Note: This is a reference cited in *AP 42, 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 reference number, the AP42 chapter and section. The file name "ref02_c01s02.pdf" would mean the reference is from AP42 chapter 1 section 2. The reference may be from a previous version of the section and no longer cited. The primary source should always be checked.

A-84-03
II-D-4

35

Shirco, Inc

2451 Stemmons Freeway • Dallas, Texas 75207 • (AC 214) 630-7511

January 17, 1980

Mrs. Ann Briggs
485 Clyde Avenue
Mountain View, CA 94042

SUBJECT: Emissions Data for Infrared Municipal Sewage Sludge Incinerators

Dear Mrs. Briggs:

Enclosed is the infrared furnace emission data which you requested in your December 10 letter. We have put the data into the format of your outline in order to facilitate its use.

Based on our field experience, we are convinced that the emission levels measured by EPA methods are directly related to furnace exhaust temperature. The higher exhaust temperatures produced by dryer sludges definitely result in reduced emissions, as indicated by our data and the data published in the recent Mitre Report.* This effect is a result of a complex interaction involving moisture concentration, excess air requirements, and other process variables. We have modified the design of our incinerators to insure that exhaust temperature is maintained at or above 1200°F. At this level, emissions for even very wet sludges are well within the NSPS limits.

We would appreciate receiving a copy of your final report of this subject. If either you or the Project Engineer have any questions relative to our information, please contact either me or Mike Hill of our organization.

Sincerely,

F.K. McGinnis III

F.K. McGinnis, III, Ph.D.
Executive Vice President

Enclosure

FKM/lb

* "A Review of Standards of Performance for New Stationary Sources-Sewage Sludge Incinerators", EPA-450/2-79-010, March 1978

Shirco, Inc

Summary of Infrared Sludge Incineration Furnace Emission Data

1/15/80

INSTALLATION 1

I. OPERATING DATA

A. Incinerator

1. Type - electric infrared
2. Dimensions - 7' x 40' (chamber volume = 120 ft^3)
3. Capacity
   a. Design - 500 lb d.s./hr
   b. Actual - 112 lb d.s./hr
4. Loading rate
   a. Design - 17.36 lb wet feed/ft^2/hr
   b. Actual - 5.47 lb wet feed/ft^2/hr
5. Temperatures
   a. Maximum - 1655°F
   b. Exhaust - 525°F
6. Auxiliary energy - electricity
7. Energy usage - 261 KW (design at 16% d.s., 60% v.s.)
8. Excess air - 50%

B. Dewatering technology

1. Type - coil vacuum filter and polymers
2. Size
   a. Design - 500 lb d.s./hr
   b. Actual - 339 lb d.s./hr
3. Sludge composition (average) - see Table I
   a. % dry solids = 15.96
   b. % volatile solids = 44.67
   c. % ash = 55.33
   d. BTU/lb v.s. = 11,250.
   e. BTU/lb wet feed = 802.
   f. % skimmings = 0.

C. Heat recovery - none

II. EMISSIONS

A. Uncontrolled emissions

1. Particulate loading*
   a. 0.3 lb/hr
   b. 3 lb/ton dry solids
   c. 0.0358 grains/SCFD
2. Particulate size distribution - see Table V
3. Test methodology
   a. Particulate loading - Code of Federal Regulations, Title 40, Chapter I, Part 60, Method 5
   b. Particulate size distribution - unspecified

*This data is from test run 5 months earlier

Shirco, Inc

4. Location of sampling - scrubber inlet
5. Number of samples - 3

B. Control device

1. Type - 3 stage perforated plate impingement scrubber
2. Size - 2'0" i.d. x 6'9"
3. Operating parameters - see Table II

C. Controlled emissions

1. Particulate loading - see Tables III and IV
2. Particulate size distribution - see Table VI
3. Test methodology
   a. Particulate loading - same as II.A.3.a.
   b. Particulate size distribution - unspecified
4. Location of sample - scrubber stack
5. Number of samples - 3

INSTALLATION 1

TABLE I

Averaged Variable	TEST RUN NO. 1	2	3	4
Belt Speed (cm/min)	9.96	9.27	10.56	8.22
Thickness of Sludge Layer (cm)	4.44	4.51	4.41	4.51
Width of Sludge Layer (cm)	122	122	122	122
Density (g/cm)	1.033	1.031	1.020	1.001
% Dry Solids	15.97	16.15	16.02	15.70
Average Throughput (lb/hr)	118.	112.	123.	94.

TABLE II

EXHAUST GAS SCRUBBER DATA

	TEST RUN NUMBER 1	2	3	4
Average Water Flow through Scurbber (gpm)	33.0	34.0	36.2	35.7
Water Spray Pressure (psi)	22	22	22	22
Pressure Differential Across Scrubber (inches H_2O)	5.6	5.6	5.6	5.6

INSTALLATION 1

TABLE III

SUMMARY OF RESULTS

Incinerator Stack

Run Number	1**	2	3
Stack Flow Rate - ACFM	1154	1120	1127
Stack Flow Rate - DSCFM*	1017	1019	986
% Water Vapor - % Vol.	4.4	4.1	4.3
% CO_2 - % Vol.	1.4	1.6	1.6
% O_2 - % Vol.	19.4	19.2	19.2
% Excess Air @ Sampling Point	1222	1074	1074
Particulates Probe, Cyclone & Filter Catch grains/dscf*	0.0308	0.0107	0.0078
grains/cf @ Stack Conditions	0.0271	0.0097	0.0068
lbs/hr	0.3	0.1	0.1
Total Catch grains/dscf*	0.0358	0.0156	0.0113
grains/cf @ Stack Conditions	0.0315	0.0142	0.0098
lbs/hr	0.3	0.1	0.1
Emission Limit Reg. I. TACB lbs/hr	3.8	3.7	3.7
Emission Rate lbs/ton dry sludge input	4.55	1.67	1.07
Federal Regulations Emission Limit lbs/ton dry sludge input	1.30	1.30	1.30

