A Quantitative Analysis of the Uncertainty of Emissions Data: A Limited Study

William B. Kuykendal
EPA/OAQPS
Jennifer Filipowski
North Carolina State University Intern
Thomas B. McMullen
EPA/Senior Environmental Employee

15th Annual Emissions Inventory Conference
New Orleans, LA
May 16-18, 2006

Acknowledgement

The authors wish to thank Southern Company Services, in general, and Krishnan Kandasamy and Fred Ellis, in particular, for their cooperation in assembling the database used in this study.

The Uncertainty Dilemma

- The emission inventory community has long struggled with how to characterize the uncertainty of emissions inventory data.
- Most recently, the NARSTO Emission Inventory Assessment highlighted the need for better characterization of uncertainty.
- The problem: Traditional uncertainty determination measures an observed value against a known “standard”. There are no “standards” for emission inventories.

Premise and Approach

- In the special case of continuous emissions monitoring (CEM) data, we assumed that we approach the “true value” of emissions from these sources.
- The approach is to estimate emissions from CEM measured sources using emission factors and activity data. The comparison of these results with the CEM data is an indication of the uncertainty of the emissions factor data.

Database Development

- Southern Company Services has assembled a robust emissions database that includes CEM data from their coal fired electric generating units.
- Hourly data were rolled up to monthly.
- Burner type and emission control technology were added.
- Emissions factors and control device efficiencies were selected from AP-42.
- Mass of coal burned was provided and used to calculate emissions.
- Analysis limited to NO_x and SO_2.

Basic Emission Estimation Equation

$$E = A \times EF \times (1-ER/100)$$

Where:

E = Emissions

A = Activity Rate

EF = Emission Factor

ER = Overall Emission Reduction Efficiency,%

Units in the Study

Combustor Type	Emission Factor Range		Emissions Reduction Efficiency Range		Number of Units
	NO_x	SO_2	NO_x	SO_2	
Tangentially Fired Bituminous	9.7-15	38S	0-78.5	0-92.5	36
Wall Fired Bituminous	11-22	38S	0-78.5	0	19
Cell Burner Bituminous	31	38S	45	0	4
Tangentially Fired Sub-bituminous	7.2	35S	17.5	0	4
Wall Fired Sub-bituminous	7.4	35S	0	0	4
TOTAL					67

Analytical Approach

CEM/AP-42 Comparisons

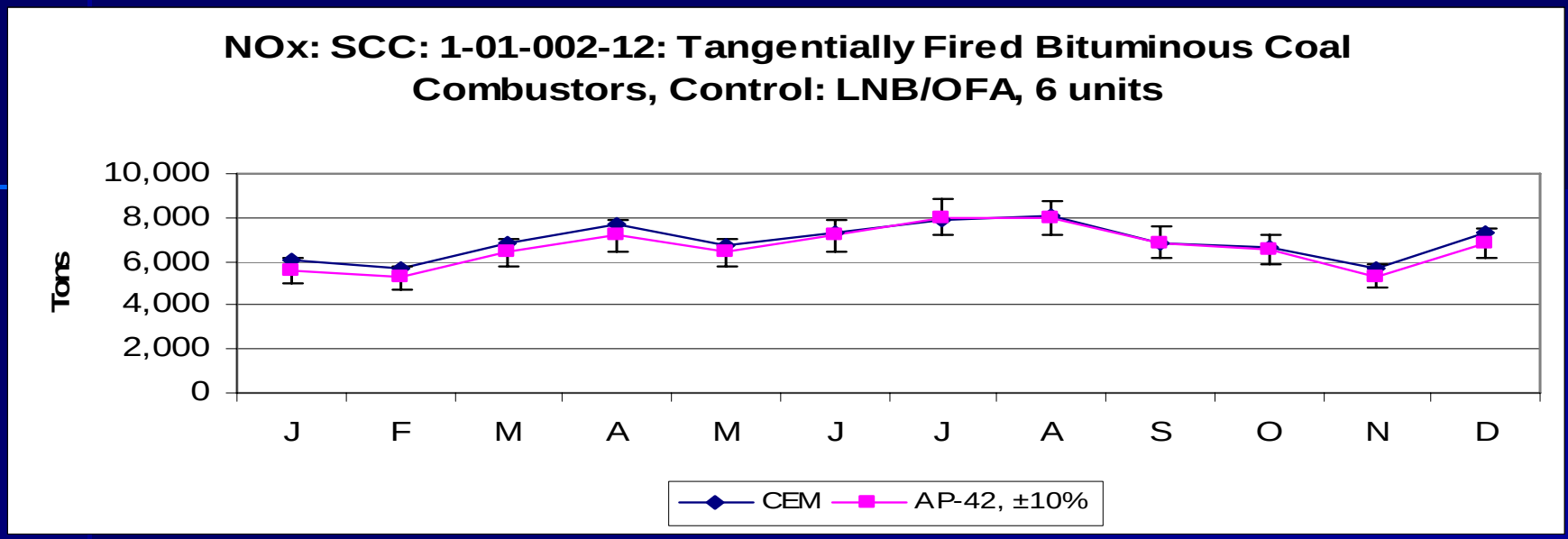
- Evaluated for monthly fluctuations
- Histograms developed for “Implied Emission Factor”
- Combustor type and burner configuration
  - Data evaluated for % difference and bias
- Tangentially Fired Units
- Wall Fired Units
- Data evaluated by emission estimation method (with and without correction term for overall emission reduction efficiency)

