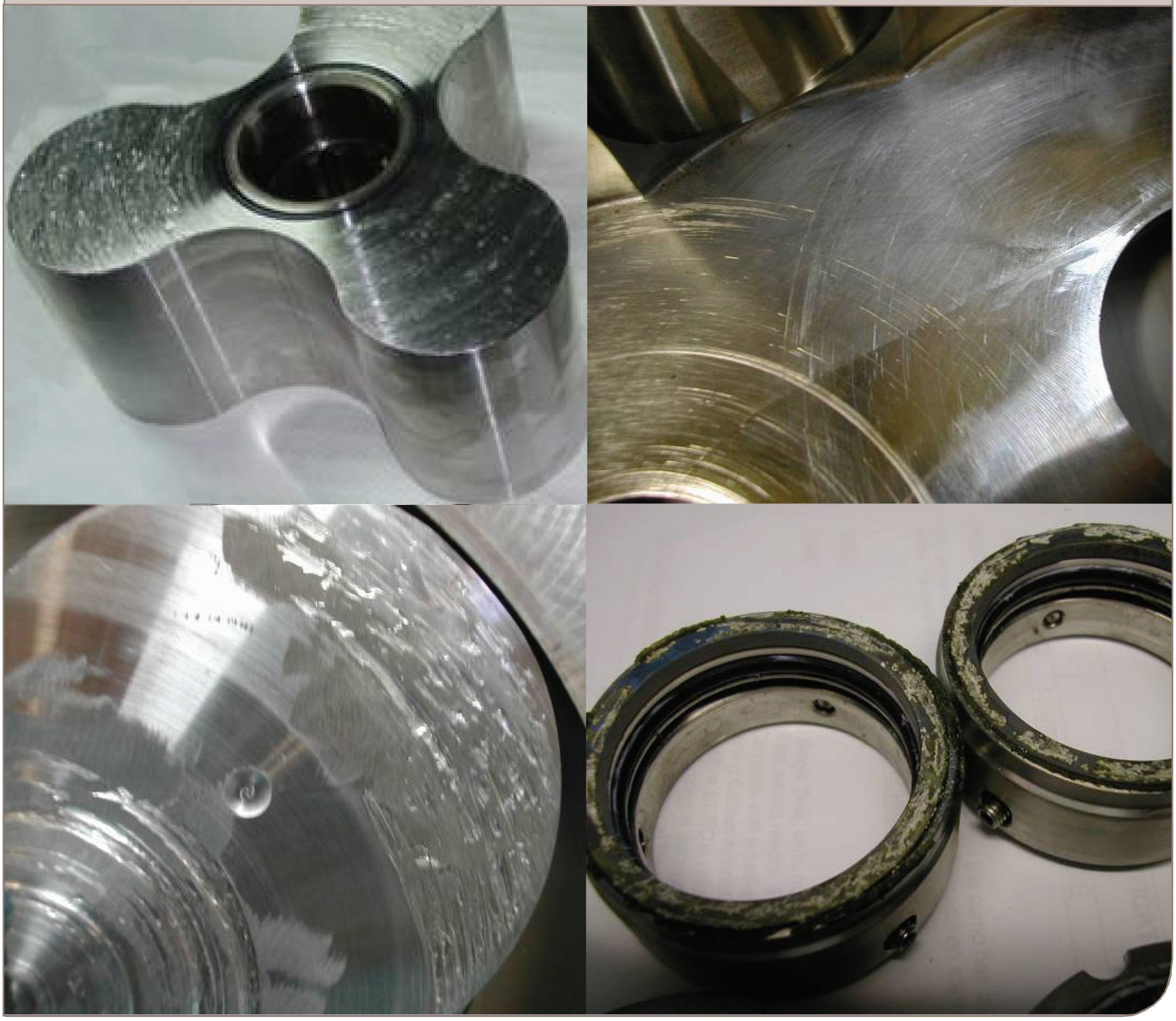
Problem Solving

Positive Displacement Pumps



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Inside View

This document has been produced to support pump users at all levels, providing an invaluable reference tool. It includes information on general Positive Displacement pump problems and their effect on rotary lobe pumps with suggestions as to probable causes and solutions.

Main sections are as follows:

Contents

1.0 Introduction

In most pumping systems, the pump is likely to be one of the most vulnerable components and systems frequently show the pump to be at fault regardless of what may be wrong.

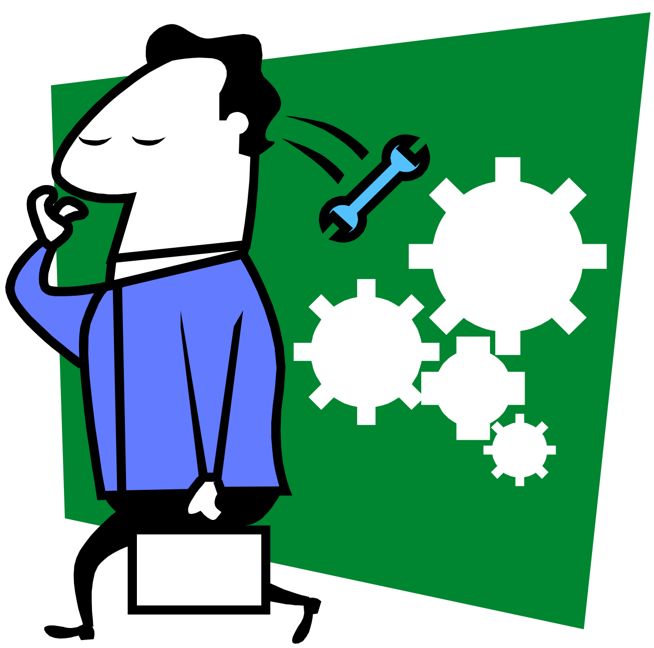
Upon investigation the likely causes of the problem are inadequate control of the pumped fluid or a change in operating requirements of which the system or pump is not capable of handling.

Pumps that are correctly installed and operated within their design parameters will give typically long trouble-free service of >10 years, unless on very arduous duties.

In order to correctly identify the problem it is important to gather as much information relating to the process as follows:

- Reconfirm original duty requirements and/or system design.
- Check for any process changes i.e. pressure, temperature, fluid viscosity etc.
- Check whether the system was undergoing routine maintenance.
- How long did the pump operate before the problem.
- Check the appearance and condition of the pump internal components.
- Check when the pump was last serviced.
- Check for any changes in pump noise or vibration.

This will save considerable time and effort in leading to the most appropriate solution. The most common problems associated with Positive Displacement pumps are shown herein with particular effects on our range of rotary lobe pumps.

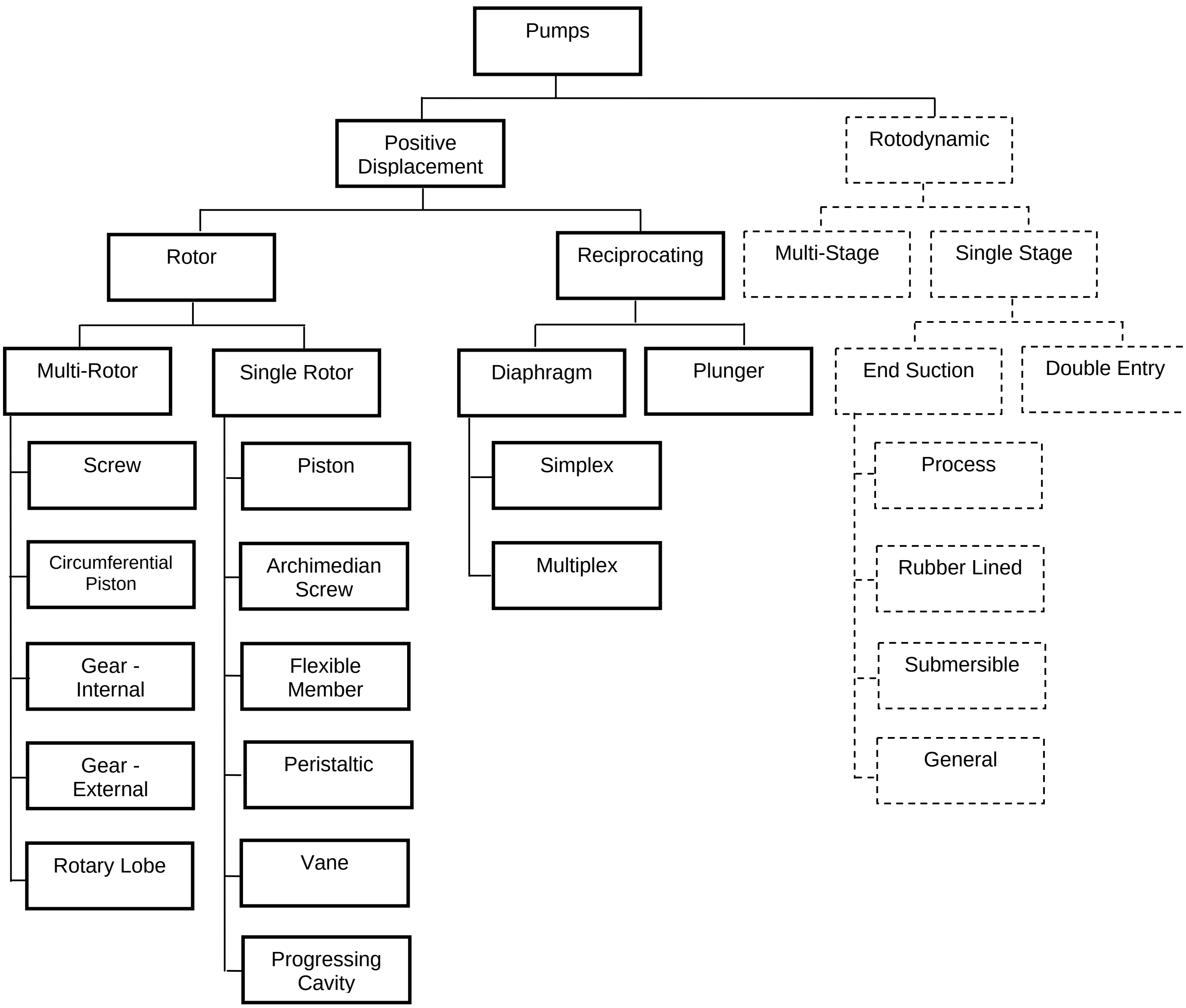


2.0 Positive Displacement Pump Problems

Typical pump problems include:

- No flow
- Excessive discharge pressure
- Excessive temperature and/or rapid temperature change
- Excessive noise or vibration
- Seal leakage

These are common for all Positive Displacement pump types shown as follows:



Typical causes are as follows:

No flow

- Pump is not primed.
- The drive unit is turning pump in the wrong direction.
- Valves are closed or there is an obstruction in the suction or discharge pipework.
- The end of the suction pipework is not submerged.
- A strainer or filter is clogged.
- Insufficient Net Positive Suction Head available (NPSHa).
- A by-pass valve is open.
- Air leak in the suction pipe.
- Air ingress through (Packed) Gland.
- Pumping element is severely worn.
- Failure in drive train.
- No power to the pump.
- Pump speed too high.
- Pumped media viscosity is higher than expected.

