Study on the Basic Components of Hydraulic Systems

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Abstract— *A hydraulic system contains and confines a liquid in such a way that it uses the laws governing liquids to transmit power and do work. This paper describes some basic systems and discusses components of a hydraulic system that store and condition the fluid. The oil reservoir (sump or tank) usually serves as a storehouse and a fluid conditioner. Filters, strainers and magnetic plugs condition the fluid by removing harmful impurities that could clog passages and damage parts. Heat exchanges or coolers often are used to keep the oil temperature within safe limits and prevent deterioration of the oil. Accumulators, though technically sources of stored energy, act as fluid storehouses.*

Keywords— *Hydraulic systems, Reservoirs, Strainers, Filters and Accumulators.*

I. HYDRAULIC RESERVOIRS

The hydraulic reservoir is a container for holding the fluid required to supply the system, including a reserve to cover any losses from minor leakage and evaporation. The reservoir can be designed to provide space for fluid expansion, permit air entrained in the fluid to escape, and to help cool the fluid. Figure 1-1 shows two typical reservoirs. Compare the two reservoirs item by item and, except for the filters and bypass valve, notice the similarities. Filling reservoirs to the top during servicing leaves no space for expansion. Most reservoirs are designed with the rim at the filler neck below the top of the reservoir to prevent overfilling. Some means of checking the fluid level is usually provided on a reservoir[1]. This may be a glass or plastic sight gage, a tube, or a dipstick. Hydraulic reservoirs are either vented to the atmosphere or closed to the atmosphere and pressurized. A reservoir stores a liquid that is not being used in a hydraulic system. It also allows gases to expel and foreign matter to settle out from a liquid. A description of each type follows.

1) **Vented Reservoir.** A vented reservoir is one that is open to atmospheric pressure through a vent line. Because atmospheric pressure and gravity are the forces which cause the fluid to flow to the pump, a vented reservoir is mounted at the highest point in the hydraulic system. Air is drawn into and exhausted from the reservoir through a vent line. A filter is usually installed in the vent line to prevent foreign material from being taken into the system. These reservoirs are used widely used in hydraulic systems due to their high reliability and ability to work under extreme conditions[2].

2) **Pressurized Reservoir.** A pressurized reservoir is sealed from the atmosphere. This reservoir is pressurized either by engine bleed air or by hydraulic pressure produced within the hydraulic system itself. Pressurized reservoirs are used on aircraft intended for high altitude flight, where atmospheric pressure is not enough to cause fluid flow to the pump.

This reservoir, or tank as it is referred to by Boeing-Vertol, is constructed of a metal housing with two internal pistons, one fixed and the other a floating piston which slides along a central tube. Attached to the floating piston is a larger tube that projects through the forward end of the tank and is calibrated to indicate FULL and REFILL fluid levels for ramp-up and ramp-down positions[3].

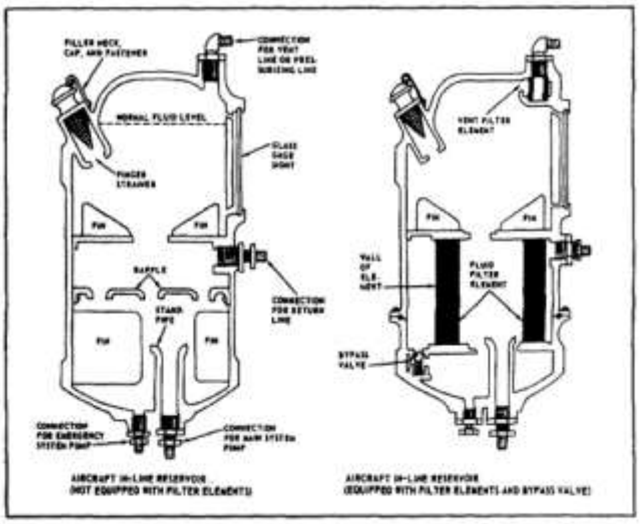

Figure 1

a. Construction. A properly constructed reservoir should be able to dissipate heat from the oil, separate air from the oil, and settle out contaminates that are in it. Reservoirs range in construction from small steel stampings to large cast or fabricated units. The large tanks should be sandblasted after all the welding is completed and then flushed and steam cleaned[2]. Doing sore moves welding scale and scale left from hot-rolling the steel. The inner surface then should be sealed with a paint compatible with the hydraulic fluid. Non bleeding red engine enamel is suitable for petroleum oil and seals in any residual dirt not removed by flushing and steam cleaning.

