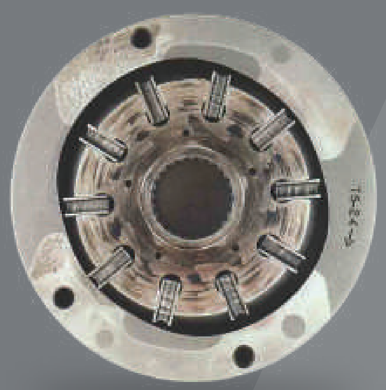
HYDRAULIC SOLUTIONS



Hydraulic Vane Pump Troubleshooting Booklet

Catalog 2020

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Description Page

I. Introduction

I-1. Presentation

The main goal of this guide is to help all HOF Vane Pump & Motor users to understand the principle causes of failure in service. Our past experience has shown that failures, occuring in the first 500 hours of service, are premature failures. Failing to follow instructions or ignoring the correct application limits and functioning of the units inevitably leads to premature failures. It is important to point out that 80% of failures are linked to fluid contamination incidents (chapter II-4)

I-2. How to use this guide

• **"The most common causes", chapter II** (page 7): Details of the major incidents you may encounter (cavitation, aeration, misalignment...) and their consequences on the vane pumps.

• **"Fault finding while the pump is running", chapter IV** (page 44): The troubleshooting tables for vane pumps. If you have a problem during working conditions, "the troubleshooting table" will help you to find out what is wrong (FAILURE-CAUSE-SOLUTION).

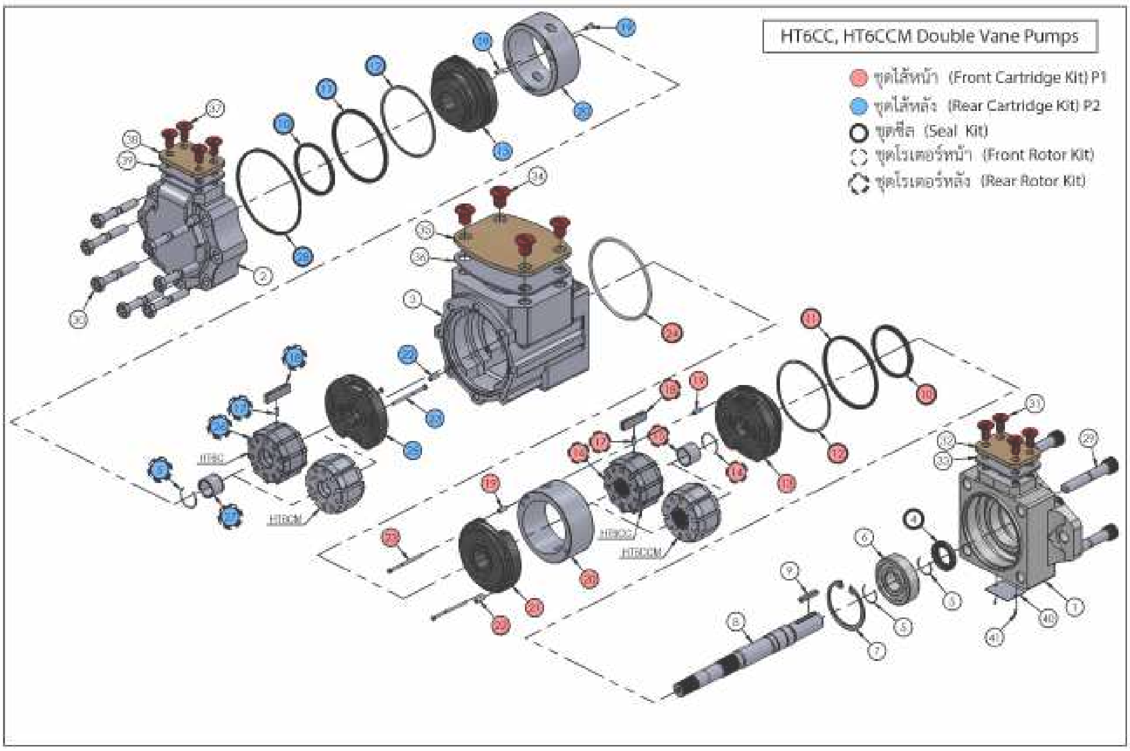
I-3. Why a HOF Vane Pump should not break down

Unlike most other hydraulic technologies, the HOF Hydraulic vane pump design is hydraulically balanced. You cannot calculate the life time of these pumps by calculating the life time of the ball bearing as no internal load (neither axial nor radial) is applied on the shaft. The only purpose of the ball bearing in the HOF Vane Pump is to absorb any external shaft misalignment or abnormal coupling loads.

As shown on the drawings hereafter, the two symmetrical high pressure zones have a self centering effect on the rotating components. This is a hydrostatic balanced pump, axially and radially.

I. Introduction

HOF Vane Pump Components Designation



Part No.	Part Designation	Part No.	Part Designation
1	Shaft end cover	22	Dowel pin
2	Back cover	23	Retaining screw
3	Housing	24	O-ring
4	Shaft seal	25	Rear plate
5	Snap ring	26	Rear rotor
6	Ball bearing	27	Sleeve
7	Retaining ring	28	Square section seal
8	Shaft (keyed or splined)	29	Screw shaft end cover
9	Key	30	Screw back cover
10,11	Square section seal	31	Plug P1
12	Back-up ring	32	Flange cover P1
13	Pressure plate	33	Flange cover seal P1
14	Snap ring	34	Plug Housing
15	Sleeve	35	Flange cover Housing
16	Front Rotor	36	Flange cover seal Housing
17	Pin-vane holdout	37	Plug P2
18	Vane	38	Flange cover P2
19	Dowel pin	39	Flange cover seal P2
20	Cam ring	40	Name plate
21	Rear plate	41	Fixing pin

I. Introduction

Each single vane is independently loaded in order to always be maintained on the cam ring contour. The specific HOF pin design reduces the possible internal leakage, reduces the possible vane/cam ring wear (due to a precise balancing of the forces under and over the vanes), lowers considerably the noise level, allowing higher pressure capabilities, extends the life time.

Added to this pin design, HOF Hydraulic has engineered the double vane lip technology. This vane technology combined with the pin design gives unique overall performances. The double lips allow the pressure all around the vane to be the same on the top as on the bottom and all sides. This is possible because of the double lips and the balance through the holes in the vanes. Here again, the components are hydrostatically balanced. Another advantage of the double lip design is the fact that the first lip seals the low pressure area and the other one seals the high pressure area. This increases the life time of the pump when working with contaminated oil. The wear, due to the particles of contamination, will have a negative effect, mainly on the first lip. The second lip, working in the high pressure area, keeps its integrity to maintain high volumetric efficiency.

This technology is unique because the wear is compensated. The effect of contamination on the HOF vane design is not a major cause of pump failure as with other pump technologies.

Every port plate and cam ring undergoes a surface treatment to increase the life time capabilities.

On each cam ring, for example, a dry lubricant coating is applied to the cam profile. This coating will assure, even in bad priming conditions, a good start-up minimizing the risk of micro-seizures. With this dry lubricant coating, the deficiency of oil is compensated but not replaced. This is done for short term deficiencies.

Our past experience shows that the most common failures are linked to the quality of the oil. As soon as there is a lack of lubricity, the failure is imminent. In addition to the pressure and the mechanical failures, all the problems are usually due to a lack of lubrication (rupture of the film of oil). The following are some examples of the common causes.

- air in the oil (cavitation, aeration),
- solid large size particles,
- chemical agents (water, incorrect additives, tar),
- too high or too low viscosity,
- overheating (shaft alignment),
- flow of the system coming back to the pump,
- poor quality of oil loosing its main chemical char acteristics,

This is why good filtration, good thermal stability, good quality of oil, a good design (hose design, bleeder, tank design), correct hydraulic knowledge will always increase the life time of all hydraulic components.

The HOF Vane Pump technology is a heavy duty engineering design that will last years if elementary precautions are taken.

