CHAPTER 5

ELECTRICITY AND ELECTRONICS

INTRODUCTION

The preceding course and the basic courses, Basic Electricity, NAVTRA 10086 and Basic Electronics, NAVTRA 10087, have discussed the principles of electricity and electronics and explained how they apply to missile launching systems. The extensive application of electricity and electronics in missile systems make understanding of the principles and their applications a necessity for the GMM. Practically every part of a weapon system is operated or activated by electrical and electronic parts. The ET, FT, and other ratings are responsible for the care and maintenance of some parts of the weapon system, but there are numerous electric and electronic parts in the launching system whose maintenance is your responsibility.

A typical firing circuit and a power control : circuit were described and illustrated in the preceding course. We explained the action of each component, so that you could trace the functioning on the drawings. Troubleshooting techniques as applied to circuits were explained and troubleshooting charts were presented. You were instructed in the use of various meters in testing and measuring electrical and electronic components. Now you should be able to teach others how to use those meters and testers. If there are some weak or fuzzy areas in your knowledge, go back and review. You cannot build advanced knowledge on a weak foundation.

This chapter will tell you more about applications of electrical and electronic components in the operation of missile systems to help you see how the principles are applied to these components. From these you should advance to the more complicated problems of adjustment, alignment, and troubleshooting of electrical and electronic equipment.

GMM AND ELECTRIC AND ELECTRONIC PARTS

All the electrical and electronic components used to operate and test the launching system are part of the GMM's responsibility. While this is no small assignment, it does leave out (for other ratings to operate and service) a complicated assortment of equipment, such as radars and radar test sets, computers, weapon direction equipment, target detection equipment, and target tracking and missile tracking apparatus.

A review of the quals (Electricity and Electronics) show that nearly all the knowledge factors in these fields are required of the GMM 3 and 2. In the practical factors, the GMM 1 and C are expected to do the troubleshooting, casualty analysis, overhaul, repair, and adjustment on electrical and electronic components of the launching system. You have learned to use the test instruments for simple maintenance and repairs. Now you must learn to use the most sophisticated testers, and to locate electrical and electronic troubles and correct them. This is practical application of the principles you have learned.

CONTROL PANELS IN LAUNCHER SYSTEMS

Table 3-1, in chapter 3, lists the control panels by Mk and Mod numbers for all the missile launching systems currently used. As development of launching systems has advanced from experimental stages, standardization has increased. This not only reduces production and maintenance costs, but simplifies training of personnel. There are still many differences in the control panels for the different systems,. and there always will be some, but the similarities are greater. However, it is still far from "if you know one you know them all." Review chapter 3. Similarities and differences in the missile launching systems were discussed in that chapter.

CONTROL PANELS OUTSIDE THE LAUNCHER SYSTEM

It is impossible to describe the operation of the launcher control panels without constant reference to the control panels in the weapons control station, CIC, and controls on the bridge. There is a constant flow of information and direction to and from the various components of the weapon system. (See fig. 3-1 in chapter 3.) Figure 5-1 shows typical location of component of a weapons system. Communication between components must keep open. In addition to indicating lights on panels, telephone communication between stations is used to relay report or orders. An alternate system must be ready to take over in the event of failure or destruction of the other.

Many of the circuits in the launcher power panels are activated from control panels outside of the launching system. They are tested in cooperation with the operator of the panel sending the activating signals. When there is any failure, the GMM checks out the connection to his panel and works with the other operator to check out the whole circuit.

Training and elevation power drives are controlled by orders from the director, relayed through the launcher captain's control panel. Load orders and firing orders are transmitted to the launchers through the weapons control station and the launcher control panel. There may be a breakdown anywhere along the system and the GMM must help to find the trouble and correct it.

CIRCUIT TESTING BY THE GMM

The preceding course, *Gunner's Mate M (Missiles) 3&2*, NAVTRA 10199 contains a chapter on use of meters for testing, making electrical measurements, and troubleshooting circuits. Review any parts about which you are not clear. A solid understanding of the underlying principles is necessary before trying to understand complicated variations.

NOTE: The routine testing of ship's weapons control circuit wiring makes use of 500-to 1000-volt meggers. These checks are performed periodically as a regular part of preventive maintenance procedures. Repeated high potential tests (over 300 volts peak) can damage synchros and other small rotating components. High potential tests involving these components should be limited to those required for qualification and acceptance at the time of manufacture. Synchros, servomotors, resolvers, tach-generators, etc., should be disconnected from the circuit when megger or ground tests are being conducted.

Missile system installations greatly increased the requirement for 400-hertz power supplies having varying degrees of voltage and frequency regulation. Missile ships have had, to install 400-hertz generating plants to satisfy the demand. All missile ships have three separate 400-hertz power systems, each consisting of two or more motor generators. One is used for the ship's service system; another supplies the continuous wave illuminators used with guidance radars, and the third the most closely regulated (voltage and frequency) 400-hertz system, is used on ships for missile systems.

Launcher electric motors are started and run under the power of a 440-volt 60-hertz ship's power supply. The slipring assembly, on the launcher stand and carriage, provides continuous interconnection between on-launcher and off-launcher electrical connections while allowing unlimited train motion of the launcher. Qn the Talos launcher, the slipring (fig. 5-2) consists basically of a 440-volt collector ring assembly, a 115-volt collector ring assembly, and a fluid slipjoint. Each collector ring assembly has a rotating and a nonrotating section (fig. 5-3). The rotating sections mount collector brushes that are connected by cabling to circuits of on-launcher equipment. The nonrotating sections mount collector rings which are connected by cabling to the circuits of the off-launcher power and control components. The rings are engaged

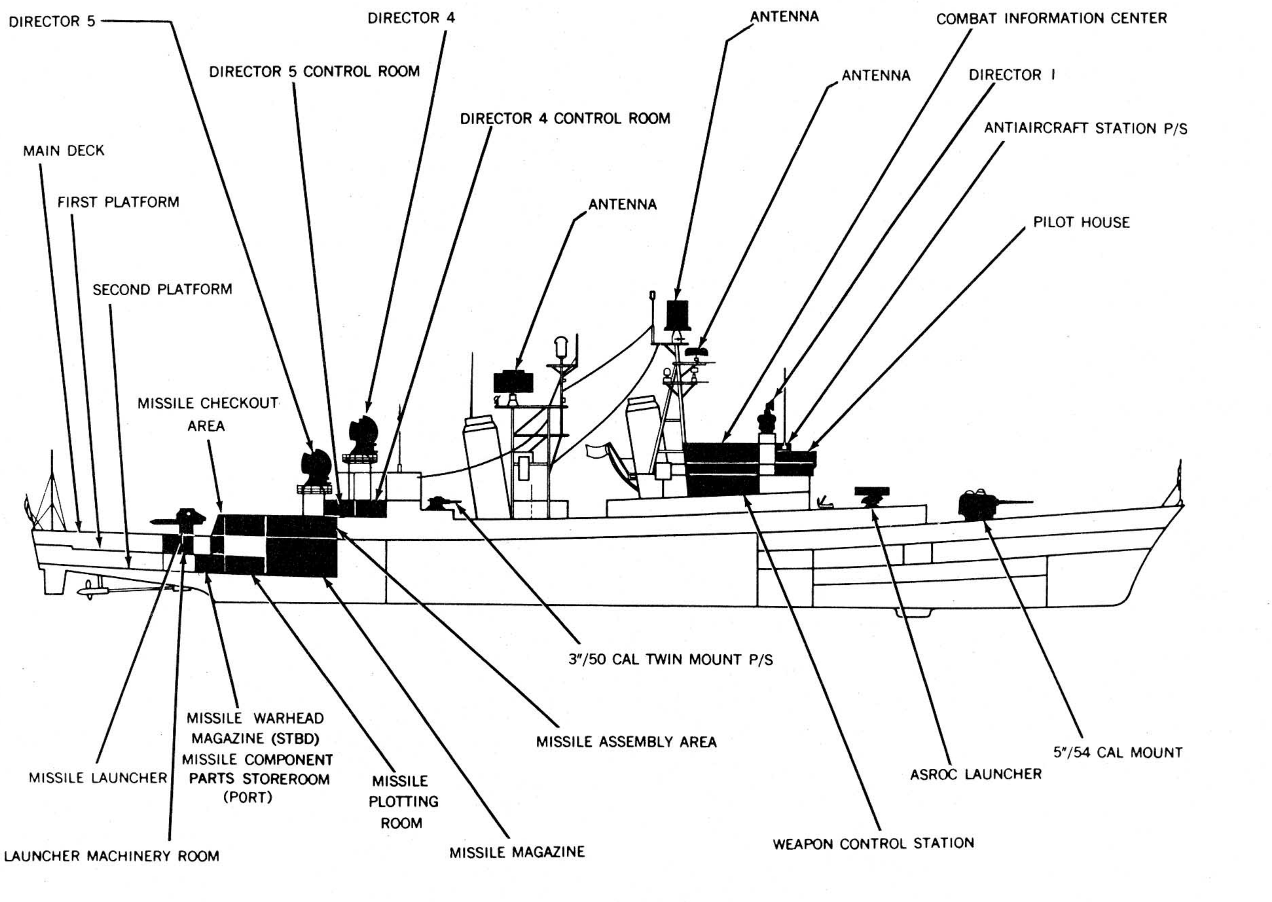

Figure 5-1.—DLG class 9 weapons system.

by the brushes of the rotating sections to complete the electrical circuits. The four brushes contained in each brush ring are electrically connected to a terminal on the outer surface of the ring (fig. 5-3). The launcher cabling connects to the terminals of the assembled brush rings.

Close voltage and frequency regulation are necessary for use in the missile system. Voltage and frequency regulated equipment can now be provided in 30-, 60-, 100-, 200-, and 300-kw sizes, with voltage balance regulators supplied when necessary. Supplying the power needed for the missile system is in the province of the ship's engineering department.

While depending on the engineering department to supply the power in the voltage and frequency desired, you have tested circuits and tubes and have used schematic diagrams, block diagrams, voltage and resistance charts, and troubleshooting charts. Experience and study will help you improve your ability to interpret the results of the tests and trace a malfunction. It is possible to track down a malfunction by checking each part or component in the circuit-following the circuit diagram until you come to the defective part. But that may take hours of tedious work. A study of the problem may reveal a shortcut that will locate the trouble in much less time. While there is much to be said for patient, dogged, stick-to-it-iveness in a troubleshooting job, the application of brainpower to locate the trouble in short order is more commendable. You cannot do this with much success, however, if your knowledge of your weapon system is superficial.

Troubleshooting Control Panel Circuits

With the enormous amount of wiring and electrical components required in a weapons system, it is not surprising that a high proportion of the failures are in the electrical system.

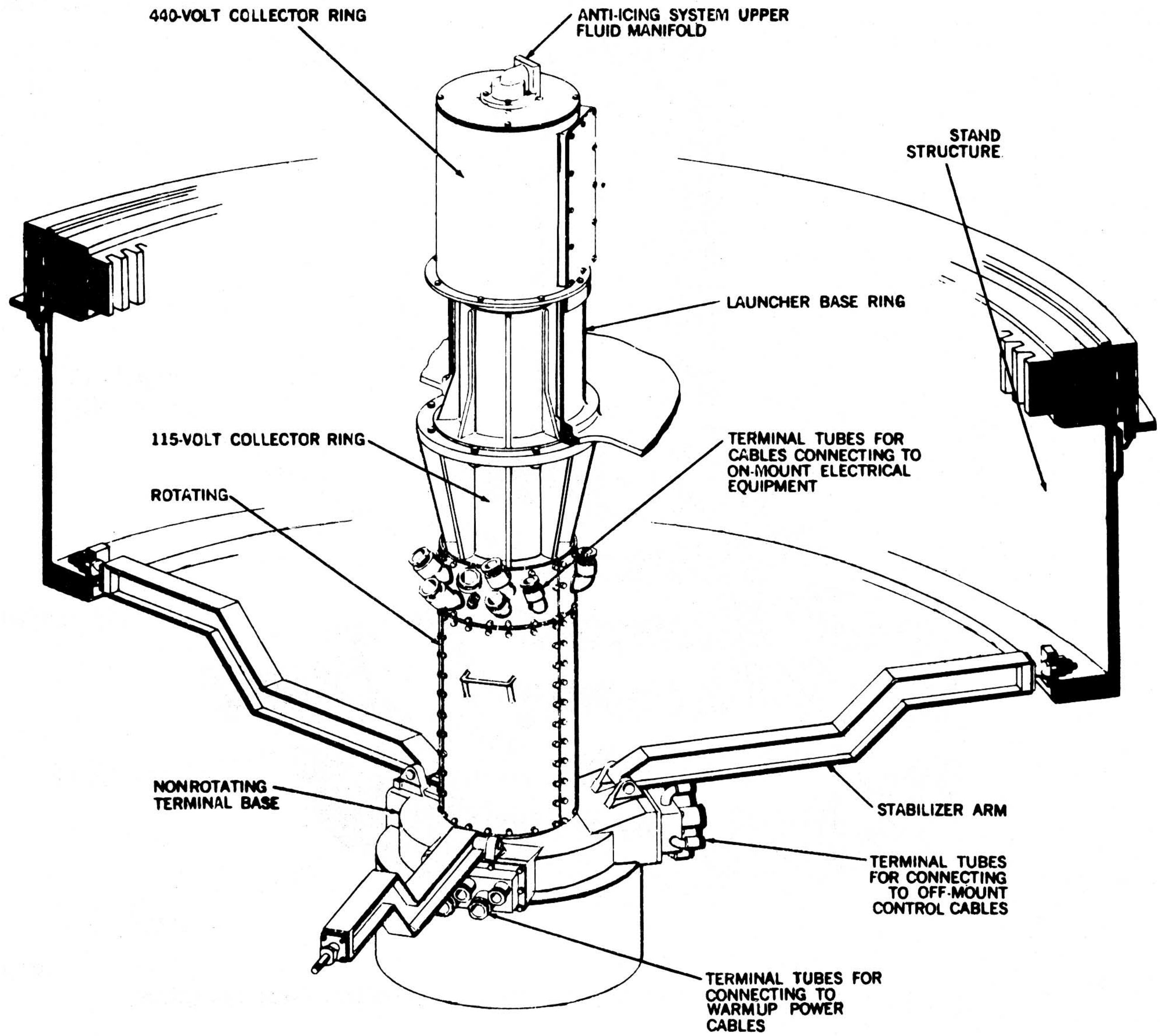

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Figure 5-2.—Slipring Mk 6 Mod 1, installed arrangement on stand and carriage of Mk 7 Mod 1 launcher (Talos).

The control and power relays of the Mk 10 Terrier launching system, for example, consist of more than 400 miniature rotary relays, 6 subminiature relays, 46 medium-size rotary relays, and 6 small-size rotary relays. These relays are in the EP1, EP2, EP4, and EP5 panels.

Conscientious application of the 3-M system is intended to reduce the incidence of failure. The MRCs give step-by-step detail of what to do for routine maintenance, but when any part of the equipment fails to perform as it should, you have to turn to the OPs for aid in troubleshooting. The OP also gives the frequency of tests, checks, inspections, and servicing of the different components. If the OP differs from the MRC in this, follow the MRC instructions.

