CHAPTER 6

HYDRAULICS IN MISSILE LAUNCHING SYSTEMS

INTRODUCTION

In the process of passing from striker to GMM 3 and then to GMM 2, you have learned the theory of hydraulics as applied to missile launching systems. You have learned how to operate the hydraulically powered handling equipment and missile launching machinery, and how to drain and refill the hydraulic systems. You know how to look for leaks, check pressure, check fluid level, charge accumulators, and disassemble, inspect, clean, and lubricate hydraulic equipment

Every missile launching system in current use is operated in part by hydraulic power. The network of piping required to carry the oil, and the valves to direct, restrict, relieve, or shut off the flow afford numerous places for trouble to develop. Constant inspection and maintenance are necessary to keep the systems operating smoothly. You know from experience that the trouble spot is sometimes hard to locate. To advance to GMM 1 or GMM C, you need to become more expert in troubleshooting hydraulic systems and learn to test, adjust repair, and overhaul them. Overhaul of the whole system is done at shipyards.

Hydraulic power drives have been used in the Navy for many years to train and elevate guns and when launchers were needed for rockets and missiles, power drives were adapted for them. The principal advantage of hydraulic power drives is their ability to move large loads smoothly and quickly. A disadvantage is the need for constant maintenance. Strict adherence to the instructions in the maintenance publications and the Maintenance Requirement Cards (MRCs) will help the equipment to retain its design characteristics of power, speed, and control, and will help to eliminate extensive repairs and costly replacement. Correct casualty analysis can be made only by someone with a thorough knowledge of how the equipment operates. When trouble develops, reach first for the OP - not for your wrench.

Hydraulic systems can actuate mechanisms almost instantaneously, with almost 100 percent efficiency; but leakage or foreign matter can make the whole system in operative. Daily checks on leakage, and constant vigilance against entrance of foreign matter, are very important parts of hydraulic system maintenance. You have learned many of the basic types of repairs, such as replacing pipes and pipe sections, fittings, gaskets, and valves; cleaning or replacing filters; venting the system of air; and replacing broken or defective mechanical parts. Now you need to learn how to adjust all parts of the hydraulic system, and to overhaul and repair any part. To qualify for GMM C you must be able to plan and supervise the repair and maintenance program. Since many parts of a launching system are operated by hydraulic power, many components are involved. There is not just one power drive unit to be maintained, but several, each with attached electrical, electronic, mechanical, and/or pneumatic components. You have to interpret the application of basic hydraulic principles in each system.

This chapter will expand on the information given in the preceding text, *Gunner's Mate M (Missiles) 3 & 2*, NAVTRA 10199 and will give information on the more technical aspects of maintenance and alignment. The safety factors will be mentioned briefly in connection with the work, but a more complete treatment will be given in chapter 12. Emphasis will be given to your responsibility in planning, implementing, and supervising maintenance and repair work, in inspection of work done by others, and testing before and after work is done on equipment. Alignment of components of a launching system is a precise operation that requires both knowledge and skill. The information in this chapter will tie in with that of the preceding chapter.

HYDRAULIC POWER IN MISSILE SYSTEMS

Hydraulic power drives are used in missile systems to load and unload missiles from a magazine stowage area to the launcher guide arm, to position missile launchers in train and elevation for firing, to load and off load missiles from ship to ship or from ship to shore, and in some systems to jettison unwanted missiles. Hydraulics are also used in the missile themselves to control the missile flight attitude through movement of missile control surfaces (wings). This chapter will explain hydraulics in launching systems so we'll not discuss hydraulics in missiles. How hydraulic systems control the missile's flight path is explained in GMM 3&2, NT 10199.

HANDLING EQUIPMENT

The use of handling equipment in loading, strikedown, strikeup, and offloading was described in chapter 2, but little was said about the source of power for the equipments used. Figure 2-17 showed hand lift trucks used to move the Asroc missile in its container. Two trucks are required. The Mk 41 has a hydraulically operated lifting arm, located at the front of the truck, to raise or lower the container. Closing the pressure-release valve and operating the hydraulic pump handle raises the lifting arm. It is lowered by opening the pressure-release valve. The Mk 42 uses a screw jack, operated by a ratchet wrench, to raise or lower the lifting arm. The Mk 41 hand lift trucks are being replaced by the Mk 42.

Transfer dollies of different mods, but similar in construction and operation are used for transferring missiles. The framework and shock absorbers protect the missile against accidental impact, and the hydraulic or hydraulic-mechanical brakes make control positive. They are called "dead-man" brakes. Some dollies are designed for use with a particular missile, and others, such as Weapon Component Transfer Dolly Mk 6 Mod 0, are adaptable to several types (Terrier missile, Terrier booster, or Tartar, in this instance). This type of transfer dolly is used for transfer at sea, and to move the missile about on deck.

Other hydraulically operated handling equipment includes ready service cranes, transfer cranes, and hydraulic booms. The strikedown elevator and hatch in the Mk 10 launching system are hydraulically operated by the loader accumulator power drive. The ship's elevators also are operated by electrohydraulic power. Hydraulic fluid provides the "muscle" for much of the moving machinery aboard ship. The electrical system activates and controls the hydraulic system.

HYDRAULICS IN THE FEEDER SYSTEM

The feeder system of a typical missile launching system includes the magazine, loader (rammer), assembler, and strikedown equipment. Tartar missiles do not require assembly areas, and have no strikedown area for checkout or repair. Otherwise, we can consider Mk 10(Terrier) as a typical launching system. What components are operated by hydraulic power?

The loader accumulator power units are located in the strikedown and checkout area and supply hydraulic power to:

1. Spanning rails and blast doors.
2. Retractable rails.
3. Floating rails on tracks.
4. Loader positioner.

Magazine Accumulator Power System

Each magazine accumulator power system has four accumulators, and supplies hydraulic fluid for operating:

1. Ready service drive motor.
2. Tray-shift mechanism.
3. Magazine hoist.
4. Magazine doors.

The ready service ring may be rotated in either direction by the hydraulic motor. The tray-shift mechanism, used to transfer a missile either from the ready service ring to the hoist, or the reverse, is moved by extending a hydraulically operated piston rod. The magazine doors are hydraulically opened upward, and may be locked open or closed by means of latches which are operated hydraulically. The hoist has a hydraulic drive unit with upper drive transmission, lower drive transmission, and drive shafts. The accumulator power supply system consists of an electric motor, piston pump, supply tank, header tank, control valve block, and four accumulators.

The location of each of the power units varies somewhat with the mark and mod of the system, and the ships on which they are installed. The Mk 10 Mod 7 system is installed forward on the 01 level of DLG-26 class ships and it has three ready service rings instead of the usual two. Mods 3 and 4 are installed aft and athwartship from each other on CV A-63 class ships, which imposes a different placement of the ready service rings (and their power units). It is not so much the location of the different units that you need to memorize, as the action and interaction of the different components in the system.

Magazines with two sides, A and B, which include all Talos and Terrier, have two magazine accumulator systems, one for each side, to supply power to the magazine components. Figure 6-1 shows the location of components in the Mk 10 Mod 7 system. The accumulator flasks are not shown in this illustration; the high pressure accumulator pump is inside the fluid-filled supply tank, and is therefore not visible. This system has one header tank common to both A and B sides.

The supply tank holds the hydraulic fluid, the motor driven pump produces the hydraulic pressure, the valves in the valve block regulate system pressures, and the accumulator flasks store energy, absorb hydraulic shocks, and prevent excessive pressure fluctuations. A solenoid assembly, attached to the valve block, actuates the dump valve to dump pressure fluid to the tank when the system is deactivated.

Systems that require a large volume of pressure fluid usually make use of a parallel piston pump instead of a gear pump. In addition, all power drives have an auxiliary pump, which may be power-driven or manually operated. This is used to provide a limited supply of hydraulic fluid for emergency operation. During maintenance or installation, the hand pump is used.

Several types of valves and a parallel piston pump were illustrated and described in *Gunner's Mate M (Missiles) 3 & 2*, NAVTRA 10199. Not all power drives have all the associated valves in one valve block but may have several separate assemblies. The valves control the volume of fluid, the direction of flow, and the pressures at which the system operates.

Figure 6-2 is a schematic of the magazine accumulator system used in the Mk 10 Mod 0 Terrier system. The accumulator flasks, one of which is shown with the internal bladder and the poppet valve, are charged with nitrogen through nitrogen valves. The pressure required varies with the temperature; refer to the data chart on the charging valve block when checking the pressure. This is one of the daily maintenance procedures; use the MRC cards if you have them aboard, and if not, use OP 2351, vol. 1. Be sure you have the latest revision.

Checking the fluid level in the header tank is another daily maintenance job. The system must be shut down before you do this. Most header tanks have a sight gauge through which you can see the fluid level. Use the MRC (or the OP) for step-by-step instructions.

The electric motor to operate the pump (inside the supply tank) is coupled to the pump through a mounting flange. The pump draws the hydraulic fluid through the intake screen and discharges the fluid under pressure to the valve block. From the valve block, the pressurized fluid is passed through the filter elements and the filter bypass valve to the unloading and starting valves. If the filters are clogged and the fluid must pass through the filter bypass valve, a light on the EP-2 panel comes on, showing that the filters must be replaced. In an emergency it is possible to continue operating the power drive when the filters are clogged, but in practice sessions you would stop the operation and replace the filters. For practice in servicing filters (fig. 6-3), remove the 12 filter elements from the multielement filter assembly, inspect the elements, replace them, and reassemble the unit. Follow the MRC instructions (or the OP). This assembly filters the pressure fluid passing from

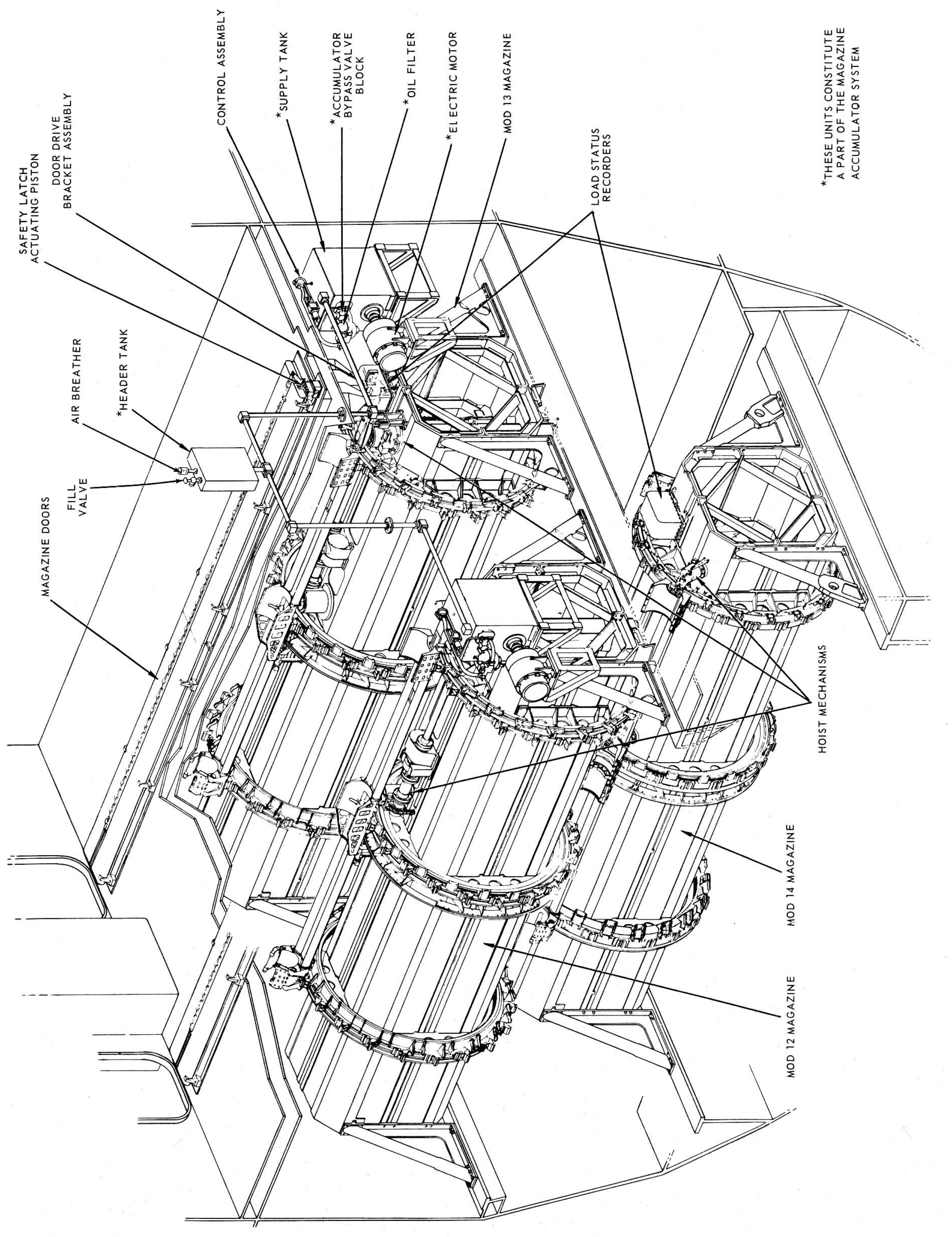

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Figure 6-1.—Guided Missile Magazine, Mk 10 Mod 7 launching system; location of magazine accumulator components.

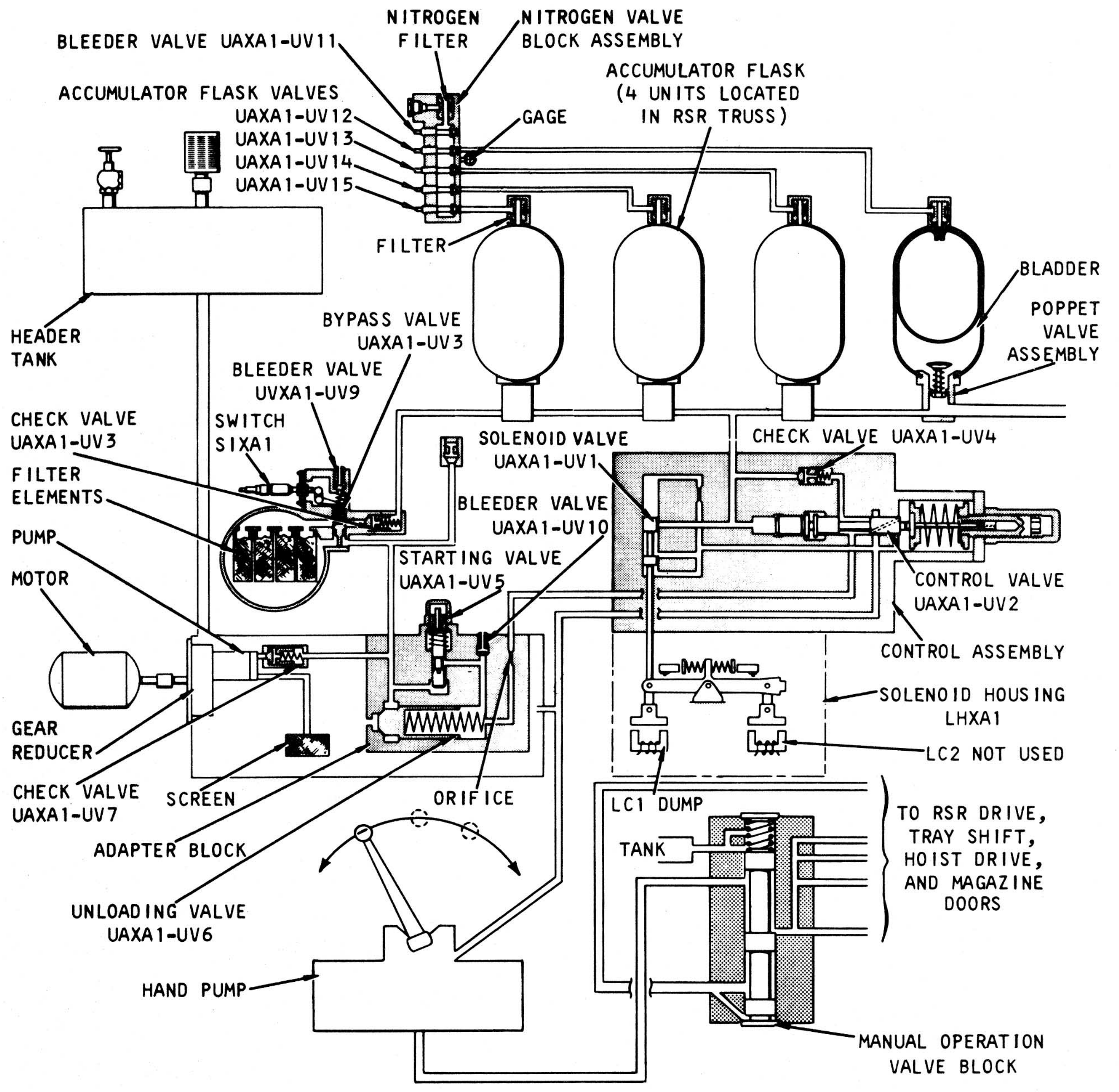

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Figure 6-2.—Hydraulic schematic of Power Drive Mk 64 Mod 0.

the adapter block to the accumulator flask assembly. It is mounted on the side of the supply tank.

The pressure fluid passes around the unloading valve, which is operated by the control valve, and goes on to the starting valve. The check valve allows the fluid to go in only one direction. The control valve maintains the pressure between the set limits (for example, 1300 to 1500 psi), by control of the unloading valve opening or closing It as needed to keep the pressure within limits. Excess pressure fluid is ported to the tank, Pressurized fluid passes through the check valve into the accumulator flasks, where

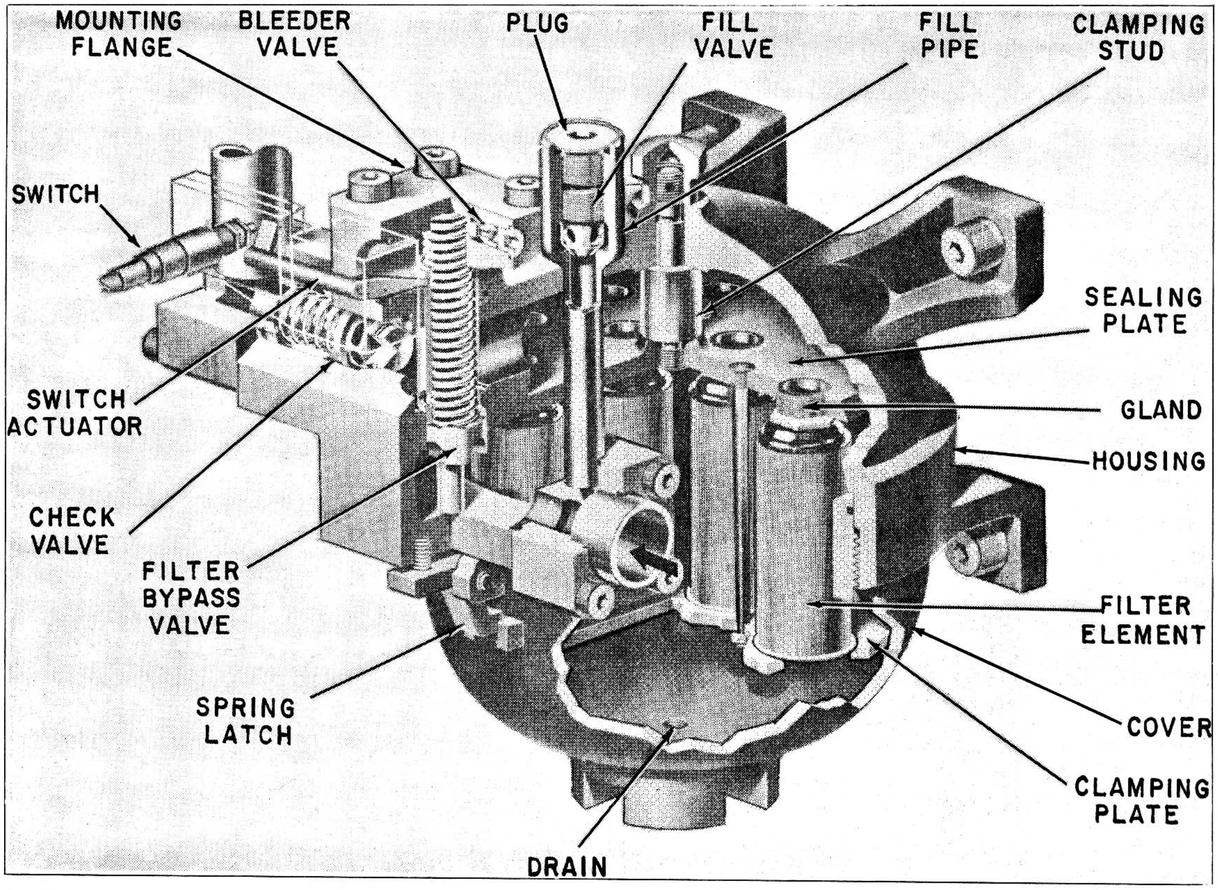

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Figure 6-3.—Multiple element hydraulic filter assembly.

some is stored to maintain a steady pressure in the system.

The connection of the hand pump to the system is also shown in figure 6-2.

TRAY SHIFT MECHANISM. - The tray shift mechanism is located at the top of the ready service ring truss at station 1, the transfer station. Its operating power comes from the magazine accumulator power system. The saddles on the tray, which hold the missile, also are operated by hydraulic power from the same source. On Mk 10 Mods 7 and 8 systems, there is an inter-ring transfer system to transfer missiles from one ready service ring to another. Hydraulic power is received from the magazine accumulator power system via piping, controlled by selector valves, solenoid valves, check valves, pilot valves, and interlock valves, actuated by electrical signals. Figure 6-4 shows the valve block for the tray shift mechanism at station 1 (the transfer station). The operating cylinder with its piston and orifice rod does the actual positioning of the tray.

The detented solenoid LHDA1 (fig. 6-4) is attached to the side of the valve block. There are two switches, but only one is shown (SIDA2). Tray shift latch-operating valves UVDA5 and UVDA4 actuate the switches. Selector valves UVDA6 and UVDA7 can port the hydraulic fluid in either direction, depending on where the fluid enters. Solenoid valve UVDA2 controls the direction of fluid flow to pilot valve UVDA3, and connects by a plunger rod to LHDA1. The pilot valve controls the direction of operation of the latch-operating valves. UVDA9 and UVDA10 are simple plunger check valves that permit leakage to return to the tank. UVDA1 is

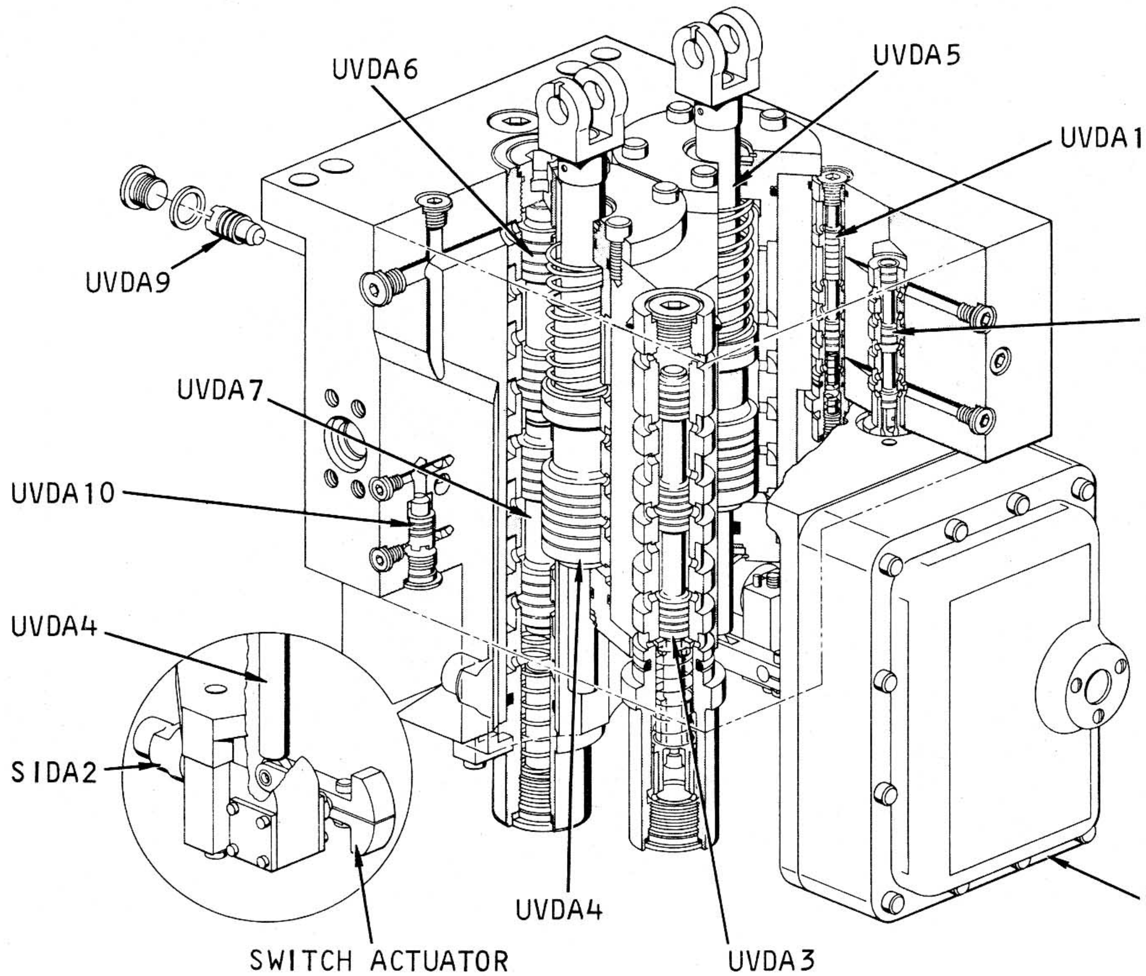

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Figure 6-4.—Station 1 tray shift control in Mk 10 Mod 7 launching system.

an interlock valve that prevents movement until the required conditions are met.

HOIST MECHANISMS. - The location of the hoist mechanisms was pointed out in figure 6-1. These, too, operate on hydraulic power from the magazine accumulator power system. The function of the hoist mechanism is to raise missiles from the ready service ring to the loader, or to return them during unloading. Figure 6-5 shows the mechanisms of the A-side hoist. The telescoping columns that raise or lower the missile are driven by chains and gearing. The hydraulic motor (B-end) drives the gearing. The upper drive is a gearbox driven by the intermediate drive shaft from the lower drive. The hoist heads contact the shoes (forward or aft) that support the missile round in the tray. The probe on the aft hoist head aligns the head with the loader trunk in the hoist-raised position. The head of the aft shoe hoist is more elaborate than the forward one.

The hydraulic control valve block is mounted on the wall of the lower transmission housing, and two detented solenoids are mounted on top of the valve block (fig. 6-5). It contains a metering valve to regulate the flow of oil, an orifice valve to control speed of the B-end by size of the orifice, a pressure-off valve to shunt pressure to the power-off brake, a selector valve to control direction of the B-end movement, a sequence selector valve to pull the appropriate latch in the hoist drive assembly, an interlock valve to prevent movement before all conditions are ready, and two solenoid valves to control the flow of fluid to the sequence selector valve. The power-off brake is used during maintenance or installation or if the pressure falls below 900 psi (normal, 1500 psi).

