START-EMERGENCY RUN pushbutton. The motor starts when the button is pushed, and it continues to run without overload protection as long as it is held down. For this reason, push buttons that are marked start-emergency run should not be kept closed for more than a second or two unless the emergency run operation is desired.

Manual controllers also may be provided with an emergency run feature. The usual means is a start-emergency run push button or lever, which keeps the main contactor coil energized despite the tripping action of the overload relay mechanism.

SHORT-CIRCUIT PROTECTION

Overload relays and contractors are usually not designed to protect motors from currents greater than about six times normal rated current of ac motors or four times normal rated current of dc motors. Since short-circuited currents are much higher, protection against short circuits in motor controllers is obtained through other devices. To protect against these short circuits, circuit breakers are installed in the power supply system, thereby protecting the controller, motor, and cables. Short-circuit protection is provided in controllers where it is not otherwise provided by the power distribution system or where two or more motors are supplied power

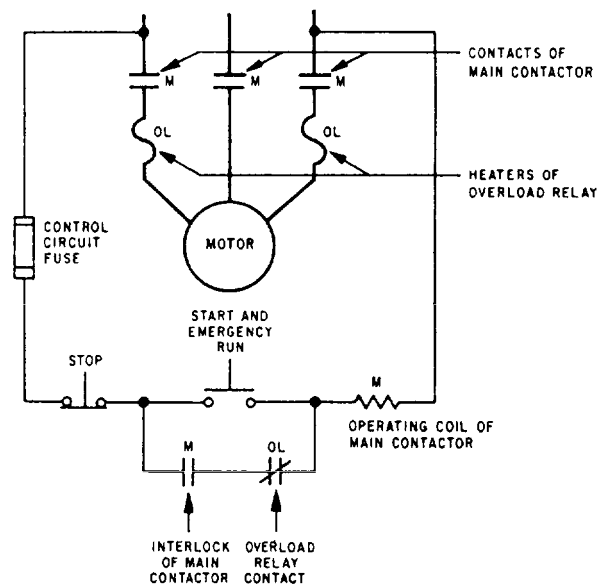


Figure 1-3-Schematic of controller with start-emergency run push button.

but the circuit breaker rating is too high to protect each motor separately.

Short-circuit protection for control circuits is provided by fuses in the controller enclosure, which provides protection for remote push buttons and pressure switches.

FULL-FIELD PROTECTION

Full-field protection is required in the controller for a dc motor when a shunt field rheostat or a resistor is used to weaken the motor field and obtain motor speeds more than 150 percent of the speed at rated field current. Full-field protection is provided automatically by a relay that shunts out the shunt field rheostat for the initial acceleration of the motor, and then cuts it into the motor field circuit. In this way, the motor first accelerates to 100 percent or full-field speed, and then further accelerates to the weakened-field speed determined by the rheostat settings.

The controller for an anchor windlass motor provides stepback protection by automatically cutting back motor speed to relieve the motor of excessive load.

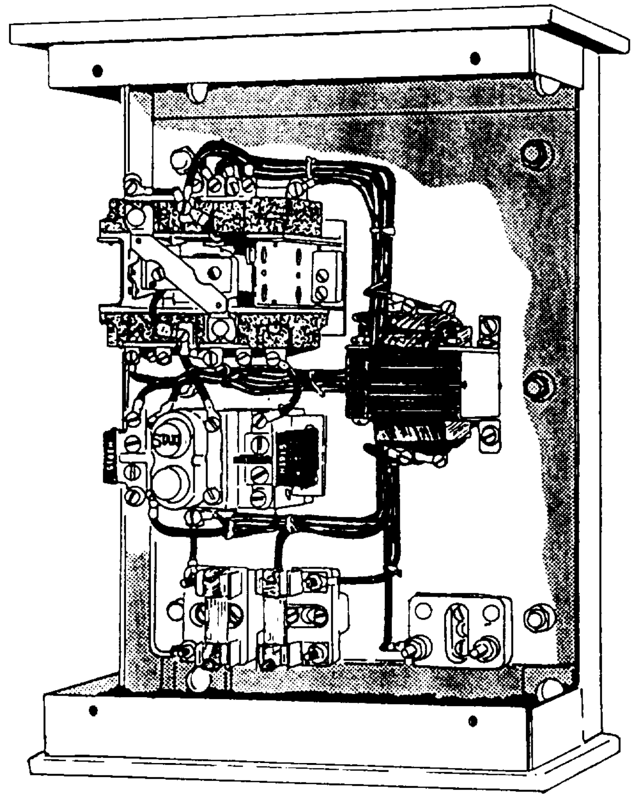


Figure 1-4.-Across-line, 3-phase controller.

LOW-VOLTAGE RELEASE (LVR)

When the supply voltage is reduced or lost altogether, an LVR controller disconnects the motor from the power supply, keeps it disconnected until the supply voltage returns to normal, and then automatically restarts the motor. This type of controller is equipped with a maintaining master switch.

LOW-VOLTAGE PROTECTION (LVP)

When the supply voltage to an LVP controller is reduced or lost, the motor is disconnected from the line. Upon restoration of power, the motor will not start until you manually depress the start push button.

MAGNETIC ACROSS-LINE CONTROLLERS

A typical 3-phase, across-line controller is shown in figure 1-4. Figure 1-5 shows a small cubical contactor for a 5-horsepower motor. All contractors are similar in appearance, but they vary in size.

An elementary or schematic diagram of a magnetic controller is shown in figure 1-2. The motor is started by pushing tie strut button. The action completes the circuit from L_1 through the control fuse, stop button, start button, the overload relay contacts, OL, and the contactor coil, M to L_3. When the coil is energized, it closes line contacts M_1, M_2, and M_3, which connect the full-line voltage to the motor. The line contactor auxiliary contact, MA, also closes and completes a holding circuit for energizing the coil circuit after the start push button has been released.

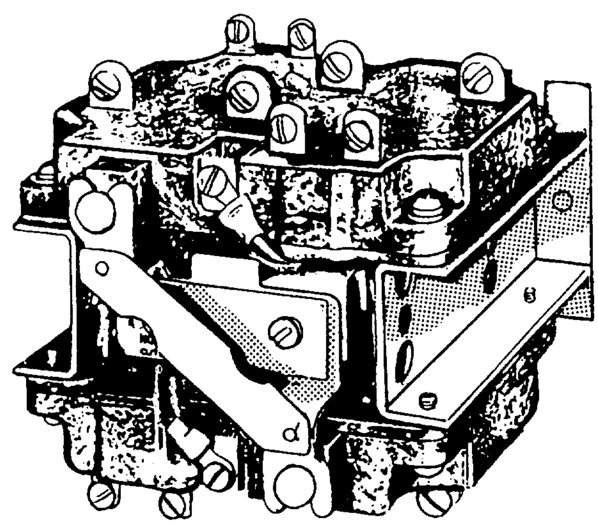


Figure 1-5.-Contactor for a 5-horsepower motor.

The motor will continue to run until the contactor coil is de-energized by the stop push button, failure of the line voltage, or tripping of the overload relay, OL.

Reversing

The rotation of a three-phase induction motor is reversed by interchanging any two of the three leads to the motor. The connections for an ac reversing controller are shown in figure 1-6. The stop, reverse, and forward push-button controls are all momentary-contact switches. Note the connections to the reverse and forward switch contacts. (Their contacts close or open momentarily, then return to their original closed or opened condition.)

If the forward pushbutton is pressed (solid to dotted position), coil F will be energized and will close its holding contacts, F_A. These contacts will remain closed as long as coil F is energized. When the coil is energized, it also closes line contacts F1, F2, and F3, which apply full-line voltage to the motor. The motor then runs in a forward direction.

If either the stop button or the reverse button is pressed, the circuit to the F contactor coil is broken, and the coil releases and opens line contacts F1, F2, F3, and maintaining contact F_A.

If the reverse pushbutton is pressed (solid to dotted position), coil R is energized and closes, holding contacts R_A and line contacts R1, R2, and R3. Note that contacts R1 and R3 reverse the connections of lines 1 and 3 to motor terminals T1 and T3. This causes the motor rotor to rotate in the reverse direction. The F and R contactors are mechanically interlocked to prevent troth being closed at the same time.

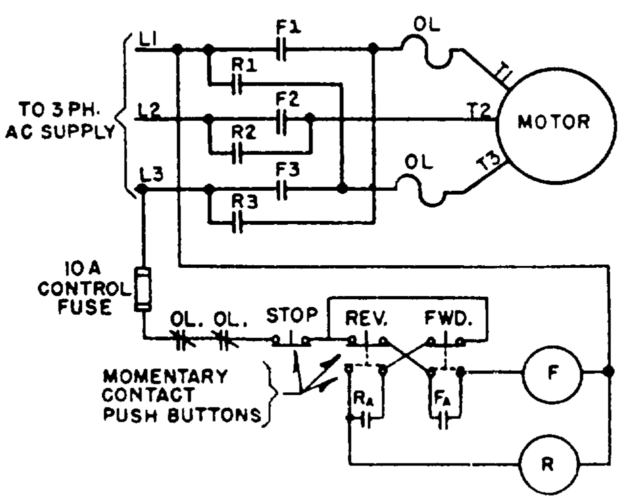


Figure 1-6-Reversing ac controller.

Momentary-contact push buttons provide LVP with manual restart in the circuit shown in figure 1-6. If either the For R operating coil is de-energized, the contactor will not reclose and start the motor when voltage is restored unless either the forward or reverse pushbutton is pressed. The circuit arrangement of the pushbuttons provides an electrical interlock that prevents the energizing of both coils at the same time.

Speed Control

When you desire to operate an ac motor at different speeds, you must use a controller with a circuit as shown in figure 1-7.

An ac induction motor designed for two-speed operation may have either a single set of windings or two separate sets of windings, one for each speed. Figure 1-7 is a schematic diagram of the ac controller for a two-speed, two-winding induction motor. The low-speed winding is connected to terminals T_1, T_2, and T_3. The high-speed winding is connected to terminals T_{11}, T_{12}, and T_{13}. Overload protection is provided by the low-speed overload (LOL) coils and contacts for the low-speed winding and the high-speed overload (HOL) contacts and coils for the high-speed winding. The LOL and HOL contacts are connected in series in the maintaining circuit, and both contacts must be closed before the motor will operate at either speed.

The control push buttons are the momentary-contact type. Pressing the high-speed push button closes the high-speed contactor by energizing coil HM. The

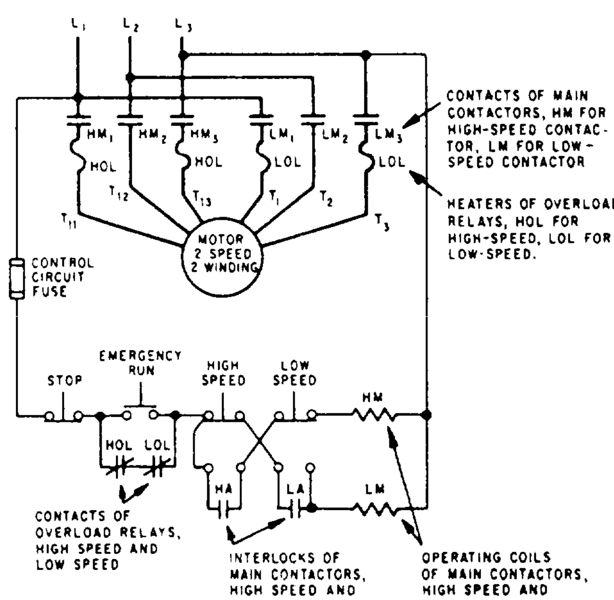


Figure 1-7.-Two-speed, ac controller.

coil remains energized after the push button is released, closing holding contacts HA. The coil, HM, also closes main line contacts HM_1, HM_2, and HM_3, applying full-line voltage to the motor high-speed winding. The motor will run at high speed until coil HM is de-energized either by opening the stop switch, a power failure, or an overload.

Pressing the low-speed push button closes the low-speed contactor by energizing coil LM. The coil remains energized after the button is released, through the holding coil contacts, LA. The coil, LM, also closes the mainline contacts, LM_1, LM_2, and LM_3, which apply the full-line voltage to the low-speed motor winding. The motor will run at low speed until coil LM is de-energized. The LM and HM contractors are mechanically interlocked to prevent both from closing at the same time.

Autotransformer Controllers

A single-phase autotransformer has a tapped winding on a laminated core. Normally, only one coil is used on a core, but it is possible to have two auto-transformer coils on the same core. Figure 1-8 shows the connections for a single-phase autotransformer being used to step down voltage. The winding between A and B is common to both the primary and the secondary windings and carries a current that is equal to the difference between the load current and the supply current.

Any voltage applied to terminals A and C will be uniformly distributed across the winding in proportion to the number of turns. Therefore, any voltage that is less than the source voltage can be obtained by tapping the proper point on the winding between terminals A and C.

Some autotransformers are designed so a knob-controlled slider makes contact with wires of the winding to vary the load voltage.

The directions for current flow through the line, transformer winding, and load are shown by the arrows in figure 1-8. Note that the line current is 2.22 amperes and that this current also flows through the part of the winding between B and C. In the part of the winding that is between A and B, the load current of 7 amperes is opposed by the line current of 2.22 amperes. Therefore, the current through this section is equal to the difference between the load current and the line current. If you subtract 2.22 amperes from 7 amperes, you will find the secondary current is 4.78 amperes.

Autotransformers are commonly used to start three-phase induction and synchronous motors and to furnish variable voltage for test panels. Figure 1-9 shows an autotransformer motor starter, which incorporates

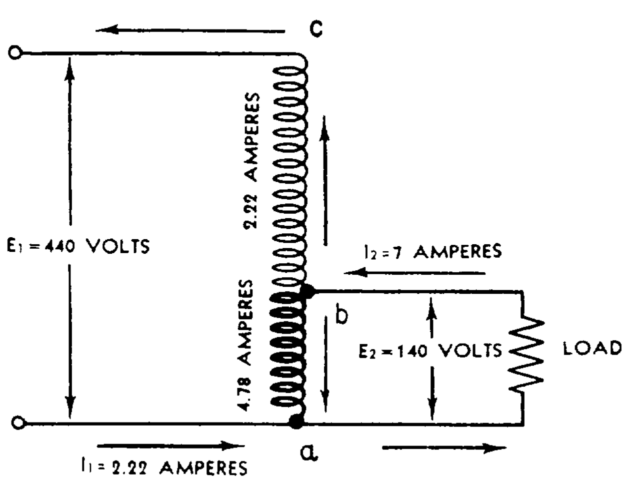


Figure 1-8.-Single-phase autotransformer.

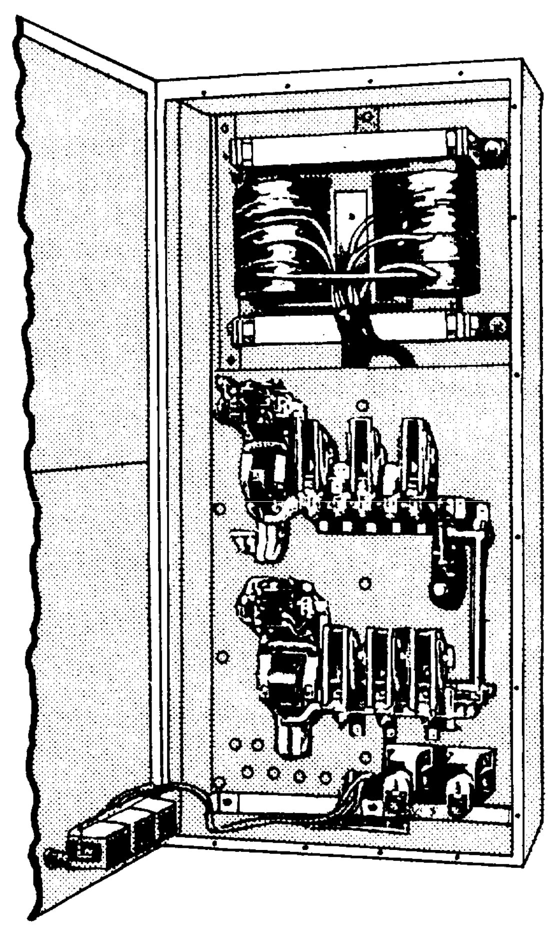


Figure 1-9.-Autotransformer controller.

starting and running magnetic contractors, an auto transformer, a thermal overload relay, and a mercury timer to control the duration of the starting cycle.

Logic Controllers

Some of the controlled equipment that you will encounter use logic systems for circuit control. For additional information in this area the Navy Electricity and Electronics Training Series (NEETS), module 13, is an excellent basic reference.

The basic concept of logic circuits is shown in figures 1-10 and 1-11. In figure 1-10, view A, an AND symbol is shown, which can be compared to the electrical circuit in figure 1-10, view B.

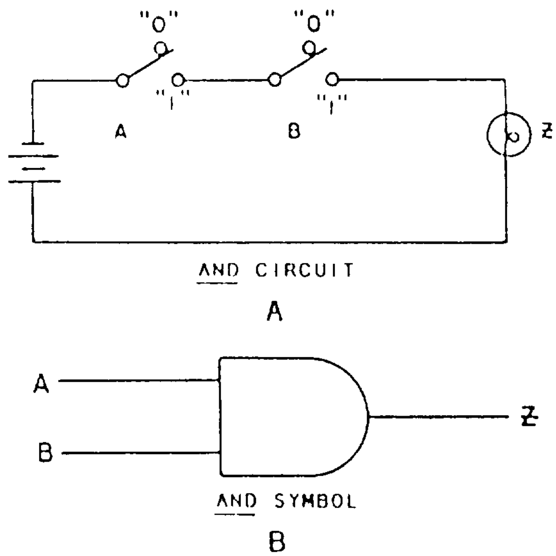


Figure 1-10.-AND symbol and circuit.

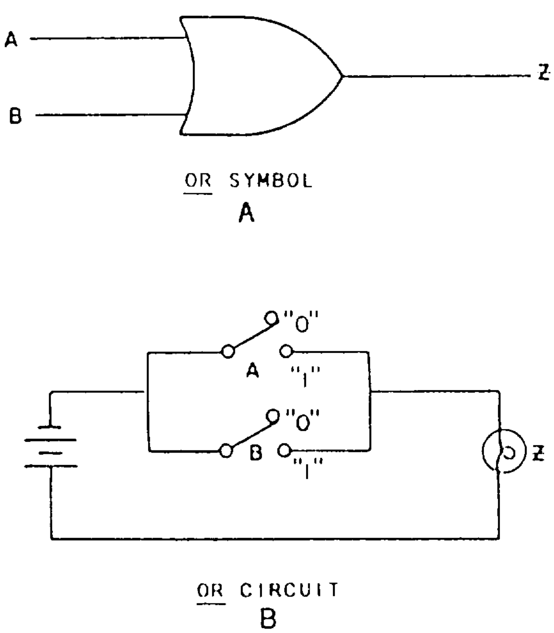


Figure 1-11.-OR symbol and circuit.

NOTE: Both switches, A AND B, must be closed to energize the lamp.

In figure 1-11, view A, art OR symbol is shown, which can be compared to the electrical circuit in figure 1-11, view B, where either switch A OR B needs to be closed to energize the lamp.

Using the characteristics of the AND and OR logic symbols, we will now discuss how they can be used in a logic controller.

One common application of logic control that is being incorporated on newer ships is the elevator system. Since this system is large and consists of many symbols, we will show only a small portion of this system.

Let us assume that the elevator platform is on the third deck and that you require it on the main deck—Refer to figure 1-12. Three conditions must be met before the elevator can be safely moved. These conditions are detected by electronic sensors usually associated with the driven component. One of the conditions is that the platform must be on EITHER the second or third deck (on a certain deck as opposed to somewhere in between). If this condition is sensed, the OR symbol will have an input, and since only one input is needed, the OR symbol also will have an output.

The other two conditions to be met are that the locking devices must be engaged and the access doors must be shut. If the sensors are energized for these two conditions, the AND symbol will have the three inputs necessary to produce an output. This output will then set up a starting circuit, allowing the motor to be started at your final command.

The advantages of these electronic switches over mechanical switches are low power consumption, no moving parts, less maintenance, quicker response, and

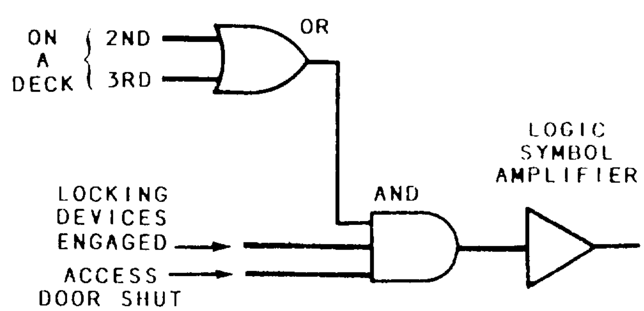


Figure 1-12.-Basic logic circuit.

less space requirements. A typical static logic panel found aboard ship is shown in figure 1-13.

Although there are logic symbols other than AND and OR, they all incorporate solid-state devices, For more information on solid-state devices refer to NEETS, module 7.

DC CONTROLLERS

The starting of all dc motors, except those with fractional horsepower, requires a temporary placing of resistance in series with the armature circuit to limit the high current at start. The starting resistance cannot be removed from the line until the motor has accelerated in speed and the counter electromotive force has increased to limit the current to a safe value.

Auxiliary motors located below deck generally drive constant-speed equipment. A rheostat in the shunt field circuit may be provided to furnish speed control for motors operating with ventilation fans, forced draft blowers, and certain pumps where conditions may require operation at more than one speed.

Small motors use one stage of starting resistance in the line for a few seconds to limit the starting current. With larger motors, two or more stages of resistance are connected in the line at start and are cut out in steps as the motor accelerates to the running speed.

Motors used with cargo winches and other deck auxiliaries operate over a wide range of speeds. Since the speed of a dc motor with a constant load varies almost directly with the voltage, stages of line resistance are used to make speed changes and to limit the current at starting. These stages of line resistance are connected in various combinations, manually selected by a master switch operating with a magnetic controller. Thus, the operator directly controls the amount of resistance in the line and the resulting speed of the motor at all times.

One-Stage Acceleration

Figure 1-14 shows a typical dc controller. The connections for this motor controller with one stage of acceleration are shown in figure 1-15. The letters in parentheses are indicated on the figures. When the start button is pressed, the path for current is from the line terminal (L2) through the control fuse, the stop button, the start button, and the line contactor coil (LC), to the line terminal (L1). Current flowing through the contactor coil causes the armature to pull in and close the line contacts (LC1, LC2, LC3, and LC4).

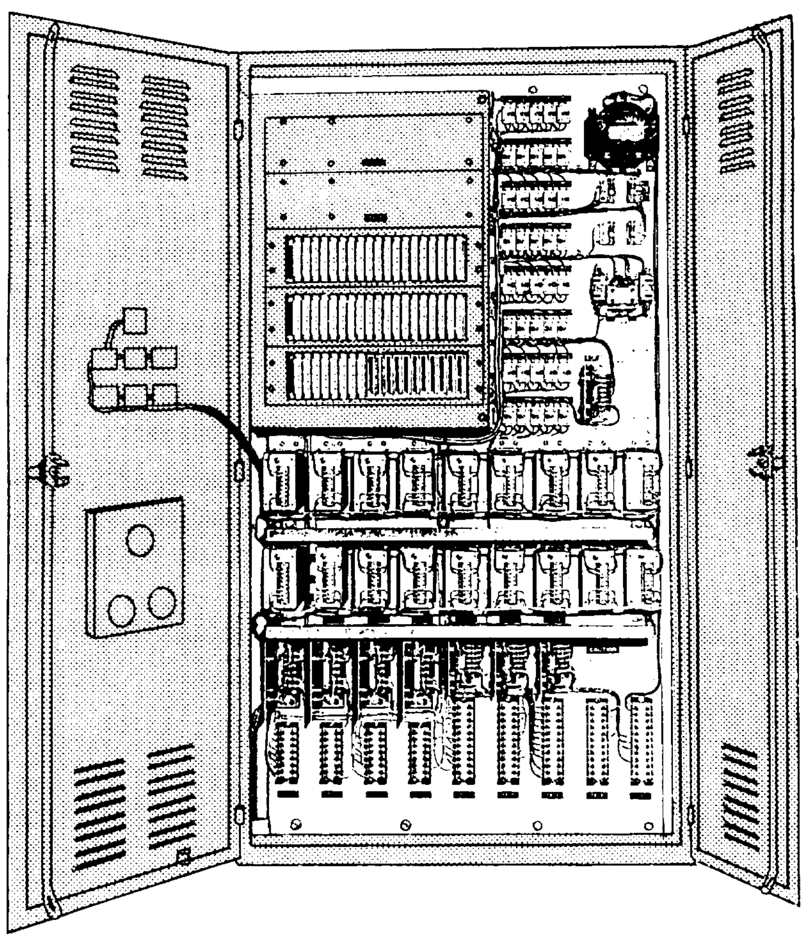


Figure 1-13.-A static logic panel for a cargo elevator.

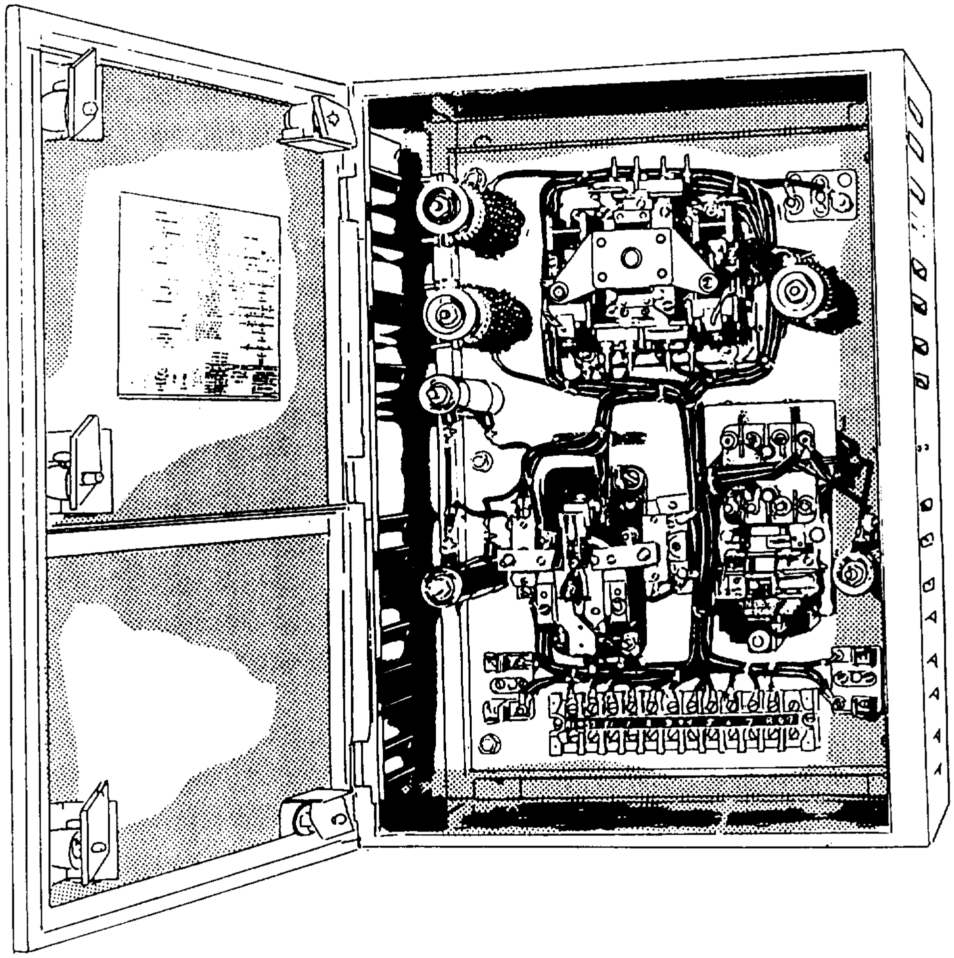


Figure 1-14.-A typical controller.

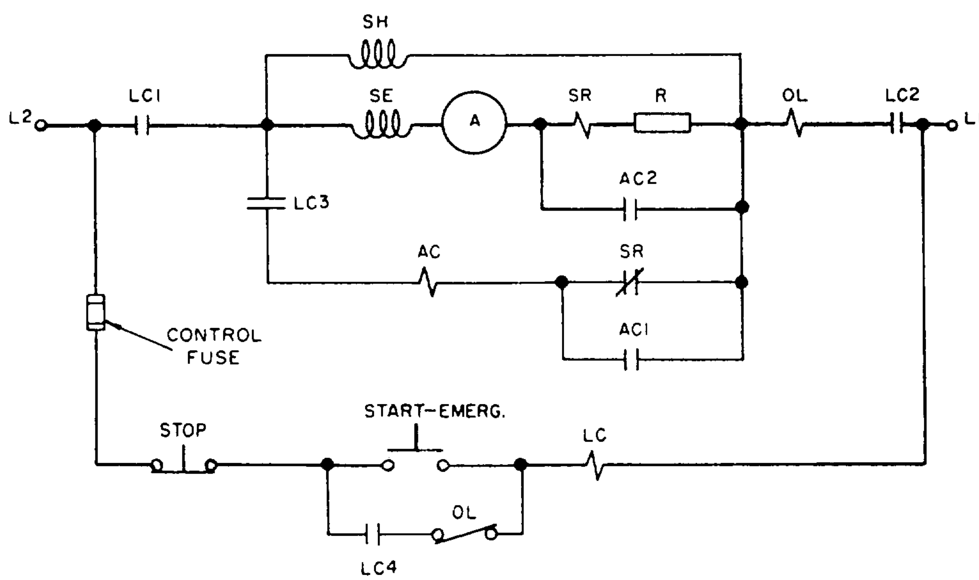


Figure 1-15.-A dc controller with one stage of acceleration.

When contacts LC1 and LC2 close, motor-starting current flows through the series field (SE), the armature (A), the series relay coil (SR), the starting resistor (R), and the overload relay coil (OL). At the same time, the shunt field winding (SH), is connected across the line and establishes normal shunt field strength. Contacts LC3 close and prepare the circuit for the accelerating contactor coil (AC). Contacts LC4 close the holding circuit for the line contactor coil (LC).

The motor armature current flowing through the series relay coil causes its armature to pull in, opening the normally closed contacts (SR). As the motor speed picks up, the armature current drawn from the line decreases. At approximately 110 percent of normal running current, the series relay current is not strong enough to hold the armature in; therefore, it drops out and closes its contacts (SR). These contacts are in series with the accelerating relay coil (AC) and cause it to pick up its armature, closing contacts AC1 and AC2.

Auxiliary contacts (AC1) on the accelerating relay keep the circuit to the relay coil closed while the main contacts (AC2) short out the starting resistor and the series relay coil. The motor is then connected directly across the line, and the connection is maintained until the STOP button is pressed.

If the motor becomes overloaded, the excessive current through the overload coil (OL) (at the top right of fig. 1-15) will open the overload contacts (OL) (at the bottom of fig. 1-15), disconnecting the motor from the line.

If the main contactor drops out because of an excessive drop in line voltage or a power failure, the motor will remain disconnected from the line until an operator restarts it with the start pushbutton. This prevents automatic restarting of equipment when normal power is restored.

Speed Control

Figure 1-16 illustrates a rheostat that is added to the basic controller ciruit to obtain varying speed.

If resistance is added in series with the shunt field the field will be weakened and the motor will speed up. If the amount of resistance in series is decreased, the field strength will increase, and the motor will slow down.

Contacts FA (fig. 1-16) are closed during the acceleration period, providing fill shunt field strength. After the motor has accelerated to the across-the-line position, contacts FA open, placing the rheostat in the shunt field circuit to provide full field protection.

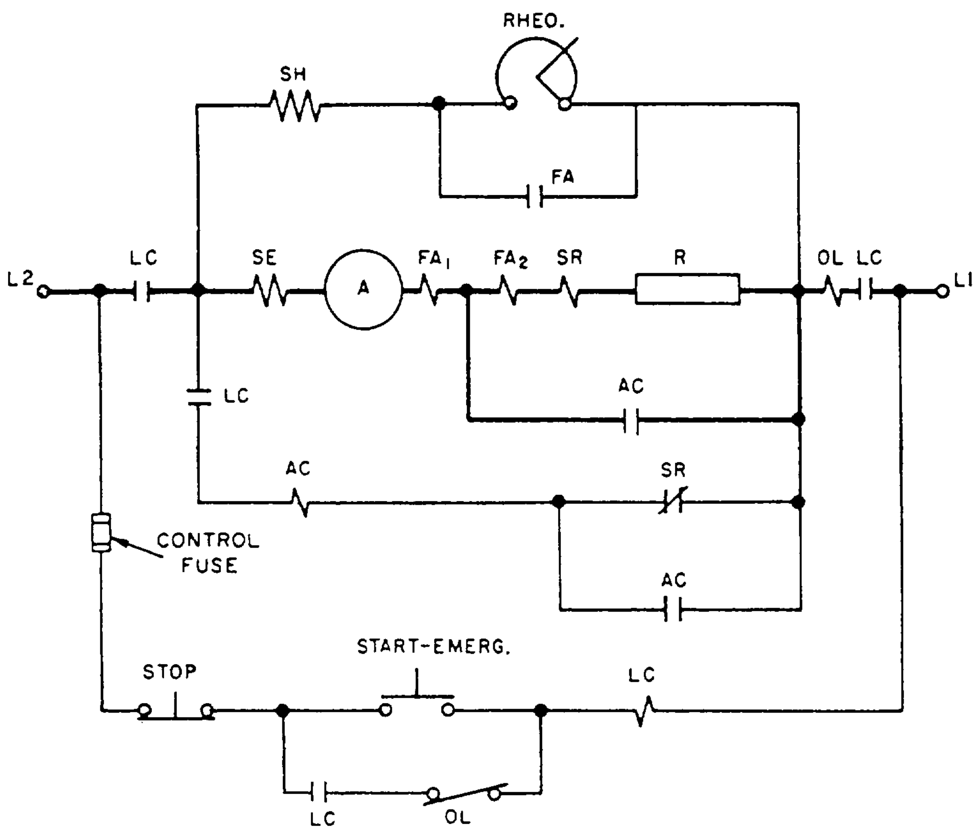


Figure 1-16.-A dc controller with shunt field rheostat.

Reversing

In certain applications, the direction in which a dc motor turns is reversed by reversing the connections of the armature with respect to the field. The reversal of connections can be done in the motor controller by adding two electrically and mechanically interlocked contractors.

A dc motor reversing connection is shown in figure 1-17. Note there are two start buttons-one marked START-EMERG FORWARD and the other marked START-EMERG REVERSE. These buttons serve as master switches, and the desired motor rotation is obtained by pressing the proper switch.

Assuming that the forward button has been pressed, the line voltage will be applied through the button to the forward contactor coil (F). This pulls in the armature and closes the normally open contacts (F_1 and F_2) in the motor armature circuit, the forward contactor holding circuit contacts (F_3), and the line contactor circuit contacts (F_4), and opens the normally closed contacts (F_5) of the reverse contactor circuit. The normally closed contacts (F_5) are electrically interlocked open when the forward contactor (F) coil is energized.

After the line contactor is energized, acceleration is accomplished in the manner described previously.

Dc Contactor

A dc contactor is composed of an operating magnet energized by either switches or relays, fixed contacts, and moving contacts. It maybe used to handle the load of an entire bus, or a single circuit or device. Larger contacts must be used when heavy currents are to be interrupted. These contacts must snap open or closed to reduce contact arcing and burning. In addition to these, other arc-quenching means are used.

Blowout Coils

When a circuit carrying a high current is interrupted, the collapse of the flux linking the circuit will induce a voltage, which will cause an arc. If the spacing between the open contacts is small, the arc will continue once it is started. If the arc continues long enough, it will either melt the contacts or weld them together. Magnetic

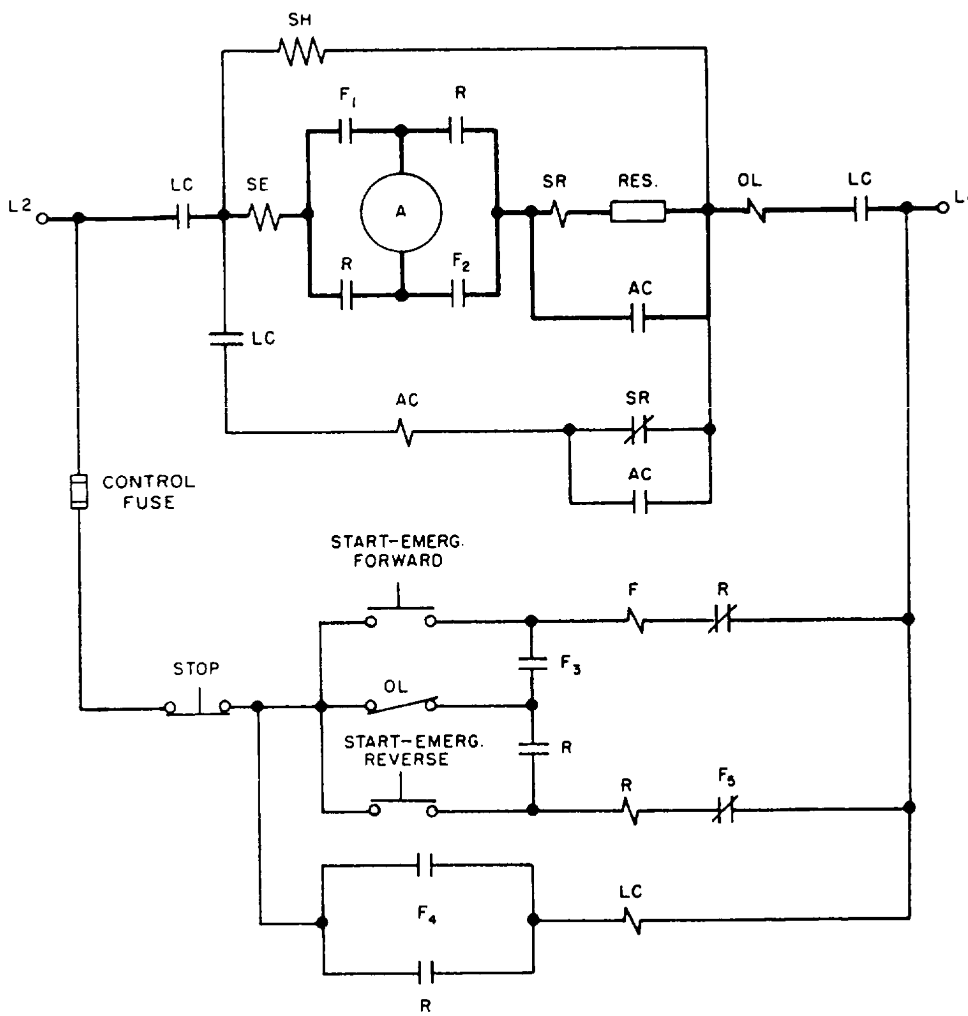


Figure 1-17.-Reversing dc controller.

blowout coils overcome this condition by providing a magnetic field, which pushes the arc away from the contact area.

The magnetic blowout operation is shown in figure 1-18. It is important that the fluxes remain in the proper relationship. Otherwise, if the direction of the current is changed, the direction of the blowout flux will be reversed and the arc will actually be pulled into the space between the contacts.

When the direction of electron flow and flux areas shown in figure 1-18, the blowout force is upward. The blowout effect varies with the magnitude of the current and with the blowout flux. The blowout coil should be chosen to match the current so the correct amount of flux may be obtained. The blowout flux across the arc gap is concentrated by the magnetic path provided by the steel core in the blowout coil and by the steel pole pieces extending from the core to either side of the gap.

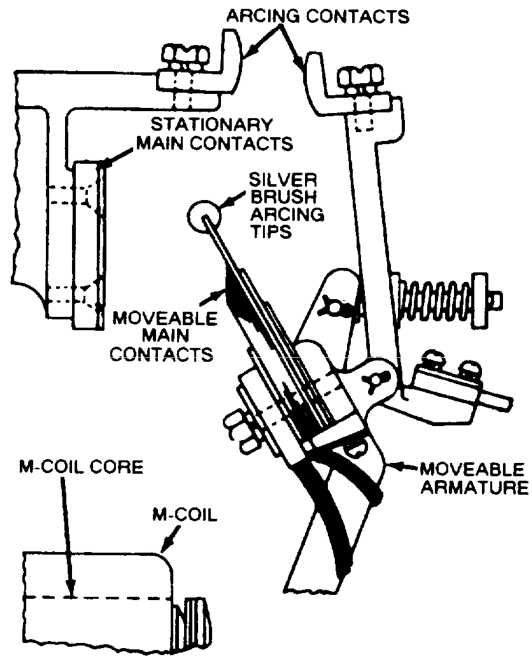


Figure 1-19.–Detailed view of arcing contacts.

Arcing Contacts

The shunt contactor shown in figure 1-19 uses a second set of contacts (1) to reduce the amount of arcing across the main contacts (5 and 6) when closing. The numbers that are in parentheses are indicated on the figure.

Shunt-type contractors will handle up to 600 amperes at 230 volts. The blowout shield has been removed in this detailed view. The diagram shows the main sections of the contactor. The arcing contacts (1) are made of rolled copper with a heavy protective coating of cadmium. These contacts are self-cleaning because of the sliding or wiping action following the initial

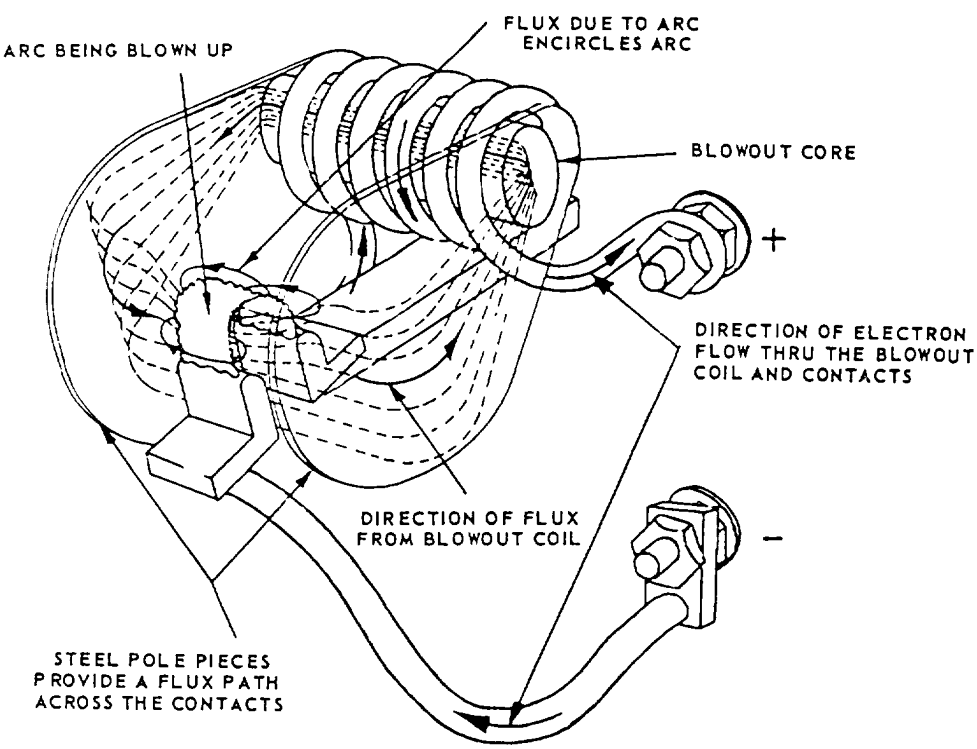


Figure 1-18.-Action of a magnetic blowout coil.

contact. The wiping action keeps the surface bright and clean, and thus maintains a low contact resistance.

The contactor is operated by connecting the coil (2) directly across a source of dc voltage. When the coil is energized the movable armature (3) is pulled toward the stationary magnet core (4). This action causes the contacts that carry current (5, 6, 7, and 1) to close with a sliding action.

The main contacts (5 and 6), called brush contacts, are made of thin leaves of copper, which are backed by several layers of phosphor bronze spring metal. A silver brush arcing tip (7) is attached to the copper leaves and makes contact slightly before the leaf contact closes. The stationary contact (5) consists of a brass plate, which has a silver-plated surface. Since the plating lowers the surface resistance, the contact surfaces should never be filed or oiled. If excessive current causes high spots on the contact, the high places maybe smoothed down by careful use of a fine ignition-type file.

You can check the operation and contact spacing by manually closing the contactor (be sure the power is off). The lowest leaf of brush contact 6 should just barely touch contact 5. If the lower leaf hits the plate too soon, bend the entire brush assembly upward slightly.

The contact dimensions should be measured with the contactor in the OPEN position.

Refer to the manufacturer's instruction book when making these adjustments.

ELECTRIC BRAKES

An electric brake is an electromagnetic device used to bring a load to rest mechanically and hold it at rest. Aboard ship, electric brakes are used on motor-driven hoisting and lowering equipment where it is important to stop the motor quickly. The type of electric brakes used depends on whether the motor is ac or dc and whether a dc motor is series or shunt wound.

AC SOLENOID BRAKE

The magnetic brake assembly shown in figure 1-20 is the main component of this electric brake. When the coil is energized, two armatures are pulled horizontally

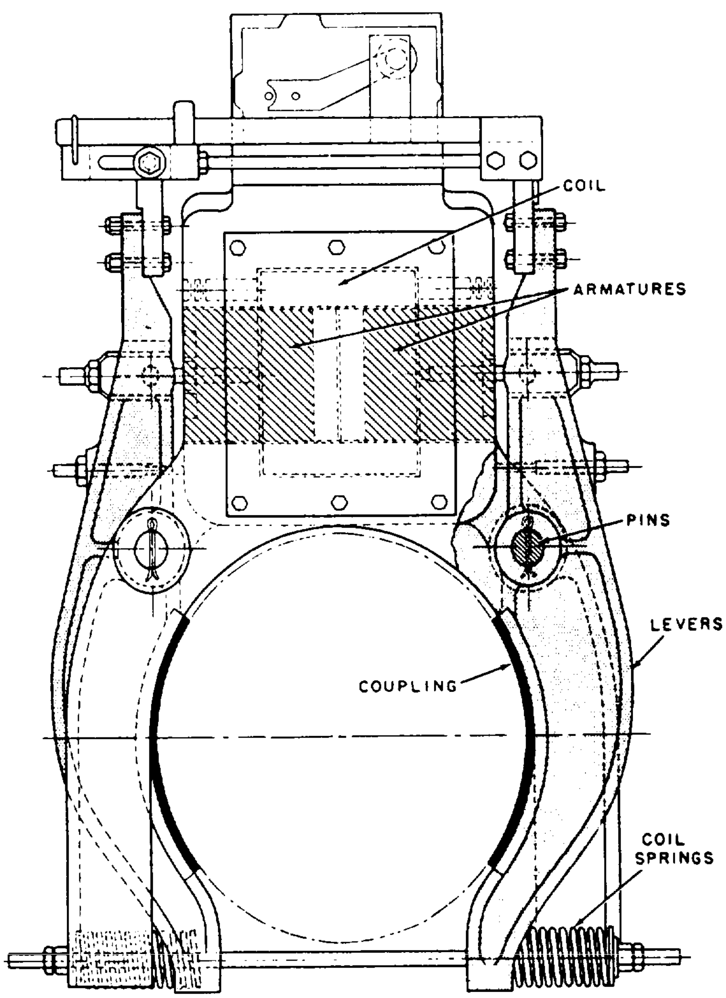
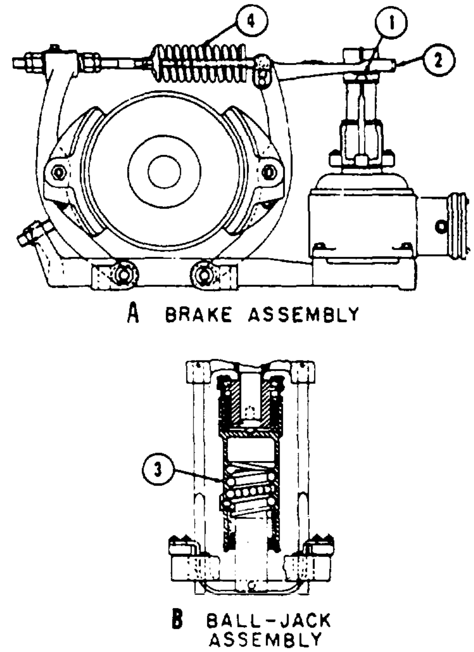


Figure 1-20.-Magnetic brake assembly.

into the coil. The armatures are mechanically linked to the levers. The levers pivot on the pins. When the magnetic pull overcomes the pressure of the coil springs, the pressure of the brake shoes on the drum is removed, allowing the drum to turn. The drum is mechanically coupled to the motor shaft or the shaft of the device driven by the motor. The coil is connected to the voltage supply lines. The method of connecting the coil (series or parallel) is determined by the coil design. The magnetic brakes are applied when the coil is not energized. A spring or weight holds the band, disk, or shoes against the wheel or drum. When the coil is energized, the armature or solenoid plunger overcomes the spring tension and releases the brake.

The ac solenoid brake frame and solenoid are of laminated construction to reduce eddy currents, which are characteristic of ac systems. Because the magnetic flux passes through zero twice each cycle, the magnetic pull is not constant. To overcome this, shading coils are used to provide pull during the change of direction of the main flux. The principal disadvantage of an ac solenoid is that it draws a heavy current when the voltage is first applied.



1. **Brake operating lever**
2. **Jack screw**
3. **Thrust element**
4. **Tension spring**

Figure 1-21.-Torque-motor brake and ball-jack assembly.

AC TORQUE-MOTOR BRAKE

The torque-motor brake uses a specially wound polyphase, squirrel-cage motor in place of a brake-release solenoid. The motor may be stalled without injury to the winding and without drawing heavy currents. Figure 1-21, view A, shows the complete mechanical arrangement of the torque-motor brake assembly, and figure 1-21, view B, is an enlarged view of the ball-jack assembly. his assembly is used with an anchor windlass.

The mechanical connection between the torque-motor shaft and the brake operating lever (1) is through a device called a ball-jack assembly, which converts the rotary motion of the torque-motor shaft to a straight line motion.

When power is applied to the torque motor, the shaft turns in a clockwise direction, resulting in an upward movement of the jack screw (2). The thrust element (3) in the jack screw pushes upward against the operating lever (1) to release the brake. As soon as the brake is fully released, the torque motor stalls across the line and holds pressure against the spring (4), keeping the brake released.

When the voltage supply to the torque motor is interrupted, the torque spring forces the brake shoes against the brake drum. This action stops and holds the windlass drive shaft.

The torque-motor brake can be released manually by raising the lever(1). However, the lever must be held manually in the UP position; otherwise, the brake will be applied.

Dc Dynamic Brake

Dynamic braking is similar to the slowing down of a moving truck by the compression developed in its engine. A dc motor also slows down when being driven by its load if its field remains excited. In this case, the motor acts as a generator and returns power to the supply, thereby holding the load. In an actual braking system, however, the dc motor is disconnected from the line. Its armature and field are connected in series with a resistor to form a loop. The field connections to the armature are reversed so the armature countervoltage maintains the field with its original polarity.

Figure 1-22 shows the connections in the dynamic braking system of a series-wound dc motor. The field switching is carried out by switches S1, S2, and S3, which are parts of a triple-pole double-throw (TPDT) assembly. These switches are magnetically operated

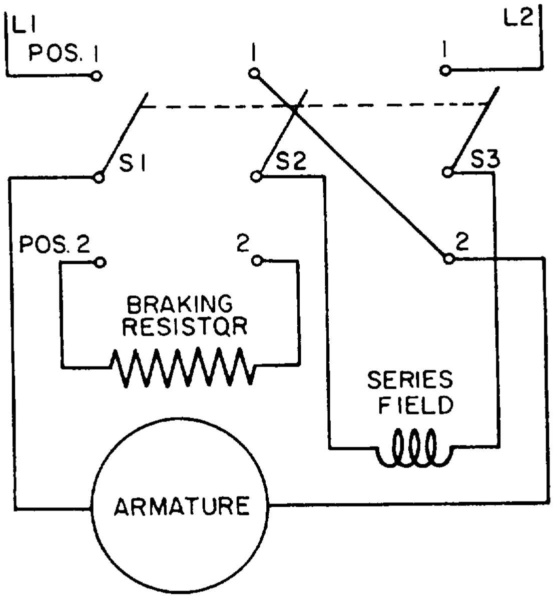


Figure 1-22.-Connections for dynamic braking of a series-wound dc motor.

from a controller. With the switch arms in position 1, the motor operates from the line. When the switch arms are in position 2, the resistor is connected in series with the field, and, at the same time, the field coil connection to the armature is reversed. Thus, as long as the armature turns, it generates a countervoltage, which forces current through the resistor and the series field. Although the direction of current flow through the armature is reversed (because of the countervoltage), the direction through the series field coil is not reversed. When operating in this way, the motor is essentially a generator that is being driven by the momentum of the armature and the mechanical load. Energy is quickly consumed in forcing current through the resistor, and the armature stops turning.

The time required to stop the motor maybe varied with different resistor values. The lower the resistance, the faster the braking action. If two or more resistors are connected by switches, the braking action can be varied by switching in different load resistors. Usually, the same braking resistors that are used to stop the motor are also used to reduce the line voltage during acceleration.

When dynamic braking is used with a dc shunt-wound motor, resistance is connected across the armature (fig. 1-23).

Switches S1 and S2 are part of a double-pole double-throw (DPDT) circuit breaker assembly. When the switch arms are connected to position 2, the armature is across the line, and motor operation is obtained. When the switch arms are in position 1, the armature is disconnected from the line and connected to the resistor. The shunt field remains connected to the line. As the armature turns, it generates a countervoltage that forces the current through the resistor. The remainder of the action is the same as described for the circuit in figure 1-22.

Although dynamic braking provides an effective means of slowing motors, it is not effective when the field excitation fails or when an attempt is made to hold heavy loads; without rotation, the countervoltage is zero, and no braking reaction can exist between the armature and the field.

Dc Magnetic Brake

Magnetic brakes are used for complete braking protection. In the event of field excitation failure, they will hold heavy loads. A spring applies the brakes, and the electromagnet releases them.

Disk brakes are arranged for mounting directly to the motor end bell. The brake lining is riveted to a steel disk, which is supported by a hub keyed to the motor shaft. The disk rotates with the motor shaft.

The band-type brake has the friction material fastened to a band of steel, which encircles the wheel or drum and may cover as much as 90 percent of the wheel surface. Less braking pressure is required and there is less wear on the brake lining when the braking surface is large.

The dc brakes are operated by a solenoid similar in design to the ac solenoid brake (fig. 1-20), except that

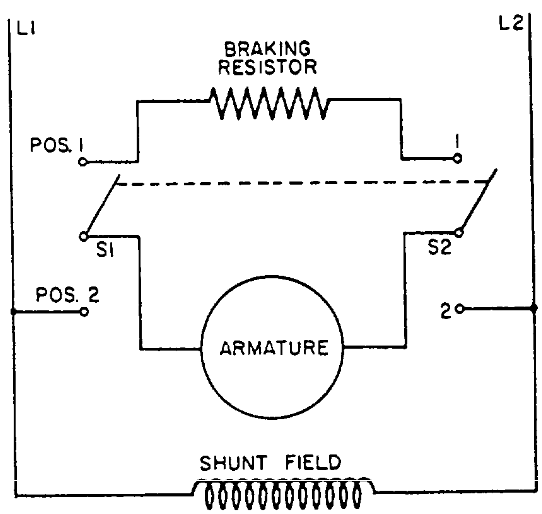


Figure 1-23.-Connections for dynamic braking of a shunt-wound dc motor.

the dc brake construction is of solid metals and requires no lamination as does the ac magnetic brake.

CONTROLLER TROUBLESHOOTING

Although the Navy maintains a policy of preventive maintenance, sometimes trouble is unavoidable. In general, when a controller fails to operate, or signs of trouble (heat, smoke, smell of burning insulation, and so on.) occur, the cause of the trouble can be found by conducting an examination that consists of nothing more than using the sense of feel, smell, sight, and sound. On other occasions, however, locating the cause of the problem will involve more detailed actions.

Troubles tend to gather around mechanical moving parts and where electrical systems are interrupted by the making and breaking of contacts. Center your attention in these areas. See table 1-1 for a list of common troubles, their causes, and corrective actions.

When a motor-controller system has failed and pressing the start button will not start the system, press the overload relay reset push button. Then, attempt to start the motor. If the motor operation is restored, no further checks are required. However, if you hear the controller contacts close but the motor fails to start, then check the motor circuit continuity. If the main contacts do not close, then check the control circuit for continuity. An example of troubleshooting a motor-controller electrical system is given in a sequence of steps that may be used in locating a fault (fig. 1-24). We will start by analyzing the power circuit.

POWER CIRCUIT ANALYSIS

When no visual signs of failure can be located and an electrical failure is indicated in the power circuit, you must first check the line voltage and fuses. Place the voltmeter probes on the hot side of the line fuses as shown at position A. A line voltage reading tells you that your voltmeter is operational and that you have voltage to the source side of the line fuses, L1-L2. You also may check between L1-L3 and L2-L3. To check the fuse in line L1, place the voltmeter across the line fuse as shown at position B between L1-L2. A voltage reading shows a good fuse in L1. Likewise, check the other two fuses between L1-L3 and L2-L3. A novoltage reading would show a faulty fuse.

If the line fuses check good, then check the voltage between terminals T1-T2, T2-T3, and T1-T3. The controller is faulty if there aren't voltmeter readings on all three of the terminal pairs, and you would then proceed to check the power contacts, overloads, and lead

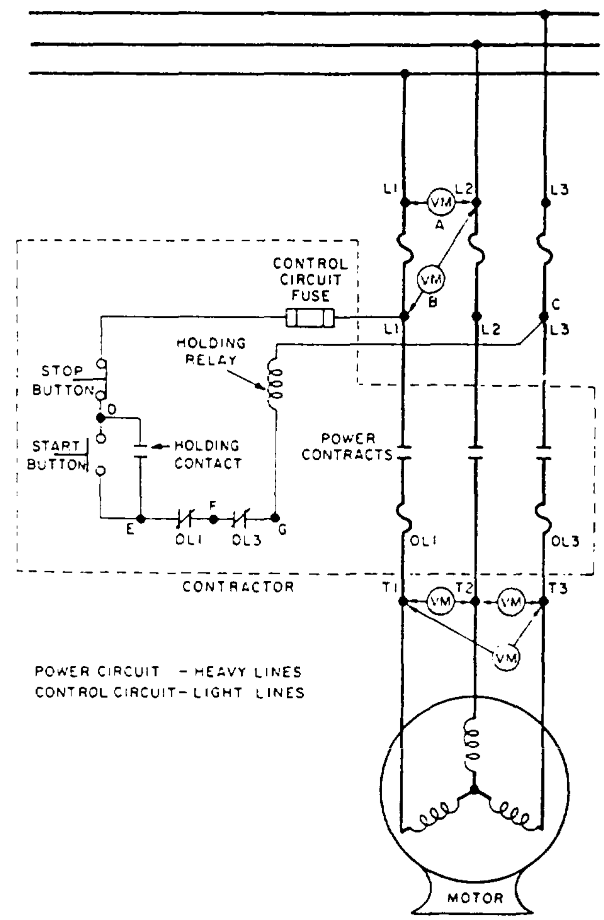


Figure 1-24-Troublesbootting a 3-phase magnetic tine starter.

connections within the controller. However, if voltage is indicated at all three terminals, then the trouble is either in the motor or lines leading to the motor.

CONTROL CIRCUIT ANALYSIS

Suppose the overload reset buttons have been reset and the start switch is closed. If the power contacts do not close, then the control circuit must be checked. The testing procedure is as follows:

1. Check for voltage at the controller lines, L1, L2, and L3.

2. Place the voltmeter probes at points C and D (fig. 1-24). You should have a voltage reading when the stop switch is closed and a no-voltage reading when the stop switch is open. The conditions would indicate a good stop switch.

3. Next, check the voltage between points C and E. If you get a no-voltage reading when the start switch is open and a voltage reading when the start switch is closed, then the start switch is good.

