EATON | Vickers

Pump Failure Analysis

How to read clues in hydraulic vane and piston pumps to learn what *really* caused them to fail.

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The Real Causes of Hydraulic Pump Failure

The pump is the "heart" of any hydraulic system. So whenever anything goes wrong in the system, it's usually the pump that gets the blame.

In fact, it's unusual for a pump failure to be caused by a defect in the pump. Actually, when a pump goes bad, it's usually just a symptom of some other problem hidden elsewhere in the system.

Typically, 90 to 95 percent of pump failures can be attributed to one or more of the following causes:

* Aeration
* Cavitation
* Contamination
* Excessive heat
* Over-pressurization
* Improper fluid

Each of these conditions leaves its own distinctive type of damage marks. It's important to recognize and understand those telltale signs. That way, the real cause of pump failure can be corrected —before another pump is needlessly destroyed.

This illustrated guide was prepared to help you pinpoint the real cause of your own pump's failure. Detailed photos show exactly the kind of damage caused by cavitation, aeration, and other problems. Both vane and piston pumps are covered.

Information is also included to help you determine whether a particular part can be reworked or must be replaced. Plus, an easy-to-follow troubleshooting chart helps you diagnose system problems before they result in component failure.

So the next time your pump breaks down, don't just blame the pump. Use this guide to prevent the same failure from happening again.

Go after the real causes of hydraulic pump failure.

Glossary

This section explains some of the terms used in this guide, along with additional information on symptoms and prevention.

Aeration

The presence of dispersed bubbles of air in a system's hydraulic fluid. An implosion effect occurs when the compressed air bubbles are subjected to system pressure at the pump outlet. This implosion can cause metal to be removed from the pressure plates, wear plates, etc. near the implosion point and result in extremely high local temperatures.

Pump aeration makes a loud, crackling noise like marbles being pumped. The noise is higher pitched at higher pressures. Excessive aeration makes the fluid look milky. It also causes components to operate erratically because of the compressibility of the air trapped in the fluid. Possible ways that air could be sucked into a pump are through faulty shaft sales and leaky inlet joints.

Cavitation

A localized gaseous condition within a liquid stream which occurs when the pressure is reduced to the vapor pressure. Put more simply, cavitation occurs when the fluid doesn't entirely fill the existing space. The noise from cavitation is similar to that heard from aeration. Cavitation can be caused by over speeding of the pump, a restricted or excessively long intake line, or fluid viscosity that's too high.

Contamination

Any material foreign to a hydraulic fluid that has a harmful effect on its performance in a system. Contaminants can be solid particles, liquids, or gases. Most contaminants cause an abrasive action in the close mating tolerance between components. This results in accelerated wear and tear.

Excessive heat

Thermal condition above a specified limit causing fluid viscosity to be affected. An extreme system duty cycle, aeration, cavitation, over-pressurization, and contamination are all factors that contribute to excessive heat. Excessive heat, in turn, accelerates oxidation in the system fluid, deteriorating its viscosity. This creates a chain reaction. Therefore, the root cause of excessive heat must be eliminated in order to effectively cure the problem.

Implosion

A sudden, violent, inward collapse. Implosion of air bubbles when subjected to hydraulic system pressure can cause severe pump damage.

Over-pressurization

Subjecting a pump to operating pressures greater than those for which it was designed. Over-pressurization creates extreme forces against various internal components and can result in premature failure

Viscosity

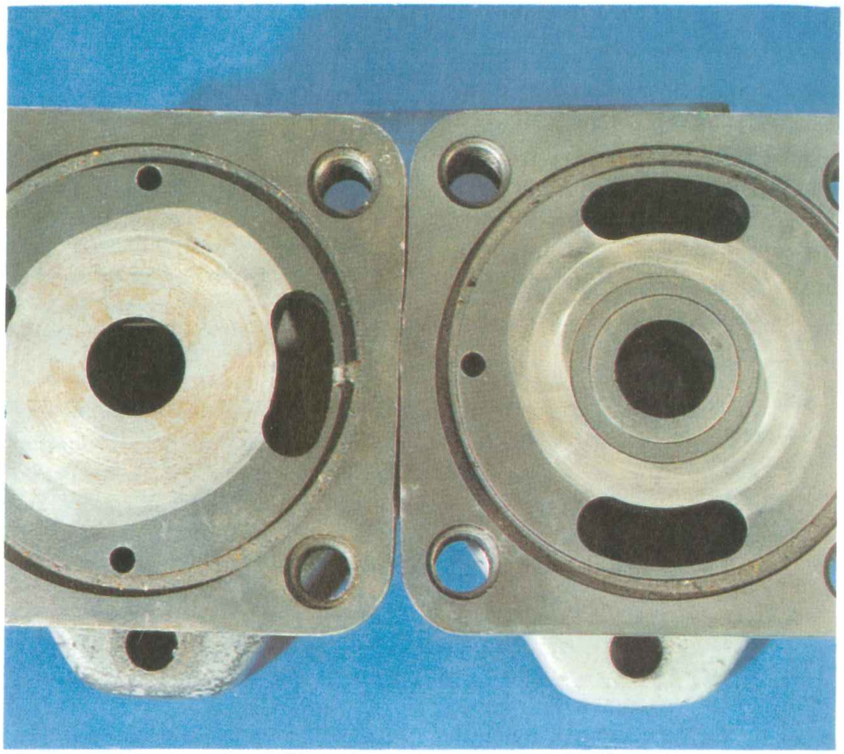
A measure of a fluid's internal friction or its resistance to flow. Higher than recommended viscosity (as might be the case with very cold oil) may cause pump cavitation. Lower than recommended viscosity can cause increased internal pump leakage and an accompanying increase in heat. Therefore fluid of the recommended viscosity level, to which the manufacturer has added appropriate additives, is one key to longer pump life.

Vane Pump Failures

Square pump body

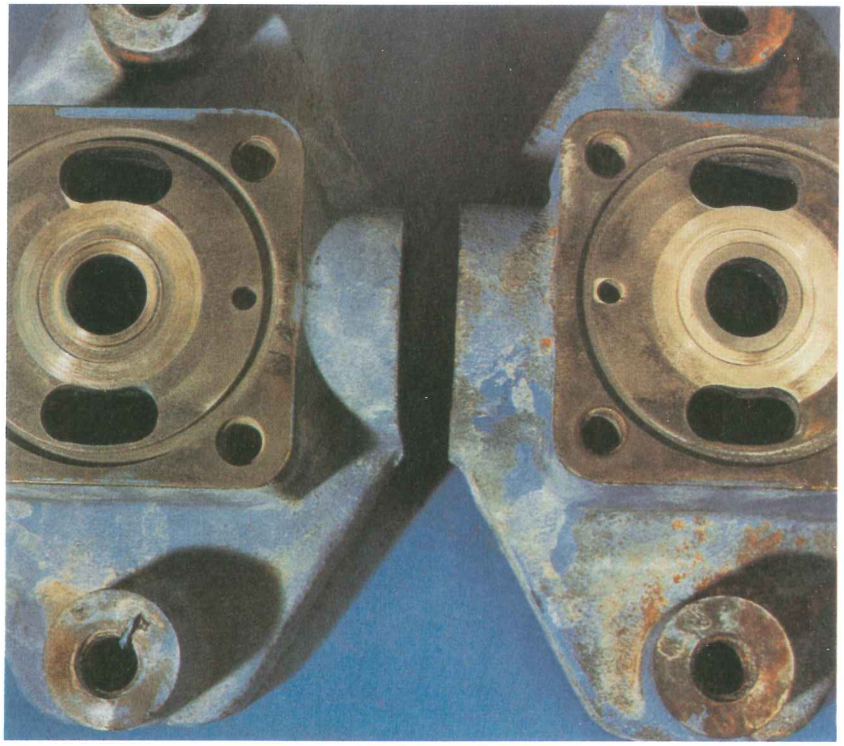
Surface scoring

This surface is normally lubrited (phosphated). It can be scored from pump seizure or severe contamination trapped between the rotor and body surface. The pump body on the left shows typical scoring. Such scored bodies can be given minor resurfacing (.005" to .010"), but must be retreated (phosphated) before being reused. If major resurfacing is performed (.010" to .020" maximum), the O-ring groove must be deepened by an equal amount.



Resurfacing requirements

The body on the left is scored badly enough to require resurfacing. The pump body surface on the right, however, has no depth of scoring — only the treatment color has worn off. Bodies in this condition can be used "as is."

