Medium - Duty Hydraulic Pumping Units - - Operation and Maintenance

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The prime consideration of an operator after the pumping unit has been installed is how to obtain the longest possible operating life, the minimum amount of nonproductive time, and the lowest overall operating cost. This problem is most easily solved by an understanding of the basic operation of the unit and the requirements of maintenance.

HYDRAULIC UNIT OPERATION

The hydraulic pumping unit provides a means of converting the output of available power sources, such as electric or internal-combustion prime movers, into a means of reciprocating the sucker rod string and thus of pumping the well. This system uses hydraulic fluid to transfer the power from the prime mover location to the polished rod. A simple circuit could be divided into three basic sections as follows: The pump and reservoir, where the power fluid is generated; the valving section, where unit control is obtained; and the power cylinder, where the pumping work is done. Fig. 1 shows a simple hydraulic circuit containing the basic components of reservoir, suction strainer, air filter, pump, relief valve, directional valve, pilot valve, work cylinder, piston, polished rod packing, and fluid piping.

The hydraulic pump converts the mechanical energy of the prime mover into hydraulic energy. The action of its vanes, or gears, creates a partial vacuum at the pump inlet that enables the atmospheric pressure in the reservoir to force liquid through the suction piping into the pump. The pump action then forces this liquid through the pump outlet into the hydraulic system. The pressure at which the pump must deliver the fluid is determined by the load in the power cylinder.

Since this load could possibly become excessive, because of the sticking of the sub-surface pump or the malfunctioning of a component of the system, a means of limiting the maximum pressure in the circuit is required. The simple relief valve, as shown, is installed in such a manner that the hydraulic pressure tending to unseat the ball is resisted by the spring pressure. When the hydraulic pressure exceeds the thrust of the spring, the ball is forced off its seat and the valve is opened. The fluid flows from the pressure line through the valve to the reservoir. This diversion of flow prevents further pressure increase in the pressure line. A common method is to set the relief valve to relieve at approximately 50 psi higher than the maximum operating pressure. Thus, the prime mover will not be damaged by excessive load nor will the hydraulic components be damaged because of excessive pressure.

The control of the unit is usually provided by a combination of pilot valve and directional valve. The pilot valve, actuated by the control ports on the cylinder, supplies the controlling force to shift the directional valve. It is the directional valve that causes the unit to cycle by the porting of the pump fluid and the cylinder fluid. As shown in Fig. 1, at the beginning of the upstroke, the constant pump pressure holds the pilot piston in such a position that it closes the constant pressure line to drain. This action pressurizes the large end of the directional valve piston, causing it to move into a position so that the pump fluid is ported to the underside of the working piston. The piston is forced upward, lifting the sucker rod string. It passes the lower reversal port, which contains a check valve that restrains the flow from the cylinder, and then the upper reversal port.

The check valve in this port allows free flow of the pressure fluid from the cylinder to the large end of the pilot valve, as shown in Fig. 2. This flow overcomes the force of the small area and moves the pilot piston to a position to connect the constant pressure line to drain. The removal of pressure from the large end of the directional valve piston allows the piston to shift into the downstroke position. The pump and cylinder fluid is then circulated back to the reservoir, allowing the work piston to begin the downstroke. The piston continues the downstroke until it passes the lower control port; then the pressure on the large end of the pilot valve is relieved, and the constant pressure moves the pilot spool into an upstroke position.

The pumping rate is determined by the upstroke time and the downstroke time, which usually are not equal in a non-counterbalanced unit such as this. The pump output, which is related to its speed of rotation, determines the upstroke speed and a manual valve adjustment controls the rate of the downstroke. A fairly rapid downstroke is usually preferred to a slow one, since it requires less horsepower and creates less heat.

As one follows through the circuit he notes that much is dependent upon the power fluid. This fluid, which could easily be called the life-blood of the unit, must transfer the energy, provide lubrication, carry contaminants to the reservoir, and maintain its desirable characteristics for an extended

