ICI Boiler NOx & SO_2 Control Cost Estimates

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OTC Committee Meeting
Modeling/Stationary & Area/Mobile Sources
Niagara Falls, NY
September 3, 2009

Outline

- Context - OTC/LADCO State Collaborative Process
  - OTC/LADCO ICI Boiler Workgroup
- Purpose for developing control cost methodology
- Partial List of reference documents used
- Types of NOx & SO_2 control equipment analyzed
- Uncontrolled NOx & SO_2 emission ranges
- Controlled NOx & SO_2 emission ranges
- Comparison of NOx & SO_2 control cost assumptions
- Summary of ICI boiler NOx & SO_2 control costs

Context - State Collaborative Process OTC/LADCO ICI Boiler Workgroup

- **OTC/LADCO December 2005 Meeting**
  - **NE and MW Commissioners/Directors met to discuss coordinating control programs to meet current NAAQS, and preparing for new, tighter NAAQS**
  - **Agreed to explore several control measures, including**
    - **One consistent environmentally-sensitive formulated gasoline**
    - **Consistent standards for a range of consumer products**
    - **ICI boilers**
- **Regular Conference Calls**
  - **On-going discussions over past couple years**
  - **Formed ICI Boiler Workgroup with staff from NE and MW states to prepare a recommendation on ICI boilers**
  - **Agreed to send letter to EPA**

Context - State Collaborative Process OTC/LADCO ICI Boiler Workgroup

- **Letter to EPA (Indiana - November 15, 2007, 16 other states - June 11, 2008)**
  - **Asked for a dialogue to address multi-pollutant air quality problems in eastern U.S.**
  - **Dialogue to include identifying strategies for achieving effective, equitable, and necessary emission reductions (e.g., 3rd phase of reductions for EGUs, and controls for existing ICI boilers)**
- **OTC/LADCO representatives met with EPA in November 2008**
  - **Discussed need for federal action on ICI Boilers including summary of ICI Boiler Workgroup's extensive analysis of technology-based control options and associated costs**
- **Technical support document being prepared to document OTC/LADCO ICI Boiler Workgroup's analysis**

Purpose for Developing Control Cost Methodology

To develop improved NOx & SO_2 control cost estimates for Industrial, Commercial and Institutional (ICI) Boilers using detailed information on direct capital equipment costs, direct installation costs, indirect capital costs and direct & indirect operating costs in a user friendly format

(Excel spreadsheets)

Background Documents

- **Numerous background documents were reviewed (EPA, DOE, OTAG, NACAA*, NESCAUM, LADCO, Federal & State regulations, etc.)**
- **Control Cost Methodology derived mainly from:**
  - **"Midwest RPO BART Engineering Analysis" MACTEC, March 30, 2005**
  - **"ACT Document – NOx Emissions from ICI Boilers", EPA 453/R-94-022, March 1994**

*NACAA formerly STAPPA & ALAPCO

Types of NOx Control Equipment Analyzed

- Low NOx Burners (LNB)
- Low NOx Burners plus Flue Gas Recirculation (LNB+FGR)
- Low NOx Burners plus Selective Non-Catalytic Reduction (LNB+SNCR)
- Selective Non-Catalytic Reduction (SNCR)
- Selective Catalytic Reduction (SCR)

Types of SO_2 Control Equipment Analyzed

- Dry Flue Gas De-Sulfurization (Dry FGD)

  This cost analysis for Dry FGD focused on spray dryer absorption systems which spray lime slurry into and absoption tower where SO_2 is absorbed by the slurry, forming calcium sulfite/calcium sulfate. These dry solids are carried out of the tower and collected by a fabric filter.

- Wet Flue Gas De-Sulfurization (Wet FGD)

  There are several different versions of Wet FGD systems. The choice of Wet FGD system may be influenced by the sulfur content of the fuel (e.g., limestone forced oxidation systems are generally when firing high sulfur coal while magnesium enhanced lime systems may be used for low and high sulfur coals). In this cost analysis the Wet FGD system used lime as the base in the scrubbing liquor. Other Wet FGD systems use caustic (NaOH) and limestone.

