Appendix D

BEST AVAILABLE CONTROL TECHNOLOGY SUPPORTING INFORMATION

This page intentionally left blank.

Middletown Coke Company
HRSG Maintenance BACT Analysis
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	$36,025,897	$6,092,038	$538,438	no	no	-10,945

Energy credit from 2.74% power production increase due to additional HRSG operating hours.

Summary of Top-Down BACT Impact Analysis Results for SO2

	Total Emissions			Economic Impacts			Environmental Impacts		Energy Impacts
Control Alternative	Uncontrolled Emission Rate (lb/hr)	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	498	39.9	275.08	$36,025,897	$6,092,038	$22,146	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
Addition of HRSGs

Total Capital Investment Cost

	Cost Base 2009 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 @ $1,774/ft (3 HRSGs)	$478,980	Note 5
e. Hot duct expansion joints (3 required)	$126,700	Note 6
f. Isolation knife gate (3 required)	$102,240	Note 7
g. Cold duct, 64 ft length per HRSG @ $1,812/ft (3 HRSGs)	$347,904	Note 8
Equipment Costs Summary:	$13,109,860	
Instrumentation (0.1*Equipment Costs)	$1,310,986	
Freight (0.05*Equipment Costs)	$655,493	
Sales Tax (0.05*Equipment Costs)	$655,493	
*****TOTAL PURCHASED EQUIPMENT COST*****	**$15,731,833**	
2. Direct Installation Cost (DIC) (0.72*PEC)		
*****TOTAL DIRECT INSTALLATION COST*****	**$11,326,919**	
3. Site Prep (SP) as required	$0	
4. Buildings (BLDG) as required	$0	
*****TOTAL DIRECT CAPITAL COST***** (PEC+DIC+SP+BLDG)	**$27,058,752**	
B. Indirect Capital Cost (ICC)		
1. Engineering (0.20*PEC)	$3,146,367	
2. Construction and Field Expenses (0.10*PEC)	$1,573,183	
3. Construction Fee (0.10*PEC)	$1,573,183	
4. Startup (0.01*PEC)	$157,318	
5. Performance Test (0.01*PEC)	$157,318	
*****TOTAL INDIRECT CAPITAL COST*****	**$6,607,370**	
C. Contingency (CONT) (0.15*PEC)	**$2,359,775**	Note 9
*****TOTAL CAPITAL INVESTMENT COST*** (TCIC)** (DCC+ICC+CONT)	**$36,025,897**	

1. All factors are derived from Guidance for Estimating Capital and Annual Costs of Air Pollution Control Systems (1983) prepared for the Ohio EPA, Table 4-3 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 2009 dollars using a factor of 1.42 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 2009 dollars using a factor of 1.42 derived from the CEP.
7. Based on e-mail from Chris Allen of Sun Coke. These costs were escalated from 2003 dollars to 2009 dollars using a factor of 1.42 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 has never been used with this technology. Cost adjustment factor for Contingency was derived from Guidance for Estimating Capital and Annual Costs of Air Pollution Control Systems (1983) prepared for the Ohio EPA, Table 4-4.

Middletown Coke Company
HRSG Maintenance BACT Analysis
Addition of HRSGs

Operation and Maintenance Costs	Cost Base 2009 dollars	
A. Direct Annual Costs (DAC)		
1. Operating Labor ($30/hr, 8 hr/shift, 3 shifts/day, 365 days/yr)	$262,800	Note 1
2. Supervisory Labor (15% of Operating Labor)	$39,420	Note 1
3. Maintenance Labor & Materials	$420,000	Note 2
4. Quick lime, 319.8 tons @ $85.6/ton	$27,375	Note 3
5. Waste disposal, 823.6 tons @ $34.86/ton	$28,711	Note 4
*****TOTAL DIRECT ANNUAL COSTS*****	**$778,306**	
B. Indirect Annual Costs (IAC)		Note 5
1. Overhead (80% of sum of all operating, supervisory and maintenance labor)	$409,776	Note 6
2. Administrative (0.02*TCIC)	$720,518	
3. Property Tax (0.01*TCIC)	$360,259	
4. Insurance (0.01*TCIC)	$360,259	
*****TOTAL INDIRECT ANNUAL COSTS*****	**$1,850,812**	

*****TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS***** **$2,629,117**
(DAC+IAC+OC)

1. Operating labor based on one additional operator. Supervisory labor derived from Guidance for Estimating Capital and Annual Costs of Air Pollution Control Systems (1983) prepared for the Ohio EPA, Table 5-1.
2. Based on Sun Coke estimate of $140,000 per HRSG per year.

