

## **Centrifugal Slurry Pump Design for Safety**

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*Slurry Pumps, Failure, OH&S, Risk*

### **INTRODUCTION**

Centrifugal slurry pumps are widely used to transport mineral slurries. Under certain operating conditions it is possible for the flow through the slurry pipeline to reduce to low or zero flowrates. Slurry particles will therefore settle out and in the worst case it is possible that they block the slurry pump intake and discharge branches. If the slurry pump continues to operate in this condition, the energy input to the water inside the pump causes the water to heat and generate steam. The pressure build-up from the steam can lead to a potentially dangerous situation and may result in the pump exploding.

The causes of blocked pipelines are reviewed to assist with the understanding of the hazards involved. Some laboratory pump test results together with field experience will be discussed in relation to what can be changed to reduce the risk and to assist in overcoming the hazards.

### **HAZARDS of BLOCKED PIPELINES**

Slurry is defined as any mixture of solid particles and a fluid (normally water). Slurry properties and particle sizes vary greatly from low to high concentration and from silt to gravel sizing. Slurry is typically mixed before entering the centrifugal slurry pump but as it travels along a pipeline, the velocity gradient in the pipe and/or the slope of the pipeline can change causing density gradients within the pipeline. As the solids start to settle, the particles are slowed on the bottom of the pipeline causing stationary or moving dunes or even plugs to form. The plugs in the pipeline can partially or totally block the pipeline causing the flow through the pipeline to decrease to very low flows and in the worst case to reduce to zero.

Shou [1] details the various conditions that plugs may form in a slurry pipeline and concludes that while it is possible to design the slurry system to minimise the occurrence of blockages, the risk of blockage cannot be entirely eliminated. Some of the common causes are:

- Operation of the pipeline at sub critical velocity or with high solids concentration above design ie at a velocity less than the settling velocity of the particle sizes in the slurry.
- Large debris eg large pieces of elastomer such as conveyor belting or tramp metal.
- Pipeline starting and stopping.
- Pipe liner collapse.
- Reducing pump speed below a level that causes particles to settle out in the pipeline.
- Inadvertent closing of both the intake and discharge valves on the pump blocking all flow.

Shou [1] provides design considerations to prevent blockage. When blockages occur, there is the immediate hazard that the centrifugal slurry pump(s) will be operating at very low or zero flow.

## **HAZARDS for CENTRIFUGAL SLURRY PUMPS at LOW FLOW**

Slurry pumps are traditionally manufactured from castings and are lined with hard metals (with low fracture toughness) or elastomer. Lined pumps have an outer ductile casing which supports the internal pump pressure loads as well as the piping loads. The outer casing is normally bolted together along a vertical joint line. The lined pump is therefore superior in withstanding pressure loads as its strength is not diminished by wear from the slurry particles or dependent upon the liner material as the casing does not require a wear or corrosion thickness allowance.

Complete information on pump explosions is difficult to find. O'Connor [2] provides some case histories. However, the effects apart from the obvious damage to property and loss of production, is that explosions can lead to personnel injury and potentially death. This is the result of a large percentage of the driver power going to heat the fluid inside the pump which turns to steam once the temperature reaches 100 C. The pressure can then rapidly rise, leading to either failure of the casing bolts and/or the pump casing. The sudden release of energy during bolt or casing failure can result in projectiles that can be thrown reportedly up to 100m. In other cases, the loads are sufficient to wrench the pump and/or drive from their foundations. The release of supersaturated steam and slurry can cause serious injuries.

To determine the temperature and pressure rise in a pump with zero flowrate, tests were conducted on an 8/6 pump with intake and discharge flanges blanked and the pump half filled with water (at atmospheric pressure) and then run at 900 r/min. Figure 1 shows that the final temperature reached was approximately 200 C at which time the pressure was 2,100 kPa. The time was approximately 45 minutes in total and for the first 25 minutes the temperature was below 100C. This time is typical and correlates well with other test work in [2].