Table 1-1.-Troubleshootlng Chart

Contacts		
Trouble	**Probable Cause**	**Remedy**
Contact chatter	Poor contact in control relay	Clean relay contact.
	Broken shading coil	Replace.
	Excessive jogging	Caution operator to avoid excessive jogging.
Overheated contact tips	Dirty contact tips	Clean and dress if necessary, according to chapter 300 or manufacturer's instructions.
	Sustained overloads	Find and remedy the cause of the overloads.
	Insufficient tip pressure	Clean and adjust.
	Loose connections	Clean and tighten.
Weak tip pressure	Wear allowance gone	Replace contacts and adjust.
	Poor tip adjustment	Adjust "gap" and "wipe."
	Low voltage, which prevents magnet sealing	Correct voltage condition.
Short tip life	Excessive filing or dressing	Follow manufacturer's instructions.
	Excessive jogging	Instruct operator in correct operation.
Welding or fusing	Abnormal starting currents	Operate manual controllers slower. Check automatic controllers for correct starting resistors and proper functioning of timing devices or accelerating relays.
	Rapid jogging	Instruct operator in correct operation.
	Short-circuit currents on contacts	Find and remedy causes of short circuits. Check feeder fuses for proper size and replace, if necessary.
Failure of the flexible conductors between fixed and moving parts of contactor	Improper installation.	See manufacturer's instructions.
	Worn out mechanically by large number of operations	Replace.
	Moisture or corrosive atmosphere.	Replace with flexible conductors suitable for application.
	Burned by arcing or overheating from loose, oxidized, or corroded connections	Clean and tighten connections.

Coils		
Trouble	**Probable cause**	**Remedy**
Coil failure:		
(a) Not overheated	Moisture, corrosive atmosphere	Use correctly insulated coils.
	Mechanical damage	Avoid handling coils by the leads.
	Vibration or shock damage	Secure coils properly.
(b) Overheated	Overvoltage or high ambient temperature	Check current and application.
	Wrong coil	Use only the manufacturer's recommended coil.
	Too frequent use, or rapid jogging	Use correct operating procedure.
	Undervoltage, failure of magnet to seal in	Check circuit and correct cause of low voltage.
	Used above current rating	Install correct coil for application.
	Loose connections to coil, or corrosion or oxidation of connection surfaces	Clean and tighten connection.
	Improper installation	See manufacturer's instructions.

Table 1-1.-Troublesbooting Chart-Continued

Electric brakes, solenoid or motor operated		
Trouble	**Probable cause**	**Remedy**
Worn or broken parts	High inertia loads, misapplication, excess temperature	Replace parts and refer to the technical manual for correct procedures.
Failure to hold load	Worn parts, out of adjustment, wrong brake lining	Replace parts with correct materials and adjust according to the technical manual.
	Grease or oil on brake drum	Clean thoroughly with approved solvent.
Failure to set	Out of adjustment, worn parts	Replace worn parts and adjust according to the technical manual.
	Mechanical binding	Clean and adjust.
	Coil not de-energized	Check circuit to make sure current is cut off.
Failure to release	Out of adjustment	Adjust according to the technical manual.
	Coil not energized	Check and repair circuit.
	Wrong coil	Replace with correct coil.
	Coil open or short circuited	Replace coil
	Motor will not run	Refer to the technical manual.
	Motor binds	Aline correctly, check bearings.

Magnets and mechanical parts		
Trouble	**Probable cause**	**Remedy**
Worn or broken parts	Heavy slamming caused by overvoltage or wrong coil	Replace part and correct cause.
	Chattering caused by broken shading coil or poor contact in control circuit	
	Excessive jogging	
	Mechanical abuse	
Noisy magnet	Broken shading coil	Replace.
	Magnet faces not true, result of mounting strain	Correct mounting.
	Dirt or rust on magnet face	Clean.
	Low voltage	Check system voltage and correct if wrong.
	Improper adjustment, magnet overloaded	Check and adjust according to the manufacturer's instruction.
Broken shading coil	Heavy slamming caused by overvoltage, magnet underloaded, weak tip pressure	Replace coil and correct the cause.
Failure to drop out	Gummy substances on magnet faces	Clean with approved solvent.
	Worn bearings	Replace.
	Nonmagnetic gap in magnet circuit	Replace magnet.
	Voltage not removed	Check coil voltage.
	Not enough mechanical load on magnet, improper adjustment	Adjust according to the manufacturer's instructions.

Overload relays		
Trouble	**Probable cause**	**Remedy**
Magnetic, instantaneous type:		
High or low trip	Wrong coil	Install correct coil.
	Mechanical binding, dirt, corrosion, etc.	Clean with approved solvent, adjust.
	Shorted turns (High trip)	Test coil, and replace if defective.
	Assembled incorrectly	Refer to manufacturer's instructions for correct assembly.
	Wrong calibration	Replace.
Magnetic, inverse time delay type:		
Slow trip	Fluid dirty, gummy, etc.	Change fluid and fill to correct level.
	Mechanical binding, corrosion, etc.	Clean with approved solvent, adjust.
	Worn or broken parts	Replace and adjust.
	Fluid too low	Drain and refill to correct level.
Thermal type:		
Failure to trip	Wrong size heater	Install correct size.
	Mechanical binding, dirt, corrosion etc.	Clean with approved solvent and adjust.
	Relay damaged by a previous short circuit	Replace.
Trips at too low temperature	Wrong size heater	Install correct size.
	Assembled incorrectly	See technical manual for correct assembly.
	Wrong calibration	Replace.
Failure to reset	Broken mechanism or worn parts	Replace.
	Corrosion, dirt, etc	Clean and adjust.
Burning and welding of control contacts	Short circuits in control circuits with fuses that are too large	Correct causes of short circuits and make sure that fuses are right size.
Turning relays, flux decay type:		
Too short time	Dirt in air gap	Clean.
	Shim too thick	Replace with thinner shim.
	Too much spring or tip pressure	Adjust according to the technical manual.
	Misalinement	Correct alinement, and remedy cause of misalinement.
Too long time	Shim worn too thin	Replace with thicker shim.
	Weak spring and tip pressure	Adjust according to the technical manual.
	Gummy substance on magnet face or mechanical binding	Clean with approved solvent and adjust.

4. Place the voltmeter probes at C and F. A voltage reading with the start button closed would indicate a good OL1, but also would indicate an open OL3, an open relay coil, or an open connection to line 3.

5. Place the voltmeter probes at points C and G and close the start switch. A no-voltage reading indicates the OL3 contacts are open.

A faulty holding relay contact will be indicated when the system operates as long as the start switch is held in, but stops when the start switch is released.

When starting a three-phase motor and the motor fails to start and makes a loud hum, you should stop the motor immediately by pushing the stop button. These symptoms usually mean that one of the phases to the motor is not energized. You can assume that the control circuit is good since the main operating coil has operated and the maintaining contacts are holding the main operating contactor in. Look for trouble in the power circuit (the main contacts, overload relays, cable, and motor).

FREQUENCY REGULATORS

Frequency regulators are used to provide a regulated frequency for frequency-sensitive equipment. To troubleshoot frequency regulators, you need to have an understanding of motor generators, as frequency and voltage regulators are part of the control circuits for motor generators. The following paragraphs will discuss motor generators and the troubleshooting of frequency regulators. Detailed troubleshooting charts for frequency regulators can be found in the service manual *Motor Generator Set 30 KW, 440.450 V AC, 60/400 Cycle, 3 Phase with Control Equipment.*

30 kW CLOSELY REGULATED MOTOR GENERATOR SET

The 30-kW 440/450-volts ac, 60/400-Hz, 3-phase motor generator set (fig. 1-25) consists of a wound rotor induction motor driving a synchronous generator. Internal control circuits include voltage and frequency regulating systems, a motor controller (magnetic starter), and generator output circuit breakers. The unit is designed for parallel operation with an identical unit. Its housing is dripproof.

The wound rotor motor and generator is a two-bearing unit with motor and generator rotors, plus a self-cooling fan mounted on a single shaft. The single row ball bearings are prelubricated, double sealed, double row width, and a "Warning Do Not Lubricate Bearings" instruction plate is mounted on the unit.

MOTOR GENERATOR

In a 30-kW motor generator, since a constant speed is required for a constant frequency, the change in motor rotor current for changes in torque requirement is accomplished through the external means of varying the tiring angle of three silicon controlled rectifiers (SCRs).

The basic operation of an SCR is as follows. The SCR has a positive-negative-positive-negative (PNPN) device structure and is the semiconductor equivalent of a gas thyratron. It is constructed by making both an alloyed PN junction and a separate ohmic contact to a diffused PNP silicon pellet. Schematic representation of the SCR is shown in figure 1-26. With reverse voltage (encircled polarities) impressed on the device (cathode positive), it blocks the flow of current as in an ordinary rectifier. With positive voltage applied to the anode (uncircled polarities), the SCR blocks the flow of current until either the forward breakdown voltage is reached, or a suitable gate pulse is applied to the gate. In practical application, the positive pulse applied to the gate is used to control the firing of the SCR. At this point, the SCR switches to a high-conduction state; the current flow is limited only by the external circuit impedance and supply voltage. The magnitude of gate impulse needed to turn on an SCR varies with temperature and

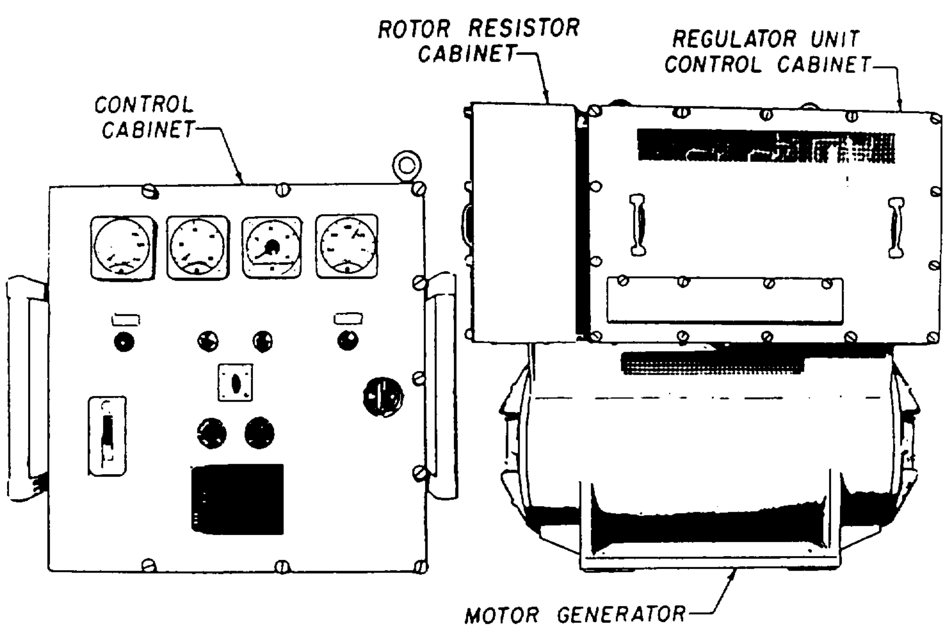


Figure 1-25.-Motor generator set with control equipment.

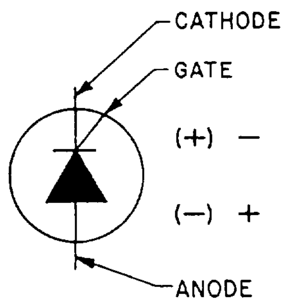


Figure 1-26.-Schematic symbol silicon controlled rectifier.

type of SCR. Recise firing is attained by a short gate pulse with an amplitude of at least 3 volts and is capable of delivering the maximum firing requirements of the SCR.

Short or delayed SCR firing time allows a small rotor current to flow, thus limiting the torque developed by the rotor required to maintain rated speed (necessary for 400 Hz) at no-load or light loads. As generator load is increased, a greater current is allowed to flow in the rotor, maintaining rated speed at an increased torque demand.

Since the synchronous speed of the stator flux is directly proportional to the input frequency of the supply to the motor, a change is necessary in the rotor torque to maintain constant speed for this variation also. The frequency regulator supplies the proper triggering pulse to the rotor SCRs controlling the current flow in the rotor, hence controlling the speed/torque of the motor.

CONTROL EQUIPMENT

The motor control consists of an ac magnetic starter containing overload protection, start and stop switches, and a frequency-regulating system. The first two components are standard; however, the frequency-regulating system is further divided into a detector, a preamp and trigger, a starter, a motor rotor control unit, and a resistor unit (fig. 1-27).

FREQUENCY REGULATOR

The detector in the frequency-regulating system is primarily a frequency-sensing transformer with a

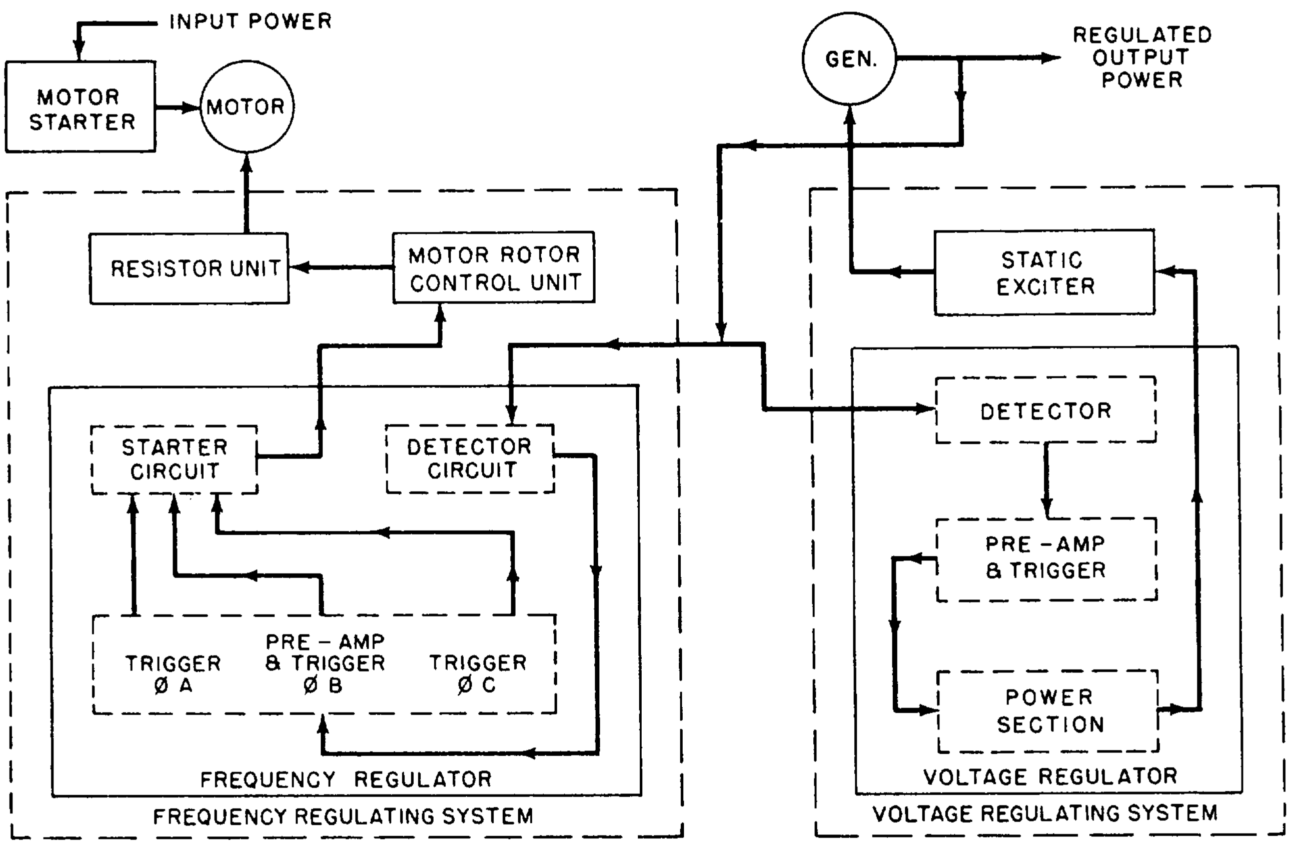


Figure 1-27.-Block diagram of current flow.

voltage output that varies linearly with changes in generator output frequency rather than generator output voltage. The signal voltage obtained from the frequency-sensing transformer is rectified, filtered, and compared in a Zener reference voltage divider, all contained within the detector circuit. This circuit provides an interesting application of Zener diodes, as shown in figure 1-28. The purpose of the Zener reference bridge is to compare a high-supply voltage with a reference voltage and to provide a low-voltage amplitude output signal voltage to be used as a base drive for a transistor.

The Zener reference bridge consists of resistors R1, R2, R3, and Zener diode D1, as shown in figure 1-28. Resistors R1, R2, and R3 are equal, and the Zener diode D1 has a breakdown rating of 10 volts. When E_{in} is equal to or less than 10 volts, negligible current will flow through R1, and the bridge is operating in mode I, as shown on the graph in figure 1-28. As E_{in} rises above 10 volts, the voltage drop across D1 remains constant at 10 volts, and the current through R2 and R3 increases, increasing the voltage drop across R2 and R3. When E_{in} equals 20 volts, the drop across resistors R1, R2, and R3 is 10 volts, so E_{out} is zero. When E_{in} is between 10 volts and 20 volts, the bridge is in mode H, as shown on the graph in figure 1-28. As E_{in} rises above 20 volts, the voltage at point B will rise above 10 volts; however, the voltage at point A will remain at 10 volts, and potential differences between points B to A will increase. For E_{in} greater than 20 volts, the bridge is in mode III, which is the normal operating mode.

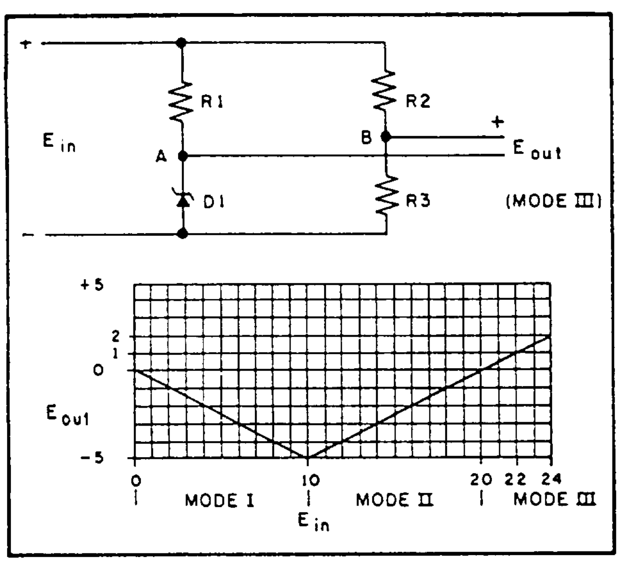


Figure 1-28.-Zener reference bridge.

Consider the input voltage E_{in} to be 22 volts; then the output voltage will be 1 volt. Next, consider the input voltage E_{in} to be 24 volts; then the output voltage will be 2 volts. Although the input voltage is 22 volts to 24 volts, the output voltage is only 1 volt to 2 volts. Therefore, without adding additional components to lower the voltage to the point where it can be used as abase drive for a transistor, the output voltage of the bridge can be used as abase drive for a transistor.

The signal leaving the Zener bridge is amplified by two dc transistor amplifiers, in the detector, before going to the preamp and trigger (fig. 1-27).

The purpose of the preamp and trigger is to amplify and convert the varying dc input voltage into controlled pulses of sufficient amplitude to fire the SCRs.

In the trigger circuit, the signal (pulse) amplitude controls the tiring point of the SCRs in the motor rotor control circuit (which are in series with large, approximately 3,000-watt resistors). Thus, control is exerted on the motor rotor.

VOLTAGE-REGULATING SYSTEM

The voltage-regulating system is composed of the voltage regulator and the static exciter (fig. 1-27). The voltage regulator receives its signal from the generator output. The static exciter receives its signal input from the power section in the voltage regulator.

The operation of the detector in the voltage regulator is similar to that of the frequency regulator, in that the detector senses a change in generator output; however, the change is in voltage rather than frequency. The increase or decrease in voltage is rectified, faltered, and compared prior to amplification. Again the comparison is made on a Zener reference bridge before amplification in dc amplifiers.

The preamp and trigger operate essentially as described in the section under frequency regulation, except that in this case the signal is fed to a power section.

The power circuit provides an application of SCR operation. This section (fig. 1-29) consists of three diodes (D1, D2, and D3) and two SCRs (SCR1 and SCR2). D2, D3, SCR1, and SCR2 are connected in the normal full-wave rectifier bridge manner. No current will flow out of the bridge (between points E and F) until the SCRs receive a trigger pulse at the gates that will turn the SCRs on. Assume that during the first half cycle of applied ac voltage (time 0 to 1), SCR 1 has its anode

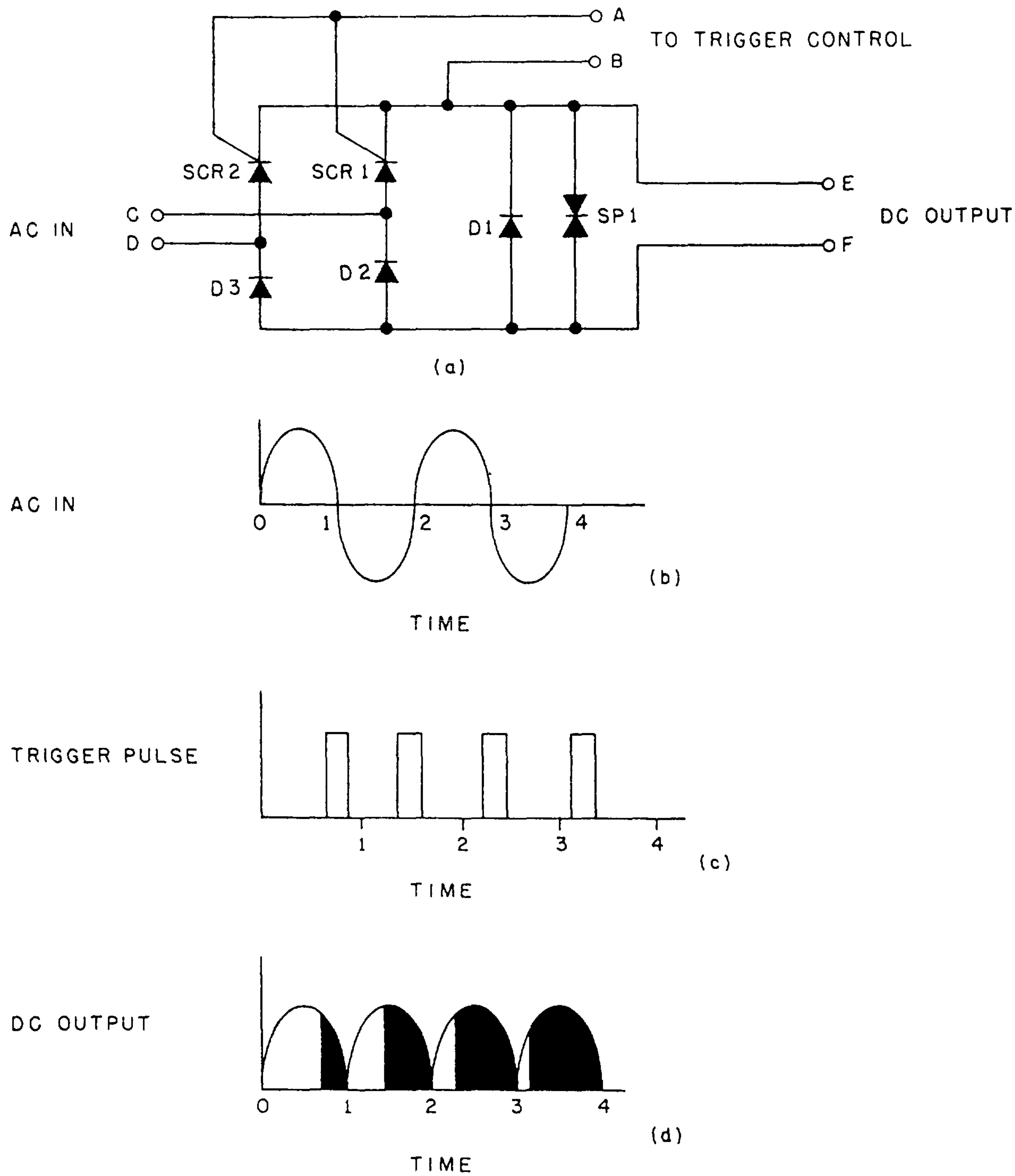


Figure 1-29.-Power circuit.

positive with respect to cathode, and a trigger pulse is applied to terminals A and B. SCR1 will conduct current, and SCR2 will block current like a normal rectifier bridge, for the remainder of the applied half cycle, as shown in figure 1-29. Diode D1 and thyrector SP1 (a General Electric silicon controlled diode used for ac surge protection) are used to protect the circuit from transients and voltage spikes. Controlling the point during any applied half cycle of ac voltage that the trigger pulse is applied to the gate of the SCRs makes it possible to control the output power of the dc power supply.

The signal developed in the power section of the voltage regulator (fig. 1-27) is used as dc control current to the static exciter.

STATIC EXCITER

The static exciter (fig. 1-30), which derives its operating power from the generator output, is designed to supply the correct amount of field current to the generator, to maintain a constant output voltage to a load that varies in magnitude or has a lagging power factor. During the motor-starting period, there is no generator output, and the generator field current is supplied by the field-flashing circuit. The field-flashing circuit derives its operating power from the 60-cycle supply voltage. his voltage is reduced to 30 volts by transformer T5, rectified by diode D2, and faltered by capacitor C3. The dc current then flows through dropping resistor R4 and excites to the generator field.

The saturable current-potential transformer (SCPT,) (fig. 1-30) has two sets of primary windings exciting a common secondary. The primary windings of T1, T2, and T3 in series with the load are current primaries. Those primary windings in parallel (T1, T2, and T3) are potential primaries. Both primaries, acting in conjunction, excite the common secondary (3-4 windings of T1, T2, and T3) to provide generator field excitation.

When a load is applied to the output, current will flow in the current primaries of T1, T2, and T3 of the SCPT. A current transformer action will take place with the common secondary 3 and 4 of T1, T2, and T3 of the SCPT that will add to the field excitation current caused in the secondary by voltage primary 1 and 2 of the SCPT. This action is explained later. L1, L2, and L3 are chokes.

The field excitation current will rise in proportion to the application of load and lagging power factor. Adding a dc control winding on the SCPT will change the coupling between primary and secondary windings. This winding controls the generator output voltage. This is accomplished by connecting the output of the voltage regulator to the dc control winding.

The signal developed in the power section of the voltage regulator (fig. 1-27) is used as dc control to the static exciter.

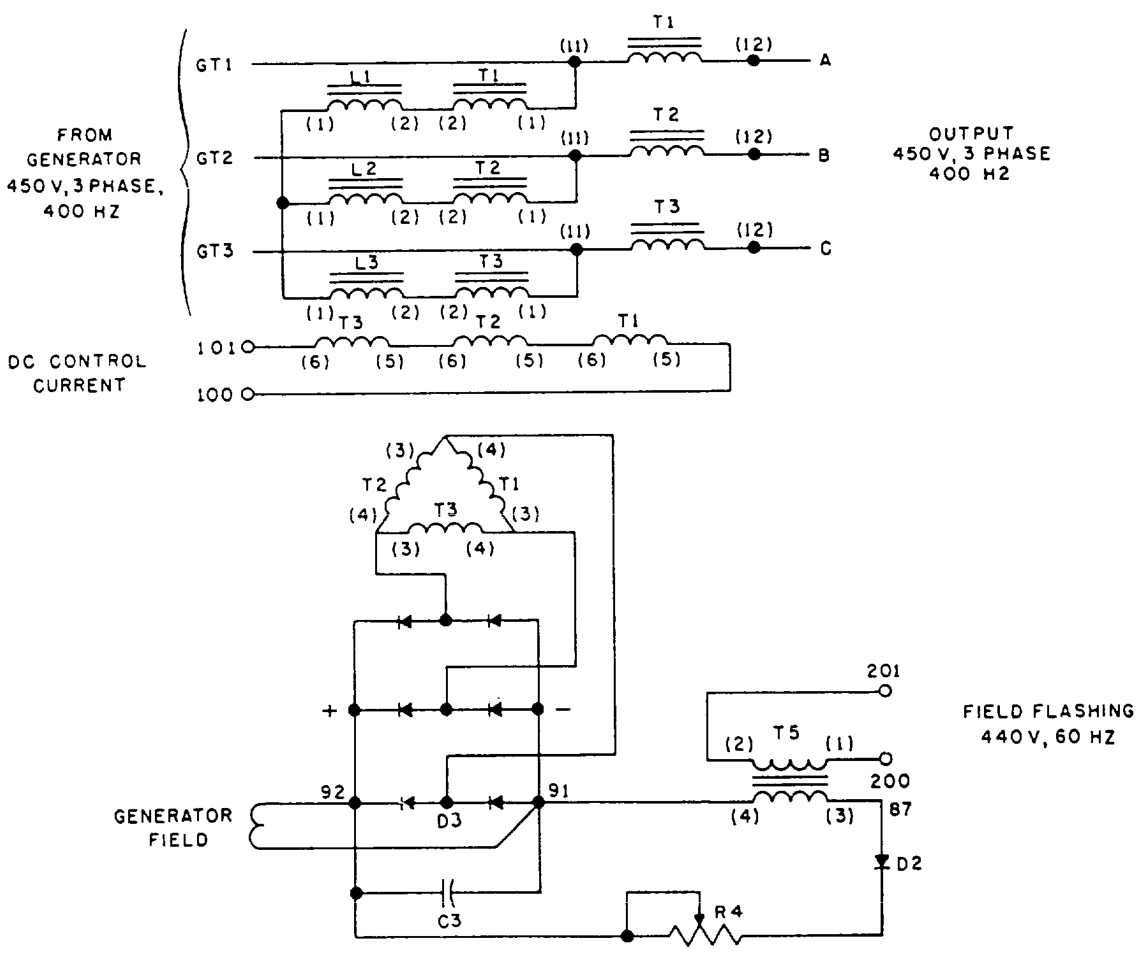


Figure 1-30.-Static exciter.

The use of the SCPT is relatively new to motor-generator application. Since the basic operation of each core in the SCPT is identical, only one core will be explained.

The basic operation of the SCPT is explained with the aid of figure 1-31. It consists of two voltage primary windings (V_{p1} and V_{p2}), two current primary windings (I_{p1} and I_{p2}), two secondary windings (V_{s1} and V_{s2}), and a dc control winding (N_c).

In figure 1-31, these windings are arranged on a three-legged E-type lamination. For simplicity, consider the leg of the transformer with windings V_{p1}, I_{p1}, and V_{s1}. The V_{p1} winding and the secondary winding (Vs1) function like a normal power transformer, and the current primary winding (I_{p1}) and secondary winding function like a normal current transformer. When either of the primary windings (V_{p1} or I_{p1}) induce a voltage into the secondary winding (V_{s1}) (the secondary winding is connected to a load), a current will flow in the secondary winding (V_{s1}). The SCPT is constructed in such a manner that the current flow in the secondary is the sum of the current that would be caused to flow by the separate windings V_{p1} and I_{p1}. As can be seen in figure 1-31, there is a voltage and current primary winding and a secondary winding on each of the cores of the SCPT The function of each is as described in the previous paragraphs.

To understand the principle of operation of the dc control winding, refer to figure 1-32. The action that takes place between the primary winding (either current primary or voltage primary), the secondary winding, and dc control winding is the same. Therefore, only a voltage primary winding (N_p) is shown in figure 1-32. The outer legs of the core are each wound with a primary and a secondary winding. The control winding is wound on the center leg. The primary and secondary windings are connected so their flux oppose each other in the center core. Thus, with the net flux of zero in the center core, no voltage is induced into the control winding. When voltage is applied to the primary windings, current flows in these windings, which are labeled I_p in figure 1-32. If the primary voltage is instantaneously positive (+) at the start of winding N_{p1}, then the current flowing through the turns of N_{p1} and N_{p2} should create the flux; 01 and 02, following the left-hand rule, which defines winding polarity.

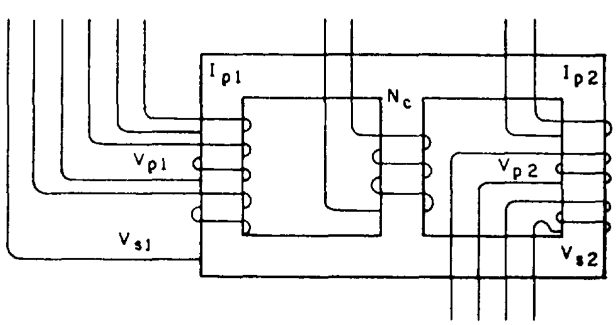


Figure 1-31.-Saturable current-potential transformer.

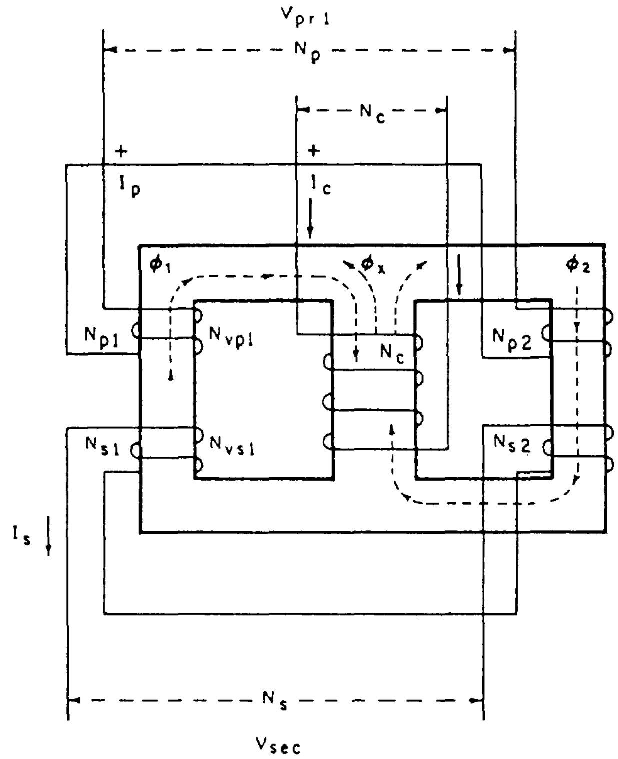


Figure 1-32.-Saturable potential transform.

The flux caused by N_{p1} is in an upward direction, and the flux caused by N_{p2} is in a downward direction. These fluxes will close their loop through the center leg of the laminated core because of the shorter path it presents; but because the fluxes are of equal magnitude, they cancel each other in the center leg and thus induce no voltage in the control winding (N_c). Because the fluxes, 01 and 02, link the secondary turns, N_{s1} and N_{s2}, a voltage is induced in each of these with a sum of V sec. The relationship that exists between the primary and secondary windings when the core is not saturated is identical to any voltage transformer with a core that is not saturated. When a direct current flows through the control winding N_c in the direction shown by I_c, a dc flux 0_x is created, according to the left-hand rule, which is in an upward direction opposing 01 and aiding 02. When the magnitude of the dc flux becomes great enough, it begins to force the core material into saturation.

Saturation may be defined as the condition in the magnetic material where an increase of magnetomotive force causes no increase in flux. The coupling of the primary and secondary voltage is accomplished only when there is a flux change; consequently, when the core material is forced into the condition where no flux change can take place, the coupling of the primary and secondary voltages becomes nonlinear, and the effect of de- coupling the secondary winding is produced. Figure 1-31 indicates the path of dc flux when the start of N_{p1} is positive. Naturally, when the applied voltage polarity reverses itself, the fluxes, 01 and 02, also reverse themselves; but the dc flux through the control winding then forces 01 into saturation before 02 is forced into saturation. Since the load on the saturable potential transformer secondary is magnetically coupled to the primary of the saturable potential transformer, the variable control current through the winding N_c will produce a variable secondary output voltage. The control current versus the output voltage characteristic of the saturable potential transformer is shown in figure 1-33. The saturable potential transformer is designed to operate in the linear position of the characteristic curve, as shown in figure 1-33.

POWER-SENSING NETWORK

The power-sensing network functions to balance the load between generators operating in parallel. In single generator operation, the power-sensing network is not used.

This network is designed to sense real power or the kilowatt (kW) output of the generator only, as opposed to kilovolt amperes (KVA) output.

This generating system has an output rating of 30 kW at 0.8 power factor, 37.5 KVA. The current in each line with this load will be 48.5 amperes at 450 volts. A 30-kW load at unity power factor will result in a current of only 38.5 amperes per line. The difference in the output current with identical kilowatt loads is the result of the flow of reactive current in the load circuit. This is known as the reactive volt ampere component of the load and is abbreviated VAR.

This VAR component of the load is caused by the current of the generator being out of phase with the voltage. The mathematical relationship of power factor, watts, VA, and VAR is shown in figure 1-34.

It is possible for the current to either lead or lag behind the voltage, and, if it is lagging (for inductive reactive loads), the power factor would be a lagging power factor.

The phase angle of the current in relation to the voltage of the generator output in combination with the magnitude of the output current is used by the power-sensing network to produce an output signal. That signal will vary in magnitude in relation to the useful output (kW) of the generator and will produce no output when the generator load is entirely VAR. Any combination of VAR and kW will produce an output signal that is directly proportional to the kW load only.

The amount of power required by the motor to drive the generator is also directly proportional to the kW output of the generator. This makes it possible to use the output signal of the power-sensing network with changing load.

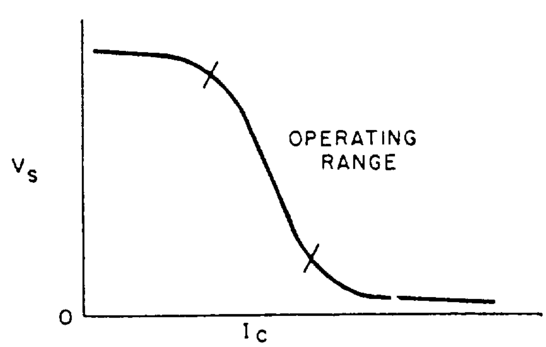
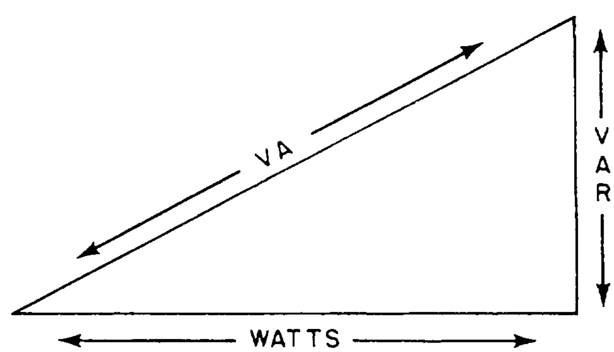


Figure 1-33.-Characteristic curve of a saturable potential transformer.



$$\text{POWER FACTOR} = \frac{KW}{KVA}$$

$$VA = \sqrt{WATTS^2 + VAR^2}$$

$$WATTS = \sqrt{VA^2 - VAR^2}$$

$$VAR = \sqrt{VA^2 - WATTS^2}$$

Figure 1-34.-Watt, VA, and VAR relationship.

A power-sensing network has been provided in one phase of the generator output (fig. 1-35) for simplicity; consider first the power-sensing circuit of generator A. This circuit consists of current transformer A/CT1 and real power-sensing rheostat A/R1. Note that power transformer A/T1 is connected from neutral to line C, and, therefore, the voltage across the primary of transformer A/T1 will be in phase with the current in line C at unity power factor. Transformer A/T2, which is the frequency-sensing transformer, is in parallel with power transformer A/T1, and, therefore, the voltage output of the secondary of transformer A/T2 is in phase with the voltage in the primary of transformer A/T1. Then, at unity power factor, the voltage across the secondary windings A/T2 will be in phase with the current in line C. Real power-sensing rheostat A/R1 is actually the load resistor for current transformer A/CT1. Therefore, when a load is applied to the output of generator A, a voltage will be impressed across rheostat A/R1, and this voltage will be in phase with the voltage across the secondary winding of transformer A/T1. The voltage from transformer A/T2 and the voltage across resistor A/R1 will add, and the sensed voltage will be an increased voltage to rectifier A/RD1. This would represent an increased output frequency; thus, the regulator would decrease the speed of the motor and thus reduce the output frequency of the generator. This is known as a frequency droop. To eliminate this droop in singular operation, a shorting bar or relay contact is placed across rheostat A/R1, thus disabling the power-sensing system. If the leads from current transformer A/CT1 to resistor A/R1 are reversed, the phase relationship of the voltage across resistor A/R1 would be 180° out of phase with the secondary of transformer A/T1. Therefore, with increasing load, the regulator would try to raise the output frequency of the generator. This is known as frequency compounding.

PARALLEL OPERATION

Refer to figure 1-35 and note that generator B has a real power-sensing system exactly as generator A. Note also that not only is current transformer A/CT1 connected across its load rheostat A/R1, but when circuit breaker CB3 is closed, it also is connected across real power-sensing rheostat B/R1. Consider what would happen if generator A were to supply the greater amount of real power to the load. There would be a difference in potential between current transformers A/CT1 and B/CT1. Due to the difference in potential, a current will flow in resistors A/R1 and B/R1 connected in parallel. The current will be in phase with the voltage out of secondary of transformer A/T1 and 180° out of phase with the secondary voltage of transformer B/T1. Hence, the regulator of generator A will decrease its output frequency, and the regulator of generator B will raise its output frequency. This will permit the generator to

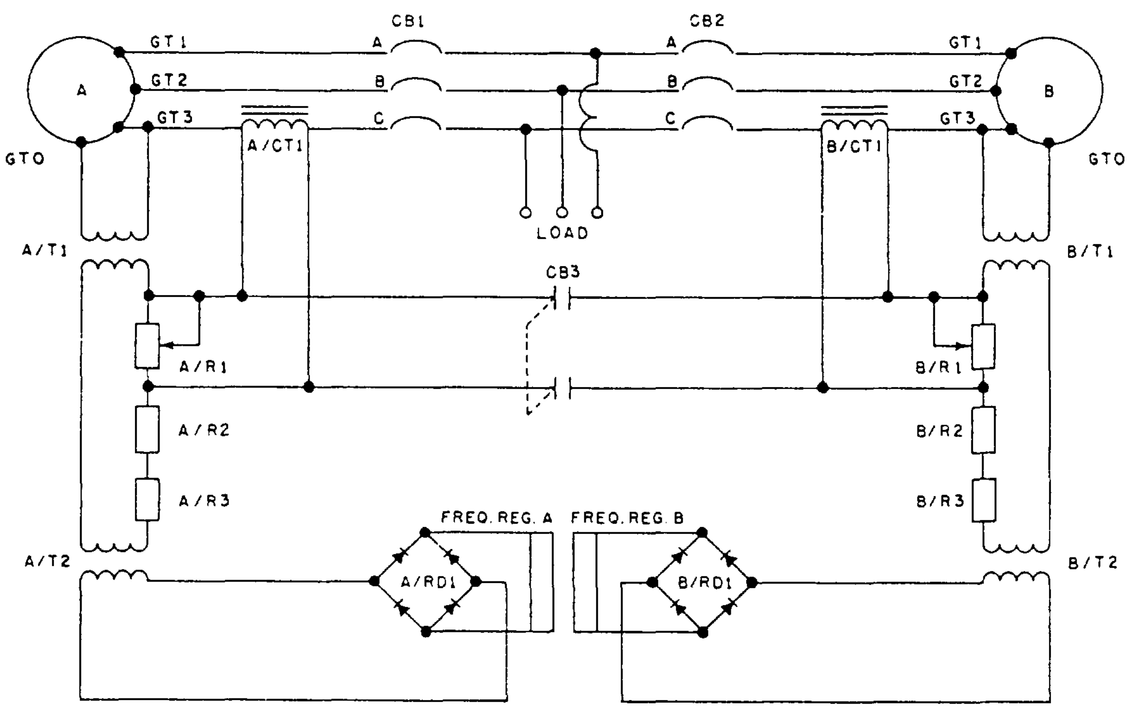


Figure 1-35.-Power sensing.

operate in parallel without speed droop with changing load and to divide the load (kW) evenly between them.

SAFETY

The inherent dangers of rotating machinery are kept to a minimum; however, it remains the responsibility of supervisory personnel to ensure that personnel performing preventive and corrective maintenance are thoroughly acquainted with the possible hazards involved. Except during supervised maintenance, all doors and covers should be in place. Since considerable semiconductor application is made here, test equipment settings and proper soldering techniques must be observed when maintenance is required.

MAINTENANCE

The 3-M system provides adequately for preventive maintenance on the motor generator. No corrective maintenance should be attempted without a thorough understanding of the pertinent sections of the manufacturer's technical manual. Troubleshooting charts are of great value when employed with test procedures in identification and isolation of problem areas.

One test that may be of some assistance is that used for silicon diodes. With this test, the silicon diodes may be tested without removal from the circuit by the use of a low-range (0-500 ohms) ohmmeter. The test is performed by readings taken with the ohmmeter leads connected across the diode in the opposite or reverse direction. This means that the positive lead of the ohmmeter will be connected to first one side of the diode and then to the opposite side. Comparison of the reading will indicate the condition of the diode. When the positive lead is connected to the anode side of the diode and the negative lead is connected to the cathode side, the ohmmeter will indicate a low value (15 ohms or less). With the ohmmeter leads reversed across the diode, a higher reading will be obtained (Refer to fig. 1-36) A front to back ratio of 10 to 1 is usually considered a good diode.

Various test setups have been devised for transistors, and often they are included in the manufacturer's technical manual.

A key to good maintenance that should be stressed is familiarity with the manufacturer's technical manual.

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

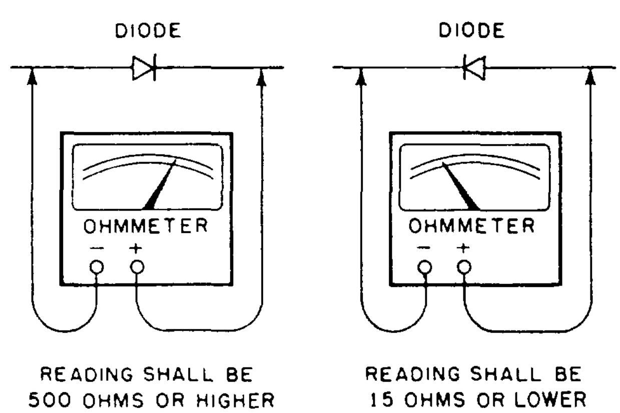


Figure 1-36.-Diode test.

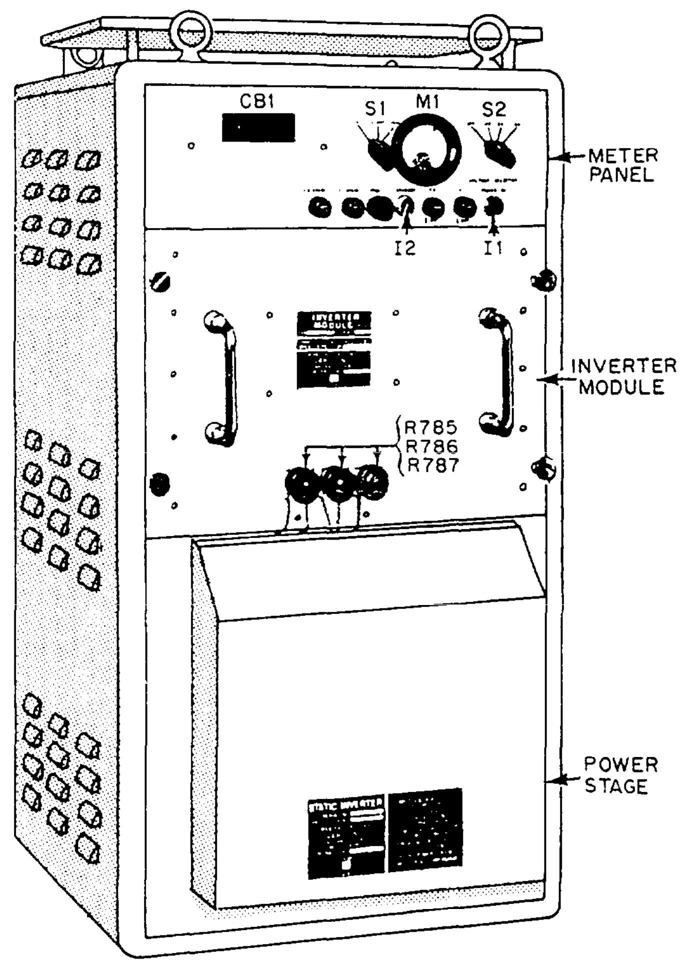


Figure 1-37.-Static inverter.

operated with a controlled 90° 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. 1-37), 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.

The meter panel assembly contains the instruments and controls necessary for the operation of the equip ment.

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.

FUNCTIONAL DESCRIPTION

A simplified functional block diagram of the model 4345A static inverter is shown in figure 1-38. A brief discussion of the various components and circuits contained in the unit follows.

Oscillator Assembly

The oscillator (fig. 1-38) consists of a 1600-Hz tuning fork controlled oscillator and a binary frequency

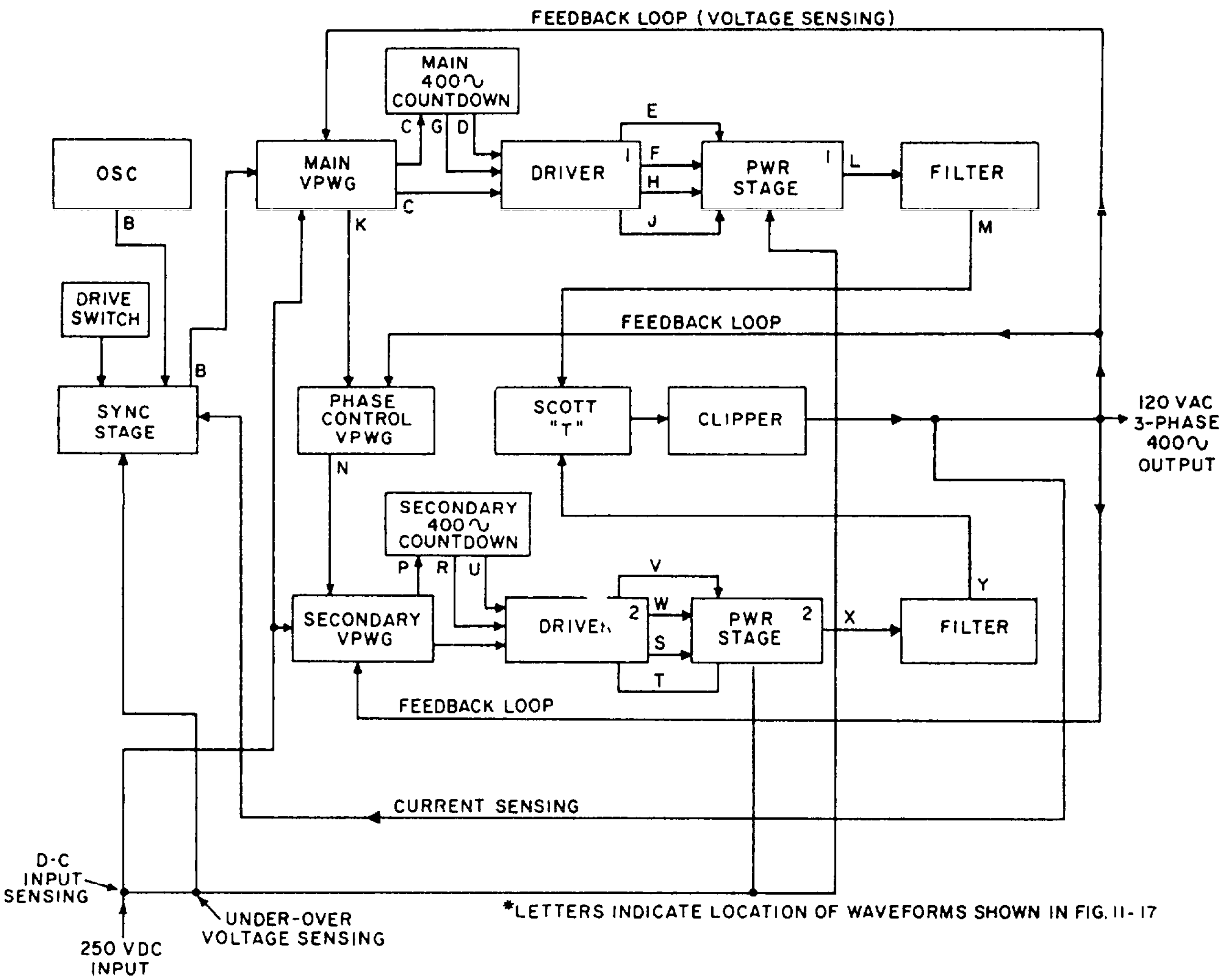


Figure 1-38.-Simplified block diagram of a static inverter.

divider (countdown) circuit. The countdown circuit reduces the 1600-Hz oscillator frequency to an 800-Hz reference frequency required by the inverter control circuits.

Variable Pulse Width Generators

The inverter module contains one variable pulse width generator (VPWG) for each inverter (main and secondary VPWG) (fig. 1-38) and one VPWG for controlling the phase angle between the inverters. Each VPWG contains a monostable (one-shot) multi vibrator, a modulator circuit, and an inverter output voltage error-sensing circuit.

The modulator circuit consists of a transistor and resistors connected in the discharge path of a capacitor. Varying the level of conduction of the transistor varies the discharge time of the capacitor, which varies the time the monostable multivibrator remains in the unstable state. The time the monostable multivibrator remains in the unstable state determines the width of the output pulse.

The monostable multivibrator used in the VPWG can be triggered only on positive pulses.

The output voltage error-sensing circuit for each VPWG receives an ac signal (via the feedback loop) proportional to the output voltage of the inverter. The ac signal is converted into a corresponding dc signal, compared with a reference signal, and the error (difference) signal is used to control the level of conduction of the transistor in the modulating circuit.

The secondary VPWG regulates the output voltage of phase AB and the phase control, and the main VPWG regulates the voltages of phases BC and CA. The phase control VPWG also provides a delay in time between triggering of the main and secondary VPWG to control the phase angle between the power stages (1 and 2) of the inverters.

The main and secondary VPWGs deliver one NM-Hz input to each of the driver stages (1 and 2) and another 800-Hz input to a binary countdown circuit that, in turn, delivers two 400-Hz inputs 180° apart to each of the driver stages.

Drivers

Each driver contains four drive pulse generators. Two of the drive pulse generators generate the triggers for the power SCRs ("turn on" SCRs), and the other two generate the triggers for the commutating SCRs ("turn off SCRs) in the power stages.

A unijunction transistor is used to generate the drive pulse trigger.

Power Stages

Each power stage contains three power and three commutating SCRs for each side of the power stage and a transformer. The SCRs switch the dc source across the primary of the transformer at a 400-Hz rate to produce a 400-Hz square-wave output. The square-wave output is filtered to produce a sine wave.

The SCR is the semiconductor equivalent of the gas thyratron tube. Once it is made to conduct, it will continue to conduct for the remaining positive half cycle (anode positive with respect to cathode). Neither the removal of the gate voltage nor the reversal of the gate voltage will stop the SCR from conducting. Conduction may be stopped only by removing the positive anode to negative cathode voltage completely or by applying a slightly greater reverse negative anode to positive cathode voltage.

The principle of operation of the power stages is illustrated in the simplified schematic diagram in figure 1-39.

When the power SCR (Q1) is triggered on by an output pulse from the driver, a rising current will flow

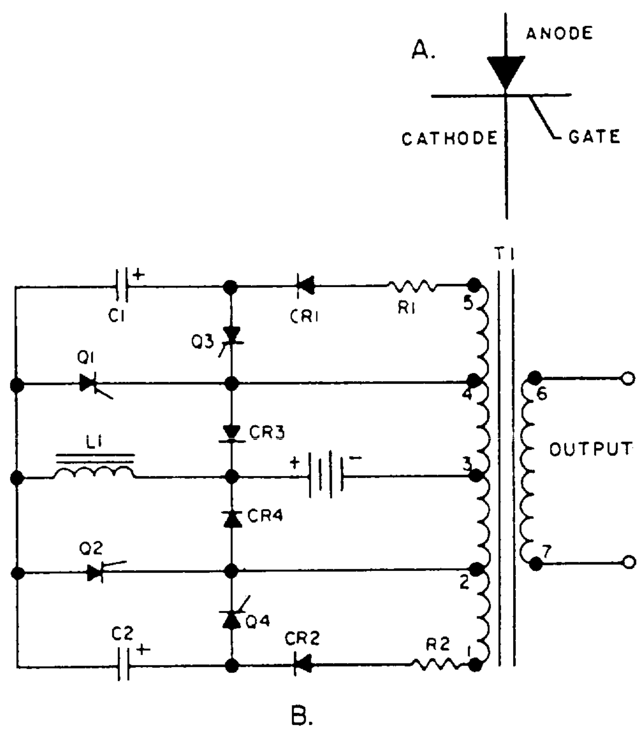


Figure 1-39.-Power stage, simplified schematic diagram.

through primary winding 3-4 of output transformer T1 (through Q1, L1, and the battery), inducing a voltage in secondary 6-7 in one direction. By autotransformer action, a voltage is also induced in winding 4-5. This voltage charges capacitor C1 through Q1, CR 1, and R1. When the commutating SCR (Q3) is triggered on by the driver, the positive voltage from the right plate of Cl is applied through Q3 (Q3 conducting) to the Q3-CR3 junction. This applies a reverse negative anode to positive cathode voltage to Q1, causing Q1 to stop conducting. Capacitor C 1 discharges through L1, CR3, and Q3. With Q1 off, the current in winding 3-4 of T1 gradually drops to zero; and slightly later when the 3-4 current ceases, the voltage between secondary terminals 6-7 drops to zero. The voltage between terminals 4-5 also drops to zero. When C1 discharges to zero, Q3 stops conducting. Because of the gradual drop of current in the 3-4 winding, the voltage induced in the 6-7 winding is of reversed polarity and low amplitude.

On the other side of the power stage, power SCR Q2 is then triggered on by the driver output, and capacitor C2 charges in the same manner as C1 charged. The operation of this side of the power stage is the same as the side just discussed. However, the polarity of the output is reversed, completing the square-wave output on the secondary of T1.

Filters

The filters (fig. 1-38) convert the square-wave outputs of power stages 1 and 2 to sine waves. Each filter consists of one series and four shunt LC filters. The series filter provides a low-impedance path for the 400-Hz fundamental frequency and a high-impedance path for the odd harmonics in the output. The predominate odd harmonics are filtered out by individual shunt filters. A shunt filter is provided for the third, fifth, seventh, and ninth harmonic. Even harmonics are negligible due to the balanced design of the push-pull power stage.

Scott “T” Transformer

The Scott “T” transformer is a center-tapped autotransformer. The output voltages from the main and secondary inverter fibers combine in the Scott “T’ transformer to produce a 120-volt, 3-phase output.

Clipper

The 3-phase clipper network, consisting of capacitors, resistors, and diodes, is connected across the 3-phase output of the Scott ‘T’ transform. The clipper network functions to reduce voltage transients in the inverter 3-phase output.

Drive Switch

The drive switch (fig. 1-37, S-1) has three positions: OFF, START, and RUN. In the OFF position, power is supplied to the standby indicator light to indicate the inverter is in the standby mode. In the standby mode, a +30-volt dc signal is supplied to the synchronizing stage. Also, in the OFF position, the input dc voltage is connected as a source of power for the control circuit +30-volt dc power supply.

In the START position, power is removed from the indicator light. Also, the +30-volt dc signal to the synchronizing stage is removed, allowing signals to pass to start the inverter properly.

When the drive switch is switched to the RUN position, the input dc voltage for the control circuit +30-volt dc power supply is disconnected and a bridge rectified output from phase CA of the inverter is used.