I. Introduction

I-4. Basic precautions for a long life time

HOF vane products are designed for long life. Some minor precautions can help to avoid premature breakdowns:

- Have a correct air bleed at start-up,
- Always check the oil velocity (inlet & outlet). This should then give the correct sizes of hoses & con nectors: maximum velocity of 1,9 m/sec. for the inlet & 6 m/sec. for the outlet.
- No strainers on the inlet line is preferred (if re-quired, 250 microns at the minimum and make sure to check the pressure drop versus the viscosity),
- Always pay attention to the viscosity of the oil versus temperature. Even a small change in tem perature can have a big effect on the viscosity. A good quality return line filter is the best solution.
- Check the pressure at the inlet port, (position of the tank, shaft rotational speed...),
- Ratio flow/tank capacity: is cooling required?
- Ensure a good shaft alignment. Improper shaft alignment is a classic weakness. Also ensure a correct mating with the coulpling. The lubrication of these links is also something to look after.
- Correct oil selection versus application condition: viscosity index, viscosity grade (ISO 32, 46, 68...), environment (biodegradability, fire resistance, normal conditions), pumping temperature range, filterability, deaeration, thermal stability are the basics to consider for a maintaining your oil,
- If the pump is used on a very fast pressure cy-cle machine, attention should be paid to the re-lationship between the pressure rise/fall gradi ent and the inlet pressure in order to avoid cavi tation. We recommend maximum limits of 5000 bar per second (72500 PSI/second) for pressure rise and 6000 bar per second (87000 PSI) for pressure fall.

II. Analysis of failures

The systematic analysis of failures permits the causes to be determined logically, these failures being either distortion, shearing, surface seizure or scoring.

If the failure is shearing, we can almost certainly say it is the consequence of a brutal or a fatique failure. A brutal failure is due to sudden increase in loads exceeding the material strength limit or its resistance to shocks. A fatique failure is the result of the tensile limit of the sensitive point of a component.

Studying the crystalline faces will allow us to determine the mechanical causes that caused the failure. This troubleshooting guide has been prepared to allow everyone to quickly reach a satisfactory conclusion. A precise and professional analysis to determine the problem is not really the purpose of this guide.

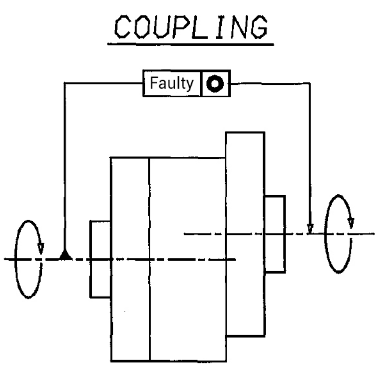
II-1. Mechanical failures

Mechanical failures are due to physical external parameters that change the mechanical structure of the materials. The causes of these incidents are mostly axial and radial shaft overloads. Rotary bending (flexion) and torsion (twisted) fatique failures.

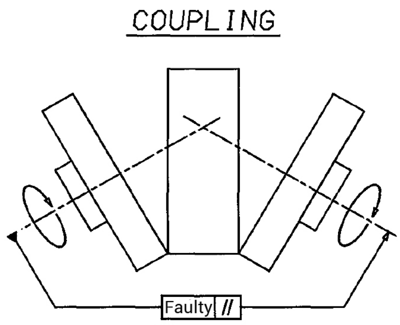
II-1-1. Problems on shafts :

Incorrect alignment, faulty mechanical link (bracket, chassis deformation, bad bell housing, loose damping elements) can create :

a) Misalignment



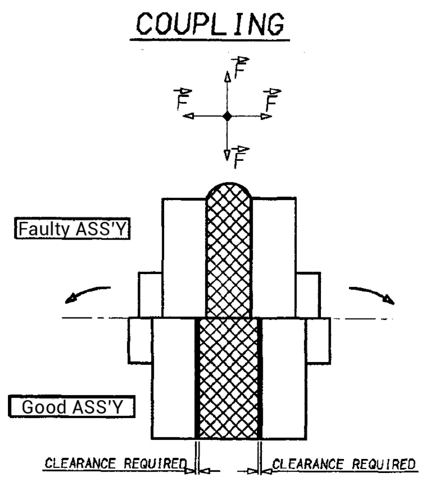
b) out of squareness



Consequence page for a) and b)

- Fretting	*p9, II-2-1*
- Shaft rupture	*p9, II-2-2-1*
	p9, II-2-2-2
- Rear bushing	*p11, II-2-5-1*
	p11, II-2-5-2
	p11, II-2-5-3
- Marked Cam ring	*p11, II-2-6*
- Shaft seal problem	*p11, II-2-7*
- Dissymmetrical wear on port plate	*p11, II-2-8*
- Ball bearing worn or destroyed	

II-1-1-1. Too tight gap between the two coupling flanges (axial loads / radial loads).



Consequence page

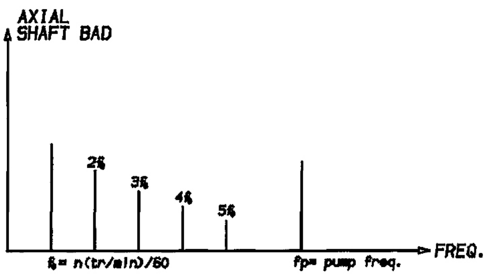
- Fretting corrosion	*p9, II-2-1*
- Shaft rupture	*p9, II-2-2-1*
	p9, II-2-2-2
- Ball bearing worn out	
- Rear bushing	*p11, II-2-5-1*
	p11, II-2-5-2
	p11, II-2-5-3

- Check with the coupling manufacturer to confirm the clearance required depending on the torque.

II. Analysis of failures

II-1-1-2. Unbalanced coupling = radial load.

II-1-1-3. Too tight load on a belt driven system (belt drives not recommended)

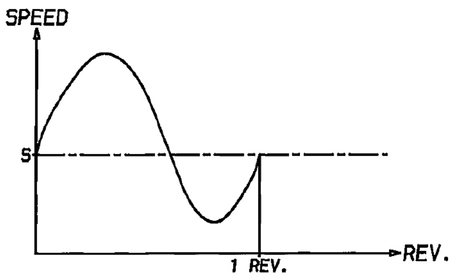


Consequence page for II-1-1-2. and II-1-1-3.

- Shaft rupture	*p9, II-2-2-2*
- Bushing	*p11, II-2-5*
- Marked Cam ring	*p11, II-2-6*
- Shaft seal problem	*p11, II-2-7*
- Dissymmetrical wear on port plate	*p11, II-2-8*

II-1-1-4. Non-homokinetic transmission due to un balanced cardan shaft (or universal joint).

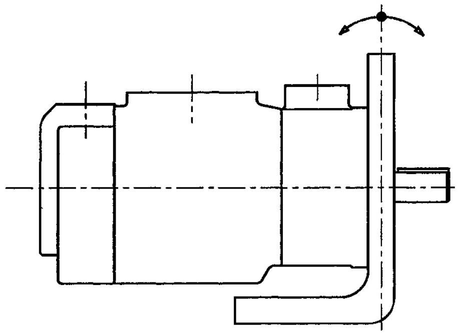
II-1-1-5. Excessive moment of inertia due to heavy couplings (like chain couplings) or very large diameter couplings.



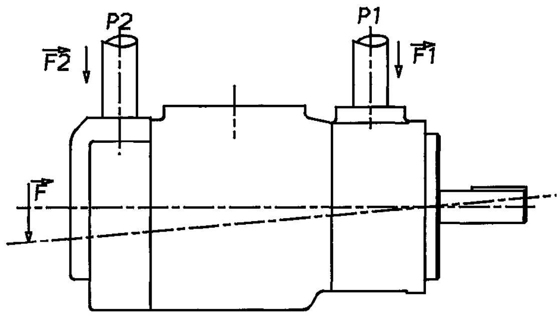
Consequence page for II-1-1-4. and II-1-1-5.

- Shaft rupture	*p9, II-2-2-2*
- Bushing	*p11, II-2-5*
- Marked Cam ring	*p11, II-2-6*
- Shaft seal problem	*p11, II-2-7*

II-1-1-6. Bracket chasis deformation (when pump under load).