NOx & SO_2 Control Efficiencies Analyzed

	NOx				SO2		
Option	**Gas**	**Oil**	**Coal**		**Gas**	**Oil**	**Coal**
Combustion Modification	Tune-ups (15%)	Tune-ups (15%)	Tune-ups (15%)				
	LNB (50%)	LNB (50%)	LNB (50%)				
	LNB + FGR (60%)	LNB + FGR (60%)	LNB + FGR (60%)				
	ULNB (75%)	ULNB (75%)	ULNB (75%)				
Fuel Treatment					COG Desulf. (95%)	Lower S Oil (75-95%)	
Post-Comb. Controls	SNCR (45%)	SNCR (45%)	SNCR (45%)				Dry Sorbent Inject. (40%)
	SCR (85%)	SCR (85%)	SCR (85%)				Dry FGD (85-95%)
							Wet FGD (85-95%)

Key Variables That Impact Cost Analyses

- Boiler Type
- Boiler Firing type
- Type of Fuel Combusted
  - **(coal, residual oil, distillate oil, natural gas)**
- Type of Emission Control
- Uncontrolled Emission Rate
- Controlled Emission Rate
- Capital Cost of Control Equipment
  - **(purchased equipment cost)**
- Financial costs (e.g., interest rates)
- Unit Capacity Factor (hours/year)
- Flue Gas Flow Rates and Temperatures
- Commodity Prices (e.g., lime, water)

ICI Boiler Uncontrolled NOx Emission Rates Used in Cost Calculations

- Wall-fired Coal 0.70 lb NOx/mmBtu
- Residual Oil 0.40 lb NOx/mmBtu
- Distillate Oil 0.20 lb NOx/mmBtu
- Natural Gas 0.20 lb NOx/mmBtu

Actual emission rates will vary based on: NOx control type, fuel type, boiler type, boiler firing type, age of boiler, current regulatory requirements, etc.

ICI Boiler Controlled NOx Emission Rates Used in Cost Calculations

- Wall-fired Coal 0.11- 0.39 lb NOx/mmBtu
- Residual Oil 0.0675 - 0.20 lb NOx/mmBtu
- Distillate Oil 0.03 - 0.11 lb NOx/mmBtu
- Natural Gas 0.03 – 0.11 lb NOx/mmBtu

Actual emission rates will vary based on: NOx control type, fuel type, boiler type, boiler firing type, age of boiler, current regulatory requirements, etc.

ICI Boiler Uncontrolled SO_2 Emission Rates Used in Cost Calculations

- Wall-fired Coal 5.00 lb SO_2/mmBtu

Actual emission rates will vary based on: SO_2 control type, fuel type, boiler type, boiler firing type, age of boiler, current regulatory requirements, etc.

ICI Boiler Controlled SO_2 Emission Rates Used in Cost Calculations

- Wall-fired Coal 0.25 - 0.75 lb SO_2/mmBtu

Actual emission rates will vary based on: SO_2 control type, fuel type, boiler type, boiler firing type, age of boiler, current regulatory requirements, etc.

Comparison of NOx Control Cost Assumptions

- Direct Capital Costs Comparison

(EPA NOx ACT/MACTEC/OTC-LADCO 2008)

- Instrumentation* (10% / 10% / 10%)
- Sales taxes* (3% / 6% / 6%)
- Freight* (5% / 5% / 5%)

* % of NOx control equipment cost

Comparison of NOx Control Cost Assumptions (Continued)

- Direct Installation Costs* Comparison

  (EPA NOx ACT / MACTEC / OTC-LADCO 2008)

  (30% / 74% / 40%)

  * % of Total Purchased Equipment Cost

- Direct Installation Costs include:

  Foundations & supports, handling, electrical, piping, insulation, painting, etc.

Comparison of NOx Control Cost Assumptions (Continued)

- Indirect Capital Costs* Comparison

  (EPA NOx ACT / MACTEC / OTC-LADCO 2008)

  (53%-86%** / 55% / 61%-92%**)

  *** % of Total Purchased Equipment Cost**

  **** Use higher % for SCR installations**

- Indirect Capital Costs include:

  Engineering supervision, construction field expenses, construction fees, start-up costs, testing & contingencies, etc.

