Note: This material is related to a section in *AP42, Compilation of Air Pollutant Emission Factors, Volume I Stationary Point and Area Sources.* AP42 is located on the EPA web site at www.epa.gov/ttn/chief/ap42/

The file name refers to the file number, the AP42 chapter and then the section. The file name "rel01_c01s02.pdf" would mean the file relates to AP42 chapter 1 section 2. The document may be out of date and related to a previous version of the section. The document has been saved for archival and historical purposes. The primary source should always be checked. If current related information is available, it will be posted on the AP42 webpage with the current version of the section.

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PARTICULATE AND GASEOUS EMISSIONS TESTS AT MUNICIPAL SLUDGE INCINERATOR PLANT "O"

Contract No. 68-02-2815
Work Assignment No. 33

Submitted to

U.S. Environmental Protection Agency
Stationary Source Emission Research Branch
Emissions Measurement and Characterization Division
Environmental Sciences Research Laboratory
Research Triangle Park, North Carolina 27711

Submitted by

Engineering-Science
7903 Westpark Drive
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February 1980

Work from Nov 1979

SECTION I

INTRODUCTION

The Stationary Source Emissions Research Branch (SSERB) of the U.S. Environmental Protection Agency (EPA) is engaged in an emissions test program proposing characterization of the type and quantity of particulate air pollutants emitted from specific source categories. Additionally, the U.S. EPA, Office of Research and Development (ORD), Municipal Environmental Research Laboratory (MERL) is interested in determination of the nature and composition of pollutant discharges to the atmosphere from municipal wastewater sludge incinerator facilities.

Under EPA Contract No. 68-02-2815, Work Assignment No. 33, Engineering-Science (ES) was retained by the ESRL Particulate Emissions Research Section for assistance in collection of particulate, particle characterization, particle sizing, gaseous pollutants, and process samples at municipal sludge incinerators serving three metropolitan areas.

During the period of November 26-30, 1979 samples were collected by PERS and ES personnel at the first of three test sites on the inlet and outlet of a wet, tray-type scrubber system controlling emissions from a seven-chambered multiple hearth sludge incinerator. For the purposes of this report the facility shall be designated "Plant O" in the interest of confidentiality.

Particulate and SO_2, SO_3, and H_2SO_4 emission tests were conducted using EPA Reference Method 5 and 8 procedures modified by single point sampling as approved by PERS personnel in conjunction with EPA Reference Methods 1-4. Simultaneous inlet and outlet Method 5/8 particulate - SO_2, SO_3, and H_2SO_4, particle characterization, particle sizing (outlet only), and gaseous samples including total hydrocarbons and oxides of nitrogen via use of continuous analyzers were taken. Particle characterization samples included use of 47 mm glass fiber, Millipore®, Nuclepore®, and Teflon® types of filter media.(1) These characterization samples along with the Pilat particle sizing samples were forwarded to ESRL for analysis. Process samples including composite pre-burn sludge samples, post-burn ash samples, and scrubber water samples for each test series were forwarded to the EPA MERL for analysis.

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This report contains the results of emission tests executed utilizing EPA Methods 5 and 8 along with field data associated with the particle characterization, Pilat impactor, total hydrocarbon, and oxides of nitrogen gaseous data. Neither analytical data subsequent to results obtained by ESRL are included in this report nor results from analysis of process samples by MERL.

Process Description

Plant "O" operates tandem seven hearth incinerators and has been on line since 1975. During normal conditions only one of the two incinerators operates at any one time. Unit No. 2 was tested during this program. The normal sludge incineration feed rate ranges from 7,000 lbs/hr during summer operations and 12,000 lb/hr during winter operations. Figure I-1 summarizes the sludge throughput process. Operating data collected during the test program and contained in Appendix C of this report indictes a fairly stable sludge flow to the unit throughout testing. Table I-1 shows process data pertinent to the hours of testing each day. The maximum operating load was maintained throughout the testing except for Friday 11/30 where the average sludge input was 3/4 ton/hr lower than the maximum. The only fuel oil used was Wednesday 11/28 between 1600 through 1800 hrs. and amounted to an insignificant 16 gallons. The remainder of the testing was conducted while the sludge was being combusted on its own (autogenous burning).

Basic to the incineration of sludge in an efficient and cost effective manner is its preparation for combustion. Incoming raw and/or waste biological sludge is processed through thickening and then subjected to a thermal conditioning pressure and heat process which breaks down the sludge solids producing smaller particles which may more easily be dewatered. The sludge is then fed onto drum-type vacuum filters where a sludge cake is produced. This cake is then moved by conveyor belt and deposited into the top of the incinerator chamber on a continuous basis. The burning sludge is then moved downward through each hearth by an intermittently rotating rake assembly. The rakes move the sludge from inner to outer areas of one hearth then back toward the center of the next hearth as it passes downward insuring more complete burning. Combustion air is supplied to the unit via induced draft and controlled by dampers around the chamber perimeter. Ash is removed to a landfill by truck.

Combustion gases exit the incinerator through a 101" x 85.75" refractory lined steel duct located at the top of the reactor. From the incinerator

TABLE I-1

SUMMARY OF INCINERATOR OPERATING DATA

PLANT "O"

DATE	TIME	TEMP #1[B] HEARTH (°F)	SCRUBBER ΔP (" H_2O)	SMOKE DENSITY (% OUTLET)	SOLIDS LOADING (LBS/HR)	FUEL OIL USED (GALLONS)	FILTER CAKE (% TOTAL SOLIDS) FILTER #1	FILTER CAKE (% TOTAL SOLIDS) FILTER #3
11/27/79	0900	1340	8.7	28	11,756	0		
	1000	1395	11.8	34	11,298	0		
	1100	1335	11.2	32	11,874	0	40.0	39.5
	1200	1345	12.2	60	11,333	0		
	1300	1430	12.4	20	11,426	0		
	1400	1350	10.6	7	11,673	0		
	1500	1340	11.5	6	11,619	0		
	1600	1345	11.6	6	11,936	0		
	1700	1390	12.0	10	14,623	0		
	1800	1340	12.0	11	14,486		41.6	38.7
Average		1361	11.4	21.4	12,202	0		
Total					122,024			
11/28/79	0900	1540	12.0	19	14,286	0	41.2	40.5
	1000	1615	11.8	--	12,371	0		
	1100	1400	10.3	--	13,145	0		
	1200	1350	10.6	10	12,416	0		
	1300	1350	10.0	9	11,444	0		
	1400	1350	11.2	10	10,361	0	41.8	----
	1500	1420	11.8	8	10,589	0		
	1600	1400	9.6	8	11,484	5.4		
	1700	1540	13.6	8	13,317	5.4	41.2	----
	1800	1360	9.9	6	11,916	5.4		
Average		1432	11.1	10	12,133	5.4		
Total					121,329	16.2		

TABLE I-1 (Cont)

SUMMARY OF INCINERATOR OPERATING DATA

PLANT "O"

DATE	TIME	TEMP #1[B] HEARTH (°F)	SCRUBBER P (" H_2O)	SMOKE DENSITY (% OUTLET)	SOLIDS LOADING (LBS/HR)	FUEL OIL USED (GALLONS)	FILTER CAKE (% TOTAL SOLIDS) FILTER #1	FILTER CAKE (% TOTAL SOLIDS) FILTER #3
11/29/79	0900	1160	12.5	18	12,233	0	40.6	---A
	1000	1195	12.0	16	11,818	0		
	1100	1215	12.9	9	12,176	0	37.8	---
	1200	1260	12.9	10	12,265	0		
	1300	1190	13.5	10	12,306	0	37.5	---
	1400	1330	10.9	4	11,598	0		
	1500	1320	10.2	4	11,004	0	38.7	---
	1600	1300	10.1	6	11,663	0		
	1700	1290	11.4	6	9,108	0		
	1800	1350	9.6	4	8,058	0		
Average		1261	11.6	8.7	11,223		38.6	
Total					112,229			
11/30/79	0900	1415	10.1	10	10,498	0	40.8	---
	1000	1405	10.0	13	10,363	0		
	1100	1390	10.2	14	10,451	0	38.3	---
Average		1403	10.1	12.3	10,437	0	39.6	
Total					31,312			

A Vacuum Filter #3 not operating.
B Temperature most closely associated with scrubber inlet test site.

TABLE II-1

SUMMARY OF PARTICULATE EMISSION RESULTS

PLANT "O" - SCRUBBER INLET

	RUN IP1	RUN IP2	RUN IP3	RUN IP4	RUN IP5	RUN IP6	AVERAGE
Particulate Emissions (lbs/hr)[1]	662.43	645.57	722.65	708.78	920.59	917.63	762.94
Stack Gas Flow Rate (scfm)[2]	32,754	28,598	35,216	33,558	31,895	31,009	32,172
Stack Gas Temperature (°F)	1,264	1,336	1,398	1,257	1,287	1,305	1,308
% O_2	13.2	11.3	12.1	12.6	11.5	12.0	12.1
% CO_2	7.0	7.6	7.5	7.5	8.1	7.1	7.5
% Isokinetic	88.0	102.4	97.4	97.7	99.8	102.1	97.9

[1] Results based on front half catch, Ref. 40, CFR 60, Appendix A, Method 5.
[2] Standard cubic feet per minute at 68°F and 29.92 inches of Mercury, dry basis.

TABLE II-1 (Cont)

SUMMARY OF PARTICULATE EMISSION RESULTS

PLANT "O" - SCRUBBER OUTLET

	RUN OP1	RUN OP2	RUN OP3	RUN OP4	RUN OP5	RUN OP6	AVERAGE
Particulate Emissions (lbs/hr)[1]	3.17	2.43	1.48	2.14	1.97	0.59	1.96
Stack Gas Flow Rate (scfm)[2] dry	41,309	38,933	31,867	38,668	38,845	34,584	37,368
Stack Gas Temperature (°F)	167	149	178	119	165	159	156
% O_2	15.3	15.3	15.3	16.0	17.0	15.5	15.7
% CO_2	6.0	6.0	6.0	4.2	4.0	5.0	5.2
% Isokinetic	78.7	94.2	97.0	94.6	92.7	96.9	92.4

1 Results based on front half catch, Ref. 40, CFR 60, Appendix A, Method 5.
2 Standard cubic feet per minute at 68°F and 29.92 inches of Mercury, dry basis.