Power Supplies

The power supplies in the inverter are the control circuit +30-volt dc power supply and the drive circuit +30-volt dc power supply. The control circuit +30-volt dc power supply provides power for all control circuits except the drivers and under-over voltage circuits. These two circuits are supplied by the drive circuit +30-volt dc power supply.

The input power for the control circuit +30 volt power supply comes from two sources. During the START mode, power is obtained from the inverter input dc source. In the RUN mode, the control circuit +30-volt dc power supply receives its input from phase CA of the inverter output.

The drive circuit +30-volt dc power supply provides power for the drivers and the under-over voltage circuits. This power is obtained from the inverter input dc voltage.

Overload Circuit

The overload circuit turns the inverter off in case of overload. An overload signal from the current-sensing circuit produces a dc signal of sufficient amplitude to trigger a unijunction transistor that, in turn, triggers a bistable multivibrator. The bistable multivibrator output is fed to the binary circuit in the SYNC stage, which switches the inverter off.

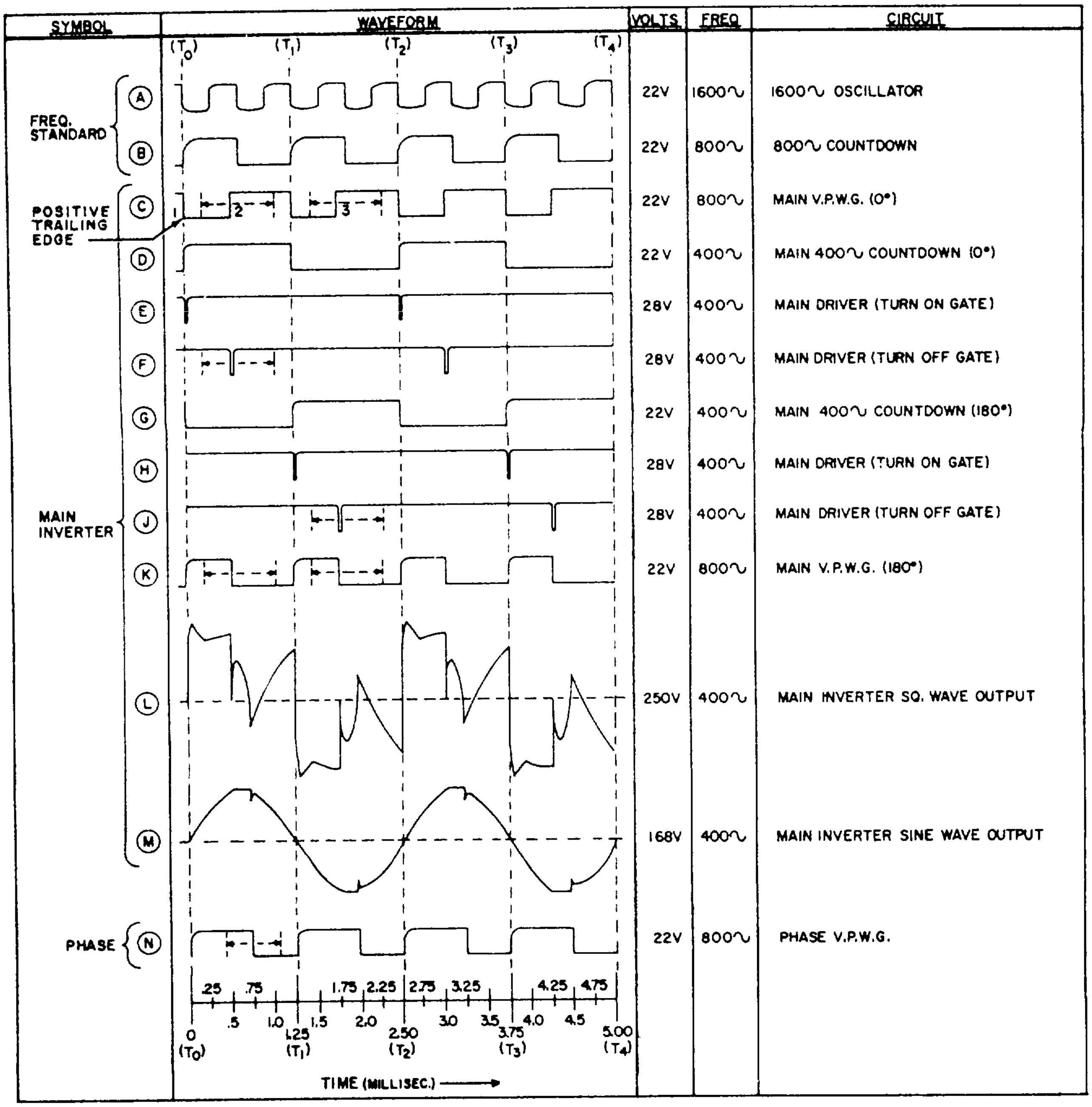
Under-Over Voltage-Sensing Circuit

The under-over voltage-sensing circuit turns the inverter off when the input dc source voltage is out of the operating range (210 to 355-volts dc) of the inverter.

A modified Schmitt trigger circuit is used to supply the interlock signal to the binary circuit in the SYNC stage. The Schmitt trigger is a form of bistable multivibrator. It differs from the conventional bistable multivibrator, in that it is at all times sensitive to the amplitude of the input signal. If the amplitude of the input signal is above a specified level, the Schmitt trigger bistable multivibrator will be in one state (one transistor conducting while the other is off); if the amplitude is below a specified level, it will be in the other state.

Dc Input Sensing

The dc input-sensing circuit compensates for changes (step changes) in the input dc voltage source. A



A.

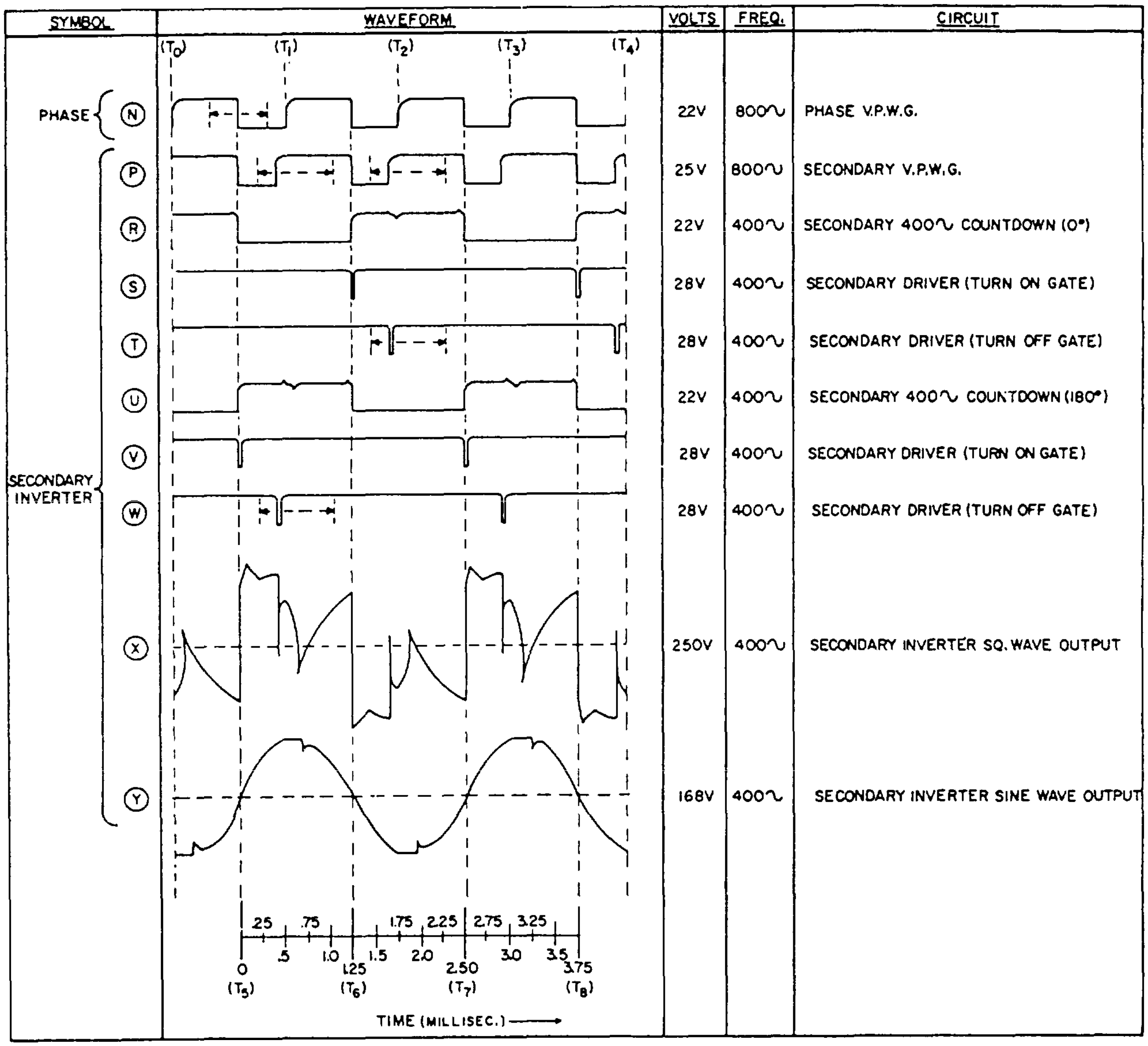
Figure 1-40.-Waveforms.

voltage-sensing network composed of resistors and capacitors is connected to the bus that supplies the de input to the inverter. Positive and negative step changes in the dc supply voltage produce positive and negative pulse outputs from the voltage-sensing network. The output pulses are fed to the pulse width modulator circuit in the main and secondary VPWGs to compensate for the voltage change.

OPERATION CYCLE

When the main power circuit breaker is ON and the drive switch is in the OFF position, the inverter is in the standby mode of operation. The standby mode is composed of a transient and a steady-state condition. The transient condition lasts for approximately 2 seconds. This 2-second time delay is provided by the delayed B+ voltage interlock to allow the inverter circuits to reach a steady state as mentioned previously.

During the standby mode, the 800-Hz countdown circuit of the oscillator supplies an 800-Hz square-wave voltage to the SYNC stage and the main VPWG (waveform B, fig. 140, view A, and fig. 1-38). A+30-volt dc signal is applied to the binary circuit in the SYNC stage via the drive switch (S1, fig. 1-37) that keeps the bistable multivibrator in the SYNC stage in the "turnoff' state.



B.

Figure 1-40.-Waveforms–Continued.

Turning the drive switch to the START position removes the 30-volt dc signal from the binary circuit and allows the first negative-going edge of the 800-Hz square wave (waveform B) to reverse the bistable multivibrator in the SYNC stage. This allows the positive-going edge of waveform B (at time 0, fig. 1-40, view A) to trigger the monostable multivibrator in the main VPWG (fig. 1-38).

The trailing edge of the first positive half of waveform C (edge No. 1, fig. 1-40, view A) from the main VPWG triggers the main 40-Hz countdown circuit. The main 400-Hz countdown output (D) triggers the pulse generator in the driver that generates the pulse (E) to trigger the power SCRs for one side of the power stage. The main 400-Hz countdown (D) and the leading edge of the second positive half of waveform C (2, fig. 1-40, view A) provide coincident gating for the pulse generator in the driver that generates the pulse (F) to trigger the commutating SCRs in this side of the power stage.

The main 400-Hz countdown output(G) triggers the pulse generator in the driver that generates the pulse (H) to trigger the power SCRs in the other half of the power stage. Waveform G and the leading edge of the next positive half of waveform C (3, fig. 1-40, view A) gate the pulse generator in the drive that generates the pulse (J) to trigger the commutating SCRs in this half of the power stage. The leading edge of waveform C controls the duration of the ON time of the power stage.

The leading edge of the 180° signal (K) from the main VPWG triggers the phase control VPWG. The phase control VPWG provides a delay in time (N) between the main and secondary VPWGs to control the phase angle between the two power stages.

The secondary VPWG is triggered by the trailing edge of the phase control VPWG signal (waveform N, fig. 140, view B). The trailing edge of waveform P from the secondary VPWG triggers the secondary 400-Hz countdown. The outputs from the secondary 400-Hz countdown (U and R) and the leading edge of the secondary VPWG output (P) trigger the pulse generators in the secondary driver in the same manner as just described for the main driver. The sequence of operation for the secondary power stage is the same as for the main power stage.

OPERATING PROCEDURE

To operate the static inverter, turn the main power circuit breaker CB1 (fig. 1-37) to ON. Turn the drive switch, S1, to the OFF position. The standby light, I2, should light. Turn the drive switch, S1, to the START position. The power on light, I1, should light, and the standby light, I2, should go out. After the output of the inverter has reached a steady state (approximately 2 seconds), turn the drive switch, S1, to the RUN position. Adjust the voltage, and adjust potentiometers R785, R786, and R787 to the required output for each phase. Use the voltage selector switch, S2, and meter, M1, to read the voltage of each phase.

The output voltages must be adjusted in the following sequence: phase CA, phase AB, and then phase BC.

To secure the inverter, turn the drive switch, S1, to the OFF position, and then turn the power circuit breaker CB1 to OFF.

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.

RECTIFIER POWER SUPPLY

The rectifier power supply is a regulated dc power supply. It is intended to furnish 120-volt dc power for interior communication and fire control application. Its input is 440-volts ±5 percent, 60 cycles ±5i percent, 3-phase. It will produce a dc output adjustable from below 117 volts to above 126 volts at a load of 1 kW. The output voltage is regulated within 5 percent against the combined effects of load and line fluctuations,

INSTALLATION

The equipment is bulkhead mounted in a drip-proof cabinet. No switches, meters, or external controls are provided. Two phase rotation lights are on the front of the cabinet. One light is for correct phase rotation of input 3-phase power and the other is for incorrect phase rotation. Fast-acting fuses are provided for circuit protection.

Voltage checks are made at the load if incorrect adjustments are made internally by repositioning a potentiometer.

PRINCIPLES OF OPERATION

The input 440-volt, 60-cycle, 3-phase power is stepped down by transformers and applied to an SCR (diode) 3-phase bridge. The output voltage of the bridge can be controlled by varying the phase that the SCRs are triggered. The output is then filtered and sent to the load.

The voltage across the load is compared with an internally generated, temperature-compensated, reference voltage. Any difference between the actual load voltage and the desired load voltage, indicated by the reference voltage, is amplified by the voltage control circuit. This amplified voltage is combined with a properly phased ac signal and applied to the trigger circuit of the SCRs. The ac signal controls the time of firing of the SCRs. By controlling the time of firing of the SCRs, the output voltage is also controlled.

The SCRs are fired earlier if the output voltage is too low. They are fired later if the output is too high. Special frequency-shaping circuits are used to ensure stability and prevent oscillations or hunting.

NO-BREAK POWER SUPPLIES

A no-break power supply is designed to provide uninterrupted electrical power by automatic takeover should the normal supply fail or momentarily deteriorate beyond the system demands. No-break power supplies are provided for communication systems, computers, navigational equipment, automated propulsion systems, and related equipment where a momentary loss of power would cause a permanent loss of information resulting in the need to recycle or reprogram the equipment. Since equipment requiring no-break power normally requires closely regulated power, no-break power supplies are designed not only to provide uninterrupted power, but also to provide power that is regulated to meet the needs of the equipment it serves.

COMPONENTS

The no-break “uninterrupted” power supply system consists of two major assemblies plus the storage batteries. The control cabinet and motor-generator set are shown in figure 1-41.

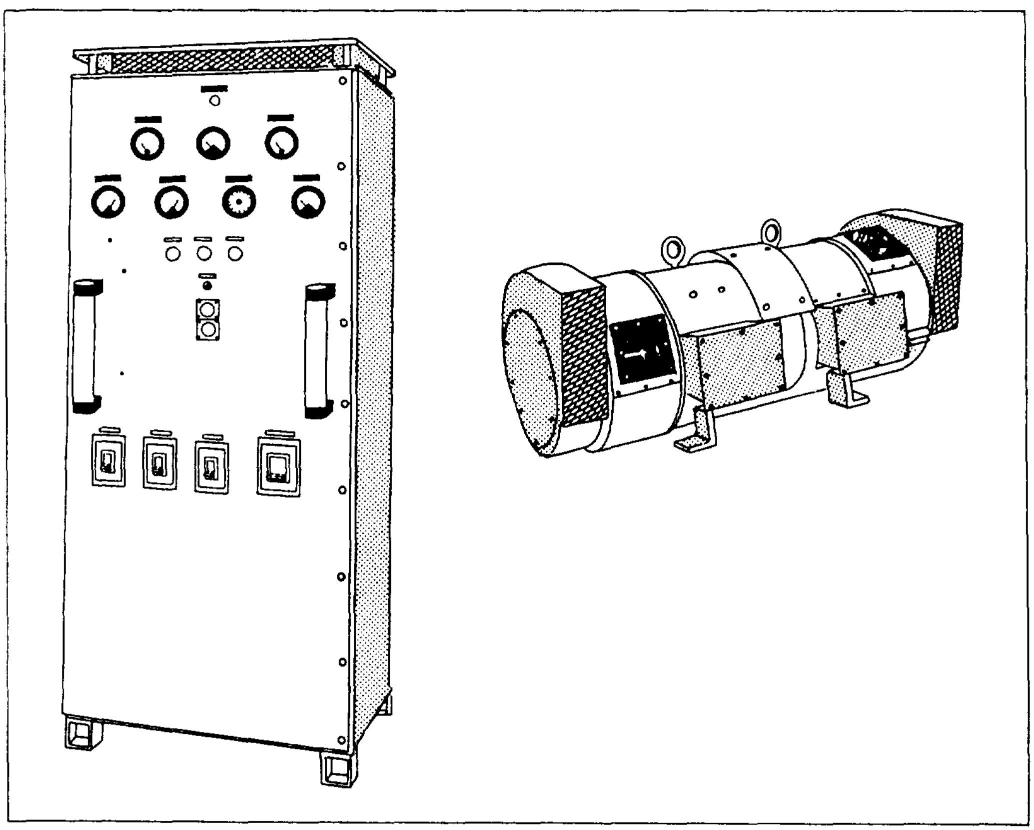


Figure 1-41.-No-break “uninterrupted” power supply system components.

The control cabinet contains all the control and monitoring equipments. The motor generator is a single-shaft unit. Either section of the motor generator can perform as the motor with the other as the generator. This permits two operational modes: NORMAL and STOP GAP.

NORMAL operation uses the normal supply (ship's generators). The motor generator is driven by the ac motor from the ship's supply, and the dc generator charges the batteries.

In STOP GAP operation, the motor generator is driven by the dc motor with power from the batteries. Under this condition the ac generator provides power to the critical load.

OPERATION

Normal ship's power (fig. 1-42) is applied to the voltage and frequency monitors. If the monitors sense the normal power to be within the frequency and voltage limits required relay action (relay #1) will allow the normal power to be applied to the load and other circuitry. (It should be noted that the relay numbers in fig. 1-41 refer to relay action sequence rather than relay designations.) Power is applied to the relay control power circuit from the battery.

When the system is turned on, the motor generator will accelerate to approximately synchronous speed as an induction motor before a time delay relay is

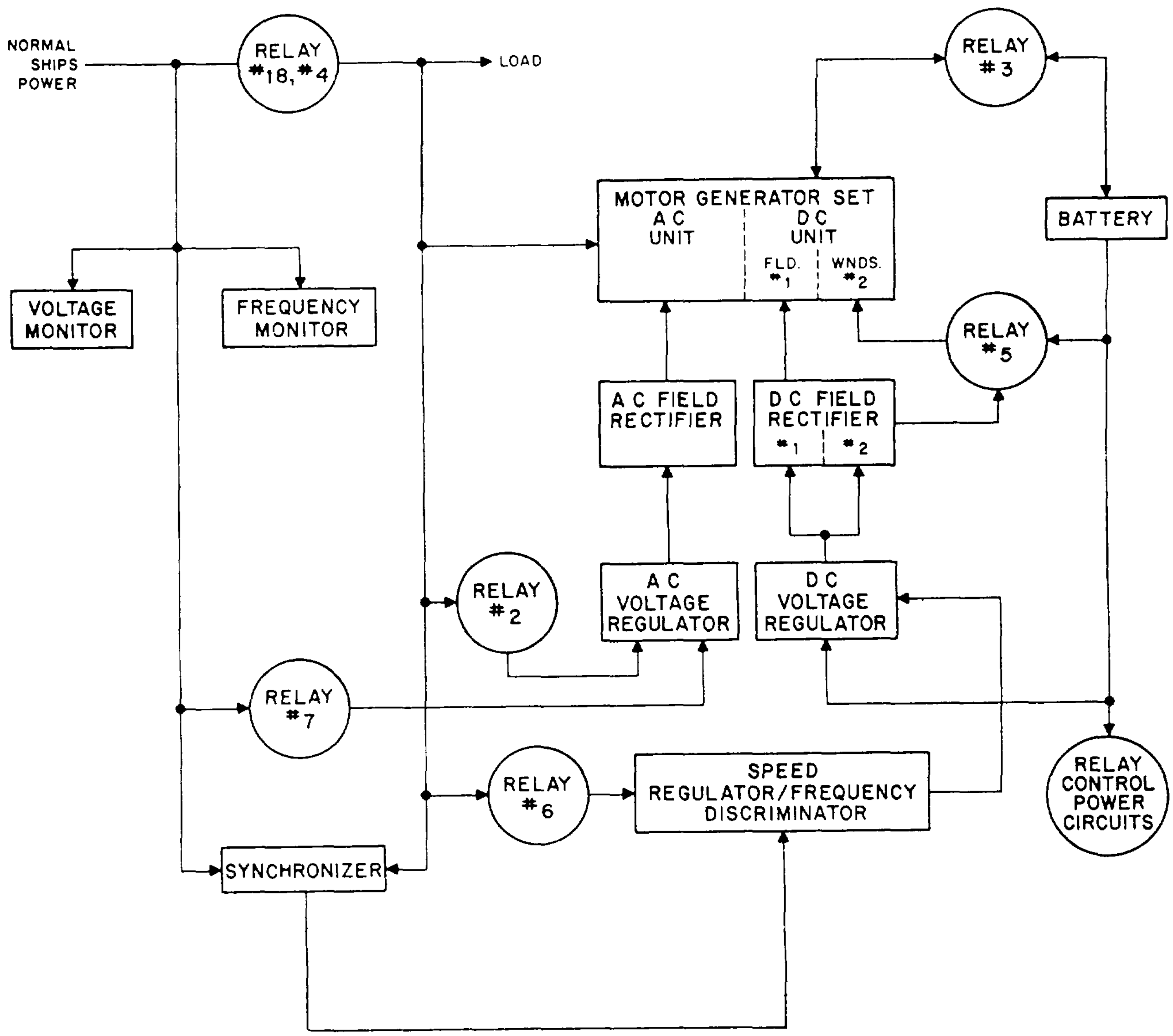


Figure 1-42.-No-break "uninterrupted" power supply system, block diagram.

energized. When the delay relay energizes (relay #2), it applies normal power to the ac field rectifier, via the ac voltage regulator, for application as field excitation to the ac motor to allow synchronous motor operation. At the same time, the dc generator is rerouted to the dc supply (relay #3) to prevent starting the motor-generator set on dc and to charge the batteries. The system is now operating in NORMAL mode.

If the normal supply falls out of its limits in either voltage or frequency, the respective monitor will sense it, and relay action (relay #4) will shut down the motor-generator set. At the same time, the dc generator field is disconnected from the dc field rectifier #2 and connected directly to the battery supply (relay #5). The dc motor speed regulator and the ac generator voltage regulator are energized (relay #6 and #7) to maintain the required motor speed and control the load voltage. The system is now in the STOP GAP mode.

If the reason for switching modes had been a voltage drop, the voltage would not have dropped below 317 volts, and the transition would have been accomplished within 1 second. In the case of a frequency drop, the change is made within 2 seconds and the frequency does not drop below 54 Hz.

When the ship's power returns to the specified limits, the synchronizer will have the normal power at one side and the ac generator power at the other. It will automatically adjust the speed regulator to match the generator frequency to the normal power. The matching is accomplished in less than 1 minute, and the system is transferred back to ac motor drive and battery charge (NORMAL mode).

MONITOR CIRCUITS

The frequency and voltage monitoring circuits are designed to switch and set from NORMAL to STOP GAP when the input frequency drops below 56 Hz or the input voltage falls below an adjustable limit (330 to 380 volts).

The voltage monitor circuitry is basically the same as the voltage-sensing and error voltage detector circuit of the voltage regulator. The frequency monitor is basically the same as the frequency discriminator and error voltage detector circuits. These circuits will be discussed later in this chapter. The big difference in the circuits is the output application. The output of the monitors is used for relay switching, since the other circuit's output is for regulation of either voltage or frequency.

VOLTAGE REGULATOR

The function of the voltage regulator is to maintain the output voltage at the preset value (2 percent) regardless of temperature or load variations. The basic circuitry for both the ac and dc regulators is similar except that the dc regulator does not use the 6-phase rectifiers in the sensing circuit. Constant generator voltage output is obtained by having the regulating circuit change the voltage feed in response to an error signal.

A differential amplifier is used in the error voltage detector circuit (fig. 1-43) to compare the generator output voltage, with a reference voltage, to produce the error signal. The error signal, acting through the modulator, modifies the timing of the pulse repetition frequency of the unijunction trigger circuits. The controlled pulses are fed to the respective field rectifier to control the average power to the generator field. The rate circuit modifies the error signal to stabilize the voltage regulator.

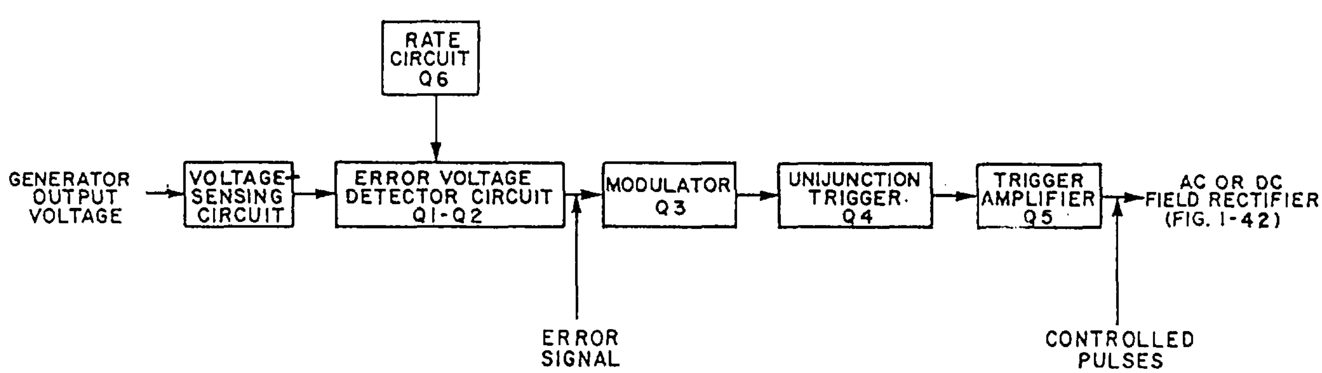


Figure 1-43.-Voltage regulator, block diagram.

Voltage-Sensing Circuit

The voltage-sensing circuit (fig. 1-44) steps down the 3-phase generator 440-volt ac output through voltage-sensing transformer T1 to 25-volt ac. Each phase is rectified by diodes CR1 through CR6 and filtered by C1 and C2. This dc voltage is proportional to the generator output voltage. The dc voltage is applied to voltage divider network R1 through R4 (R3 can be adjusted to develop the amount of voltage desired as the representative generator output) for comparison to the reference voltage in the error voltage detector circuit.

Error Voltage Detector Circuit

Transistors Q1 and Q2 (fig. 1-44) forma differential amplifier to compare the base voltages of the two transistors. The signal from the voltage-sensing circuit is applied to the base of Q1, while the reference voltage is applied to the base of Q2. The reference voltage is applied via R8, which is a factory set and locked reference voltage adjustment.

Resistor R9 is the voltage dropping resistor for CR7, and capacitor C3 reduces the ripple and noise voltages across CR7 to provide a clean dc reference voltage. Resistors R6 and R7 are load resistors for transistor Q2.

Any difference between the input voltage at the base of Q1 and the reference voltage at the base of Q2 will produce an error signal (a change in collector current). If the input voltage is higher than the reference voltage, Q1 conducts heavier than Q2 and vice versa when the reference voltage is higher than the input. The voltage drop across R6 is the error voltage that is applied to the base of the modulator Q3.

Modulator Circuits

The modulator circuit (fig. 1-44) modifies the time constant of the RC circuit (C4, R10, and the Q3 collector-emitter resistance). (The collector-emitter

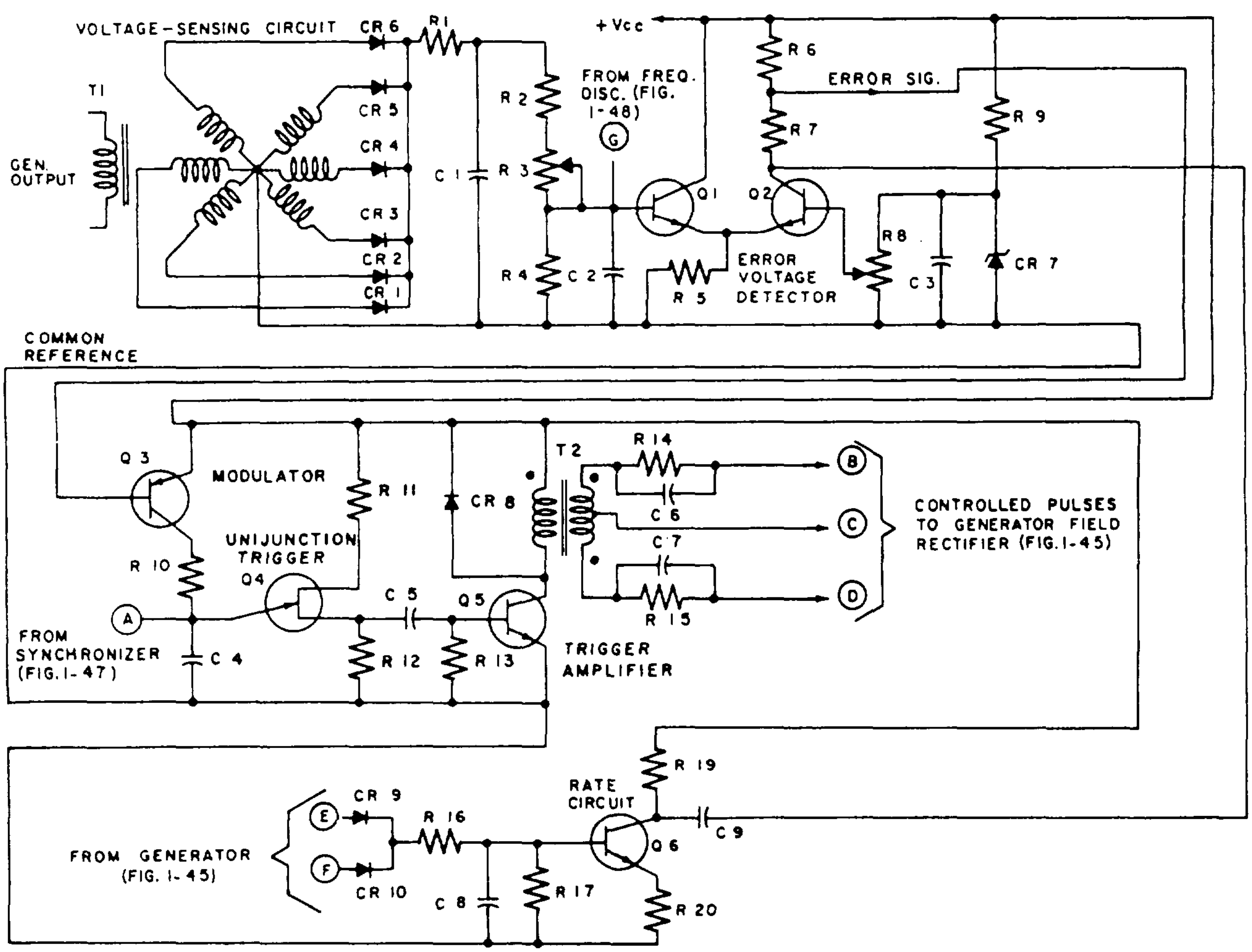


Figure 1-44.-Voltage regulator, simplified schematic.

resistance is controlled by the current through resistor R6.) An increase in the error signal across R6 decreases the collector-emitter resistance of Q3 and thus decreases the charge time of C4. If the error signal increases, the charge time of C4 is increased.

Capacitor C4 discharges when the voltage across it is approximately 9 volts (the peak point voltage of unijunction transistor Q4).

A synchronizing circuit (discussed later) clamps C4 to ground, thus delaying the RC time cycle. A rate feedback signal is also applied by the rate circuit to the collector of Q2. This signal modifies the error signal, thus stabilizing the voltage regulator.

Rate Circuit

The function of the rate circuit is to dampen the generator output voltage distortion about a set point. Otherwise, the high gain of the voltage regulator would cause the generator output voltage to hunt. The method used for damping the voltage distortion is feeding back an inverted signal (opposite to the error signal), proportional to the rate of voltage change.

The rate circuit (fig. 1-44) consists of a common emitter amplifier (Q6, R19, and R20) and an integrating circuit (R16 and C8). Resistor R17 is a discharge resistor for C8, and CR9 and CR10 are common rectifiers.

The input is supplied by the generator field rectifier (described later), integrated, and applied as forward bias to the base of Q6. Any change in the base is amplified and passed by C9 to the collector of the error detector, Q2. As this signal is opposite to the error signal, it will decrease conduction and stabilize the circuit.

Unijunction Trigger Circuit

The trigger function is performed by the unijunction trigger circuit (fig. 1-44). Unijunction transistor Q4 is a relaxation oscillator that initiates controlled rate pulses to trigger the field rectifiers. Q4 turns on when the voltage across C4 and the emitter current of Q4 reach preset values. When Q4 conducts, trigger pulses are applied to the trigger amplifier Q5.

Trigger Amplifier Circuit

The trigger amplifier (fig. 1-44) amplifies and shapes the trigger pulses. The circuit is a common emitter amplifier with RC input (R13 and C5) and transformer output (T2).

Transistor Q5 is protected against the inductive kickback voltage of T2 by diode CR8. Resistors R14 and R15 with capacitors C6 and C7 include a pulse-shaping network to prolong the life of the SCRs in the field rectifier.

GENERATOR FIELD RECTIFIER

Both the ac and dc field rectifiers are similar in operation. The function of the generator field rectifier is to provide controlled dc power to the generator field to regulate the generator input voltage with the field power being proportional to the conduction line of the SCRs.

Transformer T3 (fig. 1-45) transfers voltage from the generator that is rectified by the bridge rectifier (CR11 through CR14). The conduction of the bridge is controlled by SCRs, CR13, and CR14. One series combination of diode and SCR (CR11, CR13, or CR12, CR14) may conduct for alternate half cycles. The dc output is the controlled generator field power.

Diode CR 15 is used as an inductive kickback diode to provide a path for the current generated by the collapsing magnetic field of the generator during the idle portion of each cycle. The amount of field power can be adjusted by R21.

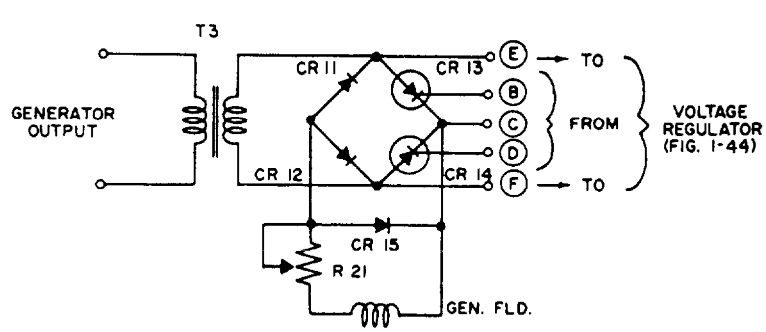


Figure 1-45.-Generator field rectifier, simplified schematic.

The SCRs accomplish power control because they are rectifiers and in an ac circuit conduct only during half of each cycle and then only after being turned on by a positive gate pulse (from the trigger amplifier). Power control is accomplished by switching the power on for a greater or smaller portion of the half cycle. Figure 1-46 shows how power can be increased as the firing point is moved along the phase time axis.

The firing point is determined by the position (or timing) of a spiked gate pulse. When applied to the SCR,

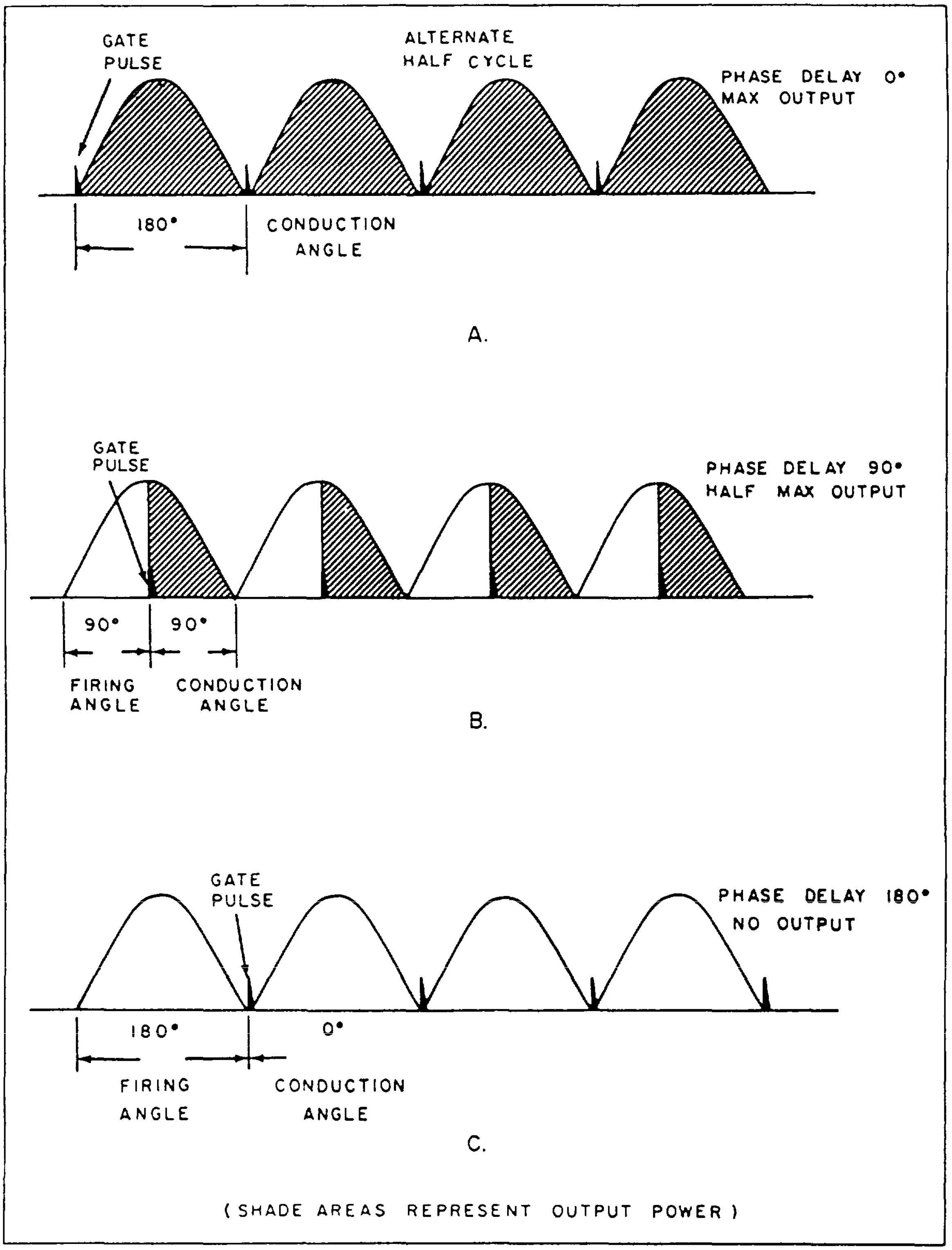


Figure 1-46.-Phase shift of gate pulse.

the pulse turns it on. By controlling the phase of the gate pulse (with respect to the supply voltage), the firing (delay) angle of the SCR gate may be delayed to any point in the cycle up to approximately 180°. Through control of the firing angle, the average power delivered to the load can be adjusted.

Referring to figure 1-46, you can see that by applying a gate pulse at 0° of the phase time axis (view A), output power will be applied during the complete half cycle. View B shows that power is obtained for a half of each half cycle by applying a pulse at 90° of the phase time axis. The other extreme of no output when the phase delay is 180° is represented in view C.

SYNCHRONIZER

The function of the synchronizer is to assure that the firing angle is always reckoned from the instant the supply voltage crosses the zero axis at each positive half cycle (fig. 1-46, view A). As shown in figure 1-47, when the SCRs are not conducting, an alternate bridge rectifier circuit is. This alternate bridge consists of diode CR12, resistor R21, the generator field, resistors R23 and R22, diode CR16, and the secondary of T3. During the alternate half cycle, the patch (dashed arrows) is the same except diodes CR 11 and CR 17 are used.

When the alternate bridge rectifier conducts, the voltage across R23 permits C4 (fig. 1-44) to charge, introducing the phase delay of the SCR gate pulse. Firing of SCRs, CR13, and CR14 applies equal potential at both ends of voltage divider R22 and R23. This removes the voltage drop across R23 and thus allows Q7 to turn off and Q8 to turn on. Thus, the timing capacitor C4 is clamped until the start of the next half cycle.

FREQUENCY DISCRIMINATOR

The speed/frequency regulator automatically maintains the motor speed and the generator frequency at a preset value despite line variations or load changes.

Constant output frequency is obtained by auto matically adjusting the power to the motor control field in response to a frequency discriminator. The frequency discriminator converts the generator output frequency to a voltage signal that is in direct proportion to the speed/frequency of the motor generator.

The speed/frequency regulator circuit is the same as the voltage regulator previously discussed. The operational difference is that the voltage regulator required an increase in generator output voltage to cause

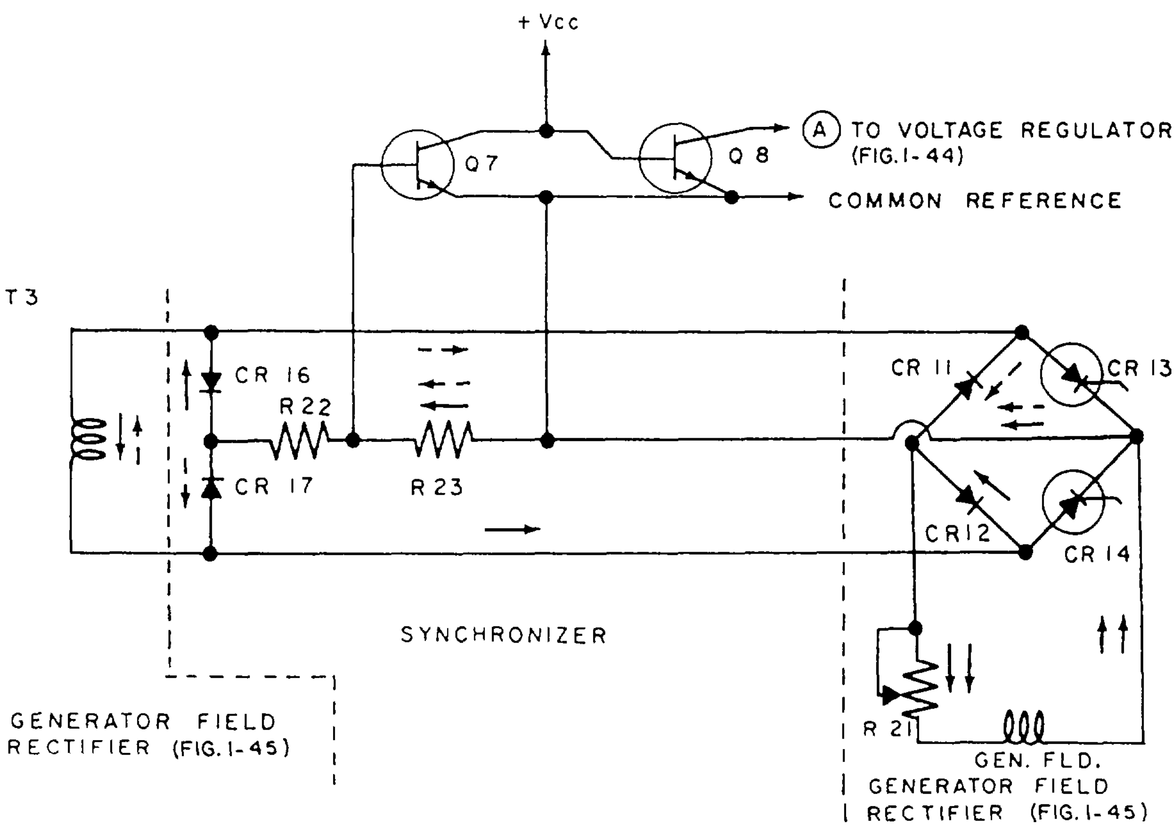


Figure 1-47.—Synchronizer, simplified schematic.

a decrease in generator field current; but, in the frequency regulator, an increase infrequency causes the field current to increase.

The discriminator circuit is shown in figure 1-48. It essentially consists of a one-shot multivibrator that puts out a constant width pulse whenever a trigger pulse is applied. The trigger circuitry is designed so a pulse is applied six times each output cycle to obtain a high enough sampling rate to decrease the response time of the circuit. The multivibrator output is integrated to provide a dc voltage that is proportional and linear with frequency.

The positive collector voltage input furnishes the circuitry operating biases and 6-phase ac is used to obtain the trigger pulses. The trigger circuitry consists of three single-phase full-wave rectifiers (CR18 and CR19, CR20 and CR21, and CR22 and CR21). Each is driven from a winding of the T1 star secondary (fig. 1-44). The rectified voltages are clipped by the Zeners (CR24, CR25, and CR26) to obtain a square pulse, which is further shaped by the differentiating circuitry of C10, C11, C12, and R24. The differentiated pulses drive the trigger transistor Q9, which saturates whenever a positive pulse is applied.

Transistors Q10 and Q11 form a one-shot multivibrator with an output that is a 2-millisecond wide pulse equal in amplitude to the collector voltage. Q11 is normally held on through R25, CR27, and R28. Thus, Q10 is held off as its base drive comes from the collector of Q11. Since Q9 saturates when a trigger pulse is applied, the collector voltage of Q10 is at ground potential whenever a pulse is applied.

Before the trigger pulse is applied, C13 has been charged to the collector voltage (Vcc) level through resistor R25 with the other end clamped to ground through diode CR27 and the base-emitter junction of Q11. When C13 discharges due to the trigger pulse, it turns Q11 off. The collector will rise to the collector voltage level, and resistor R26 will apply base current to Q10 to hold it saturated after the trigger pulse ends.

This state (Q10 on, Q11 off) will exist until C13 charges through R27 to a voltage high enough to allow Q11 to become forward biased again. At this time the output pulse ends since Q11 saturates and the base drive of Q10 is removed. The time duration of the output pulse is controlled by C13 and R27 with CR27 in the circuit to protect the base junction of Q11 from overvoltage.

The output pulse from the collector of Q11 is fed through resistor R29 to integrating capacitor C14. During the time no output pulse is present, C14 is discharged through R29 and the collector-emitter junction of Q11.

If the frequency of the generator increases, the ratio of charge time to discharge time increases, which in turn increases the discriminator output voltage proportional to the frequency shift. A decrease in frequency does the opposite. The output is applied to the error voltage detector circuit (base of Q1, fig. 1-44) or its equivalent in the frequency regulator.

MAINTENANCE

Under normal conditions, the motor-generator set and control equipment require inspection and cleaning as designated by the PMS maintenance requirement cards. When you inspect the motor generator, observe

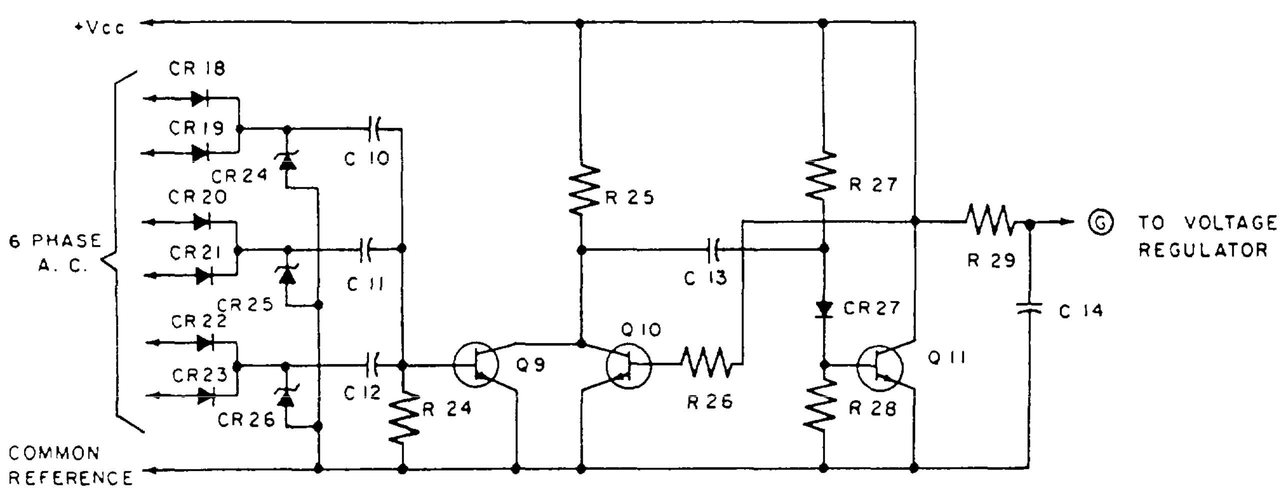


Figure 1-48.—Frequency discriminator, simplified schematic.

cleanliness, brush operation, condition of brushes and commutator, bearing temperature, and vibration.

When necessary, remove dust from the wound section with a vacuum cleaner, if available. If a vacuum cleaner is not available, use either compressed air (30 psi maximum) or a hand bellows. Be certain that the compressed air does not have any grit, oil, or moisture content in it. Use compressed air with caution, particularly if abrasive particles, such as carbon, are present, since these may be driven into the insulation and puncture it or may be forced beneath insulating tapes or other possible trouble spots. If vibration exists, check for loose parts or mounting bolts.

When cleaning the control equipment, use a vacuum cleaner or hand bellows. Accumulations of dust or dirt around components can impair the natural flow and cause overheating.

DAMP WINDINGS

Moisture in windings can soften the insulation and reduce the dielectric strength. However, considerable time is usually required before the moisture will harm the windings. By checking the insulation resistance of the winding, you can spot possible trouble and take appropriate maintenance action.

If the insulation resistance falls below 1 megohm, dry out the windings. Three recommended methods of drying are oven drying, forced warm air drying, or low-voltage current drying.

Oven drying is accomplished using a maximum temperature of 85°. The forced warm air method is simply using a fan to blow warm air across the damp windings, The air must be dry and should be in a vacuum with the temperature below 212°F.

The low-voltage current method requires circulating a limited direct current through the windings. Take care to ensure that the drying current does not exceed 80 percent of the full-load rating. When drying the field winding, remove the brushes to prevent marking or pitting the collector rings (which can occur if the brushes carry the drying current).

Check the insulation resistance at regular intervals. Remember, when using the current method, the resistance may drop temporarily as the moisture is forced to the surface of the winding. Drying should continue until the resistance is at least 1 megohm. The drying process can take days in extreme cases. When the windings are dried out, apply a coating of insulating varnish.

OIL-SOAKED WINDINGS

If oil enters the windings, insulation breakdown may be imminent, and the winding will probably have to be rewound. However, patches of oil should be removed with a clean cloth soaked in an approved solvent. Use the solvent sparingly, being careful that the insulation is not saturated as this can cause softening of the insulation. After cleaning with solvent, apply one of the drying methods.

SUMMARY

In this chapter, you were introduced to the fundamentals of the various ac and dc motor and circuit control devices to enable you to maintain, troubleshoot, and repair the equipment successfully. You were given a basic understanding of frequency regulators and the troubleshooting and repair of them as well. Most equipment installed will have a manufacturer's technical manual that should be used to adjust and repair the equipment following the recommended specifications. The *Naval Ships' Technical Manual (NSTM)*, chapter 302, will provide additional information of value to you.

CHAPTER 2

ANEMOMETER SYSTEMS

CHAPTER LEARNING OBJECTIVES

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

- *Describe the two types of anemometer (wind direction and speed indicating) systems.*
- *Identify the major components of anemometer systems.*
- *Describe the purpose and operation of the major components.*
- *Describe synchros and the procedures for zeroing different types of synchros.*
- *Describe the synchro signal amplifier and its principles of operation.*
- *Describe the procedures in performing preventive maintenance on anemometer systems.*
- *Describe the procedures to follow in troubleshooting and repairing the components in anemometer systems.*
- *Describe the crosswind and headwind computer* system

The anemometer (wind direction and speed indicator) system, circuits HD and HE, provides instantaneous and continuous indication of wind direction and speed relative to the ship's heading and speed. Wind direction and speed information is important for combat systems operations, flight operations, and maneuvering. Throughout this chapter we will use the term *wind direction and speed indicator systems* interchangably with the term *anemometer systems.*

WIND DIRECTION AND SPEED INDICATOR SYSTEMS

There are two types of wind indicating systems, type F and type B. The type F system provides both 115-volt, 60- and 400-Hz outputs. The type B system provides only 115-volt, 60-Hz outputs. Most ships have two systems installed; one for the port side of the ship and one for the starboard side of the ship.

MAJOR COMPONENTS

The major components of the system are the wind direction and speed detector, the wind direction and speed transmitter, and the wind direction and speed indicator. Throughout this chapter we will refer to these components as the detector, the transmitter, and the indicator. The synchro signal amplifier is also a component of these systems.

Detector

The detector (fig, 2-1) is a dual-purpose instrument employing two type 18CX4 synchros for transmitting the instantaneous undamped signals representing wind direction and speed to the transmitter and/or computers.

The detector should be mounted on a mast or yard-arm where it will receive unobstructed wind flow from all directions. Be careful not to submit the detector to wind currents and eddies from nearby objects. Avoid a location where flue gases or exhaust currents will strike the detector. Equipment cannot be installed in the area that will interfere with the detectors.

The direction synchro in the detector is mounted in a vertical support and is coupled to a plastic vane assembly. A speed synchro enclosed in synchro housing is mounted in the head of the vane and is geared to a screw-type rotor assembly that senses wind speed. The angular position of the vane and rotating speed of the rotor assembly are sent to their respective synchros in the transmitter. Electrical connections are made to the speed synchro through the collector ring assembly and brushes on the brush holder assembly.

Wind direction is determined by the position of the vane and is shown as degrees off the bow of the ship. The direction synchro is set to electrical zero when the vane points directly to the bow. As the wind positions

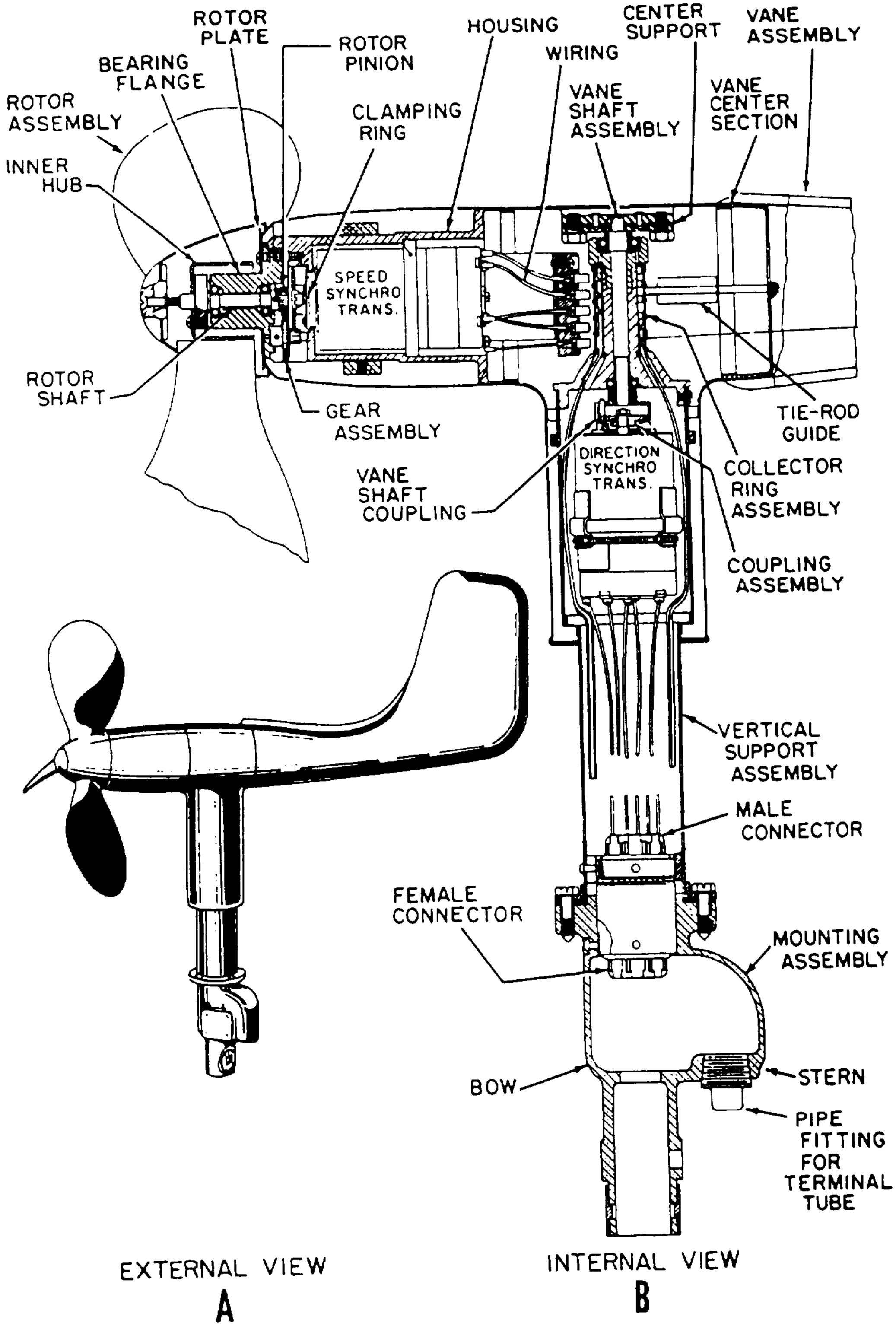


Figure 2-1.—Wind direction and speed detector.

the vane, the rotor on the synchro (directly coupled to the vane) moves angularly a like amount. The angular position of the type 18CX4 synchro is sent electrically to a 18CT4 synchro in the direction assembly of the transmitter and/or to computers.

Windspeed is determined by the speed of the rotor assembly. The rotor assembly is held directly into the wind by the vane assembly. Speed of rotation of the rotor assembly is proportional to the speed of the wind striking the blades.

Transmitter

The transmitter consists of two plug-in assemblies, a direction assembly and a speed assembly. The assemblies are housed in a common, dripproof case designed for bulkhead mounting.

The direction assembly is essentially a servo-amplifier circuit using a type 18CT4 synchro control transformer as a receiver for angular displacement signals representing the position of the vane. The purpose of the direction assembly is to receive a 400-Hz signal equivalent to a change in the position of the vane as sent by the detector and to send this change at a predetermined rate, in the form of 60-Hz and 400-Hz synchro signals, to the indicators and/or recorders.

The speed assembly consists of a servo-amplifier circuit and a roller disc-type integrator. The servo amp lifier uses a type 18CT4 synchro control transformer as a receiver for signals from the detector representing the rotating speed of the rotor assembly. The purpose of the speed assembly is to receive a signal equivalent to a change in rotational speed of the rotor assembly as sent by the detector, to amplify the signal, and to transmit this change at a linear rate, in the form of 60-Hz and 400-Hz synchro signals, to indicators and/or recorders.

