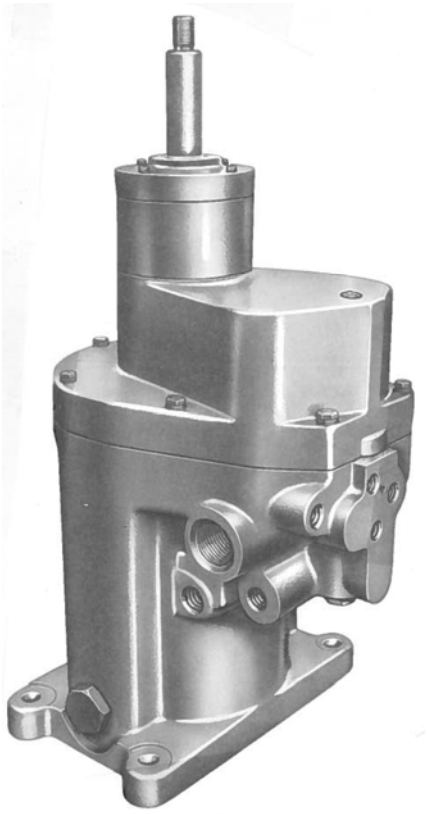
WOODWARD

Product Manual 89005
(Revision NEW, 1969)
Original Instructions



Hydraulic Amplifier (Servo Controlled)

Installation and Operation Manual

General Precautions

Read this entire manual and all other publications pertaining to the work to be performed before installing, operating, or servicing this equipment.

Practice all plant and safety instructions and precautions.

Failure to follow instructions can cause personal injury and/or property damage.

Revisions

This publication may have been revised or updated since this copy was produced. To verify that you have the latest revision, check manual *26311* , *Revision Status & Distribution Restrictions of Woodward Technical Publications*, on the *publications page* of the Woodward website:

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Proper Use

Any unauthorized modifications to or use of this equipment outside its specified mechanical, electrical, or other operating limits may cause personal injury and/or property damage, including damage to the equipment. Any such unauthorized modifications: (i) constitute "misuse" and/or "negligence" within the meaning of the product warranty thereby excluding warranty coverage for any resulting damage, and (ii) invalidate product certifications or listings.

Translated Publications

If the cover of this publication states "Translation of the Original Instructions" please note:

The original source of this publication may have been updated since this translation was made. Be sure to check manual *26311* , *Revision Status & Distribution Restrictions of Woodward Technical Publications*, to verify whether this translation is up to date. Out-of-date translations are marked with ⚠. Always compare with the original for technical specifications and for proper and safe installation and operation procedures.

Revisions—Changes in this publication since the last revision are indicated by a black line alongside the text.

Contents

Illustrations and Tables

Warnings and Notices

Important Definitions

This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.

- **DANGER**—Indicates a hazardous situation which, if not avoided, will result in death or serious injury.
- **WARNING**—Indicates a hazardous situation which, if not avoided, could result in death or serious injury.
- **CAUTION**—Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.
- **NOTICE**—Indicates a hazard that could result in property damage only (including damage to the control).
- **IMPORTANT**—Designates an operating tip or maintenance suggestion.

⚠WARNING

Overspeed / Overtemperature / Overpressure

The engine, turbine, or other type of prime mover should be equipped with an overspeed shutdown device to protect against runaway or damage to the prime mover with possible personal injury, loss of life, or property damage.

The overspeed shutdown device must be totally independent of the prime mover control system. An overtemperature or overpressure shutdown device may also be needed for safety, as appropriate.

⚠WARNING

Personal Protective Equipment

The products described in this publication may present risks that could lead to personal injury, loss of life, or property damage. Always wear the appropriate personal protective equipment (PPE) for the job at hand. Equipment that should be considered includes but is not limited to:

- **Eye Protection**
- **Hearing Protection**
- **Hard Hat**
- **Gloves**
- **Safety Boots**
- **Respirator**

Always read the proper Material Safety Data Sheet (MSDS) for any working fluid(s) and comply with recommended safety equipment.

⚠WARNING

Start-up

Be prepared to make an emergency shutdown when starting the engine, turbine, or other type of prime mover, to protect against runaway or overspeed with possible personal injury, loss of life, or property damage.

⚠WARNING

Automotive Applications

On- and off-highway Mobile Applications: Unless Woodward's control functions as the supervisory control, customer should install a system totally independent of the prime mover control system that monitors for supervisory control of engine (and takes appropriate action if supervisory control is lost) to protect against loss of engine control with possible personal injury, loss of life, or property damage.

NOTICE

Battery Charging Device

To prevent damage to a control system that uses an alternator or battery-charging device, make sure the charging device is turned off before disconnecting the battery from the system.

Electrostatic Discharge Awareness

NOTICE

Electrostatic Precautions

Electronic controls contain static-sensitive parts. Observe the following precautions to prevent damage to these parts:

- **Discharge body static before handling the control (with power to the control turned off, contact a grounded surface and maintain contact while handling the control).**
- **Avoid all plastic, vinyl, and Styrofoam (except antistatic versions) around printed circuit boards.**
- **Do not touch the components or conductors on a printed circuit board with your hands or with conductive devices.**

To prevent damage to electronic components caused by improper handling, read and observe the precautions in Woodward manual *82715*, *Guide for Handling and Protection of Electronic Controls, Printed Circuit Boards, and Modules*.

Follow these precautions when working with or near the control.

1. Avoid the build-up of static electricity on your body by not wearing clothing made of synthetic materials. Wear cotton or cotton-blend materials as much as possible because these do not store static electric charges as much as synthetics.
2. Do not remove the printed circuit board (PCB) from the control cabinet unless absolutely necessary. If you must remove the PCB from the control cabinet, follow these precautions:
   - Do not touch any part of the PCB except the edges.
   - Do not touch the electrical conductors, the connectors, or the components with conductive devices or with your hands.
   - When replacing a PCB, keep the new PCB in the plastic antistatic protective bag it comes in until you are ready to install it. Immediately after removing the old PCB from the control cabinet, place it in the antistatic protective bag.

Chapter 1.
General Information

The Woodward hydraulic amplifier is a linear, pilot-operated servo actuator used where relatively large forces are required to operate power control mechanisms such as turbine steam valves or the fuel control linkages of large engines. The servo controlled hydraulic amplifier is used in conjunction with a Woodward EG-R actuator and EG-A or EG-M electric control unit. The EG-R actuator, in response to an electric input signal from the electric control unit, controls oil flow to or from an integral control servo piston in the hydraulic amplifier. The control piston in the amplifier controls the movement of a pilot valve which directs high pressure oil from a separate external source (usually the prime mover lubricating system or an auxiliary pump) to the open (increase) side of a large double-acting power servo cylinder. Closing (decrease) forces are provided by a combination of oil at supply pressure and return spring force acting on the closing side of the power cylinder piston. The power cylinder piston, in turn, is connected to the prime mover power control mechanism.

In most applications, the power servo piston return spring (or springs) is specifically designed to counteract the unbalanced forces tending to open the steam valve or other fuel control. This, with the differential power piston, provides a balanced system with a linear response over the full stroke of the amplifier. Secondarily, the return spring ensures closing in the event of loss of oil pressure and, in the closed position during shutdown. In some applications, the return spring may provide only a low force biasing load. Various return spring preloads within a range of 50–1400 lb (222–6227 N) may be used depending on the closing forces of the steam valve itself (or other fuel control) and for the steam valve unbalance forces.

Two models of servo controlled hydraulic amplifiers are covered in this manual. Both models are basically identical except for the diameter of their respective power servo cylinders. The large model (7-1/4 inches [184 mm] diameter) is capable of 1800 ft-lb (2441 J) of work at its maximum stroke of 3 inches (76 mm) at 300 psi (2068 kPa) oil pressure (maximum) and develops a stalled force of approximately 8500 lb (37.8 kN). The small model (5-1/4 inches diameter [133 mm]) is capable of 600 ft-lb (814 J) of work at its maximum stroke of 2-1/2 inches (64 mm) at 300 psi (2068 kPa) oil pressure (maximum) and develops a stalled force of approximately 2500 lb (11.1 kN). The work output of either model amplifier is proportional to the oil pressure and length of the stroke utilized.