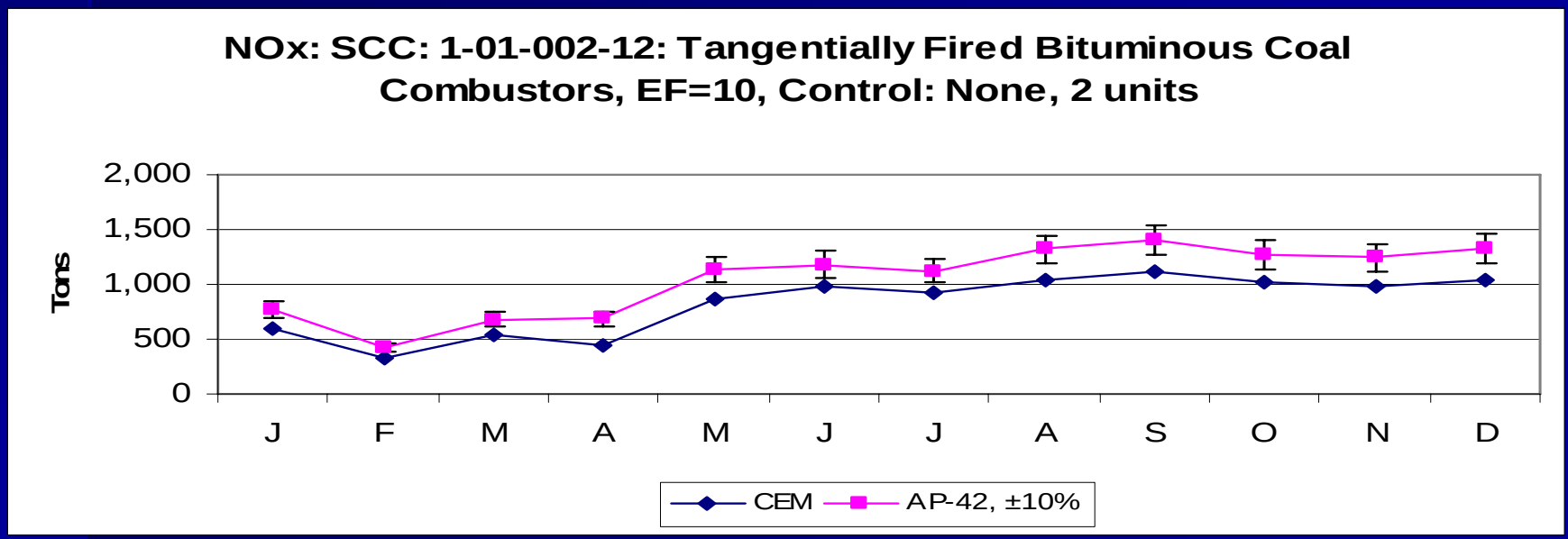
Audience Participation:
Delphi Panel

% Difference
AP-42 / CEM

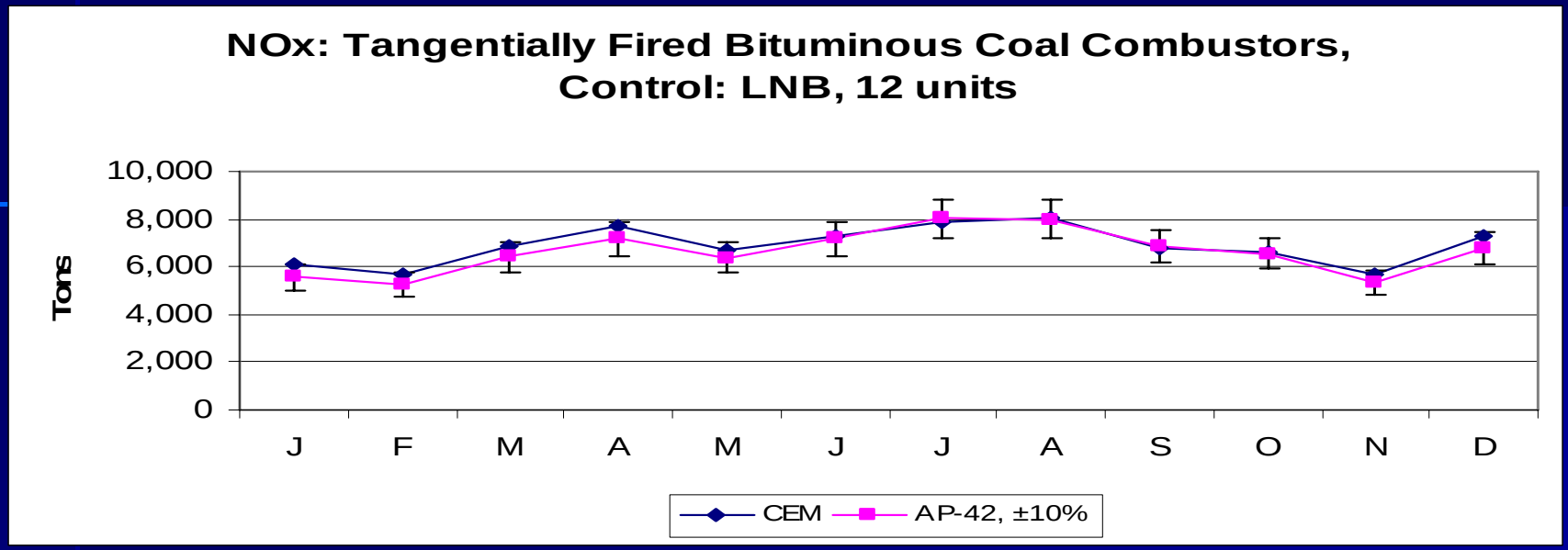
0-10
10-25
25-100
>100

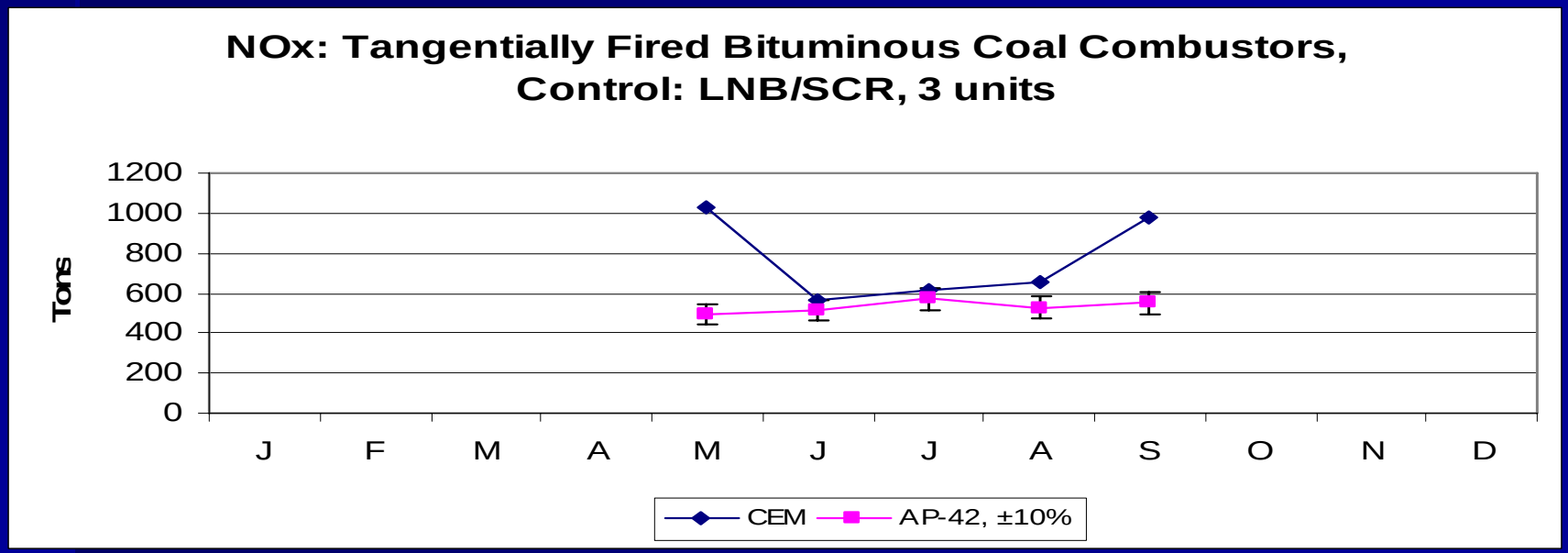
Monthly Fluctuations



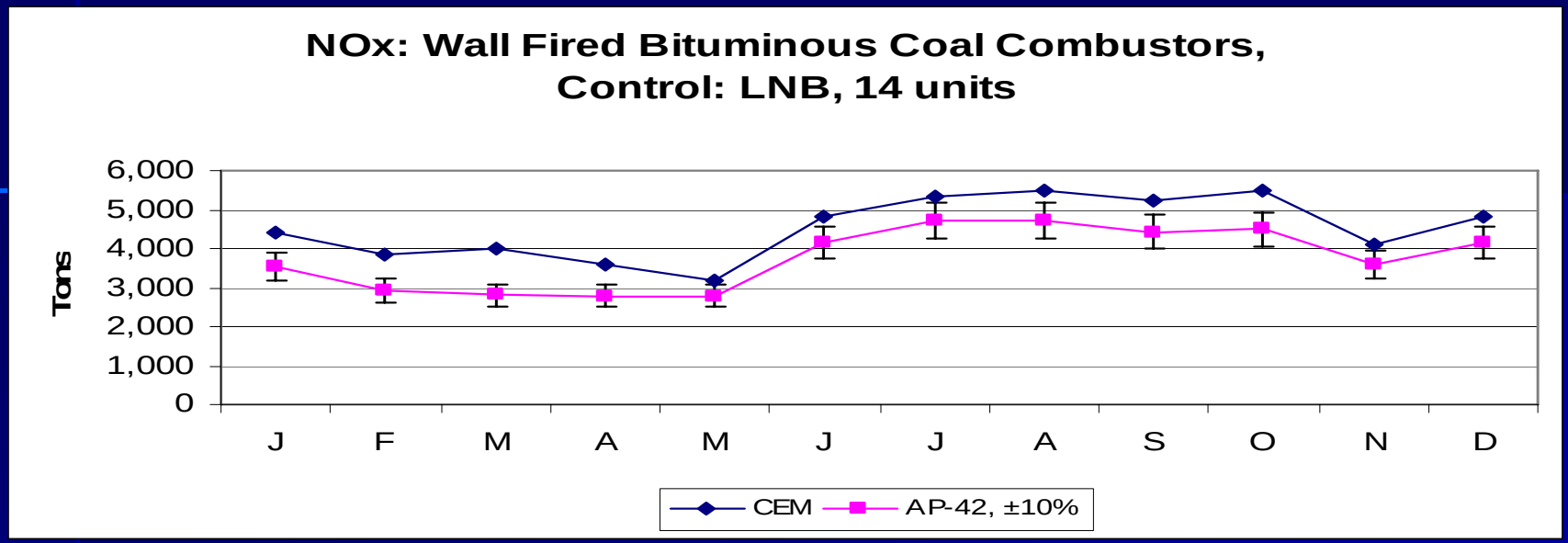


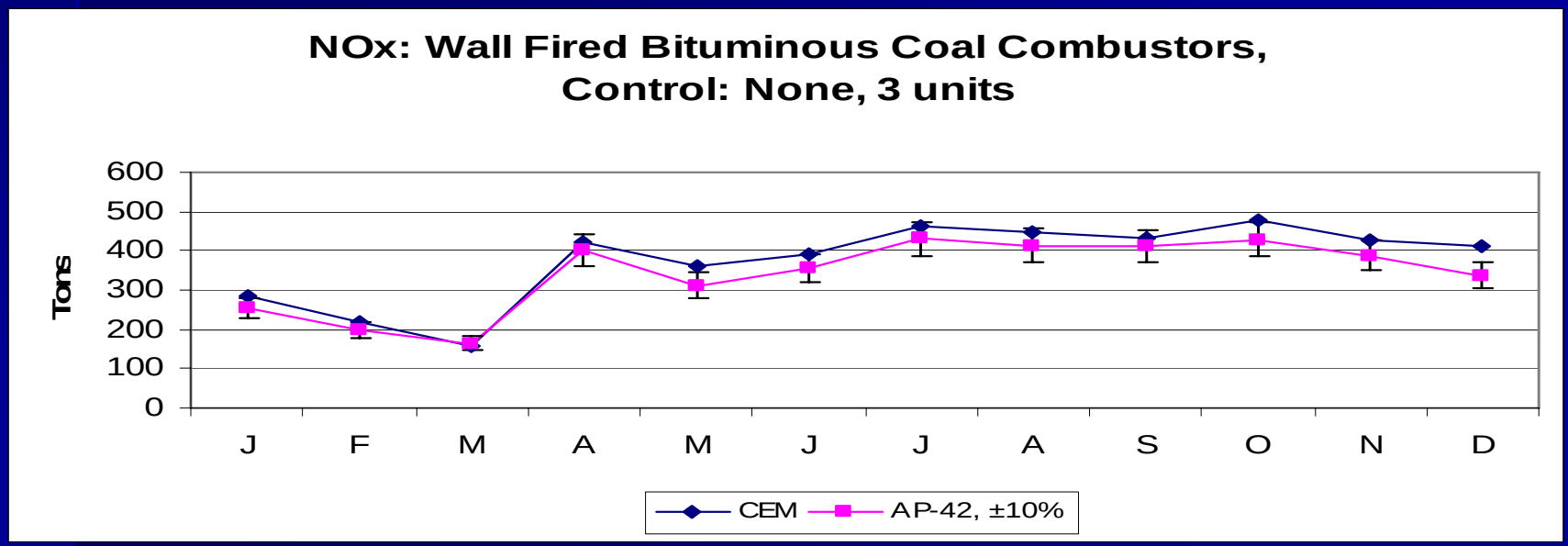
Monthly Fluctuations



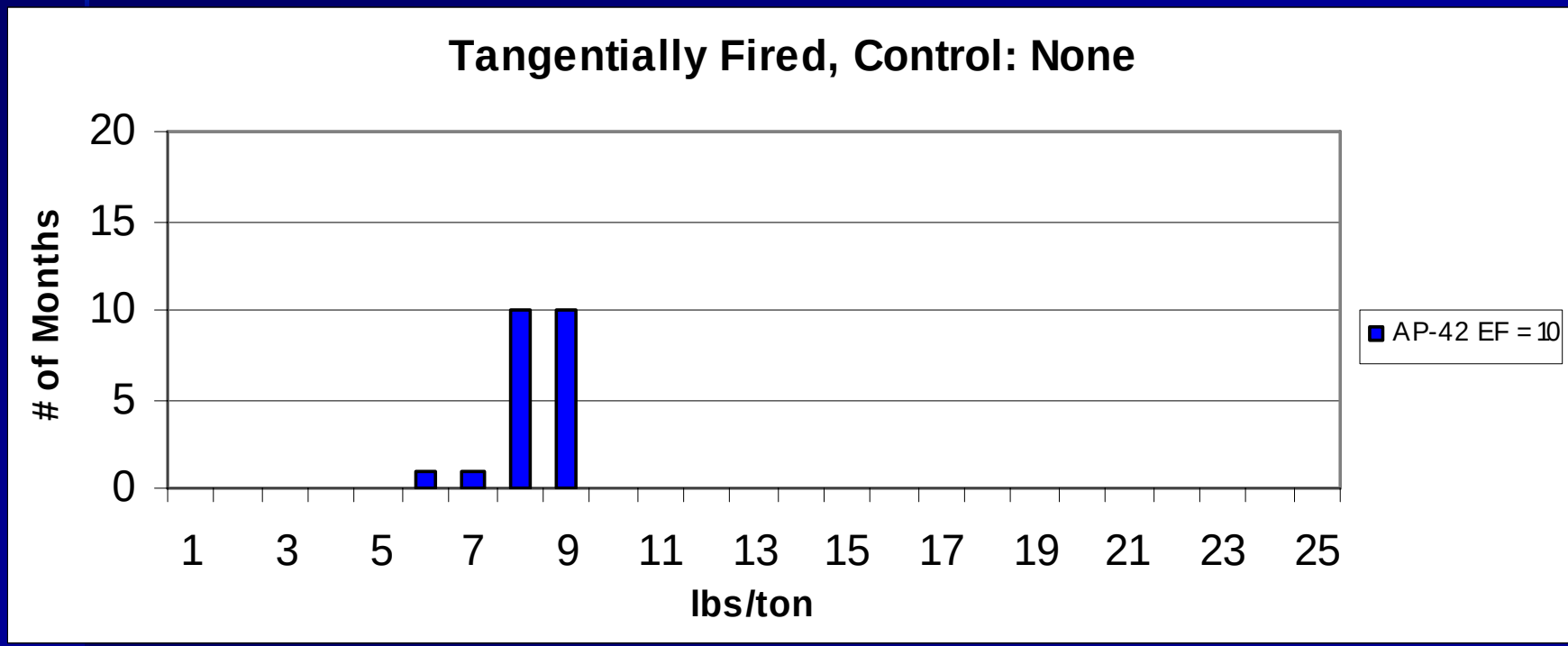


Monthly Fluctuations

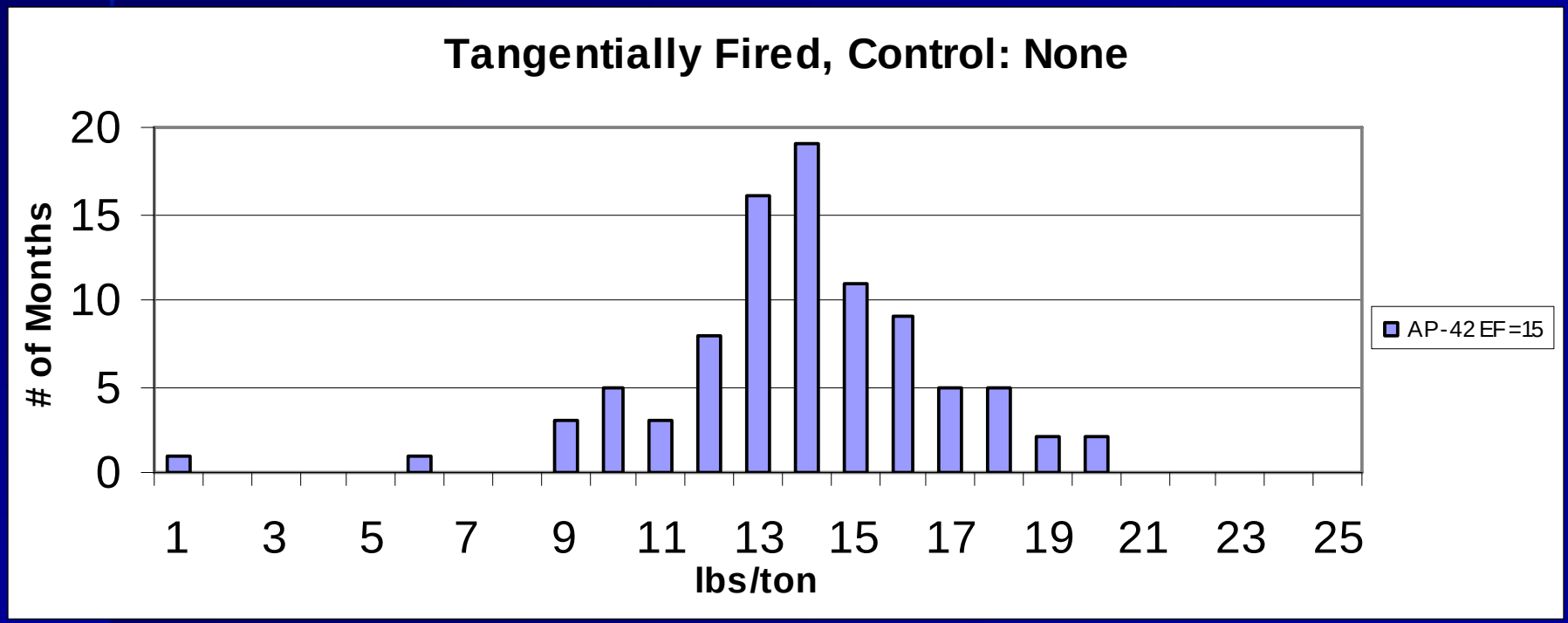




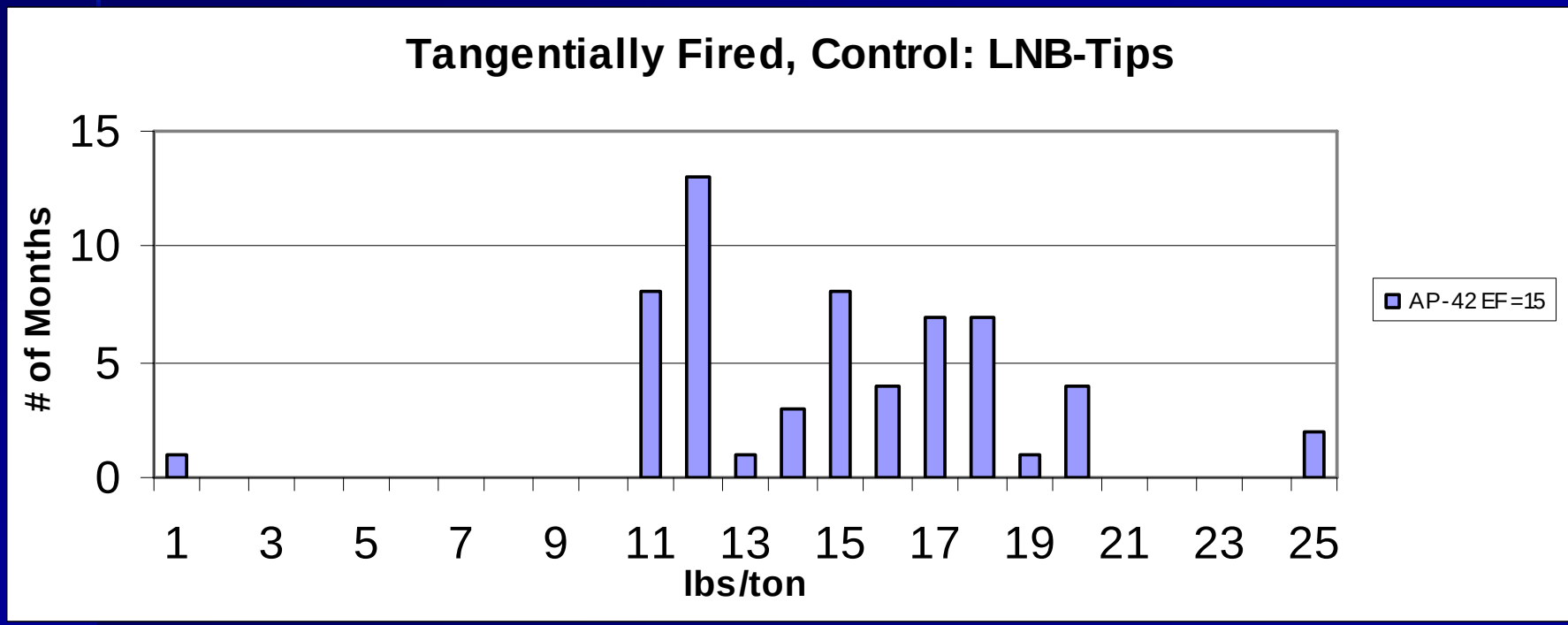
Implied Emission Factors



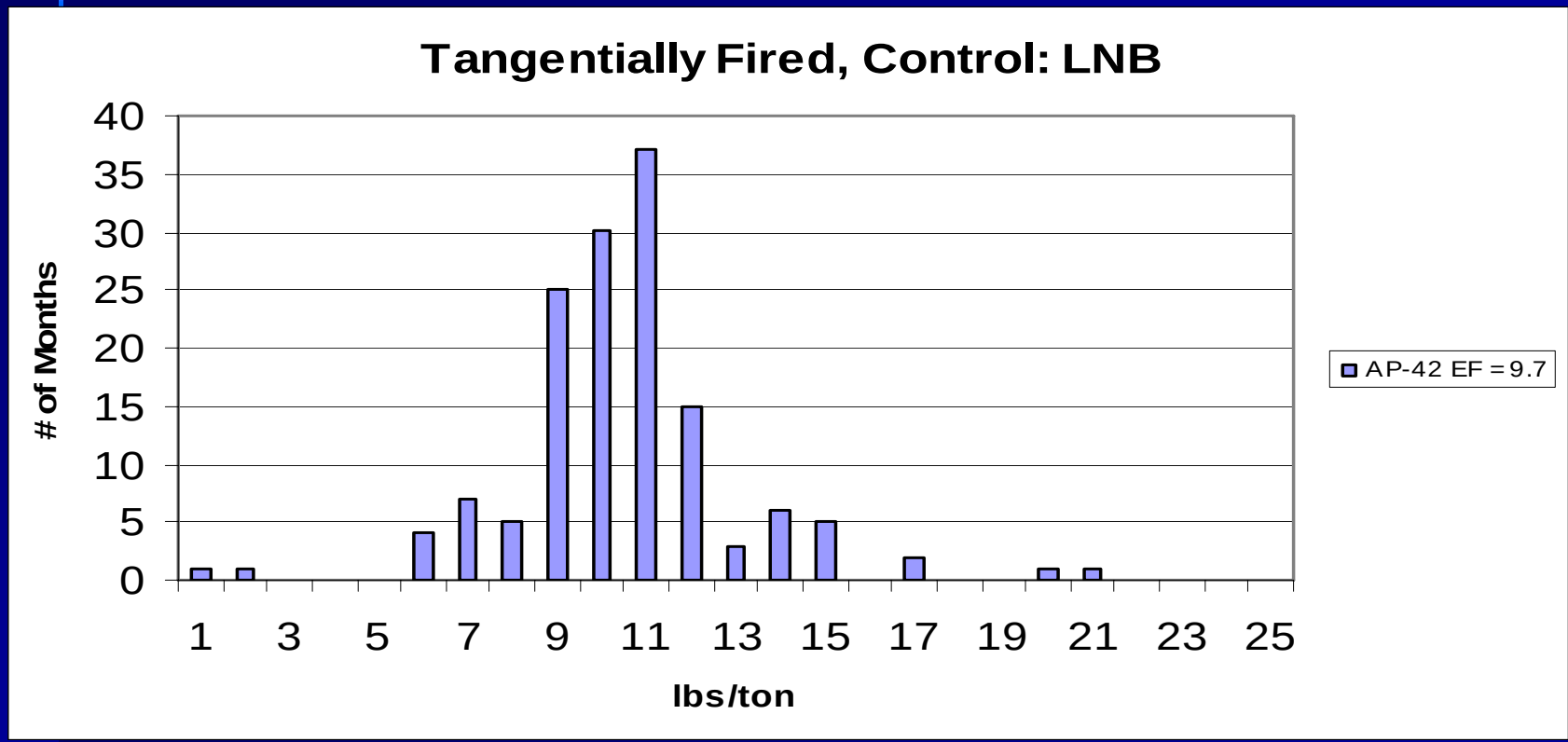
Implied Emission Factors



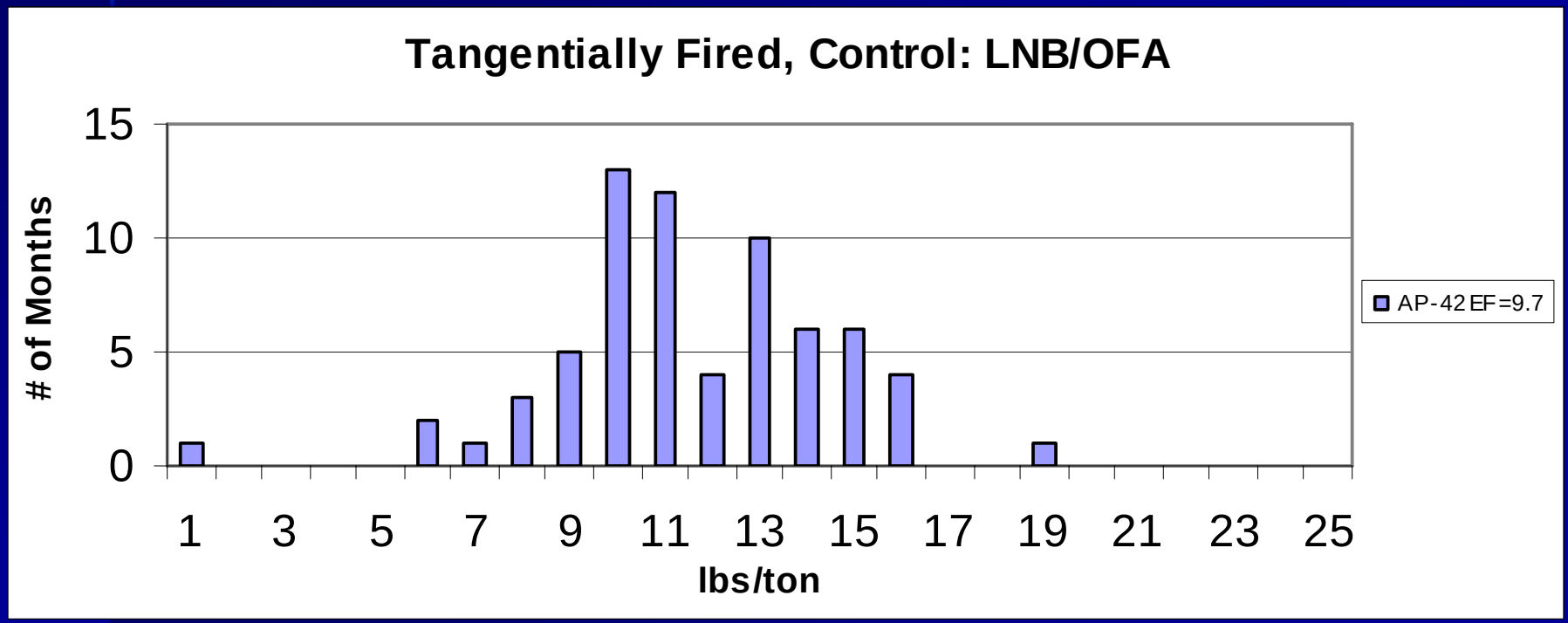
