Major Inspection & Failure Analysis

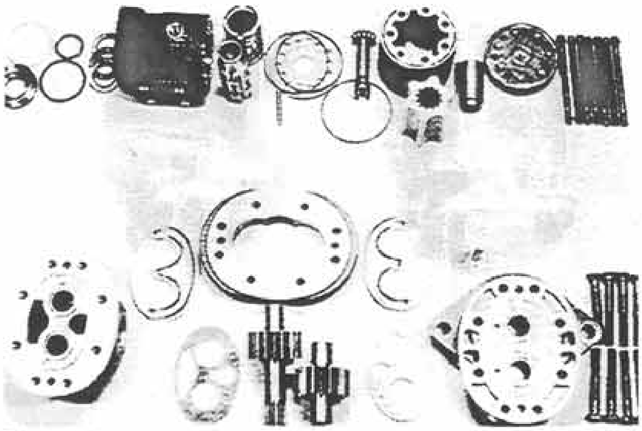


Figure 1:

Whether failures are a result of one cause or a combination of causes, we must be able to determine all of the causes to prevent further system damage and repeat failures. As a component is disassembled, our sense of sight will give us visual evidence as to how and why the failure occurred. While some are obvious, other failures need a more thorough examination so the proper corrections can be made. The real purpose of inspection is to determine which fault occurred first. The principal cause is sometimes hidden by a secondary failure. In the previous part of this program, we've given descriptive faults relating to several most critical parts of the hydraulic system. In this section, because of their nature, we will direct extra attention to the pump and steering valve in regard to inspection and failure analysis. (See Fig. 1)

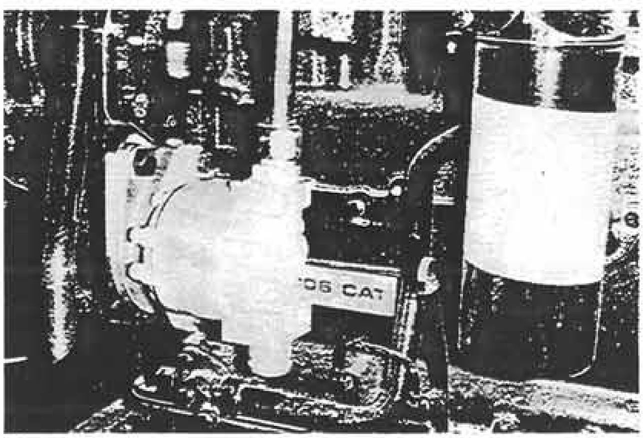


Figure 2:

Because pumps in general are the "Heart" of the hydraulic system, their condition is an indicator of the rest of the system or vice versa since a common fluid source is used. A major pump inspection can be readily accomplished since they can be quickly removed. (See Fig. 2)

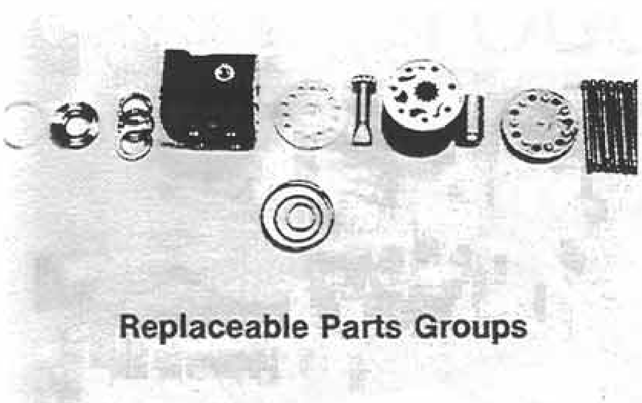


Figure 3:

Aside from internal cleaning and seal replacement, there are no recommended repair procedures for the steering valve, but some matched subassemblies are available through service parts operations. Although when a unit fails to function or tests prove it defective, we should naturally try to find the reason to prevent another such failure. (See Fig. 3)

Major Inspection & Failure Analysis

Webster and Commercial pumps are used by Steiger, but for the purpose of describing analysis, we'll look at the Webster pump. Remember that the same rules will apply to either pump. In dealing with the pump, we will list and illustrate the affected parts relating to each of our possible causes. (See Fig. 4)

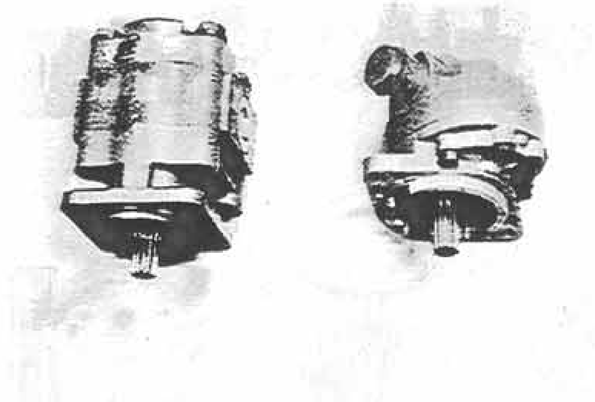


Figure 4:

MAJOR INSPECTION AND FAILURE ANALYSIS

We will use a disassembled new pump for three reasons: one, to give you the proper terminology of parts; two, to further describe operating principles; and three, to show what a new pump has in common with a good used pump.

Before disassembling a pump, clean the exterior and mark the corresponding sections with a center punch, or use a dye marker and scribe a line diagonally across the pump. (See Fig. 5)

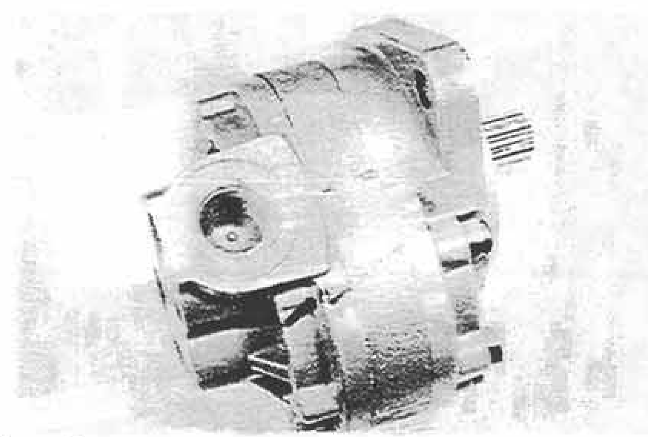


Figure 5:

Every new pump is factory tested to determine whether or not it meets acceptable performance standards. Each pump is free flow tested first, then efficiency tested with 100% filtered oil entering the pump. We surely understand why pumps are tested, but test oil being filtered also has strong merit as we will see. (See Fig. 6)

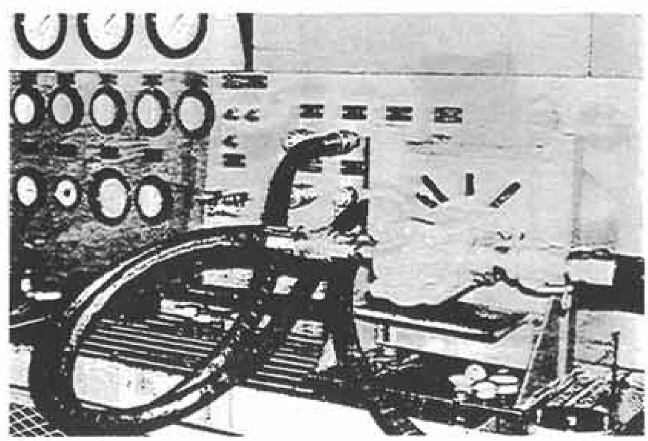


Figure 6:

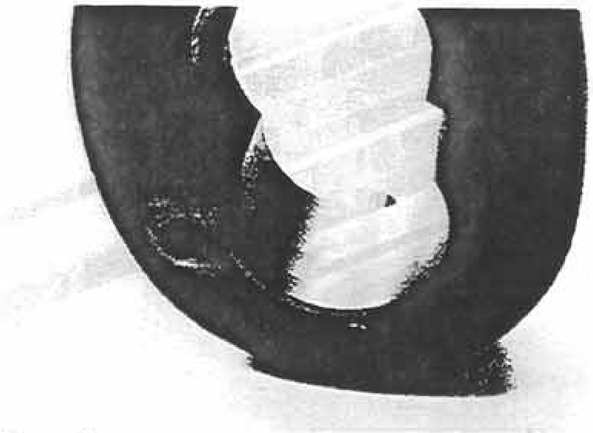


Figure 7:

Here is a typical pump housing with gear bores that display a normal appearance. During the factor test and initial break-in period, the tips of the gearteeth touch the suction side of the gear bores to form a continuous positive seal. It is common to note some material removal from the gear bores until the gears have fitted themselves. (See Fig. 7)

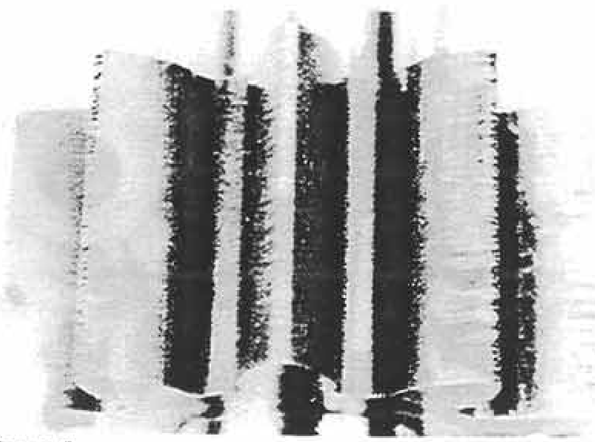


Figure 8:

The crowns or tips of the gearteeth will have an appearance to match the gear bores' finish. Also on each geartooth there is a load-bearing face and a non-load bearing face, this is determined by direction of rotation. Usually the drive gear will have a razor-like edge where the non-load-bearing faces and crowns meet. This is also a normal characteristic. The driven gear, however, will have a lesser edge because it has less chance to collect on load-bearing side of the geartooth as the force of the drive gear keeps it worn off. (See Fig. 8)

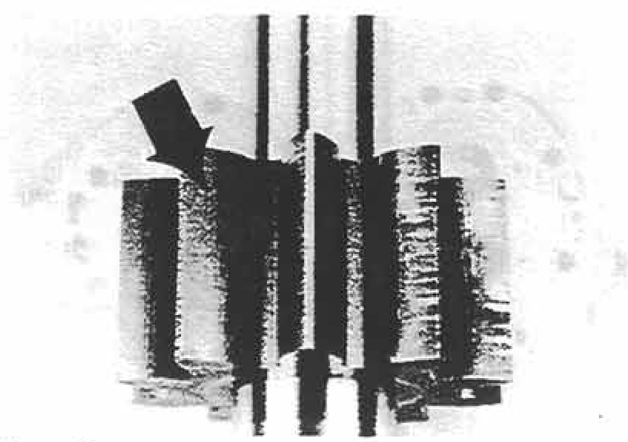


Figure 9:

The non-load-bearing sides of the gearteeth should always have a new appearance. By this we mean that the machining from gear manufacture should still be visible. (See Fig. 9)

Driving forces are applied to the load-bearing sides of the gearteeth, so the machining patterns should gradually blend into a smooth mirror-like finish as the pump sees greater usage. (See Fig. 10)

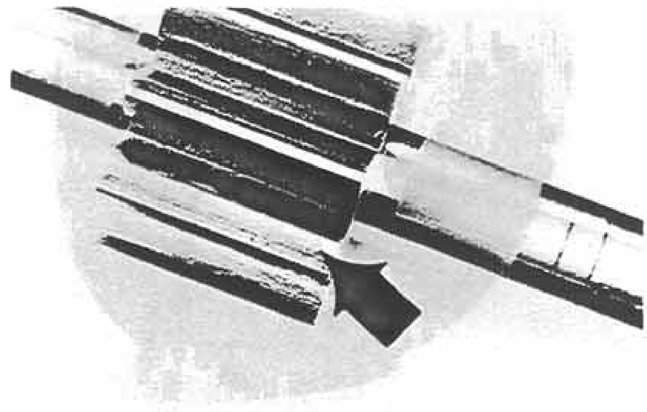


Figure 10:

The shaft journals for both gears must have a smooth surface, free of discoloration and scratches. New journals will have a fine-grained pattern left from grinding operations during production. These grains eventually polish out to high gloss. Gear thrust faces should also have the same qualities. (See Fig. 11)