Either model amplifier may be equipped with one or more special features to suit the requirements of the particular application in which it is used. In applications which require opening of the steam valve or fuel control preparatory to starting the prime mover, and which also have a source of pressurized oil available, a starting oil port is provided in the amplifier case. The port allows oil pressure to be used to hydraulically raise the amplifier pilot valve plunger since the EG-R actuator is inoperative prior to start-up of the prime mover. The starting oil supplied to the normal supply port in the amplifier is then directed by the pilot valve to the opening side of the power cylinder. The degree to which the steam valve or fuel control can be opened for starting is dependent on the oil pressure available, the valve or control opening forces, and the preload on the return spring. In addition to the above, an oil transfer sleeve may be optionally used to adapt the amplifier for use in differing applications.

The oil transfer plug is used in all “standard” applications (opening of steam valve or fuel control for cranking not required) and also in those applications where starting provisions are required and the oil pressure available for operating the amplifier is at or above the minimum pressures necessary for normal amplifier operation. The minimum operating pressure is largely determined by the preload and rate of the power piston return spring. The starting valve is substituted for the plug in applications where the oil pressure available for starting (such as from a hand pump) is below the minimum required for normal operation but is within the range of 20–25 psi (138–172 kPa).

The oil transfer sleeve is substituted for the plug in applications where a higher opening force is necessary and an equivalent decrease in closing force can be tolerated. The sleeve blocks the flow of oil to the closing side of the power cylinder and simultaneously vents the area to drain. Use of the sleeve converts the double-acting cylinder to single-acting and increases the effective piston area in the opening direction and thus the opening force available from the amplifier. The closing force is reduced to that of the return spring alone. The work capacity of the large amplifier in the opening direction is increased to 3000 ft-lb (4068 J) with a stalled force of 11 000 lb (48.9 kN).

Refer to manual 37710 for complete information concerning the EG-R actuator.

Chapter 2.
Installation

Refer to Figures 2-1 and 2-2 for overall dimensioning and connection data for the small or large model hydraulic amplifier.

The same grade and type of lubricating oil used for the prime mover will generally be satisfactory for use in the hydraulic amplifier. The oil supply to the amplifier may be provided directly from the prime mover lubricating oil system or from an auxiliary pump independent of the prime mover. If a good transient response (power piston movement in the order of 30 inches/second [762 mm/s]) is required, it is essential that the amplifier be provided with an adequate supply of oil. For the 5-1/4 inch amplifier, this rate of movement requires a flow of 330 in^3/s (5408 cm^3) or 85 US gal/min (322 L/min). The 7-1/4 inch amplifier requires a flow of 780 in^3/s (12 782 cm^3) or 200 US gal/min (757 L/min). Accumulators will be required to provide the necessary flow rate if it is impractical to do so directly from a pump.

The amplifiers should normally be mounted upright and must be at a level lower than that of the EG-R actuator. All hydraulic lines between the actuator and amplifier must have a continuous downward slope to avoid entrapment of air. Use 3/8” O.D. tubing for these connections. Connect the ports in the EG-R actuator to the correspondingly identified ports in the amplifier (A to A, C to C, E to E). Connect port D (5-1/4 inch amplifier only) to drain. All other connecting lines should be as large, short, and straight as possible. Elbows should be avoided. The drain lines should receive equal consideration. If the prime mover mounting pad has integral provisions for drain to sump or reservoir, the sealing cup (if any) in the bottom of the amplifier case may be removed to provide direct draining through the mounting pad.

Where the amplifier has porting provisions for starting oil applications, and regardless of whether starting oil is used or not, the starting oil port must be connected to drain for normal operation. The use of a 3-way valve in the starting oil line to the pilot valve plunger is recommended in applications using starting oil. If the starting oil port is plugged or otherwise closed during operation, normal leakage will result in hydraulic locking of the pilot valve plunger and render the amplifier inoperative. The area under the pilot valve plunger is internally drained in amplifiers which do not have porting provisions for starting oil.

Make certain the linkage connecting the amplifier to the fuel control or steam valve operates freely and has minimum backlash. Depress the amplifier piston rod sufficiently to compensate for expansion (usually 1/8 to 1/4 inch [3.2 to 6.4 mm]) and ensure closing of the fuel control or steam valve at shutdown when the prime mover is hot. In some cases, differential expansion may require that these dimensions be Increased. Adjust the connecting turnbuckle until the fuel control or steam valve is in the fully closed position with the rod depressed.

NOTICE **Considerable oil spray over a large area will occur if the amplifier cover is removed and the amplifier operated while under pressure.**

Provide a supply of oil at normal operating pressure for the amplifier in that particular application and connect to the amplifier supply port. Temporarily connect a separate line from the supply to port E on the amplifier using a pressure regulating valve. Turn on the oil supply to the amplifier and regulating valve. Slowly open the regulating valve and gradually increase the pressure until the fuel control or steam valve opens to the maximum power position for that application. See the specifications sheet furnished with the amplifier for the required piston rod travel. If necessary, back out the maximum stroke adjustment screw (see Figure 2-1 or 2-2) to obtain the required travel. Turn the adjustment screw in until slight contact is made and then back out 1/8 to 1/4 turn. Turn off the oil supply to the amplifier and bleed off any pressure in the line from the regulating valve to port E. Disconnect all temporary lines and make permanent connection as required.

Start the prime mover and allow to hunt until all air in the control lines to the amplifier rises to the EG-R actuator and is eliminated. Crack the connections at the amplifier until oil appears and then retighten. Vary the prime mover speed over the full range to obtain maximum excursion of the control servo piston in the amplifier to aid in expelling any air in internal amplifier passages.

