Problem Solving - Centrifugal Pumps

Inside View

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

Main sections are as follows:

1. Introduction
2. Centrifugal Pump Problems
3. Alfa Laval Solutions to Specific Centrifugal Pump Problems
4. How correct System Design and Installation can avoid potential problems
5. Problem Solving Table

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.

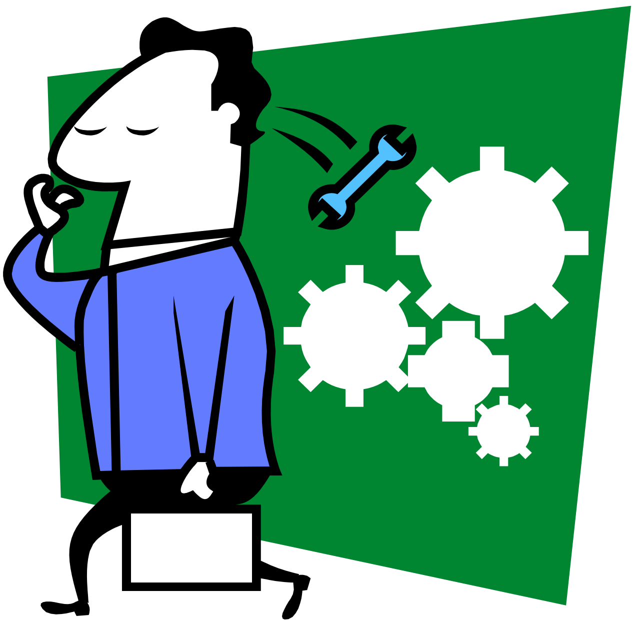
Upon investigation the likely causes of the problem are inadequate control of the pumped fluid or a change in operating requirements of which the system or pump is not capable of handling.

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 Centrifugal pumps are shown herein with particular effects on our range of Centrifugal pumps.

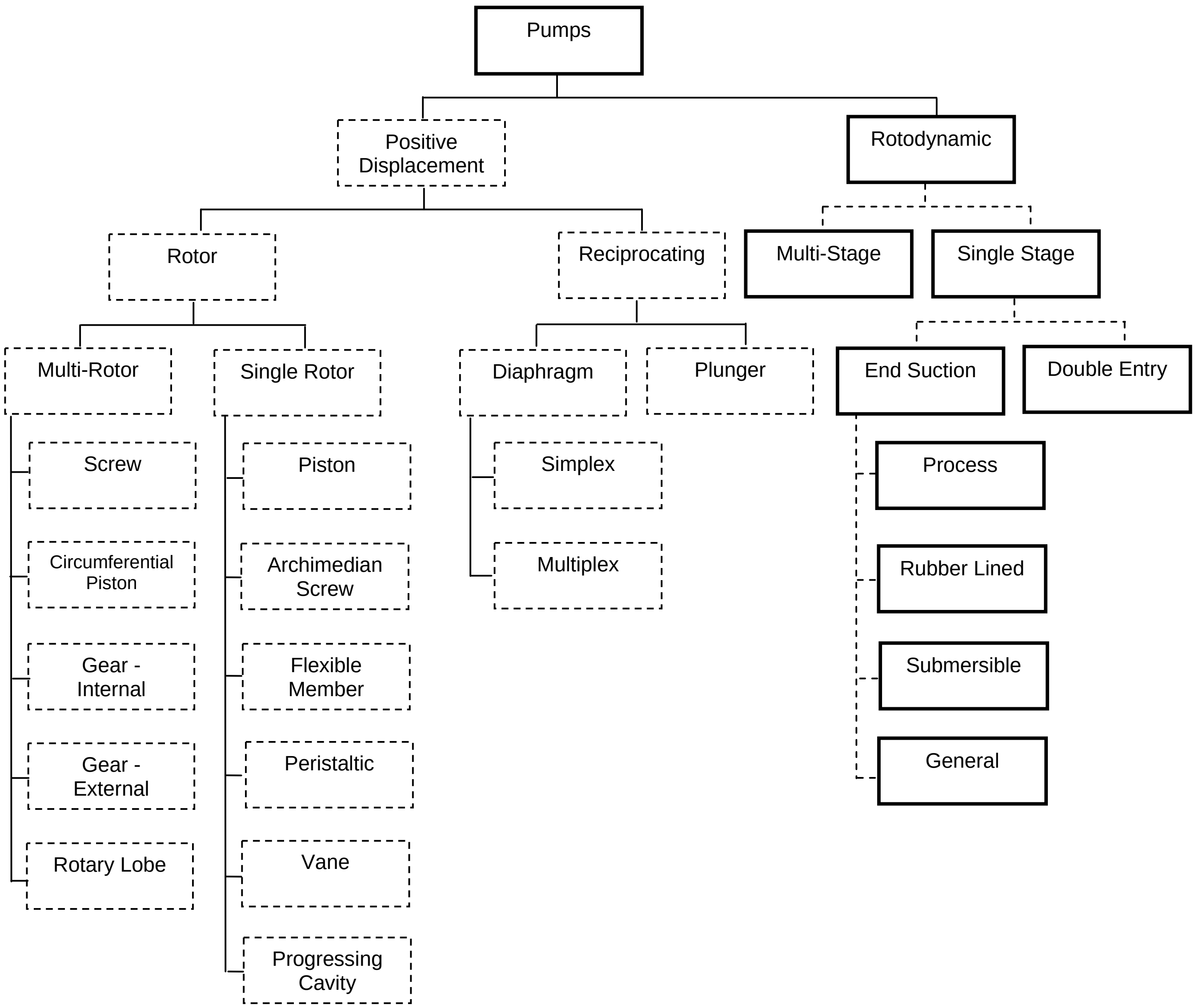


2.0 Centrifugal Pump Problems

Typical pump problems include:

- No or low flow
- No or low pressure
- Excessive power consumption
- Excessive noise or vibration
- Seal leakage

These are common for all Centrifugal pump types shown as follows:



Typical causes are as follows:

No or low flow

- Pump is not primed
- The motor 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)
- Air leak in the suction pipe
- No power to the pump
- Pump speed too low
- Pumped media viscosity is higher than expected
- Pressure is higher than calculated
- Flow switch faulty

No or low pressure

- Valves are closed or there is an obstruction in the suction or discharge pipework
- A strainer or filter is clogged on the inlet
- Flow is higher than calculated
- The motor is turning pump in the wrong direction
- Insufficient Net Positive Suction Head available (NPSHa)
- No power to the pump
- Pump speed too low
- Pumped media viscosity is higher than expected

Excessive power consumption

- Flow is higher than calculated with low outlet pressure
- Viscosity too high
- Mechanical contact in the pumphead

Excessive noise or vibration

- Pipework is not properly supported
- Pump is cavitating
- Impeller contact with casing/backplate
- Gas entrainment
- Loss of shaft support (bearing failure in motor)
- Pumped media contains unexpected abrasive particles
- Poor pipework / system design
- Dry running of seal

Seal leakage

- 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

2.1 No or low flow

2.1.1 Pump is not primed

Centrifugal pumps 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.