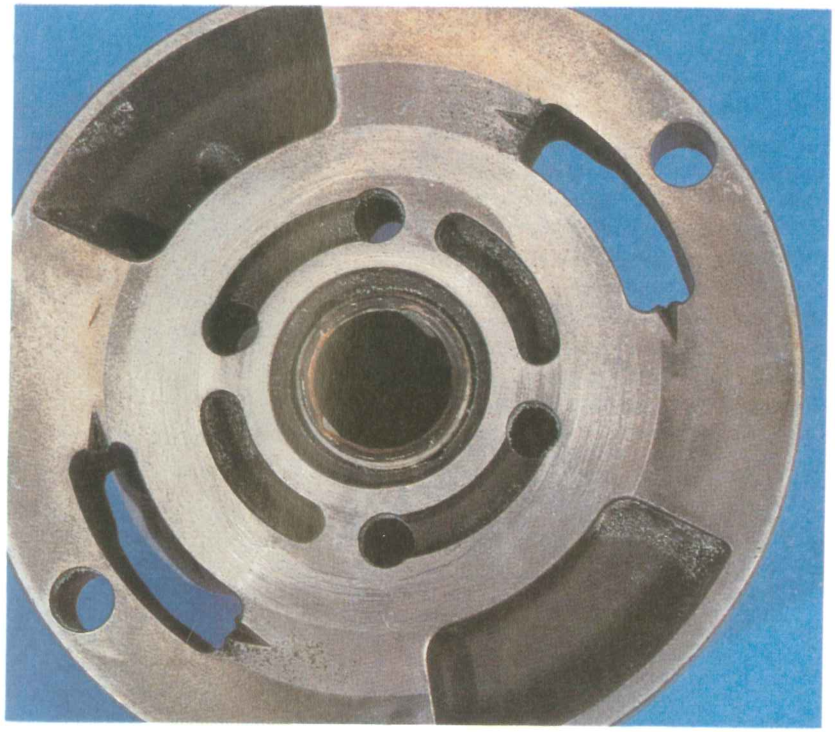


Square pump pressure plate

Signs of pump aeration

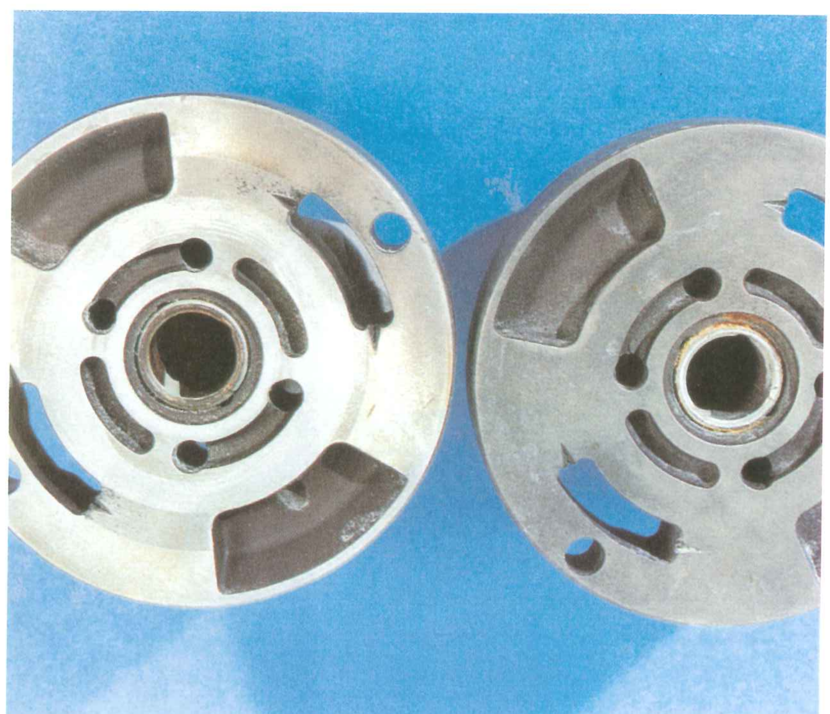
Because air is compressible, any bubbles trapped between the vanes of a pump are violently imploded when subjected to outlet pressure. If an imploded air bubble is near a pump surface, the energy released can remove material. This leaves cavitation-type pock marks (as seen here at the outlet metering notches). The particles of metal blasted away become fine contamination that can cause wear and scoring of the pressure plate and mating rotor surface.

Pump surfaces with mild aeration and cavitation marks can be resurfaced up to .010". If more than .010" is removed during resurfacing, the metering notches must be re-notched by the same amount. Any bearing or guide surfaces that are ground should always be lapped or polished to improve surface texture. After resurfacing, the plate must be retreated (phosphated) to restore the original coating.



Severe aeration damage

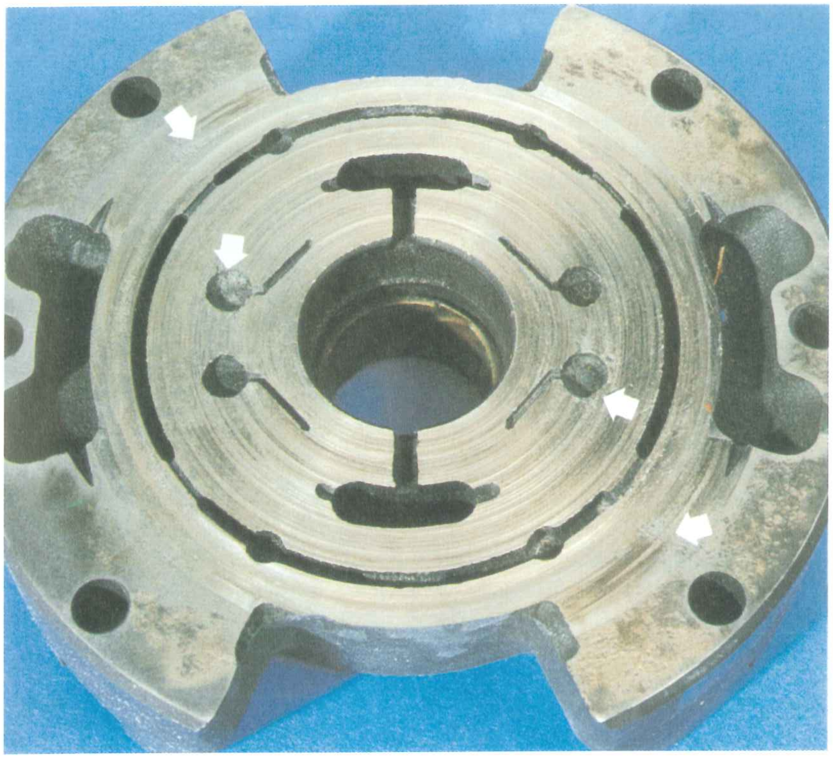
The pressure plate on the left has suffered severe damage from aeration and is beyond repair. Resurfacing would fail to restore the material that's been chipped away near the metering notches. (The plate on the right is in good condition and is shown for comparison.)



Intra-vane pump support plate

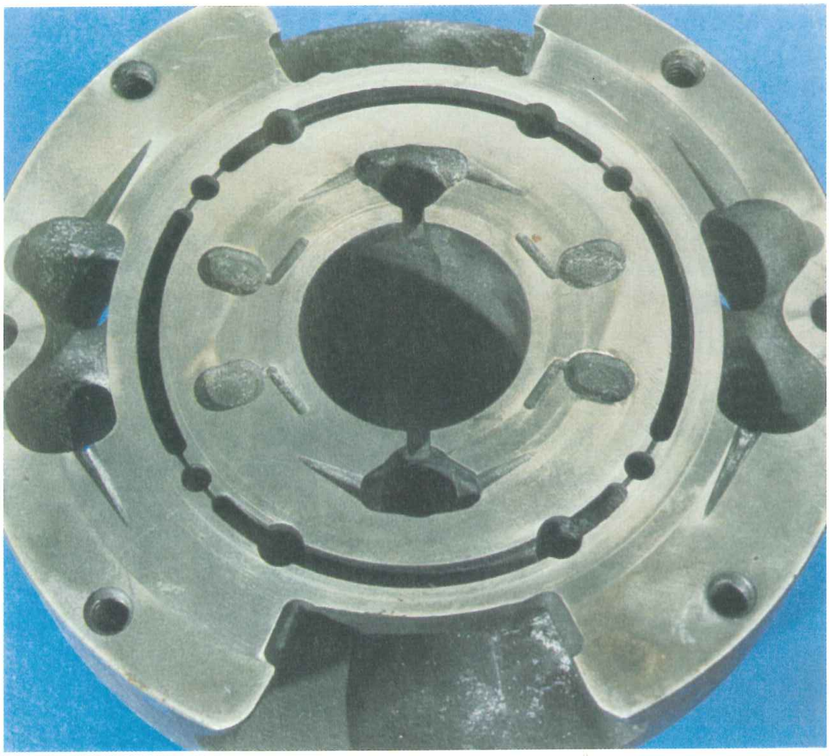
Inlet support plates damaged by aeration

The effects of aeration are similar on both inlet and outlet support plates. Here we see obvious damage caused by collapsed air bubbles. The plate surface is also badly scored. It can be resurfaced up to .010" without re-notching or deepening the grooves. Resurfacing between .010" and .020" will require re-machining the groove depth and metering notches correspondingly. Never resurface beyond .020". Remember that resurfaced plates must be properly retreated (phosphated) per specification.