Comparison of NOx Control Cost Assumptions (Continued)

- **Direct Operating Costs**
  - **Vary with type of boiler and NOx control equipment type**
- **Indirect Operating Costs**

  (EPA NOx ACT / MACTEC / OTC-LADCO 2008)
  - **Overhead* (60% / 60% / 60%)**
  - **Administrative** (2% / 2% / 2%)**
  - **Property Tax** (1% / 1% / 1%)**
  - **Insurance** (1% / 1% / 1%)**

*** % of labor & maintenance materials costs**

**** % of total capital cost**

Comparison of NOx Control Cost Assumptions (Continued)

- **Other Cost Inputs Comparison**

	(EPA NOx ACT / MACTEC / OTC-LADCO 2008)
Equipment Service Life	(10 yrs / 20 yrs / 15 yrs)
Interest Rate	(10% / 7% / 10%)
Capital Recovery Factor	(0.1627 / 0.0944 / 0.1133)

ICI Boiler NOx Control Cost Estimates ($/ton NOx removed)

- Control Technology – Low NOx Burners
- Fuel Type – Natural Gas
- 50% NOx Reduction

(from 0.20 lb. NOx/mmBtu to 0.10 lb. NOx/mmBtu)

Boiler Size	($/ton NOx removed) Capital Cost Scenario		
	Low	Medium	High
50	$10,900	$14,700	$43,600
100	$5,460	$7,350	$21,800
250	$2,190	$2,940	$8,720
750	$728	$980	$2,910

All costs shown are in 2008$ for a 66% capacity factor at 8,760 hours/year

ICI Boiler NOx Control Cost Estimates ($/ton NOx removed)

- Control Technology – Low NOx Burners
- Fuel Type – Distillate Oil
- 50% NOx Reduction

(from 0.20 lb. NOx/mmBtu to 0.10 lb. NOx/mmBtu)

Boiler Size	($/ton NOx removed) Capital Cost Scenario		
	Low	Medium	High
50	$10,900	$14,700	$43,600
100	$5,460	$7,350	$21,800
250	$2,190	$2,940	$8,720
750	$728	$980	$2,910

All costs shown are in 2008$ for a 66% capacity factor at 8,760 hours/year

ICI Boiler NOx Control Cost Estimates ($/ton NOx removed)

- Control Technology – Low NOx Burners
- Fuel Type – Residual Oil
- 50% NOx Reduction

(from 0.40 lb. NOx/mmBtu to 0.20 lb. NOx/mmBtu)

Boiler Size	($/ton NOx removed) Capital Cost Scenario		
	Low	Medium	High
50	$5,460	$7,352	$21,800
100	$2,730	$3,680	$10,900
250	$1,090	$1,470	$4,360
750	$364	$490	$1,450

All costs shown are in 2008$ for a 66% capacity factor at 8,760 hours/year

ICI Boiler NOx Control Cost Estimates ($/ton NOx removed)

- Control Technology – Low NOx Burners
- Fuel Type – Wall-fired Coal
- 50% NOx Reduction

(from 0.70 lb. NOx/mmBtu to 0.35 lb. NOx/mmBtu)

Boiler Size	($/ton NOx removed) Capital Cost Scenario		
	Low	Medium	High
50	$3,120	$4,200	$12,460
100	$1,560	$2,100	$6,230
250	$624	$840	$2,490
750	$208	$280	$831

All costs shown are in 2008$ for a 66% capacity factor at 8,760 hours/year

ICI Boiler NOx Control Cost Estimates ($/ton NOx removed)

- Control Technology – LNB plus FGR
- Fuel Type – Residual Oil
- 60% NOx Reduction
  (from 0.40 lb. NOx/mmBtu to 0.16 lb. NOx/mmBtu)

Boiler Size	($/ton NOx removed)	
	Capital Cost Scenario	
	Low	High
50	$13,200	$26,800
100	$6,600	$13,400
250	$2,640	$5,360
750	$880	$1,790

