INVESTIGATING ROOT CAUSES OF CATU COMPRESSOR STATION SHUT-DOWN DUE TO HIGH DISCHARGE TEMPERATURE

Authors: Eduardo Meçon
Pablo Adolfo Nogueira
Paulo Bruno Peres
Ricardo Pinheiro
Rodrigo Mourão
Problem Statement

- Occurrence of high temperature in the outlet of the Catu compressor station
- Some instances of station trip have occurred
- Design set point for station trip (50°C)
Root Cause Analysis

- “Fishbone” diagram

**PROCESS**
1. Excessive recirculation of natural gas
2. High suction temperature
3. High discharge temperature before cooling

**MATERIALS**
4. Internal obstruction of tubes
5. Internal corrosion of tubes
6. External corrosion of tubes

**PEOPLE**
7. Operational procedure

**EFFECT**
High Temperature After Cooling

**EQUIPMENT**
8. Number of tubes per section
9. Speed fans
10. Blade angle
11. Blade diameter
12. Number of blades per fan
13. Unproper design (heat exchanger x compressor)

**MAINTENANCE**
14. Calibration of TIT
15. Excessive plugging of tubes

**ENVIRONMENT**
16. Dirty tubes
17. Dirty blades
18. High air ambient temperature
Root Cause Analysis

- Field Inspection
Root Cause Analysis

- “Fishbone” diagram after field inspection

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Root Cause Analysis

- Design data analysis

<table>
<thead>
<tr>
<th>DESIGN VARIABLE</th>
<th>COMPRESSOR STATION OVERALL SPECIFICATION</th>
<th>COMPRESSOR SPECIFICATION</th>
<th>HEAT EXCHANGER SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet Pressure</td>
<td>60 kgf/cm²</td>
<td>62.5 kgf/cm²</td>
<td>100 kgf/cm²</td>
</tr>
<tr>
<td>Outlet Pressure</td>
<td>100 kgf/cm²</td>
<td>100.9 kgf/cm²</td>
<td>-</td>
</tr>
<tr>
<td>Inlet Temperature</td>
<td>20.0 °C</td>
<td>20-30 °C</td>
<td>82.7 °C</td>
</tr>
<tr>
<td>Outlet Temperature</td>
<td>45.0 °C</td>
<td>68.2 °C</td>
<td>51.7 °C</td>
</tr>
<tr>
<td>Nominal Vol. Flow @ 20 °C 1 atm</td>
<td>7.0x10⁶ Nm³/day</td>
<td>6.67x10⁶ Nm³/day</td>
<td>7.1x10⁶ Nm³/day</td>
</tr>
<tr>
<td>Environment Temperature</td>
<td>-</td>
<td>-</td>
<td>36.1 °C</td>
</tr>
</tbody>
</table>
# Root Cause Analysis

- Field tests

## TEST RESULTS - TURBO-COMPRESSOR C

<table>
<thead>
<tr>
<th>Variable</th>
<th>Point 01 (highest temperature after cooling)</th>
<th>Point 02 (highest environment temperature)</th>
<th>Point 03 (highest differential pressure)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>14:20h</td>
<td>14:20h</td>
<td>16:00h</td>
</tr>
<tr>
<td>Environment Temperature</td>
<td>31.3 °C</td>
<td>31.3 °C</td>
<td>29.4 °C</td>
</tr>
<tr>
<td>Temperature Before Cooling</td>
<td>67.3 °C</td>
<td>67.3 °C</td>
<td>70.0 °C</td>
</tr>
<tr>
<td>Temperature After Cooling</td>
<td>49.6 °C</td>
<td>49.6 °C</td>
<td>49.3 °C</td>
</tr>
<tr>
<td>Volume Flow @ 20 °C 1 atm</td>
<td>$8.8 \times 10^6$ Nm³/day</td>
<td>$8.8 \times 10^6$ Nm³/day</td>
<td>$8.3 \times 10^6$ Nm³/day</td>
</tr>
<tr>
<td>Differential Pressure</td>
<td>28.0 kgf/cm²</td>
<td>28.0 kgf/cm²</td>
<td>32.0 kgf/cm²</td>
</tr>
</tbody>
</table>