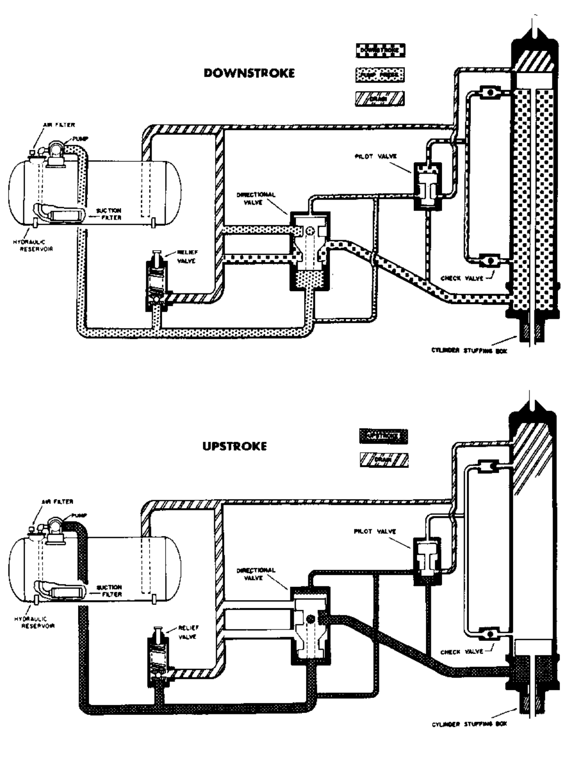


Figure 1

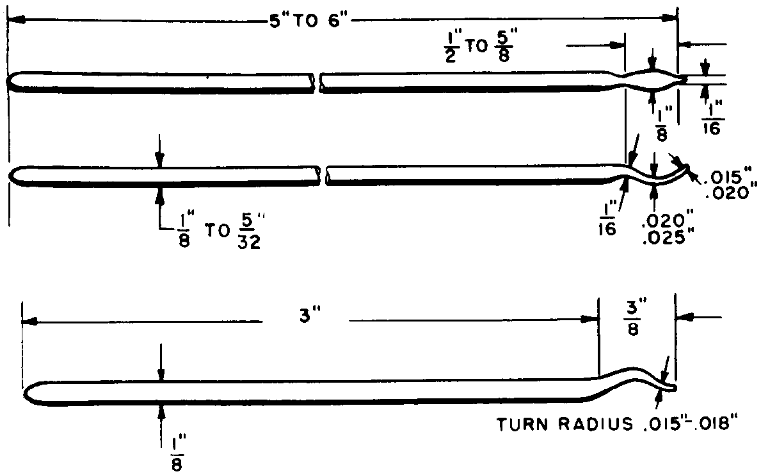


Fig. 2. Tools similar to these are recommended for removing O-rings. The top tool is used to remove seals from external grooves; the bottom tool, for removing seals from internal grooves.

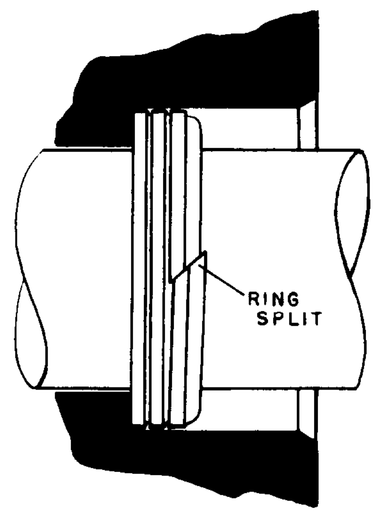


Fig. 3. When split V-rings are installed on a shaft of correct size, the rings will overlap slightly at the split. This slight overlap allows the application of pressure to the split to stop leakage there by an adjustment of the gland follower ring.

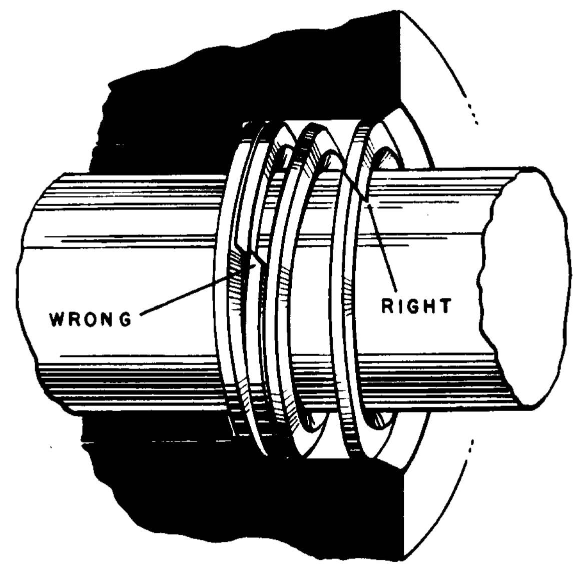


Fig. 4. When V-rings are installed, care must be taken not to get the end with the facing angle in front of the other end, as shown here. If this mistake occurs, each succeeding ring will be cocked, and a tight seal cannot be maintained.