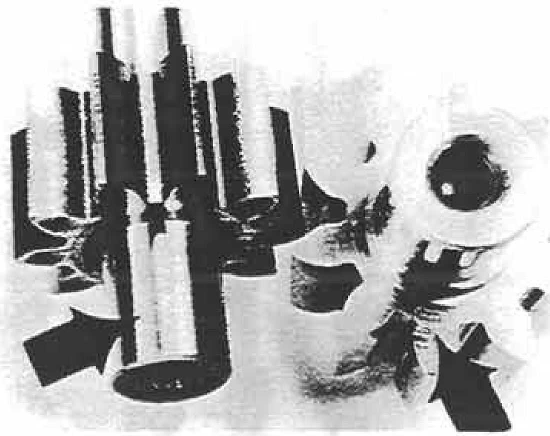


Figure 11:

Plain or sleeve bearings and roller type bearings are used to support the shaft journals, depending upon the type of pump. All pumps in this application have the bearings installed in the front and rear end covers. (See Fig. 12)

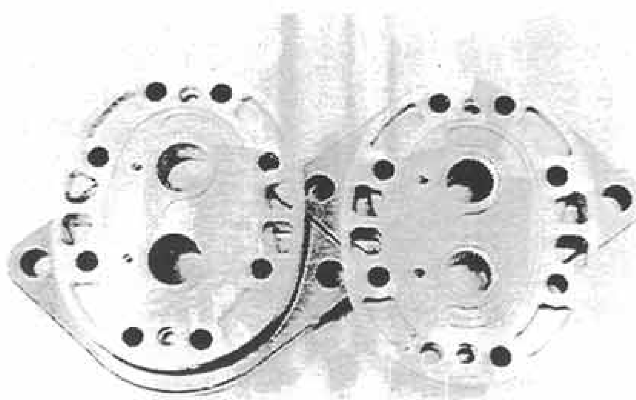


Figure 12:

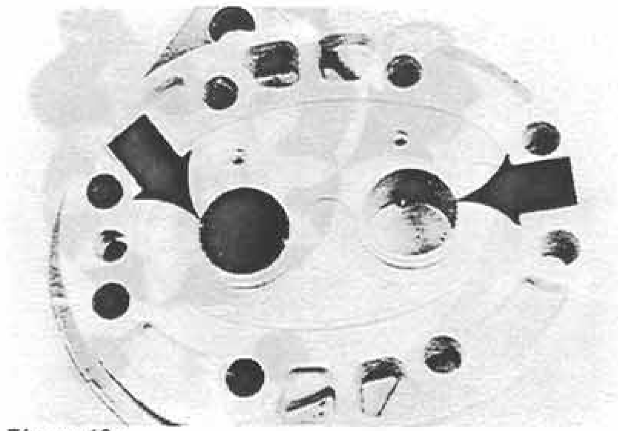


Figure 13:

Each sleeve bearing has a visible seam and is installed in the end cover as shown. The seams are directly opposed as far as possible. Also, the bearing protrusion should be 60 thousandths of an inch from the adjacent surface of the cover. The inside diameter should display a smooth finish with uniform color around the total bearing surface. (See Fig. 13)

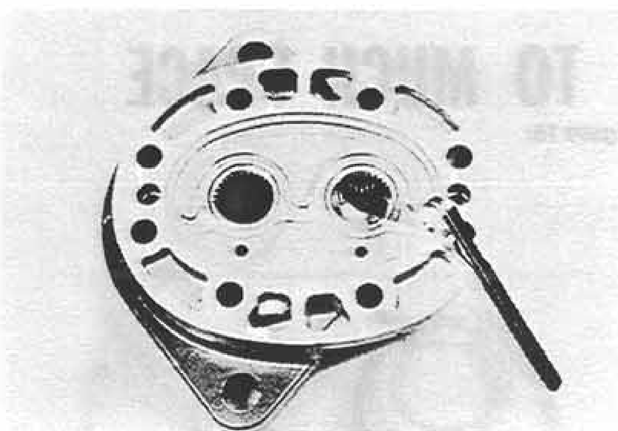


Figure 14:

If roller-type bearings are used, the finish of the individual rollers should appear like new and without excessive looseness in their retainers. The maximum space allowed should be 25 thousandths of an inch as shown. (See Fig. 14)

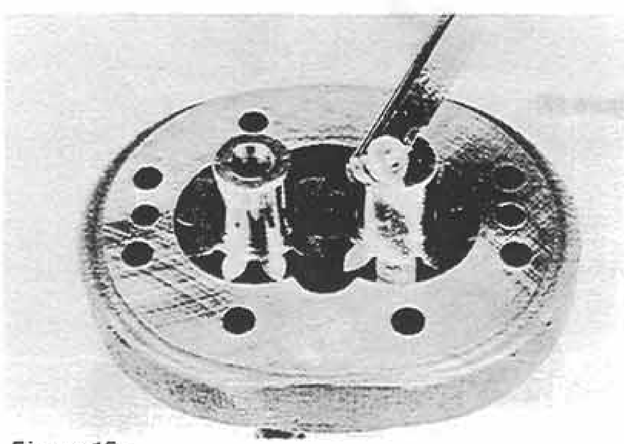
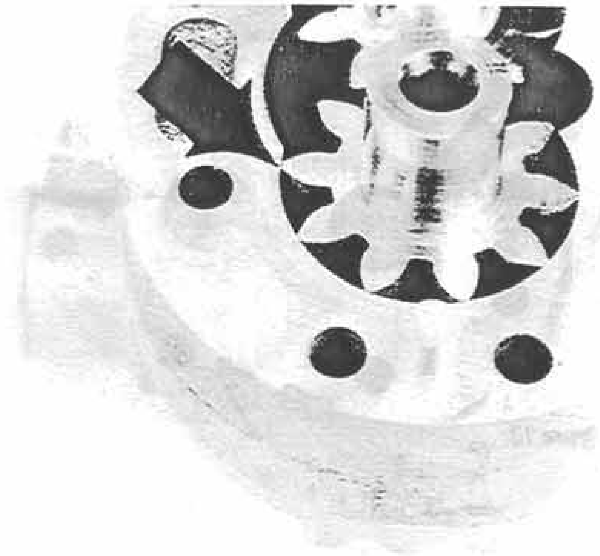


Figure 15:

The amount of wear on a mating bearing and shaft is in direct proportion to the amount of excessive material that the gears remove from the pump housing. This condition can occur if the bearings wear after pump break-in. To determine the extent of wear, temporarily fit the gears in the pump housing and apply thickness gauges until you find the one that takes up all the clearance, as shown. A maximum of 8 thousandths of an inch is permitted in a good used pump. We must stress that if this dimension is exceeded, we must replace the bearings and pump housing. (See Fig. 15)

