

MINIMIZING EMISSIONS FROM EXISTING ESP EQUIPPED MWCs

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Discussion by

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The authors have provided a very good description of the problems and potential decisions that numerous communities currently operating municipal waste combustor (MWC) facilities will face in order to meet the environmental requirements of that MACT standards promulgated by the US Environmental Protection Agency late 1995. Many communities will spend millions of dollars to upgrade air pollution control (APC) equipment and possibly other associated equipment such as fans, duct work, stacks, continuous emission monitoring systems, along with some boiler components during the next 3 to 5 years. The paper describes the program designed to provide information to determine if any equipment modifications will be needed to reduce acid gas, metals (including mercury), and dioxins and furan emissions from an existing MWC facility located in Davis, Utah.

The paper briefly describes the existing Facility and the installed APC system consisting of dry injection of sorbent material followed by a 3-field electrostatic precipitator (ESP). The authors indicated that the facility currently achieves 50% acid gas (sulfur dioxide and hydrogen chloride) removal. The authors did not state if the Facility had a continuous emissions monitor (CEM) system to measure SO₂ emissions prior to or after injection of sorbent material (Trona - a natural sodium reagent). Use of SO₂ and CO emission monitors will be required to meet the new

MACT standards. Continuous SO₂ measurements would supplement the emission measurements made during the test program and might also help the Facility determine their future needs with more long-term operating data.

The authors describes the goal of the test program that was designed to determine the effect of the following equipment and process modifications on acid gas, particulate matter, metals (in particular, mercury), and dioxins/furan emissions.

- Flue gas cooling by injecting water into the boiler after the economizer section to reduce flue gas temperature in the ESP from 430° to 300°F.
- Sorbent injection near the boiler economizer section where the gas temperature is approximately 620°F.
- Activated carbon injection, also into the boiler.

The test program appears to be well designed. The planned carbon injection rates (15 and 30 lb/hr) that were proposed for the test program are similar to levels reported previously used to reduce mercury and possibly dioxin/furan emissions from MWC facilities (Marion County, OR; Stanislaus, CA; and Camden, NJ). I assume that the proposed sorbent injection rate was sufficient to achieve the desired acid gas reduction, but this rate is dependent on the typical uncontrolled levels and this information was not given in the paper. Finally, lowering the flue gas temperature should help reduce the potential for dioxin/furan emission formation in the back-end of the boiler and ESP, and should also help improve the ESP performance, thus reducing

particulate emissions, some metals, and particulate-phase dioxin/furan emissions.

The proposed emission test program was extremely aggressive assuming that two runs each were conducted for dioxins, metals, HCl, and SO₂ and NO_x emissions. However, the discussion did not mention any problems, so I assume that the test runs were completed as planned. In addition, the test program called for numerous test parameter conditions, such as three (3) ESP operating temperatures, sorbent injection, no sorbent injection, two carbon injection rates, and various combinations of the above mentioned parameters. The numerous combinations with limited emission data points (sometimes only 2 points for a test condition), may limit the Facility's ability to determine "concrete" findings from the test data. However, these data should at least help give some valuable information as to the potential control options the Facility can pursue to meet the MACT Standards, and at a minimum, define the additional test objectives for a second test program, if one is determined to be used.

In summary, I anxiously await the published data when made available, hopefully these data can be published along with the discussion papers.

AUTHOR'S REPLY

Since this research was "work in process" when the paper deadline arrived, we sincerely appreciate this opportunity to answer Mr. Beachler's questions and formally put the major findings into the discussion volume.

The Davis County Facility has had an O₂ and CO CEMS and a COMS on each unit since start-up. A SO₂ and NO_x CEMS, assigned to one or the other unit, was added in early 1993 to support the facility's emissions minimization and process optimization program. The original CEMS and COMS were completely replaced in July 1996 and successfully RATAed the last week of August. There is a 3 year history of controlled SO₂ emissions from the facility. The test design used this information and the results confirm the plant's history.