b. Shape. Some of the design features of a reservoir. It should be high and narrow rather than shallow and broad. The oil level should be as high as possible above the opening to a pump's suction line. This prevents the vacuum at the line opening from causing a vortex or whirlpool effect, which would mean that a system is probably taking in air. Aerated oil will not properly transmit power because air is compressible[3]. Aerated oil has a tendency to break down and lose its lubricating ability.

c. Size. Reservoir sizes will vary. However, a reservoir must be large enough so that it has a reserve of oil with all the cylinders in a system fully extended. An oil reserve must be high enough to prevent a vortex at the suction line's opening. A reservoir must have sufficient space to hold all the oil when the cylinders are retracted, as well as allow space for expansion when the oil is hot. A common-size reservoir on a mobile machine is a 20- or 30-gallon tank used with a 100-GPM system. Many 10-GPM systems operate with 2- or 3-gallon tanks because these mobile systems operate intermittently, not constantly. For stationary machinery, a rule of thumb is that a reservoir's size should be two to three times a pump's output per minute[2]. A large-size tank is highly desirable for cooling. The large surface areas exposed to the outside air transfer heat from the oil. Also, a large tank helps settle out the contaminates and separates the air by reducing recirculation.

d. Location. Most mobile equipment reservoirs are located above the pumps. This creates a flooded-pump-inlet condition. This condition reduces the possibility of pump cavitations-a condition where all the available space is not filled and often metal parts will erode. Flooding the inlet also reduces the vortex tendency at a suction pipe's opening. A reservoir's location affects heat dissipation. Ideally, all tank walls should be exposed to the outside air. Heat moves from a hot substance to a cold substance; heat transfer is greatest when there is a large temperature difference[3]. Reservoirs that are built into front-end loader arms are very effective in transferring heat.

e. Ventilation. Most reservoirs are vented to the atmosphere. A vent opening allows air to leave or enter the space above the oil as the level of the oil goes up or down. This maintains a constant atmospheric pressure above the oil. A reservoir filter cap, with a filter element, is often used as a vent. Some reservoirs are pressurized, using a simple pressure-control valve rather than a vented one[1]. A pressure-control valve automatically lets filtered air into a tank but prevents air release unless the pressure reaches a preset level. A pressurized reservoir takes place when the oil and air in a tank expand from heat.

f. Line Connections. A pump suction and a tank's return lines should be attached by flanges or by welded heavy-duty couplings. Standard couplings usually are not suitable because they spread when welded. If a suction line is connected at the bottom, a coupling should extend well above the bottom, inside the tank; residual dirt will not get in a suction line when a tank or strainer is cleaned. A return line should discharge near a tank's bottom, always below the oil level. A pipe is usually cut at a 45-degree angle and the flow aimed away from a suction line to improve circulation and cooling. A baffle plate is used to separate a suction line from a return line. This causes the return oil to circulate around an outer wall for cooling before it gets to the pump again. A baffle plate should be about two-thirds the height of a tank. The lower corners are cut diagonally to allow circulation[5]. They must be larger in area than a suction line's cross section. Otherwise the oil level between a return and a suction side might be uneven. Baffling also prevents oil from sloshing around when a machine is moving. Many large reservoirs are cross-baffled to provide cooling and prevent sloshing.

g. Maintenance. Maintenance procedures include draining and cleaning a reservoir. A tank should have a dished bottom that is fitted with a drain plug at its lowest point; a plug fitting should be flush with the inside of a tank to allow for full drainage. On large tanks, access plates may be bolted on the ends for easy removal and servicing. A reservoir should have a sight gauge or dipstick for checking the oil level to prevent damage from lubrication loss[4]. The strainers on a pump's suction line may not require as much maintenance. However, an element in a filter in a return line will require regular changing. Therefore, that filter should not be inside a reservoir. When a reservoir is pressurized by compressed air, moisture can become a maintenance problem. A tank should have a water trap for moisture removal; it should be placed where it can be inspected daily.