TABLE II-2

SUMMARY OF SULFUR DIOXIDE AND SULFURIC ACID MIST EMISSIONS

PLANT "O"

DATE	TIME	RUN NUMBER	STACK GAS FLOW RATE (SCFM)	SO_2 EMISSIONS LB/DCSF x 10^{-5}	SO_2 EMISSIONS LB/HR	SO_2 EMISSIONS CONC. PPM	SO_3/H_2SO_4 EMISSIONS LB/DSCF x 10^{-5}	SO_3/H_2SO_4 EMISSIONS LB/HR	SO_3/H_2SO_4 EMISSIONS CONC. PPM
1979		Inlet							
11/27	1429	IP1	32,754	2.796	54.95	168	0.083	1.64	3.28
11/28	1158	IP2	28,598	3.541	60.75	213	0.011	1.90	4.36
11/28	1435	IP3	35,216	3.311	69.96	199	0.052	1.11	2.06
11/29	0845	IP4	33,558	3.233	65.10	195	0.255	5.13	10.02
11/29	1255	IP5	31,894	3.206	61.35	193	0.071	1.36	2.78
11/30	0925	IP6	31,009	3.117	57.99	188	0.080	1.48	3.13
			(32,172)		(61.68)			(2.10)	
		Outlet							
11/27	1434	OP1	41,309	0	0	0	0.003	0.008	0.13
11/28	1100	OP2	38,932	0.001	0.003	0.06	0.026	0.602	1.01
11/28	1447	OP3	31,867	0.010	0.168	0.59	0.015	0.278	0.57
11/29	0849	OP4	38,668	0.020	0.446	1.16	0.002	0.004	0.07
11/29	1256	OP5	38,845	0.008	0.176	0.45	0.002	0.004	0.08
11/30	0930	OP6	34,584	0.002	0.004	0.12	0.009	0.184	0.35
			(37,368)		(0.133)			(0.180)	

TABLE II-3

SUMMARY OF OXIDES OF NITROGEN DATA[1]

PLANT "O"

DATE	TIME	PPM NO			PPM NO_2			PPM NO_x		
		LOW	HIGH	AVG.	LOW	HIGH	AVG.	LOW	HIGH	AVG.
11/27	1420-1720	43.1	98.2	72.8	3.2	32.5	13.2	75.6	107.9	86.0
11/28	1100-1640	20.0	105.8	41.7	13.3	61.3	30.6	42.3	124.7	71.2
11/29	0840-1500	8.8	12.8	10.4	12.2	29.7	22.6	21.0	39.5	32.4
11/30	0930-1120	12.1	13.1	10.4	10.0	18.0	14.7	22.1	30.1	24.8

1 20-minute average values obtained from Teco Instrument strip charts.

SECTION III

SAMPLING AND ANALYTICAL PROCEDURES

Method 5/8 Samples

A standard EPA Method 5 sampling train (Figure III-1) was used for collection of the particulate and SO_2, SO_3, H_2SO_4 samples. For collection of the sulfur compounds the train was modified by placing 150 ml of 80% isopropanol in the first impinger followed by a high purity glasswool plug in the U-tube between the first and second impingers. The second and third impingers contained 100 ml each of 3% hydrogen peroxide solution and the fourth impinger was filled with approximately 400 grams of indicating silica gel dessicant. Moisture determinations were accomplished by weighing each impinger on a triple beam balance before and after a test.

All Method 5/8 samples were collected at a single sampling point within the ducts using a 5' stainless steel lined heated probe at the scrubber inlet and a 5' heated pyrex liner at the scrubber outlet. Prior to selection of a point of average velocity for collection of samples, a velocity traverse was conducted through each port. Two points, each in a different port were selected, one for the Method 5/8 samples and one for the particle characterization and Pilat impactor samples. As described in Section I of this report under "Sample Point Locations" all Method 5/8 samples were collected from Port A on the scrubber inlet and Port A on the scrubber outlet. Characterization samples were collected from Port B on the inlet and Port B on the outlet of the scrubber. No Pilat impactor samples were collected at the scrubber inlet due to excessive gas temperatures, however, Port B was used for the outlet particle sizing runs.

As much as was practical, all inlet and outlet testing in each category was conducted simultaneously although some variation existed due to the length of individual sampling runs and temporary equipment malfunctions. An effort was made by all personnel to begin each test series at nearly the same time.

At the beginning and end of each Method 5/8 sampling run the probe nozzle was capped and the sample train was leak-checked for compliance within the specified 0.02 cfm limit at 15" Hg. All test runs both inlet and outlet were found to be within this specification. After the test run and Purge was completed,

the probes were capped, disassembled, allowed to cool, and rinsed and brushed three times each with distilled H_2O and then with acetone. The filter, glass wool plug, and final impinger contents were recovered at a clean area near the sampling site. The recovered samples were then properly labelled, placed in lead-free glass sample bottles with Teflon-lined caps, and returned to the ES laboratory in McLean, Va. for analysis. A description of the sample analysis procedure is contained in Section IV of this report.

During each Method 5/8 test a 1/4" O.D. tube was inserted into the gas stream where CO_2 and O_2 samples were collected for analyses by use of a Fyrite apparatus. The average value of these replicate tests were used in computation of the dry gas molecular weights.

Six Method 5/8 tests were conducted on the scrubber inlet and were labeled IP1 through IP6. Similarly, six Method 5/8 tests were simultaneously conducted on the scrubber outlet and were labelled OP1 through OP6. The duration of the tests were each 60 minutes. Purges were conducted for 15 minutes after each test as per Method 8.

Characterization Samples

Collection of the characterization samples was conducted using a modified Method 5 sampling train in which the conventional sample box, filter holder and normal complement of impingers were replaced by an EPA-designed heated sample box, housing a stainless steel filter holder. A separate condenser immersed in an ice bath was used for moisture removal prior to sample gas metering. The stainless steel filter holder accommodated 47 mm diameter filters used for the characterization samples and was outfitted to adapt directly to a conventional 5' pyrex lined probe. Figure III-2 shows the sampling train used for collecting the characterization samples.

During the course of the testing program, Nuclepore®, Millipore®, Teflon®, and glass fiber filter media were employed to obtain characterization samples.(1) In all cases regardless of the duration of sampling, it was attempted to collect each sample at or near isokinetic sampling conditions. A standard Method 5 nomograph was utilized for determining desired sampling rates.

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Characterization samples were collected in sets. A set, as defined by the EPA test coordinator, consisted of two samples of a type A glass fiber filter, two samples each of different duration on Millipore® filters, one sample on Nuclepore© filter, and several samples on Teflon® filters.[1] The two samples collected on Millipore® filters spanned a range of particle deposition densities: the first being very light, the second slightly heavier. The objective was to provide a range of densities all suitable for measurement by the instrumental techniques utilized by PERS for analysis. Sampling durations ranged from 30 seconds to as long as three minutes. For the glass fiber filters, sampling durations ranged from 5 to 10 minutes. The objective for these samples was to collect a heavy deposition of particulate. Sample durations for the Nuclepore© filters were chosen to produce light depositions. Sampling durations ranged from 15 to 30 seconds. A range of deposition densities were collected on the Teflon® filters. Samples were collected for both one-minute and two-minute durations.

During each of the tests, the initial and final dry gas meter volumes were recorded along with elapsed time, clock time, dry gas meter temperature, heated sample box temperature, stack temperature, pump vacuum, orifice pressure differential (ΔH) and velocity pressure (ΔP). Copies of the field data sheets are contained in Appendix C.

Loading and unloading of the characterization filter holder was accomplished using forceps. Each sample was replaced in its original container immediately after collection, and the filter holder was reloaded for the next sample. A small brush was used to clean the front half of the filter holder into the filter container after each use. All loading and unloading was done at the sampling site. All characterization samples were transferred to EPA for analysis at the completion of the study.

Particle Sizing

Collection of particle size samples was conducted using both a Mark III Source Test Cascade Impactor (Pilat Impactor). Three Mark III impactors were provided by EPA for use in this study. Both button-hook type and straight nozzles were provided in order to allow sampling with the impactor in either of two positions; facing directly into the gas stream or at right angles to

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the gas stream. Figure III-3 shows the sampling train used with the Pilat impactor.

The pre-test preparation and set-up of the impactors followed the procedures outlined in the Operational Manual for the Mark III Source Test Impactor. Tared impactor collection plates and glass fiber filters were provided by EPA. All impactor set-ups and clean-ups were performed indoors in a lab area. After loading, the impactors were capped and hand-carried to the sampling site.

Before collecting each Pilat impactor sample, the impactor was inserted into the stack with the nozzle pointing away from the flow and was allowed to equilibrate to gas stream temperature. The nozzle was then turned into the flow, and a sample was collected at a constant rate calculated to be isokinetic for conditions at the sampling point.

A programmable calculator provided by EPA with a program for determining isokinetic sampling rates for a range of nominal sampling nozzle sizes was utilized. For each sample, the calculator was used to select a nominal size which corresponded to an isokinetic sampling rate falling in the range of 0.5 to 0.75 (stack conditions) for the Pilat impactor. Following selection of the nominal size, a nozzle with actual dimensions closest to the nominal size was selected for use. The programmable calculator was used to recompute the sampling rate and "ΔH" for the isokinetic sampling rate using the actual nozzle size. The location of the sampling point for the impactor samples was a point of average gas velocity within the duct. Once sampling was initiated, the sampling rate was held constant until completion of the sample, regardless of changes in stack temperature or ΔP.

During each of the tests, initial, five minute, and final dry gas readings were recorded along with elapsed time, clock time, dry gas meter temperature, pump vacuum, orifice pressure differential (ΔH) and velocity pressure (ΔP).

Six Pilat impactor samples were collected at the incinerator scrubber outlet. All samples were collected using 0.188" diameter nozzle with the impactor oriented in line with the direction of flow.

Scrubber outlet particle sizing samples numbered 1, 2, 4, 5, and 6 were of 30-minute duration. Run #3 was of 20-minute duration. During Run #2 an improper stack temperature was recorded initially on the field data sheet

averaging 166°F, however, the actual T_s averaged 125°F. This change was noted on the field data sheet and subsequently used in the flow rate calculations.