Without replacement of the pump housing at this time, the crowns of the newly positioned gears would not be able to touch the gear bores of the pump housing to cause a seal. (See Fig. 16)



TO MUCH SPACE

Figure 16:

This part is called a "pressure plate" because it responds to hydraulic pressure in the discharge cavity of the pump. When the pressure increases, the plate is forced tighter against the gear thrust faces to control fluid leakage from the discharge to inlet chamber. (See Fig. 17)

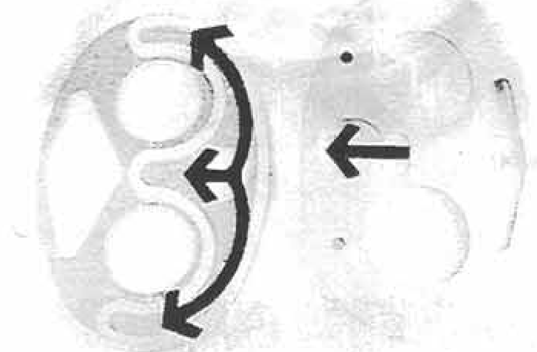


Figure 17:

Slight wear, scratching and discoloration are not considered harmful unless the entire wearing surface is affected. Usually, the center of the plate has a different appearance due to meshing gearteeth rubbing over it. As long as there is no great dimensional change, this is normal. (See Fig. 18)

Figure 18:

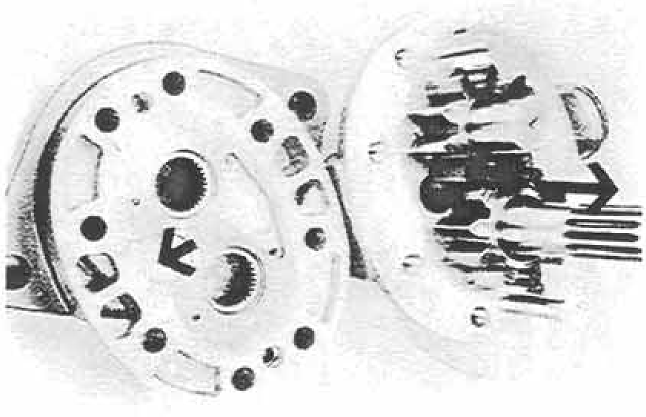


Figure 19:

A relief is machined into the plate due to the nature of gear pump design. As stated earlier, when the pump is driven and the gearteeth approach each other, oil flow is produced. When four gearteeth are in mesh, the oil trapped between them will rise in pressure as the space decreases further. The relief passage allows most of the trapped oil to escape to the discharge chamber. This feature is very important in three respects: it controls the noise of the pump, it controls pump performance and controls bearing lubrication. The trapped oil, which is unable to escape through the passage, controls the bearing lubrication aspect. Once the four meshed gearteeth have passed the relief passage, the remaining trapped oil raises slightly in pressure. (See Fig. 19)

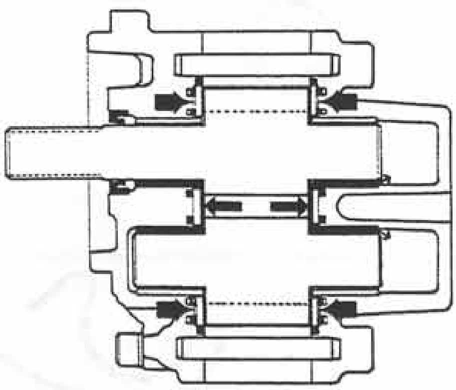


Figure 20:

For an instant, this pulse is higher than discharge pressure and seeks passage to each bearing as the pulse deflects the plate away from the gear thrust face. These events occur at such a rapid frequency that oil flow to the bearings is almost continuous. (See Fig. 20)

Figure 21:

Oil follows the path of least resistance, flowing across the bearing surfaces, then collected in the end covers and routed back to the inlet chamber. (See Fig. 21)

Some pressure plates have relief passages on inlet and discharge sides, but if there is only one relief, it must coincide with the discharge side only. (See Fig. 22)

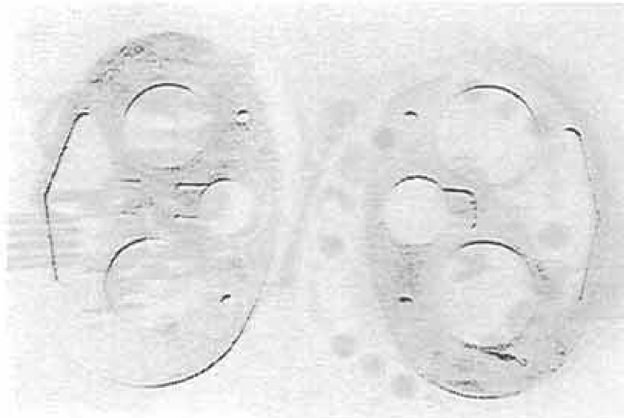


Figure 22:

Reuse of seals is not recommended, as it would be unwise to sacrifice performance for such inexpensive items. However, the used parts have a story to tell, in case there is a fault. Normally, the seals should be completely intact, have no surface damage and still be pliable (soft). (See Fig. 23)

We will now discuss causes of pump failures. The major contribution to pump failures is the use of contaminated oil. Contamination falls into two main categories; namely, the entry of dirt and the presence of metal particles.

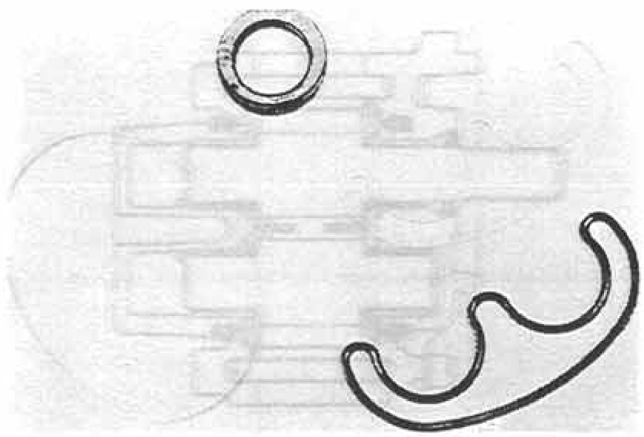


Figure 23:

To identify the fine abrasive wear caused by dirt, we must understand that many of these particles are too small to be visible. Oil containing these particles may look clean, but may be the cause of pump wear and subsequent failure. We are able to determine this by inspecting the finish on all the wear surfaces. If this type of contamination is present, we will note a dull finish that looks like fine sandblasting on the surfaces that should have a high polish. For example, the thrust faces of the gears. (See Fig. 24)

