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### Middletown Coke Company
#### HRSG Maintenance BACT Analysis
##### Option 1 - Individual Spray Quenches

### Summary of Top-Down BACT Impact Analysis Results

<table>
<thead>
<tr>
<th>Control Alternative</th>
<th>Total Emissions</th>
<th>Economic Impacts</th>
<th>Environmental Impacts</th>
<th>Energy Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Uncontrolled Emission Rate (gr/dscf)</td>
<td>Controlled Emission Rate (gr/dscf)</td>
<td>Emission Reduction (lb/hr)</td>
<td>Total Emissions (gr/dscf)</td>
</tr>
<tr>
<td>Individual Spray Quenches</td>
<td>0.049</td>
<td>105.0</td>
<td>0.005</td>
<td>10.7</td>
</tr>
</tbody>
</table>
Total Capital Investment Cost

A. Direct Capital Cost (DCC)   
1. Purchased Equipment Cost (PEC)   
   Equipment Costs Summary: $7,487,520
   Instrumentation (0.1*Equipment Costs) $748,752
   Freight (0.05*Equipment Costs) $374,376
   Sales Tax (0.03*Equipment Costs) $224,626
   **TOTAL PURCHASED EQUIPMENT COST** $8,835,274

   2. Direct Installation Cost (DIC) (0.56*PEC)   
      **TOTAL DIRECT INSTALLATION COST** $4,947,753

   3. Site Prep (SP) as required   
      $0

   4. Buildings (BLDG) as required   
      $0

   **TOTAL DIRECT CAPITAL COST** $13,783,027
   (PEC+DIC+SP+BLDG)

B. Indirect Capital Cost (ICC)   
   Engineering (0.10*PEC) $883,527
   Construction and Field Expenses (0.10*PEC) $883,527
   Construction Fee (0.10*PEC) $883,527
   Startup (0.01*PEC) $88,353
   Performance Test (0.01*PEC) $88,353
   **TOTAL INDIRECT CAPITAL COST** $2,827,288

C. Contingency (CONT) (0.15*PEC)   
   **TOTAL CAPITAL INVESTMENT COST** $17,935,606
   (DCC+ICC+CONT)

Notes:
1. All factors other than contingency are derived from Estimating Costs of Air Pollution Control, William M. Vatavuk, Lewis Publishers (1990), p. 20, using "Venturi Scrubber" factors.
2. Costs for Stack tees are based on quotations rolled into Sun estimate for nine tees @ $223,451/9 = $24,828/tee. These costs were escalated from 2003 dollars to 2008 dollars using a factor of 1.53 derived from the Chemical Engineering Plant Cost Index (CEP).
3. Costs for hot duct are based on quotations rolled into Sun Estimate of $921,873 for 9 ducts with 82 ft length each. These costs were escalated from 2003 dollars to 2008 dollars using a factor of 1.53 derived from the CEP.
4. Elbows are assumed to have the same cost as tees.
5. Costs for expansion joints are based on quotations rolled into Sun estimate of $267,677 for nine. These costs were escalated from 2003 dollars to 2008 dollars using a factor of 1.53 derived from the CEP.
6. Based on e-mail from Chris Allen of Sun Coke. These costs were escalated from 2003 dollars to 2008 dollars using a factor of 1.26 derived from the CEP.
7. Contingency is adjusted from 3 to 15% since this system has never been used with this technology.
Middletown Coke Company  
HRSG Maintenance BACT Analysis  
Option 1 - Individual Spray Quenches  

Operation and Maintenance Costs  

A. Direct Annual Costs (DAC)  
1. Operating Labor ($30/hr, 8 hr/shift, 3 shifts/day, 50 days/yr) $36,000 Note 2  
2. Supervisory Labor (15% of Operating Labor) $5,400  
3. Maintenance Labor & Materials (5% of TCI factored by 10 days of maint.) $24,569  
4. Replacement Materials (refractory replacement every 5 yrs) $70,070 Note 3  
5. Electricity @ $0.06/kW-hr × 180.6 kW × 1200 hr $13,000 Note 4  
6. Water 10,296,000 gal/yr × $0.0002/gal $2,059 Note 5  
7. Quick lime, 319.8 tons @ $90/ton $28,782 Note 6  
8. Waste disposal, 807.5 tons @ $34.86/ton $28,149 Note 7  

***TOTAL DIRECT ANNUAL COSTS*** $208,030  

B. Indirect Annual Costs (IAC)  
1. Overhead (60% of sum of all labor and maintenance materials) $39,582  
2. Administrative (0.02*TCIC) $358,712  
3. Property Tax (0.01*TCIC) $179,356  
4. Insurance (0.01*TCIC) $179,356  

***TOTAL INDIRECT ANNUAL COSTS*** $757,006  

***TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS*** $965,036  
(DAC+IAC+OC)  

1. Indirect Cost factors are derived from Estimating Costs of Air Pollution Control, William M. Vatavuk, Lewis Publishers (1990), pp. 29 and 30.  
3. Refractory replacement materials assumed to be 1/3 the PEC of the hot duct.  
4. Electricity usage for pumping water to the spray quench was estimated using the performance data of the water pump (Goulds quote). Electricity usage of air compressor was estimated using the power rating of the compressor (Ingersoll-Rand quote). Electricity cost from Electric Power Monthly, August 2008.  
5. Water requirement estimated using the calculated water flow rate of 143 gpm to the spray quench and 1200 operating hrs/yr (10 days x 24 hrs/day x 5 spray quenches). Water costs are derived from Estimating Costs of Air Pollution Control, William M. Vatavuk, Lewis Publishers (1990), p. 191.  
6. Quick lime requirement estimated assuming 1.1 reagent stoichiometric ratio, 90% reagent purity, 10 days per HRSG per year, and a calculated SO2 inlet rate of 498.3 lb/hr per HRSG. Quick lime cost from USGS Mineral Commodity Summaries, Jan 2008.  
7. Total solid waste tonnage calculated using assumptions in Note (6) and 90% SO2 removal efficiency. Waste disposal costs obtained from Sun Coke operations at the Haverhill North Coke Company.
**Middletown Coke Company**