3. 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 2009. Lime cost for 2009 was estimated using the 2008 cost and an increasing rate of $5 per metric ton as described in the article.

4. Total solid waste tonnage calculated using assumptions in Note (3) and 92% SO2 removal efficiency. Waste disposal costs obtained from Sun Coke operations at the Haverhill North Coke Company.

5. Indirect Cost factors are derived from Guidance for Estimating Capital and Annual Costs of Air Pollution Control Systems (1983) prepared for the Ohio EPA, Table 5-1.

6. Maintenance labor was estimated to be 50% of the total cost for maintenance labor and materials based on Table 5-1 in Guidance for Estimating Capital and Annual Costs of Air Pollution Control Systems (1983) prepared for the Ohio EPA.

Middletown Coke Company
HRSG Maintenance BACT Analysis
Addition of HRSGs

Cost Effectiveness		Cost Base 2009 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)		$36,025,897
*****ANNUALIZED CAPITAL INVESTMENT COSTS***** (TCIC x CRF)		$3,955,450
2. Annual O&M Costs (O&M)		$2,629,117
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***** (ACIC+O&M+PRI)		$6,092,038
B. PM Removal per Year		
1. Baseline PM level (tons/yr)	(1200 hrs of venting during HRSG maint.)	12.60
2. Controlled PM level (tons/yr)	(1200 hrs of controlled PM emissions using Option 2)	1.29
PM Removed per year (tons/yr)		11.31
*****COST EFFECTIVENESS ($/ton PM removed)*****		**$538,438**
C. SO2 Removal per Year		
1. Baseline SO2 level (tons/yr)	(1200 hrs of venting during HRSG maint.)	299.00
2. Controlled SO2 level (tons/yr)	(1200 hrs of controlled SO2 emissions using Option 1)	23.92
SO2 Removed per year (tons/yr)		275.08
*****COST EFFECTIVENESS ($/ton SO2 removed)*****		**$22,146**

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
Addition of HRSGs

Estimating reagent utilization to remove SO2 from flue gas which would otherwise be vented

# Days of venting	10	days	per HRSG	
# HRSGs	5			
SO2 in flue gas	498.3	lb/hr	per HRSG	
	7.8	lbmol/hr	per HRSG	
Stoich. CaO needed	7.8	lbmol/hr	per HRSG	CaO + SO2 + 1/2 O2 + 2 H2O --> CaSO4.2H2O
Reagent Stoich. Ratio	1.1			
CaO required	8.6	lbmol/hr	per HRSG	
	479.6	lb/hr	per HRSG	
Reagent purity	90%			
Reagent required	532.9	lb/hr	per HRSG	
	64.0	tons	per HRSG	
	319.8	tons		

Estimating solid waste produced by removing additional SO2 during HRSG maintenance

SO2 removal efficiency	92%		
Gypsum produced	7.2	lbmol/hr	
	1232.1	lb/hr	per HRSG
Unreacted CaO in byproduct	1.6	lbmol/hr	per HRSG
	87.2	lb/hr	per HRSG
Reagent impurities in byproduct	53.3	lb/hr	per HRSG
Total solid waste	1372.6	lb/hr	per HRSG
	164.7	tons	per HRSG
	823.6	tons	

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)	(lb/hr)	Controlled Emission Rate (gr/dscf)	(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	$44,152,116	$6,149,364	$1,087,009	no	no	471

Summary of Top-Down BACT Impact Analysis Results for SO2

	Total Emissions			Economic Impacts			Environmental Impacts		Energy Impacts
Control Alternative	Uncontrolled Emission Rate (lb/hr)	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	2,492	199.3	137.54	$44,152,116	$6,149,364	$44,710	no	no	471

