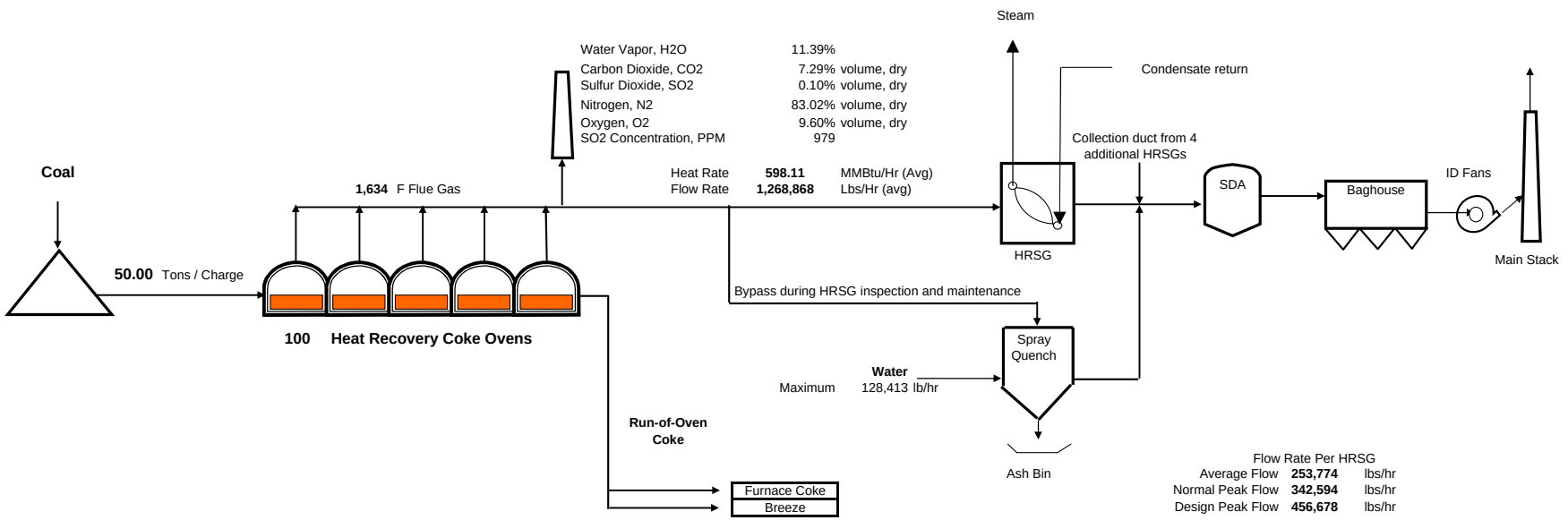
Middletown Coke Company
HRSG Maintenance BACT Analysis
Option 1 - Individual Spray Quenches

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



This page intentionally left blank.

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

Summary of Top-Down BACT Impact Analysis Results

	Total Emissions					**Economic Impacts**			**Environmental Impacts**		**Energy Impacts**
Control Alternative	Uncontrolled Emission Rate (gr/dscf)	Uncontrolled Emission Rate (lb/hr)	Controlled Emission Rate (gr/dscf)	Controlled Emission Rate (lb/hr)	Emission Reduction (tpy)	Installed Capital Cost ($)	Total Annualized Cost ($/yr)	Average Cost Effectiveness ($/ton)	Toxics Impact (yes/no)	Adverse Environmental Impacts (yes/no)	Incremental Increase Over Baseline (MW-hr/yr)
Individual Spray Quenches	0.049	105.0	0.005	10.7	11.31	$17,935,606	$2,934,269	$259,342	no	no	217