II. STRAINERS AND FILTERS

To keep hydraulic components performing correctly, the hydraulic liquid must be kept as clean as possible. Foreign matter and tiny metal particles from normal wear of valves, pumps, and other components are going to enter a system. Strainers, filters, and magnetic plugs are used to remove foreign particles from a hydraulic liquid and are effective as safeguards against contamination. Magnetic plugs, located in a reservoir, are used to remove the iron or steel particles from a liquid.

a. Strainers. A strainer is the primary filtering system that removes large particles of foreign matter from a hydraulic liquid. Even though its screening action is not as good as a filter's, a strainer offers less resistance to flow. A strainer usually consists of a metal frame wrapped with a fine-mesh wire screen or a screening element made up of varying thicknesses of specially processed wire. If one strainer causes excessive flow friction to a pump, two or more can be used in parallel. Strainers and pipe fittings must always be below the liquid level in the tank[4].

b. Filters. A filter removes small foreign particles from a hydraulic fluid and is most effective as a safeguard against contaminants. Filters are located in a reservoir, a pressure line, a return line, or in any other location where necessary. They are classified as full flow or proportional flow. Figure 2 in a full-flow filter, all the fluid entering a unit passes through a filtering element. Although a full-flow type provides a more positive filtering action, it offers greater resistance to flow, particularly when it becomes dirty. A hydraulic liquid enters a full-flow filter through an inlet port in the body and flows around an element inside a bowl. Filtering occurs as a liquid passes through the element and into a hollow core, leaving the dirt and impurities on the outside of the element[2]. A filtered liquid then flows from a hollow core to an outlet port and into the system.

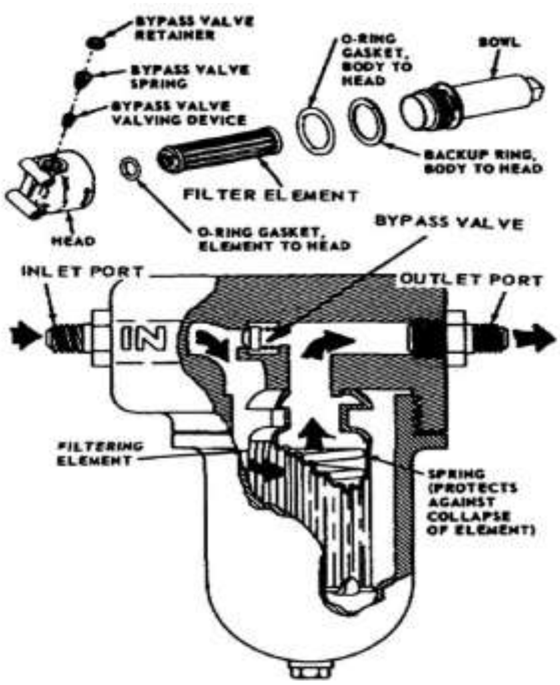

Figure 2

A bypass relief valve in a body allows a liquid to bypass the element and pass directly through an outlet port when the element becomes clogged. Filters that do not have a bypass relief valve have a contamination indicator. This indicator works on the principle of the difference in pressure of a fluid as it enters a filter and after it leaves an element. When contaminating particles collect on the element, the differential pressure across it increases. When a pressure increase reaches a specific value, an indicator pops out, signifying that the element must be cleaned or replaced[5]. This filter operates on the venturi principle in which a tube has a narrowing throat (venturi) to increase the velocity of fluid flowing through it. Flow through a venturi throat causes a pressure drop at the narrowest point. This pressure decrease causes a sucking action that draws a portion of a liquid down around a cartridge through a filter element and up into a venturi throat. Filtering occurs for either flow direction.

III. ACCUMULATORS

Like an electrical storage battery, a hydraulic accumulator stores potential power, in this case liquid under pressure, for future conversion into useful work. This work can include operating cylinders and fluid motors, maintaining the required system pressure in case of pump or power failure, and compensating for pressure loss due to leakage. Accumulators can be employed as fluid dispensers and fluid barriers and can provide a shock-absorbing (cushioning) action. Accumulators are used mainly on the lift equipment to provide positive clamping action on the heavy loads when a pump's flow is diverted to lifting or other operations. An accumulator acts as a safety device to prevent a load from being dropped in case of an engine or pump failure or fluid leak[3]. On lifts and other equipment, accumulators absorb shock, which results from a load starting, stopping, or reversal.

a. Spring-Loaded Accumulator. This accumulator is used in some engineer equipment hydraulic systems. It uses the energy stored in springs to create a constant force on the liquid contained in an adjacent ram assembly. Figure 3 shows two spring-loaded accumulators. The load characteristics of a spring are such that the energy storage depends on the force required to compress a spring. The free (uncompressed) length of a spring represents zero energy storage. As a spring is compressed to the maximum installed length, a minimum pressure value of the liquid in a ram assembly is established. As liquid under pressure enters the ram cylinder, causing a spring to compress, the pressure on the liquid will rise because of the increased loading required to compress the spring.