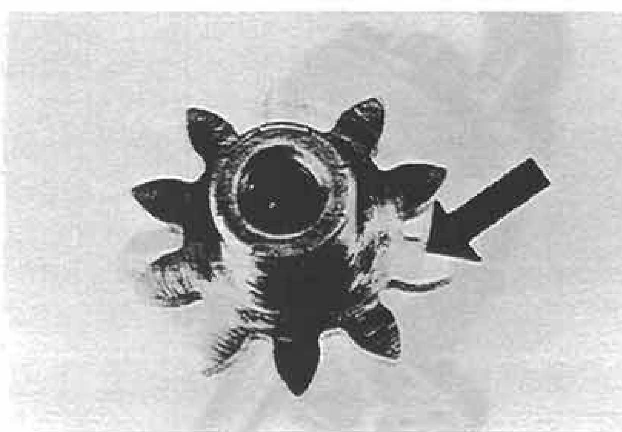


Figure 24:

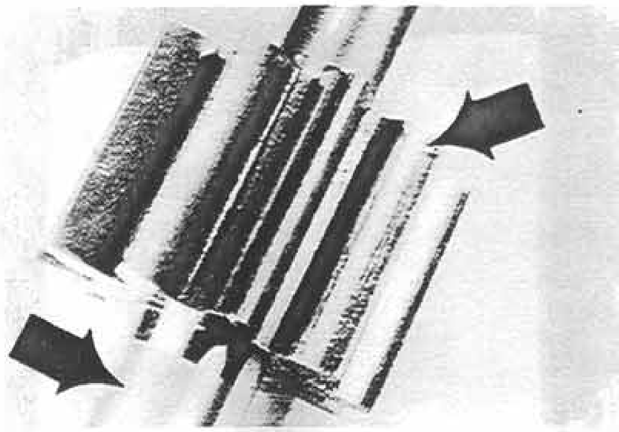


Figure 25:

The shaft journals will have a dull finish the length of the bearing surface. It may appear as if very fine sandpaper was used around the shaft. The load-bearing sides of the gearteeth will have a similar appearance. (See Fig. 25)

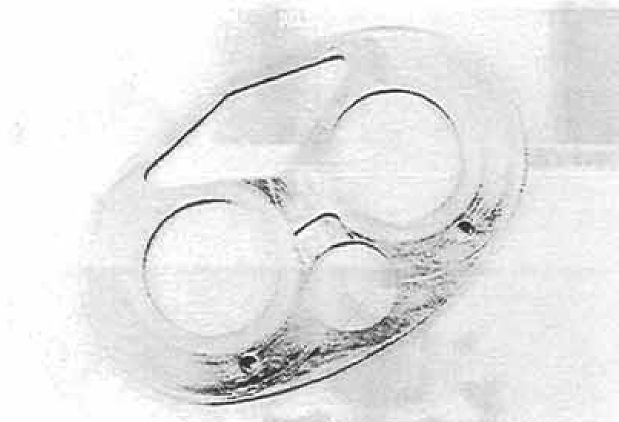


Figure 26:

The machined relief on the pressure plates normally has a sharp edge. If the edge looks as if it's been rounded, then dirt contamination will apply. The degree of damage to a normally polished surface will depend upon the size and concentration of dirt particles. Until the pump fails completely, the worst damage found is usually minor scratches because each time the particles pass through, they are crushed finer until they are nearly the same as a iapping compound. (See Fig. 26)

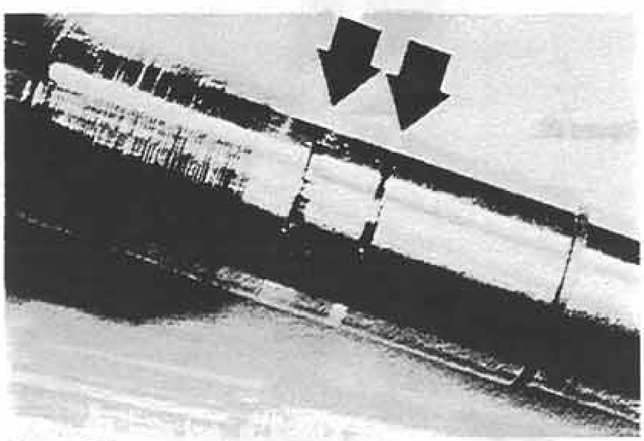


Figure 27:

If the pump has already failed from this cause, the oil seal lip will leave a cut in the shaft when abrasives become trapped there. (See Fig. 27)

In a system which is contaminated with particles of wear metal, the conditions inside the pump will be different since most metals are tougher than dirt. The presence of metal particles in the oil can be seen with a bright light. If you look close, a glittering reflection can be seen through the oil. Each one of these reflective particles has multiple cutting edges and the amount of damage caused will be in relation to their size. Once damage has begun, the metal content of the oil will increase as the system is used. (See Fig. 28)

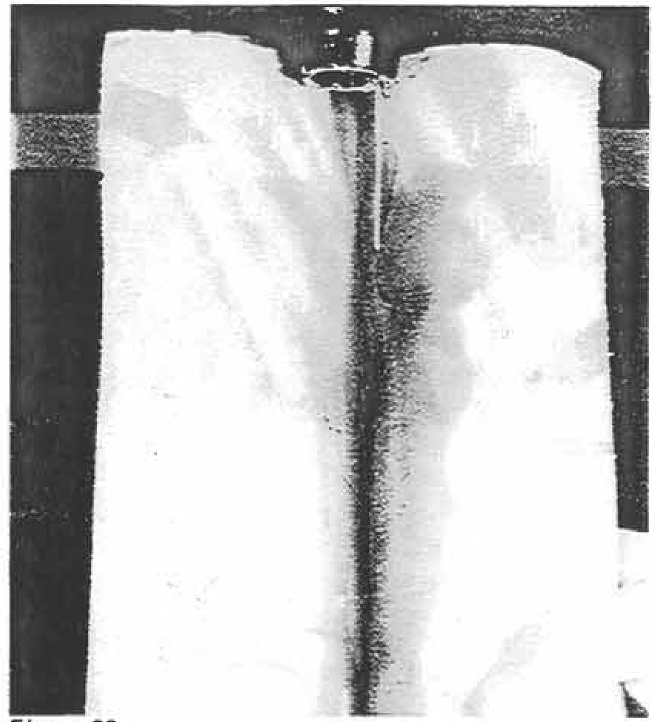


Figure 28:

The same areas of the pump are affected as before, but will indicate grooving instead of sandblasted finishes. If metal particle size was fairly large, scoring and some discoloration may be found. Gear thrust faces will have damage that matches the same areas on the pressure plates, mainly the tooth area of the gear. (See Fig. 29)

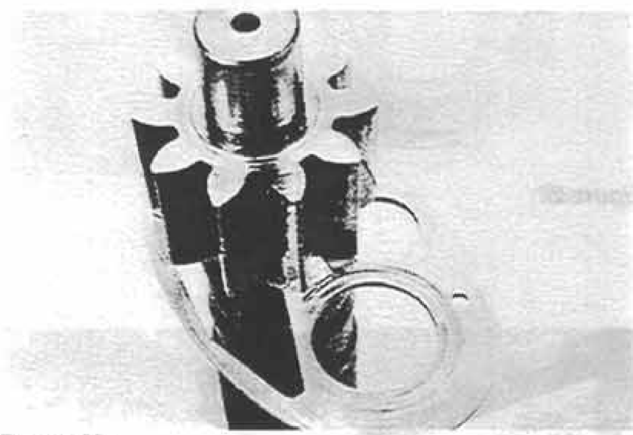


Figure 29:

Shaft journals will have scoring around them regardless of the type of bearing used. (See Fig. 30)

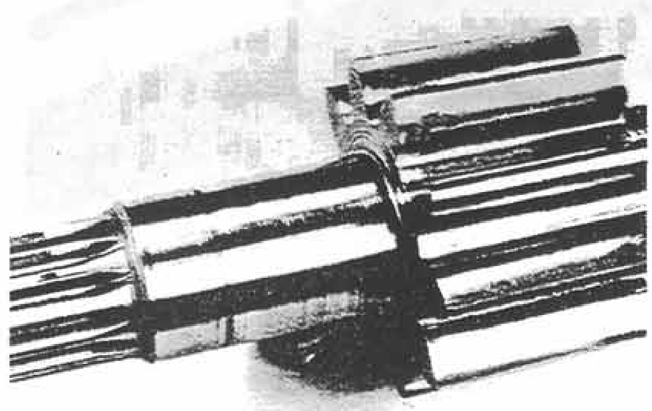


Figure 30:

Figure 31:

The gear bores of the pump housing will have grooves cut on the inlet side. You can compare the bore finish on the inlet and discharge side of the housing. Usually, when the damage is this far advanced, pump performance is very poor due to the large clearance between the gear tooth crowns and pump housing. (See Fig. 31)

The next areas of pump failure relate to the pump's inability to get enough oil from the reservoir during operation. Aeration and cavitation are similar in the signs they leave inside the pump and sounds they produce during operation. Because of these similarities, a close look is needed when checking system condition so the proper cause can be determined.

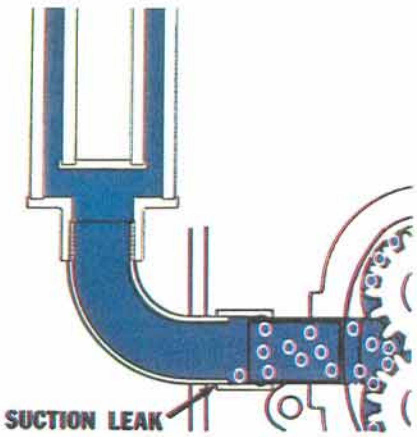


Figure 32:

Aeration is a condition describing oil that is mixed with air. Whether the mixing is done because of a low oil level in the reservoir or a suction leak between the reservoir and pump inlet, the term aeration will apply. (See Fig. 32)

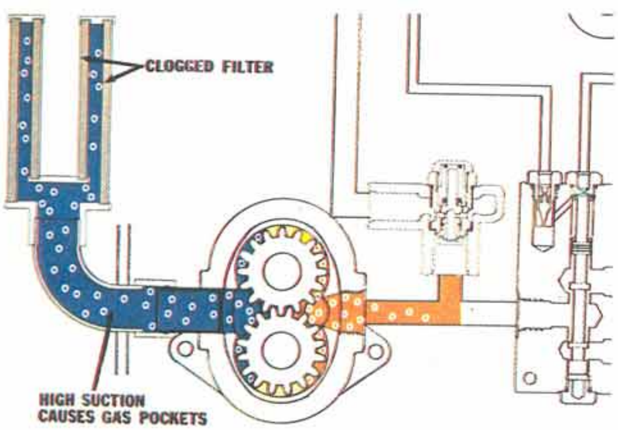


Figure 33:

Cavitation, however, is a term describing a condition seen by the pump when its inlet flow is restricted to a point of partial starvation. If the restriction causes the suction force to be strong enough, it can produce gas bubbles by means of oil vaporization. On both occasions, the pump produces a rattling sound during high free flows, but if demands are put on the pump at this speed, the sound will change to a whine. (See Fig. 33)

These forces produce mechanical reactions to cause the noise you hear and also act upon the porous items inside the pump. To better explain this, visualize air or gas bubbles in the stream of oil enroute to the discharge chamber in the pump. When reaching the discharge chamber, the pressure state changes from negative to positive (or suction to discharge) in a very short time span. If any vapors are present when this happens, a violent SLAPPING of the liquid occurs in the discharge chamber as the bubbles are forced to collapse. (See Fig. 34)