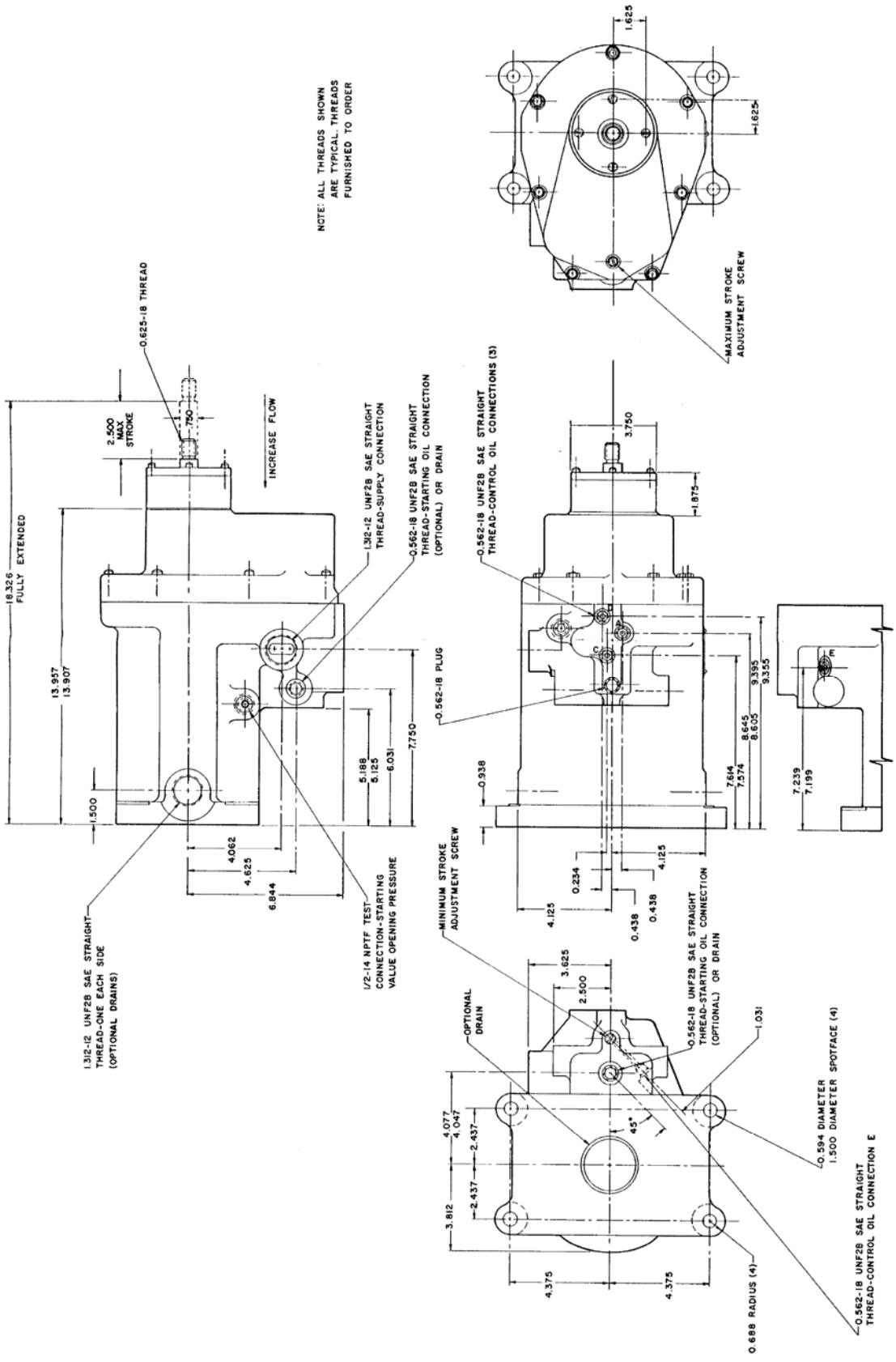

Figure 2-1. Typical Outline Drawing of 5-1/4 inch Amplifier
(Do not use for construction.)

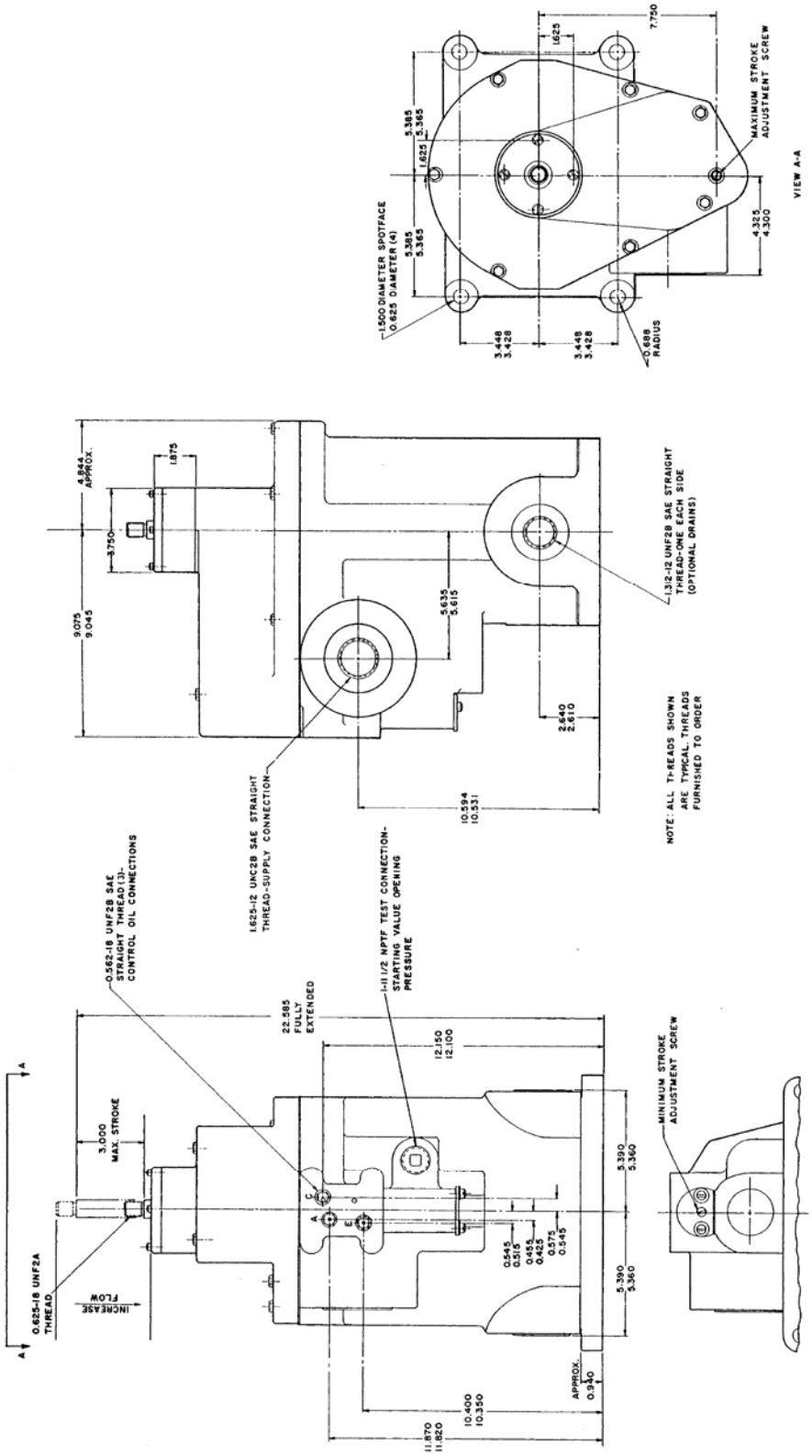

Figure 2-2. Typical Outline Drawing of 7-1/4 inch Amplifier
(Do not use for construction.)

Chapter 3.
Operation

Refer to Figure 3-1 for a schematic diagram of the hydraulic amplifier. The control ports in the hydraulic amplifier are connected to correspondingly identified ports in the EG-R actuator. Actuator buffer compensation system pressure (port A) always tends to move the amplifier control servo piston downward (decrease fuel or steam). Actuator control pressure (port E) tends to move the control piston upward (increase fuel or steam). Pressure in the compensation or buffer port and the control port are constant at steady state for all EG-R servo positions with control oil pressure being approximately one half the compensation oil pressure. The Control oil pressure varies during a transient while the compensation oil pressure changes slightly. The variations in control oil pressure causes the EG-R servo to move. Actuator pump output pressure (port C) is connected to annular seal grooves in the control piston and piston rod bores to ensure that any leakage oil comes from a part of the hydraulic circuit where it does not adversely affect control pressure or flows.

The control piston is connected to one end of a floating lever in the amplifier. Any change in position of the control piston is transmitted to the floating lever. The movement of the floating lever is transmitted to the pilot valve plunger which controls the flow of oil to and from the power servo cylinder.

Pressurized oil from the external supply source is directed from the amplifier inlet to the pilot valve plunger and to the closing (decrease) side of the power piston. The starting valve has no function during normal operation, being held in the open position by normal oil supply pressure. A functional description of the starting valve will be found at the end of this section.

When the electric control unit senses an underspeed condition and signals for an increase in speed (power), the pilot valve in the EG-R actuator directs oil to port E in the amplifier at increased pressure. The increase in control pressure input displaces the amplifier control servo piston upward. This causes an increase in pressure in the buffer system (port A) which, in turn, displaces the buffer piston in the EG-R actuator. Refer to the applicable bulletin for operation of the EG-R actuator. The upward movement of the amplifier control piston raises one end of the floating lever which lifts the amplifier pilot valve plunger, admitting oil at supply pressure (less the pressure drop occurring across the pilot valve) to the opening (increase) side of the power servo cylinder. Although the oil pressure on the opening side of the power piston is lower than that on the closing side, it acts over a much larger surface area and causes the piston to move in the opening direction and increases power. As the power piston moves, the end of the floating lever connected to the piston rod also moves in the same direction and gradually re-centers the land on the pilot valve over the oil control port. This stops movement of the power piston just as the fuel control or steam valve reaches its new position as called for by the electric control unit. The yield spring on the power piston rod over the floating lever does not have any function other than during starting of the prime mover and then only where there is a prerequisite to open the fuel control or steam valve for starting.

During an on-speed condition, the control signal to port E is maintained at a given pressure and the amplifier pilot valve plunger is held in its centered position covering the oil control port. With flow to the opening side of the power piston blocked, except to compensate for leakage, the power piston will maintain its position in relation to the speed setting of the electric control unit and load on the prime mover.

