Case Study on investigation and resolution of Dry Gas Secondary Seal Failure

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## Presenter/Author bios

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Abstract

Dry Gas (DGS) Secondary Seal installed on one of the Flash gas compressor unit at an onshore gas treatment facility failed resulting in equipment downtime and process gas flaring. During detailed tear down inspection, primary seal was found heavily contaminated with sticky oily substance that reached into the secondary seal leading to contact between the seal faces causing thermal cracks. This case study will present the problem encountered, root causes analyzed, solutions implemented, results and lessons learnt.
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# Machine Details

**Flash Gas Compressor (Two stages)**

**Electric Motor Driven**

<table>
<thead>
<tr>
<th>Operating Data:</th>
<th>Stage 1</th>
<th>Stage 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suction Pressure:</td>
<td>6.5 bara</td>
<td>20.4 bara</td>
</tr>
<tr>
<td>Suction Temp.:</td>
<td>55.5 deg C</td>
<td>49.9 deg C</td>
</tr>
<tr>
<td>Discharge Pressure:</td>
<td>21.28 bara</td>
<td>62.8 bara</td>
</tr>
<tr>
<td>Discharge Temp.:</td>
<td>139.4 deg C</td>
<td>142.5 deg C</td>
</tr>
<tr>
<td>Inlet Volume:</td>
<td>2740 m³/hr</td>
<td>781 m³/hr</td>
</tr>
<tr>
<td>Mol. Wt.:</td>
<td>29 kg/kmol</td>
<td></td>
</tr>
<tr>
<td>Speed:</td>
<td>14853 rpm</td>
<td></td>
</tr>
<tr>
<td>Train Power:</td>
<td>2010 KW</td>
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</tbody>
</table>

Unit was installed & commissioned in 2012 but running in intermittent operation.
Problem Statement

• Flash Gas Compressor unit fitted with Tandem Dry Gas seal with intermediate labyrinth.
• Both the Primary & Secondary high vent pressures are monitored with alarm as well as shutdown safeguards provided therein.
• High vent pressure alarm appeared on the Secondary Seal (non drive end) during operation in Jan-2014.
• Eventually the compressor unit tripped on Secondary seal NDE high high vent pressure limit after approx. 50 minutes.
• Dry Gas Seal failure.
**Dry Gas Seal System Schematic/Details**

**DGS Details:**

- **Tandem arrangement with intermediate labyrinth.**
- **Bi Directional T-Groove Patterns.**
- **Seal Gas Heater to maintain seal gas supply temperature.**
- **Seal gas supply with 3um duplex coalescing filter assembly (Beta Ratio = 200).**
- **Plant nitrogen being used as buffer gas for intermediate seal as well as separation gas for bearing housing.**
- **Buffer/Separation Nitrogen gas filtration with 3um duplex filters (Beta Ratio = 200).**
**Chronology of Incident**

- **28/01/14 (01:02AM)**
  - Secondary seal NDE high vent pressure alarm appeared

- **28/01/14 (01:51AM)**
  - Secondary seal NDE vent pressure exceeded the high-high limit and compressor tripped

- **28/01/14 (02:28AM)**
  - Attempted to start the unit but failed due to secondary NDE pressure high-high shutdown

- **29/01/14 (09:00AM)**
  - Inst. Checks conducted on the Secondary seal NDE Vent pressure transmitters confirmed genuine reading

- **29/01/14 (01:00PM)**
  - Verified historical data trending from DCS and confirmed DGS failure
Historical Trending of NDE Seal Pressure Monitoring

Secondary NDE Seal Vent Pressure (mbar)

