Air Preheat System Upgrade on Coker Heaters

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Furnace Improvements
Air Preheat System

- Not popular
- Misconception about NOx emissions
- Number of APH installations not in use
- Heaters operating in Natural draft mode losing energy
- Energy prices are very low ??
- Our fired heaters are not very efficient
- But???
Two identical Balanced Draft Coker Heaters -
Heat duty of each heater -
126.8 MMBtu/hr
Existing Air Preheat System

- Hot Air Temperature = 579°F
- Hot Flue Gas Temperature = 700°F
- Cold Flue Gas Temperature = 275°F
- Cold Air Temperature = 60°F
- Cold Air Temperature = 70°F
Operating Issues with Air Preheating Systems

- Air Preheater
  - Corrosion
  - Air leakage
  - High flue gas side pressure drop
- Bypass duct limitation
- Burners
  - Non uniform air flow to burners
  - Flue gas bypass to stack, ID fan limiting
- Client was throughput limited
Air Preheater Problems

• Low tube metal temperature and excessive corrosion problems:
  • Non-uniform air flow distribution
  • Cold zones in static air preheater
  • APH Design was deficient with respect to acid dew point corrosion
Existing Air Preheater

- Type: Recuperative Cast Iron
- Heat Duty: 15.05 MMBtu/hr
- Flue Gas Side Details:
  - Flowrate: 130,150 lb/hr
  - Inlet/Outlet Temperature: 700°F/275°F
  - Pressure Drop: 2.0 inches WC
- Air Side Details:
  - Flowrate: 117,700 lb/hr
  - Inlet/Outlet Temperature: 60°F/579°F
  - Pressure Drop: 4.3 inches WC
- Minimum Tube Metal Temperature: 230°F

Existing Air Preheater was corroded and leaking air into flue gas
Existing FD Fan

- Fan rated for 34,652 acfm at 120°F with 10.5inch W.C pressure rise (TB)
- Drive Arrangement- #7 SWSI
- Fan Speed- 1,200 rpm
- Motor - 100 H.P
- Steam APH is provided at the inlet
- Inlet guide vanes to control the flow
- Provided with 20 ft tall suction stack consisting of rain hood with screen, silencer and steam APH coils

Existing FD fan was limiting due to APH leakage
Suction filter was getting clogged with coke particles
Existing Steam Air Preheater

- Provided at FD Fan inlet duct to preheat air in winter to avoid Acid Dew Point Corrosion in main APH
- Heat Duty- 1.61 MMBtu/hr
- Air inlet / outlet temperature: 10 °F / 60 °F

Existing steam air preheater was undersized and getting clogged with coke particles
Existing ID Fan

- Rated for 58,530 acfm at 350°F with 5.1 inch WC static rise (TB)
- **Arrangement- #7 SWSI Grade Mounted**
- Inlet pneumatically operated damper to control the flow
- **Fan Speed- 900 rpm**
- **Motor- 75 HP**

ID fan was undersized and was limiting
Limitation of the Heaters and APH System

- **Heater**
  - High flue gas convection section exit temperature, almost 30-40% flue gas bypassing the air preheater (calculated thermal efficiency -85%)

- **Air Preheater**
  - Acid Dew Point or Cold Block Corrosion

- **ID & FD Fans**
  - ID and FD fans were limited in capacity thereby limiting the heater production

- **Combustion / Cold Air By-pass Duct was undersized**
Flue Gas Temperature Leaving Convection

Flue gas temperature to Air Preheater is higher by almost 100-180°F.
Air Preheating System Modifications

- Systems approach:
- Installation of new APH, FD fans, ID fans, Steam APH
- Modification of combustion air and flue gas ducts
- Installation of additional convection tubes
Addition of Process Coils in Convection

• Two future rows provision to be used.
• Fin configuration of process coils in future rows: 1” ht. x 0.06” thk. X 5 FPI
• 8,858 ft² additional heat transfer area in process convection
• Flue gas temperature leaving the convection section is reduced from 834°F to 701°F
Air Preheater Recommendations

- New Plate Type APH
- Preheater design revised to 300°F flue gas temperature
- 20% higher flue gas flow rate
- Steam air preheater upstream to ensure constant air temperature of 120°F
- Glass/Ceramic Coating on metal plates to avoid dew point corrosion in cold end.
- Design Heat Duty of 17.7 MMBtu/hr.
- Minimum tube metal temperature (TMT) of 279°F
## Existing and Proposed APH Comparison

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Existing</th>
<th>Proposed</th>
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</thead>
<tbody>
<tr>
<td>Absorbed Duty</td>
<td>MMBtu/hr</td>
<td>15.05</td>
<td>17.7</td>
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<tr>
<td>Air Flow Rate</td>
<td>lb/hr</td>
<td>117,700</td>
<td>155,038</td>
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<tr>
<td>Air Inlet / Outlet Temperature</td>
<td>°F</td>
<td>60 / 579</td>
<td>120 / 585</td>
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<tr>
<td>Flue Gas Flow Rate</td>
<td>lb/hr</td>
<td>130,150</td>
<td>162,714</td>
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<tr>
<td>Flue Gas Inlet / Outlet Temperature</td>
<td>°F</td>
<td>700 / 275</td>
<td>701 / 300</td>
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<tr>
<td>ΔP on Air Side (allowable/calculated)</td>
<td>in WC</td>
<td>- / 4.3</td>
<td>4.3 / 2.6</td>
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<tr>
<td>ΔP on Flue Gas Side (calculated)</td>
<td>in WC</td>
<td>2.0</td>
<td>2.9</td>
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<tr>
<td>Minimum Metal Temperature</td>
<td>°F</td>
<td>230</td>
<td>278.6</td>
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## Existing vs. Proposed FD fan