Implied Emission Factors



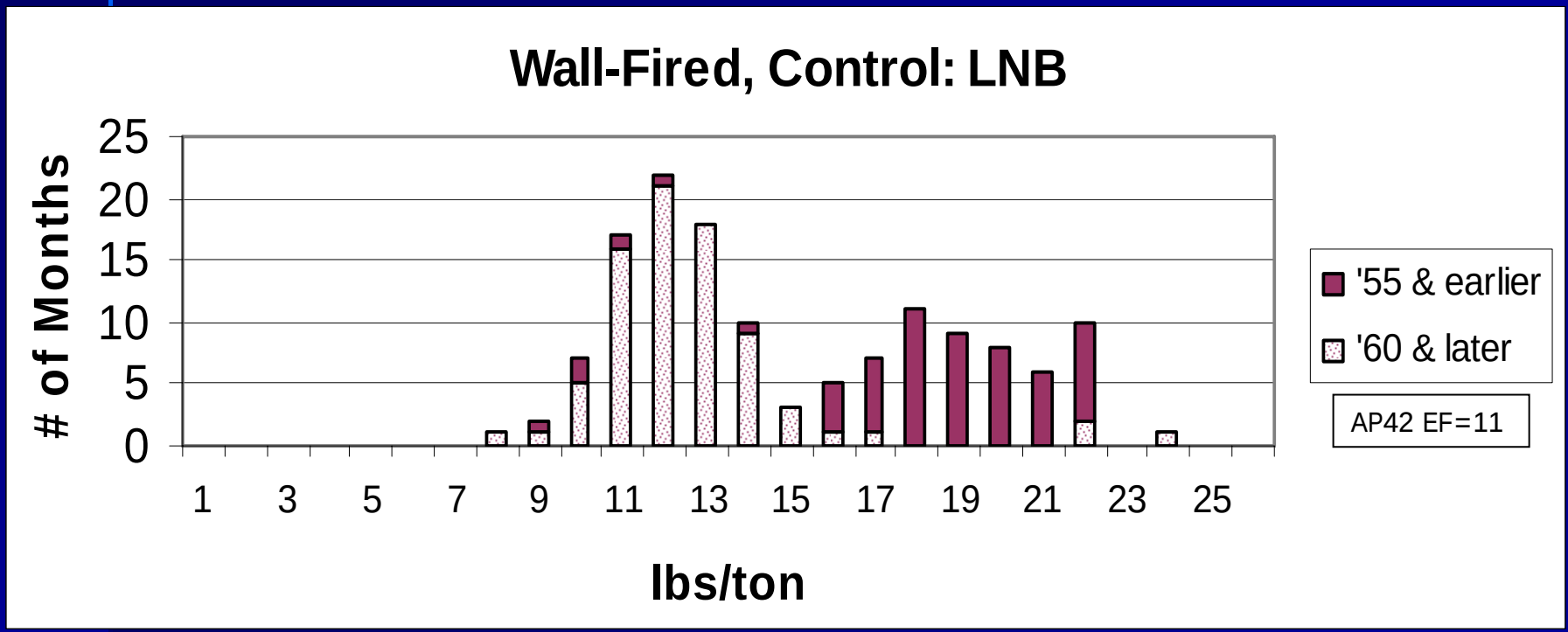
Implied Emission Factors



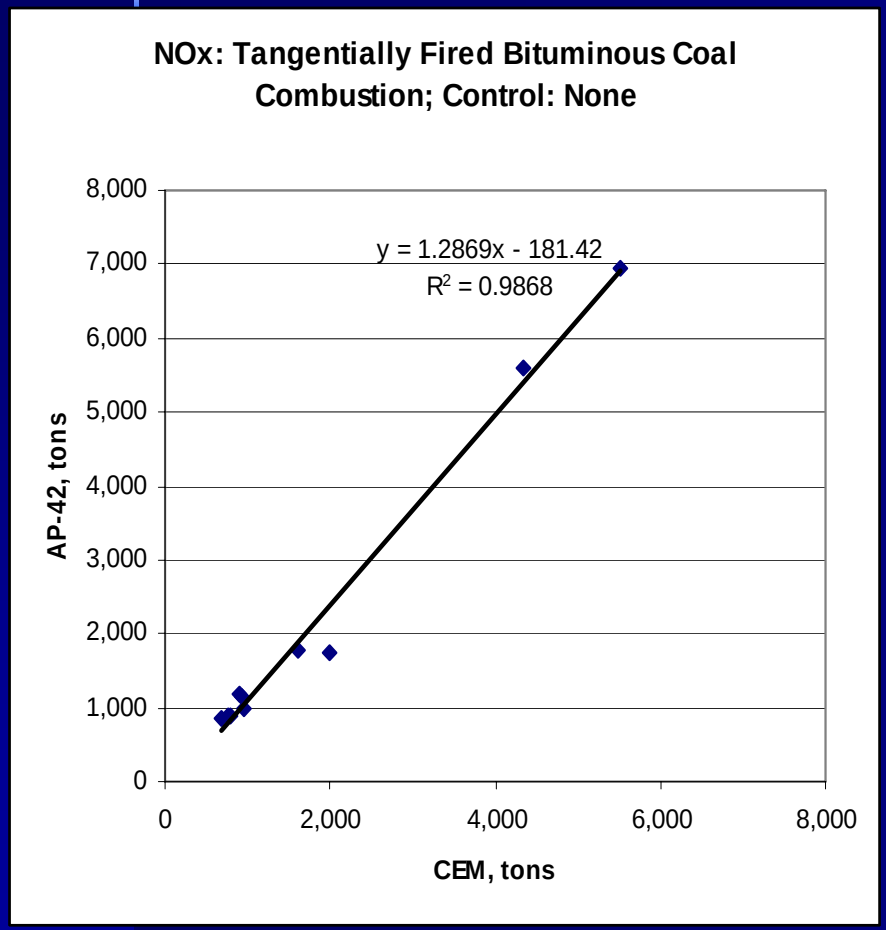
Implied Emission Factors

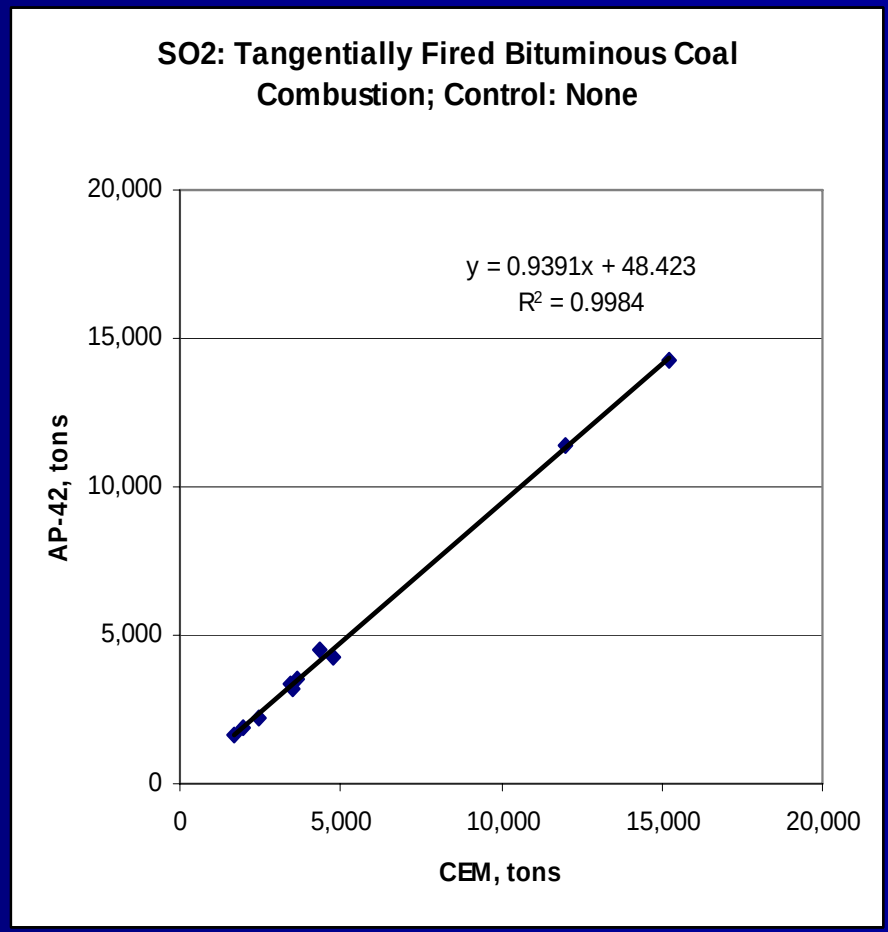


Implied Emission Factors

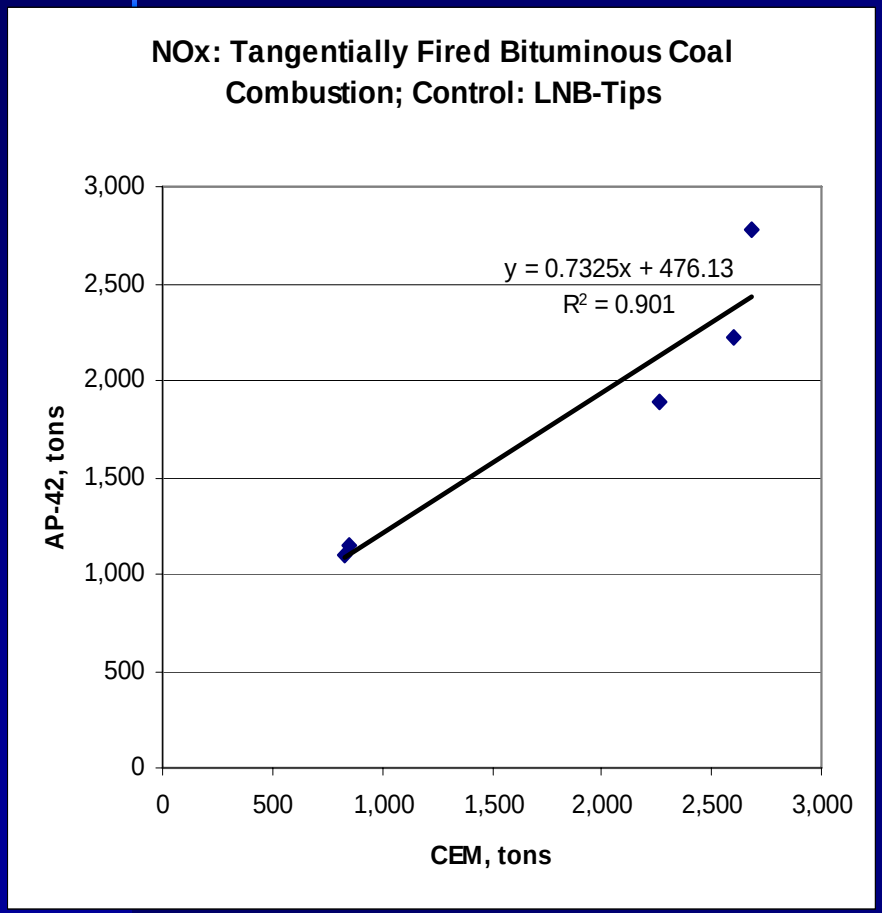


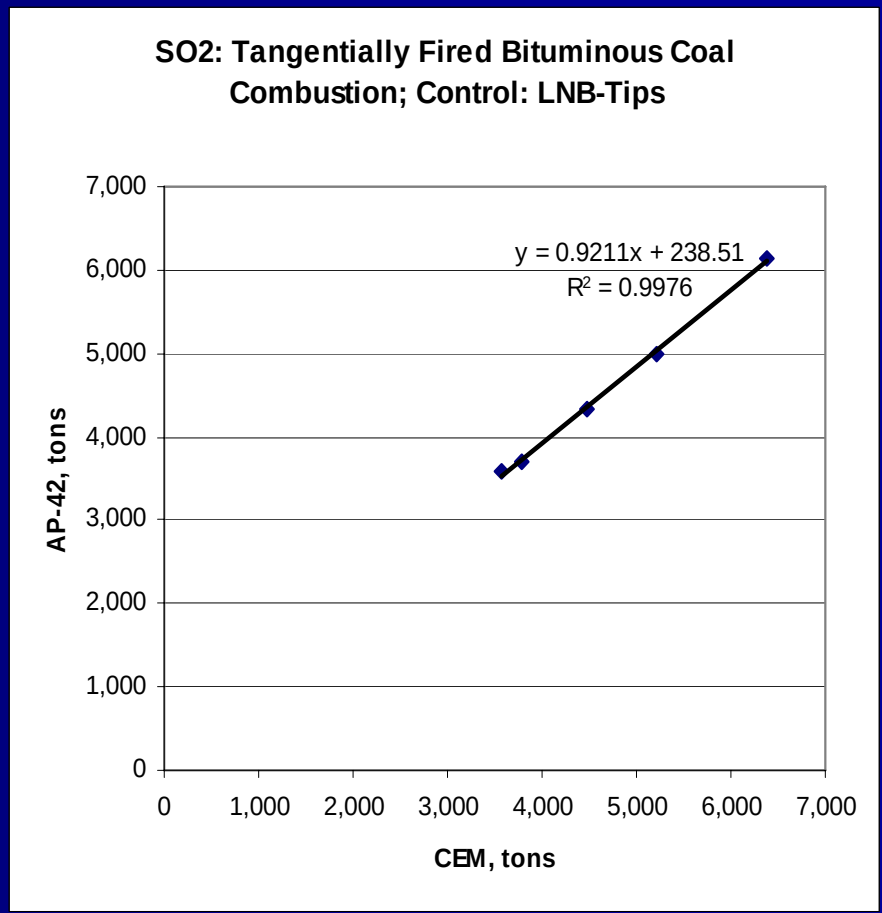
Combustor Type and Burner Configuration



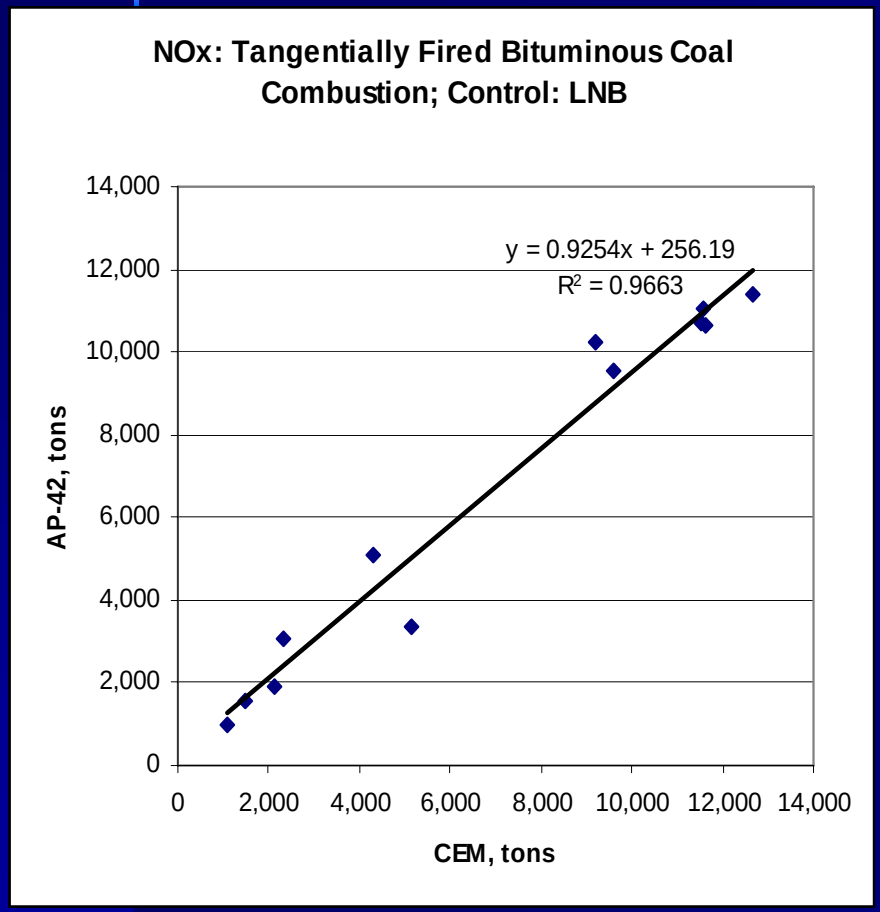


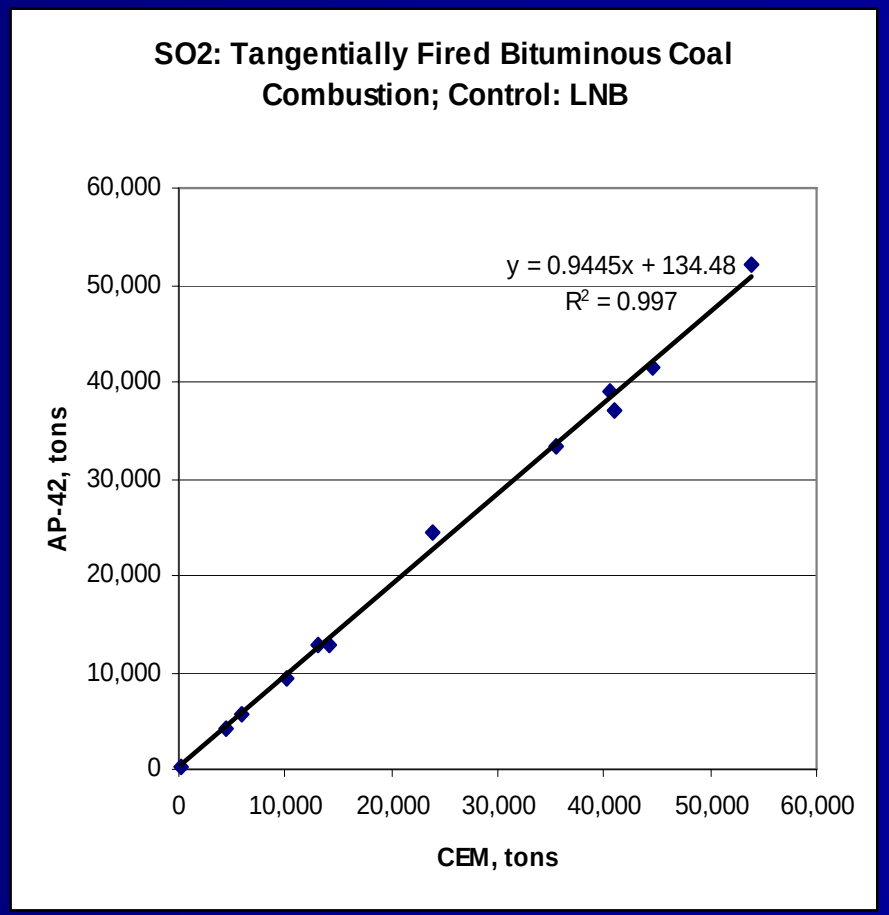
Combustor Type and Burner Configuration



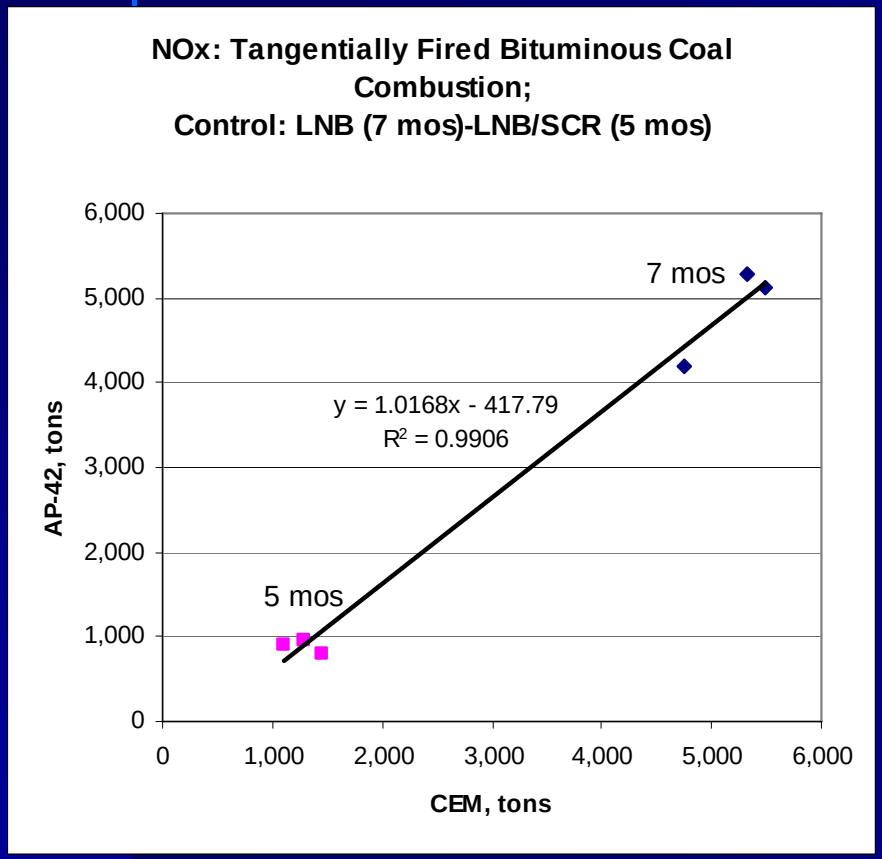


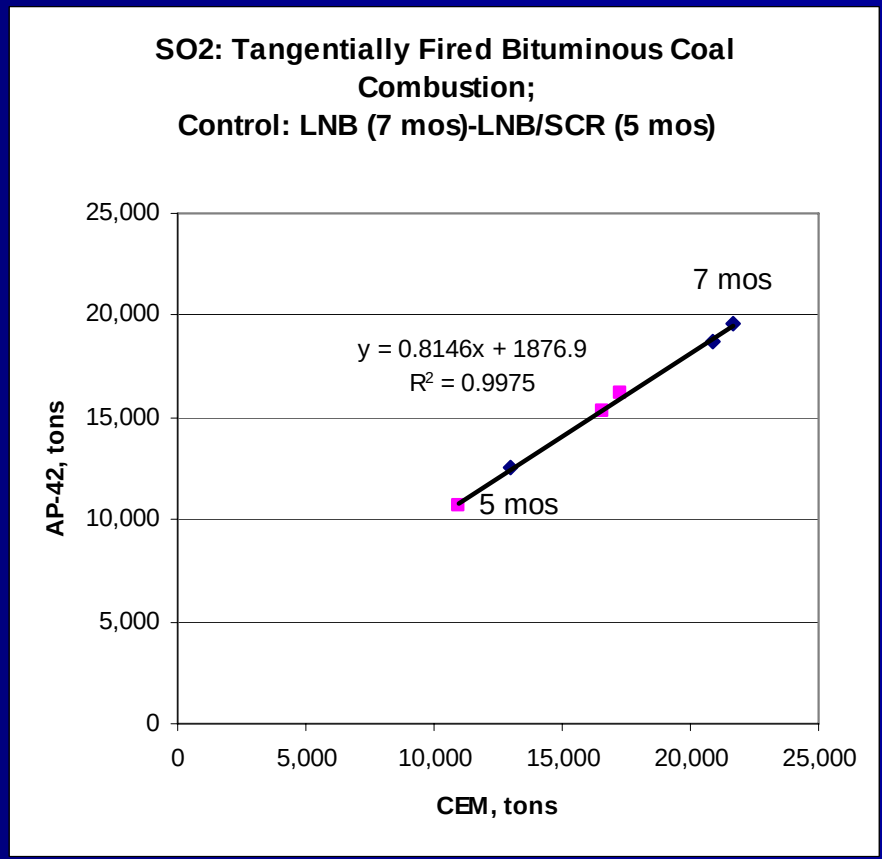
Combustor Type and Burner Configuration