**HRSG Maintenance BACT Analysis**

**Option 1 - Individual Spray Quenches**

---

**Cost Effectiveness**

<table>
<thead>
<tr>
<th>Cost Base</th>
<th>Cost Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008 dollars</td>
<td>2008 dollars</td>
</tr>
</tbody>
</table>

**A. Total Annualized Costs (incl. Capital and O&M)**

1. Annualized Capital Investment Cost (ACIC)
   - Expected Lifetime of Equipment (yrs): 15
   - Interest Rate: 0.07
   - Capital Recovery Factor (CRF): 0.1098
   - Total Capital Investment Costs (TCIC): $17,935,606

   **ANNUALIZED CAPITAL INVESTMENT COSTS**
   - $1,969,233

2. Annual O&M Costs (O&M)
   - $965,036

   **TOTAL ANNUALIZED COSTS**
   - $2,934,269

**B. PM Removal per Year**

1. Baseline PM level (tons/yr) (1200 hrs of venting during HRSG maint.): 12.60
2. Controlled PM level (tons/yr) (1200 hrs of controlled PM emissions using Option 1): 1.29

   **PM Removed per year (tons/yr)**
   - 11.31

   **PM Emissions per year (tons/yr)**
   - 1.29

   **COST EFFECTIVENESS ($/ton PM removed)**
   - $259,342

The Capital Recovery Factor is derived from EPA Air Pollution Control Cost Manual, Sixth Ed., EPA/452/B-02-001, January 2002, Chapter 2, p. 2-21, based on the lifetime and interest rate shown.
Sun Heat Recovery Coke Facility
Process Flow Diagram
Middletown Coke Company 100 Oven Case #1 - 24.5 VM

Water Vapor, H2O 11.39%
Carbon Dioxide, CO2 7.29% volume, dry
Sulfur Dioxide, SO2 0.10% volume, dry
Nitrogen, N2 83.02% volume, dry
Oxygen, O2 9.60% volume, dry
SO2 Concentration, PPM 979

Collection duct from 7 additional HRSGs
Primary HRSG
SDA
Baghouse
ID Fans
Main Stack

This option assumes 3 additional HRSGs installed along the common tunnel. When a HRSG is taken offline for inspection/maintenance, the flue gases will be redistributed to the nearest HRSG(s).

Heat Rate Flow Rate
598.11 MMBtu/hr (Avg)
1,268,868 Lbs/hr (avg)

Coal
1,634 F Flue Gas
1,634 Tons / Charge
50.00 100 Heat Recovery Coke Ovens

Run-of-Oven Coke
Furnace Coke
Breeze

Flow Rate Per HRSG
Average Flow 253,774 Lbs/hr
Normal Peak Flow 342,594 Lbs/hr
Design Peak Flow 456,678 Lbs/hr
# Middletown Coke Company

**HRSG Maintenance BACT Analysis**

**Option 2 - Addition of HRSGs**

<table>
<thead>
<tr>
<th>Control Alternative</th>
<th>Total Emissions</th>
<th>Economic Impacts</th>
<th>Environmental Impacts</th>
<th>Energy Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Installed Capital Cost ($)</td>
<td>Total Annualized Cost ($/yr)</td>
<td>Average Cost Effectiveness ($/ton)</td>
</tr>
<tr>
<td>Addition of HRSGs</td>
<td>Uncontrolled Emission Rate (gr/dscf) 0.049</td>
<td>Controlled Emission Rate (gr/dscf) 0.005</td>
<td>Emission Reduction (tpy) 10.7</td>
<td>Installed Capital Cost $35,520,812</td>
</tr>
</tbody>
</table>

Energy credit from 2.74% power production increase due to additional HRSG operating hours.
**Middletown Coke Company**  
**HRSG Maintenance BACT Analysis**  
**Option 2 - Addition of HRSGs**

