HOW AN ON-LINE MONITORING SYSTEM SUCCESSFULLY TRIPPED A 4-THROW RECIPROCATING COMPRESSOR ON THREE SEPARATE EVENTS PREVENTING MAJOR EQUIPMENT DAMAGE AND DOWNTIME

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Compressor Description

• 514 RPM - 1000 Hp Synchronous motor
• 9.5” stroke
• 4 Stages
• Ethylene Gas
• Suction Press – 2 psig
• Discharge Press – 600 psig
• Interstage cooling, separators and suction snubbers with blowdowns
Compressor On-Line Monitoring Installation

- System installed and commissioned in January 2011
- Interlocks in service July 2011
- Total of 26 Compressors on site with 416 Instrument loops

Sensors Installed
- CHS Vibration
- CYL Vibration
- Rod Position **
- CE/HE Pressure
- Roving/Crankcase Vibration

** 1st/2nd Stg RP added Feb. 2012
History of failures prior to Monitoring System

• Known as “Trash” Compressor
• Many valve failures due to liquid
• Several significant failures due to liquid
  • Head bolts found loose
  • 1st stage Aluminum piston destroyed
  • Cracks found in crankcase
• Upgrades made to liquid separation system has helped
• When compressor is down, flaring ethylene gas

Metal-Stitch Repairs

Crack in distance piece
Sequence of Events - Summary

1/11/12  10:14 pm  Interlock due to start-up with compressor full of liquid

2/18/12  6:05 am  Interlock on 2\textsuperscript{nd} Stg CHS RMS Vibration due to loose piston (from prior event)

2/22/12  12:52 pm  Interlock on 2\textsuperscript{nd} Stg CHS RMS Vibration due to incorrect crosshead to pin clearance
## Sequence of Events

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/11/12</td>
<td>10:14 pm</td>
<td>Interlock 17 seconds after started compressor due to being full of liquid</td>
</tr>
<tr>
<td>1/12/12 – 1/17/12</td>
<td></td>
<td>Repairs made – New valves on all stages, pushed pin on 1&lt;sup&gt;st&lt;/sup&gt; and 2&lt;sup&gt;nd&lt;/sup&gt; stage – no wear and clearances OK. Drained liquid from low points.</td>
</tr>
<tr>
<td>1/17/12</td>
<td>11:30 pm</td>
<td>Machine started after repairs</td>
</tr>
<tr>
<td>2/3/12</td>
<td>10:28 pm</td>
<td>Alert on 2&lt;sup&gt;nd&lt;/sup&gt; Stg CHS RMS Vibration – Segment 34</td>
</tr>
</tbody>
</table>
Interlock 17 seconds after started due to liquid
Suspected problems with 1\textsuperscript{st} & 2\textsuperscript{nd} Stages

High impacts on 1\textsuperscript{st} & 2\textsuperscript{nd} Stg

Repairs being done after started up with liquid
2nd Stg CHS ALERT (2/3/12 until 2/18/12)
Sequence of Events

2/18/12  6:05 am  Interlock on 2\textsuperscript{nd} Stg CHS RMS Vibration

2/18/12  6:14 am  Started 9 minutes after Interlock (Ooops!) Interlock on 2\textsuperscript{nd} Stg CHS RMS Vibration (ran 8 minutes with many segment violations)

2/18/12 – 2/22/12  Repairs made – Found loose 2\textsuperscript{nd} stage piston nut. Changed 1\textsuperscript{st} and 2\textsuperscript{nd} stage pistons/rods, changed 2\textsuperscript{nd} stage connecting rod and installed the RP sensors on 1\textsuperscript{st} and 2\textsuperscript{nd} stages
2nd Stg CHS – Found loose piston nut

Interlock on 2/18/13
Interlock Criteria - Any 6 segments above Alert limit for 5 consecutive revolutions
Sequence of Events (Cont’d)

2/22/12    10:14 am  Machine started after repairs. Interlock 82 seconds after machine started due to 2nd Stg Pk-Pk Variation Rod Run Out over 8 segments (suspected liquid)

2/22/12    10:41 am  Machine started a 2nd time after blowing down snubbers. Interlock 63 seconds after machine started due to 2nd Stg Pk-Pk Variation Rod Run Out over 8 Segments
Start-up after new 2nd Stg Rod installed

Rod Position - Can this be real?
2\textsuperscript{nd} Stage Reversal points

Reversal Points
Sequence of Events (Cont’d)

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<thead>
<tr>
<th>Date</th>
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<tbody>
<tr>
<td>2/22/12</td>
<td>11:00 am</td>
<td>Raised Pk-Pk Rod Run Out Interlock level from 40 mils to 80 mils</td>
</tr>
<tr>
<td>2/22/12</td>
<td>12:52 pm</td>
<td>Machine started but had interlock 25 seconds later due to 2\textsuperscript{nd} Stg CHS RMS Vibration</td>
</tr>
<tr>
<td>2/22/12 – 2/26/12</td>
<td></td>
<td>Found crosshead pin to crosshead bushing had almost zero clearance. Changed connecting rod, crosshead, crosshead slippers, pin and bushing.</td>
</tr>
<tr>
<td>2/26/12</td>
<td>9:32 am</td>
<td>Machine started and has been running well since</td>
</tr>
</tbody>
</table>
After increasing RP Intlk to 80 mils

Almost 80 mils displacement – Would have interlocked if left
At 40 mils Interlock level
2\textsuperscript{nd} Stg Pin to Bushing clearance inadequate

Tripped on high CHS vibration
Crosshead Design

Floating Style Pin

0.0005” - 0.002” clearance

0.0015” – 0.0045” clearance
Smooth operation after final repairs
What did we learn…?

• On-Line Compressor Monitoring works
• Believe the data (rod position was real!!)
• Check on a regular basis (ALARMS from 2/3/12 not recognized until 2/12/12)
• Production Protocol when getting ALARMS from System
• Interlock values are set adequately to prevent damage and not have false trips – no significant damage found during any events
• After an event, make sure to do enough checks (liquid at S/U most likely caused the 2nd stage piston to get loose over time)
• Source of water was found to be a corroded indicator nipple on 1st stage cylinder - replaced with SST indicator
Thank you for your attention

Questions?