All costs shown are in 2008$ for a 66% capacity factor at 8,760 hours/year

ICI Boiler NOx Control Cost Estimates ($/ton NOx removed)

- Control Technology – LNB plus SNCR
- Fuel Type – Residual Oil
- 65% NOx Reduction
  (from 0.40 lb. NOx/mmBtu to 0.14 lb. NOx/mmBtu)

Boiler Size	($/ton NOx removed) Capital Cost Scenario	
	Low	High
50	$13,770	$28,200
100	$7,370	$14,600
250	$3,520	$6,410
750	$1,810	$2,770

All costs shown are in 2008$ for a 66% capacity factor at 8,760 hours/year

ICI Boiler NOx Control Cost Estimates ($/ton NOx removed)

- Control Technology – SNCR
- Fuel Type – Residual Oil
- 50% NOx Reduction
  (from 0.40 lb. NOx/mmBtu to 0.20 lb. NOx/mmBtu)

Boiler Size	($/ton NOx removed) Capital Cost Scenario	
	Low	High
50	$10,550	$14,840
100	$5,900	$8,040
250	$3,110	$3,970
750	$1,870	$2,150

All costs shown are in 2008$ for a 66% capacity factor at 8,760 hours/year

ICI Boiler NOx Control Cost Estimates ($/ton NOx removed)

- Control Technology – SNCR
- Fuel Type – Wall-fired Coal
- 45% NOx Reduction

(from 0.70 lb. NOx/mmBtu to 0.39 lb. NOx/mmBtu)

Boiler Size	($/ton NOx removed) Capital Cost Scenario	
	Low	High
50	$7,210	$9,930
100	$4,260	$5,620
250	$2,480	$3,030
750	$1,690	$1,880

All costs shown are in 2008$ for a 66% capacity factor at 8,760 hours/year

ICI Boiler NOx Control Cost Estimates ($/ton NOx removed)

- Control Technology – SCR
- Fuel Type – Residual Oil
- 85% NOx Reduction
  (from 0.40 lb. NOx/mmBtu to 0.0675 lb. NOx/mmBtu)

Boiler Size	($/ton NOx removed) Capital Cost Scenario	
	Low	High
50	$11,220	$39,800
100	$5,840	$20,100
250	$2,620	$8,330
750	$1,180	$3,080

All costs shown are in 2008$ for a 66% capacity factor at 8,760 hours/year

ICI Boiler NOx Control Cost Estimates ($/ton NOx removed)

- Control Technology – SCR
- Fuel Type – Wall-fired Coal
- 85% NOx Reduction
  (from 0.70 lb. NOx/mmBtu to 0.11 lb. NOx/mmBtu)

Boiler Size	($/ton NOx removed) Capital Cost Scenario	
	Low	High
50	$6,500	$22,840
100	$3,430	$11,600
250	$1,590	$4,860
750	$770	$1,860

All costs shown are in 2008$ for a 66% capacity factor at 8,760 hours/year

ICI Boiler SO_2 Control Cost Estimates ($/ton SO_2 removed)

- Control Technology – Dry FGD
- Fuel Type – Wall-fired Coal

Boiler Size	85% SO_2 Reduction ($/ton SO_2 removed) Capital Cost		95% SO_2 Reduction ($/ton SO_2 removed) Capital Cost	
	(from 5.00 lb. to 0.75 lb. SO_2/mmBtu)		(from 5.00 lb. to 0.25 lb. SO_2/mmBtu)	
	Low	High	Low	High
100	$1,780	$7,690	$1,590	$6,880
250	$1,650	$4,010	$1,480	$3,590
750	$1,590	$2,380	$1,420	$2,130

All costs shown are in 2008$ for a 66% capacity factor at 8,760 hours/year

ICI Boiler SO_2 Control Cost Estimates ($/ton SO_2 removed)

- Control Technology – Wet FGD
- Fuel Type – Wall-fired Coal

Boiler Size	85% SO_2 Reduction (from 5.00 lb. to 0.75 lb. SO_2/mmBtu) ($/ton SO_2 removed) Capital Cost		95% SO_2 Reduction (from 5.00 lb. to 0.25 lb. SO_2/mmBtu) ($/ton SO_2 removed) Capital Cost	
	Low	High	Low	High
100	$1,840	$7,510	$1,650	$6,720
250	$1,570	$3,830	$1,400	$3,430
750	$1,440	$2,220	$1,290	$1,970