When the electric control unit senses an overspeed condition and signals for a decrease in speed (power), the pilot valve in the EG-R actuator allows oil to drain from port E in the amplifier. The decrease in control pressure input allows the buffer system pressure (port A) to displace the amplifier control servo piston downward. The downward movement of the control piston lowers one end of the floating lever and pushes the pilot valve plunger down, allowing oil to drain from the opening side of the power piston. The oil pressure acting on the opposite side of the power piston along with the return spring force causes the power piston to move in the closing direction (decrease power). Movement of the piston continues until the pilot valve plunger is again re-centered by the floating lever.

In those applications which require that the steam valve or fuel control be opened as a prerequisite to starting the prime mover, one of two methods is used depending on the available source of pressurized oil for operating the amplifier. Either method requires an additional connection to the starting oil port in the amplifier case. Make the connection using a 3-way valve with one port connected to the drain. This allows oil pressure (25 psi [172 kPa] maximum) to be used to raise the pilot valve plunger for starting since the EG-R actuator is inoperative. The yield spring permits one end of the floating lever to move upward when starting oil is applied to the plunger. The 3-way valve must be turned to drain after starting, otherwise oil will be trapped under the pilot valve plunger and render the amplifier inoperative.

In high-pressure starting-oil systems, starting oil need only be supplied to the amplifier supply port after raising the pilot valve plunger. The starting oil is directed to the opening side of the power piston thus opening the steam valve or fuel control.

In low-pressure-starting-oil system, the starting valve minimizes the forces acting on the closing side of the power piston. Starting oil pressure within the range of 20–30 psi (138–207 kPa) (typical) cannot generate sufficient force on the opening side of the power piston to overcome the combined forces of low starting oil pressure and spring force on the closing side of the piston. In shutdown position, the starting valve blocks the flow of starting oil to the closing side of the power piston and simultaneously opens the area to drain. When the prime mover starts and the normal supply pressure becomes greater than the starting oil pressure, the increasing pressure is sensed through the axial passage in the starting valve plunger. Oil flow into the area under the large diameter of the plunger begins to lift the plunger against the opposing spring force. When the pressure of the supply oil reaches a predetermined pressure, which is somewhat less than operating pressure, the plunger snaps to the open position, closing the drain passage and opening the control port which admits supply oil to the closing side of the power piston. The starting valve remains in the open position during normal operation. At shutdown, spring force returns the plunger to the closed position.

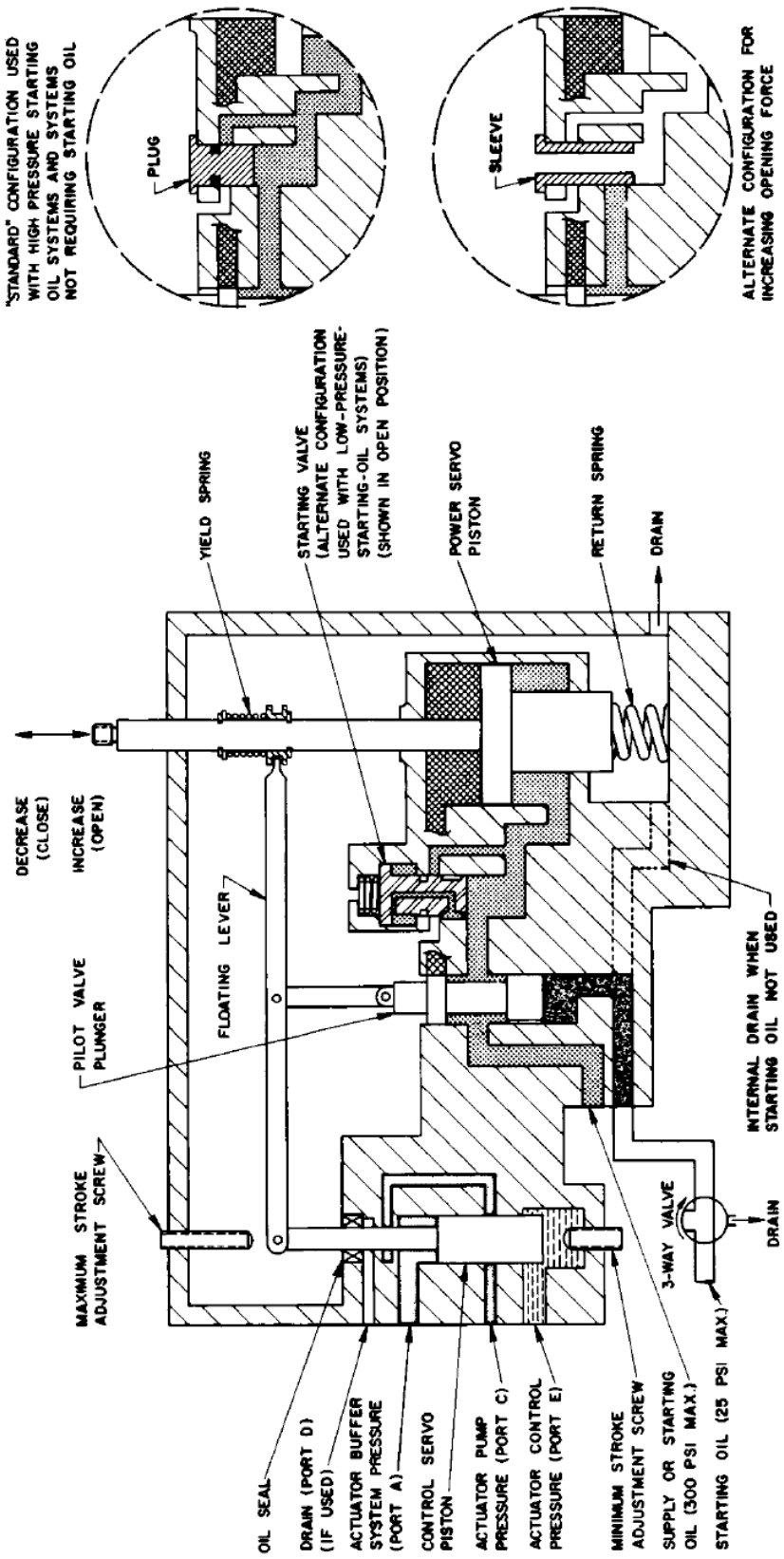

Figure 3-1. Hydraulic Amplifier Schematic Diagram

Chapter 4. Adjustments

Introduction

Refer to the specifications sheet furnished with the particular amplifier to obtain the required operating pressures and piston travel adjustments after repair or overhaul, While the test and adjustment parameters vary with the particular amplifier, the test and adjustment procedures are essentially identical. Connect a supply of oil at 65–75 °F (18–24 °C) to the amplifier supply port. The oil supply pressure should be either 60 or 80 psi (414 or 552 kPa) depending on the particular amplifier (see specifications sheet). Provide two auxiliary test hoses from the oil supply source for connection to the various control ports in the amplifier as required by the various tests and for adjustment procedures. Install a pressure regulating valve in one line and a shutoff valve in the other. Not all of the following tests or adjustments are applicable to every amplifier and need not be performed unless called for by the applicable specifications sheet, Make certain the starting oil port is open to drain during all tests and adjustments except as otherwise noted. Ports A, C, D (if any), and E must be open at all times except as otherwise noted. Provide an adequate drain from the amplifier back to the oil supply sump or reservoir. Refer to Figure 2-1 or 2-2 for an outline drawing of the 5-1/4 or 7-1/4 inch amplifier.

Minimum Stroke Adjustment

1. Connect auxiliary line with shutoff valve to port A. Open the valve.
2. Turn on oil supply to amplifier and adjust pressure to 60 psi (414 kPa) (5-1/4 inch amplifiers) or 80 psi (552 kPa) (7-1/4 inch amplifiers).
3. Adjust the minimum stroke adjustment screw to obtain a 0.005-0.010 inch (0.13–0.25 mm) (5-1/4) or 0.003-0.013 inch (0.08–0.33 mm) (7-1/4) movement (retraction) of the power servo piston rod. Turn the screw CW to increase the distance, CCW to decrease the distance.
4. Reduce the supply pressure to 0 psi (0 kPa), close the shutoff valve in the auxiliary line, and disconnect the line from port A.