Actual calculations of pressure rise need to take into account the liquid properties of specific heat and change of vapour pressure with temperature. Processes that use high temperature such as Alumina slurries at 100 C would reach critical temperature and pressure much faster than water slurry at room temperature. Normally the larger the volume of fluid in the pump, the slower the temperature rise.

Experience has shown that the loss of pressure at the pump seal or at liner or flange joints is normally far less than the rapid pressure rise once the water turns to steam.

The major types of measurement which can be utilised to monitor and / or control temperature rise and pressure are listed in Table 1. From the possible detection means, monitoring the temperature rise provides one of the most reliable for reducing the risk of pump explosion.

## **THE MINIMISATION of HAZARDS for SLURRY PUMPS**

To ascertain the risk of any pump exploding, it is necessary to review all the hazards associated with the application, system, pipeline, system controls and type of pump construction. Assigning numerical values to the quantities in the following equation, it is possible to calculate a relative risk rating for any pump.

$$\text{Risk Rating} = \text{Consequence} \times \text{Frequency} \times \text{Probability} \quad (1)$$

Design developments has been recently undertaken on two risk minimisation devices that can be used either independently or combined.

## THERMAL CUT-OUT DEVICE

A thermal cut-out device is mounted through the pumps outer casing to measure the temperature on the outside of the metal liner. The device can be set to cut-off the electric current to the motor at a safe temperature before the pressure rises to a critical level.

## PRESSURE RELIEF

A range of metal lined slurry pumps have been fitted with a failure ring mounted at the back of the shaft seal chamber designed to relieve an over-pressurisation condition. The pressure acting over the large area of the seal chamber causes a high-force on the shear lugs on the failure ring. The ring is designed to fail in shear at a pressure of approximately 1.2 times higher than the pumps maximum allowable working pressure (MAWP). As a pumps test pressure is normally 1.5 times the MAWP, the failure occurs at a safe pressure.

The ring fails allowing the O-ring seal between the end of the seal chamber and the back liner in the pump to fail, thereby allowing fluid, steam and slurry to escape out the back of the pump. The escaping fluid and steam is contained within the pump by guarding and discharged downwards to the ground between the pump casing and the base.

The failure ring should eliminate the risk of explosion if the thermal cut-out device is not fitted or does not function as intended, and all other signs or means are not activated ie the failure ring is designed as a passive safety device. Figure 2 shows the sequence of events as the pressure relief ring fails and the pressure is relieved. The failure ring must be replaced before the pump can be put back into service.

## CONCLUSION

Advances in the application and range of thermal cut-out and pressure relief (passive safety) devices will assist to reduce the potential risks of centrifugal pump explosion. These devices are simple and applicable to a wide range of applications. Further development is being undertaken to make these devices applicable to rubber-lined pumps.