* 29.92 "Hg, 68°F

** Disregard due to upset conditions

EA 765-55

INSTALLATION 1

TABLE IV

SUMMARY OF RESULTS

Incinerator Stack

Run Number	4		
Stack Flow Rate - ACFM	1092		
Stack Flow Rate - DSCFM*	955		
% Water Vapor - % Vol.	4.7		
% CO_2 - % Vol.	1.6		
% O_2 - % Vol.	19.2		
% Excess Air @ Sampling Point	1074		
Particulates Probe, Cyclone & Filter Catch grains/dscf*	0.0140		
grains/cf @ Stack Conditions	0.0122		
lbs/hr	0.1		
Total Catch grains/dscf*	0.0238		
grains/cf @ Stack Conditions	0.0208		
lbs/hr	0.2		
Emission Limit Reg. I, TACB lbs/hr	3.7		
Emission Rate lbs/ton dry sludge input	2.44		
Federal Regulations Emission Limit lbs/ton dry sludge input	1.30		

* 29.92 "Hg, 68°F

EA 765-55

INSTALLATION 1

TABLE V

Particle Size Data

Run No.: 1 - Inlet to Scrubber
Date: 2-23-77
Time: 1805-1808
Location:

Plate Number	Initial Weight (g)	Final Weight (g)	Increase (g)	% of Total	Cum. %	Effective Cut-off Diameter* (microns)
0	30.5727	30.5801				
1	19.6300	19.6346	0.0046	24.6	100.0	23.66
2	20.6558	20.6588	0.0030	16.0	75.4	15.17
3	21.2135	21.2164	0.0029	15.5	59.4	10.02
4	21.4331	21.4355	0.0024	12.8	43.9	6.82
5	11.4415	11.4430	0.0015	8.0	31.1	4.59
6	11.4399	11.4412	0.0013	7.0	23.1	2.16
7	11.5261	11.5275	0.0014	7.5	16.1	1.36
8	20.5961	20.5977	0.0016	8.6	8.6	0.92
		Total	0.0187	100.0		

Particle Density: 1.0000 gm/cm^3
Velocity Head: 2.00 $"H_2O$
Stack Temperature: 850 °F
Molecular Weight: 28.86 lb/lb-mole
Stack Pressure: 28.55 "Hg
Nozzle Diameter: 0.189 inches
Orifice Head: 0.66 $"H_2O$
Sample Volume: 2.007 ft^3
Meter Temperature: 82 °F
Sampling Rate: 0.669 cfm
% I: 96.77

EA 765-55

1-6

INSTALLATION 1

TABLE VI

Particle Size Data

Run No.: 1 - Stack
Date: 2-23-77
Time: 1733-1743
Location

Plate Number	Initial Weight (g)	Final Weight (g)	Increase (g)	% of Total	Cum. %	Effective Cut-off Diameter* (microns)
0	30.4245	30.4253				
1	26.3329	26.3243	0.0014	26.0	100.0	24.50 34.74
2	27.5630	27.5643	0.0013	23.5	74.0	15.38 21.80
3	21.2293	21.2301	0.0008	14.5	50.5	9.43 13.39
4	29.5009	29.5019	0.0010	18.2	36.0	6.97 9.897
5	11.3095	11.3098	0.0003	5.4	17.8	4.51 6.396
6	11.4854	11.4856	0.0002	3.5	12.4	2.26 3.209
7	11.6409	11.6411	0.0002	3.5	8.9	1.85 2.677
8	20.5586	20.5589	0.0003	5.4	5.4	0.98 1.391
		Total	0.0055	100.0		

Particle Density*: 1.0000 gm/cm^3
Velocity Head: 0.38 $"H_2O$
Stack Temperature: 100 °F
Molecular Weight: 28.86 lb/lb-mole
Stack Pressure: 28.98 "Hg
Nozzle Diameter: 0.189 inches
Orifice Head: 0.35 $"H_2O$
Sample Volume: 3.552 ft^3
Meter Temperature: 88 °F
Sampling Rate: 0.355 cfm
% I: 93.42

*Assumed Particle Density of 1.00 gm/cm^3. To determine true particle size, multiply the given particle size by the factor determined in the following graph.

1-7

INSTALLATION 2

I. OPERATING DATA

A. Incinerator

1. Type - electric infrared
2. Dimensions - 2 units at 8.5' x 72' each (chamber volume = 320 ft^3 each)
3. Capacity (see Table II)
   a. Design - 1200 lb d.s./hr each
   b. Actual - 409 lb d.s./hr each (average)
4. Loading rate
   a. Design - 15.62 lb wet feed/ft^2/hr
   b. Actual - 6.35 lb wet feed/ft^2/hr
5. Temperatures
   a. North unit
      (1) Maximum - 1530°F
      (2) Exhaust - 623°F
   b. South unit
      (1) Maximum - 1660°F
      (2) Exhaust - 600°F
6. Auxiliary energy - electricity
7. Energy usage - see Table VIII
8. Excess air - 50% (design)

B. Dewatering technology

1. Type - coil vacuum filter and flocculating polymers
2. Size
   a. Design - 1320 lb/hr for 20% d.s. from filter
   b. Actual - 750 lb/hr for 15% d.s. from filter
3. Sludge composition
   a. % dry solids - see Table I
   b. % volatile solids - see Table I
   c. % ash - see Table I
   d. BTU/lb - see Table I
   e. % skimmings - 0.