MAGAZINE DOORS.- The location of the magazine doors in relation to the ready service

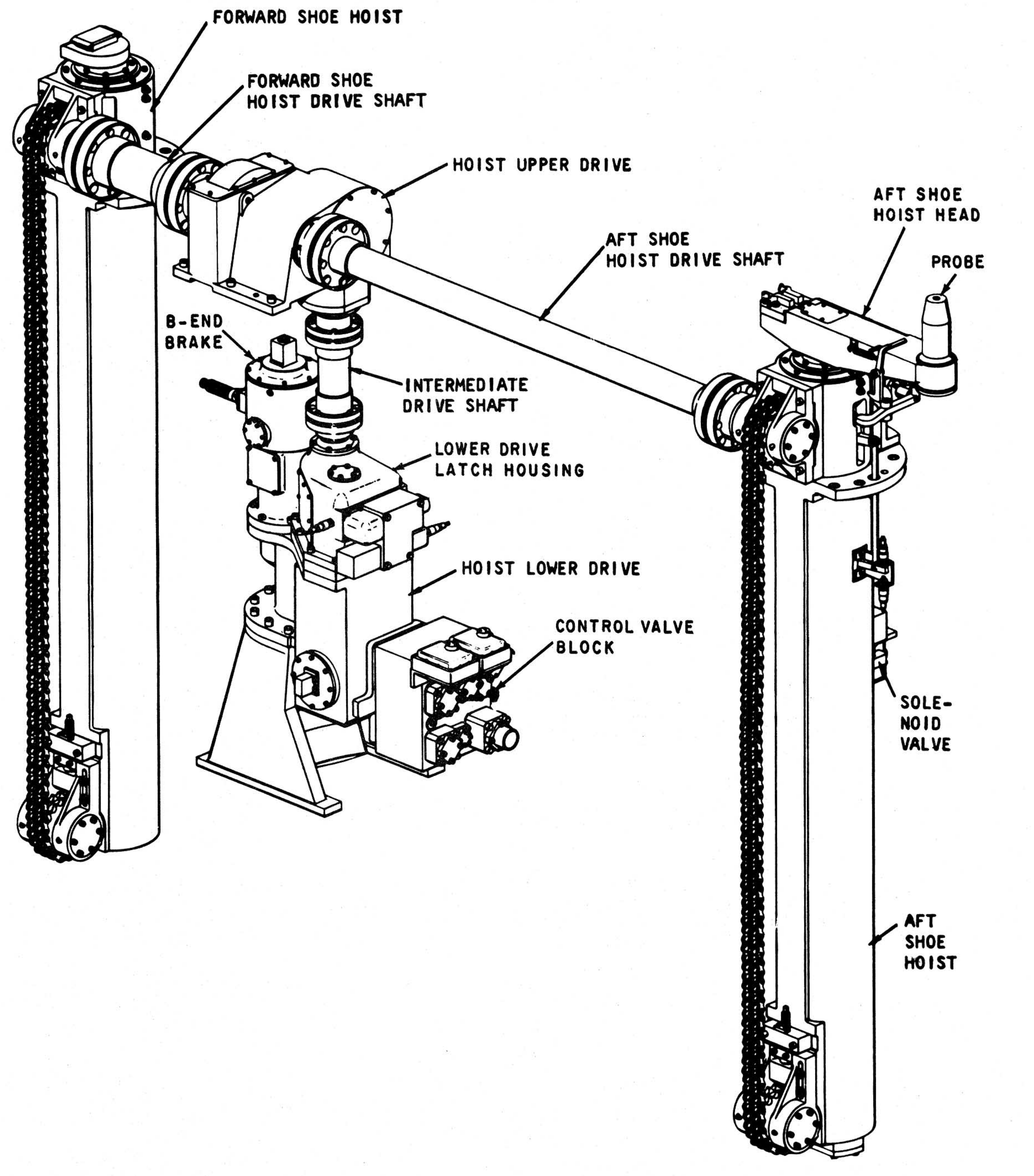

Figure 6-5.—Hoist mechanism for "A" side, Mk 10 Mod 7 launching system.

rings was shown in figure 6-1. The safety latch assembly, which resembles a giant zipper, maybe seen in figure 6-6. At the right-hand end, the safety latch actuating piston is shown, and below the door drive bracket assembly. The door drive bracket assembly includes all the components for operating the magazine doors: the switch, the door operating piston assembly, the latch control valve, the door-open and the door-closed latch, and the solenoid valve. There is a door-closed latch at each end of the doors. Electrical and hydraulic interlocks assure that the blast doors are closed and the hoist is down and latched before the doors can be opened, and that the hoist is down and latched before the doors can be closed. The hydraulic operation is through the piston assembly. It contains a directional valve and a metering valve in addition to the piston. The solenoid valve block assembly is attached to the piston block assembly. The latch control valve block is fastened behind the piston guide. The door-open latch valve block is fastened to one of the webs of the door drive bracket. The hydraulic fluid to operate these valves and pistons comes from the magazine accumulator power system.

The opening and closing of doors may seem like a minor item, but it is very important. The magazine doors are flame tight and watertight. They must never be open when the blast doors are open. All the parts, valves, switches, pistons, etc., must act in sequence. Failure of any part can disrupt the whole series of actions. If that happens, you need to get out the hydraulic schematics and the electrical drawings and trace the cause of the failure. It might be a clogged valve or a broken switch, or the pressure in the magazine accumulator might be too low. You would shut down the magazine accumulator system while locating the trouble.

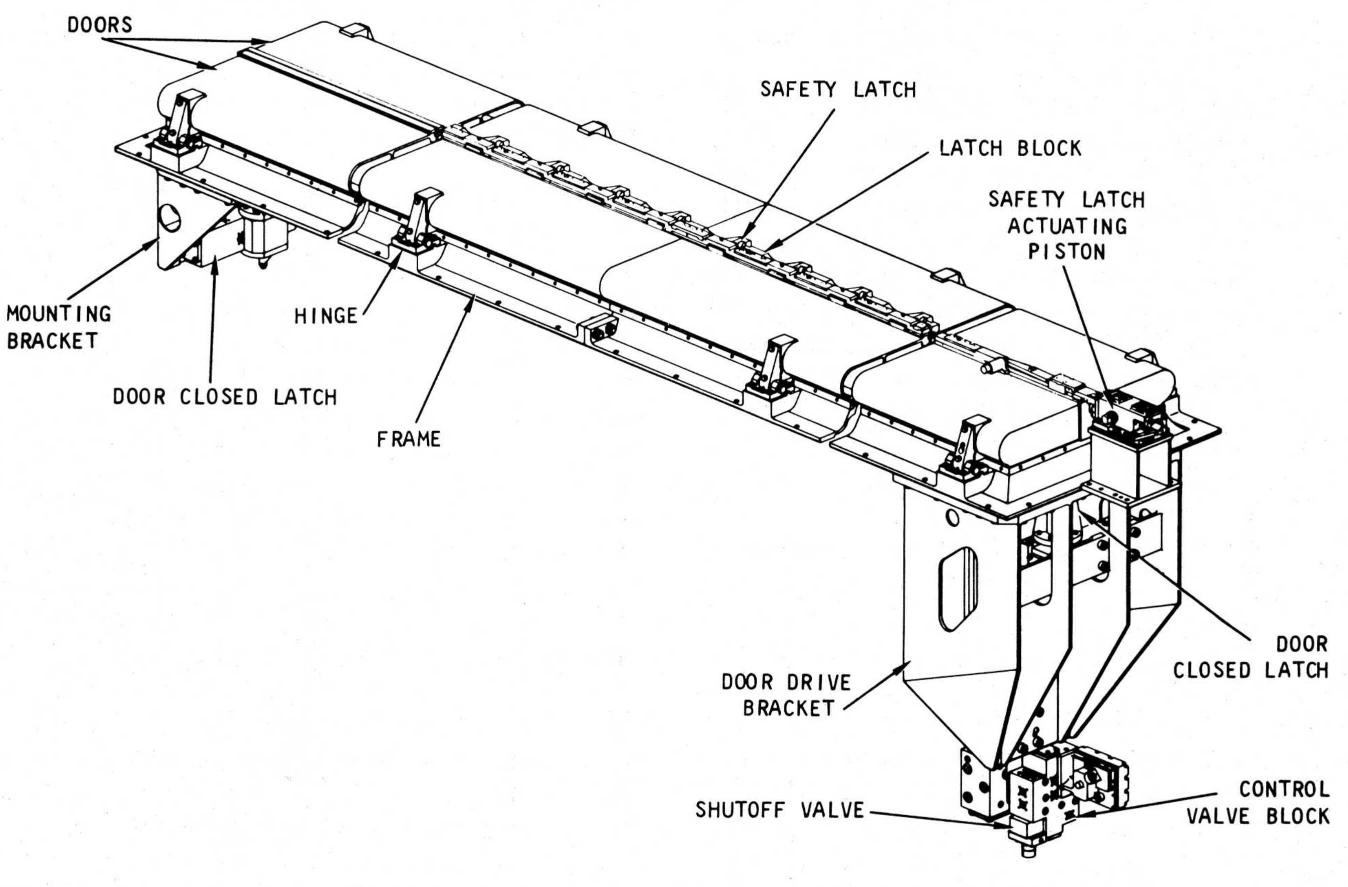

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Figure 6-6.—Magazine door assembly.

Loader Components

The loader, figure 6-7, consists of similar A-side and B-side assemblies that engage, support, and move missiles between the assembly area and the launcher, or between the assembly area and the strikedown/checkout area. Major components of the loader are the loader trunk, the tilting rail (in the Mod 5 system), the blast doors and spanning rail, the loader chain and pawl, the loader power drive. The loader has a loader horn that sounds when the system is in the unload launcher mode to warn personnel of impending movement of the missile back to the assembly area.

LOADER POWER DRIVES.- There are two accumulator-type power drives, one for the A-side and one for the B-side. Each power drive includes a tank to hold the hydraulic fluid, a motor-driven pump to develop hydraulic pressure, a series of valves to regulate system pressure, and two accumulator flasks to store energy, absorb hydraulic shocks, and prevent excessive pressure fluctuations. These components operate in the same manner as the magazine accumulator power system.

The accumulator power drive furnishes hydraulic power to operate the spanning rail, the blast door latches, the retractable rails, the floating track piston assemblies, the loader pawl positioner, the interlock valve block, the tilting rail, and the NAVSHIPS strike down checkout gear.

A second power system, a combined A-end, B-end (CAB) power unit, is located near the aft end of the loader trunk. It develops hydraulic pressure and transforms it into rotary mechanical motion to drive the loader chain.

The CAB power drive also has a power-off brake assembly. This is used to halt moving equipment, to secure driven equipment against roll and pitch when the equipment is inactive, to halt and secure equipment if there is a power failure, and to provide a means of manual operation (by hand crank) for maintenance procedures, installation, or emergency operation. A small auxiliary gear pump, driven by the same electric motor that drives the A-end, supplies the necessary hydraulic pressure for the control mechanism that controls the A-end tilt plate, and therefore the speed and direction of rotation of the B-end. The auxiliary gear pump produces 400 to 500 psi servo pressure to operate the control components of the CAB units, and delivers 100 psi (supercharge pressure) from another set of gears to replenish fluid losses from slippage and leakage.

LOADER TRUNK.-The loader trunk is made up of sections that are mounted to the overhead bulkhead. The number of sections varies with the mod of the system. The Mk 10 Mod 0 Terrier launching system has eight sections; Mods 5 and 7 have six loader trunk sections and tilting rail; Mod 8 has 12 sections. There are some differences in the trunk sections of different mods, but they are sometimes interchanged by making slight modifications. Figure 6-8 shows a trunk section made for the Mk 8 Mod 11 loader.

A number of the hydraulically operated components of the loader are mounted in the loader trunk sections. Only the control panels, the power drives, and the tilting rail control are not mounted in the loader trunk assembly. The cross-section view in figure 6-7 shows the channels or tracks in which the forward and after shoes and the chain can slide.

TILTING RAIL.-In mods that have a tilting rail, many of the moving or movable components of the loader are attached to or move in the tilting rail. Figure 6-9 shows the location of the important components on the tilting rail and the operating piston. The tilting rail takes the place of about four and half loader trunk sections in the assembly area. The trunnion supports are mounted in the ship's overhead over the magazine doors. The tilting rail receives the missile round from the hoist, moves it to the assembly area for wing and fin assembly, then tilts to the angle necessary to match the launcher load angle. The operating piston (fig. 6-9) is the unit that elevates or lowers it. Hydraulic power is obtained from the CAB power unit, which is connected at the power drive input. A hydraulic transfer pin (inside the trunnion) distributes the hydraulic fluid to the floating track piston assemblies, the positioner piston and interlock valve block, and the rail-loaded indicator assemblies, through the adapter block mounted on the trunnion (fig. 6-9) neatly

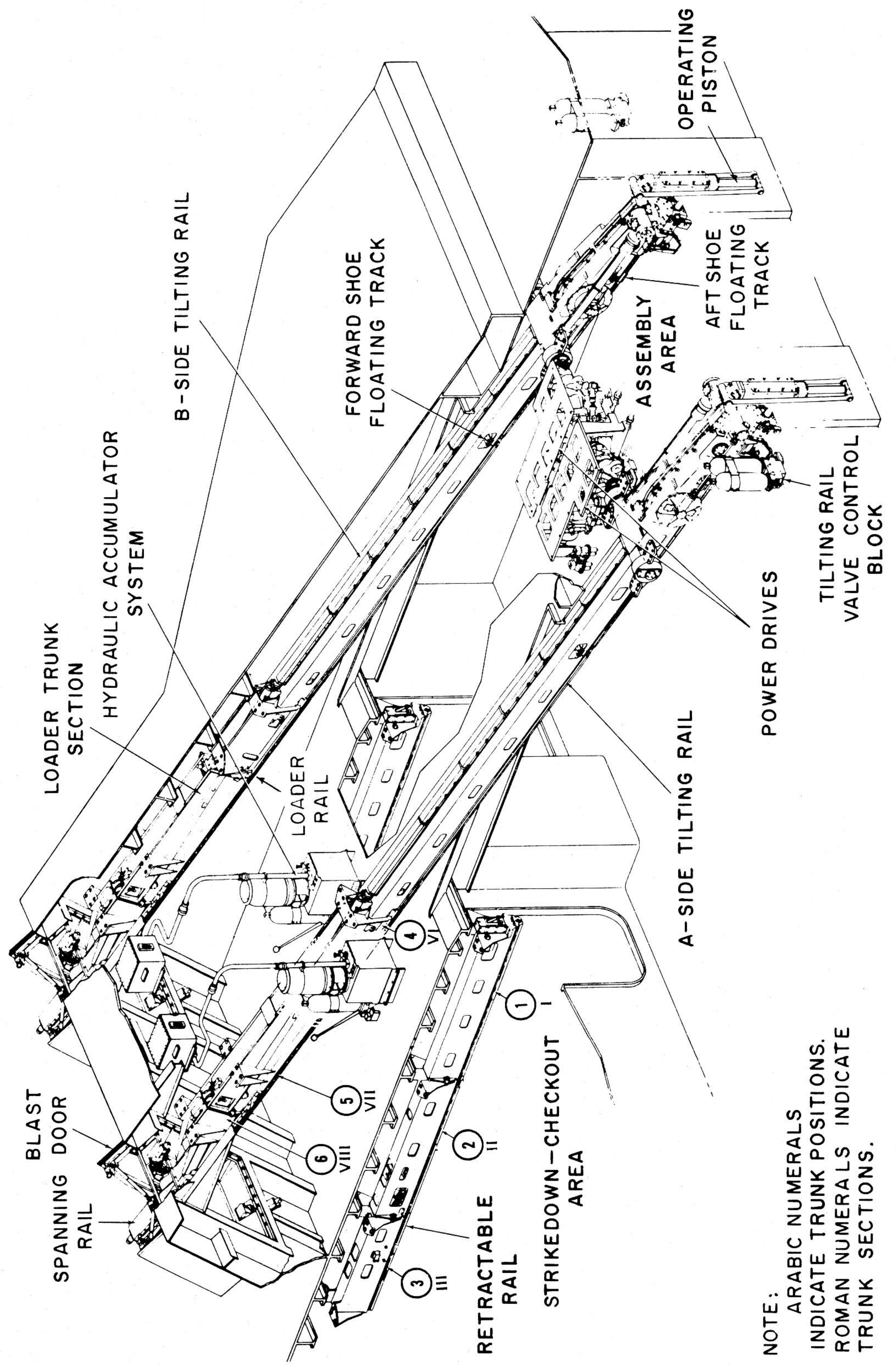

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Figure 6-7.—General arrangement of Loader Mk 5 system.

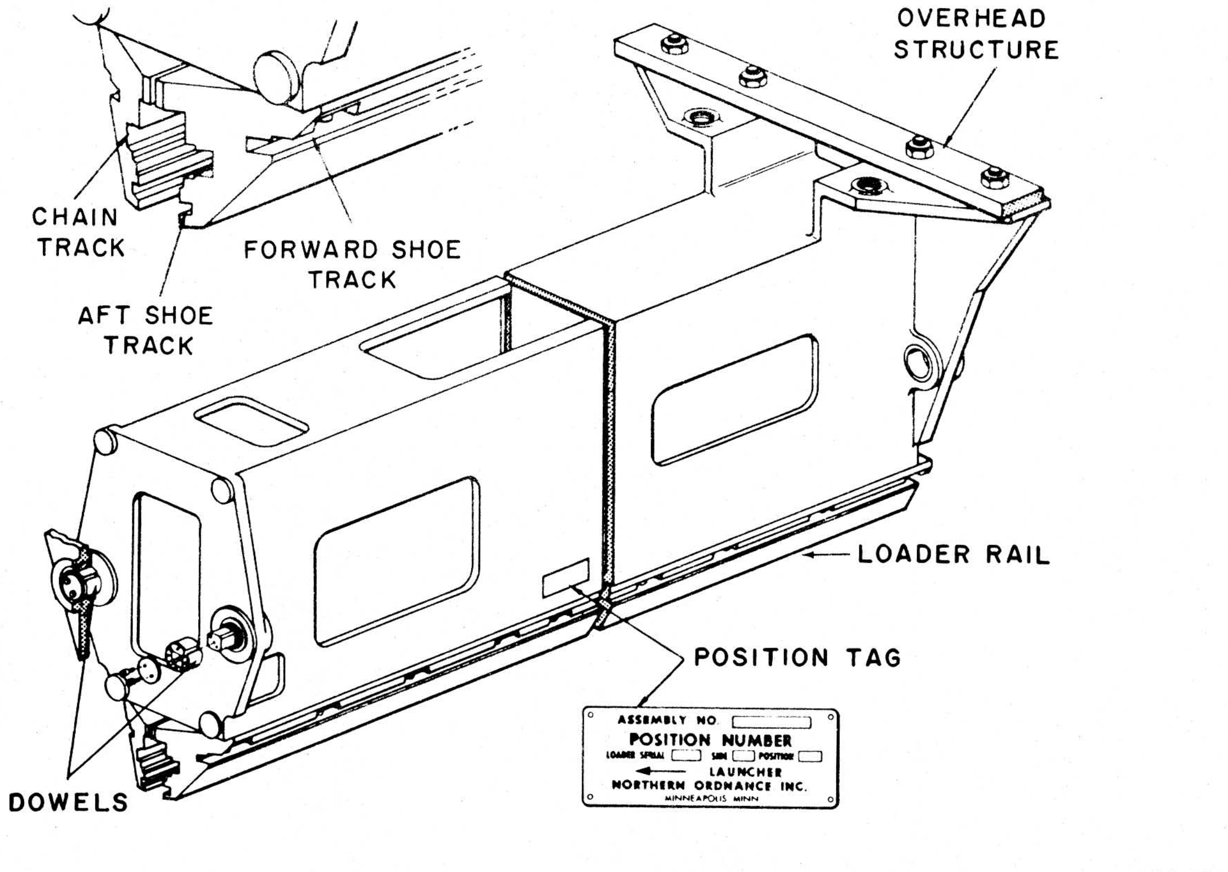

Figure 6-8.—Loader trunk section II.

buckles and folds the links of the chain to prepare the chain for stowage. Mods 1 and 13 of the Mk 8 loader do not have a chain stacker. The chain links are different in the different mods, and there are differences in the chain sprocket gear reduction and chain track housing. You need the OP for your launching system to study the operational details.

FLOATING TRACKS. - The location of the floating tracks may be seen in figures 6-7 and 6-9. In mods that do not have a tilting rail, the floating tracks are attached to the loader trunk in the same positions. The aft floating track assembly catches the aft booster shoe in its slide track, and the forward floating track assembly does the same for the forward booster shoe. They are piston operated by hydraulic fluid from the blast door power unit. The loader positioner moves the loading pawl forward about three inches, enough to slide the booster shoes out of the hoist head and into the floating track rails. The floating tracks hydraulically align the booster shoes with the track grooves of the fixed loader rail.

RETRACTABLE RAILS. - The retractable rails are used to allow the booster shoes to engage or disengage from the loader rail. They are used during strikedown and checkout (or strike-up) operations, when the rounds are raised or lowered from the loader rail. When the retractable rail segments are open, they align with the tracks of the fixed loader rail to make a continuous track. The hydraulic controls for the retractable rails are mounted in the loader trunk. An interlock switch prevents operation of the loader when the rails are open. The valves are typical solenoid, pilot, directional, interlock, latch (open and close), and check valves. An operating piston and linkages transfer the movement to the movable parts of the rails.

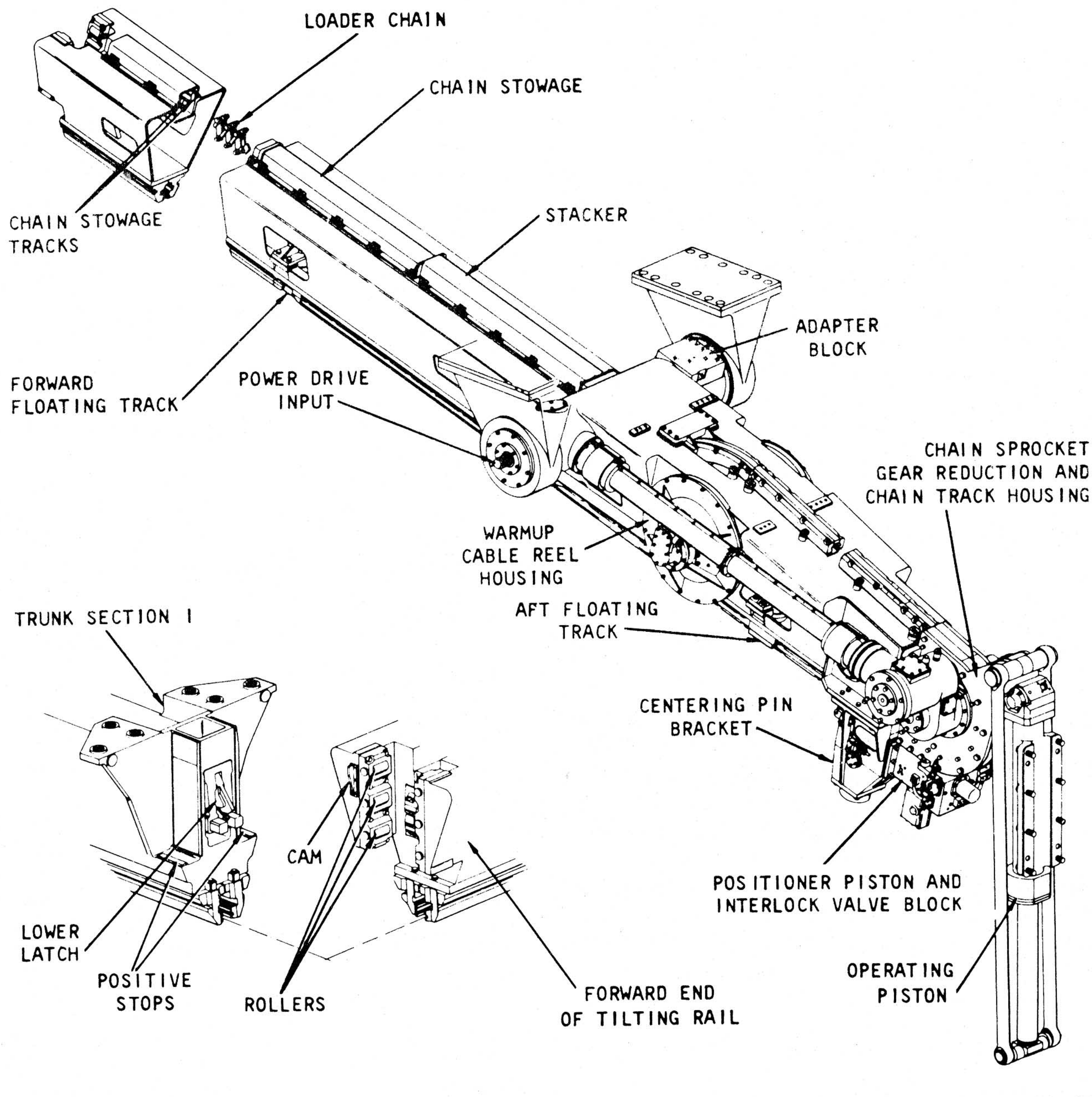

Figure 6-9.—Tilting rail and operating piston.

SPANNING RAILS AND BLAST DOORS.- When extended, the spanning rails bridge the gap between the loader rail and the guide arm rail. The spanning rail is attached at one end to the loader rail and at the other to the blast doors. The power piston that operates the spanning rail and the blast doors is mounted in the loader trunk and the hydraulic fluid is supplied by the loader accumulator. The spanning rail opens the doors as it extends, and closes them as it retracts. The spanning rail and blast doors function automatically during automatic control in load or unload cycles, but they can also be operated in step control. The blast doors are closed except during the brief time while a missile is passing through, either on its way to the launcher, or returning for unloading. Interlocks keep the doors closed at all other times.

In the Talos launching system, rails attached to the magazine doors are called spanner rails. They allow the hoist to travel to or from the loader. They form an extension of the magazine hoist rails. The rails that bridge the gap between the loader rail and the launcher guide arm rails are called the span track.

In the Tartar launching systems, the rails attached to the blast doors are called spanning rails. Tartar launching systems do not have a loader system like Terrier and Talos launching systems. Missiles are carried from the magazine to the launcher guide arm by a rammer type roller chain hoist. In the Mk 11 system it is stowed in the launcher guide arm.

HYDRAULICALLY OPERATED LAUNCHER COMPONENTS

Although launchers contain parts that are not operated hydraulically, the interconnection with hydraulic power makes it impossible to consider them apart. All missile launching systems have a fixed stand - a steel weldment on the deck, which mounts the carriage. The carriage is rotatable horizontally, to position the launcher in train. Most of the launcher components are mounted in or on the carriage. It supports the trunnion tube which holds the guides (or guide).

Guide and Guide Arms

After a missile has been brought from the magazine by the hoist, and wings and fins have been assembled to it (Terrier and Talos missiles), it is placed on the launcher; to be more exact, on the launcher guide arm. Terrier and Talos launchers have two guide arms, as does the Tartar launcher in the Mk 11 system, but the Mk 13 and Mk 22 Tartar launching systems have only one guide on the launcher. The guide arm supports the missile during the last stage of weapon handling, arming the weapon and holding it until it is launched. It contains arming devices, aft shoe latch, launcher contactor, forward restraining latch, and firing contacts. The arming device arms the missile booster by extending and winding the arming tool by means of hydraulically operated pistons.