Uncontrolled HCl and SO₂ concentrations measured during the test

program are provided in Figures 1 and 2 and Table 1. These results are comparable to the historic results provided in Rigo, H. Gregor and Chandler, A. John, Retrofit of Waste-to-Energy Facilities Equipped with Electrostatic Precipitators, ASME, CRTD Vol. 39, April 1996. Figures 3 and 4 summarize the effect of Powdered Activated Carbon on total dioxin and mercury concentrations. Figure 5 summarizes the results for the other Clean Air Act, Section 129 regulated pollutants. The calculated emissions limitations shown in the graphs are essentially permit limits. They are Upper Prediction Limits (Hahn, G. H., and W. Q. Meeker, Statistical Intervals: A Guide for Practitioners, Wiley, 1991) designed to account for test and plant variability. 95 percent of the time, five annual retests can be expected to be less than the calculated limit. These, rather than average emitted concentrations should be compared to regulatory limits since the average, by definition, is exceeded by some of the data (half, if the data is normally distributed). Individual run results are plotted as points on the graphs.

Overall the performance results were favorable. The results indicate that the facility could meet the small MWC category performance limits outlined in 40 CFR 60, Subpart Cb emissions guidelines for all pollutants and would likely meet the large facility guidelines for all but the acid gases. Reducing temperature has the anticipated effect of reducing dioxin emissions when combined with PAC; the mathematically separated effect of temperature alone was not very significant between 420°F (normal operating temperature) and 300°F (lowest temperature tested). Analysis of the data reveals that acid gas control improved with reduced APCS operating temperature.

The PAC results all indicate that 11.25 lb/hr (300 mg/dsm³ @ 7% O₂) provides an ample margin of safety on the large plant emissions limits in Subpart Cb -- 30 ng/dsm³ @ 7% O₂ for total dioxins and 80 mg/dsm³ @ 7% O₂ for mercury. To make sure that there is plenty of room, some temperature control is indicated, but there is little apparent value in dropping the APCS temperature below 350°F.

The acid gas results for Trona injection only incorporate the variability induced by

changes in stack gas flow and nominal Trona feed fluctuations because the experiment did not call for adjusting this feed rate. The results indicate that feed rates of around 1,700 mg/dsm³ @ 7% O₂ (125 lb/hr) should keep the HCl and SO₂ removal rates safely above the Subpart Cb mandated 50% removal level for small MWC facilities.

Injecting reagents increased particulate emissions slightly (compared to zero addition TSP measurements). When water spray temperature control was used as well, outlet particulate concentrations returned to no-injection levels. Cadmium and lead concentrations remained below small and large plant regulatory limits. Although spikes are evident, 3-run averages are expected to comply with Subpart Cb requirements.

The blank train data at the bottom of Table 1 demonstrate the need for careful quality control and use of quality reagents. A fiberglass filter that was accidentally mixed with the specified quartz filters displayed significantly higher background concentrations. At extremely low flue gas concentration levels, filter blanks could be the difference between compliance and non-compliance. The dioxin blank train data variability establishes that Method 23 has a method detection limit [MDL] no lower than 0.3 ng/dsm³ @ 7% O₂ and the level of quantification [LOQ] is 6.4 ng/dsm³ @ 7% O₂. The MDL could be considerably higher when full sampling variability is considered since these estimates are based on method blanks rather than dual-train results. The TSP detection limit is on the order of 0.001 gr.dsft³ @ 7% O₂ with a LOQ of 0.003 gr/dsft³ @ 7% O₂. These results indicate that some of the TSP data are within data noise and the best that can be said is that emissions are low.

Regarding the number of samples needed at each condition, triplicates at an individual test condition are needed to meet regulatory requirements (40 CFR 60.8(f), for example). Obviously, when sufficient time and money are available, triplicate (or even more replicate) data for each test condition is preferred. Given limited resources, however, statistical experimental design and reduction techniques maximize the amount of information that can be extracted from a given experiment. By fitting a multi-dimensional response surface

to the duplicate data using robust regression techniques, outliers can be identified. Then, by analyzing the full data set and the outlier free subset, meaningful conclusions can be drawn. The statistical experimental design and reduction techniques used in this demonstration project produce reliable results; isolated subsets of the data cannot be arbitrarily used with confidence due to the limitations described by Mr. Beachler.