Amplifier Closing Force (5-1/4 inch amplifiers only)

1. Connect the auxiliary line with pressure regulating valve to port E. Adjust the regulator for 20 psi (138 kPa) pressure to the amplifier.
2. Turn on oil supply to the amplifier. Slowly increase the pressure until the amplifier piston rod retracts 1/8 inch (3.2 mm) (including minimum stroke adjustment). The oil supply pressure at this point must not be less than 14.0 or 16.5 psi (97 or 114 kPa) (see specifications sheet).
3. Reduce the supply pressure to 0 psi (0 kPa) and close the regulating valve in the line to port E.

Maximum Stroke Adjustment

1. Connect the auxiliary line with pressure regulating valve to port E, if not already done. Open the regulator valve fully.
2. Turn on oil supply to amplifier and adjust pressure to 60 psi (414 kPa) (5-1/4) or 80 psi (552 kPa) (7-1/4).
3. Adjust the maximum stroke adjustment screw to obtain the specified movement (retraction) of the power servo piston rod (see specifications sheet). Turn the screw CW to decrease the distance, CCW to increase the distance.
4. Reduce the oil supply pressure to 0 psi (0 kPa) and close the regulating valve in the line to port E. Disconnect the auxiliary line from port E.

Minimum Starting Stroke

(See Specifications Sheet for applicability)

1. Connect the auxiliary line with pressure regulating valve to the starting oil port in the amplifier. Open the regulator valve fully.
2. Connect the auxiliary line with shutoff valve to port A. Open the valve.
3. Turn on the oil supply to the amplifier and adjust the pressure to 20 psi (138 kPa) (5-1/4) or 25 psi (172 kPa) (7-1/4). The power piston rod must retract the minimum distance given in the specification sheet.
4. Reduce the oil supply pressure to 0 psi (0 kPa) and close the valves in both auxiliary lines. Disconnect the auxiliary lines from the amplifier.

Starting Valve Operation

1. Remove pipe plug from test port in amplifier case (see Figure 2-1 or 2-2 for location) and connect a 0–100 psi (0–690 kPa) pressure gauge to port.
2. Turn on the oil supply to the amplifier and slowly increase the pressure while observing the pressure gauge. The gauge should show a sudden pressure increase from 0 psi (0 kPa) at the instant the starting valve opens. Note the pressure required to open the starting valve. See the specifications sheet for the required opening pressure range.
3. Reduce the oil supply pressure to 0 psi (0 kPa). Disconnect the gauge from the port in the amplifier and re-install the pipe plug.

Amplifier Hysteresis

1. Connect the auxiliary line with pressure regulator valve to port E.
2. Connect the auxiliary line with shutoff valve to port A. Open the valve.
3. Turn on the oil supply to the amplifier and adjust the pressure to 0 psi (0 kPa) (5-1/4) or 80 psi (552 kPa) (7-1/4).
4. Slowly open the pressure regulating valve in the auxiliary line to port E, increasing the pressure until the power servo piston rod retracts approximately 1/2 inch (13 mm) and then stops. Note the pressure in the “E’ line and note the pressure at which the direction of motion of the rod reverses. The pressure difference required to reverse the motion of the rod should not be greater than 2 psi (14 kPa).

Chapter 5.
Troubleshooting and Maintenance

Troubleshooting

A troubleshooting chart is provided in this section for use in determining probable causes and corrective actions for troubles which may be encountered in the field. Every possible trouble which may be experienced cannot be anticipated and may, in some instances, be due to faulty operation of other equipment used in conjunction with the amplifier. The effect of the electric control unit, EG-R actuator, and prime mover power control mechanism must be considered when troubleshooting apparent malfunctions of the hydraulic amplifier.

Amplifier troubles such as erratic operation and poor repeatability are usually caused by dirty oil. In many instances, this type of trouble can be corrected by flushing the unit with fuel oil or kerosene. The use of commercial solvents is not recommended as they may damage oil seals or gaskets.

Table 5-1. Troubleshooting Chart

Trouble	Probable Cause	Correction
Fuel control or steam valve will not open for starting (low-starting-oil-pressure systems).	Fuel control or steam valve sticking.	Disconnect linkage and check operation and force requirements of fuel control or steam valve.
	Starting valve plunger sticking in open position-plunger spring broken or missing.	Disassemble and clean amplifier. Check oil supply for contamination. Replace plunger spring.
	Starting oil pressure too low.	Increase starting oil pressure to a minimum of 20 psi (138 kPa). Do not exceed 25 psi (172 kPa).
Servo piston will not hold position—erratic over- or undershoot, full stroke either direction with minor speed or power correction.	Yield spring broken or missing.	Replace yield spring.
Fuel control or steam valve will not fully close at shutdown.	Fuel control or steam valve sticking.	Disconnect linkage and check operation of fuel control or steam valve.
	Incorrect minimum stroke adjustment.	Adjust minimum stroke of amplifier and/or connecting linkage to fuel control or steam valve. Refer to Installation chapter.
Fuel control or steam valve will not open to maximum power position.	Fuel control or steam valve sticking.	Disconnect linkage and check operation of fuel control or steam valve.
	Incorrect maximum stroke adjustment.	Adjust maximum stroke of amplifier as instructed in Installation chapter.
Amplifier goes to full open at start-up after installation.	Hydraulic lines between amplifier and EG-R actuator not properly connected.	Connect lines as instructed in Installation chapter.
Fuel control or steam valve will not open.	Low oil supply pressure.	Check prime mover lubricating oil or external oil supply system for proper operation.
	Fuel control or steam valve sticking.	Disconnect linkage and check operation of fuel control or steam valve. Check steam valve unbalance forces.
	Control servo piston sticking.	Disassemble and clean amplifier. Check oil supply for contamination.

Trouble	Probable Cause	Correction
Erratic or lagging amplifier response.	Air in hydraulic lines between EG-R actuator and amplifier.	Loosen connections at amplifier enough to establish a leak and bleed air from lines.
	Fuel control or steam valve sticking.	Disconnect linkage and check operation of fuel control or steam valve. Check steam valve unbalance forces.
	Fluctuating oil supply pressure–pump cavitation.	Check prime mover lubricating oil or external oil supply system for proper operation.
Fuel control or steam valve will not close.	Fuel control or steam valve sticking.	Disconnect linkage and check operation of fuel control or steam valve.
	Starting oil port not connected to drain or internal drain passages clogged.	Make proper connections to drain. Disassemble amplifier and clean drain passages.
	Starting valve plunger sticking in closed position-decrease side of servo piston open to drain.	Disassemble and clean amplifier. Check oil supply for contamination.
	Fatigued or broken power servo piston return spring–excessive leakage past servo piston.	Disassembly of amplifier to the extent necessary to replace the return spring or power servo piston is not recommended in the field unless absolutely necessary.

Maintenance

Disassembly

Refer to Figure 5-1 or 5-2 for disassembly of the hydraulic amplifier. Important points and special precautions to be observed are noted below. Do not disassemble the amplifier to any greater degree than necessary for replacement of worn or damaged parts.

1. When replacing wiper seal (31 or 134), pry out old seal using a screw driver or similar tool. Use care not to nick edges of bore or seating surfaces in seal plate (30 or 136).
2. Do not disturb the positions of the minimum or maximum stroke adjustment screws (23 or 163) unless necessary.
3. In the 5-1/4 inch amplifiers, the pilot valve plunger (25) cannot be removed without first removing the pilot valve sleeve (26). The plunger (129) in 7-1/4 inch amplifiers can be removed independently of the sleeve (130). The pilot valve sleeve is retained in its bore by an overlapping edge of the cylinder cover (42 or 144). Make certain to observe the following warning if removal of the cylinder cover is necessary.

⚠WARNING

Removal of the cylinder cover is not recommended except in unusual circumstances. The servo piston return spring or springs (47 to 148 and 149) may be preloaded anywhere within the range of 50 to 1400 pounds depending upon system requirements. An arbor or hydraulic press with a minimum stroke of 7 inches should be used to slightly compress the spring(s) while unbolting the cover and to permit a controlled rate of expansion for removal. Adequate provisions should be made to anchor the amplifier securely and also to prevent the piston rod from slipping off the face of the ram. This operation requires two people, one to operate the press and the second to disassemble the parts. An alternate method of cover removal is to remove two diametrically opposite hold-down screws and install two 12-inch all-thread rods for use as jack screws. Use a 5/16-18 thread for the 5-1/4 inch amplifier, and 1/2-13 thread for the 7-1/4 inch amplifier. Then, using nuts, back off the cover after removing the remaining hold-down screws.