Let's concentrate on the EP I panel, which is the basic distribution panel for all electrical power to the launching system. It contains switches, circuit breakers, fuses, relays, and

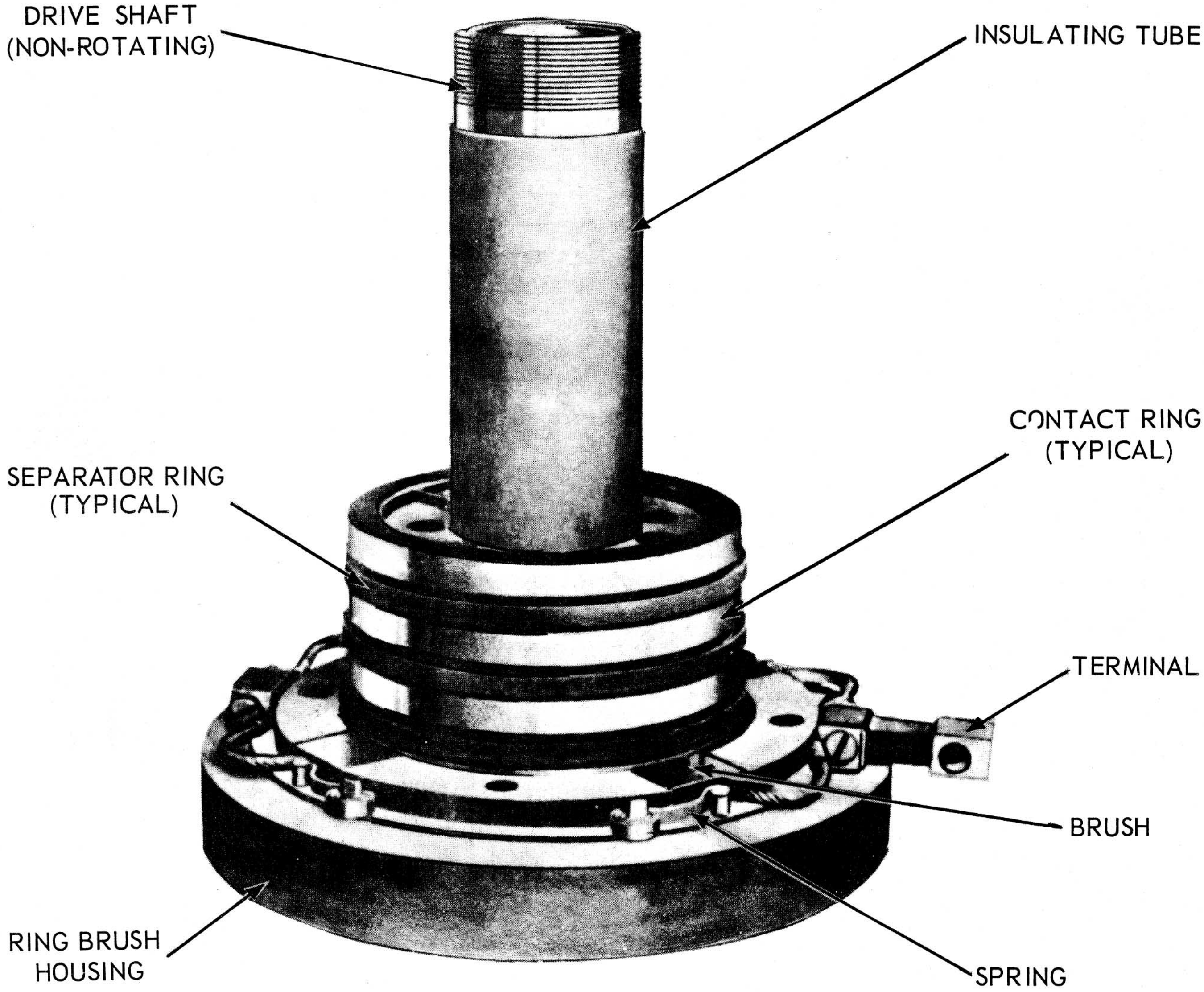

Figure 5-3.—Partially disassembled 400-volt collector ring assembly (Mk 7 Mod 1 launcher).

contactors for the power and control circuits. The launcher captain turns on the various circuits before he goes to the EP2 or launcher captain's panel, which he mans during operations. In figure 5-4 the items are identified by number. Lights in section no. I indicate that the 440-volt power has been turned on and is available on the panel. As the motors in the launching system are energized, lights in section 2 come on: (a) B-side magazine motor; (b) Train motor; (c) Elevation motor; and (d) A-side magazine motor. The circuit breakers for these motors are in section 3. Lights in section 4 indicate that the following motors are energized: (a) B-Side loader motor; (b) Launcher rails motor; (c) Circulating system motor; and (d) A-side loader motor. Section 5 has the circuit breakers for these motors. The two lights in section 6 are for A and B-side loader accumulator motors, and the circuit breakers for these are in section 7, with a third circuit breaker for the control system. When you activate the panel, you turn on all these switches and circuit breakers unless only one side of the launcher is to be used, and then you turn on only the circuit breakers and switches for that side.

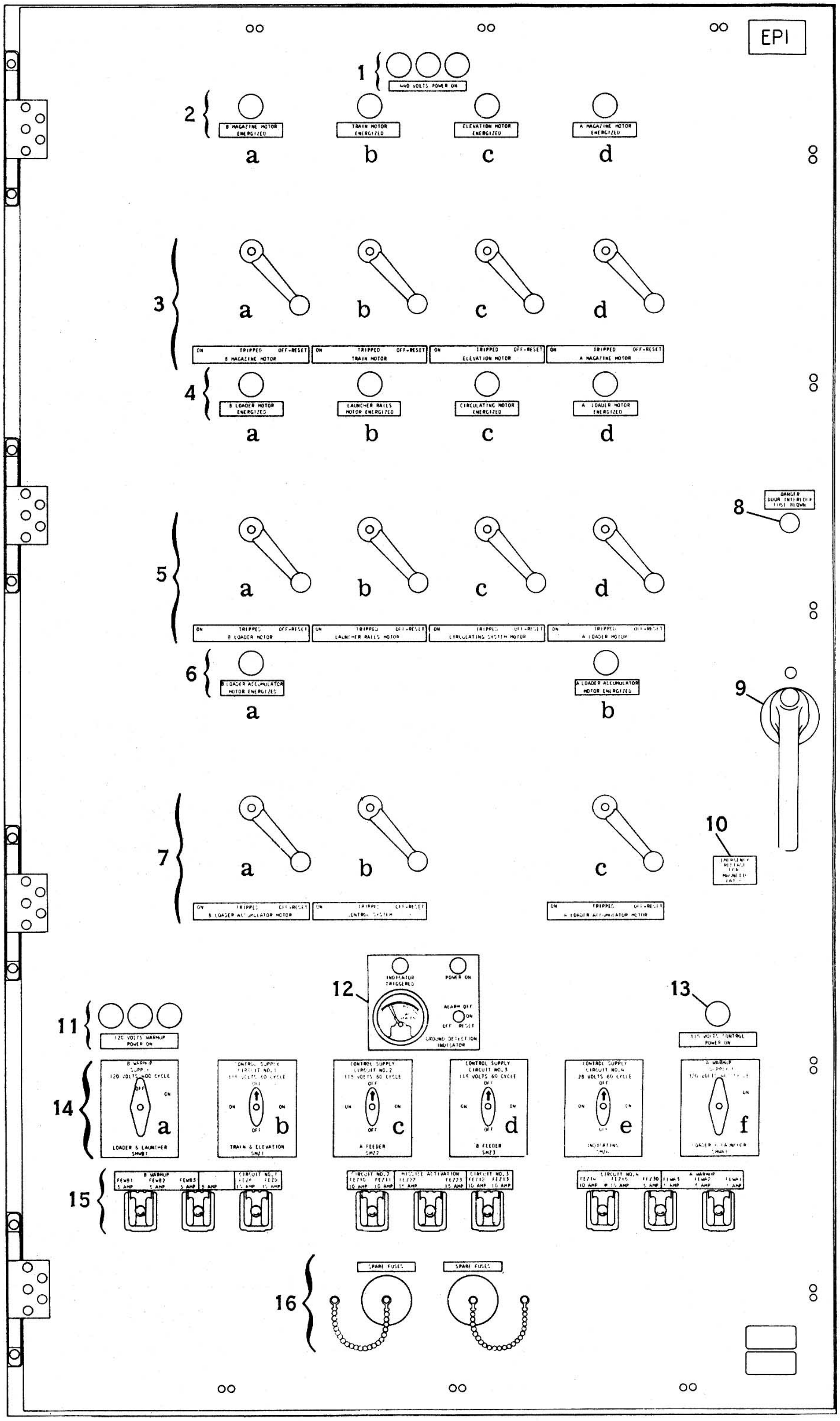

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Figure 5-4.—EP 1 panel, Terrier Mk 10 Mod 7 launching system.

Lights in section 11 indicate that power is available for the 120-volt warmup circuits and the light in section 13 indicates power available in the 115-volt control circuits. The On-Off switches for warmup supply circuits and control supply circuits are in section 14 and the fuses are in section 15. Each fuze block has two fuses and two fuse-blown indicating lights. Two extra fuses are in section 16, with screw-on watertight caps.

If light No. 8 is on, it indicates that the door interlock on the panel is inoperative. A magnetic latch on the door prevents opening it while the power is on. Before the door can be opened to , make repairs, etc., the 440-volt power must be turned off and then the door handle (no. 9) can be turned to open the door. No. 10 is an emergency release for the magnetic door latch. No. 12 is a ground detection indicator. It monitors the 117-volt control supply circuits and triggers an alarm if there is a grounded circuit. Figure 5-5 shows in outline the EP1 functions.

PRELIMINARY ISOLATION. - Let's assume that you have turned on all the switches and circuit breakers on the EP1 panel to activate the system. You notice that a fuse-blown light for switch d in section 14 is on. This means that control supply circuit No. 3 for the B-side feeder is disabled in some way. You have to find where the trouble is. Check the fuse blown light first. You will need to look inside the panel. Before you can do that, you must disconnect the power supply; the panel door will not open while the power is on. Besides, you may not work on energized electrical equipment without an express order from the ship's commanding officer: Remember safety rules for working with electrical equipment: were no rings, wristwatches, bracelets, or similar metal objects. Do not work with wet hands or wet clothing Wear no loose or flapping clothing. Discharge any capacitors before touching them - they retain a charge after they are disconnected from their power source.

You may see; the cause of the failure as soon as you look behind the panel door, but more than likely you will need to get the electrical drawings and trace the wiring until you find the trouble. The power distribution cables are numbered 0 to 99, and the wires are numbered 0 to 999. Loading control cables for the "A" side are numbered 200 to 299, and for the "B" side the numbers are 300 to 399. Wire and cable numbers are assigned in groups, with "A" or "B" added to indicate the side served by the wire or cable. For example, "WSA2022" means "Wire, single conductor, no. 2022 of the A-side loaded circuitry." The cabling schematic also identifies the type and size of wire used in each application. The drawing explains the component type designations used, such as "WS" above, and the major assembly designations, such as "LB" for Loader, B-side, or "BA" for dud jettison, A side. All electrical and hydraulic

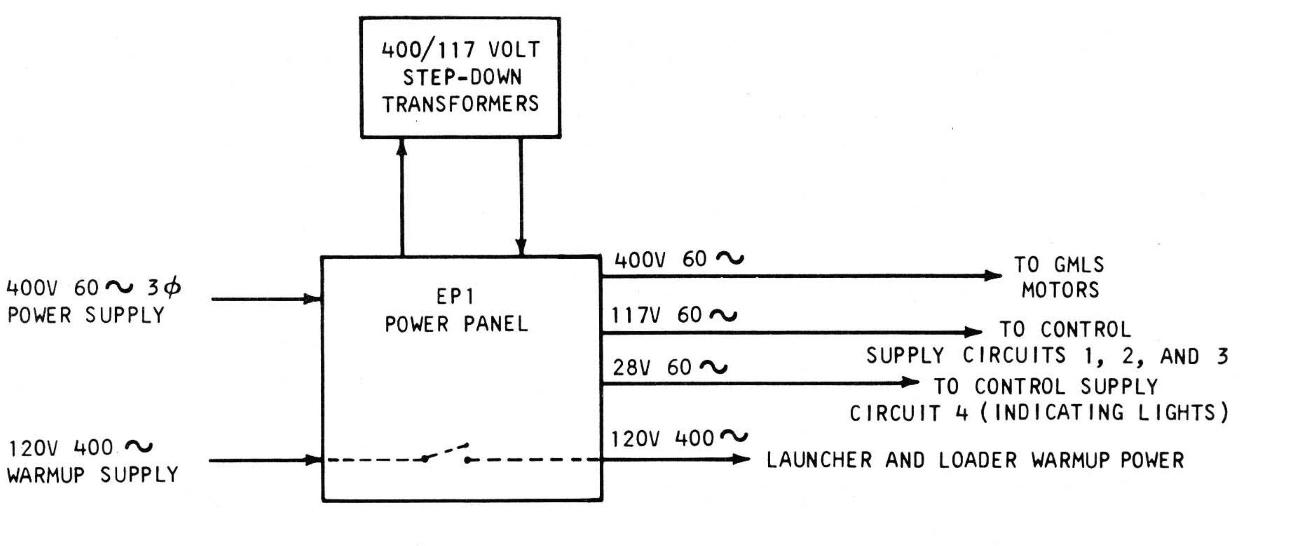

Figure 5-5.—EP 1 control panel functions.

components are identified by a combination of letters and numbers that indicate the kind of device or component, the identification of the major assembly of which it is a part, and identification of the specific component. These reference designations do not replace drawing, part, or stock numbers. They identify the part on the schematic. For example, KCLA1-1AB can be interpreted as follows:

KC-relay, control
LA-Loader, A side
1 - No. 1 among the relays associated with the A-side of the loader.
lAB-the A and B contacts on the first wafer or section of the relay. It also indicates that the A and B contacts on the first section of the relay are wired in that circuit application.

To return to the EP-1 panel and your problem. If the trouble is only a faulty fuse, replace it. However, remove and replace fuses only when the associated circuit is completely deenergized. Use a fuse puller made of insulating material. Use a fuse of the same rated voltage and amperage capacity. Never short a fuse. After you have replaced the fuse, replace the fuse cover (if it has one), then energize the circuit. A fuse may explode when the circuit is energized.

When you have located the trouble that caused the fuse to blow, and have repaired it, reactivate the panel to check the work you have done.

Since the EP1 panel is connected directly to the ship's electrical system for its power supply, you need to work with the ship's electricians when there is a failure in any of the lines connected to the ship's power supply.

CIRCUIT TROUBLE AT THE EP2 PANEL.- Assume that you have turned on all the connections at the EP1 panel and power is available for all the circuits. You are now ready to take your position at the EP2 panel. You receive orders from Weapons Control regarding the mode of operation, the type of missiles to be used, single loading or continuous loading, and whether A-side or B-side or both are to be used. You are ready to activate the EP2 panel, through which electrical power is supplied to the different units of the launching system.

The magazine, which consists of the ready service ring, the load status recorder, the hoist mechanism, and the magazine doors, is operated by hydraulic power from Power Drive Mk 64. One power drive is located on the A side and the other on the B side. Individual controls for the units are on the EP2 panel. Circuit No. 2 for control supply furnishes the l17-volt a-c electricity to operate the motor that drives the pump to develop accumulator pressure. The start circuit for the magazine accumulator motor is controlled from the EP2 panel. When the contactor (KPXA1 in fig. 5-6) is energized, it closes contacts which complete the 440-volt supply to the magazine accumulator motor (BPXA1).

Normally there will be no trouble starting the magazine accumulator motor by depressing the START-RUN pushbutton switch SMXA16A (fig. 5-6). However, a malfunction may occur at any time in such a complex equipment. It is important, therefore, to understand the motor start circuit and the relay elements it includes.

To complete the Start circuit, you position SMS1 (Control Selector Switch) at STEP, SMS2 (Operations Selector Switch) at OFF, and SMX3 (A- or B-Side Selector Switch) at A or A AND B for A-side operation, or B or A AND B for B-side operation. Control Selector Switch SMS1 must be positioned at STEP during activation in order to start the motors, and switch SMS 2 must be at OFF during that time to prevent system operation until activation is completed.

With these manual switches positioned, it is time to position the switches or relays for the , components powered by the accumulator unit. The positioning latches, both clockwise and counterclockwise, for the ready service ring must be extended so the ready service ring will not start indexing before the system is ready. Both tray shift solenoids (LHDAl-LCl and LHDAl-LC2) must be deenergized and the associated solenoid rocker arm must be at neutral to prevent indexing ahead of readiness. The normally closed (N.C.) contacts of these switches are wired into the Start circuit, so the switch elements are closed when not actuated. Hoist solenoid switches (LHHAl-SIl0l and LHHAl-SIl02) and magazine door solenoid switches (LHGAl-SI101 and LHGAl-SIl02) perform the same function - prevent premature activation of the associated parts of the launching system.