No significant damage

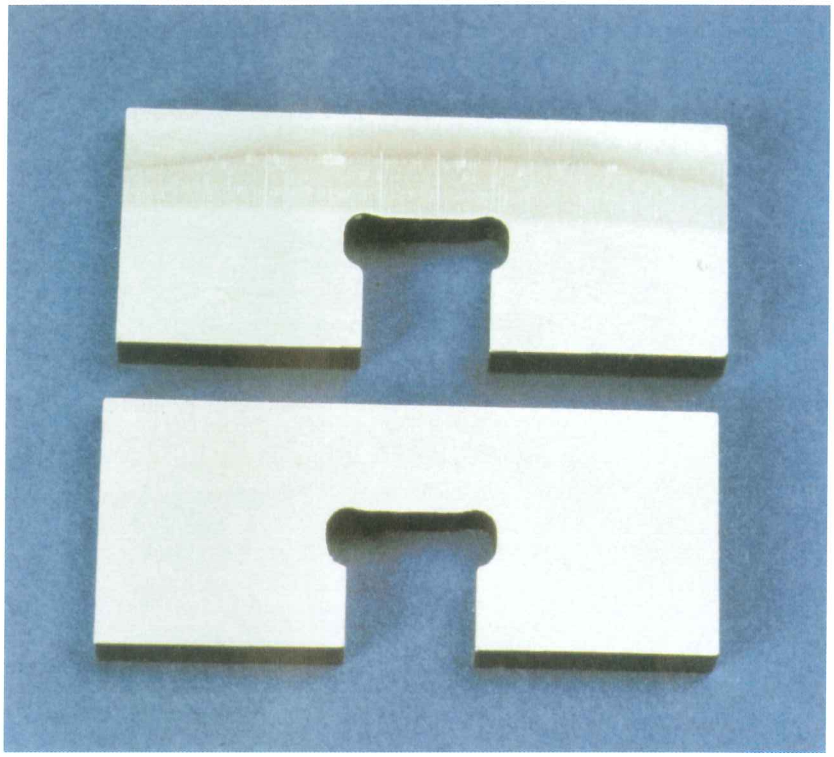
This outlet support plate doesn't show any significant wear and tear. After stoning to remove burrs, it's ready to be reinstalled.



Vane pump vanes

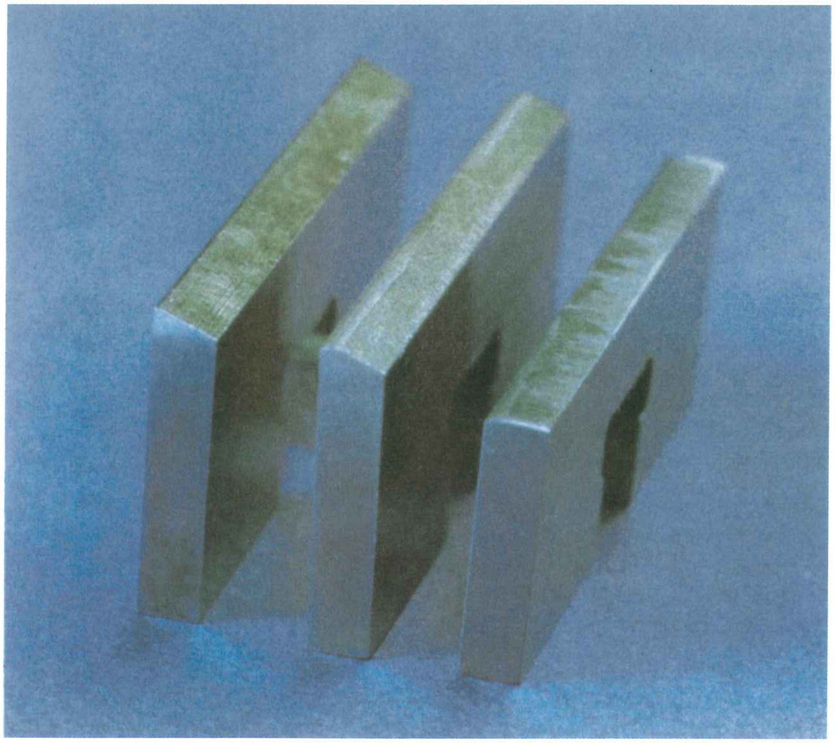
Vane frosting

Compare the appearance of new vane (bottom) with the frosted look of a vane that's been subjected to fluid contamination (top). The cartridge this vane came from should be replaced.



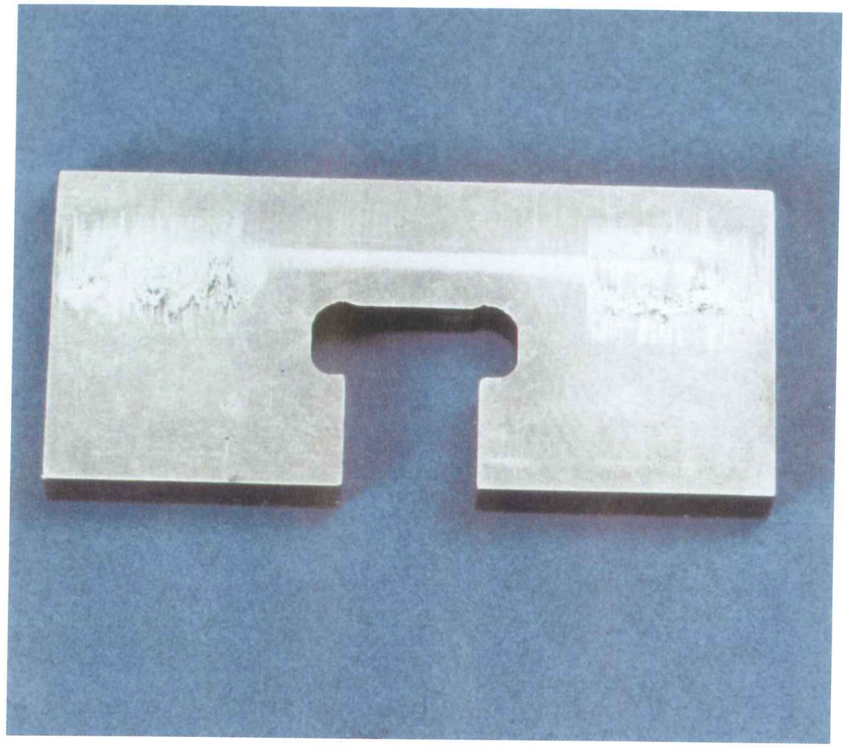
Tip wear

The vane on the left is new, and the one in the middle is worn down somewhat from fluid contamination. The extreme wear seen on the vane to the right was caused by aeration. Similar damage can also be caused by fluid in poor or marginal condition. The associated cartridge should be replaced.



Galled vane

This type of galling damage is symptomatic of over-pressure or over-temperature. This indicates a cartridge damaged beyond repair.



Vane pump cam ring

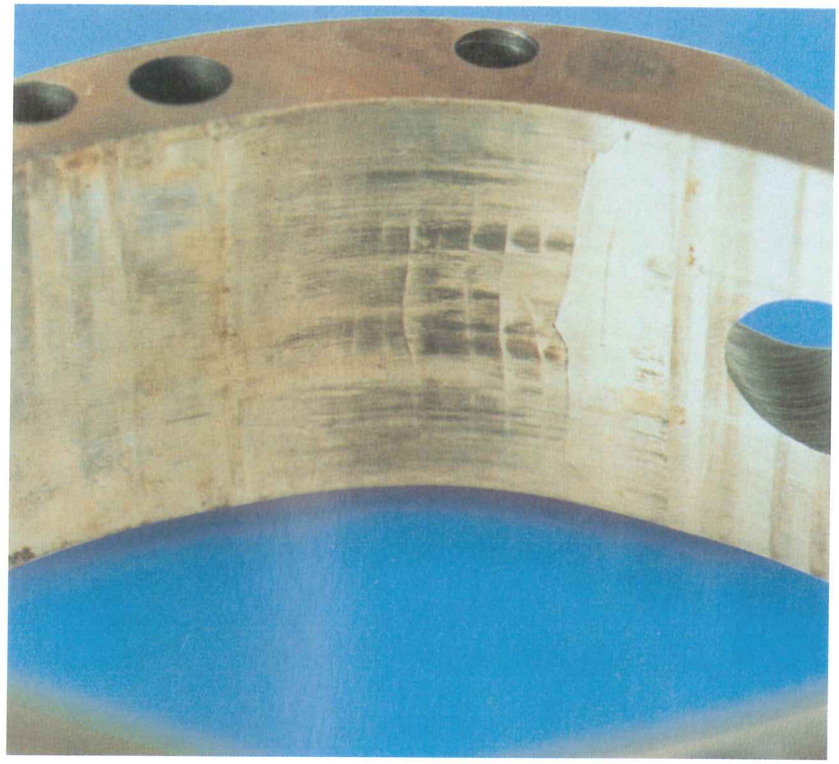
Ripple marks

Vane pump cam rings will have a shiny inner surface due to normal operation. Some rings (as seen here) may also exhibit ripple marks caused by cavitation, aeration, or contamination. These marks can vary from minor to severe. Mild ripples (between .001" and .002" deep) can be polished out and the ring reused. Always polish the cam ring in the indicated direction of rotation. Heavy rippling requires expert examination to determine whether geometrical grinding can be used to salvage the ring. Nital etching should also be performed to ensure that the surface is not softened.