- PT-7212
- PT-7213
- Alarm
- Shutdown
Failure Observations


2. Dirty Seal Gas Coalescing Filter.

3. Contaminated Seal Gas Supply piping.
Failure Observations

4. Foreign material inside the seal gas heater.

5. Very dirty Primary seal.

6. Contaminated DGS casing.
<table>
<thead>
<tr>
<th>Failure Observations &amp; DGS tear down Inspection Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Condensate deposits inside the seal casing and outside the DGS cartridge.</td>
</tr>
<tr>
<td><img src="image1.jpg" alt="Image 1" /> <img src="image2.jpg" alt="Image 2" /> <img src="image3.jpg" alt="Image 3" /></td>
</tr>
<tr>
<td>8. Seal Ring (#1) and Mating Ring (#4) from primary seal - Contaminated with rust like substance and liquid and contact traces on the sealing surface.</td>
</tr>
<tr>
<td><img src="image4.jpg" alt="Image 4" /> <img src="image5.jpg" alt="Image 5" /> <img src="image6.jpg" alt="Image 6" /></td>
</tr>
</tbody>
</table>
DGS tear down Inspection Results

9. Seal Ring (#11) and Mating Ring (#44) from secondary seal
   Heavy contract traces on the sealing surface and seal face broken in several parts

10. Seal element (#2) from primary sealing and seal element (#12) from secondary sealing -
    Heavily contaminated with rust like substance and liquid. Pitting marks on the surface.
Root Cause Failure Analysis

Direct Causes:

• Heavy face contact with wear on the rotating face sealing surface of the Secondary Seal.
• Presence of liquid dusty substance in the secondary seal gap that caused the face contact.
• Heavy contamination with rust like particles and traces of liquid in the Primary Seal/Process side.
Root Cause Failure Analysis

Indirect Causes:
• Poor seal gas supply quality due to inadequate filtration.
• Dirty seal gas supply lines and seal gas heater (improper flushing).
• Dirty and un-cleaned process gas coming in contact with the seal mating faces.
• Hydrate and liquid formation (condensation) on seal faces while seal gas expanding and loss of dew point margin.
Solutions Implemented

1. Seal Gas conditioning to prevent liquid condensation.
2. Maintaining effective heat tracing for seal gas supply piping.
3. Cleaning of the seal gas/buffer gas filter housing.
5. Replacement of seal gas coalescing filters and N2 buffer/separation gas filters.
6. Weekly Equipment Basic Care (EBC) program for the seal gas supply/vent lines & coalescing filters.
7. SAP Mplan re-scheduling to 8K PM (from 16K PM) for the seal gas filters replacement & Filter DP transmitter tapping line/needle valve inspection.
8. Ensuring no occurrence of liquid carry over during pigging activity.
Results

✓ DGS & Compressor system uptime and reliability improvement with no more Dry Gas Seal failures post solutions implementation.

✓ MTBF > 04 years and still counting....
Lessons Learnt

- Sufficient seal gas dew point margin throughout the entire seal gas system to prevent hydrate and liquid formation on seal faces.
- Adequate QA/QC checks during pre-commissioning activities especially during seal gas piping cleaning and flushing.
- Design, Operation & Maintenance considerations for the entire seal gas system to ensure reliable DGS operation.
- Dry Gas Seal health monitoring including tracking and trending of Primary as well as Secondary seal vent pressures/flows.
- Eliminate process interruption (e.g. during pigging) to prevent contaminants going into the sealing system.
Back-Up Slides
Root Cause Failure Analysis

Dry Gas Seal Leakage

- Liquid carry over in the external seal gas supply piping
  - Liquid condensation in the gas system due to C3 down
    - Further hydrocarbon dew point when C3 offline
  - Process upset during pigging
    - Happened in April 2012 at Train 1.
  - Increase in gas MW
    - Lab report - constant
- Liquid carry over from suction scrubber
  - Liquid condensation in the gas system due to C3 down
  - Hydration formation due to high DP between LTSU & sales gas line
    - Happened 4 times in 2012-2013
- Auto drain valve malfunction
  - High level trip functioning
  - High level tripped functioning
- Compressor surging
  - Response of the anti surge valves tested OK during 8K PPM

- Excessive seal pressure/temperature
  - Seal gas pressure within tolerance, seal gas temp during start-up slightly low

- Operating condition

- Maintenance
  - Excessive seal pressure/temperature
    - Seal gas pressure within tolerance, seal gas temp during start-up slightly low
  - Liquid high level inside scrubber
    - Hydration formation due to high DP between LTSU & sales gas line
      - Happened 4 times in 2012-2013
  - Liquid carry over from suction scrubber
    - Process upset during pigging
      - High level tripped functioning
    - Increase in gas MW
      - Lab report - constant