### Total Capital Investment Cost

#### A. Direct Capital Cost (DCC)

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost Base</th>
<th>Source of Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Purchased Equipment Cost (PEC)</td>
<td>2008 dollars</td>
<td></td>
</tr>
<tr>
<td>Primary and Auxiliary Equipment (EOP)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Additional HRSGs (3 required)</td>
<td>$9,969,000</td>
<td>Note 2</td>
</tr>
<tr>
<td>b. Vent stack (including &quot;Tee&quot;, stack lid, and peripherals) (3 required)</td>
<td>$585,036</td>
<td>Note 3</td>
</tr>
<tr>
<td>c. Increase in common tunnel size, 1500 ft @ $1000/ft for increased dia</td>
<td>$1,500,000</td>
<td>Note 4</td>
</tr>
<tr>
<td>d. Hot duct, 8.5 ft ID, 90 ft length per HRSG @ $1,911/ft (3 HRSGs)</td>
<td>$515,970</td>
<td>Note 5</td>
</tr>
<tr>
<td>e. Hot duct expansion joints (3 required)</td>
<td>$136,515</td>
<td>Note 6</td>
</tr>
<tr>
<td>f. Isolation knife gate (3 required)</td>
<td>$90,720</td>
<td>Note 7</td>
</tr>
<tr>
<td>g. Cold duct, 64 ft length per HRSG @ $1,812/ft (3 HRSGs)</td>
<td>$347,904</td>
<td>Note 8</td>
</tr>
<tr>
<td><strong>Equipment Costs Summary:</strong></td>
<td><strong>$13,145,145</strong></td>
<td></td>
</tr>
<tr>
<td>Instrumentation (0.1*Equipment Costs)</td>
<td>$1,314,515</td>
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</tr>
<tr>
<td>Freight (0.05*Equipment Costs)</td>
<td>$657,257</td>
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</tr>
<tr>
<td>Sales Tax (0.03*Equipment Costs)</td>
<td>$394,354</td>
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<tr>
<td><strong>TOTAL PURCHASED EQUIPMENT COST</strong>*</td>
<td><strong>$15,511,271</strong></td>
<td></td>
</tr>
</tbody>
</table>

#### B. Indirect Capital Cost (ICC)

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost Base</th>
<th>Source of Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Engineering (0.10*PEC)</td>
<td>$1,551,127</td>
<td></td>
</tr>
<tr>
<td>2. Construction and Field Expenses (0.20*PEC)</td>
<td>$3,102,254</td>
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</tr>
<tr>
<td>3. Construction Fee (0.10*PEC)</td>
<td>$1,551,127</td>
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</tr>
<tr>
<td>4. Startup (0.01*PEC)</td>
<td>$155,113</td>
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</tr>
<tr>
<td>5. Performance Test (0.01*PEC)</td>
<td>$155,113</td>
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<tr>
<td><strong>TOTAL INDIRECT CAPITAL COST</strong>*</td>
<td><strong>$6,514,734</strong></td>
<td></td>
</tr>
</tbody>
</table>

#### C. Contingency (CONT) (0.15*PEC)

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost Base</th>
<th>Source of Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOTAL CAPITAL INVESTMENT COST</strong>*</td>
<td><strong>$35,520,812</strong></td>
<td></td>
</tr>
</tbody>
</table>

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2. HRSGs cost based on Nooter Eriksen purchase order of $16,615,000 for 5 HRSGs. See email from Chris Sharp, dated 11/21/08.
3. Costs for vent stack are based on quotations rolled into Sun estimate for five stacks @ $975,060/5 = $195,012/stack.
4. A larger common tunnel along the length of the battery (1500 ft) would be required for this option. Costs for the increase in common tunnel size were estimated by Sun Coke to be $1,000/ft.
5. Costs for hot duct are based on quotations rolled into Sun Estimate of $921,873 for 9 ducts with 82 ft length each. These costs were escalated from 2003 dollars to 2008 dollars using a factor of 1.53 derived from the CEP.
6. Costs for expansion joints are based on quotations rolled into Sun estimate of $267,677 for nine. These costs were escalated from 2003 dollars to 2008 dollars using a factor of 1.53 derived from the CEP.
7. Based on e-mail from Chris Allen of Sun Coke. These costs were escalated from 2003 dollars to 2008 dollars using a factor of 1.26 derived from the CEP.
8. Costs for cold duct are based on quotations rolled into Sun Estimate of $2,900,000 for 1600 ft length.
9. Contingency is adjusted from 3 to 15% since this system arrangement has never been used with this technology.
## Middletown Coke Company
### HRSG Maintenance BACT Analysis
#### Option 2 - Addition of HRSGs

**Operation and Maintenance Costs**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost Base</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Direct Annual Costs (DAC)</strong></td>
<td></td>
</tr>
<tr>
<td>1. Operating Labor ($30/hr, 8 hr/shift, 3 shifts/day, 365 days/yr)</td>
<td>$262,800 Note 2</td>
</tr>
<tr>
<td>2. Supervisory Labor (15% of Operating Labor)</td>
<td>$39,420</td>
</tr>
<tr>
<td>3. Maintenance Labor &amp; Materials</td>
<td>$420,000 Note 3</td>
</tr>
<tr>
<td>4. Quick lime, 319.8 tons @ $90/ton</td>
<td>$28,782 Note 4</td>
</tr>
<tr>
<td>5. Waste disposal, 807.5 tons @ $34.86/ton</td>
<td>$28,149 Note 5</td>
</tr>
<tr>
<td><strong>TOTAL DIRECT ANNUAL COSTS</strong>*</td>
<td>$751,002</td>
</tr>
<tr>
<td><strong>B. Indirect Annual Costs (IAC)</strong></td>
<td></td>
</tr>
<tr>
<td>1. Overhead (60% of sum of all labor and maintenance materials)</td>
<td>$433,332</td>
</tr>
<tr>
<td>2. Administrative (0.02*TCIC)</td>
<td>$710,416</td>
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<tr>
<td>3. Property Tax (0.01*TCIC)</td>
<td>$355,208</td>
</tr>
<tr>
<td>4. Insurance (0.01*TCIC)</td>
<td>$355,208</td>
</tr>
<tr>
<td><strong>TOTAL INDIRECT ANNUAL COSTS</strong>*</td>
<td>$1,854,164</td>
</tr>
<tr>
<td><strong>TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS</strong>*</td>
<td>$2,605,166</td>
</tr>
</tbody>
</table>

