RACT EMISSION LIMIT ANALYSIS

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RACT EMISSION LIMIT ANALYSIS

BACKGROUND

A draft Reasonably Available Control Technology (RACT) based operating permit was issued to Koppers Industries, Inc. (KII), Monessen Coke Plant, Monessen, Pennsylvania in March of 1998. Several of the RACT emission limits set in the permit were based solely on a single emissions stack test performed in 1997. During a subsequent diagnostic test program in April 1998 Air/Compliance Consultants, Inc. (ACCI) determined that some of the previous test results used in the RACT determination were in error. Due to concerns regarding the proposed emission limits, Koppers initiated an extended emissions testing program. Emissions testing was conducted by ACCI on Coke Battery 1B and Battery 2 Combustion Stacks and the Pushing Emissions Control System (PECS). The extended test program was conducted in conjunction with a compliance test program to estimate the maximum hourly emissions from the facility, to determine variations in process emissions, and to provide a basis for RACT permit limits.

This report has been prepared to present test and literature data and to propose and justify a RACT limit which approximates actual operating emissions from the PECS and Battery 1B and Battery 2 Combustion Stacks. The following sections discuss our findings and recommendations.

COMBUSTION STACK DATA STATISTICAL ANALYSIS

ACCI analyzed previous emissions testing data from the Koppers Industries, Inc., Monessen Coke Plant for both Coke Battery 1B and Battery 2 Combustion Stacks. The following data summary and analysis includes compliance and extended tests performed in 1998 by ACCI, a 1997 test performed by Advanced Technology Systems, Inc. (ATS), and the 1996 tests performed by Optimal Technologies (Optimal). Emissions data for the Battery 1B combustion stack collected by ATS and Optimal was corrected for errors in the measured stack diameter and resubmitted to PADEP. Appendix A contains the tabulated data for each test on the Battery 1B and Battery 2 Combustion Stacks.

OXIDES OF NITROGEN (NO_X)

Statistical analysis was performed on Oxides of Nitrogen (NOx) (parts per million [ppm], lb/hr, lb/ton of coal) and Total Hydrocarbons (THC) as propane (ppm, lb/hr, lb/ton of coal) for data collected during the 1996, 1997, and 1998 emissions tests. Variability, standard deviation, a coefficient of variation and a range was calculated for each of these data sets. These results are listed in Table 1.

The NOx emissions measured for Battery 1B were constant in nature across all tests with a coefficient of variation of 10.3 %. Emissions data collected ranged from 331-519 ppm. However, the variation of 32.1 and the standard deviation of 44.5 show some dispersion of the data from the mean of 432.7 ppm.

The NOx emissions data for Battery 2 was equally consistent with a coefficient of variation of 10.7% and a range of 248-440 ppm. The variation of 25.9 and the standard deviation of 37.7 show less dispersion from the mean (351.5 ppm) in the emissions from Battery 2 than were recorded in Battery 1B.

TOTAL HYDROCARBONS (THC)

Statistical analysis was also performed on the THC (ppm) emissions data collected for both Battery 1B and Battery 2. These emissions varied greatly across all the years of testing at both batteries. Battery 1B showed the greatest coefficient of variation (91.5%), indicating emissions that were inconsistent in nature and broad in range (7.8-283 ppm). A variability of 27.3 and a standard deviation of 82.6 also indicate that the data are also inconsistent and widely dispersed about the mean of 90.3 ppm. Emissions data collected at Battery 2 were only slightly more consistent with a coefficient of variation of 54.9% and a range of 3-98 ppm. A variability of 28.2 and a standard deviation of 32.7 indicate that the emissions at Battery 2 are also irregular and rather widely dispersed about the mean value of 59.5 ppm.

INDUSTRY WIDE COMBUSTION STACK DATA COMPARISON

ACCI reviewed AP-42 to determine the pool of available emissions data for combustion stacks and pushing emissions control systems. No data was readily available in the literature to compare to the Monessen Coke Plant data. The only available data was that compiled by the American Coke and Coal Chemicals Institute.

The average NOx (lb/ton of coal) and THC (lb/ton of coal) emissions from the Monessen Coke Plant Battery 1B and Battery 2 were compared to the emissions from other plants in the industry, based on the emissions summary prepared by the American Coke and Coal Chemicals Institute. Table 2 summarizes these results.