4. Do not disassemble the power servo piston and piston rod (45 to 145). The piston is ground concentric with the rod after assembly and, if disassembled, cannot be properly reassembled to maintain the required concentricity.

Cleaning

Clean parts in fuel oil or kerosene. Do not use commercial solvents as they may damage gaskets or oil seals. Do not handle parts roughly or allow highly polished sealing or mating surfaces to contact other objects.

Repair

Repair should be generally limited to light burnishing of parts to remove superficial corrosion and other minor scores and scratches in finely finished surfaces. Do not remove sharp edges from lands of plungers or pistons or from oil ports in sleeves or bushings. Use a fine grit crocus cloth or paper and light oil to remove corrosion or other damage. The linkages should move freely without excessive play.

Reassembly

Refer to Figure 5-1 or 5-2 for reassembly of the hydraulic amplifier. Important points and special precautions to be observed are noted below:

1. Never reuse cotter or roll pins, replace with new parts.
2. Lubricate O-rings (preformed packings) with petrolatum or lubricating oil prior to assembly.
3, When installing O-rings over threaded surfaces, tape the threaded area to prevent damage to the O-ring.
4. Observe strict rules of cleanliness to prevent the introduction of lint or other foreign material into interior cavities.
5. Lubricate all moving parts and surfaces liberally with oil at assembly.

1. When reassembling parts of the power servo cylinder, refer to WARNING note following step 3 in the disassembly instructions. A hydraulic press is not recommended for reassembly since the operator cannot feel whether or not the piston is entering the cylinder without binding or cocking. Use an arbor press or the jack screw method for reassembly. Do not force the piston if it begins to bind in the bore. Make certain the pilot valve sleeve is installed in its bore if the sleeve is normally retained by the overlapping edge of the cylinder cover.
2. When replacing wiper seal (31 or 134), make certain to install new seal with wiping edge facing outward. Install vee seal (33 or 135) with vee facing inward.
3. After completing reassembly of the amplifier, adjust the minimum and maximum stroke as instructed in the Adjustments chapter.

Chapter 6.
Replacement Parts

When ordering replacement parts, it is essential that the following information be given:

- Hydraulic amplifier serial number and part number (shown on nameplate); needed since a manual reference number does not identify the exact part required for any one unit
- Manual number (this is manual 89005)
- Part reference number as given in the parts list, and name or description of part

Parts List—5-1/4 Inch Hydraulic Amplifier

(See Figure 5-1 for part reference numbers.)

Ref. No.	Part Name	Quantity
89005-1	Screw, 1/4-28 X 3/8", hex. hd.	2
89005-2	Lockwasher, split, 1/4" i.d.	9
89005-3	Washer, plain, 17/64" i.s., 3/4" o.d., 1/16" thk.	2
89005-4	Dowel pin	2
89005-5	Plug, 1/2-14 NPTF, soc. hd	3
89005-6	Screw, 1/4-28 X 1/2", button hd. Nylock	1
89005-7	Straight pin, drilled	2
89005-8	Cotter pin, 1/16 X 1/2"	6
89005-9	Floating lever	1
89005-10	Pivot pin	2
89005-11	Dowel pin	2
89005-12	Screw, 5/16-18 X 1", hex. hd.	4
89005-13	Lockwasher, split, 5/16" i.d.	4
89005-14	Plate (Warning)	1
89005-15	Drive Screw No.2 X 3/16"	4
89005-16	Nameplate	1
89005-17	Retaining ring, internal, 1.388" o.d.	1
89005-18	Starting valve spring seat	1
89005-19	Starting valve spring	1
89005-20	Starting valve plunger	1
89005-21	Starting valve sleeve	1
89005-22	Preformed packing, 3/8" o.d.	2
89005-23	Adjustment screw	2
89005-24	Link	1
89005-25	Pilot valve plunger	1
89005-26	Pilot valve sleeve	1
89005-27	Seal plate gasket	2
89005-28	Screw, 10-32 X 2-1/8". fil. hd.	4
89005-29	Lockwasher, split, No. 10	4
89005-30	Seal plate	1
89005-31	Wiper seal	1
89005-32	Piston rod sleeve	AR
89005-33	Vee seal	1
89005-34	Seal plate spacer	1
89005-35	Amplifier cover	1
89005-36	Yield spring	1
89005-37	Piston rod ring	1
89005-38	Retaining ring, external, 0.925" i.d.	1
89005-39	Screw, 1/4-28 X 1-3/4", hex. hd.	7
89005-40	Washer, plain, 1/4" i.d.	7
89005-41	Preformed packing, 5-1/4" o.d.	1
89005-42	Cylinder cover	1
89005-43	Set screw, 10-32 X 1/2", cone pt. Nylock	AR
89005-44	Stop ring	AR
89005-45	Servo power piston assembly	1
89005-46	Case	1
89005-47	Servo piston return spring	1
89005-48	Sealing cup	AR
89005-49	Plug, 1-5/16-12	2
89005-50	Preformed packing, 1-3/8" o.d.	2
89005-51	Plug, 9/16-18	1
89005-52	Preformed packing, 5/8" o.d.	1
89005-53	Retaining ring, external, spiral, 1.118" i.d.	1
89005-54	Linkage loading spring	1
89005-55	Pilot valve sleeve spring	1
89005-56	Servo bushing	1
89005-57	Preformed packing, 1.129" o.d.	1
89005-58	Oil seal	1
89005-59	Cover gasket	1
89005-60	Straight pin, drilled	1
89005-61	Servo (control) piston	1