The aft shoe latch mechanism has a piston-operated latch and associated linkage. When the missile is positioned on the guide arm (by the loader), the latch is hydraulically extended against the aft booster shoe to keep the missile from moving to the rear. The aft shoe latch (fig. 6-10) may be called a positioner, a positioner spade, an aft lug latch, aft motion latch, or reverse motion latch. In some launchers the aft shoe latch is locked by a detent that is hydraulically interlocked to prevent accidental retraction of the latch due to ship's motion and guide arm movements.

The forward restraining latch prevents forward movement of the missile, which might otherwise be caused by launcher depression or by ship's motion. It also holds the fired missile on the launcher until the booster has developed enough thrust to overcome the force of gravity plus the force of the adjustable spring that is part of the restraining mechanism.

The launcher contactor is hydraulically extended to apply warmup power to the missile before it is fired. On the Tartar systems, the contactor extends from the rear of the launcher into the stern of the missile.

Two booster firing contacts and two ground contacts are located in the forward section of the guide arm, one of each on each side of the arming device. They provide a double firing circuit for the booster.

The hydraulic power to move the components in the guide arm is provided by the guide arm accumulator power drive, located in the trunnion support or carriage (fig. 6-11). It supplies hydraulic fluid for both the A and B guide arm components.

Carriage-Mounted Hydraulic Parts

The parts described in the paragraphs under this heading apply specifically to the Terrier carriage mounting, but other systems employ similar ones. The location and some details may differ.

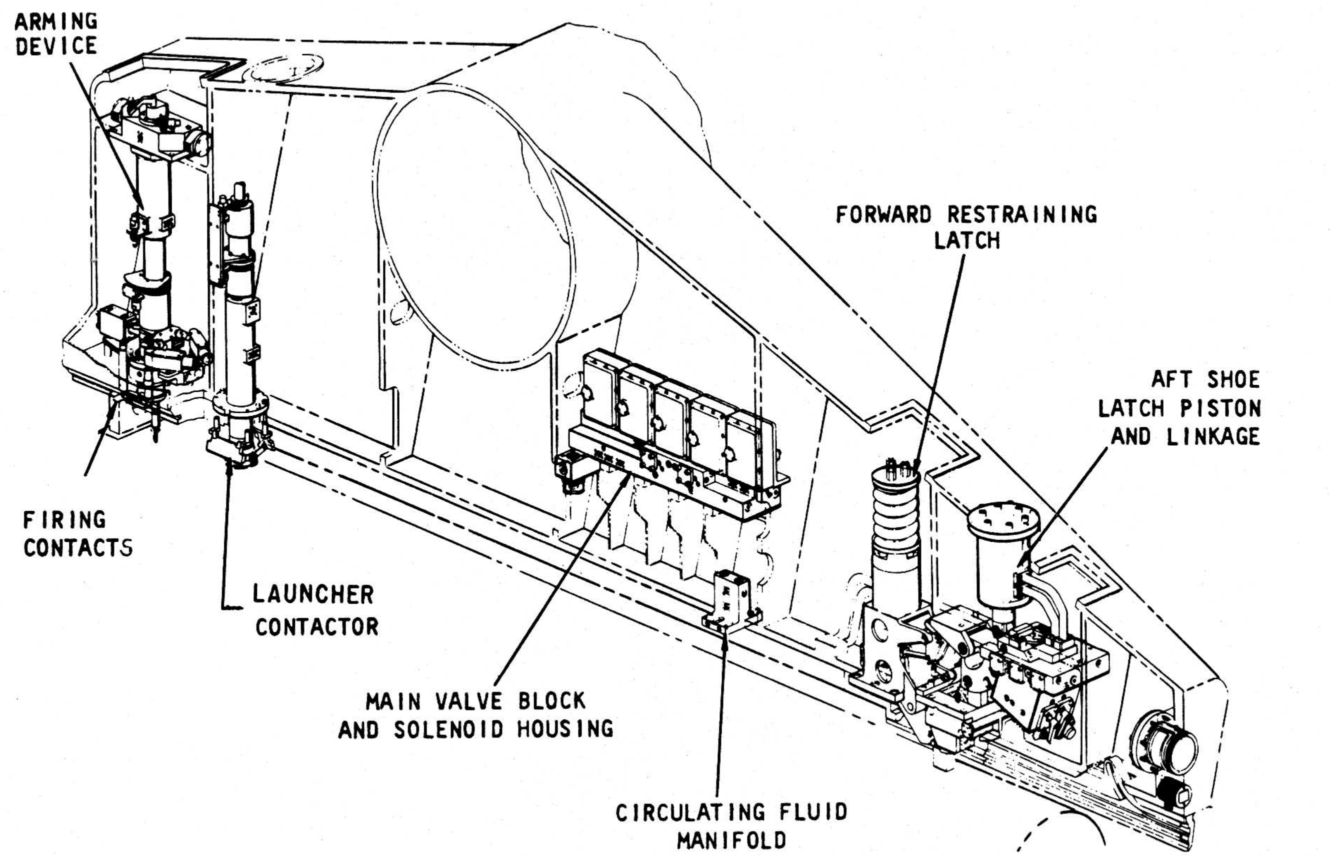

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Figure 6-10.—Guide arm components, Mk 10 launching system; general arrangement.

HYDRAULIC BREAKS. - The elevation brake is located on the reduction gear housing, which is mounted to the upper center of the carriage, below the trunnion tube. The train brake is mounted to the bottom of the carriage. Train and elevation brakes are hydraulically operated, spring-loaded, friction-disc type. During power-off conditions they remain set, preventing movement of the launcher.

TRAIN AND ELEVATION LATCHES - The elevation latch is a hydraulically operated steel pin, located below the reduction gear housing. When the latch is extended, it secures the launcher in the "Load" position. The train latch is mounted to the bottom of the carriage. It functions in the same way as the elevation latch. The elevation latch-control valve block houses the solenoids and valves which control the elevation latch. It is located below the reduction gear housing. A hand pump, mounted to the left side of the carriage, provides a means of operating the guide arms and the components of the train and elevation latches during maintenance operations or during power failure.

REDUCTION GEAR ASSEMBLY. - The train reduction-gear assembly is located within a housing mounted to the bottom of the carriage. The gears transmit the output of the hydraulic motor, at the required speed, to the pinion gear. The elevation reduction-gear assembly, enclosed in a housing, is mounted to the upper center of the carriage, below the trunnion tube. The elevation pinion gear is meshed with the elevation arc gear and is driven by the reduction-gear assembly. The train drive pinion meshes with the training circle and causes the launcher carriage to rotate in train. The elevation drive pinion causes the elevation arc to rotate the trunnion tube which causes the guide arms to elevate or depress.

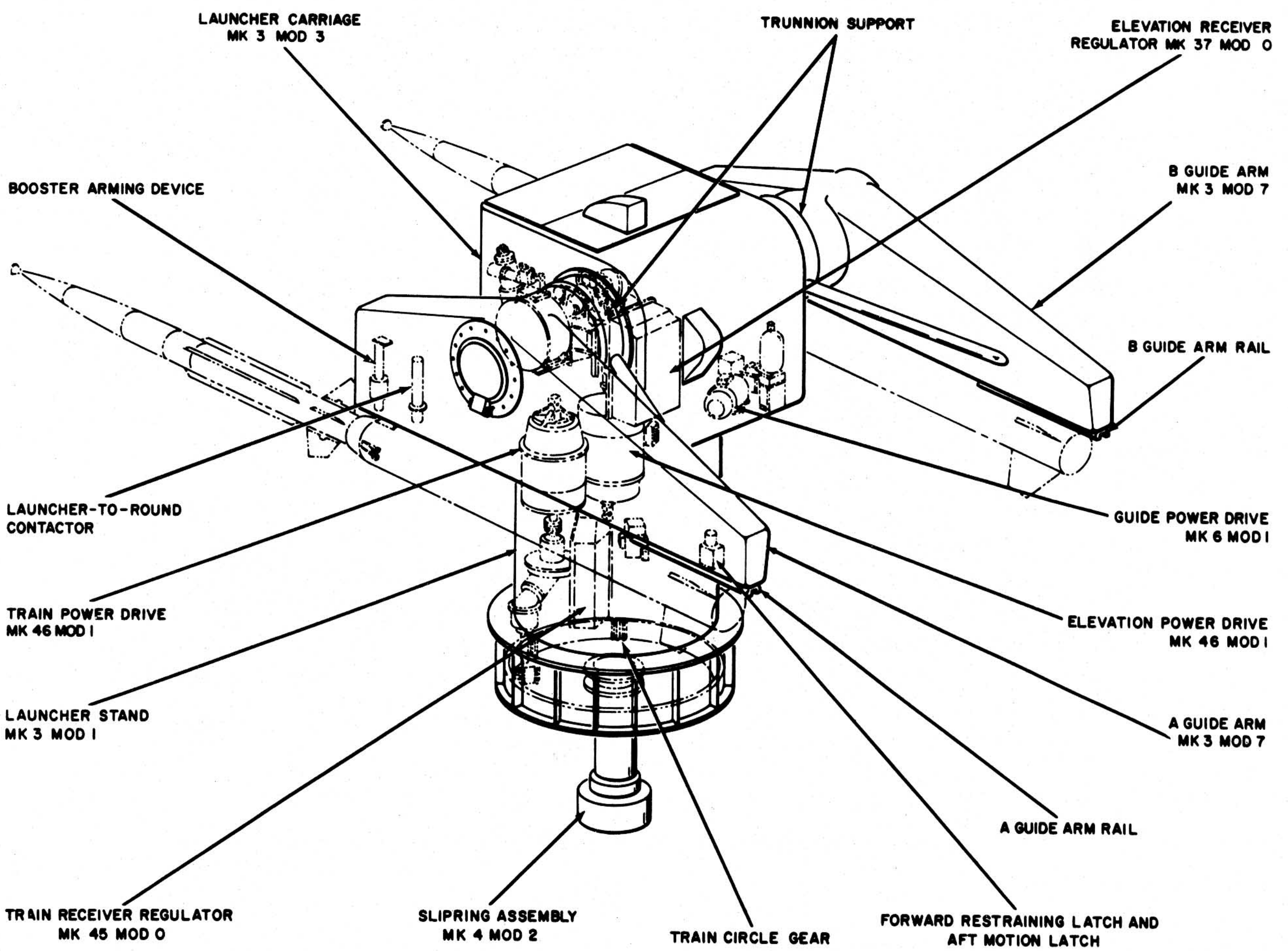


Figure 6-11.—Guided Missile Launcher Mk 5 Mod 8.

POSITIONING VALVES. - The elevation positioning valve is located below the elevation arc, and the train positioning valve is mounted to the bottom of the carriage. These valves are spring loaded and mechanically operated to ensure that the launcher is in the proper position before porting fluid to extend the securing latches (train or elevation). They actuate interlock switches when the launcher is in the "Load" position.

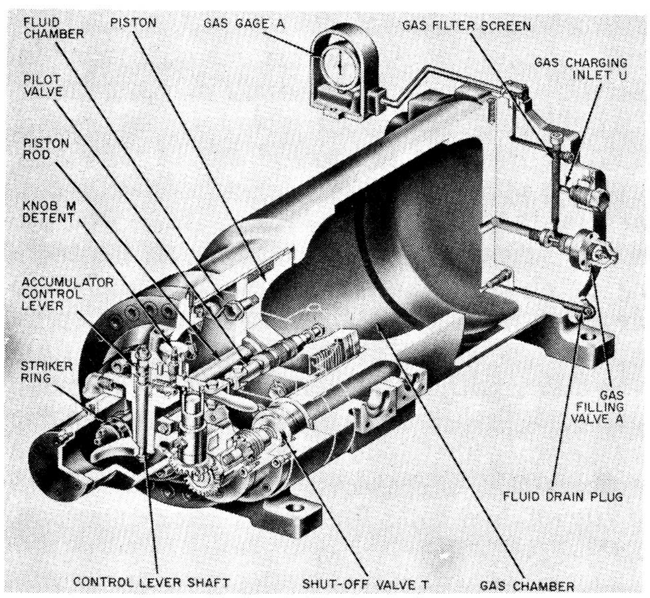
BUFFERS.-A buffer is anything that serves to deaden a shock or bear the brunt of a collision. Buffers are also used to slow down movement to avoid a violent shock or stop. Ordnance equipment uses hydraulic and pneumatic buffers, as well as spring buffers. Train and elevation buffers are used to slow down the training or elevating movement of the launcher to prevent a jerking halt. The elevation and depression buffers, mounted on each side of the trunnion tube, buff the movements of the trunnion tube and thus prevent excessive stress on the missile when the guide arms reach the elevation or depression limits. An accumulator furnishes a supply of hydraulic fluid for buffer operation.

Accumulators

Accumulators in hydraulic systems permit the use of smaller pumps than would be required if no accumulator were present. The fluid stored under pressure in the accumulator can assist fluids in motion to accomplish work when the demands of the hydraulic system require more fluid than the pump can supply. Accumulators may be used in hydraulic systems to supply fluid to compensate for leakage in closed or pressure-regulated circuits, as an emergency source of power for short periods, to operate secondary hydraulic systems, and as an auxiliary source of energy in intermittent duty systems.

Two basic types of accumulators are used in launching systems: bag and piston. The piston type is used with NAVSHIPS missile handling equipments and is shown in figure 6-12. The bag type was shown in figure 6-2 in the magazine accumulator system, and a cutaway view is shown in figure 6-13A.

Nitrogen is used to pressurize both types. The outside of the bag type is a metal shell; the bag, of neoprene, is inside, and contains the nitrogen. The bladder will fill approximately three-fourths of the inside area of the cylinder when the hydraulic pump forces oil into the flask. A spring-loaded poppet valve at the bottom of the flask prevents the bladder expanding down into the manifold if there is no hydraulic fluid in the flask.



33.183.3(94A)

Figure 6-12.—Piston type hydraulic accumulator, cutaway view.

The flask is mounted on a manifold (fig. 6-13A), and the valve block and gage (fig. 6-13B) are mounted nearby. The location of the gage and the type of nitrogen valve assembly will differ on accumulators of special ordnance systems. The nitrogen valve assembly (fig. 6-l3B) controls the compressed nitrogen. It has one valve for each flask, a bleeder valve, a nitrogen fill cap, and a porous bronze filter. A pressure gage is mounted on top of the valve block.

PISTON ACCUMULATORS perform the same functions as the bag type, although constructed differently. The steel cylinder is divided into two chambers by a movable piston (fig. 6-1), one side for the hydraulic fluid, and the other for the nitrogen.

The cylinder head of the hydraulic fluid chamber has a manifold through which the flow of fluid is automatically controlled by a pilot valve, whether in charging or discharging the accumulator. The pilot valve (fig. 6-12) is actuated by the piston rod through a linkage operated by cams in a control housing. The housing includes a manually operated shutoff valve by which the accumulator pressure can be cut out of the power drive system when the drive is not in operation, or if the accumulator fails.

The facilities for admitting nitrogen under pressure are at the other end of the accumulator cylinder. These include a gas filling valve, gas charging inlet, and gas pressure gage. The arrangement of these may vary from that shown in figure 6-12.

ACCUMULATOR OPERATION. - An accumulator of either type is located in the hydraulic power system in such a way as to apply force in the pump discharge line, and to be charged with hydraulic fluid after loss of volume from the accumulator has occurred.

An accumulator valve block, containing a control valve and check valves, maintains the desired operating pressure in the accumulator by controlling the output of the hydraulic pump. The control valve is adjusted to limit the maximum pressure in the accumulator; and is designed to control the minimum pressure. (Typical accumulator pressure is 1300-1500 psi.) When the accumulator is being charged, fluid from the pump flows through check valve 1 (fig. 6-14), around the lower land of the control valve, and

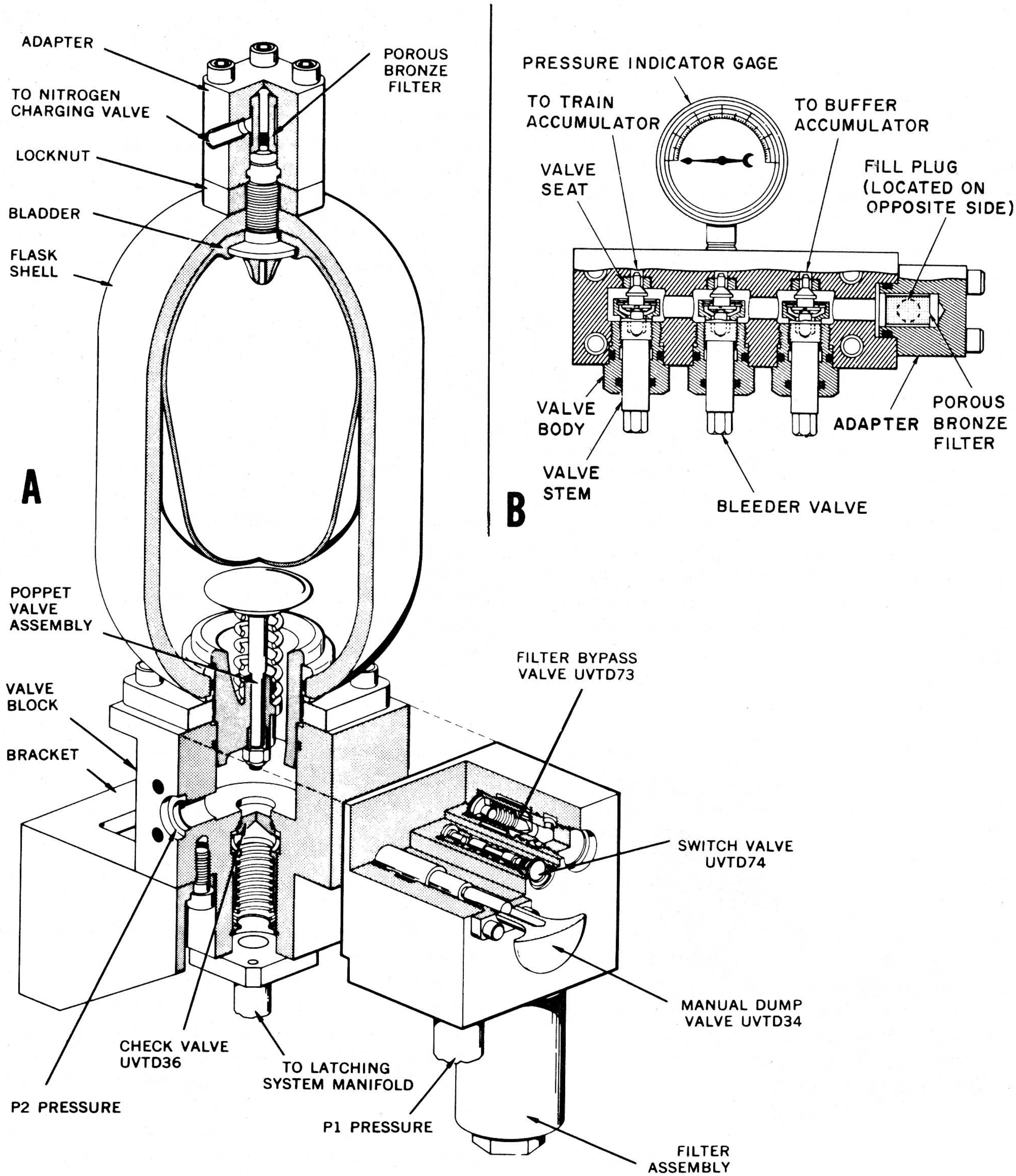


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Figure 6-13.—Hydraulic accumulators: A. Bag type accumulator, cutaway view; B. Nitrogen valve block assembly.

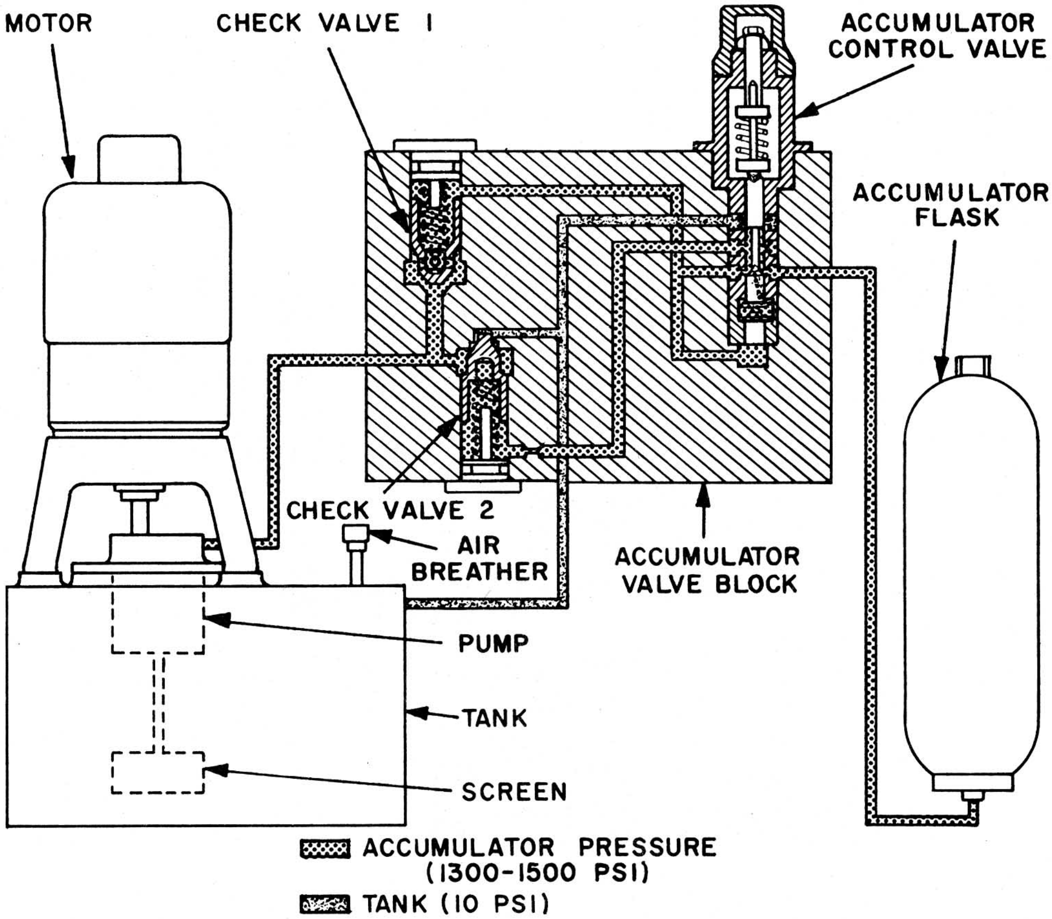

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Figure 6-14.—Schematic, accumulator unit, charging cycle.

into the accumulator. When the accumulator becomes fully charged, the pump output is ported through check valve 2 to the tank.

The control valve has a spring and seat, a two-land plunger, and a piston. The piston is larger in diameter than the lower land of the plunger, against which it bears. A cross-port in the lower land of the plunger ensures equal pressure on each end of the lower land chamber. Accumulator pressure is always available at the bottom of the piston. As the charging cycle begins, the spring holds down the plunger and piston, and the hydraulic fluid passes into the accumulator. As the accumulator fills, the piston and the plunger are pushed upward, compressing the spring. When the spring is compressed enough, flow to the accumulator is blocked off and check valve 2 lifts and vents the pump output to the tank. When the accumulator pressure drops to the minimum set for it, the charging cycle is repeated.

Power Drives

As noted in the preceding paragraphs, each launching system has several power drives. To distinguish them, the location or use of the power drive is included as part of the name, as hoist power drive. The train and elevation power drives on the launcher are the ones most often referred to simply as the "power drives" of the launching system. They are two separate electro-hydraulic systems which control the movements of the launcher in train and elevation (fig. 6-15).

The function of the power drives is to make the launcher position correspond to the ordered positions (orders from fire control, under normal, automatic operation) with the least

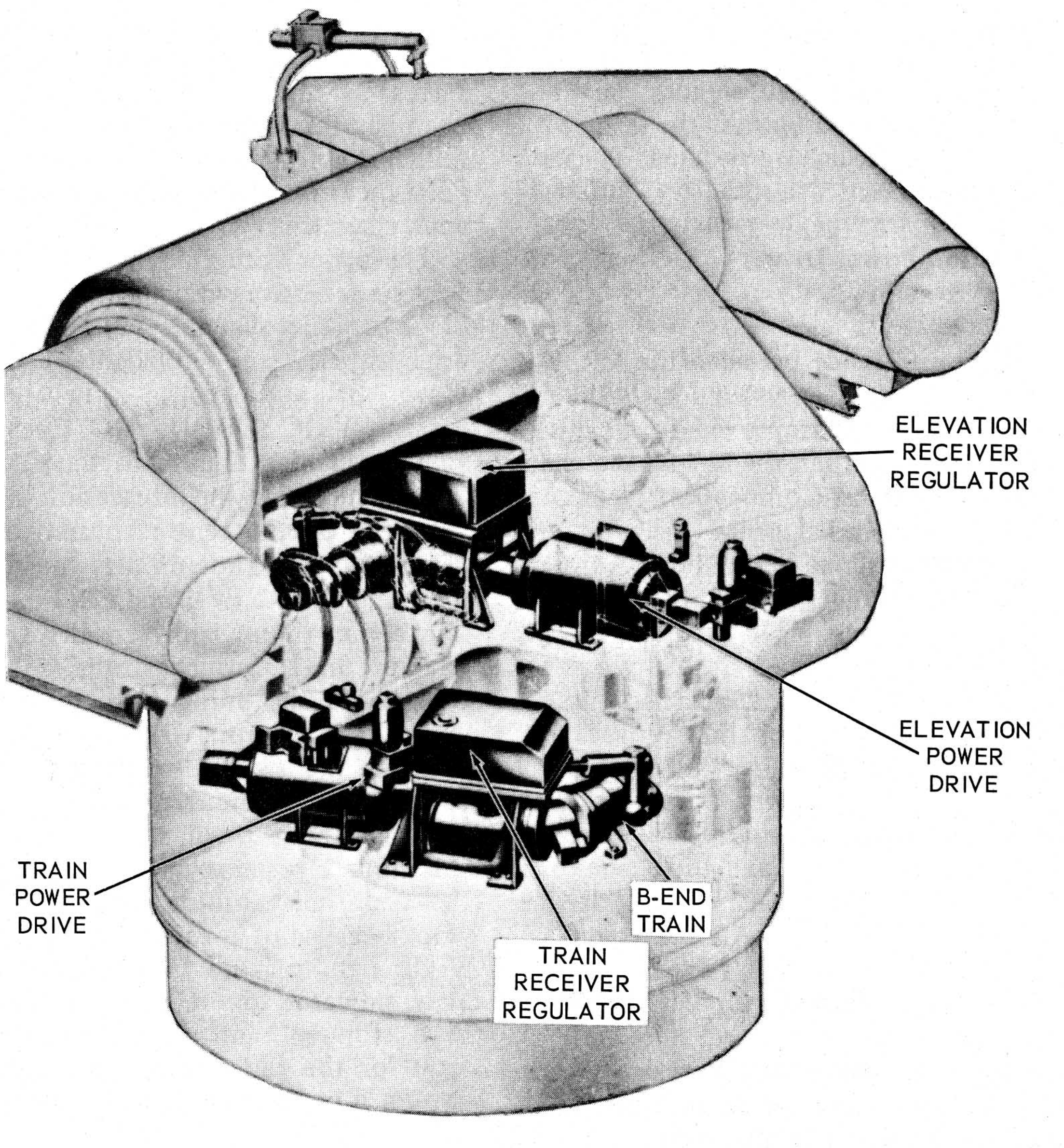

Figure 6-15.—Train and Elevation Power Drive Mk 50 Mod 1 (Talos).

possible error at all tlInes. The design of the train and elevation power drives is very similar, but they are not interchangeable.