Excessive discharge pressure

- Valves are closed or there is an obstruction in the discharge pipework.
- A strainer of filter is clogged.
- Pumped media viscosity is higher than expected.
- Discharge pressure is higher than calculated.

Excessive temperature

- Too high process temperature.
- Increase in ambient temperature.

Excessive noise or vibration

- Pump and driver are misaligned.
- Pipework is not properly supported.
- Pumped media viscosity is too high.
- Pump is cavitating.
- Relief valve oscillating.
- Foundation or anchor bolts have become loose.
- Pumphead contact.
- Pump speed too high.
- Gas entrainment.
- Loss of shaft support (bearing failure).
- Pumped media contains unexpected abrasive particles.
- Poor pipework / system design.

Seal leakage (see section 2.1 for further detail)

- Pumped media contains unexpected solids.
- Chemical corrosion / attack.
- Pump is cavitating.
- Too high discharge pressure.
- Too high temperature.
- Pump / shaft vibration.
- Incorrect fitting.
- Incorrect selection of seal materials.
- Pump allowed to run dry.
- Insufficient or no auxiliary flushing services.

Condition	Effect on Positive Displacement Pump Types				
	Gear	**Lobe**	**Peristaltic**	**Progressing Cavity**	**Vane**
Dry Running	Gear wear / failure	None, providing gland area is flushed.	Hose damage	Stator failure - shedding into pumped media	Vane damage
Excessive Temperature	Pumphead contact	Pumphead contact	Hose failure	Stator failure	Vane damage
Excessive Discharge Pressure	Gear / Shaft breakage	Pumphead seizure	Hose failure	Stator failure	Pumphead contact
Cavitation	Reduced flow / Gear wear / Erosion	Reduced flow / Pumphead contact / Erosion	Reduced flow / Hose damage	Reduced flow / Stator failure	Reuced flow / Vane damage
Unexpected Hard Solids	Pump seizure / Jamming	Pumphead contact / Jamming	Hose failure - shedding into pumped media	Stator failure / Jamming	Pump seizure / Jamming

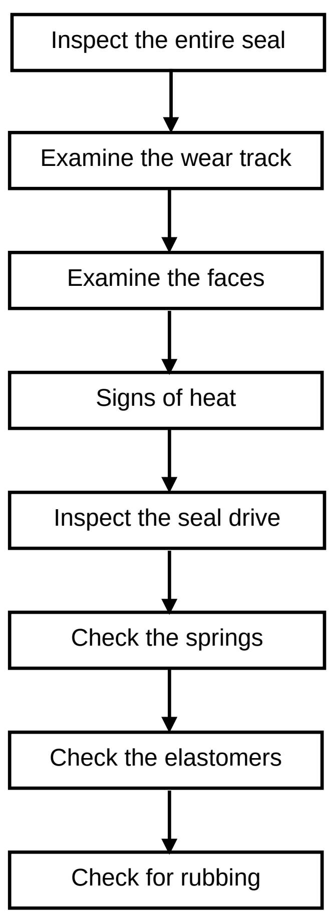
2.1 Seal Leakage

Mechanical seals are precision designed and manufactured products, yet one of the most common causes of failure in Positive Displacement pump types is due to the malfunction of its mechanical seal. By design mechanical seals are friction contact devices and can be subjected to a very wide range and often hostile operating environments. Selecting the correct mechanical seal is imperative to avoid any seal leakage i.e. mounting attitude, seal face combination and elastomer selection.

To assist in identifying why a particular mechanical seal has leaked it is important to record as much information as possible:

- How long has the seal been in operation (months, days, hours)? Is the seal subject to continuous or intermittent running?
- Check for any process changes i.e. pressure, speed, temperature and pumped media details.
- Where is the seal leaking from? i.e. under sleeve, behind gasket, along shaft etc.
- How badly is the seal leaking? i.e. constant or variable, only when shaft is stationary.
- Check seal flush flow rate and pressure if single flushed or double flushed mechanical seals are used.
- Check for any pump cavitation and/or vibration.

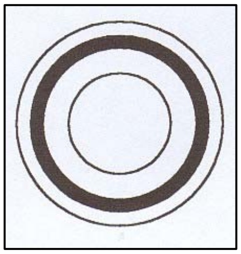
For solving any seal leakage problem it is advisable to adopt a systematic approach as follows:



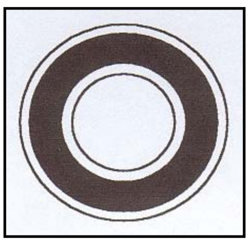
2.1.1 Inspect the entire seal

Do not try to solve a seal leakage problem by looking at only the parts that look important. Both the primary rotating and stationary seal faces should be inspected, as well as secondary seals such as 'O' rings, cups or gaskets. The shaft sleeve and inside of the seal housing/casing should also be inspected. Look for any deposits, chips or broken components. Look for any wear debris near to seal faces.

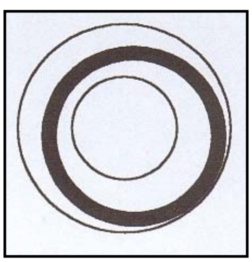
2.1.2 Examine the wear track



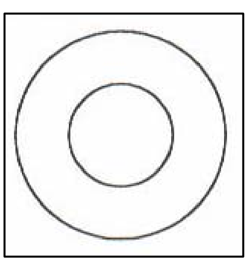
Normal wear pattern
Cause:
If leakage is present it is probably due to problems with elastomeric secondary seals.
Solution:
Replace both primary seal faces and secondary seals.



Wide wear pattern
Cause:
This indicates that the pump shaft is running eccentrically due to being bent from misalignment, bearing failure, shaft deflection or severe pipe strain.
Solution:
Replace shaft and seals. Check shaft is correctly aligned, and check system pressures and alleviate any pipe strain.

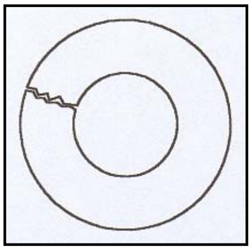


Off centre wear pattern
Cause:
This indicates that the seal faces are not running concentric to one another or the stationary face is not central in the gland area.
Solution:
Replace seals and install correctly by referring to the seal manufacturers fitting instructions.



Non contact pattern
Cause:
This indicates that the rotary face is not mating with the stationary face. This can be due to incorrect installation, slipping of the drive mechanism or loss of anti-rotation devices.
Solution:
Install seals correctly by referring to the seal manufacturers fitting instructions and check that anti-rotation devices are present.

2.1.3 Examine the faces



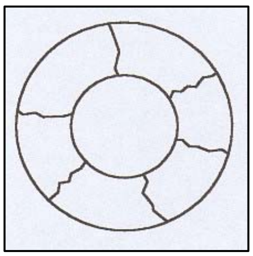
Cracked ceramic face

Cause:

Over tightening or mishandling.

Solution:

Replace seals and install correctly by referring to the seal manufacturers fitting instructions and handle with care.



Thermal shock

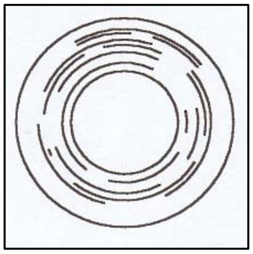
Cause:

Thermal stress is a common cause of fracture and usually occurs when the seal face is subjected to rapid temperature change i.e. after pumping hot media the pump/seal is cleaned with a cold cleaning fluid.

Solution:

Replace seals and investigate process and CIP temperature regimes and change accordingly.

Example of crack in seal insert caused by thermal shock



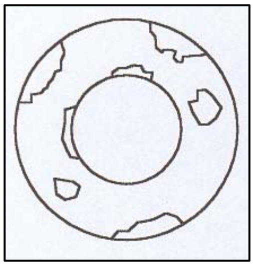
Heavy wear or scoring

Cause:

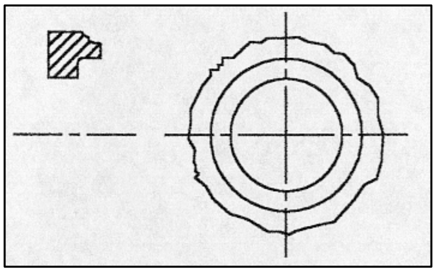
This often occurs with seals in severe abrasive service with the seal faces separating, letting in large particles between the seal faces. These particles then embed in the soft face (carbon) and grind the hard face.

Solution:

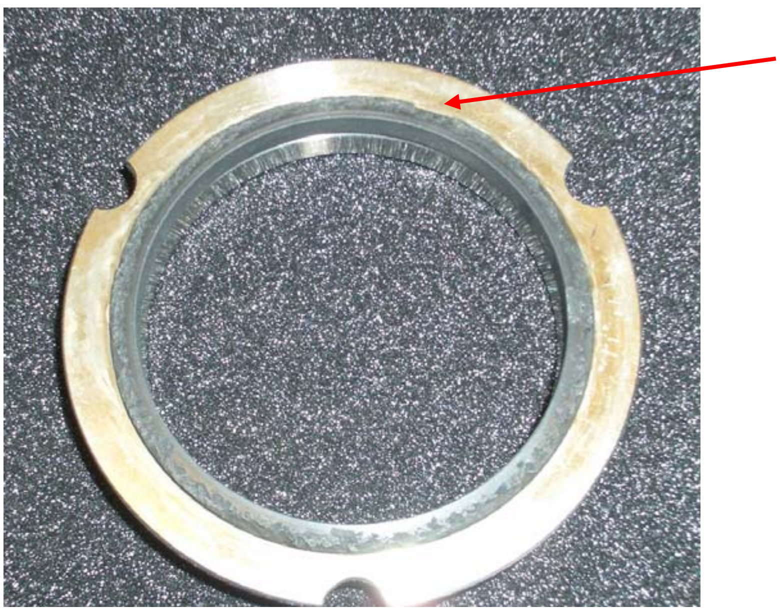
Replace seals with a hard face combination such as silicon carbide and/or provide a flush to the seal area.



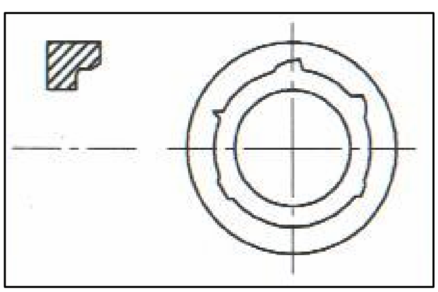
<u>Coating removal</u>
Cause:
This is due to incompatibility of the plating or base material with the pumped media causing chemical attack to part the different materials.
Solution:
Replace seals with different seal face material that is compatible with pumped media from seal manufacturer's recommendations.