2.1.2 The motor is turning pump in the wrong direction

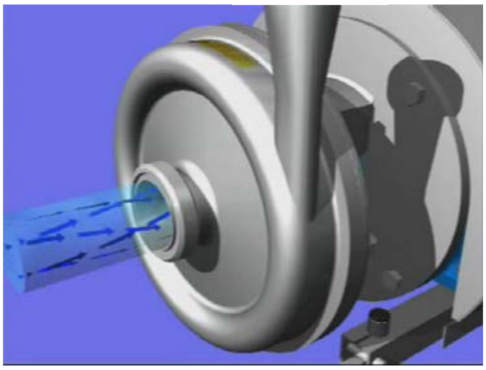
Centrifugal pumps should never be allowed to operate in the wrong direction of rotation. If the pump is not fitted with an impeller screw the impeller may unscrew from the shaft making contact with the casing, thereby causing seizure.

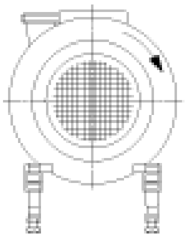
Impeller damage

To ensure correct direction of rotation the motor can be started and stopped momentarily to check the motor fan is rotating clockwise as viewed from the rear end of the motor.

Fluid Out

Fluid In





Correct rotation

View from rear end

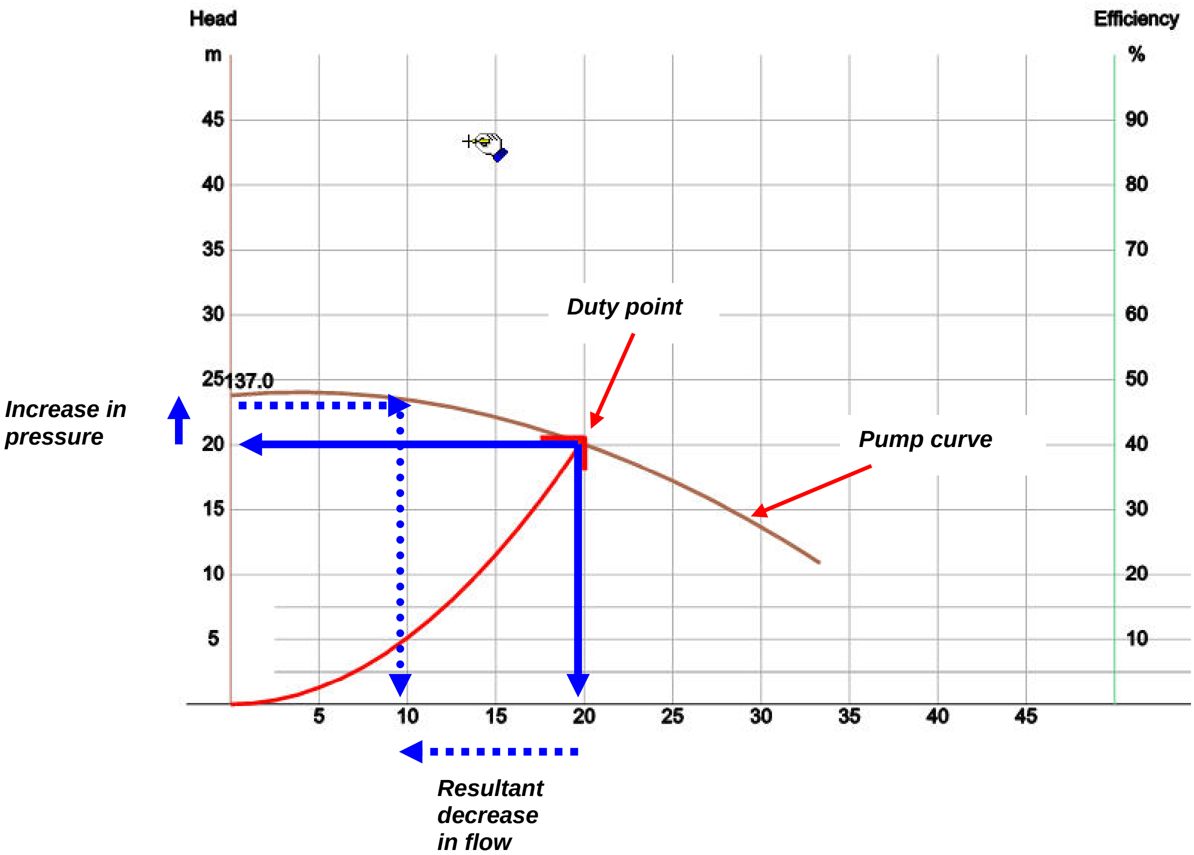
If an impeller screw is fitted, the pump is still capable of achieving low flow with the motor turning in wrong direction.

Impeller screw

If pump is operating in reverse rotation, use motor manufacturers instructions to ensure appropriate direction.

2.1.3 Valves are closed or there is an obstruction in the suction or discharge pipework

Any obstruction in the pipework and/or valves being closed can significantly increase pressure. An increase in pressure on the outlet will have the effect of a decrease in flow, highlighted in curve below:



The following symptons may occur:

- Low outlet pressure (see 2.2.1)
- Seal dry running (see 2.5.4)
- Increase in noise/vibration (see 2.4)
- Reduced NPSHa (see 2.1.6)

2.1.4 The end of the suction pipework is not submerged

In this situation no fluid will be allowed to enter the pump, cavitation may occur (see 2.1.6 below) and potential for dry running of seal (see 2.5.4).

2.1.5 A strainer or filter is clogged

If a strainer or filter is clogged in the suction pipework, this will have the effect of increasing pressure loss thereby decreasing flow as described in 2.1.6 below. If a strainer or filter is clogged in the discharge pipework, this will have the effect of increasing pressure loss thereby decreasing flow as described in 2.1.3 above.