(DAC+IAC+OC)

1. Indirect Cost factors are derived from Estimating Costs of Air Pollution Control, William M. Vatavuk, Lewis Publishers (1990), pp. 29 and 30.
3. Based on Sun Coke estimate of $140,000 per HRSG per year.
4. Quick lime requirement estimated assuming 1.1 reagent stoichiometric ratio, 90% reagent purity, 10 days per HRSG per year, and a calculated SO2 inlet rate of 498.3 lb/hr per HRSG. Quick lime cost from USGS Mineral Commodity Summaries, Jan 2008.
5. Total solid waste tonnage calculated using assumptions in Note (4) and 90% SO2 removal efficiency. Waste disposal costs obtained from Sun Coke operations at the Haverhill North Coke Company.
## Middletown Coke Company
### HRSG Maintenance BACT Analysis
#### Option 2 - Addition of HRSGs

### Cost Effectiveness

<table>
<thead>
<tr>
<th>Cost Effectiveness</th>
<th>Cost Base</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Total Annualized Costs (incl. Capital and O&amp;M)</strong></td>
<td>2008 dollars</td>
</tr>
<tr>
<td>1. Annualized Capital Investment Cost (ACIC)</td>
<td></td>
</tr>
<tr>
<td>Expected Lifetime of Equipment (yrs)</td>
<td>15</td>
</tr>
<tr>
<td>Interest Rate</td>
<td>0.07</td>
</tr>
<tr>
<td>Capital Recovery Factor (CRF)</td>
<td>0.1098</td>
</tr>
<tr>
<td>Total Capital Investment Costs (TCIC)</td>
<td>$35,520,812</td>
</tr>
<tr>
<td><strong>ANNUALIZED CAPITAL INVESTMENT COSTS</strong></td>
<td>$3,899,994</td>
</tr>
<tr>
<td>(TCIC \times CRF)</td>
<td></td>
</tr>
<tr>
<td>2. Annual O&amp;M Costs (O&amp;M)</td>
<td>$2,605,166</td>
</tr>
<tr>
<td>3. Annual Power Revenue Increase (Credit) (PRI)</td>
<td></td>
</tr>
<tr>
<td>2.74% increase in power revenue due to additional HRSG operating hours</td>
<td></td>
</tr>
<tr>
<td>($45/MWH \times 45.6 MW \times 8760 \text{ hr/yr} \times 2.74%)</td>
<td>($492,529)</td>
</tr>
<tr>
<td><strong>TOTAL ANNUALIZED COSTS</strong></td>
<td>$6,012,631</td>
</tr>
<tr>
<td>(ACIC+O&amp;M+PRI)</td>
<td></td>
</tr>
<tr>
<td><strong>B. PM Removal per Year</strong></td>
<td></td>
</tr>
<tr>
<td>1. Baseline PM level (tons/yr) (1200 hrs of venting during HRSG maint.)</td>
<td>12.60</td>
</tr>
<tr>
<td>2. Controlled PM level (tons/yr) (1200 hrs of controlled PM emissions using Option 2)</td>
<td>1.29</td>
</tr>
<tr>
<td><strong>PM Removed per year (tons/yr)</strong></td>
<td>11.31</td>
</tr>
<tr>
<td><strong>PM Emissions per year (tons/yr)</strong></td>
<td>1.29</td>
</tr>
<tr>
<td><strong>COST EFFECTIVENESS ($/ton PM removed)</strong></td>
<td>$531,419</td>
</tr>
</tbody>
</table>

Middletown Coke Company
Spray Dryer/Baghouse Maintenance BACT Analysis
Redundant Spray Dryer/Baghouse System

Sun Heat Recovery Coke Facility
Process Flow Diagram
Middletown Coke Company 100 Oven Case #1 - 24.5 VM

Coal

50.00 Tons/Charge

1,634 F Flue Gas

100 Heat Recovery Coke Ovens

Run-of-Oven Coke

Steam

Collection duct from 4 additional HRSGs

Primary SD/BH System

HRSG

SDA

Baghouse

Bypass during primary SD/BH inspection and maintenance

Redundant SD/BH System

SDA

Baghouse

Furnace Coke Breeze

Flow Rate Per HRSG
Average Flow 253,774 lbs/hr
Normal Peak Flow 342,594 lbs/hr
Design Peak Flow 456,678 lbs/hr

Water Vapor, H2O 11.39%
Carbon Dioxide, CO2 7.29% volume, dry
Sulfur Dioxide, SO2 0.10% volume, dry
Nitrogen, N2 83.02% volume, dry
Oxygen, O2 9.60% volume, dry
SO2 Concentration, PPM 979

Heat Rate 598.11 MMBtu/Hr (Avg)
Flow Rate 1,268,868 Lbs/Hr (avg)

Breeze Design Peak Flow 456,678

ID Fans

Main Stack

Heat Rate 598.11 MMBtu/Hr (Avg)
Flow Rate 1,268,868 Lbs/Hr (avg)
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<table>
<thead>
<tr>
<th>Control Alternative</th>
<th>Total Emissions</th>
<th>Economic Impacts</th>
<th>Environmental Impacts</th>
<th>Energy Impacts</th>
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<tbody>
<tr>
<td></td>
<td>Uncontrolled Emission Rate (gr/dscf)</td>
<td>Controlled Emission Rate (gr/dscf)</td>
<td>Emission Reduction (lb/hr)</td>
<td>Installed Capital Cost ($)</td>
</tr>
<tr>
<td>Redundant SD/BH</td>
<td>0.049</td>
<td>105.0</td>
<td>0.005</td>
<td>10.7</td>
</tr>
</tbody>
</table>
## Total Capital Investment Cost