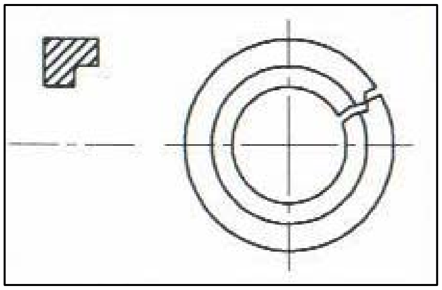
<u>Chipping on outside diameter</u>
Cause:
This is evident in soft seal face material (carbon) due to the solidification of pumped media on the face outside diameter causing breakage upon start up. Severe cavitation could also cause this problem.
Solution:
Replace seals and provide a flush to the seal area and/or eliminate any pump cavitation problems (see 3.1.4).



Example of chipping on outside diameter of seal face



<u>Chipping on inside diameter</u>
Cause:
This is evident in soft seal face material (carbon) due to abrasive particles in the pumped media damaging the seal face. Severe cavitation could also cause this problem.
Solution:
Replace seals with a hard face combination such as silicon carbide and provide a flush to the seal area and/or eliminate any pump cavitation problems (see 3.1.4).



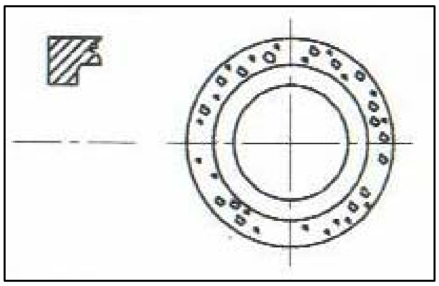
<u>Cracked carbon</u>

Cause:

This is usually caused by over compression, vibration or the swelling of an elastomer on the inside diameter, putting the carbon in tension. Problem could also be mishandling.

Solution:

Replace seals and install correctly by referring to the seal manufacturers fitting instructions and handle with care. Check elastomers are compatible with the pumped media from seal manufacturer's recommendations.



<u>Pitting, blistering or corrosion</u>

Cause:

Mechanical seals are selected for particular applications and should not be subject to these problems. However severe corrosion can occur if used on incompatible pumped media. Also this can occur when a poor grade of carbon is being used, or when retrofitted by someone other than the original manufacturer - here gases are trapped within the material which vaporise during operation, thereby allowing solidification of pumped media on the seal faces giving shearing and tearing effects.

Solution:

Replace seals with faces that are compatible with pumped media and/or an improved carbon grade. Corrosive attack of carbon can be eliminated by selecting carbons which are relatively binder free upon seal manufacturer's advice.

Example of pitting corrosion on stainless steel

Example of crevice corrosion on a stainless steel face

Worn spot in the stationary ring

Cause:

This usually occurs on soft face materials such as carbon or stainless steel but can arise in other materials under severe conditions. The usual cause of failure is a flush line being directed at the static face causing erosion. If the flush media contains abrasive particles and/or flow rate is excessive, the effect will be increased.

Solution:

- *Ensure flush is directed tangentially to the seal faces.*
- *Reduce flush flow rate.*
- *Eliminate any abrasive particles from the flush media.*
- *Change to hard face combination such as silicon carbide.*

An example of seal faces being subject to chemical attack

An example of mechanical seal failure whereby the pumped media has been allowed to solidify on the seal faces causing leakage.

Fitting a flushed mechanical seal arrangement will alleviate this problem.

2.1.4 Signs of heat

If any discoloration of the seal parts is observed, then high friction between the seal faces has been created. Further evidence in 'O' ring hardening and 'setting' may support this. The seal faces will also show signs of excessive wear and possible heat distress in the form of thermal cracking.

Cause:

The most probable causes are dry running, flashing, or very poor face lubrication. Flashing being 'boiling of the fluid film' on the seal faces. Other causes could be incorrect fitting of the seal causing high friction and thereby high temperatures within the seal or the pump is operating at excessive pressures or speed.

Solution:

- *Ensure seal does not run dry in the application. If this cannot be avoided a single seal with flush or a double seal with a barrier fluid should be considered ensuring proper lubrication of the seal.*
- *Ensure the seal is properly installed as per seal manufacturers fitting instructions.*
- *Ensure the pump operates at specified pressure and/or speed.*

An example of a mechanical seal where the seal faces have been allowed to run dry

The sealing surface is scored

Burnt debris found on the inner diamete

'O' ring is deformed (being axially moved from the fitted position close to the shaft step)

Burnt 'o' ring residues on the outer diameter

2.1.5 Inspect the seal drive

Mechanical seal designs all use some method to transmit torque from the shaft to the rotary seal face and mostly this is achieved by pins or grub screws. Seals are usually loose in torsion, that is, outside the pump you can twist them slightly before they engage. The pins or grub screws should be inspected for any signs of wear.

Worn drive dogs or slots

Cause:

This can be caused by 'slip stick', where the two seal faces will stick together causing excessive stress on the drive pins. This 'stress' is then transferred back to the seal face causing it to accelerate and then stick again. Instead of a smooth rotary motion, the seal face is being beaten around in its circular path. Slip stick is caused by a lack of face lubrication. The wear can also be the result from vibrations within the pump and could also be the result from a static face not being fitted squarely to the shaft causing axial movement of the rotary face.

Solution:

- *Ensure the seal is properly installed as per seal manufacturers fitting instructions.*
- *Ensure the pump operates at specified pressure and/or speed.*
- *A single seal with flush or a double seal with a barrier fluid should be considered ensuring proper lubrication of the seal.*
- *Ensure any vibrations are eliminated.*

Worn inner diameter of spring retainer

Cause:

This can be caused by the grub screws not being properly tightened during installation of seal. Also extreme shear stress between the seal faces due to pumped media properties has overcome the grip of the grub screws. The grub screws will show signs of severe wear. This failure is very often combined with longer periods of non-operation for the pump and poor cleaning cycles.

Solution:

- *Ensure the seal is properly installed as per seal manufacturers fitting instructions.*
- *For media having tacky properties, a single seal with flush or a double seal with a barrier fluid should be considered ensuring proper lubrication of the seal.*
- *Ensure proper cleaning cycle is applied within the process.*

2.1.6 Check the springs

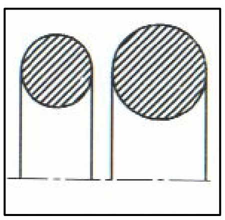
Springs fail usually because of a combination of chemical attack and high stresses. Stress corrosion can occur for stainless steel springs used in certain pumped media containing either chlorine, bromine, iodine, fluorine ions or compounds of these elements. The free ions will attack the protecting chrome oxide layer of the stainless steel and while the oxide layer is being attacked the flaw will open up small cracks. If the oxide particles wedge into these cracks a sudden failure can occur.
Other causes of failure can be:

- Within single seal configurations where a very small leakage can be detrimental for the spring as local concentrations will be high.
- Fatigue, which is the result from repeated load changes generated by repeated compression/decompression of the spring. This could be the result from a static face not being fitted squarely to the shaft.

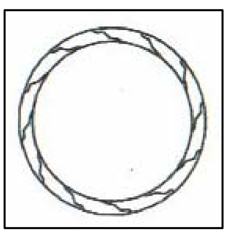
Solution:

- *Ensure the concentration of corrosive elements on the spring is minimised by using either a single flush or a double seal arrangement.*
- *Change spring material to a more corrosion resistant material, such as Hastelloy.*
- *Ensure vibrations within the pump are minimised.*
- *Ensure axial movement is within specification.*
- *Ensure the seal is properly installed as per seal manufacturers fitting instructions.*

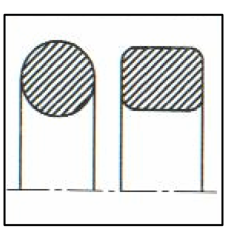
2.1.7 Check the elastomer



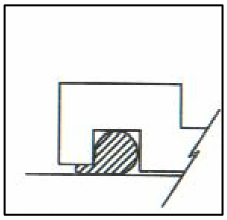
<u>Swollen, sticky or disintegrating</u>
Cause:
This is generally caused by chemical incompatibility with pumped media.
Solution:
Replace with different elastomer material that is compatible from seal manufacturer's recommendations.



<u>Hard or cracked</u>
Cause:
This is generally caused by excessive heat and/or chemical attack. Usually the source of heat is the face or a metal to metal contact of two parts. Excessive face heat is caused by lack of lubrication and subsequent high friction. It could also be a sign that the pump has run dry.
Solution:
Ensure seal does not run dry in the application. If this cannot be avoided a single seal with flush or a double seal with a barrier fluid should be considered ensuring proper lubrication of the seal.
Replace with different elastomer material that is compatible from seal manufacturer's recommendations.



<u>Compression set</u>
Cause:
This is caused where the 'O' ring has been unable to withstand the temperature of the pumped media - the 'O' ring loses its roundness and becomes square in section. This may also occur if too much heat is generated at the seal faces.
Solution:
Reduce pumped media temperature and/or replace with different elastomer material that is compatible from seal manufacturer's recommendation and can withstand high temperature required.



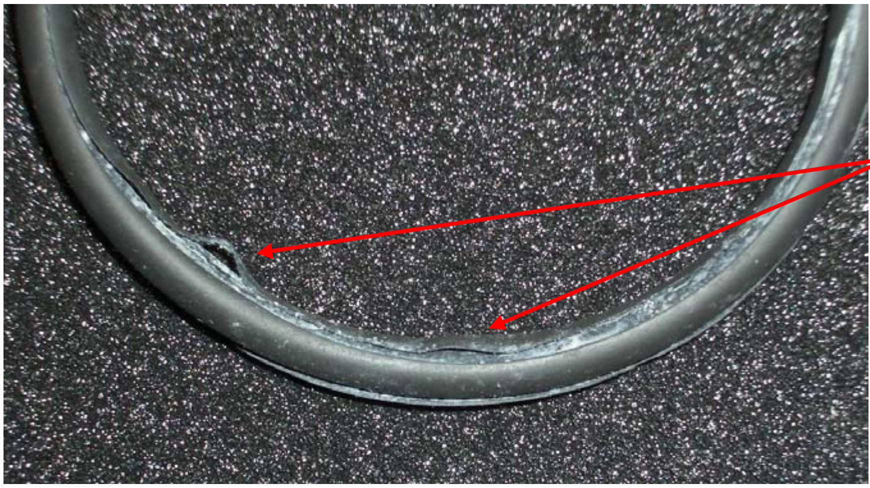
Extruded

Cause:

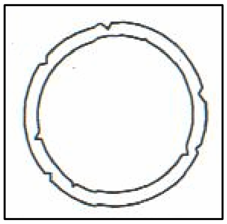
This is caused by excessively high pressure and/or the size of the seal ‘O’ ring groove being incorrect. As the ‘o’ ring extrudes it will tear in the gap between shaft and seal ring.

Solution:

Replace elastomer and reduce system pressures. Also check that the ‘O’ ring groove size is correct by referring to seal manufacturer.



Example of ‘O’ ring damaged by excessive pressure



Cuts or nicks

Cause:

This is the most common failure and normally occurs during installation.

Solution:

By its nature elastomers slide on to the shafts with some interference and care should be taken when sliding new elastomers over any sharp edges, shoulders or old grub screw marks to avoid damage.