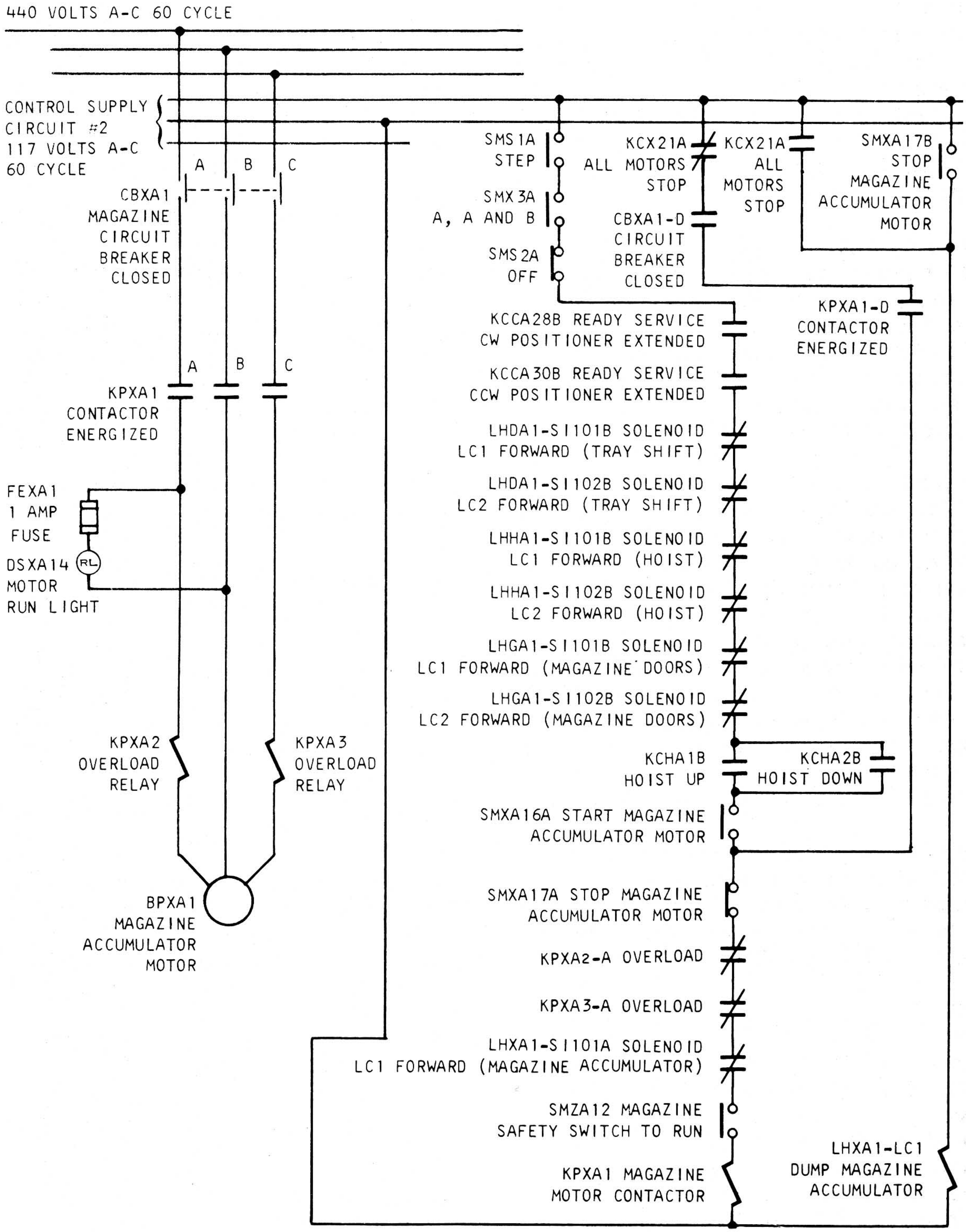

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Figure 5-6.—Start and Run circuits for accumulator system motor.

Relay elements KCHA1 and KCHA2 keep the hoist in either the latched up or latched down position so it will not be stopped in midcycle. The magazine door solenoid switches (LHGA1-SI101 and LHGA1-SI102) remain deenergized at this time so the doors will not open. Both overload relay elements (KPXA2) and (KPXA3) are closed because there is no overload in the 440-volt power supply to magazine motor BPXA1. The remaining elements between SMXA16A and the KPXA1 coil remain closed during the motor-state procedure. The Magazine Motor STOP switch (SMXA17) is spring-held in the closed position unless it is depressed to stop the motor. Also closed is LHXA1-SI101, the solenoid switch to dump magazine accumulator pressure if it becomes necessary. The solenoid LCI will not energize until the motor has been stopped.

Now, with all the manual switches properly positioned and the associated interlocks closed, you are ready to press the Magazine-Motor START-RUN button, SMXA16. This completes the l17-volt circuit to the coil of the motor contactor KPXA1.

When the contactor coil is energized, it closes contacts A, B, and C of relay KPXA1 in the 440-volt motor power circuit and contact D in the motor run circuit. The motor should start and begin driving the parallel piston pump.

Suppose the motor doesn't run after you have pressed the start button. Maybe somebody forget to push Magazine Safety Switch to RUN (SMZA12), a manual switch on the EP4 panel which must be positioned to RUN. If that is not the cause of the nonoperation, you will need to get the drawings for the system to trace down the cause of the failure. The schematic helps you picture the layout of the system, but you will need the electrical diagrams to make the proper corrections. Review the check list to make sure you did not omit any step in the activation. The checklists posted at the panel should be used every time the panel is activated.

COMPONENT ISOLATION. - Once the source of trouble has been isolated to a particular circuit, several aids and short-cuts are available for isolating the defective component. Three probable sources of trouble in circuits are: an open relay coil, an open diode, or a shorted diode. When isolating troubles, first determine which coils of the relays are energized when a pushbutton is pressed. The drawing or the maintenance manual may have a listing of the coils of the relays for each circuit. Check each circuit systematically for opens, and for shorts. There is little likelihood of a shorted relay coil, but a diode wired across the coil of the relay may be shorted, and that would cause a fuse to blow as soon as the circuit to the relay is completed. Shorted diodes in other circuits may cause no such giveaway reaction but may permit current to pass through other diodes. Those are more difficult to locate. When the shorted diode is isolated from the associated circuitry, do not assume it is bad; its forward and backward resistance should be checked.

CHECKING RELAYS. - Relays suspected of faulty action may be checked with the relay test equipment mounted on the inner side of the EP2 panel front door (fig. 5-7), next to the door latch. Before testing relays, the pins should be examined to be sure that they are not bent. To straighten bent pins, firmly seat the relay in the pin straightener mounted in the top of the test panel (fig. 5-7). Terminal pins on a plug-in type of relay are shown in figure 5-8B. After any necessary straightening, insert the terminal pins into the test socket (fig. 5-7). The toggle switch SMZl9 applies (or removes) power to the coil of the relay being tested. SMZl9 also switches the circuitry of the test socket to permit testing of the normally open or normally closed internal circuits of the relay as desired. Selector switch SMZl8 permits checking the individual internal circuits of the relay, normally on or normally closed, as determined by the position of SMZI9. As each internal circuit of the relay is tested by positioning SMZI8, indicator light DSZl3 indicates whether the relay is operating properly.

INTERLOCK SWITCHES. - The switches on the control panels are chiefly manual switches of pushbutton, rotary, or toggle types. Numerous interlock switches are used throughout the launching system. They are actuated by mechanical motion or hydraulic pressure, and are used to monitor equipment functions. The design varies with the application, but usually consists of one or more switch elements

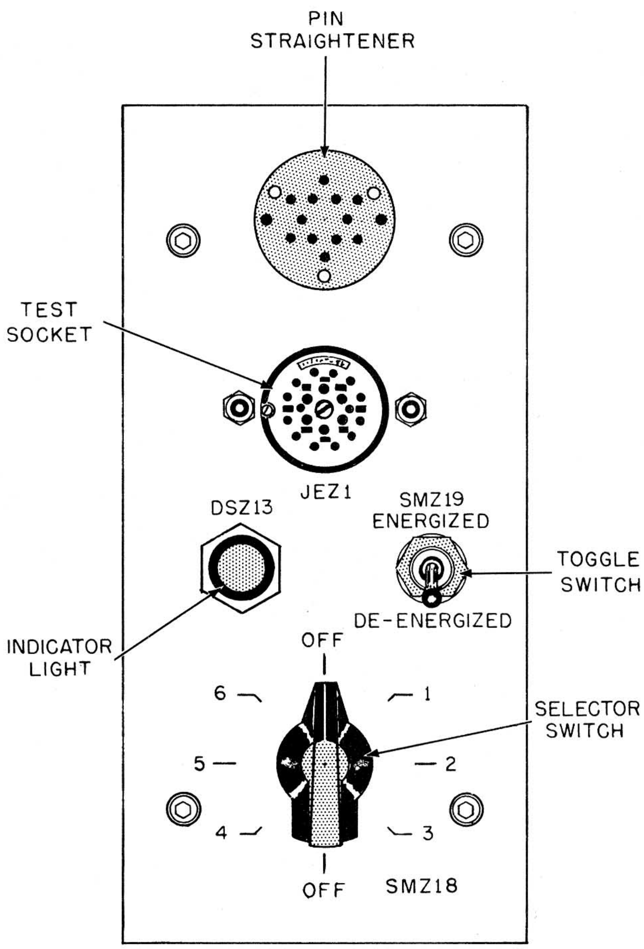

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Figure 5-7.—Relay test panel on the EP 2 panel, Mk 10 launching system.

mounted to an actuating device. They assume that related equipment is at a certain position or has performed a certain function, so that operation will be in sequence. For example, the hoist cannot raise a missile to the loader if the magazine doors are closed. The circuit energizing the solenoid which controls hoist raise operation contains an interlock that does not allow circuit completion until the magazine doors are open and secured. This interlock is a relay wired into the solenoid circuit. When the relay is energized the interlock is closed. The relay energizes when the associated interlock switch, mounted to the magazine door equipment, is actuated. This switch actuates when the magazine doors have fully opened and the door lock latch is engaged. Other interlock switches in the circuit assure that the loader is in position (retracted) above the magazine doors and that the tray shift on the ready service ring is positioned to hoist. Even the motor start circuit includes interlocks. They assure that powered equipment is not halted in midcycle.

When interlock switches malfunction, the entire switch assembly is removed and a replacement unit is installed. Before the replacement unit is installed, it should be checked electrically with the switch test device (special tool 1614018) to be sure that it functions properly.

The interlock switches of the Mk 10 Mod 0 launching system control are of two types. The majority of the switches are sensitive switch assemblies, and the rest are microswitches mounted in the solenoid housings and in the load status recorder assembly. The OP for the system has a listing of all the sensitive switches, the location of each, its function, the reference drawings, and instructions for adjustment, with an additional listing of solenoid, interlock switches mounted on brackets and secured to the supporting frames of the primary solenoids in the switch housing (fig. 5-9). The assemblies are of right-hand and left-hand configuration, so when you are replacing one, be sure to get the correct one.

Before disconnecting any switch for replacement, be sure to mark down or note the connection of each lend so you can connect the leads of the replacement in exactly the same way. Use a soldering iron to remove the leads, and when attaching the new leads, solder them in place, after placing the switch assembly in position and securing it lightly. Adjust the air gap (fig. 5-9) with the solenoids deenergized, according to the reference drawing for that switch. Tighten the locknuts after making adjustments.

LOAD STATUS RECORDER. - We mention the lead status recorder here as an example of a complex electromechanical assembly (fig. 5-10). One is located on each ready service ring, mounted on the outboard side of the truss. Its two basic sections are a relay board assembly and a switch and cam actuator assembly. It monitors the missile type and condition at all 20 stations in the ready service ring and sends this information to the control panels (EP2, and EP4 (5) in the form of interlock switch and visual

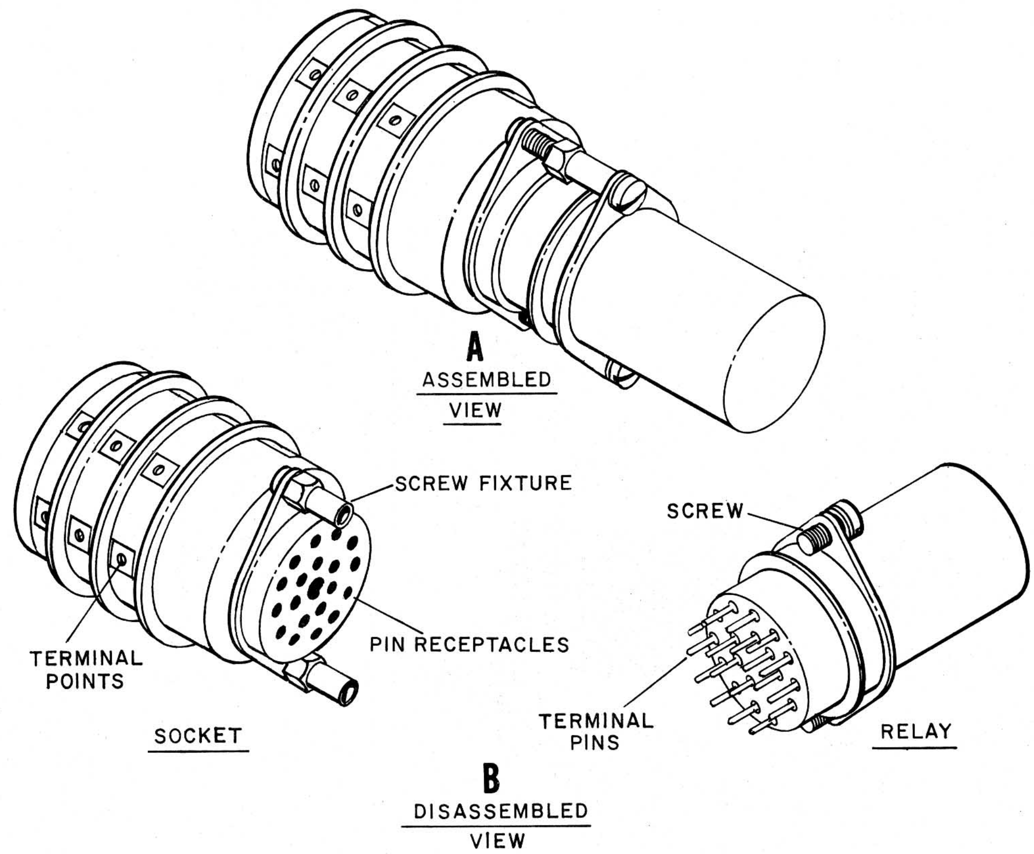

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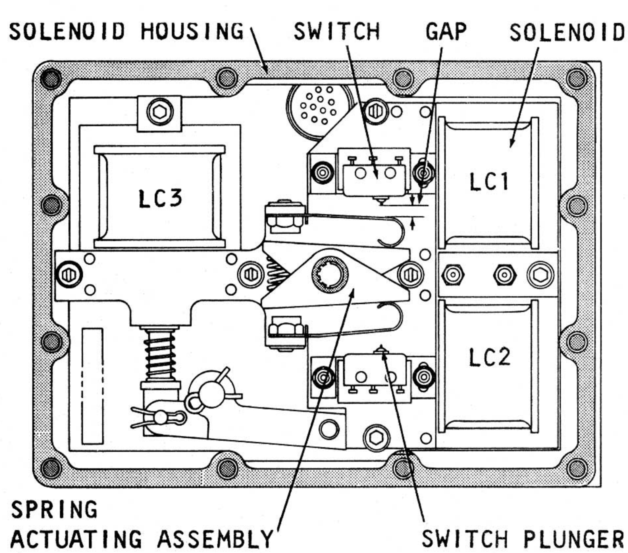
Figure 5-8.—Plug-in relay and socket assembly: A. Assembled view; B. Disassembled view.