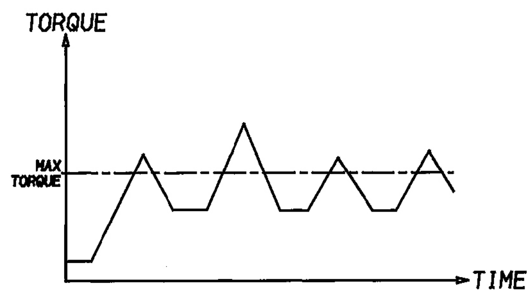
II-1-1-7. Hose strain (reaction) force (brutal pres sure compression / decompression, rigid hoses mounting strain...).



Consequence page for II-1-1-6. and II-1-1-7.

- Shaft rupture	*p9, II-2-2-1*
	p9, II-2-2-2
- Bushing problems	*p11, II-2-5*
- Marked Cam ring	*p11, II-2-6*
- Seal problems	*p11, II-2-7*
- Wear on port plate	*p11, II-2-8*

II-1-1-8. Over torque limits (too high pressure ver-sus displacement for the capacity of the shaft cho -sen)



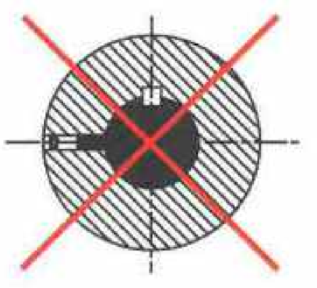
Consequence page

- Shaft rupture (torsional fatique)	*p9, II-2-2-3*
- Shaft wear	*p10, II-2-3*
	p10, II-2-4

II. Analysis of failures

II-1-2. Bad shaft / Coupling connection :

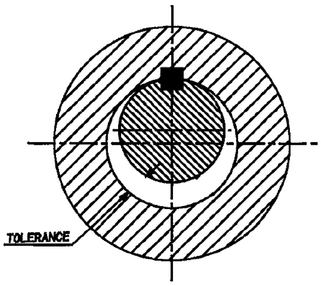
II-1-2-1. “Coupling screw” not properly positioned on the key (keyed shaft).



Consequence page

- Shaft rupture	*p9, II-2-2-1* *p9, II-2-2-2*
- Rear bushing	*p11, II-2-5-1* *p11, II-2-5-2* *p11, II-2-5-3*

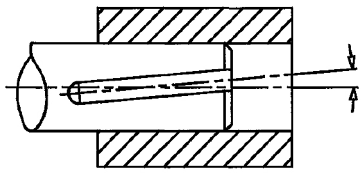
II-1-2-2. - Faulty manufacturing (machining) of the couplings:
- Poor diameter fit tolerance between the shaft di ameter and the coupling diameter.



Consequence page

- Fretting	*P9, II-2-1*
- Shaft rupture	*p9, II-2-2-3*
- Shaft worn out	*p10, II-2-4*

- Key way in the coupling is not properly centered with the main bore axis
- Poor heat treatment (too high or too low)

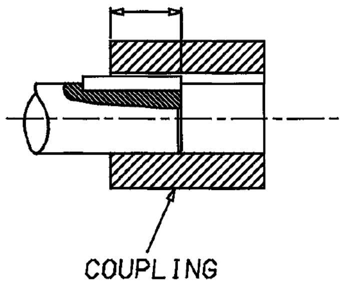


Consequence page

- Shaft rupture	*p10, II-2-3* *p10, II-2-4*

II-1-2-3. Shaft not properly utilized (too small sur face of spline or key used)

II-1-2-4. Insufficient (or no) lubrication of splined shafts/ coupling.

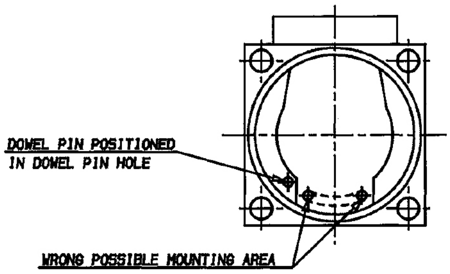


HOF Hydraulic advises shaft lubrication using a grease with a Disulfide of Molybdenum base

Consequence page

- Wear of the splines	*p10, II-2-3*
- Wear of the key	*p10, II-2-4*
- Spline wear	*p10, II-2-3*

II-1-3. Cartridge dowel pin not positioned correctly in the housing.

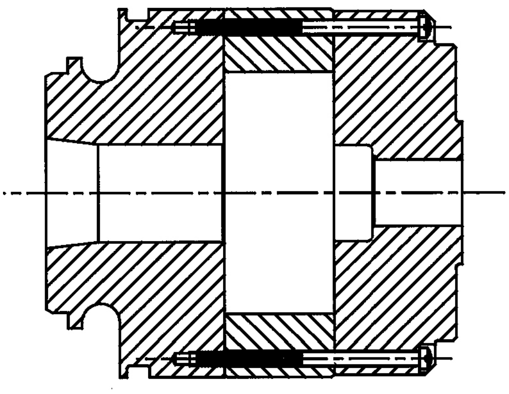


Consequence page

- Dowel pin rupture	*p12, II-2-9*
- No pressure possible	
- Unconstant flow	
- Noisy	

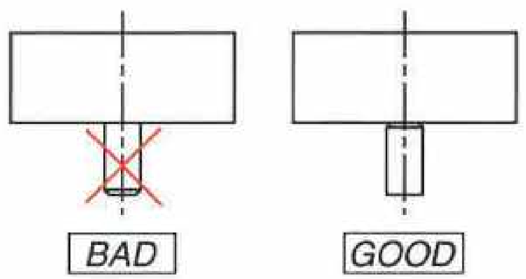
II. Analysis of failures

II-1-4. Incorrectly mounted cartridge screws. With any cartridge modifications, caution must be taken to check that the rotor/ vanes can rotate freely. Vanes can potentially tilt and in this case, would be squeezed in between the port plates.



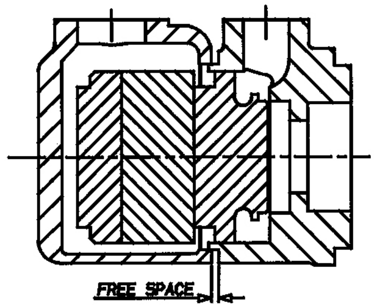
Consequence page
- Vane marks *p8, II-1-7*
- Vane marks *p12, II-2-12*

II-1-5. Hollow pin-vane incorrectly mounted in the HT6*M, Mobile version (pin up side down).



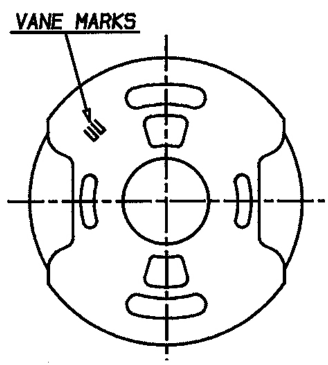
Consequence page
- Noisy
- Flow unstable

II-1-6. Loose pump screws (after modifying the pump, the screws were not tightened at the proper torque and worked loose).



Consequence page
- Broken screws *p12, II-2-11*

II-1-7. Marks on distribution plates that disturb the cycle of the pump. Even a small scratch between the intet & the pressure area can destabilize the vane.



Consequence page
- Vane marks *p12, II-2-12*
- Noisy
- Pressure limited
- Flow unconstant

II. Analysis of failures

II-2. The consequences of mechanical failures

II-2-1. Fretting corrosion :

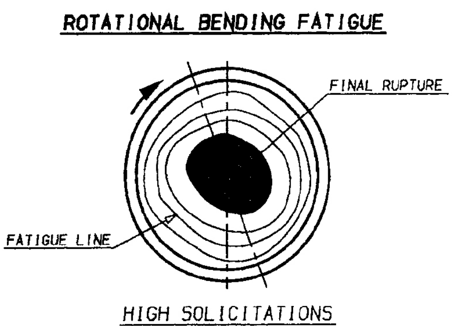
Fretting appears when the solicitations are great and when there is a slight vibration movement. These movements will “create” metallic oxides. Being very abrasive, they will weaken the structure of the component and will favour start-up of the fatique rupture (twisted).