Figure 1. Hydrogen chloride emissions test results and calculated emissions limitations.

Hydrogen Chloride – PPMdv @ 7% O2						
Trona lb/hr	PAC lb/hr	STACK TEMPERATURE - °F				average
		420	350	320	300	
0	0	542 394				468
150	0	340	148		170	211
		341	160		177	
		193				
		158				
150	15		174 141	169 257		185
150	30	300	221	247	139	249
		252	260			
			399			
			175			
average		315	210	224	162	243

Hydrogen Chloride Removal Efficiency						
Trona lb/hr	PAC lb/hr	STACK TEMPERATURE - °F				average
		420	350	320	300	
0	0					
150	0	27%	68%		64%	55%
		27%	66%		62%	
		59%				
		66%				
150	15		63% 70%	64% 45%		60%
150	30	36%	53%	47%	70%	47%
		46%	44%			
			15%			
			63%			
average		44%	55%	52%	65%	53%

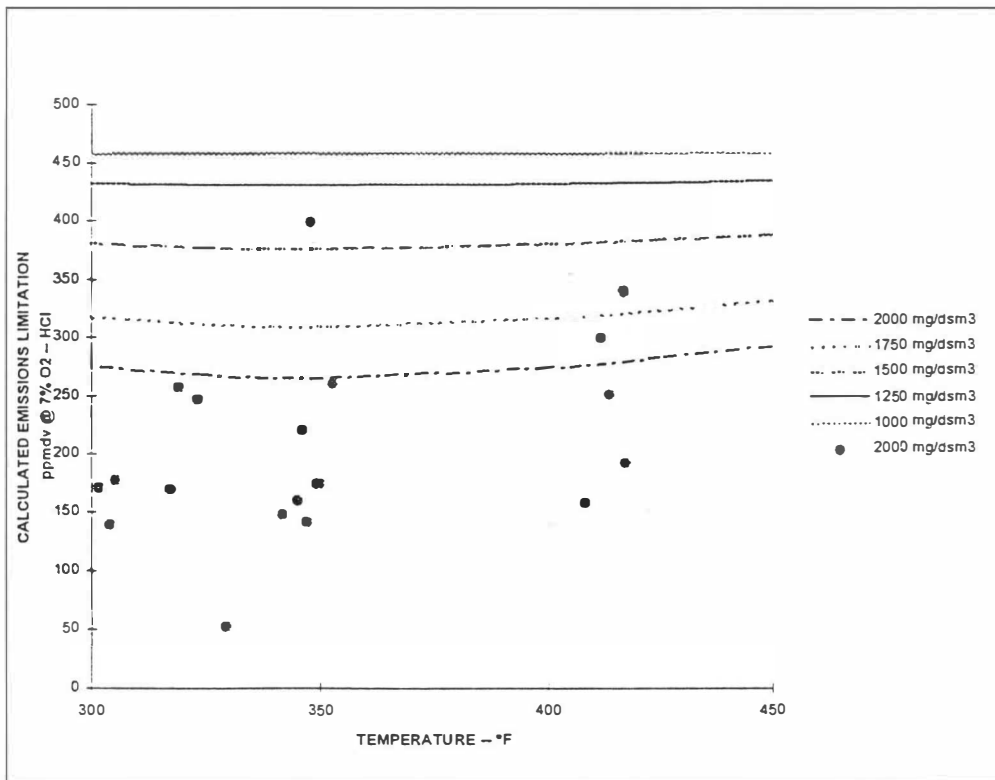


Figure 2. Sulfur dioxide emissions test results and calculated emissions limitations.