94.130
Figure 5-9.—Typical solenoid switch assembly.

light indications. The ring of lights on the EP2 panel shows what the recorder tells; it is in the ready service ring at each station. Shipboard correction or adjustment of the electrical components should not be attempted; remove the defective unit, such as a triple switch or single switch element, return it for repair, and install a new unit. If the load status recorder malfunctions mechanically, order a replacement from the supply system.

The proper operation of the load status recorder can be checked during the daily exercise of the launching system. Each time the ready service ring is indexed to another station, notice if the lights representing the stations in the ready service ring rotate in the same direction and amount. If there are empty trays or trays with dud missiles, the EMPTY and DUD indications can be checked. The checking must be done in Step operation, operating from the EP2

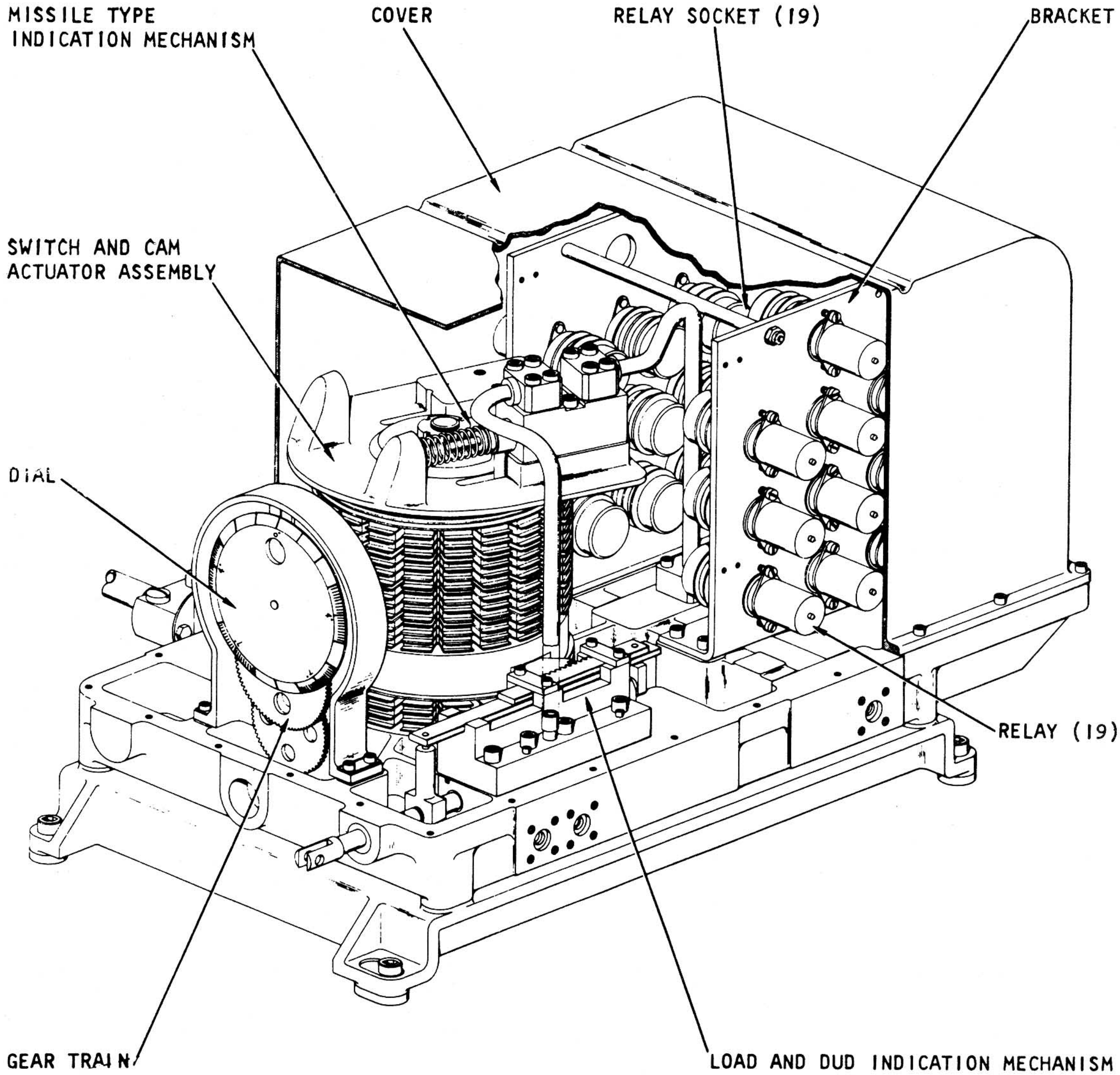


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Figure 5-10.—Load status recorder.

panel. For unload assembly, unload launcher, checkout, or strikedown, the EP4 (or EP5) panel must be used to rotate the ready service ring. The loading pattern was set into the load status recorder at the time the missiles were loaded, and if the recorder is operating properly, the lights on the control panels should read back the same as the loading pattern. The color of the light indicates the type of tray or round. Three amber lights inside each circle of lights (representing the ready service rings) indicate the meaning of the lights in the circular pattern as DUD, EMPTY, or LOADED. If you push the DUD button (of those three), the lights should go on for all the trays that hold dud missiles. If you push the EMPTY button, the lights representing trays that are empty should come on. If you activate the LOADED button, the lights for all the trays containing missiles should come on, the color indicating the type of missile in each. In each case, the light indications should agree with the loading pattern established at the time of loading, unless the tray assignment has been changed, or the missile has been unloaded.

SAFETY RULES

It is your duty as a supervising petty officer to instruct and remind your men of the safety rules and see that they obey them. The first class and CPO should conduct lessons on safety. Chapter 12 contains safety rules for electricity and electronics, as well as for other situations.

SERVOMECHANISMS

An apparatus that includes a servomotor (or servo for short) is often called a servomechanism. And what is a servomotor? It is a power-driven mechanism, commonly an electric motor, which supplements a primary control operated by a comparatively feeble force. The primary control many be a simple lever, an automatic device such as a photoelectric cell or a meter for measuring position, speed, voltage, etc., to whose variations the motor responds, so that it is used as a correctional or compensating device. A servo is a control device, a power amplifier, and a closed-loop system. *Gunner's Mate M (Missiles) 3&2*. NAVTRA 10199 described and illustrated the fundamentals of servomechanisms. They are used m all the power drives, and the principles apply to all of them - only the details of application vary in the different launching systems. Servos may be electrical, mechanical electronic, hydraulic, or combinations of these, but all use the feedback principle. One or more power amplifier are part of any servosystem. There must be an input and an output, and between these, an error detector and an error reducer. Each of these essential components may have many parts, so that even a simple schematic may seem like a complicated maze. Remembering the essential parts of a servo d the direction of the signals are helpful in tracing through the schematic.

Troubleshooting

Since the launchers must be trained and elevated every day as part of routine training and maintenance, any defects or failures in the servomechanisms of those systems will be evident. Servomechanisms are used in connection with so many parts of a missile launching system, no one application can be considered as typical. Their use in the training and elevating system is one of their most extensive applications. The receiver-regulators are described in the next chapter. The emphasis there is on the hydraulic of the system. Following are some suggestions for trouble-shooting the electrical parts. But first review the four steps:

Step 1.-Observe the equipment's operation.

Step 2.-Make an internal visual check.

Step 3.-Localize the trouble to the faulty parts, using meters, electrical prints, and maintenance publications.

Step 4.-Replace or repair the defective part; test the system's operation afterward.

Electrical Prints

Locating components and tracing circuits is generally easier when using electrical prints than working on the wiring itself. Tracing the mass of wiring, terminal strips, and obscured test points is virtually eliminated when using the prints. The components are grouped in the prints in a more orderly manner. There are several types of circuit diagrams. Those most commonly found in your OPs and MRCs are wiring diagrams.

These diagrams are especially helpful in understanding the operation of the equipment. They show the parts of the circuit and how they are connected. They do not show how the parts look or how they are constructed - the components are illustrated by symbols.

SYMBOLS. - There are several publications containing lists of symbols, and from past experience you can probably identify many of them. As a first class or chief you must enlarge your knowledge in this field, beyond the basics required for the third class.

For the most part symbols are standard, but there are variations. For all their variations, symbols are really simplified sketches of the devices they stand for. If you are reasonably familiar with the devices they represent, you should have little trouble identifying the symbols in the schematics. Unusual or special ones are explained on the drawing.

STRAIGHT LINING.-As there are tricks in all trades, there is one in circuit tracing. It is called "straight lining."

Wiring diagrams and schematics are often a complicated maze of many circuits, accomplishing many functions. You must acquire the ability to disregard all circuits that are unnecessary to the one you are attempting to trace. The resulting circuit, depicted on one drawing, will show only the circuits necessary for one particular function. This important feature of circuit tracing is called straight lining.

Faulty Switches

The preceding course, *Gunner's Mate M (Missiles) 3&2*, NAVTRA 10199, traced for you a typical power control circuit and a typical firing circuit, and showed you how interlocking worked in the circuits, and how parts of the circuit operated in a definite sequence. When you are tracing a circuit to locate a casualty, remember to include the interlocking switches that can prevent activation along any part of the circuit. If a faulty switch is found, it should be replaced or adjusted. Be absolutely certain that a switch is faulty before replacing it. It may only need adjustment to operate properly. If a switch is replaced, it must be adjusted within the equipment. Adjustment of interlock switches requires familiarity with the function of the switch contacts in the associated control circuits. Study the applicable schematic wiring diagrams. The complete control circuit is shown in the applicable elementary wiring diagrams for the system control.

Interlock switches must be checked periodically to be sure they are actuating and deactuating properly. Check them electrically to make sure that they are making and breaking as required. When an interlock switch malfunctions because of mechanical wear or damage, replace the entire switch. The Mk 10 Mod 7 Terrier launching system uses eight types of interlock switches: (1) sensitive switch assembly, used throughout the system; (2) microsensitive switch, two used in the EP1 panel; (3) 2PB switch assembly, used within the loader-control cam housing; (4) type A rotary switch, used in, the Asroc adapter rail; (5) single switch assembly, used within the dud-jettison solenoid housings and within the load status recorders; (6) paired switch elements used within the solenoid housing, loader-control cam housing, contactors, and magnetic circuit breakers; (7) paired switch-element assemblies, used throughout the system in standard solenoid assemblies and in loader-control solenoid assemblies; and (8) triple switch-element assembly, used in the load status recorder

The maintenance instructions for the different switches usually are included in the OP with the instructions for the component to which each is attached or which it activates. The MRCs give the most up-to-date routine maintenance instruetions for each component. Pull the appropriate MRC card for each day's maintenance work.

AMPLIFIERS

Amplification of signals is necessary in the launching system and in the missiles, as well as in the fire control system. In electronics and electrical engineering, vacuum tube amplifiers, transistors, and magnetic amplifiers are widely used. There are many types and arrangements of these, but the purpose of all is to increase the magnitude of a quantity. Amplifiers associated with electric and electronic components are arranged to reproduce in their output circuits a voltage or current greater in magnitude than that applied to their input circuits. Electron tube amplifiers may be grounded-cathode, grounded-grid, or grounded-plate (cathode follower) type. There may be a chain of amplifiers, called cascade or multistage amplifier.

The conventional electron tube amplifier is the grounded-cathode type, which has the cathode at ground potential at the operating frequency, and the input applied between the control grid and ground, and the output load connected between plate and ground.

The grounded-grid amplifier is an electron-tube circuit in which the control grid is at ground potential at the operating frequency, with input applied between cathode and ground, and output load connected between plate and ground. The grid-to-plate impedance of the tube is in parallel with the load instead of acting as a feedback path.

A grounded plate amplifier has a large negative feedback and is often used as an impedance matching device. The plate is at ground potential at the operating frequency, with input applied between grid and ground, and output load connected between cathode and ground.

MAGNETIC AMPLIFIERS

The magnetic amplifier is rapidly becoming an important device in electrical and electronic equipment. Amplifiers of type have many features which are desirable in missile systems. The advantages include (1) high efficiency (90%); (2) reliability (long life, freedom from maintenance, reduction of spare parts inventory); (3) ruggedness (shock and vibration resistance, overload capability, freedom from the effects of moisture); (4) stability; and (5) no warmup time. The magnetic amplifier has no moving parts and can be hermetically sealed within a case similar to the conventional dry type transformer.

The magnetic amplifier has a few disadvantages. For example, it cannot handle low-level signals (except for special applications); it is not useful at high frequencies; it has a time delay associated with magnetic effects; and the output waveform is not an exact reproduction of the input waveform. The term "amplification" in general refers to the process of increasing the amplitude of the voltage, current, or power.

The term "amplification factor" is the ratio of the output to the input. The input is the signal that controls the amount of available power delivered to the output.

Until comparatively recent times, magnetic control has had little application in missile electronic equipment since existing units were slow in response and were of excessive size and weight. But with the development of new and improved magnetic materials, there has been a parallel development of magnetic circuits for tubeless amplification; and many of these units are now employed in automatic pilots, static a-c voltage regulators, and in associated test equipment. .

Magnetic amplifiers are devices which control the degree of magnetization in the core of a coil to control the current and voltage at the load or output. One of the oldest forms of magnetic amplifiers, the SATURABLE REACTOR, contains at least two coils wound ,on a common core made of magnetic material. A d-c control voltage is applied to one of the coils; and the resulting current serves to modify the reactance of the second winding by causing magnetic saturation of the common core. The second coil is a series element in the a-c load circuit so that current. variations take place in the load in accordance with those made in the control voltage. In more complex magnetic amplifiers, the input, or control signal, may be either d-c or a properly phased a-c voltage.

In addition to saturable reactors, there are numerous types of magnetic units in use, including voltage regulators, low- and high- frequency amplifiers, and servomotor controllers. The purpose of this discussion is to present the operating principles of these devices and to give representative examples of magnetic circuits employed in missile electrical equipment. To understand the theory of magnetic amplifiers, it is necessary that you understand the theory of magnetism and magnetic circuits. This information may be found in the Navy training course *Basic Electricity*, NAVTRA 10086. The basic principles of operation of magnetic amplifiers are also discussed in that text. The quals require this knowledge at the B-4 level.

Magnetic amplifiers are not new; saturable core control has been used as early as 1885. In the United States, saturable core devices have been used to control heavy electrical machinery since about 1900. Refinement and improvement have made magnetic amplifiers usable for more delicate and accurate controls. They are now used for gun and launcher servo systems; high- speed digital computers; and pulse-forming, memory, and scanning circuits in radio, radar, and sonar equipment. Development of reliable semiconductor rectifiers, magnetic-core material of high permeability, improved input and output devices, automatic means of winding toroidal cores, use of sealed, self-contained units, and new means of testing, matching, and grading have greatly expanded the use of magnetic amplifiers.

APPLICATIONS OF MAGNETIC AMPLIFIERS

The magnetic amplifier has found application in many different type circuits. These circuits may employ diodes, vacuum tubes, and transistors. Such circuits may be found in voltage regulators (d-c and a-c), servoamplifiers, and audio amplifiers. The GMM will be mainly concerned with their application in servo systems and voltage regulators.

The application of magnetic amplifiers varies with the different launching systems. In the Mk 9 launching system, the EP8 and EP9 control panels house the amplifiers. They are located on the transfer cars, A side and B side. The transfer cars are operated by hydraulic power, but the amplifiers amplify the electrical signals that actuate the switches. The power panel is the voltage supply source for magnetic amplifiers in the system. There are magnetic amplifiers in the lift assembly and power drive unit, in the cell door and missile stop mechanism assembly, in the extractor assembly, subassemblies, and power drive. This transfer car is used to move a selected missile from its cell to the stage 1 rammer rail in a loading operation, or to move the missile to the checkout handling rail for a checkout or strikedown operation. In stow operation, the car will return the missile from the stage 1 rammer rail to a selected cell and it will also return a missile from the handling rail to a selected cell after completion of checkout or when arming the ship. In all these functions, magnetic amplifiers are used to amplify the signals. If the magnetic amplifier is out of adjustment, the transfer car movement will be slow or sluggish or it will hunt. You need the OP for the launching system for detailed steps in the adjustment of magnetic amplifiers.