### A. Direct Capital Cost (DCC)

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost Base</th>
<th>Source of Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Purchased Equipment Cost (PEC) 2008 dollars</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary and Auxiliary Equipment (EQP)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Redundant spray dryer/baghouse system</td>
<td>$14,617,000</td>
<td>Note 2</td>
</tr>
<tr>
<td>b. Additional cold duct with elbows, dampers, and &quot;Tee&quot;</td>
<td>$1,450,000</td>
<td>Note 3</td>
</tr>
<tr>
<td>Equipment Costs Summary:</td>
<td>$16,067,000</td>
<td></td>
</tr>
<tr>
<td>Instrumentation (0.1*Equipment Costs)</td>
<td>$1,606,700</td>
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</tr>
<tr>
<td>Freight (0.05*Equipment Costs)</td>
<td>$803,350</td>
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</tr>
<tr>
<td>Sales Tax (0.03*Equipment Costs)</td>
<td>$482,010</td>
<td></td>
</tr>
<tr>
<td><em><strong>TOTAL PURCHASED EQUIPMENT COST</strong></em></td>
<td>$18,959,060</td>
<td></td>
</tr>
</tbody>
</table>

### A.1. Direct Installation Cost (DIC) (0.72*PEC)

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost Base</th>
<th>Source of Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td><em><strong>TOTAL DIRECT INSTALLATION COST</strong></em></td>
<td>$13,650,523</td>
<td></td>
</tr>
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</table>

### A.2. Site Prep (SP) as required

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Prep (SP) as required</td>
<td>$0</td>
</tr>
</tbody>
</table>

### A.3. Buildings (BLDG) as required

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buildings (BLDG) as required</td>
<td>$0</td>
</tr>
</tbody>
</table>

### A.4. Total Direct Capital Cost (PEC+DIC+SP+BLDG)

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost Base</th>
</tr>
</thead>
<tbody>
<tr>
<td><em><strong>TOTAL DIRECT CAPITAL COST</strong></em></td>
<td>$32,609,583</td>
</tr>
</tbody>
</table>

### B. Indirect Capital Cost (ICC)

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Engineering (0.10*PEC)</td>
<td>$1,895,906</td>
</tr>
<tr>
<td>2. Construction and Field Expenses (0.20*PEC)</td>
<td>$3,791,812</td>
</tr>
<tr>
<td>3. Construction Fee (0.10*PEC)</td>
<td>$1,895,906</td>
</tr>
<tr>
<td>4. Startup (0.01*PEC)</td>
<td>$189,591</td>
</tr>
<tr>
<td>5. Performance Test (0.01*PEC)</td>
<td>$189,591</td>
</tr>
<tr>
<td><em><strong>TOTAL INDIRECT CAPITAL COST</strong></em></td>
<td>$7,962,805</td>
</tr>
</tbody>
</table>

### C. Contingency (CONT) (0.15*PEC)

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contingency (CONT) (0.15*PEC)</td>
<td>$2,843,859</td>
</tr>
</tbody>
</table>

### ***TOTAL CAPITAL INVESTMENT COST*** (TCIC)

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost Base</th>
</tr>
</thead>
<tbody>
<tr>
<td><em><strong>TOTAL CAPITAL INVESTMENT COST</strong></em> (TCIC)</td>
<td>$43,416,247</td>
</tr>
</tbody>
</table>

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2. Redundant SD/BH system cost based on Hamon purchase order of $14,617,000 for the primary SD/BH system. See email from Chris Sharp, dated 11/21/08.
3. Cost of additional cold duct and associated fittings/materials required for the redundant SD/BH system was assumed to be 50% of the cost for the primary SD/BH system. The primary system cold duct costs were taken from the Kokosing MCC schedule of value provided by Chris Sharp in the 11/21/08 email (Materials was assumed to be 50% of the total installed cost).
4. Contingency is adjusted from 3 to 15% since this system arrangement has never been used with this technology.
Middletown Coke Company
Spray Dryer/Baghouse Maintenance BACT Analysis
Redundant Spray Dryer/Baghouse System

Operation and Maintenance Costs

Cost Base
2008 dollars

A. Direct Annual Costs (DAC)
1. Operating Labor ($30/hr, 40 hr/shift, 3 shifts/day, 10 days/yr) $36,000 Note 2
2. Supervisory Labor (15% of Operating Labor) $5,400
3. Maintenance Labor & Materials (5% of TCI factored by 10 oper/maint days) $59,474
4. Electricity @ $0.06/kW-hr × 3510.6 kW × 120 hr $25,276 Note 3
5. Water 632,160 gal/yr × $0.0002/gal $126 Note 4
6. Quick lime, 159.9 tons @ $90/ton $14,391 Note 5
7. Waste disposal, 403.8 tons @ $34.86/ton $14,076 Note 6

***TOTAL DIRECT ANNUAL COSTS*** $140,668

B. Indirect Annual Costs (IAC)
1. Overhead (60% of sum of all labor and maintenance materials) $60,525
2. Administrative (0.02*TCIC) $868,325
3. Property Tax (0.01*TCIC) $434,162
4. Insurance (0.01*TCIC) $434,162