2.1.6 Insufficient Net Positive Suction Head available (NPSHa)

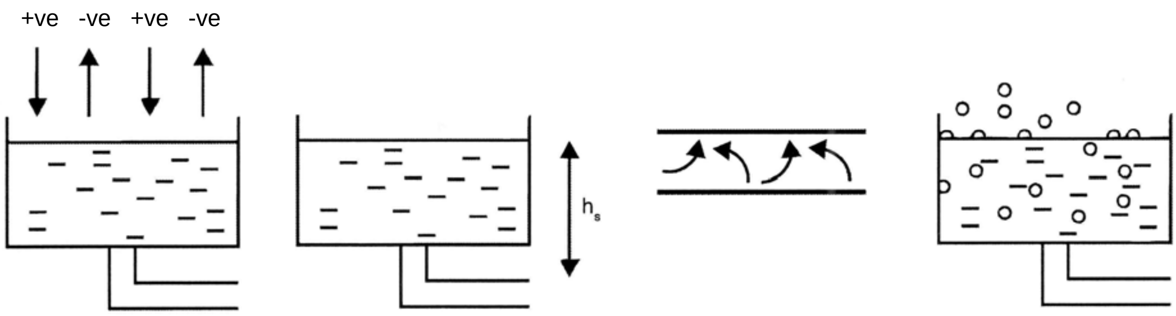
For satisfactory pump operation the condition at the inlet of a pump is critical. The system on the inlet side of the pump must allow a smooth flow of fluid to enter the pump at a sufficiently high pressure to avoid cavitation. This is called the **N**et **P**ositive **S**uction **H**ead, generally abbreviated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



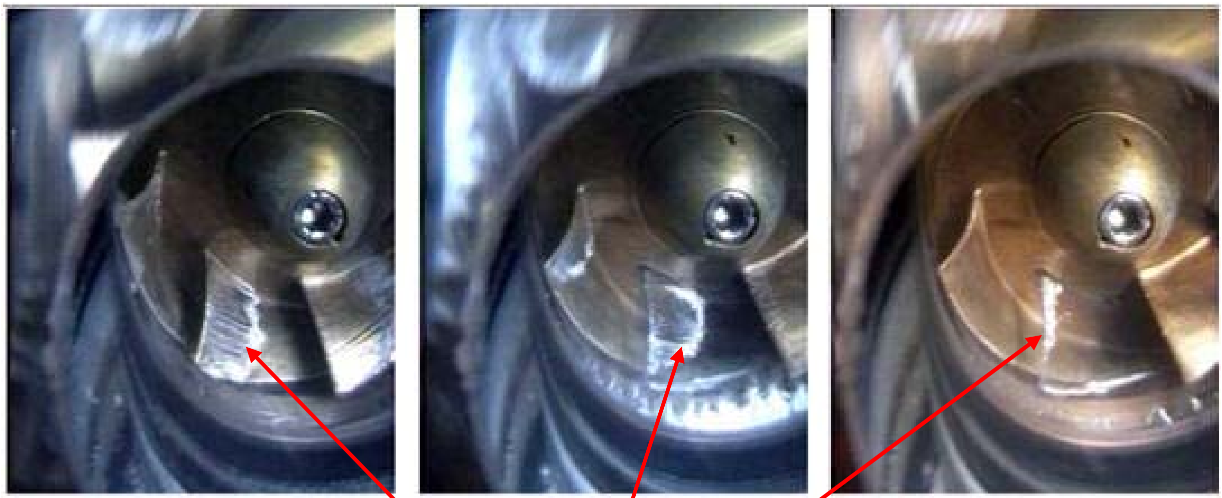
Where:

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)

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 of 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 which will damage pump components.

For many 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. Adversely if the product is too hot there is risk of product vaporisation.

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, seals and drive train. The surface of these components are typically perforated and pitted as material is eroded by implosive forces.



Vapour bubbles forming

Damage due to cavitation

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.
- Size the pump correctly ensuring NPSHa > NPSHr

2.1.7 Air leak in the suction pipe

Air in the suction pipework or entrained gas in the pumped media has the effect of reduced pump performance 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.

2.1.8 No power to the pump

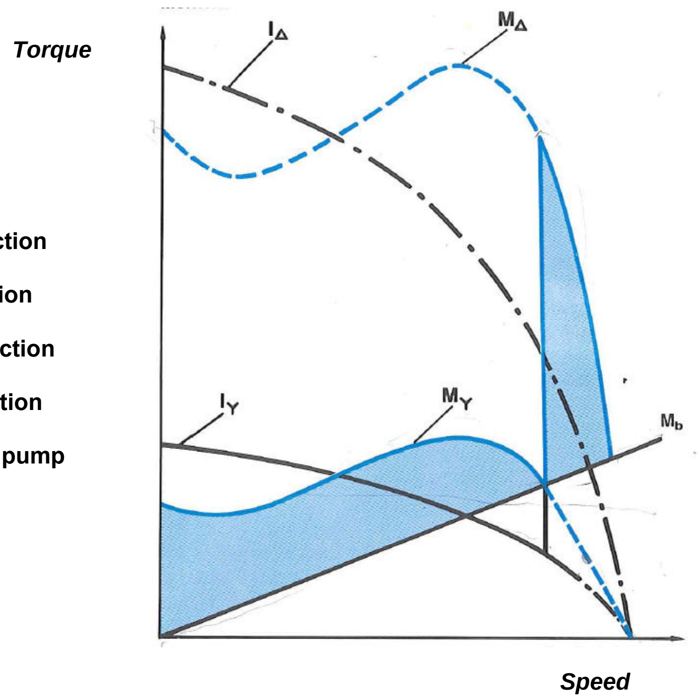
In this situation the cause is mainly due to incorrect wiring of the electric motor, check motor manufacturers instructions.

Other factors to be taken into consideration:

- Check switchgear
- Check starting current
- Check thermistor motor protection
- Check programming of the frequency inverter (if used) is correct.
- Check flow switch (if used) is operating correctly

2.1.9 Pump speed too low

If the pump is equipped with a star/delta starting method and it does not shift between the star and delta connection the pump will remain on low speed in the star connection.



I_Δ = Current in delta connection

I_Y = Current in star connection

M_Δ = Torque in delta connection

M_Y = Torque in star connection

M_b = Load from centrifugal pump

If the soft start is not correctly programmed the pump will not reach the design speed. The soft start provides a smooth start at the time, as the starting current is limited. The magnitude of the starting current is directly dependent on the static torque requirement during a start and on the mass load that is to be accelerated. In many cases the soft starter saves energy by automatically adapting the motor voltage continually to the actual requirement. This is particularly important when the motor runs with a light load.

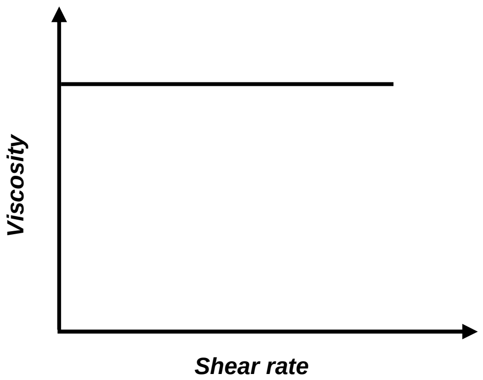
2.1.10 Pumped media viscosity is higher than expected

Centrifugal pumps typically handle low viscosity pumped media i.e. 800 cP max. Above this figure the power will exceed the maximum rating of the motors and the performance of the pump will be greatly affected.

Viscous drag will decrease the pump's efficiency resulting in a reduced performance and a higher power requirement which may exceed the maximum power rating of the motor.

