Compressor Failures due to CO$_2$ Corrosion

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• To present failures that occurred with compressors in different production platforms offshore Brazil, due to the presence of $\text{CO}_2$ in process gas.

• To present the actions taken to recover the damages and minimize the corrosion effects.

• To present some references about $\text{CO}_2$ corrosion criteria.
• Theses failures occurred in different production rigs such as P-50, P-51 and P-54.
• The compressors suffered internal damage due to the formation of carbonic acid in unfavourable process conditions.
• The damage found was slightly different on each platform due to specific design characteristics, such as the presence or not of guiding vanes and different manufacturers.
• Three 2,000,000 SCMD compression trains installed in a 180,000 bpd FPSO (in operation since April 2006).
• Three stage compressor trains, consisting of a back-to-back LP and a straight-through HP compressors.
• Amine plant, individual for each train, in between LP and HP compressors for CO₂ capture.
• Degradation in question occurred in a single train (last to enter in operation, in February 2007), due to prolonged unavailability of its associated amine plant.
Between March and July 2008, high pressure compressor C showed high vibration levels during start-ups.

Further investigation of the event by the Technical Support team found an unstable, rapidly increasing, sub-synchronous vibration in the 40-45 Hz range.

During this period, in which it failure, a performance monitoring routine was not yet implemented.

The vibration was diagnosed as an aerodynamic instability.
• The HP bundle was removed and sent to the turbomachinery workshop for inspection and posterior repair.
• When disassembled in the workshop, the cause of the aerodynamic instability was clear: severe material loss and deposits in both inlet and diffuser vanes of the first stage and impeller.
• Repair/replacement of the damaged bundle components took place at operator turbomachinery workshop.
• The inlet guide vanes were rebuilt, the inlet labyrinths and all other consumables were replaced.
• The bundle was reassembled in the compressor and returned to operation.
Three 2,000,000 SCMD compression trains installed in a 180,000 bpd semi submersible platform (in operation since May 2008).

Three stage compressor trains, consisting of a straight-through LP and a back-to-back HP compressors.

Degradation in question occurred in the last compression stage in all three compression trains.
After six months of compressor operation, it was observed a continuous and marked reduction in polytropic efficiency only in the high pressure compressor.

No high vibration was observed.

In order to restore the design efficiency, HP bundles were disassembled and sent to turbomachinery workshop for inspection and repair.

Corroded areas were found at both casing and bundle, and heavy deposits at first diffuser and impeller.

The corrosion product was analyzed and confirmed that the corrosion was due to the presence of CO₂ (Siderite – FeCO₃).
Compressor Description – P-51

Corrosion on casing and counter-casing and deposit on first impeller and diffuser
• Corrective and mitigation action were carried out to minimize the issue such as: completion of suction lines thermal insulation; review of the scrubbers design; and provision for a corrosion inhibitor system.

• The chosen action, in agreement with the manufacturer, was to implement an electroless nickel plating on the compressor (casing, counter-casing and first diaphragm) and to superheat the gas at stage suction.
• Three 2,000,000 SCMD compression trains installed in a 180,000 bpd FPSO (in operation since Nov/2007).
• Three stage compressor trains, consisted of a back-to-back LP and a straight-through HP compressors.
• A deep degradation in question occurred in all three HP compressors.
Compressor Description – P-54

- At the beginning of 2011, HP compressor A faced several trips due to high vibration during normal operation.
- Further investigation of the event by the Technical Support team found an unstable, rapidly increasing, sub-synchronous vibration in the 45-50 Hz range.
It was also observed a reduction in both head and polytropic efficiency.
In order to restore the design efficiency, HP bundle was disassembled and sent to turbomachinery workshop for inspection and repair.

Corroded areas were found at both casing, IGV and diaphragm, and erosion at first, second and third diaphragm.

The corrosion product was analyzed and confirmed that the corrosion was due to the presence of CO2 (Siderite – FeCO3).
Corrosion and erosion on counter-casing as well as inlet wall
• Repair/replacement/cleaning of the bundle components took place at operator turbomachinery workshop.
• The first inlet guide vanes, labyrinths and consumables were replaced.
• Final solution is under analysis. Two possibilities are being considered: same coating solution used in P-51 or new components entirely manufactured in material resistant to CO$_2$ corrosion.
• All of the components had failure mode associated with CO$_2$ attack.

• All of the failed components were manufactured with carbon steel or low alloy steel.

<table>
<thead>
<tr>
<th>Components</th>
<th>P-50</th>
<th>P-51</th>
<th>P-54</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casing</td>
<td>ASTM A266 CL4</td>
<td>ASTM A350 LF3</td>
<td>ASTM A266 CL4</td>
</tr>
<tr>
<td>IGV</td>
<td>ASTM A36</td>
<td>--</td>
<td>ASTM A36</td>
</tr>
<tr>
<td>Counter-casing</td>
<td>--</td>
<td>ASTM A182 F22</td>
<td>--</td>
</tr>
<tr>
<td>Diaphragm</td>
<td>ASTM A36</td>
<td>ASTM A350 LF2</td>
<td>ASTM A36</td>
</tr>
</tbody>
</table>
- API Specification 6A (Specification for Wellhead and Christmas Tree Equipment)

<table>
<thead>
<tr>
<th>Retained Funds</th>
<th>Relative Corrosivity</th>
<th>Partial Pressure of CO₂ (psia)</th>
<th>Partial Pressure of CO₂ (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Service</td>
<td>noncorrosive</td>
<td>&lt;7</td>
<td>(&lt;.05)</td>
</tr>
<tr>
<td>General Service</td>
<td>slightly corrosive</td>
<td>7 to 30</td>
<td>(.05 to .21)</td>
</tr>
<tr>
<td>General Service</td>
<td>moderately to highly corrosive</td>
<td>&gt;30</td>
<td>(&gt; .21)</td>
</tr>
<tr>
<td>Sour Service</td>
<td>noncorrosive</td>
<td>&lt;7</td>
<td>(&lt;.05)</td>
</tr>
<tr>
<td>Sour Service</td>
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</tr>
</tbody>
</table>
• User has an internal standard for monitoring, interpretation and corrosion control in pipes, which combines CO₂ partial pressure, gas velocity and temperature to classify relative corrosivity. The CO₂ partial pressure limit in the internal standard is close to the API Spec 6A limit.
• The analysis of the compressor internal materials should be more careful in the design phase.
• For the compressor materials specification, if the process gas composition has CO$_2$ and H$_2$O, manufacture shall consider plant inefficiencies, such as scrubber liquid carry-over and pressure/temperature loss in pipings. Compressor non running, cold and pressurized conditions should also be considered.
• API 6A – 7$^{th}$ Edition- November,1999 is a good reference for CO$_2$ corrosion criteria and material selections.
• As a rule of thumb to protect the compressor from CO₂ corrosion, for upstream service the gas should be considered saturated with water and all surfaces in contact with wet process gas should be protected.
• Gas should be considered wet if its temperature is lower than 10°C above its dew point.
• The compressor failures were detected through different way, which shows that the condition monitoring of machine should have different diagnostics tools.
• Questions?

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