Reliability and Performance Improvements to a Hydrogen Recycle Compressor
Part I

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Hydrogen Recycle Compressor

- Ingersoll Rand MGGB barrel compressor
- HDS Hydrogen Recycle service
- Originally installed in 1960’s

2,500 hp
1785 rpm
motor

6.5:1

5 stage compressor
11,600 rpm
Original Problem

- Multiple trips due to current phase difference on motor
- Caused by the compressor surging
- Unit rates limited due to inadequate hydrogen to oil ratio
Original vs Actual Operating Conditions

- Reduction in mole weight of gas has drastically changed the operating conditions of the machine.

<table>
<thead>
<tr>
<th></th>
<th>Design</th>
<th>Actual</th>
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</thead>
<tbody>
<tr>
<td>$P_1$ psia</td>
<td>450</td>
<td>415</td>
</tr>
<tr>
<td>$T_1$ F</td>
<td>100</td>
<td>110</td>
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<tr>
<td>Flow ACFM</td>
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<td>1950</td>
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<tr>
<td>$P_2$ psia</td>
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<td>520</td>
</tr>
<tr>
<td>MW</td>
<td>6.75</td>
<td>4.5</td>
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</table>
Operating Concerns

- Because of the low mole weight, the suction throttle valve was 100% open (no longer in control) and the compressor had been pushed back on its curve to meet the head demand of the system.

- Operations thought something was wrong with the machine because when they opened the spill-back valve, it caused the machine to surge.

- Because the machine could not produce anymore head and the throttle valve was 100% open, opening the spillback was actually harmful to the machine because it moved it further out on the curve, which caused it to surge.
Surge Control Ineffective

- When suction throttle valve is 100% open, opening the spill back increases the flow, which reduces the discharge pressure, and causes the compressor to surge.
Future Operating Conditions

- If things weren’t bad enough, operations also informed us that the mole weight would decrease even further in about 6 months due to a process design change.

- Process engineers were not concerned because they said their model showed the machine would operate fine because of reduced system pressure drop.
New Design Conditions

- New process design with lower mole weight called for higher flow rate and lower discharge pressure because of design modifications to reactor.

<table>
<thead>
<tr>
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<th>Original Design</th>
<th>Proposed Design</th>
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<tr>
<td>$P_1$</td>
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<tr>
<td>$T_1$</td>
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<td>100</td>
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<tr>
<td>Flow</td>
<td>ACFM</td>
<td>2620</td>
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<tr>
<td>$P_2$</td>
<td>psia</td>
<td>625</td>
</tr>
<tr>
<td>MW</td>
<td></td>
<td>6.75</td>
</tr>
<tr>
<td>Speed</td>
<td>rpm</td>
<td>11,600</td>
</tr>
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</table>
Problems with New Design Conditions

- Higher suction pressure of 450 psia allows no control, i.e. this requires suction throttle valve to have no pressure drop.

- Approximately 30% increase in flow, with no increase in head required? Reactor modifications would decrease pressure drop in loop, but it seemed unlikely that this large an increase in flow could be accomplished with no increase in head. Process model didn’t adequately predict existing pressure drop of system.

- Compressor is already operating at surge, no margin of error available.
Proposed Modifications

- The increased head requirement of the lower mole weight lends itself to a speed increase of the compressor.

- Lower mole weight lowers power required so new motor is not required.

- Speed increase is more economically feasible than aero modifications and more timely.
Proposed New Design Conditions

- New speed of 12,500 rpm was selected by maximizing speed for head production, but limiting power for potential higher mole weight gas.

<table>
<thead>
<tr>
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<th>Original Design</th>
<th>Re-rate</th>
<th>Re-rate hp limit</th>
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<td>Speed</td>
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<td>11,600</td>
<td>12,500</td>
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<tr>
<td>Power</td>
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Impeller Modifications

- Impellers were originally 4140, but were replaced with 410 SS in 2001

- Third party FE study used to analyze stresses in impellers at higher speed.

- Stresses at 12,500 rpm exceeded allowable for 410 SS

- Decision made to replace 410 SS with 17-4 PH
FE Study
Timing

- Final process design completed and approved in December 2005

- T/A window for modifications was in April 2006

- Approx 12 weeks to manufacture new impellers and gears

- Rotor study completed which recommended bearing and oil seals modifications as well.
Results

- Compressor is able to operate away from surge with suction throttle valve in control
- No more trips due to surge
- Low vibration
- Power within limits of motor