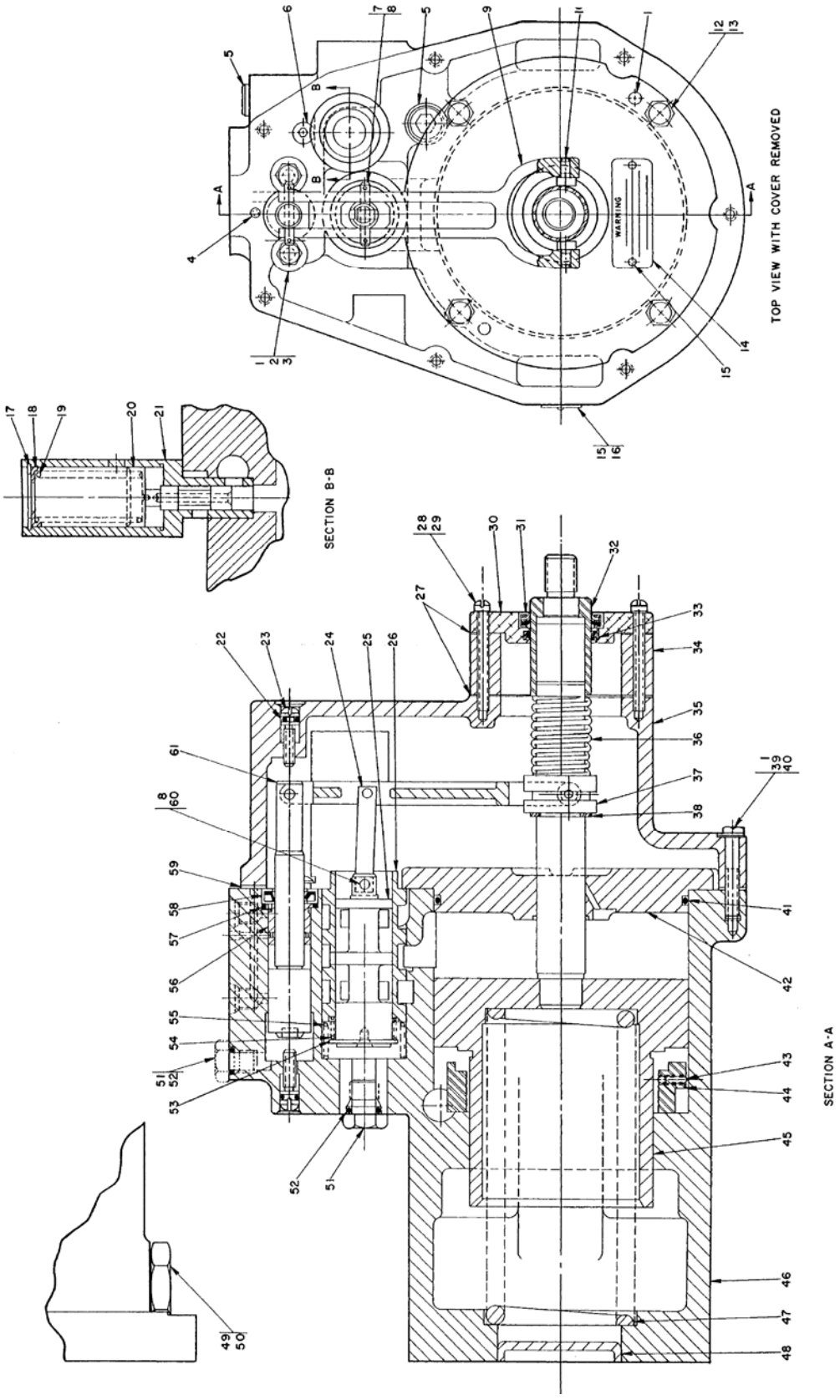

Figure 5-1. 5-1/4 Hydraulic Amplifier Assembly

Parts List—7-1/4 Inch Hydraulic Amplifier

(See Figure 5-2 for part reference numbers.)

Ref. No.	Part Name	Quantity
89005-100	Screw, 1/4-28X 1/2", hex. hd.	2
89005-101	Lockwasher, split, 1/4"	12
89005-102	Washer, plain, 1/4"	11
89005-103	Servo champ	1
89005-104	Cotter pin, 1/16 X 1/2"	6
89005-105	Straight pin, drilled	2
89005-106	Dowel pin	2
89005-107	Drive screw, No. 2 X 3/16"	4
89005-108	Plate, warning	1
89005-109	Screw, 1/2-13X 1-1/4", hex. hd.	4
89005-110	Lockwasher, internal tooth, 1/2"	4
89005-111	Washer, plain, 1/2"	4
89005-112	Pivot pin	2
89005-113	Nameplate	1
89005-114	Floating Lever	1
89005-115	Plug, 1-11-1/2 NPT, sq. hd.	1
89005-116	Starting valve plunger	1
89005-117	Starting valve spring	1
89005-118	Starting valve sleeve	1
89005-119	Retaining ring, internal, 1.388" o.d.	1
89005-120	Starting valve plunger stop	1
89005-121	Screw, 1/4-28 X 1/2", soc. hd.	1
89005-122	Clamp	1
89005-123	Preformed packing, 1-1/4" o.d.	1
89005-124	Plug (Transfer)	1
89005-125	Sleeve (Transfer)	1
89005-126	Screw, 1/2-28 X 5", hex. hd.	2
89005-127	Straight pin, drilled	1
89005-128	Link	1
89005-129	Pilot valve plunger	1
89005-130	Pilot valve sleeve	1
89005-131	Seal plate gasket	2
89005-132	Screw, 10-32 X 1-7/8", fil. hd.	4
89005-133	Lockwasher, split, No. 10	4
89005-134	Wiper seal	1
89005-135	Vee seal	1
89005-136	Seal plate	1
89005-137	Piston rod sleeve	AR
89005-138	Seal plate spacer	1
89005-139	Yield spring	1
89005-140	Piston rod ring	1
89005-141	Retaining ring, external, 0.925" i.d.	1
89005-142	Screw, 1/4-28 X 1-3/4", hex. hd.	5
89005-143	Preformed packing, 7-1/4" o.d.	1
89005-144	Cylinder cover	1
89005-145	Servo (power) piston assembly	1
89005-146	Case	1
89005-147	Sealing cup	AR
89005-148	Servo piston return spring (Inner)	AR
89005-149	Servo piston return spring (Outer)	1
89005-150	Spring seat	1
89005-151	Plug, 1-5/16-12	2
89005-152	Preformed packing, 1.380" o.d.	2
89005-153	Pilot valve sleeve spring	1
89005-154	Linkage loading spring	1
89005-155	Screw, 1/4-28 X 5/8", hex. hd.	2
89005-156	Servo stop	1
89005-157	Preformed packing, 1-1/16 o.d.	1
89005-158	Servo bushing	1
89005-159	Servo spacer	1
89005-160	Cover gasket	1
89005-161	Amplifier cover	1
89005-162	Servo (control) piston	1
89005-163	Adjustment screw	2
89005-164	Preformed packing, 3/8" o.d.	2

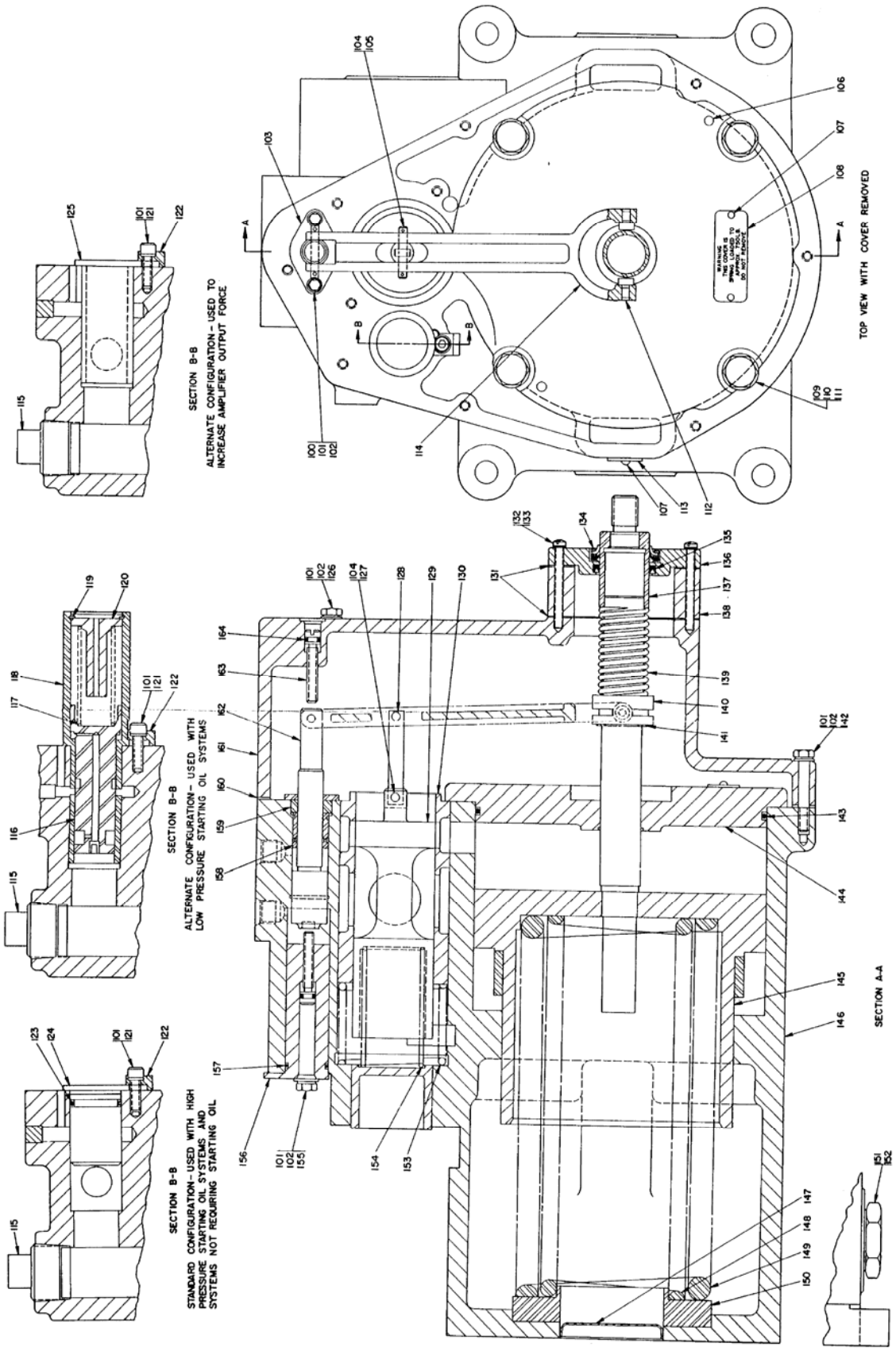

Figure 5-2. 7-1/4 Hydraulic Amplifier Assembly

Chapter 7.
Service Options

Product Service Options

If you are experiencing problems with the installation, or unsatisfactory performance of a Woodward product, the following options are available:

- Consult the troubleshooting guide in the manual.
- Contact the manufacturer or packager of your system.
- Contact the Woodward Full Service Distributor serving your area.
- Contact Woodward technical assistance (see "How to Contact Woodward" later in this chapter) and discuss your problem. In many cases, your problem can be resolved over the phone. If not, you can select which course of action to pursue based on the available services listed in this chapter.