2.1.8 Check for accidental rubbing

In a troubleshooting approach it is important to carefully inspect the shaft, seal and seal chamber if possible, looking for signs of rubbing. For pumps handling high temperature pumped media the rubbing of parts may only take place when the pump is hot. When cooled, the worn marks may become covered over and not be as noticeable.

Some causes for accidental rubbing are:

- Flush or barrier fluid pipework entering the seal housing and extending into the seal area itself.
- Housings which do not pilot, slip down and hit the seal.
- Gaskets slip into the seal cavity.
- Rotary or stationary rings which do not pilot and come into contact with the shaft.
- Build up of scale in the seal area.
- Seal area not concentric with the shaft.
- Excessive shaft deflection caused by throttling the discharge or otherwise operating the pump at its wrong capacity or pressure.

Solution:

- *Ensure the shaft and seal area is per specification by checking with pump/seal manufacturers.*
- *Ensure the seal is properly installed as per seal manufacturers fitting instructions.*
- *Ensure operating conditions as those for which the pump/seal was selected? i.e. pressure, speed, temperature and product details.*

Fretting on pump shaft/shaft sleeve

Cause:

Fretting corrosion is the result from a constant back and forth movement of the secondary seal over shaft/shaft sleeve causing permanent damage, appearing pitted or shiny bright. Fretting corrosion is most common for PTFE secondary seals. This will be the result from axial vibrations or pressure pulsations.

Solution:

- *Eliminate axial movement of the shaft.*
- *Eliminate pressure pulsations.*
- *Ensure hardness of shaft/shaft sleeve is per specification by checking with pump manufacturer.*
- *Consider hardening of the shaft/shaft sleeve for severe applications referring to pump manufacturer.*

2.1.9 External Symptoms of Seal Failure

Symptoms	***Possible Causes***
Seal squeals	*No seal lubrication.*
Carbon deposits	*Lack of lubrication causes carbon to grind away.* *Liquid film vaporising/flashing between the faces.*
Seal spits and sputters (popping)	*Liquid film vaporising/flashing between the faces.*
Seal drips steadily (heavy leakage is normally from the faces rather than the ‘o’ rings)	***Primary:*** *Faces not flat.* *Faces cracked, chipped or blistered.* *Distortion of seal faces for thermal or mechanical reasons.* ***Secondary:*** *Seals nicked or scratched during installation.* *Leakage of fluid under pump shaft sleeve.* *‘O’ rings have been compression set (hard and brittle).* *‘O’ rings subjected to chemical attack (soft and sticky).* *Incorrect seal materials specified.* ***Seal Hardware:*** *Spring failure.* *Erosion damage.* *Corrosion of drive mechanism.*
Pump/Shaft Vibration	*Shaft misalignment.* *Cavitation.* *Bearing failure.*

3.0 Typical Problems and their effect on Rotary Lobe Pumps

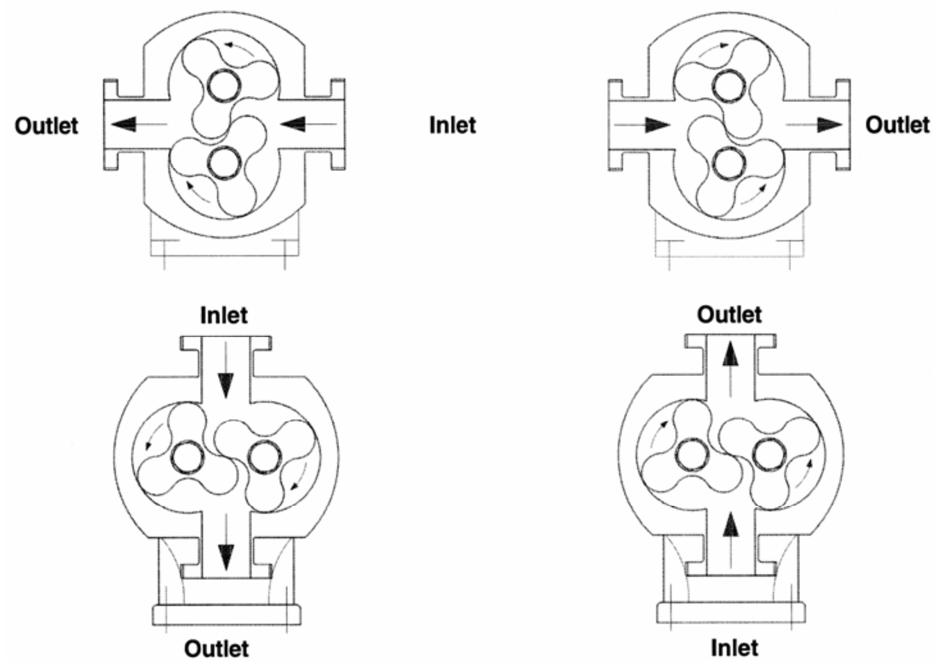
3.1 No Flow

The cause of this problem is normally due any of the following:

- Incorrect direction of shaft rotation.
- Excessive discharge pressure and/or change in fluid viscosity.
- Inability to prime
- Cavitation.
- Gas content.

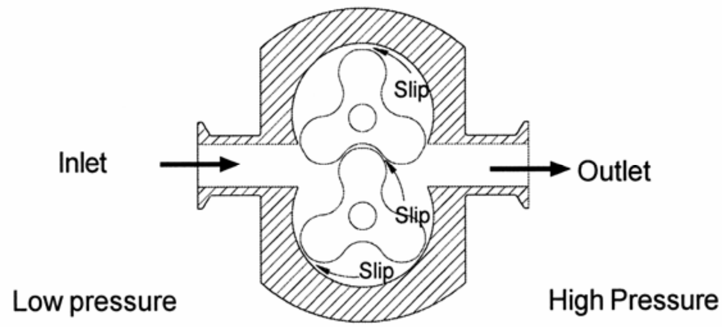
3.1.1 Shaft Rotation

This although obvious is often overlooked. The direction of flow is dictated by the direction of drive shaft rotation. Reversing the direction of rotation will reverse the flow direction.



3.1.2 Excessive Discharge Pressure and/or Change in Fluid Viscosity

Rotary lobe pump performance on low viscosity fluids is greatly affected by excessive discharge pressure and/or changes in fluid viscosity. This is due to ‘Slip’, defined as the fluid lost by leakage through the pump clearances. The direction of slip will be from the high pressure to the low pressure side of the pump i.e. from pump outlet to pump inlet. The amount of slip is dependent upon several factors.

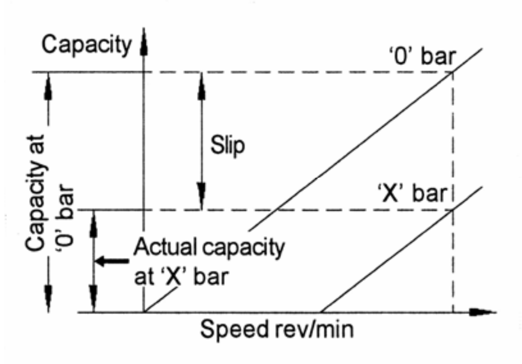


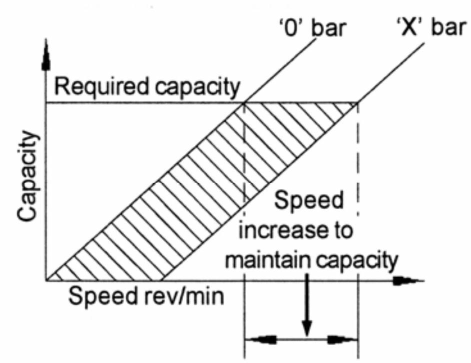
Clearance Effect

Increased clearances will result in greater slip. The size and shape of the rotor will be a factor in determining the amount of slip.

Pressure Effect

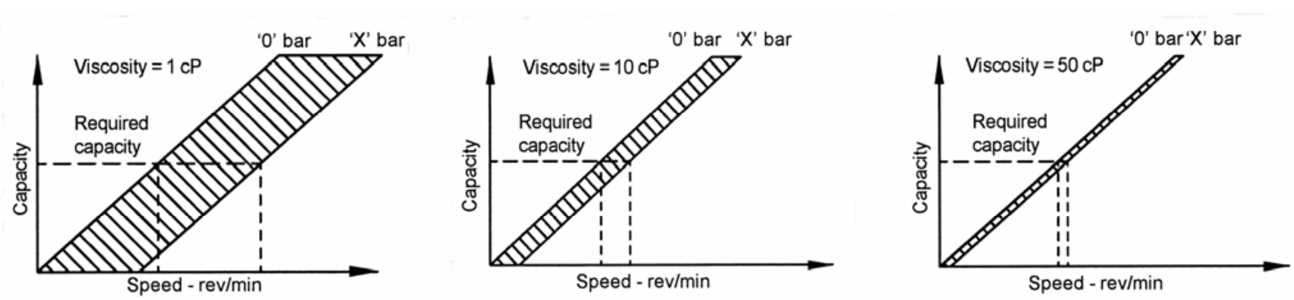
The amount of slip will increase as pressure increases which is shown below. For a given pump speed the amount of slip can be seen as the capacity at ‘zero’ bar less the capacity at ‘X’ bar. To overcome this amount of slip it will be necessary to increase the pump speed to maintain the capacity required.





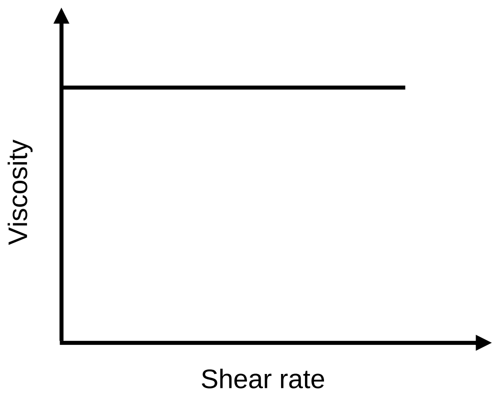
Viscosity Effect

The amount of slip will decrease as fluid viscosity increases. The effect of viscosity on slip is shown below. The pressure lines will continue to move towards the ‘zero’ pressure line as the viscosity increases.



Poor pump performance may be attributed to an unexpected change in fluid viscosity. In some fluids the viscosity is constant regardless of the shear forces applied to the layers of fluid. These fluids are known as Newtonian fluids whereby at a constant temperature the viscosity is constant with change in shear rate or agitation.

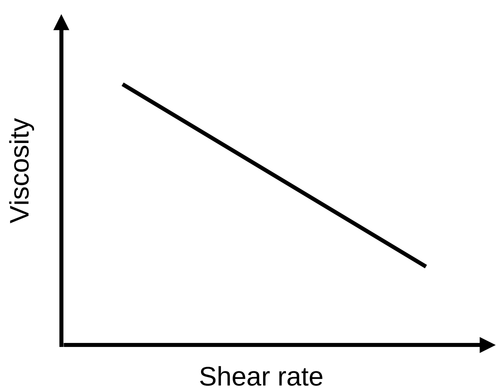
Newtonian Fluid Behaviour



Typical Newtonian fluids are:
- Water
- Beer
- Hydrocarbons
- Milk
- Mineral Oils
- Resins
- Syrups

However, there are many fluids which do not follow this linear law, these fluids are named Non-Newtonian fluids. Of these, Psuedoplastic fluids can have an affect on pump performance if not taken into consideration upon initial pump sizing. With Psuedoplastic fluids the viscosity decreases as shear rate increases, but initial viscosity may be so high as to prevent start of flow in a normal pumping system.