The electric power for the power drive is supplied from the ship's power supply through the power panel.

The power unit consists of an electric motor, an A-end hydraulic pump, an enclosed gear train, a stroke control assembly or control cylinder, a transfer valve, and the B-end motor. The receiver-regulator is located with these components, and is functionally a part of the power drive. How they operate together is descnbed later in this chapter.

The train and elevation power drive controls of the GMLS Mk 13 are located off-mount but the power drives are mounted inside the stand in the inner structure. The magazine power drives are also located in the inner structure of the stand. The ready service ring is in the outer structure of the stand. The location of components of the train and elevation power drives of the Mk 13 launching system is shown in *Gunner's Mate M (Missiles) 3 & 2*, NAVTRA 10199.

That text also illustrates a number of devices used in hydraulic systems, such as various types of valves, buffer, dashpot, filter, strainer, and gear pump. Differences in the number of power units used by the "one-armed" Mk 13 and the larger launching systems (Terrier and Talos) were also pointed out.

Train and Elevation Power Drives of Mk 22 Tartar System

The overriding difference between the Mk 22 and other missile launching systems is its small size. It handles Tartar and Improved Tartar missiles, but fewer of them than the Mk 11 and the Mk 13 launching systems. Compact arrangement of components necessitated some changes in placement of parts, and some combination of functions. The Train Power Drive Mk 67 Mod 0 also drives the hoist. It has a shift and clutch mechanism that enables it to drive the launcher or the hoist. In the mk 22, it is the launcher that moves to a position above the missile to be loaded; the ready service ring doesn't rotate. The elevation power drive elevates and depresses the launcher guide. The major components of the train/hoist and the elevation power drives are the same: an electric drive motor, a hydraulic system, a CAB unit, and a drive train. The hydraulic systems have the same type of auxiliary pump, auxiliary relief valve assembly; and accumulator assembly; they differ only in capacity. The train/hoist power drive has a speed reducer and a lubrication pump that are not duplicated in the elevation power drive. Both systems use a common supply tank and common header tank.

The main supply tank, which holds about 110 gallons of fluid, is integral with the skirt adapter assembly (fig. 6-16). This is not to be confused with the main tank of the launcher guide power unit, which is fastened on the under side of the base ring and protrudes above it. That tank holds only about 20 gallons of hydraulic fluid. The location of the launcher guide power unit is also shown in figure 6-16, as are other launcher components. The train/hoist and elevation header tank is mounted in the base ring adjacent to the train/hoist power-off brake. The header tank for the launcher guide power unit is in the front end of the guide arm. A header tank provides a head of fluid to prevent entrance of air into hydraulic lines, which would cause erratic behavior of the hydraulic components. It also serves as an expansion and heat dissipation chamber for returning fluids. A strainer in the return-flow pipe strains out solid particles to keep them from getting into the servo and supercharge systems.

The major components of the train and elevation power drives are: (1) electric drive motors,(2) hydraulic systems, (3) CAB units, and (4)drive trains.

ELECTRIC DRIVE MOTORS. - These provide mechanical inputs to the CAB units, auxiliary pumps, and the lubrication pump. They are mounted on the center column of the carriage (fig. 6-17). The motors are activated by switching on the EP-l and EP-2 panels. The train lubrication pump is driven directly by the electric motor. It furnishes lubricant to the speed reducer. If the pump fails, the pressure in the discharge line drops. The lowered pressure, deactuates the switch, stops the motor and prevents motor burnout. An excess of pressure in the CAB unit also will stop the electric motor by actuating a pressure-cutout switch. When either the train/hoist motor or the elevation motor stops because of pressure cutout, the All Motors STOP light on the BP-2 panel starts blinking. This indicates to the operator why the motors have stopped, and warns him that he should look for the cause of the pressure buildup and correct it before restarting the motors.

HYDRAULIC SYSTEMS. - The main components are an auxiliary pump, an auxiliary-relief-valve assembly, and an accumulator assembly. The train/hoist and the elevation hydraulic systems are identical except in capacity. The train/hoist system is the larger one; it supplies power for operation of the train and the hoist systems. The pumps are of the type described in *Fluid Power*, NAVPERS 16193 as gear pumps; they may have helical or spur gears or a combination. The pumps operate the power-off brake, the receiver-regulator, the CAB unit, and the main relief valve of the CAB unit. The train/hoist system also operates the hoist selector valve block assembly, and the hoist control assembly. The relief valve block contains filters.

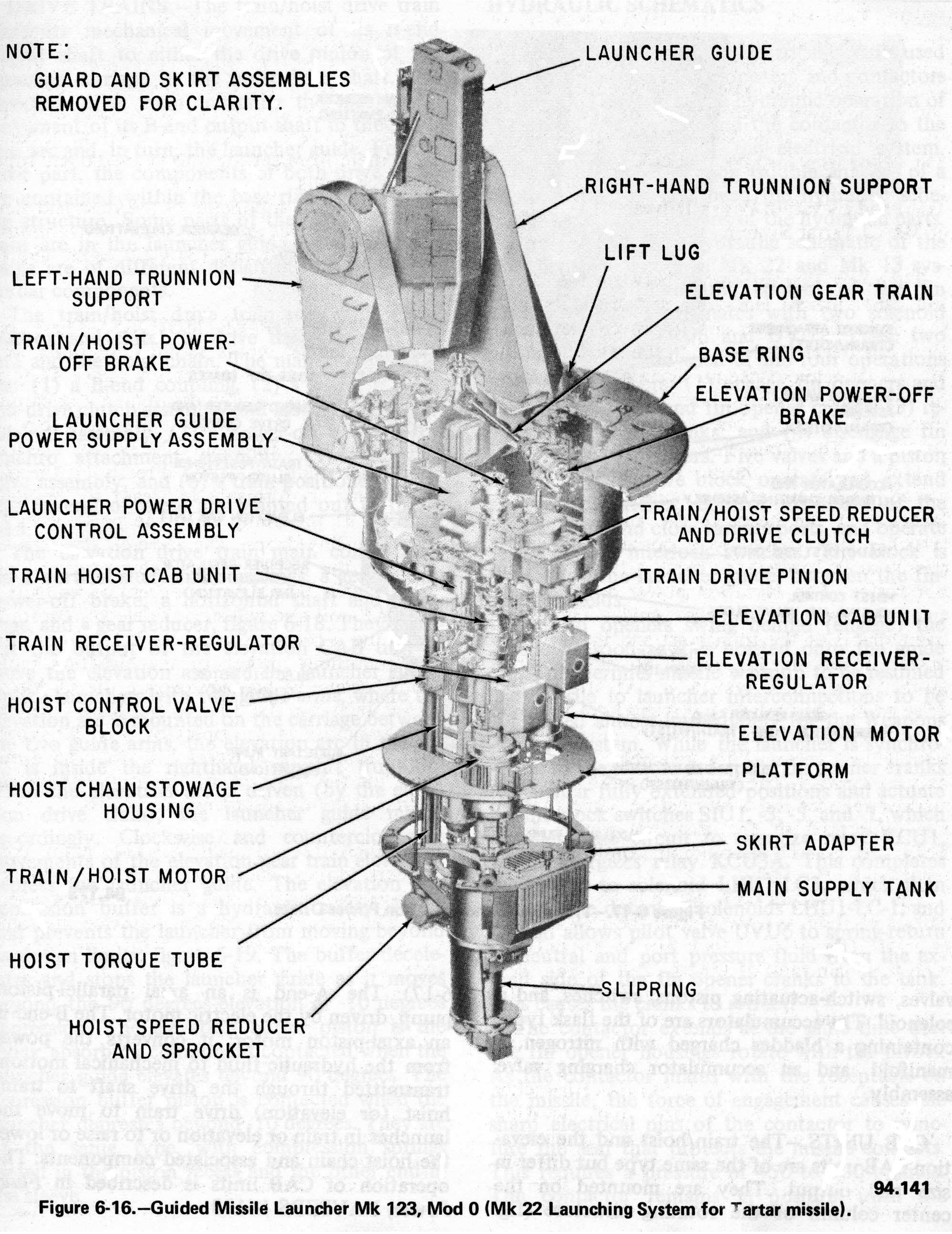

Figure 6-16.—Guided Missile Launcher Mk 123, Mod 0 (Mk 22 Launching System for Tartar missile).

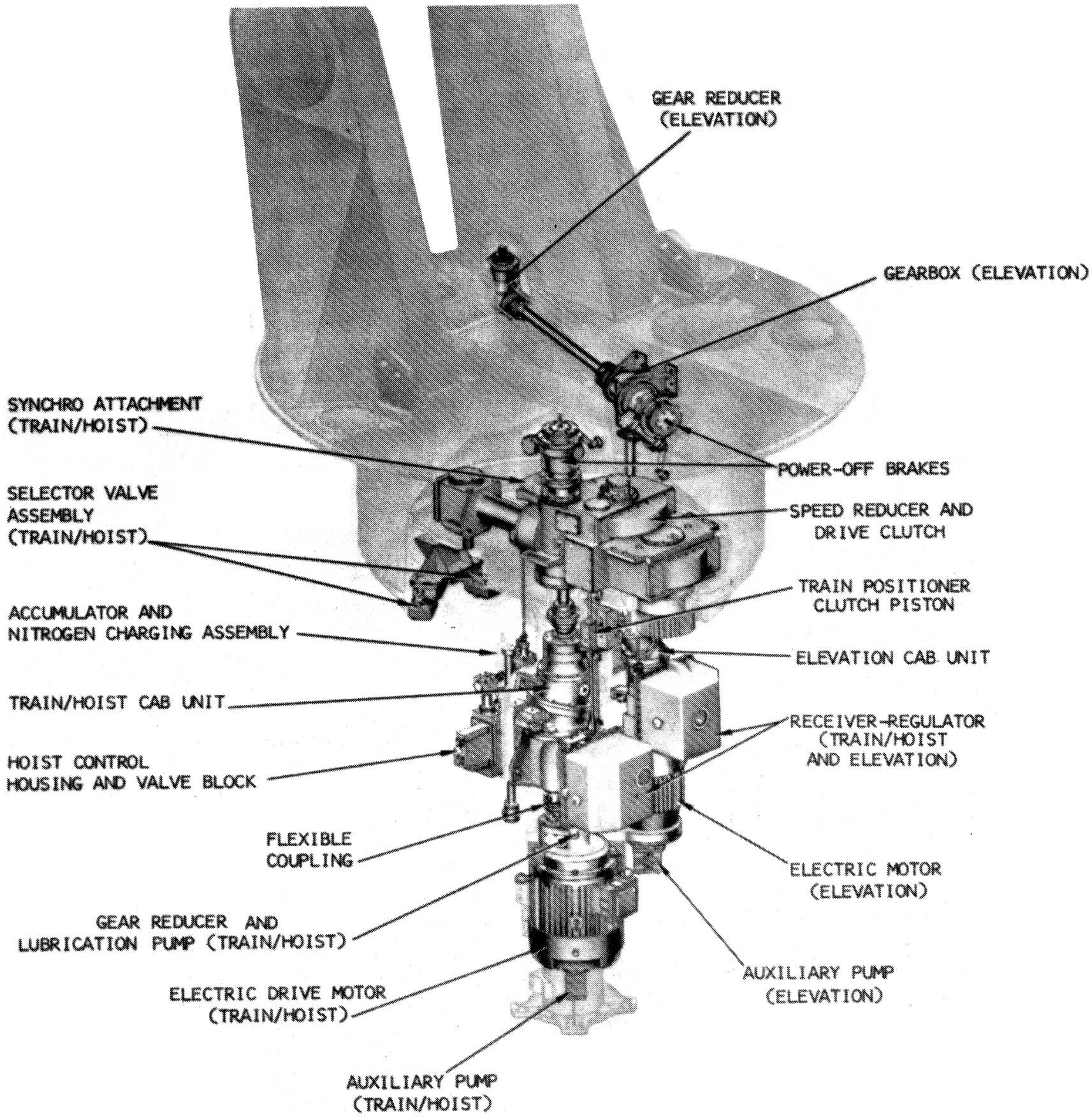

Figure 6-17.—Train/Hoist and Elevation Power Drives.

valves, switch-actuating pistons, switches, and a solenoid. The accumulators are of the flask type, containing a bladder charged with nitrogen, a manifold, and an accumulator charging valve assembly.

CAB UNITS. - The train/hoist and the elevation CAB units are of the same type but differ in size and output. They are mounted on the center column of the rotating structure (fig. 6-17). The A-end is an axial parallel-piston pump, driven by the electric motor. The B-end is an axial piston motor; It converts the power from the hydraulic fluid to mechanical motion, transmitted through the drive shaft to train/hoist (or elevation) drive train to move the launcher in train or elevation or to raise or lower the hoist chain and associated components. The operation of CAB units is described in *Fluid Power*, NAVPERS 16193.

DRIVE TRAINS. - The train/hoist drive train transmits mechanical movement of its B-end output shaft to either the drive pinion of the launcher carriage or the hoist drive shaft. The elevation drive train transmits the mechanical movement of its B-end output shaft to the elevation arc and, in turn, the launcher guide. For the most part, the components of both drive trains are contained within the base ring of the rotating structure. Some parts of the elevation drive train are in the launcher guide. The two drive trains are of different design but contain some similar components.

The train/hoist drive train uses a common gearbox and clutch to drive the rotating structure and the hoist chain. The main components are: (1) a B-end coupling, (2) a speed reducer and drive clutch assembly and associated retractable-rail assembly, (3) a power-off brake, (4) a synchro attachment assembly, (5) a selector valve assembly, and (6) a train-positioner assembly. Several of these are pointed out in figure 6-15.

The elevation drive train main components are a vertical shaft and couplings, a gear box, a power-off brake, a horizontal shaft and couplings, and a gear reducer, figure 6-18. They transmit the output of the elevation CAB unit to move the elevation arc and the launcher guide. Unlike launchers with two guide arms, where the elevation arc is mounted on the carriage between the two guide arms, the elevation arc in the Mk 22 is inside the right-hand support trunnion. When the elevation arc is driven (by the elevation drive train), the launcher guide moves accordingly. Clockwise and counter-clockwise movements of the elevation gear train elevate or depress the launcher guide. The elevation and depression buffer is a hydraulic safety device that prevents the launcher from moving beyond its design limits, figure 6-19. The buffer decelerates and stops the launcher guide as it moves beyond the 90 degrees elevation or -10 degrees depression. The elevation buffer piston is the shock absorbing component contacted when the launcher guide elevates beyond 90 degrees. The depression buffer piston is contacted when the launcher depresses beyond -10 degrees. They are of the same type, with compression springs seated in the piston recess and the other end in the sleeve.

HYDRAULIC SCHEMATICS

Chapter four shows the electrical circuits used in step operation of fin openers and contactors in the Mk 13 system. The hydraulic operation of the fin opener cranks and the contactor to the missile is actuated by the electrical system. When you are performing trouble analysis of a component, you also need the hydraulic schematic to trace the actions of the hydraulic parts. Figure 6-20 shows a hydraulic schematic of the fin opener assembly in Mk 22 and Mk 13 systems. Primary hydraulic control of the fin opener assembly originates with two solenoid operated valves UVU6 and UVU7. These two pilot valves initiate each of the four operations of the fin openers: (1) engage fin openers and contact or; (2) extend fin opener cranks; (3) retract fin opener cranks; and (4) disengage fin openers and contactors. Five valves and a piston in the control valve block operate and extend and retract latches, control the speed of the pivots, open and close various ports, and operate some of the interlock switches. The block is located on the launcher guide, between the fin-opener shields.

The fin openers swing behind (engage) the missile as soon as it is hoisted onto the guide rail. This permits missile warmup to be resumed and missile to launcher interconnections t be completed almost immediately for the Weapons Control System. While the launcher is synchronizing to the remote order, the fin opener cranks reach their fully extended positions and actuate the interlock switches SIU1, -3, -5, and -7, which complete the circuit to energize relay KCU1, which energizes relay KCU3A. This completes the circuit to solenoid LHU1-LC3, which then releases the detent of solenoids LHU1-LC-1, and -2, and allows pilot valve UVU6 to spring-return to neutral and port pressure fluid from the extend side of the fm opener cranks to the tank. This causes the cranks to retract.

The contactor extends at the same time that the fm opener housings rotate with the pivots. As the contactor mates with the receptacle on the missile, the force of engagement causes the sharp electrical pins of the contactor to puncture the seal that protects the missile contacts. This requires a pressure of 450 to 500 pounds. The contactor remains in position until the

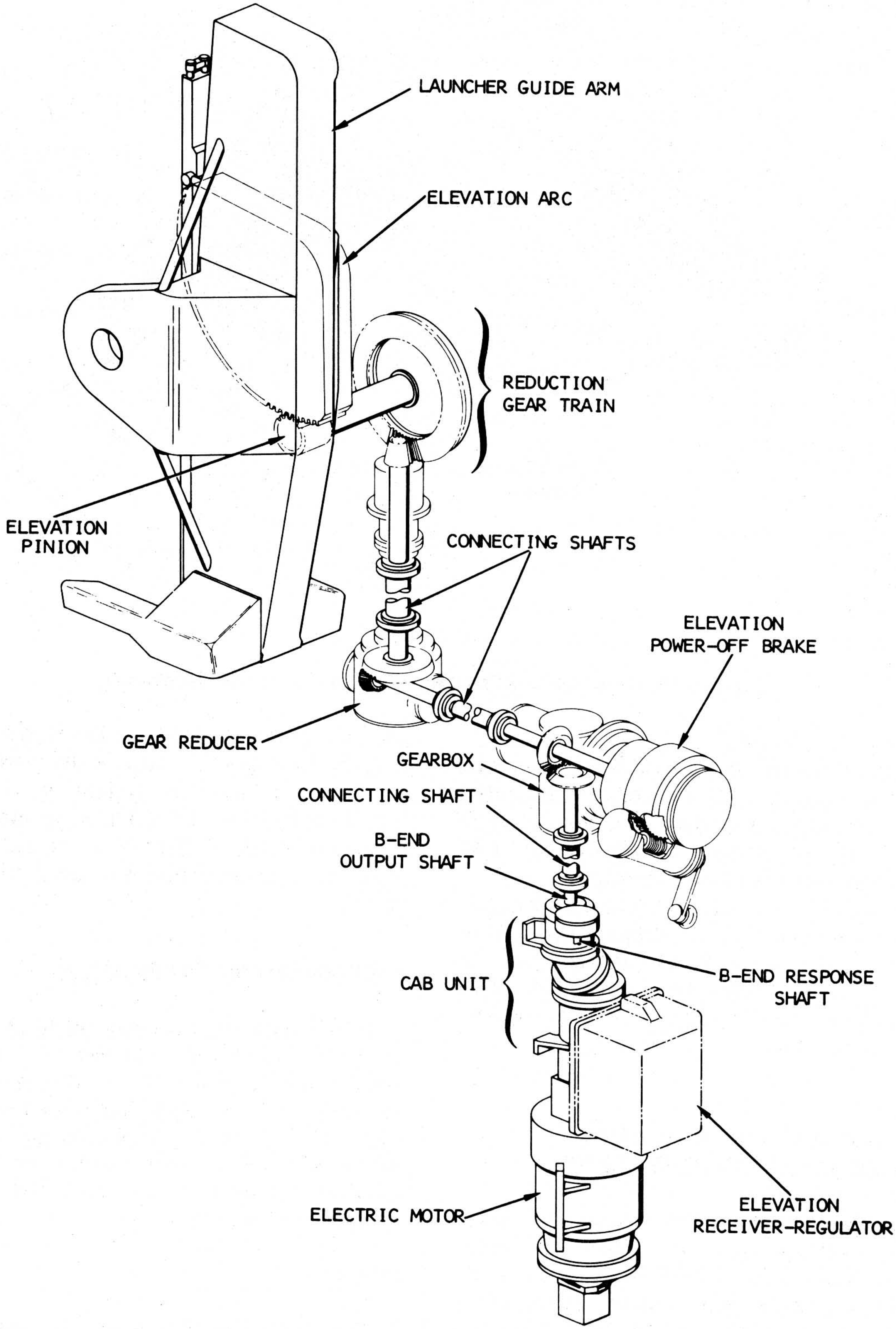

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Figure 6-18.—Elevation Drive: Mechanical Schematic.

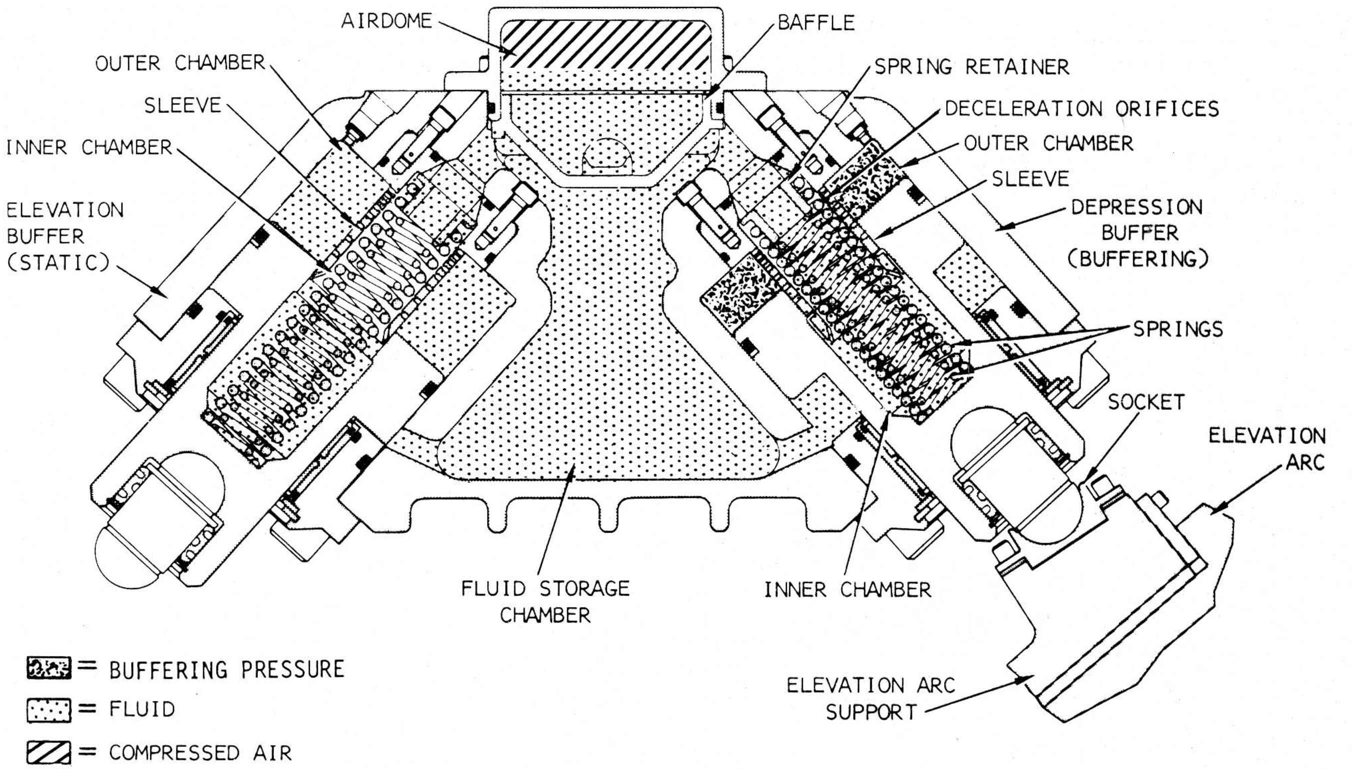

Figure 6-19.—Elevation and Depression Buffers: Hydraulic Schematic.

order to fire is received.

This small sample of a hydraulic schematic shows how electric and hydraulic schematics must be considered together. The electric components start the action; the hydraulic components carry out the electrical orders.

Study the OP and follow through on hydraulic schematics so you will understand the flow of hydraulic power through the system and its translation into mechanical movement. This knowledge will be invaluable to you in trouble-shooting the system.

ADJUSTMENT AND REPAIR OF HYDRAULIC SYSTEMS

To tell in detail how to adjust and repair hydraulic systems used in missile launching systems would require several large volumes. To work on any system, you need the drawings for that system as installed on your ship, and the applicable OPs and ODs. The types of valves used in the power drive for the ready-service ring may be the same as those in the power drive for the train or elevation system on the launcher, but their numbers or other designations and the locations would differ. In a general course like this, we cannot name the particular valve to adjust.

SHIPBOARD MAINTENANCE

Initial adjustments were made at the time of installation. Later adjustments aboard ship should be undertaken only after competent personnel have determined that adjustment is necessary. Brake valves, replenishing pump relief valves, and the control pressure pump are some components of a drive system that are adjusted whenever necessary.

Filters

The indicating lights on the control panels pinpoint some troubles, such as clogged filters.

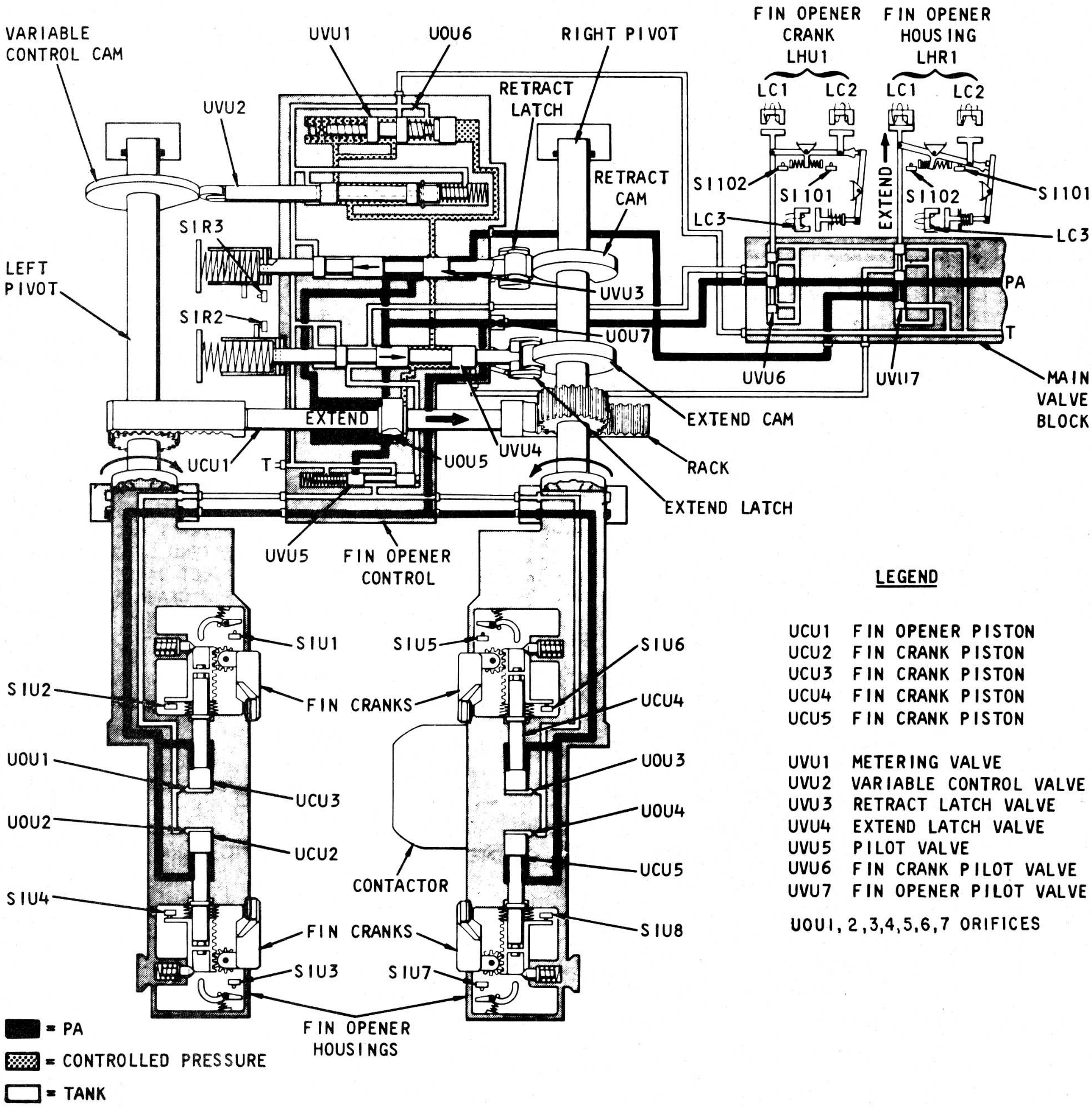

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Figure 6-20.—Hydraulic schematic; fin openers and contactor extended (engaged); Tartar Mk 13 and Mk 22.