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

Total Capital Investment Cost

	Cost Base 2009 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 (0.05*Equipment Costs)	$803,350	
*****TOTAL PURCHASED EQUIPMENT COST*****	**$19,280,400**	
2. Direct Installation Cost (DIC) (0.72*PEC)		
*****TOTAL DIRECT INSTALLATION COST*****	**$13,881,888**	
3. Site Prep (SP) as required	$0	
4. Buildings (BLDG) as required	$0	
*****TOTAL DIRECT CAPITAL COST***** (PEC+DIC+SP+BLDG)	**$33,162,288**	
B. Indirect Capital Cost (ICC)		
1. Engineering (0.20*PEC)	$1,928,040	
2. Construction and Field Expenses (0.10*PEC)	$3,856,080	
3. Construction Fee (0.10*PEC)	$1,928,040	
4. Startup (0.01*PEC)	$192,804	
5. Performance Test (0.01*PEC)	$192,804	
*****TOTAL INDIRECT CAPITAL COST*****	**$8,097,768**	
C. Contingency (CONT) (0.15*PEC)	**$2,892,060**	Note 4
*****TOTAL CAPITAL INVESTMENT COST*** (TCIC)** (DCC+ICC+CONT)	**$44,152,116**	

1. All factors are derived from Guidance for Estimating Capital and Annual Costs of Air Pollution Control Systems (1983) prepared for the Ohio EPA, Table 4-3 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 a redundant system has never been used with this technology. Will require same guarantee as primary system. Ultimate configuration of fans, stack, dampers, ductwork, and controls not known without engineering design. Cost adjustment factor for Contingency was derived from Guidance for Estimating Capital and Annual Costs of Air Pollution Control Systems (1983) prepared for the Ohio EPA, Table 4-4.

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

Operation and Maintenance Costs	Cost Base 2009 dollars	
A. Direct Annual Costs (DAC)		
1. Operating Labor ($30/hr, 40 hr/shift, 3 shifts/day, 10 days/yr)	$36,000	Note 1
2. Supervisory Labor (15% of Operating Labor)	$5,400	Note 2
3. Maintenance Labor & Materials (5% of TCI factored by 10 oper/maint days)	$60,482	Note 3
4. Electricity @ $0.0671/kW-hr × 3510.6 kW × 120 hr	$28,267	Note 4
5. Water 632,160 gal/yr × $0.0002/gal	$126	Note 5
6. Quick lime, 159.9 tons @ $85.6/ton	$13,687	Note 6
7. Waste disposal, 411.8 tons @ $34.86/ton	$14,355	Note 7
*****TOTAL DIRECT ANNUAL COSTS*****	**$158,319**	
B. Indirect Annual Costs (IAC)		Note 8
1. Overhead (80% of sum of all operating and maintenance labor)	$57,313	Note 9
2. Administrative (0.02*TCIC)	$883,042	
3. Property Tax (0.01*TCIC)	$441,521	
4. Insurance (0.01*TCIC)	$441,521	
*****TOTAL INDIRECT ANNUAL COSTS*****	**$1,823,398**	

*****TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS***** **$1,981,717**
(DAC+IAC+OC)

1. 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.

2. Supervisory labor derived from Guidance for Estimating Capital and Annual Costs of Air Pollution Control Systems (1983) prepared for the Ohio EPA, Table 5-1.

3. Maintenance labor and materials cost derived from Estimating Costs of Air Pollution Control, William M. Vatavuk, Lewis Publishers (1990), pp. 27.

4. 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, May 2009.

5. 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.

6. 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 2009. Lime cost for 2009 was estimated using the 2008 cost and an increasing rate of $5 per metric ton as described in the article.

7. Total solid waste tonnage calculated using assumptions in Note (6) and 92% SO2 removal efficiency. Waste disposal costs obtained from Sun Coke operations at the Haverhill North Coke Company.

8. Indirect Cost factors are derived from Guidance for Estimating Capital and Annual Costs of Air Pollution Control Systems (1983) prepared for the Ohio EPA, Table 5-1.

9. Maintenance labor was estimated to be 50% of the total cost for maintenance labor and materials based on Table 5-1 in Guidance for Estimating Capital and Annual Costs of Air Pollution Control Systems (1983) prepared for the Ohio EPA.