The direction assembly and the speed assembly are basically a servo unit made up of a synchro control transformer, a followup motor, and a synchro transmitter.

The transmitter should be mounted in a location that is convenient for wiring and servicing. Consideration for protection from the elements is important, as the case is dripproof but not waterproof. Ensure the case is grounded

Indicator

The wind direction and speed indicator (fig. 2-2) is a dual unit consisting of a wind direction assembly and a windspeed assembly. The two assemblies are the same,

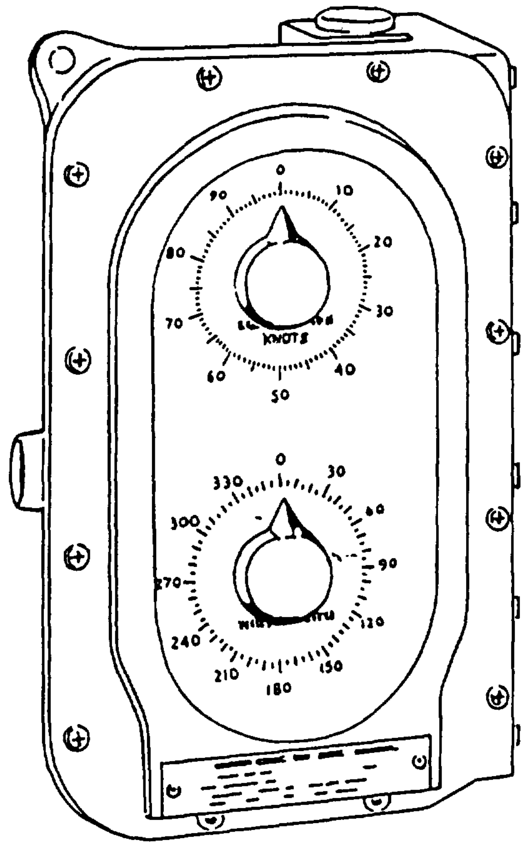


Figure 2-2.—Wind indicator.

with the exception of their graduated dials, and are housed in a watertight case, therefore eliminating consideration of the elements when determining location.

The design of the wind indicating equipment, type F, allows for the use of a type B indicator with the system if so desired. The mounting for both types of indicators are basically the same. The selected indicator should be mounted on a bulkhead or stationary surface, according to the applicable dimensions. The location selected will depend upon the intended use of the indicator and the convenience for wiring and servicing.

The assemblies mount on individual baseplates. The assemblies and baseplates are enclosed in a metal housing to form a complete wind direction and speed indicator unit.

The direction synchro receiver receives the angular displacements from the synchro transmitter in the direction assembly of the transmitter unit and indicates these displacements on the direction dial. The direction dial is graduated in 10° intervals from 0° to 360°.

The speed synchro receiver receives the angular displacements from the synchro transmitter in the speed assembly of the transmitter unit and indicates these displacements on the speed dial. The dial is graduated in 5-knot intervals from 0 to 100 knots, covering 360°. A revolving pointer directly attaches to the shaft.

The dials and pointers are illuminated by red lights. No lamps in parallel supplied from a 115/6-volt transformer inside the housing provide dial illumination for each assembly. A knob on the side of the case controls a rheostat for varying the intensity of the illumination.

If the dials are indicating inaccurately, and you decide to orient the speed and direction dials to a different position, it will be necessary to zero the synchros after the dials are repositioned. Zeroing synchros is discussed later in this chapter.

NOTE: The type B indicator does not have dials that can be repositioned. Consider this fact when mounting the component.

The synchros in the indicator, either a 18TRX6 or 18TRX4, electrically connect to the synchros in the transmitter. The synchros in the indicator assume the positions dictated by the transmitter synchros. The pointers fastened to the rotor shafts of the synchros indicate wind direction and windspeed on separate circular dials.

SYNCHROS

In performing the required PMS and maintenance on wind direction and indicating systems and on synchro signal amplifiers (discussed later in this chapter), you should have an understanding of synchros. The following paragraphs will discuss synchros and the zeroing of synchros.

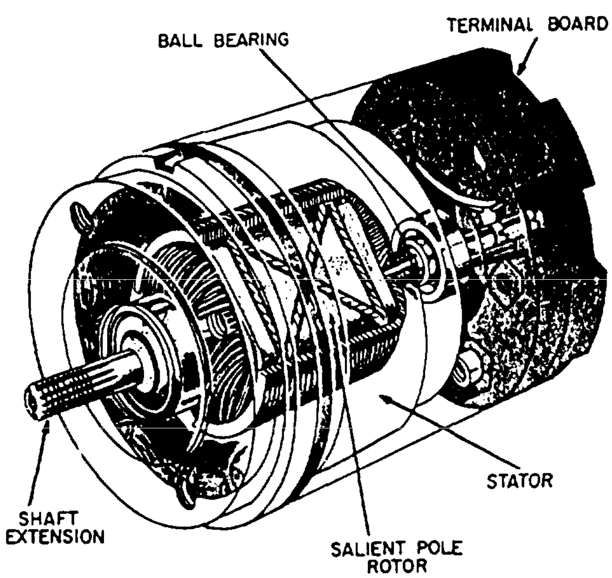


Figure 2-3.—Phantom view of a synchro.

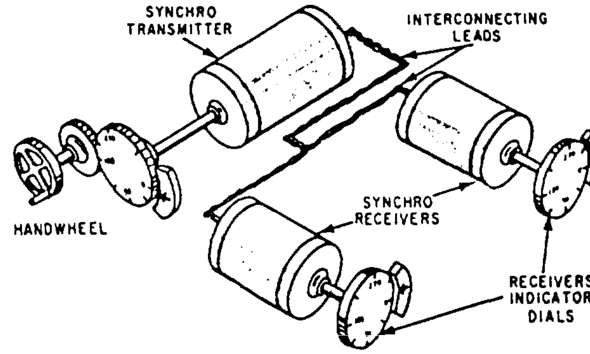


Figure 2-4.—A simple synchro system.

Synchros (fig. 2-3) are used primarily for the rapid and accurate transmission of information between equipment and stations. Synchros are seldom used singly. They work in teams, and when two or more synchros are interconnected to work together, they form a synchro system. Such a system may, depending on the types and arrangement of its components, be put to various uses. Figure 24 shows a simple synchro system that can be used to transmit different types of data.

STANDARD SYNCHRO CONNECTIONS

In systems in which a great many synchro units are used, it is necessary to have a closely defined set of standard connections to avoid confusion. The conventional connection is for counterclockwise rotation for an increasing reading.

The standard connections of a simple synchro transmission system consisting of a synchro transmitter and receiver is shown in figure 2-5. The R1 transmitter and receiver leads connect to one side of the 115-volt ac supply line. The R2 transmitter and receiver leads connect to the other side of the line. The stator leads of both the transmitter and receiver connect lead for lead; that is, S1 connects to S1, S2 to S2, and S3 to S3. Thus, when sending an increasing reading over the transmission system, the rotor of the synchro receiver will turn in a counterclockwise direction.

When it is desired, the shaft of the synchro receiver turns clockwise for an increasing reading. The R1 and R2 transmitter and receiver leads connect as before. The S1 transmitter lead connects to the S3 receiver lead, and the S2 transmitter lead to the S1 receiver lead.

ZEROING SYNCHROS

If synchros are to work together properly in a system, they must be correctly connected and aligned in respect to each other and to the other devices with which they are used. The reference point for alignment of all

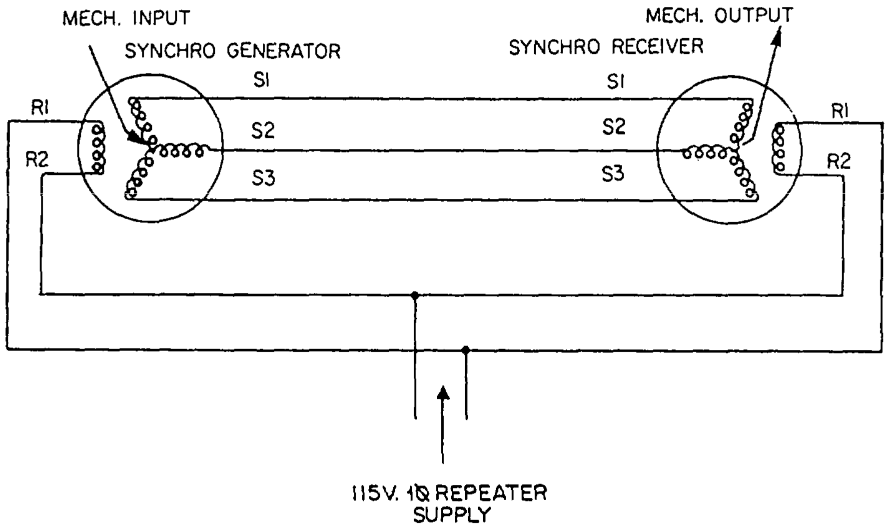


Figure 2-5.—Transmission system diagram; standard connections of a simple synchro.

synchro units is electrical zero. The mechanical reference point for the units connected to the synchros depends upon the particular application of the synchro system. Whatever the application, the electrical and mechanical reference points must be aligned with each other. The mechanical position is usually set first, and then the synchro device is aligned to electrical zero. Each type of synchro has a combination of rotor position and stator voltages that is its electrical zero.

There are various methods for zeroing synchros. Some of the more common zeroing methods are the voltmeter and the electrical lock methods. The method used depends upon the facilities and tools available and how the synchros are connected in the system. Also, the method for zeroing a unit whose rotor stator is not free to turn may differ from the procedure for zeroing a similar unit whose rotor or stator is free to turn.

Voltmeter Method

The most accurate method of zeroing a synchro is the ac voltmeter method. The procedure and the test-circuit configuration for this method vary somewhat, depending upon which type of synchro is being zeroed. Transmitters and receivers, differentials, and control transformers each require different test-circuit configurations.

For the ac voltmeter method to be as accurate as possible, an electronic or precision voltmeter having a 0- to 250-volt and a 0- to 5-volt range should be used. On the low scale, this meter can also measure voltages as low as 0.1 volt.

Regardless of the synchro to be zeroed, there are two major steps in each procedure. The first step is the coarse or approximate setting. The second step is the fine setting. The coarse setting ensures the device is zeroed on the 0° position rather than the 180° position. Many synchro units are marked in such a manner that the coarse setting may be approximated physically by aligning two marks on the synchro. On standard synchros, this setting is indicated by an arrow stamped on the frame and a line marked on the shaft, as shown in figure 2-6. The fine setting is where the synchro is precisely set on 0°.

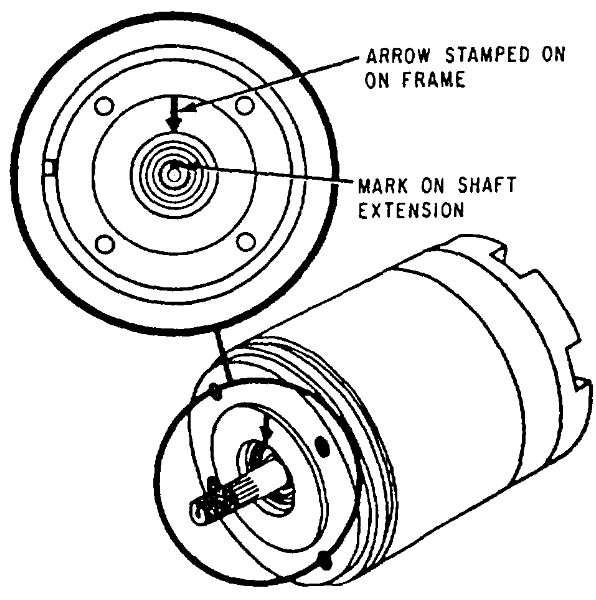


Figure 2-6.—Coarse eletrical zero markings.

ZEROING TRANSMITTERS AND RECEIVERS (VOLTMETER METHOD).– A synchro transmitter, CX or TX, is zeroed if electrical zero voltages exist when the device whose position the CX or TX transmits is set to its mechanical reference position. A synchro receiver, TR, is zeroed if, when electrical zero voltages exist, the device actuated by the receiver assumes its mechanical reference position. In a receiver or other unit having a rotatable stator, the zero position is the same, with the added provision that the unit to which the stator is geared is set to its reference position. In the electrical zero position, the axes of the rotor coil and the S2 coil are at zero displacement and the voltages measured between terminals S1 and S3 will be minimum. The voltages from S2 to S1 and from S2 to S3 are in phase with the excitation voltage from R1 to R2.

The following method may be used to zero transmitters and receivers:

1. Carefully set the unit whose position the synchro transmits to its zero or mechanical reference position.

2. De-energize the synchro circuit and disconnect the stator leads. Set the voltmeter to its 0- to 250-volt scale and connect it into the synchro circuit as shown in figure 2-7, view A.

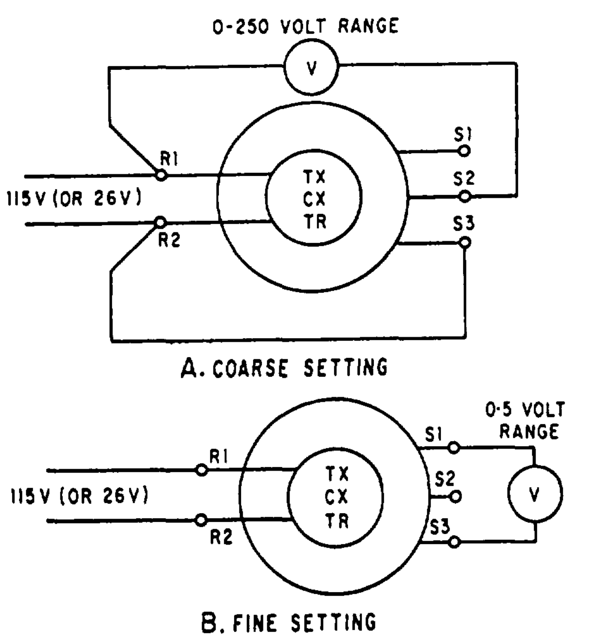


Figure 2-7.—Zeroing a transmitter or receiver by the voltmeter method.

NOTE: Many synchro systems energize by individual switches. Therefore, be sure the synchro power is off before working on the connections.

3. Energize the synchro circuit and turn the stator or rotor until the meter reads about 37 volts (15 volts for a 26-volt synchro). This is the coarse setting, and it places the synchro at about electrical zero.

4. De-energize the synchro circuit and connect the meter as shown in figure 2-7, view B, using the 0- to 5-volt scale.

5. Re-energize the synchro circuit and adjust the rotor or stator for a null (minimum voltage) reading. This is the fine electrical zero position of the synchro.

The common electrical zero position of a TX-TR synchro system can be checked with a jumper. Put the transmitter and receiver on zero and intermittently jumper S1 and S3 at the receiver. The receiver should not move. If it does, the transmitter is not on zero and should be checked again.

ZEROING DIFFERENTIAL SYNCHROS (VOLTMETER METHOD).– A differential is zeroed when it can be inserted into a system without introducing a change in the system. In the electrical zero position, the axes of coils R2 and S2 are at zero displacement. If a differential synchro requires zeroing, the following method may be used:

1. Carefully and accurately set the unit to be zeroed to its zero or mechanical reference position.

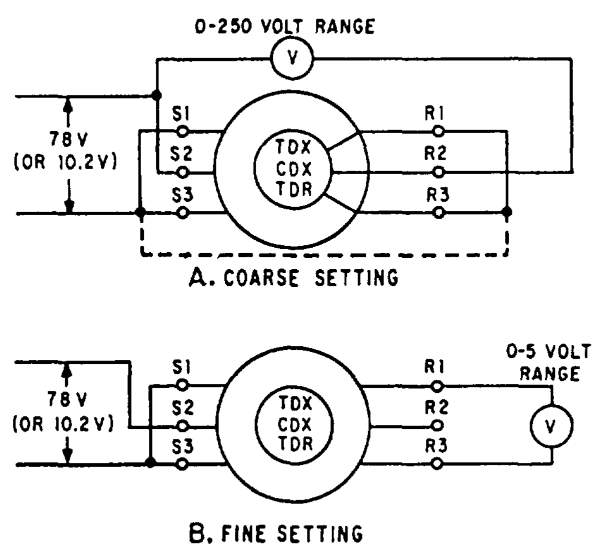


Figure 2-8.—Zeroing differential synchros by the voltmeter method.

2. De-energize the circuit and disconnect all other connections from the differential leads. Set the voltmeter on its 0- to 250-volt scale and connect as shown in figure 2-8, view A. If a 78-volt supply is not available, you may use 115 volts. If you use 115 volts instead of 78 volts, do not leave the unit connected for more than 2 minutes or it may overheat and may cause permanent damage.

3. Energize the circuit, unclamp the differential's stator, and turn it until the meter reads minimum. The differential is now approximately on electrical zero. De-energize the circuit and reconnect it as shown in figure 2-8, view B.

4. Re-energize the circuit. Start with a high scale on the meter and work down to the 0- to 5-volt scale to protect the meter movement. At the same time, turn the differential transmitter until a zero or null (minimum voltage) reading is obtained. Clamp the differential stator in this position, ensuring the voltage reading does not change, de-energize, and connect all leads for normal operation. This is the fine electrical zero position of the differential.

ZEROING A CONTROL TRANSFORMER (VOLTMETER METHOD).– Two conditions must exist for a control transformer (CT) to be on electrical zero. First, its rotor voltage must be minimum when electrical zero voltages are applied to its stator. Second, turning the shaft of the CT slightly counterclockwise produces a voltage across its rotor in phase with the rotor voltage of the CX or TX, supplying excitation to its stator. Electrical zero voltages, for the stator only, are the same as for transmitters and receivers.

To zero a CT by the voltmeter method, use the following procedure:

1. Set the mechanism that drives the CT rotor to zero or to its reference position. Also, set the transmitter that is connected to the CT to zero or its reference position.

2. Check to ensure there is zero volts between S1 and S3 and 78 volts between S2 and S3. If these voltages cannot be obtained, it will be necessary to rezero the transmitter.

NOTE: If 78 volts from the transmitter cannot be used and an autotransformer is not available, use a 115-volt source. The CT should not be energized for more than 2 minutes in this condition because it will overheat and may cause permanent damage.

3. De-energize the circuit and connect the circuit as shown in figure 2-9, view A. To obtain the 78 volts required to zero the CT, leave the S1 lead on, disconnect the S3 lead on the CT, and put the S2 lead (from CX) on S3. This is necessary since 78 volts exist only between S1 and S2 or S2 and S3 on a properly zeroed CX. Now energize the circuit and turn the stator of the CT to obtain a minimum reading on the 250-volt scale. This is the coarse or approximate zero setting of the CT.

4. De-energize the circuit, reconnect the S1, S2, and S3 leads back to their original positions, and then connect the circuit as shown in figure 2-9, view B.

5. Re-energize the circuit. Start with a high scale on the meter and work down to the 0-to 5-volt scale to protect the meter movement. At the same time, turn the stator of the CT to obtain a zero or minimum reading on the meter. Clamp down the CT stator, ensuring the reading does not change. This is the fine electrical zero position of the CT.

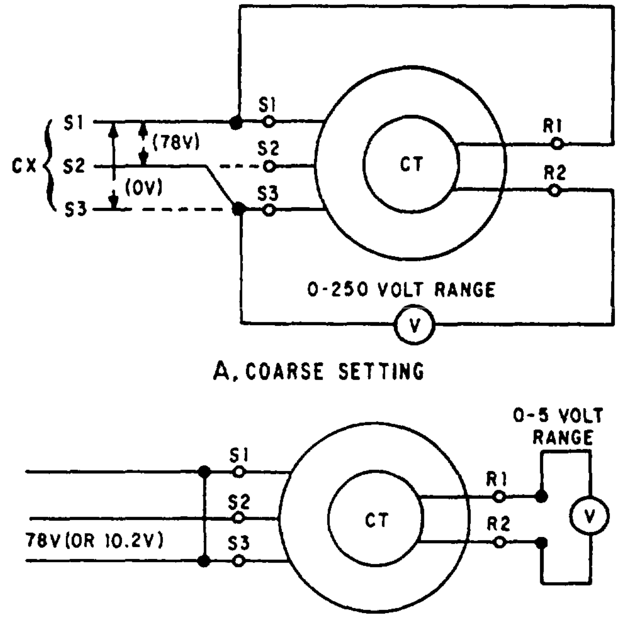


Figure 2-9.—Zeroing a control transformer by the voltmeter method.

Zeroing Multispeed Synchro Systems

If multispeed synchro systems are used to accurately transmit data, then the synchros within the systems must be zeroed together. This is necessary because these synchros require a common electrical zero to function properly in a system.

First, establish the zero or reference position for the unit whose position the system transmits. Then, zero the most significant synchro in the system and work down to the least significant. For example, zero the coarse synchro, then the medium synchro, and finally the fine synchro. When zeroing these synchros, consider each synchro as an individual unit and zero accordingly.

There are a few 3-speed synchro systems. These systems require zeroing in an identical reamer as the dual-speed systems. First, zero the most significant synchro in the system and then work down to the least significant.

Remember that all synchros in a system must have a common electrical zero position.

Electrical Lock Method

The electrical lock method (although not as accurate as the voltmeter method) is perhaps the fastest method of zeroing synchros. However, this method can be used only if the rotors of the units to be zeroed are free to turn and the lead connections are accessible. For this reason, this method is usually used on the TR because, unlike transmitters, the TR shaft is free to turn.

To zero a synchro by the electrical lock method, de-energize the unit, connect the leads, as shown in figure 2-10, and apply power. The synchro rotor will then quickly snap to the electrical zero position and lock. As stated before, you may use 115 volts as the power supply instead of 78 volts if the unit does not remain connected for more than 2 minutes.

SYNCHRO MAINTENANCE AND TROUBLESHOOTING

Synchro units require careful handling at all times. NEVER force a synchro unit into place, NEVER drill holes into its frame, NEVER use pliers on the threaded shaft, and NEVER use force to mount a gear or dial on the shaft.

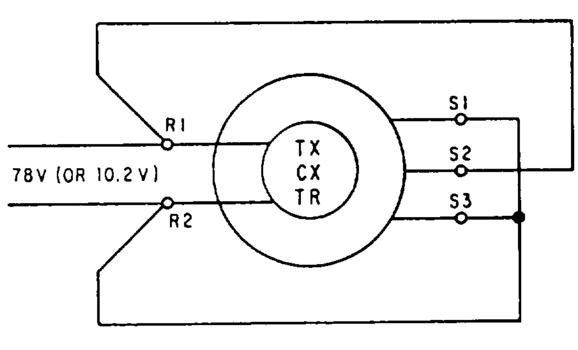


Figure 2-10.—Zeroing a synchro by the electrical lock method.

In maintaining synchros, there are two basic rules to apply:

1. IF IT WORKS, LEAVE IT ALONE.
2. IF IT GOES BAD, REPLACE IT.

Shipboard synchro troubleshooting is limited to determining whether the trouble is in the synchro or in the system connections. You can make repairs to the system connections, but if something is wrong with the unit, replace it.

SYNCHRO SIGNAL AMPLIFIER

The reason for using synchro signal amplifiers is to reduce the size of synchro transmitters. These smaller synchro transmitters are used in wind indicators and other sensing devices that are more accurate if there is only a small load on their outputs.

You should already know the operating principle of the synchro signal amplifier. The input to the amplifier is from a small synchro transmitter or two small transmitters that give a coarse and a fine signal. The input signal controls a small servomotor. This servomotor drives one or more large synchros into a position corresponding to the position of the input synchro. The output from the large synchros is then used as needed to drive several synchro receivers.

Synchro signal amplifiers must meet some or all of the following operational requirements:

- Accept a low-current synchro signal, amplify the signal, and use the amplifier signal to drive large-capacity synchro transmitters.
- Isolate oscillations in a synchro load that may be reflected from the input signal bus.
- Permit operation of a 60- or 400-Hz synchro load from either a 60-or 400-Hz synchro bus.
- Provide multiple charnel output transmission of a single-channel input signal.
- Permit operation of a synchro load independent of the input synchro excitation.

A block diagram of a synchro signal amplifier is shown in figure 2-11.

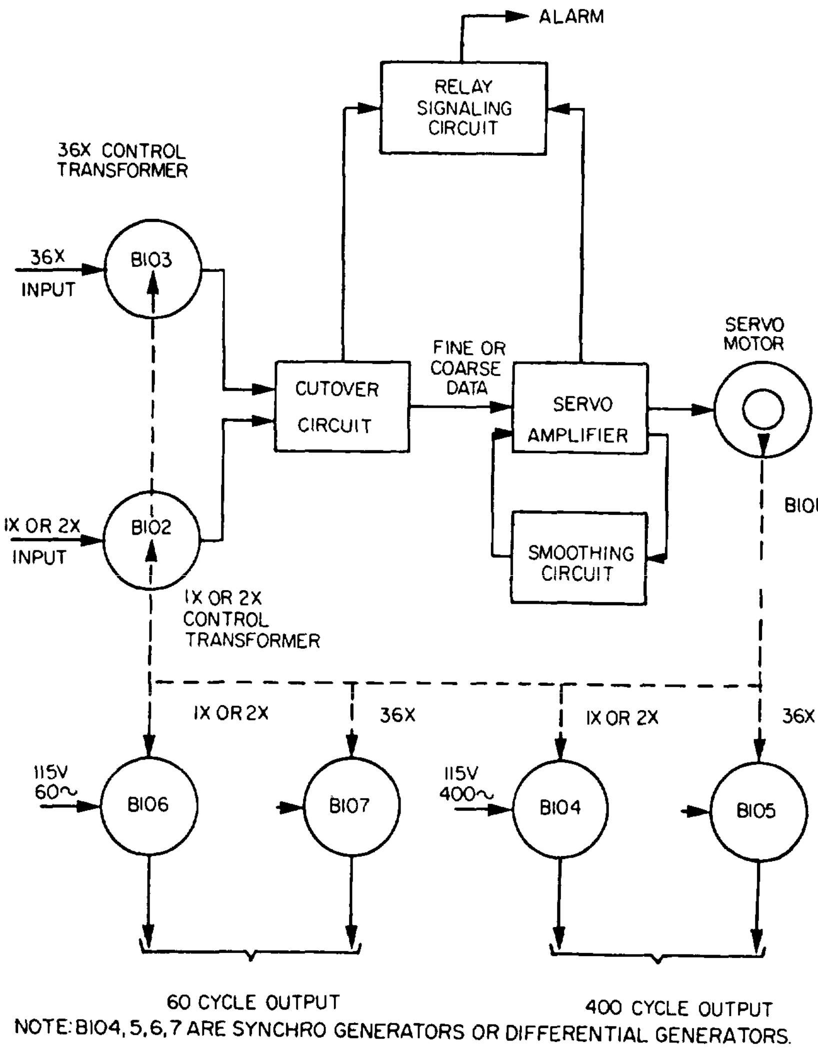


Figure 2-11.—Block diagram of a synchro signal amplifier.

GENERAL DESCRIPTION

E- and F-type synchro signal amplifiers will be discussed in this section of the chapter. The major difference between the two types is that the type E operates with 60-Hz supply and input. The type F operates with 400-Hz supply and input signals. The different supply and input frequencies require that the E- and F-type units use different synchro control transformers, servomotors, synchro capacitors, and amplifiers. Both types have provisions for four output synchros: two for 60-Hz and two for 400-Hz transmission. Both types of synchro signal amplifiers are designed to provide for input and output transmission at any of the following combinations of speeds:

- 1 and 36 speed
- 1 speed
- 36 speed
- 2 speed
- 2 and 36 speed

The E- and F-type synchro signal amplifiers consist of subassemblies housed in a dripproof case. These cases are the same on both types of synchro signal amplifiers. The internal subassemblies are similar in design. The only differences are the ones previously covered.

The subassembly is easily accessible through a front access door in the case that can be opened by loosening screws in the door. The door has hinges and supporting chains so it can be lowered and used as a service platform for the internal subassembly. An alarm switch, a dial window, four indicator lights, and a double fuse holder are mounted on the front access door. A schematic diagram of the subassembly is provided on the inside of the front access door.

Terminal boards on the inside bottom of the case serve as a common junction for connecting the ship's wiring. Access plates on both sides of the synchro signal amplifier provides for external cabling. Stuffing tubes are mounted to these plates as required at installation, and the external cabling is run through the stuffing tubes.

Speed changes from 1 speed to 2 speed and vice versa are made by installing change gears. These gears are not normally furnished with the synchro signal amplifier. Both the E- and F-type units have a dial with two scales, one on each side. One scale is calibrated every degree from 0° to 360° and is driven at 1 speed, when 1 speed is used. The other scale is calibrated 60° either side of zero (300° to 0° and 0° to 60°), and this scale is used when a 2-speed transmission is needed. The dial turns over when changing from 1 speed to 2 speed or vice versa.

When either unit is operating from a low 1- or 2-speed input, you must make some minor wiring changes. Connections between the terminals on the plug-in damping unit should be changed from those shown for 1 and 2 speed and 36 sped to those shown for 1 or 2 speed. This connects the normally disconnected low-speed synchro control transformer. These connections also remove the antistickoff voltage, which will be discussed later in this chapter.

PRINCIPLES OF OPERATION

The synchro signal amplifier is actually a synchro data repeater. It accepts synchro data from remote transmitters, aligns associated output synchros to electrical correspondence with the remote transmitters, and retransmits the data to other equipment. Synchro transmission is increased by using larger output synchros than the remote transmitter.

Since the output synchros are driven to electrical correspondence with the remote transmitters by gearing, a power supply of a different frequency may be used for the output synchros. This gives the synchro signal amplifier another attribute, as a frequency converter.

A higher accuracy is obtained from a synchro signal amplifier with a 36-speed input than would be obtained from a l-speed input. By virtue of the 36 speed revolving 36 times the angular distance that the 1 speed would revolve in response to the same reading, a vernier effect is achieved so that a higher accuracy is obtained

Synchro Operation

The synchro transmitter resembles a small bipolar 3-phase motor. The stator is wound with a three-circuit Y-connected winding. The rotor is wound with a single-circuit winding. Electrically, the synchro acts as a transformer; all voltages and currents are single phase. By transformer action, voltages are induced in the three elements of the stator winding, the magnitude depending upon the angular position of the rotor.

The synchro receiver is constructed essentially the same, both mechanically and electrically, except it is provided with a mechanism for dampening oscillations.

Consider the simplest synchro transmission system, where the transmitter and receiver units are connected as shown on figure 2-5. If the receiver rotor were free to turn, it would take a position where induced stator voltages would be equal to the transmitter voltages. Under such a condition there is no current flow. However, if the transmitter rotor was displaced by any angle, the stator voltage balance would be altered and current would flow in the stator windings. This current flow would set up a two-pole torque, turning the receiver rotor to a position where the induced stator voltages would again be equal. Therefore, any motion given to the rotor of one unit would be transmitted to the rotor of the other unit where it is duplicated thereby setting up a system of electrically transmitted mechanical motion.

The synchro signal amplifier transmission system depends upon the type of transmitter described in the previous paragraphs, but its receiver is a synchro control transformer. The purpose of the synchro control transformer is to supply, from its rotor terminals, an ac voltage whose magnitude and phase polarity depend upon the position of the rotor and voltages applied to its stator windings. Since its rotor winding is not connected to the ac supply, it does not induce voltage in the stator coils. As a result, the stator current is determined by the high impedance at the windings and it is not affected appreciably by the rotor's position. Also, there is no detectable current in the rotor and, therefore, no torque striving to turn the rotor. The synchro control transformer rotors cannot on their own accord turn to a position where the induced currents are once again of balanced magnitude. The synchro amplifier cycle of operation must take place to turn the rotor of the synchro control transformer.

A synchro amplifier cycle of operation takes place as follows:

1. A change occurs in the remotely transmitted synchro data.

2. The signal received by the synchro control transformers in the mechanical unit is, as an error voltage, amplified and used to operate the servomotor. The servomotor, through gearing, turns the synchro control transformer rotors until the error voltages are zero (or, in the low-speed unit, matched to the stickoff voltage), thereby stopping the turning or follow-up action.

3. Simultaneous with step 2, the servomotor also drives the rotors of the output synchros into alignment with the new input signal.

Synchro Connections of a Synchro Amplifier

The conventional connection is for counterclockwise rotation for increasing reading-an increasing reading is when the numbers associated with the action being measured are increasing. The five wires of a synchro system are numbered in such a way that the shaft of a normal synchro will turn counterclockwise. When an increasing reading is sent over the wires provided, the synchro is connected as follows:

R1 to terminal block terminal B

R2 to terminal block terminal BB

S1 to terminal block terminal B1

S2 to terminal block terminal B2

S3 to terminal block terminal B3

When the shaft of the synchro is to be driven clockwise for an increasing reading, the connections to the terminal bus should be as follows:

R1 to terminal block terminal B

R2 to terminal block terminal BB

S3 to terminal block terminal B1

S2 to terminal block terminal B2

S1 to terminal block terminal B3

For a synchro control transformer, these con- nections will apply to the stator, but the rotor connections go to the input of the servo amplifier.

Cutover Circuit

The purpose of the cutover circuit is to automatically select the error voltage from either the high (36 speed) or low (1 or 2 speed) synchro control transformer and feed it to the servo-amplifier input terminals. The low-speed control transformer is connected when the error is large (more than 2 1/20), and the high-speed control transformer is connected when the error is small (less than 2 1/20).

The cutover circuit (fig. 2-12) consists of six diodes (CR12A through CR17) and three resistors (R12, R13, and R14). The circuit operates on the principle that

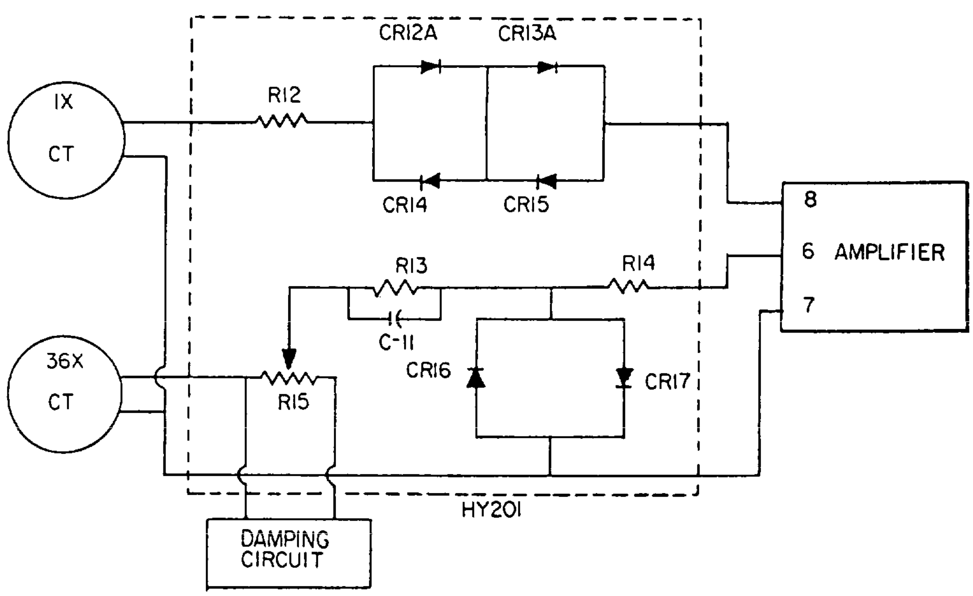


Figure 2-12.—Cutover circuit.

diodes, connected back to back, act as nonlinear resistances. When a high voltage appears across the diodes, it appears as a low resistance or a short circuit. When a low voltage appears across the diodes, it appears as a high resistance or an open circuit.

When control transformer error voltages are small, diodes CR12A, 13A, 14, and 15 act as a high resistance and block the low speed (1X) signal from the servo amplifier. Diodes CR 16 and 17 act as a high resistance and allow the lightspeed (36X) signal to pass to the servo amplifier.

When the error voltages are high, diodes CR12A, 13A, 14, and 15 act as a low resistance and pass the low-speed signal to the servo amplifier. Diodes CR16 and 17 act as a low resistance and short the high-speed signal before it reaches the servo amplifier. Resistors R12, 13, and 14 are current-limiting resistors.

Antistickoff

The low-speed control transformer output winding connects in series with a 2.7-volt winding of the power transformer. This small, constant voltage (called the antistickoff voltage) is added to the output voltage of the low-speed control transformer. It, in effect, shifts the angular position of the control transformer null, or position of zero output. The antistickoff voltage is either in phase or 180° out of phase with the low-speed control transformer output.

If the high- and low-speed control transformers were set to electrical zero at the same position, there would be a point at 0° and 180° where the error voltage would equal zero. Within 2 1/2° of the 180° point, the 36-speed error signal would drive the servomotor to synchronize the control transformers at the 180° point. The control transformers would also synchronize at the 180° point if the synchro signal amplifier were energized when the control transformers were within 2 1/2° of the 180° point.

To remove the chance of synchronization of the control transformers at the 180° point, the low-speed control transformer is rotated 2 1/2° from correspondence with the high-speed control transformer null, or zero, position. An antistickoff voltage of constant magnitude and phase is added to the single-speed control transformer output. The resultant voltage is now zero at the 185° point instead of the 180° point. At either side of the 185° point, both the 36-speed and single-speed voltage tend to drive the synchro transmitters toward true zero.

Servo Amplifier

The servo amplifier is a 10-watt plug-in amplifier with a push-pull output stage that feeds the semomotor control winding. The servo amplifier drives the servomotor, which, in turn, repositions the control transformer rotors to null the error voltage to the servo amplifier. The amplifier has an internal power supply operating from 115 volts ac. It provides 12 volts dc and unfiltered 40 volts dc for the amplifier stages. In addition, the power supply power transformer supplies reference voltage for the servomotor and antistickoff voltage.

The amplifiers for 60- and 400-Hz units are similar except for the power transformers and capacitors.

Gear train oscillation, or hunting, is caused by overshoot as the servo reaches its null. To prevent this, clamping circuits introduce a stabilizing voltage at the amplifier input. This stabilizing voltage is proportional to acceleration or deceleration of the unit.

Alarm Circuit

The alarm circuits in the synchro signal amplifier monitor the 60- and 400-Hz output excitation, servo excitation, and follow-up error. With all power sources present and a follow-up error of less than 2 1/2°, the four indicator lights on the access door will light. If one of these conditions fails, the appropriate light will go out, indicating the problem area, and an alarm will sound.

With the equipment normally energized and the alarm switch in the ON position, the alarm circuit will be open. A loss of any of the three power sources, a follow-up error of more than 2 1/2°, or putting the alarm switch in the OFF position will close the alarm circuit, causing an alarm to sound.

Gear Train

The gear train consists of a series of tine pitch, precision, spur gears. They link together the rotors of the two control transformers, four output synchros, and the servomotor.

MAINTENANCE OF SYNCHRO SIGNAL AMPLIFIERS

The synchro signal amplifier should require little attention in service, there being few parts inside the amplifier unit or the synchros that need lubrication or replacement under normal operating conditions.

The alarm circuit takes the place of many routine checks, since failure of the synchro signal amplifier output to follow the input or loss of input excitation automatically completes the alarm circuit. The only routine checks that are required are a monthly check of the alarm circuit and yearly inspection of the gearing.

When inspecting the gearing, if dirt is found, clean the gears. If a gear shows excessive wear, replace it. Turn the gears manually, with the equipment de-energized, noting whether the gears mesh smoothly.

Under normal conditions, the synchro signal amplifier will require no lubrication. All rotary devices, such as synchros, gear teeth, ball bearings, and so on, are factory lubricated for the life of the equipment.

TROUBLESHOOTING ANEMOMETER SYSTEMS

Troubleshooting wind direction and indicating systems is simple once you have identified that you have a problem. Many potential problems can be avoided by careful preventive maintenance. If the trouble is not avoided, you can at least identify it by following the Planned Maintenance System (PMS) procedures. The principles of operation of the various components of the systems were included in this chapter to aid you in troubleshooting.

When troubleshooting the systems, you should refer to the troubleshooting tables given in chapter 4 of the technical manual *Operation and Maintenance Instruction - Wind Indicating Equipment, Type F,* NAVSHIPS 0965-108-9010. These troubleshooting tables can be very useful in that they enable personnel to locate malfunctions and take the necessary corrective action. They are also a quick reference guide.

MAINTENANCE OF ANEMOMETER SYSTEMS

Preventive maintenance for the system consists of periodic inspections, cleaning, and lubrication. You should refer to the appropriate technical manual for specific procedures to follow. Many potential troubles in the system can be avoided by careful preventive maintenance.

DETECTOR

Most ships have a detector mounted port and starboard on the mast. By switching from one to the other while watching the indicator and comparing the readings, you can determine if there is a problem with a detector. Every 90 days and after exposure to high winds, inspect the detector mounting and tighten the mounting bolts if necessary. The rotor and vane also should be inspected every 90 days. Turn the rotor by hand to confirm that it turns freely. Rotate the vane through 360° in both directions to assure it rotates freely. If friction or binding of the vane is suspected, perform the friction test. Every 6 months, the detector should be inspected, lubricated, and, if conditions warrant, cleaned. Refer to the technical manual for specific procedures.

TRANSMITTER

Every 6 months, the transmitter should be inspected, lubricated, and, if warranted, cleaned. When inspecting the transmitter, you should inspect the following:

- All moving parts for freeness.
- Gears for excessive wear and broken teeth.
- Bearings, gears, and other moving parts for gummed oil, dust, and so on.
- Sensitive switches; turn them over and replace if worn.
- Driving discs for wear.

INDICATOR

Watch the indicator periodically for uneven movement of the pointer as this indicates a possible problem. By comparing the pointer movement of one indicator with another, you can determine if the trouble is in a single indcator or in the system. Erratic indications, resulting from excessive friction, often can be avoided by cleaning and oiling of the units. Other causes of excessive friction may be discovered during periodic maintenance inspection. When beginning a periodic inspection, observe the indicators when there is enough wind to act on the vane and rotor. The indicator requires no lubrication.

CROSSWIND AND HEADWIND COMPUTER

An elaborate development of a transmission system is the crosswind and headwind computer system, designed for use aboard CVAs. Although this system is not at present intended for use aboard other vessels, its design should be interesting to you as an application of synchro and servomechanism basics.

The crosswind and headwind computer receives relative wind direction and speed information from a wind direction and speed indicator system, as shown in figure 2-13. The output from the computer is in the form of variable voltages. These voltages represent the factors of windspeed from dead ahead, across the beam, and parallel to and across the angled deck of the carrier. These voltages are applied to indicators that provide direct reading of crosswind and headwind speeds in knots. The crosswind and headwind computer assembly is shown in figure 2-14, and a functional diagram of the computer assembly is shown in figure 2-13. In figure 2-13, the heavy lines represent signal flow and the dashed lines represent mechanical linkages that make the system self-synchronous.

WINDSPEED CIRCUIT

The windspeed circuit takes the synchro signal from the windspeed transmitter and converts it to a corresponding voltage that is proportional to the speed of the wind. This windspeed voltage is then applied to the wind direction circuit where the crosswind and headwind components are developed.

The windspeed synchro signal input is applied to the stator of the control transformer in the windsped circuit. The output of the control transformer is an error voltage representing the difference between the electrical angle of the synchro signal and the mechanical angle of the stator in the control transformer. This error voltage feeds to the servo amplifier through a transformer, not shown in the functional diagram. The purpose of the transformer is to compensate for the phase shift caused by the inductance of the windings of the control transformer rotor. The signal fed to the amplifier is either 0° or 180° from correspondence with the line voltage. The amplifier is a push-pull type, and applies an output voltage to the second coil of the servomotor, thereby controlling the direction and speed of the motor.

The servomotor drives a gear train that positions the rotor of the control transformer, driving it until it corresponds with the input signal. The gear train also positions the arm of the precision potentiometer that regulates the dc power supply input. The position of the arm of the potentiometer determines the amount of voltage applied to the sine-cosine potentiometer in the wind direction circuit. This voltage is proportional to the

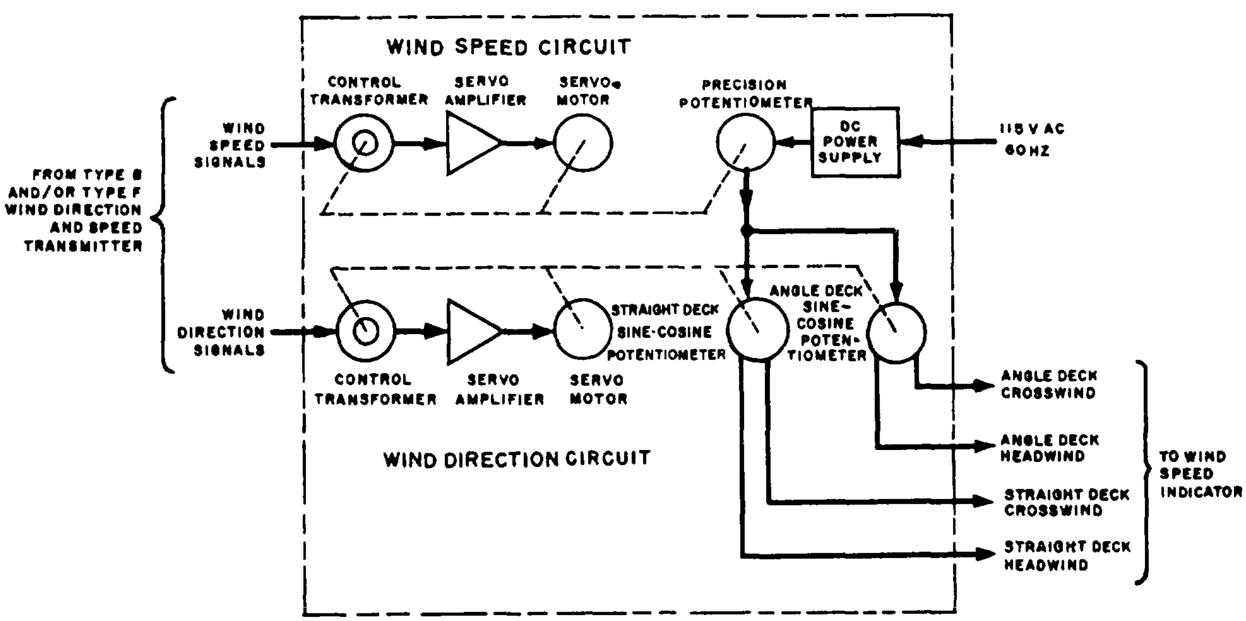


Figure 2-13.—Computer system, functional diagram.

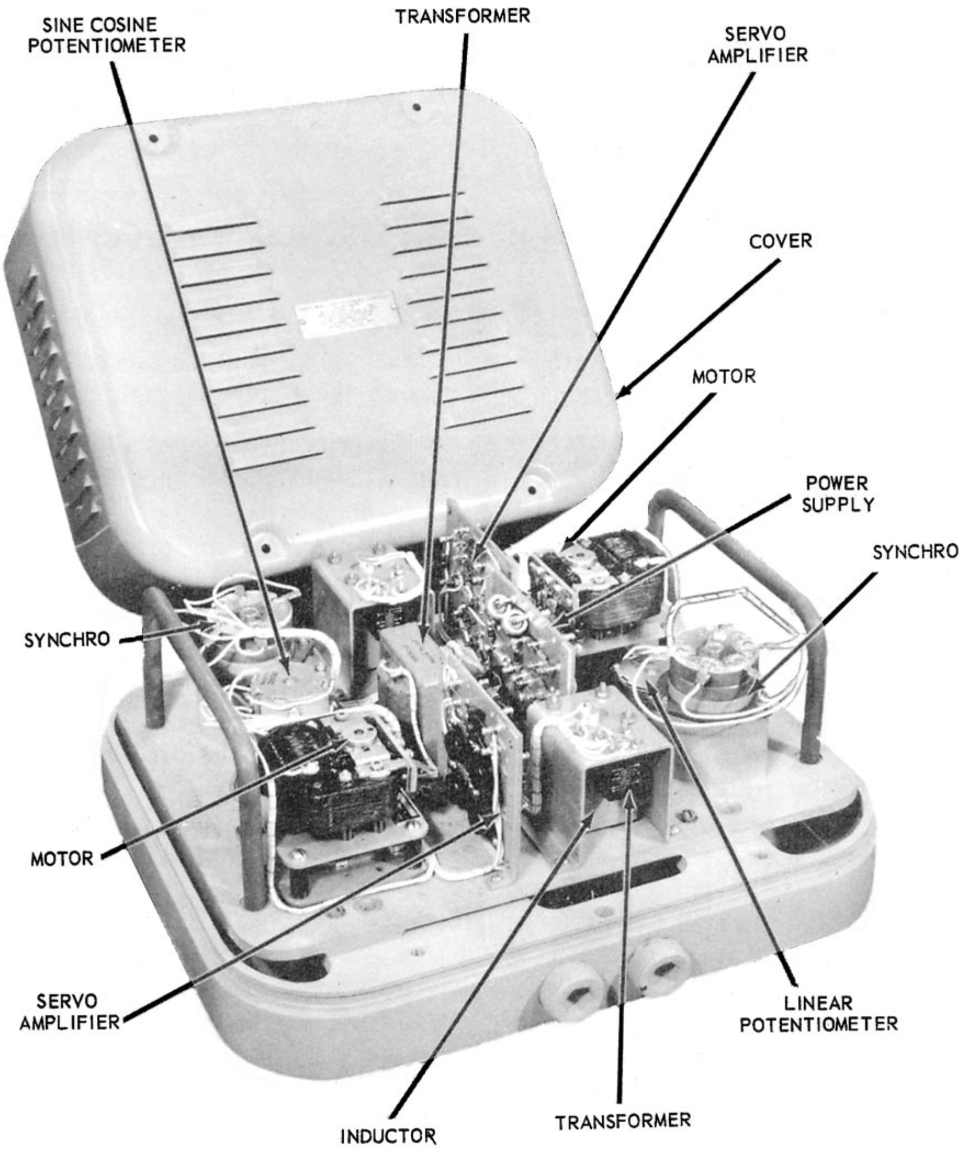


Figure 2-14.–Cross and headwind computer assembly.

speed of the wind. The function of components is the same as in the synchro amplifier just described, except that this mechanism positions a potentiometer instead of a synchro transmitter.

WIND DIRECTION CIRCUIT

The wind direction circuit converts the synchro signal output of the wind direction transmitter into volt-ages proportional to the desired crosswind and head-wind components of windspeed. This is done with a mechanism similar to the one used in the windspeed circuit, which positions a sine-cosine potentiometer, to which the windspeed voltage from the other circuit is applied.

The sine-cosine potentiometer contains four stacked sections, one for each of the desired components of windspeed. The signals from the angled deck sections lag the signals from the straight deck sections by 10°

The dc power supply is a highly regulated unit that converts 115-volt, 60-Hz power to a 40-volt dc output.

INDICATOR

The crosswind component signals are applied to the crosswind indicator of the indicator assembly (shown in fig. 2-15). The headwind component signal is applied to the other indicator in the assembly. The indicators have microammeter movements. The headwind indicator is calibrated for 50 microampere full-scale deflection, which corresponds to 60 knots. The dial reads from 0 to 60 knots in 1-knot increments. The crosswind indicator is calibrated for ±25 microampere for full-scale deflection left and right. The crosswind scale reads from 30 knots port to 30 knots starboard in 1-knot increments. The rheostat on the assembly connects in series with the secondary of the line transformer and the illuminating lamps, and is used to control their intensity.

MAINTENANCE AND TROUBLESHOOTING

The maintenance of this unit is outlined in the appropriate PMS documents. The technical manual for the equipment contains an adequate troubleshooting chart. Therefore, there should be no difficulty in keeping the unit running. You should be sure that personnel trying to repair the amplifier units are familiar with the proper techniques for working with transistors and that they follow the instructions in the proper technical manual. The manufacturer has specified the use of certain meters for analyzing the condition of the components of the unit, and, where possible, these should be used.

SYNCHRO SIGNAL CONVERTER AND SYNCHRO SIGNAL ISOLATION AMPLIFIER

Another of the recent developments in the use of synchro signals is in the synchro signal converter and synchro signal isolation amplifier shown in figure 2-16.

The problem of retransmitting accurate wind information devoid of error and unwanted feedback to the transmitter has existed for some time. The additional problem of conversion of a 60-Hz signal for use in computers is also not new. The synchro signal isolation amplifier receives its signal from the wind system and prepares it for the converter, allowing the exact signal to be converted to 400 Hz.

ISOLATION AMPLIFIER

The amplifier contains two chassis that are the same, one for direction and one for speed. The principles of

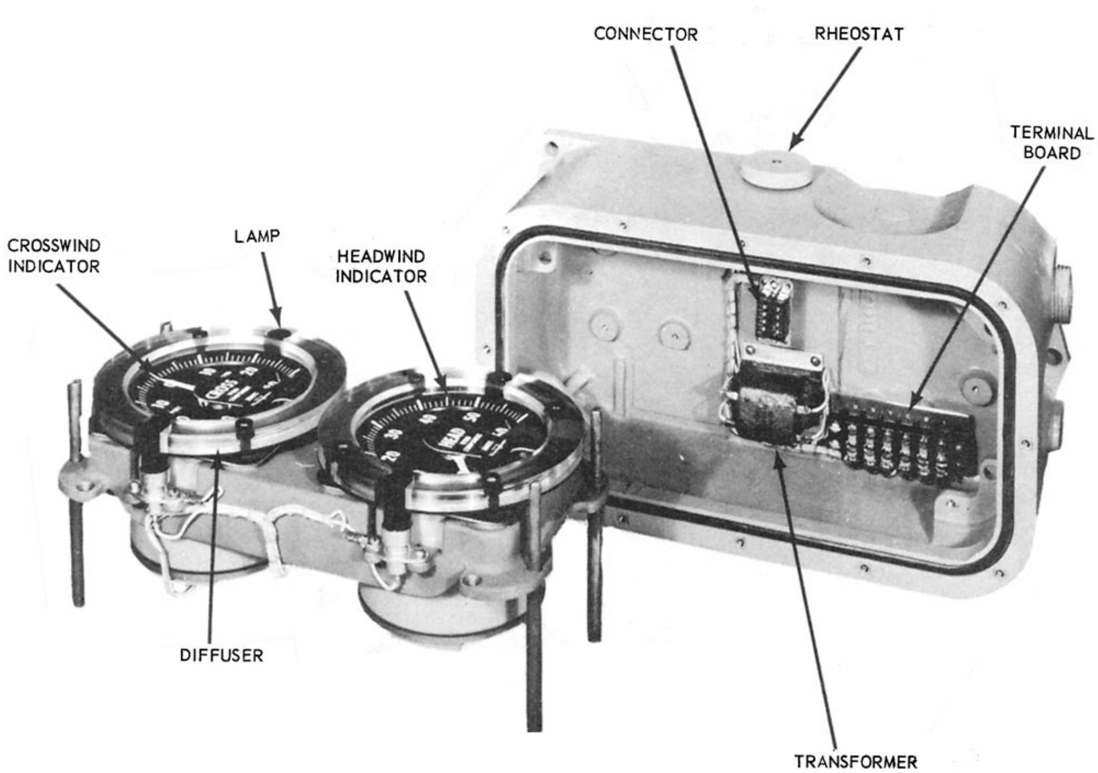


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Figure 2-15.–Indicator assembly.

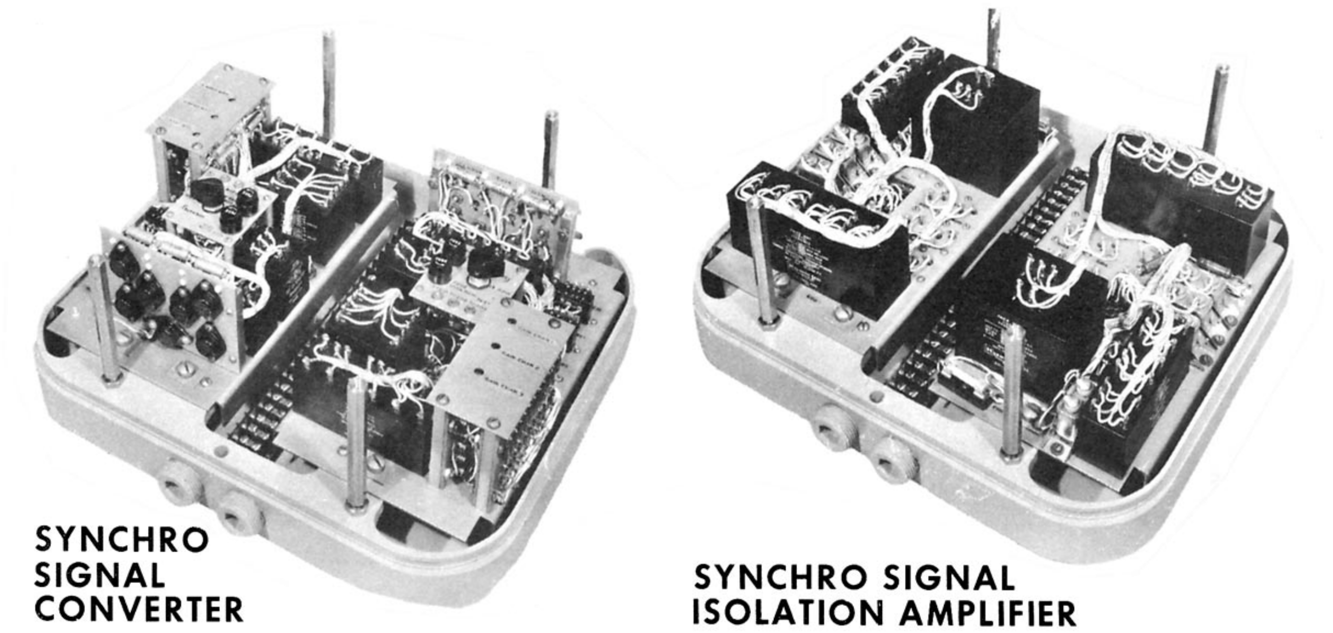

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Figure 2-16.—Synchro signal converter and synchro signal isolation amplifier.

one apply to the other. Each chassis consists of three channels that are the same in circuitry and operation; thus, the principles of operation of only one channel will be explained. (See fig. 2-17.)

The sine-wave output from the stator winding of an external synchro is applied to the primary winding of the input transformer. The signal is stepped down and fed into a transistor amplifier operating in the class B push-pull configuration.

The input impedance of the amplifier is high, and the output impedance is low. This condition prevents any torque feedback from the output synchro (due to

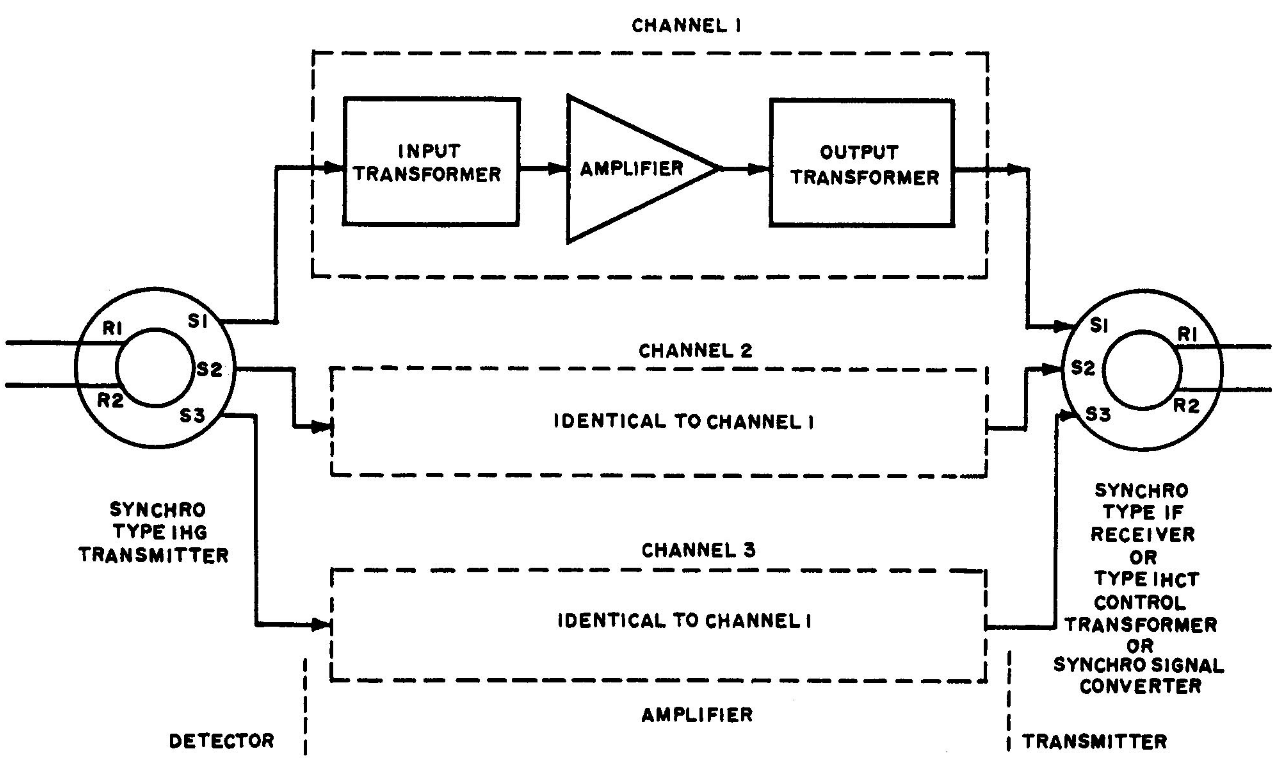


Figure 2-17—-Simplified amplifier block diagram (direction or speed).