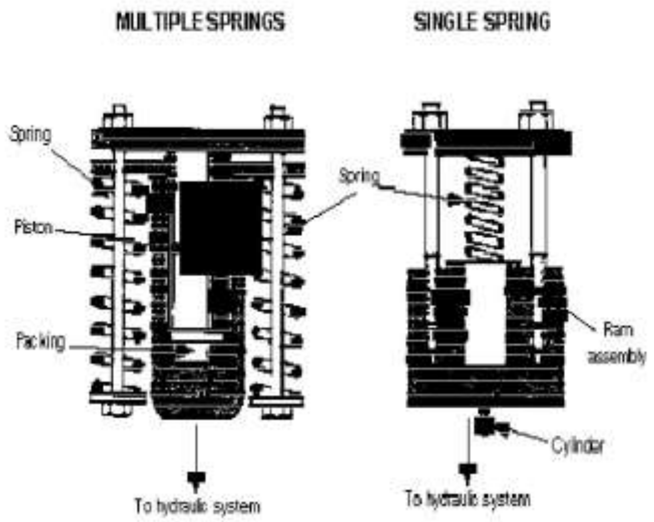

Figure 3

b. Bag-Type Accumulator. This accumulator Figure 4 consists of a seamless, high-pressure shell, cylindrical in shape, with domed ends and a synthetic rubber bag that separates the liquid and gas (usually nitrogen) within the accumulator. The bag is fully enclosed in the upper end of a shell. The gas system contains a high-pressure gas valve. The bottom end of the shell is sealed with a special plug assembly containing a liquid port and a safety feature that makes it impossible to disassemble the accumulator with pressure in the system. The bag is larger at the top and tapers to a smaller diameter at the bottom. As the pump forces liquid into the accumulator shell, the liquid presses against the bag, reduces its volume, and increases the pressure, which is then available to do work[5].

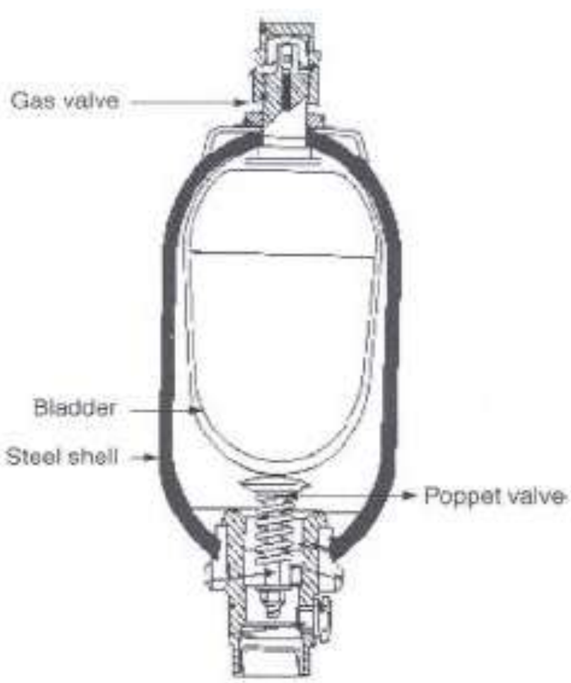

Figure 4

c. Piston-Type Accumulator. This accumulator consists of a cylinder assembly, a piston assembly, and two end-cap assemblies. The cylinder assembly houses a piston assembly and incorporates provisions for securing the end-cap assemblies. An accumulator contains a free-floating piston with liquid on one side of the piston and precharged air or nitrogen on the other side Figure 5. An increase of liquid volume decreases the gas volume and increases gas pressure, which provides a work potential when the liquid is allowed to discharge. The piston accumulator serves the same purpose and operates by the same principles as do the diaphragm and bladder accumulators. As fluid pressure from the system enters the left port, forcing the piston down against the initial air charge in the right chamber of the cylinder. A high-pressure air valve is located at the right port for charging the unit. A drilled passage from the fluid side of the piston to the outside of the piston provides lubrication between the cylinder walls and the piston.

