2009 Timeline Conclusions

Seal failure took place as filter flow increased from 50% to 100%.

Seal failed whilst filter DP was steadily increasing.

Filter DP rapidly increases when Trains 1, 2 and 3 shutdown, it is unclear which train has the greater influence on filter DP.

Train 2 starts up DP steadily rises

Seal failure occurs as DP steadily rises

Filter flow at 60% and filter DP was registering a variation.

3.6. Plant Inspection Findings

Filter Element

Operations facilitated the removal of the filter vessel cover to determine the reasons for the apparently low DP across the filter. Upon removal of the cover the element was found to be disintegrated. The filter sieve was visually inspected for debris and congestion was observed on the sieve. Some large solid plastic like particles were also found in the filter element. The element was collected and placed in a bag for future investigation. The basket was inspected in the workshop and was found to be distorted to a convex shape at the base possibly due to over-pressurisation. Pictures of the filter and mechanical seals are included in **Appendix D**.

Damaged Mechanical Seals

Inspection of the seals showed that there was extensive debris (black tar like deposits with solids) accumulation inside the bellows of the primary and secondary containment seals and guide sleeves of all seals (pictures included in **Appendix D**). The shaft sleeves were found heavily marked and scratched shown as follows:

Physical damage to the bellows and seal faces was not visible, however this does not conclude that there is no damage present. The deposits were dry at the time of inspection it is not known if at the time of removal from the pump the deposits were actually sticky. There may be implications on seal integrity and life if this is found to be the case. Further inspection by John Crane is required to fully assess the condition of the mechanical seal components.

4. Failure Causes

The RCA process and inspections confirmed a number of possible causes for the seal failures as follows:

4.1. Debris in Oil

The heating oil contains solids this is evident from the observed variation of filter DPs according to timeline operating data and from the deposits were found inside the seals. The filter DP seems to increase with train start, stop and load changes. Some seal failures seem to occur within a few days following train startups and shutdowns and filter changes. Failed mechanical seals contained significant quantities of solid deposits on all critical internal surfaces of both the primary and containment seals. Although yet to be confirmed by further investigations there are three possible root causes of the formation of deposits.

- From within the hot oil circuit externally from the seals, this is but one possible cause of seal failures.
- Solids might also be generated within the seals by frictional heating between stationary and moving parts.
- Due to possible oxidation of hot oil in the seal from the quench gas.

The nitrogen contains at least 3% oxygen which together with frictional heating and residence time may be a cause for degradation of the oil within the seal. Degradation of oil can accelerate with a combination of high skin temperature and residence time. This may occur within the fired heater and the waste heat recovery unit (WHRU) tubes though this argument is not supported by inspections. Operations state that increasing flows through the hot oil system actually reduces heat transfer rates in the process heat exchangers. This is evident when the temperature in the hot oil vessel increases. It is therefore not presently possible to reduce oil temperatures by increased flow.

Detailed examination by John Crane specialists is required to assess the true extent of any damage in the seals and also review the current seal auxiliaries set-up for correct quench gas flows.

4.2. Low Filter Flow

The operating side stream flow through the hot oil filter 06-V-323 is typically 2000TPD compared the PFD filter flow of 4458TPD, a shortfall of 45%. Based on filter design the normal/design rated flow should be 4158TPD. The low flow reduces debris removal efficiency from the system and the hot oil pump operating duty point and this may be a contributing towards high vibrations since they are confirmed to increase with reducing pump duty (**Appendix B**). Furthermore, the filter DP transmitter 06-PDI-3259 is not efficiently able to detect DPs at low flow (since the transmitter is operating at the lower end of the normal operating range) thus explaining the low DPs observed.