NO_x and THC Analytical Procedure

Tests were conducted on three municipal sludge incinerators, two multiple hearth devices, and one fluidized bed unit, each with wet scrubber systems controlling emissions from combustion. All three thest sites were tested using similar sampling delivery and analytical measuring systems. Each site was tested on a continuous basis for the oxides of nitrogen and total hydrocarbons.

A Thermo Electron Model 44 Dual Chamber Single Detector was used for NO_x testing. The Model 44 can monitor either for NO_x or NO. The actual component of measurement was determined by a selector switch on the front panel of the instrument.

A sample delivery system was used to condition the stack gases prior to measurement by the NO_x and THC analyzer. A 30-foot teflon line (1/4-inch O.D.) was heated and maintained at a temperature of 200°F. Temperature control was accomplished by using a Theostat to control current flow to the heated line. An Omega Digital Temperature Readout, Model 175-KFI, Type K Thermocouple was used to monitor the temperature of the teflon line. Moisture within the delivery system was controlled by two 50 ml borosilicate glass knock-out pots connected in series by 1/4-inch O.D., 316 stainless steel tubing. The knock-out pots were continuously submerged in an ice bath. Following the knock-out pots, a 50 ml glass tube packed with indicating silica gel was used to trap any small amounts of moisture remaining in the sample. When the silica gel was more than 50 percent spent, the silica gel tube was replaced with a freshly packed tube of silica gel. See Figure III-4 for a schematic presentation of the sample delivery and conditioning system, and the NO_x and THC analyzer.

A 0.1 millivolt instrument output was connected to a linear, Model 555, Single Pen Chart Recorder. Zero drift and calibration curve data were collected before and after each analyses. A multipoint calibration curve was developed and a correlation coefficient calculated. Three different concentrations of span gas were used for the multipoint calibration. The cylinder concentration was determined by Scott Environmental of Pleasantville, Pennsylvania.

Total hydrocarbon analysis was performed by using a Scott Model 166 Total Hydrocarbon Analyzer. The analyzer is equipped with a single flame ionization detector and can measure the THC content of the sample gas on a continuous basis. The 0-1 MV output was connected to a Linear Model 505 Strip Chart Recorder. To increase the linearity of the analyzer, a combination supply fuel consists of a 60 percent helium and 40 percent hydrogen gas blend. Prior to analysis, a multipoint calibration was introduced to the instrument and a one span check after each test.

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P

PARTICULATE AND GASEOUS EMISSIONS TESTS AT MUNICIPAL SLUDGE INCINERATOR PLANT "P"

Contract No. 68-02-2815
Work Assignment No. 33

Submitted to

U.S. Environmental Protection Agency
Stationary Source Emission Research Branch
Emissions Measurement and Characterization Division
Environmental Sciences Research Laboratory
Research Triangle Park, North Carolina 27711

Submitted by

Engineering-Science
7903 Westpark Drive
McLean, Virginia 22102

February 1980

SECTION I

INTRODUCTION

The Stationary Source Emissions Research Branch (SSERB) of the U.S. Environmental Protection Agency (EPA) is engaged in an emissions test program proposing characterization of the type and quantity of particulate air pollutants emitted from specific source categories. Additionally, the U.S. EPA, Office of Research and Development (ORD), Municipal Environmental Research Laboratory (MERL) is interested in determination of the nature and composition of pollutant discharges to the atmosphere from municipal wastewater sludge incinerator facilities.

Under EPA Contract No. 68-02-2815, Work Assignment No. 33, Engineering-Science (ES) was retained by the ESRL Particulate Emissions Research Section for assistance in collection of particulate, particle characterization, particle sizing, gaseous pollutants, and process samples at municipal sludge incinerators serving three metropolitan areas.

During the period of December 3-7, 1979 samples were collected by PERS and ES personnel at the second of three test sites on the inlet and outlet of a wet, tray-type scrubber system controlling emissions from an eight-chambered multiple hearth sludge incinerator. For the purposes of this report the facility shall be designated "Plant P" in the interest of confidentiality.

Particulate and SO_2, SO_3, and H_2SO_4 emission tests were conducted using EPA Reference Method 5 and 8 procedures modified by single point sampling as approved by PERS personnel in conjunction with EPA Reference Methods 1-4. Simultaneous inlet and outlet Method 5/8 particulate - SO_2, SO_3, and H_2SO_4, particle characterization, particle sizing (outlet only), and gaseous samples including total hydrocarbons and oxides of nitrogen via use of continuous analyzers were taken. Particle characterization samples included use of 47 mm glass fiber, Millipore®, Nuclepore®, and Teflon® types of filter media.(1) These characterization samples along with the Pilat particle cascade impactor samples were forwarded to ESRL for analysis. Process samples including composite pre-burn sludge samples, post-burn ash samples, and scrubber water samples for each test series were forwarded to the EPA MERL for analysis.

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This report contains the results of emission tests executed utilizing EPA Methods 5 and 8 along with field data associated with the particle characterization, Pilat impactor, total hydrocarbon, and oxides of nitrogen gaseous data. Neither analytical data subsequent to results obtained by ESRL are included in this report nor results from analysis of process samples by MERL.

Process Description

Plant "P" operates a single eight hearth rotating rake incinerator. Combustion of the sludge is supplemented by use of natural gas with burners located in hearth #'s 2, 4, 6, and 8. Normal operation of the incinerator is about four days per week on a 24-hour basis until the sludge supply is exhausted. The sludge incineration feed rate ranges from 6000 lbs/hr to 10,500 lbs/hr wet. During the test program the sludge feed averaged 6,708 lbs/hr on Thursday 12/6 and 8,625 lbs/hr on Friday 12/7. Table I-1 summarizes pertinent incinerator operating parameters maintained throughout the testing. A copy of the operating log for the incinerator is located in Appendix E of this report along with a summary of average sludge percent solids and volatiles prepared by the plant laboratory. At no time during the testing did the sludge achieve an autogenous burn. Combustion was aided by use of natural gas at the average rate of 43.8 ft^3 and 39.9 ft^3 during the two days testing, respectively.

Basic to the incineration of sludge in an efficient and cost effective manner is its preparation for combustion. Figure I-1 shows a diagram of the basic process. Incoming raw and/or waste biological sludge is processed through thickening and then subjected to a thermal conditioning pressure and heat process which breaks down the sludge solids producing smaller particles which may more easily be dewatered. The sludge is then fed to drum-type vacuum filters where a sludge cake is produced. This cake is then moved by conveyor belt and deposited into the top of the incinerator chamber on a continuous basis. The burning sludge is then moved downward through each hearth by a rotating shaft and rake assembly. The rakes move the sludge from inner to outer areas of one hearth and back toward the center of the next hearth as it passes downward insuring more complete burning. Combustion air is supplied by induced draft. Ash is removed to a storage hopper and then removed by truck to a landfill.

TABLE I-1

SUMMARY OF INCINERATOR OPERATING DATA

PLANT "P"

DATE	TIME	HEARTH #1 TEMP. (°F)	SCRUBBER PRESSURE DROP ("H_2O)	OXYGEN IN EXHAUST GAS (%)	BOILER STEAM FLOW (LBS/HR)	NATURAL GAS USED (FT^3)	SLUDGE FEED RATE (LBS/HR WET)
12/6/79	0800	1,130	3.8	11	4,000	8	
	0900	1,250	4	13	5,500	2	
	1000	1,250	3.8	11.5	5,000	2	
	1100	1,390	3	10	5,500	3	
	1200	1,300	3.8	10.5	5,000	3	
	1300	1,300	4	8	5,000	3	
	1400	1,310	4	7.5	5,500	3	
	1500	1,150	4.2	5	5,000	2	
	1600	1,400	4.2	7	6,000	2	
	1700	1,070	4	10	5,000	2	
	1800	1,170	4	7	5,000	2	
	1900	1,200	4	7	5,000	2	
Average		1,243	3.9	8.9	5,125	2.8	6,708
Total					61,500	34	73,778
12/7/79	0800	1,060	5	6.3	5,000	2	
	0900	990	4.2	6	5,000	2	
	1000	1,040	5	15	5,000	2	
	1100	1,160	4	13	5,000	2	
	1200	1,250	4	12	5,000	2	
	1300	1,060	4	15	5,000	2	
	1400	1,140	4	15	5,000	2	
	1500	1,200	4	15	5,000	2	
	1600	1,150	3.2	18	5,000	2	
	1700	1,320	4	13	5,000	2	
Average		1,137	4.1	12.8	5,000	2	8,625
Total					50,000	20	77,625

TABLE II-1

SUMMARY OF PARTICULATE EMISSION RESULTS

PLANT "P" - SCRUBBER INLET

	RUN IP1	RUN IP2	RUN IP4	RUN IP5	RUN IP6	AVERAGE
Particulate Emissions (lbs/hr)[1]	17.77	38.52	68.72	74.27	56.06	51.07
Stack Gas Flow Rate (scfm)[2]	6,670	6,834	9,779	9,013	8,653	8,190
Stack Gas Temperature (°F)	439	454	469	465	468	459
% O_2	15.3	15.3	18.5	15.3	15.3	15.9
% CO_2	6.8	6.8	5.0	6.8	6.8	6.4
% Isokinetic	99.5	100.9	99.9	100.3	103.4	100.8

1 Results based on front half catch, Ref. 40, CFR 60, Appendix A, Method 5.
2 Standard cubic feet per minute at 68°F and 29.92 inches of Mercury, dry basis.

TABLE II-1 (Cont)

SUMMARY OF PARTICULATE EMISSION RESULTS

PLANT "P" - SCRUBBER OUTLET

	RUN OP1	RUN OP2	RUN OP4	RUN OP5	AVERAGE
Particulate Emissions (lbs/hr)[1]	2.36	2.04	7.72	14.14	6.56
Stack Gas Flow Rate (scfm)[2]	12,442	15,604	20,813	16,527	16,346
Stack Gas Temperature (°F)	141	128	125	133	132
% O_2	12.0	12.0	11.3	11.3	11.6
% CO_2	5.0	5.0	3.0	3.0	4.0
% Isokinetic	112.7	106.6	103.3	100.4	105.8

1 Results based on front half catch, Ref. 40, CFR 60, Appendix A, Method 5.
2 Standard cubic feet per minute at 68°F and 29.92 inches of Mercury, dry basis.