Incident page

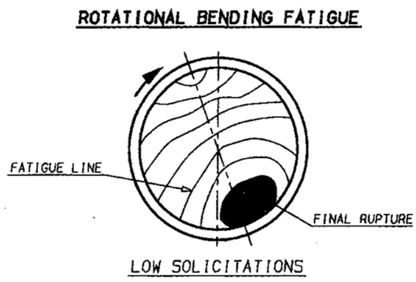
- Bad shaft/ coupling link	*p7, II-1-2-1*
- Bad coupling manufacturing	*p7, II-1-2-2*
- Bad grease when assembly	

II-2-2. Fatique shaft rupture :

II-2-2-1. Perpendicular, center, rotational bending fatique rupture.



II-2-2-2. Perpendicular, over-center rotational bending fatique rupture.

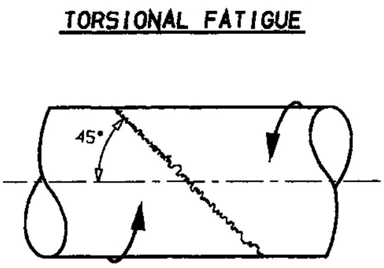


Incident page for II-2-2-1 and II-2-2-2

- Bad alignment	*p5, II-1-1a*
- Out of squareness	*p5, II-1-1b*
- Unbalanced coupling	*p6, II-1-1-2*
- Too high radial load	*p6, II-1-1-3*
- Non homokinetic	*P6, II-1-1-4*
- Too great moment of inertia	*P6, II-1-1-5*
- Bracket chassis deformation	*P6, II-1-1-6*
- Hose strain force	*P6, II-1-1-7*
- Bad shaft/ Coupling link	*P7, II-1-2-1*

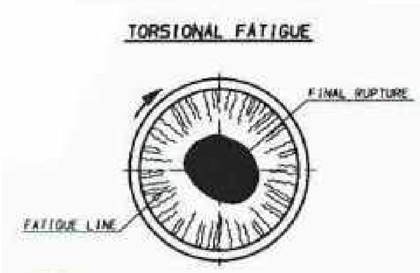
II-2-2-3. Twisted torsional rupture.

II. Analysis of failures



Incident page
- *Fretting corrosion* *p9, II-2-1*
- *Over torque limits* *p6, II-1-1-8*

II-2-2-4. Perpendicular, torsional fatique rupture.



Incident page
- *Torsional fatique with peak torque values* *p6, II-1-1-8*

II-2-3. Shaft splines/ keyed shaft worn out on total length.

Incident page
- *Incorrect shaft/ coupling connection* *p7, II-1-2-2*
- *Insufficient lubrication (Grease)*
- *Over torque values* *p6, II-1-1-8*
- *Highly cycled*

II-2-4. Shaft splines/ keyed shafted worn out on part of the length.

Incident page
- *Over torque value* *p6, II-1-1-8*
- *Utilized key surface or splined surface was too small* *p7, II-1-2-3*

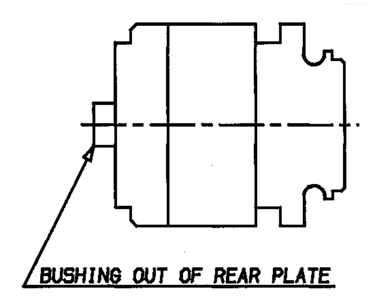
II. Analysis of failures

II-2-5. Bushing/ bearing problems :

II-2-5-1. Front or back bearing/ bushing with heavy wear

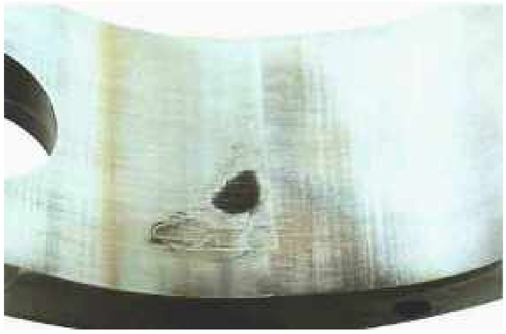
II-2-5-2. Bushing “welded” on the shaft

II-2-5-3. Back bushing moving out of the rear port plate



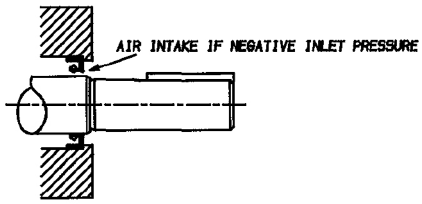
Incident page
- Problems on shafts p5-6, II-1-1
- Incorrect shaft/ coupling connection p7, II-1-2

II-2-6. Cam ring marked by the rotor on the smallest diameter. The contact between the rotor and the cam ring is important, damage will transform the hardness of the cam ring and create local tensions (cracks).

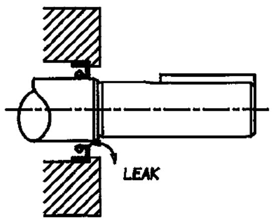


II-2-7. Seal loosing contact with the shaft on one area :

- air intake



- leakage



II-2-8. Dissymmetrical wear on the side plates

Incident page for II-2-6. to II-2-8.
- Problems on shafts p5-6, II-1-1
- Incorrect shaft/ coupling connection p7, 10, II-1-2

II. Analysis of failures

II-2-9. Dowel pin broken

Incident page
- Over torque limits *p6, II-1-1-8*
- Cartridge not properly mounted in the housing *p7, II-1-3*

II-2-10. Noisy

Incident page
- Hollow pin-vane *p8, II-1-5*

II-2-11. Broken screws

Incident page
- Loose pump fasteners *p8, II-1-6*

II-2-12. Parallel marks on the port plate (vane marks)

- Titled vanes marked the port plate but the pump did not rotate.

- Titled vanes but the pump rotated. The result is scars on the port plate.

Incident page
- Cartridge not properly assembled *p8, II-1-4*

II. Analysis of failures

II-3. Pressure failures: Overshoot & Pressure gradients

II-3-1. Pressure overshoot :

System pressures are rising constantly, and with this, the pressure overshoot rises also. The effects on pumps, whichever technology is used, are bad. We have split-up this description into two different categories: "Instant pressure overshoot" and "Cycled overpressurization". The final consequences of these are the same, that is to say the failure of components. We will see that the failing components are damaged differently if it is Instant pressure overshoot or Cycled overpressurization. The valves and the pipes rigidity and length around the pumps have a great impact on these pressure peaks. It can be a system problem or a valve problem that opens the main security valve. The pump is or is not protected by a check valve. The fact is that the pressure rises over the initial settings or designed settings. This problem is mainly seen when the valves tend to open (or close for a check valve) too slowly. These pressure peaks can reach 2 to 5 times the pressure settings. Not readable with standard manometer, electronic sensors recording traces will show the facts. When the check-valve closes itself too slowly, the flow will come backwards into the pump. This problem will be seen in the cycled overpressurization.

II-3-2. Instant pressure overshoot :

This is a brutal high peak of pressure. The consequence is that the mechanical strength of the material is exceeded. This will cause some brutal failures of components such as the side plates (on the high pressure distribution area), the rotor (split), the cam ring (cracked), the shaft (broken), the dowel pin (cut in two).

II-3-3. The consequences of instant pressure overshoot :

II-3-3-1. Cracks or rupture of the pressure plate

II-3-3-2. Cracks or rupture of the rotor

II-3-3-3. Cam ring cracked

II-3-3-4. Shaft broken : perpendicular "clean cut"

II. Analysis of failures

II-3-3-5. Dowel pin cut in two

II-3-4. Cycled overpressurization :

The pressure rating of the system is just over the allowed pressure specified. This will give, on a long term, a fatique failure. It is the sum of the pressures exceeding limits that will weaken the mechanical strength of the components. These specific failures are seen on the following components: cam ring, vanes, shaft, side plates, rotor splines or the rotor ruptures between the two vane slots bulbs of the rotor (as page 19, II-3-3-2)

Another effect is the distortion of the cam rings' external diameter due to this overpressure. The consequence of this expansion is to reduce the space between the rotor OD and the minor diameter of the cam ring. When this gap is too narrow, the rotor may come in contact with the cam ring. If both cam distortion and shaft misalignment happen at the same time, then this contact often arises.