Courtesy of Socony-Vacuum Oil Co., Inc.

period of time. One should have a basic understanding of the requirements of the hydraulic oil, because as it fails to maintain its required characteristics, the unit maintenance increases.

Viscosity, probably the most important physical property of the oil, is the specification used in the determination of the oil for a particular application. Defined as the measure of resistance to flow, it can aptly be described as the syrupy quality of the fluid. The most common method of determining relative viscosities is the Saybolt Universal. This system measures the numbers of seconds required for 60 cubic centimeters of oil to flow by gravity through a standard orifice. The tests are conducted at 100 F and 210 F, and the results are stated as number of seconds SSU (Saybolt Second Universal).

The pump usually determines the desired viscosity for the circuit, since it is the part most affected by viscosity and viscosity changes. In general, centrifugal pumps require a hydraulic fluid of from 100 to 150 SSU, whereas the vane and gear type of pumps requires viscosities in the range of 300 SSU at 100 F.

A viscosity that is too high will cause excessive fluid friction (and hence will increase the oil temperature) and sluggish operation and will increase the power consumption. A viscosity that is too low will cause an increase in internal and external leakage, in pump slippage, and in the rate of wear of moving parts, and it may result in failure of the pump.

The viscosity limits for safe operation are selected as 4000 SSU maximum and 70 SSU minimum. If the viscosity should exceed 4000 SSU because of cold temperature conditions, the oil would not have sufficient fluidity to be drawn into the pump in the necessary volume. This condition might cause cavitation at the pump intake and scoring or seizure of the pump itself because of a lack of sufficient oil for lubricating purposes. Conversely, if the oil viscosity in the reservoir is 70 SSU, it will be below this figure in the bearings of the pump, where the heat is generated and the load is carried, and bearing failure may result.

For obtaining as wide an operating temperature range as possible, an oil with a viscosity index of above 90 is usually recommended. The viscosity index is a measurement of the rate of change of viscosity with change in temperature. An oil having a high index will change less in body with temperature than an oil having a low index will. The ambient temperature conditions will also affect the oil selection. In a cold climate an oil with a viscosity of 150 SSU at 100 F may be required for a positive-displacement pump to assure fluidity.

The oil should have high oxidation stability. Oxidation of petroleum base oils results in the formation of oil-insoluble materials such as sludge and varnish deposits. Accumulation of deposits will ultimately lead to plugging of small lines, piston rings, orifices, and valves. Inoperation will usually result, particularly if the system is shut down for a period of time and is allowed to cool to ambient temperature.

The oil should contain a rust preventative. These additives tend to plate the surfaces that they contact and thus form a coating that prevents water and oxygen from acting on the metal. An added benefit of this coating is realized when the equipment is removed from production for a period of time. Under reasonable storage conditions, the coating will prevent internal corrosion for approximately four to six months.

Demulsibility. The ease or rapidity with which the oil separates from any water with which it may become mixed is an indication of demulsibility. The emulsions are caused by the introduction and consequent admixture of condensate water and vapor introduced into the system through breathing vents or ports. The oil should separate readily from the water and should not form emulsions which break up very slowly.

Good resistance to foaming. Foaming is the entrapment of minute air bubbles by a film of hydraulic oil which causes faulty operation of valves and various hydraulic controls as well as the more serious condition of pump cavitation.

The proper type of hydraulic oil containing the required amounts of additives will result in lower wear rates, better protection against rusting and deposit formation, and good control of foaming tendencies, providing cleaner system, more dependable operation, less repair and maintenance cost, and longer trouble-free life.

UNIT MAINTENANCE

The prime consideration of the manufacturer is to provide a unit design that not only does the required job but also does not demand an excessive amount of maintenance. Hydraulic equipment maintenance is related primarily to two factors--hydraulic oil condition and external leakage. Probably less attention is paid to the power fluid condition and more costly downtime is caused by it than most operators realize.

Hydraulic Oil Condition

The three major adverse oil conditions which may result in unit failure are high operating temperatures, oil contamination, and excessive foaming. An understanding of the causes of these conditions will aid in their prevention and elimination, with increased equipment life.