TABLE II-2

SUMMARY OF SULFUR DIOXIDE AND SULFURIC ACID MIST EMISSIONS

PLANT "P"

DATE	TIME	RUN NUMBER	STACK GAS FLOW RATE SCFM	SO_2 EMISSIONS LB/DCSF x 10^{-5}	SO_2 EMISSIONS LB/HR	SO_2 EMISSIONS CONC. PPM	SO_3/H_2SO_4 EMISSIONS LB/DSCF x 10^{-5}	SO_3/H_2SO_4 EMISSIONS LB/HR	SO_3/H_2SO_4 EMISSIONS CONC. PPM
1979		Inlet							
12/6	1115	IP1	----------	----------	----------	VOID	----------	----------	----------
12/6	1350	IP2	6,834	4.482	18.379	270	0.046	0.188	1.80
12/6	1505	IP3	----------	----------	----------	VOID	----------	----------	----------
12/7	0830	IP4	9,779	2.940	17.247	177	0.011	0.065	0.44
12/7	1015	IP5	9,013	3.470	18.762	209	0.054	0.294	2.14
12/7	1250	IP6	8,653	3.342	17.350	201	0.032	0.165	1.25
			(8570)		(17,934)			(0.178)	
		Outlet							
12/6	1204	OP1	12,443	0	0	0	0.028	0.021	1.08
12/6	1655	OP2	15,604	0.002	0.015	0.096	0.061	0.57	2.39
12/7	0902	OP3	19,256	0.059	0.686	3.58	0.032	0.37	1.25
12/7	1227	OP4	20,813	0.075	0.940	4.53	0.011	0.14	0.46
			(17,029)		(6,410)			~~(1,101)~~ (6.275)	

Oxides of Nitrogen

NO, NO_2, and NO_x values of the scrubber outlet gas stream were obtained via use of a TECO 44 NO/NO_x analyzer. Average 20-minute strip chart readings are included on the field data sheets located in Appendix C. Table II-3 is a summary of oxides of nitrogen values obtained during the two days of sampling at Plant "P". NO concentrations ranged from a low of 18.9 ppm to a high of 139.9 ppm while the low daily average was 96.2 ppm and the high daily average was 105.0 ppm.

NO_2 values for the same period resulted in concentrations from 0 to 63.5 ppm while the low daily average was 15.1 ppm and the high daily average was 30.6 ppm. The corresponding NO_x values ranged from a low of 18.9 ppm to a high of 152.6 ppm for the test periods while the low daily average was 111.3 ppm and the high daily average was 135.7 ppm.

Total Hydrocarbons

THC values obtained from the scrubber outlet are contained in Appendix C. Average concentrations ranged from 3 ppm to 6.4 ppm during the two days testing.

TABLE II-3

SUMMARY OF OXIDES OF NITROGEN DATA[1]

PLANT "P"

DATE	TIME	PPM NO			PPM NO_2			PPM NO_x		
		LOW	HIGH	AVG.	LOW	HIGH	AVG.	LOW	HIGH	AVG.
1979										
12/6	1100-1800	18.9	138.5	96.2	0	51.1	15.1	18.9	145.8	111.3
12/7	0820-1600	50.8	139.9	105.0	2.5	63.5	30.6	111.9	152.6	135.7

1 20-minute average values obtained from Teco Instrument strip charts.

SECTION III

SAMPLING AND ANALYTICAL PROCEDURES

Method 5/8 Samples

A standard EPA Method 5 sampling train (Figure III-1) was used for collection of the particulate and SO_2, SO_3, H_2SO_4 samples. For collection of the sulfur compounds the train was modified by placing 150 ml of 80% isopropanol in the first impinger followed by a high purity glasswool plug in the U-tube between the first and second impingers. The second and third impingers contained 100 ml each of 3% hydrogen peroxide solution and the fourth impinger was filled with approximately 400 grams of indicating silica gel dessicant. Moisture determinations were accomplished by weighing each impinger on a triple beam balance before and after a test.

All Method 5/8 samples were collected at a single sampling point within the ducts using 5' stainless steel probes and 5' heated pyrex liners at both the scrubber inlet and outlet. Prior to selection of a point of average velocity for collection of samples, a velocity traverse was conducted through each port. Two points were selected, one for the Method 5/8 samples and one for the particle characterization and Pilat impactor samples. As described in Section I of this report under "Sample Point Locations" all Method 5/8 samples were collected from Port A on the scrubber inlet and Port A on the scrubber outlet. Characterization samples were collected from Port A on the inlet and Port B on the outlet of the scrubber. No Pilat impactor samples were collected at the scrubber inlet, however, Port B was used for the outlet particle sizing runs.

As much as was practical, all inlet and outlet testing in each category was conducted simultaneously although some variation existed due to the length of individual sampling runs and temporary equipment malfunctions. An effort was made by all personnel to begin each test series at nearly the same time.

At the beginning and end of each Method 5/8 sampling run the probe nozzle was capped and the sample train was leak-checked for compliance within the specified 0.02 cfm limit at 15" Hg. All test runs both inlet and outlet were found to be within this specification. After the test run and Purge was completed, the probes were capped, disassembled, allowed to cool, and rinsed and brushed

three times each with distilled H_2O and then with acetone. The filter, glass wool plug, and final impinger contents were recovered at a clean area near the sampling site. The recovered samples were then properly labelled, placed in lead-free glass sample bottles with Teflon-lined caps, and returned to the ES laboratory in McLean, Va. for analysis. A description of the sample analysis procedure is contained in Section IV of this report.

During each Method 5/8 test a 1/4" O.D. tube was inserted into the gas stream where CO_2 and O_2 samples were collected for analyses by use of a Fyrite apparatus. The average value of these replicate tests were used in computation of the dry gas molecular weights.

Six Method 5/8 tests were conducted on the scrubber inlet and were labeled IP1 through IP6. Five Method 5/8 tests were simultaneously conducted on the scrubber outlet and were labelled OP1 through OP5. The duration of the tests were each 45 minutes. Purges were conducted for 15 minutes after each test as per Method 8.

Characterization Samples

Collection of the characterization samples was conducted using a modified Method 5 sampling train in which the conventional sample box, filter holder and normal complement of impingers were replaced by an EPA-designed heated sample box, housing a stainless steel filter holder. A separate condenser immersed in an ice bath was used for moisture removal prior to sample gas metering. The stainless steel filter holder accommodated 47 mm diameter filters used for the characterization samples and was outfitted to adapt directly to a conventional 5' pyrex lined probe. Figure III-2 shows the sampling train used for collecting the characterization samples.

During the course of the testing program, Nuclepore®, Millipore®, Teflon®, and glass fiber filter media were employed to obtain characterization samples.(1) In all cases regardless of the duration of sampling, it was attempted to collect each sample at or near isokinetic sampling conditions. A standard Method 5 nomograph was utilized for determining desired sampling rates.

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(1) Mention of trade names or specific products does not constitute endorsement by the Environmental Protection Agency.

Characterization samples were collected in sets. A set, as defined by the EPA test coordinator, consisted of two samples of a type A glass fiber filter, two samples each of different duration on Millipore® filters, one sample on Nuclepore® filter, and several samples on Teflon® filters.(1) The two samples collected on Millipore® filters spanned a range of particle deposition densities: the first being very light, the second slightly heavier. The objective was to provide a range of densities all suitable for measurement by the instrumental techniques utilized by PERS for analysis. Sampling durations ranged from 30 seconds to as long as three minutes. For the glass fiber filters, sampling durations ranged from 5 to 10 minutes. The objective for these samples was to collect a heavy deposition of particulate. Sample durations for the Nuclepore® filters were chosen to produce light depositions. Sampling durations ranged from 15 to 30 seconds. A range of deposition densities were collected on the Teflon® filters. Samples were collected for both one-minute and two-minute durations.

During each of the tests, the initial and final dry gas meter volumes were recorded along with elapsed time, clock time, dry gas meter temperature, heated sample box temperature, stack temperature, pump vacuum, orifice pressure differential (ΔH) and velocity pressure (ΔP). Copies of the field data sheets are contained in Appendix C.

Loading and unloading of the characterization filter holder was accomplished using forceps. Each sample was replaced in its original container immediately after collection, and the filter holder was reloaded for the next sample. A small brush was used to clean the front half of the filter holder into the filter container after each use. All loading and unloading was done at the sampling site. All characterization samples were transferred to EPA for analysis at the completion of the study.

Particle Sizing

Collection of particle size samples was conducted using both a Mark III Source Test Cascade Impactor (Pilat Impactor). Three Mark III impactors were provided by EPA for use in this study. Both button-hook type and straight nozzles were provided in order to allow sampling with the impactor in either of two positions; facing directly into the gas stream or at right angles to

(1) Mention of trade names or specific products does not constitute endorsement by the Environmental Protection Agency.

the gas stream. Figure III-3 shows the sampling train used with the Pilat impactor.

The pre-test preparation and set-up of the impactors followed the procedures outlined in the Operational Manual for the Mark III Source Test Impactor. Tared impactor collection plates and glass fiber filters were provided by EPA. All impactor set-ups and clean-ups were performed indoors in a lab area. After loading, the impactors were capped and hand-carried to the sampling site.

Before collecting each Pilat impactor sample, the impactor was inserted into the stack with the nozzle pointing away from the flow and was allowed to equilibrate to gas stream temperature. The nozzle was then turned into the flow, and a sample was collected at a constant rate calculated to be isokinetic for conditions at the sampling point.

A programmable calculator provided by EPA with a program for determining isokinetic sampling rates for a range of nominal sampling nozzle sizes was utilized. For each sample, the calculator was used to select a nominal size which corresponded to an isokinetic sampling rate falling in the range of 0.5 to 0.75 (stack conditions) for the Pilat impactor. Following selection of the nominal size, a nozzle with actual dimensions closest to the nominal size was selected for use. The programmable calculator was used to recompute the sampling rate and "ΔH" for the isokinetic sampling rate using the actual nozzle size. The location of the sampling point for the impactor samples was a point of average gas velocity within the duct. Once sampling was initiated, the sampling rate was held constant until completion of the sample, regardless of changes in stack temperature or ΔP.