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

Total Capital Investment Cost

	Cost Base 2008 dollars	Source of Estimate
A. Direct Capital Cost (DCC)		
1. Purchased Equipment Cost (PEC)		
Primary and Auxillary Equipment (EQP)		
a. Spray quench towers with inlet refractory & rotary valves (5 required)	$3,500,000	SDS Inc. Quote
b. 8.5 ft ID "Tee", (5 required)	$189,934	Note 2
c. Hot duct, 8.5 ft ID, 110 ft length per HRSG @ $1,911/ft	$1,051,050	Note 3
d. Hot duct elbows, 3 per HRSG, 8.5 ft ID	$569,803	Note 4
e. Hot duct expansion joints (5 required)	$227,526	Note 5
f. Air compressor, 1,380 cfm @ 100 psig	$84,529	I-R Quote
g. Water pump (257 gpm @ 326 ft head - 5 required)	$28,900	Tencarva Quote
h. Isolation knife gate (5 required)	$151,200	Note 6
i. Flow control damper (5 required)	$94,500	Note 6
j. Increased SO_2 control system size	$864,209	Calc #2
k. Increased collection duct size (includes all steel ductwork)	$725,870	Calc #2
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***** (PEC+DIC+SP+BLDG)	**$13,783,027**	
B. Indirect Capital Cost (ICC)		
1. Engineering (0.10*PEC)	$883,527	
2. Construction and Field Expenses (0.10*PEC)	$883,527	
3. Construction Fee (0.10*PEC)	$883,527	
4. Startup (0.01*PEC)	$88,353	
5. Performance Test (0.01*PEC)	$88,353	
*****TOTAL INDIRECT CAPITAL COST*****	**$2,827,288**	
C. Contingency (CONT) (0.15*PEC)	**$1,325,291**	Note 7
*****TOTAL CAPITAL INVESTMENT COST*** (TCIC)** (DCC+ICC+CONT)	**$17,935,606**	

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 derivec 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	Cost Base 2008 dollars	
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.

2. Operating labor derived from Estimating Costs of Air Pollution Control, William M. Vatavuk, Lewis Publishers (1990), pp. 26 for venturi scrubber.

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 stoichometric 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.

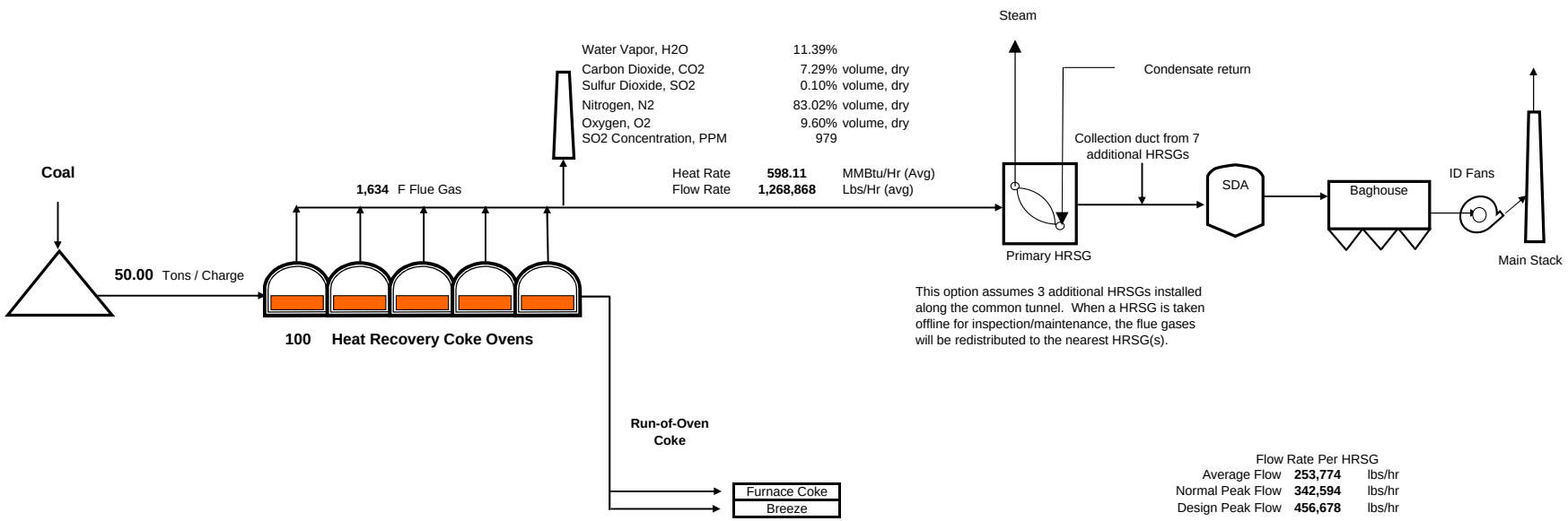
Middletown Coke Company
HRSG Maintenance BACT Analysis
Option 1 - Individual Spray Quenches