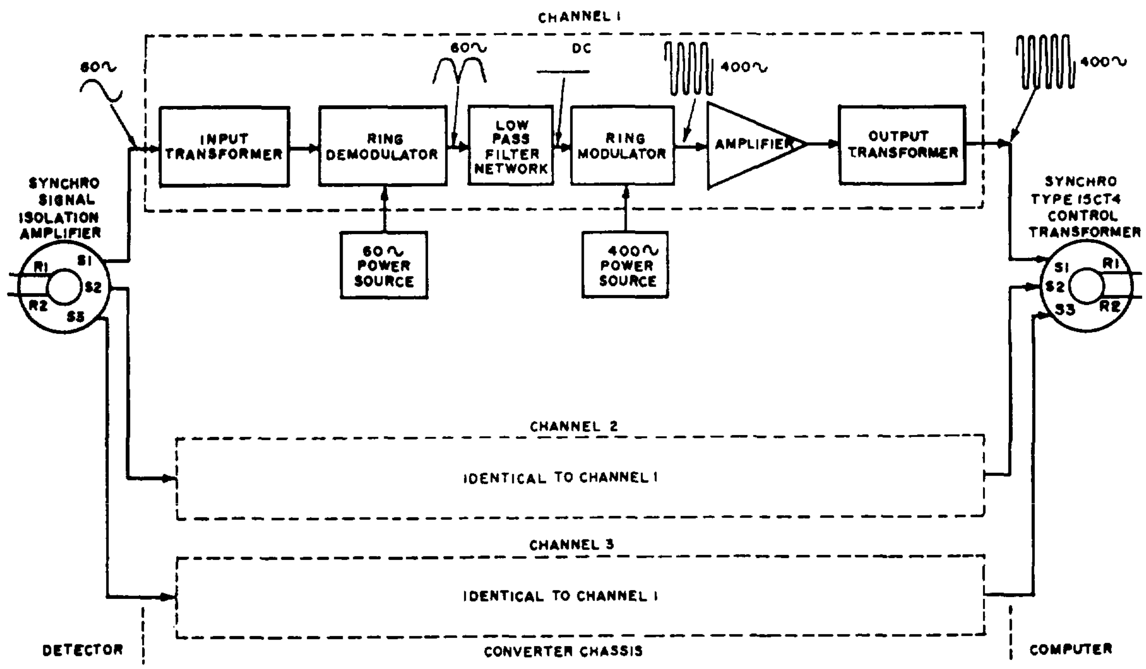


Figure 2-18.—Simplified converter block diagram (direction or speed).

phase differences between the input and output synchros) from being reflected into the converter. The amplified signal is transformed into sufficient amplitude and is applied with the outputs of the two other channels.

CONVERTER

The converter also contains two chassis that are the same, one for direction and one for speed. The principles of operation of one apply to the other. Each chassis consists of three channels that are alike in circuitry and operation; thus, the principle of operation of only one channel is discussed. (See fig. 2-18.)

The sine-wave output from one stator winding of an external synchro or the synchro isolation amplifier is applied to the primary winding of the input transformer of the converter. The stepped down signal is sent to the ring-demodulator stage. The ring-demodulator stage is excited by the voltage from a 60-Hz excitation transformer. The sine wave from the synchro is either in phase or 180° out of phase with the excitation voltage. If the sine wave is in phase, the demodulated signal is a positive, pulsating dc voltage. If the sine wave is out of phase, the demodulated signal is a negative, pulsating dc voltage. The pulsating dc voltage enters a low-pass filter network. The output of the filter network is pure direct current at a level dependent upon the amplitude of the signal voltage from the synchro stator.

The dc signal is then fed into a ring-modulator stage that is excited by the voltage from a 400-Hz excitation transformer. The output of the ring modulator is a 400-Hz sine wave with an amplitude proportional to the magnitude of the dc signal. Two power transistors operating in the class B push-pull amplifies the 400-Hz signal.

The amplified 400-Hz signal is sent through an output transformer that steps up the amplitude to 90 volts, the required level for excitation of a type 15CT4 synchro control transformer.

MAINTENANCE

Once initially set up for proper operation, the synchro signal converter and isolation amplifier unit requires a minimum of maintenance. As with all transistorized units, heat can be a problem, and careful selection of location is necessary.

Preventive maintenance should be limited to cleaning all units periodically.

Corrective maintenance requires the use of specific metering, outlined in the manufacturer's technical manual

CHAPTER 3

STABILIZED GLIDE SLOPE INDICATOR SYSTEM

CHAPTER LEARNING OBJECTIVES

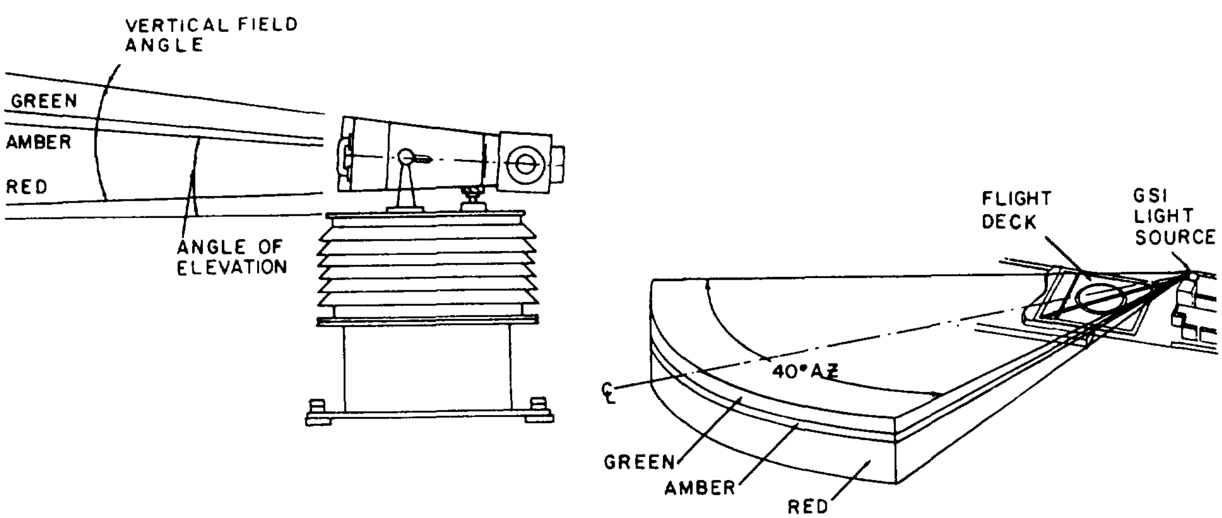
Upon completion of this chapter, you should be able to do the following:

- *Describe the stabilized glide slope indicator (SGSI) system and its associated components.*
- *Identify the purpose and principles of operation of the components of the SGSI system.*
- *Describe the procedures to follow when troubleshooting the SGSI system*
- *Describe the procedures to follow when performing maintenance on the SGSI system*

The stabilized glide slope indicator (SGSI) system consists of a GSI cell mounted on top of an electrohydraulic stabilized platform. The GSI cell is an optical viewing system used to indicate to a pilot the aircraft approach angle to a landing platform or ship. The GSI system is an electrohydraulic optical landing aid designed for use on ships equipped for helicopter operations. By use of the SGSI, a helicopter pilot may visually establish and maintain the proper glide slope for a safe landing. The system is self-contained, relying on the ship for 115 volts ac 400-Hz and 440 volts ac 60-Hz power.

The GSI, which is mounted on a stable platform, provides a single bar of light either green, amber, or red (fig. 3-1). The cell face acts as a window through which the pilot views the light. The color of the light bar indicates to the pilot of the approaching aircraft whether the aircraft is above (green), below (red), or on (amber) the correct glide slope. By varying the aircraft altitude to keep the amber light bar visible, the pilot maintains the correct glide path to the ship's landing pad. The bar of light is formed by the combined actions of source light, Fresnel lens, and lenticular lens.

To steady the GSI with respect to the pitching and rolling motions of the ship, the light cell is mounted on an electrohydraulic stabilized platform. This equipment uses a local gyro for reference and develops electronic error signals that, in turn, control hydraulic cylinders that move the platform in the opposite direction to the ship's pitch and roll axis. The system incorporates a failure detection circuit that turns off the lights in the event of stabilization failure.



F'igure 3-1.—Glide slope indicator and light beam.

SGSI SYSTEM COMPONENTS

The assemblies that comprise the SGSI system are as follows (fig. 3-2):

- Electronic enclosure assembly
- Remote control panel assembly
- Hydraulic pump assembly
- Transformer assembly
- GSI assembly
- Stabilized platform assembly

ELECTRONICS ENCLOSURE ASSEMBLY

The electronics enclosure assembly (fig. 3-3) is the signal processing distribution and control center for the system. It contains the circuits, amplifiers, and other electrical and electronic components required to control the major components of the system.

To understand the system operation, you must understand feedback control systems. A feedback control system compares an input signal with a reference signal and then generates an error signal. This error signal is then amplified and used to drive the output in a direction to reduce the error. This type of feedback system is often referred to as a servo loop. A gyro, mounted on the stabilized platform, acts as the reference of the system. Since the gyro is stable, synchro transmitters located on the gimbals will sense any motion of pitch or roll. As the ship begins to pitch or roll, an error signal is developed by the synchro transmitter stators. Look at the block diagram in figure 3-4 and follow the path of the error signal through the electronic enclosure assembly. (The block diagram represents either the pitch or the roll control loops. They are identical electrically.)

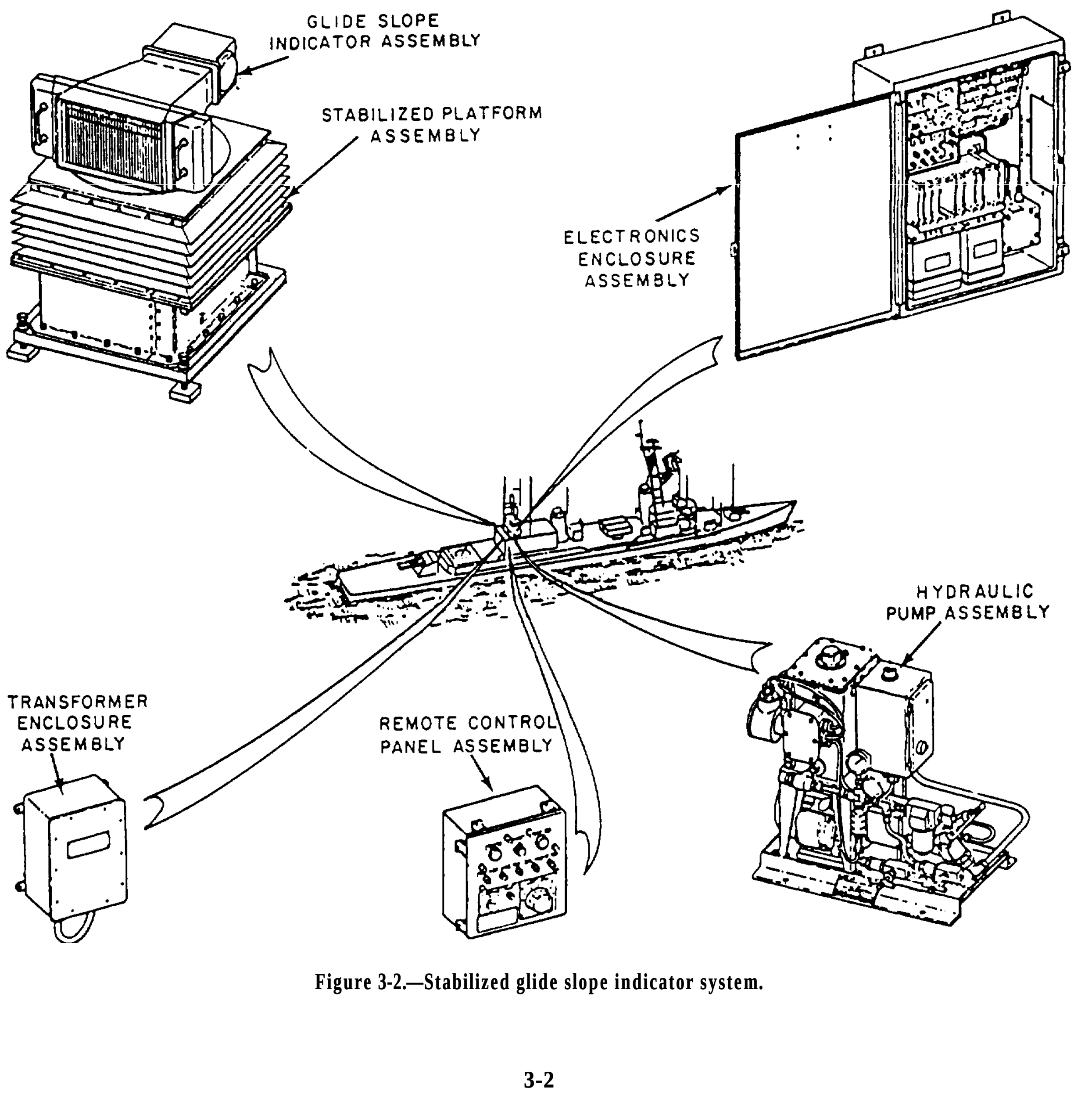


Figure 3-2.—Stabilized glide slope indicator system.

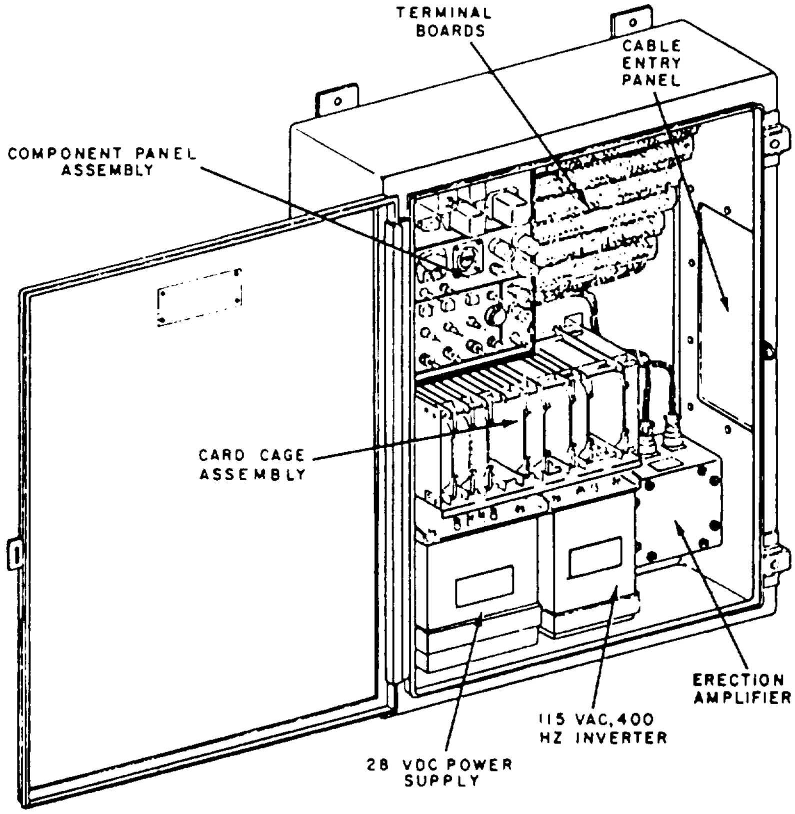


Figure 3-3.—Electronics enclosure assembly.

From the transmitter stators the error signal is sent to the gyro demodulator, where the signal is changed from ac to dc. The signal then goes through a stab-lock relay (described later) and is amplified as it moves through the servo amplifier, which in turn operates the servo valve. The servo valve opens and allows hydraulic

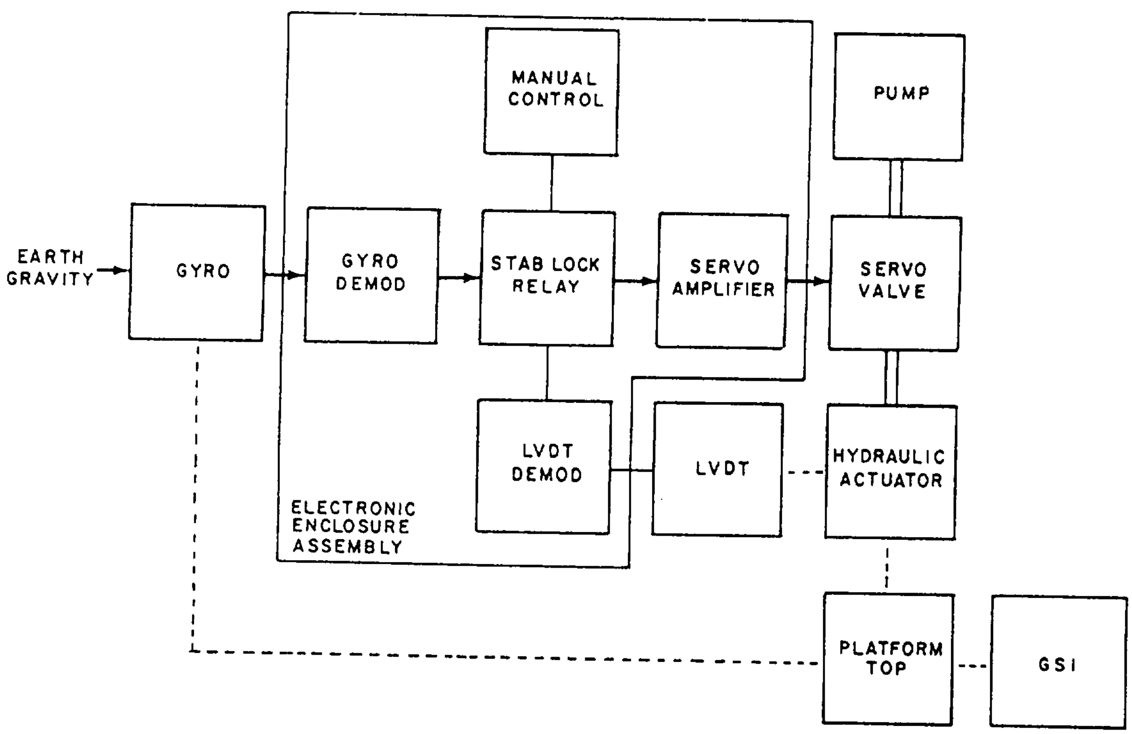


Figure 3-4.—Stabilization circuits, block diagram.

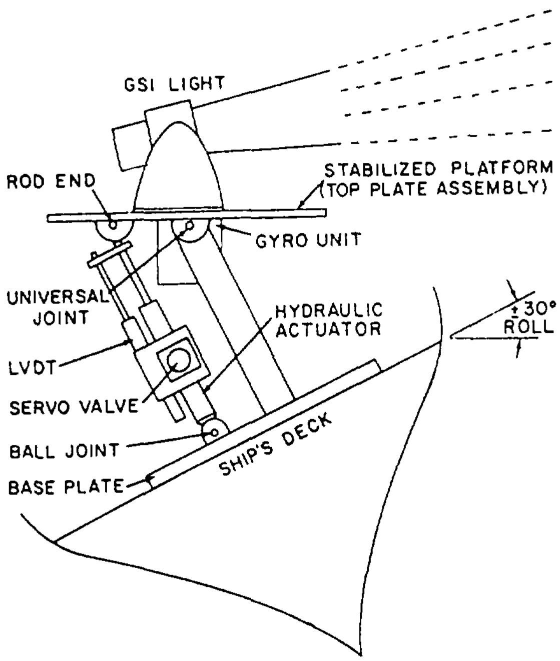


Figure 3-5.—Stabilized platform assembly, functional diagram.

fluid to enter the hydraulic actuator (fig, 3-5), thereby leveling the platform and thus canceling the error signal.

When this occurs, a READY light is actuated on the remote control panel. If the system develops a malfunction and the error signal is not canceled, an error-sensing circuit will light the NOT READY light on the remote control panel and turn off the GSI.

In the previous paragraphs, we discussed the normal mode of operation in the electronics portion of the system. The stabilization lock feature (stab-lock relay) tests and aligns the GSI. Referring to figure 3-6, you will see internal gyro stab-lock and ship gyro stab-lock push buttons and two test switches, one of which is pitch-off-roll.

As previously mentioned, the error signal in the normal mode goes through a stab-lock relay. When the stab-lock button is pushed, the normal error signal supplied from the gyro is stopped at this point (see

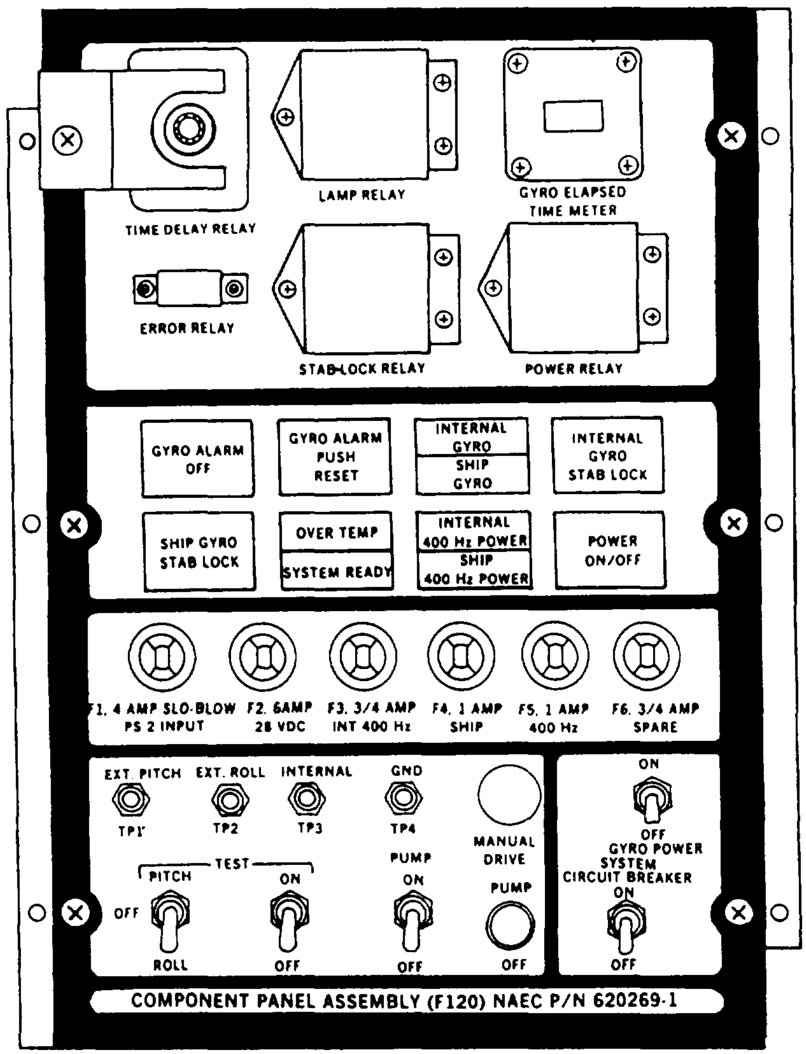


Figure 3-6.—Compenents panel assembly (P/O electronics enclosure-F100) controls and indicators.

fig. 3-7). When the stab-lock button is pushed, the error signal comes from the linear voltage differential transformer (LVDT) when the test switch is in the off position. The core of the LVDT is mechanically attached to the hydraulic actuator, which levels the platform. As the actuator moves, the core also moves, thereby supplying a signal proportional to the amount of roll or pitch. These signals can be measured to aid in the maintenance and alignment of the system. Revisions are also made to drive the platform manually using the test switches and the manual drive potentiometer.

REMOTE CONTROL PANEL ASSEMBLY

The remote control panel (fig. 3-8) is located in the flight operations control room. TM panel provides

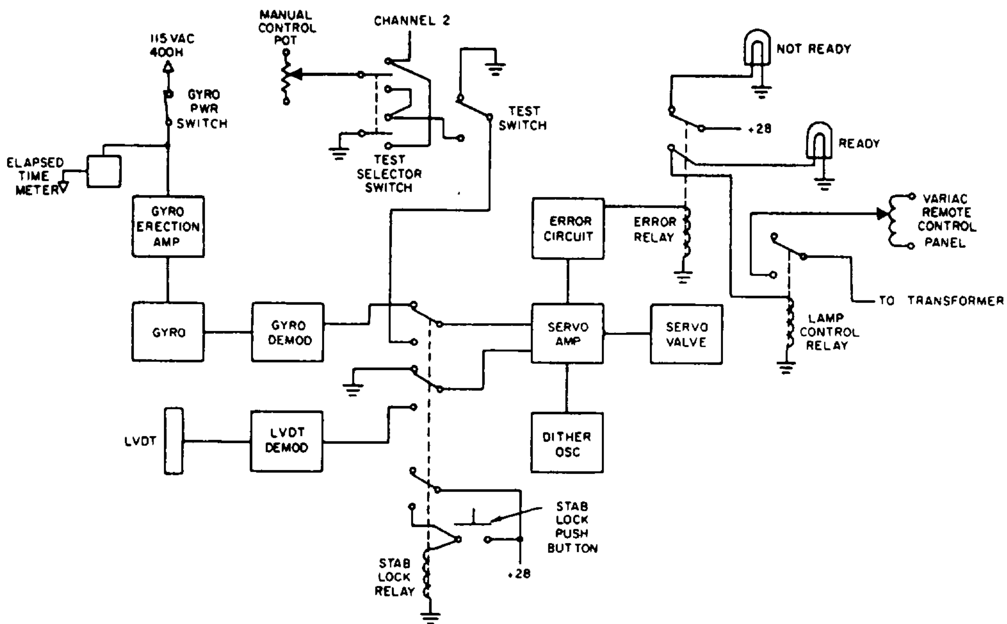


Figure 3-7.—Stabilization control circuit–signal flow.

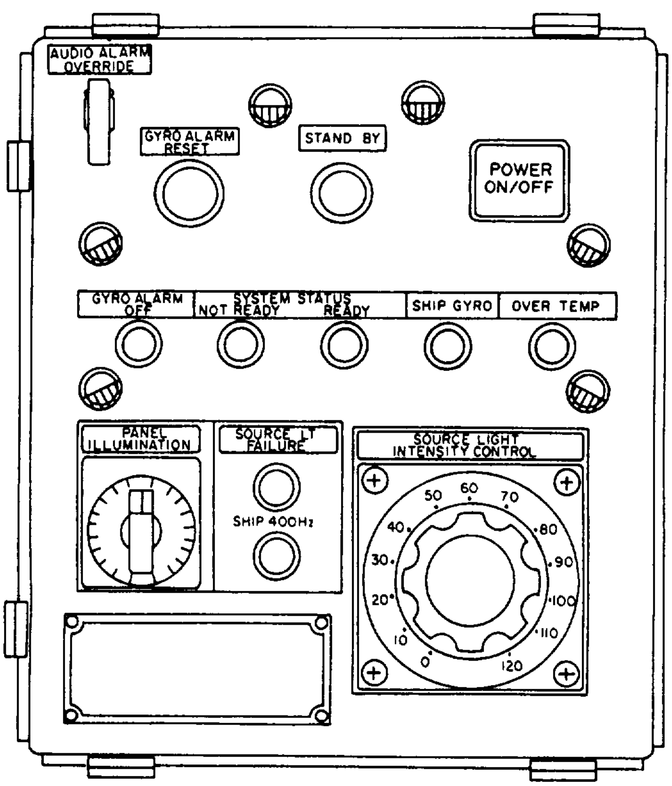


Figure 3-8.—Remote control assembly.

control and indicators for operating and monitoring the SGSI system from a remote location. It contains the READY and NOT READY lights deseribed previously. The panel also contains an OVERTEMP light to indicate when the hydraulic fluid is heated to a temperature higher than 135°F±5°, a source failure light to indicate that one or more of the GSI source lights are burned out, a variable transformer to control the intensity of GSI light, and a panel illumination control. A standby light will be energized when the main switch on the electronic enclosure assembly is on.

HYDRAULIC PUMP ASSEMBLY

The hydraulic pump assembly (fig. 3-9) is a self-contained medium-pressure, closed-loop system used to supply hydraulic pressure for the stabilized platform. This assembly consists of an electric pump motor, a coupling unit, a hydraulic pump reservoir, valves, piping, and an electrical system. All components are mounted on a steel base and comprise a complete self-contained 1400-psi hydraulic power supply.

Hydraulic fluid is stored in a reservoir and piped to a motor-driven pump. The output is pressurized by the

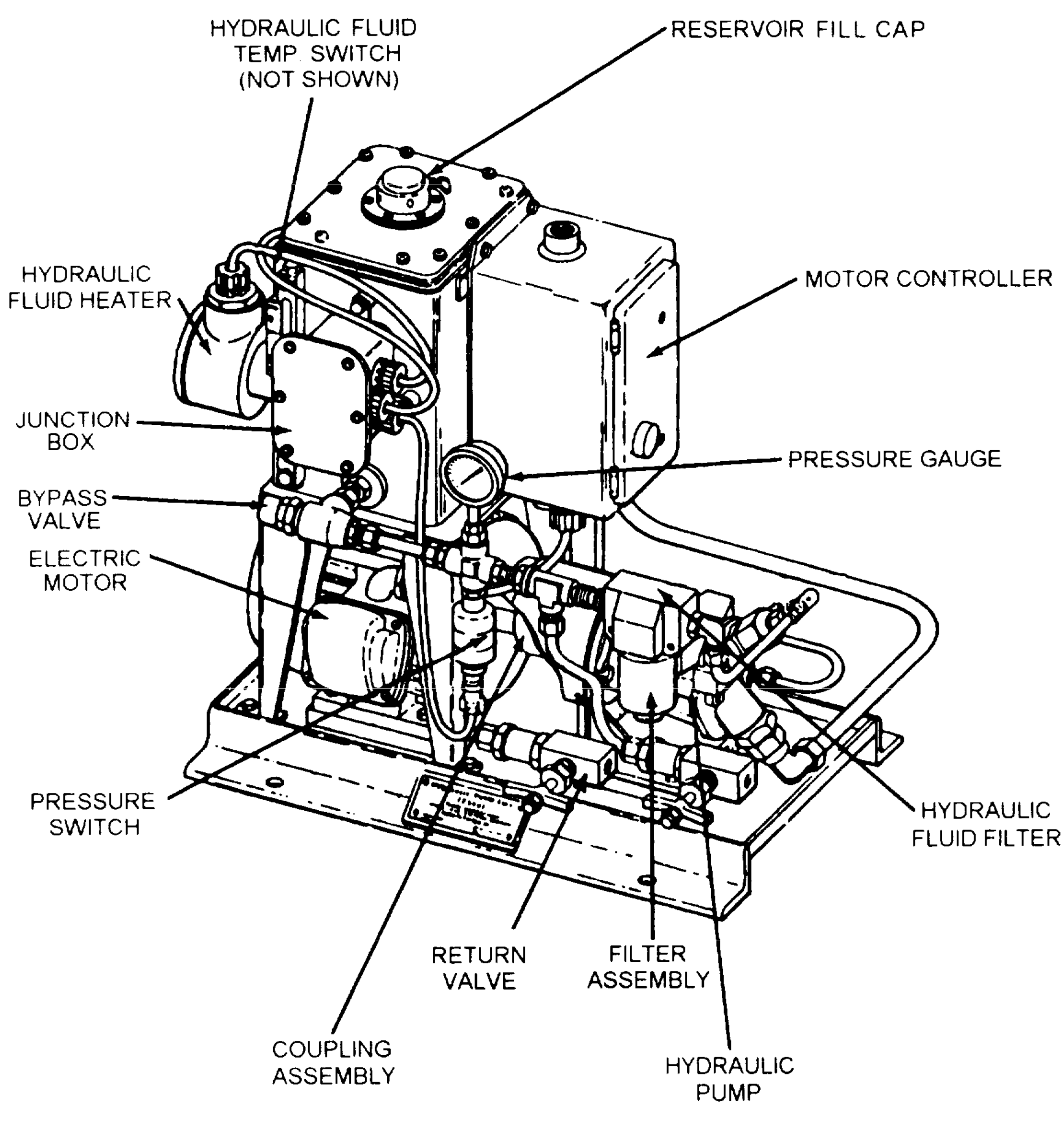


Figure 3-9.—Hydraulic pump assembly.

pump to 1400 psi, filtered, and piped to the power supply output line where it is available to the external system through a shutoff valve. On the return line, fluid is returned from the external system to the reservoir at a reduced pressure of 75 psi. A shutoff valve is also used in this low-pressure line. Electrical power is obtained from ship's power system and connected through the motor controller and junction box. This assembly is located as close as possible to the stabilized platform. It provides hydraulic fluid at 1400 psi to the hydraulic actuator on the stabilized platform. The motor and controller operate on 440-volt, 3-phase received from normal ship's power supply. The temperatures witches (not shown) operate the OVERTEMP light on the remote control panel. Also, a pressure switch in the hydraulic pump discharge line will close at 1200 psi. If not closed, the pressure switch will de-energize the electronic panel assembly on low oil pressure. Hydraulic fluid heaters in the oil reservoir maintain the temperature at approximately 70°F±5°.

TRANSFORMER ASSEMBLY

The transformer assembly is a weathertight enclosure mounted within 3 feet of the stabilized platform. An interconnecting cable, which is part of the transformer assembly, connects the transformer assembly to the GSI. This assembly is located as close as possible to the stabilized platform. Its purpose is to step down the voltage for the source light (GSI) from 115 volts ac to 18.5 volts ac.

GLIDE SLOPE INDICATOR ASSEMBLY

The GSI assembly consists of two major subassemblies: the mounting base assembly and the indicator assembly. The indicator assembly is supported in the mounting base assembly, which is mounted on the stabilized platform. The incoming system cable connects at the rear of the right-hand heater compartment. The mounting base assembly provides the means to accurately position the indicator assembly in relation to the landing pad. The mounting base is then secured in this position by the retractable plunger. Indicator elevation is controlled by the elevation adjustment knob. The GSI sits in the trunnions of the mounting base assembly.

STABILIZED PLATFORM ASSEMBLY

The stabilized platform assembly is mounted to the ship's deck in close proximity to the helicopter landing area. This assembly contains a local gyro, gimbaled platform, hydraulic cylinders, and electrically operated servo valves. More information on the stabilized platform is given later in this chapter.

PRINCIPLES OF LENSES USED IN THE GSI SYSTEM

There are two types of lenses used in the optical portion of the GSI system: the Fresnel lens and the lenticular lens. A discussion of the principles of the piano-convex lens is provided so the physical characteristics of this type of lens may be compared with the physical characteristics of the Fresnel lens.

PLANO-CONVEX LENS

A piano-convex lens has a plane, or flat, surface and a spherical surface. This type of lens is a positive, or collective, lens; that is, a lens in which the light rays are collected at a focus to form an image. The radius of the spherical surface of the lens is known as the radius of curvature.

FRESNEL LENS

The Fresnel lens is a lightweight and relatively thin sheet of transparent Lucite material. The refraction of light rays by the Fresnel lens is collective, as in a piano-convex lens; however, the Fresnel lens differs from a piano-convex lens, as shown in figure 3-10. One surface of the Fresnel lens consists of a number of stepped facets. These facets are circular, concentric grooves that extend from the center of the lens to the edges. The slope of each facet is independent of the slope of all other facets. These slopes are designed to provide a perfect focus of the light rays that pass through the lens. Thus, the Fresnel lens provides an advantage over a piano-convex spherical lens in that the plano-convex spherical lens causes spherical aberration of

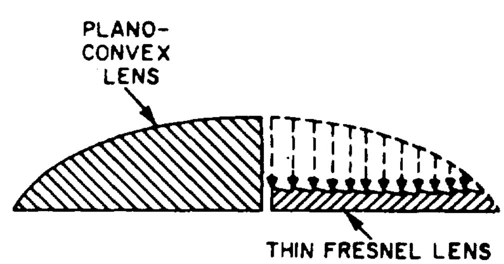


Figure 3-10.—Comparison of the physical characteristic of piano-convex lens and Fresnel lens.

light rays, as illustrated in figure 3-11. When the rays of light, parallel to the principal axis of a convex spherical lens, pass through zones near the edge of the lens, the principal focus occurs at a point that is closer to the lens than the focus for rays that pass through the lens near the principal axis. Therefore, the light rays from a plano-convex spherical lens tend to scatter. The Fresnel lens also can be formed around a suitable radius to minimize astigmatism. Astigmatism of a lens is the inability of the lens to bring all the light rays from a point on an object to a sharp focus to form the image.

The optical characteristics of the Fresnel lens will vary appreciably with a change in temperature. If the lens temperature is allowed to vary beyond operational limits, three effects will be observed. First, the size of the bar of light near the center of the lens is different from that which is seen near the center of the lens when the lens is at design temperature. Also, as the observer moves up or down, the size of the bar of light appears to change as the image moves from the lens center to the transition line between cell assemblies. The transition line is defined as the physical break between the cells. If the ambient temperature is higher than design temperature, the bar of light at the center appears smaller than the design bar of light, and it blooms to a larger-than-design bar of light at the transition line between cells. If the ambient temperature is lower than design temperature, the opposite conditions occur.

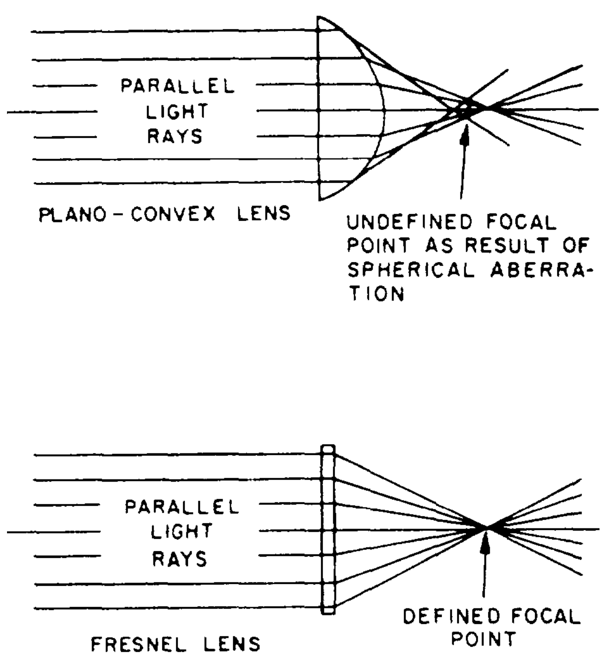


Figure 3-11.—Comparison of optical characteristics of piano-convex lens and Fresnel lens.

The second effect that will be observed is that the motion of the bar of light from the cell center to the transition line does not appear to be smooth. At higher-than-design temperature, the bar of light disappears in the observed cell before it starts to appear in the adjacent cell. At lower-than-design temperatures, the bar of light disappears into the transition line before a bar of light starts to appear in the adjacent cell. At extreme temperatures, it is possible to get blank areas or double bars of light at or near the transition line.

The last effect that will be observed is that the vertical field angle (angle of the lens from top to bottom as viewed from the front) is larger when the ambient temperature is higher than design temperature and smaller when the ambient temperature is lower than the design temperature. To maintain design characteristics of the Fresnel lens, the lens-heating compartments are maintained at a temperature that is relatively constant. The Fresnel lenses are each enclosed in a separate compartment in which a lenticular lens serves as the front and an optical glass serves as the back of the compartment. Hot air is circulated in the compartment under thermostatic control.

LENTICULAR LENS

A lenticular lens is placed in front of each Fresnel lens. Each lenticular lens consists of many long, convex, cylindrical lenses placed side by side, as shown in figure 3-12. Each individual lens has the same short focal length. The area in which the light source (the object) can be viewed is spread by the short focal length of the lenticular lens. If the object consists of a multiple-light source with spacing between the lights, the object appears to an observer looking into the lens as a continuous band of light that fills the width of the lens. In the GSI system, the arrangement of the lenses with respect to the source lamps and the physical properties of the lenses cause the source lamps to appear as a single light image 12 inches wide and approximately 1/2 inch high. The object appears as a continuous band of light regardless of the observer's position in the azimuthal range of the lenticular lens. The azimuthal range is the angular position (expressed in degrees) in a horizontal plane in which a pilot of an approaching aircraft can observe the band of light. The azimuthal range of the lenticular lens used in the Fresnel system is 40° (see fig. 3-12). The appearance of the height of the object is not affected by the lenticular lens.

The lenticular lens in the GSI assembly is manufactured with three different color segments to eliminate the need for filters and their subsequent light

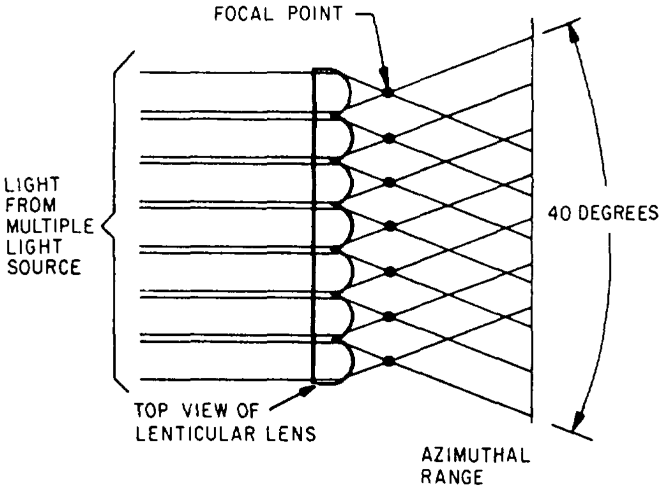


Figure 3-12.—Optical characteristics of the lenticular lens.

attenuation. The top segment is colored green, the middle segment is amber, and the large bottom segment is colored red. When projected, the resulting glide path has the viewing zone as shown in figure 3-13. The GSI cell was designed so 1 inch on its face is equal to 1° of arc. Thus, the 1° amber is 1 inch on the cell face.

The stowlock assembly provides a means of securing the source light indicator in a fixed position when the system is not in operation. The stowlock assembly is located directly below the source light indicator assembly and is secured to the deck-edge boom. The shipbuilder's junction box is used as a junction point for various cables of the system, as are all junction boxes that are a part of the system.

SYSTEM OPERATION, TROUBLESHOOTING, AND MAINTENANCE

The following paragraphs provide information on operating, checking-out, troubleshooting, and maintaining the SGSI system. We will discuss some of the things that can be done to keep the SGSI operating efficiently.

When troubleshooting the SGSI system, you should refer to the troubleshooting charts in the *Stabilized Glide Slope Indicator (SGSI) Mk 1 Mod 0 (Incorporating Gyro Failure Alarm) for Air Capable and Amphibious Assault Ships,* NAVAIR 51-5B-2, technical manual. By using the charts/tables in the technical manual for overall system checkout procedures, you will know what controls must be set during the performance of the checkout procedure. These tables also list the location of each control, the necessary instructions for the proper use of these controls, and the normal indications that should be observed during the operation of these controls. When an abnormal indication is observed during the checkout procedures, certain additional procedures must be performed that use the controls available within the equipment to establish conditions that enable maintenance personnel to isolate malfunctions with a minimum use of test equipment. By using these procedures,

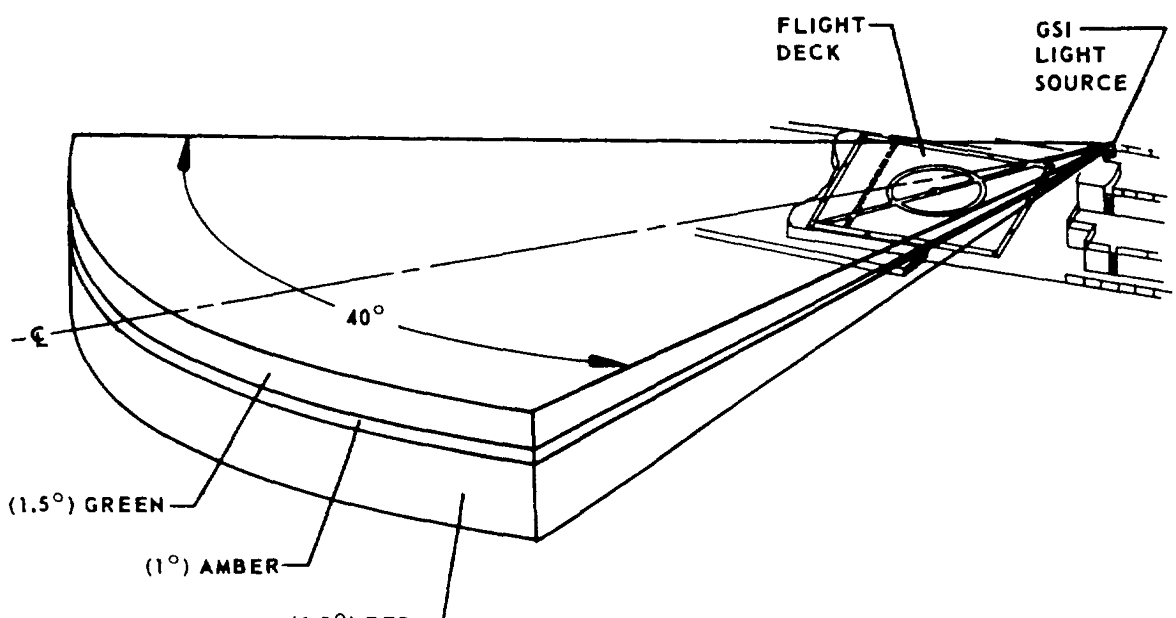


Figure 3-13.—Viewing zone of glide slope indicator.

you can locate the cause of the specific malfunction and perform the recommended corrective maintenance.

Maintenance is an ongoing process to keep the equipment operating effciently and consists of preventive and corrective maintenance. For all maintenance requirements for the SGSI system, you should refer to the maintenance requirement cards (MRCs). There are maintenance items to be performed weekly, quarterly, semiannually, and annually. System maintenance must be performed on a regular basis regardless of use cycle. Deterioration and/or damage to equipment may result if system maintenance is not performed regularly. The information given in the following paragraphs is not intended to replace preventive maintenance cards or the applicable technical manuals. This information should familiarize you with some of the requirements and procedures to keep the equipment in top notch operating condition.

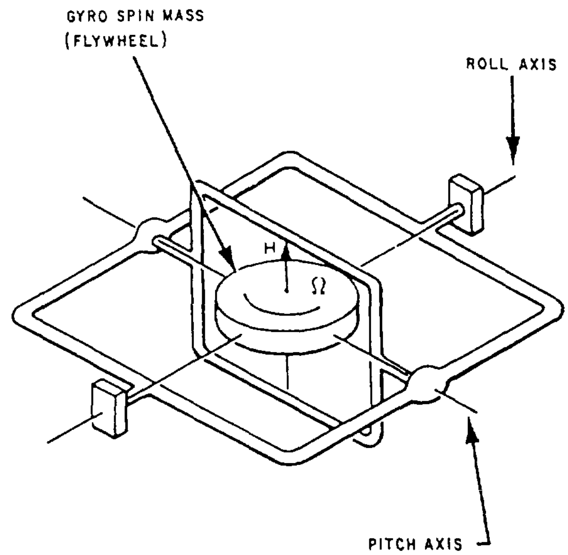


Figure 3-14.—Vertical gyro, simplified schematic.

GYRO ALARM OFF

If a failure occurs in the error sensing circuitry or if the ship's gyro information or gyro reference voltage is not being sent to the SGSI, a ready light cannot be obtained. This will keep the lamp relay de-energized and not allow the source lamps to illuminate. Operation in the internal gyro mode is still possible through the activation of the gyro alarm off switch-indicator on the component panel assembly. Since the gyro alarm off switch-indicator disables the independent failure detection circuit, a gyro alarm off indicator is automatically illuminated in both the electronic enclosure and the remote control panel. Servo error sensing is not affected by activation of gyro alarm off. Depressing the gyro alarm off push button will activate the ready light and allow the source lamps to illuminate if no other system problems exist.

GYRO FAILURE ALARM CIRCUIT TESTS

These tests are to be performed once a week when the SGSI is being used for air operations. These tests will ensure that all failure monitoring circuits are operational.

VERTICAL GYROSCOPE

The vertical gyroscope is basically a mechanical device. The essential element of the gyroscope is a flywheel rotating at high angular velocity about an axis. The flywheel is mounted within gimbals that allow it two degrees of freedom as shown in figure 3-14.

When the flywheel of the gyroscope is rotating at high speed, its inertia is greatly increased. This causes the flywheel to remain stationary within the gyro gimbal structure. To align the gyroscope flywheel to the local earth gravity vector (downward pull of gravity), a pendulum sensor is attached under the spinning flywheel. In operation, the pendulum is held suspended within a magnetic sensor with the magnetic sensor measuring the difference between the pendulum axis and the spin motor axis. The sensor output is amplified and used to drive a torque motor that causes the gyro flywheel to rotate in a direction to reduce the sensor output. In actual operation, the pendulum sensor is affected by lateral accelerations that cause it to oscillate about true position. To correct for this oscillation, the gyro circuits time constants are long. The long time constants cause the gyros flywheel to ignore periodic variations of the pendulum and align itself to the average pendulum position. Figure 3-15 shows the essential elements of the gyro.

CELL ALIGNMENT

For a pilot to use the SGSI for an accurate landing, the cell must be properly aligned. There are two adjustments necessary for this alignment. One adjustment is focusing the cell and the other is setting the beam angle in reference to the GSI base plate.

Cell Focusing

As shown in the simplified cell schematic, figure 3-16, you can see that by moving the light mask into

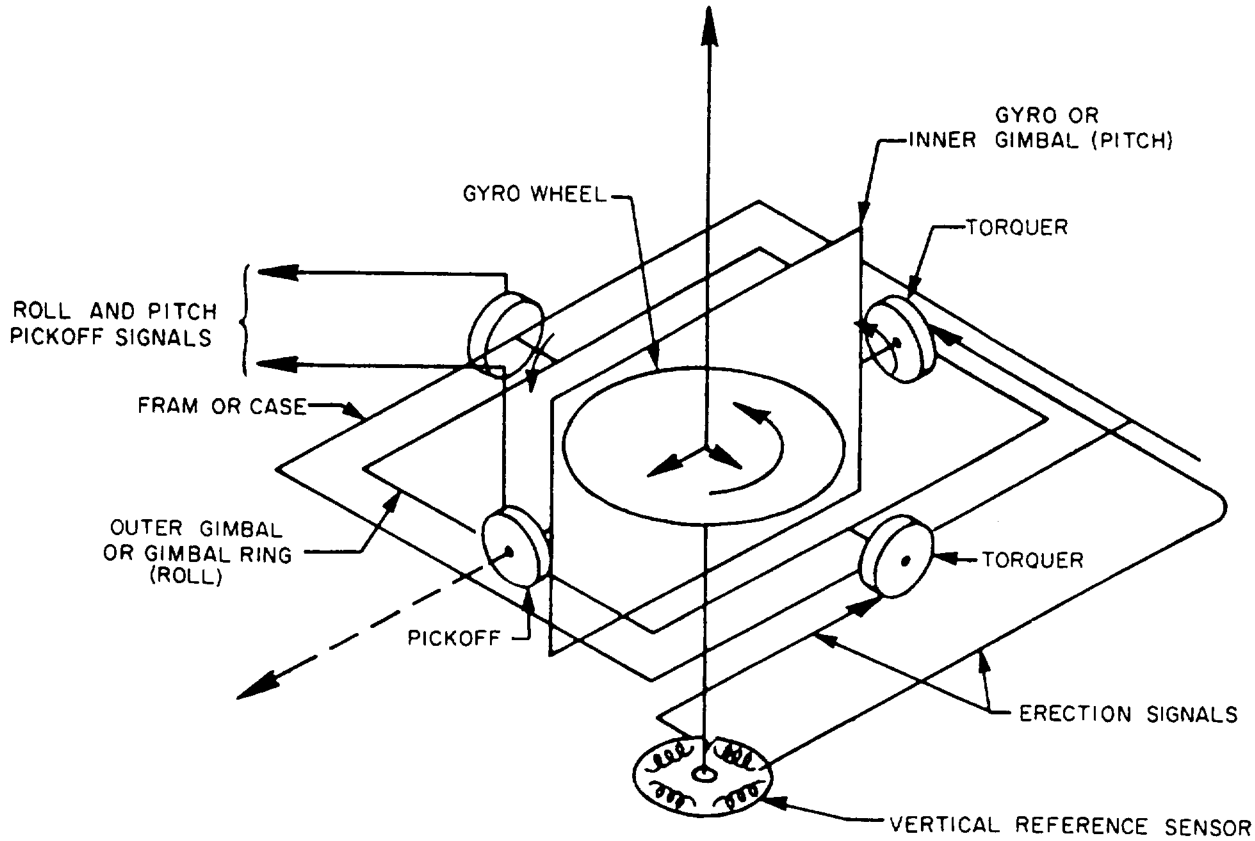


Figure 3-15.—Vertial gyro, schematic diagram.

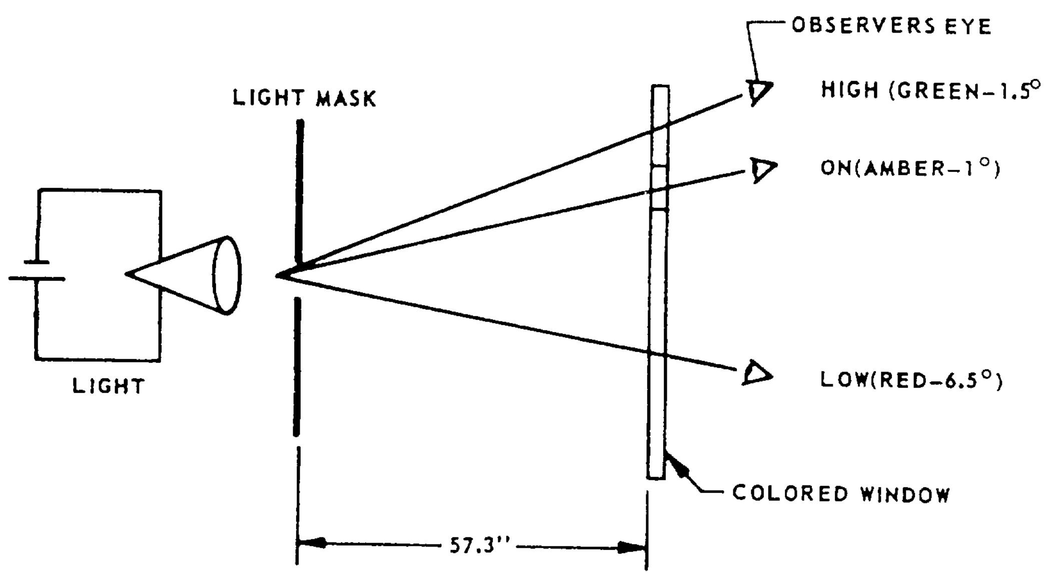


Figure 3-16.—Simplifled cell schematic.

or away from the colored filter changes the sensitivity of the cell. The sensitivity can be defined as how fast the light bar will appear to move in the cell as an observer traverses from the bottom to the top of the cell. If the light mask is close to the colored filter, the sensitivity is decreased and the angle that a viewer would move through in going from the bottom to the top of the cell is increased. If the light mask is moved away from the colored filter, the sensitivity is increased and the angular coverage of the window decreases.

Thus, the cell can be focused and the sensitivity set by moving the light source and slots in relation to the colored filter (fig. 3-17). In the GSI cell, the distance from the slots to the Fresenel lens is 16.8 inches. The cell is calibrated so the 1-inch amber section of the lenticular lens is exactly 1 degree of arc. A typical cell calibration setup is shown in figure 3-18.

To focus the cell, it must be placed on a level plate and two screens 10 feet (±1/8 inch) apart must be set up in front of the cell (see fig. 3-18). Turn the cell on and measure the height of the amber at screen one and subtract it from the height of the amber at screen two (fig. 3-19). If the cell is properly focused, the difference should be 2-3/32inch±1/8 inch. A dark band will appear between each of the colors due to light scattering at the interface; this band should be split evenly to obtain height measurements.

Beam Angle

The angle of the light beam to the horizon must be accurate and remain constant so a pilot may maintain a fixed rate to the ship. The glide slope angle is set using the degree plate on the right side of the cell and is checked on-the platform by means of pole checks to ensure the proper settings.

At the same time the cell is focused it can be calibrated for proper glide slope. Referring to figure 3-19, you can see that the same screen arrangement can be used for measuring the angle of the red/amber inter- face.

Set the baroscope supplied with the system on top of the level plate and mark off a reference mark on each screen. Adjust the cell glide angle using the knurled knob under the lamp housing until the difference between the reference mark on the red/amber interface on screen two is equal to 6-9/32 inches ±7/32 inch. Drill and pin the degree plate so it indicates three degrees.

In this measurement, the cell should project the beam on the two screens and the center of the dark band between the red and amber filter should be used for all measurements.

The slot through which the light bar is formed determines the size of the light bar as it is viewed through the cell face. In this system, it is not adjustable.

THERMAL CONTROL

Temperature control of the GSI includes cooling of the projection lamp compartment and temperature

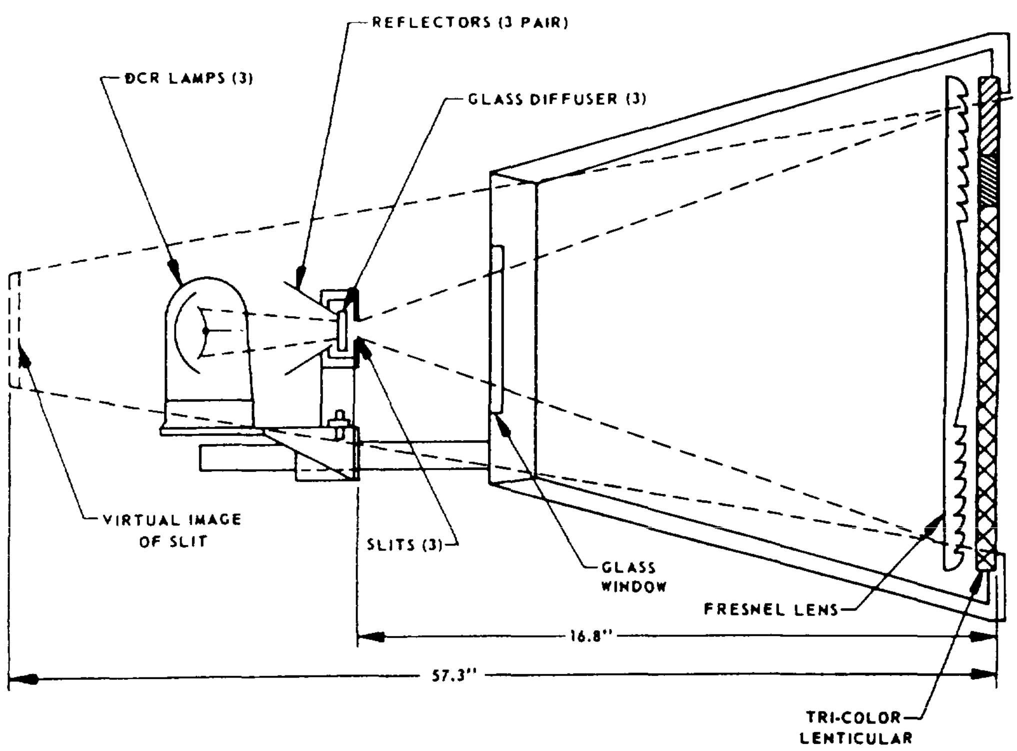


Figure 3-17.—Gulide slope indicator, simplified functional diagram.