During each of the tests, initial, five minute, and final dry gas readings were recorded along with elapsed time, clock time, dry gas meter temperature, pump vacuum, orifice pressure differential (ΔH) and velocity pressure (ΔP).

Source Pilat impactor samples were collected at the incinerator scrubber outlet. All samples were collected using 0.250" diameter nozzle with the impactor oriented in line with the direction of flow. Scrubber outlet particle sizing samples numbered 1, 2, and 3 were of 30-minute duration.

NO_x and THC Analytical Procedure

Tests were conducted on three municipal sludge incinerators, two multiple hearth devices, and one fluidized bed unit, each with wet scrubber systems

controlling emissions from combustion. All three thest sites were tested using similar sampling delivery and analytical measuring systems. Each site was tested on a continuous basis for the oxides of nitrogen and total hydrocarbons.

A Thermo Electron Model 44 Dual Chamber Single Detector was used for NO_x testing. The Model 44 can monitor either for NO_x or NO. The actual component of measurement was determined by a selector switch on the front panel of the instrument.

A sample delivery system was used to condition the stack gases prior to measurement by the NO_x and THC analyzer. A 30-foot teflon line (1/4-inch O.D.) was heated and maintained at a temperature of 200°F. Temperature control was accomplished by using a Theostat to control current flow to the heated line. An Omega Digital Temperature Readout, Model 175-KFI, Type K Thermocouple was used to monitor the temperature of the teflon line. Moisture within the delivery system was controlled by two 50 ml borosilicate glass knock-out pots connected in series by 1/4-inch O.D., 316 stainless steel tubing. The knock-out pots were continuously submerged in an ice bath. Following the knock-out pots, a 50 ml glass tube packed with indicating silica gel was used to trap any small amounts of moisture remaining in the sample. When the silica gel was more than 50 percent spent, the silica gel tube was replaced with a freshly packed tube of silica gel. See Figure III-4 for a schematic presentation of the sample delivery and conditioning system, and the NO_x and THC analyzer.

A 0.1 millivolt instrument output was connected to a linear, Model 555, Single Pen Chart Recorder. Zero drift and calibration curve data were collected before and after each analyses. A multipoint calibration curve was developed and a correlation coefficient calculated. Three different concentrations of span gas were used for the multipoint calibration. The cylinder concentration was determined by Scott Environmental of Pleasantville, Pennsylvania.

Total hydrocarbon analysis was performed by using a Scott Model 166 Total Hydrocarbon Analyzer. The analyzer is equipped with a single flame ionization detector and can measure the THC content of the sample gas on a continuous basis. The 0-1 MV output was connected to a Linear Model 505 Strip Chart Recorder. To increase the linearity of the analyzer, a combination supply fuel consists of a 60 percent helium and 40 percent hydrogen gas blend.

Prior to analysis, a multipoint calibration was introduced to the instrument and a one span check after each test.

5
Q

PARTICULATE AND GASEOUS EMISSIONS TESTS AT MUNICIPAL SLUDGE INCINERATOR PLANT "Q"

Contract No. 68-02-2815
Work Assignment No. 33

Submitted to

U.S. Environmental Protection Agency
Stationary Source Emission Research Branch
Emissions Measurement and Characterization Division
Environmental Sciences Research Laboratory
Research Triangle Park, North Carolina 27711

Submitted by

Engineering-Science
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McLean, Virginia 22102

February 1980

SECTION I

INTRODUCTION

The Stationary Source Emissions Research Branch (SSERB) of the U. S. Environmental Protection Agency (EPA) is engaged in an emissions test program proposing characterization of the type and quantity of particulate air pollutants emitted from specific source categories. Additionally, the U. S. EPA, Office of Research and Development (ORD), Municipal Environmental Research Laboratory (MERL) is interested in determination of the nature and composition of pollutant discharges to the atmosphere from municipal wastewater sludge incinerator facilities.

Under EPA Contract No. 68-02-2815, Work Assignment No. 33, Engineering-Science (ES) was retained by the ESRL Particulate Emissions Research Section for assistance in collection of particulate, particle characterization, particle sizing, gaseous pollutants, and process samples at municipal sludge incinerators serving three metropolitan areas.

During the period of December 10-14, 1979 samples were collected by PERS and ES personnel at the third of three test sites on the inlet and outlet of a wet, tray-type scrubber system controlling emissions from an fluidized bed sludge incinerator. For the purposes of this report the facility shall be designated "Plant Q" in the interest of confidentiality.

Particulate and SO_2, SO_3, and H_2SO_4 emission tests were conducted using EPA Reference Method 5 and 8 procedures modified by single point sampling as approved by PERS personnel in conjunction with EPA Reference Methods 1-4. Although simultaneous inlet and outlet Method 5/8 particulate - SO_2, SO_3, and H_2SO_4 samples had been planned to be taken, only outlet Method 5/8 tests were conducted due to adverse inlet gas pressures and temperatures. Particle characterization, particle sizing (outlet only), and gaseous samples including total hydrocarbons and oxides of nitrogen via use of continuous analyzers were taken. Particle characterization samples included use of 47 mm glass fiber, Millipore©, Nuclepore©, and Teflon© types of filter media.(1) These characterization samples along with the Pilat particle cascade impactor samples were forwarded to ESRL for analysis. Process samples including composite

(1) Listing of trade names or specific products does not constitute endorsement by the U. S. Environmental Protection Agency.

pre-burn sludge samples, post-burn ash samples, and scrubber water samples for each test series were forwarded to the EPA MERL for analysis.

This report contains the results of emission tests executed utilizing EPA Methods 5 and 8 along with field data associated with the particle characterization, Pilat impactor, total hydrocarbon, and oxides of nitrogen gaseous data. Neither analytical data subsequent to results obtained by ESRL are included in this report nor results from analysis of process samples by MERL.

Process Description

The fluidized bed wastewater sludge incinerator at Plant "Q" went on line in 1978. The incinerator consists of a refractory lined vertical cylindrical vessel with a sand bed in the lower section supported by a grate as shown in Figure I-1. Dewatered sludge cake is injected above the grate and combustion air flows upward under pressure fluidizing the mixture of hot sand and sludge. Bed differential pressures ranged from 37" H_2O to 45" H_2O during the test periods. Supplemental #2 fuel oil is supplied to the bed through burners above and below the bed. Combustion air is preheated by electric coils to a temperature of 950°F. Combustion of the sludge occurs between 1400-1500°F. Ash is removed from the unit after passing through the cooling venturi where it is combined with the scrubber water outflow and removed to a sediment tank.

Necessary heat for raising the sludge to its kindling temperature is derived from the reservoir of heat in the reactor bed. Mixing of fuel oil and sludge through the entire bed along with optimum contact of oxygen from the forced draft insures rapid combustion. Retention of organic particles by the bed until they are reduced to mineral ash prevents build-up of clinkers. The ash is constantly being carried into the exhaust by the upflow of gases as well as spent sand from the reactor bed which are reduced in size by the violent motion in the reactor. This sand loss is measured at about 5-7 lbs per 8 hours of operating time.

Air flow to the reactor is controlled by an oxygen analyzer located downstream of the combustion zone. The #2 oil auxiliary fuel feed rate is controlled by reactor temperature sensors installed around the bed perimeter. A summary, Table I-1, shows basic operating parameters measured during the test program. Operating logs for both the vacuum filtration system and the incinerator are included in Appendix D of this report.

TABLE I-1

SUMMARY OF INCINERATOR OPERATING DATA

PLANT "Q"

DATE	TIME	REACTOR GAS DISCHARGE TEMP. (°F)	REACTOR BED PRESSURE DROP (" H_2O)	FLUIDIZING (AIR FLOW) SCFM	#2 FUEL OIL (GPH)	TOTAL SLUDGE INPUT (LBS/HR DRY)
12/11/79	0828	1245	37	4850	52	
	0928	1265	40	4500	22	
	1028	1290	40	4500	23	
	1128	1310	40	4500	23	
	1228	1340	40	4500	24	
	1328	1325	40	4550	19	
	1428	1330	40	4500	19	
Average		1301	39.6	4557	26	1,123
Total					182	7,863
12/12/79	0820	1345	40	5000	64	
	0917	1360	45	4800	12	
	1017	1385	42	5000	8	
	1117	1390	40	5100	7	
	1217	1410	40	5050	8	
	1317	1395	40	5050	7	
	1417	1400	40	5050	5	
	1517	1405	40	5050	10	
Average		1386	40.9	5013	15.1	1,882
Total					121	15,056
12/13/79	0827	1390	42	5100	27	
	1927	1330	42	5000	11	
	1027	1420	42	5050	18	
	1127	1435	42	5050	2	
	1227	1445	42	5050	2	
	1327	1450	42	5050	0	
	1427	1430	42	5050	0	
Average		1414	42	5050	8.6	2,522
Total					60	17,653

SECTION II

SUMMARY OF RESULTS

Particulate Tests

Particulate emissions from the scrubber outlet at Plant "Q" ranged from a low of 0.11 lbs/hr during test OP7 to a high of 0.30 lbs/hr during test run OP4 and averaged 0.21 lbs/hr for the span of the test program. Table II-1 shows emission and pertinent stack data obtained during the tests. Tests OP1, OP2, and OP3 were conducted at under isokinetic flow rates of 87.4%, 87.7%, and 83.4% respectively due to overestimation of the stack gas moisture content. No scrubber inlet Method 5/8 samples were obtained at this site due to the high pressure conditions existing in the duct.

SO_2 and SO_3/H_2SO_4 Emissions

No Method 5/8 tests were conducted at the scrubber inlet test site due to adverse sampling conditions. Table II-2 displays the sulfur species obtained from the scrubber outlet test site. Sulfur dioxide emissions ranged from 0.28 to 1.11 lbs/hr and averaged 0.64 lbs/hr while corresponding concentrations ranged from 4.7 to 19.8 ppm and averaged 11.1 ppm for the seven scrubber outlet tests.

SO_3/H_2SO_4 emissions ranged from 0.01 to 0.213 lbs/hr and averaged 0.05 lbs/hr. Corresponding concentrations ranged from 0.14 to 2.27 ppm averaging 0.55 ppm for the seven outlet tests.