C. Heat recovery - none

II. Emissions

A. Uncontrolled emissions

1. Particulate loading - see Table III
2. Particulate size distribution - see Tables IV and V
3. Test methodology
   a. Particulate loading - Code of Federal Regulations, Title 40, Chapter I, Part 60, Method 5
   b. Particulate size distribution - Coulter Counter
4. Location of sampling - scrubber inlet
5. Number of samples - 3 per incinerator

B. Control device

1. Type - two stage multi-venturi (130 caps/tray)
2. Size - 4'3" x 11'0" each
3. Operating parameters
   a. North unit
      (1) Δp = 9.0 in. w.c.
      (2) scrubber water = 29.2 gpm
   b. South unit
      (1) Δp = 8.3 in. w.c.
      (2) scrubber water = 31.6 gpm

C. Controlled emissions

1. Particulate loading - see Tables II, III, VI, VII
2. Particulate size distribution - not analyzed
3. Test methodology - see II.A.3.a.
4. Location of sampling - scrubber stack
5. Number of samples - 3 per incinerator

INSTALLATION 2

Shirco,Inc

TABLE I

COMPARISON OF

SLUDGE PROPERTY MEASUREMENTS

MAY 23 - 24, 1978

DATE/TIME	STACK SAMPLING RUN NUMBER	AVG. MEASURED % DRY SOLIDS		VALUE OF PROPERTY DURING TIME PERIOD % VOLATILE SOLIDS		HHV - BTU/LB VOL.	
		SHIRCO	NTMWD				
MAY 23							
10:00 am - 11:00 am	1	17.58	16.18	60.57	63.66	11,663	10,021
12:30 pm - 1:30 pm	2	18.31	17.23	65.34	65.80	10,857	9,696
2:00 pm - 3:00 pm	3	16.25	16.42	65.71	65.01	9,618	9,626
8:30 am - 4:30 pm	-	16.80	16.01	64.64	65.60	10,419	9,843
MAY 24							
12:30 pm - 1:30 pm	1	19.11	20.82	65.83	66.95	10,870	10,701
3:00 pm - 4:00 pm	2	16.53	17.64	65.98	67.43	10,095	9,960
4:00 pm - 5:00 pm	3	15.17	14.59	65.70	66.61	10,215	9,558
9:00 am - 5:30 pm	-	16.57	17.42	65.44	66.40	10,260	10,320

INSTALLATION 2

Shirco,Inc

TABLE II

INCINERATOR STACK TESTS

MAY 23 - 24, 1978

SUMMARY OF RESULTS

TEST DATE	UNIT	RUN NO.	% DRY SOLIDS*	SLUDGE FEED (LB/HR DRY SOLIDS	MEASURED EMISSIONS (LB/HR)	EMISSIONS (LB PARTICULATES/TON D.S.) INDIVIDUAL RUN	EMISSIONS (LB PARTICULATES/TON D.S.) AVERAGE	RATIO: MEASURED TO ALLOWABLE EMISSIO INDIVIDUAL RUN	RATIO: MEASURED TO ALLOWABLE EMISSIO AVERAGE
5/23/78	North	1	16.88	392	0.057	0.29	0.92	0.22	0.7
		2	17.82	442	0.244	1.10		0.85	
		3	16.33	393	0.267	1.36		1.05	
				(average 409)					
5/24/78	South	1(1)	19.97	481	0.354	1.47	1.27	1.13	0.97
		2	17.10	435	0.232	1.07	1.54	0.82	1.1
		3(2)	14.88	310	0.321	2.07		1.59	
				(average 409)					

*Average of Shirco and NTMWD measurements

(1) Oxygen controller not functioning properly

(2) Power supply circuit breaker tripped in mid-run and required 20 minutes to reset, during which time furnace temperatures dropped approximately 300°F

INSTALLATION 2

Shirco, Inc

TABLE III
INCINERATOR STACK TEST
MAY 23 - 24, 1978
ESTIMATED SCRUBBER EFFICIENCY

DATE	UNIT	RUN NUMBER	MEASURED PARTICULATE EMISSIONS (TABLE II) (LB/TON D.S.)	*UNCONTROLLED EMISSIONS (SCRUBBER INLET) (LB/TON D.S.)	OVERALL SCRUBBER EFFICIENCY (%)	
					INDIVIDUAL RUN	3-RUN AVERAGE
5/23/78	North	1	0.29	10.1	97%	91%
		2	1.10	10.1	89%	
		3	1.36	10.1	87%	
5/24/78	South	1	1.47	14.8	90%	90%
		2	1.07	14.8	93%	
		3	2.07	14.8	86%	

*5/22/78 measurements on North and South scrubber inlets

METCO

INSTALLATION 2

TABLE IV

Particle Size Data

Run No.: 1
Date: 5/22/78
Time: 1258-1313
Location: North Inlet Duct

Plate Number	Filter Number	Initial Weight (g)	Final Weight (g)	Increase (g)	% of Total	Cum. %	Effective Cut-off Diameter* (microns)
0							
1	II-4	0.1782	0.1785	0.0003	9.4	90.6	8.2
2	I-4	0.1622	0.1617	0	0	90.6	5.2
3	II-3	0.1744	0.1747	0.0003	9.4	81.2	3.4
4	I-3	o.1629	0.1629	0	0	81.2	2.3
5	II-2	0.1765	0.1766	0.0001	3.1	78.1	1.5
6	I-2	0.1624	0.1617	0	0	78.1	0.72
7	II-1	0.1782	0.1792	0.0010	31.3	46.8	0.45
8	I-1	o.1625	0.1625	0	0	46.8	0.30
F	1	0.1936	0.1951	0.0015	46.8	0	--
			Total	0.0032	100.0		

Particle Density*:	1.000	gm/cm^3
Velocity Head:	1.85	$"H_2O$
Stack Temperature:	564	^oF
Molecular Weight:	26.87	lb/lb-mole
Stack Pressure:	29.01	"Hg
Nozzle Diameter:	0.242	inches
Orifice Head:	2.40	$"H_2O$
Sample Volume:	12.927	ft^3
Meter Temperature:	90	^oF
Sampling Rate:	2.013	cfm @ stack conditions
% I:	95.1	

*Assumed Particle Density of 1.00 gm/cm^3. To determine true particle size, multiply the given particle size by the factor determined in the following graph.