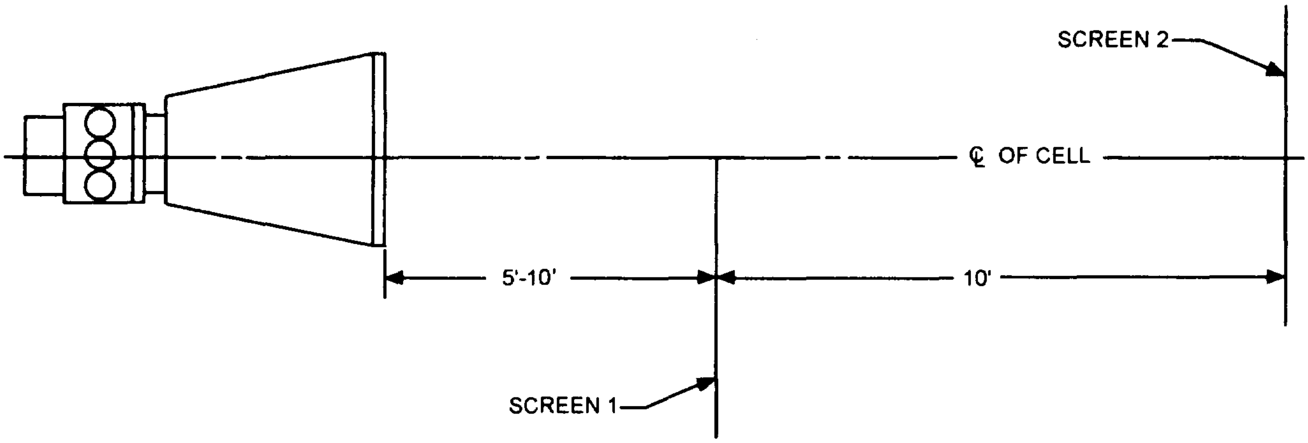
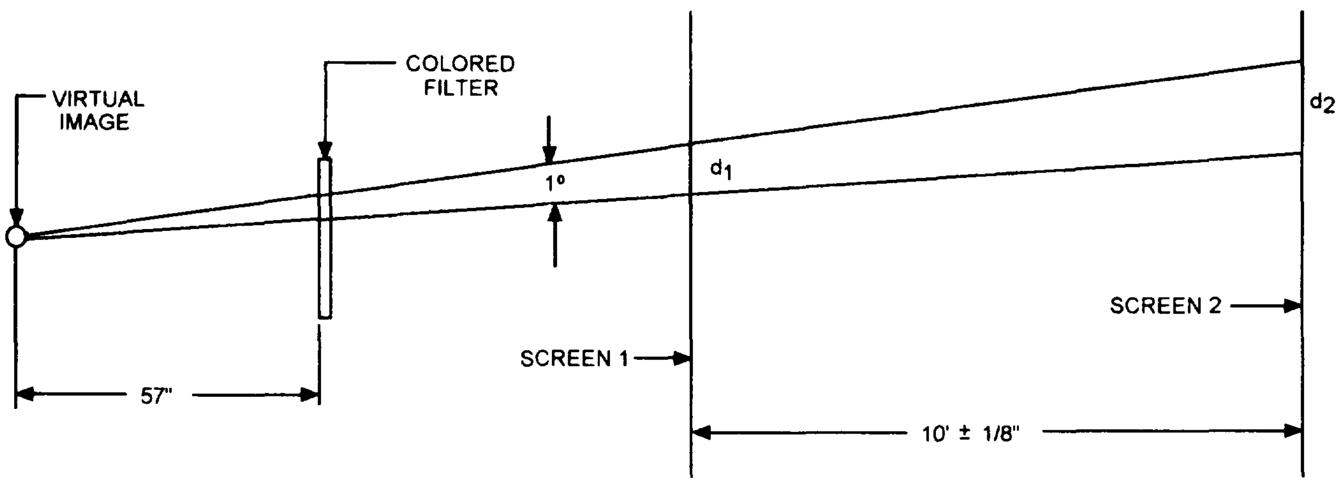


Figure 3-18.—Typical cell calibration setup (overhead view).



$$d_2 - d_1 = 120'' \tan 1° = 120\,(.01746)$$
$$d_2 - d_1 = 2.0952 = 2,3/32'' \pm 1/8$$

Figure 3-19.—Cell focusing measurements.

regulation in the lens compartment. These are discussed in the following paragraphs.

Projection Lamp Compartment Cooling

The three projection lamps used in the GSI generate large amounts of heat when they are operated at full intensity. Cooling of this compartment is accomplished by a blower/louver arrangement. A special design louver assembly is located on each side of the projection lamp shroud This design allows entry of cooling air while maintaining a weather seal to keep moisture, dirt, and so on from entering. Cool air is drawn in through the rear louver by the blower fan, and exhausts through the side louver after absorbing heat radiated by the projection lamps.

Lens Assembly Temperature Control

Temperature control of the Fresnel/lenticular lens assemblies is important to prevent lens distortion fog-ging, or other environmental reactions. In the GSI, lens temperature control is achieved by blowers, heaters, and thermal switches.

The temperature control circuits (see figs. 3-20 and 3-21) are used to regulate operating temperatures in the GSI assembly. When power is applied at the remote control panel, voltage is applied to the heaters and blowers to the left and right of the lens assemblies. Blower motors B1 and B2 begin to operate as soon as voltage is applied. Control thermoswitches S1 and S2 are set at 100 +10°F. To keep this temperature constant, S1 and S2 open and close as the temperature rises and falls in the GSI assembly. As the thermoswitches open and close, power is removed from or applied to heaters H1 and H2. If S1 and S2 fail to open, backup thermoswitches S3 and S4 will open, preventing damage to the lenses. A simplified schematic of the cell wiring appears in figure 3-20.

GSI TRANSFORMER

The GSI uses three 21-volt 150-watt projection lamps for its light source. This is about 21 amps of current and would cause considerable voltage drop if long cables were used, thus the transformer assembly is mounted close to the GSI light and uses a fixed length of cable (10 feet) from the transformer secondary to the GSI cell connector. The system autotransformer supplying the primary voltage to the transformer is located in the remote control panel. A simplified schematic is shown in figure 3-21.

STABILIZED PLATFORM SYSTEM

The stabilized platform system is an electro-hydraulic served platform used to stabilize the GSI against the ship's pitch and roll. This keeps the tricolored GSI light at a fixed angle to the horizon. The stabilization is termed a one-to-one stabilization system. This means that for each degree of pitch or roll of the

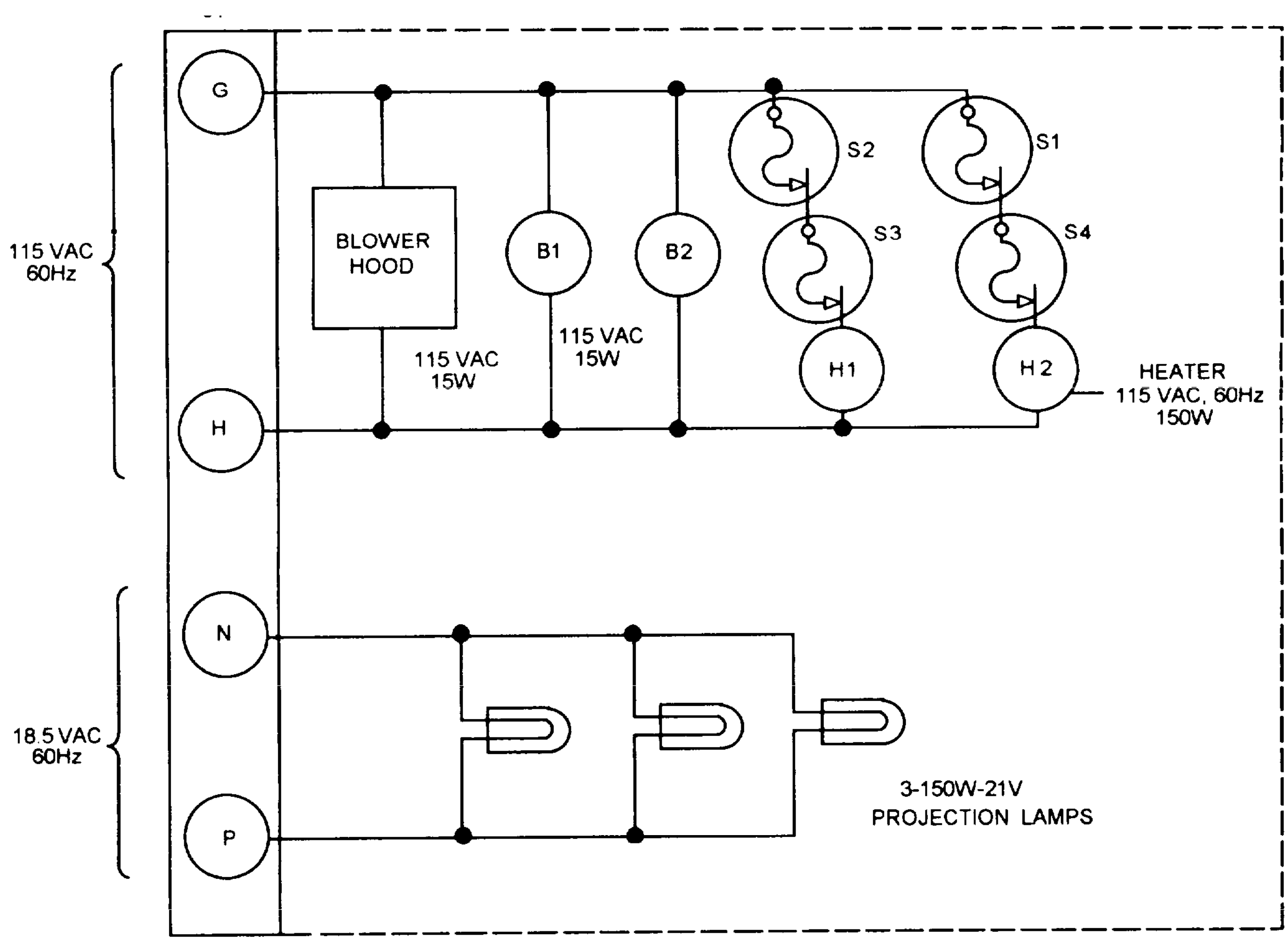


Figure 3-20.—GSI cell, simplified schematic.

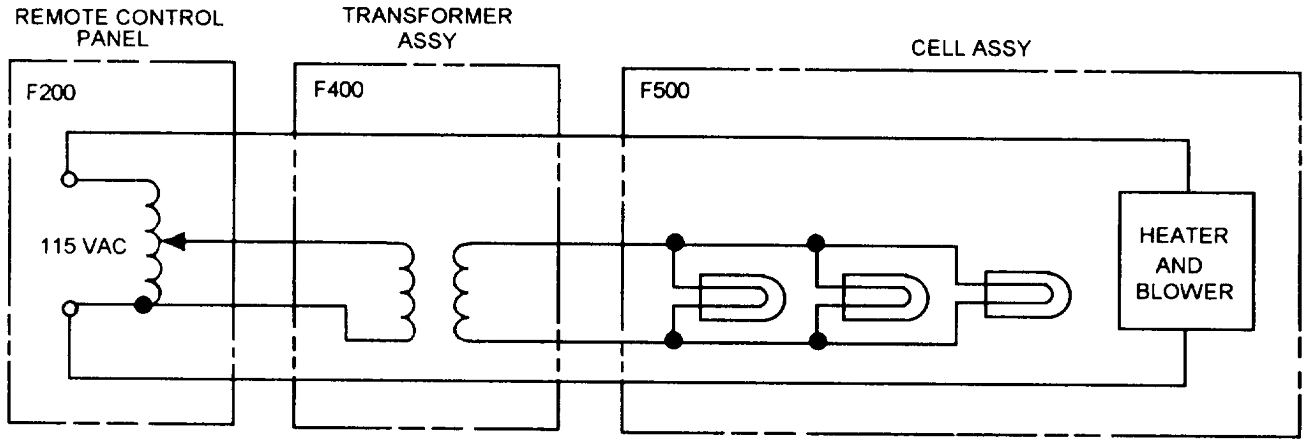


Figure 3-21.—Cell power.

ship, the platform pitches or rolls an equal amount in the opposite direction. Thus, the platform remains level to the horizon or more precisely perpendicular to the local earth gravity vector.

Operational Modes

The system has four operational modes: internal gyro, internal gyro stabilization lock ship gyro, and ship gyro stabilization leek.

SGSI SYSTEM NORMAL OPERATING PROCEDURE.- Stabilization from the internal gyro is the normal mode of system stabilization and is preferred to ship gyro mode because of higher system accuracy and addition of the gyro failure alarm. The system should always be operated in this mode as opposed to ship gyro operation unless a system failure prevents it. Operating control is normally conducted from the remote control panel from which the operator can turn the system on and vary the intensity of the source light. The system may also be turned on at the electronics enclosure assembly when the POWER ON/OFF push button is depressed. Adjustment of the source light intensity, however, can only be adjusted at the remote control panel. The normal mode is the interred gyro mode, where the gyro acts as the system sensor detecting any eviations from platform level. In this mode the platform will always remain level and cannot be offset.

INTERNAL GYRO STABILIZATION LOCK MODE.- The internal gyro stab-leek mode disconnects internal gyro signals from the stabilization loop and locks the platform in a neutral position for test, alignment, and troubleshooting purposes. The system must be set to internal gyro for internal stab-leek operation. While in this mode, the test switches and manual drive potentiometer can be operated to enable insertion of signals independent of the local gyro. This mode enables the operator to isolate and test various parts of the system while disabling other parts.

SHIP GYRO STABILIZATION MODE.- Ship gyro stabilization is provided as an alternative to platform-mounted internal gyro stabilization. The system should be operated in the internal gyro mode unless component failure disables that portion of the circuitry since switching to the ship's gyro reduces system accuracy. The internal gyro/ship gyro switch-indicator is on the component panel assembly. A ship gyro indicator on the remote control panel serves to remind system operators when the alternative stabilization source is in use.

SHIP GYRO STABILIZATION LOCK MODE.- The ship gyro stabilization leek mode disconnects the ship's gyro signals at the input to the gyro signal card assembly and replaces them with ground reference or manual drive potentiometer signals. This permits check-out and troubleshooting of ship gyro stabilization and stabilization error detecting circuitry. The internal gyro/ship gyro switch-indicator on the component panel assembly should be placed in the ship gyro position to enable the stabilized platform to track manual drive signals. The lamp control relay extinguishes GSI source lamps while operating in this stab-leek mode.

Platform Configuration

The stable platform consists of a flat top plate to which the GSI is affixed. The top plate is attached to the base plate through a universal joint and a center post and is moved by two hydraulic actuators that are coupled to the top plate with two axis rod ends. The universal joints and rod ends allow the platform to tilt in two axes. These are designated pitch and roll to match ship motions for which the platform compensates. Figure 3-22 illustrates a platform compensating for a roll motion, showing the major components of the platform.

SERVO LOOPS

To understand the system operation, you need to have an understanding of feedback control systems. A feedback control system is a system where an input signal is compared with the system output and an error signal is generated. This error signal is then amplified and used to drive the output in a direction to reduce the error.

Assuming the input and output pots are initially equal, then the difference in voltage is zero and there is no error. If the input command pot is moved, then an error is generated. The amplifier amplifies the error and drives the power actuator that moves the output pot in a direction to reduce the error. Thus, in a feedback system, the output can be made to follow the input. This type of feedback system is often referred to as a servo loop.

The GSI stable platform uses two servo loops in each axis, the gyro loop and the LVDT loop. In the gyro loop, the gyro is used as an error detector sensing the downward pull of gravity at its particular location. his is termed *earth's local gravity vector.* The gyro lines itself up with this downward pull and any difference between the gyro case and its internal reference provides an output. This output is used as an error signal to correct the platform top to earth level.

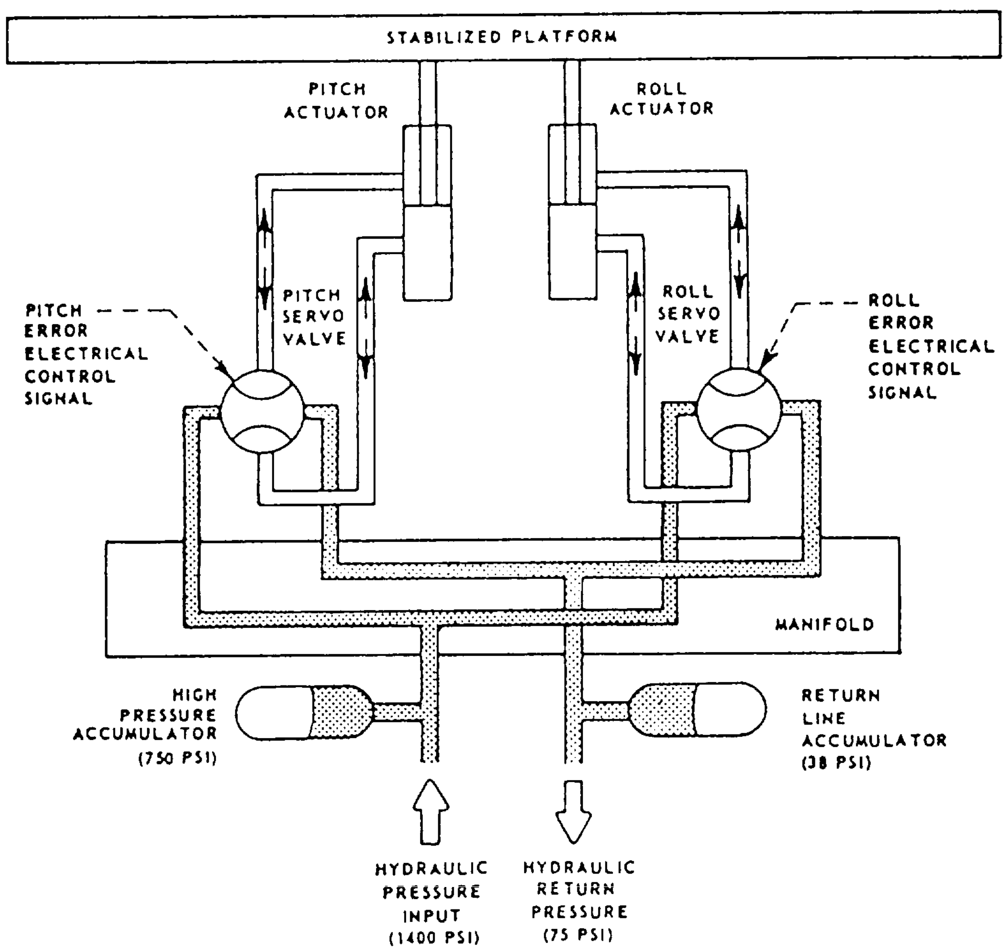


Figure 3-22.—Functional diagram of the stabilized platform assembly.

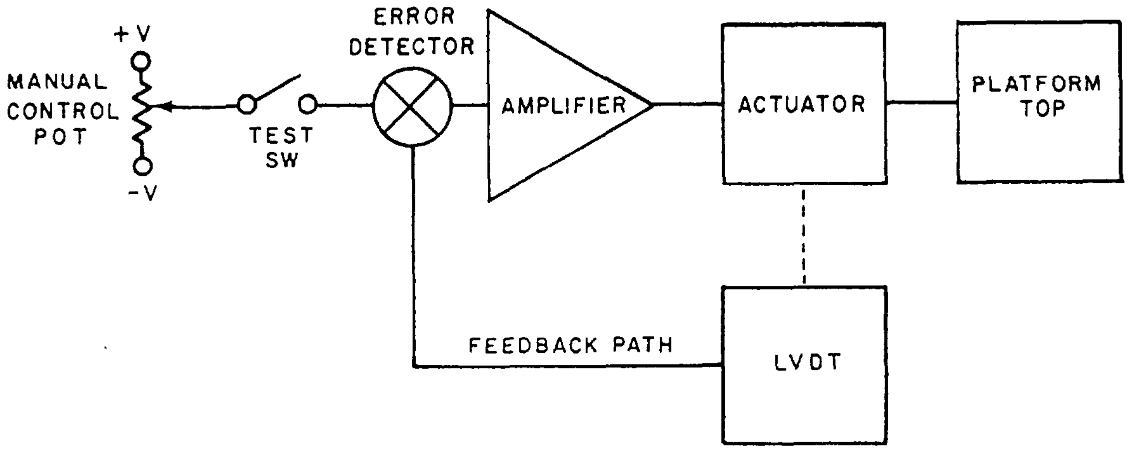


Figure 3-23.—LYDT servo loop.

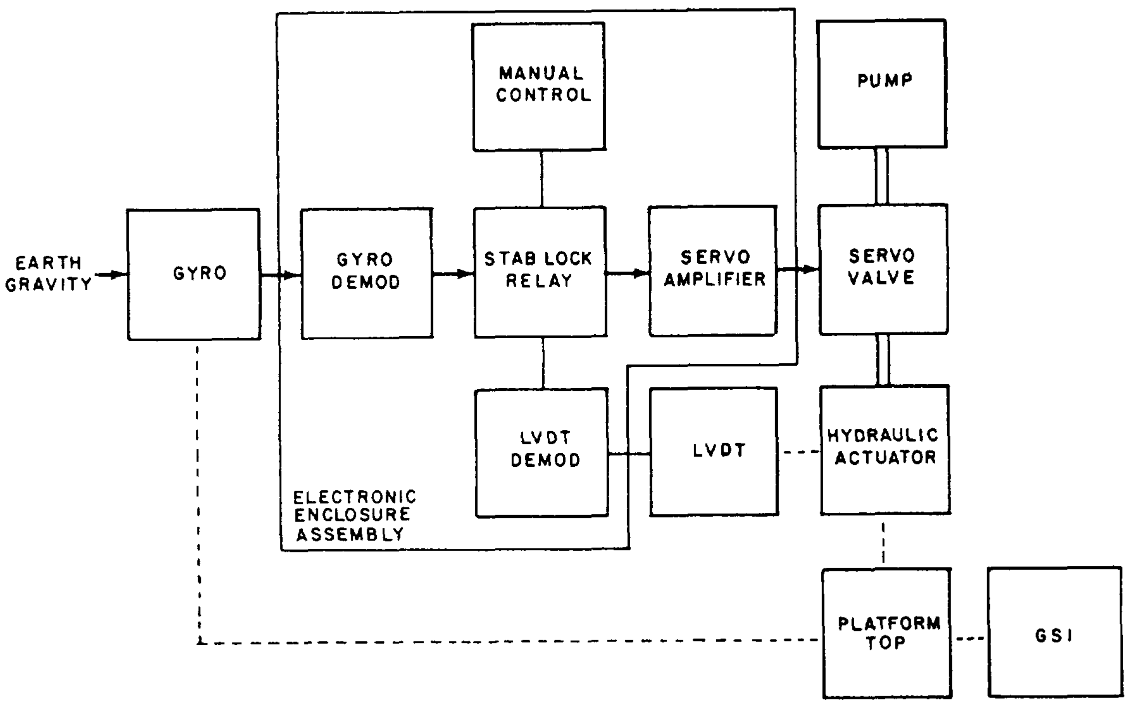


Figure 3-24.—Stabilization circuits, block diagram.

The LVDT loop is quite similar to the gyro feedback loop, only the sensor is changed Figure 3-23 shows that the LVDT is mechanically connected to the actuator to sense its position pot. The feedback signal from the LVDT is connected to the error detector. The LVDT has as its input either zero (stab-lock) or a signal from the manual position pot. With the manual position pot switched out of the circuit, the input to the error detector is zero (ground). The LVDT is adjusted so its output is zero when the platform top is level to its base, thus errors are only generated when the LVDT has an output and these are amplified and drive the output to zero.

In operation, any voltages measured in the servo loops are small and are proportional to the system error.

The complete system servo feedback loop (single channel) is shown in figure 3-24. This incorporates both the gyro and stab-lock loops and the switching between them.

Figure 3-25 shows the signal flow in the servo loop. For example, in gyro normal mode, the gyro is powered through the gyro power switch and the gyro erection amp. The gyro synchro signal is converted to dc in the gyro demodulator and goes through the stab-lock relay into the servo amplifier. The servo amplifier drives the servo valve that moves the cylinder to correct platform position. Any servo errors are compared in the error circuit and trigger the error relay if the errors are large enough. The error relay will turn on the NOT READY light and turn off the GSI light. Stab-lock mode is similar and can also be followed on figure 3-25.

OPERATIONAL AMPLIFIERS

Operational amplifiers (op-amps) are used throughout the stable platform system as amplifiers, oscillators, and comparators. To understand the different circuits, you need to have a basic understanding of op-amps. An operational amplifier is a high gain (10,000 or greater), highly stable, dc amplifier. It is used most often to perform analog computer functions such as summing and integration.

The op-amps used in this system are integrated circuit types using a configuration as shown in figure 3-26.

An op-amp is a very high gain device, whose output is the amplified difference between the inverting and noninverting inputs. If feedback is added, the op-amp will try to keep the voltage difference between the two inputs near zero.

The most common form of op-amp is the inverting amplifier, as shown in figure 3-27. With the noninverting input tied to ground, the inverting input will be close to ground and is referred to as a virtual ground. The higher the amplifier gain, the closer the point will be to ground and for all computations it is assumed to be ground. If an input voltage (V_{in}) is applied to the circuit of figure 3-27, a current will flow in R_{in}. The amplifiers will amplify and invert the current and provide an output voltage. The output voltage will cause a current to flow in RF that will exactly cancel that flowing through R_{in}. If the currents do not cancel, the difference between them will be amplified until they do.

Multiple input circuits are similar to the inverting amplifier circuit. The gain of each input is controlled by

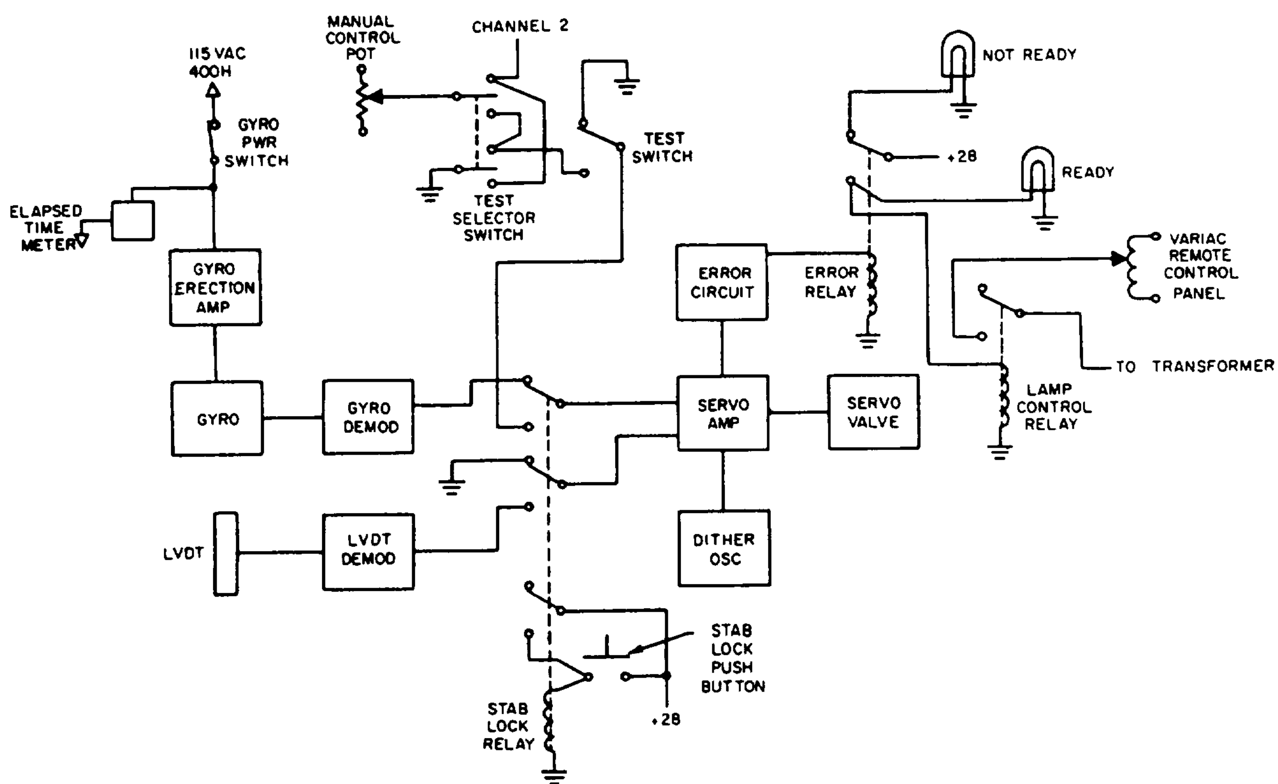


Figure 3-25.—Stabilization control-signal flow.

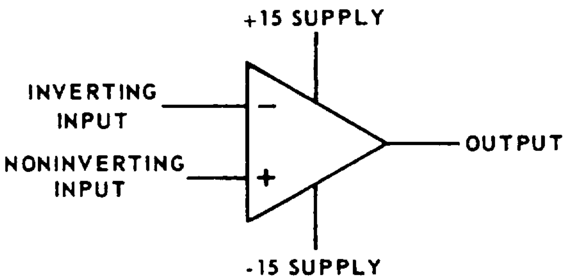


Figure 3-26.–Op-amp diagram.

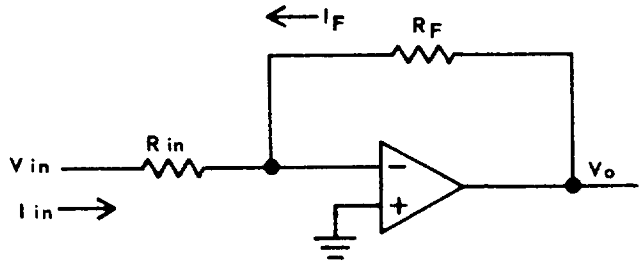


Figure 3-27.—Inverting amplifier diagram.

its input resistor and the feedback resistor with the inputs added.

No voltage greater than 15 volts should be applied to any pin of an op-amp or damage will result. The op-amps output is short-circuit protected; thus, shorting the op-amps outputs will not damage them. Op-amps exhibit three common types of failures: no output, saturated positive, and saturated negative. A saturated voltage is one that is maximum for a particular op-amp usually greater than 11 volts. Any op-amp whose output is greater than 11 volts and does not change with varying inputs may be defective. Check for large inputs and open feedback resistors before replacing the op-amp.

SYSTEM ELECTRONICS

The GSI system electronics is divided into 13 fictional areas as follows:

- Gyro demodulator
- LVDT
- LVDT demodulator card
- LVDT oscillator
- LVDT demodulator
- Servo amplifiers
- Dither oscillator
- Error circuit
- Gyro alarm circuits
- Gyro signal card
- Source light failure detector
- Power distribution circuits

Gyro Demodulator

The gyro demodulator is a nonrepairable item. The gyro demodulator receives 115-volts ac, 400-Hz reference signals from stator leads S1 and S3 of the pitch and roll synchros in the gyro. The demodulator converts the ac synchro signals to dc with the in-phase ac signal positive and the out-of-phase signal being negative. This type of demodulator is called a phase-sensitive rectifier. For an in-phase signal, the device behaves as a bridge rectifier with a capacitor falter to remove ripple.

The internal gyro synchros that feed the demodulator are excited with 26 volts ac, 400 Hz and have a maximum output between S1 and S3 of 11.8 volts ac at ±90° rotation. When the signals are demodulated by the gyro demodulator, the output is ±10 volts dc at ±90° of rotation from horizontal.

Linear Voltage Differential Transformer

The LVDT is an ac electromechanical transducer that converts physical motion into an output voltage whose amplitude and phase are proportional to position.

In operation, an ac excited primary winding is coupled to two secondary windings by a moveable core placed between them (fig. 3-28). Displacement of the

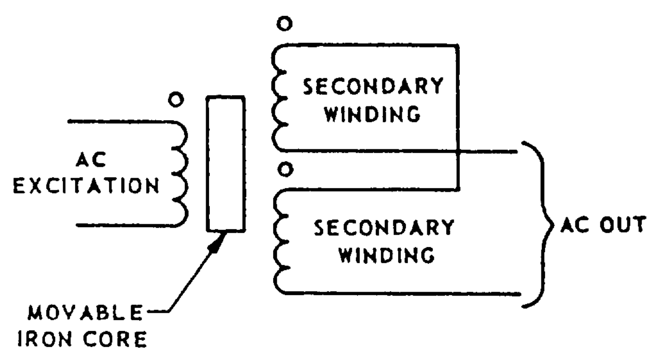


Figure 3-28.—LVDT aimplified schematic

core from its null position causes the voltage in one winding to increase, while simultaneously reducing the voltage in the other winding. The difference between the two voltages varies with linear position.

LVDT Demodulator Card

The LVDT demodulator card supplies a constant voltage ac excitation to the LVDT primaries and converts the pitch and roll LVDT amplitude and phase signals to a variable dc voltage. This is accomplished in three separate circuits: the LVDT oscillator and the pitch and roll demodulators.

LVDT Oscillator

The LVDT oscillator consists of a quadrature oscillator and a power amplifier. The quadrature oscillator is used to generate a constant-amplitude, constant-frequency sine wave. The power amplifier is a low-output-impedance driver used to power the LVDT primaries and the pitch and roll demodulator diode switches.

To understand the operation of the quadrature oscillator, assume capacitor C3 of figure 3-29 is initially charged positive. The noninverting integrator IC3-1 will charge C1 so its output goes positive. This positive voltage will cause the inverting integrator IC3-2 to charge its capacitor C2 and its output will go negative. This negative voltage will discharge C3. This will continue until C3 is charged negative and then reverse, causing the circuit to oscillate. The zener diodes clamp the output and stabilize the amplitude so the output voltage is a stable 6.5 volts ac.

LVDT Demodulator

The pitch and roll LVDT demodulator are identical except for their gains. They are called phase sensitive demodulators. The input to the demodulator is a variable-voltage, variable-phase signal from the LVDT. This signal is full-wave rectified and filtered and its output polarity is positive for signals out of phase with the reference and negative for signals in phase.

Servo Amplifiers

The pitch and roll servo amplifier circuit cards are identical except for the gains and servo compensation. Three inputs are summed into amplifier A1: LVDT,

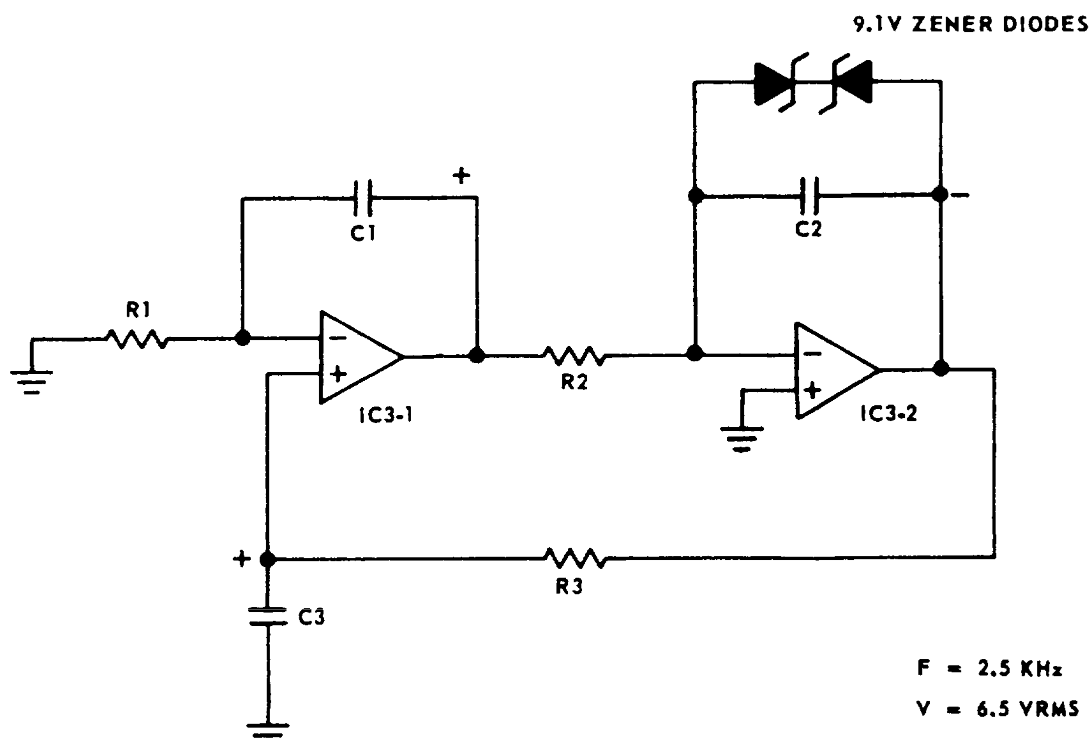


Figure 3-29.—LVDT quadrature oscillitator.

gyro/manual control, and rate gyro. In normal operation, only gyro signals are used. In stab-lock mode, the LVDT signal is the input with manual control being used for testing.

The zero adjustment on the two amplifiers are used to reduce any offsets in the amplifiers to zero. The compensator circuit (R3-C1) is used to reduce the system gain at higher frequencies. At high frequencies, the capacitor will act as a short circuit and the op-amp gain will be cut in half. Amplifier A2 is used as a voltage-to-current driver. This is necessary because the servo valve is current controlled. The current driver (A2) circuit is similar to the voltage amplifier previously described.

When a voltage is applied to the amplifier input, a current flows in the servo valve coil and through resistor R12. The current in R23 causes a voltage drop across itself. This voltage is provided as feedback to the input through R11. If 1 volts dc is applied to TP-B, a current will flow through R12 to generate 1 volt across it since $G_u =$ R11/R8 = 1.R12 is 105 ohms, so the current in R12 for 1-volt input is approximately 10 ma (fig. 3-30). The other input to A2 is from the dither oscillator and is attenuated by a voltage divider.

Dither Oscillator

The dither oscillator provides a high-frequency (compared to system response) signal to the servo valves to keep them in constant motion to prevent sticking at null.

The dither oscillator is a phase shift oscillator. It depends on the phase shifts inherent in RC networks to shift the phase of the amplifier feedback 180°. This will cause a sustained oscillation if the amplifier gain is high enough. The gain also determines the quality of the sine wave.

Resistor R5 (amplifier gain control) is adjusted until the amplifier starts oscillation and has a clean sine wave with no flattening of the tops. The zener diode acts as an upper limit for the amplitude. The relay on the dither oscillator is parallel to the stab-lock relay, which controls the rate gyro information.

Error Circuit Card

The error circuit card is used to monitor the pitch and roll servo errors. It allows monitoring of the gyro's internal pendulum reference for test purposes. Since the system is not perfect, servo errors are present. Voltages representing system errors are compared with a reference voltage that represents the maximum allowed system error. If it is exceeded the system will go from ready to not ready and turn out the GSI light. System errors existing during turn-on would trigger a false not ready light. To prevent this, a delay is included in the error circuit.

A schematic of the error circuit is shown in figure 3-31. Errors may be of either polarity; thus the op-amp A3 accept signals on both its inverting and noninverting inputs. If the servo error is positive and on the roll axis, it will pass through diode CR7 and resistor R12. This voltage will be added to the reference voltage set on pot R8. If the reference is greater than the error, the output of op-amp A3 will be positive. Its amplitude will be 3.25 times the difference of the error voltage minus one half the reference.

Servo error gain is 7.5. Capacitor C5 averages out the varying error signals so short-term errors (spikes) do not trigger errors. The output of op-amp A3 drives transistor switch Q1, which turns on the error relay. In its energized state, the error relay turns on the remote panel READY lamp and actuates the GSI lamp control relay.

The delayed start circuit is charged when the system first goes into ready. Capacitor C7 keeps the system in ready (error relay energized) for about 6 seconds to allow the system errors to settle out.

Gyro Alarm Circuits

The SGSI system incorporates an independent failure detection circuit that detects any failure that will result in a loss of stabilization. It does this by comparing an input from the ship's gyro with the output of the platform LVDT. When the system is operating correctly in the internal gyro mode, the output of the LVDTs is directly proportional to the ship's motion. If the ship's motion from the LVDTs is out of phase (reverse polarity) to the ship motion from the ship's gyro, the two will cancel. Any voltage left over from the summation will be the error between the ship gyro and the platform. The error is compared against a preset limit, and if it exceeds this limit the platform error relay is tripped. The ship gyro input is required for the gyro alarm and is also used for ship gyro stabilization and for the rate lead. The rate lead circuits are used to reduce velocity lag of the platform and increase system dynamic accuracy. In the ship gyro stabilization mode, the system operates at a reduced accuracy due to null errors and LVDT linearity error. Therefore, the ship gyro mode is to be used as a backup mode only.

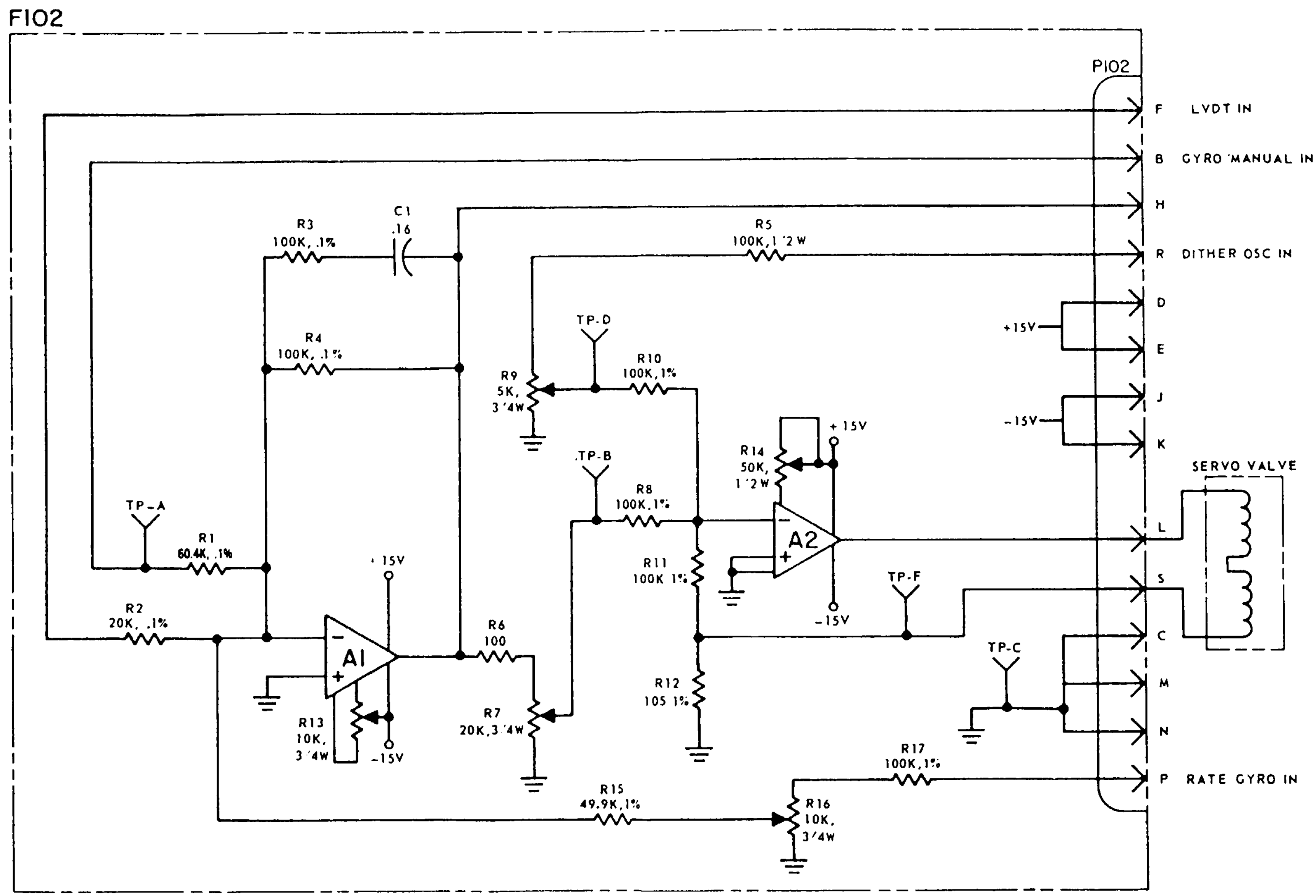


Figure 3-30.–Pitch servo amplifier card assembly (F102), schematic diagram.

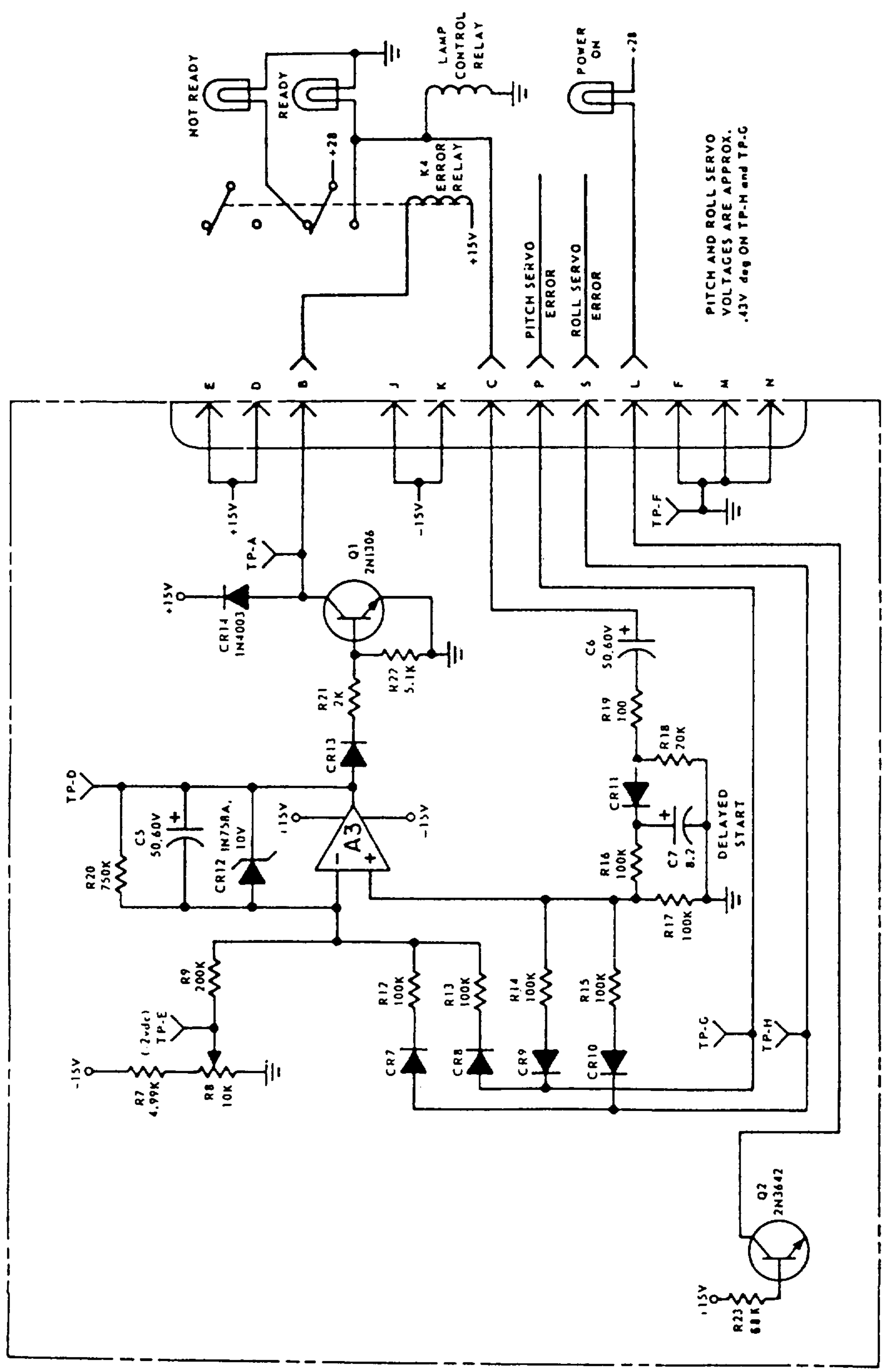


Figure 3-31.–Error circuit, schematic diagram.

A simplified signal flow diagram of the gyro alarm circuits is shown in figure 3-32. The switches are shown in the normal mode of operation; namely, internal gyro operation with the failure alarm armed The gyro alarm circuit is only tied to the system in this mode by the system supplies and the error relay. In operation, the ship gyro signal is converted to a dc signal in the linear synchro to dc converter (F110/F111). This signal goes through the ship gyro stab-lock switch, is amplified in the F106 card and is summed with a scaled voltage from the platform LVDTs and an offset voltage that makes up for alignment differences between the ship gyro and the platform base. This summed signal (error voltage) is applied to the F110/F111 card, full-wave rectified, faltered and compared against a preset threshold. If the error voltage exceeds the preset threshold, the comparator trips and removes the +15 volts from the error relay. This turns off the SGSI cell and gives a not ready indication at the remote panel. The comparators on the F110/F111 cards are electrically latching relays. If the error is removed, these relays can be reset by pushing the gyro alarm reset button to remove latching voltage.

The gyro alarm failure alarm circuit can be disabled by pushing the gyro alarm OFF push button. This supplies +15 volts dc to one side of the error relay and effectively disconnects the gyro failure alarm circuits. In addition an interlock circuit prevents unwanted platform oscillation when the alarm circuit is not actuated.

Gyro Demodulator Board

The gyro demodulator board contains a synchro to dc converter and a gyro error detector circuit. The F110 and F111 are identical cards: one is used in the pitch channel and the other in roll. The synchro to dc converter is a sealed module not repairable by shipboard personnel.

Gyro Error Detector Circuit

The gyro error detector circuit consists of a precision N-wave rectifier, a filter, a voltage comparator, a transistor, and a relay. The input signal to this card is the summation of the ship's gyro and the platform LVDTs.

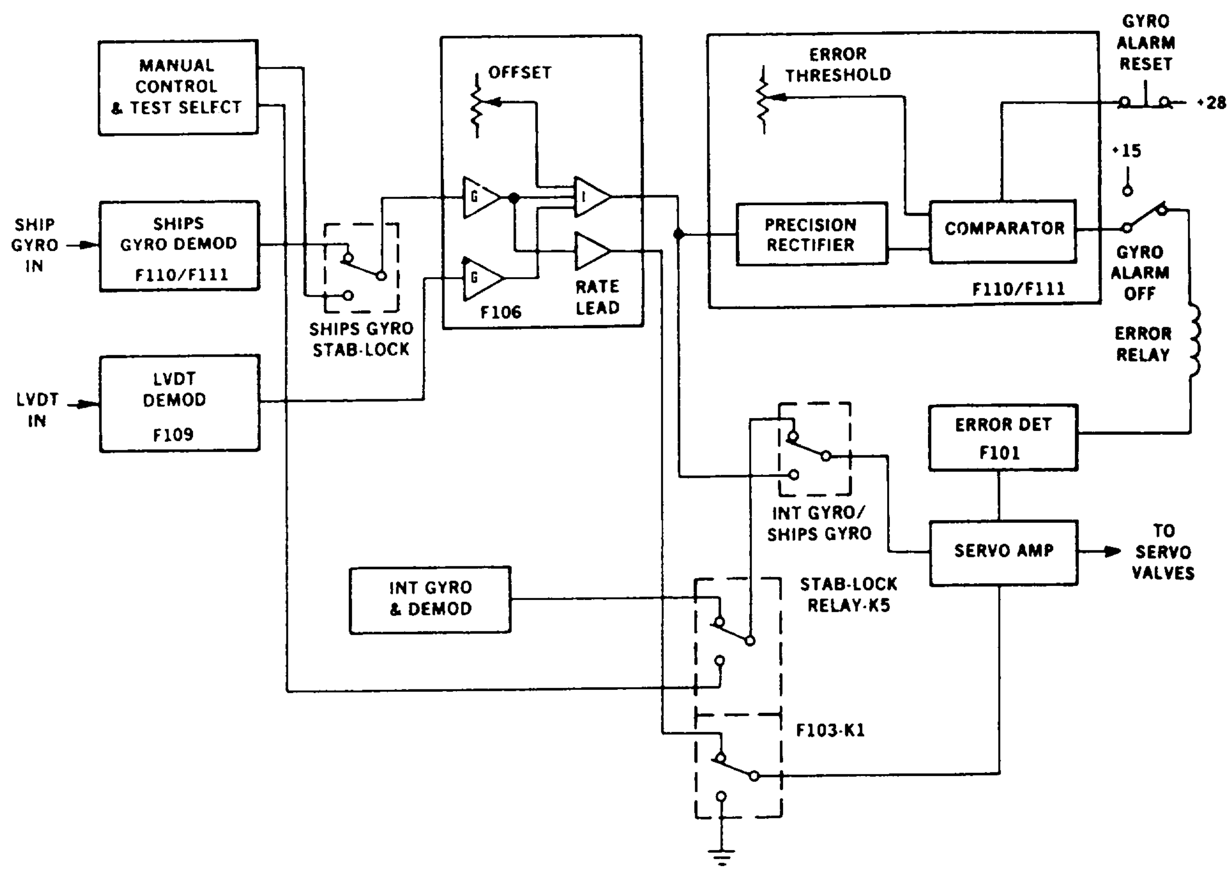


Figure 3-32.—Cyro alarm circuits—signal flow.

Gyro Signal Card Assembly

The gyro signal card (F106) amplifies and sums the demodulated pitch and roll synchro signals from the ship's gyro with the platform LVDT outputs. It also provides offset adjustments to make up for any difference in alignment between the ship's gyro and platform. In addition, rate lead signals are derived by differentiating the ship gyro signals.

Source Light Failure Detector

The source light failure detector is a circuit that monitors the voltage and current going to the three source lights. When one or more of the source lamps fail, the source light failure indicator on the remote panel is illuminated

Power Distribution Circuits

The system requires two power sources from the ship 440-volts ac, 60-Hz, 2.7-amp power for the pump and 115-volts ac, 60-HZ, 15-amp power for the rest of the system. In standby (system circuit breaker on), the system heaters and standby lights are on. When the POWER ON push buttons are depressed, the internal power supplies are energized except for the ±15 volts dc. The ±15 volts dc supply is energized after the time delay relay has timed out, the hydraulic pump is running, and system hydraulic pressure is normal. Then, the hydraulic pressure switch is actuated.

HYDRAULIC COMPONENTS

The SGSI system uses hydraulic pressure for motive power. A constant-pressure, variable-delivery hydraulic pump supplies hydraulic pressure. Pressure fluctuations are dampened by accumulators. The fluid is gaited by servo valves into either side of the hydraulic cylinders. The fluid pressure then causes the cylinders to move the platform.

The hydraulic system is sensitive to dirt and other contaminants. Therefore, care must be used when adding fluid or opening any part of the hydraulic system.

Refer to the hydraulic pump assembly shown in figure 3-9 when studying the following paragraphs.

Hydraulic Accumulator

The hydraulic accumulators used in this system are steel cylinders with internal rubber bladders. Before putting the accumulators in service, the bladders are pressurized with dry nitrogen to 700 psig for the high--pressure accumulator and 38 psig for the low-pressure accumulator.

When hydraulic pressure is applied, the accumulator falls with fluid and the bladder is compressed until the dry nitrogen charge pressure equals that of the hydraulic system. In this system, it is 1400 psig. Because of the bladder compression, the accumulator will absorb pressure fluctuations and prevent hydraulic hammer. If the system momentarily requires a higher flow than the pump will supply, the accumulator will provide it and be recharged when the demand has passed.

Hydraulic Cylinder

The hydraulic cylinders used in this system are linear actuators. Hydraulic fluid gaited by the servo valve will push the piston in either direction. The hydraulic pressure exerted by the piston is 1400 psig in extension and 700 psig in compression. Extreme care must be exercised when working on the system due to the amount of force available.

The cylinder is an inherently reliable device requiring little maintenance in normal use. However, the only required maintenance is cleaning dirt and grit off the actuator rod and tightening the packing gland nut if a leak develops. Do not overtighten the gland nut or the packing will bind on the rod, causing the cylinder to chatter in operation. If cylinder replacement becomes necessary, the defective cylinder must be returned through supply charnels for overhaul.

System low-amplitude vibration, or chatter in some cases, may be traceable to cylinder internal binding; in which case the cylinder should be replaced.

Servo Valve

Servo valves are commonly used in closed-loop servo systems. They control the flow of fluid to or from the load actuator in proportion to the impact current signal to the valves' torque motor.

Hydraulic Pump

The hydraulic pump used in this system is a constant-pressure, variable-delivery pump. It is similar to a constant voltage source in which current will vary upon demand. Referring to figure 3-9, hydraulic fluid is gravity fed from the reservoir to the pump unit through the pump case fill piping to ensure that the pump case is full at all times, thus keeping air out of the line. The motor-driven pump draws fluid through a suction strainer, located in the reservoir, into the pump where it is pressurized to 1400 psi and applied to the hydraulic pressure line. A fluid flow filter removes solid impurities greater than 3 microns in size. In the event the filter becomes clogged, it is bypassed. The filter output then flows past the pressure gauge, the pressure switch, and the bypass valve. The pressure gauge should indicate 1400 psi in normal operation, and the pressure switch should be closed for pressures above 1200 psi. The bypass valve is normally closed and will open only if the pressure exceeds 1800 psi.

If the pump is operating normally, the bypass valve will be closed and the fluid will flow through the check valve and out the gate valve to the system. The check valve is a one-way valve. The fluid returning from the system flows through the return gate valve and check valve into the reservoir. The return check valve only allows fluid to flow in one direction and requires 75 psi of pressure before it will open. This maintains the return line pressure at 75 psi.

For the pump, heater, and overtemperature switch to operate properly, the fluid reservoir must be properly filled. Too little fluid may actually cause the pump to overheat.

Pump Motor Contactor

The motor controller usually has 440 volts ac applied to it. The pump is actuated by applying 115 volts ac to the motor controller relay. The pump motor is protected by thermal overloads, located in the motor controller. A thermal overload is a relay that is actuated by heat. Motor current flows through a low-value resists, generating a small amount of heat. If the current increases beyond a specified value (3.7 amps), the heat generated will melt a solder bond on a ratchet wheel, which holds back a spring-loaded relay. This will cut the pump power by opening the circuit to the motor control relay. The thermal relay should then be allowed to cool before pushing the reset button on the pump controller.

The pump motor is factory wired for 440-volts ac operation and should not be changed as the motor controller current limits are set for 440-volts ac operation.

Hydraulic Fluid Heater

The fluid heater is a 175-watt immersion-type heater. The fluid must be kept at approximately 70°F or greater to prevent it from becoming too viscous and causing servo errors. The heater is a Calrod type with a built-in thermostat. The thermostat is normally factory set but may be adjusted if necessary. To adjust the heater, unscrew the cover plate by turning counterclockwise and use the internal screwdriver adjustment to set the temperature. It will take about a half hour for the temperature to stabilize.

Overtemperature Switch

The overtemperature switch is a mechanically adjustable immersion-type thermoswitch. It is used to indicate overheating of the pump oil. It does not indicate a direct failure. In a warm environment of approximately 85°F the oil temperature will be about 120°F. An increase in oil temperature will most likely be due to increased fluid viscosity or a clogged pump falter. If this is the case, the pump should be drained and flushed with warm water, and the fluid and filter replaced.