Psuedoplastic Fluid Behaviour



Typical Psuedoplastic fluids are:
- Blood
- Emulsions
- Gums
- Lotions
- Soap
- Toothpaste
- Yeast

Sizing a pump and drive unit on the assumption that a fluid's 'at rest' viscosity is the same as that under pumping conditions can result in an incorrectly sized pump and drive unit being applied, such that performance will not be as desired.

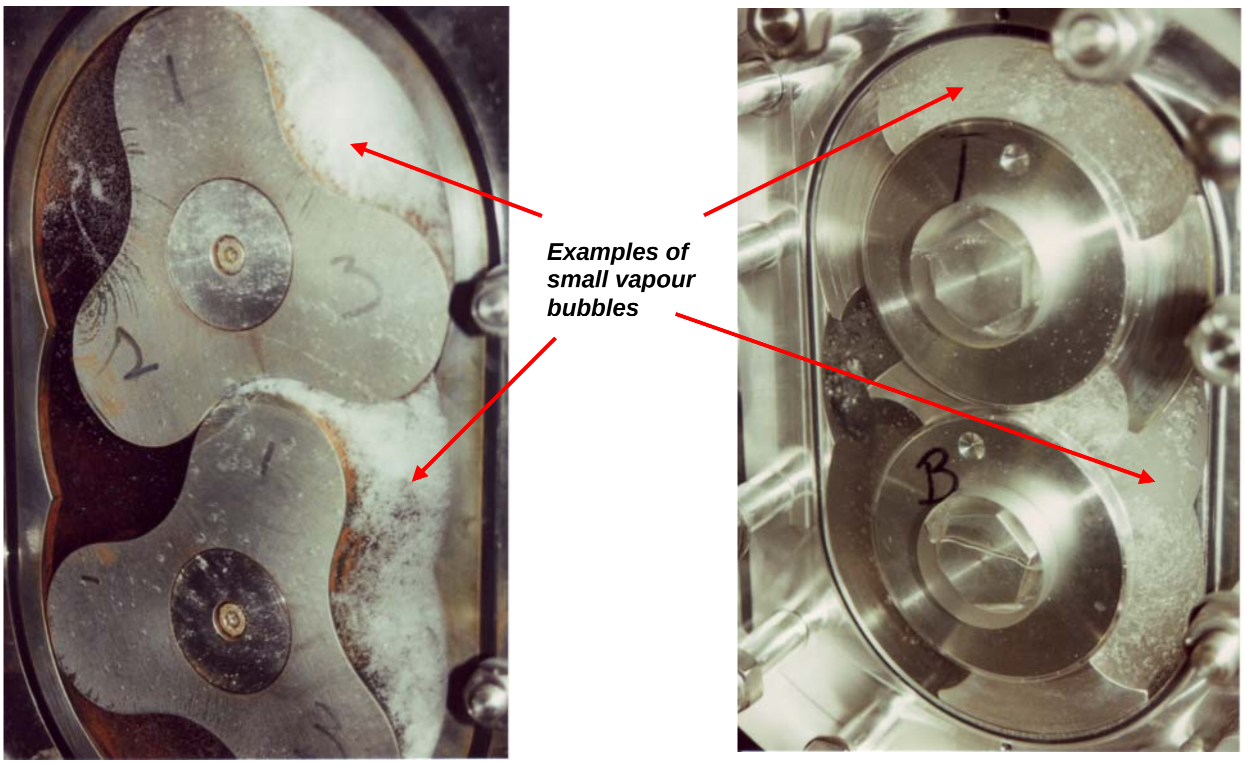
For example, a liquid soap can have an 'at rest' viscosity of 12000 cP but at the applied shear in a pump the applicable viscosity can be as low as 50 cP. If the pump was sized based upon the 'at rest' viscosity of 12000 cP, the pump speed would be relatively slow. As the applicable viscosity in the pump is 50 cP, the result would be the pump not producing the expected design flow rate. Therefore to achieve the flow rate required it will be necessary to increase the pump speed thereby changing drive unit, or even replacing pump and drive unit with a larger model.

3.1.3 Inability to Prime

Rotary lobe pumps may be classed as ‘self priming’. This means that within limits, they are capable of evacuating (pumping) a modest amount of air from the suction side of the pump to the discharge side of the pump. Filling the inlet system with fluid or at least filling the pump (wetted pumping elements) will make a major improvement in the pump’s priming capability.

3.1.4 Cavitation

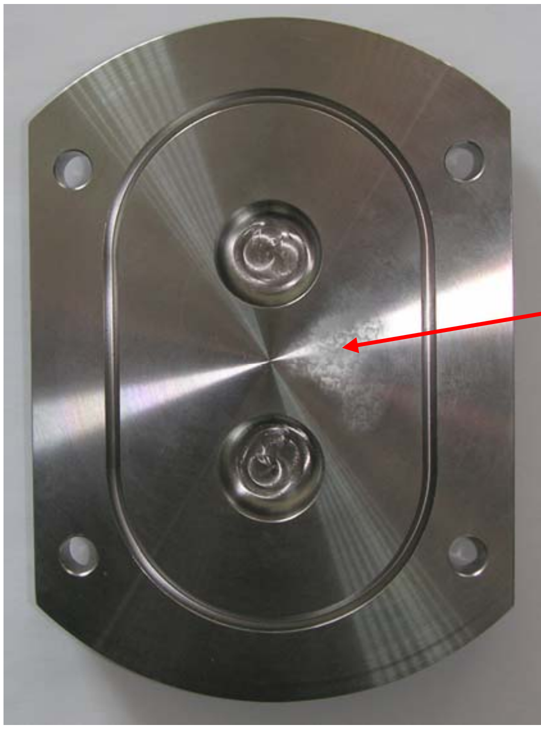
The term cavitation is derived from the word cavity, meaning a hollow space. In pump terminology, cavitation is an undesirable vacuous space in the inlet port of the pump normally occupied by fluid. The lowest pressure point in a pump occurs at the pump inlet - due to local pressure reduction part if the fluid may evaporate generating small vapour bubbles known as ‘vacuoles’. These vacuoles are carried along by the fluid and implode instantly when they get into areas of higher pressure.



Tri-lobe Rotor Pump **Circumferential Piston Pump**

For all pump application problems, cavitation is the most commonly encountered. It occurs with all types of pumps, rotary, centrifugal or reciprocating, caused by insufficient system inlet pressure to the pump. This can be due to an inlet system restriction, excessive fluid viscosity or excessive pump speed. Inlet restrictions can include dirty or clogged inlet strainers, debris floating in the fluid supply that covers the inlet piping intake, or rags. If the fluid is cooler than design temperature, its viscosity may be too high causing excessive friction (pressure loss) in the inlet piping system.

Cavitation is frequently accompanied by noise, vibration and significant increase in discharge pressure pulsation and/or loss of flow. If a pump is allowed to cavitate over long periods this will cause damage to the pumphead components and drive train. The surface of these components are typically perforated and pitted as material is eroded by implosive forces.



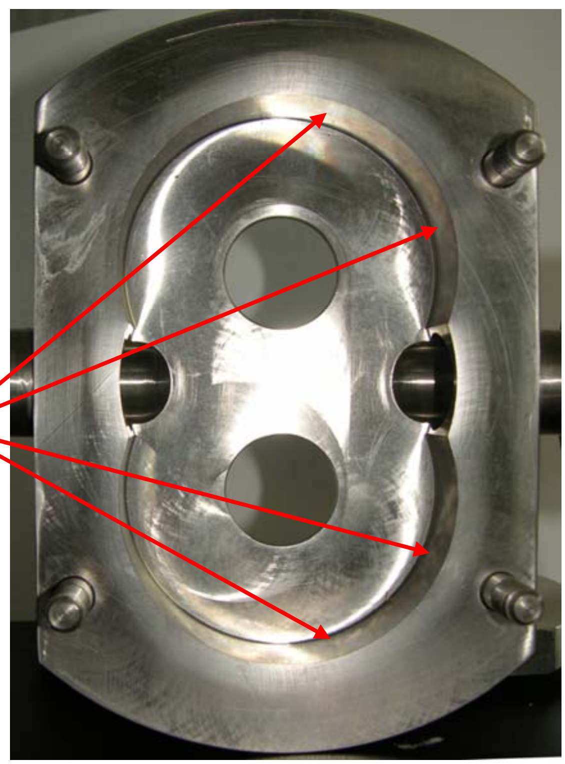
Typical cavitation effect on pump rotorcase cover.

Severe cavitation will be evident even after a short operating period. Blemishes will appear on the rotorcase cover on the discharge side of the pump where vacuoles implode in the high pressure region.

Ultimately this will erode the stainless steel cover as with the rotor.

Typical cavitation effect on pump rotorcase.

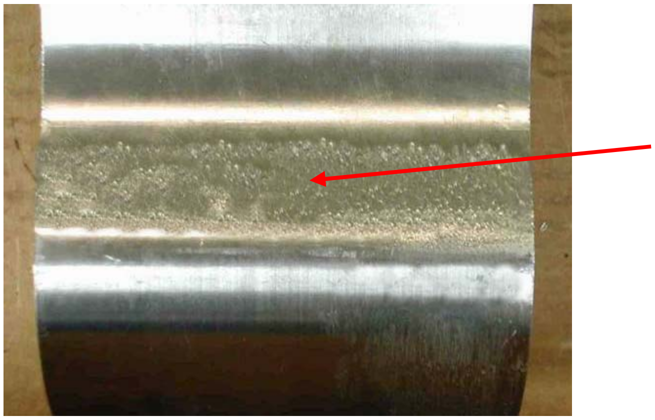
Cavitation can cause damage within the rotorcase as a consequence of shock loading the shafts. In extreme cases this can result in the rotor tips making contact with the casing as well as material erosion from imploding



Suction

Contact areas

Discharge



Cavitation effect on pump rotor may result in rotor to rotor contact.