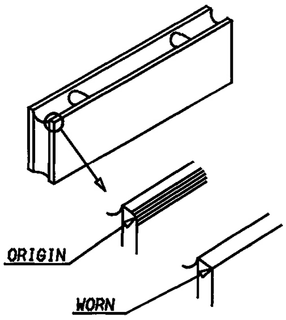
Another distortion effect is this overpressure pushing on the pressure plate. The distortion of the pressure plate will, in its center, reduce the normal clearance between the port plates and the rotor. The film of oil lubrication between these components will be reduced. The temperature will rise because of the narrow gap and a friction welding will result. The total seizure will then be the consequence if the local temperature rises too high.

The system is not secured with a check valve or the check valve is too slow to open.

During the opening time of the "slow" relief valve, the flow delivered from actuators or the pump has to go somewhere. Usually, the relief valve opens and this flow goes back to the tank. Here, not being able to go back to the tank, The flow will go back to the pump. If the check valve closes fast enough, the pressure will increase and accelerate the relief valve opening to allow the flow back to the tank. If there is no check valve or if it is too slow, the flow will return to the pump. This flow will then push the rotor forwards, which will wear the rotors' splines. The gap between the rotor & the side plates will then be increased and create a local cavitation. This local cavitation will suck the oil lubricating the sides. Without enough oil, the local overheat will start a pump seizing. The vanes will have marks on both sides, the splines of the shaft and the rotor will be worn (on both splined teeth flanks)...

II-3-5. The consequences of cycled overpressurization :

II-3-5-1. Vanes



II-3-5-2. Cam ring :

- rupture/ cracks

-rotor/ cam ring contact in the "small diameter"

II. Analysis of failures

II-3-5-3. Shaft :

- internal spline worn

- rupture : torsional fatique ruptures

Perpendicular : few cycles but very high torque

Twisted : often under high cycling

II-3-5-4. Side plates deformations = contact on the smallest diameter of the rotor.

II-3-6. Pressure gradients :

The pressure increase/ decrease delay, can often be forgotten within the design of basic hydraulic systems. The velocity of this increse/ decrease is very important. Beyond the fact that it stresses the raw material, it has some big effects on the velocity of the oil. These sudden pressure changes modify the internal leakage of the pumps. The HOF vane technology can be used safely up to 6000 PSI per second. Over these limits, phenomena such as cavitation, hose decompression effects can appear. A positive inlet pressure and no inlet strainer are recommended to avoid a too high inlet vacuum.

II-3-7. Consequences of too high pressure gradients :

II-3-7-1. Cam ring fatique rupture

II. Analysis of failures

II-3-7-2. Rotor/ side plates seizure : This is due to a very strong cavitation when the pressure de crease is dramatic. The sudden flow required is so large that the instant local velocity rises and creates the cavitation.

II. Analysis of failures

II-4. Physical, Chemical or Hydraulic Failures

All the following failures are linked, one way or another, to the quality of the lubricant, poor filtration or poor inlet conditions. Either there is some contamination (air, particles, water...), or some temperature problems, or a poor oil edging, or cavitation or fluid aeration problems.

II-4-1. Start-up without a proper air bleed :

Vane pumps are designed and manufactured with a dry lubricant capability. The dry graphite lubricant coating on the cam ring and the surface treatment on the distribution plate are done to lubricate during start-ups.

- If the suction column of oil does not build up, the pump will not be lubricated enough and be damaged. The consequence of this lack of lubrication is local overheating. Depending on how long this lasts, A consequence could result in a seizure between the port plates and the rotor. The local temperature is so high that the film of oil between the components disappears, and then the metal to metal contact will create friction and then the "welding seizure".

- If the column of oil does build up but the air bleed is not complete, the pump will not work properly. The pressure will not build up correctly, the flow could be lower than required, the pumping will be erratic and noisy.

- If the inlet velocity is too low, under 0.5 m./sec., the air will stay trapped in the pump and in the inlet pipe.

The consequence of incorrect air bleed are seen in the next paragraph.

II-4-2. Air contamination (creating the foaming of the oil) :

When we talk about air in the oil, it is the simplification of a complex chemical transformation. What we will call air is more a mix of different gases than air. This explains why under pressure, these gases will implode and create a very high local temperature.

The pressure causes an ignition and the gases will combust at temperatures as high as 1300°C. The result is the destruction of the fluid giving to it a black color and a "burnt" smell. This phenomenon is also known as the "Lorentz" or "diesel" effect.

II-4-2-1. Aeration :
This phenomenon is the fact that some air is brought into the system and, with the turbulence of the flow, generates a foamed substance.

This new "fluid" has lost all the requirements of the original fluid and, therefore, lost all the capabilities of a standard hydraulic fluid. The consequences of such a transformation are different depending on the quantity of air brought into the system.

This problem could be caused by different external problems, independent or not :

- Suction pipe not sealed under vacuum, therefore sucking air,

- Deteriorated shaft seal (or high radial load creating an air intake),

- Inlet tube in front of the return line (amplifying the foaming).

- Turbulence created by a high velocity around the inlet tube (not enough suction surface),

- Return line coming back to the reservoir over the oil level. It is required that the lowest point of the return line must always be under the oil level (five times the pipe diameter),

- Oil level of the reservoirs too low compared to the suction level,

- Too small tank (high velocity in the tank),

- Fluid in movement (bad tank design on mobile ap plications),

- Bad deaeration capabilities of the fluid and/ or the tank. Baffles can help "pushing" the air to the surface. If the "vein flow" is too rapid and if no baffle is there to bring to the surface these bub bles, they will go back to the inlet area. This air going to the pump will deteriorate it.

- Bad baffle design. If the fluid is to pass over the baffle, the maximum speed has to stay under 0.5 m./sec. to avoid turbulence,

- Venturi effect on a return pipe

- Anti-siphon holes drilled in the return pipes,

- Water pollution that will create steam due to local overheating. This steam in contact with oil will create foaming (see page 35 for more details).

II. Analysis of failures

II-4-2-2. Consequences of Aeration :
The vanes are going to be completely unbalanced due to the abnormal fluid compressibility (due to quantity of air in the oil). The vanes, usually hydrostatically balanced (without air), will move sideways with such erratic movements that the vanes will destroy their lubricant film of oil that links them to the side plates. Doing so, the vanes, hardened metal surface, will start to wear the side plates in die cast or ductile iron.

The marks will start in the discharge area and, de pending on the quantity of air, will more or less cre ate a groove.

During all these turbulences, the most noticeable fact is going to be an usual noise level.

II-4-2-2-1. If the quantity of air is erratic or not too heavy, the effects are scores only on the port plates in the suction area.

II-4-2-2-2. If under very severe aeration, this groove can mark deeply the port plates from the suction area to the outlet area. The width of the groove is then the width of the vane.

II-4-2-2-3. In very heavy air conditions, the vane is so unbalanced that it can even sometimes break.

II-4-2-2-4. Noisy

Before suffering such a disastrous wear, the vanes being so unsteady will make a lot of noise, the flow will not be the as required and/or the pressure le- vel will not be obtained. The physical aspect of the oil will be “milky” on the surface as the oil and the air create a foam.

II. Analysis of failures

II-4-2-3. Cavitation-Deaeration :

When a depression arises in the suction port, the gas (combustible) and aromatic substances dissolved in the fluid (6 to 7%) will evaporate. Depending on the type of fluid, this deaeration will occur between 100 and 150 mm of HG (around -0.2 bar). Under this depression (or vacuum), small bubbles of a diameter of 0.2 to 0.3 mm. will be formed. The natural appearance of oil is translucent. Under cavitation and because of this small "bubbles", the fluid will have a "cloudy" appearance. Depending on the value of the vacuum, the quantity of suspended bubbles will be more or less important. As these bubbles have a small diameter, they will reach the surface of the oil tank very slowly (bad deaeration characteristics). As an example, 100 liters of a foamed oil by cavitation will take 4 hours to become translucent again. When the fluid reaches local hot temperatures and is compressed (at the "critical pressure"), these bubbles implode and create a shock wave known as the diesel effect, the impact of these "combustion explosions", will create erosion in the shape of a crater (cavities) when located near a metallic surface. These detached metallic particles are very likely to cause, on a medium term base, a seizure between the pumps' moving parts.