***TOTAL INDIRECT ANNUAL COSTS*** $1,797,174

***TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS*** $1,937,843 (DAC+IAC+OC)

1. Indirect Cost factors are derived from Estimating Costs of Air Pollution Control, William M. Vatavuk, Lewis Publishers (1990), pp. 29 and 30.
2. Operating labor based on 5 operating personnel working 8 hour shifts during 5 days of the redundant SD/BH operation and an assumed 5 days of startup/shutdown activities associated with the redundant system. Operating labor estimate based on "Flue Gas Desulfurization Technology Evaluation", National Lime Association, March 2007 pp 40.
3. Electricity requirement is based on 4000 HP for the ID fans, atomizers, pumps, and lime slaker and fan motor/pump efficiencies of 85%. Electricity cost from Electric Power Monthly, August 2008.
4. Water requirement estimated using the calculated water flow rate of 87.8 gpm to the spray dryer and 120 operating hrs/yr (5 days x 24 hrs/day). Water costs are derived from Estimating Costs of Air Pollution Control, William M. Vatavuk, Lewis Publishers (1990), p. 191.
5. Quick lime requirement estimated assuming 1.1 reagent stoichiometric ratio, 90% reagent purity, 5 days of SD/BH maintenance per year, and a calculated SO2 inlet rate of 2492 lb/hr. Quick lime cost from USGS Mineral Commodity Summaries, Jan 2008.
6. Total solid waste tonnage calculated using assumptions in Note (5) and 90% SO2 removal efficiency. Waste disposal costs obtained from Sun Coke operations at the Haverhill North Coke Company.
Middletown Coke Company  
Spray Dryer/Baghouse Maintenance BACT Analysis  
Redundant Spray Dryer/Baghouse System

Cost Effectiveness

A. Total Annualized Costs (incl. Capital and O&M)
   1. Annualized Capital Investment Cost (ACIC)
      Expected Lifetime of Equipment (yrs) 15
      Interest Rate 0.07
      Capital Recovery Factor (CRF) 0.1098
      Total Capital Investment Costs (TCIC) $43,416,247
      ***ANNUALIZED CAPITAL INVESTMENT COSTS*** $4,766,871
      (TCIC x CRF)

   2. Annual O&M Costs (O&M) $1,937,843

   ***TOTAL ANNUALIZED COSTS*** $6,704,713
   (ACIC+O&M+PRI)

B. PM Removal per Year
   1. Baseline PM level (tons/yr) (120 hrs of venting during SD/BH maint.) 6.30
   2. Controlled PM level (tons/yr) (120 hrs of controlled PM using the redundant SD/BH) 0.64

   ***PM Removed per year (tons/yr)*** 5.66
   ***PM Emissions per year (tons/yr)*** 0.64

   ***COST EFFECTIVENESS ($/ton PM removed)*** $1,185,177

The Capital Recovery Factor is derived from EPA Air Pollution Control Cost Manual, Sixth Ed., EPA/452/B-02-001, January 2002, Chapter 2, p. 2-21, based on the lifetime and interest rate shown.
PURPOSE:
This calculation estimates the flow rate and gas composition of the combustion gas stream from one battery of 100 coke ovens after water quenching to cool gas when 1 HRSG is off line for inspection.

ASSUMPTIONS:
1. The flue gas to each HRSG that will be routed to the water quench has the following flow and composition:
   - Maximum Flow = 89,977 dscfm
   - Maximum Flow = 401,255 acfm
   - Maximum Flow = 101,547 wscfm
   - Average Flow = 56,429 wscfm
   - Temperature = 1,634 °F
   - Moisture = 11.39% vol
   - O₂, dry basis = 9.60% vol
   - CO₂, dry basis = 7.29% vol
   - SO₂, dry basis = 0.098% vol
   - N₂, dry basis = 0.83% vol
   - CO and NOX at ppm levels

   1. These values were taken from the heat and material balance Excel workbook “HMB_MMC100-24.5VM-50ton-8H2O”, sheet “FG_Design Rates” supplied by Richard Westbrook. The column “Select” was used for these values.

2. These values were taken from the heat and material balance Excel workbook “HMB_MMC100-24.5VM-50ton-8H2O”, sheet “Flue Gas Composition” supplied by Richard Westbrook. The column “Select” was used for these values.

2. The required spray quench outlet temperature will be controlled between 350 and 450 °F, with a design outlet temperature of 400 °F.

3. Heat loss from the ducting and quench is zero; all temperature reduction is due to evaporative cooling.

4. Spray cooling water is at 68 °F with no appreciable solids or other contaminants requiring consideration in the material balance.
5. Standard conditions are 68 °F and 1 atm pressure.

6. Specific heats for combustion gases are taken from Perry’s Chemical Engineers Handbook, Fifth Edition, p. 3-119 to 3-125, based on the average of the heat capacities at 1,634 °F and 400 °F:

   - Water vapor = 0.522 Btu/lb-°F
   - CO2 = 0.275 Btu/lb-°F
   - N2 = 0.261 Btu/lb-°F
   - O2 = 0.25 Btu/lb-°F
   - SO2 = 0.178 Btu/lb-°F

7. The specific heat of liquid water is assumed constant at 1 Btu/lb-°F. The specific heat of water vapor from 212 °F to 400 °F is taken from Perry’s, assuming an average of 0.474 Btu/lb-°F. The heat of vaporization of water is 970.3 Btu/lb.