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Existing</th>
<th>Proposed</th>
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</thead>
<tbody>
<tr>
<td>Combustion Air Flow Rate</td>
<td>lb/hr</td>
<td>141,240</td>
<td>168,832</td>
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<tr>
<td>Air Temperature</td>
<td>°F</td>
<td>120</td>
<td>125</td>
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<tr>
<td>Static Pressure Rise</td>
<td>inch WC</td>
<td>10.5</td>
<td>14.07</td>
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<tr>
<td>Maximum Fan Speed</td>
<td>rpm</td>
<td>1,200</td>
<td>1,200</td>
</tr>
<tr>
<td>Motor Rating</td>
<td>HP</td>
<td>100</td>
<td>150</td>
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</table>
# Existing vs. Proposed ID fan

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Existing</th>
<th>Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flue Gas Flow Rate</td>
<td>lb/hr</td>
<td>156,180</td>
<td>207,249</td>
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<tr>
<td>Flue Gas Temperature</td>
<td>°F</td>
<td>350</td>
<td>400</td>
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<tr>
<td>Static Pressure Rise</td>
<td>inch WC</td>
<td>5.0</td>
<td>10.62</td>
</tr>
<tr>
<td>Maximum Fan Speed</td>
<td>rpm</td>
<td>900</td>
<td>1,200</td>
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<tr>
<td>Motor Rating</td>
<td>HP</td>
<td>75</td>
<td>200</td>
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New ID fan motor is three times larger than the existing ID fan motor
Ducting Modifications

1. Combustion Air Duct Modification

- **FD fan suction stack:**
  - Additional 20 ft FD fan suction stack

- **Cold Air bypass duct:**
  - Size increased from 1’-8” (current size) to 3’-4”
  - Sized for Full Air Flow during forced draft operation

- **FD fan discharge duct:**
  - Smoother transition to APH
  - Angled baffle plates and turning vanes
Ducting Modifications

• Hot Air Duct Modification:
  • Smooth outlet transition from APH with turning vanes
  • Guide vanes and baffles
  • Pressure drop plate to increase the air side pressure drop to 0.68 inch WC in burners

2. Flue Gas Duct Modification

• Hot Flue Gas Duct Modifications
  • Inlet transition to APH has gradual expansion with angled baffles

• Cold Flue Gas Duct Modifications
  • New duct with turning vanes
New FD fan Suction Stack

- 40 ft height from FD fan flange inlet (20 ft more than existing suction stack)
- 90 degree elbow
- Provided with fine wire mesh screen to block bird feathers entering APH
New Cold Air Bypass Duct

- Increased size to 3’-4” from 1’-8” (outside plate)
- Controlled by pneumatically operated, tight shut off damper
# Steam Preheat Coil

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Existing Steam Preheater</th>
<th>New Steam Preheater Coils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Duty</td>
<td>MMBtu/hr</td>
<td>1.61</td>
<td>6.11</td>
</tr>
<tr>
<td>Air Inlet Temperature</td>
<td>°F</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Air Outlet Temperature</td>
<td>°F</td>
<td>60</td>
<td>180</td>
</tr>
</tbody>
</table>

Picture of Steam Preheat Coil in Manufacturing Facility
Existing v/s New Steam Preheater

Existing Steam APH Layout

New Steam APH in Discharge Duct

Proposed Steam APH Layout

Existing Steam APH In Fan Suction
Existing and Proposed FD fan Discharge Duct

Smotherer Transition, Angled baffles and turning vanes provide uniform air flow
Velocity RMS Deviation at APH Inlet

RMS deviation at APH inlet is: ± 91.0%

RMS deviation at APH inlet is: ± 13.9%

Normal velocity profile at APH inlet (after Steam APH)

Due to physical constraints on duct shape it was not feasible to further improve the flow distribution

Note: Recommended RMS Deviation of velocity is in the range of ± 5%
Hot Air Duct Modification for Uniform Air Flow

- Air preheat outlet
- Smooth and turning vanes are added
- Reduced dead zones and recirculation
Air Flow Path Lines colored by Velocity

- Recirculation is reduced as compared to existing case with change in duct design and adding turning vanes
- Pressure drop is reduced by 0.05 inches WC as compared to existing design

[Diagram showing existing and proposed flow paths with color mapping for velocity]

Existing

Proposed

Recirculation

APH outlet
Hot Air Duct Modification for Uniform Air Flow to Burners

Pneumatic Operated Dampers
Hot Air Duct – Proposed Geometry

Pressure drop across the burner is considered: 0.68 inches WC

Modified inlet duct along with turning vanes

Isometric view

Burner Inlet

APH outlet

Damper

Proposed
Air Flow Variation to Burners

- Deviation from average flow rate per burner based on simulation results

Comparison

- Mass flow distribution across all the burners is significantly improved for the proposed case
- Improved air flow distribution across burners for other ducts is similar
Hot Flue Gas Inlet Duct to Air Preheater

[ft/s]

Existing  Proposed
Flue Gas Velocity Profile at ID Suction

[ft/s]

Velocity distribution throughout the duct has improved in the proposed case.

Significant reduction in the recirculation zone for the proposed case.

Uniform velocity distribution is achieved at the inlet of ID fan for proposed case.
Flue Gas Velocity Path Lines at ID Suction

Flue gas flow separation at the bends is reduced

Significant reduction in swirling velocity near the inlet of ID fan
Key Benefits

• Thermal Efficiency of the coker heater increased by 7-8% after the revamp.
• Heater production rate was improved after APH replacement.
• Production rate increased by 4,500 Barrels per day for each heater
• Overall project cost – Total $7.5 Million for two heaters
• At about $8 per Barrel it provided $26 Million additional revenue per year
• Payout -4 months
Thank You!