- Construction & Commissioning
  - Excessive seal pressure/temperature
    - Seal gas pressure within tolerance, seal gas temp during start-up slightly low
  - Liquid carry over from suction scrubber
    - Process upset during pigging
      - High level tripped functioning
    - Increase in gas MW
      - Lab report - constant

- Mechanical failure
  - Liquid carry over from suction scrubber
  - Process upset during pigging
  - Increase in gas MW

- Material failure
  - Liquid carry over from suction scrubber
  - Process upset during pigging
  - Increase in gas MW

- Cause Ruled out based on factual information
- Possible but could not be validated
Root Cause Failure Analysis

**Dry Gas Seal Leakage**

- Operating condition
  - Seal Gas Filter maintenance
    - Seal gas filter DP monitoring
      - DP across filter within range.
      - Tubing/needle valve on DP TX blockage
    - Filter replacement during 16K PPM
      - Found dirty with black carbon dirt / soot

- Maintenance
  - Seal gas filter DP transmitters calibration
    - Calibrated during 8K PPM
  - Transmitters calibration (leakage monitoring)
    - Calibrated during 8K PPM

- Construction & Commissioning
  - Insufficient seal gas and N2 supply pressure
    - No alarm/trip event recorded. Historical trending OK

- Mechanical failure

- Material failure

**Cause Ruled out based on factual information**

**Cause validated based on factual information**
Root Cause Failure Analysis

- Operating condition
  - Dry Gas Seal Leakage
    - Construction & Commissioning
      - Improper installation
        - Installed by Vendor. No evidence of wrong installation was found during DGS removal
      - Foreign particles in the seal gas supply piping/cooler
      - Left-over material inside piping during construction
    - Insufficient flushing
      - Black plastic foil stuck inside seal gas heater
    - Dirty seal gas piping (black carbon dirt)
    - Lack of preservation
      - Unlikely. Train 2 OK
  - Mechanical failure
    - Material failure
  - Maintenance

- Material failure
  - Maintenance

- Cause Ruled out based on factual information
- Cause validated based on factual information
Root Cause Failure Analysis

Dry Gas Seal Leakage

- Operating condition
  - Seal “hang-up” (excessive axial gap)
  - Surging which impact on the displacement of gas seals internals.
  - Response of the anti surge and recycle valves OK – Checked during 16K PPM

- Maintenance
  - Normal wear and tear
  - Axial & thrust bearing position within tolerance – Checked during 16K PPM

- Construction & Commissioning
  - Alignment & vibration failures
  - Vibration – below alarm
    Alignment check during 16K PPM – within tolerance

- Mechanical failure
  - Breakage / fracture
    - Broken Secondary sealing ring

- Material failure
  - Seal groove clogging by the foreign particle
  - Contaminated with liquid dusty substance
  - Shaft sleeve heavily contaminated with rust like substance

- Cause validated based on factual information
- Cause Ruled out based on factual information
Root Cause Failure Analysis

- **Dry Gas Seal Leakage**
  - Operating condition
    - Overheating due to heat generation
    - Erosion of seal faces
    - Solid particles enter the seal
    - Pipe corrosion
    - Poor filtration
  - Construction & Commissioning
    - Overheating due to heat generation
    - Erosion of seal faces
    - Internal seal corrosion
  - Mechanical failure
    - Blistering of seal face
    - Liquid enter the seal
    - Water corrosion
    - Condensate formation inside seal chamber
  - Maintenance
    - Lube oil due to defective barrier
    - Liquid carry over from process to seal supply
    - Unlikely, Seal gas temp > 90 °C and seal gas heater functioning
  - Material failure
    - Liquid enter the seal
    - Water corrosion
    - Condensate formation inside seal chamber

- **Evident of black carbon dirt in the seal gas line.**
- **Traces of liquid contaminant.**
- **Cause Ruled out based on factual information**
- **Cause validated based on factual information**