ACME Industrial Plant
Recirculation Pump Seals
Oversight Board Meeting

February 18, 2004

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Board Concerns

Purpose of presentation is to address Board Concerns relating to Recirculation Pump Seal performance, as follows:

• Apparent similarity of corrective measures from 2001 and 2002 failures
• Details surrounding 2003 failure
• Relevance of foreign material to seal failures and controls used during maintenance to prevent this impact
Presentation Outline

• Seal Design Overview
• Summary of Root Causes
• Foreign Material Considerations
• Conclusion
• Questions and Answer
Seal Design Overview

• Three stage cartridge seal
• Seal faces provide primary sealing function
• Seal o-rings provide secondary sealing and stabilizing functions
• All events to be discussed relate to sealing o-rings within the upper seal
• First two events (2001 and 2002 failures) at shaft to upper sleeve o-ring
• Most recent event (2003 failure) at stationary face to carrier o-ring
2001 Seal Performance

• All four Recirculation Pump Seals experienced gradual increasing upper seal leakage
• Total leakage (for all four seals) reached approximately 2 GPM
• Cause determined to be a poorly designed o-ring joint at upper sleeve to shaft location (inadequate “squeeze”)
• Supplier redesigned upper sleeve to increase o-ring squeeze and add a stabilizing o-ring
• All seals inspected, modified and reinstalled during 2001 maintenance shutdown
• Seal inspections revealed signs of leakage on low pressure side of o-ring on all four seals, confirming leakage location
2002 Seal Performance

- “A” Pump seal began leaking immediately at plant startup
- “B” Pump seal operated normally
- “C” and “D” Pump seals began gradual increasing leakage trend within two months of startup
- Maximum total leakage during run was once again approximately 2 GPM
- Similarity of symptoms suggested that the location of the malfunction had been determined but that the cause was still undetermined
2002 Root Cause Investigation

- Multi-organizational effort
- Seal supplier subcontracted third party root cause analysts to perform independent evaluation
- ACME employed yet another firm to perform independent, third party review of cause analysis and recommended seal modifications
- Extensive Finite Element (FEA) modeling used to determine mechanical, hydraulic and thermal effects on problematic o-ring joint
2002 Root Cause Investigation

• Location of leakage once again determined to be at upper sleeve to shaft o-ring
• Cause analysis (FEA modeling) determined one or both of the following failure modes:
  • RC#1 - Elevated temperature causes premature degradation of o-ring material
  • RC#2 - Differential thermal expansion and pressure effects increase o-ring gap, creating leakage flow path
• Eight design changes made to address one or both root causes (provided to Board in separate attachment)
2002 Root Cause Investigation

- Maintenance inspection revealed:
  - No obvious evidence of RC#1, o-ring damage (Met Lab analysis later revealed signs of minor surface wear)
  - Evidence of sleeve distortion that supported RC#2, thermal expansion effects
  - That foreign material damage to “A” Pump seal faces was likely cause of initial leakage at startup
2003 Failure of “A” Pump Seal

• “A” Pump upper seal failed (sudden, significant leakage) approximately three days after reaching full system pressure
• Lower and middle stages responded as designed, with pressure equally distributed between the two
• No precursor events or symptoms were visible prior to seal failure
2003 Root Cause Investigation

- Initial investigation performed with assistance from seal supplier (on site) and O-ring supplier (by phone)
- Seal inspection revealed extruded upper seal, stationary face to carrier o-ring
- Lower seal, stationary face to carrier o-ring also found to be partially extruded
- Cause determined to be insufficient material hardness of new o-ring installed during recent maintenance
2003 Root Cause Investigation

- Determined event was unrelated to 2001 and 2002 failures based on:
  - Failure occurred in portion of seal untouched by previous modifications
  - Failure mode (sudden large increase in leakage) and mechanism (o-ring extrusion) were quite different than previous events
  - Also noted that stationary face and carrier assembly design is well proven in industry
2003 Photos of Failed O-ring

Location of Failed O-Ring
2003 Failures Corrective Measures

• Interim – All o-rings placed on hold pending completion of root cause
• All stock o-rings will be returned to supplier for hardness verification prior to installation in spare seals
• Procurement controls will be implemented to require 100% hardness verification (and labeling) of all seal o-rings
Conclusion

• The latest event is unrelated to previous two, as evidenced by the nature and location of the o-ring failure.
• The 2002 investigation corrective measures are comprehensive and high confidence exists that they are sufficient to prevent recurrence of event.
• Foreign material is a concern with seal performance; however, the majority of recent seal leakage concerns are design related.

*Technical Writing Expert*: It is proven that a person retains information if they hear it repeated three times. In a presentation, main body points are presented in the introduction, the body, and then in the conclusion. In the next two slides, the engineer recaps all his main points. This is especially important because the presentation had been 30 minutes. This is the speaker’s last chance to ensure his points were made, and he is successful with his persuasive argument.
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