NO, NO_2 and NO_x Results

Table II-3 shows values obtained from the NO-NO_x analyzer strip charts. Field data sheets are contained in Appendix C. NO values ranged from a low of 15.1 ppm to a high of 153.1 ppm with a low daily average of 40.6 ppm on 12/13 and a high daily average of 136.3 ppm. Corresponding NO_2 values calculated were 0 to 74.5 ppm with a low daily average of 14.2 ppm on 12/13 and a high daily average of 62.1 ppm on 12/11. NO_x values recorded were from a low of 35.2 ppm to a high of 226.1 ppm with a low daily average of 55.9 ppm on 12/13 to a high daily average of 202.6 ppm on 12.11.

THC Results

Values for ppm for total hydrocarbon concentrations at the scrubber outlet are contained in Appendix C. Values ranged from a low of 10.0 ppm to a

TABLE II-1

SUMMARY OF PARTICULATE EMISSION RESULTS

PLANT "Q" - SCRUBBER OUTLET

	RUN OP1	RUN OP2	RUN OP3	RUN OP4	RUN OP5	RUN OP6	RUN OP7	AVERAGE
Particulate Emissions (lbs/hr)[1]	0.25	0.20	0.23	0.30	0.24	0.13	0.11	0.21
Stack Gas Flow Rate (scfm)[2]	5,937	5,755	5,858	6,157	6,242	5,565	5,203	5,817
Stack Gas Temperature (°F)	62	81	81	94	93	97	94	86
% O_2	12.3	12.3	12.3	9.0	9.0	9.5	9.5	10.6
% CO_2	5.7	5.7	5.7	7.7	7.7	7.5	7.5	6.8
% Isokinetic	87.4	87.7	83.4	101.4	98.1	98.4	97.6	93.4

[1] Results based on front half catch, Ref. 40, CFR 60, Appendix A, Method 5.
[2] Standard cubic feet per minute at 68°F and 29.92 inches of Mercury, dry basis.

TABLE II-2

SUMMARY OF SULFUR DIOXIDE AND SULFURIC ACID MIST EMISSIONS

PLANT "Q"

DATE	TIME	RUN NUMBER	STACK GAS FLOW RATE (SCFM)	SO_2 EMISSIONS LB/DCSF x 10^{-5}	SO_2 EMISSIONS LB/HR	SO_2 EMISSIONS CONC. PPM	SO_3/H_2SO_4 EMISSIONS LB/DSCF x 10^{-5}	SO_3/H_2SO_4 EMISSIONS LB/HR	SO_3/H_2SO_4 EMISSIONS CONC. PPM
(NO INLET TESTS AT THIS SITE)									
1979									
12/11	1005	OP1	5,937	0.008	0.278	4.70	0.006	0.021	0.23
12/11	1130	OP2	5,755	0.008	0.282	4.92	0.004	0.012	0.14
12/11	1316	OP3	5,858	0.010	0.336	5.75	0.005	0.017	0.19
12/12	1100	OP4	6,151	0.208	0.770	12.55	0.058	0.213	2.27
12/12	1300	OP5	6,242	0.224	0.837	13.46	0.007	0.026	0.27
12/13	1205	OP6	5,565	0.328	1.096	19.75	0.010	0.035	0.41
12/13	1331	OP7	5,203	0.280	0.875	16.88	0.008	0.026	0.33
			(5816)		(0.639)			(0.050)	

TABLE II-3

SUMMARY OF OXIDES OF NITROGEN DATA[1]

PLANT "Q"

DATE	TIME	PPM NO			PPM NO_2			PPM NO_x		
		LOW	HIGH	AVG.	LOW	HIGH	AVG.	LOW	HIGH	AVG.
1979										
12/11	1000-1420	113.7	153.1	136.3	52.6	74.5	62.1	169.2	226.1	202.6
12/12	1100-1500	35.5	60.8	46.3	18.4	35.5	23.6	61.0	81.1	72.3
12/13	0820-1440	15.1	70.6	40.6	0	30.3	14.2	35.2	80.6	55.9

1 20-minute average values obtained from Teco Instrument strip charts.

high of 11.1 ppm on 12/11, from 6.6 to 7.0 ppm on 12/12 and from 6.2 to 8.0 ppm on 12/13. The mean ppm values for the three days testing were 10.7 ppm, 6.9 ppm, and 7.3 ppm, respectively.

POM Results

Field data sheets and isokinetic sampling results are contained in Appendix A and Appendix C of this report. The POM samples were analyzed by Battelle Memorial Institute Labs in Columbus, Ohio.

SECTION III

SAMPLING AND ANALYTICAL PROCEDURES

Method 5/8 Samples

A standard EPA Method 5 sampling train (Figure III-1) was used for collection of the particulate and SO_2, SO_3, H_2SO_4 samples. For collection of the sulfur compounds the train was modified by placing 150 ml of 80% isopropanol in the first impinger followed by a high purity glasswool plug in the U-tube between the first and second impingers. The second and third impingers contained 100 ml each of 3% hydrogen peroxide solution and the fourth impinger was filled with approximately 400 grams of indicating silica gel dessicant. Moisture determinations were accomplished by weighing each impinger on a triple beam balance before and after a test.

All Method 5/8 samples were collected at a single sampling point within the ducts using a 5' stainless steel probe and a 5' heated pyrex liner at the scrubber outlet. Prior to selection of a point of average velocity for collection of samples, a velocity traverse was conducted through each port. Two points, each in a different port were selected, one for the Method 5/8 samples and one for the particle characterization and Pilat impactor samples. As described in Section I of this report under "Sample Point Locations" all Method 5/8 samples were collected from Port A on the scrubber outlet. Characterization samples were collected from Port B on the outlet of the scrubber. No Method 5/8 samples or Pilat impactor samples were collected at the scrubber inlet due to excessive gas temperatures and pressures, however, Port B was used for the outlet particle sizing runs.

At the beginning and end of each Method 5/8 sampling run the probe nozzle was capped and the sample train was leak-checked for compliance within the specified 0.02 cfm limit at 15" Hg. All test runs were found to be within this specification. After the test run and Purge was completed, the probes were capped, disassembled, allowed to cool, and rinsed and brushed three times each with distilled H_2O and then with acetone. The filter, glass wool plug, and final impinger contents were recovered at a clean area near the sampling site. The recovered samples were then properly labelled, placed in lead-free glass sample bottles with Teflon-lined caps, and returned to the ES laboratory in

McLean, Va. for analysis. A description of the sample analysis procedure is contained in Section IV of this report.

During each Method 5/8 test a 1/4" O.D. tube was inserted into the gas stream where CO_2 and O_2 samples were collected for analyses by use of a Fyrite apparatus. The average value of these replicate tests were used in computation of the dry gas molecular weights.

Seven Method 5/8 tests were conducted on the scrubber outlet and were labelled OP1 through OP7. The duration of the tests were each 60 minutes. Purges were conducted for 15 minutes after each test as per Method 8.

Characterization Samples

Collection of the characterization samples was conducted using a modified Method 5 sampling train in which the conventional sample box, filter holder and normal complement of impingers were replaced by an EPA-designed heated sample box, housing a stainless steel filter holder. A separate condenser immersed in an ice bath was used for moisture removal prior to sample gas metering. The stainless steel filter holder accommodated 47 mm diameter filters used for the characterization samples and was outfitted to adapt directly to a conventional 5' pyrex lined probe. Figure III-2 shows the sampling train used for collecting the characterization samples.

During the course of the testing program, Nuclepore®, Millipore®, Teflon®, and glass fiber filter media were employed to obtain characterization samples.(1) In all cases regardless of the duration of sampling, it was attempted to collect each sample at or near isokinetic sampling conditions. A standard Method 5 nomograph was utilized for determining desired sampling rates.

Characterization samples were collected in sets. A set, as defined by the EPA test coordinator, consisted of two samples of a type A glass fiber filter, two samples each of different duration on Millipore® filters, one sample on Nuclepore® filter, and several samples on Teflon® filters.(1) The two samples collected on Millipore® filters spanned a range of particle deposition densities: the first being very light, the second slightly heavier. The objective was to provide a range of densities all suitable for

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measurement by the instrumental techniques utilized by PERS for analysis. Sampling durations ranged from 30 seconds to as long as three minutes. For the glass fiber filters, sampling durations ranged from 5 to 10 minutes. The objective for these samples was to collect a heavy deposition of particulate. Sample durations for the Nuclepore© filters were chosen to produce light depositions. Sampling durations ranged from 15 to 30 seconds. A range of deposition densities were collected on the Teflon© filters. Samples were collected for both one-minute and two-minute durations.

During each of the tests, the initial and final dry gas meter volumes were recorded along with elapsed time, clock time, dry gas meter temperature, heated sample box temperature, stack temperature, pump vacuum, orifice pressure differential (ΔH) and velocity pressure (ΔP). Copies of the field data sheets are contained in Appendix C.

Loading and unloading of the characterization filter holder was accomplished using forceps. Each sample was replaced in its original container immediately after collection, and the filter holder was reloaded for the next sample. A small brush was used to clean the front half of the filter holder into the filter container after each use. All loading and unloading was done at the sampling site. All characterization samples were transferred to EPA for analysis at the completion of the study.

Particle Sizing

Collection of particle size samples was conducted using both a Mark III Source Test Cascade Impactor (Pilat Impactor). Three Mark III impactors were provided by EPA for use in this study. Both button-hook type and straight nozzles were provided in order to allow sampling with the impactor in either of two positions; facing directly into the gas stream or at right angles to the gas stream. Figure III-3 shows the sampling train used with the Pilat impactor.

The pre-test preparation and set-up of the impactors followed the procedures outlined in the Operational Manual for the Mark III Source Test Impactor. Tared impactor collection plates and glass fiber filters were provided by EPA. All impactor set-ups and clean-ups were performed indoors in a lab area. After loading, the impactors were capped and hand-carried to the sampling site.

Before collecting each Pilat impactor sample, the impactor was inserted into the stack with the nozzle pointing away from the flow and was allowed to equilibrate to gas stream temperature. The nozzle was then turned into the flow, and a sample was collected at a constant rate calculated to be isokinetic for conditions at the sampling point.