APPLICATIONS IN SERVOMECHANISMS

One of the most frequent uses of magnetic amplifiers in electrical equipment is in servomechanism systems. In these applications, the magnetic units have the desirable features of long life, minimum need for servicing, and the ability to handle large amounts of power for energizing electric motors and other load actuating devices.

Motor Controller

Figure 5-11 shows a magnetic servoamplifier which controls the voltages for both phases of a two-phase electric motor. The input signals for the magnetic amplifier are produced by a phase detector. These drive V1 and V2, which are

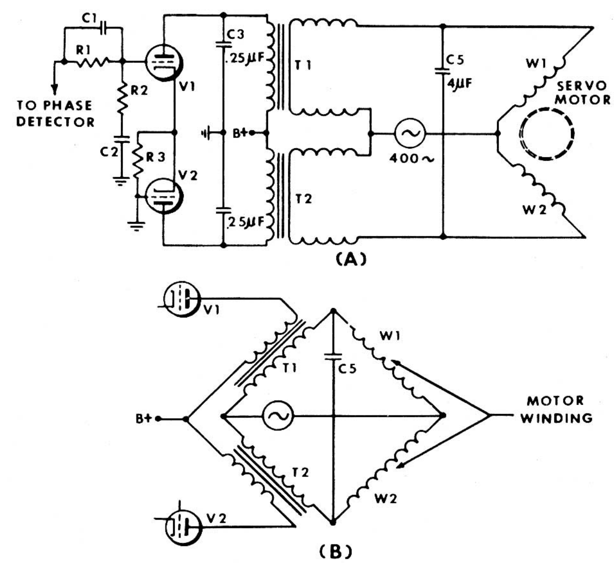

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Figure 5-11.—Magnetic amplifier used to control a two-phase induction motor.

connected as a cathode coupled paraphase amplifier working into two saturable reactors. Note that the magnetic amplifier is working with cathode tube amplifiers.

With zero input, both tubes (fig. 5-11) draw equal amounts of current in the plate circuits. These currents are insufficient to saturate the cores of the reactors; and therefore, the impedance of each load winding is very high and the resulting load currents of each load winding is very small. In this condition the circuit is a balanced bridge as indicated in part (B) of figure 5-11, and the motor does not rotate since in-phase voltages are applied to the motor windings.

When an input control signal is supplied from the phase detector, one of the tubes (depending upon the polarity and amplitude of the signal) goes into heavier conduction than the other. Under full conduction conditions, the reactor in one plate circuit then appears as a low impedance and the other reactor approaches the open-circuit condition. The bridge is then unbalanced; and capacitor C5 is effectively connected in series with one of the motor windings, where it causes a phase shift and the motor begins to rotate.

Assume, for example, that V1 (fig. 5-11) goes into heavy conduction and that V2 is at effective cut-off. The inductance of the secondary of Tl is then practically zero and motor winding WI is connected across the a-c source. The inductance of the secondary of T2 is high so that the winding resembles an open circuit; and motor winding W2 is then connected across the a-c source through the phasing capacitor. The phase relations, of the resulting currents cause the motor to rotate in a direction determined by which winding is connected in series with the capacitor. Upon reversal of the control signal, the conditions described also reverse; and W1 is placed in series with the capacitor so that the motor then turns in the opposite direction.

POWER SUPPLY REGULATOR

The equipment power supplies of missile systems must meet certain basic requirements which include ruggedness, long life, and freedom from excessive maintenance problems. To meet these requirements, the development of power supply equipment has resulted, in many cases, in the elimination of the electron tube as the chief cause of failure. The magnetic amplifier has been used to replace the complex arrangements usually necessary for good voltage regulations; and the solid-state power diode is often employed instead of the fragile vacuum tube. An example of a circuit with these components is shown in figure 5-12.

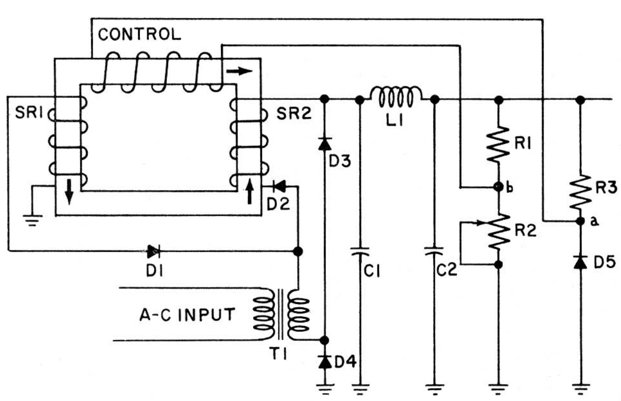

Figure 5-12.—Power supply using magnetic amplifier voltage regulator

Magnetic Amplifier Control

The circuit is a conventional full-wave bridge rectifier utilizing a magnetic amplifier to control the output and also a Zener diode as a part of the regulating system. The Zener diode element is a solid-state equivalent of the gaseous regulator tube and maintains a constant voltage across the terminals regardless of variations of the current it conducts, within the specified operating range. In the schematic shown (fig. 5-12), the connection of the Zener diode is the reverse of that of an ordinary rectifying diode since in this example it is the inverse breakdown voltage characteristic which is employed for regulation.

Current flow (fig. 5-12) during one half cycle is through the load, choke Ll, diode D3, the secondary of Tl, and diode Dl, then returning to ground through SRI of the reactor. During the other half cycle, the current flows through the load, Ll, SR2, D2, the secondary of Tl, and D4 to ground. In addition to the load current, there is conduction through D5 and R3 and also through R2 and Rl.

The control winding of the magnetic amplifier is energized by the voltage between the junction of Rl and R2 and the upper terminal of the Zener diode, D5. When the output voltage is of the proper value, the potential across the control winding (and therefore the current through it) sets the magnetic bias of the reactors at the operating point, which is well up on the magnetization curve to obtain a high percentage of the source voltage.

If the output voltage tends to rise, the voltage at point a remains constant due to the action of the Zener diode; but the voltage at point b increases. This causes a change in the current flowing in the control winding so that the bias point is shifted to a value that results in lower conduction in the load coils. As a result, the voltages across SR1 and SR2 are increased and the output voltage decreases.

When the output voltage tends to decrease, the potential at point b falls with respect to that at point a and the control current changes the bias to a point of higher conduction.. This lowers the voltage drops across the a-c coils of the reactors and increases the valve of the output. Capacitors Cl and C2, together with Ll, are connected to form a pi-section filter which smoothes the output to give a nearly pure d-c voltage. Resistor R2 is adjustable, being set to the value for optimum operating voltage in normal use. It also provides a means for making adjustments to compensate for any changes that occur in the circuit components.

A gas-filled regulator tube (VR-75) could be used in place of the Zener diode. The voltage regulation and operation would be the same, but a VR tube requires much higher power supply voltages.

ZENER DIODES. - If you looked in the index of any of the basic texts previously mentioned you would not find the word Zener listed. Zener effect and Zener diodes, however, are given some discussion in chapters 2 and 3 of *Basic Electronics*, NAVTRA 10087. Avalanche breakdown is sometimes called Zener effect, after the American physicist Clarence Zener, who made theoretical investigations of the problem of electrical breakdown of insulators. The breakdown mechanism in PN transistor junctions is not the same as in insulators but, in spite of this, the name Zener voltage is often given to breakdown voltage of junctions. The reverse voltage at which the current suddenly begins to make its sharp descent is called Zener breakdown voltage. The use of the word "breakdown" does not mean that the diode is destroyed, but rather that the normal negative reverse current increases suddenly and sharply. A typical Zener diode curve is shown in figure 5-13.

Zener diodes are used chiefly as regulation and reference elements. When a reverse voltage is applied, no current will be passed until there is a breakdown in the convalent bond of the atoms, causing a sharp increase in current flow in the reverse direction. If this happened in a regular PN junction diode, it would be considered defective, but Zener diodes are designed to be self- healing and can be used repeatedly without damage. The point of breakdown or avalanche is built into the diode and can be made to occur at various voltages. In figure 5-13, approximately 20 volts is applied.

PUSH-PULL. - A push-pull amplifier is a balanced amplifier. There are two identical signal branches connected so as to operate in

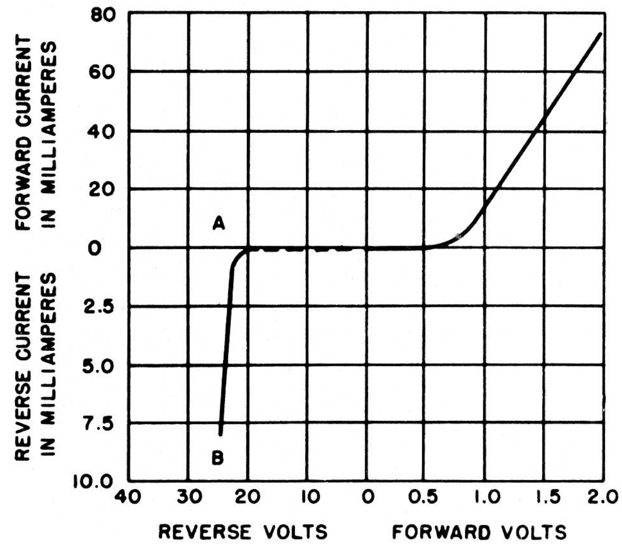

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Figure 5-13.—Zener diode characteristic curve.

phase opposition and with input and output connections each balanced to ground.

A paraphase amplifier is essentially a combination amplifier and phase inverter. It is sometimes used in place of transformers to operate push-pull circuits. Paraphase amplifiers are described in *Basic Electronics,* NAVTRA 10087.

Transistor Amplifiers

Transistor amplifiers may be used in place of electron tube amplifiers. A transistor amplifier must have three-element (two-junction) semiconductors to amplify a signal, just as a three-element electron tube is needed for amplification. There are also three types of transistor amplifiers, according to which part is grounded: grounded emitter, grounded base, and grounded collector. The above text describes the theories and operating characteristics of vacuum tubes and of transistors. Transistors are designed to perform the same functions as vacuum tubes. As they are solid-state semiconductors, they are much less fragile than vacuum tubes. Of course, failure can be caused by misuse, such as current overloading, or application of too high a voltage. Faults in manufacturing, or flaws in the material can cause mechanical failure. Radiation affects them so they must be shield. Most failures are caused by the effects of moisture on the surface. Hermetic sealing of the transistors by manufacturers is now the usual practice. Since transistors are so very small, a speak of dust falling across a junction can completely short-circuit it. A dust free atmosphere is a practical necessity in a transistor-fabrication plant.

It is believed that transistors will far outlast vacuum tubes. At present no missile launching system has changed completely over to transistors, but one gun system has, so you can expect this change in the future. Magnetic amplifiers will continue to be used, alone and with transistors instead of vacuum tubes.

SERVOAMPLIFIER

The purpose of a servoamplifier is to control an output in a manner dictated by an input. Normally, the servosystem's signal input is at a low energy level and must be greatly increased to perform an appreciable amount of work. This is the job of the servoamplifier. The amplifier controls a large power source which is activated by a low-powered error signal. This is shown in figure 5-14A. Figure 5-14B shows a simple power control using a triode as the controlling element and a battery as the power reservoir.

There are just about as many different amplifiers as there are jobs for amplifiers to do. Each part of the amplifier is selected to do a particular part of the total job. You can't just look at a circuit and understand why everything is there. The best way to analyze an amplifier is to divide it into stages, coupling circuits, decoupling circuits, and biasing networks. In *Basic Electronics*, NAVTRA 10087 you studied each of these circuits-you know what they are supposed to do. *Basic Electricity*, NAVTRA 10086 tells you that servoamplifiers may be of the vacuum-tube type or the magnetic type, and combinations of these. *Basic Electronics*, has a chapter on the use of electron tubes for amplifying voltage and power, and another chapter on servosystems, including servoamplifiers.

Servoamplifiers can be broadly divided into functional stages. You have learned how the error signal is selected, and modulated or demodulated to suit the individual amplifier. The first stage or stages of amplification increase the voltage of the error signal. When the signal voltage is amplified a sufficient amount, it is used as the input to the power stage. Here the primary concern is current delivered at a steady voltage under load conditions. The push-pull type amplifier is extensively used in missile servo- systems. A push-pull amplifier is preceded by a phase inverter or paraphase amplifier. The power stage may be one or more stages, depending on the power output needed.

In general, the higher the gain of the amplifier, the tighter the control and the more accurate the servosystem. An increase in the system gain will reduce the system velocity errors and increase the speed of response to inputs. An increase in system gain also reduces those steady-state errors resulting from restraining torques on the servo load. However, to obtain these advantages, the servosystem must pay a price in the form of a greater tendency toward instability. A linear servo system is said to be stable if the response of the system to any discontinuous input does not exhibit sustained or growing oscillations. The highest gain that can be used is limited by consideration of stability.

Review of Use in Launching System

The preceding course, *Gunner's Mate M (Missiles), 3&2*, NAVTRA 10199, described and illustrated servosystems (with amplifiers) used to control error signals in launcher power drives. Amplifiers associated with ordnance actually do more than amplify. Some power drive amplifiers change the incoming a-c synchro signal to a d-c signal that can be used-to control a servomotor. In amplifiers associated with ordnance equipment, the power supply normally is built into, and therefore is physically part of the amplifier. Many amplifiers in ordnance equipment have two rectifiers: one in the power supply to provide the required d-c voltages and the other to convert the a-c input signal to a d-c signal.

Examples of other amplifier functions include stabilizing, synchronizing, speed limiting, position limiting, and current limiting. Amplifiers associated with ordnance equipment are nearly always classed as power amplifiers. A voltage amplifying stage is used only if it is necessary to increase an input voltage. The number and type

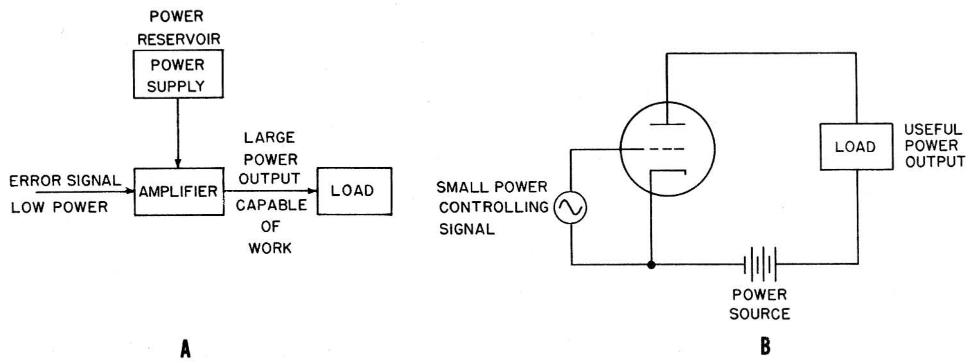

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Figure 5-14.—Amplifier's job in a servo; A. Controlling a large power source; B. Power control with a triode.

of amplifier functions is determined to some extent by the type of output controlled by the amplifier.

Gain, Phase, and Balance Adjustments

In many servo systems the gain of the amplifier can be varied by an adjustment. The gain adjustment governs the amplitude or amount of the signal voltage applied to the amplifier or one of its stages. Normally, the highest gain possible, with the servosystem posessing a satisfactory degree of stability, is the most desirable.

In a-c servosystems another adjustment which can control the sensitivity of the system is the phase adjustment. The phase adjustment is used to shift the phase relationship between the signal voltage and a reference voltage. In an amplifier with phase shift control the grid signal is shifted in phase with reference to the plate voltage of a tube. The tube's firing point is delayed or advanced, depending upon the phase Shift of the grid signal. The phase shift can vary the firing time of the tube over the plate's entire positive alternation.

A phase control is included in some servo-systems using a-c motors. The two windings of the a-c servosystems using a-c motors. The two windings of the a-c servomotor should be energized by a-c voltages that are 90° apart. This phase adjustment is included in the system to compensate for any phase shift in the amplifier circuit. The adjustment may be located in the control amplifier, or, in the case of a split-phase motor, it may be in the uncontrolled winding.