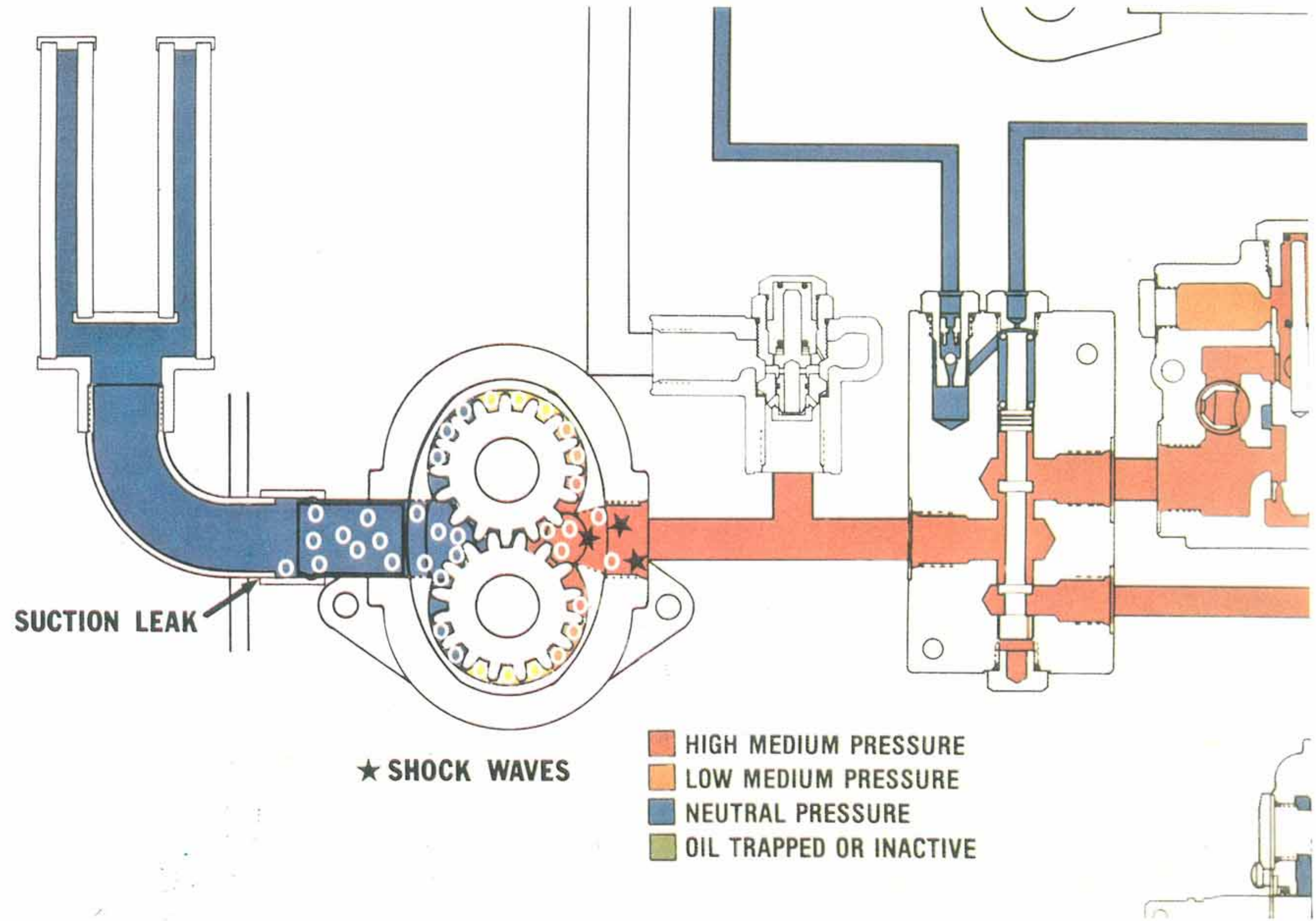

SUCTION LEAK
★ SHOCK WAVES
HIGH MEDIUM PRESSURE
LOW MEDIUM PRESSURE
NEUTRAL PRESSURE
OIL TRAPPED OR INACTIVE

Figure 34:

Figure 35:

This action in turn will erode metal from parts having the softest and most porous materials. In this case it would be the pump housing and pressure plates in the discharge area. The affected areas of the pump housing and pressure plates will have the appearance of having microscopic bits of metal pulled out, leaving many tiny holes. (See Fig. 35)

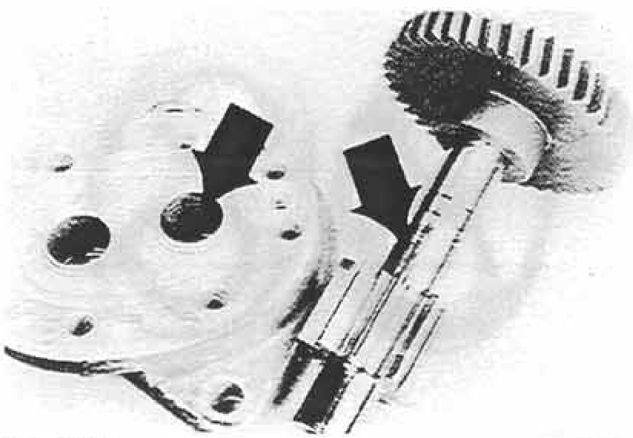


Figure 36:

Poor lubrication of the pump bearings is influenced when bubbles are present in the oil. The most critical are pumps equipped with plain bearings when the engine drive gear is supported directly on the pump shaft. Because of the greatest load, combined with the conditions described, it is likely for extreme bearing wear nearest the engine gear with or without much influence upon the other bearings. (See Fig. 36)

Figure 37:

Excessive temperatures may cause aeration of the oil due to a chain reaction. Some pump models have a steel suction tube pressed into the pump cover and the joint is sealed with a special epoxy. When the hydraulic system is abused by either improper accessories or high usage of the relief valves, we know the oil will absorb heat. If the temperature becomes too high, the aluminum pump cover may expand away from the steel tube and loosen the epoxy sealant. This can disguise a potential fault when the system cools down and, in the meantime, it can fool a good technician looking for an air leak. (See Fig. 37)

If a pump is run in an overheated condition, the heat will scorch oil onto the pressure plates to give a black color. The gears and shafts will usually have black streaks on surfaces that otherwise show little or no damage. The pump seals, if not already destroyed, will be brittle. (See Fig. 38)

Figure 38:

When we see pressure plates that have their bearing material smeared, welded or separated from their backing, then we know that lack of oil was the cause. The oil level in the reservoir may be low enough to supply the pump only part of the time, or a large air leak is present somewhere in the suction line. (See Fig. 39)

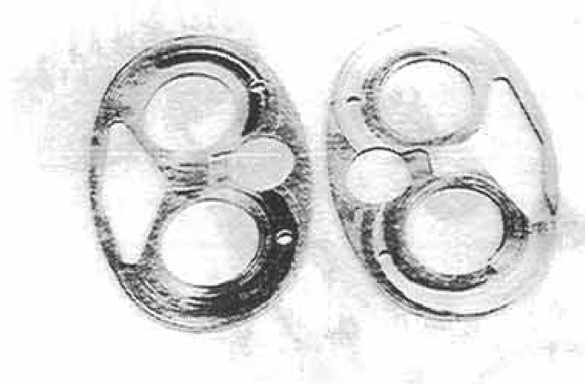


Figure 39:

The pump housing and drive shaft are parts most likely to become damaged if the pump is overloaded by pressure. If relief valves fail to function, a surge of high pressure can cause breakage of the driveshaft or pump housing. The same type of shaft damage may take longer to happen if the relief valve setting is too high or if the pump is incorrectly mounted to the engine when a spline drive is used. (See Fig. 40)

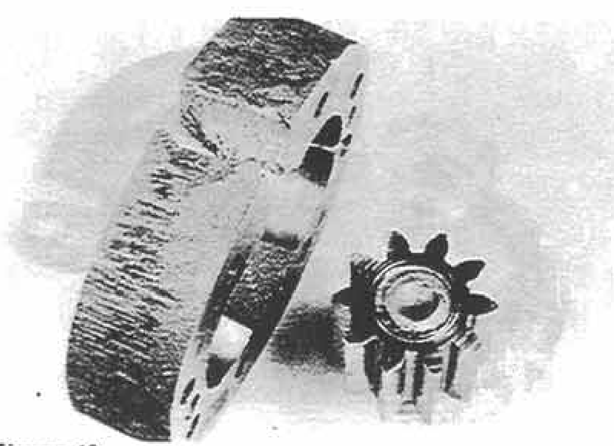


Figure 40:

Figure 41:

Many pumps have failed or lacked performance simply by careless reassembly or installation. Here are a few examples of common incidents. Pressure plates, if installed backwards, will allow the plate seals to wash out, thus permitting fluid flow from the discharge to enter the inlet chamber. Continued operation causes erosion of the end cover near the bearing bores. (See Fig. 41)

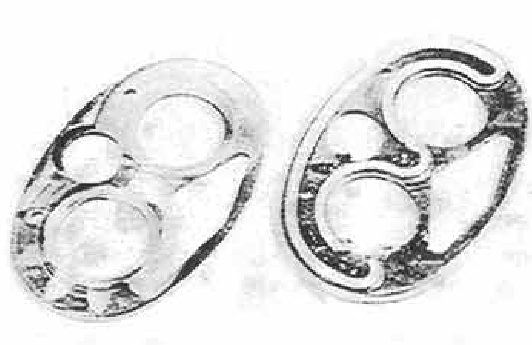


Figure 42:

Gear thrust faces can cut into the pressure plate if the seals under the plate aren't properly positioned in their slots. The drive shaft on some pumps has a spline drive to fit the engine coupling. If the drive shaft does not enter the coupling freely to its proper length, the same result will be seen. (See Fig. 42)

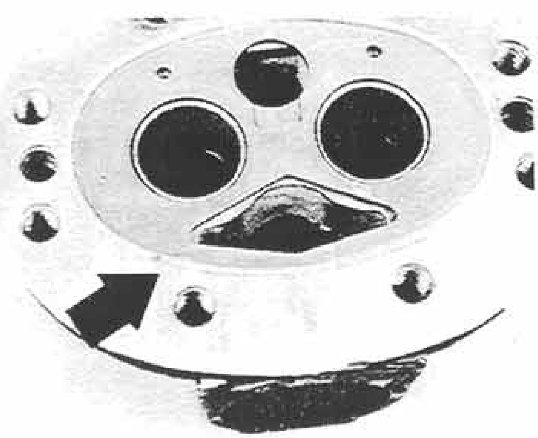


Figure 43:

External leakage is usually the result if the end cover seals become pinched or if foreign material is caught between the end covers and pump housing at reassembly. (See Fig. 43)

Pumps which have the engine gear directly on the pump drive shaft must be mounted squarely and torqued evenly to the engine flange. Otherwise edge loading can cause failure of the engine gear teeth. (See Fig. 44)

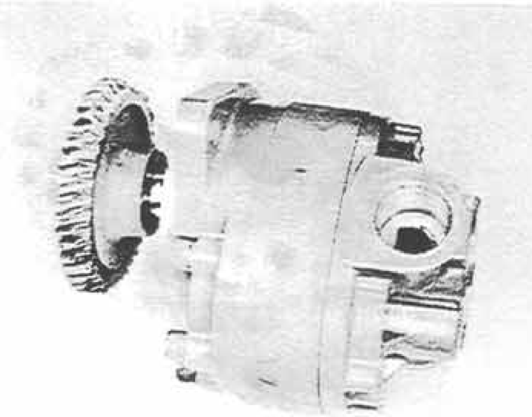


Figure 44:

During the reassembly of this type of pump, ensure that the large radius in the pump housing and the triangular opening in the pressure plates register on the inlet side of the pump when completely assembled. (See Fig. 45)

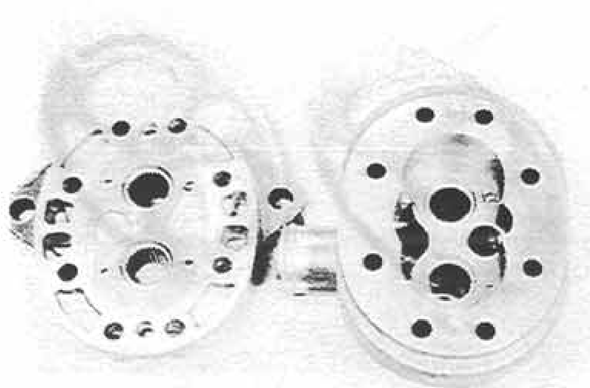


Figure 45:

Steering valve assemblies which did not pass tests should be opened for inspection. In certain cases a unit may have been removed for an obvious reason which did not require testing. For example, internal seizure. Regardless of the type of problem, a reasonable attempt should still be made to pin down the direct cause. All mating surfaces of the spools and housing have a matched fit with a clearance that is rated in millionths of an inch. Knowing this makes it easy to realize that contamination and temperature play a major role in the life and performance of the valve.

You may encounter a complaint from a customer that said, "It steers normally, but sometimes locks up before operating normally again." The symptom described here is thermal shock. When the hydraulic system is operating at a much higher temperature than the steering valve and suddenly the steering is used, a fast temperature change may "swell" the spools inside of the housing. (See Fig. 46)

After the whole assembly stabilizes in temperature, it will usually resume normal functions. Remember that a small quantity of oil at system temperature must pass through the valve during neutral steering demands. If any blockage prevents proper flow and temperature stability, then thermal shock can occur. Inside the steering valve, ensure that all passages are open and all parts are absolutely free of debris. Note that it would also be wise to check the entire load-sense circuit for cleanliness. (See Fig. 47)