A programmable calculator provided by EPA with a program for determining isokinetic sampling rates for a range of nominal sampling nozzle sizes was utilized. For each sample, the calculator was used to select a nominal size which corresponded to an isokinetic sampling rate falling in the range of 0.5 to 0.75 (stack conditions) for the Pilat impactor. Following selection of the nominal size, a nozzle with actual dimensions closest to the nominal size was selected for use. The programmable calculator was used to recompute the sampling rate and "ΔH" for the isokinetic sampling rate using the actual nozzle size. The location of the sampling point for the impactor samples was a point of average gas velocity within the duct. Once sampling was initiated, the sampling rate was held constant until completion of the sample, regardless of changes in stack temperature or ΔP.

During each of the tests, initial, five minute, and final dry gas readings were recorded along with elapsed time, clock time, dry gas meter temperature, pump vacuum, orifice pressure differential (ΔH) and velocity pressure (ΔP).

Four Pilat impactor samples were collected at the incinerator scrubber outlet. All samples were collected using 0.250" diameter nozzle oriented in line with the direction of flow.

Scrubber outlet particle sizing sample number 1 was of 30-minute duration. Run #2 was of 50-minutes duration. Runs #3 and #4 were both of 60-minutes duration.

A significant change in sampling procedure was undertaken at this scrubber outlet site in order to avoid moisture droplet formation on the impactor plates. The impactor was connected downstream at a 5' heated glass lined probe and nozzle and placed inside of the particle characterization oven. The sampling temperature used for the flow rate calculation was the oven temperature. The impactor was allowed to stabilize for about one hour prior to sampling.

NO_x and THC Analytical Procedure

Tests were conducted on three municipal sludge incinerators, two multiple hearth devices, and one fluidized bed unit, each with wet scrubber systems controlling emissions from combustion. All three thest sites were tested using similar sampling delivery and analytical measuring systems. Each site was tested on a continuous basis for the oxides of nitrogen and total hydrocarbons.

A Thermo Electron Model 44 Dual Chamber Single Detector was used for NO_x testing. The Model 44 can monitor either for NO_x or NO. The actual component of measurement was determined by a selector switch on the front panel of the instrument.

A sample delivery system was used to condition the stack gases prior to measurement by the NO_x and THC analyzer. A 30-foot teflon line (1/4-inch O.D.) was heated and maintained at a temperature of 200°F. Temperature control was accomplished by using a Theostat to control current flow to the heated line. An Omega Digital Temperature Readout, Model 175-KFI, Type K Thermocouple was used to monitor the temperature of the teflon line. Moisture within the delivery system was controlled by two 50 ml borosilicate glass knock-out pots connected in series by 1/4-inch O.D., 316 stainless steel tubing. The knock-out pots were continuously submerged in an ice bath. Following the knock-out pots, a 50 ml glass tube packed with indicating silica gel was used to trap any small amounts of moisture remaining in the sample. When the silica gel was more than 50 percent spent, the silica gel tube was replaced with a freshly packed tube of silica gel. See Figure III-4 for a schematic presentation of the sample delivery and conditioning system, and the NO_x and THC analyzer.

A 0.1 millivolt instrument output was connected to a linear, Model 555, Single Pen Chart Recorder. Zero drift and calibration curve data were collected before and after each analyses. A multipoint calibration curve was developed and a correlation coefficient calculated. Three different concentrations of span gas were used for the multipoint calibration. The cylinder concentration was determined by Scott Environmental of Pleasantville, Pennsylvania.

Total hydrocarbon analysis was performed by using a Scott Model 166 Total Hydrocarbon Analyzer. The analyzer is equipped with a single flame ionization detector and can measure the THC content of the sample gas on a

continuous basis. The 0-1 MV output was connected to a Linear Model 505 Strip Chart Recorder. To increase the linearity of the analyzer, a combination supply fuel consists of a 60 percent helium and 40 percent hydrogen gas blend. Prior to analysis, a multipoint calibration was introduced to the instrument and a one span check after each test.

5

Incomplete

PARTICULATE AND GASEOUS EMISSIONS TESTS AT MUNICIPAL SLUDGE INCINERATOR PLANT "R"

Contract No. 68-02-2815
Work Assignment No. 33

Submitted to

U.S. Environmental Protection Agency
Stationary Source Emission Research Branch
Emissions Measurement and Characterization Division
Environmental Sciences Research Laboratory
Research Triangle Park, North Carolina 27711

Submitted by

Engineering-Science
7903 Westpark Drive
McLean, Virginia 22102

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SECTION I
INTRODUCTION

The Stationary Source Emissions Research Branch (SSERB) of the U.S. Environmental Protection Agency (EPA) is engaged in an emissions test program proposing characterization of the type and quantity of particulate air pollutants emitted from specific source categories. Additionally, the U.S. EPA, Office of Research and Development (ORD), Municipal Environmental Research Laboratory (MERL) is interested in determination of the nature and composition of pollutant discharges to the atmosphere from municipal wastewater sludge incinerator facilities.

Under EPA Contract No. 68-02-2815, Work Assignment No. 33, Engineering-Science (ES) was retained by the ESRL Particulate Emissions Research Section for assistance in collection of particulate, particle characterization, particle sizing, gaseous pollutants, and process samples at municipal sludge incinerators serving four metropolitan areas.

During the period of April 21-24, 1980 samples were collected by PERS and ES personnel at the fourth test site on the inlet and outlet of a wet, single pass cyclone scrubber system controlling emissions from a Nichols-Herschoff seven-chambered multiple hearth sludge incinerator. For the purposes of this report the facility shall be designated "Plant R" in the interest of confidentiality.

Particulate and SO_2, SO_3, and H_2SO_4 emission tests were conducted using EPA Reference Method 5 and 8 procedures modified by single point sampling as approved by PERS personnel in conjunction with EPA Reference Methods 1-4. Simultaneous inlet and outlet Method 5/8 particulate - SO_2, SO_3, and H_2SO_4, particle characterization, particle sizing, and gaseous samples including oxides of nitrogen via use of a continuous analyzer were taken. Particle characterization samples included use of 47 mm glass fiber, Millipore®. Nuclepore®, and Teflon® types of filter media.(1) These characterization samples along with the Pilat particle sizing samples were forwarded to ESRL for analysis. Process samples including composite pre-burn sludge samples, post-burn ash samples, and scrubber water samples for each test series were forwarded to the EPA MERL for analysis.

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(1) Listing of trade names or specific products does not constitute endorsement by the U.S. Environmental Protection Agency.

This report contains the results of emission tests executed utilizing EPA Methods 5 and 8 along with field data associated with the particle characterization, Pilat impactor, and oxides of nitrogen gaseous data. Neither analytical data subsequent to results obtained by ESRL are included in this report nor results from analysis of process samples of MERL.

Process Description

Plant "R" operates four seven hearth incinerators in building #2 and has been on line since 1969. During normal conditions all of the incinerators are in operation. Unit No. 3 was tested during this program. Sludge incineration feed rates ranged from 14-15 tons/hr during this test program. Figure I-1 summarizes the sludge throughout process. Operating data collected during the test program and contained in Appendix C of this report indicates characteristic sludge flow to the unit throughout testing. Number 2 fuel oil was used to suppliment combustion at approximately 40 gph. The unit does not reach autogenous burning nor is it designed for such operation. Figure I-2 shows the plant operations schematic.

Basic to the incineration of sludge in an efficient and cost effective manner is its preparation for combustion. Incoming raw and/or waste biological sludge is processed through thickening. No Zimpro process is installed at this facility. The sludge is then fed onto drum-type vacuum filters where a sludge cake is produced. This cake is then moved by conveyor belt and deposited into the top of the incinerator chamber on a continuous basis. The burning sludge is then moved downward through each hearth by an intermittently rotating rake assembly. The rakes move the sludge from inner to outer areas of one hearth then back toward the center of the next hearth as it passes downward insuring more complete burning. Combustion air is supplied to the unit via induced draft and controlled by dampers around the chamber perimeter. Some ash is recycled through the incinerator to aid combustion while the remainder is removed to landfills.

Combustion gases exit the incinerator through a 40.5 x 37' ID refactory lined steel duct located at the top of the reactor. From the incinerator outlet the gases flow to a common breaching and stack.

Sampling Location - Scrubber Inlet

Combusiton gases exiting the incinerator pass horizontally through a refractory lined steel duct to a vertically decending rectangular duct measuring 40" x 37 1/2" ID. Four 4" nominal ports were installed along the vertical duct leading to the scrubber at 34" downstream from the nearest flow distrubance as illustrated in Figure I-3.

Location of Sampling Points - Scrubber Inlet

As shown in Figure I-4, 36 traverse points, 9 per port, were utilized for the inlet site. Although this number of points is less than required by EPA method 1 criteria, it was determined that this number of points would yield an accurate gas flow profile from which to choose average velocity points for sampling.

Sampling Location - Scrubber Outlet

As cleaned exhaust gases leave the scrubber they are drawn through a 32" ID steel pipe to a damper and ID fan and then on to the common breeching. Two (2) 4" nominal ports were installed at 90° 13" above the floor level as illustrated in Figure I-5. A 1 1/2" pipe tap was installed about 30" downstream from the larger ports in order to facilitate gaseous sampling.

Location of Sampling Points - Scrubber Outlet

Forty-eight traverse points were selected for velocity traverses on the outlet duct. The sampling location is just upstream of a damper and ID fan. However, it was convenient for sampling and sufficient for the purposes of the test program. Sampling point dimensions are illustrated in Figure I-6.

SECTION II

SUMMARY OF RESULTS

Particulate Tests

Emissions from the scrubber inlet at plant "R" for particulates ranged from a low of 9.6 lbs/hr during test IP1 to a high of 196.3 lbs/hr during test IP3 and averaged 96.2 lbs/hr for the seven inlet tests. Corresponding scrubber outlet tests run simultaneously showed emission rates ranging from a low of 1.5 lbs/hr during test OP5 to a high of 14.4 lbs/hr during test OP8 and averaged 4.9 lbs/hr. Table II-1 is a summary of particulate emissions and pertinent test data. Emission values calculated by using lbs per 1000 lbs of dry gas corrected to 50% excess air were computed on the outlet tests. Values ranged from a low of 0.044 during test OP5 to a high of 0.898 lbs/1000 lbs dry gas during test OP7. Correction to 50% excess air was assumed on the combusiton of #2 fuel oil in absence of a sludge fuel analysis.