Cam rings can also crack or break completely at their weakest cross sectional point. This type of failure is caused by pressure surges beyond the pump's design specification.

Heat checked surface

This indicates one or more system problems including an aerated inlet, excessive temperature, or marginal fluid quality. Heat checked cam rings should be replaced.



Seizure damage

Pump seizures (as evidenced by galling or metal transfer) can make local temperatures rise dramatically. These high temperatures cause discoloration of the cam ring, as seen here. In this particular case, the local temperature was so high that the vane tips literally fused into the ring contour. A ring in this condition cannot, and should not, be reworked.

Comparison of two failed cam rings

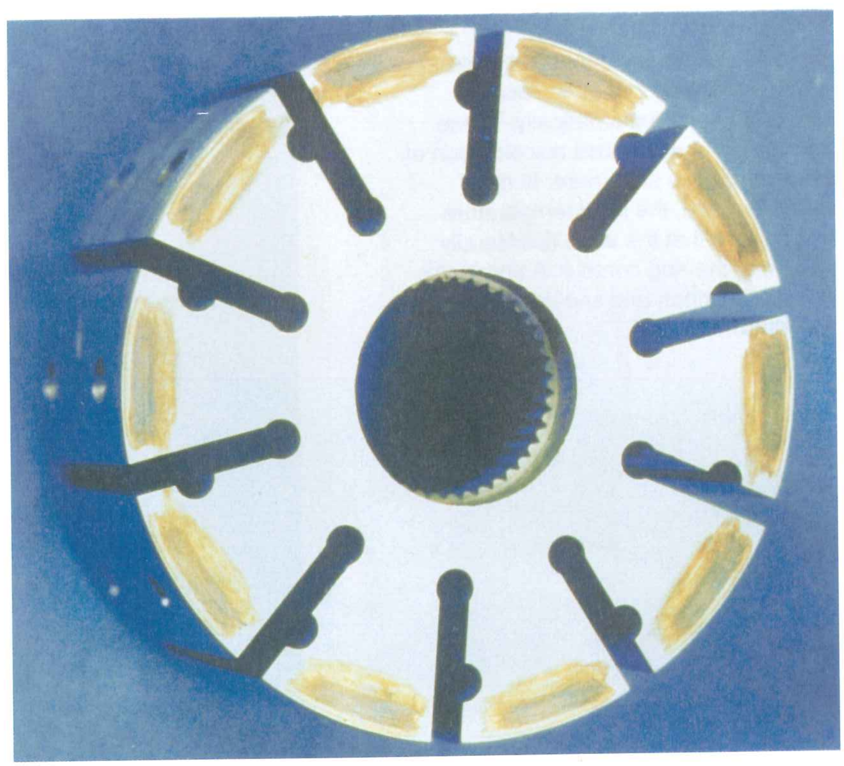
The ring on the left has mild rippling and can be repolished and use again. The one on the right, however, has decomposed badly from extreme heat and show evidence of pump seizure. It must be replaced.

Vane pump rotor

Rotor surfaces can be badly scored by contamination and/or seizure. Vane slots can also get worn and scored by fluid contamination.

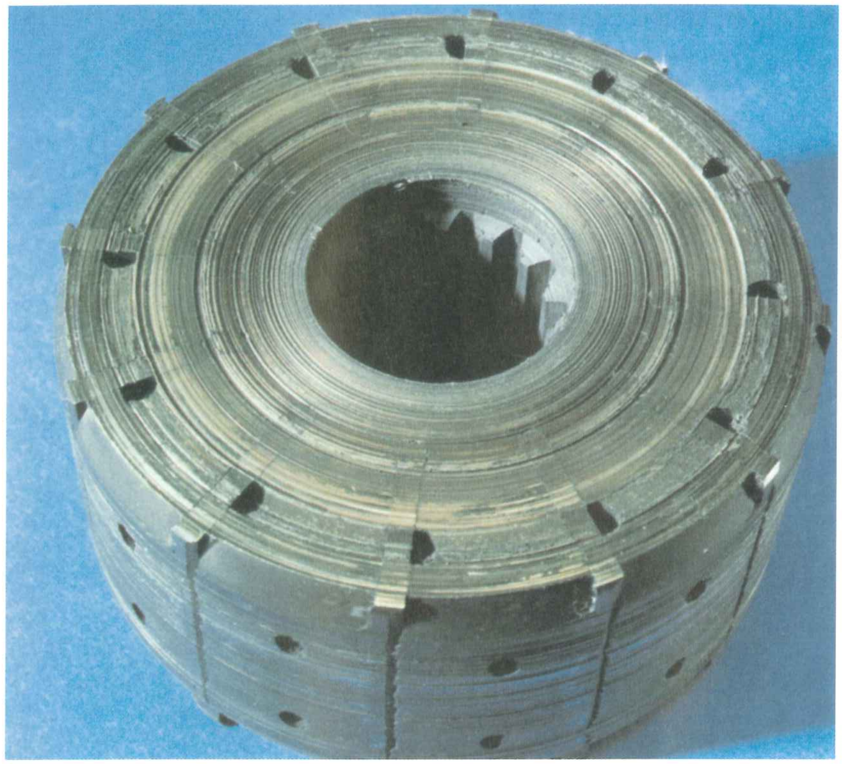
Rotor smear

A rotor in this condition is a sign of over-pressure or low inlet pressure. The cartridge should be replaced.



Typical damage

Seizure type failures can be due to fluid contamination, dry run, lack of lubricity in the fluid, high system temperature, or improper clearance between cam ring and rotor thicknesses. Rotors with vane slots worn more that .0002" cannot be reused. Scored rotor surfaces like the one shown here cannot be reworked and should be replaced.

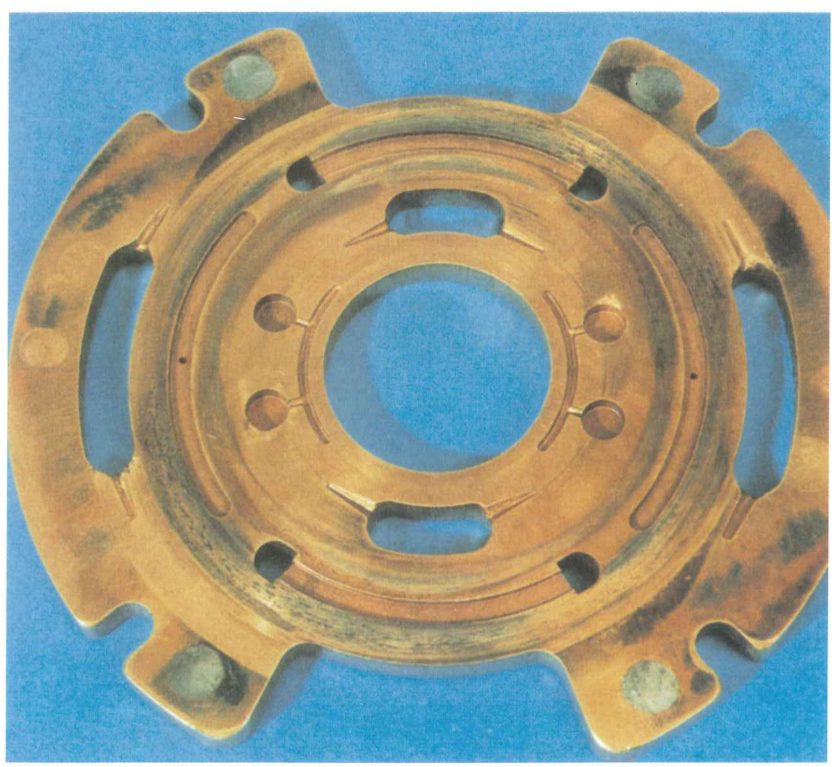


VQ pump flex plates

Flex plates play a key role in VQ pump operation. The bronze surface of these plates is critical to proper performance.

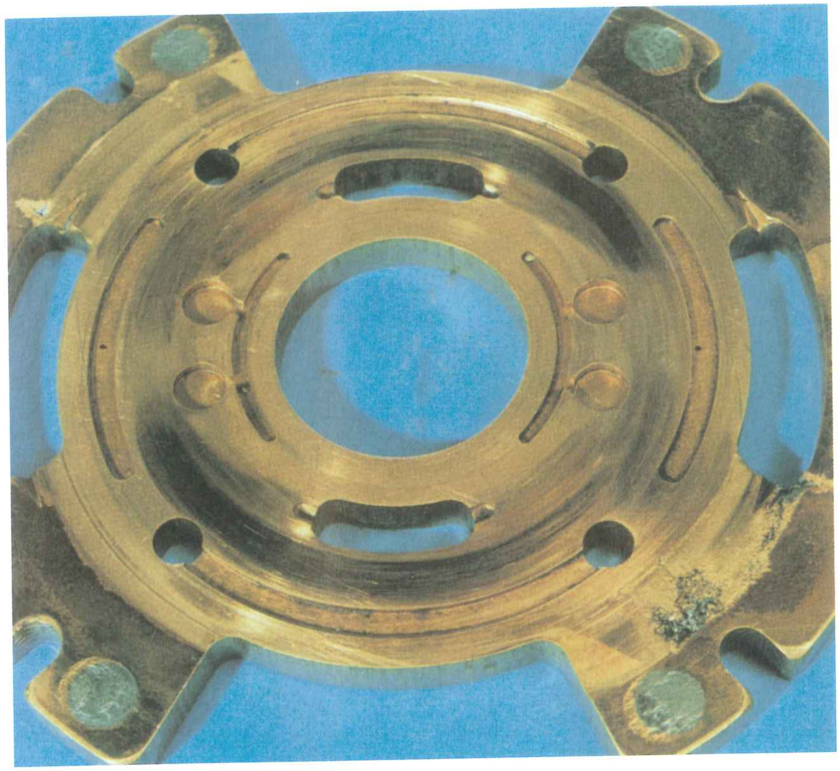
Normal discoloration

This flex plate displays a typical amount of discoloration. The discoloration alone should have no effect on pump operation.