The overtemperature switch is adjusted by prying the cap off the protruding stem and inserting a screwdriver in the stem.

Hydraulic Pressure Switch

The hydraulic pressure switch is a single-pole, double- throw, pressure-actuated switch. It is used to turn on the system electronics when there is enough pressure to stabilize the system. It is normally set to actuate at 1200 psi.

The pressure switch is adjusted by turning the label until the inner body is exposed. It can be turned with a screwdriver or other instrument inserted in the inner body holes. The pressure switch setting is decreased by turning the inner body counterclockwise as viewed from the connector end.

The hydraulic pressure switch is a nonrepairable item that must be replaced if it is not operating properly.

CHAPTER 4

TECHNICAL ADMINISTRATION

CHAPTER LEARNING OBJECTIVES

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

- *Describe the system used for equipment calibration.*
- *Identify the calibration echelons established for calibrating equipment.*
- *Describe the Metrology Automated System for Uniform Recall and Reporting (MEASURE) program.*
- *Recognize the procedure to follow for requesting calibration of equipment.*
- *Describe the different calibration statuses of equipment.*
- *Describe the procedures in updating equipment calibration schedules.*
- *Recognize the procedures used to instruct IC watch standers.*

As an IC Electrician Second Class, your administrative responsibilities will include updating various forms and schedules concerning equipment calibration. You will also be responsible for instructing your personnel on IC watch standing. This will include ensuring that your personnel are informed of safety precautions and procedures to follow when they are standing the various IC watches. Therefore, this chapter will give you some background on the Navy Metrology and Calibration (METCAL) program, the Metrology Automated System for Uniform Recall and Reporting (MEASURE) program, and IC watch standing, which will include electrical safety.

THE NAVY METROLOGY AND CALIBRATION PROGRAM

Metrology is the science and art of measurement for the determination of conformance to technical requirements. It includes the development of standards and systems for absolute and relative measurements. Although measurement methods have changed considerably since ancient times, the basic concept of using calibration to maintain the accuracy of tools and measuring devices to manufacture quality products and maintain quality performance has not changed.

Calibration assures us that our weapon systems are working right and that the parts obtained from different manufacturers will fit together as they should. The success of our Navy depends on the use of accurate and reliable measuring instruments, and the best way to assure continued accuracy is by periodic calibration performed by skilled technicians.

The increased complexity of ship systems (especially weapons, propulsion, and navigation) has made it necessary to improve the quality and accuracy of measurements. Problems existed in measurements because the measurements of one activity did not agree with those of another activity even though identical items were being measured. In such cases, there was a tendency to “write off” the discrepancies as variations in the measuring instrument. But, in fact, most of any discrepancy was due to the lack of standardized measurements. It was the purpose of standardizing instrument measurements that the Navy METCAL program was established. This program emphasizes the need to complete measurement standardization throughout the Navy.

The Navy has established the METCAL program to ensure traceability and accuracy of instrument calibration to the National Institute of Standards and Technology (NIST). To operating personnel, this means that any instrument used aboard ship for quantitative measurement must be calibrated and that the standards used are more accurate than the shipboard instruments. The accuracy of a standard must be traceable, through documentation by each higher calibration activity, to the

NIST. Each instrument calibrated (including standards) must bear evidence that it is in calibration. This evidence is in the form of a calibration label affixed to the instrument. This label provides the date and place of calibration and the next due date for calibration. The METCAL program provides for periodic calibration of most instruments. The responsibility for assignment of these periodic calibration intervals has been given to the Metrology Engineering Center (MEC).

The calibration of all measuring devices is based on, and is dependent upon, the basic international and national standards of measurement. Since we cannot rush off to the NIST every time we need to measure a length, a mass, a weight, or an interval of time, the NIST prepares and issues a great many practical standards that can be used by government and industry to calibrate their instruments. Government and industry, in turn, prepare their own practical standards, which are applicable to their own requirements. Thus, there is a continuous linkage of measurement standards that begins with the international standards, comes down through the national standards, and works all the way down to the rulers, weights, clocks, gauges, and other devices that we use for everyday measurement.

For further information and detailed assignment of the METCAL program, refer to NAVMAT Instruction 4355.67.

CALIBRATION TERMS AND DEFINITIONS

Before proceeding, it is necessary for us to discuss some of the commonly used terms associated with the instrument calibration program used by the Navy. It is important that you understand the meaning of these terms and use them correctly. Many of these terms will be used throughout this text. Other very important terms are listed in the glossary, appendix II. Refer to it as often as necessary.

CALIBRATION

Calibration is the act of comparing a measurement system or device of unverified accuracy to a measurement system or device of known and greater accuracy to detect and correct any variation from required performance specifications.

The calibration process involves the use of approved instrument calibration procedures (ICPs). It includes any adjustments or incidental repairs that are necessary to bring a standard or an instrument being calibrated within specified limits.

STANDARD

A standard is a laboratory-type device that is used to maintain continuity of value in the units of measurement. Its accuracy is ensured through periodic comparison with higher echelon or national standards. A standard may be used either to calibrate a standard of lesser accuracy or to calibrate test and measurement equipment directly.

TRACEABILITY

Traceability is the unbroken chain of properly conducted and documented calibration of equipment from the fleet through higher echelons to the National Bureau of Standards (NBS).

TEST AND MONITORING SYSTEMS

Test and monitoring systems (TAMS) are the instruments used for all quantitative measurements except metrology standards. TAMS can also be referred to as precision measurement equipment (PME), test and measuring equipment (T&ME), or test, measuring, and diagnostic equipment (TMDE).

OPERABLE EQUIPMENT

Operable equipment is equipment that before being submitted to calibration is found by review of its performance history and by cursory electrical and physical examinations to be operational in all its required functions.

INCIDENTAL REPAIRS

Incidental repairs are those repairs found necessary during calibration of an operable equipment to bring it within its specified tolerances. These include the replacement of parts that, although worn sufficiently to prevent calibration, do not otherwise render the equipment inoperative. This repair work is normally performed incidental to the calibration of standards.

TRACEABILITY OF STANDARDS

The U.S. Department of Commerce, National Institute of Standards and Technology, located at Gaithersburg, Maryland, is the focal point in the federal government for maintaining and advancing standards and technology for the physical and engineering sciences. NIST provides the common reference for Navy scientific measurements and certifies the standards used by the type I Navy Standards Laboratory (NSL). Figure 4-1 is a flow chart of the traceability of test measuring and diagnostic equipment.

TYPE I NAVY STANDARDS LABORATORY

The type I NSL is located at the Western Standards Laboratory, Naval Air Rework Facility, North Island, San Diego, California. A detachment is located at the Naval Station, Navy Yard Annex, Washington, D.C. The operation of the laboratory and its detachment is under the cognizance of the Naval Air Systems Command. The NSL maintains and disseminates the most accurate units of measurement within the Navy METCAL program and obtains calibration services from and maintains traceability to the NIST. In performing its functions, the NSL provides services for the systems commands, cognizant laboratories, and project managers.

TYPE II NAVY STANDARDS LABORATORIES AND REFERENCE STANDARDS LABORATORIES

Type II NSLs and reference standards laboratories (RSLs) provide the second highest echelon of calibration services within the Navy. Type II NSLs obtain standards calibration services from type I NSLs and calibrate standards from lower echelon laboratories. RSLs are similar in capability and operation to the type II NSLs. In addition, shipyard RSLs provide calibration support for mechanical instrumentation.

NAVY CALIBRATION LABORATORIES (SHORE)

Navy calibration laboratories (NCLs) obtain calibration services from higher echelon laboratories. The capabilities of these laboratories vary. Their mission is twofold: (1) to maintain standards of measurement within the activity, and (2) to calibrate and repair standards and to calibrate and accomplish incidental repair on fleet and shore activity test and measuring equipment.

MECHANICAL INSTRUMENT REPAIR AND CALIBRATION SHOPS

Mechanical instrument repair and calibration shops (MIRCS) are located on board tenders (other than FBM), repair ships, and specified shore activities. Their function is to calibrate and repair mechanical and electromechanical measuring devices installed aboard ships and submarines. Standards used by MIRCs are submitted to a higher echelon laboratory for calibration.

FLEET MECHANICAL CALIBRATION LABORATORIES

Fleet mechanical calibration laboratories (FMCLs) are on board FBM submarine tenders to provide calibration services for FBM submarine mechanical, test, and measurement equipment. Standards from these laboratories arc submitted to higher echelon laboratories

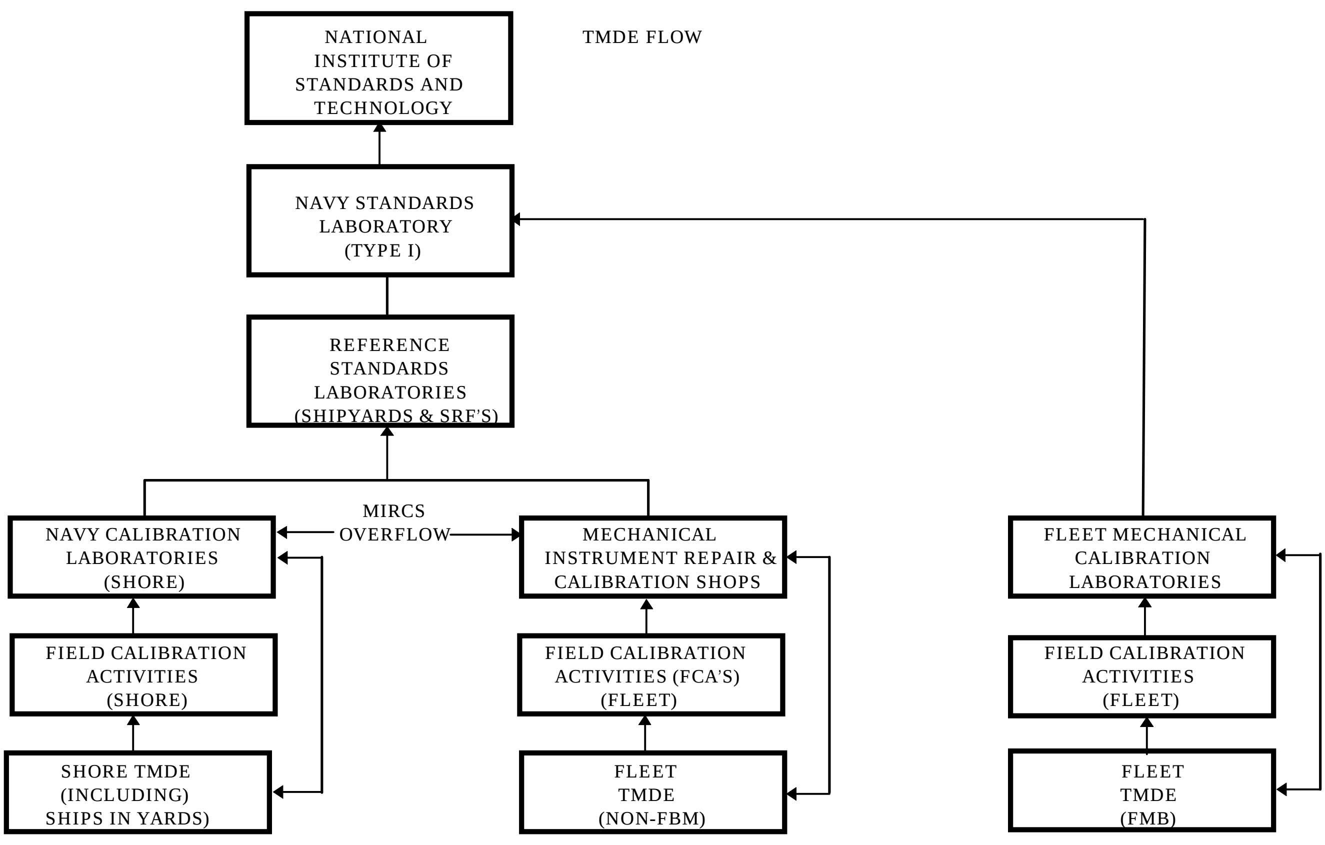


Figure 4-1.—Test measuring and diagnostic equipment traceability flow chart.

for calibration. The FMCLs are operated by IM personnel with an 1821 NEC. The basic difference between the MIRCs and the FMCL is that the FMCL has the additional capability for optical calibration.

FIELD CALIBRATION ACTIVITIES

Navy field calibration activities (FCAs) make up the next lower echelon. These activities have been set up to enable user activities to calibrate locally such specific types of instruments as pressure gauges, temperature gauges, and electrical meters, rather than send them to a laboratory. Calibration is performed by specially trained personnel. Most ships in the fleet have designated FCAs.

SUPPORT FOR CALIBRATION STANDARDS

To receive calibration support for standards, you should take the following steps:

1. Request funds from the type commander.

2. Request calibration services, by official message, from the supporting laboratory.

3. Makeup a recalibration schedule with the help of the supporting laboratory. This schedule will minimize the delay in getting your standards recalibrated and back in service.

METROLOGY AUTOMATED SYSTEM FOR UNIFORM RECALL AND REPORTING

In an effort to ensure that all equipment requiring calibration and/or servicing is maintained at maximum dependability, the Chief of Naval Material implemented the MEASURE program. It is the Navy's single data reporting system for the TAMs and the Navy METCAL program.

As an IC Electrician Second Class, you will be required to update calibration schedules. Therefore, you should have a thorough understanding of the MEASURE program and be familiar with the forms and reports used with this system. You will be required to check documents for completeness and accuracy and to assist customers in the completion of these documents. Information on how to use this program effectively and how to complete the necessary documents accurately is provided in the latest edition of the *Measure Users Manual*, OP43P6.

Several documents are used to update the database of the MEASURE system. These documents will be discussed in the following paragraphs.

The MEASURE system is a tool for your use. It is only as good as the information that is put into it. It is important that all information be thoroughly legible, accurate, and consistent.

INVENTORY REPORT FORMS

The MEASURE Test Measuring and Diagnostic Equipment (TMDE) Inventory Report Form and the MEASURE Calibration Standards Inventory Report Form provide the initial input of data pertaining to TAMS equipment and calibration. This information, when stored in a computer, establishes a data base for all MEASURE forms and reports.

NOTE: Since computers cannot think, completeness and accuracy of information is essential to make the program effective.

Inventory report forms are submitted to an intermediate level activity of FCA for screening. This activity determines whether or not it has the capabilities for the calibration of the equipment listed in the inventory. Items that are outside the capability of this activity are noted on the inventory report form. The report forms are forwarded to a METCAL representative for validation. They are then forwarded to the MEASURE Operational Control Center (MOCC) in Concord, California, and are entered into the data bank. The customer is provided with an automated inventory and a set of preprinted METER cards.

Normally, the inventory forms are only used for the initial input of data. However, if 10 or more items are to be added to the inventory, an appropriate inventory report form can be used. This form is prepared in the same manner as the initial inventory report except that the words *Add-On-Inventory* are entered above the customer activity code block at the top center of the form.

METER CARD

The METER card (fig. 4-2) is a five-part, color-coded form to which the equipment identification (ID) and receipt tag is attached. It is filled out by either the customer or the calibrating activity and is used to report information and transactions pertaining to TAMS and calibration standards.

The METER card, either preprinted by the MOCC or handprinted by the customer activity, contains all

MODEL/PART NO. (1)	PART OF: (2)	MFR. CODE (3)	SERIAL NUMBER (4)	CUSTOMER ACTY (5)	SUB CUSTODIAN (6)	SCHEDULED LAB CODE (7)	U/C (8)	ITEM CONTROL NO (9) SN 2597
MODEL/PART NO. (CHANGE) (1A)	PART OF: (CHANGE) (2A)	MFR. CODE (CHANGE) (3A)	SERIAL NUMBER (CHANGE) (4A)	CUSTOMER ACTY (CHANGE) (5A)	SUB CUSTODIAN (CHANGE) (6A)	LAB CODE (CHANGE) (7A)	EQUIPMENT CONTROL NO (10)	

NOMENCLATURE (11)	SUB CATEGORY CODE (12)	NATIONAL STOCK NUMBER (13)	PLANT ACCOUNT NO (14)	QTY. (15)	SERVICING ON SITE (16)	DATE LAST SVCD (17) MO DAY YR	CALIBRATION DUE (18) MO DAY YR

INVENTORY/RECALL INSTRUCTIONS (19)		MO.	DAY	YR.
1				
2	RESCHEDULE DATE TO:			
3	ADD TO INVENTORY			
4	TRANSFER CUSTODY TO: ACTIVITY IN BLOCK 5A			
5	DELETE FROM INVENTORY			
6				
7	RECORD MAN HOURS ONLY			

REMARKS (20)

FOR LABORATORY USE ONLY

SERVICING LAB CODE (21)	SHOP NO. (22)	DATE RECEIVED (23) MO DAY YR
		DATE INDUCTED (23A) MO DAY YR
LAB TYPE (24)	VALUE IF FIXED STD (25)	DATE COMPLETED (26) MO DAY YR
STANDARD HOURS (27)	METRL CYCLE (28)	NEXT DUE DATE (29) MO DAY YR
CLASS STD (36)	APPROVED PROCEDURE (37)	
PHASE/LEVEL (38)	PROCEDURE USED (39)	
MAN HOUR CALIB (40)	CALIB JOB ORDER NO (41)	
MAN HOUR REPAIR (42)	REPAIR JOB ORDER NO (43)	
MODIF HOURS (44)	SEB NUMBER (45)	
GSE REWORK NO (46)	SEC NUMBER (47)	
1ST TECHNICIAN (48)	2ND TECHNICIAN (49)	SUPERVISOR (50)

ENTER OUT OF TOLERANCE VALUES ONLY

PROCEDURE STEP NUMBER (30)	FUNCTION TESTED (31)	NOMINAL VALUE (32)	FIRST MEAS VALUE (33)	LOWER TOLERANCE (34)	UPPER TOLERANCE (35)

PARTS REPLACED

CIRCUIT SYMBOL (51)	PART NUMBER (52)	MFR CODE (53)	NATIONAL STOCK NUMBER (54)	COST OF PART (55)	QTY (56)	TO AWAITING PARTS (57) MO DAY YR	OFF AWAITING PARTS (58) MO DAY YR

SERVICING LABEL ATTACHED (59)		TYPE OF EQUIPMENT (60)	
1	CALIBRATED	1	ELECTRONIC
2	SPECIAL CALIBRATION	2	COAXIAL/MICROWAVE
3	REJECTED	3	OPTICAL/DIMENSIONAL
4	CALIBRATION NOT REQ	4	PHYSICAL/MECHANICAL
5	INACTIVE	5	ELECTRICAL
6	REPAIR (NO LABEL)	6	SPECIAL SUPPORT

CONDITION RECEIVED (61)		DELAY STATUS (62)	
1	IN TOLERANCE	1	PARTS
2	OUT OF TOLERANCE	2	TECH DATA
3	OPER FAIL/IN OP	3	STANDARDS
4	DAMAGED	4	PERSONNEL
EQUIPMENT STATUS (63)		5	ACCESSORIES
1	COND BEYOND ECON REPAIR	6	BACKLOG
2	RET'D TO CUSTOMER UNCALIBRATED	7	OTHER

METROLOGY EQUIPMENT RECALL AND REPORT
OPNAV FORM 4790 / 58 (07 / 74) METER CARD

REQUEST REPLY FROM: ☐ MEC POMONA ☐ NASCR PAC ☐ NASCR LANT (64)

☐ (65) CAL LAB STANDARD

DPF COPY

Figure 4-2.—Metrology Equipment Recall and Report Meter Card.

information necessary to identify a single piece of TAMS equipment and to update the data base.

This card is used to record a calibration action, to add or delete equipment in the inventory, to reschedule equipment for calibration at other than the prescribed time, to transfer custody of equipment from one activity to another, or strictly to record man-hours for a completed calibration.

The white copy of the completed METER card is forwarded to the MOCC where the information is keypunched into a computer to update the MEASURE data base. The new information is then printed on another METER card and sent to the customer activity to be used the next time another transaction is to be completed.

Accurate data, completeness, and legibility in filling out the METER card are essential.

EQUIPMENT IDENTIFICATION AND RECEIPT TAG

The receipt and identification tag, attached to the METER card, bears the same control number as the METER card. Like the METER card, it is a five-part, color-coded form.

Blocks A, B, C, D, and E of this form contain the same information that is contained in blocks 1, 3, 4, 9, and 11 of the METER card. This information is used to identify the equipment being calibrated. Both block T of the ID tag and block 5 of the METER card identify the customer; however, this information is abbreviated on the METER card.

One copy of the ID tag is given to the customer as a receipt. The other four copies are kept by the calibrating facility. Unlike the METER card, no part of the ID tag is sent to the MOCC. The MOCC automatically enters this information when it preprints the METER card.

MEASURE REFERRAL CARD

The MEASURE referral card is used to forward questions, recommendations, and comments pertaining to MEASURE to concerned authorities. Instructions regarding the preparation of the referral card are found in the *Measure Users Manual*.

CALIBRATION CATEGORIES

When you are updating equipment calibration schedules, you need to know the calibration status of the equipment. Every item should have a label affixed to it that indicates the calibration status of that item. All labels must be attached in a conspicuous place, so as to be readily seen by all interested persons, and all tags must remain attached to the instruments as long as the information on the tag is pertinent.

In the following sections we will discuss the labels and the tags, and the criteria for their use.

CALIBRATED

This label (black lettering, white background), which comes in three different sizes, is the most commonly used label in the METCAL program. It indicates that an instrument is within its applicable tolerance on all parameters.

CALIBRATED - REFER TO REPORT

This label (red lettering, white background), which comes in two sizes, is used when actual measurement values and associated uncertainties must be known for the instrument to be used.

SPECIAL CALIBRATION

There are two Special Calibration labels (black lettering, yellow background). They differ in size and content. There is also a Special Calibration tag that is used with the smaller of the two labels. The Special Calibration label is used when some unusual or special condition in the calibration should be known to the user and/or the calibrator. These special conditions may be deviations from usual calibration tolerances, multiple calibration intervals, or requirements for in-place calibration. All conditions requiring special calibration are described either directly on the large label, or on the tag, when the small label is used. The following information amplifies these special calibrations.

USER CALIBRATION

Some TAMS may be calibrated by the user and the instrument does not need to be sent to a calibration facility. For example, some instruments are provided with their own standards and must be calibrated either each time they are used or very frequently. Some instruments, such as oscillographic recorders, may require calibration before, during, and after each use. Some automatic test equipments require self-calibration tests to be performed each time they are used. Still other instruments are calibrated as part of checkout procedures performed daily or weekly. The requirement for calibration by the user and the calibration interval (each Use, daily, weekly, every 100 hours, each overhaul, and so on) is indicated in the METRL. The User Calibration label (black lettering, white background) must be used when the calibration is performed by the user. This label is not replaced at each calibration. When the label is first affixed to the instrument, a notation is made about the appropriate calibration interval. Records of calibrations performed, when other than each time used, are maintained in conformance with normal maintenance practices; that is, maintenance log and maintenance action form.

INACTIVE

If an individual instrument due for recalibration is not expected to be used for some time in the future, recalibration may be indefinitely postponed by affixing an Inactive label (green lettering, white background) to the instrument. The Inactive label must remain on the instrument until the instrument is recalibrated, and the instrument will NOT be used while bearing the Inactive label. It must be calibrated before it can be used.

CALIBRATION NOT REQUIRED

Standards and TAMS not requiring calibration are shown as NCR in the METRL. The No Calibration Required label (orange lettering, white background) is affixed to and should remain on the instrument until its calibration requirements change. When an instrument is not listed in the METRL as NCR, the following criteria must be used for placing the instrument in the No Calibration Required category:

1. The instrument does not make quantitative measurements nor does it provide quantified outputs.

2. The device is “fail-safe” in that any operation beyond specified tolerances will be apparent to the user.

3. All measurement/stimulus circuits are either monitored by calibrated instruments during their use or are dependent on external, known or calibrated, sources for performance within required limits.

When it is determined that an instrument falls into the Calibration Not Required category, the label is annotated as to the authority on which the decision was based, such as METRL, technical manual, letter, or message from higher authority. In the case of instruments that normally require periodic calibration but are not used to perform quantitative measurements, the label should bear the notation “Not used for quantitative measurements.”

REJECTED

In the event an instrument fails to meet the acceptance criteria during calibration and cannot be adequately repaired, a Rejected label (black lettering, red background) must be placed on the instrument. All other servicing labels must be removed. In addition to the Rejected label, a Rejected tag giving the reason for rejection and any other pertinent information is affixed to the instrument. The Rejected label and tag remain on the instrument until it is repaired and recalibrated. The instrument MUST NOT be used while bearing a Rejected label.

CALIBRATION VOID IF SEAL BROKEN

This label (black lettering, white background) is placed over readily accessible (usually exterior) adjustments to prevent tampering by the user when such tampering could affect the calibration. The label must not cover any adjustments or controls that are part of the normal use and operation of the instrument. This label is also used to prevent removal and/or interchange of plug-in modules, subassemblies, and so on, when such removal or interchange can affect the calibration.

WATCH STANDING

Shipboard personnel stand a variety of watches, all important to the ship and to the ship’s company. In particular, your personnel stand the IC and gyro room, telephone switchboard, damage control central, and sounding and security watches. The IC and gyro room watch is long and usually uneventful until a gyro alarm sounds or until the electrical supply is shifted. At this time, the person on watch must be alert. There are always minor repairs needed, such as to sound-powered telephones, which can be used to keep the person alert, but “skylarking” should be outlawed. The telephone switchboard operator should be well indoctrinated, and then periodically checked to make sure he/she is rendering good service to the ship. Personal calls require specific permission, and your operator should require adherence to regulations in this regard. The damage control central and sounding and security watches are independent watches and are under limited supervision.

You should make sure your personnel are performing their watch standing duties properly and alertly. When problems occur, take immediate action. Only through careful counseling, adequate instructions, and periodic checks can you assure the watch standing of your personnel.

The usual means of training watch standers is by an apprentice program where the person stands watches under instruction and supervision until he/she is qualified to do the job on his/her own. Whether or not the person is qualified depends on the judgment of the person assigned to instruct and supervise him/her. This system is not always dependable for the following reasons:

1. The person in training may learn bad practices as well as good from the instructor. This problem can be partially remedied by rotating the person's watch so he/she receives indoctrination from more than one watch stander.

2. A person can stand numerous watches without experiencing a casualty, and without being exposed, through simulation, to all the possible casualties the watch stander may experience.

By recognizing the potential for these problems you can compensate for them by preparing watch-station qualification checkoff sheets and by supervising the indoctrination of watch standers to the extent necessary to ensure that they become fully qualified. By these means you can be sure that the inservice training of watch standers is delivering the qualified personnel that you need.

SECURITY TRAINING

As a supervisor, you will have responsibilities in the security area, both in safeguarding information you possess and in indoctrinating your personnel in proper procedures for handling classified information. Your security training responsibilities are part of an overall security, orientation, education, and training program that is the responsibility of your commanding officer and directed to all hands.

The object of security training is to develop in all hands a sense of personal responsibility for protecting classified information and equipment. This training is done either through use of group lessons, using lectures and films, or by having personnel study the *Information Security Program Regulation Manual,* OPNAV Instruction 5510.1H, or other printed information on security. In and near areas where classified material is used and stored, posters are placed to remind personnel of their duties in respect to security.

The following list contains some of the things personnel should be taught about security:

- Their responsibilities for security
- The importance of security and the penalties for violating security regulations
- The techniques used by foreign intelligence agents and agencies
- Their responsibilities for reporting any attempt or suspected attempt of foreign intelligence activities to gain U.S. defense information

Any IC personnel having duties in a telephone exchange should be aware that although interior communications within a ship are fairly secure, once telephone conversations get to the beach, they are very easily intercepted by taps on land lines and interceptions of microwave telephone transmissions.

As part of security training, personnel having access to classified information should be briefed periodically. The following points should be emphasized:

1. Divulge classified information only to personnel who have the necessary security clearance and who must have the information to perform their official duties.

2. Personnel who have classified information have the responsibility for protecting it.

3. Personnel must be alert and ready to defend themselves against any possible espionage or subversion.

4. Discussing any classified information over a telephone is prohibited.

In addition to routine briefings, personnel who have access to classified information should be briefed before traveling to or through communist countries where there may be an attempt to subvert, or obtain, information from them. If any of your subordinates have close relatives living in communist controlled countries, they should receive a special briefing, which your command will arrange.

TEAM TRAINING

The following procedure, recommended for training a team and its members, is especially applicable to engineering casualty control training:

1. Analyze the duties of each person in the team.

2. Permit the team (or individual) to perform a rehearsal or "dry run" of the operation slowly and without pressure.

3. Drill for greater speed and accuracy. Emphasize correct procedures in early drills and increase emphasis on speed as drills progress.

4. Allow the team (or individual) to perform the actual operation.

5. Evaluate and discuss the performance with your personnel.

PERSONNEL QUALIFICATIONS STANDARDS

The Personnel Qualification Standards (PQS) program is another element in the Navy's overall training program. It is used to help develop in personnel the skills necessary to perform their assigned duties.

The *Personnel Qualification Standard (PQS) Management Guide,* NAVEDTRA 43100-1D, provides information on the PQS concept and describes its implementation into the training program of operational units of the Navy.

The purpose of the program is to assist in qualifying trainees to perform their duties. It is recommended that trainees carry their qualification cards with them so they can take advantage of training "targets of opportunity" that may occur during their daily routine. Individuals are allowed to progress at a pace that fits their individual learning ability. This progress, of course, is contingent upon time periods established by department heads and division officers. Although designed for a different purpose, the PQS program helps to prepare personnel for advancement. When studying theory questions, trainees are referred to applicable training manuals and other sources of information.

To determine what equipment or watch station is in the PQS program and to obtain the stock number for a particular PQS booklet, refer to NAVSUP 2002 or CNET Notice 3500.

Each qualification standard has four main subdivisions in addition to a preface, introduction, glossary, bibliography, and feedback form. These subdivisions are as follows:

100 Series—Theory

200 Seris—System

300 Series—Watchstations (duties, assignments, or responsibilities)

400 Series—Qualification cards

The introduction explains the use of the qualification standard in terms of what it will mean to the user as well as how to apply it.

The theory (100 series) section specifies the knowledge of theory necessary as a prerequisite to the study of the specific equipment or system for which the PQS was written.

The system (200 series) section breaks down the equipment or systems to be studied into functional sections. PQS items are constructed as clear, concise statements/questions according to a standard format. The answers must be extracted from the various manuals covering the equipment or systems for which the PQS is written. This section asks the user to explain the function of the system, to draw a simplified version of the system from memory, and to use this drawn schematic or the schematic provided in the maintenance manual while studying the system or equipment. Emphasis is given to such areas as maintenance management procedures, components, component parts, principles of operation, system interrelations, numerical values considered necessary to operation and maintenance, and safety precautions. A study of the items in the system section provides the individual with the required information concerning what the system or equipment does, how it does it, and other pertinent aspects of operation.

The watch stations (300 series) section includes questions regarding the procedures the individual must know to operate and maintain the equipment or system. In this section, the questions advance the qualification process by requiring answers or demonstrations showing the ability to use the knowledge covered in the system section and to maintain the system or equipment. Areas covered include normal operation; abnormal or emergency operation; emergency procedures that could limit damage and/or casualties associated with a particular operation; operations that occur too frequently to be considered mandatory performance items; and maintenance proeedures/instructions such as checks, tests, repairs, replacements, and so on.

The qualification cards (400 series) section covers the accounting documents used to record the individual's satisfactory completion of items. A complete PQS package should be given to each person being qualified so he or she can use it at every opportunity to become fully qualified in all areas of the appropriate rating and the equipment, system, or watch station for which the PQS was written. At what point to begin a PQS booklet will depend on the individual's assignment within an activity. Upon transfer to a different activity, each individual usually must requalify.

As a Petty Officer Second Class, you will be able to use the required watch station PQS to help train the personnel assigned to your watch section. It will also give you a way of documenting the progress of each person in qualifying as an IC Electrician watch stander.

SAFETY

Safety is the responsibility of all personnel. Personnel injury or death due to electric shock and damage to equipment require that all personnel adhere strictly to applicable safety precautions. With electrical and electronic equipment, safety violations could result in immediate equipment damage and severe personnel injury.

If you are in doubt about applicable electrical or electronic safety precautions, refer to *NSTM,* chapters 300 and 400, the *Standard Organization and Regulations of the U.S. Navy (SORM),* ONNAVINST 3120.32B, and *NAVOSH Program Manual for Forces Afloat,* OPNAVINST 5100.19B. Remember, safety is paramount!

Safety Responsibilities

U.S. Navy Regulations, article 0712 states: "The Commanding Officer shall require that all persons concerned are instructed and drilled inapplicable safety precautions and procedures, that these are complied with, and that the applicable safety precautions, or extracts therefrom, are posted in appropriate places, In any instance where safety precautions have not been issued, or are incomplete, he shall issue or augment such safety precautions as he deems necessary, notifying, when appropriate, higher authorities concerned."

Navy Regulations also spells out specific responsibilities of the executive officer, engineer officer, division officer, and engineering officer of the watch. These regulations are intended to make safety a prime responsibility of supervisors. Commanding officers cannot delegate their safety responsibilities, but they can delegate their authority to officers and petty officers to ensure safety precautions are understood and enforced.

As a supervisor, you must be aware of the safety of personnel and ensure they receive the necessary training and information in regards to safety. The most important step in maintaining safe working conditions is a thorough indoctrination of all personnel. For example, when new safety posters or precautions are received, supervisors are responsible for interpreting the messages correctly. In this way, they will ensure all personnel interpret and observe the approved safety rules and procedures correctly. It is essential that all repair and maintenance work be accomplished without personnel injury or damage to equipment.

Enforcing Safety

Safety precautions, as all rules, laws, or regulations, should be enforced. It is your duty to take appropriate action any time you see any person disregarding a safety precaution. You should require that all jobs be done according to applicable safety precautions.

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

Safe Electrical/Electronic Maintenance

Electrical/electronic maintenance is, to some extent, hazardous due to the nature of the work. Safety must rank as a prime concern because of the inherent danger of electrical shock.

EFFECTS OF ELECTRICITY.— The factors that determine whether you receive a slight or fatal shock are (1) the amount and duration of current flow, (2) the parts of the body involved, and (3) the frequency of the current if it is ac. Generally, the greater the current flow and the length of time one is subjected to it will determine the damage done. The extent of the current through you to vital nerve centers and organs may determine whether or not you survive the electric shock. The frequency of the current is also a determining factor, with 60- and 400-Hz current flow being more dangerous than dc.

The ability to resist an electrical shock will vary from person to person and day to day. The Naval Sea Systems Command (NAVSEA) has summarized the relationship of current magnitude to degree of shock:

1. At about 1 milliamp (0.001 ampere), shock is perceptible.

2. At about 10 milliamps (0.01 ampere), shock is sufficient to prevent voluntary control of muscles.

3. At about 100 milliamps (0.1 ampere), shock is usually fatal if it lasts for 1 second or more.

SAFE PRACTICES.— When working on electrical or electronic circuits, you must observe applicable safety precautions and follow approved procedures. These precautions should be scrupulously followed by both yourself and the person working with you.

1. Electrical and electronic circuits often have more than one source of power. Take time to study the schematics or wiring diagrams of the entire system to ensure that all power sources are secured and tagged out.

2. If pertinent, inform the remote station regarding the circuit on which work will be performed.

3. Use one hand when you turn switches on or off. Keep the doors to switch and fuse boxes closed, except when working inside or replacing fuses.

4. After frost making certain that the circuit is dead, use a fuse puller to remove cartridge fuses.

5. All supply switches or cutout switches from which power could possibly be fed should be secured in the off or open (safety) position and tagged with a red danger tag (NAVSHIPS 9890/S(REV)).

6. Keep clothing, hands, and feet dry if at all possible. When it is necessary to work in wet or damp locations, use a dry steady platform to sit or stand on, and place a rubber mat or other nonconductive material on top of the platform. Use insulated tools and insulated flashlights of the molded type when required to work on exposed parts. In all instances, repairs on energized circuits must be made with the primary power not applied except in case of emergency, and then only after specific approval has been given by the commanding officer. When approval has been obtained to work on equipment with the power applied, keep one hand free at all times (behind you or in your pocket).

7. Never short out, tamper with, or block open an interlock switch.

8. Keep clear of exposed equipment; when it is necessary to work on it, wear approved, tested rubber gloves and work with one hand as much as possible.

9. Avoid reaching into enclosures except when absolutely necessary; when reaching into an enclosure, use rubber gloves to prevent accidental contact with the enclosure.

10. Make certain that equipment is properly grounded.

11. Turn off the power before connecting alligator clips to any circuit.

12. Never use your finger to test a "hot" line. Use approved meters or other indicating devices.

It is the responsibility of every person connected with equipment maintenance to discover and eliminate unsafe work practices.

Sources of Safety Information

Included among the available sources of safety information are directives, instructions, and notices issued by the Chief of Naval Operations, the *NSTMs*, manufacturers' technical manuals, safety notices, and bulletins published periodically.

SAFETY DIRECTIVES AND PRECAUTIONS.— The items in the various safety directives and publications are designed to cover usual conditions in naval activities. Commanding officers and others in authority are authorized and encouraged to issue special precautions to their commands to cover local conditions and unusual circumstances. Guidance for the promotion of accident prevention aboard ship is contained in the *Navy Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat*, OPNAVINST 5100.19B, and the *Navy Occupational Safety and Health (NAVOSH) Program Manual*, OPNAVINST 5100.23B. Safety directives and precautions should be followed to the letter in their specific application. Should any occasion arise in which any doubt exists as to the application of a particular directive or precaution, the measures to be taken are those which will achieve maximum safety. The safety officer is available to assist in interpreting and suggesting ways of implementing safety directives and precautions.

NAVAL SHIPS' TECHNICAL MANUAL.— Chapter 300, "The Electrical Plant General," gives clear and concise electrical safety precautions that should be "required study material for all hands." Although some areas may need explanation to nonrated personnel, many items of common sense are stressed. This material should be included in the training of all personnel, with heavy emphasis placed on the correct procedure for artificial respiration.

Other chapters of the *NSTM*, including chapter 430, "Interior Communications," give specific precautions related to specific areas.

MANUFACTURERS' TECHNICAL MANUALS.— Applicable safety precautions are written in all equipment technical manuals. Generally speaking, most training underscores the Principle of Operation and the Maintenance sections of these manuals, yet fails to place proper emphasis on safety items. Often the precautions are located in the front of the manual before the table of contents, where they are easily overlooked.

Senior petty officers should ensure that each person sent out on a maintenance action is instructed on the precautions to be observed. Too often high voltage sources and alternate power sources mentioned in the Safety section of the technical manual are overlooked or forgotten by junior electricians until the screwdriver is in place.

MAINTENANCE REQUIREMENT CARDS.— Each maintenance requirement card (MRC) used in the Navy has a section devoted to safety precautions to be observed by the person who performs the maintenance action prescribed on the card. Sometimes, this section contains only a reminder to observe standard safety precautions. But, whatever they are, the leading petty officer responsible for the maintenance action should ensure that each person in his/her work group is instructed in the safety precautions and observes them while performing his/her tasks.

PERIODICALS.— Many sources of safety information are distributed on a monthly or quarterly basis by various naval activities. The Naval Safety Center publishes the *Ships Safety Bulletin* and *Fathom*, a quarterly surface ship and submarine safety review. Fathom presents accurate and current information on the subject of nautical accident prevention. *Safety Review*, published monthly by the Chief of Naval Material (CHNAVMAT), contains information on the safe storage, handling, or other use of products and materials. Articles dealing with safety appear often in *Electronics Information Bulletin*, *Deckplate*, and *Surface Warfare* magazine.

Fire Safety

The best way to control any fire is not let it happen. When working on equipment, personnel should always be aware that circuit protective devices, such as fuses and circuit breakers, are frost-line insurance against overheating and must be in good condition. The filter is an important part of filtered ventilating systems. If the filter is clogged, the equipment will run hot and may bum out. If the filter is not in place or has holes in it, dust will get into the system and present a possible fire hazard. When falters are replaced, the replacement filter must be the same type as the original. When equipment is opened, components and wiring insulation should be inspected for signs of overheating. To avoid dangerous short circuits, electrical insulation must be of the correct type and in good condition. In addition to ensuring good performance and long equipment service life, careful workmanship will help prevent fires. A badly made connection that vibrates loose or a conductor that carries high voltages too close to another can cause an arc. Pulling fuses on energized circuits should be avoided since an arc can result. When it comes to fire prevention, the fewer sparks the better.

If a fire or overheated condition occurs in electrical equipment, the circuit should be de-energized as quickly as possible. Carbon dioxide (CO_2) is to be used in fighting electrical fires because it is nonconductive and thereby the safest to use in terms of personnel safety, and because it offers the least likelihood of doing equipment damage. However, if the discharge horn is allowed to touch an energized circuit, the horn may transmit a shock to the handler, due to frost on the horn.

Outside Safety

IC Electricians perform maintenance on equipment located throughout the ship. A leading petty officer may have personnel working simultaneously on the bridge, in the engine room and fireroom, and in several other spaces. It is imperative that all of these personnel 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 it is just as likely to be injured or killed as the one who doesn't properly use a safety harness when aligning the anemometer (circuits HD, HE).

Live Circuits

More often than not, it is impossible to align de-energized equipment. Gyro repeaters, engine order telegraphs, and other synchro systems require adjustment "hot"; therefore, several precautions must be observed whenever the work is being done on energized electrical equipment.

1. Provide ample illumination.

2. Do not wear a wrist watch, rings, watch chain, metal articles, or loose clothing that might make accidental contact with live parts or that might accidental] y catch and throw some part of the body into contact with live parts. Clothing and shoes should be as dry as possible.

3. Insulate the worker from ground by means of insulating material covering any adjacent grounded metal with which he/she might come in contact. Suitable insulating materials are rubber mats, dry canvas, dry

phenolic material, or even heavy dry paper in several thicknesses. Be sure any such insulating material is dry, has no holes in it, and has no conducting materials embedded in it. Cover sufficient areas so adequate latitude is permitted for movement by the worker in doing the work

4. Use insulated hand tools.

5. Insofar as practicable, provide insulating barriers between the work and any live metal parts immediately adjascent to the work to be done.

6. Use only one hand in accomplishing the work if practical. Wear a rubber glove on the hand not used for handling tools. If the work being done permits, wear rubber gloves on both hands.

7. Have personnel stationed by circuit breakers or switches, and telephone manned if necessary, so the circuit can be de-energized immediately in case of emergency.

8. Have immediately available a person qualified in mouth-to-mouth respiration and cardiac massage for electric shock.

Tagging Procedure

For many years the Navy has recognized the value of tagging circuits upon which personnel are working, but a good tagging procedure is worthless unless it is backed up by the petty officers in charge. Often junior personnel tend to take tags lightly—a tendency that could prove fatal. Then too, there have been cases where personnel have long since left the ship and the tags they installed remain in place. When this happens, the entire circuit must be checked for grounds and shock hazards before the tags are removed and the circuit energized.

Recently there has been a tendency to supply power to certain nonvital circuits, such as the wardroom buzzer system, from local lighting panels. Since power is taken from a lighting panel, the repairing IC Electrician must tag the circuit using a red danger tag before working on it.

If more than one repairman is engaged in repairing apiece of equipment, each person should tag the circuit and, upon completion of work, each should remove his/her own tag.

Working Aloft

When radio or radar antennas are energized by transmitters, workers must not go aloft until steps have been taken to ensure that no danger exists. A casualty can occur from even a small spark drawn from a charged piece of metal or rigging. Although the spark itself may be harmless, the "surprise" may cause the worker to let go his grasp involuntarily. There is also shock hazard if nearby antennas are energized, such as those on stations ashore or aboard a ship moored alongside or across a pier.

Danger also exists from rotating antennas that might cause personnel working aloft to fall by knocking them from their perch. Motor safety switches controlling the motion of antennas must be tagged and locked open before anyone is allowed aloft close to such antennas.

Personnel working near a stack must wear the recommended oxygen breathing apparatus. Among other toxic substances, stack gas contains carbon monoxide. Carbon monoxide is too unstable to buildup to a high concentration in the open, but prolonged exposure to even small quantities is dangerous.

Each time a person goes aloft to work he/she must follow established procedures listed here:

1. Get permission of the communications watch officer (CWO) and the OOD.

2. Check with the engineer officer to ensure that the boiler safety valves are not being set.

3. Get the assistance of another person along with a ship's Boatswain's Mate who is qualified in rigging.

4. Wear a safety harness. To be of any benefit, the best harness must be fastened securely as soon as the place of work is reached. Some workers had complained on occasion that a safety harness is clumsy and interferes with movement. True as this maybe, it is also true that a fall from the height of an antenna is usually fatal.

5. Keep both hands free for climbing. Tools are not to be carried in hand; an assistant can lift them to the work site.

6. Secure tools with preventer lines to keep them from dropping on a shipmate.

7. Keep a good footing and firm grasp at all times. The nautical expression HOLD FAST serves as a good memory device, in case one is needed.

Shore Connections

The connection of the ship's service telephone system to a shore exchange is a frequent evolution carried out by junior IC Electricians. There are two possible hazards: the 48-volt dc power supply and the 90-volt ring current used in telephones.

Any hazard due to the ship's telephones can be avoided by keeping the manual switchboard de-energized during connection. In making the shore connection, the IC Electrician must assume the circuit is energized (as is the practice in some ports) and act accordingly.

Connection at some piers is made by plug-in-type plugs and the hazards are minimized; however, where lug and screw connections are made, emphasis must be placed on live circuit precautions.

On many ships, IC Electricians assist in connecting and disconnecting ship's service power to shore power. The applicable guidelines are contained in *Electrician's Mate 1&C*, NAVEDTRA 10547-E.

IC Room Safety

Since a major portion of the IC Electrician's time is spent working in the IC room or IC workshop, it is important that supervisory personnel examine the personnel hazards present in these areas. It is mandatory, of course, that the area be initially laid out with the proper rubber matting and that the workbench and test switchboard be installed with maximum safety for personnel as a prime consideration.

Maintenance and Repair

As an IC Electrician Second Class, you will be expected to supervise and train personnel when standing watch. Most commands have a trouble-call log in either DC central or in the IC/gyro room. There is usually one to three personnel on watch in the IC/gyro room depending on the size of the command. If not, there is always someone with the duty of responding to casualties when they occur. You, as a supervisor, will be expected to train your watch personnel on how to respond to these calls and the hazards they may encounter.

SWITCHBOARDS AND ENCLOSED EQUIPMENT.— The hazards involved to the operator and the repairman regarding switchboards have been greatly reduced in recent years by the installation of dead-front service-type switchboards. These and other enclosed equipments, however, require specific care in servicing and cleaning.

Switches should be operated with the safety of both the operator and other personnel in mind. Before closing any switch, be sure the circuit is ready in all respects to be energized. Make sure all personnel working on the circuit are notified that it is to be energized.

When operating circuit breakers or switches, use only one hand if possible. Use judgment in replacing blown fuses. Only fuses of 10 ampere capacity or less should be removed or replaced in energized circuits. Fuses larger than 10 ampere ratings should be removed or replaced only when the circuit is de-energized. Do not work on any energized circuit, switchboard or other piece of electrical equipment unless absolutely necessary. Do not undertake any work on energized switchboards without first obtaining the approval of the commanding officer. When you have received permission to work on a live circuit, DO NOT attempt to do so by yourself; have another person (safety observer), qualified in first aid for electrical shock, present at all times. The person stationed nearby should also know the circuits and the location of switches controlling the equipment and should be given instructions to pull the switch immediately if anything unforeseen happens. The worker within the enclosure must always be aware of the nearness of other live circuits. Use rubber gloves where applicable and stand on approved rubber matting.

Circuits or equipment to be worked on should be de-energized by opening all switches through which power could be supplied and then testing the circuit with a voltmeter or voltage tester. These switches should then be tagged with danger tags. In case more than one party is engaged in repair work on a circuit, a danger tag for each party should be placed on the supply switches.

A cardinal, yet often violated, rule regarding enclosed equipment is never override or disable an interlock. The Navy designed the interlock in the circuit and no one should be allowed to violate it.

Dirt, dust, lint, and excessive oil must be removed from IC equipment. Junior personnel should, before they begin a cleaning evolution, be instructed in and take adequate precautions for their safety. Two general cleaning rules are as follows:

1. Loose dust and dirt should be removed with a vacuum cleaner or clean rags. Low-pressure compressed air may be used provided the air is free of foreign particles and moisture. Normal ship's service air is 100 psi and must be reduced to approximate y 30 psi before it is used.

2. Oil or hard dirt may require a cloth dampened with inhibited methyl chloroform for adequate cleaning. Extreme care must be used on steel and varnish.

IN-SHOP REPAIRS.— Many repairs made in the IC room involve equipment normally used in other parts of the ship. To make these repairs, it is often necessary to use hand and portable electric tools.

Safe Practices for Hand Tools.— Normally, you should have no problems when working with hand tools. In all likelihood, however, you have seen some dangerous practices in the use of hand tools that should have been avoided. One unsafe practice involves the use of tools with plastic or wooden handles that are cracked, chipped, broken, or otherwise unserviceable. This practice is sure to result in accidents and personnel injuries, such as cuts, bruises, and foreign objects being thrown in the eyes. If these unserviceable tools are not repairable, discard or replace them.

Safety with Portable Electric Tools.— Portable electric tools should be clean, properly oiled, and in good repair. Before they are used, inspect the tool for proper grounding. The newer double insulated, plastic case tools have a two-conductor cord and a two-prong plug.

If a tool is equipped with a three-prong plug, it should be plugged into a grounded-type electrical outlet. Never remove the third prong from the plug. Make absolutely sure the tool is properly grounded according to *NSTM,* chapter 300. Observe safety precautions and wear rubber gloves when plugging in and operating portable electric tools under particularly hazardous conditions. Examples of particularly hazardous conditions are wet decks, bilge areas, or working over the side in rafts or boats.

Before issuance of any portable electrical equipment, the attached cable with plug (including extension cords, when used) should be examined visually to assure it is in satisfactory condition. (Tears, chafing, exposed insulated conductors, and damaged plugs are causes for cable or plug replacement.) Any portable electrical equipment with its associated extension cords should be tested before to issue with an approved tool tester or plugged into a dummy (or de-energized) receptacle and tested for resistance from equipment housing to ship's structure with an ohmmeter (the resistance of the grounding circuit must be less than 1 ohm). Move or work the cable with a bending or twisting motion. A change in resistance will indicate broken strands in the grounding conductor. If this is found, replace the cable. 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 the Planned Maintenance System (PMS) is installed, tests should be conducted according to the MRCs.

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

–Inspect the tool cord and plug before using the tool. Do not use the tool if its cord is frayed or its plug is damaged or broken. Do not use spliced cables except in an emergency that warrants the risk involved.

–Before using the tool, lay all portable cables out so you and others cannot 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" for receptacle ends of the cord. All extension cords must have nonconductive plugs and receptacle housings.

–Connect the tool cord into the extension cord (when required) before inserting the extension cord into a live receptacle. After using the tool, unplug the extension cord (if any) from the live receptacle before unplugging the tool cord from the extension cord. Do not unplug the cords by yanking on them.

–Stow the tool in its assigned place after you are through using it.

Nonstandard Equipment.— The practice of having unauthorized or jury-rigged electrical equipment on board is a hazard and must be dealt with as such. The only way to ensure that jury-rigged and unauthorized equipment is not being used is for you personally to make checks for such installations.

Alterations

Naval regulations provide that no alterations are permitted to be made to ships until authorized by NAVSEA. Some of the reasons for this regulation that are particularly applicable to IC systems are as follows:

1. NAVSEA is responsible for the design and maintenance of IC systems in all naval ships. Therefore, it is necessary that NAVSEA have accurate information as to all existing installations.

2. In the interests of standardization, it is necessary that all requests for alterations be forwarded to NAVSEA so the alteration may be authorized for all ships in which similar conditions exist.

3. In the interests of conserving funds, NAVSEA weighs the importance and necessity of all alterations so available funds may be most wisely used.

4. Many alterations that seem desirable to the ships may have unsuspected defects or disadvantages not immediately apparent to ship's personnel. In this respect NAVSEA acts as a clearing house for information from numerous sources, including other bureaus and offices of the Naval Establishment.

Electric Shock

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

Additional information on watch standing and safety can be found in *Basic Military Requirements*, NAVEDTRA 10054-F, and in the military requirements training manuals.

APPENDIX I

GLOSSARY

ALARM ACKNOWLEDGE– Push button that must be depressed to silence an alarm horn.

ALARM LOG– Record of quantities that are in an alarm condition only.

ANALOG DATA– Data represented in continuous form, as contrasted with digital data having discrete values.

AND GATE– (1) An electronic gate whose output is energized only when every input is in its prescribed state. An AND gate performs the function of the logical "AND"; also called an AND circuit. (2) A binary circuit, with two or more inputs and a single output, in which the output is a logic 1 only when all inputs are a logic 1 and the output is a logic 0 when any one of the inputs is a logic 0.

ANNUNCIATOR– A device that gives an audible and a visual indication of an alarm condition.

ASSEMBLY– A number of parts or subassemblies, or any combination thereof, joined together to perform a specific function.

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– Drawing of a system using blocks for components to show the relationship of components.

CALIBRATION ACTIONS– The number of calibrations performed by the related calibration activity (laboratory) during the reporting period.

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.

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, transistor, and so forth.

COMPUTER– A data processor that can perform substantial computation, including numerous arithmetic or logic operations, without the intervention by a human operator during the run.

CONDITION– State of being of a device, such as ON-OFF, GO-NO GO, and SO forth.

CONTINUOUS DISPLAY– Electrical instrument giving a continuous indication of a measured quantity.

CONTROL MODE– Method of system control at a given time.

CONTROL POWER– Power used to control or operate a component.

CONTROL TRANSMITTER (CX)– A type of synchro that converts a mechanical input, which is the angular position of its rotor, into an electrical output signal. The output is taken from the stator windings and is used to drive either a CDX or CT.

CONTROL TRANSFORMER (CT)– A type of synchro that compares two signals: the electrical signal applied to its stator and the mechanical signal applied to its rotor. The output is an electrical voltage, which is taken from the rotor winding and is used to control a power-amplifying device. The phase and amplitude of the output voltage depends on the angular position of the rotor with respect to the magnetic field of the stator.

CONTROL SIGNAL– Signal applied to a device that makes corrective changes in a controlled process.

CONTROL DIFFERENTIAL TRANSMITTER (CDX)– A type of synchro that transmits angular information equal to the algebraic sum or difference of the electrical input supplied to its stator, and the mechanical input supplied to its rotor. The output is an electrical voltage taken from the rotor windings.

CONVERTER– A device for changing one type of signal to another; for example, alternating current to direct current.

CORRECTIVE MAINTENANCE– Includes location and repair of equipment failures.

CORRESPONDENCE– The term given to the positions of the rotors of a synchro receiver when both rotors are on 0 degree or displaced from 0 degree by the same angle.

DAMPING– (1) The process of smoothing out oscillations. (2) In a meter, this process is used to keep the pointer of the meter from overshooting the correct reading. (3) A mechanical or electrical technique used in synchro receivers to prevent the rotor from oscillating or spinning. Damping is also used in servo systems to minimize overshoot of the load.

DATA TRANSMISSION–The transfer of information from one place to another or from one part of a system to another.

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.

DEMODULATOR– A circuit used in servosystems to convert an ac signal to a dc signal. The magnitude of the dc output is determined by the magnitude of the ac input signal, and its polarity is determined by whether the ac input signal is in or out of phase with the ac reference voltage.

DIGITAL– 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.

DRIFT– A slow change in some characteristics of a device, such as frequency, current, and direction.

ELECTRICAL ZERO– A standard synchro position, with a definite set of stator voltages, that is used as the reference point for alignment of all synchro units.

ELECTRICAL-LOCK– A synchro zeroing method. This method is used only when the rotors of the synchros to be zeroed are free to turn and their leads are accessible.

EMERGENCY– An event or series of events in progress that will cause damage to equipment unless immediate, timely, and correct procedural steps are taken.

ERROR DETECTOR– The component in a servo system that determines when the load has deviated from its ordered position, velocity, and so on.

ERROR SIGNAL– (1) In servo systems, the signal whose amplitude and polarity or phase are used to correct the alignment between the controlling and the controlled elements. (2) The name given to the electrical output of a control transformer.

EXCITATION VOLTAGE– The supply voltage required to activate a circuit.

FAIL– Loss of control signal or power to a component. Also breakage or breakdown of a component or component part.

FAIL POSITION– 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.

FREQUENCY– (1) The number of complete cycles per second existing in any form of wave motion, such as the numbers of cycles per second of an alternating current. (2) The rate at which the vector that generates a sine wave rotates.

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.

GATE– As applied to logic circuitry, one of several types of electronic devices that will provide a particular output when specified input conditions are satisfied. Also, a circuit in which a signal switches another signal on or off.

GENERATOR– A machine that converts mechanical energy to electrical energy by applying the principle of magnetic induction. A machine that produces ac or dc voltage, depending on the original design.

GYRO– Abbreviation for gyroscope.

GYROSCOPE– A mechanical device containing a spinning mass mounted so it can assume any position in space.

HERTZ– A unit of frequency equal to one cycle per second.

HYDRAULIC ACTUATOR– A device that converts hydraulic pressure to mechanical movement.

INACTIVE CODE– An asterisk (*) preceding the customer/laboratory code indicating that the activity is inactive (not currently accepted by MEASURE), and no updating occurs. (formats 100 & 105)

INTERLOCK– A device that prevents an action from taking place at the desired time, but that allows the action when all required conditions are met.

JACKING GEAR– An electric motor-driven device that rotates the turbine shaft, reduction gears, and line shaft at a low speed.

LINEAR– Straight line relationship where changes in one function are directly proportional to changes in another function.

LOGIC– The basic principles and applications of truth tables, interconnections of off-on circuit elements, and other factors involved in mathematical computation in automatic data processing systems and other devices.

LOGIC DIAGRAMS– In computers and data processing equipment, a diagram representing the logical elements and their interconnections without necessarily expressing construction or engineering details.

LOGIC INSTRUCTION– Any instruction that executes a logic operation that is defined in symbolic logic, such as AND, OR, NAND, or NOR.

MAINTENANCE– Work done to correct, reduce, or counteract wear, failure, and damage to equipment.

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.

METRL CYCLE– The number of months established as the optimum period of time the corresponding equipment can be used before recalibration is required.

MFR– A five-character alpha/numeric or three-character alphabetical code representing the specific manufacturer for the corresponding equipment model number.

MODIFICATION MAN-HOURS– The total man-hours expended on modifications by the related calibration activity (laboratory) during the reporting period.

MODIFICATION ACTIONS– The number of modifications performed by the related calibration activity (laboratory) during the reporting period.

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.

NO-BREAK POWER SUPPLY– A device that supplies temporary power to the console during failure of the normal power supply.

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.

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 3-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 LOOP– System having no feedback.

OPERATING CHARACTERISTICS– Combination of a parameter and its set point.

OR GATE– A gate that performs the logic OR function. It produces an output 1 whenever any or all of its inputs is/are 1.

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.

PERIPHERAL– Existing on or new the boundary of a surface or area.

PILOT MOTOR– A small dc motor that drives the input shaft of an actuator.

POWER SUPPLY– A module that converts the 115-volt 60-hertz incoming power to ac or dc power at a more suitable voltage level.

PRINTED CIRCUIT BOARD– Devices usually plugged into receptacles that are mounted in modules.

PRIORITY– Order established by relative importance of the function.

PROTECTIVE FEATURE– Feature of a component or component part designed to protect a component or system from damage.

RECEIVER– (1) The object that responds to the wave or disturbance. Same as DETECTOR. (2) Equipment that converts electromagnetic energy into a visible or an audible form. (3) In radar, a unit that converts rf echoes to video and/or audio signals.

REFERENCE POINT– A point in a circuit to which all other points in the circuit are compared.

REFERENCE SIGNAL– Command signal that requests a specific final condition.

RELAY– An electromagnetic device with one or more sets of contacts that change position by the magnetic attraction of a coil to an armature.