METCO

INSTALLATION 2

TABLE V

Particle Size Data

Run No.: 1
Date: 5/22/78
Time: 1610-1630
Location: South Inlet Duct

Plate Number	Filter Number	Initial Weight (g)	Final Weight (g)	Increase (g)	% of Total	Cum. %	Effective Cut-off Diameter* (microns)
0							
1	II-8	0.1787	0.1781	0	0	100.0	11.0
2	I-8	0.1607	0.1604	0	0	100.0	6.8
3	II-7	0.1781	0.1782	0.0001	2.9	97.1	4.6
4	I-7	0.1637	0.1640	0.0003	8.8	88.3	3.1
5	II-6	0.1772	0.1778	0.0006	17.7	70.6	2.0
6	I-6	0.1609	0.1607	0	0	70.6	0.96
7	II-5	0.1775	0.1778	0.0003	8.8	61.8	0.60
8	I-5	0.1624	0.1627	0.0003	8.8	53.0	0.41
F	2	0.1829	0.1847	0.0018	53.0	0	--
			Total	0.0034	100.0		

article Density*:	1.000	gm/cm^3
elocity Head:	1.95	$"H_2O$
tack Temperature:	559	^oF
olecular Weight:	26.81	lb/lb-mole
tack Pressure:	29.04	"Hg
ozzle Diameter:	0.181	inches
rifice Head:	0.75	$"H_2O$
ample Volume:	9.911	ft^3
eter Temperature:	93	^oF
ampling Rate:	1.150	cfm at stack conditions
I:	94.4	

*Assumed Particle Density of 1.00 gm/cm^3. To determine true particle size, multiply the given particle size by the factor determined in the following graph.

METCO

INSTALLATION 2

TABLE VI

SUMMARY OF RESULTS

North Unit Stack 5/23/78

Run Number	1	2	3
Stack Flow Rate - ACFM	2784	2738	2728
Stack Flow Rate - DSCFM*	2538	2455	2471
% Water Vapor - % Vol.	3.7	5.0	3.9
% CO_2 - % Vol.	1.6	2.7	1.8
% O_2 - % Vol.	18.2	17.1	18.2
% Excess Air @ Sampling Point	596	412	607
Particulates Probe, Cyclone & Filter Catch grains/dscf*	0.0026	0.0116	0.0126
grains/cf @ Stack Conditions	0.0023	0.0104	0.0114
lbs/hr	0.057	0.244	0.267
Total Catch grains/dscf*	--	--	--
grains/cf @ Stack Conditions	--	--	--
lbs/hr	--	--	--
Sludge Feed Rate-lbs/hr Dry Solids	392	442	393
Emission Rate-lbs/Ton of Dry Solids	0.291	1.104	1.359

* 29.92 "Hg, 68°F

78-05

2-8

INSTALLATION 2

TABLE VII

SUMMARY OF RESULTS

South Unit Stack 5/24/78

Run Number	2	3	4
Stack Flow Rate - ACFM	1923	2294	2371
Stack Flow Rate - DSCFM*	1757	2111	2165
% Water Vapor - % Vol.	3.2	2.6	3.3
% CO_2 - % Vol.	3.2	2.2	2.0
% O_2 - % Vol.	16.2	17.6	18.0
% Excess Air @ Sampling Point	314	482	563
Particulates Probe, Cyclone & Filter Catch grains/dscf*	0.0235	0.0128	0.0173
grains/cf @ Stack Conditions	0.0214	0.0117	0.0157
lbs/hr	0.354	0.232	0.321
Total Catch grains/dscf*	--	--	--
grains/cf @ Stack Conditions	--	--	--
lbs/hr	--	--	--
Sludge Feed Rate-lbs/hr Dry Solids	481	435	310
Emission Rate-lbs/Ton of Dry Solids	1.472	1.067	2.071

* 29.92 "Hg, 68°F

78-05

INSTALLATION 3

I. OPERATING DATA

A. Incinerator

1. Type - electric infrared
2. Dimensions - 6' x 32' (chamber volume = 70 ft^3)
3. Capacity
   a. Design - 237 lb d.s./hr
   b. Actual - 53 lb d.s./hr (average)
4. Loading rate
   a. Design - 14.1 lb wet/ft^2/hr
   b. Actual - 4.85 lb wet/ft^2/hr
5. Temperatures (average)
   a. Maximum - 1600°F
   b. Exhaust - 480°F
6. Auxiliary energy - electricity
7. Energy usage - 115 KW
8. Excess air - 108%

B. Dewatering technology

1. Type - flocculating polymers and gravity/multi-roll belt press
2. Size
   a. Design - unknown
   b. Actual - 100 lb d.s./hr
3. Sludge composition - see Table I

C. Heat recovery

1. Type - heat pipe coil combustion air preheater
2. Size - 48" x 21¼" x 13-3/8" with 6 rows and 7 FPI
3. Recovery - 215,000 BTU/hr
4. Effect on emissions - not analyzed, heat used for power recovery only

II. EMISSIONS

A. Uncontrolled emissions - not analyzed

B. Control device

1. Type - venturi scrubber with cyclone separator (with sprays)
2. Size - 2' 10" x 7' 10" (separator)
3. Operating parameters - see Table II

C. Controlled emissions

1. Particulate loading - see Table II
2. Particulate size distribution - see Table III
3. Test methodology

a. Particulate loading - Federal Code of Regulations, Title 40, Sub-chapter C, Part 60.85, Methods 1-5
b. Particulate size distribution - not specified