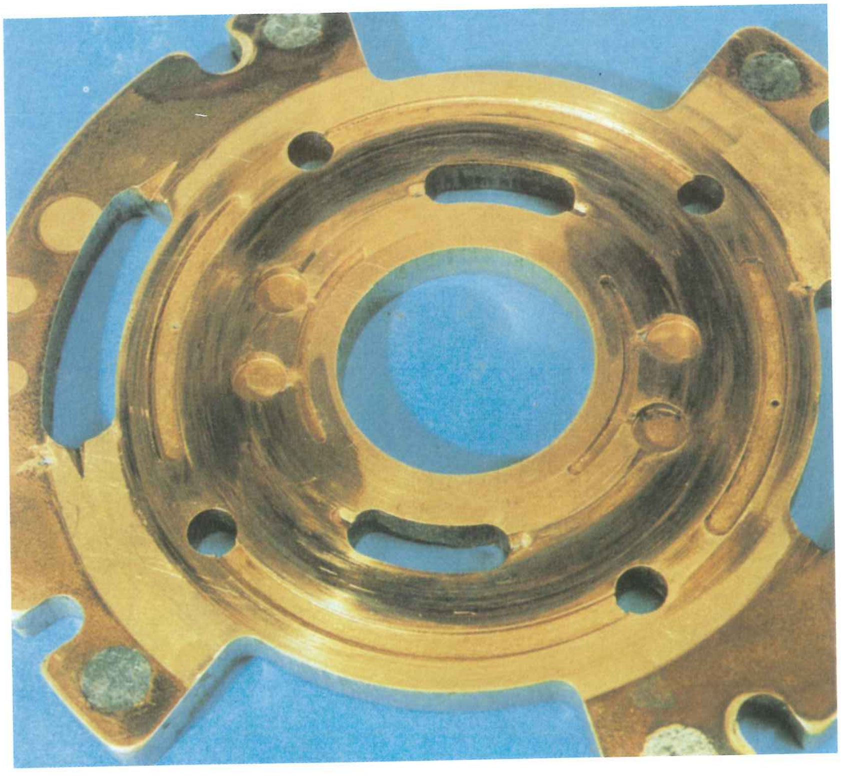
Severe aeration damage

The erosion on this VQ flex plate was caused by collapsed air bubbles (aeration) near the outlet port metering notches. If the damage isn't too severe, the plate can be resurfaced to a maximum .005" of material removal. The flex plate shown here is damaged so badly that resurfacing can no longer be done.



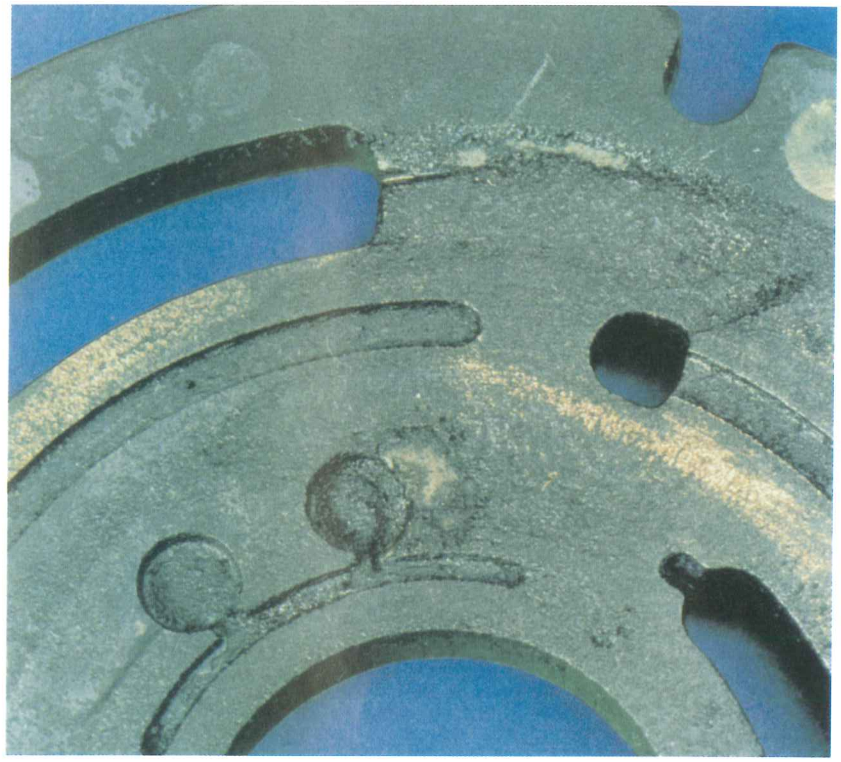
Reworkable flex plate

The erosion on this plate is less severe. It can be resurfaced and used again, even though it's somewhat discolored from heat.



Darkening and erosion

Damage like that seen here is the result of excessive system temperature. After this problem has been corrected, the entire cartridge should be replaced.



Piston Pump Failures

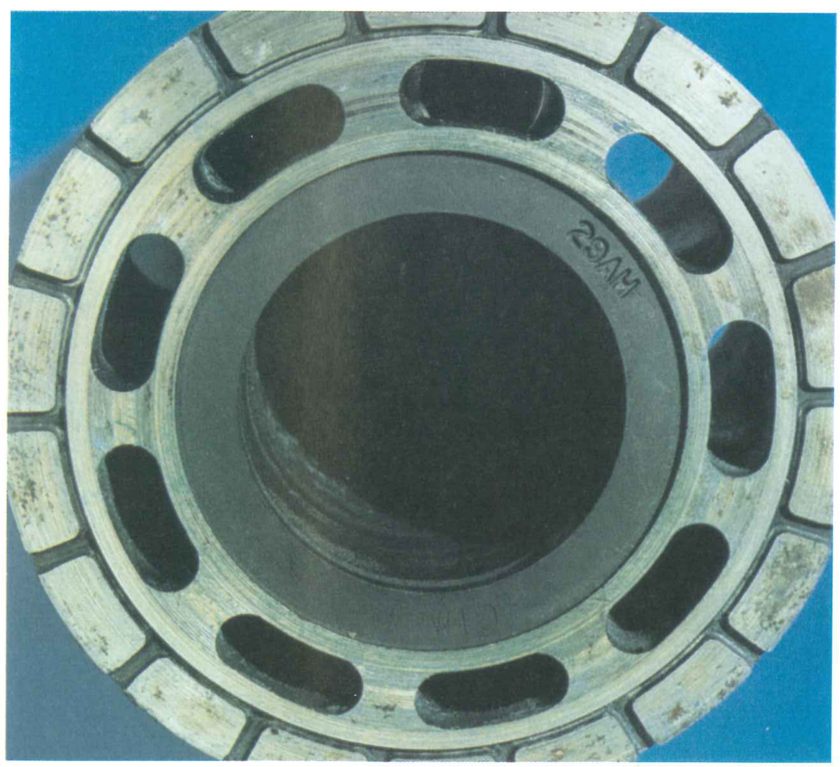
Cylinder block

The individual cylinder bores within a cylinder block are prone to excessive wear and tear. This can be due to dry run, lack of lubricity in the fluid, or foreign contaminants. Cylinder blocks with worn or scored bores should never be reused.

The top surface of a cylinder block that contacts the valve plate can also become scored or pitted due to improper operating conditions such as aeration, cavitation, contamination, and high system temperature.