The average NOx (lb/ton of coal) emission factor for the industry, including the Monessen Coke Plant, is equal to 1.21 lb/ton of coal. The average NOx emissions from Battery 1B and Battery 2, Monessen Coke Plant, were 1.77 and 1.04 (lb/ton of coal), respectively. The emissions from Battery 1B were higher than the industry average, but were less than several other coke-making facilities. The average NOx emissions from Battery 2 were below the industry average. The average THC (lb/ton of coal) emissions for Monessen Battery 1B and Battery 2 were below the industry average of 0.47 lb/ton of coal. Battery 1B had an average emission rate of 0.41 lb/ton of coal and Battery 2 average emissions were 0.19 lb/ton of coal. Based on this analysis, it appears as though the emissions data for KII is reasonable for this class of source.

The THC emissions for a combustion stack consist of the by products of fuel combustion and a contribution from coke oven wall leaks. Combustion is regulated by plant operators who adjust fuel to air ratios based on temperature and oxygen concentration in the stack. Hydrocarbons also enter the flue gas through small cracks in the oven walls. Plant emissions can be affected by repair and maintenance programs conducted by the facility. Although the wall maintenance program will reduce emissions from the facility and extend the life of the ovens, aging may cause a general trend towards increasing the emissions.

PUSHING EMISSIONS CONTROL SYSTEM STATISTICAL DATA ANALYSIS

The PECS includes a movable suction hood, which is located above the coke hot car and a baghouse which traps particulate emissions during the push cycle. Typically, 27 ovens are pushed in an 8-hour turn at the Monessen Coke Plant. ACCI conducted emission measurements at the exhaust stack of the baghouse during a total of 79 pushes.

ACCI analyzed data from the PECS at the Monessen Coke Plant. Statistical analysis was performed on both NOx (ppm) and THC (ppm) emissions data to obtain an average, variability, standard deviation, coefficient of variation, and minimum and maximum values from three test programs. Emissions data collected by ATS (1996) and Optimal (1997) was analyzed along with the ACCI test data. Appendix B contains the emissions data used for the PECS analysis which included data from 223 separate pushes from the three separate test programs. The statistical analysis of the PECS emissions data is summarized in Table 3. The variability (2.6) and the coefficient of variation (39.9%) of the NOx emissions indicated that the data is consistent in nature and somewhat close in range. The NOx values recorded ranged from 2.3-21.7 ppm. The standard deviation of 3.4 suggests that much of the data is close to the mean value of 8.5 ppm.

The variability (0.45) and coefficient of variation (39.9%) indicate that the THC pushing emissions are also consistent in nature and somewhat close in range, The THC values recorded across all years of testing range from 0.2-3.9 ppm. The standard deviation of 0.56 indicates that most of the recorded values are close to the mean value of 1.41 ppm.

The level of accuracy for the measurements at these low levels may also be affected by the instrument accuracy. The detection limit for the ACCI Hydrocarbon analyzer is 1 ppm. The stated sensitivity of the NOx monitor used by ACCI is 0.1 ppm.

PROPOSED EMISSIONS LIMITS

Statistically derived emission limits were developed by ACCI for both Battery 1B and Battery 2 Combustion Stacks and the PECS using standard statistical methodologies.

An upper 95% confidence statement was used to derive a lb/hr limit based on the standard deviation and the mean of the 1-hour stack test data. This suggests that 95% of the time additional 1-hour stack tests will find that the NOx and VOC emissions will most likely fall within the proposed 1-hour emission limits. The confidence interval accounts for fluctuations in stack test data and emissions due to testing equipment accuracy, length of testing period, and process variations. The following equation was used to determine the upper bound (UB) of the 95% confidence interval:

$$UB = \bar{y} + t_{.05}\sqrt{s^2\left(\frac{n+1}{n}\right)}$$

where $t_{.05}$ is the tabulated Student's t value, y is the average of the data, s is the standard deviation of the 1-hour stack test data, and n is the number of 1-hour stack tests performed.

A 95% confidence interval was used to propose the annual NOx and VOC emission limits on a ton per year (tpy) basis for both the Battery 1B and Battery 2 Combustion Stacks and the PECS. This statistic returns the confidence band for the sample mean, which is a range on either side of the actual mean. The calculation was based on the standard deviation and sample size of 1-hour stack test data. A confidence interval (CI) is calculated in accordance with the following equation:

$$CI = 1.96 * \frac{S_d}{\sqrt{n}},$$

where, S_d is the standard deviation of the stack test data and n is the number of 1-hour stack tests performed. The CI is then added to the sample mean (average test result) to establish the upper 95% confidence interval. The upper confidence interval says that, with 95% certainty, that the actual mean emissions of the facility will be within the proposed annual NOx and VOC emission limits. Appendix C contains the sample calculations.