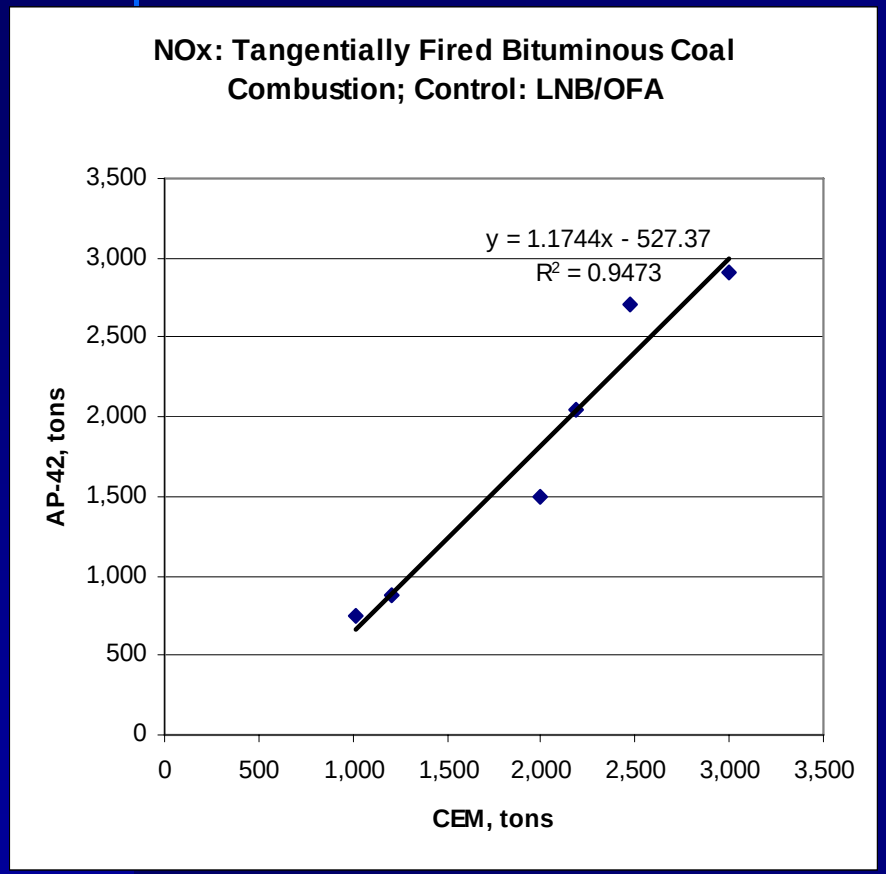


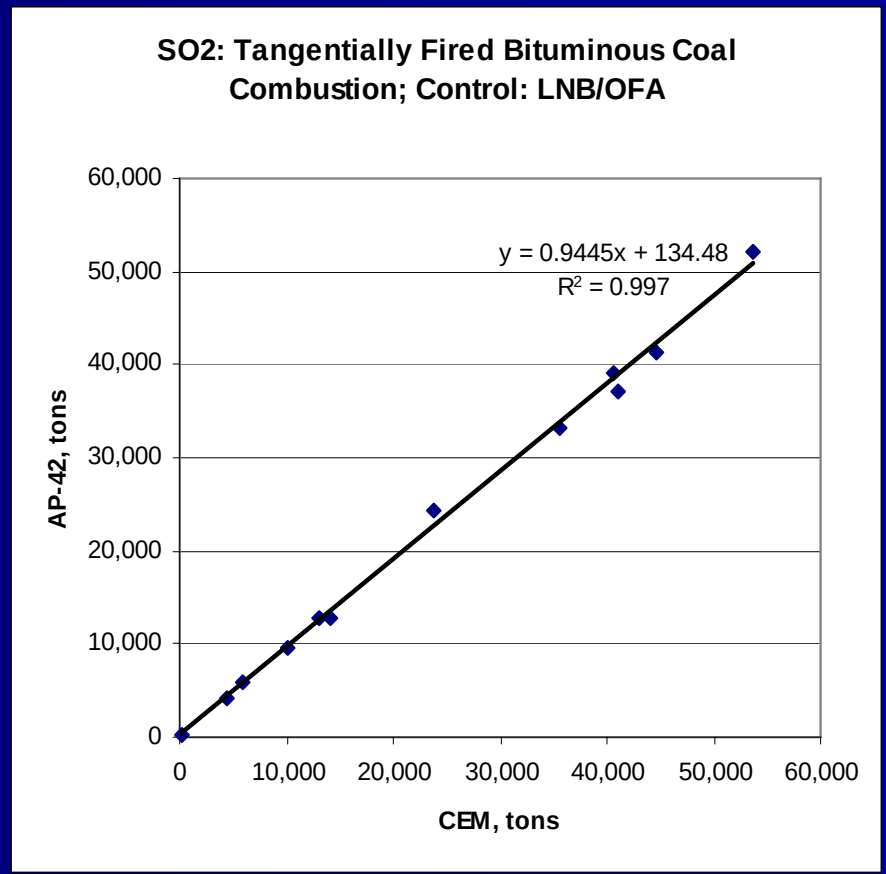
Combustor Type and Burner Configuration





Combustor Type and Burner Configuration

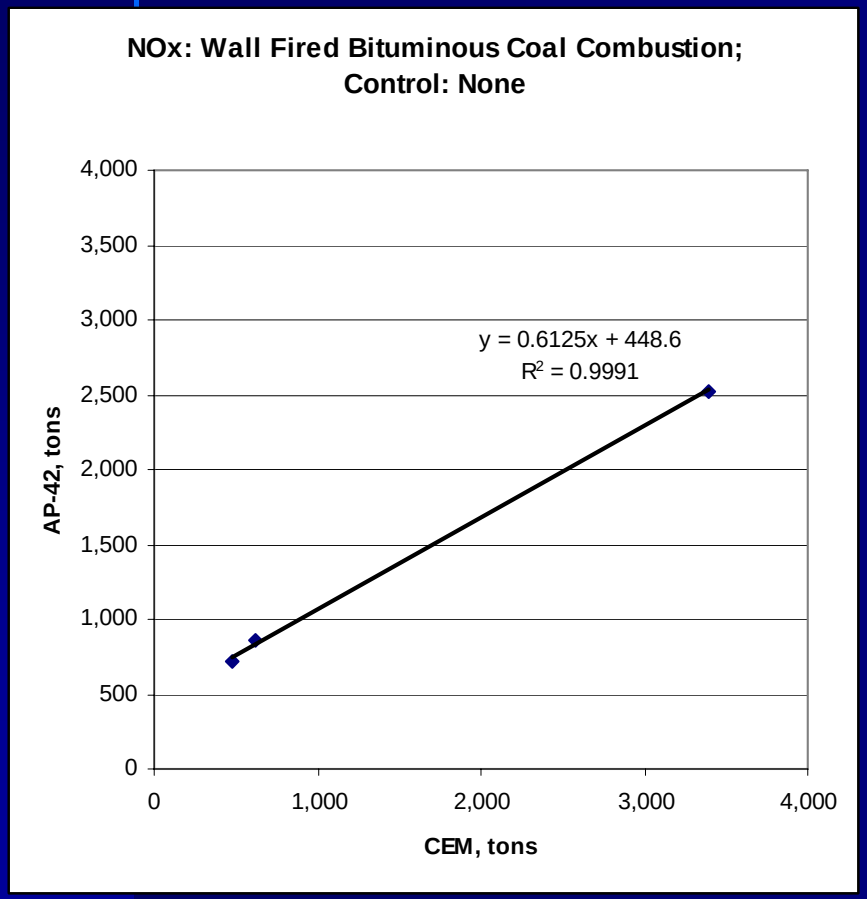


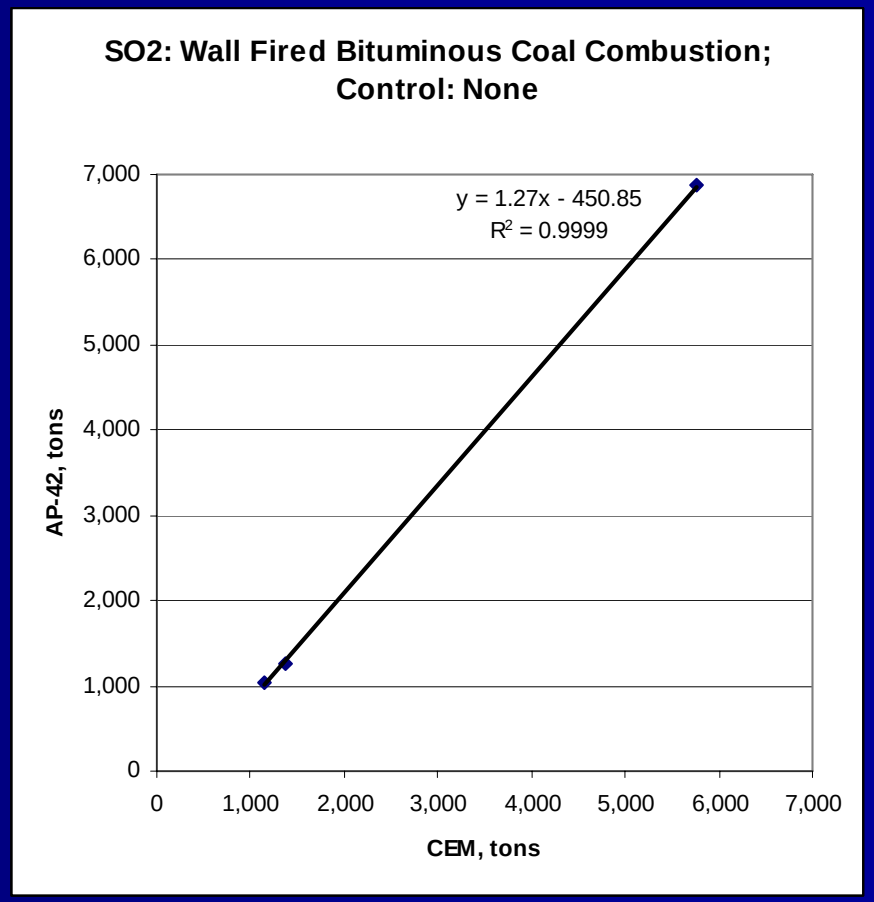


Tangentially Fired Bituminous Coal Combustors

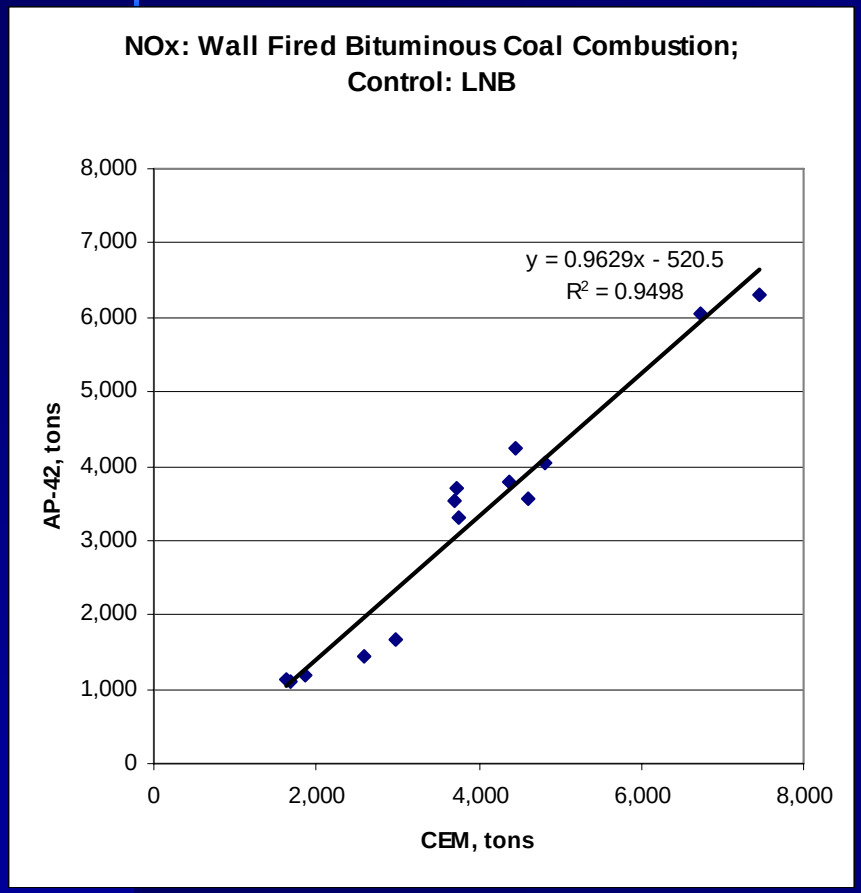
Units	Control Eq		AP-42 NOx (tons)	CEM NOx (tons)	% Difference	AP-42 SO2 (tons)	CEM SO2 (tons)	% Difference
10	None	**SUM:**	**21,995**	**18,501**	**-18.88%**	***50,249***	***52,992***	***5.18%***
		MAX:	6,947	5,512	13.01%	*14,273*	*15,213*	*10.37%*
		MIN:	841	673	-32.34%	*1,667*	*1,653*	*-3.65%*