High oil temperature. Excessive operating temperatures and short component life go hand-in-hand. When one realizes that above 140 F the oxidation rate of the oil doubles for each increasing increment of 18 F, he appreciates the need for temperature control. The oil reservoir which serves the basic function of fluid storage also provides the means for temperature control. The capacity of the tank is usually 2 1/2 times the maximum rate of flow in gallons per minute, and the tank contains a baffle to slow down the fluid circulation within it, thus allowing the maximum amount of time for the oil to dissipate its heat to the atmosphere. Since it serves this function, the reservoir should always be exposed to the prevailing breeze, if possible, and should not be placed in a cellar.

The major source of heat is due primarily to the orificing of high-pressure fluid to atmospheric pressure; therefore, the relief valve setting should be adjusted as low as possible. Fifty psi above maximum operating pressure is considered good practice. Another source of heat is the slippage of high-pressure fluid through the pump and the control valves. A worn valve or pump can be an expensive part when the effect is added to the unit maintenance cost. In general, a maximum reservoir temperature of 130 F is desired. This temperature can be simply estimated by placing a hand on the tank exterior. Temperatures up to 125 F can be borne by the hand, but above this figure they become progressively more painful to the touch. If the temperature exceeds the desirable, a cooler should be investigated or the operating rate of the unit should be reduced.

Clean system. The statement, "Seventy-five percent of all hydraulic maintenance trouble is caused by dirty oil" is not an exaggeration. Foreign matter in the hydraulic fluid can create excessive wear, increase power loss, cause scoring or seizing of the valves and the pump, hasten oxidation of the oil, and substantially increase replacement and maintenance costs. The design of the reservoir tends to control the contamination and to provide a collecting point for it. The large tank, plus the baffle, reduces the oil circulation rate and thus allows solids to settle at the bottom.

In addition, the vent cap or air intake port is provided with an air filter to restrict the admission of dust or dirt. This filter requires periodic cleaning in a solvent, and it should be dipped in a light-weight oil before installation. All covers and access ports are provided with gaskets that should be checked for tightness to prevent entrance of foreign matter into the reservoir.

Although the system is cleaned and flushed after having been tested by the manufacturer and good installation practice is followed at the well, the hydraulic oil will inevitably become contaminated with foreign matter. Therefore, some form of filtration on the pump, usually a fine-mesh wire screen, must be provided to prevent the contaminates from being recirculated through the pump and the circuit.

Although common terminology refers to this device as a suction filter, the actual nomenclature is a strainer. The Joint Industry Conference (J.I.C.) distinguishes between the two types of units according to a basic difference in their type of construction. Thus a strainer is "a device for the removal of solids from a fluid wherein the resistance to motion of such solids is a straight line", and a filter is "a device for the removal of solids from a fluid wherein the resistance to motion of such solids is in a tortuous path." The filter, with its tortuous flow path and finer screen, provides the optimum filtration but also offers the greatest resistance to flow. Therefore, the strainer with the coarser screen and with the minimum flow resistance is used in the pump suction.

A 100- to 200-mesh screen, found on most suction strainers, will provide adequate filtration for the average pumping unit. The strainers are usually sized to provide at least four times the net area of the suction line in order to minimize the flow resistance. Since the strainer is not visible, determining how often it should be removed for cleaning is often difficult. The optimum situation is to have a regular maintenance program wherein all units receive weekly or monthly cleaning, as the field operating conditions warrant. This procedure, of course, is desirable but because of the heavy demand on the maintenance crew's time, it is rarely realized.

The common method is to clean the strainer initially after two or three weeks' operation. This method is good insurance, since contaminates sometimes remain in the unit after flushing by the manufacturer and also enter during transit and installation of the unit. Thereafter, a cleaning schedule related to operating conditions should be maintained. The danger signals of a noisy pump or of one that is not producing its rated capacity should require an immediate check of the suction strainer.

Unless the same polished rod operates in the well crude and also in the hydraulic fluid, the suction strainer is usually adequate. But if the crude contaminates the hydraulic oil, additional filtration should be provided. A fuller's earth filter, which contains a clay-like material having high absorption power, will maintain the oil free from all contaminates, both soluble and insoluble. Although it tends to remove some of the oil additive, it removes all of the oxidation products such as gums, resins, lacquers, and so on, as quickly as they are formed.

Foaming. The presence of air in the hydraulic oil not only provides an audible result as it passes through the pump but also is the cause of other objectionable effects. Accelerated oil oxidation, reduced unit efficiency and hence increased horsepower, irregular operation and increase in oil temperature caused by the compressibility of the air, and cavitation of the pump are direct results of entrapped air.