All costs shown are in 2008$ for a 66% capacity factor at 8,760 hours/year

Summary

- Methodology contains sufficient level of detail to develop improved NOx and SO_2 control cost estimates
- Excel format is user friendly and allows flexibility for user to input case specific data
- Excel format allows user to update data as newer data becomes available

Bonus Material

San Joaquin Valley APCD
ICI Boiler NOx Control Cost Estimates
Final Draft Staff Report (9/18/08)

- Control Technology – Ultra Low NOx Burners
- Fuel Type – Natural Gas
- 69% NOx Reduction

[from 30 ppmv (0.036 lb. NOx/mmBtu) to 9 ppmv (0.011 lb. NOx/mmBtu]

Boiler Size	Capital Cost ($)	($/ton NOx removed)	
		Capacity Factor	
		50%	75%
44	$114,172	$13,931	$9,289
68	$127,200	$11,748	$7,833
92	$151,766	$10,754	$7,170
115	$179,672	$10,556	$7,037
130	$194,560	$10,234	$6,823
150	$214,411	$9,914	$6,609

Comparison of NOx and SO_2 Control Cost Estimates for ICI Boilers

Literature Values
MACTEC 2008 Results
Modified CUECost Results
January, 2009

Data Sources of NOx & SO_2 Control Cost Estimates

- Literature - Refers to data taken from NESCAUM report "Applicability and Feasibility of NOx, SO_2 and PM Emission Control Technologies for ICI Boilers", November 2008, Executive Summary, Table ES-1.
- MACTEC 2008 - Refers to data derived using the MACTEC methodology with corrections and assumptions developed by the OTC/LADCO ICI Boiler Workgroup.
- Modified CUECost - Refers to the data taken from NESCAUM report "Applicability and Feasibility of NOx, SO_2 and PM Emission Control Technologies for ICI Boilers", November 2008, Chapter 5, Tables 5-4 and 5-5.

Cost Estimates for NOx Control Technology Options ($/ton NOx Removed)

Control Technology	Fuel Type	Cost Method	Boiler Size	
			100 MMBTU/hr	250 MMBTU/hr
Low NOx Burners - Gas	Gas	Literature[1]	$750 - $7,500	
		MACTEC 2008[2]	$5,460 - $21,800	$2,190 - $8,720
		Modified CUECost[3]	$5,715	$4,151
Low NOx Burners - Dist. Oil	Distillate Oil	Literature[1]	$750 - $7,500	
		MACTEC 2008[2]	$5,460 - $21,800	$2,190 - $8,720
Low NOx Burners - Res. Oil	Residual Oil	Literature[1]	$750 - $7,500	
		MACTEC 2008[2]	$2,730 - $10,900	$1,090 - $4,360
		Modified CUECost[3]	$4,559	$3,305
Low NOx Burners - Coal	Coal	Literature[1]	$750 - $7,500	
		MACTEC 2008[2]	$1,560 - $6,230	$624 - $2,490
		Modified CUECost[3]	$3,155	$2,290

1. Literature values are in 2006$.
2. MACTEC 2008 values are in 2008$ for a 66% capacity factor at 8,760 hours/year.
3. Modified CUECost values are in 2006$ for a 66% capacity factor at 8,760 hours/year.

Cost Estimates for NOx Control Technology Options ($/ton NOx Removed)

Control Technology	Fuel Type	Cost Method	Boiler Size	
			100 MMBTU/hr	250 MMBTU/hr
SNCR - Coal (Wall-fired)	Coal	Literature[1]	$1,300 - $3,700	
		MACTEC 2008[2]	$4,260 - $5,620	$2,480 - $3,030
		Modified CUECost[3]	$4,817	$2,422
SCR - Coal (Wall-Fired)	Coal	Literature[1]	$2,000 - $14,400	
		MACTEC 2008[2]	$3,430 - $11,600	$1,590 - $4,860
		Modified CUECost[3]	$6,668	$4,763

1. Literature values are in 2006$.
2. MACTEC 2008 values are in 2008$ for a 66% capacity factor at 8,760 hours/year.
3. Modified CUECost values are in 2006$ for a 66% capacity factor at 8,760 hours/year.