Cost Effectiveness		Cost Base 2008 dollars
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
(TCIC x CRF)		
2. Annual O&M Costs (O&M)		$965,036
*****TOTAL ANNUALIZED COSTS*****		$2,934,269
(ACIC+O&M)		
B. PM Removal per Year		
1. Baseline PM level (tons/yr)	(1200 hrs of venting during HRSG maint.)	12.60
2. Controlled PM level (tons/yr)	(1200 hrs of controlled PM emissions using Option 1)	1.29
PM Removed per year (tons/yr)		11.31
PM Emissions per year (tons/yr)		1.29
*****COST EFFECTIVENESS ($/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.

Middletown Coke Company
HRSG Maintenance BACT Analysis
Option 2 - Addition of HRSGs

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



Flow Rate Per HRSG

Average Flow	**253,774**	lbs/hr
Normal Peak Flow	**342,594**	lbs/hr
Design Peak Flow	**456,678**	lbs/hr

This page intentionally left blank.

Middletown Coke Company
HRSG Maintenance BACT Analysis
Option 2 - Addition of HRSGs

	Total Emissions					**Economic Impacts**			**Environmental Impacts**		**Energy Impacts**
Control Alternative	Uncontrolled Emission Rate (gr/dscf)	Uncontrolled Emission Rate (lb/hr)	Controlled Emission Rate (gr/dscf)	Controlled Emission Rate (lb/hr)	Emission Reduction (tpy)	Installed Capital Cost ($)	Total Annualized Cost ($/yr)	Average Cost Effectiveness ($/ton)	Toxics Impact (yes/no)	Adverse Environmental Impacts (yes/no)	Incremental Increase Over Baseline (MW-hr/yr)
Addition of HRSGs	0.049	105.0	0.005	10.7	11.31	$35,520,812	$6,012,631	$531,419	no	no	-10,945

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

	Cost Base 2008 dollars	Source of Estimate
A. Direct Capital Cost (DCC)		
1. Purchased Equipment Cost (PEC)		
Primary and Auxillary Equipment (EQP)		
a. Additional HRSGs (3 required)	$9,969,000	Note 2
b. Vent stack (including "Tee", stack lid, and peripherals) (3 required)	$585,036	Note 3
c. Increase in common tunnel size, 1500 ft @ $1000/ft for increased dia	$1,500,000	Note 4
d. Hot duct, 8.5 ft ID, 90 ft length per HRSG @ $1,911/ft (3 HRSGs)	$515,970	Note 5
e. Hot duct expansion joints (3 required)	$136,515	Note 6
f. Isolation knife gate (3 required)	$90,720	Note 7
g. Cold duct, 64 ft length per HRSG @ $1,812/ft (3 HRSGs)	$347,904	Note 8
Equipment Costs Summary:	$13,145,145	
Instrumentation (0.1*Equipment Costs)	$1,314,515	
Freight (0.05*Equipment Costs)	$657,257	
Sales Tax (0.03*Equipment Costs)	$394,354	
*****TOTAL PURCHASED EQUIPMENT COST*****	**$15,511,271**	
2. Direct Installation Cost (DIC) (0.72*PEC)		
*****TOTAL DIRECT INSTALLATION COST*****	**$11,168,115**	
3. Site Prep (SP) as required	$0	
4. Buildings (BLDG) as required	$0	
*****TOTAL DIRECT CAPITAL COST***** (PEC+DIC+SP+BLDG)	**$26,679,387**	
B. Indirect Capital Cost (ICC)		
1. Engineering (0.10*PEC)	$1,551,127	
2. Construction and Field Expenses (0.20*PEC)	$3,102,254	
3. Construction Fee (0.10*PEC)	$1,551,127	
4. Startup (0.01*PEC)	$155,113	
5. Performance Test (0.01*PEC)	$155,113	
*****TOTAL INDIRECT CAPITAL COST*****	**$6,514,734**	
C. Contingency (CONT) (0.15*PEC)	**$2,326,691**	Note 9
*****TOTAL CAPITAL INVESTMENT COST*** (TCIC)** (DCC+ICC+CONT)	**$35,520,812**	