Tables 4 and 5 compare the proposed emission limits and the draft RACT Operating Permit Limits for NOx and VOC emissions from these sources derived using the above methodology.

The proposed permit limits are based on a large pool of test data and standard statistical analysis methods. ACCI considers the limits to provide a fair representation of expected plant emissions. The hydrocarbon limits should be valid for the next 5-year period. At the end of the 5-year period, however, hydrocarbon emissions may need to be re-evaluated to determine whether battery aging has had an effect on their levels. At the end of the 5-year period, recent test results will be evaluated to determine whether the emission limits should be revised for the next 5-year period.

CONCLUSIONS

An extensive test program and literature review was conducted for the Combustion Stacks and the PECS at the Monessen Coke Plant. The testing program indicated that the previously proposed RACT limits were inappropriate and would be impossible to meet in the long term. ACCI conducted an extended test program and a statistical analysis of available test data to determine an appropriate RACT limit for the Monessen Coke Plant. Tables 4 and 5 present the proposed RACT limits.

REFERENCES

Advanced Technology Systems, Inc. June 1997. Measurement of Particulate Matter, Volatile Organic Compound, Nitrogen Oxides, Carbon Monoxide, and Visible Emissions from Battery 1B and 2 Pushing Emissions Control System Compliance Test Program, Koppers Industries, Inc., Monessen, Pennsylvania.

Advanced Technology Systems, Inc. June 1997. Measurement of Particulate Matter, Volatile Organic Compound, Nitrogen Oxide, Carbon Monoxide, and Visible Emissions from Battery 1B and Battery 2 Combustion Stacks Compliance Test Program, Koppers Industries, Inc., Monessen, Pennsylvania.

Air/Compliance Consultants, Inc. August 1998. Emissions Evaluation of Batteries 1B and 2 Pushing Emissions Control System, Battery 1B Combustion Stack, Battery 2 Combustion Stack, Koppers Industries, Monessen Coke Plant, Monessen, Pennsylvania.

Optimal Technologies. December 1996. Emissions Evaluations of Battery 1B and 2 Pushing Emissions Control System, Battery 1B Combustion Stack, and Battery 2 Combustion Stack, Koppers Industries, Inc., Monessen, Pennsylvania.

Steel, R.G.D., J.A. Torrie, D.A. Dickey, 1997. Principles and Procedures of Statistics a Biometrical Approach. McGraw-Hill, New York, NY.

American Coke and Coal Chemicals Institute, Unpublished Test Data for Coke Battery Combustion Stacks, circa 1995

Table 1. Statistical Analysis Results for NOx and THC Emissions from Battery 1B and Battery 2, Koppers Industries, Inc., Monessen Coke Plant

STATISTICAL PARAMETER	BATTERY 1B					
	NOx (ppm)	NOx (lb/hr)	NOx (lb/ton of coal)	THC[1] (ppm)	THC (lb/hr)	THC (lb/ton of coal)
Average	432.7	104.5	1.8	90.3	29.5	0.5
Variability	32.1	7.1	0.1	27.3	12.1	0.2
Standard Deviation	44.5	12.4	0.2	82.6	23.7	0.4
Coefficient of Variation[2]	10.3	12.9	12.9	91.5	80.4	80.4
Minimum	331.9	83.1	1.4	1.0	0.0	0.0
Maximum	519.4	131.7	2.2	301.0	88.2	1.5

STATISTICAL PARAMETER	BATTERY 2					
	NOx (ppm)	NOx (lb/hr)	NOx (lb/ton of coal)	THC (ppm)	THC (lb/hr)	THC (lb/ton of coal)
Average	351.5	61.3	1.0	59.5	11.5	0.2
Variability	25.9	6.9	0.1	28.2	6.4	0.1
Standard Deviation	37.7	9.8	0.2	32.7	7.4	0.1
Coefficient of Variation[2]	10.7	15.9	15.9	54.9	63.9	63.9
Minimum	248.0	40.3	0.7	3.0	0.4	0.0
Maximum	410.0	80.5	1.4	98.0	20.0	0.3