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

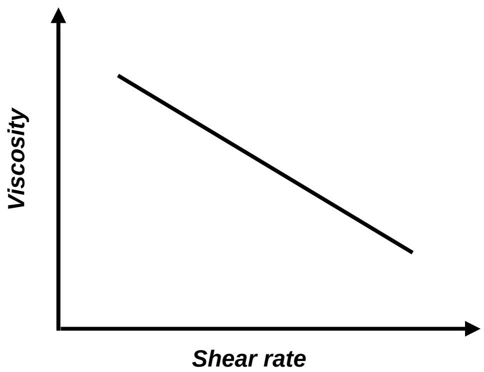


Typical Newtonian fluids are:

- *Water*
- *Beer*
- *Hydrocarbons*
- *Milk*
- *Mineral Oils*
- *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

In general terms, low viscosity Newtonian fluids are best handled with Centrifugal type pumps and Psuedoplastic fluids are best handled with Positive Displacement Rotary Lobe type pumps.

2.1.11 Pressure is higher than calculated

Any increase in viscosity will increase pressure losses in the system. This will affect the system curve resulting in less flow. To overcome this, the solution will be to increase pump speed. However care must be taken as this will increase NPSHr which may affect the NPSHa of the system as described in 2.1.6.

2.1.12 Flow switch faulty

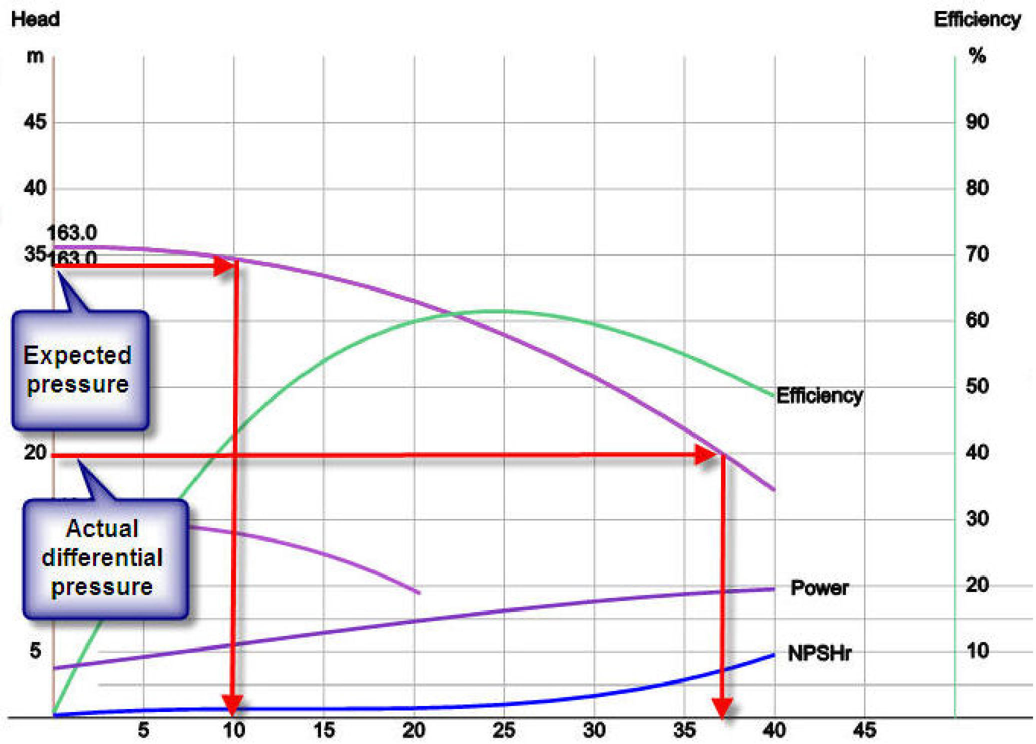
A faulty flow switch can result in no power getting to the pump, hence no pump operation.

2.2 No or low pressure

2.2.1 Valves are closed or there is an obstruction in the inlet pipework
See 2.1.3

2.2.2 A strainer or filter is clogged on the inlet
See 2.1.5

2.2.3 Flow is higher than calculated
If the delivered flow from the pump is higher than calculated it can be related to the system pressure being lower than expected.