This problem can be caused by different external problems (independent or linked)

Suction strainer :

- Clogged by a foreign contaminant,

- Clogged by a too high viscosity,

- Too small in flow rate/pressure drop.

- Filtration in the return line and no suction strainer is still what we recommend to avoid the above mentioned problems.

- Too long inlet hose,

- Too small inlet hose (too small section on the whole piping or restricted in one area),

- Inlet tube, in the tank, too close from the panel of the tank,

- Inlet tube, in the tank, with a too small suction surface creating local turbulence (deaeration the fluid). Cut the tube on an angle to increase this suction surface and avoid local high velocities,

- Too high or too low inlet velocity (0.5 to 1.9 m./sec. is the velocity required),

- Tank too far away from the pump (horizontally or vertically),
- Excessive shaft speed,

- Air filter on the tank clogged or sized incorrectly generating a vacuum in the tank.

- Reservoirs' oil level too low compared to the suction level (when all cylinders are extend for example),

- Inlet tube in front of the return line (amplifying the foaming),

- Too small tank (high velocity in the tank),

- Bad aeration capabilities of the oil and of the tank. Baffles can help "pushing" the air to the surface. If the "vein flow" is too rapid and if no baffle is there to bring to the surface these bubbles, they will go back to the inlet area. This air in the pump will deteriorate it.

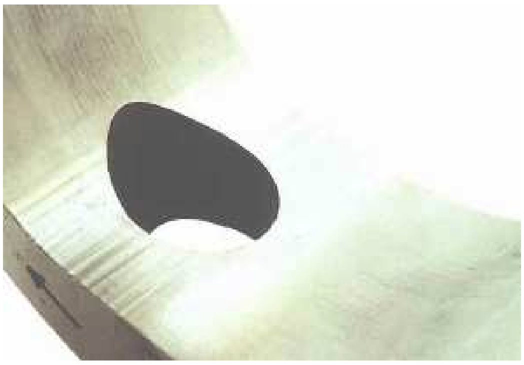
- Incorrectly sized filtration on return line, will increase the velocity and deaerate the oil.

II-4-2-4. Consequences when the pump has cavitation :

II-4-2-4-1. Noise level : much higher than usual. Under pressure, this noise level is amplified.

II. Analysis of failures

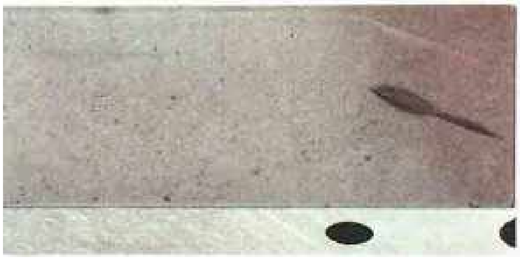
II-4-2-4-2. Ripples on the cam ring : The vanes are hydrostatically balanced to avoid excessive loads on the vane lips. Under suction cycle, the pin com pensates the out of balanced load due to the cam profile. When the depression is over the design lim its, the vane bounces, creating ripples on the cam ring profile. The depth of these marks is proportion -al to the strength of the depression.



II-4-2-4-3. Craters : These erosion craters are sometimes difficult to observe as the pump may have already seized. These craters come from erosion, caused either by an explosion/implosion, or by depressurisation.

When the fluid trapped between the two vanes is sucked in with a certain percentage of air in suspension, an explosion can occur. When this trapped volume is compressed, these air bubbles explode and create craters in the side plates in the area between the suction port and the pressure port, around the pressure bleed slots.

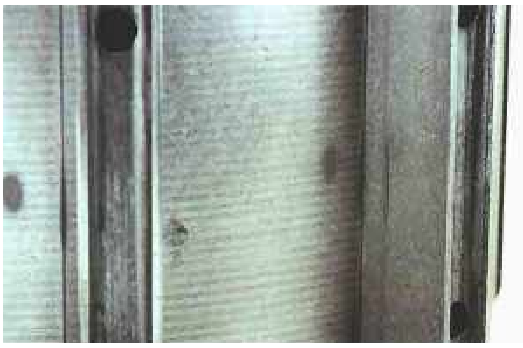
- Vanes



- Pins

II. Analysis of failures

II-4-2-4-4. "Black marks" : The local depression consequences can be seen on the vanes (top lips and on the center of the vane), on the port plates (in the inlet area) and on the center of the cam ring (just after the inlet "feeding hole"). These "black marks" can be transformed into small craters in the port plates near the outlet bleed slots as the air bubbles explosion occurs.



II-4-2-4-5. Seizure of the pump :
Due to a lack of fluid, the vacuum generated, when really severe, will suck the oil on the side of the pump (between the rotor and the side plates). This will have the effect of breaking the film of oil that lubricates these surfaces. The surfaces will then heat-up and this local over-heat will modify the standard lubricity into a dry friction. The result is a seizure between the rotor and the side plates. (This heavy contamination coming from the creation of craters, can cause the particles to effect the lubrication of the pump and lead to seizure.)

II-4-3. Solid particle contamination :

Unlike a lot of different technologies, HOF vane units do not generate contamination.

Contaminants are an important consideration. A lot of research has been conducted in regards to fluid cleanliness. One of the main factors in any type of hydraulic pump failure is particle contamination. The consequences are rapid wear and therefore, premature failure. In a hydraulic circuit, the pump is the flow generator. Being so, it becomes the most sensitive unit to contamination and, therefore, will be the first component to fail.

Nature of particles :
The main particles are made up of metallic oxide, silica, carbon and organic materials.

Origin of particles:
- A common large particle is the metallic oxide coming from welding burrs when the welded piping has not been cleaned-up properly.

- The silica comes from the surrounding dust. This dust will enter into the system through cylinders' sealing, through air intakes (absence of air filters), dirty environment and the tank not properly sealed.

II-4-4. Consequences of solid particle contamination :

Depending on the size of the particles, the consequences can go from a gentle ground finish on the vane lips, cam surface, side plates to the total destruction of the cartridge.

It is obvious that under perfect filtration conditions, the rubbing of the vanes in the rotor is reduced to a minimum by the action of the oil under pressure which is located all around the vanes.

II. Analysis of failures

II-4-4-1. Vanes :
a). The vane lips edges. The particles in the fluid will have a grinding effect between the top of the lips and the cam ring profile. When the contaminant is too big or too stiff, the vane lip edges can break.

b). The vane surface. If the film of oil between the vanes and the rotor is contaminated, there will be a rubbing effect in this area. These rubbing marks (contamination marks) will be vertical and of the height of the vanes' transition (displacement).

II-4-4-2. Cam ring :
Between the vane lip and the cam ring, if the film of oil is contaminated. This will wear the inner surface of the cam ring.

On the edge of the cam ring contour, (with a slight chamfer when new), you will find a sharp angle (edge). If the wear is heavy, the cam ring can have little burrs in this area.

II-4-4-3. Rotor/Vanes :
In the rotors' slots, the rubbing wear between the slots and the vanes will also leads to vertical contamination marks. (page 32 II-4-4-2b)

II-4-4-4. Rotor/side plates :
When the particles in suspension in the fluid are greater than half of the clearance between the thickness of the rotor and the thickness of the cam ring, seizure occurs in the peripheral diameter of the rotor and the port plates.

II. Analysis of failures

II-4-4-5. Rotor :
The rubbing effect will also appear in-between the side of the rotor and the side plates. This will create a torque between the two vane slots. This torque causes a reasonably high level of fatique in the materials' weakest area, between the two bulb slots of the rotor. If this fatique level exceeds the design limits, this portion of the rotor will break.

II-4-4-6. Rotor/side plates/ vanes :
Large contamination particle damage (like the "carbon" welding balls) are usually seen on the port plates (blocked in the slots) or/and on the top of the vanes/rotor. In each case, they will have an effect on the vane lips, either on the top or on the sides. The "rubbing" action will either destroy the vane lips or weld the vane to the rotor, breaking the cam ring.