[1] THC as propane

2 Coefficient of Variation = (100) (standard deviation/average)

Table 2. Industry Wide Data Comparision of Combusiton Stack Emissions

Battery	Emission Factors (lb/ton coal) NOx	VOC[1]
LTV Pittsburgh No. P1	1.91	0.16
LTV Pittsburgh No. P2	1.56	0.11
LTV Pittsburgh No. P3S	2.47	1.39
LTV Pittsburgh No. P3N	2.12	0.59
LTV Pittsburgh No. P4	1.22	3.36
Inland No. 9	0.47	0.01
Bethlehem Burns Harbor No. 1	2.78	0.01
Bethlehem Burns Harbor No. 2	0.69	0.04
Bethlehem Lackawanna No. 7	0.98	0.02
Bethlehem Lackawanna No. 8	1.02	0.03
Bethlehem PA - Battery A	0.69	ND
Bethlehem PA No. 2	0.22	0.00
Bethlehem PA No. 3	0.23	0.00
Sloss Nos. 3,4	1.18	0.05
Monessen Battery 1B	1.77	0.50
Monessen Battery 2	1.04	0.20
Average	**1.21**	**0.48**
Variability	**0.62**	**0.61**
Standard Deviation	**0.80**	**0.95**
Minimum	**0.22**	**0.00**
Maximum	**2.78**	**3.36**

[1] Emission Factors for Monessen Battery 1B and Monessen Battery 2 are given as propane, others are unknown.

Table 3. Summary of Statistical Analysis Results for NOx and THC Emissions, Pushing Emissions Control System, Koppers Industries, Inc., Monessen Coke Plan

STATISTICAL PARAMETER	NOx (ppm)	NOx (lb/hr)	THC[1] (ppm)	THC[1] (lb/hr)
Average	8.5	6.6	1.4	1.1
Variability	2.6	2.1	0.5	0.4
Standard Deviation	3.4	2.7	0.6	0.5
Coefficient of Variation	39.9	40.9	39.9	40.4
Minimum	2.3	1.8	0.2	0.2
Maximum	21.7	17.9	4.0	2.9

[1] THC as propane

Table 4. Comparison of the RACT Permit Limit and the Proposed Limit for NOx Emissions, Koppers Industries, Inc., Monessen Coke Plant.

Emission Source	RACT Permit Limit		Proposed Revised Limit	
	TPY	lb/hr	TPY	lb/hr
Battery 1B Combustion Stack	286	60.7	476	131
Battery 2 Combustion Stack	246	55.4	287	81
PECS	4.8	7.8	31	12

Table 5. Comparison of the RACT Permit Limit and the Proposed Limit for VOC Emissions, Koppers Industries, Inc., Monessen Coke Plant.

Emission Source	RACT Permit Limit		Proposed Revised Limit	
	TPY	lb/hr	TPY	lb/hr
Battery 1B Combustion Stack	1	0.3	146	54
Battery 2 Combustion Stack	1.9	0.5	64	26
PECS	0.6	1.1	5.2	2

APPENDIX A

COMBUSTION STACK DATA

Table A-1. Test Results Summary, Battery 1B Combustion Stack, Koppers Industries, Inc., Monessen Coke Plant.