2.2.4 The motor is turning in the wrong direction
See 2.1.2

2.2.5 Insufficient Net Positive Suction Head available (NPSHa)
See 2.1.6

2.2.6 No power to the pump
See 2.1.8

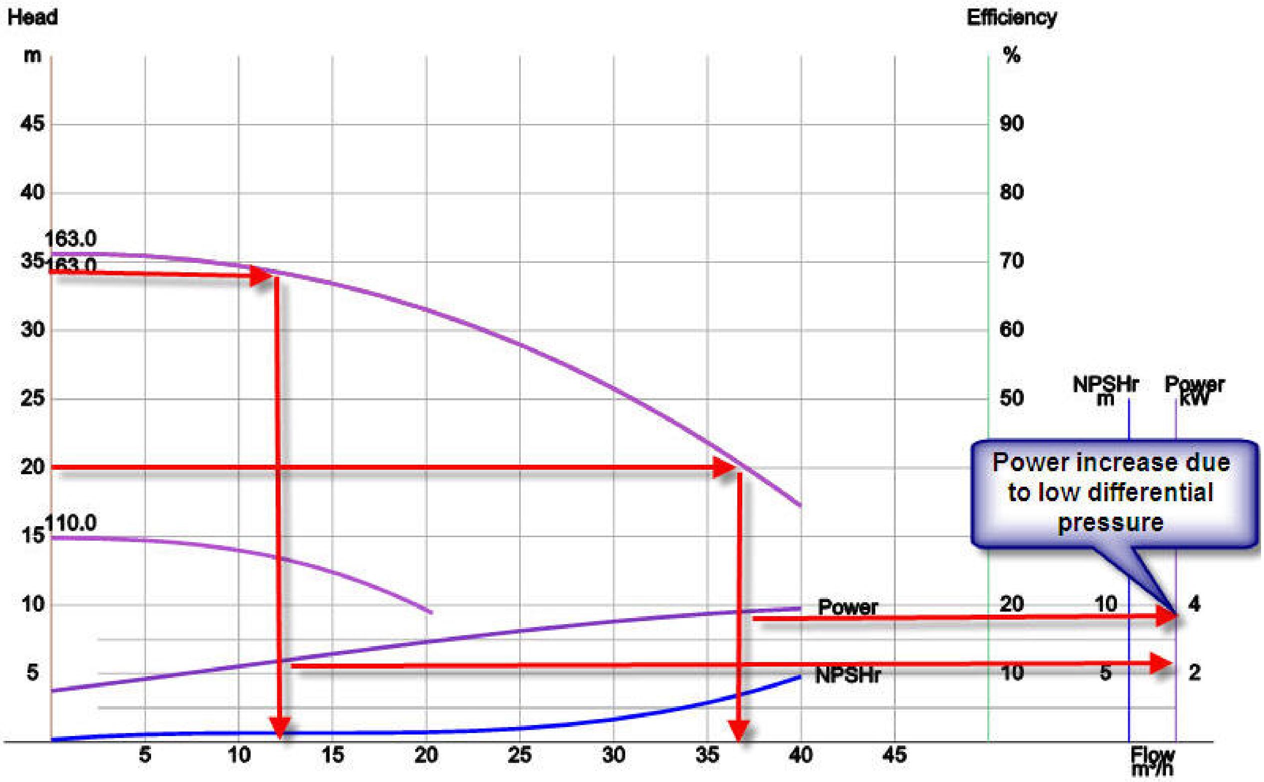
2.2.7 Pump speed too low
See 2.1.9

2.2.8 Pumped media viscosity is higher than expected
See 2.1.10

2.3 Excessive power consumption

2.3.1 Flow is higher than calculated with low outlet pressure

This will increase the flow rate, thereby increase in power consumption. Throttling the discharge pressure by the addition of an orifice or valve will increase the system pressure and thereby reduce the flow.



2.3.2 Viscosity too high

Any increase in fluid viscosity will increase the pressure losses and reduce pump efficiency, thereby increasing the power absorbed. Too much power can overload the motor protection.

2.3.3 Mechanical contact in the pumphead

See 2.4.3.

2.4 Excessive noise and vibration

2.4.1 Pipe work is not properly supported

The pump must not be allowed to support any of the pipework weight and correct installation guidelines should be followed.

2.4.2 Pump is cavitating

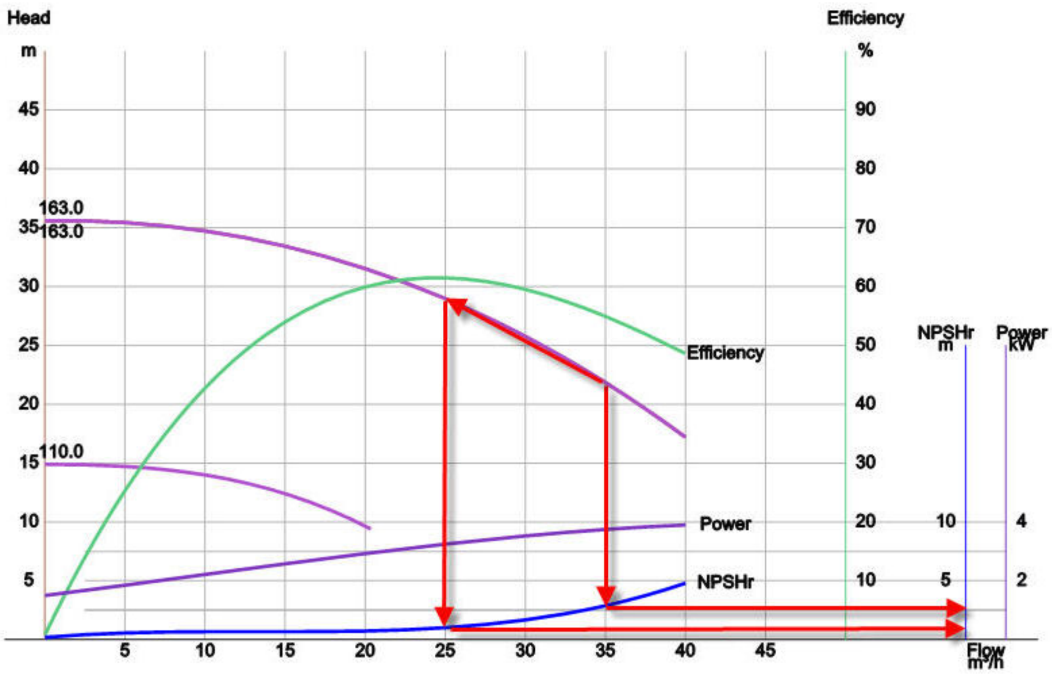
See 2.1.6

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

Damage due to cavitation

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.
- Size the pump correctly ensuring NPSHa > NPSHr



2.4.3 Impeller contact with casing/backplate

Contact is mainly attributed to:

- Incorrect clearance between impeller and backplate
- Worn bearings on motor
- Excessive high inlet pressure
- Foreign object
- Pressure shock
- Incorrect rotation

Incorrect clearance between impeller and backplate

It is important the correct distance is set between the impeller and the backplate (refer to Instruction Manual).

Initial contact between front of impeller and pump casing

Here the impeller position was adjusted so as not to rub on the pump casing but instead began to rub on the backplate

Damage to backplate and back of impeller due to constant rubbing. Initial contact may have damaged the motor bearings so clearances cannot be reset correctly as the shaft and impeller are floating.

Worn bearings on motor
See 2.4.5

Excessive high inlet pressure
???????

Foreign object
Fitting a strainer in the suction pipework prior to pump inlet will eliminate and foreign objects being allowed to enter the pump.

Pressure shock
???????

Incorrect rotation
See 2.1.2

2.4.4 Gas entrainment

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.

2.4.5 Loss of shaft support (bearing failure in motor)

Bearing failure can occur for a number of reasons such as:

- Excessive high inlet pressure
- Temperature exceeding pump design limits
- Cavitation
- Coupling/Shaft mis-alignment
- Inadequate lubrication
- Excessive pressure surges

Examples of motor bearing failure

2.4.6 Pumped media contains unexpected abrasive particles

If any hard solid particle is allowed to enter the pump it is likely to cause damage to pumphead components. Use of a strainer or filter prior to pump suction will avoid this problem.

Scoring marks due to ingress of hard foreign object

2.4.7 Poor pipe work / system design

See 4.0

It is important that installation guidelines are followed.

2.4.8 Dry running of seal

See 2.5.4

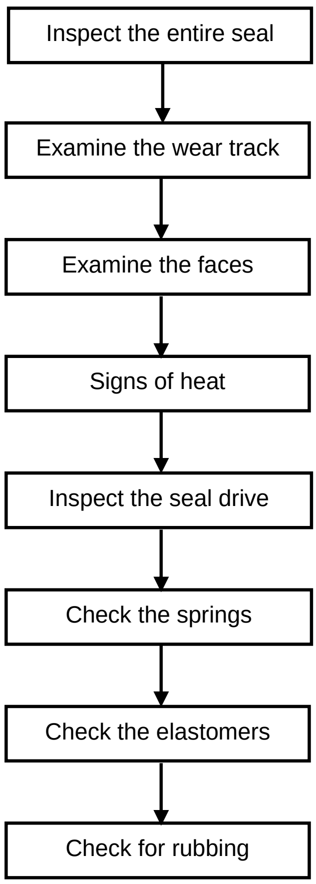
2.5 Seal Leakage

Mechanical seals are precision designed and manufactured, yet one of the most common causes of failure in Centrifugal pump types. 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. seal faces and/or elastomers.
- 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.