II-4-4-7. Side plates :
Another sign of contaminated oil is some possible erosion craters on the port plates at the inlet/suc tion bleed slots area. These erosion craters would come from the abrasive fine particles in a local high velocity area.

II-4-5. Water contamination :

Depending on the type of fluid, the water contamination can be different. For mineral oils, this limit should not exceed 500 ppm (particles per million). This limit for esters and vegetable oils is a maximum 500 ppm. The water contamination will modify the chemical structure of the fluid (oxidation of the fluid increases the TAN*). Having an excess of water, this water can be transformed into steam under the action of the pressure. Another effect of this excess is the modification of the "compressibility module".

- The fluid will be destroyed and lose its characteristics/ performance. The oxidation of the fluid will modify the TAN. The higher acidity of the fluid will destroy the additives. This, added to the local heat created, will transform (or carbonize) the fluid. It will modify the molecular structure. The colour of the fluid will turn creamy (milky).

- Destroying the additives means the lubricity will be worse, the thermal stability very poor.

- The excess of water can also bring in bacteria that can damage the fluid. This can be seen by the resulting gelatinous mass within the tank and other components.

- The most common consequence is the appearance of rust on all metallic surfaces. This will modify the nature of the contacts between surfaces. This can lead to the start of local micro-seizures due to a lack of required lubricant.

- When polluted with water, the whole system must be flushed and then drained two or three times until obtaining a clean translucent oil when running.

This water pollution can come from various causes:

II. Analysis of failures

- Condensation coming from a high hydrometric level (big temperature variations),

- A leak in the water exchanger,

- Tank not water-tight,

- Storage of the oil barrel outside vertically,

- High pressure water cleaning of the machines (water going under the seals of cylinders on offhighway vehicles for example).

*TAN : Total Acid Number.

II-4-6. Consequences of Water contamination :

II-4-6-1. Deposits can be seen on the vanes. This deposit will modify the performance of the pump because of the deterioration of the mechanical efficiency (the varnish will “stick" the vanes in the slots of the rotor).

On the cartridge, it changes the colour of the bronze bushing (due to the modification of the acidity) and leaves a deposit on the external diameter.

II-4-6-2. - The fluid can produce foaming because of the steam. The appearance of foaming oil due to water is a milky or creamy typical aspect. The consequences are identical to the aerated fluid.

II-4-6-3. - The fluid compressibility will fluctuate and therefore destabilize the vanes. This will be seen on the cam ring surface as ripples and on the sharp vane lips edges. In this case, the noise level will be high and the flow & pressure capabilities deteriorated.

II-4-6-4. - Due to these fluid transformations, the mechanical consequences go from performance being deteriorated to the destruction of the pump if the local temperatures are extreme (Here, phos phate oil additive deposit).

II. Analysis of failures

II-4-7. Viscosity Failures :

Depending on the environment, the temperatures can considerably modify the original wanted Viscosity. The influence of the temperature differences on the Viscosity is enormous.

The vane components are designed to work for a wide possible range of Viscosity. When a problem occurs, the Viscosity is either too high or too low.

When the Viscosity is too high, over 2000 cSt (9240 SSU), the problem is that the fluid has a big resistance and the Velocity will drop. This resistance can create local vacuum, that is to say deaeration of the fluid. This will ruin the lubricity of the pump. Under high Viscosity and low rotation, the vanes can stick and stay stuck in the rotor. The consequence is that there is no flow coming out of the pump.

When the Viscosity is too low, under 8 cSt (52 SSU), it will decrease the film thickness designed to lubricate all the components in motion. If the Viscosity is very low, it could mean that the temperature is high. Tests carried out have shown that a tank temperature of 50°C (122°F) could mean a local temperature in the pump of up to 130°C (266°F). If the viscosity is calculated on the tanks temperature, we can easily figure out the very low viscosity when the oil is at 130°C (266°F).

II-4-8. Consequences of Viscosity Failures :

II-4-8-1. Too high viscosity :
- Seizure due to the high cavitation not allowing the rotating group to be lubricated.

II-4-8-2. Too low viscosity :
- Erosion on the port plates.

- Scars on the side plates & rotor due to a bad lubricity.

II-4-9. Unsuitable fluids :

Viscosity index choice :

If the fluid was chosen by an OEM in Norway for a local sale but the application is to work in Saudi Arabia, the choice of the fluid will have to take into consideration the specific application environment.

Forgetting this can lead into deep trouble. Too high Viscosity will probably cause cavitation and a lack of lubrication, too low Viscosity will lead to a too thin film of oil and therefore create a local heat point.

In both extremes, the consequences can be fatal breakdowns.

Filterability :

If the fluid does not have good filterability properties, the filters will be clogged rapidly. The flow will have to go through the by-pass and therefore not be filtrated anymore and will heat-up the system (due to the open by-pass).

II. Analysis of failures

Poor filterability can either come from a low quality fluid, or from a fluid sensitive to any contaminant destroying its chemical homogeneity (water, solvants, grease).

Oxidation resistance :

Contaminants can modify the acidity of the fluid and therefore become very corrosive. Such a modified fluid will corrode the steel components and produce corrosion residues. These residues will increase the Viscosity. Increased Viscosity will increase the pressure drops. Increased pressure drops will then increase the temperature and cause local overheat.

Deaeration capabilities :

This is another very important topic. If the fluid chosen requires too long a time to allow the air to reach the surface of the tank, this can become a big problem. Air in big quantities has a destroying effect on all pump technologies. If the flow versus the size of the tank is small, if the tank design is incorrect (inlet near return line for example), if the tank is slightly pressurized, the oil will not deaerate fast enough. The air bubbles will then be sucked by
the pump. Under pressure, these bubbles will then explode.

Polluted fluid :

This is an important topic and, nowadays, well known at least for the solid particle contamination. The manufacturing clearances becoming tighter and tighter, a good filtration is required. This even though our double lip technology resists contamination well.

Another problem can be the impact of another fluid creating a reaction between the original fluid and the contaminant. Fluids are becoming more and more sophisticated.They also become more and more sensitive to their environment and any contaminant can destroy the original characteristics. It is common for example to see fluids “destroyed” by a high water content (chemical, other fluid, particles). Refined oils will even be more sensitive than brand new ones.

Density :

It is important to know the specific gravity of the fluid used. Because the density from one fluid to another can vary a lot. The suction head has to be designed with that parameter. The specific gravity of a standard oil (ISO 46) will be around 0.88.The specific gravity of a water-glycol (60 glycol/40 water) will be around 1.08. Knowing this value, just check the minimum required Absolute pressure in our catalogues to optimize your system.

Conclusion on the fluids :

A common problem is the deterioration of the fluid. This deterioration can come either from the quality of the fluid (low quality or not using a reputable fluid manufacturer), or from an external contamination, (solid particles, other fluids, chemical transformations, water), or from air. The consequences always lead to a low performing pump or to a premature breakdown.

II-4-10. Unsuitable grease :

Unsuitable lubricant on the shaft and coupling assembly. We recommend for all grease lubricants to be based with disulfide of molybdenum. The main characteristic of this grease is that it is the best for heavy duty applications. It has a very good specific load characteristic, avoids stick-slip and fretting corrosion, has a good penetrability and enables easy dismantling.

III. Troubleshooting table

This following section is here to help you when the hydraulic system or component does not work as required. These solutions are the most common ones we have seen and experienced in the field. Please always remember that a clean system and a correct air bleed will solve a lot of incidents.