1. All factors are derived from Estimating Costs of Air Pollution Control, William M. Vatavuk, Lewis Publishers (1990), p. 20, using "fabric filter" factors.
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	Cost Base 2008 dollars	
A. Direct Annual Costs (DAC)		
1. Operating Labor ($30/hr, 8 hr/shift, 3 shifts/day, 365 days/yr)	$262,800	Note 2
2. Supervisory Labor (15% of Operating Labor)	$39,420	
3. Maintenance Labor & Materials	$420,000	Note 3
4. Quick lime, 319.8 tons @ $90/ton	$28,782	Note 4
5. Waste disposal, 807.5 tons @ $34.86/ton	$28,149	Note 5
*****TOTAL DIRECT ANNUAL COSTS*****	**$751,002**	
B. Indirect Annual Costs (IAC)		
1. Overhead (60% of sum of all labor and maintenance materials)	$433,332	
2. Administrative (0.02*TCIC)	$710,416	
3. Property Tax (0.01*TCIC)	$355,208	
4. Insurance (0.01*TCIC)	$355,208	
*****TOTAL INDIRECT ANNUAL COSTS*****	**$1,854,164**	

*****TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS***** **$2,605,166**
(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 derived from Estimating Costs of Air Pollution Control, William M. Vatavuk, Lewis Publishers (1990), pp. 26 for venturi scrubber.

3. Based on Sun Coke estimate of $140,000 per HRSG per year.

4. Quick lime requirement estimated assuming 1.1 reagent stoichometric 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.

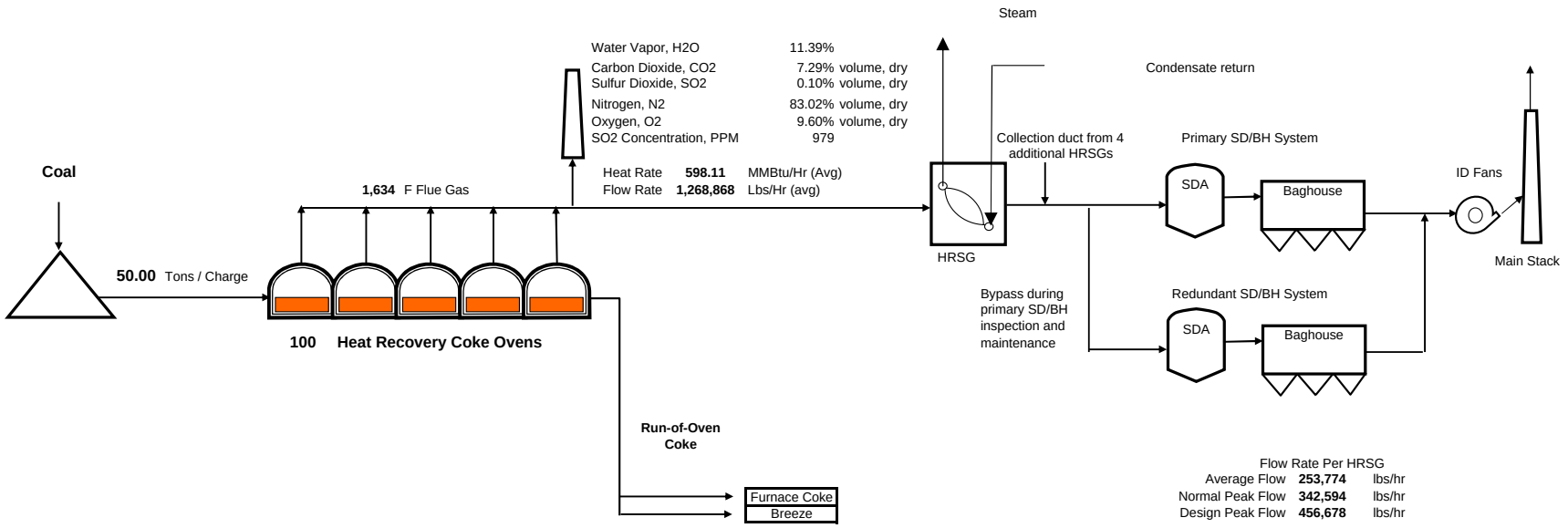
Middletown Coke Company
HRSG Maintenance BACT Analysis
Option 2 - Addition of HRSGs