5	LNB Tips	**SUM:**	**9,141**	**9,228**	**0.95%**	**22,765**	**23,421**	**2.80%**
		MAX:	2,780	2,678	16.31%	6,151	6,377	4.23%
		MIN:	1,103	834	-34.63%	3,591	3,565	-0.75%
12	LNB	**SUM:**	**79,594**	**82,691**	**3.75%**	**272,894**	**287,208**	**4.98%**
		MAX:	11,394	12,678	34.42%	52,208	53,783	9.44%
		MIN:	980	1,091	-31.68%	303	263	-15.13%
3	*LNB, 7 mos*	***SUM:***	***14,579***	***15,584***	***6.45%***	***50,872***	***55,503***	***8.3%***
		MAX:	*5,274*	*5,497*	*11.97%*	*19,570*	*21,660*	*10.4%*
		MIN:	*4,185*	*4,754*	*1.10%*	*12,609*	*12,984*	*2.9%*
15	LNB, All	**SUM:**	**94,172**	**98,275**	**4.17%**	**323,766**	**342,711**	**5.53%**
		MAX:	11,394	12,678	34.42%	52,208	53,783	10.4%
		MIN:	980	1,091	-31.68%	303	263	-15.13%
3	LNB/SCR. 5 mos	**SUM:**	**2,665**	**3,841**	**30.61%**	**42,148**	**44,862**	**6.0%**
		MAX:	955	1,444	44.15%	16,182	17,273	7.83%
		MIN:	807	1,113	18.82%	10,661	10,982	2.92%
6	LNB/OFA	**SUM:**	**10,783**	**11,876**	**9.20%**	**52,919**	**59,173**	**10.57%**
		MAX:	2,907	2,998	27.34%	14,706	16,951	15.74%
		MIN:	743	1,011	-9.43%	3,698	4,076	0.02%
36		**GRAND SUM:**	**138,757**	**141,721**	**2.09%**	**491,847**	**523,159**	**5.99%**
		MAX:	11,394	12,678	44.15%	52,208	53,783	15.74%
		MIN:	743	673	-34.63%	303	263	-15.13%