III-1. Troubleshooting Table for pumps

III-1-1. No flow, no pressure

a) Is the pump rotating?

a-1) Check if the coupling is rotating. If not, check the rotation of the electric motor.

a-2) Check the keys of the pump and E* motor shaft.

a-3) Check that the shaft is not broken.

b) Is the rotation in the correct direction?

b-1) Check if the rotation of the pump corresponds to the arrow on the name plate.

b-2) Check if the wiring of the electric motor is correct.

c) Is the air bleed-off done?

c-1) Check that no air is still located in the pressure line. Loosen a connector.

d) How are the inlet conditions?

d-1) Check if the inlet valve is not closed.

d-2) Check the oil level.

d-3) Check if the inlet hose in the tank is under the oil tank level.

d-4) Check if an air intake is not disturbing the inlet (missing inlet flange seal, air trapped in suction line as examples).

d-5) Check if the pump is not located too high above the oil level.

d-6) Check if the tank is not completely sealed. Then the lack of atmospheric pressure will not allow the pump to prime.

d-7) Check if all connections and seals are air-tight.

e) Is the Viscosity too high?

e-1) Check if the oil characteristics are compatible with the temperature and the pumps requirements. Too high Viscosity will “stick” the vein fluid and cause the pump to suck the oil correctly.

f) Is the pump flow going somewhere else?

f-1) Check the hydraulic circuit and the main functions. Doing so, you will check if all the valves are set or work properly.

f-2) Check if the main relief valve is not set at an extremely low pressure and therefore bringing all the flow back to the tank.

f-3) Check if in the directional valves the spools are not sticking in a position that brings the flow back to the tank.

f-4) check if the check valve is not mounted “upside down”.

g) Is the actuator working correctly?

g-1) Check if the motor does not let all the flow leak internally.

g-2) Check if the cylinder inner seals are not ruined.

h) Is the speed high enough?

h-1) Check if the minimum speed is reached. Mobile pumps require 400 rpm and industrial pumps require 600 rpm.

III. Troubleshooting table

III-1-2. Not enough flow (0r not the flow required)

a) Are the components OK?

a-1) Check the displacement of the pump.

a-2) Check if the speed of the pump is not too low or too high (E motor or thermic engine sized too small so dropping the speed too low...).

a-3) Check if the main relief valve is not set at an extremely low pressure and therefore venting some flow back to the tank.

a-4) Check if in the directional valves the spools are not sticking in a position that brings part of the flow back to the tank.

a-5) Check if the hydraulic motor is not leaking internally due to a bad efficiency, low viscosity.

a-6) Check if the cylinder inner seals are not ruined and therefore allow internal leakage.

b) Is the connection from the tank to the pump correct?

b-1) Check if there is no air intake between the pump and the inlet pipe (bad seals for example).

b-2) Check if the inlet hose is convenient for the required velocity (0,5 < V < 1,9 m/s).

b-3) Check if the pump is not too high compared to the oil level or if the pump is not too far from the tank (check the inlet absolute pressure with the catalog values).

b-4) Check if the gate valve is not semi-open.
b-5) Check if the inlet strainer is sized correctly (250 m mesh mini.) or not clogged.

c) Is the tank design correct?

c-1) Check if the oil level is correct.

c-2) Check if the suction pipe is under the oil level during the complete cycle of the machine.

c-3) Check if the inlet hose fitted in the tank is cut with an angle wider than 45°.

c-4) Check if this inlet hose is not too close to the tank wall or to the bottom of the tank and therefore limits the “vein flow”.

c-5) Check if the suction hose is not located near the return line and therefore sucking a lot of air coming from these turbulences.

c-6) Check if baffles are required to allow correct deareation of the fluid.

c-7) Check if the air filter is not clogged or under sized (not well dimensioned).

c-8) Check if the tank is not fully tight, not allowing the atmospheric pressure to apply.

d) Is the oil correct?

d-1) Check if the oil characteristics are compatible with the pumps requirements.

d-2) Check if the viscosity is not too high, therefore “sticking” some vanes in the rotor or blocking the vein fluid.

d-3) Check if the high temperature does not destroy the viscosity of the fluid. Doing so, the internal leakage will “consume” the flow.

III. Troubleshooting table

III-1-3. No pressure

a) Is the hydraulic circuit correctly designed?

a-1) Check the hydraulic circuit schematic.

b) Is the circuit correctly piped?

b-1) Compare the schematic to the piped circuit.

c) Are the components working properly?

c-1) Check the main sequences. Doing so, you will check if all the valves are set or work properly.

c-2) Check if the main relief valve is not set at an extremely low pressure and therefore bringing all the flow back to the tank.

c-3) Check if in the directional valves the spools are not sticking in a position that brings the flow back to the tank.

II-1-4. Not enough pressure

a) Check as when “no pressure” IV-1-3.

b) Is the system well dimensioned?

b-1) Check if the flow required is not over the available flow and therefore cannot build-up pressure.

c) Is there an internal leakage somewhere that maintains a certain pressure?

c-1) Check all the possible faulty components, from the pump to all the receptors and intermediates (high pressure seals, mechanical wear).

III. Troubleshooting table

III-1-5 - Uncommon noise level

a) Is the noise coming from the pump?

a-1) Check the mechanical link of the shaft pump : alignment, balancing of the coupling or Universal joint, key properly fastened,

a-2) Check if the air bleed has been done correctly.

a-3) Check if there is no air intake from the tank to the pump (or through the shaft seal).

a-4) Check if the hose strain force does not create this noise.

a-5) Check if the oil level is correct.

a-6) Check if the oil in the tank is not aerated.

a-7) Check if the strainer is not clogged and is correctly sized

a-8) Check if the inlet pipe is under the oil level.

a-9) Check if the air filter is not clogged or too small.

a-10) Check if the speed is not compatible with the catalogue values.

a-11) Check if the oil is compatible with the catalogue recommendations.

a-12) Check if the inlet pressure is not higher than the outlet pressure.

b) Is the noise coming from the surroundings?

b-1) Check the hoses and see if the noise is not coming back to the pump this way.

b-2) Check the pressure piping and see if it amplifies the noise.

b-3) Check if the structure of the tank is stiff enough to avoid amplification/resonance.

b-4) Check the E motor fan.

b-5) Check the balancing of the E motor.

b-6) Check the water cooler and its theoretical limits.

b-7) Check the filtration unit, its capacity and if the noise does not come from the opened by-pass valve.

III. Troubleshooting table

III-1-6. Unusual heat level

a) Does the heat appear when the pump is running without pressure?

a-1) Check the oil level and the suction pipe. Is the oil coming to the pump (check the length of the pipe, its internal diameter, all that could influence the inlet pressure)?

a-2) Check if the air bleed has been done correctly.

a-3) Check if the flow versus the volume of oil in the tank is correct to obtain a good cooling effect.

a-4) Check if a cooler is required or, if there is one, if it is well dimensioned.

a-5) If there is a cooler, check if it is working (example for water cooler: is the water flow open or sufficient).

a-6) Check if the hydraulic circuit is not bringing back the flow directly to the inlet port. Doing so, it would create a very small closed circuit not able to cool down the fluid.

a-7) Check the quality of the fluid.

a-8) Check the velocity of the fluid.

a-9) Check the filtration unit, its capacity and if the heat does not come from the open by-pass valve or if it is under-dimensioned (bigger delta P).

b) Does the heat appear when the pump is running with pressure?

b-1) Check the viscosity.

b-2) Check the pressure rating.

b-3) Check if the cooler is working correctly or well dimensioned.

b-4) Check if the relief valve is not creating this heat because always open.

b-5) Check if any other component in the system is not creating this heat due to an internal defect.

b-6) Check if there is a big temperature differential between the inlet and the outlet.

III. Troubleshooting table

III-1-7 - Shaft seal leakage

a) Is the seal destroyed?

a-1) Check the alignment and the correct power transmission (non homokinetic movement, high radial force as examples).

a-2) Check the inlet pressure and compare it to the catalogue values.

a-3) Check suction conditions. Seal can be damaged if there is any vacuum.

a-4) Check if the external environment is not too dirty and therefore ruining the seal.

b) Is the seal only leaking?

b-1) Check the alignment of the front shaft and check if there is any radial load.

b-2) Check if seal lip has not been cut during a maintenance operation.

b-3) Check if the inlet pressure is not over or under the catalogue values. This has to be done for the whole cycle because the inlet pressure can vary from time to time.

b-4) Check if the seal material has not been modified due to a too warm environment. The seal can vulcanize and stop sealing correctly.

b-5) Check the acidity of the oil that can “burn” the seals material. It will therefore destroy the elasticity of the sealing.

b-6) Check if the chosen seal (high pressure seal for example) is not too stiff for the use. If the environment requires some elasticity due to a gentle misalignment, a high pressure seal will not be able to follow the movement and therefore leak.

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