Cost Estimates for SO_2 Control Technology Options ($/ton SO_2 Removed)

Control Technology	Fuel Type	Cost Method	Boiler Size	
			100 MMBTU/hr	250 MMBTU/hr
Fuel Switch 0.3%S to 0.05%S	Distillate Oil	Price Differential[1]	$1,200 - $2,000	
Fuel Switch 1.0%S to 0.5% S	Residual Oil	Price Differential[1]	$1,900 - $3,800	
Dry FGD – Coal	Coal	Literature[2]	$1,600 - $5,200	
		MACTEC 2008[3]	$1,590 - $7,690	$1,480 - $4,010
		Modified CUECost[4]	$7,909	$3,694
Wet FGD (Wall-Fired)	Coal	Literature[2]	$1,900 - $5,200	
		MACTEC 2008[3]	$1,650 - $7,510	$1,400 - $3,830
		Modified CUECost[4]	$9,547	$4,427

1. Price Differential values are in 2008$ for a 66% capacity factor at 8,760 hours/year.
Price differential between 0.3%S and 0.05%S distillate oil ranged from 2.1 to 3.5 cents per gallon
Price differential between 1.0%S and 0.5%S residual oil ranged from 7.5 to 15.0 cents per gallon
2. Literature values are in 2006$.
3. MACTEC 2008 values are in 2008$ for a 66% capacity factor at 8,760 hours/year.
4. Modified CUECost values are in 2006$ for a 66% capacity factor at 8,760 hours/year.

Additional Information

Recommended National ICI Boiler NOx & SO_2 Emission Limits and Control Cost Estimates

Work in Progress

4th DRAFT (1/15/09)

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January, 2009

Recommended National ICI Boiler NOx Emission Limits

- **Gaseous Fuels (natural gas, refinery gas, blast furnace gas, coke oven gas)**
  - **Phase I (2012 - 2015)**
    - **<50 - 100 MMBtu/hr - Combustion Tuning**
    - **> 100 MMBtu/hr - 0.10 lb NOx/MMBtu or 50% NOx reduction**
  - **Phase II (2015 - 2018)**
    - **< 50 MMBtu/hr - 0.05 - 0.10 lb NOx/MMBtu or 50% NOx reduction**
    - **50 - > 100 MMBtu/hr - 0.05 - 0.10 lb NOx/MMBtu or 60% NOx reduction**

Recommended National ICI Boiler NOx Emission Limits (Continued)

- **Distillate Oil (#2 fuel oil)**
  - **Phase I (2012 - 2015)**
    - **<50 - 100 MMBtu/hr - Combustion Tuning**
    - **> 100 MMBtu/hr - 0.10 lb NOx/MMBtu or 50% NOx reduction**
  - **Phase II (2015 - 2018)**
    - **< 50 MMBtu/hr - 0.08 - 0.10 lb NOx/MMBtu or 50% NOx reduction**
    - **50 - > 100 MMBtu/hr - 0.08 - 0.10 lb NOx/MMBtu or 60% NOx reduction**

Recommended National ICI Boiler NOx Emission Limits (Continued)

- **Residual Oil (#6 fuel oil)**
  - **Phase I (2012 - 2015)**
    - **<50 - 100 MMBtu/hr - Combustion Tuning**
    - **> 100 MMBtu/hr - 0.20 lb NOx/MMBtu or 60% NOx reduction**
  - **Phase II (2015 - 2018)**
    - **< 50 MMBtu/hr - 0.20 lb NOx/MMBtu or 50% NOx reduction**
    - **50 - 100 MMBtu/hr - 0.20 lb NOx/MMBtu or 60% NOx reduction**
    - **> 100 MMBtu/hr - 0.20 lb NOx/MMBtu or 70% NOx reduction**