**CALCULATIONS:**

The required heat transfer to the spray quench water is equal to the enthalpy loss required to take the gas from 1,634 °F to 400 °F. The mass flow of each of the major gases (water, N2, O2, CO2, and SO2) is calculated as follows (ignoring the particulate and gases present in ppm concentrations):

1. \( F_{M,Ti} = 60 \text{ min/hr} \times [F_{Vd} \div (1 - M_{fi})] \div 385.30 \text{ ft}^3/\text{lb-mol} \)

   Where:
   - \( F_{M,Ti} \) = Total molar flow rate of combustion gas into the quench (lb-mol/hr)
   - \( F_{Vd} \) = Volumetric flow rate of dry gas into the quench (dscfm)
   - \( M_{fi} \) = Moisture fraction in combustion gas into the quench, by volume

   \( 385.30 \text{ ft}^3/\text{lb-mol} = \) Molar volume of an ideal gas at standard temperature and pressure of 68 °F and 1 atm

2. \( F_{M,Ti} = 60 \text{ min/hr} \times [89,977 \text{ dscfm} \div (1 - 0.1139)] \div 385.30 \text{ ft}^3/\text{lb-mol} \)

   \( F_{M,Ti} = 15,813 \text{ lb-mol/hr} \)

The moisture flow is then:
3. \[ F_{m,w} = 15,813 \text{ lb-mol/hr} \times 18 \text{ lb/lb-mol} \times 0.1139 = 32,428 \text{ lb/hr} \]

Where:
\( F_{m,w} \) = The mass flow of water in the combustion gas stream into the quench

The molar flow of the dry gas is:

4. \[ F_{M,d} = F_{V,d} \times 60 \text{ min/hr} \div 385.30 \text{ ft}^3/\text{lb-mol} \]

Where:
\( F_{M,d} \) = Molar flow of dry gas into the quench (lb-mol/hr)

5. \[ F_{M,d} = 89,977 \times 60 \div 385.30 = 14,012 \text{ lb-mol/hr} \]

The molar flows of oxygen, carbon dioxide, nitrogen, and sulfur dioxide are based on the percentages in Assumption 1:

6. \[ F_{M,O2} = 14,012 \times 0.0960 = 1,344.9 \text{ lb-mol/hr} \]

7. \[ F_{M,CO2} = 14,012 \times 0.0729 = 1,021.0 \text{ lb-mol/hr} \]

8. \[ F_{M,N2} = 14,012 \times 0.8302 = 11,632.0 \text{ lb-mol/hr} \]

9. \[ F_{M,SO2} = 14,012 \times 0.00098 = 13.7 \text{ lb-mol/hr} \]

The mass flow of each gas is based on molecular weight:

10. \[ F_{m,O2} = 1,344.9 \text{ lb-mol/hr} \times 32 \text{ lb/lb-mol} = 43,036 \text{ lb/hr} \]

11. \[ F_{m,CO2} = 1,021.0 \text{ lb-mol/hr} \times 44 \text{ lb/lb-mol} = 44,924 \text{ lb/hr} \]

12. \[ F_{m,N2} = 11,632.0 \text{ lb-mol/hr} \times 28 \text{ lb/lb-mol} = 325,695 \text{ lb/hr} \]

13. \[ F_{m,SO2} = 13.7 \text{ lb-mol/hr} \times 64 \text{ lb/lb-mol} = 878 \text{ lb/hr} \]

The enthalpy to cool each gas constituent to 400°F is based on the mass flow of each gas and the
The total enthalpy required to cool the entire gas stream is:

19. \( E_{AT,T} = 20.89 + 13.28 + 15.25 + 104.92 + 0.19 \) 
   \( E_{AT,T} = 154.53 \) MMBtu/hr

The enthalpy to heat the water from 68 °F liquid to 400 °F vapor is split into three parts: 1) the specific heat of liquid water, 2) the heat of vaporization at 212 °F, and 3) the specific heat of water vapor from 212 °F to 400 °F.

20. \( E_{VW,68 - 400} = [1 \text{ Btu/lb} \times (212 - 68)] + 970.3 \text{ Btu/lb} + [0.474 \text{ Btu/lb} \times (400 - 212)] \) 
    \( E_{VW,68 - 400} = 1,203.4 \) Btu/lb

The water required for spray quenching is therefore:

21. \( F_{m,\text{quench}} = 154.53 \text{ MMBtu/hr} \times 10^6 \div 1,203.4 \text{ Btu/lb} = 128,413 \text{ lb/hr} \)

Expressed as a volumetric flow:

22. \( F_{v,\text{quench}} = 128,413 \text{ lb/hr} \div 8.34 \text{ lb/gal} \div 60 \text{ min/hr} = 257 \text{ gpm} \)
This flow establishes the capacity of the required spray quench pumps. The pump head required is based on the use of a required nozzle pressure of 100 psig (230 ft TDH), a nozzle height of 80 ft, and 16 ft TDH piping loss (assuming 5% of total pump head), for a pump requirement of 326 ft TDH.