Sulfur Dioxide -- PPMdv @ 7% O2						
Trona lb/hr	PAC lb/hr	STACK TEMPERATURE - °F				average
		420	350	320	300	
0	0	131 85				108
150	0	96 41 43	48 34		53 56	53
150	15		53 48	46 25		43
150	30	62 49	41 37 42 51	36 52	34	45
average		72	44	40	48	53

Sulfur Dioxide Removal Efficiency						
Trona lb/hr	PAC lb/hr	STACK TEMPERATURE - °F				average
		420	350	320	300	
0	0					
150	0	11% 62% 60%	56% 69%		51% 48%	51%
150	15		51% 56%	57% 77%		60%
150	30	43% 55%	62% 66% 61% 53%	67% 52%	69%	59%
average		46%	59%	63%	56%	56%

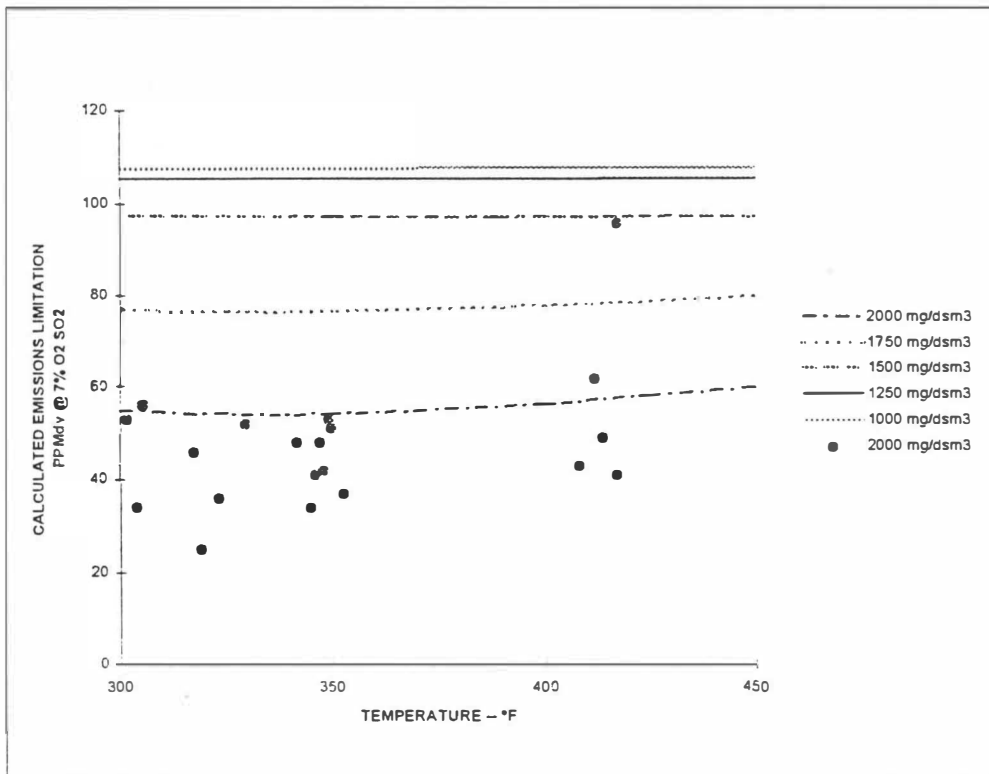


Figure 3. Total dioxin emissions test results and calculated emissions limitations.

Total Dioxins – ng/dsm3 @ 7% O2						
Trona lb/hr	PAC lb/hr	STACK TEMPERATURE - °F				average
		420	350	320	300	
0	0	115 98				107
150	0	116 91 87	83 250		151 127	129
150	15		5.3 4.5	12 11		8.3
150	30	37 15	20 17 7.4 3.4	3.0 3.3	6.0 <u>154</u>	13
average		80	49	7.4	95	57

Note: Underlined values excluded from averages.

Total Dioxin Removal Efficiency						
Trona lb/hr	PAC lb/hr	STACK TEMPERATURE - °F				average
		420	350	320	300	
0	0					
150	0					
150	15		97% 97%	92% 93%		95%
150	30	76% 90%	87% 89% 95% 98%	98% 98%	96% <u>2%</u>	94%
average		83%	94%	95%	96%	95%

Note: Underlined values excluded from averages.