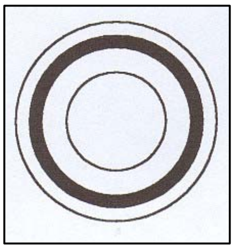
For solving any seal leakage problem it is advisable to adopt a systematic approach as follows:



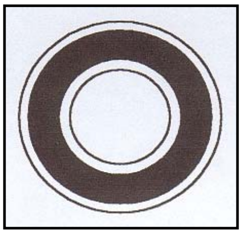
2.5.1 Inspect the entire seal

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.

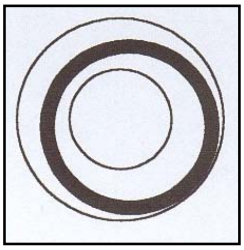
2.5.2 Examine the wear track



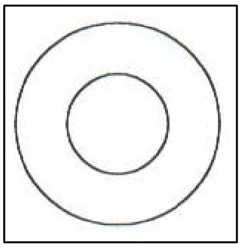
<u>Normal wear pattern</u>
Cause:
If leakage is present it is probably due to problems with elastomeric secondary seals.
Solution:
Replace both primary seal faces and secondary seals.



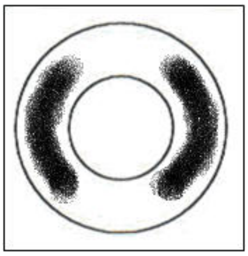
<u>Wide wear pattern</u>
Cause:
This indicates that the pump shaft is running eccentrically due to being bent from misalignment, bearing failure, shaft deflection or severe pipe strain.
Solution:
Replace shaft, seal and motor bearings if applicable. Check shaft is correctly aligned, and check system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



<u>Off centre wear pattern</u>
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 and check shaft alignment.

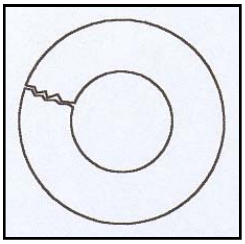


<u>Non contact pattern</u>
Cause:
This indicates that the rotary face is not mating with the stationary face. This can be due to incorrect installation, slipping of the drive mechanism or loss of anti-rotation devices.
Solution:
Install seals correctly by referring to the seal manufacturers fitting instructions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

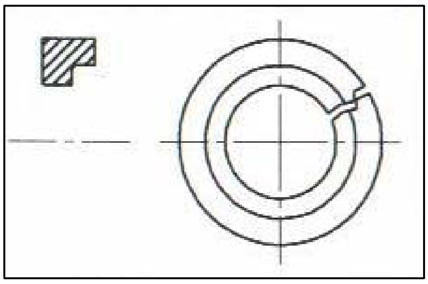


Partial wear pattern
Cause:
This indicates that the rotary face is not fully mating with the stationary face. This can be due to incorrect installation, excessive tightening of the stationary face or thermal expansion in the pipework.
Solution:
Install seals correctly by referring to the seal manufacturers fitting instructions and prevent thermal expansion entering the pump.

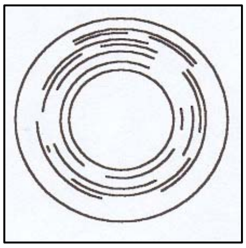
2.5.3 Examine the faces



Cracked silicon carbide face
Cause:
Over tightening or mishandling.
Solution:
Replace seals and install correctly by referring to the seal manufacturers fitting instructions and handle with care.



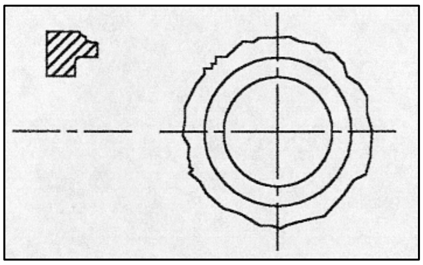
Cracked carbon
Cause:
This is usually caused by over compression, vibration or the swelling of an elastomer on the inside diameter, putting the carbon in tension. Problem could also be mishandling.
Solution:
Replace seals and install correctly by referring to the seal manufacturers fitting instructions and handle with care.
Check elastomers are compatible with the pumped media from seal manufacturer's recommendations.



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.

Example of excessive wear due to abrasive application i.e. UHT chocolate milk.

Solution would be to use a double flushed mechanical seal



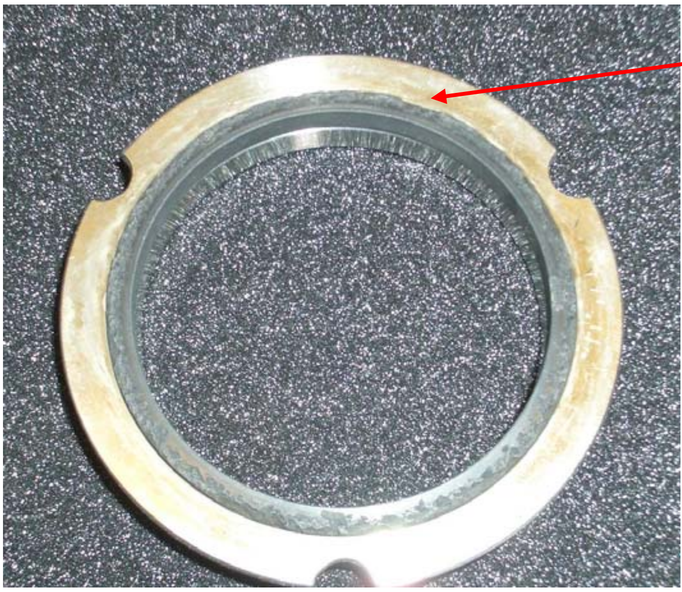
<u>Chipping on outside diameter</u>

Cause:

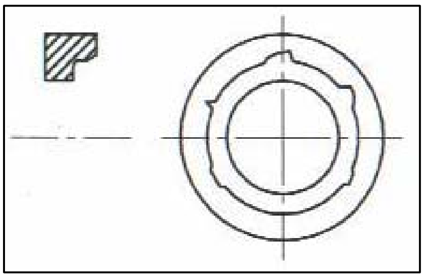
This is evident in soft seal face material (carbon) due to the solidification of pumped media on the face outside diameter causing breakage upon start up. Severe cavitation could also cause this problem.

Solution:

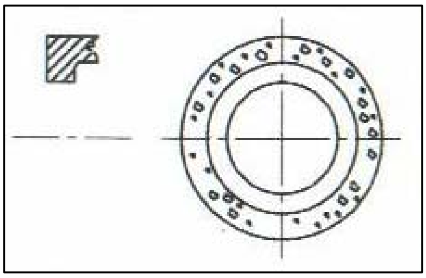
Replace seals and provide a flush to the seal area and/or eliminate any pump cavitation problems (see 2.1.6).