Recommended National ICI Boiler NOx Emission Limits (Continued)

- **Coal (Wall-fired) > 100 MMBtu/hr**
  - **Phase I (2012 - 2015) - 0.30 lb NOx/MMBtu**
  - **Phase II (2015 - 2018) - 0.10 - 0.14 lb NOx/MMBtu**
- **Coal (Tangential) > 100 MMBtu/hr**
  - **Phase I (2012 - 2015) - 0.30 lb NOx/MMBtu**
  - **Phase II (2015 - 2018) - 0.10 - 0.12 lb NOx/MMBtu**
- **Coal (Cyclone) > 100 MMBtu/hr**

  Phase I & Phase II - 0.19 lb NOx/MMBtu

Recommended National ICI Boiler NOx Emission Limits (Continued)

- **Coal (Stoker)**
  - **Phase I (2012 - 2015)**
    - **50 - 100 MMBtu/hr - Combustion Tuning**
    - **>100 MMBtu/hr - 0.30 lb NOx/MMBtu**
  - **Phase II (2015 - 2018)**
    - **50 - 100 MMBtu/hr - 0.30 lb NOx/MMBtu**
    - **>100 MMBtu/hr - 0.22 lb NOx/MMBtu**
- **Coal (Fluidized Bed)**
  - **Phase I (2012 - 2015)**
    - **50 - 100 MMBtu/hr - Combustion Tuning**
    - **>100 MMBtu/hr - 0.15 lb NOx/MMBtu**
  - **Phase II (2015 - 2018)**
    - **50 - >100 MMBtu/hr - 0.08 lb NOx/MMBtu**

Recommended National ICI Boiler SO_2 Emission Limits

- **Coke Oven Gas - > 100 MMBtu/hr**
  - **Phase I (2012-2014) & Phase II (2014-2018) remove 95% of Sulfur from coke oven gas**
- **#2 Distillate Oil - < 50 - >250 MMBtu/hr**
  - **Phase I (2012-2014) - 500 ppm Sulfur or 0.05 lb SO_2/MMBtu**
  - **Phase II Northeast Inner Zone States* (2016) - 15 ppm Sulfur**
  - **Phase II Elsewhere (2018) - 15 ppm Sulfur**
- **#6 Residual Oil - < 50 - >250 MMBtu/hr**
  - **Phase II Northeast Inner Zone States* (2012) - 0.3-0.5% Sulfur**
  - **Phase II Elsewhere (2018) - 0.5% Sulfur**

*** The Northeast Inner Zone States are the same as specified in the MANE-VU "low sulfur oil strategy" Statement (6/20/07) namely NJ, NY,DE & PA.**

Recommended National ICI Boiler SO_2 Emission Limits (Continued)

- **Coal (and other solid fuels)**
  - **Phase I (2012-2015)**
    - **50 - 100 MMBtu/hr - 2.0 lb SO_2/MMBtu or 30% reduction***
    - **100 - 250 MMBtu/hr - 1.2 lb SO_2/MMBtu or 85% reduction***
    - **> 250 MMBtu/hr - 0.25 lb SO_2/MMBtu or 85% reduction***
  - **Phase II (2012-2015)**
    - **50 - 100 MMBtu/hr - 2.0 lb SO_2/MMBtu or 30% reduction***
    - **100 - 250 MMBtu/hr - 0.25 lb SO_2/MMBtu or 85% reduction***
    - **> 250 MMBtu/hr - 0.25 lb SO_2/MMBtu or 85% reduction***

*** % reduction is from uncontrolled SO_2 emissions in base year 2002**

Recommended National ICI Boiler NOx Emission Limits

(% values are %NOx reductions. All other values are lb. NOx/MMBTU.)