Servosystems using push-pull amplifiers must be balanced so that when there is no signal input to the amplifier, its output will be zero, and the servomotor will stand still with no creep. The push-pull amplifier must ensure equal torque in both directions of the servomotor.

Gain, phase, and balance adjustments are often present in one amplifier. These adjustments tend to interact so that when one of them is changed, it may affect the others. Therefore, after making anyone adjustment it is a good practice to check the other adjustments.

Magnetic Amplifiers Used as Servocontrol Amplifiers

A somewhat different type of servoamplifier used in launching equipment is the magnetic amplifier.

The servomotor used in conjunction with the magnetic amplifier shown in figure 5-15 is an a-c type. The uncontrolled phase may be connected in parallel with transformer T1 by utilizing a phase-shifting capacitor, or it may e connected to a different phase of a multi phase system. The controlled phase is energized by the magnetic amplifier, and its phase relationship is determined by the polarity of the d-c error voltage.

The magnetic amplifier consists of a transformer (Tl) and two saturable reactors, each having three windings. Notice that the d-c bias current flows through a winding of each reactor and the windings are connected in series-aiding. This bias current is supplied by a d-c bias power source. The d-c error current also flows through

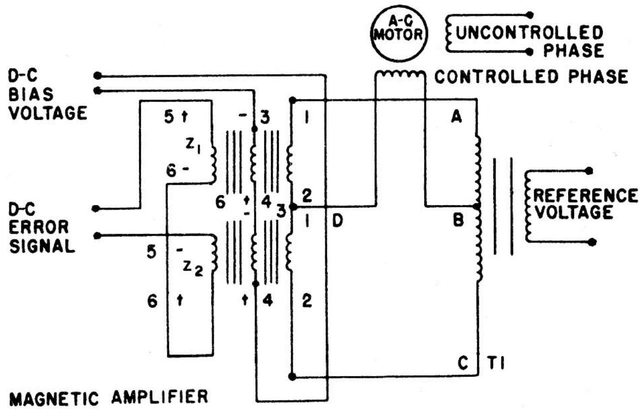

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Figure 5-15.—Magnetic servoamplifier, schematic.

a winding in each reactor; however, these windings are connected in series-opposing.

The reactors, Z1 and Z2, are equally and partially saturated by the d-c bias current when no d-c error signal is applied. The reactance of Zl and Z2 is now equal, resulting in points Band D being at equal potential. There is no current flow through the controlled phase winding.

If an error signal is applied, causing the current to further saturate Z2, the reactance of its a-c winding is decreased. This current through Z1 will tend to cancel the effect of the d-c bias current and increase the reactance of its a-c winding. Within the operating limits of the circuit, the change in reactance is proportional to the amplitude of the error signal. Hence, point D is now effectively connected to point C, causing motor rotation. Reversing the polarity of the error signal will cause the direction of rotation to reverse.

The basic magnetic servoamplifier discussed above has a. response delay equal to approximately 6 to 20 Hz. In some applications this delay would be excessive, creating too much error. However, this delay can be reduced to about one Hz. by using special push-pull circuits.

Polarized magnetic amplifiers can distinguish between control current polarities, but they can change only load current magnitude, not load current direction (polarity). Nearly all servo devices associated with ordnance equipment power devices require magnetic amplifiers with an output that varies in both polarity and magnitude. The push-pull (sometimes called duodirectional) magnetic amplifier meets those requirements. If control current is zero, load current also is zero. Likewise, if the control current increases in a positive direction, load current also increases in a positive direction.

Servoamplifiers in Launching Systems

The amplification of the train and elevation signals is an outstanding example of the use of servoamplifiers in launching systems. It was applied in the training and elevation of guns on gun mounts, and when missile launching systems were designed, the devices and methods were borrowed for this new application.

The small electrical input signals must be amplified into usable signals of sufficient magnitude to operate the electrohydraulic servo-valves of the receiver-regulators. The amplification system is common to both power drives and consists of a dual channel magnetic amplifier, made up of four magnetic amplifier stages mounted on a common chassis, and a power supply. One channel of the amplifier services the train power drive and the other channel services the elevation power drive. In each channel, one magnetic amplifier stage is the primary servo- system amplifier and the other is the velocity system servoamplifier.

The primary system servoamplifier receives position error voltage signal from the 1- and 36-speed synchro control transformers in the receiver-regulator. The amplifier also receives an unfiltered velocity signal from the rate generators in the remote, local, or dummy director. It mixes and amplifies these signals and uses the resultant output to operate the primary electro- hydraulic servovalve. The input circuit of the primary amplifier limits the voltages to the magnetic amplifier stage control windings and provides automatic changeover from the l-speed signal control to the 36-speed signal control when the launcher position error reduces to less than five degrees of correspondence with the order signal. It also receives an amplifier load supply voltage and a synchro offset voltage from the power supply. The train primary amplifier input circuit applies the offset voltage to the output of the I-speed synchro control transformer for stick-off purposes. The offset voltage is not applied to the elevation primary amplifier.

The velocity system servoamplifier receives a filtered velocity signal from the rate generators in the remote, local, or dummy director. The amplifier also receives an electrical feedback signal from the velocity and integration potentiometers of the receiver regulator. The velocity amplifier mixes and amplifies these signals and . uses the resulting output to operate the velocity electrohydraulic servovalve. The input circuit of the velocity amplifier provides the gain control I for the velocity input and voltage controls for the potentiometers; it mixes the velocity signal input with the potentiometer signals, and applies the resulting signal to the control windings of } the magnetic amplifier stage.

The potentiometer voltage supply circuit provides a frequency-sensitive, regulated, and filtered voltage for the velocity and integration potentiometers of the receiver regulator. The regulated voltage supply prevents fluctuation of the integration and velocity system outputs and compensates for the varying line frequencies to stabilize the electric drive motor and B-end error of the power drive.

Repair, Replacement, or Adjustment

Unless specifically directed otherwise, defective amplifier units are removed as a unit and ; replaced. They may be returned to the vendor for repair. Only one adjustment is normally J necessary on the power panel. VOLT ADJ should be set to give an output of 48.0 v at terminals 1 and 2 with all amplifier panels connected, and 115 v 400 hertz applied to the power panel inputs 28 and 29 (Mk 9 Mod 0 launching system).

Some adjustments made at the factory are not changed on shipboard. Hermetically sealed components are always replaced rather than repaired. Before replacing such a unit, double check all associated circuitry (resistors, wiring, etc.). When a defective component is replaced, adjust it and the channel in which it operates, following the instructions for your equipment.

All amplifier channel balance adjustments have been set at the factory. On installation, and weekly thereafter, the balance of both stages of amplification should be checked, using the meters installed in the amplifier panel.

Demodulators are balanced at the factory and no further adjustment should normally be necessary except on replacement, or in case the setting at balance adjustment is disturbed.

Rectifiers are very important components of magnetic amplifiers. Series rectifiers may be checked by the use of a cathode-ray oscilloscope. Whenever possible,. the waveform across a rectifier suspected of being defective should be compared to waveforms observed across other rectifiers in the same circuit.

SYNCHROSYSTEMS

The preceding course, *Gunner's Mate M (Missiles) 3&2*, NAVTRA 10199 described and illustrated uses of synchros and synchro data in missile launching systems, so we'll just have a brief review.

Synchros are seldom used alone. 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 uses which vary from positioning a sensitive indicator to controlling the motors which move a launcher weighing many tons. If the synchro system provides a mechanical output which does the actual positioning, as in the case of the indicator, it is a torque system. If it provides an electrical output which is used only to control the power which does the mechanical work, it is a control system. Control synchros are usually part of a larger system called a servo (automatic control) system. In many cases, the same system is called upon to perform both torque and control functions.

The individual synchros which make up a torque system are designed to meet the demands placed on them by the mechanical load, which such a system is expected to handle. However, the comparatively small mechanical output of a torque synchro system is suitable only for very light loads. Even when not heavily loaded, a torque system is never entirely accurate. When larger amounts of torque, or a higher degree of accuracy, or both are required, torque synchro systems give way to control synchros used as components of servosystems. Synchros control, and servos provide the torque. The distinguishing unit of any synchro control unit is the control transformer (CT).

Servosystems Using Synchros

A servo, servosystem, or a servomechanism (the three terms mean the same thing) is an automatic control device widely used in the Navy and distinguished by several special characteristics. There are many different types of servosystems, and not all of them use synchros. The purpose of servo systems in which control synchros are used is to supply larger amounts of power and a greater degree of accuracy than is possible with synchros alone.. Another equally important characteristic of the servo is its ability to supply this power automatically, at the proper time, and to the degree regulated by the need at each particular moment. All that the system requires. To perform the specific task for which it is designed is an order defining the desired results. When such an order is received, the servo compares the desired results with the existing conditions, determines the requirements, and applies power accordingly, automatically correcting for any tendency toward error which may occur during the process.

There are various ways in which these results are obtained. Whether it be amplidyne or hydraulic power drives of many different types, the end result is always the same and that is the positioning of the launcher in accordance with input orders received from remote control stations. To function in this manner a servosystem must meet five basic requirements:

1. It must be able to accept an input order defining the desired result, and translate this order into usable form.
2. It must feed back, from its output, data concerning the existing conditions over which it exercises control.
3. It must compare this data with the desired result expressed by the input order and generate an error signal proportional to any difference which this comparison shows.
4. It must, in response to such an error signal, issue the proper correcting order to change existing conditions to those required.
5. It must adequately carry out its own correcting order.

In functional terms the components normally found in a servosystem using synchros are identified as a data input device, a data output device, an amplifier, a power control device, a drive motor, and a feedback device.

Servo Terminology

In addition to those already mentioned, a number of specialized terms are used in connection with servosystems: The more common of these are defined here.

OPEN-CYCLE CONTROL of a servosystem means actuation of the servo solely by means of the input data, the feedback device being either removed or disabled. It should be clearly understood here that any mechanism must include a feedback provision to be classified as a servo; but in testing certain servo characteristics, an open-cycle control is often useful. Under such conditions the elements involved are frequently referred to as an open servoloop.

CLOSED-CYCLE CONTROL refers to normal actuation of the system by the difference between input and output data, with the feedback device operative.

CONTINUOUS CONTROL is used to describe uninterrupted operation of the servosystem on its load, regardless of the smallness of the error.

DEVIATION or error of a servo, is the difference between input and output.

ERROR SIGNAL or error voltage is the corrective signal developed in the system by a difference between input and output.

INSTRUMENT SERVOS and POWER SERVOS are designations used to classify servo-mechanisms according to their power output. An instrument servo is one rated at less than 100 watts maximum continuous output; a servo whose rating exceeds this amount is a power servo.

Classification of Servos by Use

A convenient classification of servosystems can be made in accordance with their use, the most common of which are as position servos and velocity servos. The position servo is used to control the position of its load and is designed so that its output moves the load to the position indicated by the input. The velocity servo is used to move its load at a speed determined by the input to the system.

Many servosystems cannot be fitted into either category. For example, a third type of servo is used to control the acceleration rather than the velocity of its load. And special applications of the different types are used for calculating purposes, the servo making a desired computation from mechanical or electrical information and delivering the answer in the form of mechanical motion, an electrical signal, or both.

ZEROING SYNCHROS

If synchros are to work together properly in a system, it is essential that they be correctly connected and aligned in respect to each other and to the other devices, such as directors and launchers with which they are used. Needless to say, the best of ordnance equipment would be ineffective if the synchros in the data transmission circuits were misaligned electrically or mechanically. Since synchros are the heart of the transmission systems, it only stands to reason that they must be properly connected and aligned before any satisfactory firing can be expected.

Electrical zero is the reference point for alignment of all synchro units. The mechanical reference point for the units connected to the synchros depends upon the particular application of the synchro system. As a GMM on board ship, .your primary concern with mechanical reference point will be the centerline of the ship for launcher train and the standard reference plane for launcher elevation. Remember that whatever the system, the electrical and mechanical reference points must be aligned with each other.

There are two ways in which this alignment can be accomplished. The most difficult way is to have two men, one at the transmitter and one at the receiver or control transformer, adjust the synchros while talking over sound powered telephones or some other communication device. The better way is to align all synchros to electrical zero. Units may be zeroed individually, and only one man is required to do this work. Another advantage of using electrical zero is that trouble in the system always shows up in the same way. For example, in a properly zeroed TX-RT system, a short circuit from S2 to S3 causes all receiver dials to stop at 60 degrees or 240 degrees.

In summary, zeroing a synchro means adjusting it mechanically so that it will work properly in a system in which all other synchros are zeroed. This mechanical adjustment is accomplished normally by physically turning the synchro rotor or stator. Synchro, Servo and Gyro Fundamentals, NAVTRA 10105, describes standard mounting hardware and gives simple methods for physiclly adjusting synchros to electrical zero. Additional information about synchros may also be obtained from Military Handbook MIL-HDBK-225 (AS) Synchros Description and Operation (supercedes OP l303).

Electrical Zero Conditions

For any given rotor position there is a definite set of stator voltages. One such rotor-position-stator-voltage condition can be established as an arbitrary reference point for all synchros which are electrically identical.

CONTROL TRANSFORMERS. - A synchro control transformer is zeroed if its rotor voltage is minimum when electrical zero voltages are applied to its stator. Turning the CT's shaft slightly counterclockwise will produce a voltage between R 1 and R2 which is in phase with the voltage between Rl and R2 of the synchro transmitters, CX or TX, :supplying excitation to the CT stator. Electrical zero voltages, for stator only, are the same as for transmitters and receivers.

Zeroing Procedures

The procedure used for zeroing depends upon the facilities and tools available and how the synchros are connected in the system. Synchros may be zeroed by use of only a voltmeter synchro testers, or other synchros in the system.

When zeroing differentials and control transformers, it is helpful to have a source of 78 volts (10.2 volts .for 26-volt umts).

Regardless of the method used, there are two major steps in each zeroing procedure: first, the coarse (or approximate) setting, and second, the fine setting. Many units are marked in such a manner that the coarse setting may be approximated physically on standard units; an arrow is stamped on the frame and a line is marked on the shaft extension.

ZEROING A CONTROL TRANSFORMER USING AN A-C VOLTMETER.-Using a voltmeter with a 0- to 250- and 0- to 5-volt scale, control transformers may be zeroed as follows:

1. Remove connections from control transformer and reconnect as shown in figure 5-16A.
2. Turn the rotor or stator to obtain minimum voltage reading.
3. Reconnect meter as shown in figure 5-16 B, and adjust rotor or stator for minimum reading.
4. Clamp the control transformer in position and reconnect all leads for normal use.

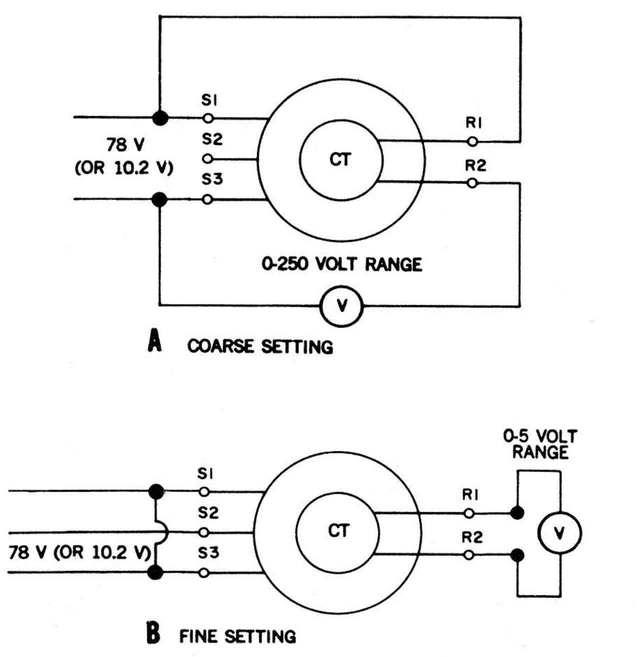

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Figure 5-16.—Zeroing a CT, using a voltmeter.