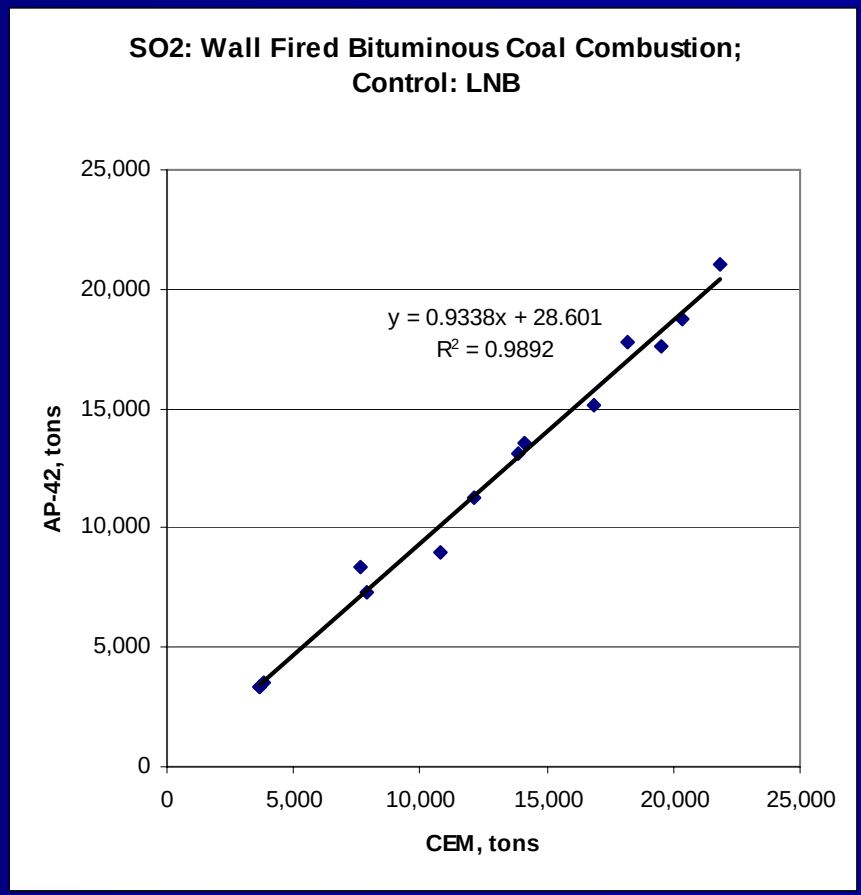
Combustor Type and Burner Configuration





Combustor Type and Burner Configuration

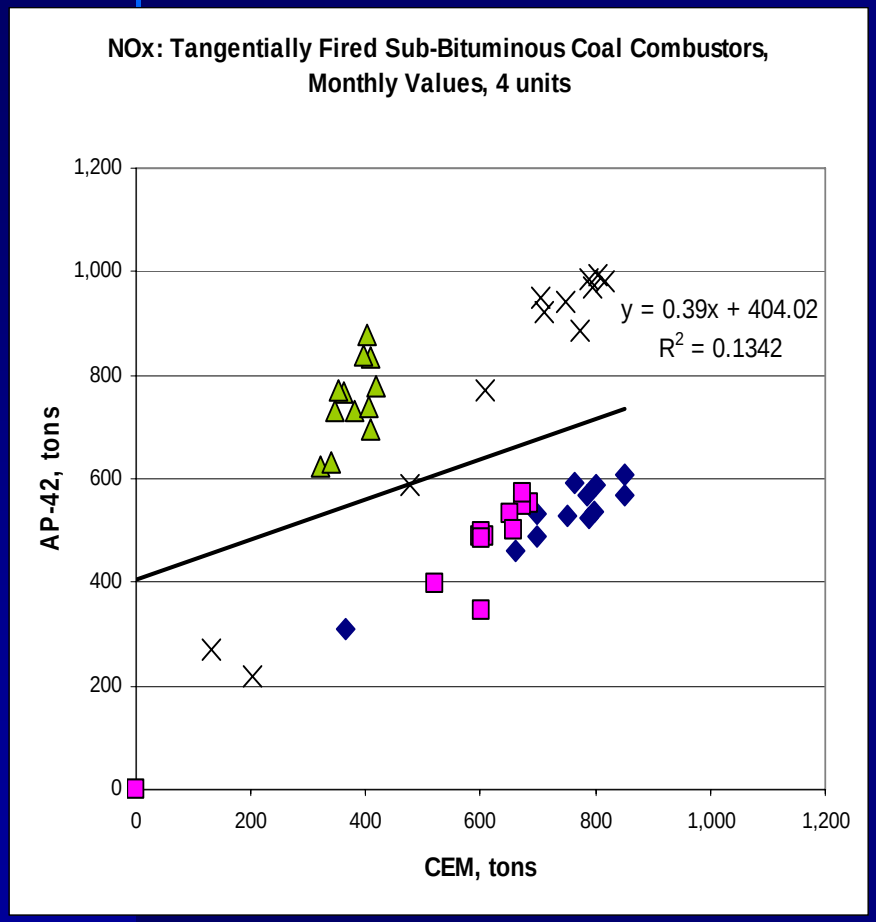


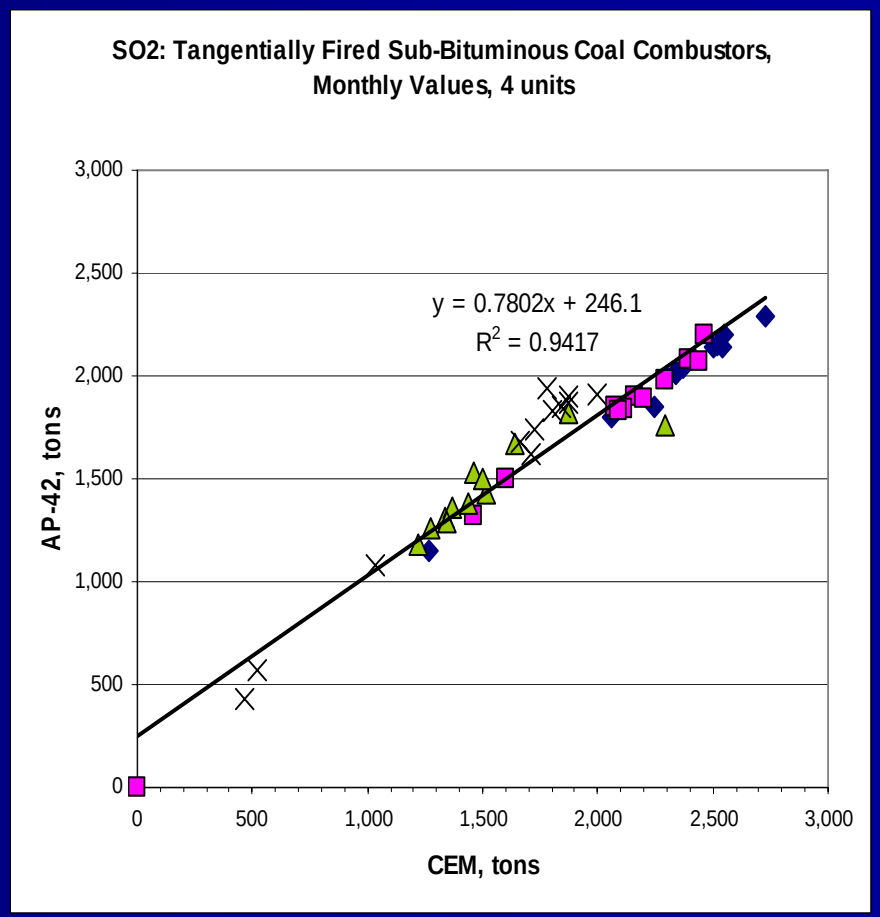


Wall Fired Bituminous Coal Combustors

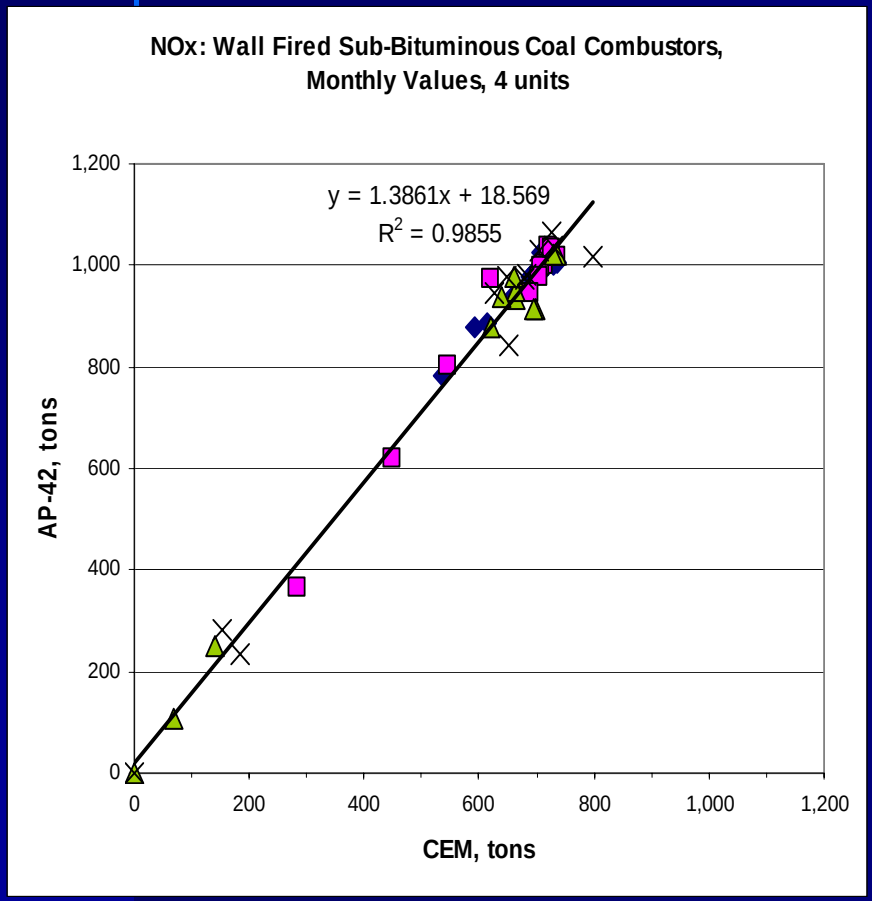
Units	Control Eq		AP-42 NOx, tons	CEM NOx, tons	% Difference	AP-42 SO2, tons	CEM SO2, tons	% Difference
3	None	**SUM:**	**4,095**	**4,489**	**8.77%**	**9,164**	**8,281**	**-10.67%**
		MAX:	2,528	3,397	25.59%	6,864	5,759	10.06%
		MIN:	712	478	-49.04%	1,037	1,153	-19.19%
14	LNB	**SUM:**	**45,054**	**54,355**	**17.11%**	**163,139**	**174,266**	**6.39%**
		MAX:	6,291	7,451	44.17%	21,011	21,810	16.79%
		MIN:	1,107	1,619	0.77%	3,315	3,622	-10.23%
1	LNB/OFA		2,853	3,986	28.42%	14,728	15,532	5.18%
1	LNB/OFA, 7 mos		2,082	2,568	18.94%	15,870	17,044	6.89%
	LNB/OFA/SCR, 5 mos		501	724				
19		**GRAND SUM:**	**54,084**	**65,398**	**17.30%**	**202,901**	**215,123**	**5.68%**
		MAX:	6,291	7,451	44.17%	21,011	21,810	16.79%
		MIN:	1,107	1,619	0.77%	3,315	3,622	-10.23%