Rotor flank showing effect of typical cavitation damage where minute particles of the rotor material are eroded by implosions of vacuoles

Ensuring Sufficient Net Positive Suction Head (NPSH)

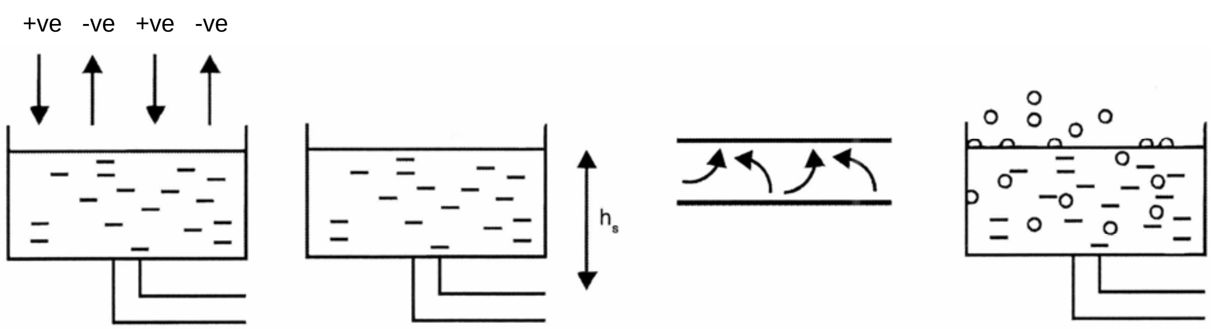
For satisfactory pump operation the condition at the inlet of a pump is critical. The system on the inlet side of the pump must allow a smooth flow of fluid to enter the pump at a sufficiently high pressure to avoid cavitation. This is called the **N**et **P**ositive **S**uction **H**ead, generally abbreviated **NPSH**.

It is critical that the net positive suction head available (NPSHa) in the system is greater than the net positive suction head required (NPSHr) by the pump. The value of NPSHa in the system is dependent upon the characteristic of the fluid being pumped, inlet piping, the location of the suction vessel, and the pressure applied to the fluid in the suction vessel. This is the actual pressure seen at the pump inlet. It is important to note, it is the inlet system that sets the inlet condition and not the pump.

NPSHa is calculated as follows:

NPSHa (metres) =

Pressure action on Surface of liquid (Pa) **±** Static suction head (h_s) – Pressure drop (h_{fs}) – Vapour pressure (Pvp)



Where:

Pa	=	Pressure absolute above fluid level (bar)
h_s	=	Static suction head (m)
h_{fs}	=	Pressure drop in suction line (m)
Pvp	=	Vapour pressure (bar a)

Suggestions for avoiding cavitation

- Keep pressure drop in the inlet line to a minimum i.e. length of line as short as possible, diameter as large as possible, and minimal use of pipe fittings such as tees, valves etc.

- Maintain a static head as high as possible.

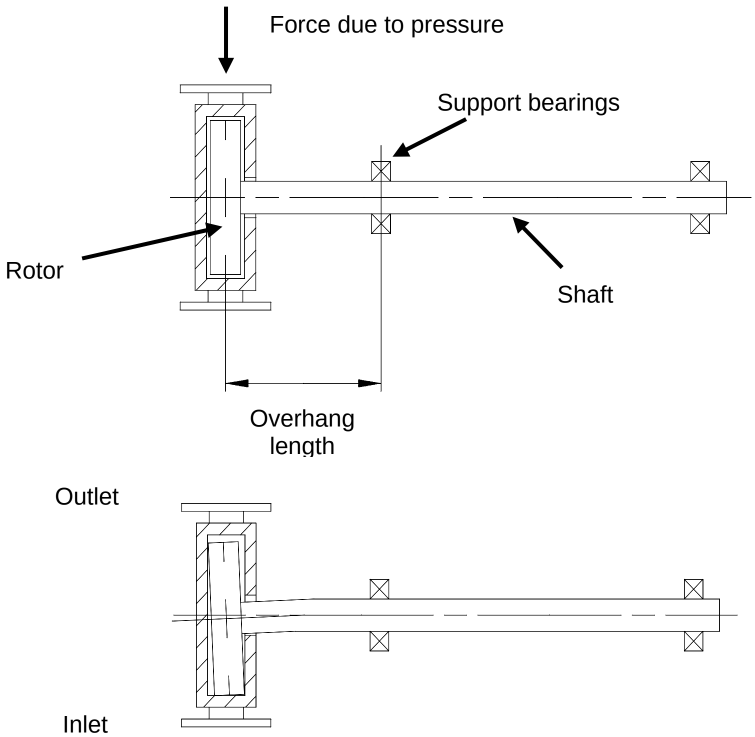
- Reduce fluid temperature, although caution is needed as this may have an effect of increasing fluid viscosity, thereby increasing pressure drop.

3.1.5 Gas Content

Gas in the inlet pipework or entrained gas in the pumped media has the same impact on pump operation and creates the same symptoms as cavitation. This can occur under other circumstances such as a pump operating at an inlet pressure below local atmospheric pressure. In this instance it is quite likely that air is being drawn into the pipework through a loose pipe connection or pump casing joint, leaking inlet valve stem, defective or otherwise damaged joint gasket in the pipework system.

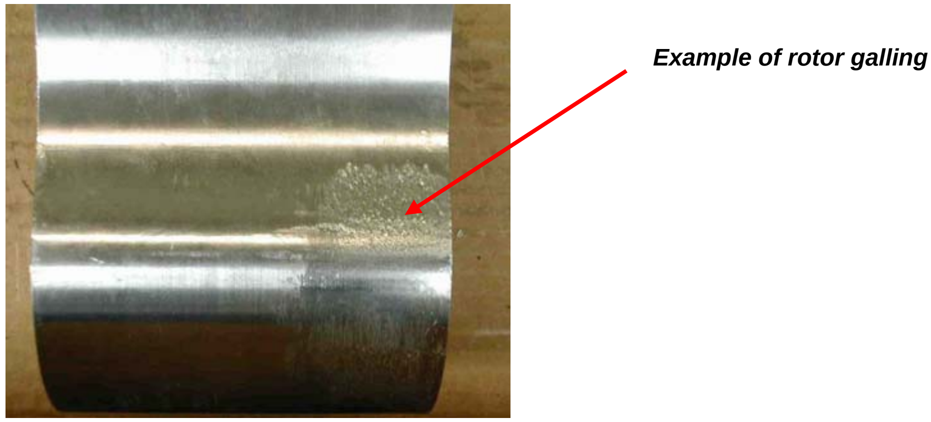
3.2 Excessive Discharge Pressure

The design concept of the rotary lobe pump is to have no contacting parts in the pumphead. This requires having the shaft support bearings to be mounted outside of the pumphead, which results in an overhung load, caused by the rotors fitted to the shafts as shown below.



The effect of pressure on the rotors will cause shaft deflection, which could result in contact between rotors, rotorcase and rotorcase cover. To allow for this pressure effect, clearances are built into the pumphead between surfaces that may contact. For the Series S, X and D pump ranges there is only one pressure rating, which is the maximum differential pressure of the particular pump model. However, the Series A and G pump ranges have more than one pressure rating.

Should the pressure rating be exceeded it is likely that as product wetted parts of the Series S, X and A pump ranges are predominantly manufactured from stainless steel any contact between rotating and stationary parts would cause 'galling' and possible pump seizure.



Due to the positive action of the rotary lobe pump any restriction on the outlet side of the pump, either partial or total, may result in excessive pressure developing in the pumphead. To protect pump, drive unit and also limit pressure build up within associated process equipment it is advisable to install overload protection such as:

- Fitting an external spring-loaded pressure relief valve to the outlet side of the pump which will open under high pressure and allow fluid to return to the inlet side of the pump via a by-pass loop.

or

- Fit the pump with an integral pressure relief valve.

or

- Use proprietary electronic devices.

Rotor tip contact will be initially visible on the discharge side of the rotorcase cover internal face.

If overload continues pump is likely to be damaged beyond repair.

Suction

Discharge

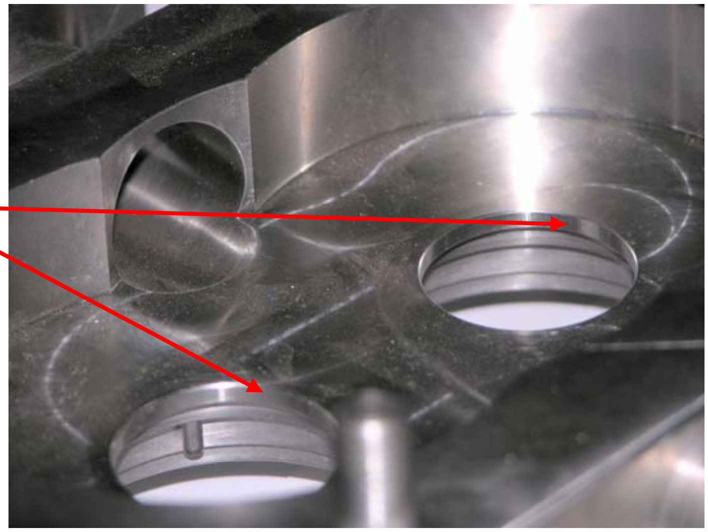
Discharge

Suction

Rotor tip contact will be initially visible on the suction side of the rotorcase rear face.

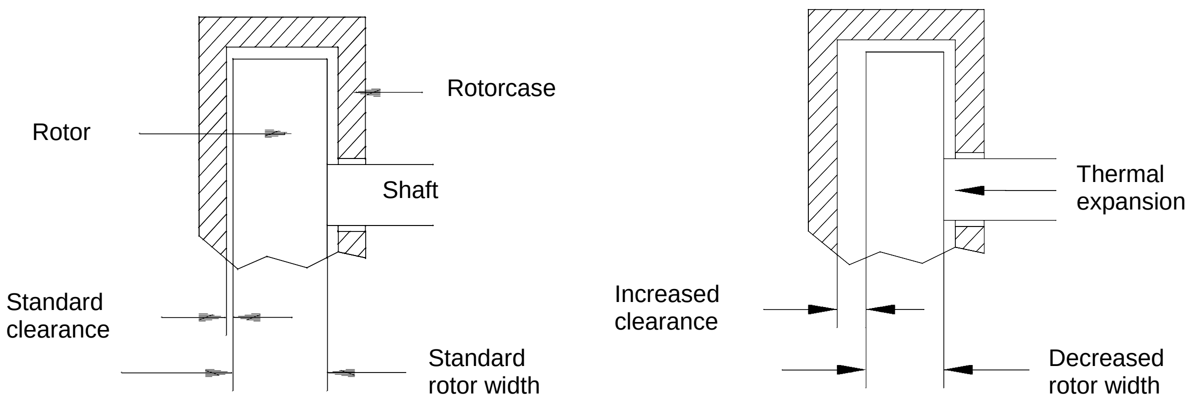
If overload continues pump is likely to be damaged beyond repair.

If damaged areas on the rotorcase cover, rotors and rotor case have been polished to attempt repair, one area is usually forgotten, the inside diameter of the gland bushing.



3.3 Excessive Temperature and/or Rapid Temperature Change

Changes in temperature will cause expansion upon heating or contraction upon cooling, to the pump rotorcase and gearcase components. The most significant result is the movement between shaft and gearcase/rotorcase allowing the rotors to move forward or backward in the rotorcase. With the rotors being allowed to move forward there will be a reduction to the front clearance. To compensate for this, the Series S, A, G and D pump ranges have increased clearances as shown below.