Let us use as, an example the power drive in the Mk 10 Mod 0 launching system for the Terrier. This is the power drive used to operate the ready-service ring, the tray shift mechanism, the magazine doors, and the magazine hoist mechanism. The oil filter assembly is mounted on the supply tank, above the electric drive motor. The assembly contains twelve micronic filter elements which filter out any foreign particles of 10-micron size or larger before the oil is pumped to the magazine components. When the filters become cogged and the filter bypass valve opens, a clogged-filter switch mechanism illuminates a light on the EP-2 panel, indicating that the filter news changing. After the filters have been changed, the filter assembly is filled with oil through the filler plug on the filter, which forces out air that was in the filters and keeps air out of the system.

Some power drives use disposable, cartridge type filters. These require no maintenance except replacement of the cartridge, as in the system above. If the filter element has to be cleaned, follow the instructions for the type of filter and observe the safety precautions for the cleaning method and materials used.

Full-flow types filter all the oil that passes through the pumps. Such filters may have a relief valve to allow bypassing of the oil if the filter element is clogged. A bypass filter is one which filters only a portion of the oil passing through the pump. Figure 6-21 is an example of a bypass filter. More correctly, it is called a proportional flow filter. It consists of a cylinder containing a filter element made up of a number of packs of perforated paper discs. Spring action

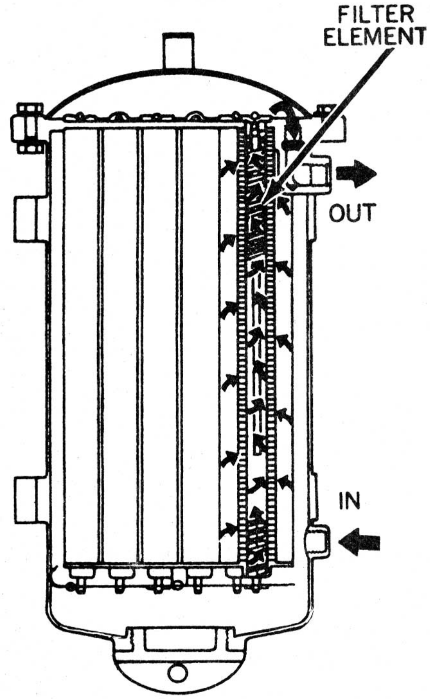

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Figure 6-21.—Auxiliary bypass filter.

maintains a uniform pressure on each of the packs. Oil passes from the outside of the pack, where the foreign matter is deposited, to the center passage, and through the outlet at the head of the filter.

To clean this type of filter, lift the head, with the filter packs attached, from the body of the filter. Connect a low pressure air supply to the oil outlet of the system. This allows the air to blow back through the element. When a white foam appears along the entire length of the pack, it is clean.

If you remember to observe the rules for keeping contaminants out of hydraulic systems, the filters will seldom need cleaning. Keep the containers of hydraulic fluid tightly closed except when actually transferring the fluid. Strain the fluid into the hydraulic system, even though you are pouring from a freshly opened can. Keep all openings on the hydraulic system closed so water, dust, dirt, or any other contaminant cannot get in. Even with the greatest care, however, it is not possible to keep out every bit of foreign matter. Also, bits of metal wear off during operation of pumps, gears, valves, and other parts of the hydraulic system. Therefore, filters are installed at numerous places in the system to catch all those bits. The MRCs and the OPs on maintenance tell you how often each filter is to be checked as a matter of routine. By regular frequent checking of filters, and replacement, you can greatly reduce the down time of hydraulic systems. Testing of samples of hydraulic fluid taken from the accumulator supply tanks detects deterioration of the fluid. Use the MRC instructions for obtaining the samples.

A typical micronic type filter unit is shown in figure 6-22. It consists of a single element filter assembly, a filter bypass valve, a switch valve, a filter clogged switch, and switch actuator. If the filter element starts to clog, it retards the flow of hydraulic fluid and causes a pressure differential on the opposite ends of switch valve UV-1 (fig. 6-22). When the pressure differential reaches a preset setting, the higher pressure at the input end of switch valve UV-1, causes the valve to shift to the right against the spring end of the valve which opens a pressure port to the switch actuator. When this occurs, a Filter Clogged light (red lamp) begins to blink on one

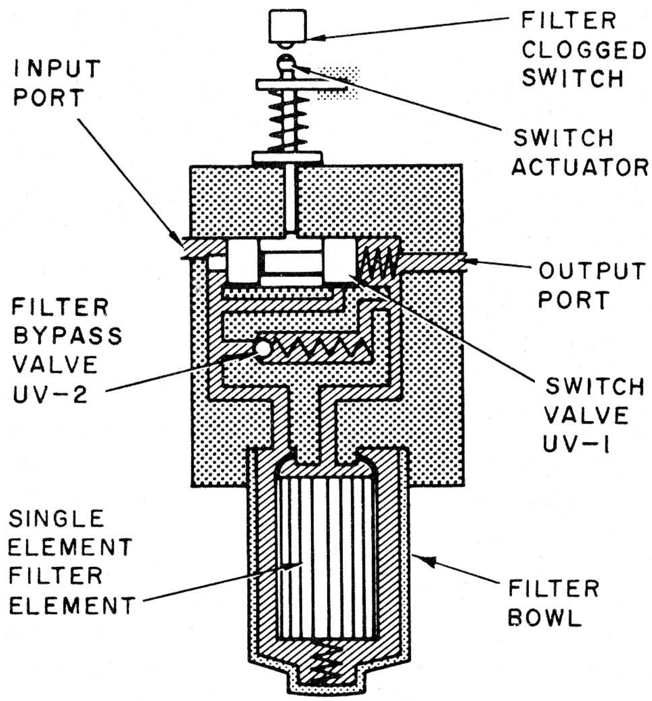

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Figure 6-22.—Filter unit.

or more of the control panels. When the lamp blinks, the launcher captain at the EP-2 panel must determine the location of the clogged filter and take appropriate maintenance action according to ship's doctrine. As long as the filter remains clogged and the pressure differential reaches a preset setting above that regulated by the filter bypass valve UV-2 an valve spring (fig. 6-22), the bypass valve will open and port hydraulic fluid around the filter element and flow directly into the system through one output port. The replaceable filter element is a treated cellulose paper formed in vertical convolutions which catch and hold dirt and other solid particles. (Some filter elements are made of other fibrous material or of metal discs and rods which can be cleaned and reused if a new filter element is not available, or it may be set aside to be cleaned later and placed in storage for reuse. They need to be thoroughly dry before reuse.)

Before you change a filter element, turn off the hydraulic system and release the system pressure.

WARNING: Be sure that system pressure is relieved before disassembling or removing hydraulic components. High system pressure can cause serious injury to personnel.

Arrange to catch hydraulic fluid that will spill from the bottom of the filter unit when the bowl is removed. Unscrew and remove the filter bowl, then pull the filter element off the head. Install a new or properly cleaned filter element and an O-ring, seating them firmly on the filter head. Examine the O-ring in the filter bowl; replace if it is faulty. Coat the external threads of the filter head with petrolatum and reassemble the filter bowl to the head. Install the safety wire. If the filter continues to clog, the hydraulic system may need to be drained, flushed, and refilled.

Valves

The daily and weekly operational checkouts may reveal need for adjusting one or more valves. Types of valves used in hydraulic systems are described and illustrated in *Fluid Power* NAVTRA-16193 and some general instructions for installation and maintenance are given. See also the illustrations and descriptions in chapter 8 of this text, and in the preceding text, *Gunner's Mate M (Missiles) 3 & 2*, NAVTRA 10199-Be.

Numerous valves, simple and compound, are used in the hydraulic components of missile launching systems, and in the missiles. Note the number and variety of valves in that small segment of a launching system shown in figure 6-20. The same principles of operation apply to all, regardless of complexity, but the components and their method of assembly may differ. Whenever a valve has to be disassembled, be sure to get the drawing showing all the parts and the order of assembly. The automatic valves, such as regulators, relief valves, and safety valves, should not be disturbed except at over haul, unless found faulty. Foreign matter in the valve seat, scoring and grooving of parts, or plugging of openings may cause the valve to stick or fail to close completely. The usual remedy for such conditions, as in fact for practically all serious valve troubles, is to dismantle the valve, thoroughly clean all parts, replace those that are damaged, and reassemble. You may have done this with the simpler valves, or under supervision. Maintenance of compound relief valves is fundamentally the same as that of simpler types. You can generally tell that a compound relief valve is not functioning properly because it will overheat, and will operate sluggishly or erratically, or at the wrong pressure. The valve will usually clean itself if you start the pump and back off the adjustment screw on the pilot valve a little by turning it counterclockwise so that the pressure control spring responds to a lower pressure. The adjustment screw should never be removed completely while the system is under pressure. (Some instructions require complete release of system pressure before adjusting: check the instructions for your launching system.) After a flow of liquid has cleaned the valve, carefully reset the adjustment screw, using a pressure gage. The relief valve should be set to open at about 25 percent more than the maximum normal operating pressure.

CHECK VALVES require little attention overlong periods of time. Leakage may be caused by a tiny particle of foreign matter between the checking device (ball, cone, or poppet) and its seat. It will be necessary to remove the valve and disassemble it completely for cleaning. Remember the warning about high pressure systems - shut off power and release the pressure before removing any part from the hydraulic system.

If no scratches are found on the valve seat or the checking device, wash all parts in clean hydraulic fluid of the same type as used in the system. Inspect the housing and the checking device for evidence of corrosion. A slightly rough surface can be smoothed by buffing. Replace the valve if there is corrosion or excessive roughness. A cone type check valve may have a tendency to lean to one side, in which case the movable part may dig into the soft aluminum body of the housing and stick there.

Remember that the arrow on the housing must point in the direction of the flow of liquid through the valve. Before removing a check valve from a line, mark the adjacent structure, indicating the direction in which the arrow points. When installing the check valve, grip the wrench flats of the check valve at the end to which the connecting tubing is being installed. Do not grip the opposite end. This will prevent the possibility of distorting the valve body, which would cause the valve to leak.

When a valve has to be disassembled for cleaning and replacement of broken or worn parts, such as a broken spring, deteriorated O-ring, or scored valve plunger, it is important that the correct parts be used, and that they are assembled in the proper order. The MRC gives all the steps in order. The OP with the illustrated parts breakdown (IPB) identifies every part by name and stock number. A neat, orderly workbench is essential so parts can be laid out in order. A dust-free area helps in keeping dirt out of the valve when reassembling.

Through constant use, working parts may become worn, springs may be weakened or cracked, and O-ring and backup rings may become deteriorated. Vibrations can cause metal parts to crystallize and crack. However, keeping dirt, moisture, and air out of the hydraulic system is the best preventive of trouble. Daily inspections will detect leaks that can be corrected by simple tightening; daily checking of pressures and fluid levels can detect other troubles before they become major ones.

Valves are not disassembled as a routine maintenance procedure; they are disassembled only if they are not functioning properly.

Pumps

As a rule the pumps in hydraulic power drive systems require little maintenance other than proper lubrication and a clean hydraulic system to operate in. Signs of trouble are overheating, unusual noise, or failure to deliver the designed output. A frequent cause of noise is failure of oil to reach the pump. The oil level in the reservoir may be low, or there may be clogged lines or filters. Since the pump depends on the hydraulic fluid for lubrication, failure of the supply will soon cause the pump to heat up and will probably cause its parts to bind.

Another cause of abnormal noise is poor alignment between a pump and its driving mechanism. This condition will cause worn parts and possible leakage, reducing the pump's efficiency. Correcting the misalignment can be a major repair job, but the trouble will not correct itself-it will get worse.

Pounding or rattling noises in axial piston pumps may be unavoidable because of a partial vacuum produced in the active system during high speed operation or under heavy loads. The noise should stop when the load is reduced. If it does not, bleed air from the system at the vents.

Hydraulic systems which perform satisfactorily and show no evidence of sludge, corrosion, etc., should not be opened. Cover plates should be kept tightly secured, and should not be opened without good reason.

Use special care when you reassemble a rotary gear type pump. The rotors operate in a pump casing or body. End plates enclose the rotors on each side. When tightening the screws that hold the sections together, use only moderate force. Make them just tight enough to allow free movement of the rotor with no leakage.

The routine inspection, lubrication, checking of fluid level and pressure are tasks for the GMM 3 and GMM 2. They use the MRCs for instructions, and check off each job on the work schedule after completion. Your job is to supervise and check the work, and make sure it is done at the intervals scheduled, whether daily, weekly, or otherwise.

Motors

Hydraulic motors are activated by receiving fluid flow from the power pump. This fluid, under pressure, forces the motor pistons away from the flow source, thus resulting in a rotation of the motor drive shaft. The pressure buildup in the high pressure line between the pump and motor will be in direct proportion to the mechanical output or work required of the motor. The motor speed will vary directly with the amount of fluid pumped to the motor. The direction of rotation can be instantly reversed without harming the motor. The direction of flow is controlled by a selector valve.

A fixed displacement hydraulic motor may be used with a variable displacement hydraulic pump. A radial piston motor is usually used with a radial piston pump, and an axial piston motor with an axial piston pump. See *Fluid Power*, NAVTRA 16193 for descriptions.

Hydraulic motors are self lubricating; daily inspection for leakage is usually all the maintenance needed. If the motor must be removed for overhaul or corrective maintenance, be sure to plug all openings of connecting pipes so no dirt will get into the system. Use a lifting device to transfer the motor to the workbench. Figure 6-23 illustrates a typical hydraulic piston-type motor. Disassemble the parts carefully to avoid marring or scratching smooth surfaces. This is especially necessary where the fit must be exact to prevent oil leakage, as at oil seals. Follow the disassembly and reassembly instructions in the OP for the power system. The correct order makes the work easier, and is less likely to result in damage to parts by excessive use of force.

When removing the roller bearings, take care that the rollers do not fall out. As you remove each part, carefully place it on a cloth or paper-covered space in the order of removal. There are several small parts that can easily be lost. Do not throw away a part until you have a replacement part for it. You may need it for comparison, even though the stock number for the new part is the same as the old. A flaw or defect in a part may not be visible until after the part is cleaned. Inspect each part after you have cleaned it. Do not leave bare parts exposed any longer than necessary without the protection of a coat of oil. Rust can develop quickly and mar the polished surface of a precision-fitted part.

On some later modes of B-end motors, a hydraulic equalizing valve is mounted on each side. These valves were set when the power driveways tested. If the motor is removed, or replaced, adjustment can be made so that exactly equal pressures can be developed in each B-end motor high pressure line. Gages can be mounted on the B-end motor when pressure tests are to be made. The snubber and fittings that accommodate the gages are located beside the equalizing valves.

Troubleshooting

When scheduled maintenance or system testing (DSOT) reveals a fault, system trouble-shooting procedures begins. The use of trouble-shooting charts and procedures contained in PMS/SMS system manuals (OPs) isolates the fault. After finding and isolating the fault, system manuals direct the maintenance personnel to the appropriate instructions for correcting the malfunctions. Corrective maintenance instructions consist of either Corrective Maintenance Cards (CMCs) or a volume of the system OPs for corrective maintenance. System OPs have

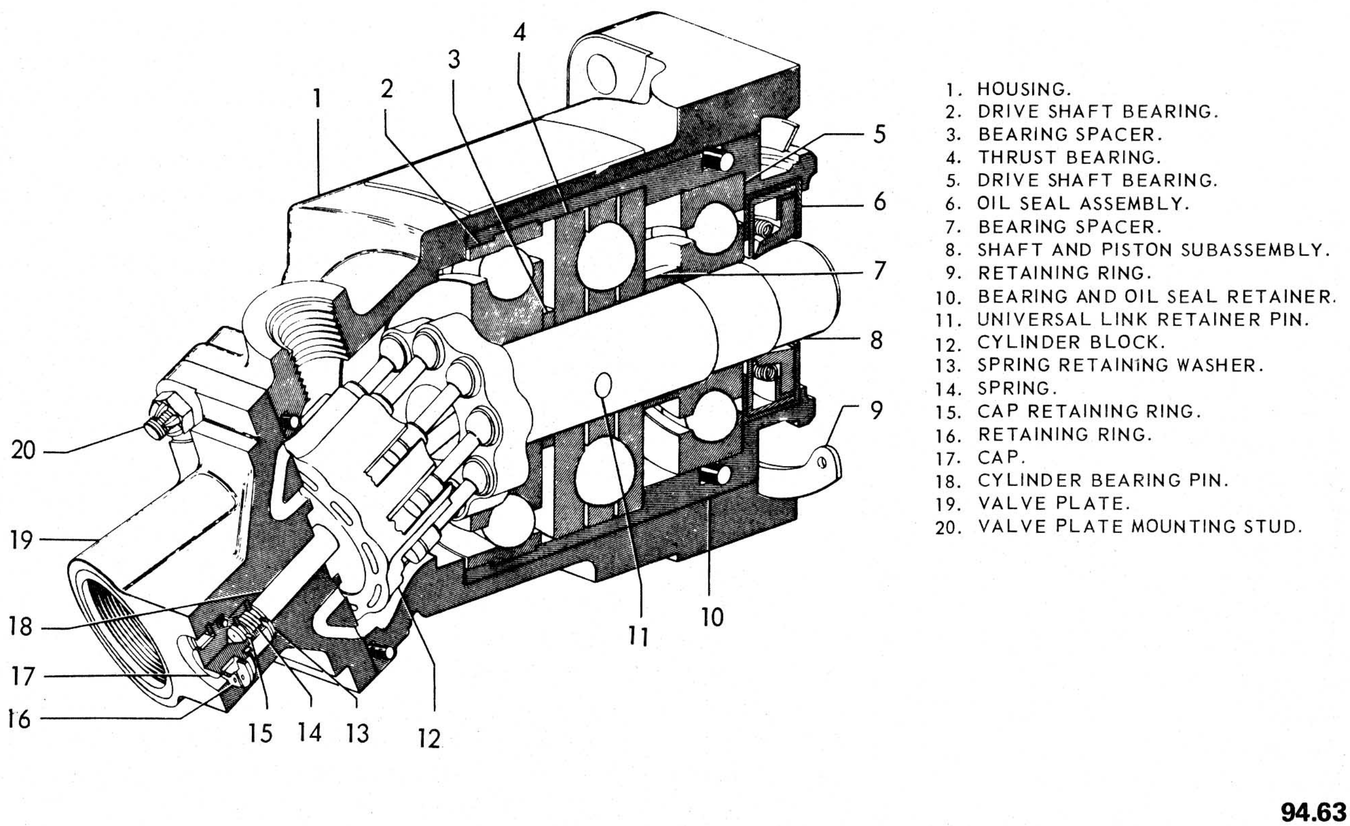

Figure 6-23.—Typical hydraulic motor, piston type.

volumes which contain detailed instructions for the performance of nonscheduled maintenance within the capabilities of ship's personnel using shipboard facilities. These instructions are for the alignment, adjustment, repair, and replacement of parts and components. Other volumes contain detailed instructions for maintenance that require the facilities of a shipyard or depot. These instructions cover dismantling, repair, replacement, and alignment of major assemblies and subassemblies.

ADJUSTMENT AND REPAIR AT A NAVY YARD OR REPAIR TENDER

Given careful daily maintenance and inspection, hydraulic systems can be used for long periods of time without major repairs. Break-downs can occur, however, in spite of the best care you can give. Size and weight of some components make repair. aboard ship difficult or impossible; alignment of such components may require the facilities of a shipyard or a repair tender. Attempts by unskilled personnel to overhaul or repair components can result in serious damage to costly equipment, and possible personnel injury. Before disassembling any part, be sure you can put it together again, correctly, and understand how it should operate. The illustrated parts drawings are essential for the less experienced men, and help even the most experienced men to check themselves on reassembly.

Alignment of large components may require yard or tender facilities. Critical adjustments may need to be deferred yard or tender work. Train and elevation power drive units are not normally removed or installed by ship personnel. While it is possible for shipboard personnel to remove the train or elevation power unit, it is recommended that such removal be accomplished during major overhaul. If the power unit has to be removed before yard or tender facilities are available, it is better to remove it by disassembling than to try to remove it as a unit when adequate handling facilities are not available.

Realigning a launcher rail is a task of considerable proportions. Arrange for tender or yard assistance, if possible. Do not readjust the launcher rail unless it is absolutely necessary.

Removal of excessive backlash in train and elevation drives is best reserved for overhaul. Excessive backlash causes misalignment between the launcher and the weapons system; insufficient backlash causes galling and binding.

Repair and overhaul of train and elevation gear boxes are tasks for tender and shipyard personnel. Although ship personnel can remove, disassemble, and reassemble the gear boxes, getting the proper alignment and backlash within the gear box, and properly aligning the gearbox to the sector gear or training circle, wouldn't be possible with the equipment normally available on board.

Lest these paragraphs give the impression that few adjustment and repair jobs are done aboard ship, look over the list of maintenance procedures for the system now assigned to you. There are several maintenance manuals that list the tests, repairs, alignments, adjustments, and servicing of a launching system that are done on shipboard. While this list includes such minor items as changing a light bulb, there are many complicated adjustments, such as interlock switch actuation adjustments.

RECEIVER-REGULATORS

Receiver-regulators are located on the launcher with the power drive units (figs. 6-11 and 6-18). The two control systems - train system and elevation system - consist of similar electric, hydraulic, and mechanical equipment. Each system receives its own order signals; the train system receives train order signals through its receiver-regulator, and the elevation system receives elevation order signals through the elevation receiver-regulator. During normal (automatic) operation, the train and elevation systems convert electrical signals received from a remotely located computer into hydraulic movements. These hydraulic movements control the velocity, acceleration, and position of the launcher carriage and the guides or guide arms.

Basically, the power drive consists of a CAB unit and a receiver-regulator. The CAB unit is composed of a B-end (hydraulic motor) and an A-end (hydraulic pump): The B-end converts fluid flow into mechanical motion. The output shaft of the B-end drives the launcher through reduction gears. Therefore the speed and direction of launcher movement is determined by the speed and direction of the B-end output.

The A-end is the hydraulic pump that supplies pressure fluid to the B-end. The fluid flow supplied by the A-end determines the speed of the B-end, while the direction of fluid flow from the A-end to the B-end governs the direction of the B-end rotation.

The A-end output is determined by two stroking pistons controlled by the receiver-regulator. These pistons "stroke" the A-end tilt plate, and thus regulate both the quantity and the direction of fluid flow from the A-end. The A-end is driven at a nearly constant speed by a unidirectional electric motor. The receiver-regulator controls the hydraulic fluid ported to the stroking pistons, and thereby regulates the CAB unit operation. The regulator components position the A-end tilt late so the B-end output is in accordance with the electrical signal input order to the receiver-regulator. The position signals are sent from the computer to both the train and elevation systems. Synchro transmitters (CX) at the computer initiate the signal voltages; synchro receivers (CT) in the receiver-regulators receive the signals.

Figure 6-24 is a simple sketch of the synchro control system components, showing how they interact. A signal voltage (primary or position signal), transmitted by CX to CT, indicates the desired position of the launcher. The CT acts as a differential, combining the actual position of the driven equipment indicated by the mechanical responses with the ordered position. Two other systems, not discussed here, can control the tilt of the A-end plate and therefore the position of the launcher. A velocity system improves the synchronizing capabilities of the launcher; the integration system improves the accuracy of the launcher.

The CT output is a signal voltage proportional to the B-end error. The B-end error is the difference between the ordered position of the driven equipment (launcher) and its actual position. The CT output is transmitted to the amplifier, where it is amplified and sent back to the

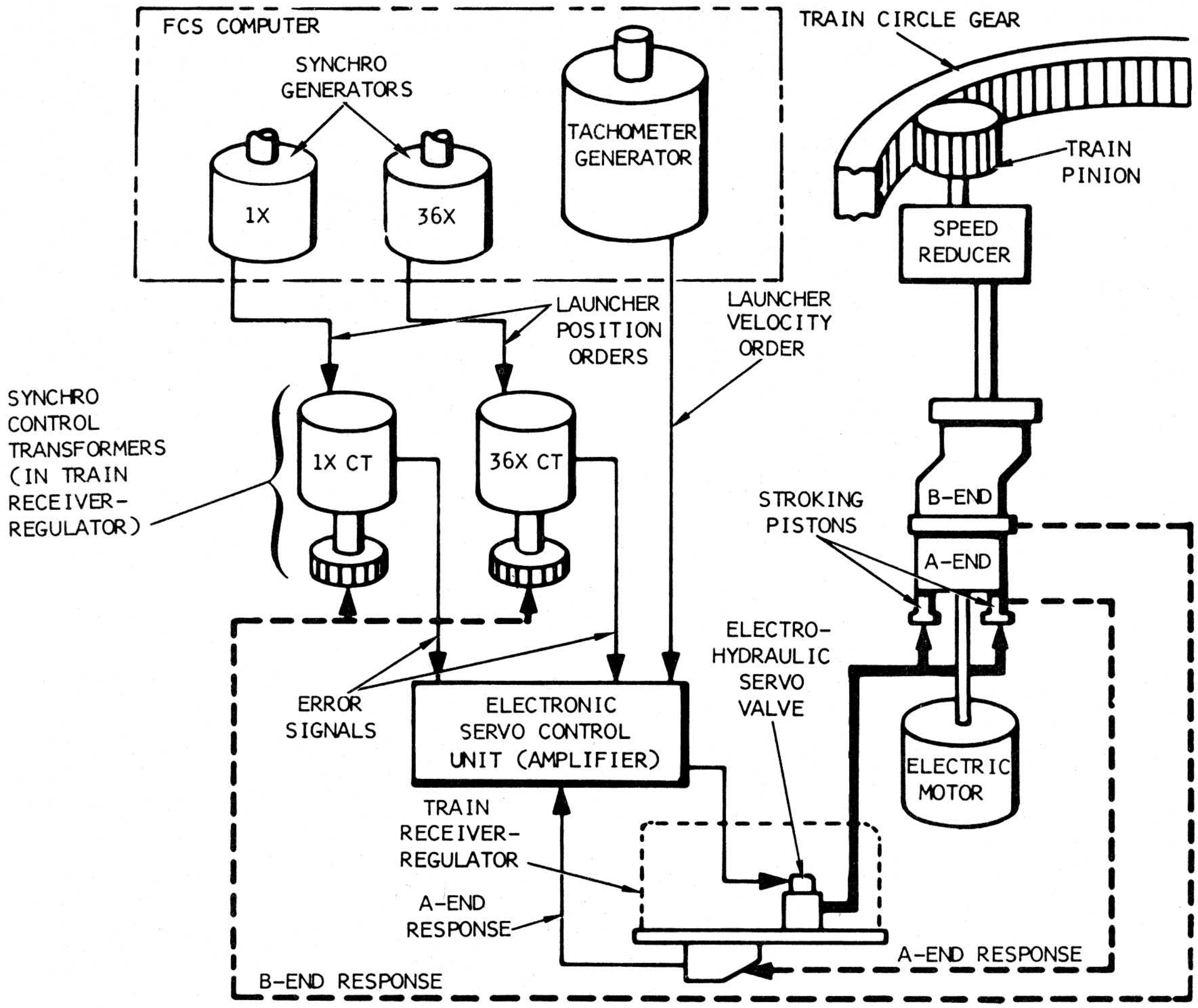

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Figure 6-24.—Launcher synchro control system and amplifier.

receiver-regulator. There it drives an electrohydraulic servo valve which transforms the amplified electrical input into a proportional hydraulic movement, and moves the launcher to the position ordered. If the target is moving, the position of the launcher has to be corrected with each new signal from the computer.