Top surface scoring

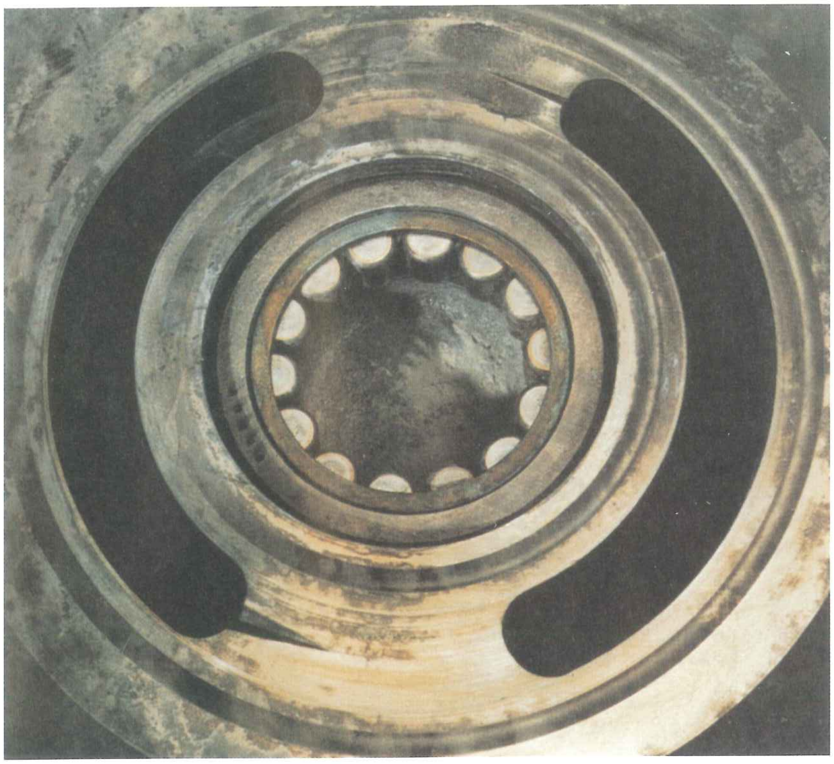
This picture shows evidence of scoring on the top surface due to contamination. In cases such as this, the cylinder block can be relapped or reground .005" to .015". Reworked blocks should always be adequately treated (lubrited or sandstrom coated) before reuse.

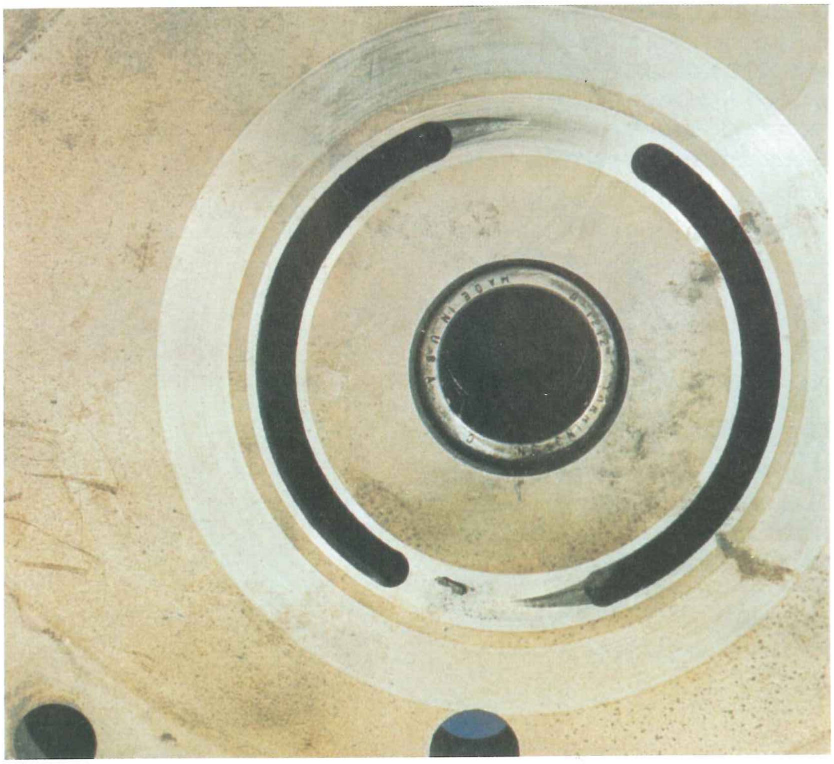


Valve plate

Aeration damage

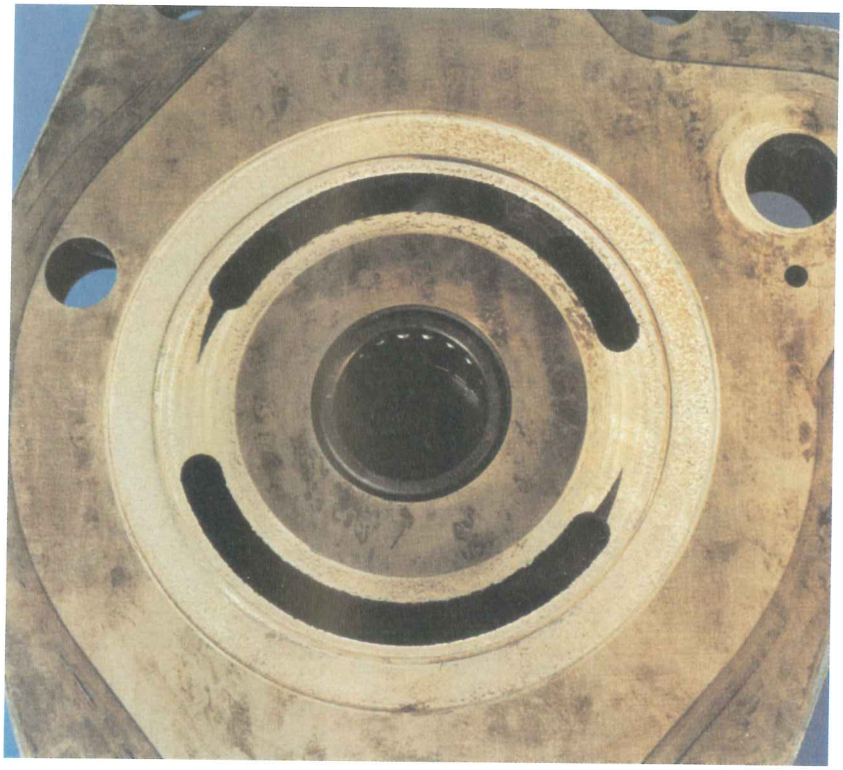
Aerational effects on piston pump valve plates are very similar to those seen on vane pump pressure, wear, and flex plates. Erosion marks are evident on both valve plates shown here.





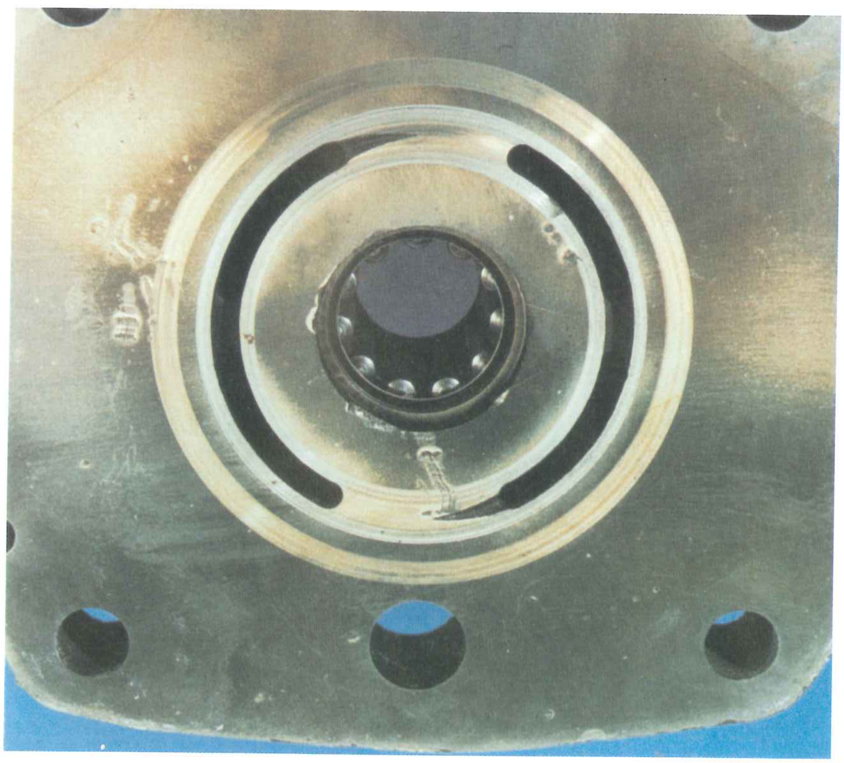
Surface scoring

The valve plate surface can become scored due to a number of factors, including contamination. Scored surfaces like the one in this picture can be resurfaced up to .015". Rework the metering notches a corresponding amount. The resurfaced plate should then be retreated per specification (re-nitempered). Note that the bearing must be removed prior to any rework.



Large particle damage

This valve plate was badly gouged by a large piece of foreign material.