4. Location of sampling - scrubber stack
5. Number of samples - 5

INSTALLATION 3

TABLE I

FEED CAKE, DISCHARGE ASH AND THROUGHPUT DATA

Run Number	1	2	3	4	5	6
Feed Cake*						
% moisture	81.6	81.7	83.0	83.6	81.9	80.7
% dry solids	18.4	18.3	17.0	16.4	18.1	19.3
% ash(wet)	6.4	6.2	5.6	5.4	5.9	6.3
% ash(dry)	34.9	34.0	32.8	32.6	32.4	32.5
Heating value (BTU/lb)	11626	11490	10859	11145	11435	11240
Discharge Ash						
% volatiles	0.64	0.65	0.51	0.50	0.94	0.96
Throughput**						
lbs/hr wet	323.2	287.3	358.2	264.7	271.1	302.1
lbs/hr,dry	60.5	54.2	58.5	41.6	46.6	56.6

* From analysis of feed cakes performed by Food, Chemical & Research Laboratories, Inc.

** Data from Shirco, Inc. Calculated on feed cake analysis by Shirco, Inc.

INSTALLATION 3

TABLE II

PARTICULATE CONCENTRATIONS AND EMISSION RATES

Run Number	1800-1*	1800-2	1800-3	1800-4	1800-5	1800-6
Duration (min)	60	60	60	62	60	55
Average sampling stack gas temp (degrees F.)	100	81	80	78	76	80
Average Stack Gas velocity (ft/sec)	53.6	64.84	37.43	40.29	34.20	39.1
Flow Rate (SCFH $x10^4$)	5.022	6.404	3.66	3.997	3.404	3.89
Isokinetic Sampling rate	96.11	93.5	102.9	104.6	100.3	94.4
Total Particulate Catch (mg)	67.62	39.50	55.76	45.24	54.85	51.9
Grain Loading Concentration (in grains/SCF) 1) at stack molar 2) at 12% CO_2	0.024	0.011	0.019	0.014	0.021	0.02
Emission Rate (lbs/hr) 1) at stack molar 20 at 12% CO_2	0.175	0.104	0.100	0.077	0.101	0.11
Emission Rate (lbs.particulate emissions per dry ton feed)	5.78	3.84	3.42	3.73	4.33	3.97
Δp Across Scrubber (in. w.c.)	-	16.0	9.5	11.2	11.5	13.0
Scrubber Water Flow at design (gpm)	-	60.	60.	60.	60.	60.

*Disregard due to upset conditions

INSTALLATION 4

I. OPERATING DATA

A. Incinerator

1. Type - electric infrared
2. Dimensions - 6' x 32' (chamber volume = 70 ft^3)
3. Capacity
   a. Design - 200 lb d.s./hr
   b. Actual - 108 lb d.s./hr (average)
4. Loading rate
   a. Design - 11.9 lb wet feed/ft^2/hr
   b. Actual - 8.03 lb wet feed/ft^2/hr
5. Temperatures (average)
   a. Maximum - 1600°F
   b. Exhaust - 1139°F
6. Auxiliary energy - electricity
7. Energy usage - 88.3 KW (average)
8. Excess air - 50%

B. Dewatering technology

1. Type - flocculating polymers and belt filter press
2. Size
   a. Design - unknown
   b. Actual - 200 lb d.s./hr
3. Sludge composition (average)
   a. % dry solids - 23.2
   b. % volatile solids - 66.5
   c. % ash - 33.5
   d. BTU/lb volatile solids - 11,373.
   e. BTU/lb wet feed - 1,755.
   f. % skimmings - 0.

C. Heat recovery

1. Type - air to air combustion air preheater (horizontal model)
2. Size - 16" x 16" x 6'
3. Recovery - 184,000 BTU/hr
4. Effect on emissions - not analyzed, heat used for power recovery only

II. EMISSIONS

A. Uncontrolled emissions - not analyzed

B. Control device

1. Type - venturi scrubber with chevrons in separator (plus sprays)
2. Size - 20" i.d. x 6'9" (separator)
3. Operating parameters

a. Δp = 8.5 in. w.c.
b. Venturi spray flow = 15 gpm
c. Flow to separator sprays = 20 gpm

C. Controlled emissions

1. Particulate loading - see Table I
2. Particulate size distribution - not analyzed
3. Test methodology - Code of Federal Regulations, Title 40, Chapter I, Part 60, Method 5
4. Location of sampling - scrubber stack
5. Number of samples - 3

INSTALLATION 4

Table I
Summary of Test Data

Run No.	Vol std	% moisture	Ts (°R)	sCFM	% Isokinetics	Feed Dry Sludge Tons/hr	Particulate Concentration lb/hr	Particulate Concentration lbs/Ton dry solids
1	43.038	12.0	583	558	104	0.0436	0.126	2.890
2	-VOID---	----	---	---	---	---------	-----	-----
3	39.666	5.4	551	642	106	0.0538[2]	0.088	1.636
4	50.706	5.2	553	849	102	0.0538[2]	0.064	1.190
5	52.097	5.6	557	858	104	0.0538[2]	0.068	1.264

1. Corrected to 100% isokinetics. Front half only reported.

2. An average of the dry weight per hour between the hours 1:40 p.m. and 6:30 p.m. was used to calculate the lbs emissions/Ton dry solids.