		Boiler Size (MMBTU/Hour)		
Fuel Type		**< 50**	**50-100**	**> 100**
Gaseous Fuels (natural gas, refinery gas, blast furnace gas, coke oven gas)	Phase I	Comb. Tuning	Comb. Tuning	0.10 or 50%
	Phase II	0.05 - 0.10 or 50%	0.05 - 0.10 or 60%	0.05 - 0.10 or 60%
Distillate Oil (#1.#2)	Phase I	Comb. Tuning	Comb. Tuning	0.10 or 50%
	Phase II	0.08 - 0.10 or 50%	0.08 - 0.10 or 60%	0.08 - 0.10 or 60%
Residual Oil (#4,#5,#6)	Phase I	Comb. Tuning	Comb. Tuning	0.20 or 60%
	Phase II	0.20 or 50%	0.20 or 60%	0.20 or 70%
Coal - Wall	Phase I			0.30
	Phase II			0.10 - 0.14
Coal - Tangential	Phase I			0.30
	Phase II			0.10 - 0.12
Coal - Cyclone	Phase I			0.19
	Phase II			0.19
Coal - Stoker	Phase I		Comb. Tuning	0.30
	Phase II		0.30	0.22
Coal - FBC	Phase I		Comb. Tuning	0.15
	Phase II		0.08	0.08
Wood and Non-Fossil Solid Fuel	Phase I		Comb. Tuning	0.30
	Phase II		0.30	0.22

Recommended National ICI Boiler SO_2 Emission Limits

Fuel Type		Boiler Size (MMBtu/Hour)			
		< 50	50-100	100-250	> 250
Gaseous Fuels (coke oven gas)	Phase I			Treated COG with 95%S compounds removed	Treated COG with 95%S compounds removed
	Phase I			Treated COG with 95%S compounds removed	Treated COG with 95%S compounds removed
Distillate Oil (#1, #2)	Phase I	0.05%S (500ppm), or 0.05 lb/MMBTU	0.05%S (500ppm), or 0.05 lb/MMBTU	0.05%S (500ppm), or 0.05 lb/MMBTU	0.05%S (500ppm), or 0.05 lb/MMBTU
	Phase II **Northeast States Inner Zone**	Further reduce Sulfur content to 15ppm by 2016	Further reduce Sulfur content to 15ppm by 2016	Further reduce Sulfur content to 15ppm by 2016	Further reduce Sulfur content to 15ppm by 2016
	Phase II **Elsewhere**	Further reduce Sulfur content to 15ppm by 2018	Further reduce Sulfur content to 15ppm by 2018	Further reduce Sulfur content to 15ppm by 2018	Further reduce Sulfur content to 15ppm by 2018
Residual Oil (#4, #5, #6)	Phase I	0.5%S (or 0.54 lb/MMBTU)	0.5%S (or 0.54 lb/MMBTU)	0.5%S (or 0.54 lb/MMBTU)	0.5%S (or 0.54 lb/MMBTU)
	Phase II **Northeast States Inner Zone**	#4 Fuel Oil 0.25%S no later than 2012	#4 Fuel Oil 0.25%S no later than 2012	#4 Fuel Oil 0.25%S no later than 2012	#4 Fuel Oil 0.25%S no later than 2012
		#6 Fuel Oil 0.3-0.5% no later than 2012	#6 Fuel Oil 0.3-0.5%S no later than 2012	#6 Fuel Oil 0.3-0.5%S no later than 2012	#6 Fuel Oil 0.3-0.5%S no later than 2012
	Phase II **Elsewhere**	#4 Fuel Oil 0.25-0.5%S no later than 2018	#4 Fuel Oil 0.25-0.5%S no later than 2018	#4 Fuel Oil 0.25-0.5%S no later than 2018	#4 Fuel Oil 0.25-0.5%S no later than 2018
		#6 Fuel Oil 0.5%S no later than 2018	#6 Fuel Oil 0.5%S no later than 2018	#6 Fuel Oil 0.5%S no later than 2018	#6 Fuel Oil 0.5%S no later than 2018
Coal (and other solid fuels)	Phase I		2.0 lb/MMBtu or 30% reduction*	1.2 lb/MMBtu or 85% reduction*	0.25 lb/MMBtu or 85% reduction*
	Phase II		2.0 lb/MMBtu or 30% reduction*	0.25 lb/MMBTU or 85% reduction*	0.25 lb/MMBTU or 85% reduction*
			** = % reduction based on uncontrolled emissions in base year (2002)*		