To enable the launcher to be positioned more accurately, the train and elevation synchro control systems have CXs and CTs in pairs. Each pair consists of a coarse synchro called 1X (one-speed) and a fine synchro called 36X (36-speed).The CXs are located at the computer and the CTs are at the receiver-regulator. The rotor movement of the 1X coincides with the launcher movement, while the rotor of the 36X CT will move 36 degrees for every degree of launcher movement. As long as the system is on automatic operation, the launcher is moved in train and elevation on signal from the computer. In local operation, the launcher is moved by moving the train and elevation dials as ordered by the Weapons Control Station. (On some systems the dials cannot be changed manually.) Figure 6-25 shows the train and elevation local control dials, 1-speed and 36-speed, on the EP-3 panel for the Mk 5 launcher (Terrier). The train and elevation error indicator meters (fig. 6-25) show how much adjustment is needed. The local control knobs, one for train and one for elevation, are used to make the adjustment. Behind the face of the EP-2 panel are the synchro control

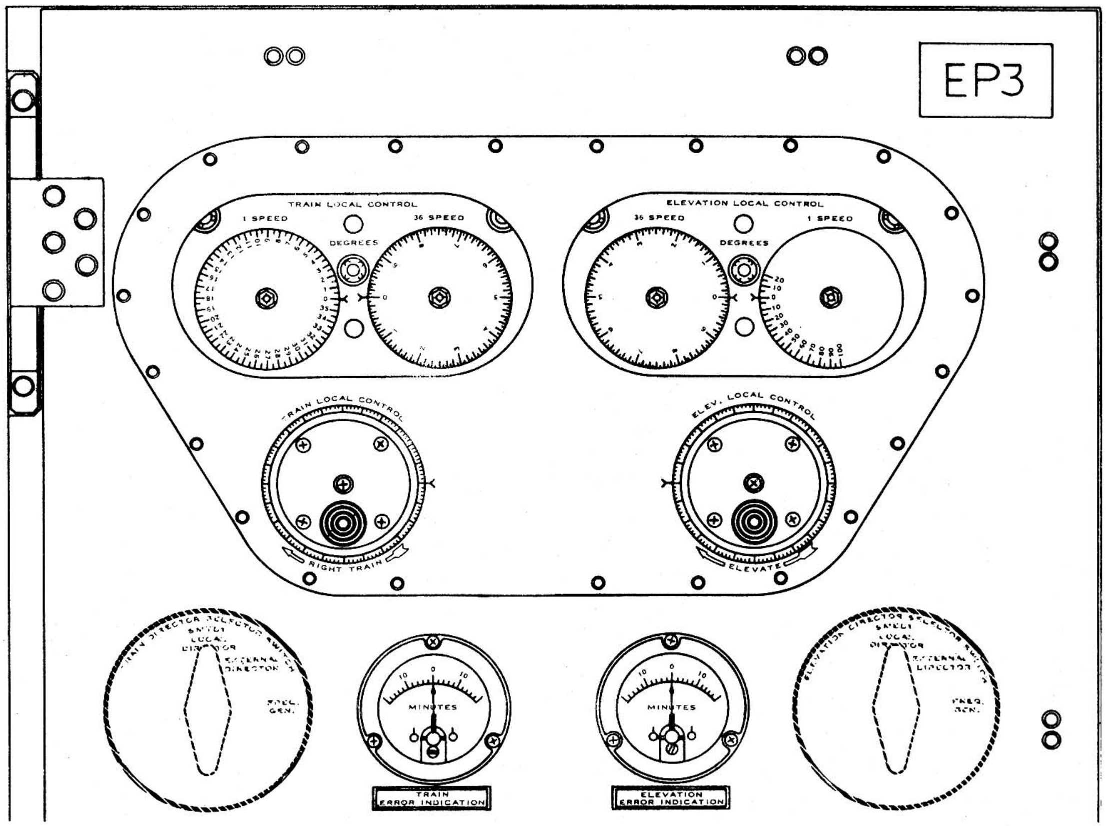

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Figure 6-25.—Train and elevation dials, local control station, EP-3 panel, Launcher Mk 5 (Terrier).

transmitters, tachometer generators, gear trains, and flywheels (one set for train and one for elevation) to transmit the motion to adjust the position of the launcher. For adjustments of less than 4.8 degrees, the 36-speed dial is used. For larger changes, the 1-speed dial is adjusted first to bring the launcher position to within 4 to 5 degrees of the ordered position. Then the fine adjustment is made with the 36-speed dial. LOCAL control may be used to stow weapons, exercise the launcher (without loading a weapon), and to purge the hydraulic system of air during maintenance or in an emergency. LOCAL control cannot be used for loading and firing. This simple statement points out the absolute necessity for keeping the system in perfect operating condition. The failure of one small part can inactivate the whole launching system. You must learn to repair hydraulic, electric, and mechanical parts of the system. The ability to locate the trouble quickly and surely is very valuable.

Synchro systems are discussed in the preceding chapter and also in the preceding course, *Gunner's Mate M (Missiles) 3 & 2*, NAVTRA 10199 and in *Basic Electricity*, NAVTRA 10086. These all emphasize the electrical aspects of the operation.

TARTAR RECEIVER-REGULATORS

The following description of Tartar receiver-regulators are those used with GMLS Mk 13 and Mk 22. The receiver-regulator is mounted less than 2 inches from the main supply tank. The heating and cooling of the hydraulic fluid tends to create a vacuum in the receiver-regulator cases, which causes air from the main supply tank to be sucked into the receiver-regulator cases. The air breather on the main supply tank allows salt or humid air to enter the tank. This air would cause damage if it reached the receiver-regulator parts. To prevent this, an expansion chamber with a quantity of inert gas is connected to the top of the main supply tank.

The receiver-regulator cases port through this chamber in such a way that only the inert gas can ever enter the receiver-regulator cases when a vacuum is created.

Remote train and elevation order signals originate in the missile fire control system. Order signals may also originate in the control transmitters within the launching system (EP-3 panel). These signals are used in the LOCAL control mode of operation, which is used primarily for daily workout or routine maintenance.

The receiver-regulators on the Mk 116 launcher of the Missile Launching System Mk 13 are different from preceding models in sever always. The Mk 116 launcher uses an amplifier (electronic servo control unit) which electrically performs many of the functions that were previously performed hydraulically by other types of receiver-regulators. A modified synchro system is used, with the B-end response positioning the synchro rotors. There is no rotary piston response. Only one modified electrohydraulic servovalve is used. Both chambers of the electro-hydraulic servovalve plunger are utilized, and each chamber is directly connected to the A-end stroking piston. The two stroking pistons have equal areasfor hydraulic pressure to act upon.

The A-end response is transmitted electrically by a potentionmenter to the amplifier and mechanically to the limit stop and automatic tracking cutout systems. A modified limit stop system is used to mechanically return the electrohydraulic servovalve, and thus the A-end, to neutral.

The automatic tracking cutout system uses the limit stop system to stop the power drive. There are no hydraulic velocity and integration systems in the regulator. However, a velocity signal is electrically applied to the amplifier.

Guided Missile Launching System Mk 13 Mods 1, 2, and 3 use Launcher Mk 126 Mod 1, and a number of changes have been made in the associated equipment. The principal change in the train and elevation systems is the redesign of the electronic servo control units. Minor modifications have also been made in the train and elevation drive motors, the servo and supercharge hydraulic systems, and the receiver-regulators.

The Mk 48 Mod 1 train receiver-regulator is the same as the Mk 48 Mod 0 receiver-regulator except for the synchro gear, the stroke response assembly, and the automatic tracking cutout valve block assemblines. The Mk 49 Mod 1 elevation receiver-regulator differs from the Mk 49 Mod 0 regulator in the same way.

The modified stroke response assembly includes an electrical connector to facilitate replacement of the stroke response potentiometer. A resistor has been added to the synchro gear assemblies, which is wired to the tachometer generator. The automatic tracking cutout valve block assembly has been mounted with rollers above and below the limit stop actuating cam to prevent binding.

Some of the check valves that arc on the auxiliary relief valve assembly in the Mk 13 Mod 0 have been relocated on the header tank cover in the Mods 1,2, and 3.

The train and elevation auxiliary pumps in the Mk 13 Mods 1, 2, and 3 furnish supercharge pressure at approximately 150 psi instead of 100 psi as in the Mod 0. The servo pressure remains the same, approximately 525 psi at 3 gallons per minute (gpm).

The only changes in the CAB units (hydraulic transmission) involve the safety relief valves. They are compound valves mounted on the valve plate between the A-end pump and the B-end motor. The assembly consists of the valve block, six valves, and two orifices. The valves serve to limit maximum pressure buildup in the high-pressure output line of the A-end pump and prevent cavitation by porting hydraulic fluid to the low pressure (suction) line of the A-end pump. (This compensates for fluid lost through slippage and leakage.)

The train and elevation amplifiers are identical, and share a common power supply in a transistorized Electronic Servo Control Unit which is mounted in the EP-2 control panel. Thirteen printed circuit cards in a rack on top of the main chassis plug into 13 female receptacles in the back of the compartment.Each of the amplifiers (train and elevation) requires an identical set of six printed circuits, one card for each of six primary stages in the functioning of the amplifier.

Figure 6-26 is a block diagram of the six stages, each representing a printed circuit card, of an amplifier. The electronic servoamplifier is

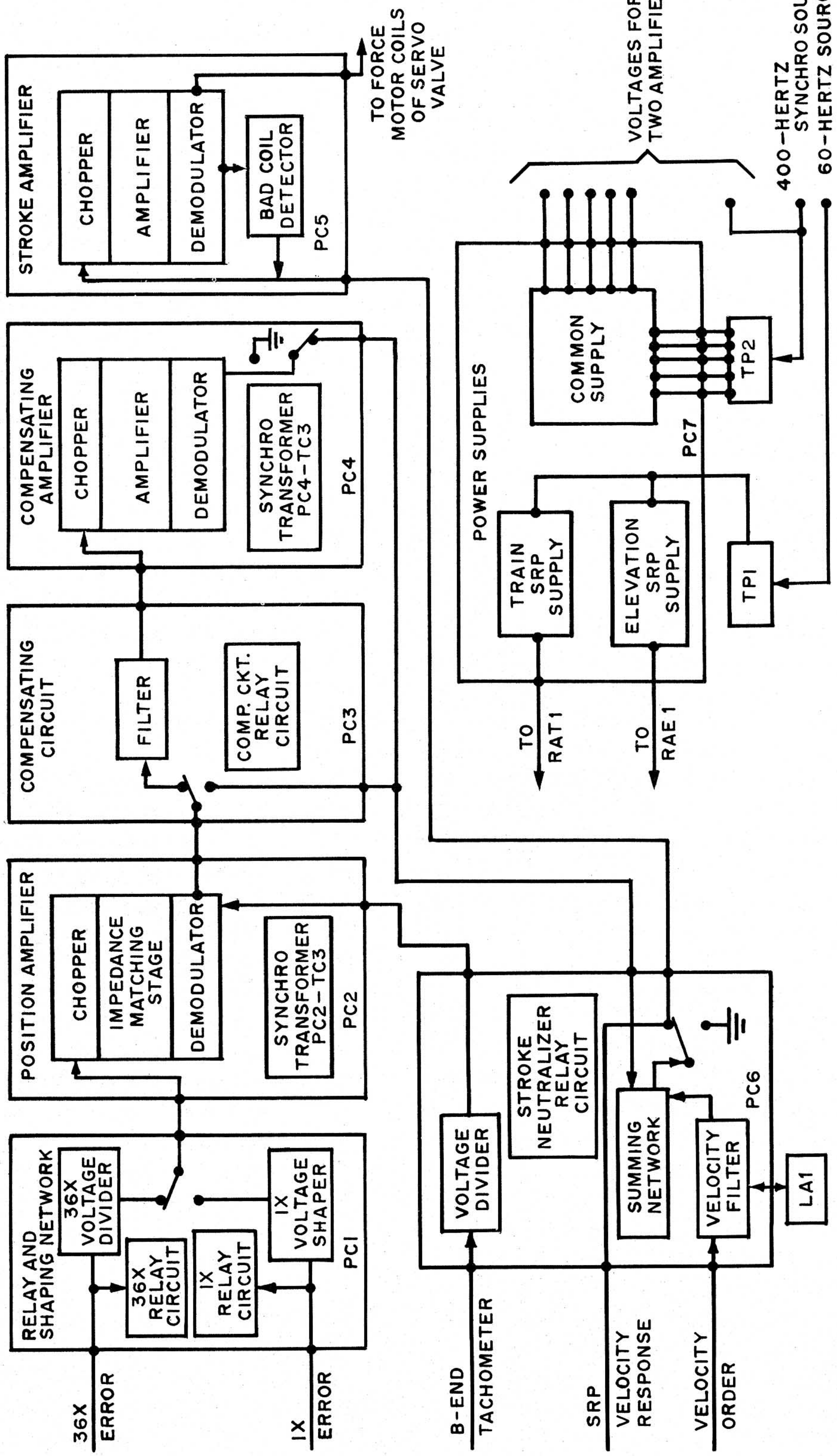

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Figure 6-26.—Amplifier Circuit Cards, Functional Diagram.

one of the components of the servomechanism that keeps the launcher synchronized until the missile leaves the guide rail. The receiver-regulators are the error detectors in the system, comparing the remote orders (from the launcher computer in the fire control system) with the actual launcher position. The amplifier processes the error. The processed position error becomes the velocity required of the launcher to correct the position error. It is one of the inputs to the velocity controller, which detects any difference between the order velocity and the launcher velocity and makes it a control order to the stroking pistons. The electrical order comes from the electronic servoamplifier to the electro-hydraulic servo valve, which converts the order into hydraulic orders and admits hydraulic pressure to the stroking pistons according to the orders. The CAB unit supplies the response information to complete the servo loop, sending position information to the receiver-regulators.

TERRIER RECEIVER-REGULATORS

The receiver-regulators are mounted to the center of the launcher carriage, directly above the CAB units. Servo pressure at 400 psi is supplied to the receiver-regulator valves and pistons. There are two major servo systems in the receiver-regulators: the power drive and the velocity drive systems.

The signal for moving the launcher to the correct train and elevation position for dud jettisoning comes from a fixed synchro in the EP-2 panel. There is a switch for each launcher arm, A and B. Air motors provide a means of training or elevating the launcher for maintenance.

Figure 6-27 shows a receiver-regulator with the cover removed, and some of the main components are named. It contains a multitude of components, here grouped into seven logical sections to simplify location and identification:

1. The main valve block (including the electrohydraulic servovalves).
2. The nonpointing zone valve block.
3. The limit stop assembly.
4. The B-end response.
5. The synchros and their accompanying gearing.
6. The rotary piston assembly.
7. The A-end response assembly.

Between the limit stop assembly and the elevation indicator dials are two B-end response gears. One of the B-end response gears drives the synchro gearing assembly and the other gear drives the limit stop assembly. The B-end response shaft that drives the gears leads through an opening in the regulator base plate. The B-end tachometer is driven by the limit stop gearing.

The synchro gearing assembly includes five visible synchros with the gearing immediately below them, and indicator dials. The dials are visible through the window in the cover of the receiver-regulator.

The A-end response shaft leads into the receiver-regulator through an opening in the base plate, and is not visible in figure 6-27. The rotary piston assembly is attached to the inboard side of the main valve block and lies below the rotary switch cam.

Except for minor differences, the train receiver-regulator is identical to the elevation regulator. The train rotary piston cam has a slightly different contour than the elevation rotary piston cam, but it operates similarly. The contour is different because of the different acceleration and velocity specifications in train.

The nonpointing zone components of the train and elevation receiver-regulators prevent the launcher guide arms from training or elevating into any part of the ship's structure. The train limit stop does not have a gear and rack as does the elevation limit stop assembly, but contains a nonpointing zone cam. The cam may be halted by pistons in the nonpointing zone valve block. By means of the gear and rack, the power drive can elevate the launcher arm above the nonpointing zone.

The train B-end response assembly differs from the elevation B-end response assembly in design because of mounting position. The train B-end response is coupled to the train gear reduction.

Receiver-regulators used with early models of the Mk 5 launcher (also Mk 7 launchers for Talos) use torque motors and rotary valves instead of electro hydraulic servovalves. The torque motors are controlled by conventional tube

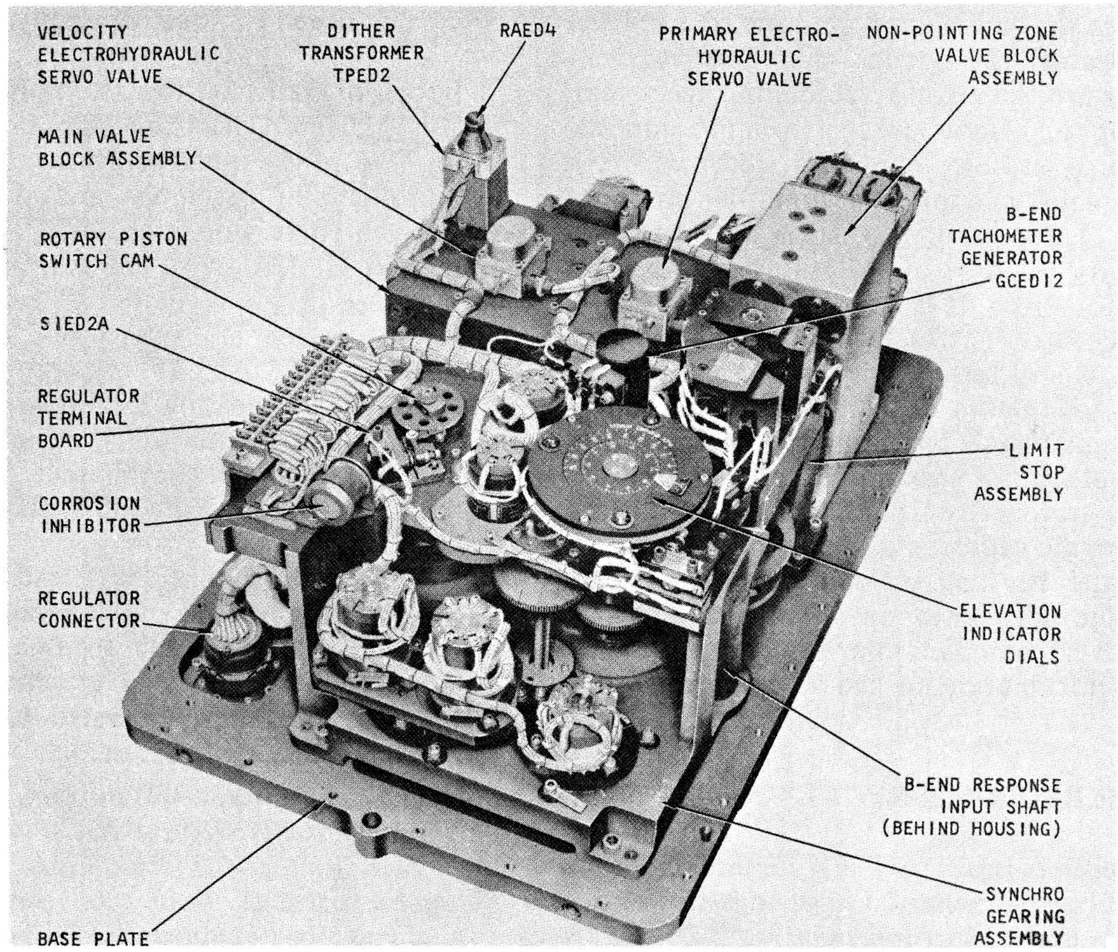

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Figure 6-27.—Elevation receiver-regulator, Mk 5 launcher; cover removed.

amplifiers instead of magnetic amplifiers. The function of the electrohydraulic servovalve is to convert an electrical signal from the train (or elevation) primary amplifier into a proportional hydraulic order. It does this with a minimum of friction and negligible time delay. Figure 6-28 is a cutaway view of an electrohydraulic servovalve. There are four ports in the base of the valve. One port supplies hydraulic fluid at 400 psi to the servovalve, one port leads to the tank, and a third port supplies control pressure from the servovalve to the rotary piston neutralizing valve. The fourth port is blocked off and not used.

The hydraulic pressure ordered by the electrical input is applied to the end of the servovalve plunger and positions it. The plunger position results in the output of control pressure, proportional to the electrical input, which is sent through the control port.

The force motor (fig. 6-28) consists of two permanent magnets, two pole pieces, two coils and a reed. One end of the reed is centered in the air gap between the two pole pieces and the other end is centered between two nozzles in the mixing chamber. The reed is the armature of the magnetic circuit and is polarity conscious. The force motor transforms the electrical input, a differential current, into a proportional force on the motor reed. The hydraulic amplifier converts the reed movements into corresponding differential pressures. The differential pressures cause the plunger to shift. A decreasing order signal causes a shift to the left; an increasing order signal causes a shift to the right.

Adjustment can be made on the adjustment

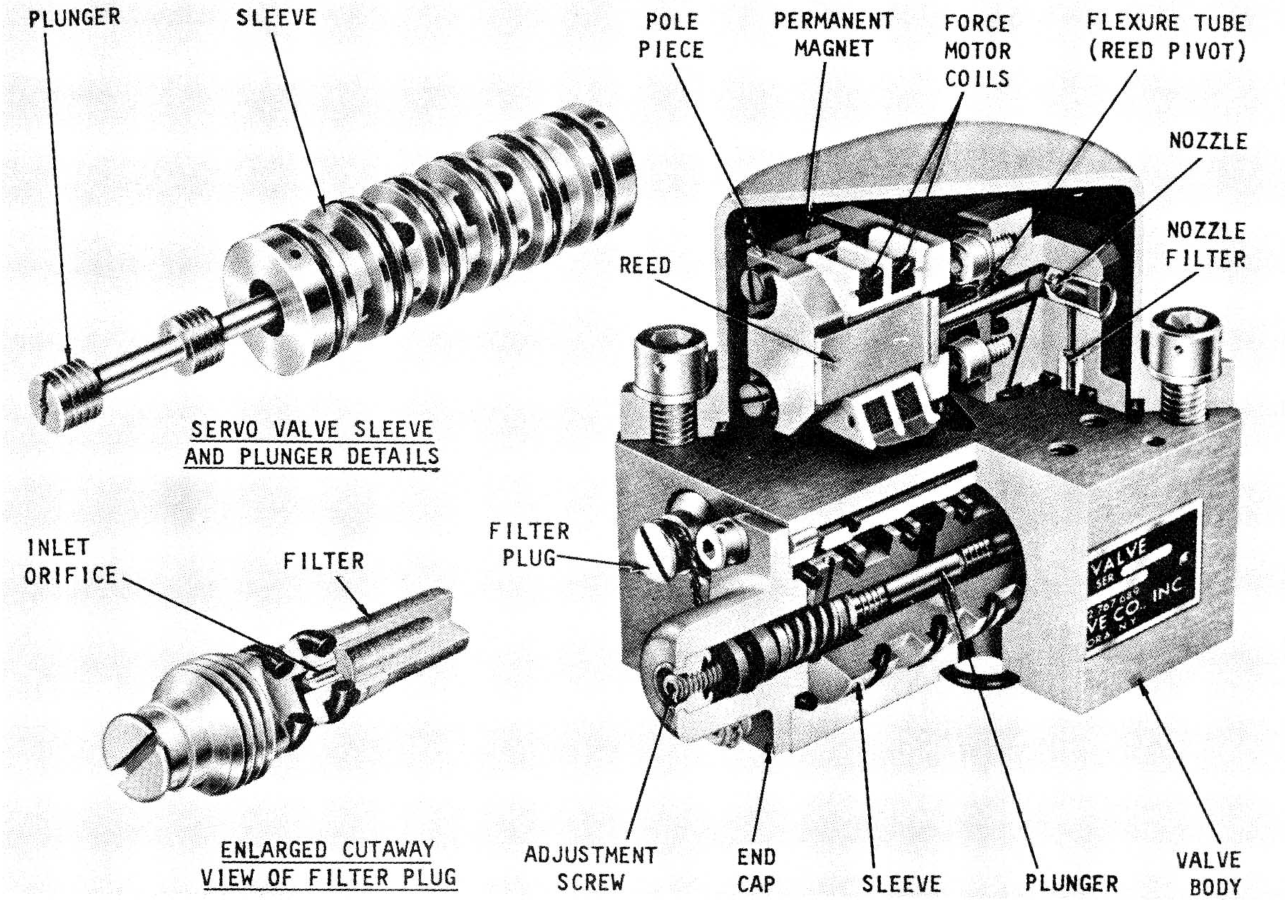

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Figure 6-28.—Electrohydraulic servovalve cutaway view.

screw (fig. 6-28). The filters may need to be cleaned, or the whole valve may need to be disassembled, cleaned, and reassembled. Servovalves are used in several of the hydraulic systems, and you need to be able to maintain and repair them.

TALOS RECEIVER-REGULATORS

There are many similarities between the Mk 7 and the Mk 12 launching systems, and in many cases the equipments are identical. The basic principles of hydraulics and electricity apply to both systems. Equipments that are the same are the Area 1 accumulator, the mechanical and hydraulic aspects of the loader (except the power drive), and the mechanical and hydraulic aspects of the span track and the blast doors.

The receiver-regulators used with the Mk 7 and Mod 0 launcher and Mk 50 Mods 0 and 1 power drives make use of torque motors and rotary valves. On the Mod 2 power drives, electrohydraulic servovalves are used. The primary (position) and the velocity electrohydraulic servovalves for train and for elevation are in the receiver-regulators. Magnetic amplifiers are located on the EP2 panel. These amplify the train and elevation electrical signals so the signals are strong enough to tilt the A-end plate and thus start movement of the hydraulic fluid which will move the launcher in the direction and amount ordered.

Local train and elevation orders are transmitted by the local order synchro transmitters mounted in the internal director section of Test Panel Mk 203 Mod 0, the EP-3 panel. The transmitters are positioned by operation of the controls on the EP-3 panel to set the train and elevation indicator dials on the face of the panel to the positions ordered. There are fine and coarse dials for train and elevation on the control panel and also on the receiver-regulators. Remote control is in the form of electrical signals from the fire control computer that processes the information from a radar antenna mount. Two channels of control signals are fed to the train and elevation drives. One is a position order and the other is a velocity order. The synchro transmitter in the computer transmits a position order to the IXCT in the receiver regulator of the launcher. The stator of this CT is geared to the B-end of the hydraulic transmission. If the launcher is not positioned at the same bearing as the transmitted order, a voltage is developed on the rotor of the CT to represent launcher position error (angular difference between actual launcher position and the ordered launcher position). This error voltage is placed on the input terminals of the magnetic amplifier in the EP-2 panel. The error signal, amplified, is sent back to the receiver regulator, which then applies tilt to the A-end of the hydraulic transmission. The amount of tilt of the A-end governs the speed of the B-end. A gear reduction unit reduces the speed before it is applied to the drive pinion to drive the carriage. As the carriage rotates to the ordered position, the error reduces until it is zero.