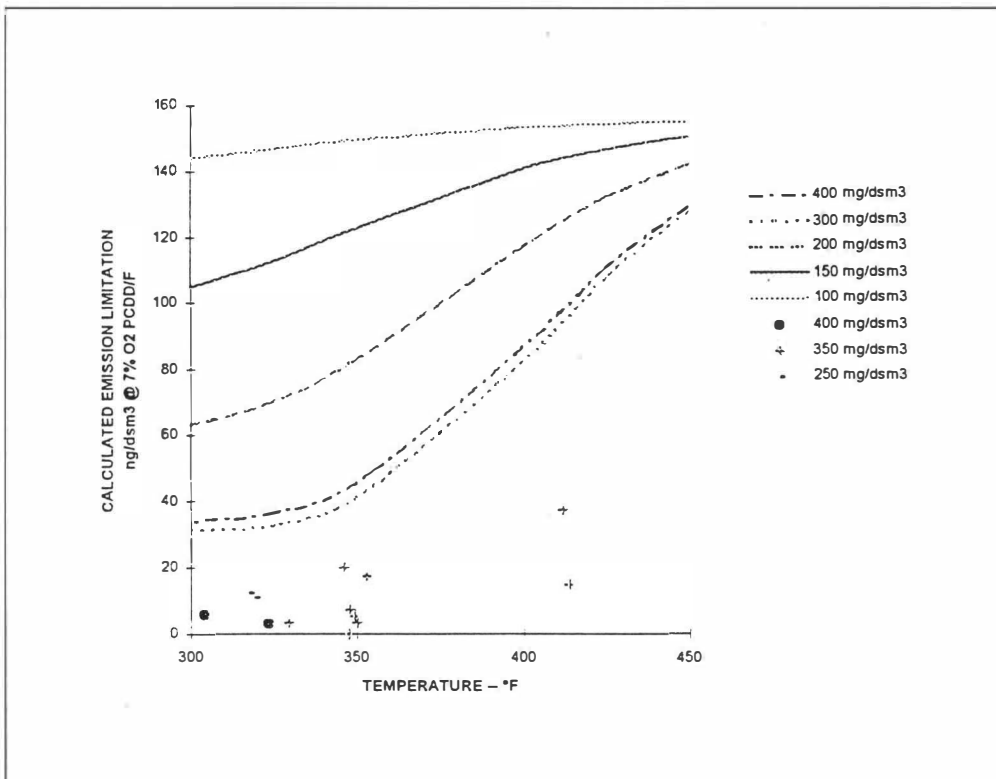


Figure 4. Mercury emissions test results and calculated emissions limitations.

Mercury – ug/dsm3 @ 7% O2						
Trona lb/hr	PAC lb/hr	STACK TEMPERATURE - °F				average
		420	350	320	300	
0	0	145 69				107
150	0	155 92 247	89 202		104 258	164
150	15		20 25	22 17		21
150	30	60 43	20 24 22 22	17 15	22 <u>296</u>	54
average		116	53	18	170	86

Note: Underlined values excluded from averages.

Total Mercury Removal Efficiency						
Trona lb/hr	PAC lb/hr	STACK TEMPERATURE - °F				average
		420	350	320	300	
0	0					
150	0					
150	15		90% 87%	89% 91%		89%
150	30	69% 78%	90% 88% 89% 89%	91% 92%	88% <u>-53%</u>	94%
average		74%	89%	91%	88%	95%

Note: Underlined values excluded from averages.