INSTALLATION 5

I. OPERATING DATA

A. Incinerator

1. Type - electric infrared.
2. Dimensions - 3.5' x 13' (chamber volume = 9.75 ft^3)
3. Capacity
   a. Design - unspecified
   b. Actual - 22. lb d.s./hr
4. Loading rate
   a. Design - unspecified
   b. Actual - 9.22 lb wet feed/ft^2/hr
5. Temperatures
   a. Maximum - 1650°F
   b. Exhaust - 1250°F*
6. Auxiliary energy - electricity
7. Energy usage - 1.18 KWH/lb d.s. (26KW)
8. Excess air - 50%

B. Dewatering technology

1. Type - unspecified
2. Size - unspecified
3. Sludge composition (paper pulp)
   a. % dry solids - 20.4
   b. % volatile solids - 62.3
   c. % ash - 37.7
   d. BTU/lb volatile solids - 8,724

C. Heat recovery

1. Shell and tube combustion air preheater
2. Size - 1.5' x 1.5' x 1.5'
3. Recovery - 11,640 BTU/hr
4. Effect on emissions - not analyzed, used for power recovery only

II. EMISSIONS

A. Uncontrolled emissions

1. Particulate loading - see Tables I and III
2. Particulate size distribution - see Tables IV, V, VI, and Figure 1
3. Test methodology
   a. Particulate loading - Code of Federal Regulations, Title 40, Chapter I, Part 60, Method 5
   b. Particulate size distribution - cascade impactor
4. Location of sample - afterburner outlet
5. Number of samples - 3

*Exhaust temperature achieved with an afterburner

Shirco,Inc

B. Control Device

1. Type - venturi scrubber with separator (with sprays and chevron)
2. Size - 12" i.d. x 5'0"
3. Operating parameters
   a. Δp = 4 in. w.c.
   b. scrubber water = 10 gpm

C. Controlled emissions

1. Particulate loading - see Tables II and III
2. Particulate size distribution - see Tables VII, VIII, IX, and Figure 1
3. Test methodology
   a. Particulate loading - same as II.A.3.a.
   b. Particulate size distribution - same as II.A.3.b.
4. Location of sample - scrubber stack
5. Number of samples - 3

INSTALLATION 5

TABLE I

SUMMARY OF RESULTS

Afterburner Outlet

Run Number	1	2	3
Stack Flow Rate - ACFM	286	279	262
Stack Flow Rate - DSCFM*	100	88	89
% Water Vapor - % Vol.	27.72	31.72	29.90
% CO_2 - % Vol.	2.8	3.7	4.8
% O_2 - % Vol.	17.0	16.1	14.6
% Excess Air @ Sampling Point	399.7	312.4	216.0
Particulates Probe, Cyclone & Filter Catch grains/dscf*	0.1152	0.1355	0.1466
grains/cf @ Stack Conditions	0.0402	0.0426	0.0499
lbs/hr	0.10	0.10	0.11
Total Catch grains/dscf*	0.4792	0.6133	0.5733
grains/cf @ Stack Conditions	0.1670	0.1929	0.1953
lbs/hr	0.41	0.46	0.44
SO_2 Emissions ppm	216.1	221.9	222.8
NO_x Emissions ppm	133.5	125.0	173.7
Total Hydrocarbons (as methane) ppm	265	334	234
SO_3 Emissions ppm	78.1	108.2	110.2

* 29.92 "Hg, 68°F

TABLE II

SUMMARY OF RESULTS

Scrubber Stack

Run Number	1	2	3
Stack Flow Rate - ACFM	101	104	102
Stack Flow Rate - DSCFM*	87	87	89
% Water Vapor - % Vol.	8.38	7.80	7.28
% CO_2 - % Vol.	4.0	3.8	3.6
% O_2 - % Vol.	16.2	16.4	16.6
% Excess Air @ Sampling Point	327.5	345.5	365.1
Particulates Probe, Cyclone & Filter Catch grains/dscf*	0.0522	0.0460	0.0625
grains/cf @ Stack Conditions	0.0450	0.0385	0.0539
lbs/hr	0.04	0.03	0.05
Total Catch grains/dscf*	0.0778	0.0753	0.1162
grains/cf @ Stack Conditions	0.0671	0.0631	0.1002
lbs/hr	0.06	0.06	0.09
SO_2 Emissions ppm	61.2	56.9	56.4
NO_x Emissions ppm	115.9	99.1	86.9
Total Hydrocarbons (as methane) ppm	104	182	205
SO_3 Emissions ppm	2.4	1.6	3.2

* 29.92 "Hg, 68°F

INSTALLATION 5

TABLE III

EMISSIONS TESTING

RESULTS

LOCATION TEST NO.	DATE	PARTICULATE LAODING		AVERAGE TOTAL LOADING (GR/DSCF)	SCRUBBER PARTICULATE EFFICIENCY
		FRONT HALF GR/DSCF	TOTAL GR/DSCF		
SCRUBBER IN 1	11/8	0.1152	0.4792	0.5553	83.8%
SCRUBBER IN 2	11/8	0.1355	0.6133		
SCRUBBER IN 3	11/8	0.1466	0.5733		
SCRUBBER OUT 1	11/9	0.0522	0.0778	0.0897	
SCRUBBER OUT 2	11/9	0.0460	0.0753		
SCRUBBER OUT 3	11/9	0.0625	0.1162		

TABLE IV

PARTICLE SIZE DATA

Run No.: 1
Date: 11/8/79
Time: 1132-1134
Location: Afterburner Outlet

Plate Number	Filter Number	Initial Weight (g)	Final Weight (g)	Increase (g)	% of Total	Cum. %	Effective Cut-off Diameter* (microns)
0							
1	II-B5	0.1465	0.1565	0.0100	29.0	71	13.5
2	I -B12	0.1342	0.1367	0.0045	13.0	58	8.3
3	II-B4	0.1503	0.1545	0.0042	12.2	45.8	5.6
4	I -B11	0.1345	0.1379	0.0034	9.9	35.9	3.8
5	II-B3	0.1473	0.1532	0.0059	17.1	18.8	2.4
6	I -B10	0.1341	0.1366	0.0025	7.2	11.6	1.20
7	II-B2	0.1491	0.1512	0.0021	6.1	5.5	0.76
8	I -B9	0.1333	0.1351	0.0018	5.2	0.3	0.51
F	76	0.1870	0.1871	0.0001	0.3	0.0	<0.51
			Total	0.0345	100.0		