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>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.

Example of pitting corrosion on stainless steel

Example of crevice corrosion on a stainless steel face

Example of electro-chemical corrosion on WFI application (LKH UltraPure pump) using incorrect seal face material

Solution would be to ensure use of designated high grade silicon carbide seal faces for LKH Ultrapure pumps

Example of seal faces being subject to chemical attack

<u>Product solidification/burning</u>

Cause:

Product solidification/burning on the seal faces can cause wear on start-up reducing seal life.

Solution:

Fitting a flushed mechanical seal arrangement can alleviate this problem.

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

Example of seal failure from milk application whereby at temperatures >45°C the lactose and protein of the milk will burn on the seal faces due to insufficient cooling and lubrication – hence damage on faces.

2.5.4 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 diameter

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

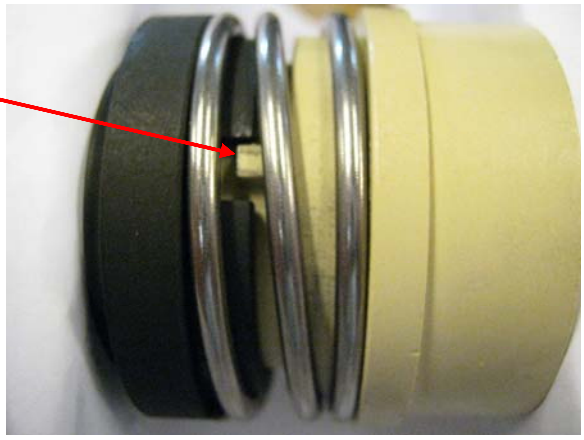
Burnt 'o' ring residues on the outer diameter

Further example of mechanical seal faces being allowed to run dry

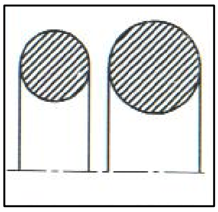
2.5.5 Inspect the seal drive

Mechanical seal designs all use some method to transmit torque from the shaft to the rotary seal face. For the mechanical seals used on the LKH and SolidC centrifugal pumps this takes the form of a drive pin on the rotating part correctly engaging in the slot of the stationary part.

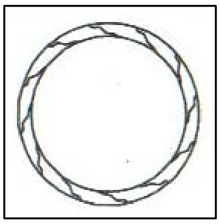
Drive pin



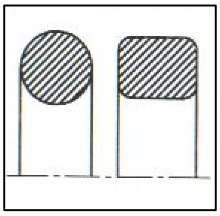
2.5.6 Check the elastomer



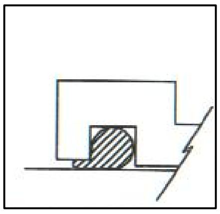
<u>**Swollen, sticky or disintegrating**</u>
Cause:
This is generally caused by chemical incompatibility with pumped media.
Solution:
Replace with different elastomer material that is compatible from seal manufacturer's recommendations.



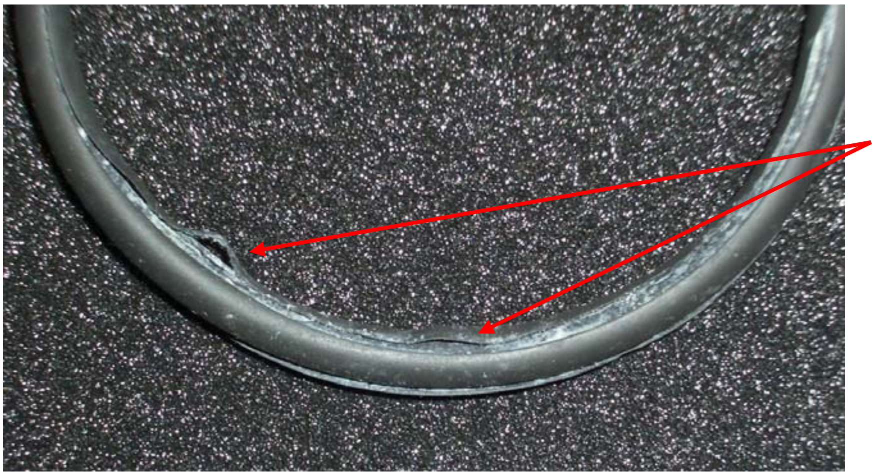
<u>Hard or cracked</u>
Cause:
This is generally caused by excessive heat and/or chemical attack. Usually the source of heat is the face or a metal to metal contact of two parts. Excessive face heat is caused by lack of lubrication and subsequent high friction. It could also be a sign that the pump has 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.



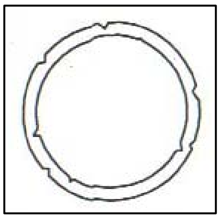
<u>Compression set</u>
Cause:
This is caused where the 'O' ring has been unable to withstand the temperature of the pumped media - the 'O' ring loses its roundness and becomes square in section. This may also occur if too much heat is generated at the seal faces.
Solution:
Reduce pumped media temperature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



<u>Extruded</u>
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



<u>Cuts or nicks</u>
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.

2.5.7 External Symptoms of Seal Failure

<u>Symptoms</u>	***<u>Possible Causes</u>***
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.*
Pump/Shaft Vibration	*Shaft misalignment.* *Cavitation.* *Bearing failure.* *Dry running*

3.0 Alfa Laval Solutions for Specific Centrifugal Pump Problems

Specific pump problems include:

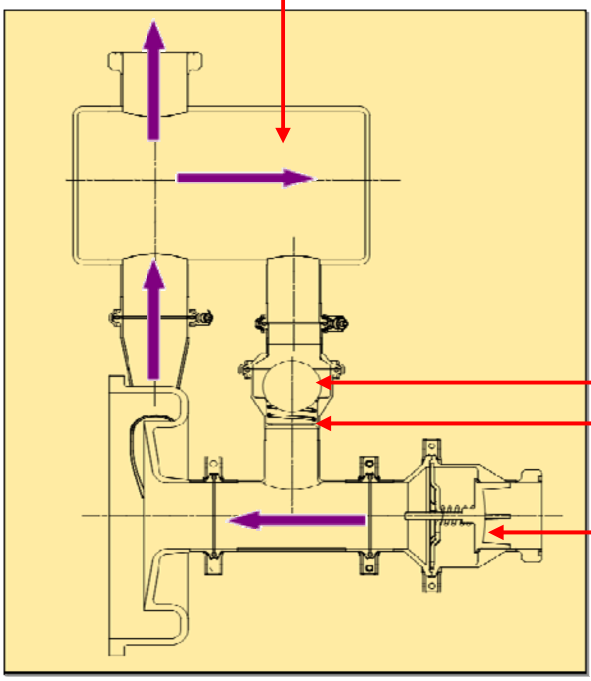
- Ability to self-prime
- Ability to handle high inlet pressures
- Rouging

3.1 Ability to self-prime

The Alfa Laval LKHSP self-priming centrifugal pump is specifically designed for pumping liquids containing air or gas without losing its pumping ability.