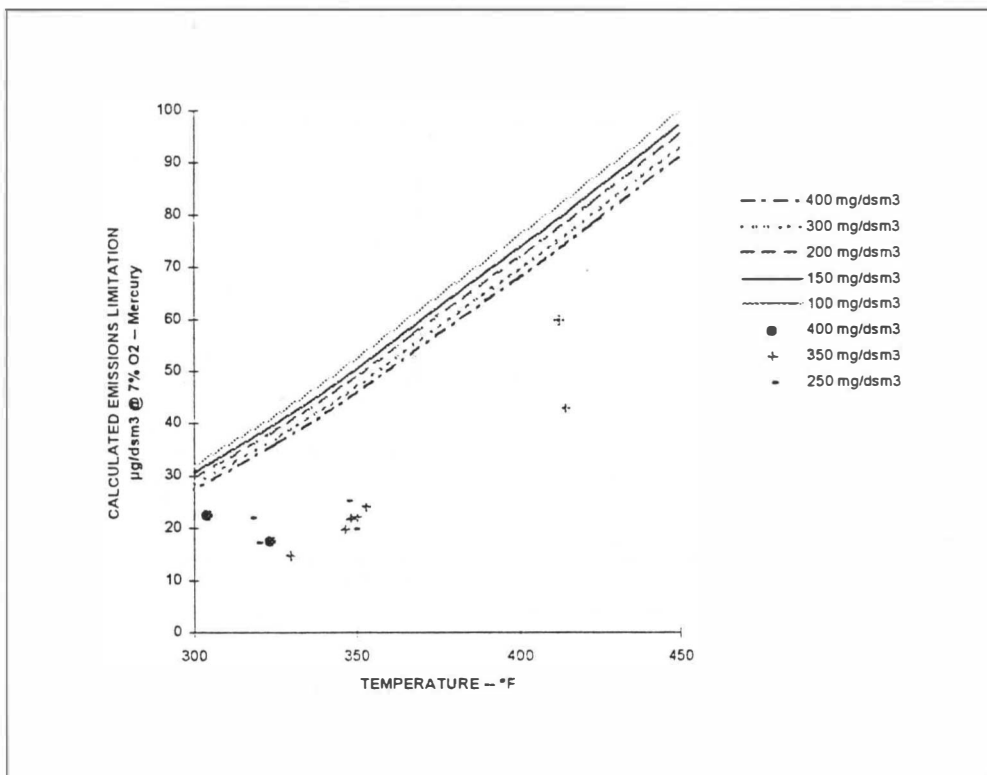


Figure 5. Other pollutant test results.

Particulates -- mg/dsm3 @ 7% O2						
Trona lb/hr	PAC lb/hr	STACK TEMPERATURE - °F				average
		420	350	320	300	
0	0	6.7 2.9				4.8
150	0	20.5 9.4 12.4	4.6 4.0		2.5 0.9	7.8
150	15		1.3 5.8	2.0 7.6		4.2
150	30	5.5 6.9	0.2 5.0	<u>30.5</u> <u>19.7</u>	6.3	4.8
average		9.2	3.5	4.8	3.3	7.7

Note: Underlined values excluded from averages.

OPACITY -- PERCENT						
Trona lb/hr	PAC lb/hr	STACK TEMPERATURE - °F				average
		420	350	320	300	
0	0	1.7 1.8				1.8
150	0	2.4 2.3 2.4	2.1		2.8 3.1	2.5
150	15		2.3 2.7	2.1		2.4
150	30	2.2 2.2	2.0 2.3 2.0 2.5	1.7 1.9	3.0	2.2
average		2.2	2.3	1.9	2.9	2.3

Cadmium -- ug/dsm3 @ 7% O2						
Trona lb/hr	PAC lb/hr	STACK TEMPERATURE - °F				average
		420	350	320	300	
0	0	16 9				12
150	0	18 12 14	6 8		7 9	11
150	15		7 133	58 90		72
150	30	16 17	4 6 7 9	262 16	12	39
average		14	23	107	9	34

Lead -- ug/dsm3 @ 7% O2						
Trona lb/hr	PAC lb/hr	STACK TEMPERATURE - °F				average
		420	350	320	300	
0	0	168 82				125
150	0	249 293 485	104 220		115 102	224
150	15		112 183	80 111		121
150	30	163 170	60 141 126 110	146 210	103	137
average		230	132	137	107	160

Table 1. Emissions data summary for the Davis County Testing.