Expressed as a molar flow:

23. \( F_{M,\text{quench}} = \frac{128,413 \text{ lb/hr}}{18 \text{ lb/lb-mol}} = 7,134.1 \text{ lb-mol/hr} \)

The total molar gas flow out of the quench is therefore:

24. \( F_{M,T_0} = 15,813.1 \text{ lb-mol/hr} + 7,134.1 \text{ lb-mol/hr} = 22,947.2 \text{ lb-mol/hr} \)

Expressed as a volumetric flow:

25. \( F_{V,T_0} = \frac{22,947.2 \text{ lb-mol/hr} \times 385.30 \text{ ft}^3/\text{lb-mol} \times 60 \text{ min/hr}}{60 \text{ min/hr}} = 147,359 \text{ scfm} \)

The percentage increase in maximum flow is therefore:

26. \( \Delta F_{\text{wscfm},1 \text{ HRSG},\text{max}} = \left[ \frac{147,359}{101,547} - 1 \right] \times 100 = 45.1 \% \)

This flow increase establishes the required increase in the size of ductwork downstream of each spray quench.

The percentage increase in average flow will be the same percentage, since the flue gas composition and temperature are assumed to be the same at both flow conditions. The average usage rate for water is therefore proportional to the difference in wet flow rates. The average water usage rate is calculated as:

27. \( F_{m,\text{quench},\text{av}} = \frac{128,413 \text{ lb/hr} \times 56,429 \text{ wscfm} \div 101,547 \text{ wscfm}}{71,358 \text{ lb/hr}} \)

Converting to gpm:

28. \( F_{v,\text{quench},\text{av}} = \frac{71,358 \text{ lb/hr} \div 8.34 \text{ lb/gal} \div 60 \text{ min/hr}}{143 \text{ gpm}} \)

This flow establishes the water usage rate for each HRSG.
The peak molar flow (from Equation 2) from 5 HRSGs during normal operation is:

29. \[ F_{M,5\text{ HRSG, max}} = 15,813 \text{ lb-mol/hr} \times 5 = 79,066 \text{ lb-mol/hr} \]

The peak flow when one HRSG is off line with its bypass cooled via spray quench is:

30. \[ F_{M,4\text{ HRSG & 1 quench, max}} = 15,813 \text{ lb-mol/hr} \times 4 + 22,947 \text{ lb-mol/hr} \]
\[ F_{M,4\text{ HRSG & 1 quench, max}} = 86,200 \text{ lb-mol/hr} \]

The percentage increase in flow to the central treatment system is:

31. \[ \Delta F_{wscfm,5\text{ HRSG, max}} = \left( \frac{86,200}{79,066} \right) - 1 \times 100 = 9.02\% \]

This increase establishes the required size increase for the central SO$_2$ scrubber system.
PURPOSE:
This calculation estimates the increase in size and costs for the existing SO₂ scrubber system if flue gas bypassing one HRSG is cooled by spray quenching and routed to the central SO₂ scrubber system.

ASSUMPTIONS:
1. See Calculation 1, Water Quenching Material Balance, for calculation of flows.

2. The equipment purchase costs for one planned SO₂ scrubber system, designed to handle flows from 5 HRSGs without quenching, are based on the attached proposals for that system, summarized below:

   - DFGD System = $14,617,000 (includes ID fans)
   - Compressed Air System = $100,000
   - Ash System = $1,200,000
   - Stack = $1,100,000
   - Total for SO₂ System = $17,017,000
   - Ductwork = $2,900,000

3. The exponents used for deriving costs for increased equipment sizes are taken from Perry’s Chemical Engineering Handbook, Sixth Edition, pp. 25–69 (attached). An exponent of 0.6 was assumed for equipment not included in the list on that table (noted as default). The exponents used are:

   - DFGD System = 0.545 (avg. of vertical vessel and dust collector)
   - Compressed Air System = 0.84 (compressor)
   - Ash System = 0.50 (based on conveyor systems)
   - Stack = 1.00 (stack)
   - Ductwork = 0.60 (default)

4. The increase in ductwork costs are based on the increase in flow from one HRSG of 45.1%, since the collection duct sizing will require an increase at each HRSG, even though only one unit will operate at the same time (see Calculation 1, Equation 26). The increase in other SO₂ scrubber costs is based on the increased flow in the combined gas stream of 9.02% (see Calculation 1, Equation 31).

   - Increase in maximum flow from one HRSG = 45.1 % (Calc. 1, Eq. 26)
   - Increase in flow to central treatment system = 9.02 % (Calc. 1, Eq. 31)
CALCULATIONS:
The exponents are used per the method in Perry’s to derive the cost factor for each item:

1. DFGD System = \( 1.0902^{0.545} = 1.0482 \)
2. Compressed Air System = \( 1.0902^{0.84} = 1.0753 \)
3. Ash System = \( 1.0902^{0.50} = 1.0441 \)
4. Stack = \( 1.0902^{1.00} = 1.0902 \)
5. Ductwork = \( 1.4511^{0.60} = 1.2503 \)

The costs for the equipment sized to accommodate the increased flows from spray quenching are therefore:

6. DFGD System = $14,617,000 \times 1.0482 = $15,321,539
7. Compressed Air System = $100,000 \times 1.0753 = $107,530
8. Ash System = $1,200,000 \times 1.0441 = $1,252,920
9. Stack = $1,100,000 \times 1.0902 = $1,199,220
10. Total for \( \text{SO}_2 \) System = Sum of costs above = $17,881,209
11. Ductwork for System = $2,900,000 \times 1.2503 = $3,625,870

The cost differentials for the \( \text{SO}_2 \) system and ductwork due to quenching are:

12. \( \Delta \text{Cost}_{\text{SO}_2} = \) $17,881,209 - $17,017,000 = $864,209
13. \( \Delta \text{Cost}_{\text{Duct}} = \) $3,625,870 - $2,900,000 = $725,870