SYNCHRO TESTERS

Synchro testers of the type shown in figure 5-17 are used primarily for locating a defective synchro. They also provide a fairly accurate method of setting synchros on electrical zero. To zero a synchro with the tester, connect the units as shown in figure 5-17 and turn the synchro until the tester dial reads 0 degrees. This is the approximate electrical zero position. Momentarily short S1 to S3 as shown. If either the synchro or tester dial moves, the synchro is not accurately zeroed, and should be shifted slightly until there is no movement when Sl and S3 are shorted.

NOTE: By exercising proper caution it is possible to perform all the preceding zeroing procedures using 115 volts where a source of 78 volts is not available. If 115 volts is applied instead of 78 volts, do not leave the synchro connected for more than 2 minutes or it will over- heat and may be permanently damaged.

Summary

The described zeroing methods apply to all standard synchros and prestandard Navy synchros.

Before testing a new installation and before hunting trouble in an existing system, first be certain all units are zeroed. Also, be sure the device's mechanical position corresponding to electrical zero position is known before trying to zero the synchros. The mechanical reference position corresponding to electrical zero varies; therefore, it is suggested that the instruction books and other pertinent information be care. fully read before attempting to zero a particular synchro system. The MRCs and the OP for the system should be studied, as there are likely to be some differences from the general instructions given in NAVTRA 10105. For example, OP 2665, volume 3, *Guided Missile Launching System Mark 13 Mod 0*, gives step-by-step instructions for replacement and adjustment procedures for train and elevation regulator CTs. If an operational check indicates that a synchro control transformer in the regulator is not operating properly, replace and adjust the synchro.

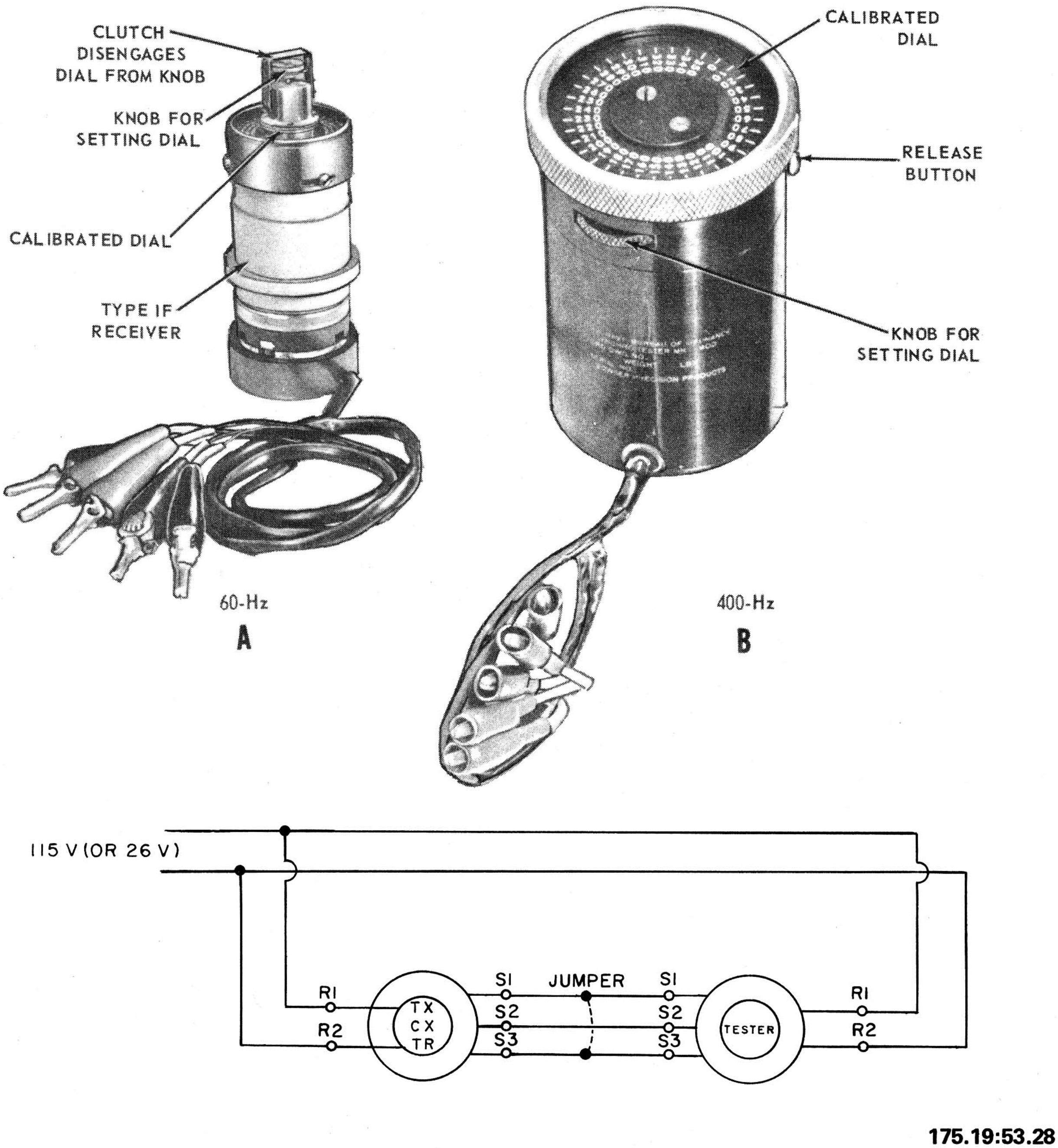

Figure 5-17.—Zeroing a CT, using a synchro tester.

Note that you do not attempt to adjust. the malfunctioning synchro; you remove that one and put in a new one, then adjust that. Two tests with a voltmeter are described for zeroing the synchro, and then the method of checking that the newly installed synchro is not 180 degrees out of phase. The power source used is 115-v, 400-hertz supplied from the launcher position generators to the S1 and S3 terminals through R1 and R2 terminals.

Figure 5-18 shows a train synchro gear assembly which points out the synchros and the dials. The elevation synchro gear assembly is very similar, but it has a sixth synchro which supplies the coarse (2X) elevation error signals in a remote jettison operation. It is mounted on the bracket holding the indicating dials. All the synchros are held in position with capscrew held lugs, making alignment easier.

MAINTENANCE

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

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

Synchros are no longer considered as repairable items. Replaced synchros should be disposed of in accordance with current instructions. Unless in an emergency with no replacement available, NEVER take a unit apart or try to lubricate it. The gearing (fig. 5-18) should be lubricated, using an atomizer, any time the cover of the receiver-regulator is removed, but do not lubricate switches, or the tachometer. Use the MRC for instructions.

TROUBLESHOOTING SYNCHRO SYSTEMS

Shipboard synchro troubleshooting is limited to determining whether the trouble is in the synchro or in the system connections; but if something is wrong with the unit, replace it. Generally, there are two major categories of troubles occurring in synchro systems. These are (1) those likely to occur in new installations, and (2) those likely to occur after the system has been in service a while.

All synchro casualties are not electrical, however, and do not require special equipment to uncover. One fairly common trouble affecting synchro operation is friction. Bearings must be especially clean, allowing the synchro rotor to turn freely. The slightest sticking will cause an error in route position, because there is little torque on the rotor when it is nearly in agreement with the incoming signal. Friction may also be caused by bent shafts and improper mounting of the synchro in the equipment. Early consideration should be given to the possibility of friction when troubleshooting faulty synchro operation. The synchros are not tested individually but are checked in the shipboard performance tests. If the test does not meet the standard requirements, then a search is made for the faulty component

Adjustments

While adjustments are a vital part of maintenance, they are too numerous to be covered here. Instead, a word of caution: At the time of installation, your control equipment was adjusted by well qualified personnel using special tools and equipment. For this reason, adjustments should be undertaken only after qualified personnel have verified that an adjustment is necessary. A good habit to cultivate when making adjustments is to scribe gears at their original point of mesh, and count threads or teeth to the position of the new adjustment. These measures will prove most valuable when an adjustment is later found to be incorrect or unnecessary.

New Installations

In a newly installed system, the trouble probably is the result of improper zeroing or wrong connections. Make certain all units are zeroed correctly; then check the wiring. Do not trust the color coding of the wires. Best check them out with an ohmmeter. A major source of trouble is improper excitation. Remember, the entire system must be energized from the power source for proper operation.

Existing Installations

In systems which have been working, the most common trouble sources are:

Switches-Shorts, opens, grounds, corrosion, wrong connections.

Nearby equipment-Water or oil leaking into synchro from other devices. If this is the trouble, correct it before installing a new synchro.

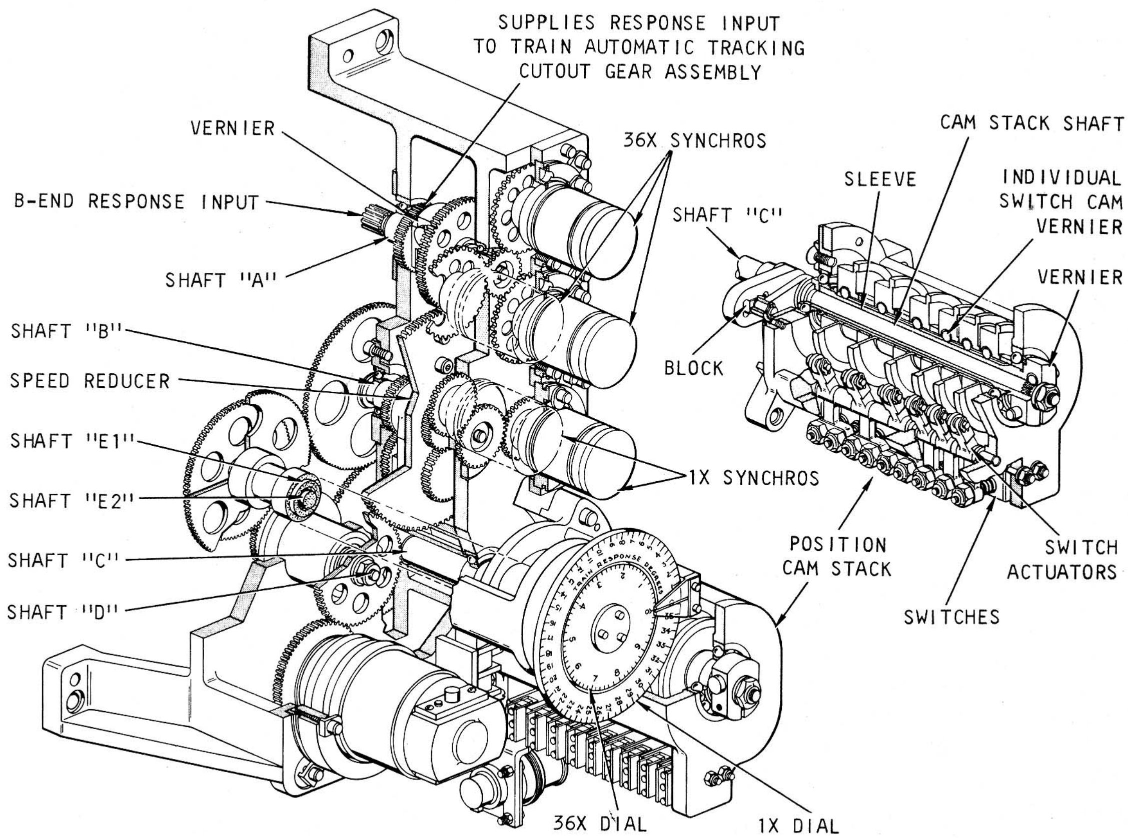

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Figure 5-18.—Train synchro gear assembly.

Terminal boards-Loose lugs, frayed wires, correction, and wrong connections.

Zeroing-Units improperly zeroed.

Wrong connections and improper zeroing in any system are usually he result of careless work or inadequate information. Do not rely on memory when removing or installing units. Refer to the applicable instruction book or standard plan. Tag unmarked leads or make a record of the connections. Someone else may need the information.

OSCILLOSCOPE, DUMMY DIRECTOR, AND DUAL TRACE RECORDER

The words oscilloscope and oscillograph are sometimes used interchangeably, but they do not represent the same equipment. An oscilloscope shows on a fluorescent screen the changes in a varying voltage. These changes show as wavy lines, and are not recorded. An oscillograph records the alternating-current wave forms or other electrical oscillations, using a pen (or pens) to mark the trace on graph paper. The trace can be studied and compared with previous traces on the same equipment, or traces on similar equipment as part of testing and troubleshooting procedures. Both forms of the instrument make use of cathode rays. The cathode ray oscilloscope was described in the preceding course, and its electrical-electronic operation explained.

OSCILLOGRAPHS

The use of Error Recorder Mk 12, or Mk 12 Mod 1, which is primarily an oscillograph, is described in chapter 10. It is used with the Asroc, Tartar, and Talos missile launchers; Mk 9 is used with Terrier systems in the missile plotting room to check the performance of the computer. Telemetric Data Recording Set AN/SKH-l, located in the director control room, includes a direct reading oscillograph. A 20-pen Operations Recorder is located in the missile plotting room to record event signals from the two missile fire control systems. Operational faults in the missile system can be located by analysis of the tracings made by the error records.

Telemetric Data Receiving, Recording, and Scoring Set AN/SKQ-2 is used to receive and record telemetric signals from guided missiles in flight. It also can be used to provide 5-track oscillographic records of the missile preflight checkout.

Dummy Directors

The error recorder used by GMMs is used in connection with the dummy director, described in chapter 10.

The dummy director is a portable instrument designed to produce dynamic signals required to test launcher power drive performance. The Talos launching system uses two Mk 1 Mod 6 dummy directors, one for train and one for elevation tests. They are used in conjunction with the launcher test panel (EP3 panel of MLSC Mk 10 Mod 0). Other test equipment supplied with the Mk 7 Mod 1 launching system includes: (1) one frequency signal generator, (2) two limiter and demodulator units, Model E, (3) a dual-channel oscillograph with chart paper, black ink, and spare pens, (4) a Triplett Model 630NA volt ohm-milliammeter or equivalent, with test leads, and (5) test instrumentation cabling. They are all used with the launcher test panel.

Missile Stimulator Section

Do not confuse the missile simulator (chapter 10) with the missile stimulator section in the Guided Missile Test Set AN/DSM-54(V), and later models. The missile stimulator section provides simulated flight and guidance control signals to the missile, upon command of the program section. The following modules make up the missile stimulator: reference signal generator, integrator, FM generator, synchronizer, pulse delay, pulse signal generator, RF signal generator, function generator, and missile relay control. It is not used to test the launcher.

Dual Trace Recorder

Since the oscillograph has two channels, two different traces may be taken at the same time. This allows corresponding trace results to be compared to learn more about the launcher operation. Normally, three types of test traces are taken: B-end error traces, velocity .traces, and position traces (fig. 5-19 A, B, C).

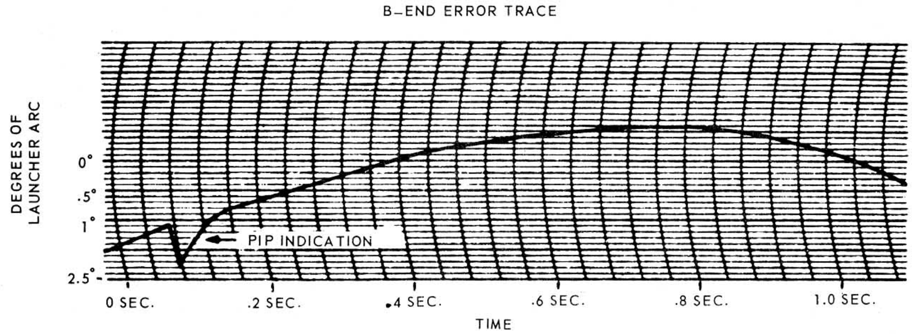
NOTE: Always calibrate the Brush oscillograph before recording any traces.

The voltages for the B-end error trace are obtained from the 36-speed synchro (in the receiver-regulator), geared to the B-end response. The synchro rotor is geared to rotate at 36-speed while the stator is electrically connected to the 36-speed synchro generator in the controlling test director. The rotor output voltage (a 400-hertz alternating voltage) indicates the error between the generating director and the B-end response shaft. The CT rotor output volt ages are circuited through the control test panel to the limiter and demodulator unit and then to the oscillograph.