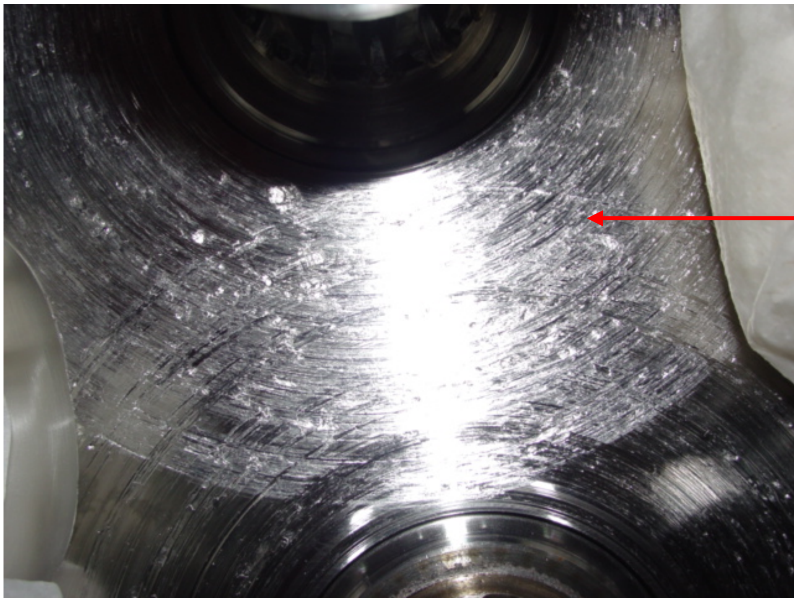
The clearance is exaggerated to show the temperature

Series S, A, G and D pumps are designed for three rotor temperature ratings:

- 70°C (*158°F*)
- 130°C (*266°F*)
- 200°C (*392°F*)

For the Series X pump range, the design of the mechanical seal eliminates any contact between the fluid being pumped and the shaft. This results in the shaft not being subjected to the full temperature variation and therefore only one rotor temperature rating of 150°C (*302°F*) is necessary.

It is imperative during any CIP operation that pumps are not subjected to rapid temperature changes i.e. hot to cold, as pump seizure can result from thermal shock.



Rotorcase with marks attributed to thermal shock. Here the shafts have contracted at a faster rate than the rotorcase, thereby causing contact with rear casing face.

Rear rotor face with signs of rotorcase contact, indicative of rapidly decreasing temperature i.e. thermal shock - hot to cold.

Cold to hot shock would cause rotors to contact rotorcase cover.

3.4 Excessive Noise or Vibration

Excessive noise and/or vibration can be a symptom of many things such as:

- Cavitation
- Mechanical damage to pump assembly
- Misalignment of drive
- Harmonics with other elements of the system

Cavitation, as previously described in 3.1.4, is especially true if the discharge pressure is fluctuating or pulsating.

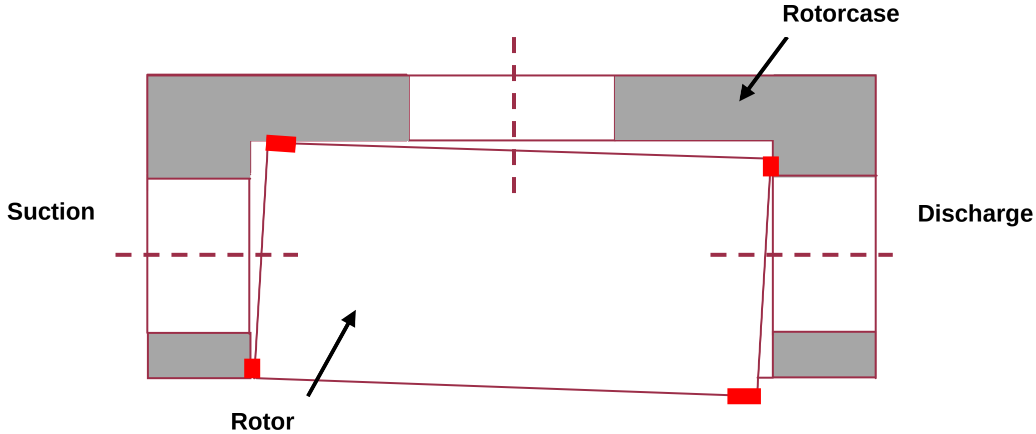
Mechanical causes of noise and vibration can include:

- Shaft misalignment
- Loose couplings
- Loose pump and/or driver mountings
- Loose pump and/or driver guards
- Worn or damaged pump driver
- Worn pump bearings
- Valve noise seemingly coming from the pump

Valves, especially on the discharge side of the pump can sometimes go into a hydraulic vibration mode caused by operating pressure, flow rate and the valve design. Resetting or a change in an internal valve component is usually sufficient to solve the problem.

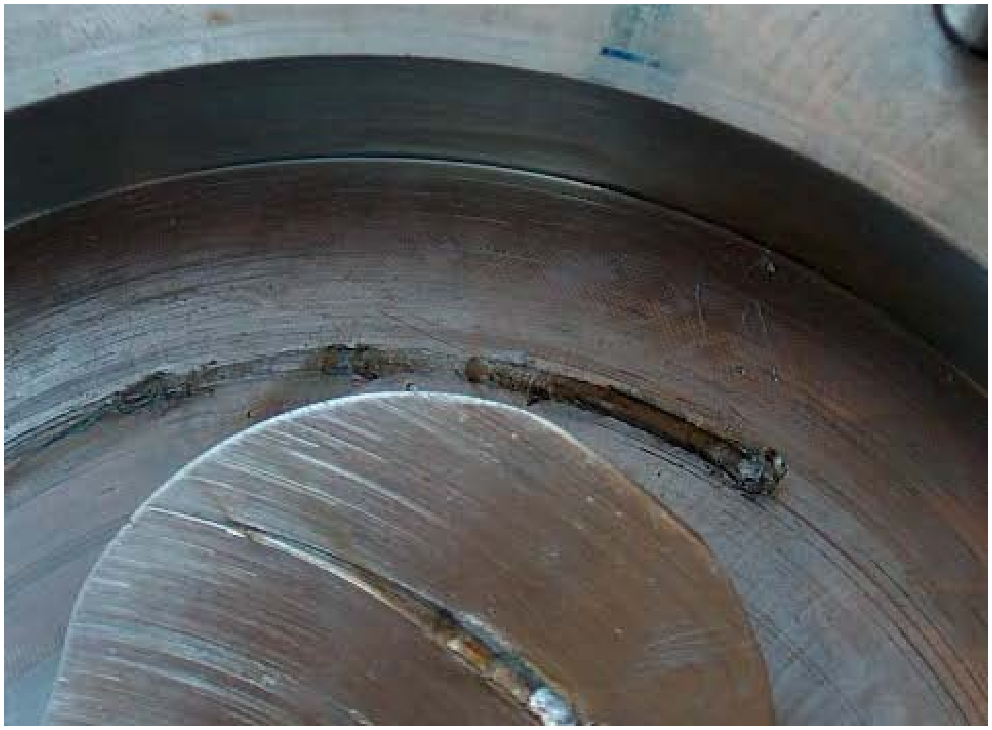
3.5 Pump Head Contact Summary

For successful pump operation, rotary lobe pumps should operate without any contact of pump head components. Should contact occur, consideration should be given as to the position the rotor has had to move with respect to the rotorcase, rotorcase cover and/or other rotor to create the mark pattern as shown below. Also noted should be the factors that could have induced this relative movement i.e. pressure, temperature, shaft movement, casing movement, etc.



<u>Contact Marks</u>	***<u>Possible Cause</u>***
Rotor and Rotorcase Cover (full face).	*High temperature and/or rapid temperature increase.* *Loss of axial shaft retention.* *Loss of rotor retention.* *Insufficient front clearance.*
Rotor and bottom of Rotorcase (full face).	*Rapid temperature decrease.* *Loss of axial shaft retention.* *Insufficient back clearance.*
Rotorcase cover (discharge side), Rotorcase (inlet side on back face and bore) and Rotor (tips tapering front to back and front and back face outer diameter).	*High pressure.*
Rotor (all lobes on same flank).	*Loss of timing.*
Rotor (all lobes on both flanks and some tips) and Rotorcase (corresponding with rotor tip marks)	*Cavitation.*
Rotorcase (bore and back face, more severe at outer diameter) and Rotor (tips and front and back face).	*Abrasive pumped media.*
Rotor (indentation in profile, in or near mesh).	*Large hard solid.*
Rotorcase (indentation in bore).	*Large or hard solid.*
All product wetted surfaces (deterioration of surface).	*Corrosion.*

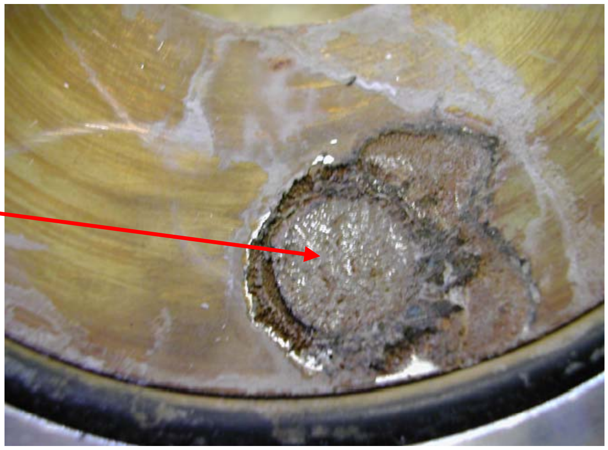
Examples of 'galling' caused by initial hard solid passing through pump



Example of corrosion on pump rotor.

Example of corrosion on pump rotorcase port.

Example of corrosion on pump rotorcase cover.



4.0 How correct System Design and Installation can avoid potential problems

To ensure optimum pump operation it is important that any pump unit is installed correctly. When designing a pumping system consideration should be given to the pipework, pump protection and operation. Other factors such as baseplate mounting, coupling alignment and pre-start up checks should also be noted.

4.1 Pipework

- Have short straight inlet pipework.
  - This will reduce friction losses in the pipework, thereby improving the NPSH available.

- Avoid bends, tees and any restrictions close to either suction or discharge side of pump. Use long radius bends wherever possible.
  - This will minimise pressure losses and/or turbulence in the pipework.

- Keep pipework horizontal where applicable.
  - This will reduce possibility of air locks.

- Confirm the Net Positive Suction Head (NPSH) available from the system exceeds the NPSH required by the pump (see 3.1.4).
  - This is crucial for ensuring the smooth operation of the pump and preventing cavitation.

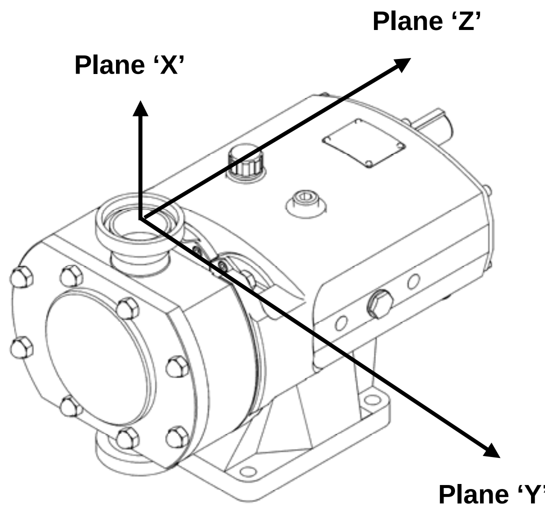
- Avoid suction lifts and manifold/common suction lines for two rotary lobe pumps running in parallel
  - This will prevent vibration or cavitation.