Foaming is usually a result of the return fluid's entering the reservoir with such force that it causes an agitating action. Slippage of fluid past the piston rings and during the valve action also contributes to entrapment of air in the oil. The reservoir design of a baffle and a slow circulation rate, in combination with an oil containing an anti-foaming inhibitor, will control the normal amount of foaming. If excessive foaming is apparent, other causes such as low oil level in the reservoir permitting the suction strainer to become uncovered, a loose connection or leak in the suction line allowing air to be drawn into the system, or contaminated oil should be investigated.

A good quality of hydraulic oil of the desired specifications will provide long, trouble-free service. An understanding of the causes of oil failure and the danger signals of oil deterioration, in combination with the required maintenance, will add operating years not only to the oil but also to the unit. When the oil in the unit must be changed, the best investment an operator can make is the additional time required to clean the complete circuit thoroughly to ensure continued low-cost operation.

External Leakage

External leakage of hydraulic oil provides a visible and usually expensive example of required maintenance. This leakage can occur at the packing joints, such as the polished rod stuffing box or the gasket joints, or at the piping connections.

Packing seals. The equipment manufacturer provides super-finished surfaces for the packing to operate on and holds dimensions of the packing cavities to close tolerances to assure leak-free operation. Replacement of these seals should be carefully done in order to avoid damaging the sealing surfaces.

The Socony-Vacuum Oil Co., Inc., in Technical Bulletin, *"Care of Packing in Hydraulic Machines,"* compiled the following recommendations covering installation, maintenance, and replacement of hydraulic packings:

> When the seal rings of a packing begin to leak and have to be replaced, there are improper procedures that can result in an unsatisfactory installation and may even make it impossible to again make a tight seal. Correct installation of seal rings, on the other hand, can be accomplished without increased time or costs, and the packing, given good operating care, will last its expected life.

Removing old seals. After the gland follower ring has been removed or the piston has been pulled from its cylinder, the condition of the gland and the sealing rings should be carefully observed, particularly if the seal being replaced has failed prematurely. Inspection should be made for evidence of extrusion, lack of lubrication, dirt, undue wear, and scratches on the rod, the cylinder, or the gland. Ordinarily, the removal of V-rings will require a tool--usually an auger with a flexible shaft or a brass or a copper rod with a hook at one end. When removal tools are used, utmost care should be taken not to scratch either the gland, the shaft, the rod, or the piston. A scratch on the gland surface will usually cause leakage, and one on the rod or the shaft will cause both leakage and seal-ring wear. A scratch on the rod, unless it is deep, can usually be stoned out, and the shaft can be polished with fine crocus cloth. Removing a scratch on the gland is often difficult because of the restricted access to the gland. When the sealing rings are removed, the rod should not be in its extreme outward position, because if it is and the rod is scratched, the scratch will most likely be in under the gland where it cannot be reached, and the rod will then have to be removed from the cylinder so that the scratch can be polished out.

Special tools, such as those shown in Fig. 2, can be made for the removal of both external and internal O-ring seals, and if carefully used, they can permit easy removal without damage.

Selection of replacement packing. When replacement sealing rings are ordered, the packing manufacturer should be given full particulars concerning the rod or cylinder diameter, the gland or groove diameter and the gland length, the operating temperatures and pressures, the fluid expected to be sealed, and the type of seal. Most packing manufacturers have a wide variety of materials from which they can make sealing rings. The particular material best suited for any installation will depend on the temperatures, the pressures and the fluid involved. When a stock of sealing rings of various types, sizes, and material is maintained, obviously the replacement rings selected must be correct for the job. Seal material unsuited to the conditions may soften, wear excessively, or harden and may cause prema-

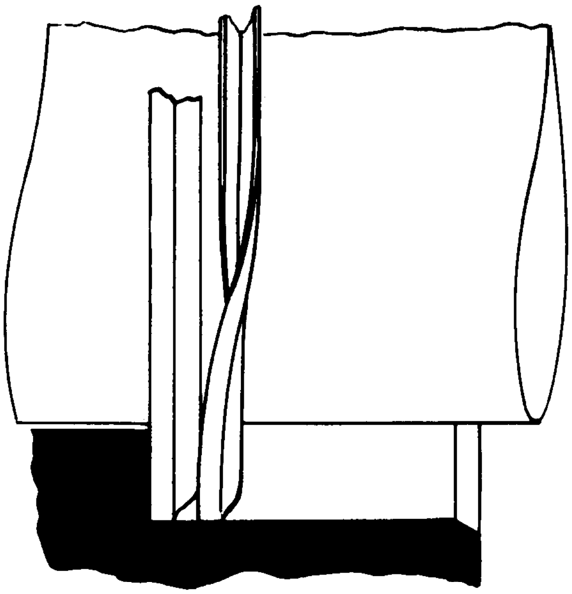


Fig. 5. When V-rings are placed in large-diameter glands, care must be taken to prevent twisting, which would cause a leaky seal.