When the situation is continually changing, as when the radar is tracking a moving target, the launcher must keep moving to follow the error signal, which could make it rough. A smooth operation of the launcher is made possible by the use of the velocity channel as an additional means of stroking the A-end. The velocity order is also received from the computer. The signal is amplified in the EP-2 panel, and sent t the receiver regulator, which causes a proportional tilt in the A-end. The electrohydraulic servovalve is part of the receiver regulator. It converts the electrical signal into hydraulic actuation.

A third system for power drive control is the integration system. It differs from primary and velocity control in that it is initiated within the receiver regulator. It is used only when the launcher is within one degree of synchronization and it prevents the launcher from hunting back and forth over the synchronization point. The integration system detects a small primary error through the displacement of primary stroke valve UVTD2 and responds to it by putting a movement on the stroke control lever through the velocity piston. Movement of UVTD2 acts on one end of a lever-arm linkage and the other end is pivot-mounted to a stationary point on the regulator valve block. As an example of how an integration signal is developed, a small increasing order through the primary system will be discussed.

The small downward displacement of UVTD2, figure 6-29 will cause a proportional downward displacement of integrator control valve UVTD7. UVTD7 supplies control pressure through neutralizing valve UVTD20 to the integration piston UCTD8. Any movement of UVTD7 from its neutral, position will cause a pressure change in the chamber above, UCTD8. Due to the decrease in pressure at the top of UCTD8, the integration piston starts to move up. The final position of UCTD8 represents the volume of fluid that has flowed to or from UVTD7. This volume is a measure of the sum of the primary error for each unit of time that the error existed.

The movement of UCTD8 generates an electrical signal through RATD5, (fig. 6-29), the integration potentiometer. The integration signal is amplified by the velocity amplifier and applied to the primary system to the stroke control level through the velocity system. The velocity potentiometer develops a response signal through RATD4 to electrically cancel the integration signal.

The integration system is cut out when large error signals are applied to the power drive servo system.

The train and elevation limit stop systems are located in the receiver regulators. Their function is to stop movement of the launcher and/or guide arms when moving into a fixed limit or nonpointing zone, or when a power failure occurs.

INDICATING EQUIPMENT

The position of the launcher must be known to the man who presses the firing key, the man who must make the decision whether to fire, and the men who position the launcher. The information must be presented simultaneously to all of them. The indicating lights are on the

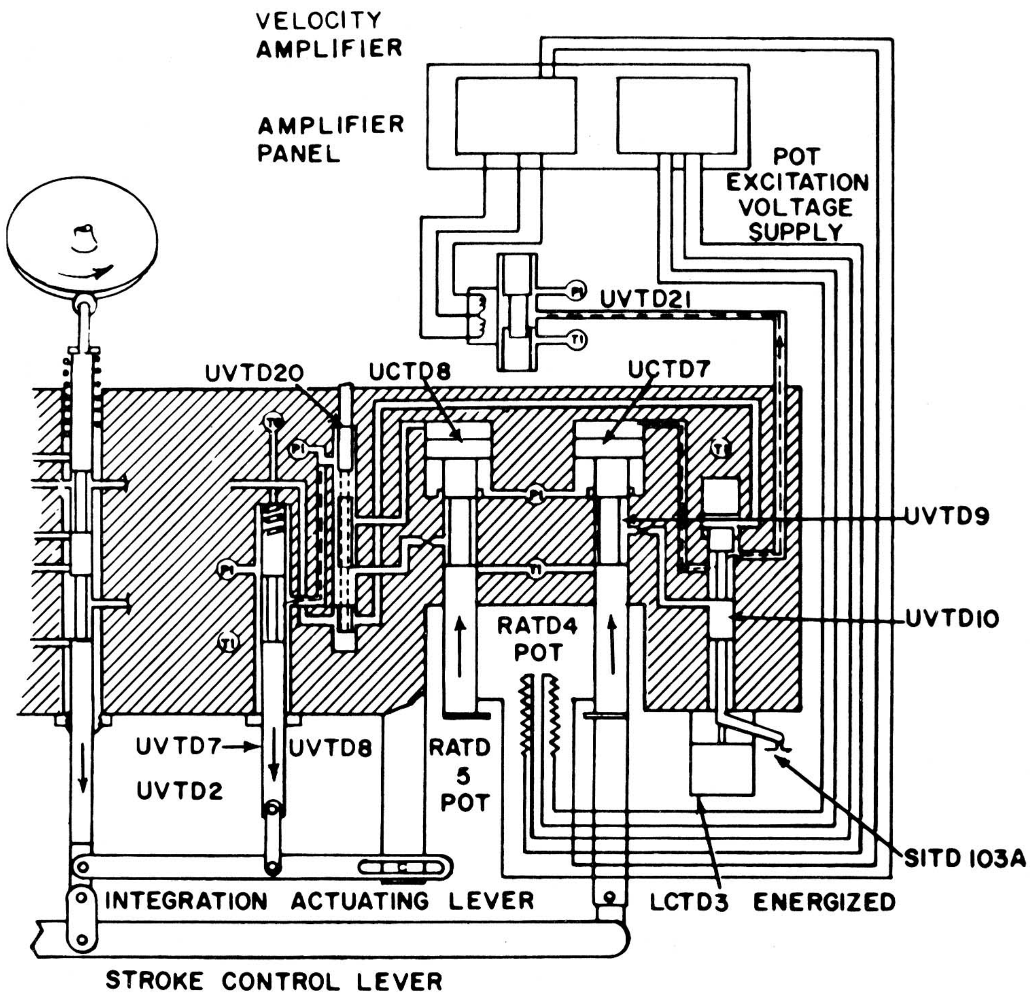

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Figure 6-29.—Increasing order operation of the integration system.

launcher captain's control panel, in the weapons control station, and on the bridge. Train and elevation position and order dials on the launcher captain's control panel indicate the actual train and elevation positions and the ordered positions. (These dials cannot be changed manually.) Launcher elevation is shown in minutes of elevation arc, and train is shown in degrees. When the observed position and the ordered position match, the launcher is in firing position and the TRAIN IN SYNC and ELEVATION IN SYNC lights illuminate. When all parts of the missile and the launcher are ready, the READY-TO-FIRE window on the panel lights up. The missile may not be fired until all lights show that everything is in readiness.

Within the weapons system are numerous equipments called indicators, all designed to supply information to the operators. The train position indicator and the elevation position indicator are two of these. All the panels in the launching system, manned and unmanned, are indicating panels. Numerous panels and consoles in the Weapons Direction System (WDS) provide indications of weapons system conditions to the operators. Among those of interest to the GMM are the Weapon Assignment Console (WAC), Director Assignment Console (DAC), Target Selection and Tracking Console, master control panel, casualty weapons direction panel, casualty firing panel, missile status indicator panel, and control indicator panel. Some of these are in the Combat Information Center (CIC) and some are in the Weapons Control Station (WCS). Intersystem communication between the Weapons Direction Equipment and the guided missile launching system transmits orders to the control panels in the launching system and feedback from the launching system is transmitted back to the Weapons Control Station to indicate the carrying out of the order. For example, a load-select order is transmitted to the EP-2 panel as a light indication that shifts from flashing to steady when the EP-2 panel operator positions the A or B Selector switch to match the position ordered. This switch continuously feeds back an indication of the switch position to Weapons Control. Information on missile status (Armed/Safe, or Unsafe) is sent through the EP-2 panel to Weapons Control. Firing status is transmitted to Weapons Control as Missile Ready, Missile Firing, Dud, etc.

What happens if the launcher and missile are in readiness, but one or more of the necessary indicator lights are not on? The actual cause of this failure may be merely a burned out light bulb on the panel, but you don't actually know what is wrong until you check and find the trouble. Know-how acquired through daily checkouts should help you locate the trouble quickly and surely. In a combat situation, loss of even a short time can be critical. Your knowledge of launching system checkout can be the saving factor.

In addition to automatic equipment, sound-powered telephone circuits provide rapid interchange of information between missile system stations. These circuits are independent of electrical power from ship supply and can therefore continue to function when other systems fail.

TESTING AND MAINTENANCE

Each system has some provision for continuing operation if part of the system is inactivated by casualty. In the Terrier system it is called casualty mode of operation. Duplicate control panels and consoles are ready to be placed in operation in emergency, and ways of bypassing some controls are provided. The OP for the system describes casualty operation of the Terrier system.

Other missile systems have an auxiliary mode or emergency mode. In the Tartar system, Step control can be used for emergency if the automatic circuitry is inoperative. Manual operation is used for maintenance, checking, and installation, as well as for emergency. The Talos system has auxiliary mode in step control. The purpose<;>f these "extra" methods of firing is not to avoid making repairs on the system, but for use in an emergency in a combat situation. Train your men in the use of them so they will know what can be used in an emergency. Manual operation is strictly for maintenance, repair, and exercise.

SHIPBOARD RECEIVER-REGULATOR ADJUSTMENTS

The components of receiver-regulators are not fragile, but adjustments are precise and delicate, and therefore maintenance must be performed with care by trained, competent men. Improper care and maintenance procedures can destroy critical adjustments which require extensive realignment. Misalignment or binding of the various mechanisms can cause erratic launcher movement. The real cause of the trouble may be difficult to locate, so make a careful study of the problem before attempting to make any adjustment or repair.

Shipboard maintenance of receiver regulators includes replacement and adjustment of electro-hydraulic servovalves, velocity and integration potentiometers, and input synchro control transformers. One man operates the panel while another performs adjustments. Telephone communication between them is essential.

To replace an electrohydraulic servovalve, deactivate the system and dump fluid pressure from the regulator by draining the system to the level of the main supply tank. Then loosen the capscrews which secure the servovalve to the top of the main valve block in the receiver-regulator, and disconnect the cable plug. Replace with a new servovalve, tighten the capscrews, and reconnect the cable plug. A dowel pin in the base of the servovalve assures that the valve is positioned correctly.

After the servovalve is positioned, it is ready for adjustment. The servovalve spool position is adjusted by means of the adjustment setscrew (fig. 6-28). To adjust the primary electrohydraulic servovalves, energize the primary system but leave the velocity system deenergized. Adjust the primary electrohydraulic servovalve for zero difference current. Use the adjustment setscrew to adjust the valve spool. The difference current can be checked at the amplifier test points (fig. 6-30, 10A and 10B on the test points). Be sure the meter switch is turned to TRAIN PRIMARY when testing the train servovalve, and to ELEV PRIMARY when testing the elevation servovalve.

The adjustment of the velocity electrohydraulic servovalves is made in a similar manner. Activate the velocity system but not the primary system. Make sure the velocity potentiometer is adjusted to zero volts from the amplifier test point 8B to ground. With the setscrew (fig. 6-28) adjust the servovalve spool to zero difference current at velocity test points 10A and 10B (fig. 6-30). Turn the meter switch to TRAIN VELOCITY and the train test switch to 10 when checking the train velocity valve. To check the difference current on the elevation velocity servovalve, be sure to turn the meter switch to ELEVATION VELOCITY and the elevation test switch to 10.

When an operational check shows faulty operation of a potentiometer, it should be replaced and adjusted. There are four potentiometers ill the amplifier assembly shown in figure 6-30, two integration potentiometers, and two for train and elevation velocity. A volt meter is needed to make the adjustment of the potentiometer arm to zero volts before beginning removal or testing of any part. Deenergize the velocity system. Follow the instructions in the OP for your weapon system.

The position of the launcher, compared to the position indicated on the receiver-regulator dials must be checked at regular intervals. If there is any difference between the actual position of the launcher and the dial indication, adjustment must be made to the vernier on the regulator B-end responsible shaft. If the B-end vernier is adjusted, the launcher load order synchros will also require adjustment. Refer to your OP for the methods of doing this. Shut off power to the system when replacing any parts. Careful readjustment is necessary whenever a new part is placed in the system.

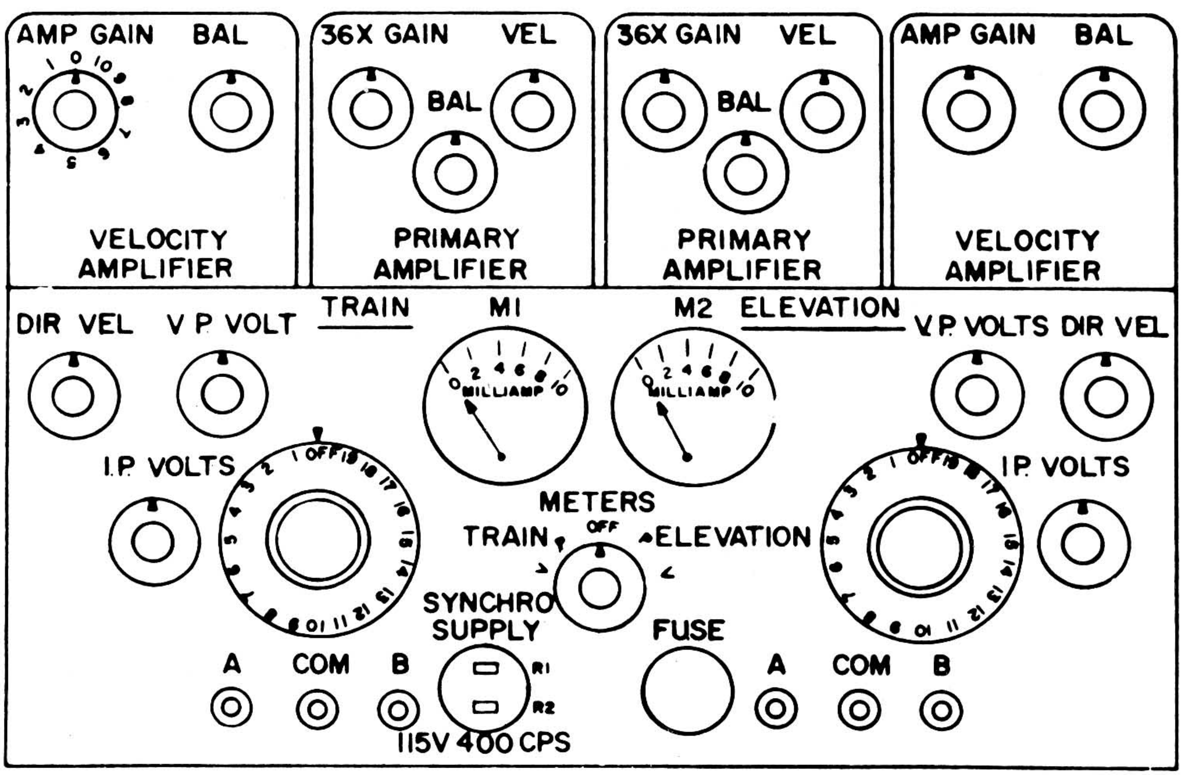


Figure 6-30.—Front panel of amplifier.

MAINTENANCE OF RECEIVER-REGULATORS

Quarterly, or after each 360 hours of operation, secure the launcher intrain and elevation, and remove the housing cover of the receiver-regulator (train and elevation receiver-regulators receive the same maintenance). With the lubricant specified for your equipment, lubricate the rotary piston switch bearings, pivots, and rollers; A-end stroke response switch arm, bearings, pivots, and rollers; main valve block bearings, adjustable gears, and pinions; blind zone cutout gearing bearings, pivots, and rollers; blind zone cutout gearing brake block linkage and bearings; and all synchro gearing and bearings except those located within the synchros.

Remove the fluid power transmission fitting protective cap on the A-end stroke response and lubricate the fitting with a hand gun containing the prescribed fluid mixture. Check and refill, or add the specified corrosion inhibitor if required, at the synchro gearing assembly level.

Plan to adjust the power drive interlock switches at the same time, so the receiver-regulator covers do not have to be removed oftener than necessary. Most of the interlock switches are adjusted at the receiver-regulator. When possible, interlock switches are adjusted with the power off. Turn off power at the power panel.

Switch actuation is checked by a continuity indication at the nearest terminal. Switch lead termination between switches is sometimes common so that one lead must be disconnected. Because of the complexity of the wiring, the disconnected lead should be tagged and, after adjustment, reconnected immediately.

Communication must be established between the manual operator and the person or persons performing the switch adjustment. You will need to have the drawings showing the location of the switches for your power drive system, the OP, and a check sheet listing each switch so you can record your tests: Some of the interlocking switches can be checked with the power off and a 1.5-volt test lamp connected to the switch terminals in the regulator.

Train and elevation blind zones are fixed on the individual installations and are permanently recorded. You need a copy of the record when checking the stop positions of the launcher in train and elevation. Compare the train and elevation stop positions with the recorded limits. The air drive motor is used to move the launcher slowly in train and elevation for testing. Listen for the click of the solenoid that indicates actuation, and record the B-end position at that time. Use the OP for complete instructions.

Adjustment of the various interlock switches of the train and elevation power drives requires familiarity with the operation of the associated control circuitry and the actuating mechanisms. Equipment required includes a continuity checker with a self-contained, power supply and a regulated and adjustable hydraulic fluid supply with a pressure gage.

Some special tools are used in adjustment and maintenance of parts of receiver-regulators. The correct tools make the work easier; they are a necessity for exacting adjustments. Follow through on the care of the tools. See that they are put back in their proper places, in undamaged condition. If a tool becomes damaged during use, do not put it back on the tool rack or in the tool kit, but recondition it or replace it.

WARNING: Make sure that power to the power drive system is shut off prior to removing receiver-regulator covers or auxiliary relief and brake control valve switch and solenoid housings for switch adjustments, unless switch adjustment requires power operation. Remove the safety switch handles from the power and control panels. Keep all panel doors and solenoid housing covers secured at all times except when being serviced. Do not position any SOLENOID by hand unless specifically ordered to do so.

Maintain the schedule of lubrication setup for your equipment and use the lubricants specified on the lubrication chart. An atomizer is used where very light lubrication is needed yet all parts must be reached by the oil. Do not over-lubricate or use the wrong type of lubricant.

Equipment adjustments should be made only when actually required. When switches, relays, solenoids, etc., malfunction, do not attempt to repair them. Replace the faulty unit with a functional one, replace and tighten all screws, nuts, etc., and then test-operate to be sure it functions properly in place. Make adjustments then if necessary, following OP instructions.

TROUBLE ANALYSIS

The response (or lack of it) of the launcher to signals from the weapons control station or the control panel is an indication of the condition of the system. In the daily exercise of the launcher, watch for any erratic movement. Trace the cause, and make the necessary adjustment or repair. Then test the adjustment or repair by again operating the launcher. Leakage in the hydraulic system can be located by visual inspection. Noisy operation may be due to lack of circulating hydraulic oil, either because of insufficient oil or blockage of the supply. Air in the hydraulic system also causes noisy operation. Overheating of any part is usually due to lack of lubrication. The remedies for these troubles are fairly simple.

When the launcher makes erratic response to the order signal, the trouble may be more difficult to locate and adjust. If the launcher will move in only one direction, look for trouble in the valves in the B-end and A-end. An improperly adjusted pilot valve in the A-end may permit the launcher to override the control signal. If the launcher moves several degrees beyond the ordered position (or stops before reaching the ordered position), the synchros are not properly adjusted to null. If the launcher is slow in responding to the control signal, the control pump filters may be clogged, the torque motor coils may be improperly adjusted, the oil level may be too low, the control pressure relief valve may be improperly set, the B-end relief valves may be improperly set, or there may be a defective part.

WARNING: Make sure that power to the power drive system is shut off before removing receiver-regulator covers or making any adjustments.

MISSILE CONTROL COMPONENTS AND SYSTEMS

Guidance and control are sometimes spoken of as if they were one and the same. They are two parts of the problem of getting the missile to the selected target after it is fired. The main reason for controlling a missile in flight is to gain increased accuracy for missiles with extended ranges.

A missile guidance system keeps the missile on the proper flight path from launcher to target, in accordance with signals received from a control point. The missile control system keeps the missile in the proper flight attitude. Together, the guidance and control components of any guided missile determine the proper flight path to hit the target, and control the missile so that it follows this determined path. Missiles accomplish this "path control" by the processes of tracking, computing, directing and steering. The first three processes of path control are performed by the guidance system, steering is done by the control system.

GMM 3&2, NT 10199, described the external control surfaces of guided missiles such as wings and fins and explained the effects of natural forces acting upon them and how the missile compensates for them. The remainder of this chapter explains the characteristics of some of the numerous mechanical, hydraulic, and pneumatic systems used to control the steering components to maintain a stable missile flight. We will deal with the general principles, rather than the actual design of any specific missile.

Types of Control Systems

Missile control signals may come from inside the missile, from an outside source, or from both. Regardless of which method of control is used, some source of power must be produced to control the steering surfaces of the missile. This power is initially produced within the missile by hot gases, compressed or high pressure air, or by electrical means. The power is transmitted from the supply source to the movable steering controls by pneumatic, electrical, or mechanical means, or by using a hydraulic transfer system in conjunction with the sources mentioned above.

Before getting into the details of specific types of control, let us first take a general look at several possible controllers and compare some of their advantages and disadvantages.

A pneumatic system which depends on tanks of compressed air is obviously limited in range. Since air or any other gas is compressible, the movement of a pneumatic actuator is slow due to the time it takes to compress the air in the actuator to a pressure sufficient to move it. Hydraulic fluid is practically incompressible and will produce a faster reaction on an actuator, especially when the actuator must move against large forces. Thus, large, high speed missiles (Talos) are controlled by hydraulic actuators.

Very few missiles have been designed which do not have some part of their control systems operating by electricity. The use of an all electric control system would place all the equipment, except the propulsion unit, within the electrical field. This would simplify manufacture, assembly, and maintenance. Also, it would be easier to transmit information or power to all parts of the missile by wires, rather than by hydraulic or pneumatic tubing.

An all mechanical control system in a missile is not very probable. In an all mechanical system, error information would be transferred from a mechanical sensor by some mechanical means such as a gear train, cable, rotating or sliding shaft, or chain linkage. This linkage would then connect to the correcting devices such as control surfaces.

The major disadvantages of a mechanical control system are that too much power would be required to move the necessary (and heavy) gear trains and linkages, and the installation of an all mechanical system would be extremely difficult in the small spaces of a missile.

To gain advantages and offset disadvantages of the different types of control, combinations are used, such as pneumatic-electric, hydraulic-electric, hydraulic-mechanical, or others.

Missile Control Servosystem

A missile control subsystem is a servomechanism. A servomechanism takes an order and carries it out. In carrying out the order, it determines the type and amount of difference between what should be done and what is being done. Having determined this difference, the servomechanism then goes ahead to change what is being done to what should he done. To perform these functions, a servomechanism must be able to:

1. Accept an order which defines the result desired.
2. Evaluate the existing conditions.
3. Compare the desired result with the existing conditions, obtaining a difference between the two.
4. Issue an order based on the difference so as to change the existing conditions to the desired result.
5. Carry out the order.

For a servomechanism to meet the requirements just stated, it must be made up of two systems - an error detecting system and a controlling system. The load, which is actually the output of the servo, can be considered part of the controller.

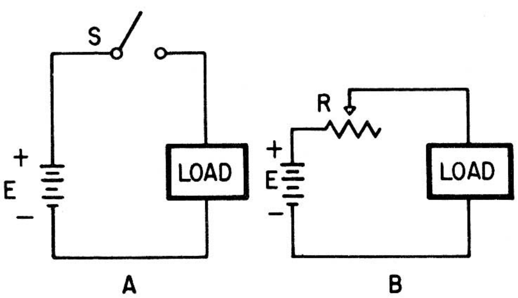
By means of servo systems, some property of a load is made to conform to a desired condition. The property under control is usually the position, the rate of rotation, or the acceleration of the load. The system may be composed of electrical, mechanical, hydraulic, pneumatic, or thermal units, or of various combinations of these units. The load device may be anyone of an unlimited variety; a missile control surface, the output shaft of an electric motor, and a radar tracking antenna are a few typical example.

Discontinuous and Continuous Control

The simplest form of control can be illustrated by the elementary circuit shown in figure 6-31A. The circuit contains a source of power, a switch, or controlling device; and an unspecified load. The elements are connected in series. When the switch is closed, energy flows to the load and performs useful work; when the switch is opened, the energy source is disconnected from the load. Thus, the flow of energy is either zero or a finite value determined by the resistance of the circuit. Operation of this general type is called DISCONTINUOUS CONTROL.

In figure 6-31 B, the circuit is modified by substitution of a rheostat for the switch; and the circuit now provides CONTINUOUS CONTROL.

By displacing the rheostat contact, the circuit resistance is varied continuously over a limited range of values. The energy expended in the load is then varied over a corresponding range rather than byintermittent, or on-off action as in discontinuous control. Both these simple examples represent a fundamental property of control systems in general: the energy required to control the system is small compared with the quantity of energy delivered to the load.



33.60
Figure 6-31.—Elementary control circuit: A. Discontinuous control; B. Continuous control.

Open- and Closed- Loop Servosystems

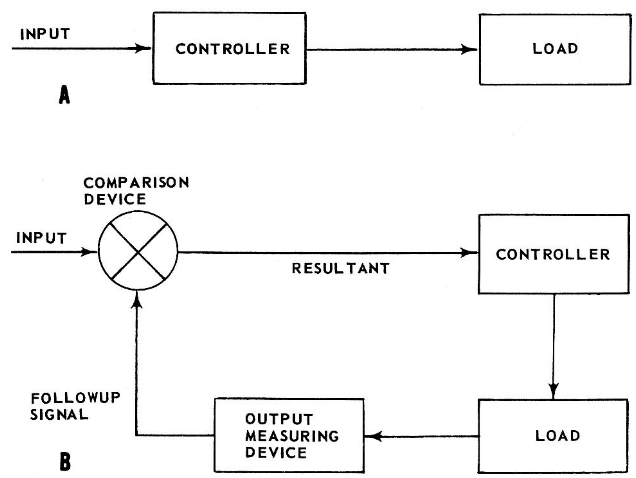
In the examples given above, the power source is controlled directly by manual adjustment of a switch or of a rheostat. In more complicated servo systems, control signals are applied to the power device by the action of an electrical or a mechanical device rather than by manual means.

Automatic servosystems can be divided into two basic types: open-loop and closed-loop systems. The essential features of each are indicated by the block diagrams in figure 6-32.

In both systems, an input signal must be applied which represents in some way the desired condition of the load.

In the open-loop system shown in figure 6-32A, the input signal is applied to a controller. The controller positions the load in accordance with the input. The characteristic property of open-loop operation is that the action of the controller is entirely independent of the output.

The operation of the closed-loop system (fig. 6-32B) involves the use of followup. The output as well as the input determines the action of the controller. The system contains the open-loop components plus two elements which are added to provide the followup function. The output position is measured and a followup signal proportional to the output is fed back for comparison with the input value. The resultant is a signal which is proportional to the difference between input and output. Thus, the system operation is dependent on input and output rather than on input alone.



33.61
Figure 6-32.—Basic types of automatic servosystems: A. Open-loop; B. Closed-loop.

Of the two basic types, closed-loop control (also called followup control) is by far the more widely used, particularly in applications where speed and precision of control are required. The superior accuracy of the closed-loop system results from the followup function which is not present in open-loop systems. The closed-loop device goes into operation automatically to correct any discrepancy between the desired output and the actual load position, responding to random disturbances of the load as well as to changes in the input signal.

