Reliability Improvement for Turboexpander-Compressor System

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Outline

• Introduction
• Turboexpander-Compressor Challenges
  1. Buffer Gas Excessive Flow
  2. Expander Speed Limit
• Execution Optimization
• Lessons Learned
• Concluding Remarks
Hawiyah NGL Plant

- Plant was commissioned in 2009.
- Three trains to recover Ethane-rich NGL.
- Each train has two 50% turboexpander-compressors.
- Reliability of EC system directly impacts production and operating economics.

![Diagram of Hawiyah NGL Plant](image)
Turboexpander-Compressor System

Compressor Suction
Compressor Discharge
Mechanical Center Section
Expander Suction
Expander Discharge

Reliability Improvement for Turboexpander-Compressor System
Mechanical Center Section

Bearing Housing

Auxiliary Bearing  Electromagnet  Position Sensor  IGV assembly
Performance Assessment Survey

The turboexpander exhibited three problems:

1. Buffer gas excessive flow (Bearing Housing)
2. Wheel imbalance (Compressor)
3. High magnetic bearing current (Expander)

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Challenge 1: Buffer Gas Performance

Buffer Gas Functions:

1. Rejects heat generated by magnetic bearings and shaft windage.
2. Protects auxiliary bearings from process gas.

Buffer Gas = Sealing Gas + Cooling Gas
Challenge 1: Description

During Pre-Commissioning:
• Piping vibration at seal gas supply valves.
→ Increased valves and piping from 1” to 2” for stiffness.

Subsequent Performance Problems:
1. High dP across on-skid seal gas filters.
2. Potential machine trip due to low seal gas dP.
Challenge 1: Analysis and Solution

Problem Analysis:
• Cooling gas flow could be reduced, such that bearings temperatures remain < 230 °F.

Implemented Solution:
• Reduced the size of \textit{internal} orifices to 1/8” to restrict the cooling gas flow.
Challenge 1: Realized Enhancements

- Seal gas consumption was optimized by internally reducing orifice diameters.
- Filter cartridge life was increased due to reduced seal gas flow.
- Turboexpander trip due to low seal gas supply differential pressure was eliminated.
Challenge 2: Expander High Current

• Some machines could not be placed back online after planned shut down.
• Once started up, machines exhibited high magnetic bearing current on expander side.
• When the machine was shut down, high current still persisted.
• Lateral shaft translation by AMB control system was necessary to restore magnetic bearing parameters to acceptable levels.
Challenge 2: Internal Inspection

- Failed Screw
- Non-failed Screw
- Expander Rub

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Challenge 2: Analysis

Expander Side View

IGV Front View

Guide vanes

Follower

Follower Locator

Bearing Current

Abnormal

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Challenge 2: Screw Failure Analysis

Low-Stress
High-Cycle
Fatigue
Old vs. New Screws

**Cap Screw Design**
- Socket-head
- Flanged-head

**Fillet between head and Shank**
- Small radius
- Larger radius
  - Beveled washer

**Material**
- A320-L7
- A286
  - ↑ 60% tensile
  - ↑ 500% fatigue

Reliability Improvement for Turboexpander-Compressor System
Safely Removed Rotating Assembly
# Readiness and Execution

## Secure shutdown windows and resources – **User Role**

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## Expedite material manufacturing/delivery – **Manufacturer Role**

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## Findings Summary

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<th>Finding/Cause</th>
<th>Corrective Action</th>
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<tr>
<td><strong>Excessive seal gas flow</strong></td>
<td>• Reduced orifice size to 1/8”.</td>
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<td>▸ Oversized cooling-gas orifice.</td>
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<td>▸ Parameter difficult to estimate a priori.</td>
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<td><strong>Rubbed expander wheel</strong></td>
<td>• Replaced damaged wheels.</td>
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<td>▸ Failure of expander follower screws (IGV assembly).</td>
<td>• Upgraded screw material and design.</td>
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<td>▸ Improper screws design and material selection.</td>
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Lessons Learned

User’s Perspective

• Conduct joint review of equipment/piping layout by manufacturer and user prior to construction approval.
• Implement Management of Change for modifications made at construction phase.

Manufacturer’s Perspective

• Develop analytical tools to more accurately determine pressures acting on IGV components.
• Redefine fastener selection process to provide a better safety margin.
Lessons Learned - Continued

Manufacturer’s Perspective

- Modified expander follower design:
  a) Adjusted component geometry to ensure mounting stability of IGV assembly members.
  b) Improved mounting screw material and geometry.
Concluding Remarks

- Turboexpander availability was boosted from 65% to 98%
- Active magnetic bearings have outstanding resistance to major rotor imbalance events.
- Corrective actions effectiveness was confirmed based on inspection findings.
- The key to success was outstanding coordination for
  - Shutdown windows
  - Spare parts and material manufacturing
  - Technical and field support