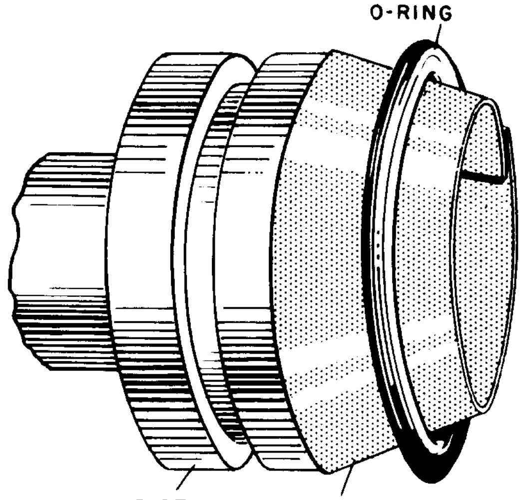


Fig. 6. Shim stock, shaped to form a cone, will aid the slipping of an O-ring over the edge of a piston or a piston rod that has not been properly beveled.

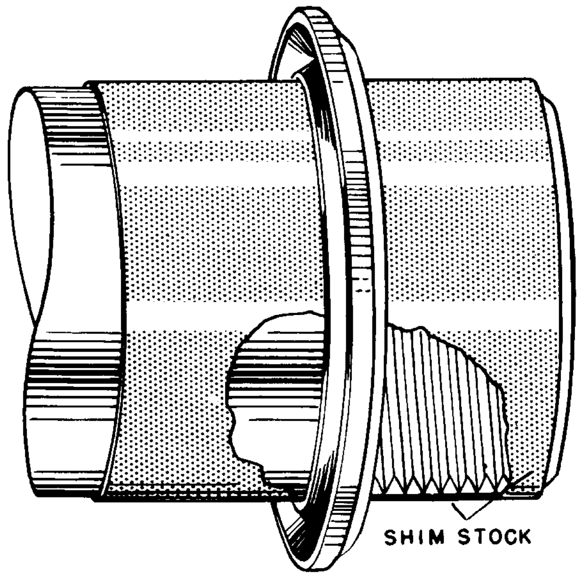


Fig. 7. During installation, damage to V-rings by threads that have not been undercut can be prevented by wrapping them with shim stock.

Courtesy of Socony-Vacuum Oil Co., Inc.

ture failure.

Installing new rings. Before new rings are installed, the gland or O-ring should be scrupulously clean, and all surfaces over which the rings must slide during installation should be lubricated. Dipping the packing in hydraulic oil, particularly if it is leather, before installation is good practice.

With V-rod packings, the male support ring is installed first, assurance being made that the flat face of the ring seats squarely on the bottom of the gland. Each sealing ring is then installed separately, the sealing lips facing the pressure. Wooden sticks with a V cut in their ends to fit the heel of the sealing ring have been found convenient for pushing each ring into the gland so that it seats squarely on the previous ring before the next one is installed. Pointed metal tools, such as screw drivers, should never be used, because of the danger of scoring the rod or of injuring the packing. The joints of split rings should be staggered alternately, 180 degrees and then 90 degrees. The surfaces of the angle split should mate and overlap slightly at the joint (Fig. 3) and should not be cut. When split rings are installed, care should be taken not to get the end with the facing angle in front of instead of behind the other end, as shown in Fig. 4. If this mistake does occur, the next ring and all following rings will be cocked. If any of the rings are cocked, the seal will not give satisfactory performance. When V-packing is installed in large-diameter glands, special care is needed to guard against twisting the packing (Fig. 5). Split rings should not be used where rotary motion is involved. Finally, the female support ring is installed, concave face toward the pressure. When solid (not split) sealing rings are used, the gland follower ring should be installed with spacers so that it can be bolted or screwed up tight, metal-to-metal, and yet can exert only very slight pressure on the rings. When the sealing rings are split, the gland ring must exert enough pressure to seal the joints. Spring-loaded glands are often recommended for use wherever space permits.