Cost Effectiveness	Cost Base 2008 dollars
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)	$35,520,812
*****ANNUALIZED CAPITAL INVESTMENT COSTS*****	$3,899,994
(TCIC x CRF)	
2. Annual O&M Costs (O&M)	$2,605,166
3. Annual Power Revenue Increase (Credit) (PRI)	
2.74% increase in power revenue due to additional HRSG operating hours	
($45/MWH*45.6MW*8760 hr/yr*2.74%)	($492,529)
*****TOTAL ANNUALIZED COSTS*****	$6,012,631
(ACIC+O&M+PRI)	
B. PM Removal per Year	
1. Baseline PM level (tons/yr) (1200 hrs of venting during HRSG maint.)	12.60
2. Controlled PM level (tons/yr) (1200 hrs of controlled PM emissions using Option 2)	1.29
PM Removed per year (tons/yr)	11.31
PM Emissions per year (tons/yr)	1.29
*****COST EFFECTIVENESS ($/ton PM removed)*****	**$531,419**

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.

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



This page intentionally left blank.

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

	Total Emissions					**Economic Impacts**			**Environmental Impacts**		**Energy Impacts**
Control Alternative	Uncontrolled Emission Rate (gr/dscf)	Uncontrolled Emission Rate (lb/hr)	Controlled Emission Rate (gr/dscf)	Controlled Emission Rate (lb/hr)	Emission Reduction (tpy)	Installed Capital Cost ($)	Total Annualized Cost ($/yr)	Average Cost Effectiveness ($/ton)	Toxics Impact (yes/no)	Adverse Environmental Impacts (yes/no)	Incremental Increase Over Baseline (MW-hr/yr)
Redundant SD/BH	0.049	105.0	0.005	10.7	5.66	$43,416,247	$6,704,713	$1,185,177	no	no	421

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

Total Capital Investment Cost

	Cost Base 2008 dollars	Source of Estimate
A. Direct Capital Cost (DCC)		
1. Purchased Equipment Cost (PEC)		
Primary and Auxillary Equipment (EQP)		
a. Redundant spray dryer/baghouse system	$14,617,000	Note 2
b. Additional cold duct with elbows, dampers, and "Tee"	$1,450,000	Note 3
Equipment Costs Summary:	$16,067,000	
Instrumentation (0.1*Equipment Costs)	$1,606,700	
Freight (0.05*Equipment Costs)	$803,350	
Sales Tax (0.03*Equipment Costs)	$482,010	
*****TOTAL PURCHASED EQUIPMENT COST*****	**$18,959,060**	
2. Direct Installation Cost (DIC) (0.72*PEC)		
*****TOTAL DIRECT INSTALLATION COST*****	**$13,650,523**	
3. Site Prep (SP) as required	$0	
4. Buildings (BLDG) as required	$0	
*****TOTAL DIRECT CAPITAL COST***** (PEC+DIC+SP+BLDG)	**$32,609,583**	
B. Indirect Capital Cost (ICC)		
1. Engineering (0.10*PEC)	$1,895,906	
2. Construction and Field Expenses (0.20*PEC)	$3,791,812	
3. Construction Fee (0.10*PEC)	$1,895,906	
4. Startup (0.01*PEC)	$189,591	
5. Performance Test (0.01*PEC)	$189,591	
*****TOTAL INDIRECT CAPITAL COST*****	**$7,962,805**	
C. Contingency (CONT) (0.15*PEC)	**$2,843,859**	Note 4
*****TOTAL CAPITAL INVESTMENT COST*** (TCIC)** (DCC+ICC+CONT)	**$43,416,247**	

1. All factors are derived from Estimating Costs of Air Pollution Control, William M. Vatavuk, Lewis Publishers (1990), p. 20, using "fabric filter" factors.
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 values 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 stoichometric 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	Cost Base 2008 dollars
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.

URS	CALCULATION SHEET	
	CALCULATION 1	REVISION 0
ORIGINATOR: Chandra Sastry		DATE: 12/11/08
CHECKED BY: Steve Belding		DATE: 12/11/08
PROJECT: Middletown Coke Company BACT Analysis		JOB #: 39400297
SUBJECT: Water Quenching Material Balance		

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 [1.]
   - Maximum Flow = 401,255 acfm [1.]
   - Maximum Flow = 101,547 wscfm [1.]
   - Average Flow = 56,429 wscfm [1.]
   - Temperature = 1,634 ^{o}F [1.]
   - Moisture = 11.39% % vol [2.]
   - O_2, dry basis = 9.60% % vol [2.]
   - CO_2, dry basis = 7.29% % vol [2.]
   - SO_2, dry basis = 0.098% % vol [2.]
   - N_2, dry basis = 0.83 % vol [2.]
   - 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 ^{o}F, with a design outlet temperature of 400 ^{o}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 ^{o}F with no appreciable solids or other contaminants requiring consideration in the material balance.