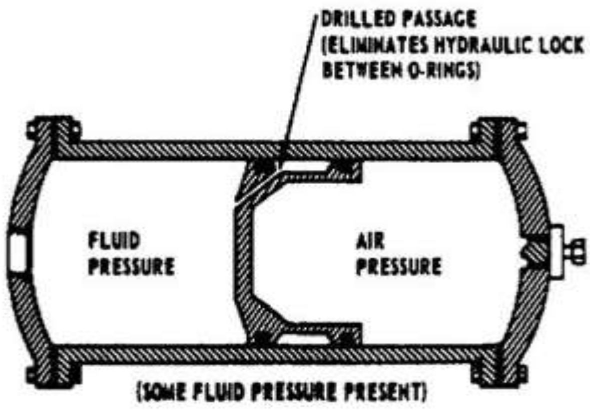

Figure 5

d. Diaphragm Accumulator. The diaphragm accumulator consists of two hollow, hemispherical metal sections bolted together at the center. Notice in Figure 6 that one of the halves has a fitting to attach the unit to the hydraulic system; the other half is equipped with an air valve for charging the unit with compressed air or nitrogen. Mounted between the two halves is a synthetic rubber diaphragm that divides the accumulator into two sections. The accumulator is initially charged with air through the air valve to a pressure of approximately 50 percent of the hydraulic system pressure[2]. This initial air charge forces the diaphragm upward against the inner surface of the upper section of the accumulator. When fluid pressure increases above the initial air charge, fluid is forced into the upper chamber through the system pressure port, pushing the diaphragm down and further compressing the air in the bottom chamber. Under peak load, the air pressure in the lower chamber forces fluid back into the hydraulic system to maintain operating pressure. Also, if the power pump fails, the compressed air forces a limited amount of pressurized fluid into the system.

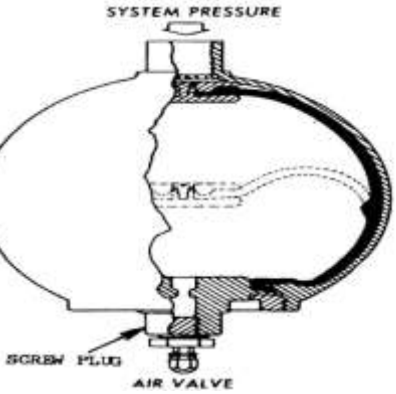

Figure 6

IV. PRESSURE GAUGES.

Pressure gauges are used in liquid-powered systems to measure pressure to maintain efficient and safe operating levels. Pressure is measured in psi. Flow measurement may be expressed in units of rate of flow-GPM or cubic feet per second (cfs). It may also be expressed in terms of total quantity-gallons or cubic feet. Gauge readings indicate the fluid pressure set up by an opposition of forces within a system. Atmospheric pressure is negligible because its action at one place is balanced by its equal action at another place in a system. flow depends on the quantities, flow rates, and types of liquid involved[4]. All liquid meters (flow meters) are made to measure specific liquids and must be used only for the purpose for which they were made. Each meter is tested and calibrated. In a nutating-piston-disc flow meter, liquid passes through a fixed-volume measuring chamber, which is divided into upper and lower compartments by a piston disc. During operation, one compartment is continually being filled while the other is being emptied. As a liquid passes through these compartments, its pressure causes a piston disc to roll around in the chamber. The disc's movements operate a dial (or counter) through gearing elements to indicate that a column of fluid that has passed through the meter.

Figure 7

V. HYDRAULIC MOTORS

Hydraulic motors are installed in hydraulic systems to use hydraulic pressure in obtaining powered rotation. A hydraulic motor does just the opposite of what a power -driven pump does. A pump receives rotative force from an engine or other driving unit and converts it into hydraulic pressure. A hydraulic motor receives hydraulic fluid pressure and converts it into rotative force. Figure 8 shows a typical hydraulic motor. The two main ports through which fluid pressure is received and return fluid is discharged are marked A and B, respectively[5]. The motor has a cylinder block-and-piston assembly in which the bores and pistons are in axial arrangement, the same as in a hydraulic pump. Hydraulic motors can be instantly started, stopped, or reversed under any degree of load; they can be stalled by overload without damage. The direction of rotation of a hydraulic motor can be changed by reversing the flow of fluid into the ports of the motor.

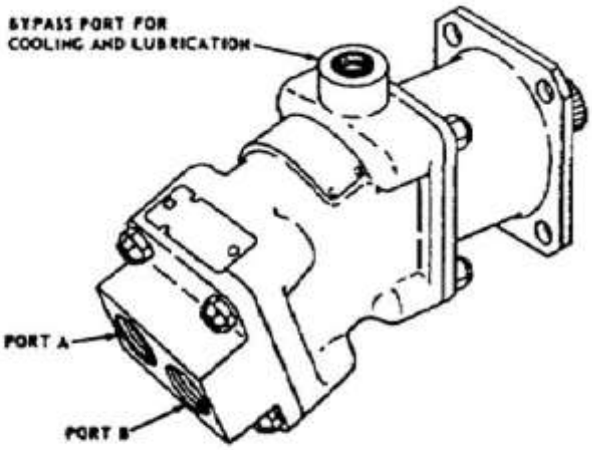

Figure 8

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