When rings of any type are installed, great care is needed to prevent scuffing the sealing surfaces, which is easily done when solid V-rings and O-rings are placed over a rod or a piston, because the rings are smaller in diameter and must be stretched slightly. Likewise when solid V-rings are pushed into their gland, scuffing the ring is easy, because the outside diameter of the ring lip is slightly greater than the diameter of the gland. If the end of the rod or the piston over which the ring must be started is square and does not have a chamfer with a taper of 30 degrees or less, damage to the ring can be prevented by using a piece of shim stock to form a cone over which the rings can be easily slid (Fig.6). Shim stock can also be used to aid in starting a solid V-ring into its gland or any type of packing into its cylinder and to protect rings against scuffing when they have to be pushed over screw threads (Fig. 7). O-rings are easily pinched if the proper chamfers (30 degrees or less) are not provided on the cylinder or the rod. If the sealing surfaces of any type of sealing ring are damaged even slightly, the performance of the seal will be greatly impaired.

Where the surface finish of a rod or a shaft has been roughened, changing from homogeneous sealing rings to leather or fabricated rings may be desirable. When such a change is made, it must be recognized that the dimensions of homogeneous and fabricated seal rings are not the same. Homogeneous V- and leather V-rings are interchangeable. With V-rings, the change can be made, but the gland will accommodate fewer fabricated rings (one less in most cases), and changing the spacers used in bolting up the follower ring may be necessary. Glands designed for homogeneous U-rings or flange seals may not accommodate fabricated seal rings, as the dimensions of these rings have not been standardized.

Proper operation and maintenance. Some of the principal enemies of rod-packing life are dirt, metal chips, sand, and so on. Any of these solids that adhere to the rod tend to be carried into the packing where they interfere with the sealing action. If they are abrasive, the rod may be scored, or worn, and the scoring, in turn, will increase the rate of sealing-ring wear and leakage. Exposed rods and valve stems are sometimes damaged by tools dropped on them by operators or maintenance men. For minimizing this trouble, the rods should, where feasible, have protecting shields that will also keep sand and other solids away. Metal wiper rings or synthetic rubber wiper strips can be installed outside of the packing to keep the solids from getting into the seal itself. The use of cleaning devices is a generally recommended practice. Flange-rings and U-rings installed with their lips facing away from the pressure and leather back-up rings are also used for this purpose.

All sealing rings, particularly homogeneous rubber rings, require lubrication. Without lubrication, packing friction is high and ring wear is rapid. If the hydraulic fluid is oil, lubricant is always present. However, if seals are too tight, the rod may leave the packing dry, without lubricant, resulting in rapid wear of the sealing rings. On rotating shafts, lack of lubrication may result in the wearing of a groove in the shaft as well as in rapid wear of the packing. This wearing is likely to happen if the shaft is soft (below 200 Brinell).

The importance of rod and cylinder finish, or smoothness, to packing life has been repeatedly stressed. If, for any cause, scores, scratches, or roughness develops, the part should be refinished at the earliest opportunity. Packing life will be short until the condition has been rectified.

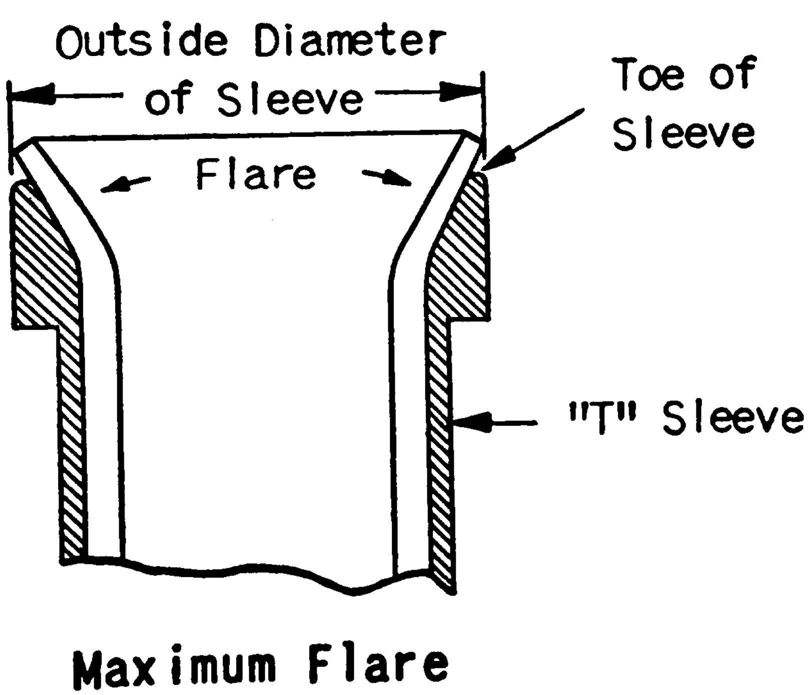
Rod eccentricity in passing through the packing is detrimental to the life of any packing. With O-rings and homogeneous V-rings, the maximum allowable eccentricity is 0.002 to 0.005 inch, depending on the rod diameter. The packing should not be part of the rod-supporting area.