OEM and Packager Support: Many Woodward controls and control devices are installed into the equipment system and programmed by an Original Equipment Manufacturer (OEM) or Equipment Packager at their factory. In some cases, the programming is password-protected by the OEM or packager, and they are the best source for product service and support. Warranty service for Woodward products shipped with an equipment system should also be handled through the OEM or Packager. Please review your equipment system documentation for details.

Woodward Business Partner Support: Woodward works with and supports a global network of independent business partners whose mission is to serve the users of Woodward controls, as described here:

- A **Full Service Distributor** has the primary responsibility for sales, service, system integration solutions, technical desk support, and aftermarket marketing of standard Woodward products within a specific geographic area and market segment.
- An **Authorized Independent Service Facility (AISF)** provides authorized service that includes repairs, repair parts, and warranty service on Woodward's behalf. Service (not new unit sales) is an AISF's primary mission.
- A **Recognized Engine Retrofitter (RER)** is an independent company that does retrofits and upgrades on reciprocating gas engines and dual-fuel conversions, and can provide the full line of Woodward systems and components for the retrofits and overhauls, emission compliance upgrades, long term service contracts, emergency repairs, etc.
- A **Recognized Turbine Retrofitter (RTR)** is an independent company that does both steam and gas turbine control retrofits and upgrades globally, and can provide the full line of Woodward systems and components for the retrofits and overhauls, long term service contracts, emergency repairs, etc.

You can locate your nearest Woodward distributor, AISF, RER, or RTR on our website at:

www.woodward.com/directory

Woodward Factory Servicing Options

The following factory options for servicing Woodward products are available through your local Full-Service Distributor or the OEM or Packager of the equipment system, based on the standard Woodward Product and Service Warranty (5-01-1205) that is in effect at the time the product is originally shipped from Woodward or a service is performed:

- Replacement/Exchange (24-hour service)
- Flat Rate Repair
- Flat Rate Remanufacture

Replacement/Exchange: Replacement/Exchange is a premium program designed for the user who is in need of immediate service. It allows you to request and receive a like-new replacement unit in minimum time (usually within 24 hours of the request), providing a suitable unit is available at the time of the request, thereby minimizing costly downtime. This is a flat-rate program and includes the full standard Woodward product warranty (Woodward Product and Service Warranty 5-01-1205).

This option allows you to call your Full-Service Distributor in the event of an unexpected outage, or in advance of a scheduled outage, to request a replacement control unit. If the unit is available at the time of the call, it can usually be shipped out within 24 hours. You replace your field control unit with the like-new replacement and return the field unit to the Full-Service Distributor.

Charges for the Replacement/Exchange service are based on a flat rate plus shipping expenses. You are invoiced the flat rate replacement/exchange charge plus a core charge at the time the replacement unit is shipped. If the core (field unit) is returned within 60 days, a credit for the core charge will be issued.

Flat Rate Repair: Flat Rate Repair is available for the majority of standard products in the field. This program offers you repair service for your products with the advantage of knowing in advance what the cost will be. All repair work carries the standard Woodward service warranty (Woodward Product and Service Warranty 5-01-1205) on replaced parts and labor.

Flat Rate Remanufacture: Flat Rate Remanufacture is very similar to the Flat Rate Repair option with the exception that the unit will be returned to you in “like-new” condition and carry with it the full standard Woodward product warranty (Woodward Product and Service Warranty 5-01-1205). This option is applicable to mechanical products only.

Returning Equipment for Repair

If a control (or any part of an electronic control) is to be returned for repair, please contact your Full-Service Distributor in advance to obtain Return Authorization and shipping instructions.

When shipping the item(s), attach a tag with the following information:

- return authorization number;
- name and location where the control is installed;
- name and phone number of contact person;
- complete Woodward part number(s) and serial number(s);
- description of the problem;
- instructions describing the desired type of repair.

Packing a Control

Use the following materials when returning a complete control:

- protective caps on any connectors;
- antistatic protective bags on all electronic modules;
- packing materials that will not damage the surface of the unit;
- at least 100 mm (4 inches) of tightly packed, industry-approved packing material;
- a packing carton with double walls;
- a strong tape around the outside of the carton for increased strength.

NOTICE

To prevent damage to electronic components caused by improper handling, read and observe the precautions in Woodward manual 82715, *Guide for Handling and Protection of Electronic Controls, Printed Circuit Boards, and Modules*.

Replacement Parts

When ordering replacement parts for controls, include the following information:

- the part number(s) (XXXX-XXXX) that is on the enclosure nameplate;
- the unit serial number, which is also on the nameplate.

Engineering Services

Woodward offers various Engineering Services for our products. For these services, you can contact us by telephone, by email, or through the Woodward website.

- Technical Support
- Product Training
- Field Service

Technical Support is available from your equipment system supplier, your local Full-Service Distributor, or from many of Woodward's worldwide locations, depending upon the product and application. This service can assist you with technical questions or problem solving during the normal business hours of the Woodward location you contact. Emergency assistance is also available during non-business hours by phoning Woodward and stating the urgency of your problem.

Product Training is available as standard classes at many of our worldwide locations. We also offer customized classes, which can be tailored to your needs and can be held at one of our locations or at your site. This training, conducted by experienced personnel, will assure that you will be able to maintain system reliability and availability.

Field Service engineering on-site support is available, depending on the product and location, from many of our worldwide locations or from one of our Full-Service Distributors. The field engineers are experienced both on Woodward products as well as on much of the non-Woodward equipment with which our products interface.

For information on these services, please contact us via telephone, email us, or use our website: **www.woodward.com**.

How to Contact Woodward

For assistance, call one of the following Woodward facilities to obtain the address and phone number of the facility nearest your location where you will be able to get information and service.

Electrical Power Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 6762 6727
Germany	+49 (0) 21 52 14 51
India	+91 (129) 4097100
Japan	+81 (43) 213-2191
Korea	+82 (51) 636-7080
Poland	+48 12 295 13 00
United States	+1 (970) 482-5811

Engine Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 6762 6727
Germany	+49 (711) 78954-510
India	+91 (129) 4097100
Japan	+81 (43) 213-2191
Korea	+82 (51) 636-7080
The Netherlands	+31 (23) 5661111
United States	+1 (970) 482-5811

Turbine Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 6762 6727
India	+91 (129) 4097100
Japan	+81 (43) 213-2191
Korea	+82 (51) 636-7080
The Netherlands	+31 (23) 5661111
Poland	+48 12 295 13 00
United States	+1 (970) 482-5811

You can also locate your nearest Woodward distributor or service facility on our website at:

www.woodward.com/directory

Technical Assistance

If you need to telephone for technical assistance, you will need to provide the following information. Please write it down here before phoning:

Your Name	
Site Location	
Phone Number	
Fax Number	
Engine/Turbine Model Number	
Manufacturer	
Number of Cylinders (if applicable)	
Type of Fuel (gas, gaseous, steam, etc)	
Rating	
Application	
Control/Governor #1	
Woodward Part Number & Rev. Letter	
Control Description or Governor Type	
Serial Number	
Control/Governor #2	
Woodward Part Number & Rev. Letter	
Control Description or Governor Type	
Serial Number	
Control/Governor #3	
Woodward Part Number & Rev. Letter	
Control Description or Governor Type	
Serial Number	

If you have an electronic or programmable control, please have the adjustment setting positions or the menu settings written down and with you at the time of the call.

We appreciate your comments about the content of our publications.

Send comments to: icinfo@woodward.com

Please reference publication 89005.

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as well as authorized distributors and other authorized service and sales facilities throughout the world.**

Complete address / phone / fax / email information for all locations is available on our website.