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

Cost Effectiveness		Cost Base 2009 dollars
A. Total Annualized Costs (incl. Capital and O&M)		
1. Annualized Capital Investment Cost (ACIC)		
Expected Lifetime of Equipment (yrs)		20
Interest Rate		0.07
Capital Recovery Factor (CRF)		0.0944
Total Capital Investment Costs (TCIC)		$44,152,116
*****ANNUALIZED CAPITAL INVESTMENT COSTS***** (TCIC x CRF)		$4,167,647
2. Annual O&M Costs (O&M)		$1,981,717
*****TOTAL ANNUALIZED COSTS***** (ACIC+O&M+PRI)		$6,149,364
B. PM Removal per Year		
1. Baseline PM level (tons/yr)	(120 hrs of venting during SD/BH maint.)	6.30
2. Controlled PM level (tons/yr)	(120 hrs of controlled PM using the redundant SD/BH)	0.64
PM Removed per year (tons/yr)		5.66
*****COST EFFECTIVENESS ($/ton PM removed)*****		**$1,087,009**
C. SO2 Removal per Year		
1. Baseline SO2 level (tons/yr)	(120 hrs of venting during SD/BH maint.)	149.50
2. Controlled SO2 level (tons/yr)	(120 hrs of controlled SO2 using the redundant SD/BH)	11.96
SO2 Removed per year (tons/yr)		137.54
*****COST EFFECTIVENESS ($/ton SO2 removed)*****		**$44,710**

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

Estimating reagent utilization to remove SO2 from flue gas which would otherwise be vented

# Days of venting	5	days	
SO2 in flue gas	2491.7	lb/hr	
	38.9	lbmol/hr	
Stoich. CaO needed	38.9	lbmol/hr	CaO + SO2 + 1/2 O2 + 2 H2O --> CaSO4.2H2O
Reagent Stoich. Ratio	1.1		
CaO required	42.8	lbmol/hr	
	2398.2	lb/hr	
Reagent purity	90%		
Reagent required	2664.7	lb/hr	
	159.9	tons	

Estimating solid waste produced by removing additional SO2 during SD/BH maintenance

SO2 removal efficiency	92%		
Gypsum produced	35.8	lbmol/hr	
	6160.6	lb/hr	per HRSG
Unreacted CaO in byproduct	7.8	lbmol/hr	per HRSG
	436.0	lb/hr	per HRSG
Reagent impurities in byproduct	266.5	lb/hr	per HRSG
Total solid waste	6863.2	lb/hr	per HRSG
	411.8	tons	per HRSG

Estimating electricity requirement

Primary SD/BH System		
Fan power requirement	4000	HP
Fan motor efficiency	85%	
Electricity consumed	3510.6	kW

Estimating water requirement for the redundant SD/BH system

Total mass flow rate into SD	1,268,868	lb/hr

Flue gas composition			
CO2	10.1%	by weight	
H2O	7.3%	by weight	
SO2	0.2%	by weight	
N2	72.9%	by weight	
O2	9.6%	by weight	
Flue gas inlet temperature	400.0	F	
Flue gas exit temperature	250.0	F	
Specific heats			
CO2	0.24	Btu/lb-degF	(from 250F to 400F)
H2O	0.47	Btu/lb-degF	(from 250F to 400F)
SO2	0.15	Btu/lb-degF	(from 250F to 400F)
N2	0.25	Btu/lb-degF	(from 250F to 400F)
O2	0.23	Btu/lb-degF	(from 250F to 400F)
Sp. Heat of water vapor	0.47	Btu/lb-degF	(from 212F to 250F)
Sp. Heat of liquid water	1.00	Btu/lb-degF	
Heat of vaporization of water	970.3 F	Btu/lb	
Average sp. heat of flue gas	0.26	Btu/lb-degF	(from 250F to 400F)

Enthalpy required		
To cool flue gas from 400F to 250F	49.74	MMBtu/hr
To heat water from 68F to 212F	144	Btu/lb
To vaporize water at 212F	970.3	Btu/lb
To heat water vapor from 212F to 250F	17.9	Btu/lb
Total enthalpy required to heat water from 68F to 250F	1132.2	Btu/lb
Water required		
Total cooling water required	43,933	lb/hr
Total cooling water required	87.8	gpm