TEST	Stack Dia. (in)	Flow Rate (ACFM)	Flow Rate (SCFM)	Flow Rate (DSCFM)	O2 Conc. (% Vol)	Oxides of Nitrogen (ppm)	Oxides of Nitrogen (lb/hr as NO2)	Oxides of Nitrogen (lb/ton coal)	Total Hydrocarbons (as propane) (ppm)	Total Hydrocarbons (as propane) (lb/hr)	Total Hydrocarbons (as propane) (lb/ton coal)
ACCI 1998 Compliance Test											
Run 1	135	86,204	42,887	35,451	5.47	467	118.66	2.01	68	19.99	0.34
Run 2	135	92,437	44,580	36,882	5.79	464.1	122.68	2.08	86	26.28	0.44
Run 3	135	84,322	40,785	33,841	5.47	468.9	113.73	1.93	101	28.24	0.48
ACCI 1998 Extended Test											
15:38-16:38	135	87,654	42,751	35,391	5.47	442.6	112.26	1.90	118.6	34.76	0.59
17:18-18:18	135	87,654	42,751	35,391	5.47	478.4	121.34	2.05	112	32.82	0.56
18:28-19:28	135	87,654	42,751	35,391	5.47	497.6	126.21	2.14	168	49.24	0.83
19:38-20:38	135	87,654	42,751	35,391	5.47	506.6	128.5	2.18	211	61.84	1.05
20:48-21:48	135	87,654	42,751	35,391	5.47	519.4	131.74	2.23	301	88.22	1.49
21:58-22:58	135	87,654	42,751	35,391	5.47	487.6	123.68	2.09	283	82.94	1.40
23:08-0:08	135	87,654	42,751	35,391	5.47	492.4	124.9	2.11	264	77.37	1.31
0:18-1:18	135	87,654	42,751	35,391	5.47	476.6	120.89	2.05	239	70.04	1.19
1:18-2:18	135	87,654	42,751	35,391	5.47	471.4	119.57	2.02	220.7	64.68	1.10
ACCI 1998 Diagnostic Test											
09:10-10:10	135			36,748	5.95	417	109.83	1.86	28	8.6	0.15
10:10-11:10	135			34,376	5.7	442	108.9	1.84	32	13.38	0.23
11:24-12:24	135			34,417	6.46	427	105.32	1.78	37	15.49	0.26
12:24-13:24	135			34,370	5.52	461	113.56	1.92	43	17.97	0.30
13:24-14:24	135			33,932	5.97	439.67	106.92	1.81	40.6	16.75	0.28
14:34-15:24	135			31,314	5.58	443.2	99.47	1.68	52.6	20.03	0.34
16:27-17:27	135			34,071	6.64	398	97.19	1.65	63	26.1	0.44
17:27-18:27	135			32,991	5.21	459	108.53	1.84	72	28.88	0.49
18:27-19:27	135			32,385	5.78	455	105.61	1.79	70	27.57	0.47
19:27-20:27	135			31,924	6.12	452	103.42	1.75	64	24.85	0.42
20:27-21:27	135			32,544	5.51	476	111.02	1.88	65	25.72	0.44
21:27-22:27	135			31,924	6.12	452	103.42	1.75	64	24.85	0.42
22:27-23:27	135			34,293	6.06	424	104.21	1.76	75	31.28	0.53
23:27-00:27	135			34,133	5.96	432	105.68	1.79	66	27.39	0.46
00:27-01:27	135			32,373	6.41	431	100	1.69	58	22.83	0.39
01:27-02:27	135			33,701	6.87	410	99.03	1.68	57	23.36	0.40
02:27-03:27	135			33,126	6.31	435	103.27	1.75	50	20.14	0.34
03:27-04:27	135			31,924	6.15	416	95.18	1.61	81	31.44	0.53
04:27-05:27	135			31,301	6.31	420	94.22	1.60			
05:27-06:27	135			34,281	6.67	380	93.36	1.58			
06:27-07:27	135			32,523	6.58	374	87.18	1.48			
07:27-08:27	135			31,915	6.58	374	85.55	1.45			
08:27-09:27	135			31,282	7.29	379	84.97	1.44			
ATS 1997 Corrected Test											
Run1	135	88,771.30	45,475.30	37,048.60	5	331.9	88.2	1.49	7.8	0.04	0.00
Run 2	135	86,301.40	44,022.40	35,886.30	4.5	393.3	87.3	1.48	15.6	0.09	0.00
Run 3	135	83,686.00	42,569.60	34,724.00	5.5	333.6	83.1	1.41	7.8	0.04	0.00
Optimal 1996 Corrected Test											
Run1	135	84,213.50	39,834.70	70,973.10	11.7	364.4	89.1	1.51	0.98	0.2	0.00
Run 2	135	83,139.60	39,334.20	33,445.80	12.3	410.04	97.8	1.66	8.71	1.9	0.03
Run 3	135	70,973.10	33,362.30	28,368.00	12	440.19	89.3	1.51	4.53	0.9	0.02
AVERAGE						432.71	104.47	1.77	90.33	29.45	0.50
VARIABILITY						32.12	7.05	0.12	27.30	12.11	0.21
STANDARD DEVIATION						44.52	13.43	0.23	82.63	23.68	0.40
COEFFICIENT OF VAR						10.29	12.85	12.85	91.47	80.40	80.40
MIN						331.90	83.10	1.41	0.98	0.04	0.00
MAX						519.40	131.74	2.23	301.00	88.22	1.49
ppper 95% confidence level						519.98	130.78	2.21	252.28	75.85	1.28
Upper 99% confidence level						547.40	139.05	2.35	303.18	90.43	1.53

Table A-2. Test Results Summary, Battery 2 Combustion Stack, Koppers Industries, Inc., Monessen Coke Plant.