5. Standard conditions are 68 ^oF 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 ^oF and 400 ^oF:

- Water vapor = 0.522 Btu/lb-^oF
- CO_2 = 0.275 Btu/lb-^oF
- N_2 = 0.261 Btu/lb-^oF
- O_2 = 0.25 Btu/lb-^oF
- SO_2 = 0.178 Btu/lb-^oF

7. The specific heat of liquid water is assumed constant at 1 Btu/lb-^oF. The specific heat of water vapor from 212 ^oF to 400 ^oF is taken from Perry's, assuming an average of 0.474 Btu/lb-^oF. 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 ^oF to 400 ^oF. The mass flow of each of the major gases (water, N_2, O_2, CO_2, and SO_2) is calculated as follows (ignoring the particulate and gases present in ppm concentrations):

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

Where:

$F_{M,Ti}$ = Total molar flow rate of combustion gas into the quench (lb-mol/hr)

F_{Vdi} = Volumetric flow rate of dry gas into the quench (dscfm)

M_{fi} = Moisture fraction in combustion gas into the quench, by volume

385.30 ft^3/lb-mol = Molar volume of an ideal gas at standard temperature and pressure of 68 ^oF and 1 atm

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

$F_{M,Ti} = 15{,}813$ lb-mol/hr

The moisture flow is then:

3. $F_{m,wi}$ = 15,813 lb-mol/hr × 18 lb/lb-mol × 0.1139 = 32,428 lb/hr

Where:
$F_{m,wi}$ = The mass flow of water in the combustion gas stream into the quench

The molar flow of the dry gas is:

4. $F_{M,di} = F_{Vdi} \times 60$ min/hr ÷ 385.30 ft^3/lb-mol

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

5. $F_{M,di}$ = 89,977 × 60 ÷ 385.30 = 14,012 lb-mol/hr

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

6. $F_{M,O2i}$ = 14,012 × 0.0960 = 1,344.9 lb-mol/hr

7. $F_{M,CO2i}$ = 14,012 × 0.0729 = 1,021.0 lb-mol/hr

8. $F_{M,N2i}$ = 14,012 × 0.8302 = 11,632.0 lb-mol/hr

9. $F_{M,SO2i}$ = 14,012 × 0.00098 = 13.7 lb-mol/hr

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

10. $F_{m,O2i}$ = 1,344.9 lb-mol/hr × 32 lb/lb-mol = 43,036 lb/hr

11. $F_{m,CO2i}$ = 1,021.0 lb-mol/hr × 44 lb/lb-mol = 44,924 lb/hr

12. $F_{m,N2i}$ = 11,632.0 lb-mol/hr × 28 lb/lb-mol = 325,695 lb/hr

13. $F_{m,SO2i}$ = 13.7 lb-mol/hr × 64 lb/lb-mol = 878 lb/hr

The enthalpy to cool each gas constituent to 400°F is based on the mass flow of each gas and the

average specific heat in Assumption 6:

14. $E_{\Delta T,W}$ = 32,428 lb/hr × 0.522 Btu/lb-^oF × (1,634 - 400)^oF ÷ 10^6 Btu/MMBtu
    $E_{\Delta T,W}$ = 20.89 MMBtu/hr

15. $E_{\Delta T,O2}$ = 43,036 lb/hr × 0.25 Btu/lb-^oF × 1,234 ^oF ÷ 10^6 Btu/MMBtu
    $E_{\Delta T,O2}$ = 13.28 MMBtu/hr

16. $E_{\Delta T,CO2}$ = 44,924 lb/hr × 0.275 Btu/lb-^oF × 1,234 ^oF ÷ 10^6 Btu/MMBtu
    $E_{\Delta T,CO2}$ = 15.25 MMBtu/hr