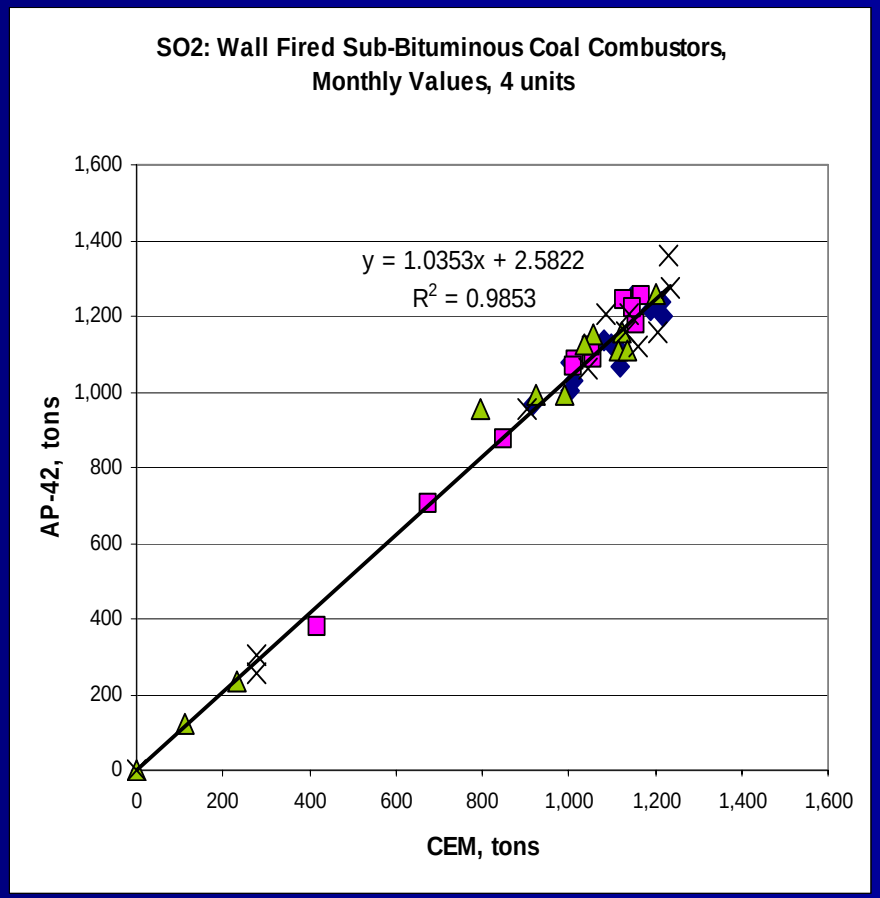
Combustor Type and Burner Configuration



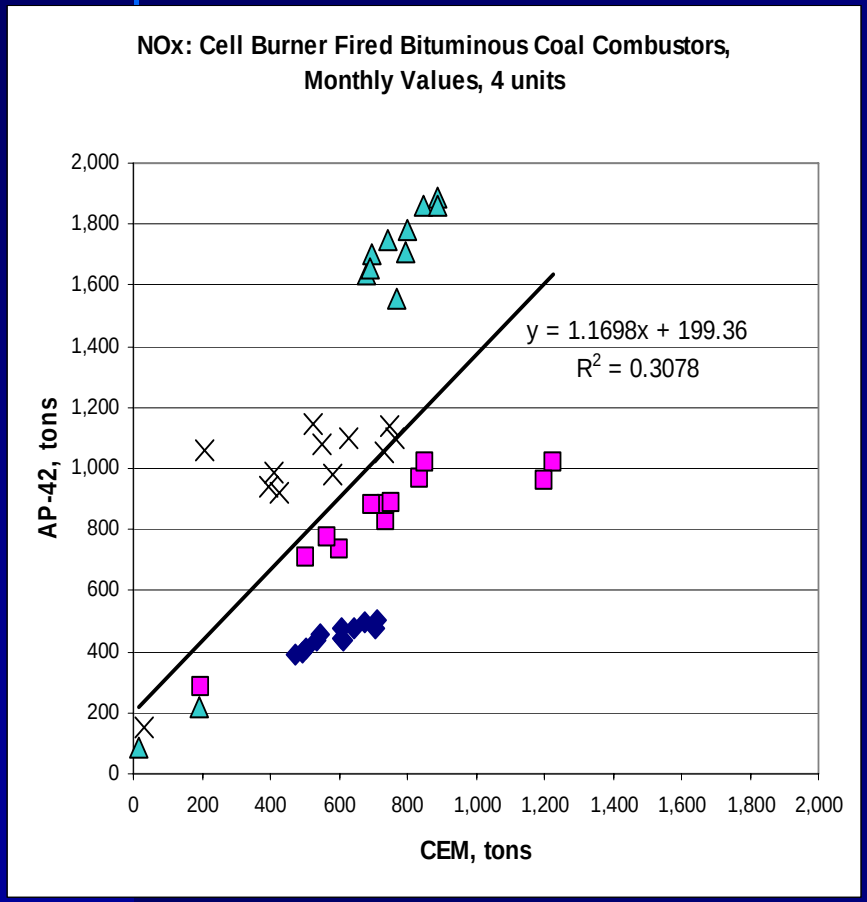


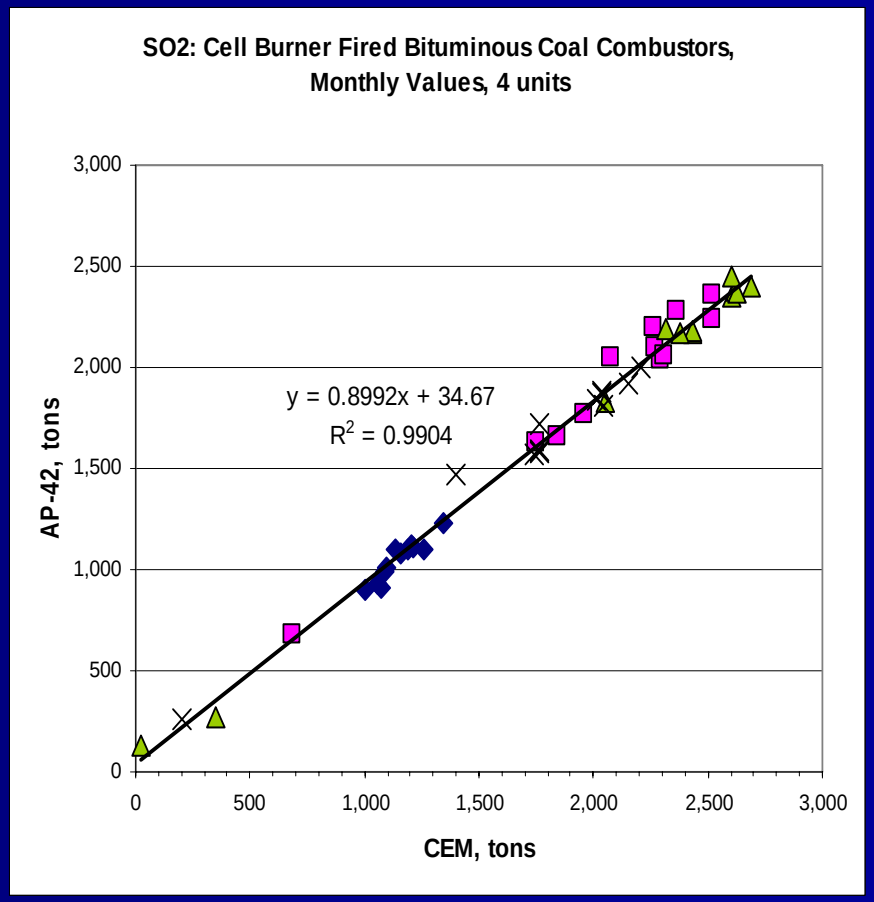
Combustor Type and Burner Configuration





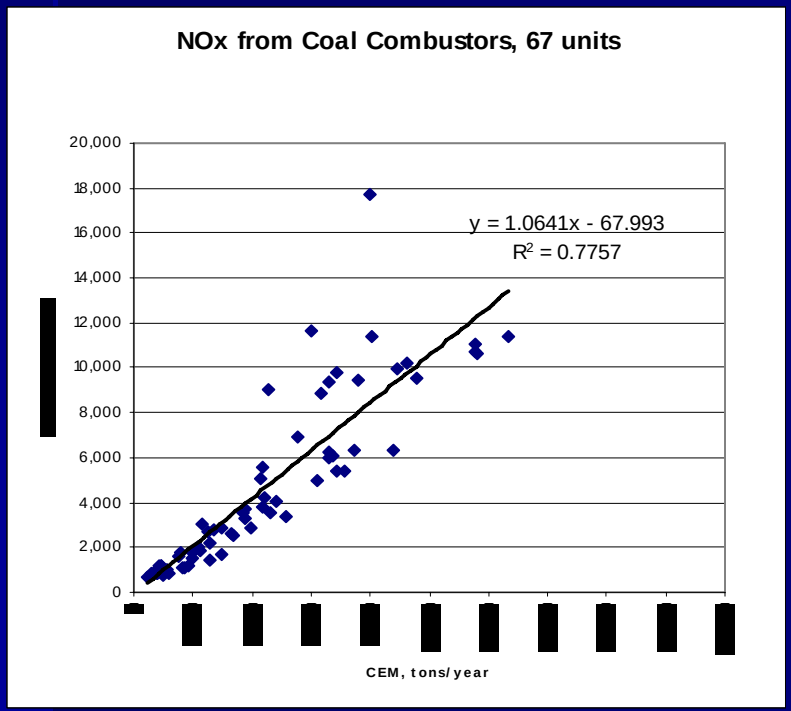
Combustor Type and Burner Configuration

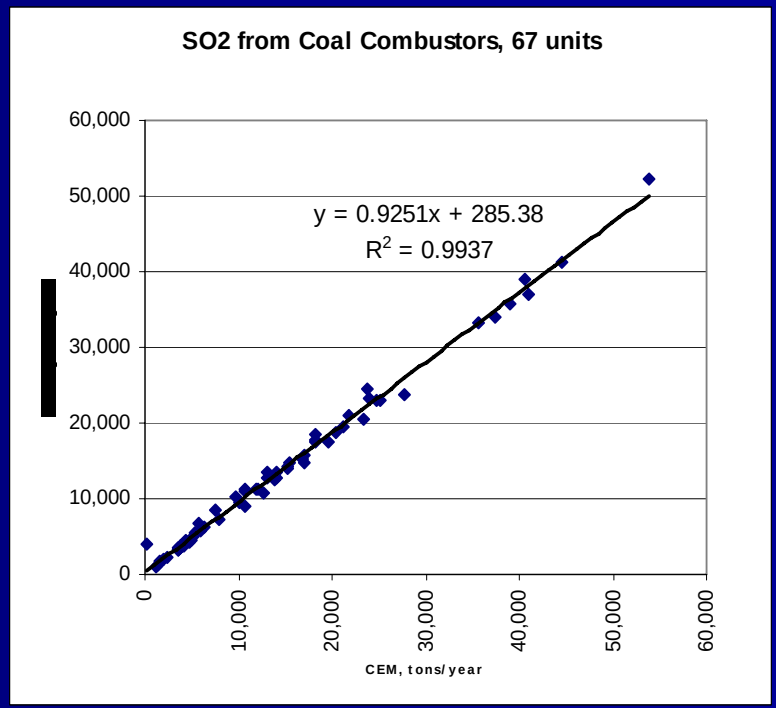




Results Summary

COAL	Units	Emission Factor NOx (tons)	CEM NOx (tons)	% Difference	Emission Factor SO2 (tons)	CEM SO2 (tons)	% Difference
Wall Fired Bituminous Coal Combustors	19	54,585	66,122	17.45%	202,901	215,123	5.68%
Tangentially Fired Bituminous Coal Combustors	36	138,757	141,721	2.09%	495,581	523,159	5.27%
Cell Burner Fired Bituminous Coal Combustors	4	44,699	30,031	-48.84%	78,043	84,937	8.12%
Wall Fired Sub-Bituminous Coal Combustors	4	39,464	27,828	-41.81%	45,902	44,218	-3.81%
Tangentially Fired Sub-Bituminous Coal Combustors	4	30,225	27,775	-8.82%	80,162	87,609	8.50%
	67	**307,730**	**293,478**	**-4.86%**	**902,588**	**955,047**	**5.49%**





Basic Emission Estimation Equation

$$E = A \times EF \times (1-ER/100)$$

Where:

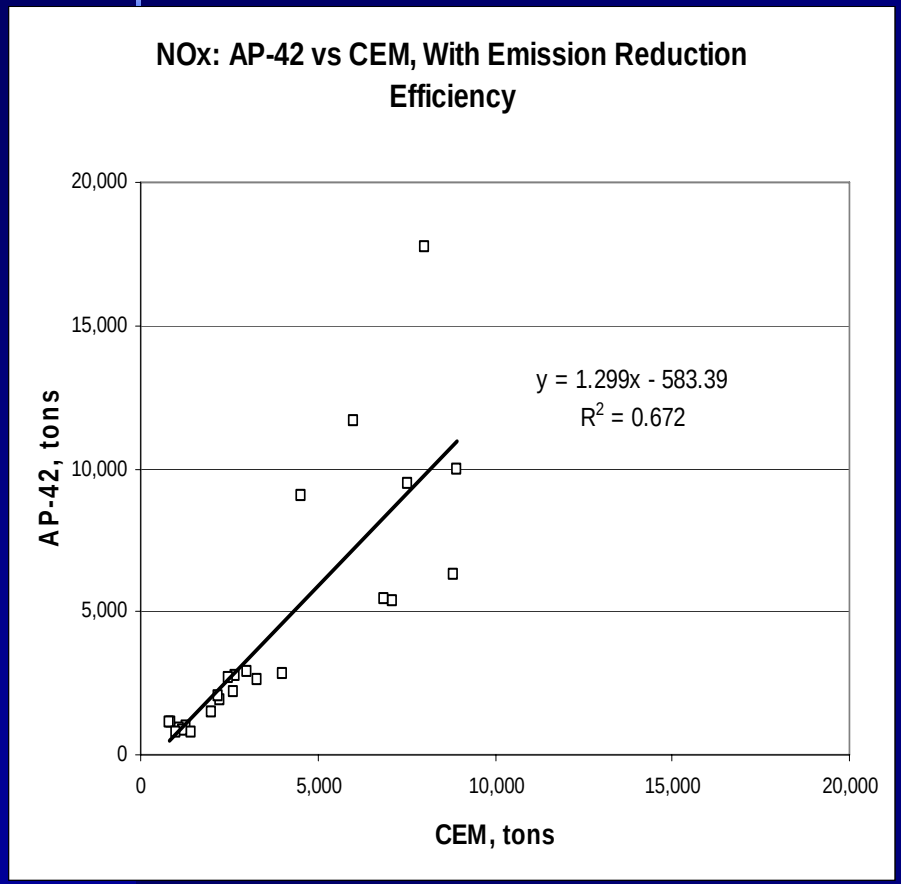
E = Emissions

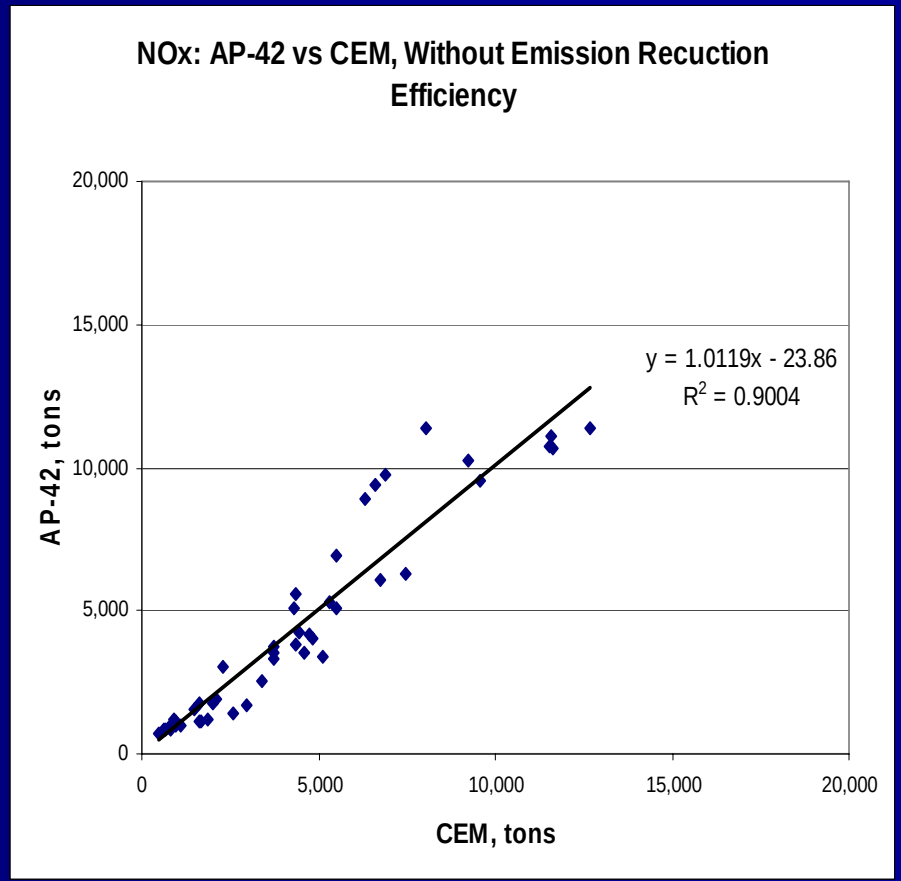
A = Activity Rate

EF = Emission Factor

ER = Overall Emission Reduction Efficiency,%

Emission Estimation Method





Conclusions

- For high quality emission factors with good activity data, estimates agree in the range of 5%
- For an individual source, emission factor estimates can have much larger differences
- Scatter was greater for NO_x data with no consistent bias
- SO_2 results were very consistent with a negative bias for the AP-42 EF
- Agreement is better when no correction term is used