When lower-quality hydraulic oil is in service and temperatures are high, solid oxidation products eventually form which may collect in the packing and cause leakage or which may form lacquer-like deposits on the rod or cylinder and cause leakage and increased wear.

When correctly slected sealing material is carefully and properly installed in well-designed glands of machines kept in good repair, leakage of hydraulic fluid can be kept to extremely small proportions, and packing will last its expected life. With minimum leakage, peak production can be maintained, and hazards and labor costs for cleaning and oiling will be reduced. Also advantage can be taken of the benefits of long oil life, minimized deposits, and reduced wear that result from the use of high-quality hydraulic oil.

Piping connections. The leakage of oil at joints such as pipe, tube, or hose connections usually does not commence until after the unit has been in operation for a period of time. The typical leak develops gradually from a small oozing of oil into a periodic droplet which may eventually become quite large. Although these leaks are developed by the unit vibration, by pressure surges, and by repeated strains on the piping, they are basically caused by other factors: improper cutting and flaring of the tubing; careless threading and make-up of the pipe; poor installation of the tubing and piping runs, resulting in unnecessary strains, lack of proper support, and use of inferior materials. These points are important in the original assembly of the unit and are even more important when modifications and repairs are made in the field.

Tubing. The tubing material selected for pressure piping should be SAE 1010 dead-soft, cold-drawn seamless-steel tubing used with steel fittings. The tubing should be cut square with a tube cutter, rather than with a hack saw, and should be carefully deburred. The flaring tools designed for the type of fitting required should be utilized, and care should be taken to avoid over-working the flare. A work-hardened flare will make the tube end more susceptible to cracking by vibration. For the correct length and diameter of the flare, the outside corner of the flare should extend beyond the maximum inside diameter of the top of the sleeve but not beyond the outside diameter of the sleeve, as shown in Fig. 8.



Courtesy of The Parker Appliance Company

Figure 8

When tubing is being bent, as required in any particular installation, the possible effect of the bending on leakage at the tubing fittings should be considered. For example, tube bends close to fittings must be carefully made so that the roundness and straightness of the portion of the tube entering the fitting will not be disturbed. Neither should that portion of the tube be indented or scratched. Tube bends should be carefully made, preferably with commercial tube-bending tools.

Tubing runs should have as few bends as possible, but they should have at least one bend to provide for expansion and contraction with temperature changes. In other words, straight runs, especially short ones, should be avoided, since expansion and contraction with temperature changes would strain the tube fittings and would probably cause leaks to develop.

The minimum radius of a tube bend should be three tube diameters.

After necessary bends have been made, a tubing run should be of correct length with ends accurately aligned so that the ends will not have to be strained into position when the connections are made.

Pipe. Leaks at threaded joints are usually the result of imperfect or rough threads caused by a dull threading die, by burrs, by inclusion of foreign matter, or by lack of correct pipe-thread compound. Often, the leak results from the loosening of the joint, which may be corrected by merely tightening the joint. Addition of a clamp or a support will eliminate vibration, and thus the joint will resist the tendency to loosen.

The basic tolerances of pipe threads classify them as non-precision threads. Because of this loose tolerance, the pipe-thread compound should provide not only the required lubrication for makeup but also a seal against fluid leakage. This seal must resist vibration, but yet it must permit relatively easy breakout of the joint. When piping is replaced, assurance that all internal surfaces are clean should be exacted.

SUMMARY

An understanding of the basic hydraulic circuit and of the function of the components will simplify the why and how of a regular maintenance program to obtain the optimum unit operation and the lowest overall operating cost.