17. $E_{\Delta T,N2}$ = 325,695 lb/hr × 0.261 Btu/lb-^oF × 1,234 ^oF ÷ 10^6 Btu/MMBtu
    $E_{\Delta T,N2}$ = 104.92 MMBtu/hr

18. $E_{\Delta T,SO2}$ = 878 lb/hr × 0.178 Btu/lb-^oF × 1,234 ^oF ÷ 10^6 Btu/MMBtu
    $E_{\Delta T,SO2}$ = 0.19 MMBtu/hr

The total enthalpy required to cool the entire gas stream is:

19. $E_{\Delta T,T}$ = 20.89 + 13.28 + 15.25 + 104.92 + 0.19
    $E_{\Delta T,T}$ = 154.53 MMBtu/hr

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

20. $E_{VW,68 - 400}$ = [1 Btu/lb-^oF × (212 – 68)] + 970.3 Btu/lb + [0.474 Btu/lb-^oF × (400 – 212)]
    $E_{VW,68 - 400}$ = 1,203.4 Btu/lb

The water required for spray quenching is therefore:

21. $F_{m,quench}$ = 154.53 MMBtu/hr × 10^6 ÷ 1,203.4 Btu/lb = 128,413 lb/hr

Expressed as a volumetric flow:

22. $F_{v,quench}$ = 128,413 lb/hr ÷ 8.34 lb/gal ÷ 60 min/hr = 257 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. $F_{M,quench}$ = 128,413 lb/hr ÷ 18 lb/lb-mol = 7,134.1 lb-mol/hr

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

24. $F_{M,To}$ = 15,813.1 lb-mol/hr + 7,134.1 lb-mol/hr = 22,947.2 lb-mol/hr

Expressed as a volumetric flow:

25. $F_{V,To}$ = 22,947.2 lb-mol/hr × 385.30 ft^3/lb-mol ÷ 60 min/hr = 147,359 scfm

The percentage increase in maximum flow is therefore:

26. $\Delta F_{wscfm,1\ HRSG,max}$ = [(147,359 ÷ 101,547) – 1] × 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. $F_{m,quench,\ av}$ = 128,413 lb/hr × 56,429 wscfm ÷ 101,547 wscfm
$F_{m,quench,\ av}$ = 71,358 lb/hr

Converting to gpm:

28. $F_{v,quench,av}$ = 71,358 ÷ 8.34 lb/gal ÷ 60 min/hr = 143 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. $F_{M,5\ HRSG,max}$ = 15,813 lb-mol/hr × 5 = 79,066 lb-mol/hr

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

30. $F_{M,4\ HRSG\ \&\ 1\ quench,max}$ = 15,813 lb-mol/hr × 4 + 22,947 lb-mol/hr

$F_{M,4\ HRSG\ \&\ 1\ quench,max}$ = 86,200 lb-mol/hr

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

31. $\Delta F_{wscfm,5\ HRSG,max}$ = [(86,200 ÷ 79,066) - 1] × 100 = 9.02 %

This increase establishes the required size increase for the central SO_2 scrubber system.

URS	CALCULATION SHEET	
	CALCULATION 2	REVISION 0
ORIGINATOR: Chandra Sastry		DATE: 12/11/08
CHECKED BY: Steve Belding		DATE: 12/11/08
PROJECT: Middletown Coke Company BACT Analysis		JOB #: 39400297
SUBJECT: Water Quenching Material Balance		

PURPOSE:

This calculation estimates the increase in size and costs for the existing SO_2 scrubber system if flue gas bypassing one HRSG is cooled by spray quenching and routed to the central SO_2 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 SO_2 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	×	1.0482	=	$15,321,539
7.	Compressed Air System	=	$100,000	×	1.0753	=	$107,530
8.	Ash System	=	$1,200,000	×	1.0441	=	$1,252,920
9.	Stack	=	$1,100,000	×	1.0902	=	$1,199,220
10.	Total for SO_2 System	=	Sum of costs above			=	$17,881,209
11.	Ductwork for System	=	$2,900,000	×	1.2503	=	$3,625,870

The cost differentials for the SO_2 system and ductwork due to quenching are:

12. $\Delta Cost_{SO2}$ = $17,881,209 - $17,017,000 = $864,209

13. $\Delta Cost_{Duct}$ = $3,625,870 - $2,900,000 = $725,870