- Include eccentric reducers on suction lines.
  - This will minimise pressure losses and/or turbulence in the pipework.

- Avoid the use of blind tees.
  - This will avoid pressure pulsing and thereby noise and possible pump damage.

- Include for seal flushing pipework and/or media for heating/cooling jackets and saddles.
  - This will ensure satisfactory seal operation and/or maintain pumped media temperature in pumphead.

- All pipework must be supported.
  The pump must not be allowed to support any of the pipework weight and the moments and forces attributed to each particular pump should be taken into consideration.



Example of a poor pump installation, not adhering too many of the considerations advised

4.2 Protection

- Protect the pump against blockage from hard solid objects e.g. nuts, bolts, welding slag etc.
    - This will prevent possibility of pumphead seizure.

- Protect the pump from accidental operation against a closed valve by using relief valves, pressure switches or current limiting devices.
    - This will prevent over pressurisation.

- Ensure any automated valve systems do not permit directional switching valves to close or partially close.
    - This will avoid ‘dead heading’ the pump on discharge.

- Fit valves, if two pumps are to be used on manifold/common discharge lines.
    - This will prevent over pressurisation.

- Fit suction and discharge monitoring devices.
    - This will assist in any diagnostics.

- Include for monitoring equipment in ATEX defined hazardous areas if applicable.
    - This will ensure safety with monitoring of seal temperature, pressure and flow.

4.3 Operation

- Do not subject rotary lobe pumps to rapid temperature changes.
    - This will prevent thermal shock and possible pumphead seizure.

- Ensure pumped media is maintained at the correct temperature.
    - This will avoid dramatic increase in viscosity leading to possible over pressurisation and/or cavitation.

- Try to allow at least 1 m for pump access.
    - This will ease maintenance all round the pump.

- Ensure fluid flow velocity is sufficient.
    - This will avoid pumped media settling out, thereby restricting flow and increasing pressure.

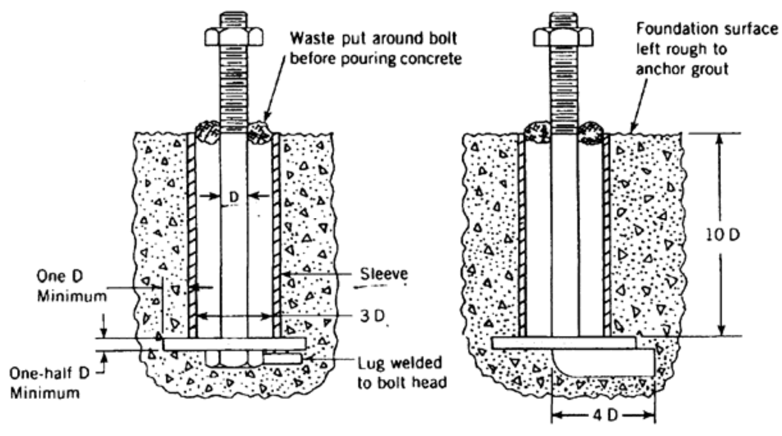
Example of a poor installation showing a short radius bend fitted directly on to the pump discharge connection.

Good engineering practice would dictate to position the bend at least 10 pipe diameters away from the pump discharge connection.

4.4 Baseplate Foundations

Pumps when supplied with a drive unit are normally mounted on a baseplate which have pre-drilled fixing holes to accept base retaining bolts. To provide a permanent rigid support for securing the pump unit, a foundation is required which will also absorb vibration, strain or shock on the pumping unit. Methods of anchoring the baseplate to the foundation are varied, they can be studs embedded in the concrete either at the pouring stage as shown below, or by use of epoxy type grouts. Alternatively mechanical fixings can be used.

The foundation should be approx. 150 mm longer and wider than the baseplate. The depth of the foundation should be proportional to the size of the complete pump unit. For example, a large pump unit foundation depth should be at least 20 times the diameter of the foundation bolts.



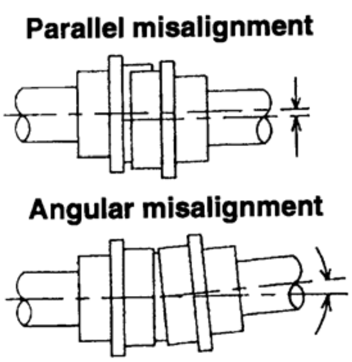
D = Diameter of foundation bolts

The drawing above shows two typical methods for foundation bolt retaining. The sleeve allows for ‘slight’ lateral movement of the bolts after the foundation is poured. Rag or waste paper can be used to prevent the concrete from entering the sleeve while the foundation is poured. A minimum of 14 days is normally required to allow the curing of the concrete prior to pump unit installation.

Example of poor installation where underside of base shows bolts only free standing on the floor.

4.5 Coupling Alignment

Before the pump unit is installed it is important to ensure that the mounting surface is flat to avoid distortion of the baseplate, which may cause pump/motor shaft misalignment and pump/motor unit damage.



Once the baseplate has been secured, the pump shaft to motor shaft coupling alignment should be checked and adjusted as necessary. This is achieved by checking the maximum angular and parallel allowable misalignments for the couplings as stated by the coupling manufacturer.

4.6 Pre-start up Checks

Before the pump unit is started it is important to ensure that pre-start up checks are made as follows:

- Check that the pipework system has been purged to remove welding slag and any other debris. For purging purposes a bypass should be installed around the pump. Dependent upon the cleaning/purging velocity this may need to be done more than once.
  Minimum recommended velocity 1.5 - 3.0 m/s.

- Check that all obstructions have been removed from the pipework and pump.

- Check that all the pump connections and pipework joints are tight.

- Check that pump and drive lubrication levels are correct.

- Check that seal flushing is connected if applicable.

- Check that all valves in the system are open.

- Check that all safety guards are in place.

- Check that pumped media is flowing in correct direction by starting and stopping pump.

5.0 Problem Solving Table

The table shown offers probable causes and solutions to the most common problems encountered:

Problem																	
No flow	Under capacity	Irregular discharge	Low discharge pressure	Pump will not prime	Prime lost after starting	Pump stalls when starting	Pump overheats	Motor overheats	Excessive power absorbed	Noise and vibration	Rotor wear	Syphoning	Seizure	Mechanical seal leakage	Packed gland leakage	**Probable Causes**	**Solutions**
✓																Incorrect direction of rotation.	Reverse motor.
✓																Pump not primed.	Expel gas from suction line and pumping chamber and introduce fluid.
✓	✓	✓	✓		✓					✓						Insufficient NPSH available.	Increase suction line diameter. Increase suction head. Simplify suction line configuration and reduce length. Reduce pump speed.
	✓	✓	✓		✓					✓						Fluid vaporising in suction line.	Increase suction line diameter. Increase suction head. Simplify suction line configuration and reduce length. Reduce pump speed.
✓	✓	✓		✓	✓					✓						Air entering suction line.	Remake pipework joints.
	✓	✓		✓	✓					✓						Strainer or filter blocked.	Service fittings.
	✓				✓	✓	✓	✓	✓					✓		Fluid viscosity above rated figure.	Increase fluid temperature. Decrease pump speed. Check seal face viscosity limitations.
	✓															Fluid viscosity below rated figure.	Decrease fluid temperature. Increase pump speed.
							✓			✓	✓		✓	✓		Fluid temperature above rated figure.	Cool the pumphead. Reduce fluid temperature. Check seal face and elastomer temperature limitations.
						✓		✓	✓							Fluid temperature below rated figure.	Heat the pumphead. Increase fluid temperature.
										✓	✓		✓	✓		Unexpected solids in fluid.	Clean the system. Fit strainer to suction line. If solids cannot be eliminated, consider fitting double mechanical seals.
✓	✓	✓			✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	Discharge pressure above rated figure.	Check for obstructions i.e. closed valve. Service system and change to prevent problem recurring. Simplify discharge line to decrease pressure.
							✓	✓	✓				✓			Gland over-tightened.	Slacken and re-adjust gland packing.
	✓	✓			✓					✓					✓	Gland under-tightened.	Adjust gland packing.
														✓	✓	Seal flushing inadequate.	Increase flush flow rate. Check that flush fluid flows freely into seal area.
	✓							✓	✓	✓						Pump speed above rated figure.	Decrease pump speed.
	✓															Pump speed below rated figure.	Increase pump speed.

Problem																Probable Causes	Solutions
No flow	Under capacity	Irregular discharge	Low discharge pressure	Pump will not prime	Prime lost after starting	Pump stalls when starting	Pump overheats	Motor overheats	Excessive power absorbed	Noise and vibration	Rotor wear	Syphoning	Seizure	Mechanical seal leakage	Packed gland leakage		
	✓						✓	✓	✓	✓	✓		✓			Pump casing strained by pipework.	Check alignment of pipes. Fit flexible pipes or expansion fittings. Support pipework.
										✓	✓		✓			Flexible coupling misaligned.	Check alignment and adjust mountings accordingly.
							✓	✓	✓	✓	✓		✓			Insecure pump driver mountings.	Fit lock washers to slack fasteners and re-tighten.
							✓	✓	✓	✓	✓		✓			Shaft bearing wear or failure.	Refer to pump supplier for advice and replacement parts.
							✓	✓	✓	✓			✓			Worn un-synchronised timing gears.	Refer to pump supplier for advice and replacement parts.
							✓	✓	✓	✓	✓		✓			Insufficient gearcase lubrication.	Refer to pump supplier's instructions.
✓	✓						✓	✓	✓	✓	✓		✓			Metal to metal contact of rotors.	Check rated and duty pressures. Refer to pump supplier.
	✓		✓													Worn rotors.	Fit new rotors.
	✓									✓						Rotorcase cover relief valve leakage.	Check pressure setting and re-adjust if necessry. Examine and clean seating surfaces. Replace worn parts.
	✓									✓						Rotorcase cover relief valve chatter.	Check for wear on sealing surfaces, guides etc - replace as necessary.
	✓															Rotorcase cover relief valve incorrectly set.	Re-adjust spring compression - valve should lift approx. 10% above duty pressure.
✓				✓												Suction lift too high.	Lower pump or raise liquid level.
														✓	✓	Pumped media not compatible with materials used.	Use optional materials.
												✓				No barrier in system to prevent flow passing back through pump.	Ensure discharge pipework higher than suction tank.
														✓	✓	Pump allowed to run dry.	Ensure system operation prevents this. Fit single flushed or double flushed mechanical seals. Fit flushed packed gland.
										✓						Faulty motor.	Check and replace motor bearings.
	✓															Too large pumphead clearances.	Fit new rotors and ensure clearances are as per recommendations.
✓																Rotors missing i.e. after service.	Fit rotors.

How to contact Alfa Laval

Contact details for all countries are continually updated on our website. Please visit www.alfalaval.com to access the information direct.