TEST	Stack Dia. (in)	Flow Rate (ACFM)	Flow Rate (SCFM)	Flow Rate (DSCFM)	O2 Conc. (% Vol)	Oxides of Nitrogen (ppm)	Oxides of Nitrogen (lb/hr as NO2)	Oxides of Nitrogen (lb/ton coal)	Total Hydrocarbons (as propane) (ppm)	Total Hydrocarbons (as propane) (lb/hr)	Total Hydrocarbons (as propane) (lb/ton of coal)
ACCI 1998 Compliance Test											
Run 1		62,524	30,466	26,261	4.46	341.5	64.28	1.09	42	8.77	0.15
Run 2		60,923	29,401	24,229	4.38	327.5	56.87	0.96	52.9	10.66	0.18
Run 3		61,014	29,450	24,732	3.9	349	61.86	1.05	60.5	12.21	0.21
ACCI 1998 Extended Test											
16:41-17:41		61,487	27,772	25,074	4.25	323	58.04	0.98	51	10.41	0.18
19:01-19:59		61,487	27,772	25,074	4.25	248	44.57	0.75	41	8.39	0.14
20:09-21:09		61,487	27,772	25,074	4.25	345	61.99	1.05	66	13.47	0.23
21:19-22:19		61,487	27,772	25,074	4.25	330	59.3	1.00	82	16.74	0.28
22:29-23:29		61,487	27,772	25,074	4.25	371	66.67	1.13	81	16.53	0.28
23:39-0:39		61,487	27,772	25,074	4.25	332	59.66	1.01	94	19.19	0.32
0:49-1:49		61,487	27,772	25,074	4.25	346	62.17	1.05	96	19.59	0.33
1:59-2:59		61,487	27,772	25,074	4.25	344	61.81	1.05	98	20	0.34
3:09-4:09		61,487	27,772	25,074	4.25	346	62.18	1.05	92	18.79	0.32
4:19-5:19		61,487	27,772	25,074	4.25	366	65.77	1.11	95	19.4	0.33
5:29-6:29		61,487	27,772	25,074	4.25	368	66.13	1.12	91	18.57	0.31
6:39-7:39		61,487	27,772	25,074	4.25	371	66.67	1.13	95	19.39	0.33
ATS 1997 Corrected Data											
Run 1		88,916.60	45039.5	38210.9	5.5	331.9	77.6	1.31	44.7	3.1	0.05
Run 2		88916.6	45039.5	38210.9	7.5	393.3	80.5	1.36	19.8	1.3	0.02
Run 3		77584.1	39373.2	33561.7	8	333.6	71.2	1.21	3	0.4	0.01
Optimal 1996 Corrected Data											
Run 1		40231.1	20948.6	17981.6	12.7	364.4	46.6	0.79	15.28	1.9	0.03
Run 2		36420	18666.3	15832.3	12.3	410.04	40.3	0.68	16.2	1.8	0.03
Run 3		38149.2	19588.9	16614.9	11	440.19	52.2	0.88	12.97	1.5	0.03
AVERAGE						351.50	61.26	1.04	59.49	11.53	0.20
VARIABILITY						25.90	6.91	0.12	28.20	6.39	0.11
STANDARD DEVIATION						37.66	9.75	0.17	32.66	7.36	0.12
COEFFICIENT OF VAR						10.71	15.92	15.92	54.90	63.88	63.88
MIN						248.00	40.30	0.68	3.00	0.40	0.01
MAX						410.04	80.50	1.36	98.00	20.00	0.34

APPENDIX C

SAMPLE CALCULATIONS

SAMPLE CALCULATIONS

STANDARD DEVIATION

$$s = \sqrt{\frac{n\sum x^2 - \left(\sum x\right)^2}{n(n-1)}}$$

$$s = \sqrt{\frac{(21)(80698.99) - (1286.37)^2}{21(21-1)}}$$

$$s = \sqrt{\frac{39805.01}{440}}$$

$$s = 9.75$$

UPPER 95% CONFIDENCE STATEMENT (UB)

$$UB = \bar{y} + t_{.05}\sqrt{s^2\left(\frac{n+1}{n}\right)}$$

$$UB = 61.26 + 1.960\sqrt{(9.75)^2\left(\frac{21+1}{21}\right)}$$

$$UB = 61.26 + 19.56 \cong 81 \text{ tpy NOx}$$

CONFIDENCE INTERVAL (CI)

$$CI = 1.96 * \frac{S_d}{\sqrt{n}}$$

$$CI = 1.96 * \frac{9.75}{\sqrt{21}}$$

$$CI = 1.96 * 2.13$$

$$CI = 4.17$$

$$\text{Limit} = CI + \bar{y}$$

$$\text{Limit} = 4.17 + 61.26 = 65.43 \text{ lb/hr NOx}$$