ROTOR– The rotating member of a synchro that consists of one or more coils of wire wound on a laminated core. Depending on the type of synchro, the rotor functions similar to the primary or secondary winding of a transformer.

SCALING– Applying a factor of proportionality to data or signal levels.

SCAT CODE– The subcategory (SCAT) code assigned to the equipment, if applicable.

SEB NUMBER– The number of the support equipment change that contains the modification implemented on the corresponding equipment by the related calibration activity (laboratory).

SELSYN– Self-synchronizing device or synchromotor.

SENSING POINT– Physical and/or functional point in a system at which a signal may be detected or monitored in an automatic operation.

SENSOR– A device that is sensitive to temperature, pressure, position, level, or speed.

SERVICING LABEL (SL)– A label attached to the equipment to indicate the status of the equipment after servicing.

SERVO AMPLIFIER– Either ac or dc amplifiers used in servo systems to build up signal strength. These amplifiers usually have relatively flat gain versus frequency response, minimum phase shift, low output impedance, and low noise level.

SERVO SYSTEM– An ac or dc motor used in servo systems to move a load to a desired position or at a desired speed. The ac motor is usually used to drive light loads at a constant speed, while the dc motor is used to drive heavy loads at varying speeds.

SET POINT– Numerical value of a parameter at which an alarm is actuated.

SIGNAL– A general term used to describe any ac or dc of interest in a circuit; for example, input signal.

SILICON CONTROLLED RECTIFIER PACKAGE– A device that furnishes controlled dc power to a device.

SINE WAVE– (1) 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. (2) The basic synchronous alternating waveform for all complex waveforms.

SOLID STATE– Class of electronics components, such as transistors, diodes, integrated circuits, silicon controlled rectifiers, and so forth.

SPAN– Distance between two points.

SPECIAL FUNCTION– Unique service performed by a system; usually above and beyond the direct designed intent of the system.

STANDARD PRINT– Standard drawing, schematic, or blueprint produced in the applicable technical manual or other official technical publication.

STATOR– The stationary member of a synchro that consists of a cylindrical structure of slotted laminations on which three Y-connected coils are wound with their axes 120° apart. Depending on the type of synchro, the stator's functions are similar to the primary or secondary windings of a transformer.

STATUS LOG– Record of the instantaneous values of important conditions having analog values.

SUBASSEMBLY– Consists of two or more parts that form a portion of an assembly or a unit.

SWITCH– (1) A device used to connect, disconnect, or change the connections in an electrical circuit. (2) A device used to open or close a circuit.

SYNCHRO– A small motorlike analog device that operates like a variable transformer and is used primarily for the rapid and accurate transmission of data among equipments and stations.

SYNCHRO SYSTEM– Two or more synchros interconnected electrically. The system is used to transmit data among equipments and stations.

SYNCHRO TROUBLESHOOTING– The locating or diagnosing of synchro malfunctions or breakdowns by means of systematic checking or analysis.

SYNCHRONIZER– A circuit that supplies timing signals to other radar components.

SYNCHRONOUS– A type of teletypewriter operation where both transmitter and receiver operate continuously.

SYSTEM– A combination of sets, units, assemblies, subassemblies, and parts joined together to form a specific operational function or several functions.

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.

TEST POINT– A position in a circuit where instruments can be inserted for test purposes.

THRESHOLD– The least value of current or voltage that produces the minimum detectable response.

TOLERANCE– An allowable deviation from a specification or standard.

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.

TROUBLE INDICATORS– Signal lights used to aid maintenance personnel in locating troubles quickly.

TROUBLE TABLES– Tables of trouble symptoms and probable causes, furnished by many manufacturers to help technicians isolate problems.

TROUBLESHOOTING– The process of locating and diagnosing faults in equipment by means of systematic checking or analysis.

TURNING GEAR– See JACKING GEAR.

UNIT– (1) An assembly or any combination of parts, subassemblies, and assemblies mounted together. Normally capable of independent operation. (2) A single object or thing.

UNIT IDENTIFICATION CODE (UIC)– A three-character alpha/numeric code representing the Naval Aviation Maintenance Program (NAMP) 3-M organization code for the respective customer/laboratory.

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.

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.

WAVEFORM– The shape of the wave obtained when instantaneous values of an ac quantity are plotted against time in rectangular coordinates.

ZEROING– The process of adjusting a synchro to its electrical zero position.

APPENDIX II

REFERENCES USED TO DEVELOP THE TRAMAN

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Assignment Questions

Information: The text pages that you are to study are provided at the beginning of the assignment questions.

ASSIGNMENT 1

Textbook Assignment: "Manual Bus Transfer, Motor Controllers, and Frequency Regulators," chapter 1, pages 1-1 through 1-32.

A. Manual controller
B. Magnetic controller
C. Across-the-line controller
D. Dc resistor controller
E. Ac primary resistor controller
F. Ac secondary resistor controller
G. Static variable-speed controller
H. Autotransformer controller
J. Reactor controller

Figure 1A

IN ANSWERING QUESTIONS 1-1 THROUGH 1-8, REFER TO FIGURE 1A.

1-1. In what controller are resistors inserted in the secondary circuit of a wound-rotor ac motor for starting or speed control?

1. B
2. C
3. E
4. F

1-2. What controller throws the connected load directly across the main supply line?

1. A
2. B
3. C
4. D

1-3. What controller consists of solid-state and other devices that regulate motor speeds in indefinite increments through a predetermined range?

1. H
2. G
3. F
4. E

1-4. What controller has a resistor in series with the armature circuit of the motor?

1. D
2. C
3. B
4. A

1-5. What controller is operated by hand directly through a mechanical system?

1. A
2. C
3. G
4. J

1-6. What controller has its contacts closed or opened by electro-mechanical devices operated by local or remote master switches?

1. H
2. F
3. D
4. B

1-7. In what controller are resistors inserted in the primary circuit of the motor to control both starting current and speed?

1. E
2. F
3. G
4. H

1-8. What controller starts the motor at a reduced voltage and then connects the motor to the supply line?

1. C
2. D
3. F
4. H

1-9. Manual bus transfer switches are most commonly used for what class of equipment or circuit?

1. Emergency
2. Nonvital
3. Vital
4. Casualty

1-10. Motor controllers are used aboard ship to start large motors because the starting current is lower than the running current.

1. True
2. False

1-11. Which of the following is NOT a manually operated master switch?

1. Drum
2. Selector
3. Toggle
4. Pressure

1-12. The contactors of a magnetic controller are operated by which of the following means?

1. Electromechanical devices
2. A remote control master switch
3. A locally controlled master switch
4. Each of the above

1-13. What type of controller is used to start a 1/4-hp dc motor?

1. A dc resistor motor controller
2. A static variable-speed controller
3. An across-the-line controller
4. An autotransformer controller

1-14. In the secondary circuit of a wound-rotor motor, what type of controller is used to insert resistance?

1. An ac secondary resistor
2. A dc secondary resistor
3. An ac primary resistor
4. An autotransformer

1-15. Which of the following is a disadvantage of an open-transition compensator?

1. The motor may slip into phase during transition
2. The resistor dissipates too much heat
3. The wound rotor has a tendency to overspeed
4. The motor may slip out of phase during transition, causing an overload

1-16. A master switch that is mounted in the controller is classified as what type of switch?

1. Local
2. Remote
3. Momentary
4. Maintaining

1-17. In a magnetic controller, what circuit is opened by an overload relay?

1. The circuit through the main contacts
2. The circuit through the master switch
3. The circuit through the control fuse element
4. The circuit through the main operating coil

1-18. Which of the following is a coarse adjustment to the thermal overload relay?

1. Changing the heater element
2. Changing the magnetic air gap
3. Increasing the distance between the heater and the sensitive unit
4. Decreasing the distance a bimetallic strip has to move to open the circuit

A. Dashpot
B. Bimetal
C. Induction
D. Solder pot
E. Single metal

Figure 1B

IN ANSWERING QUESTIONS 1-19 THROUGH 1-21, REFER TO THE TYPES OF OVERLOAD RELAYS LISTED IN FIGURE 1B.

1-19. Which relay is NOT a type of thermal overload relay?

1. A
2 B
3. C
4. D

1-20. A heat-sensitive element that lengthens when heated to open the contacts is used in which type of relay?

1. B
2. C
3. D
4. E

1-21. Which type of relay is manufactured for exclusive use in ac circuits?

1. A
2. C
3. D
4. E

1-22. In the instantaneous and time-delay magnetic overload relays, how should you adjust the current settings?

1. By replacing the heating unit
2. By changing the distance of the air gap between the armature and the coil
3. By changing the distance between the induction coil and the tube
4. By changing the distance between the heater and the heat-sensitive unit

1-23. Which of the following types of overload relays requires a time delay before it is reset?

1. Dashpot
2. Magnetic
3. Solder pot
4. Each of the above

1-24. A controller protecting a motor is able to disconnect it from the power supply, keep it disconnected, and then restart it automatically when conditions return to normal. What form of protection is the controller providing?

1. Low-voltage
2. Low-voltage release
3. Overload
4. Each of the above

1-25. A reversing type of controller that protects a 3-phase induction motor against low voltage and overload causes the motor to stop running due to line voltage failure. After line voltage is restored, how is the motor restarted?

1. By automatic means
2. By the operator pressing the forward push button or the reverse button
3. By reversal of any two of the three leads to the motor
4. By the operator resetting the circuit breaker on the power panel

1-26. One type of ac motor speed controller regulates the speed of an ac motor by performing which of the following actions?

1. Increasing and decreasing stator current
2. Switching from one set of stator windings to another
3. Increasing and decreasing the voltage of the power source
4. Shunting different values of resistance across the stator windings

1-27. A 3-phase autotransformer is used in starting 3-phase induction motors and synchronous motors because of its ability to perform what function?

1. Furnish variable voltage
2. Reverse the direction of rotation of the motor rotor
3. Switch motor stator connections from wye to delta
4. Switch motor stator connections from delta to wye

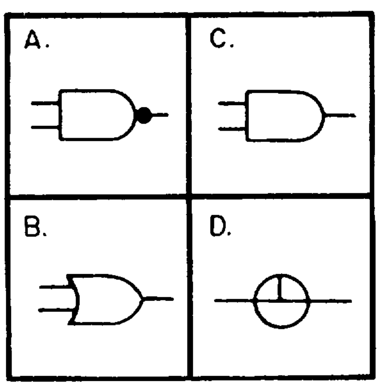

Figure 1C

IN ANSWERING QUESTIONS 1-28 AND 1-29, REFER TO THE SYMBOLS SHOWN IN FIGURE 1C.

1-28. Which symbol represents an AND logic symbol?

1. A
2. B
3. C
4. D

1-29. Which symbol represents an OR logic symbol?

1. A
2. B
3. C
4. D

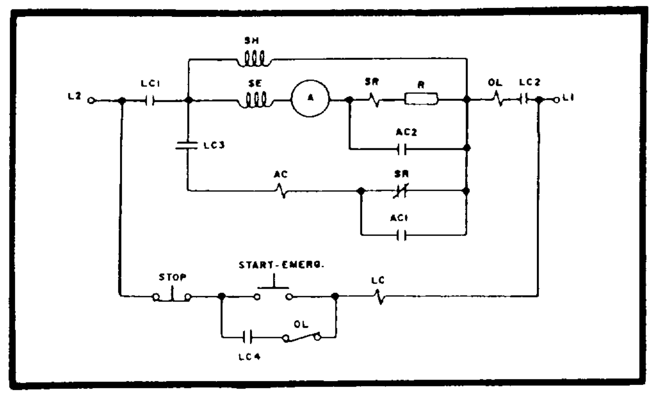

Figure 1D

IN ANSWERING QUESTIONS 1-30 THROUGH 1-33, REFER TO THE DC CONTROLLER WITH ONE STAGE OF ACCELERATION SHOWN IN FIGURE 1D.

1-30. If the start button is pressed, what action will cause line contacts LC1 and LC2 to close?

1. Closing of line contacts LC4
2. Operation of contactor coil LC
3. Operation of overload relay coil OL
4. Current flowing through armature A and contacts LC3

1-31. After closing contacts LC1, LC2, and LC3, the controller accelerates the motor. The controller connects the motor across the line in what manner?

1. By the SR contact completing the circuit to coil AC
2. By contact AC2 shorting out the starting resistor
3. By allowing coil SR to restore, closing the SR contact
4. Each of the above

1-32. After the motor is connected directly across the line, what should you do to interrupt the circuit?

1. Press the stop button
2. Press the start-emergency button
3. Short out the series relay coil
4. Short out the starting resistor

1-33. To vary the speed of the motor, how should you change the controller circuitry?

1. Disconnect the SR relay
2. Disconnect the shunt field winding
3. Connect a rheostat in series with the SH winding
4. Connect a rheostat in parallel with the AC coil

1-34. Magnetic blowout coils quench the arc across contacts by which of the following actions?

1. They increase the contact separation
2. They provide a magnetic flux that blows out the arc
3. They oppose the current flow
4. They pull the arc toward the contacts

1-35. Why are shaded coils used in an ac solenoid brake?

1. To overcome eddy currents
2. To reduce eddy currents
3. To make magnetic pull constant
4. To reduce vibration

1-36. In the operation of the torque motor brake, what action applies the brake shoes to the brake wheel?

1. The torque motor advances the jack screw upward
2. The torque motor acts to increase the pressure in the torque spring
3. The torque motor stalls, permitting the brake to act
4. The torque motor circuit opens, releasing the spring

1-37. In a series dc motor, how is dynamic breaking usually accomplished?

1. The motor is disconnected from the line
2. The armature and field are connected in series with a resistor to form a loop
3. Both 1 and 2 above
4. The field is disconnected from the line

1-38. A dc motor is slowed by dynamic braking when its turning armature generates a countervoltage that forces current through a connected braking resistor. This resistor is connected in what manner for (a) dc series-wound motors and (b) dc shunt-wound motors?

1. (a) Across the armature; (b) in series with the field
2. (a) In series with the field; (b) across the armature
3. (a) Across the armature; (b) across the armature
4. (a) In series with the field; (b) in series with the field

1-39. When dynamic braking is used with a dc shunt-wound motor, when, if ever, does the generated countervoltage equal zero?

1. When the motor armature stops turning
2. When the motor armature is turning and lifting a heavy load
3. When the brake is energized
4. Never

IN ANSWERING QUESTION 1-40, REFER TO TABLE 1-1 IN YOUR TEXTBOOK.

1-40. If controller contact tips overheat, what action(s) should maintenance personnel take?

1. Replace the blowout coil
2. Clean and adjust the contacts
3. Instruct the operator In the correct operation
4. Replace the shading coil

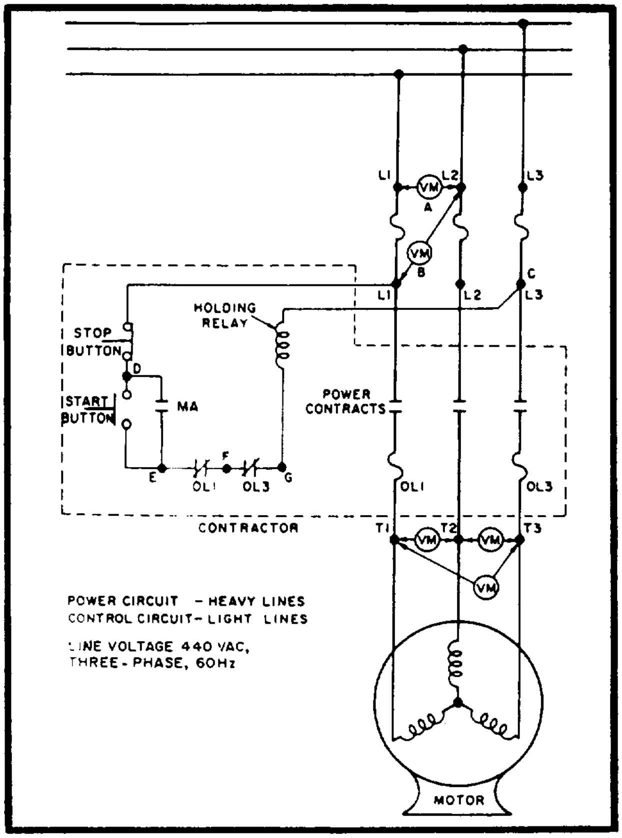

Figure 1E

IN ANSWERING QUESTIONS 1-41 THROUGH 1-43, REFER TO THE 3-PHASE MAGNETIC LINE STARTER SHOWN IN FIGURE 1E.

1-41. If a voltage is read at position A, and no voltage is present at position B, which of the following statements is true?

1. The voltmeter is defective
2. All fuses are good
3. L1 fuse is defective
4. L2 fuse is defective

1-42. After the start button is released, which of the following conditions will cause the motor to stop?

1. The holding relay is open
2. The power contacts on L1 did not close
3. The holding relay contacts did not close
4. OL1 is defective

1-43. With the start button depressed, what voltage will be present between points B and D?

1. 440 V
2. 220 V
3. 110 V
4. 0 V

1-44. Which of the following factors is a requirement of a 30-kW-m-g set to maintain a constant frequency?

1. Constant voltage
2. Constant amperage
3. Constant speed
4. Constant resistance

1-45. Which of the following semiconductors is equivalent to a gas-filled thyratron tube?

1. SCR
2. Transistor
3. Diode
4. Mosfet

1-46. Which of the following factors can vary the magnitude of the gate impulse needed to turn on an SCR?

1. Voltage
2. Resistance
3. Temperature
4. Amperage

1-47. What is the minimum required voltage of the gate pulse for precise firing of an SCR?

1. 1V
2. 2V
3. 3V
4. 4V

1-48. Which of the following is/are NOT a part of the control equipment for a motor generator?

1. Overload protection
2. Start and stop switches
3. Frequency-regulating system
4. Motor

IN ANSWERING QUESTIONS 1-49 THROUGH 1-52 REFER TO FIGURE 1-28 OF YOUR TEXTBOOK.

1-49. What is the breakdown rating of the Zener diode D-1?

1. 5 V
2. 10 V
3. 15 V
4. 20 V

1-50. When voltage in is 10 volts or less, negligible current will flow through R-1. The bridge is operating in what mode?

1. I
2. II
3. III
4. IV

1-51. When voltage in is 20 volts, the drop across resistors R-1, R-2, and R-3 is 10 volts. What is the voltage out equal to?

1. 0 V
2. 5 V
3. 10 V
4. 15 V

1-52. If the voltage in is greater than 20 volts, the bridge is operating in what mode?

1. I
2. II
3. III
4. IV

1-53. How many dc amplifiers are used to amplify the output from the Zener bridge before going to the preamp and trigger?

1. One
2. Two
3. Three
4. Four

1-54. What is the purpose of the preamp and trigger?

1. To amplify the varying dc input
2. To convert the varying dc input
3. Both 1 and 2 above
4. To convert varying ac input

1-55. When an SCR is in a high state of conduction, the output current is limited only by what factor?

1. Supply voltage
2. External circuit impedance
3. Gate impulse magnitude
4. External circuit impedance and supply voltage

1-56. The detector in the frequency-regulating system is what type of device?

1. Resistance measuring device
2. Voltage-sensing transformer
3. Linear frequency-sensing transformer
4. Nonlinear frequency-sensing transformer

IN ANSWERING QUESTIONS 1-57, REFER TO FIGURE 1-28 IN THE TEXTBOOK.

1-57. Which components form the Zener reference bridge?

1. R1 and R2 only
2. R1 and D1 only
3. R1, R2, and R3 only
4. R1, R2, R3, and D1

1-58. The operation of the detector in the voltage regulator is similar to that of the frequency regulator except that the detector senses which of the following changes in a generator?

1. Current rather than frequency
2. Speed rather than frequency
3. Voltage rather than frequency
4. Each of the above

IN ANSWERING QUESTION 1-59, REFER TO FIGURE 1-29 IN THE TEXTBOOK.

1-59. What components form the power circuit?

1. D1, D2, and D3 only
2. D1, D2, D3, SCR1, SCR2, and SP1
3. SCR1 and SCR2 only
4. SCR1, SCR2, and SP1 only

IN ANSWERING QUESTION 1-60, REFER TO FIGURE 1-30 IN THE TEXTBOOK.

1-60. The field-flashing circuit consists of which of the following components?

1. T3, D3, T5, and C3
2. T5, D2, R4, and C3
3. T1, T2, and T3
4. L3, D2, D3, and T1

1-61. What component is added to the saturable current-potential transformer to change the coupling between the primary and secondary windings?

1. A dc control winding
2. An ac control winding
3. A filter capacitor
4. A resistor

1-62. What windings on the saturable current-potential transformer function as a power transformer?

1. Voltage windings Vp1 and Vs1
2. Current windings Ip1 and Ip2
3. Windings Vp1, Vp2, and Nc
4. Windings Vp1 and Ip2

IN ANSWERING QUESTION 1-63, REFER TO THE TRANSFORMER IN FIGURE 1-32 IN THE TEXTBOOK.

1-63. Assume that the core is not saturated and the voltage of the saturable potential transformer is positive at the start of winding NP1. What will happen to the flux 01 and 02 in the center leg of the transformer?

1. Flux 01 will cause an increase in flux 02
2. Flux 02 will cause flux 01 to increase
3. Flux 01 and 02 will cancel each other
4. Flux 01 will cause a decrease in flux 02

1-64. When is the saturation point of the magnetic material reached?

1. When an increase in magnetomotive force causes no further increase in flux
2. When a decrease in magnetomotive force causes no further decrease in flux
3. When an increase in magnetomotive force causes an increase in flux
4. When a decrease in magnetomotive force causes an increase in flux

1-65. When two generators are operating in parallel, the power-sensing network functions to balance which of the following factors?

1. Kilowatt load
2. Kilovolt ampere output
3. Unity power factor
4. VAR component of the load

IN ANSWERING QUESTIONS 1-66 THROUGH 1-68, REFER TO FIGURE 1-35 IN THE TEXTBOOK.

1-66. The load current-sensing transformer for generator A is represented by which alpha/numeric designation?

1. A/T1
2. A/T2
3. A/CT1
4. B/CT1

1-67. When will a shorting bar be placed across CB3 contacts to eliminate frequency droop?

1. When A and B are operating in parallel
2. When A or B is operating by itself
3. When A is carrying more load than B
4. When A is carrying less load than B

1-68. The power-sensing system functions to keep generators A and B operating in parallel under which of the following conditions?

1. When circuit breaker CB3 is open
2. When transformer A/CT1 is connected across rheostats A/R2 and B/R2
3. When transformer B/CT1 Is connected across rheostats B/R1 and A/R2
4. When circuit breaker CB3 is closed

1-69. What front-to-back ratio is usually an indication of a good diode?

1. 5 to 1
2. 1 to 5
3. 1 to 10
4. 10 to 1

1-70. The model 4345A static inverter has two single-phase static inverters that are operated with how many degrees of controlled phase difference?

1. 90°
2. 180°
3. 270°
4. 360°

1-71. The 4345A static inverter develops a 400-Hz, 3-phase output. What is the input voltage?

1. 220 volts ac
2. 120 volts ac
3. 120 volts dc
4. 250 volts dc

1-72. What component(s) enables the inverter to convert a 2-phase input to 3-phase power?

1. Oscillator assembly
2. Variable pulse width generator
3. Scott T-connected transformers
4. Power stage

1-73. What is the reference frequency used in the 4345A static inverter control circuits?

1. 1600 Hz
2. 800 Hz
3. 400 Hz
4. 60 Hz

1-74. On the 4345A static inverter, where on the cabinet is the resistor subassembly located?

1. Front
2. Back
3. Side
4. Bottom

1-75. What assembly contains the controls of the static inverter?

1. Power stage assembly
2. Inverter module assembly
3. Resistor subassembly
4. Meter panel assembly

ASSIGNMENT 2

Textbook Assignment: "Manual Bus transfers, Motor Controllers, and Frequency Regulators," chapter 1, and "Anemometer Systems," chapter 2, pages 1-32 through 2-18 .

2-1. The level of conduction in the modulating circuit is controlled by which of the following signals?

1. An ac feedback signal
2. A synchronous pulse from the oscillator
3. The output of driver stages
4. The dc voltage level input

2-2. What is the only way to stop an SCR from conducting once it has already started conducting?

1. Remove the gate voltage
2. Reverse the gate voltage
3. Apply a slightly greater reverse negative anode to positive cathode voltage
4. Apply a slightly greater reverse positive anode to negative cathode voltage

IN ANSWERING QUESTION 2-3, REFER TO FIGURE 1-39 IN THE TEXTBOOK.

2-3. When Q1 stops conducting, what action causes the induced voltage in the 6-7 winding to reverse polarity?

1. A sudden drop to zero of current in the 3-4 winding of T1
2. A gradual drop to zero of curent in the 3-4 winding of T1
3. A sudden rise of current in the 3-4 winding of T1
4. A gradual rise of current in the 3-4 winding of T1

2-4. The Scott T-connected transformer will produce a 3-phase, 120-volt output from which of the following inputs?

1. A 3-phase, 120-volt filtered input
2. A 3-phase, 120-volt unfiltered input
3. A single-phase 0° controlled input
4. Two single-phase, 90° controlled inputs

2-5. What component in the inverter reduces voltage transients in the inverter 3-phase output?

1. Drive switch
2. Filters
3. Scott "T" transformer
4. Clipper network

2-6. When the main power circuit breaker is in the OFF position, the drive switch performs which of the following functions?

1. Shows that the static inverter is on standby
2. Supplies a +30-volt dc signal to the synchronizing stage
3. Enables the input dc voltage to be the power source for the control circuit +30 volt dc power supply
4. Each of the above

2-7. During the RUN mode, the control circuits receive power from which of the following sources?

1. +30-volt dc power source
2. Input dc power source
3. CA phase of the inverter
4. Inverter dc input voltage

2-8. In the STANDBY mode, a +30-volt dc signal is applied to the binary circuit in the sync stage via the drive switch. This keeps the bistable multivibrator in the sync stage in what state?

1. Turn on
2. Turn off
3. Free running
4. Saturation

IN ANSWERING QUESTION 2-9, REFER TO FIGURE 1-40 IN THE TEXTBOOK.

2-9. The duration of the ON time of the power stage is determined by which of the following control signals?

1. Leading edge of waveform C
2. Trailing edge of waveform C
3. Leading edge of waveform P
4. Trailing edge of waveform P

2-10. The output voltages of the static inverter must be adjusted in what phase sequence?

1. AB, BC, CA
2. BC, CA, AS
3. CA, AB, BC
4. AB, CA, BC

2-11. Voltage checks on the rectifier power supply are made at the load. If incorrect, how are the voltages adjusted?

1. Internally by repositioning a lead on a trapped transformer
2. Internally by positioning a potentiometer
3. Externally by positioning a potentiometer
4. Externally by a switch that changes leads on a tapped transformer

2-12. What is used to control the bridge circuit output voltage of the rectified power supply?

1. A variable voltage SCR trigger pulse
2. A variable polarity SCR trigger pulse
3. A variable SCR firing time
4. A variable number of SCRs that can be triggered

2-13. In the no-break power supply system, the outputs of the voltage and frequency monitors are primarily used for what purpose?

1. Meter indications
2. Field excitation
3. Regulator controls
4. Relay switching

2-14. The voltage-sensing circuit steps down the 3-phase generator 440-volt ac output to what voltage?

1. 50 volts ac
2. 50 volts dc
3. 25 volts ac
4. 25 volts dc

IN ANSWERING QUESTIONS 2-15 AND 2-16, REFER TO THE MODULATOR CIRCUIT SHOWN IN FIGURE 1-44 IN THE TEXTBOOK.

2-15. What will happen to capacitor C4 when voltage peaks at the unijunction transistor Q4?

1. It will short
2. It will open
3. It will charge
4. It will discharge

2-16. What is the purpose of connecting CR8 across the primary of T2?

1. To shunt out the self-induced voltage of T2
2. To develop collector voltage on Q5
3. To control the firing point of Q5
4. To bypass T2 when Q5 is conducting

2-17. The SCRs of the generator field recifier control power by varying which of the following factors?

1. Voltage of the trigger pulse
2. Timing of the gate pulse on each half cycle
3. Current of the gate pulse
4. Resistance of the generator field

2-18. When the generator output voltage decreases, the voltage regulator will increase the generator field current. How can you cause the frequency regulator to increase this field current?

1. By increasing the generator frequency
2. By decreasing the generator frequency
3. By increasing the generator voltage
4. By keeping the generator voltage constant

2-19. What total number of mounted anemometers are there on most ships?

1. One
2. Two
3. Three
4. Four

2-20. Which of the following is NOT a major component of the wind indicating system?

1. Wind direction and speed detector
2. Wind speed and direction transmitter
3. Wind direction and gyro compass
4. Wind speed and direction indicator

2-21. The type F wind indicating system provides what output(s)?

1. 115 V, 60 Hz
2. 115 V, 400 Hz
3. Both 1 and 2 above
4. 220 V, 60 and 400 Hz

2-22. The graduated dials in a type B indicator are different than those in a type F indicator.

1. True
2. False

2-23. The direction transmitter subassembly of the wind transmitter contains what total number of control transformers?

1. One
2. Two
3. Three
4. Four

2-24. What component in the speed transmitter subassembly of the wind transmitter changes linear displacement to angular displacement?

1. The synchronous integrator
2. The differential assembly
3. The magnetic amplifier
4. The friction disk and roller assembly

2-25. How is the speed dial of a wind indicator numbered?

1. 0 to 100 in 5-knot intervals
2. 0 to 99 in 10-knot intervals
3. 0 to 190 in 1-knot intervals
4. 0 to 360 in 10-knot intervals

2-26. How is the dial of the direction indicator marked?

1. 0 to 360 degrees in 1-degree intervals
2. 0 to 360 degrees in 5-degree intervals
3. 0 to 360 degrees in 10-degree intervals
4. 0 to 360 degrees in 15-degree intervals

2-27. The conventional connection for synchros is for a counterclockwise rotation with an increasing reading.

1. True
2. False

2-28. When it is desired for the shaft of the synchro receiver to turn clockwise for an increasing reading, the leads should be connected in which of the following ways?

1. S1 transmitter lead to S3 receiver lead
2. S2 transmitter lead to S1 receiver
3. Both 1 and 2 above
4. R1 transmitter lead to R2 receiver lead

2-29. What is the reference point for the alignment of all synchros?

1. Mechanical zero
2. Electrical zero
3. Mechanical null
4. Electrical null

2-30. What is the most accurate method of zeroing a synchro?

1. The dc voltmeter method
2. The ac voltmeter method
3. The synchro tester method
4. The electric lock method

2-31. During synchro alignment, what is the purpose of the coarse setting?

1. To ensure a setting of zero degrees rather than 180°
2. To prevent the voltmeter from being overloaded
3. To keep the synchro device from overheating
4. To correct the fine setting

2-32. If a synchro receiver is properly zeroed, when do the stator windings have electrical zero voltages?

1. When the rotor is moving
2. When the rotor is stopped
3. When the rotor is at 270°
4. When the rotor is at its reference position

2-33. In the electrical zero position, the axes of the rotor coil and what other coil(s) are at zero displacement?

1. S1
2. S2
3. S1 and S2
4. S3

2-34. When the synchro is at zero, which windings will have minimum voltage between them?

1. S1 to S2
2. S2 to S3
3. S1 to S3
4. R1 to R2

2-35. The electrical zero position of a TX-TR synchro system can be checked by intermittently jumping which of the following windings at the receiver?

1. S1 and S2
2. R1 and S1
3. R2 and S3
4. S1 and S3

2-36. A differential synchro is at electrical zero if the axes of which of the following coils are at zero displacement?

1. S1 and S2
2. S2 and S3
3. R2 and S2
4. S1 and R1

2-37. When a 115-volt source is used during the zeroing of a differential synchro, what is the maximum time the circuit can be energized without causing damage to the synchro?

1. 1 minute
2. 2 minutes
3. 15 minutes
4. 30 minutes

2-38. On a properly zeroed CT, what voltage exists only between S1 and S2 or S2 and S3?

1. 115 V
2. 110 V
3. 90 V
4. 78 V

2-39. If multispeed synchro systems are used to accurately transmit data, then the synchros within the system must be zeroed separately.

1. True
2. False

2-40. What method of zeroing a synchro is the fastest but NOT the most accurate?

1. The dc voltmeter method
2. The ac voltmeter method
3. The electrical lock method
4. The synchro tester method

2-41. The electrical lock method of zeroing a synchro requires accessible leads and which of the following conditions?

1. A rotor free to turn
2. A stator free to turn
3. A supply voltage to the stators
4. A zero-volt potential between S1 and S2

2-42. The electrical lock method is normally used to zero which type of synchro?

1. CT
2. TX
3. TR
4. CX

2-43. What is the purpose of the signal synchro amplifier?

1. To reduce the size of synchro transmitters
2. To provide quicker information
3. To provide feedback to the synchro transmitter
4. To match the impedance of the system

2-44. Synchro signal amplifiers used with shipboard equipment are designed to perform all except which of the following functions?

1. Feed signals originating in the synchro loads back to the input bus, in phase with the input
2. Operate two synchro loads from one input source
3. Operate large capacity synchro transmitters with low current inputs
4. Operate 400-Hz synchro loads with 60-Hz inputs

2-45. Both E- and F-type synchro signal amplifiers have provision for what total number of output synchros?

1. One
2. Two
3. Three
4. Four

2-46. The major difference between the type E- and type F-synchro signal amplifiers is that the type E is designed for operation on (a) what input and the type F is designed for operation on (b) what input?

1. (a) 400 Hz only; (b) 60 Hz only
2. (a) 60 Hz only; (b) 400 Hz only
3. (a) 60 and 400 Hz; (b) 400 Hz only
4. (a) 60 Hz only; (b) 60 and 400 Hz

2-47. What total number of scales is provided on the dial of both the type E- and type F-synchro signal amplifiers?

1. One
2. Two
3. Three
4. Four

2-48. Speed changes from 1 speed to 2 speed and vice-versa can be made in the type E- and type F-synchro signal amplifiers by which of the following actions?

1. Making wiring changes
2. Turning the dial over
3. Installing change gears
4. Both 2 and 3 above

2-49. When the type E- or type F-synchro signal amplifier is operated from a low 1- or 2-speed input, it is necessary to make some minor wiring changes. What do these minor wiring changes accomplish?

1. Disconnect the low-speed synchro control transformer only
2. Connect the antistickoff voltage only
3. Connect the low-speed synchro control transformer and disconnect the antistickoff voltage
4. Disconnect the low-speed synchro control transformer and connect the antistickoff voltage

2-50. How is the stator of a synchro transmitter wound?

1. With a two-circuit, parallel-connected winding
2. With a two-circuit, series-connected winding
3. With a three-circuit, delta-connected winding
4. With a three-circuit, Y-connected winding

2-51. A synchro amplifier cycle of operation takes place during which of the following conditions?

1. When a change occurs in the remotely transmitted synchro data
2. When the signal received by the synchro control transformers in the mechanical unit is, as an error voltage, amplified and used to actuate the servomotor which, through gearing, turns the control transformer rotors until the error voltages are zero
3. When the servomotor drives the rotors of the output synchros into alignment
4. Each of the above

2-52. When the shaft of a synchro is to be driven clockwise for an increasing reading, to which terminal on the terminal block should the S3 lead be connected when standard synchro connections are used?

1. B1
2. B2
3. B3
4. BB

2-53. What is the purpose of a cutover circuit?

1. To serve as the preamplifier for the servo amplifier
2. To switch from fine to coarse data
3. To detect out-of-alignment conditions between fine and coarse data
4. To drive the relay-signaling circuit

2-54. To prevent the synchro amplifier system from locking in at 180° out of phase, an antistickoff voltage is applied to what component?

1. The fine synchro generator
2. The coarse synchro generator
3. The low-speed control transformer
4. The high-speed control transformer

2-55. Gear train oscillation, or hunting, is prevented in a synchro signal amplifier by introducing a stabilizing voltage at what component?

1. The servo amplifier input
2. The servo amplifier output
3. The low-speed CT
4. The high-speed CT

2-56. The external alarm of a synchro amplifier will be energized under all except which of the following conditions?

1. When the input and output synchros are excited and the alarm switch is off
2. When the input and output synchros are excited and the alarm switch is on
3. When the alarm switch is on and one or more of the input or output synchros are not excited
4. When the servo unit fails to follow the input signal, within 2.5°

2-57. The crosswind and headwind computer system is designed for use aboard which of the following vessels?

1. PFs
2. DLGs
3. CLGs
4. CVAs

2-58. The crosswind and headwind computer receives its input (a) in what form and (b) from what source?

1. (a) Relative wind direction; (b) speed from HD and HE circuits
2. (a) True wind direction; (b) speed from CIC
3. (a) Relative wind direction; (b) speed from CIC
4. (a) True wind direction; (b) speed from HD and HE circuits

2-59. The phase shift that is inherent in each control transformer of the crosswind and headwind computer is compensated for by what means?

1. An inductor in parallel with the error signal
2. A transformer
3. Negative feedback in the servo amplifier
4. Positive feedback in the servo amplifier

2-60. What is the phase relationship between the straight deck crosswind signal, A, and the angled deck crosswind signal, B?

1. A leads B by 10°
2. A lags B by 10°
3. A leads B by 30°
4. A lags B by 30°

2-61. Which of the following is a purpose of the synchro signal converter and the synchro signal isolation amplifier?

1. Elimination of unwanted feedback
2. Retransmission of accurate information without error
3. Conversion of 60-Hz signals to 400-Hz signals
4. Each of the above

2-62. What feature of the synchro signal isolation amplifier prevents torque feedback from the output synchro from being reflected into the converter?

1. Low amplification factor
2. High amplification factor
3. High input impedance, low output impedance
4. Low input impedance, high output impedance

2-63. The output signal from the low-pass filter network in the synchro signal converter can be described by which of the following phrases?

1. It is a pure direct current
2. It is a pulsating direct current
3. It is a 60-Hz alternating current
4. It is a 400-Hz alternating current

ASSIGNMENT 3

Textbook Assignment: "Stabilized Glide Slope Indicator System," chapter 3, pages 3-1 through 3-26

3-1. Which of the following information in reference to a landing platform or ship does the GSI indicate to a pilot?

1. Distance
2. Location
3. Approach speed
4. Approach angle

3-2. What is the source of power of the GSI system?

1. 115 volts ac 400 Hz and 440 volts ac 60 Hz
2. 115 volts ac 60 Hz and 220 volts ac 400 Hz
3. 115 dc and 440 volts ac 400 Hz
4. 115 volts dc and 115 volts ac 160 Hz

3-3. The light bar of the GSI contains which three colors?

1. Yellow, red, and green
2. Red, orange, and green
3. Green, amber, and red
4. Yellow, amber, and red

3-4. If the pilot is on the correct glide path, which of the following colors will he see?

1. Red
2. Amber
3. Yellow
4. Green

3-5. The bar of light is formed by the combined actions of which of the following lights/lens?

1. Source light, Fresnel lens, and lenticular lens
2. Source light, Fresnel lens, and collector lens
3. Fresnel lens, lenticular lens, and colored lens
4. Source light, lenticular lens, and contact lens

3-6. The stabilized platform uses what reference to develop electronic error signals?

1. 115 volts ac
2. 115 volts dc
3. Internal gyro
4. Local gyro

3-7. What does the failure detection circuit do in case of stabilization failure?

1. It automatically switches to a standby stabilization
2. It switches all three colors in the light bar to red
3. It turns off the lights
4. It switches to a standby GSI

3-8. The feedback control system is essentially a servo loop.

1. True
2. False

3-9. When the GSI is operating normally, the LVDT generates the error voltage that determines the position of the stable platform.

1. True
2. False

A.	Electronic enclosure assembly
B.	Remote control panel assembly
C.	Hydraulic pump assembly
D.	Transformer assembly
E.	GSI assembly
F.	Stabilized platform assembly

Figure 3A

IN ANSWERING QUESTIONS 3-10 THROUGH 3-15, REFER TO FIGURE 3A.

3-10. What assembly is the signal processing distribution and control center for the system?

1. A
2. C
3. B
4. D

3-11. What assembly is a self-contained, medium-pressure, closed-loop system used to supply hydraulic pressure for the stabilized platform?

1. A
2. B
3. C
4. D

3-12. What assembly steps down the voltage for the source light from 115 volts ac to 18.5 volts ac?

1. B
2. C
3. D
4. F

3-13. What assembly is mounted to the ship's deck in close proximity to the helicopter landing area?

1. A
2. C
3. E
4. F

3-14. What assembly is made up of the mounting base assembly and the indicator assembly?

1. A
2. B
3. E
4. F

3-15. What assembly provides control and indicators for operating and monitoring the SGSI system from a remote location?

1. A
2. B
3. C
4. D

3-16. The error signal from the electronic enclosure assembly is generated by what system?

1. Feedback control system
2. Reference signal system
3. Servo loop control system
4. Gyro signal system

3-17. What components mounted on the gimbals senses any motion of pitch and roll?

1. Synchro transmitters
2. Synchro receivers
3. Synchro resolvers
4. Levels

3-18. The error signal is changed from an ac signal to a dc signal by what component?

1. Stab-lock relay
2. Power transformer
3. Servo amplifier
4. Gyro demodulator

3-19. When the platform becomes level, what action occurs?

1. Hydraulic fluid enters the actuator
2. An error signal is generated
3. The READY light is lighted
4. The NOT READY light is lighted

3-20. What FEATURE tests and aligns the GSI?

1. Gyro transmitter
2. Failure detection circuit
3. Servo amplifier
4. Stab-lock relay

3-21. What is the location of the remote control panel?

1. In the engineering log room
2. On the bridge
3. In the flight operations control room
4. On the flight deck

3-22. The overtemp light comes on when the hydraulic fluid heats to what minimum temperature?

1. 115 ±5°
2. 125 ±5°
3. 135 ±5°
4. 145 ±5°

3-23. When the stab-lock button is pushed, the error signal is caused by what component?

1. The gyro
2. The linear differential transformer
3. The potentiometer
4. The gyro signal synchro amplifier

3-24. What system consists of the electric pump motor, a coupling unit, a hydraulic pump reservoir, valves, piping, and an electrical system?

1. The hydraulic pump assembly
2. The transformer assembly
3. The remote control assembly
4. The glide slope indicator assembly

3-25. What is the operating pressure of the GSI hydraulic system?

1. 1400 psi
2. 1300 psi
3. 1200 psi
4. 1000 psi

3-26. Hydraulic fluid heaters in the oil reservoir maintain the temperature at approximately what value?

1. 80° ±5°
2. 85° ±5°
3. 70° ±5°
4. 75° ±5°

3-27. The pressure switch in the hydraulic pump discharge line will close at what pressure?

1. 1400 psi
2. 1200 psi
3. 1300 psi
4. 1000 psi

3-28. The purpose of the transformer assembly is to step-down the 115-volt ac source voltage to what voltage?

1. 24.0 volts dc
2. 18.5 volts dc
3. 24.0 volts ac
4. 18.5 volts ac

3-29. What do the light rays from a piano-convex spherical lens tend to do?

1. Form an astigmatism
2. Converge all at one point
3. Pass through the lens near the principle axis
4. Scatter

3-30. Which of the following effects is NOT a characteristic of operating the Fresnel lens outside specific temperature limits?

1. The three colors run together vertically to form one solid color
2. The size of the bar of light near the center of the lens is different from that which is seen near the center of the lens
3. The motion of the bar of light from cell center to transition line does not appear to be smooth
4. The vertical field angle is either larger or smaller

3-31. What is the azimuthal range of the lenticular lens used in the Fresnel system?

1. 20°
2. 30°
3. 40°
4. 50°

3-32. What is the color of the lenticular lens in the (a) top segment and (b) bottom segment?

1. (a) Green; (b) red
2. (a) Amber; (b) red
3. (a) Green; (b) amber
4. (a) Red; (b) Green

3-33. When the Fresnel system is not operating, what component secures the source light indicator assembly in a fixed position?

1. Junction box
2. Stowlock assembly
3. Deck-edge boom
4. Roll power drive assembly

3-34. What is the essential element of the vertical gyroscope?

1. A pendulum
2. A thermal switch
3. A projection lamp
4. A flywheel

3-35. When performing the cell alignment of the GSI, what total number of adjustments must you make?

1. One
2. Two
3. Three
4. Four

3-36. In the GSI cell, what is the total distance from the slots to the Fresnel lens?

1. 15.0 in.
2. 15.8 in.
3. 16.0 in.
4. 16.8 in.

3-37. What total number of projection lamps is used in the GSI?

1. One
2. Two
3. Three
4. Four

3-38. In the GSI, lens temperature control is achieved by which of the following devices?

1. Blowers
2. Heaters
3. Thermal switches
4. All of the above

3-39. In the GSI, control thermoswitches S1 and S2 are set to operate at what temperature?

1. 110° +10°F
2. 100° +10°F
3. 98° +10°F
4. 96° +10°F

3-40. The transformer assembly uses what fixed length of cable from the transformer secondary to the GSI cell connector?

1. 10 ft
2. 7 ft
3. 5 ft
4. 4 ft

3-41. Unless a system failure prevents it, the GSI should always be operated in what mode?

1. Ship gyro
2. Ship gyro stab-lock
3. Internal gyro stab-lock
4. Internal gyro

3-42. What mode of operation enables the operator to isolate and test various parts of the system while disenabling other parts?

1. Ship gyro
2. Internal gyro
3. Internal gyro stab-lock
4. Ship gyro stab-lock

3-43. From what assembly/panel does the operator control the intensity of the source light?

1. Electronic enclosure assembly
2. Transformer assembly panel
3. Remote control panel
4. Stabilized platform assembly

3-44. The LVDT loop is exactly the same as the gyro feedback loop.

1. True
2. False

3-45. The universal joints and rod ends allow the platform to tilt in what total number of axes?

1. One
2. Two
3. Three
4. Four

3-46. The GSI stable platform uses what total number of servo loops in each axis?

1. One
2. Two
3. Three
4. Four

3-47. When the output of the LVDT is zero, what is the position of the platform top in relation to the base?

1. Above
2. Below
3. Level
4. Fluctuating

3-48. Which of the following is NOT a way in which op-amps are used in the stable platform system?

1. Amplifiers
2. Demodulators
3. Comparators
4. Oscillators

3-49. What will happen if feedback is added to the amplified inverting and noninverting inputs of an op-amp?

1. The voltage difference between the inputs will increase
2. The voltage difference between the inputs will remain the same
3. The voltage difference between the Inputs will decrease slightly
4. The voltage difference between the inputs will be close to zero

3-50. Which of the following is NOT a common type of failure for an op-amp?

1. Saturated positive
2. Saturated negative
3. No output
4. Output changes with varying inputs

A. Gyro demodulator
B. LVDT
C. LVDT demodulator card
D. LVDT oscillator
E. LVDT demodulator
F. Servo amplifier
G. Dither oscillator
H. Error circuit
I. Gyro alarm circuits
J. Gyro signal card assembly
K. Source light failure detector
L. Power distribution circuits

FIGURE 3B

IN ANSWERING QUESTIONS 3-51 THROUGH 3-61, REFER TO FIGURE 3B.

3-51. An electromechanical transducer that converts physical motion into an output voltage whose amplitude and phase are proportional to position.

1. B
2. C
3. D
4. E

3-52. Consists of a quadrature oscillator and a power amplifier.

1. A
2. B
3. D
4. G

3-53. Supplies a constant voltage ac excitation to the LVDT primaries and converts the pitch and roll LVDT amplitude and phase signals to a variable dc voltage.

1. A
2. C
3. H
4. J

3-54. Has three inputs summed into amplifier A1.

1. E
2. F
3. J
4. K

3-55. Has a signal that is full-wave rectified and filtered, whose output polarity is positive for signals out of phase with the reference and negative for signals in phase.

1. J
2. H
3. F
4. E

3-56. Provides a high-frequency signal to the servo valves to keep them in constant motion to prevent sticking at null.

1. L
2. K
3. H
4. G

3-57. Monitors the pitch and roll servo errors.

1. A
2. B
3. H
4. I

3-58. Detects any failure that will result in a loss of stabilization.

1. G
2. H
3. I
4. J

3-59. Amplifies and sums the demodulated pitch and roll synchro signals from the ship's gyro with the platform LVDT outputs.

1. A
2. J
3. K
4. L

3-60. Monitors the voltage and current going to the three source lights.

1. L
2. K
3. J
4. I

3-61. Provides two sources of power to the system.

1. L
2. J
3. G
4. A

3-62. The SGSI system uses hydraulic pressure for motive power.

1. True
2. False

3-63. The hydraulic accumulators used in the SGSI are steel cylinders with internal rubber bladders. The bladders are pressurized with dry nitrogen to what pressure for the (a) high-pressure end (b) low-pressure accumulators?

1. (a) 38 psig; (b) 700 psig
2. (a) 700 psig; (b) 38 psig
3. (a) 70 psig; (b) 380 psig
4. (a) 380 psig; (b) 70 pslg

3-64. The hydraulic cylinders used in the SGSI are linear actuators. The hydraulic pressure exerted by the piston is 1400 psig in extension. What is the pressure exerted in compression?

1. 700 psig
2. 500 psig
3. 400 psig
4. 200 psig

ASSIGNMENT 4

Textbook Assignment: "Technical Administration," chapter 4, pages 4-1 through 4-16.

4-1. The science and art of measurement is known by what term?

1. Meteorology
2. Traceability
3. Metrology
4. Physics

4-2. What is the calibration of all measuring devices based on?

1. The basic international and national standards of measurements
2. The advanced national standards of measurement
3. The 16 principles of calibration procedures
4. The American standards of measurement

4-3. What is the purpose of the METCAL program?

1. To ensure traceability and accuracy of instrument calibration to NIST
2. To ensure traceability and accuracy of instrument. calibration to the CNO
3. To ensure traceability and accuracy of medical equipment
4. To ensure traceability and accuracy of periscopes

4-4. The accuracy of a standard must be traceable, through documentation by each higher calibration activity, to what activity?

1. NAVSEA
2. NSL
3. NIST
4. RSL

4-5. Each instrument calibrated must bear evidence that it is in calibration. This evidence is in what form?

1. A stamp on the instrument
2. A color coding on the instrument
3. A letter from NIST taped to the instrument container
4. A calibration label affixed to the instrument

4-6. The METCAL program provides for periodic calibration of most instruments. The responsibility for assignment of these periodic calibration intervals has been given to what activity?

1. NSL
2. MEC
3. RSL
4. NAVSEA

4-7. The common reference for Navy scientific measurements is provided by what activity?

1. NIST
2. MEC
3. NAVSEA
4. OPNAV

4-8. What activity certifies the standards used by the type I NSL?

1. MEC
2. NAVSEA
3. NIST
4. OPNAV

A. STANDARD
B. CALIBRATION
C. TEST AND MONITORING SYSTEM
D. TRACEABILITY
E. INCIDENTAL REPAIR
F. OPERABLE EQUIPMENT

FIGURE 4A

IN ANSWERING QUESTIONS 4-9 THROUGH 4-14, REFER TO FIGURE 4A.

4-9. The unbroken chain of properly conducted and documented calibration.

1. F
2. E
3. D
4. B

4-10. Equipment used for quantitative measurement.

1. B
2. C
3. E
4. F

4-11. The comparison of a measurement device of unverified accuracy to a device of known and greater accuracy.

1. B
2. C
3. E
4. F

4-12. A laboratory device used to maintain continuity of value in the units of measurement.

1. F
2. C
3. D
4. A

4-13. A piece of equipment that is performing satisfactory before being submitted for calibration.

1. A
2. C
3. E
4. F

4-14. Replacement of parts that prevent calibration, but do not render the equipment inoperative.

1. F
2. E
3. D
4. B

4-15. The operation of the type I NSL and its detachment is under the cognizance of what command?

1. NAVSEA
2. NAVAIRSYSCOM
3. TYCOM
4. SECNAV

4-16. In performing its function, the NSL provides services for the systems commands, cognizant laboratories, and what personnel?

1. Air Force personnel
2. Civil engineers
3. Safety supervisors
4. Project managers

4-17. What echelon of calibration is provided by the reference standard laboratories?

1. First
2. Second
3. Third
4. Fourth

4-18. Type II NSLs obtain standards calibration services from which of the following activities?

1. Type I NSLs
2. Type II RSLs
3. Type III NSLs
4. MEC

4-19. What activities have been set up to enable user activities to calibrate locally such specific types of instruments as pressure gauges, temperature gauges, and electrical meters?

1. NSLs
2. FCAs
3. RSLs
4. NCLs

4-20. To receive calibration support for standards, you should take which of the following steps?

1. Request funds
2. Request calibration services
3. Make up a recalibration schedule
4. Each of the above

4-21. The initial data input for the MEASURE program is submitted on what form?

1. Format 350
2. Inventory report form
3. METER card
4. Format 310

4-22. After the initial inventory report form has been submitted, what minimum number of items being added to the inventory would allow the use of the inventory report form again?

1. One
2. Five
3. Seven
4. Ten

4-23. The inventory report form information is entered into the data bank by what person/activity?

1. MEC
2. METCAL rep
3. MOCC
4. MIRCS

A.	TMDE INVENTORY REPORT FORM
B.	OP43P6
C.	METER CARD
D.	EQUIPMENT ID AND RECEIPT TAG
E.	NAVSUP 4500
F.	OP4700

FIGURE 4B

IN ANSWERING QUESTIONS 4-24 THROUGH 4-29. REFER TO FIGURE 4B.

4-24. Attached to the METER card.

1. A
2. B
3. C
4. D

4-25. Used to report information and transactions pertaining to TAMS and calibration standards.

1. A
2. B
3. C
4. E

4-26. Contains information on how to use the MEASURE program.

1. A
2. B
3. E
4. F

4-27. Provides the initial input of data pertaining to TAMS equipment and calibration.

1. A
2. D
3. E
4. F

4-28. Contains all information necessary to identify a single piece of TAMS equipment and calibration.

1. A
2. C
3. D
4. F

4-29. Bears the same control number as the METER card.

1. A
2. B
3. C
4. D

4-30. What document is used to forward questions, recommendations, and comments pertaining to MEASURE to concerned authorities?

1. A MEASURE referral card
2. A METER card
3. A TMDE inventory report form
4. An equipment ID and receipt tag

IN ANSWERING QUESTIONS 4-31 and 4-32, REFER TO FIGURE 4-2 IN THE TEXT.

4-31. What blocks describe an item?

1. 1 and E
2. 11 and D
3. 19 and E
4. 4 and D

4-32. What does block 65 identify?

1. Rejected piece of equipment
2. Calibration lab standard
3. Phase/level standard
4. Accessories

4-33. Which, if any, of the following copies of the receipt and ID tags are sent to the MOCC?

1. White
2. Pink
3. Green
4. None of the above

4-34. A calibrated label is used when which of the following conditions is met?

1. A specific tolerance is requested by the user
2. A specified condition requested cannot be met
3. The instrument fails at more than one test point within its range
4. All parameters to be tested are within tolerance

4-35. What label/tag must be used when certain conditions must be known to the user and/or the calibration technician?

1. USER CALIBRATION
2. CALIBRATED
3. SPECIAL CALIBRATION
4. NO CALIBRATION REQUIRED

4-36. Which of the following labels requires that an instrument must be calibrated before it can be used?

1. CALIBRATED--REFER TO REPORT
2. CALIBRATION VOID IF SEAL BROKEN
3. CLEANED FOR OXYGEN USE
4. INACTIVE

4-37. The overall security, orientation, education, and training program is the responsibility of what person?

1. The commanding officer
2. The executive officer
3. The security officer
4. The engineer officer

4-38. Ways by which you can help make personnel security conscious include which of the following methods?

1. Stressing the importance of security and the penalties for violating security regulations
2. Relating the techniques that enemies have used to acquire classified information
3. Using posters in appropriate places as reminders of an individual's duties concerning security matters
4. All of the above

4-39. What is the best means of developing individuals and teams into efficient working units?

1. Teaching by the show-and-tell method
2. Drilling and practicing on the job
3. Showing technical films and closed-circuit television programs
4. Conducting classroom lectures and informal group discussions

4-40. The PQS program is designed to help you train your personnel for which of the following reasons?

1. To qualify for advancement
2. To discharge their leadership responsibilities
3. To perform their assigned duties
4. To become familiar with off-ship IC equipment and systems

4-41. Each qualification standard has four main subdivisions. What series is for watch standers?

1. 100
2. 200
3. 300
4. 400

4-42. What section (series) of PQS breaks down the equipment or systems to be studied into functional sections?

1. 100
2. 200
3. 300
4. 400

4-43. What section of the PQS is used to record the individual's satisfactory completion of an item?

1. Theory
2. Qualification
3. Watchstation
4. System

4-44. Which of the following factors determines whether you receive either a slight or fatal shock?

1. Amount and duration of current flow
2. Parts of the body involved
3. Frequency of current
4. Each of the above

4-45. What amperage is usually fatal if it lasts for 1 second or more?

1. 1 mA
2. 10 mA
3. 50 mA
4. 100 mA

4-46. Doors to switch and fuse boxes should be closed except under which of the following conditions?

1. When replacing fuses
2. When the area around the box is not manned
3. During battle stations
4. After knock-off of ship's work

4-47. What individual must give approval to work on energized circuits?

1. Executive officer
2. Engineer officer
3. Commanding officer
4. Division officer

4-48. Should a situation arise where a doubt exists as to the application of a particular directive or precaution, what measures should be taken?

1. Those that will achieve maximum safety
2. Those that will achieve minimum safety
3. Higher authority should be contacted
4. Division officer's advice should be followed

4-49. Which, if any, of the following NSTM chapters gives clear and concise electrical safety precautions that should be required study material for all hands?

1. 555
2. 430
3. 300
4. None of the above

4-50. What piece of software, used in PMS, has a section devoted to safety precautions?

1. Weekly schedule
2. Work center PMS manual
3. Maintenance requirement card
4. Quarterly schedule

4-51. What is the best way to control any fire?

1. Use a 1 1/2-inch fire hose
2. Use a CO_2 fire extinguisher
3. Use a PKP fire extinguisher
4. Do not let the fire happen

4-52. Which of the following agents should be used to fight electrical fires?

1. PKP
2. CO_2
3. Water
4. AFFF

4-53. A technician working on a live circuit can help avoid accidents by taking which of the following precautions?

1. Removing rings, watches, and loose clothing before starting work
2. Wearing rubber gloves on both hands
3. Using insulated hand tools
4. All of the above

4-54. When more than one repairman is working on circuits that have a common supply, what procedure should be used for tagging circuits and removing tags?

1. Only one repairman tags the supply and removes the tag when the work is completed
2. At least two repairmen tag the supply; one repairman removes the tags when the work is completed
3. Each repairman tags the supply and removes only his/her tag when his/her work is completed
4. Each repairman tags the supply; the repairman completing his/her work last removes the tags

4-55. What individual must grant permission before a person can go aloft?

1. Officer of the deck
2. Engineer officer
3. Commanding officer
4. Command duty officer

4-56. What two hazardous voltages may be encountered when the ship's service telephone system is connected to a shore exchange?

1. 115 volts ac and 220 volts ac
2. 220 volts ac and 48 volts dc
3. 115 volts ac and 90 volts ac
4. 90 volts ac and 48 volts dc

4-57. Which, if any, of the following switchboards has greatly reduced hazards to operators and repairmen?

1. Live front
2. Semi-dead front
3. Dead front
4. None of the above

4-58. Fuses of what maximum rating may be removed from a circuit before it is de-energized?

1. 10 amperes only
2. 15 amperes only
3. 25 amperes only
4. Any rating

4-59. What is the purpose of having an on-the-scene observer when you are working on a live circuit?

1. To ensure that all safety precautions are followed and to run errands
2. To ensure that all safety precautions are followed and to give first aid if necessary
3. To deliver messages and to locate specifications in NSTM, chapter 300
4. Each of the above

4-60. Extension cords used with portable electric tools should NOT exceed what maximum length?

1. 25 ft
2. 50 ft
3. 100 ft
4. 200 ft

4-61. Naval regulations provide that no alterations are permitted to be made to ships until authorized by what command or individual?

1. Type commander
2. Commanding officer
3. Naval Sea Systems Command
4. Chief of Naval Operations