Piston/shoe subassembly

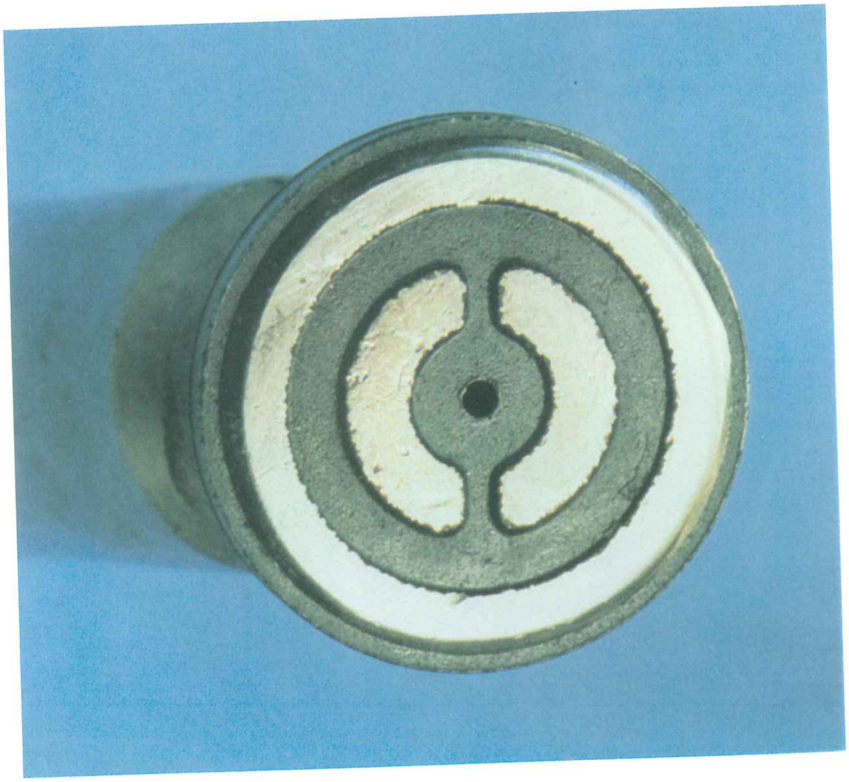
If all piston shoes thicknesses are not within prescribed limits, the out-of-tolerance shoes may experience “lifting”. Another possible cause of shoe “lift” is pump cavitation. Eventually the shoe may come completely off the piston and inflict catastrophic damage.

Piston head contamination damage

Shoes can also become loose on the piston head as a result of severe scoring and pitting from contamination. Old shoes should never be re-swedged.

“Rolling”

Shoe lift and cavitation produce a “rolling” effect that rounds off the shoe edge. Another symptom is scoring on the shoe surface, as evident in this picture.



Ruined pistons

Telltale effects of contamination and seizing on the piston diameter can be seen in these photos. Pistons in this condition cannot be reworked.

Comparison for reuse

The piston on the right has obvious damage and should be replaced. The one on the left, however, is in relatively good condition and can be used again.

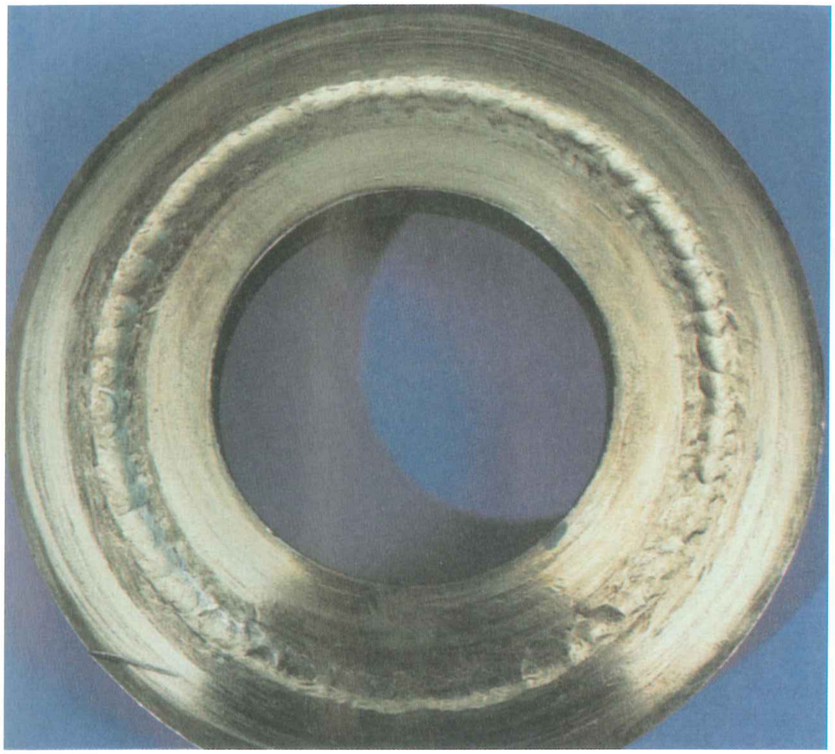
Swash plate

Evidence of shoe lift

Swash plates can also be harmed by the lifting and "rolling" of piston shoes, as seen here. The surface of the swash plate can be reground to .015" maximum, but must then be re-nitempered.

Severe swash plate damage

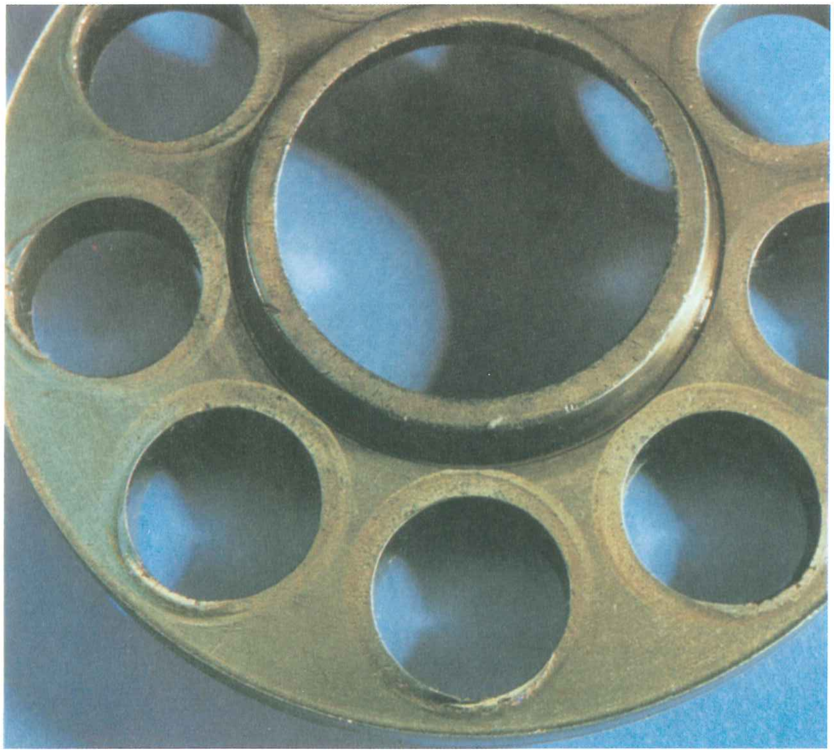
This picture shows the kind of pounding that happens when a shoe comes completely off its piston. This plate can't be reworked and must be scrapped.



Shoe plate

More lifting damage

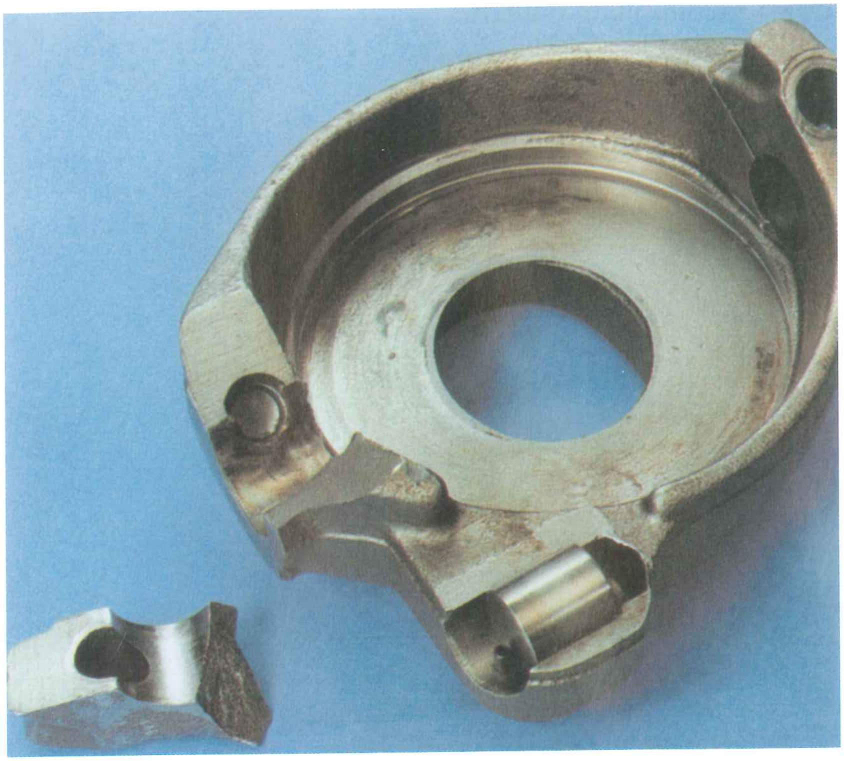
The effects of shoe lifting also appear on the shoe plate, which is apparent in this picture. A plate like this should not be reused. A shiny or scored surface in the center area that supports the spherical washer is also cause for shoe plate rejection.



Yoke

Shattered yoke

The bolts that secure the pintles to the yoke are subject to continuous loading and unloading forces. Improper torquing of one of the bolts, or an unusually high frequency of loading/unloading, can cause bolt failure and yoke breakage, as seen here.