Controllable Factors

The missile control system is actually a closed-loop servomechanism in itself. It is able to detect roll, pitch, and yaw. and it is able to position the movable control surfaces in accordance with this attitude information. It is very important that you understand that the control surfaces are not positioned, on the basis of attitude information alone. It is again pointed out that movement information, guidance signals, and control surface position information are continuously analyzed in the computer network. The correction signals are continuously generated on the basis of all this information.

Overall Operation

Before studying the individual components of the missile control system, let us take a brief look at the operation of the system as a whole. Figure 6-33 shows the basic missile control system in block diagram form. Free gyroscopes provide physical (spatial) references from which missile attitude can be determined. For any particular missile attitude, free gyro signals are sent from the gyroscopes to the computer network of the missile. These signals are proportional to the amount of roll, pitch, and yaw at any given instant. After these signals have been compared with other information (for example, guidance signals), correction signals result. The correction signals are orders to the controller to position the control surfaces. The purpose of the amplifier is to build the weak correction signals up to sufficient strength to cause actuation of the controller As in any closed-loop servosystem, followup information plays an important role. A followup mechanism continuously measures the positions of the control surfaces and relays signals back to the computer network.

EXTERNAL FOLLOWUP.-In addition to the internal followup which is actually measured by a mechanism, we can think of the missile's movement detecting devices as providing an external followup feature. The fact that the gyroscopes continuously detect changing missile attitude introduces the idea of external followup.

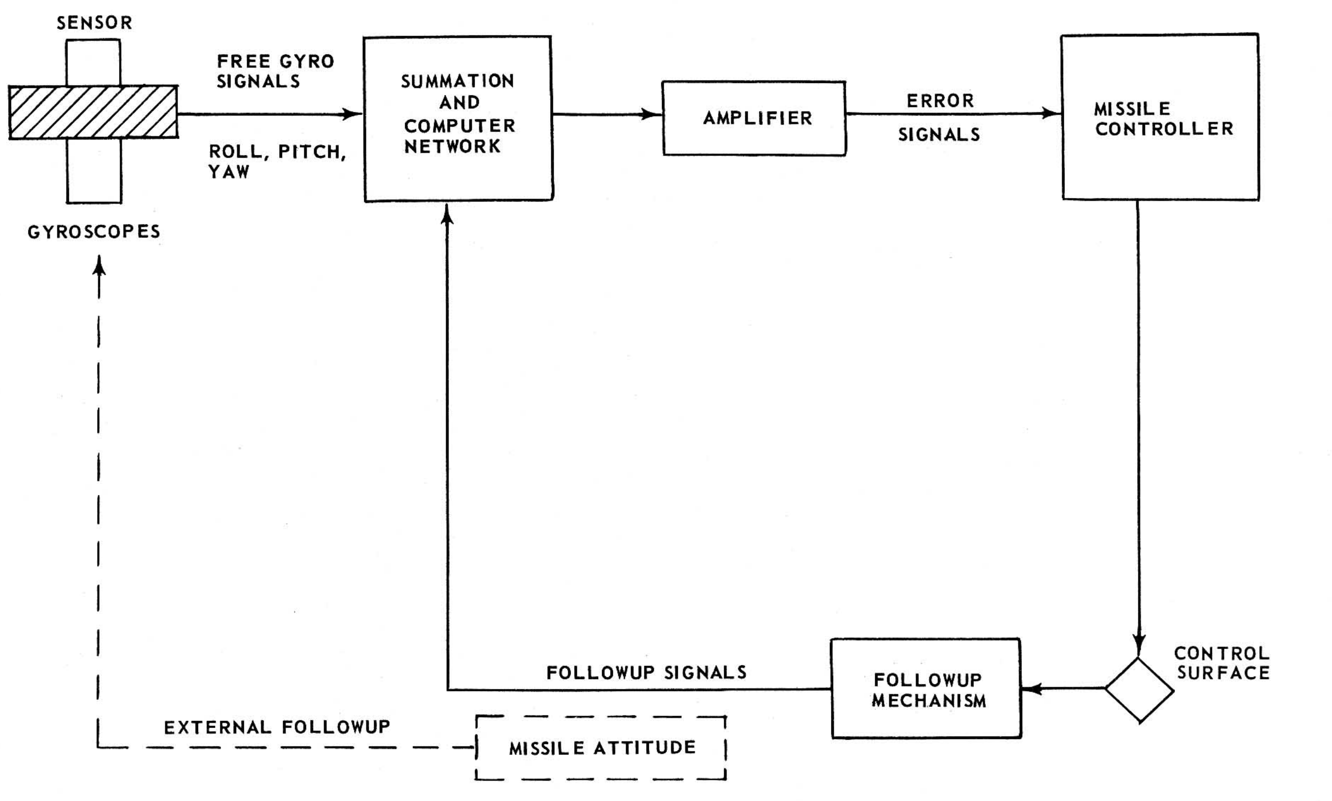


Figure 6-33.—Basic missile control system.

This is represented by the dotted line in figure 6-33.

Components of Missile Control Systems

Figure 6-33 have named parts of a missile control system and some of the components have been discussed. The components may be grouped according to their functions. They cannot be strictly compartmentalized as they must work together and there is overlapping. Devices for detecting missile movement may be called error-sensing devices. The amount and direction of error must be measured by a fixed standard; reference devices provide the signal for comparison. Correction-computing devices compute the amount and direction of correction needed and correction devices carry out the orders to correct any deviation. Power output devices amplify the error signal, but the prime purpose is to build up a small computer output signal to a value great enough to operate the controls. The use of feedback loops provides for smooth operation of the controls.

Do not confuse the missile control system with the weapons control system. The weapons direction system and the fire control systems and their related components comprise the weapons control system. These shipboard equipments control all weapons aboard, including guns, missile s, and torpedoes. The missile control systems are in the missile, and may receive direction from shipboard equipment.

CONTROLLER AND ACTUATOR UNITS

A controller unit in a missile control system responds to an error signal from a sensor. There are several types of controller units, and each type has some feature that makes it better suited for use in a particular missile system.

Solenoids

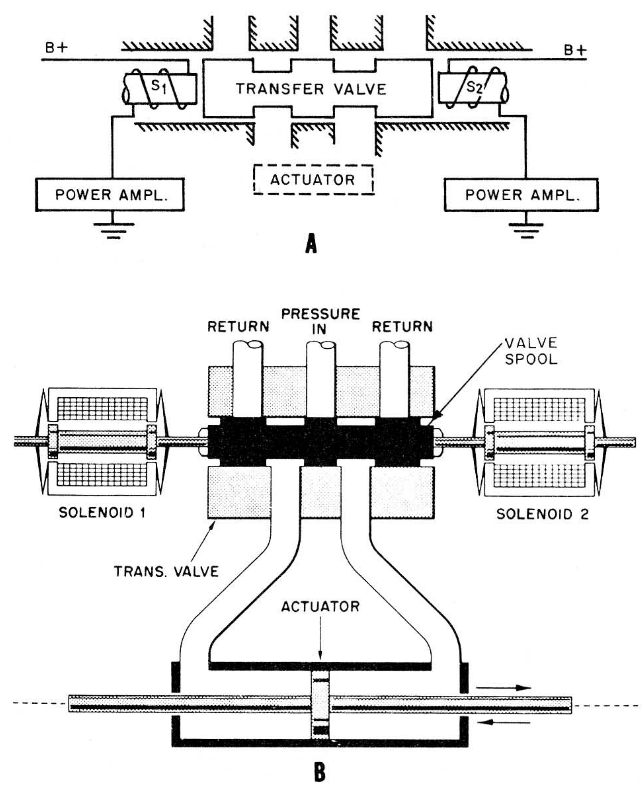
A solenoid consists of a coil of wire wound around a nonmagnetic hollow tube; a moveable soft iron core is placed in the tube. When a magnetic field is created around the coil by current flow through the winding, the core will center itself in the coil. This makes the solenoid useful in remote control applications since the core can be mechanically connected to valve mechanisms, switch arms, and other regulating devices. Two solenoids can be arranged to give double action in certain applications.

Transfer Valves

Figure 6-34 shows an application in which two solenoids are used to operate a hydraulic transfer valve. The object is to move the actuator which is mechanically linked to a control surface or comparable device.

The pressurized hydraulic fluid, after it leaves the accumulator, is applied to the transfer valve shown in figure 6-34B. The valve is automatically operated by the response of the solenoids to electrical signals generated by the missile computer network.

If solenoid #1 in the figure is energized, it will cause the valve spool to move to the left. This will permit pressurized fluid to be ported to the



33.184

Figure 6-34.—Transfer valve: A. Closed position (schematic); B. Hydraulic transfer valve and actuator.

right-hand side of the actuator and cause its movement to the left. If solenoid #2 is energized, the valve spool will move to the right, causing actuator movement to the right in the same manner. When neither coil is energized, the valve is closed (fig. 6-34A).

The transfer valve just described has one disadvantage in that it operates in an on-off manner. This means that it provides positive movement of the control surfaces, either full up or full down, full right or full left. A finer control is usually more desirable in missile systems. The servovalve (fig. 6-35) provides this control. With neither of the windings energized (or a balanced current flowing through both), the magnetic reed is centered as shown (fig. 6-35). In this condition, high pressure hydraulic fluid from the input line cannot pass to the actuator since the center land of the spool valve blocks the inlet port. The pressurized fluid flows through the alternate routes, through the two restrictors (fixed orifice), passes through the two nozzles, and returns to the sump without causing

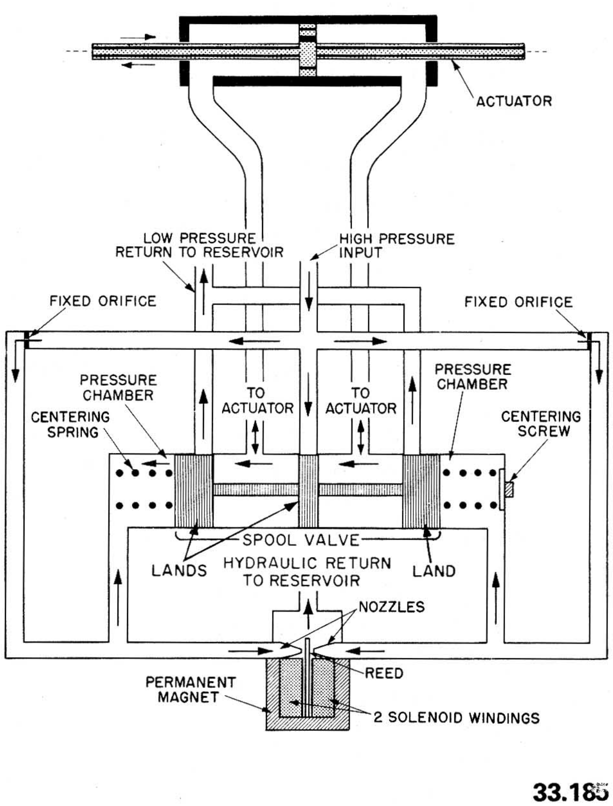


Figure 6-35.—Servovalve.

any movement of the actuator. If the right-hand solenoid is energized, the magnetic reed will move to the right, blocking off the flow of high pressure fluid through the right-hand nozzle. Pressure will build up in the right pressure chamber. This will move the valve to the left. In moving left, the center land will open the high pressure inlet and permit fluid flow directly to the right-hand side of the actuator. At the same time, the left-hand land of the spool will open the low pressure return line and permit flow to the sump from the left-hand side of the actuator. This process will cause actuator movement to the left. By energizing the left-hand solenoid, the reed will move to the left, and the entire process will be reversed, the actuator then being moved to the right. The actuator can be used to physically position a control surface.

Relays

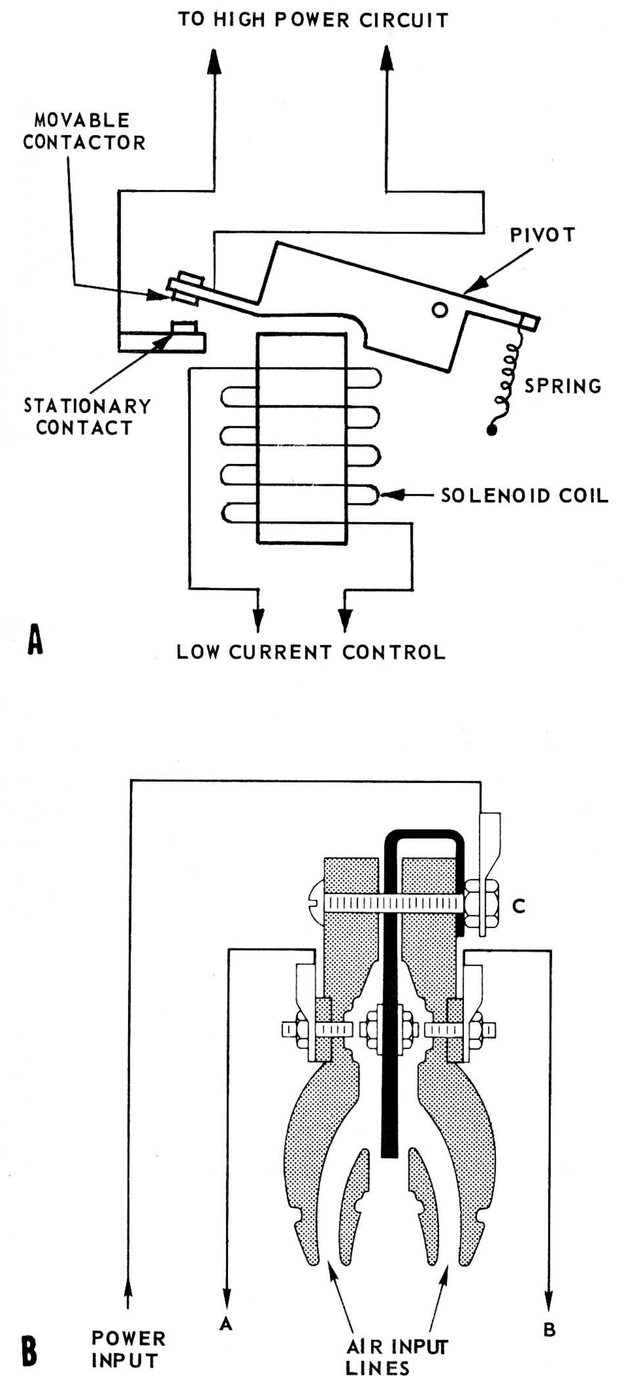
Relays are used for remote control of heavy-current circuits. The relay coil may be designed to operate on very small signal values, such as the output of a sensor. The relay contacts can be designed to carry heavy currents.

Figure 6-36A shows a relay designed for controlling heavy load currents. When the coil is energized, the armature is pulled down against the core. This action pulls the moving contact against the stationary contact, and closes the high current circuit. The relay contacts will stay closed as long as the magnetic pull of the coil is strong enough to overcome the pull of the spring.

The relay just described has a fixed core. However, some relays resemble a solenoid in that part of the core is a moveable plunger. The moving contacts are attached to the plunger, but are electrically insulated from it.

Figure 6-36B shows a form of relay that can be used in a pneumatic control system. Two air pressure lines are connected to the air input ports. The relay operates when its arm is displaced by air pressure. A modified design of this type relay might be used in a hydraulic-electric system, in which case the diaphragm would be moved by hydraulic fluid pressure.

The actuator unit is the device that converts the error detected by the sensor into mechanical motion to operate the appropriate control device that will correct the error or compensate for it. The actuator must be able to respond rapidly, with a minimum time lag between detection of error and movement of the flight control surfaces or other control device. At the same time, it must produce an output proportional to the error signal and powerful enough to handle the load. Figure 6-34B shows a double-acting piston-type hydraulic actuator in which hydraulic fluid under pressure can be applied to either side of the piston. The piston is mechanically connected to the load.



144.32
Figure 6-36.—Some types of relays in missiles: A. Low current relay; B. Air-actuated relay.

PRINCIPAL TYPES

Actuating units use one or more of three energy transfer methods: hydraulic, pneumatic, or electrical. Each of these has certain advantages, as well as certain design problems, mentioned earlier in this chapter. Control devices make use of more than one method of energy transfer but are classified according to the major one used. Combinations are hydraulic-electric, and pneumatic-electric. Mechanical linkages are used to some extent by all of them.

Hydraulic Actuators

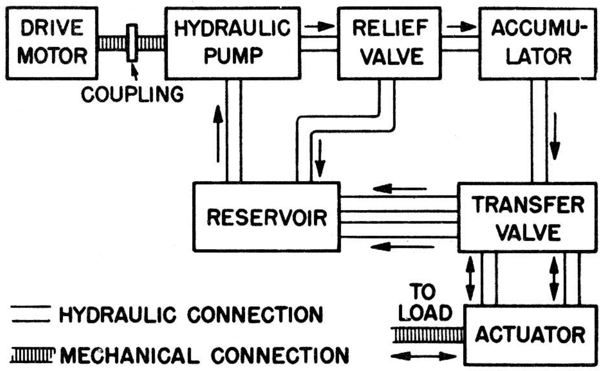
Pascal's Law states that whenever a pressure is applied to a confined liquid, that pressure is transferred undiminished in all directions throughout the liquid, regardless of the shape of the confining system.

This principle has been used for years in such familiar applications as hydraulic door stops, hydraulic lifts at automobile service stations, hydraulic brakes, and automatic transmissions.

Generally, hydraulic transfer units are quite simple in design and construction. One advantage of a hydraulic system is that it eliminates complex gear, lever, and pulley arrangements. Also, the reaction time of a hydraulic system is relatively short, because there is little slack or lost motion. A hydraulic system does, however, have a slight efficiency loss due to friction.

HYDRAULIC - ELECTRIC CONTROL DEVICES. - The hydraulic-electric method of actuating movable control surfaces has been used more than any other type of system. As previously mentioned, the most important advantages of this type of system are the high speed of response and the large forces available when using hydraulic actuators.

You have studied several of the components shown in the simplified block diagram of a hydraulic-electric controller (fig. 6-37). This



33.182
Figure 6-37.—Basic hydraulic controller.

system is comprised of (1) a RESERVOIR which contains the supply of hydraulic fluid, (2) a MOTOR and a PUMP to move the fluid through the system, (3) a RELIEF VALVE to prevent excessive pressures in the system, (4) an ACCUMULATOR which acts as an auxiliary storage space for fluid under pressure and as a damping mechanism which smoothes out pressure surges within the system, and (5) a TRANSFER VALVE which controls the flow of fluid to the actuator.

Most of these components of the system have been covered in the preceding pages. The theory of hydraulic piston displacement is explained in *Fluid Power*, NAVTRA 16193 and hydraulic pumps are also illustrated and explained. Pumps used in missile systems generally fall into two categories-gear and piston.They are usually driven by an electric motor within the missile.,

Electric Actuators

The electric actuators used to control the deflection of control surfaces are replacing many of the hydraulic systems now used in some missiles. Figure 6-38 shows a mechanical schematic of an actuator used in the Standard Missile. The missile has four actuators and, since the operation of each is identical, only one will be discussed.

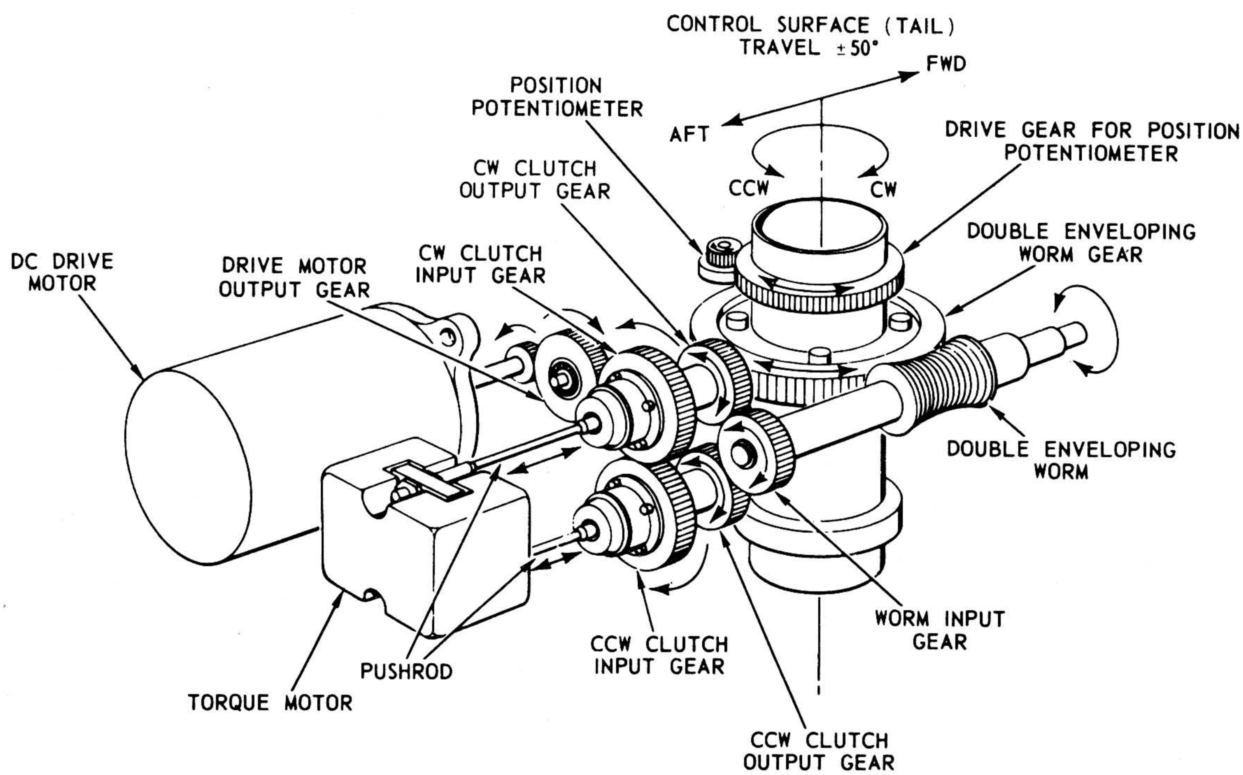


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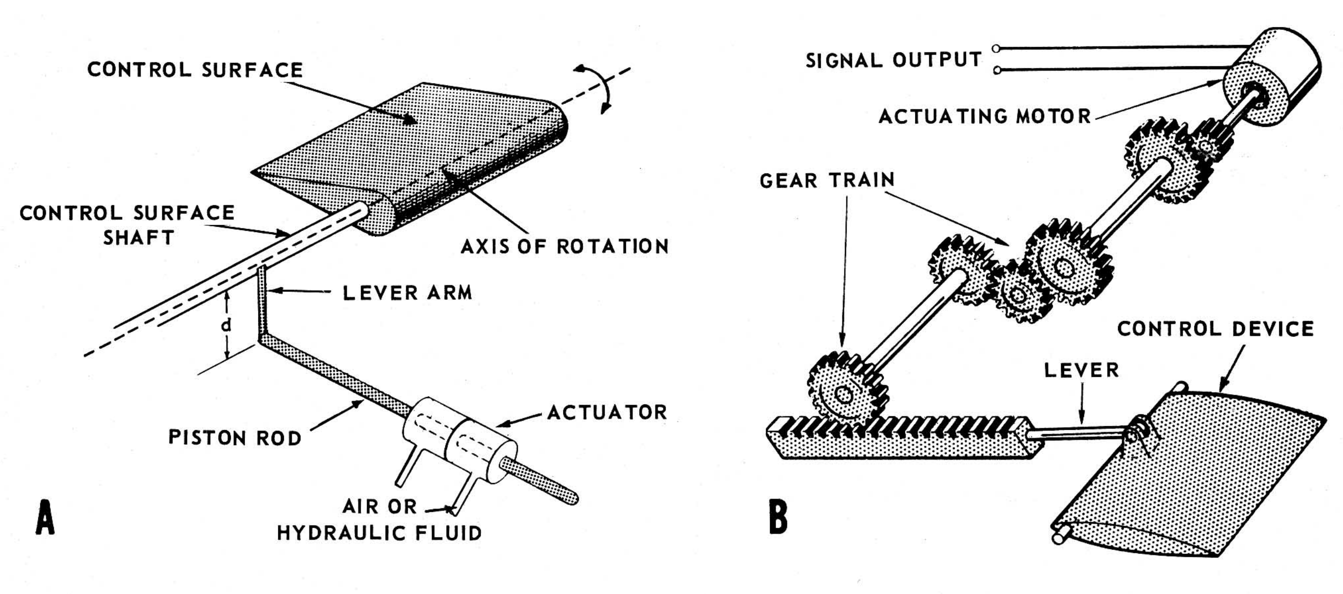
Figure 6-38.—(U) Electric Tail Actuator, Mechanical Schematic Diagram.



33.194

Figure 6-39.—Mechanical linkages: A. Actuator and load linked by lever arm; B. Gear train type of mechanical linkage.

The drive motor (fig. 6-38) runs continually (after missile activation) in the same direction so that the drive motor output gear, and the CW and CCW clutch input ears rotate continually in the direction indicated by the arrows. Either clutch output gear rotates in the direction of the corresponding clutch input gear when the clutch is engaged; either clutch output gear is free to turn in either direction when the corresponding clutch is disengaged. Since only one clutch can be engaged at a given time, one of the clutch output gears is always free to turn in either direction. Either clutch is engaged when the corresponding pushrod is advanced forward into the clutch by the torque motor in response to the output of the missile control system.

Prior to the missile control system activation, the torque motor receives no input from the system, consequently both clutches are disengaged and neither clutch output gear rotates. After system activation, one of the two coils in the torque motor is energized, (depending on the signal output from the control system) resulting in the engagement of one of the clutches. When the CW clutch is engaged, the CW output gear rotates in the direction of the CW clutch input gear rotation, and drives the worm input gear to cause CW rotation of the control surface. When the CCW clutch is engaged, the control surface rotates CCW.

Mechanical Linkage

We have discussed the various control systems, but have not discussed in detail the mechanical means of linking the flight control surfaces to the actuator. In addition to providing a coupling means, the linkage may also be used to amplify either the force applied or the speed of movement.

A mechanical linkage between an actuator and a load is shown in figure 6-34A. The distance d on the drawing represents the distance from the control surface shaft to the point where the force is applied. The control surface moves because force exerted by the piston is applied at a distance from the axis of rotation, and thus produces a torque. Other mechanical linkages may consist of an arrangement of gears, levers, or cables (fig. 6-39B).

A number of mechanical systems may be grouped together to form a combination system.

This system uses levers, cables, pulleys, and a hydraulic actuator. However, a system using this kind of control is not suited for high speed missiles.

SUMMARY

This chapter explained the hydraulic systems used in some missiles and missile launchers. The hydraulic principles are the same in all of them; in application of the principles they differ only in details. Each hydraulic power drive has an A-end pump and a B-end motor; some systems use a radial piston type, and other systems use axial piston types or parallel piston types. All are started. by an electric motor, which may vary in size, manufacture, and other details.

Methods of maintenance and repair of filters, valves, pumps, and motors common to all the system are given. Within the limitations of the facilities available, a GMM 1 or C should be able to repair and maintain most parts of a hydraulic system. The size rather than the complexity of the component may be the determining factor. With an understanding of how the parts work together and the aid of parts lists and illustrations, checkoff lists, MRCs, and maintenance OPs and ODs, the GMM 1 or C can adjust and repair the most complex parts and train his men in the maintenance of the system. Although the present day trend is to replace malfunctioning units with new ones, avoiding time-consuming disassembly and repair, the new unit must operate correctly when in place. It may require delicate adjustment after installation. To do this you need to know how it operates, so you can understand how to adjust it.

Since so much of the launching system is dependent on the interaction of electric and hydraulic components, testing of the system operation will be discussed further in a later chapter.