Particle characterizations and particle sizing tests conducted have field data sheets included in Appendix B of this report as are the M5/8 field data sheets. Particle analyses were conducted by EPA and are not included in this report.

SO_2 and SO_3/H_2SO_4 Emissions

A summary of scrubber inlet and outlet sulfur species collected through EPA Method 8 procedures are outlined in Table II-2. SO_2 emissions averaged 34.7 lbs/hr for the scrubber inlet showing a high of 43.0 lbs/hr during run IP6 and a low of 27.5 lbs/hr during run IP2. Corresponding SO_2 concentrations ranged from 4.16 to 996 ppm and averaged 692 ppm during the inlet tests. SO_3/H_2SO_4 values ranged from 1.8 to 3.7 lbs/hr and averged 2.4 lbs/hr for the seven inlet tests.

Simultaneous scrubber outlet tests showed SO_2 emissions from 2.8 to 13.9 lbs/hr averaging 7.4 lbs/hr for the seven tests. Corresponding SO_2 concentration values ranged from 40.2 to 187.2 ppm and averaged 92.4 ppm. SO_3/H_2SO_4 emissions for the scrubber outlet ranged from 0.26 to 1.59 lbs/hr.

Oxides of Nitrogen

Table II-3 shows scrubber outlet concentrations for NO, NO_2, and NO_x during the four day testing. Values for ppm represented as lows and highs are 20-minute averages of strip chart recordings and averages represent the mean of those 20-minute averages.

Total Hydrocarbons

Total hydrocarbon concentrations were not monitored during this period due to analyzer malfunctions.

SECTION III

SAMPLING AND ANALYTICAL PROCEDURES

Method 5/8 Samples

A standard EPA Method 5 sampling train (Figure III-1) was used for collection of the particulate and SO_2, SO_3, H_2SO_4 samples. For collection of the sulfur compounds the train was modified by placing 150 ml of 80% isopropanol in the first impinger followed by a high purity glasswool plug in the U-tube between the first and second impingers. The second and third impingers contained 100 ml each of 3% hydrogen peroxide solution and the fourth impinger was filled with approximately 400 grams of indicating silica gel dessicant. Moisture determinations were accomplished by weighing each impinger on a triple beam balance before and after a test.

All Method 5/8 samples were collected at a single sampling point within the ducts using a 5' pyrex lined heated probe at the scrubber inlet and a 3' heated pyrex lined probe at the scrubber outlet. Prior to selection of a point of average velocity for collection of samples, a velocity traverse was conducted through each port. Two points, each in a different port were selected, one for the Method 5/8 samples and one for the particle characterization and Pilat impactor samples. As described in Section I of this report under "Sample Point Locations" all Method 5/8 samples were collected from Port A on the scrubber inlet and Port A on the scrubber outlet. Characterization samples were collected from Port B on the inlet and Port B on the outlet of the scrubber. Pilat impactor samples were collected at the scrubber inlet from Port C.

As much as was practical, all inlet and outlet testing in each category was conducted simultaneously although some variation existed due to the length of individual sampling runs and temporary equipment malfunctions. An effort was made by all personnel to begin each test series at nearly the same time.

At the beginning and end of each Method 5/8 sampling run the probe nozzle was capped and the sample train was leak-checked for compliance within the specified 0.02 cfm limit at 15" Hg. All test runs both inlet and outlet were found to be within this specification. After the test run and Purge was completed,

the probes were capped, disassembled, allowed to cool, and rinsed and brushed three times each with distilled H_2O and then with acetone. The filter and final impinger contents were recovered at a clean area near the sampling site. The recovered samples were then properly labelled, placed in lead-free glass sample bottles with Teflon-lined caps, and returned to the ES laboratory in McLean, Va. for analysis. A description of the sample analysis procedure is contained in Section IV of this report.

During each Method 5/8 test a 1/4" O.D. steel tube was inserted into the gas stream where stack gas samples were collected for analyses by use of an Orsat apparatus. The average value of these replicate tests were used in computation of the dry gas molecular weights.

Seven Method 5/8 tests were conducted on the scrubber inlet and were labeled IP1 through IP7. Similarly, eight Method 5/8 tests were simultaneously conducted on the scrubber outlet and were labelled OP1 through OP8. The duration of the tests were between 45 and 60 minutes. Purges were conducted for 15 minutes after each test as per Method 8. Test OP8 was performed for particulates only.

Characterization Samples

Collection of the characterization samples was conducted using a modified Method 5 sampling train in which the conventional sample box, filter holder and normal complement of impingers were replaced by an EPA-designed heated sample box, housing a stainless steel filter holder. A separate condenser immersed in an ice bath was used for moisture removal prior to sample gas metering. The stainless steel filter holder accommodated 47 mm diameter filters used for the characterization samples and was outfitted to adapt directly to a conventional 5' pyrex lined probe. Figure III-2 shows the sampling train used for collecting the characterization samples.

During the course of the testing program, Nuclepore®, Millipore®, Teflon®, and glass fiber filter media were employed to obtain characterization samples.(1) In all cases regardless of the duration of sampling, it was attempted to collect each sample at or near isokinetic sampling conditions. A standard Method 5 nomograph was utilized for determining desired sampling rates.

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Characterization samples were collected in sets. A set, as defined by the EPA test coordinator, consisted of two samples of a type A glass fiber filter, two samples each of different duration on Millipore® filters, one sample on Nuclepore® filter, and several samples on Teflon® filters.(1) The two samples collected on Millipore® filters spanned a range of particle deposition densities: the first being very light, the second slightly heavier. The objective was to provide a range of densities all suitable for measurement by the instrumental techniques utilized by PERS for analysis. Sampling durations ranged from 30 seconds to as long as three minutes. For the glass fiber filters, sampling durations ranged from 5 to 10 minutes. The objective for these samples was to collect a heavy deposition of particulate. Sample durations for the Nuclepore® filters were chosen to produce light depositions. Sampling durations ranged from 15 to 30 seconds. A range of deposition densities were collected on the Teflon® filters. Samples were collected for both one-minute and two-minute durations.

During each of the tests, the initial and final dry gas meter volumes were recorded along with elapsed time, clock time, dry gas meter temperature, heated sample box temperature, stack temperature, pump vacuum, orifice pressure differential (H) and velocity pressure (P). Copies of the field data sheets are contained in Appendix C.

Loading and unloading of the characterization filter holder was accomplished using forceps. Each sample was replaced in its original container immediately after collection, and the filter holder was reloaded for the next sample. A small brush was used to clean the front half of the filter holder into the filter container after each use. All loading and unloading was done at the sampling site. All characterization samples were transferred to EPA for analysis at the completion of the study.

Particle Sizing

Collection of particle size samples was conducted using both a Mark III Source Test Cascade Impactor (Pilat Impactor). Three Mark III impactors were provided by EPA for use in this study. Both button-hook type and straight nozzles were provided in order to allow sampling with the impactor in either of two positions; facing directly into the gas stream or at right angles to

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the gas stream. Figure III-3 shows the sampling train used with the Pilat impactor.

The pre-test preparation and set-up of the impactors followed the procedures outlined in the Operational Manual for the Mark III Source Test Impactor. Tared impactor collection plates and glass fiber filters were provided by EPA. All impactor set-ups and clean-ups were performed in the PERS van. After loading, the impactors were capped and hand-carried to the sampling site.

Before collecting each Pilat impactor sample, the impactor was inserted into the stack with the nozzle pointing away from the flow and was allowed to equilibrate to gas stream temperature. The nozzle was then turned into the flow, and a sample was collected at a constant rate calculated to be isokinetic for conditions at the sampling point.

A programmable calculator provided by EPA with a program for determining isokinetic sampling rates for a range of nominal sampling nozzle sizes was utilized. For each sample, the calculator was used to select a nominal size which corresponded to an isokinetic sampling rate falling in the range of 0.5 to 0.75 (stack conditions) for the Pilat impactor. Following selection of the nominal size, a nozzle with actual dimensions closest to the nominal size was selected for use. The programmable calculator was used to recompute the sampling rate and "ΔH" for the isokinetic sampling rate using the actual nozzle size. The location of the sampling point for the impactor samples was a point of average gas velocity within the duct. Once sampling was initiated, the sampling rate was held constant until completion of the sample, regardless of changes in stack temperature or ΔP.

During each of the tests, initial, five minute, and final dry gas readings were recorded along with elapsed time, clock time, dry gas meter temperature, pump vacuum, orifice pressure differential (ΔH) and velocity pressure (ΔP).

Five Pilat impactor samples were collected at the incinerator scrubber inlet. All samples were collected using 0.250" diameter buttonhook nozzle with the impactor oriented in line with the direction of flow.

NO_x and THC Analytical Procedure

Tests were conducted on the municipal sludge incinerator, two multiple hearth devices, and one fluidized bed unit, each with wet scrubber systems

controlling emissions from combustion. All three test sites were tested using similar sampling delivery and analytical measuring systems. The site was tested on a continuous basis for the oxides of nitrogen.

A Thermo Electron Model 44 Dual Chamber Single Detector was used for NO_x testing. The Model 44 can monitor either for NO_x or NO. The actual component of measurement was determined by a selector switch on the front panel of the instrument.

A sample delivery system was used to condition the stack gases prior to measurement by the NO_x analyzer. A 30-foot teflon line (1/4-inch O.D.) was heated and maintained at a temperature of 200°F. Temperature control was accomplished by using a theostat to control current flow to the heated line. An Omega Digital Temperature Readout, Model 175-KFI, Type K Thermocouple was used to monitor the temperature of the teflon line. Moisture within the delivery system was controlled by a method 5 impinger train connected in series by 1/4-inch O.D., 316 stainless steel tubing. The impingers were continuously submerged in an ice bath. See Figure III-4 for a schematic presentation of the sample delivery and conditioning system, and the NO_x and THC analyzer.

A 0.1 millivolt instrument output was connected to a linear, Model 555, Single Pen Chart Recorder. Zero drift and calibration curve data were collected before and after each analyses. A multipoint calibration curve was developed and a correlation coefficient calculated. Three different concentrations of span gas were used for the multipoint calibration. The cylinder concentration was determined by Scott Environmental of Pleasantville, Pennsylvania.