Fig 1. 8/6 Temperature and Pressure Rise

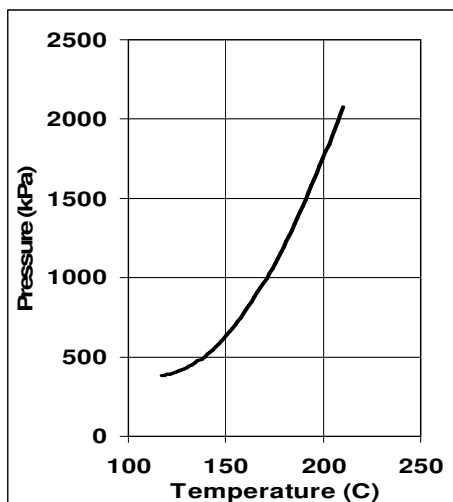
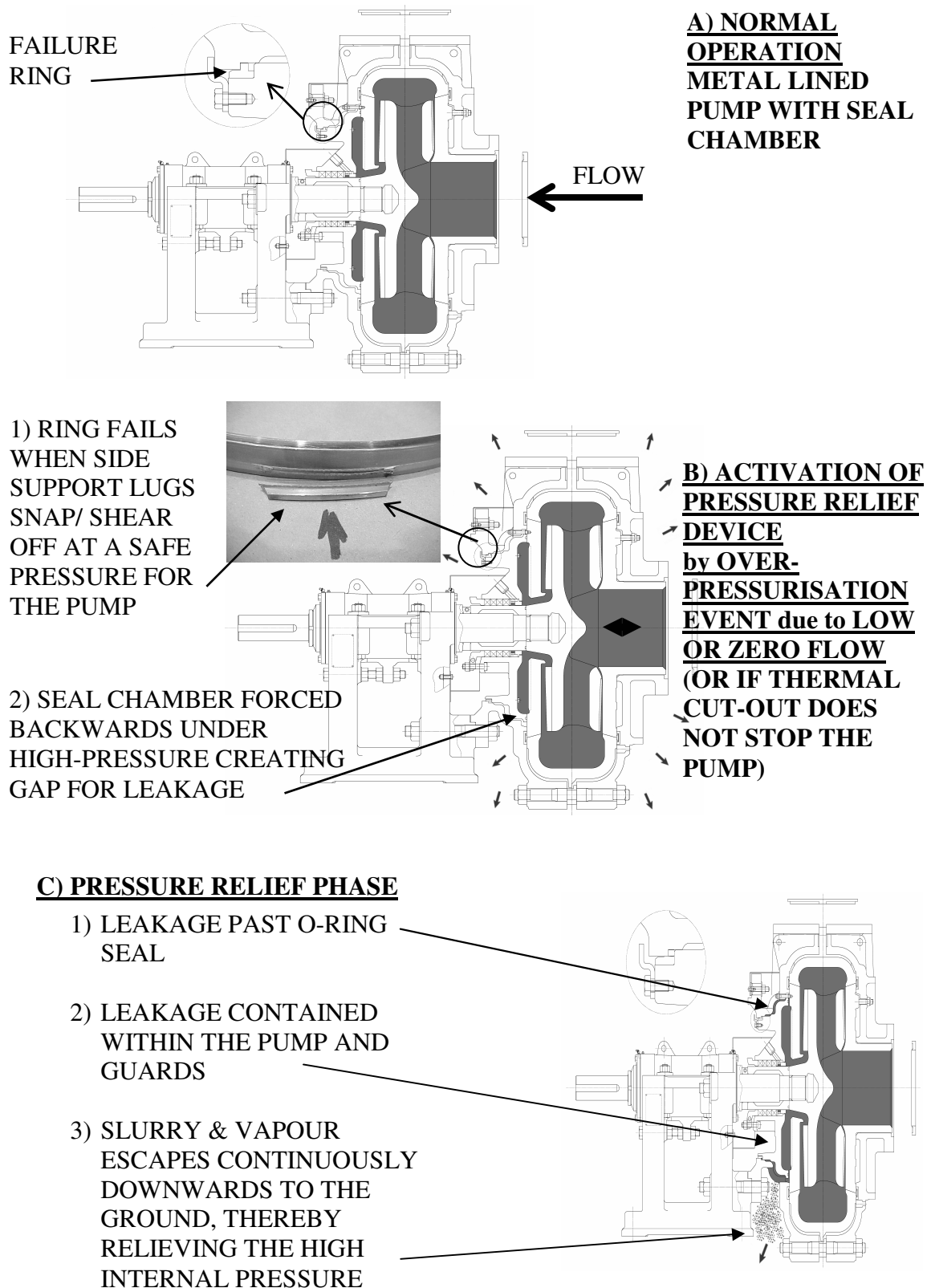


Table 1 – Over-pressure Detection

Detection Means	Reliability
Visual	Poor
Pressure	Poor
Flow	Poor to Good.
Temperature	Good for metal lined pumps.
Motor Current	Poor
Density	Poor
Pump starting and stopping	Poor
Burst Discs (or pressure relief valves in pipeline)	Poor
Flow bypass pipeline	Poor

- [1] G Shou PSI “Slurry pipeline blockage, theory & practice”, BHR Hydrotransport 16, 2004.
- [2] B P O’Connor, AngloGold “Centrifugal pump explosions”, BHR Hydrotransport 16, 2004.
- [3] Weir Warman Technical Bulletin number 30, 2005



**FIGURE 2 Pressure Relief Sequence**