DATE	TEST I.D.	TRONA lb/h	PAC mg/dsm ³ lb/h	Ttgt °F	O ₂ %	CO ₂ %	CO PPMdv	SO ₂ -24 PPMdv	all @ 7% O ₂ hr geo PPMdv	THC PPMdv	Opacity %	TEMP Deg F	Stack FLOW DSm ³ /hr	HF	PPMdv @ 7% O ₂ Cl ₂	HCl Eff	TSP mg/dsm ³	Cd µg/scm ³
951117	T01	150	1,938	0	10.9	9.5	56	96	11%	269	2.0	417	48,810	3.1	0.8	340	20.5	18
951117	T02(HCl)	150	1,980	0	10.9						2.4			3.0	0.7	341		
951118	T02	150	2,065	0	11.1	9.1	70	41	62%	256	1.5	417	46,731	(2.6)	(0.4)	193	9.4	12
951118	T03	150	2,008	0	10.8	9.4	83	43	60%	227	1.2	408	46,622	(2.5)	3.3	158	12.4	14
951119	T04	150	1,994	27	10.0	9.3	62	62	43%	227	0.9	412	47,917	7.7	(0.4)	300	5.5	16
951119	T05	150	1,960	27	10.9	9.2	69	49	55%	236	1.1	414	48,252	3.0	1.6	252	6.9	17
951120	T06	0	0	0	10.3	9.6	42	131		242	0.7	408	45,283	2.5	(0.1)	542	6.7	16
951120	T07	0	0	0	10.4	9.7	52	85		236	0.6	389	43,249	3.3	3.0	394	2.9	9
951121	T08	150	2,011	27	10.3	10.0	48	41	62%	242	1.0	346	44,407	2.4	0.05	221	4	4
951121	T09	149	2,090	27	10.7	9.4	70	37	66%	223	0.1	353	44,151	(2.4)	(0.03)	260	6	6
951122	T10	151	2,041	27	11.0	9.3	70	46	57%	499	0.6	296	47,037	2.8	(0.04)	196	11	11
951122	T11	150	1,989	31	10.7	9.5	63	34	69%	215	1.2	304	46,715	(2.4)	(0.03)	139	12	12
951123	T12	151	1,995	0	10.7	9.6	63	53	51%	260	0.5	302	46,667	2.5	(0.04)	170	7	7
951123	T13	150	2,033	0	11.1	9.0	61	56	48%	270	1.8	305	47,382	2.7	0.08	177	9	9
951124	T14	150	1,920	27	10.7	9.4	78	42	61%	259	0.2	348	48,367	3.5	(0.04)	399	7	7
951124	T15	150	1,925	27	10.5	9.5	58	51	53%	264	0.8	350	47,105	(2.4)	0.10	175	9	9
951125	T16	150	1,902	20	10.6	9.5	84	53	51%	353	1.2	349	48,285	(2.4)	0.05	174	7	7
951125	T17	150	2,057	19	10.7	9.5	70	48	56%	251	1.1	347	45,059	(2.5)	0.07	141	133	133
951126	T18	150	1,939	0	10.0	10.1	60	48	56%	219	0.3	342	44,791	3.0	0.06	148	6	6
951126	T19	150	2,050	0	10.4	9.7	97	34	69%	216	3.0	345	43,969	11.1	0.3	160	8	8
951127	T20	149	1,967	19	10.3	9.7	50	46	57%	241	0.4	318	45,137	(2.4)	0.6	169	58	58
951127	T21	150	1,964	20	10.5	9.5	101	25	77%	249	5.1	319	46,290	2.6	0.3	257	90	90
951128	T22	150	2,204	27	10.9	9.2	62	36	67%	233	0.5	323	42,920	(2.5)	0.3	247	262	262
951128	T23	150	1,975	27	10.0	10.1	56	52	52%	237	0.7	330	43,924			20	16	16
951118	blank-1 (glass)																0.6	(0.40)
951126	blank-2(quantz)																-0.7	(0.44)
951129	blank-3(quantz)																0.4	(0.41)
	Detection Limit																2.0	
	Limit of Quantification																6.8	

notes: PAC flow during T10 was interrupted. The actual PAC addition rate may have been zero for this run

A glass filter was used during T15 instead of a quartz filter. Lead and Mercury are back ground corrected.

A mercury sample was not separated from the probe rinse for run T15, result may be 10 percent low.

Parenttheses identify the detection limit for below detection limits results.

Underlining indicates Runs and values discussed above