## TEST RESULTS - TURBO-COMPRESSOR D

<table>
<thead>
<tr>
<th>Variable</th>
<th>Point 01 (highest temperature after cooling)</th>
<th>Point 02 (highest environment temperature)</th>
<th>Point 03 (highest differential pressure)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>15:00h</td>
<td>13:50h</td>
<td>15:20h</td>
</tr>
<tr>
<td>Environment Temperature</td>
<td>29.4 °C</td>
<td>31.4 °C</td>
<td>27.6 °C</td>
</tr>
<tr>
<td>Temperature Before Cooling</td>
<td>66.0 °C</td>
<td>64.3 °C</td>
<td>66.2 °C</td>
</tr>
<tr>
<td>Temperature After Cooling</td>
<td>49.8 °C</td>
<td>48.0 °C</td>
<td>48.2 °C</td>
</tr>
<tr>
<td>Volume Flow @ 20 °C 1 atm</td>
<td>$9.1 \times 10^6$ Nm³/day</td>
<td>$9.2 \times 10^6$ Nm³/day</td>
<td>$9.1 \times 10^6$ Nm³/day</td>
</tr>
<tr>
<td>Differential Pressure</td>
<td>30.0 kgf/cm²</td>
<td>28.0 kgf/cm²</td>
<td>31.2 kgf/cm²</td>
</tr>
</tbody>
</table>
Root Cause Analysis

- “Fishbone” diagram after field tests

**PROCESS**
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**EQUIPMENT**
8. Number of tubes per section
9. Fan speed
10. Blade angle
11. Blade diameter
12. Number of blades per fan
13. Improper design (heat exchanger x compressor)

**MAINTENANCE**
14. Instrument calibration
15. Excessive plugging of tubes

**ENVIRONMENT**
16. Dirty tubes
17. Dirty blades
18. High environment temperature

**EFFECT**
High Temperature After Cooling
Process Simulation

- Environment temperature of 40ºC
Process Simulation

- Environment temperature of 35ºC
Process Simulation

- Environment temperature of 30ºC
Concluding Remarks

- The influence of the environmental temperature on the performance of the heat exchangers in Catu for values above 30°C is evident.
- By simulation results, the heat exchangers in Catu are meeting the specifications of service for which they were designed (seven million Nm$^3$/d per machine), despite field tests have shown insufficient operating margin.
Concluding Remarks

- It is clear that the sizing of the Catu’s heat exchangers could have considered a larger number of operating points, as provided in the datasheet of the compressor.

<table>
<thead>
<tr>
<th>OPERATING CONDITIONS (look for end sheets notes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL DATA ON PER UNIT BASIS / production year</td>
</tr>
<tr>
<td>STAGE</td>
</tr>
<tr>
<td>GAS HANDLED: Natural gas (NG)</td>
</tr>
<tr>
<td>CORROSIVE COMPOUNDS: (see gas analysis)</td>
</tr>
<tr>
<td>STARTING GAS:</td>
</tr>
<tr>
<td>STD FLOW Rate: 10^6 Nm3/d (1.013 bar; 20C):</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>NORMAL</th>
<th>OTHER CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>YEAR: 2007</td>
<td>2008 2009 2010 2011 2012 RATED</td>
</tr>
<tr>
<td>STAGE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GAS HANDLED:</td>
<td>NG</td>
<td>NG NG NG NG NG NG NG</td>
</tr>
<tr>
<td>CORROSIVE COMPOUNDS</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>STARTING GAS:</td>
<td>NG</td>
<td></td>
</tr>
<tr>
<td>STD FLOW Rate:</td>
<td>pipeline</td>
<td>6.94 9.33 11.70 16.28 18.98 20.95 20.00</td>
</tr>
<tr>
<td>MASS FLOW, WET,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Qty. of Compressors</td>
<td>Compr. 01 compr 01 02 02 02 03 03</td>
<td></td>
</tr>
</tbody>
</table>
Additionally, the current operational flows for Catu rarely exceed five million Nm³/d, demanding the operation of only one machine with partial opening of its anti-surge valve. And the opening of the anti-surge valve increases the compressor suction temperature, also impacting the performance of Catu heat exchangers. These observations confirm the main actors for the occurrence of high temperatures at the station outlet as from the "fishbone" diagram.
Mitigation Measures

Worst case scenario with the new set point
Definite Solution

- Increase the heat exchanger capacity. Some technical solutions may be adopted in this direction, with different degrees of cost, effectiveness and facility of implementation. This heavily depends on the scenarios for the future movement of gas in the system of gas pipelines that includes the Catu station.
Lessons Learned

• The dimensioning of a compression plant, and especially for the heat exchangers, must foresee the serving of a higher number of operational points

• The maximum admissible temperature for natural gas in pipelines should be more thoroughly considered for new projects involving gas compressor stations, and revised if necessary

• The operational teams should participate more effectively since the beginning of any undertaking involving the transport of natural gas, mainly for compressor stations