The LKHSP self-priming pump can be used for emptying tanks, as CIP return pump and similar applications where there is a risk of air or gas mixing with the liquid in the suction line.

LKHSP Self-Priming Pump



During operation the water in the pump re-circulates within the confines of the system with the ball valve open. The recirculation creates negative pressure which opens the non-return valve letting in fluid and air. As the pump is now delivering fluid, the pressure increases and closes the ball valve. The pump subsequently functions as a standard centrifugal pump.

For satisfactory operation the static head on discharge line should be less than 8 metres. If the static head is higher than this figure, the spring in the ball valve between the tank and the inlet of the pump cannot open which will result in the pump being unable to prime.

3.2 Ability to handle high inlet pressures

The Alfa Laval LKHP, LKHI and Multi-Stage centrifugal pumps have motors fitted with special bearings to handle high inlet pressures. It is important to ensure the motors lubrication is regularly maintained to avoid total bearing/pump failure.

LKHP Pump for inlet pressures up to 40 bar

LKHI Pump for 16 bar inlet pressure

LKH Multi-Stage Pump

3.3 Rouging

Rouging refers to a form of corrosion found in stainless steel. Rouging is a thin film, usually reddish-brown or golden in color, of iron oxide or hydroxide, typically on found on stainless steels. The contrast between this film and shiny metal accentuates this aesthetics problem. The rouge film typically wipes off easily with a light cloth, but it reforms while the process fluid is in contact with the stainless steel. This problem is most chronic in the pharmaceutical industry on the interior surfaces of high purity water (i.e. water for injection, WFI) distillation units, storage tanks, distribution systems (piping, valves, pump housings, fittings, etc.) and process vessels.

As stated, rouge is ferric oxide (i.e. rust), but the film may contain not only iron but also chromium and nickel compounds in various forms, and hence the film may vary in colour and tenacity. Rouging is experienced more on type 304/304L stainless steel than on type 316/316L, and less on electropolished surfaces than mechanically polished surfaces. Particles of rust can become dislodged and be dispersed throughout a piping distribution system, often collecting on in-line filters.

Stainless steel is ‘stainless’ owing to the fact that the alloy forms a thin, protective, tenacious, transparent oxide film that protects it against destructive corrosive elements in aqueous solutions. This film is composed of chromium oxide, and is said to make the steel ‘passive’ against corrosion. Exposure to moist air will provide this passivation within a matter of minutes, and the film will thicken with time.

The passive layer on the surface of stainless steels can breakdown by the interaction of ultra pure water, which is devoid of ionic elements, leading to rouging. The ionic pull of the water is strong enough to strip the protective chromium oxide off the steel surface. This results in the stainless steel having to re-passivate by reforming another layer of chromium oxide film, which incorporates the rouge causing discoloration. During the brief time it takes to re-passivate, a thin layer of the stainless steel dissolves, or corrodes. The major elements composing stainless steel are iron, chromium and nickel. The chromium and nickel ions are soluble and go into the bulk solution. The iron, however, precipitates above a pH of 3 as iron hydroxide that readily oxidizes to ferric oxide, which is red in colour (i.e. rouge). If this progresses uniformly across the surface of the steel, and the de-passivation / re-passivation process is cycled many times, then the surface of the stainless steel takes on a light golden to dark brown appearance depending on the ionic state of the various oxide layers and their depth.

Discoloration effect of rouging

In high purity water systems the rouge may be of three types:

- Class I Rouge originating from external sources, usually by erosion or cavitation of pump surfaces.
- Class II Rouge originating from chloride induced corrosion of the stainless steel surfaces.
- Class III Rouge, either blue or black, found in high temperature steam systems.

Rouging can take place in pure water, ultra-pure water, steam, treated potable water or untreated process water.

The Alfa Laval LKH UltraPure centrifugal pump has the option of having the product wetted components manufactured from stainless steel with <1% delta ferrite level to alleviate this problem.

LKH UltraPure Pump

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.

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 2.1.6).
  - This is crucial for ensuring the smooth operation of the pump and preventing cavitation.
- Avoid suction lifts and manifold/common suction lines for two centrifugal 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 where applicable.
  - This will ensure satisfactory seal operation.
- All pipework must be supported. The pump must not be allowed to support any of the pipework weight.

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 closed inlet and outlet valves.
  - This will prevent catastrophic pumphead seizure.

4.3 Operation

- 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 0.5 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.

4.4 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 seal flushing is connected if applicable.

- Check that all valves in the system are open.

- Check that the motor rotation is correct.

5.0 Problem Solving Table

The table shown below 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	Pump element wear	Seizure	Mechanical seal 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. Decrease fluid temperature - check effect of increased viscosity?
	✓	✓	✓		✓					✓				Fluid vaporising in suction line	Increase suction line diameter. Increase suction head or pressure on fluid surface, Simplify suction line configuration and reduce length. Decrease fluid temperature - check effect of increased viscosity?
✓	✓	✓		✓	✓					✓				Air entering suction line	Remake pipework joints
	✓	✓		✓	✓					✓				Strainer or filter blocked	Service fittings
	✓				✓	✓	✓	✓	✓				✓	Fluid viscosity above rated figure	Increase fluid temperature. Increase motor speed. Check seal face viscosity limitations.
	✓													Fluid viscosity below rated figure	Decrease fluid temperature
							✓			✓	✓	✓	✓	Fluid temperature above rated figure	Cool the pump casing. Reduce fluid temperature . Check seal face and elastomer temperature limitations.
						✓		✓	✓					Fluid temperature below rated figure	Heat the pump casing. 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.
													✓	Seal flushing inadequate	Increase flush flow rate. Check that flush fluid flows freely into seal area.
	✓						✓	✓	✓	✓	✓	✓		Pump casing strained by pipework	Check alignment of pipes. Fit flexible pipes or expansion fittings. Support pipework.
✓	✓						✓	✓	✓	✓	✓	✓		Metal to metal contact of pumping element	Check rated and duty pressures. Refer to pump maker.
	✓		✓											Worn pumping element	Fit new components
✓				✓										Suction lift too high	Lower pump or raise liquid level
													✓	Fluid pumped not compatible with materials used	Use optional materials
													✓	Pump allowed to run dry	Ensure system operation prevents this. Fit single or double flushed mechanical seals.
										✓				Faulty motor	Check and replace motor bearings
	✓													Too large clearance between impeller and back plate/casing	Reduce clearance between impeller and back plate/casing
	✓													Too small impeller diameter	Fit larger size impeller - check motor size
✓														Pumping element missing i.e. after service	Fit pumping element

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