Shaft Failures

Vane and piston pump shafts

Pump shaft failures are generally caused by repeated stress. Like a chain that is only as strong as its weakest link, shaft damage will occur when the stresses encountered at the weakest point of the shaft finally exceed its strength.

There are two primary types of metal fatigue that are responsible for most pump shafts failures: rotational bending fatigue and torsional fatigue.

Rotational bending fatigue

This shaft broke cleanly at a 90° angle to its axis of rotation. This type of failure is due to rotational bending fatigue. A likely cause is misalignment between the pump and its "prime mover" that makes the shaft flex slightly with each revolution. Fractures like this usually start in some area of concentrated stress that is at least partially perpendicular to the shaft axis. These weak points in the shaft can include grooves, fillets, and holes.

The shaft shown here has the ripple marks typically founts with rotational bending fatigue failures. These marks indicate that the shaft was unevenly loaded or unbalanced. The smoother area near the edge is where the fracture started. The curved ripples get gradually courser, with a rough, shell-like spot where the shaft finally ruptured.

Torsional fatigue

This shaft failure was caused by torsional fatigue. This fatigue is caused by the forces generated during normal operation. When these forces are repeated thousands or even millions of times, with varying stress levels and load cycles, eventually the shaft can simply wear out.

Torsional fatigue fractures can take a variety of shapes, depending on the shaft geometry and loading direction. Torsion that is always in the same direction usually causes one long spiral fracture at about a 45° angle to the shaft axis, as shown here.

Troubleshooting Chart

Find the **SYMPTOM** being experienced, then read down that column. The < arrows will point out the most likely **CAUSES**. The following pages list repairs that may eliminate each of the numbered **CAUSES.**

	SYMPTOM									
CAUSE	Pump making noise	No system pressure	Breakage of parts inside pump housing	External oil leakage around the pump	Pump not pumping	Excessive wear	Heating caused by power unit (reservoir, pump, relief valves, coolers)	Heating because of system	Erratic action	Leakage
1. Restricted inlet	<		<		<	<			<	
2. Air leaks	<				<				<	
3. Air entrainment	<					<			<	
4. Reservoir air vent plugged	<									
5. Pump rotation or speed incorrrect	<				<					
6. Oil viscosity too high	<		<		<		<			
7. Oil viscosity too low						<			<	<
8. Filter or strainer too dirty or filter too small	<		<			<				
9. Pump out of line with driving motor	<		<			<				
10. Pump head too loose or faulty head gasket	<	<								<
11. Pump head too tight			<							
12. Stuck pump vane	<	<							<	
13. Cavitation	<		<			<				
14. Pump malfunction	<	<	<		<	<	<	<	<	<
15. Relief valve not functioning properly		<	<			<	<	<	<	
16. Incorrect control valve setting		<								
17. Internal leakage in valves, cylinders, or pumps		<					<	<	<	
18. Excessive pressure above maximum pump rating			<			<				<
19. Low fluid level in reservoir			<		<	<			<	
20. Dirt in pump	<	<	<							
21. Packing worn or damaged				<						<
22. Fluid contaminated with dirt or water	<		<			<				
23. Oil cooler clogged							<	<		
24. Restricted lines			<			<				
25. Reservoir too small	<		<		<	<			<	
26. Valve deposits									<	
27. Pilot pressure too low									<	
28. Electrical solenoid problems									<	
29. Loosened fittings										<
30. Dried or worn seals or O-rings	<								<	<
31. Line breakage			<			<				<

Suggested Repairs

1. **Restricted inlet:**

   Check line from reservoir to pump. Be sure filters and strainers are not clogged.

2. **Air leaks:**

   (a) At pump intake piping joints. Test by pouring oil on joints while listening for change in sound of operation. Tighten as required.
   (b) At pump shaft, test by pouring oil on shaft seal while listening for change in sound of operation. Follow manufacturer's recommendation when changing packing.
   (c) Air drawn in through inlet pipe opening. Check to be certain suction and return lines are well below oil level in reservoir. Add oil to reservoir if necessary.

3. **Air entrainment:**

   If oil level is low or return line to reservoir is installed above oil level, air bubbles will form in oil in reservoir. Check oil level and position of return line.

4. **Reservoir air vent plugged:**

   Air must be allowed to be breathed into reservoir. Clean or replace breather.

5. **Pump rotation or speed incorrect:**

   Some pumps will deliver oil over wide range of speeds; others must turn at recommended speed to give appreciable flow. First find out speed recommended by manufacturer; then, with speed counter if possible, check speed of pump. If speed is wrong, look for trouble in driving motor. Some types of pumps can turn in either direction without causing damage; others are designed to turn in one direction only. Check belts, pulleys, gears, motor connections. Reversed leads on 3-phase motors are most common cause of wrong rotation.

6. **Oil viscosity too high:**

   If oil is too heavy, some types of pumps cannot pick up prime. You can make very rough check of viscosity by first getting some oil that is known to have correct viscosity. Then, with both oils at same temperature, pour one quart of each oil through small funnel. Heavier oil will take noticeably longer time to run through. Oil that is too heavy can do great harm to hydraulic systems. Drain and refill with oil of correct viscosity.

7. **Oil viscosity too low:**

   Check pump manufacturer's recommendations. Oil with anti-wear agents is needed.

8. **Filter or strainer too dirty or filter too small:**

   Filter and strainer must be kept clean enough to permit adequate flow. Check filter capacity. Be sure that original filter has not been replaced with one of smaller capacity. Use oil of quality high enough to prevent rapid sludge formation.

9. **Pump out line with driving motor:**

   Check alignment. Misalignment may be caused by temperature variation. Coupling may not have been installed properly or belt tension may be incorrect.

10. **Pump head too loose, or faulty head gasket:**

    Test by pouring oil over head. Replace gasket or tighten head as necessary.

11. **Pump head too tight:**

    Follow manufacturer's instructions when re-assembling. Pumps assembled after overhaul may be assembled too tightly. This reduces clearances and increases rubbing friction.

12. **Stuck pump vane** (vane type pump)**:**

    Inspect for wedged chips or sticky oil and re-assemble.

13. **Cavitation** (formation of vacuum in pump)**:**

    Check for clogged or restricted intake line, plugged air vent in reservoir. Check strainers in intake line. Oil viscosity may be too high. Check recommendations.

14. **Pump malfunction:**

    Install pressure gage and block system just beyond relief valve. If no appreciable pressure is developed and relief valve is OK, look for mechanical trouble in pump. Replace worn or broken parts.

15. **Relief valve not functioning properly:**

    Valve setting not high enough:
    – Increase setting of valve.
    Valve leaking:
    – Check seat for score mark and repeat.
    Spring in relief valve broken:
    – Replace spring and re-adjust valve.

16. **Incorrect control valve setting** (oil "short-circuited" to reservoir)**:**

    If open-center direction control valves are unintentionally set at neutral position, oil will return to reservoir without meeting any appreciable resistance and very little pressure will be developed. Scored control-valve pistons and cylinders can cause this trouble. Replace worn parts.

17. **Internal leakage in valves, cylinders, or pumps:**

    Determine location. Progressively block off various parts of circuit.

18. **Excessive pressure above maximum pump rating:**

    Check relief or regulator valve maximum setting.

19. **Low fluid level in reservoir:**

    Add recommended oil and check level on both sides of tank baffle to be certain pump suction line is submerged. If oil supply is low, less oil will be available to carry away just as much heat. This will cause rise in oil temperature, especially in machines without oil coolers. Be sure oil is up to proper level.

20. **Dirt in pump:**

Dismantle and clean.

21. **Packing worn or damaged:**

Tighten packing gland or replace packing. Trouble may be caused by abrasives in oil. If this is suspected, make thorough check of points where abrasives may be entering system.

22. **Fluid contaminated with dirt or water:**

Install adequate filter or replace oil more often. Determine source of material and correct.

23. **Oil cooler clogged:**

On any machine equipped with oil cooler, high temperatures are probably expected. Temperatures that run high normally will go even higher if oil cooler passages are clogged. If clogged cooler is found, try to blow it out with compressed air. If this does not work, try solvents.

24. **Restricted lines:**

Check for crimped lines or obstructions.

25. **Reservoir too small** (may vortex or fail to provide adequate cooling)**:**

Replace with larger reservoir, or install cooler.

26. **Valve deposits:**

Repair or replace valves. Usually caused by high sediment level or oil oxidation.

27. **Pilot pressure too low:**

Normally runs about 50 psi. Consult manufacturer's instructions.

28. **Electrical solenoid problems:**

Make electrical repairs.

29. **Loosened fittings:**

Tighten, reseal, or replace O-rings, if present. Check fittings for signs of cracks or improper installation.

30. **Dried or worn seals or O-rings:**

Replace or tighten worn components. Switching to seal-control oil may help.

31. **Line Breakage:**

Hose configuration:
- Check for twists, tight bends, sags, etc. Install hose supports.

Hose quality:
- Cheap hose usually has short life Possible operator abuse.
- Install spiral shielding or armor.
- Inspect for correct size, and check for kinked or crimped hose.

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