Particle Density*: 1.00 gm/cm^3
Velocity Head: 0.447 $"H_2O$
Stack Temperature: 842 °F
Molecular Weight: 26.04 lb/lb-mole
Stack Pressure: 29.37 "Hg
Nozzle Diameter: 0.242 inches
Orifice Head: 0.35 $"H_2O$
Sample Volume: 0.570 scf
Meter Temperature: 63 °F
Sampling Rate: 0.990 cfm @ stack conditions
%I: 82.3

* Assumed Particle Density of 1.00 gm/cm^3.

TABLE V

PARTICLE SIZE DATA

Run No.: 2
Date: 11/8/79
Time: 1335-1337
Location: Afterburner Outlet

Plate Number	Filter Number	Initial Weight (g)	Final Weight (g)	Increase (g)	% of Total	Cum. %	Effective Cut-off Diameter* (microns)
0							
1	II-B9	0.1460	0.1544	0.0084	31.4	68.6	11.5
2	I -B16	0.1394	0.1458	0.0064	24.0	44.6	7.2
3	II-B8	0.1508	0.1546	0.0038	14.2	30.4	4.8
4	I -B15	0.1347	0.1355	0.0008	3.0	27.4	3.2
5	II-B7	0.1514	0.1518	0.0004	1.5	25.9	2.1
6	I -B14	0.1404	0.1413	0.0009	3.4	22.5	1.02
7	II-B6	0.1508	0.1509	0.0001	0.4	22.1	0.64
8	I -B13	0.1343	0.1355	0.0012	4.5	17.6	0.44
F	77	0.1925	0.1972	0.0047	17.6	0.0	<0.44
			Total	0.0267	100.0		

Particle Density*: 1.00 gm/cm^3
Velocity Head: 0.483 $"H_2O$
Stack Temperature: 855 °F
Molecular Weight: 25.67 lb/lb-mole
Stack Pressure: 29.32 "Hg
Nozzle Diameter: 0.242 inches
Orifice Head: 0.43 $"H_2O$
Sample Volume: 0.725 scf
Meter Temperature: 69 °F
Sampling Rate: 1,349 cfm @ stack conditions
%I: 108.5

* Assumed Particle Density of 1.00 gm/cm^3.

TABLE VI

PARTICLE SIZE DATA

Run No.: 3
Date: 11/8/79
Time: 1547-1549
Location: Afterburner Outlet

Plate Number	Filter Number	Initial Weight (g)	Final Weight (g)	Increase (g)	% of Total	Cum. %	Effective Cut-off Diameter* (microns)
0							
1	II-B13	0.1457	0.1504	0.0047	35.1	64.9	13.0
2	I -B20	0.1374	0.1404	0.0030	22.4	42.5	8.0
3	II-B12	0.1461	0.1468	0.0007	5.2	37.3	5.4
4	I -B19	0.1409	0.1415	0.0006	4.5	32.8	3.7
5	II-B11	0.1458	0.1465	0.0007	5.2	27.6	2.8
6	I -B18	0.1388	0.1396	0.0008	6.0	21.6	1.15
7	II-B10	0.1458	0.1472	0.0014	10.4	11.2	0.72
8	I -B17	0.1404	0.1405	0.0001	0.8	10.4	0.49
F	78	0.1858	0.1872	0.0014	10.4	0.0	<0.49
			Total	0.0134	100.0		

Particle Density*: 1.00 gm/cm^3
Velocity Head: 0.425 $"H_2O$
Stack Temperature: 895 °F
Molecular Weight: 25.96 lb/lb-mole
Stack Pressure: 29.24 "Hg
Nozzle Diameter: 242 inches
Orifice Head: 0.30 $"H_2O$
Sample Volume: 0.577 scf
Meter Temperature: 71 °F
Sampling Rate: 1.081 cfm @ stack conditions
%I: 91.7

* Assumed Particle Density of 1.00 gm/cm^3.

TABLE VII

PARTICLE SIZE DATA

Run No.: 1
Date: 11/9/79
Time: 1506-1511
Location: Scrubber Stack

Plate Number	Filter Number	Initial Weight (g)	Final Weight (g)	Increase (g)	% of Total	Cum. %	Effective Cut-off Diameter* (microns)
0							
1	II-B17	0.1454	0.1465	0.0011	6.5	93.5	11.5
2	I -B24	0.1355	0.1360	0.0005	2.9	90.6	7.1
3	II-B16	0.1462	0.1474	0.0012	7.0	83.6	4.8
4	I -B23	0.1361	0.1362	0.0001	0.6	83.0	3.3
5	II-B15	0.1460	0.1480	0.0020	11.8	71.2	2.1
6	I -B22	0.1356	0.1375	0.0019	11.2	60	1.02
7	II-B14	0.1464	0.1493	0.0029	17.1	42.9	0.64
8	I -B21	0.1387	0.1425	0.0038	22.3	20.6	0.44
F	79	0.1932	0.1967	0.0035	20.6	0.0	<0.44
			Total	0.0170	100.0		

Particle Density*: 1.00 gm/cm^3
Velocity Head: 0.02 $"H_2O$
Stack Temperature: 90 °F
Molecular Weight: 28.34 lb/lb-mole
Stack Pressure: 29.33 "Hg
Nozzle Diameter: 0.497 inches
Orifice Head: 1.2 $"H_2O$
Sample Volume: 3.116 scf
Meter Temperature: 63 °F
Sampling Rate: 0.723 cfm @ stack conditions
%I: 110.2

* Assumed Particle Density of 1.00 gm/cm^3.