The B-end position trace voltages also are obtained from the 36-speed CT. Through the proper switching on the control test panel, the output voltage produced will indicate the B-end position, and not error. The position output voltage also goes through the limiter and demodulator unit, and is recorded by the oscillograph.

The B-end velocity trace voltages are obtained from the d-c tachometer generators located in the receiver-regulator. The tachometer generators are geared directly to the regulator B-end response input shafts and furnish a d-c voltage which is proportional to the B-end velocity. The tachometer output is circuited through test instrumentation to the oscillograph.

READING TEST TRACES.- Test traces are read like ordinary graph curves. They illustrate the error, position, or velocity of the launcher at the time the tests were made. Traces below the



TRACE NOTES

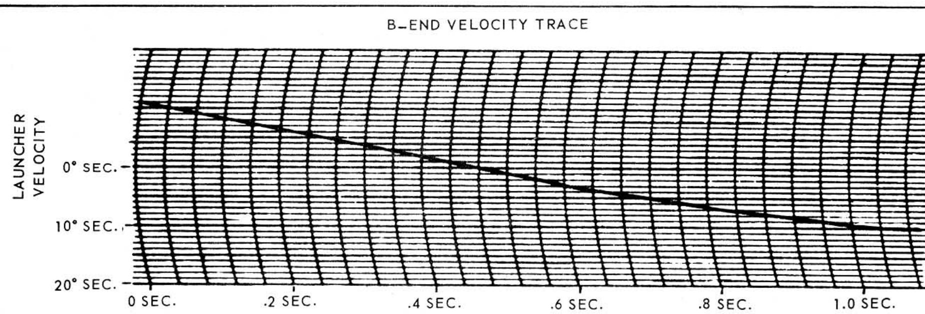
(1) THE MAXIMUM ERROR OCCURS AT THE START OF THE ABOVE TRACE.

(2) ZERO ERROR OCCURS TWICE; ONCE AT .4 SECOND AND AGAIN JUST AFTER 1 SECOND.

(3) THE PIP INDICATION IS NOT THE ERROR CURVE BUT AN INDICATION OF A SWITCH OR RELAY ACTUATION POINT. JOIN THE TWO ENDS OF THE PIP INDICATION WITH A LINE THAT FOLLOWS THE CONTOUR OF THE ERROR TRACE TO FIND THE ERROR AT THAT TIME.

(4) ALWAYS CHECK THE LEFT-HAND SCALE ON ERROR TRACES.

A



TRACE NOTES

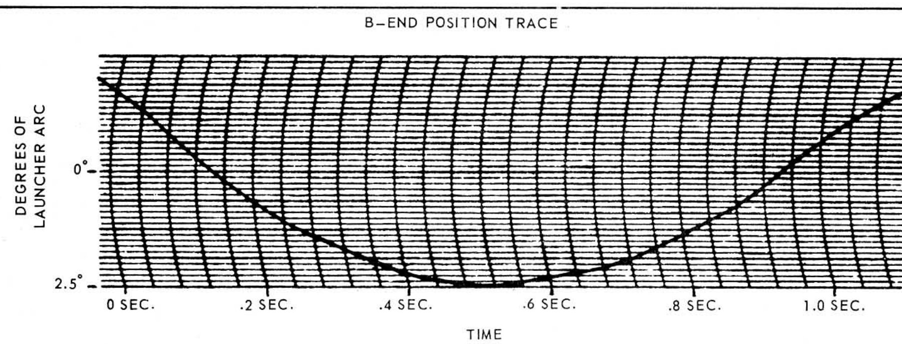
(1) THE LAUNCHER IS FOLLOWING A ROLL SIGNAL.

(2) THE LAUNCHER TRAVELS IN AN OPPOSITE DIRECTION WHEN THE TRACE CROSSES THE ZERO VELOCITY LINE.

(3) THE LAUNCHER REACHED A CREST OR TROUGH OF THE ROLL SIGNAL AT ABOUT .48 SECONDS, THE TIME WHEN IT HAS ZERO VELOCITY.

NOTE: THE LAUNCHER HAS ZERO VELOCITY AT THE CREST OR TROUGH OF A ROLL SIGNAL.

B



TRACE NOTES

(1) THE LAUNCHER IS FOLLOWING A ROLL SIGNAL WITH AN AMPLITUDE OF 2.5 DEGREES.

(2) THE LAUNCHER REACHES THE CREST OR BOTTOM OF THE ROLL AT ABOUT .5 SECONDS.

(3) THE LAUNCHER HAS MAXIMUM VELOCITY WHEN THE POSITION TRACE PASSES THROUGH ZERO.

(4) THE LAUNCHER HAS MINIMUM VELOCITY WHEN THE POSITION TRACE REACHES A CREST OR A TROUGH.

C

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Figure 5-19.—Oscillograph traces of launcher response: A. Sample error trace; B. Sample position trace; C. Sample velocity trace.

zero reference line are of the opposite phase from traces above the zero reference line. Be certain to check the following when reading test traces: (1) type of test being checked; (2) type of trace being.. used; (3) test conditions; (4) calibration on the left margin of the graph; and (5) the time allotted for each of the vertical graph divisions.

Use the calibration curve shown in figure 5-20 to determine the exact B-end positions when they are less than 5 degrees.

As the error and position trace voltages are generated by the 36-speed synchros, difficulty may arise in reading test traces if the error or position reading is greater than 2.5 degrees. The 36-speed sysnchro is geared to rotate 36 degrees for each 1-degree movement of the launcher. A launcher movement of 2.5 degrees therefore corresponds to 90 degrees rotation of the synchro. Since a synchro generates maximum output with a 90-degree rotor or stator displacement, the maximum trace indication occurs at an error or position displacement of 2.5 degrees. Error or position traces greater than 2.5 degrees require a special method of indication.

Since a complete revolution of a 36-speed synchro corresponds to 10 degrees of launcher movement, one complete cycle of a position or error trace corresponds to 10 degrees of launcher movement. For example, if the error or trace position consists of 6 1/2 cycles, the trace will measure 65 degrees of position or error (10 x 6.5).

CALIBRATION OF TRACE RECORDER.- The missile launching system control and its test panels may differ in switch arrangement, identification, and circuitry not only for different missile systems, but for different installations of the same missile system. You will need the elementary wiring diagrams to determine actual identification of switches and positions, and what each switch controls. Use only the special cables supplied for interconnections of test instruments and the test panels of the missile launching system control.

The oscillograph is calibrated during launcher testing procedures; and the before any launcher shipboard tests are made, the following general checkoffs must be performed.

1. Check the oil level at the main supply tank.
2. Check the oil level and all gear housings associated with the train and elevation power drives.
3. Lubricate the launcher components properly.
4. Charge the launcher accumulators properly.
5. Vent all hydraulic units properly.
6. Check the train warning bell operation.
7. Train the launcher through its maximum limits to verify free and unobstructed launcher train movements.
8. Elevate and depress the launcher guide arms to their maximum limits of travel to verify free and unrestricted guide arm movements.

On systems that have train and elevation air motors, those are used for items 7 and 8. Power drives are not activated for these checks.

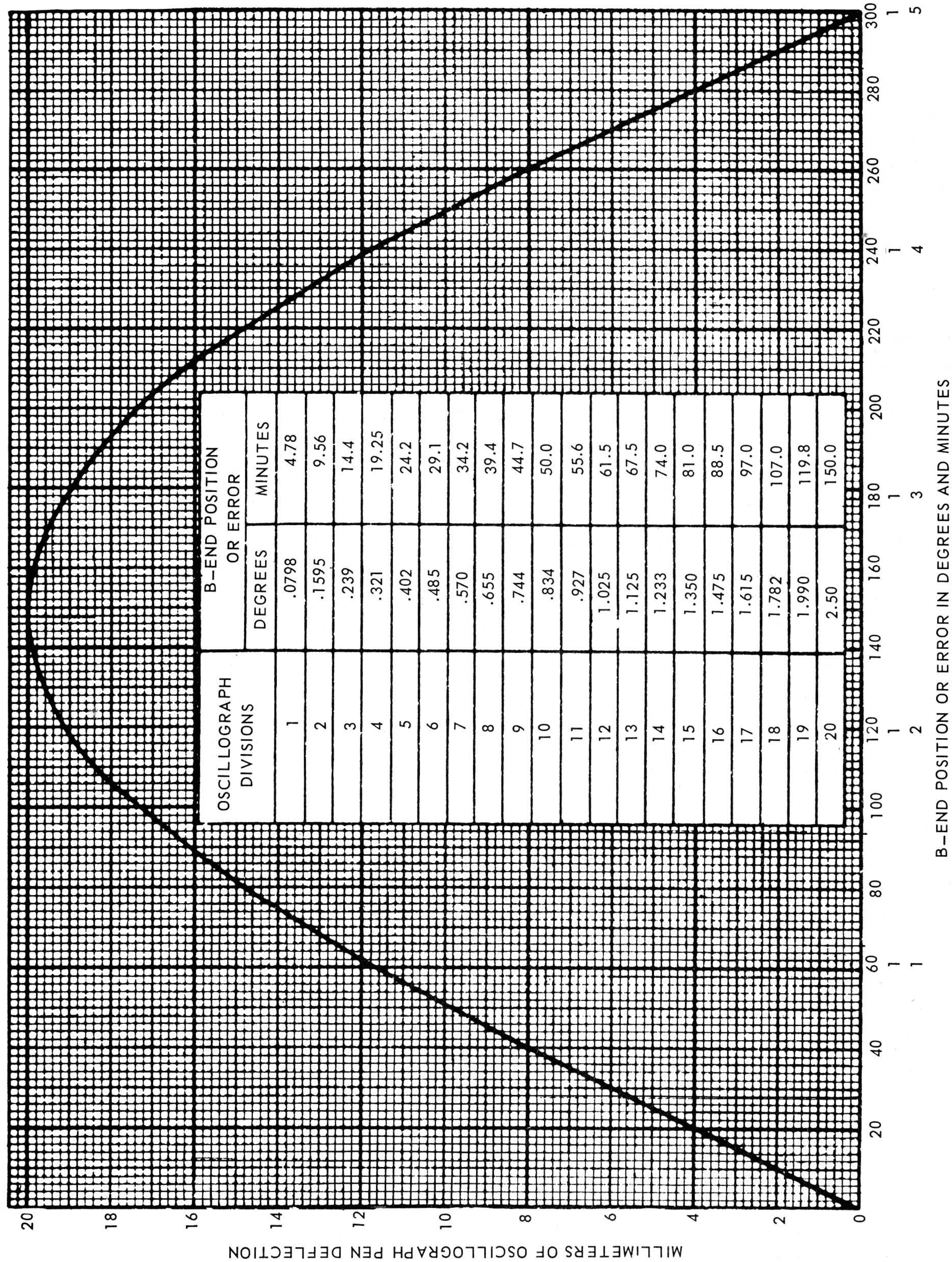
CAUTION: Do not move the guide arms or start power drives unless it is known that the firing cutout mechanism is adjusted properly. Failure to do so may result in extensive damage to the firing cutout mechanism.

9. Load the launcher rails with standard inert missiles or equivalent unless specified otherwise for the individual test being performed.
10. Check general condition of test instrumentation and service as required. Use black ink in the oscillograph so that test traces can be reproduced clearly.

After all these preliminary checks are made, activate the launcher by switching on the EP1 power panel, and start the train and elevation motors. The BP2 panel should be switched to STEP control, and control switched to the EP3 panel. The test cables are connected to the EP3 panel. Allow the train and elevation power drives to operate at least 30 minutes before making test traces.

Two different methods of calibration are used. Error and position traces are calibrated by one method and velocity traces are calibrated by a second method.

The error trace uses three possible calibration scales: a 10-minute full-scale calibration, a



OSCILLOGRAPH DIVISIONS	B-END POSITION OR ERROR DEGREES	MINUTES
1	.0798	4.78
2	.1595	9.56
3	.239	14.4
4	.321	19.25
5	.402	24.2
6	.485	29.1
7	.570	34.2
8	.655	39.4
9	.744	44.7
10	.834	50.0
11	.927	55.6
12	1.025	61.5
13	1.125	67.5
14	1.233	74.0
15	1.350	81.0
16	1.475	88.5
17	1.615	97.0
18	1.782	107.0
19	1.990	119.8
20	2.50	150.0

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Figure 5-20.—Position and error trace calibration curve.

20-minute full-scale calibration, and a 2.5-degree full-scale calibration.

The position trace is normally calibrated with only one scale, a 2,5-degree full-scale calibration.

The velocity trace uses one calibration scale for elevation and train tests. The train velocity trace is calibrated with a forty-degree-per-second full-scale calibration.

Allow the test equipment at least 10 minutes to warm up before attempting any calibration procedures. (Varies with different systems; check your OP and the MRC.)

Obtain the instructions for calibrating the oscillograph (error recorder) used with your missile launching system and proceed with the calibration. After you have completed the calibration of the oscillograph, it is ready to be used in testing the accuracy of the launcher. With the; Talos system, these tests are numbered consecutively through test No. 51 B. They are described in OP 3590 *Guided Missile Launcher, Mark 7 Mod 1, Description, Operation, and Maintenance*. There are many similarities between the train and elevation tests, but each power drive must be tested separately. For example:

Elevation (Train) Accuracy Test

Test 1. Simple harmonic motion test.

Test 2. Static test.

Test 3. Five-degree-per-second constant veocity test.

Test 4. Ten-degree-per-second constant veocity test.

Test 5. Fifteen-degree-per-second constant velocity test.

Test 6. Elevation (train) velocity and acceleration test.

Tests 6A and 6B. Launcher elevation (train) synchronized indicator tests

The train power drive requires an additional t{ test in this series-25-degrees-per-second constant velocity test.

Other tests in this group of fifty-one are elevation (train) synchronizing tests, fixed displacement; elevation (train) harmonic motion synchronizing tests; elevation (train) synchro power failure tests; elevation (train) main power. failure tests; elevation (train) return to load tests; and elevation (train) frequency response tests.

The error recorder is used to make traces in each of the tests, the maximum operating errors are calculated, and the traces are compared with typical traces. Copies of typical traces are included in the OP or OD. The traces made at installation of the launching system on the ship are kept aboard for comparison.

Elevation accuracy tests on shipboard include a simple harmonic motion test, a static operation test, and constant velocity tests. The same types of tests are made for train accuracy. Constant velocity and synchronizing tests are performed at different speeds and at different angles of train and elevation, each performed according to specific instructions in the OP.

These tests are performed annually unless circumstances require otherwise. A suspected malfunction may require certain tests to be performed more frequently. Operational tests may be needed to determine if the launcher follows order signals accurately, or to check some other function of the launcher. All the men who perform the test must be familiar with the equipment and the procedure. Although you follow the steps according to a checkoff list, studying the procedure beforehand will do much for a smooth operation. If you are the leading petty officer, you will check the work of the other men.

The launcher test equipment is stowed in the shipboard instrument storage cabinet when not in use.

SIMILARITIES AND DIFFERENCES

The principles explained in *Basic Electricity*, NAVTRA 10086 and *Basic Electronics*, NAVTRA 10087 apply to all the missile systems. The details of application of these principles in the different weapon systems must be left to the OPs and ODs for each system. If you have acquired a firm knowledge of the basic principles, you can understand the use of them in the system in your ship. If you are not so sure of your knowledge in some areas, make a careful re-study of any part you do not understand. Other petty officers can help you. The complicated network of electrical and electronic parts in a weapons system cannot be kept in working order if you do not understand how it works. It is too sophisticated a system to maintain by guesswork.

SUMMARY

This chapter points out the uses of different electric and electronic devices in launching systems. It tells how they function and how you are to test them, The basic principles of servos, amplifiers, and synchros are applied to specific functions in the launching system.

Some of the newer electronic items that have been placed in launching systems were introduced. As more use is made of transistors, printed circuits, and miniaturized units, you need to apply the knowledge of the principles to the particular uses. You will also need to develop skill in maintenance of these items.

While safety needs to be emphasized every day, and caution can never be relaxed around electrical equipment, the applicable safety regulations are placed in chapter 12.