TABLE VIII

PARTICLE SIZE DATA

Run No.: 2
Date: 11/9/79
Time: 1720-1725
Location: Scrubber Stack

Plate Number	Filter Number	Initial Weight (g)	Final Weight (g)	Increase (g)	% of Total	Cum. %	Effective Cut-off Diameter* (microns)
0							
1	II-B21	0.1452	0.1469	0.0017	12.3	87.7	14.5
2	I -B28	0.1356	0.1357	0.0001	0.7	87.0	9.0
3	II-B20	0.1459	0.1476	0.0017	12.3	74.7	6.2
4	I -B27	0.1341	0.1346	0.0005	3.6	71.1	4.2
5	II-B19	0.1467	0.1479	0.0012	8.7	62.4	2.65
6	I -B26	0.1360	0.1375	0.0015	10.9	51.5	1.30
7	II-B18	0.1452	0.1476	0.0024	17.4	34.1	0.83
8	I -B25	0.1359	0.1374	0.0015	10.9	23.2	0.56
F	80	0.1867	0.1899	0.0032	23.2	0.0	<0.56
			Total	0.0138	100.0		

Particle Density*: 1.00 gm/cm^3
Velocity Head: 0.028 $"H_2O$
Stack Temperature: 112 °F
Molecular Weight: 28.38 lb/lb-mole
Stack Pressure: 29.38 "Hg
Nozzle Diameter: 0.367 inches
Orifice Head: 0.45 $"H_2O$
Sample Volume: 1.895 scf
Meter Temperature: 63 °F
Sampling Rate: 0.454 cfm @ stack conditions
%I: 104.6

* Assumed Particle Density of 1.00 gm/cm^3.

TABLE IX

PARTICLE SIZE DATA

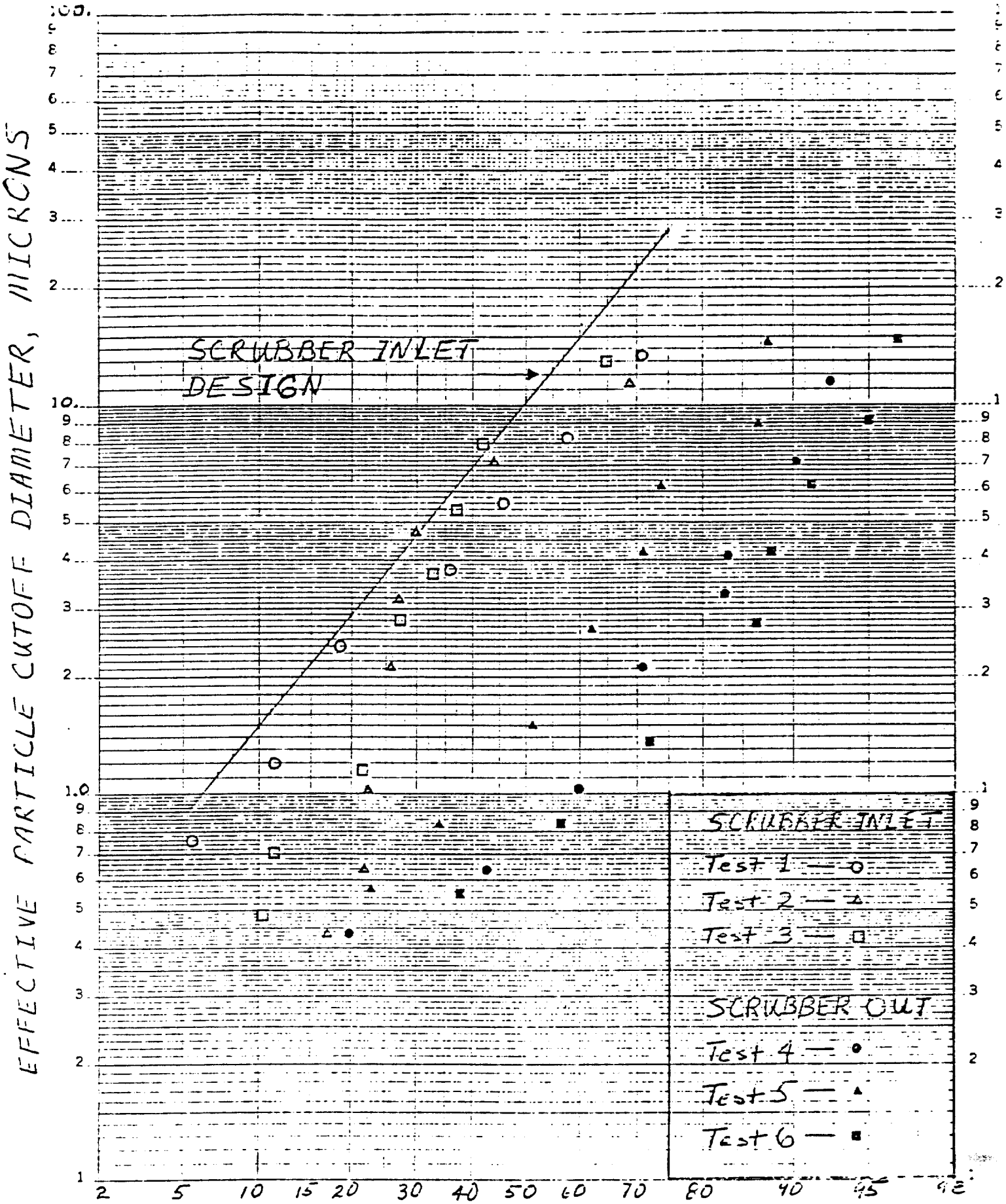
Run No.: 3
Date: 11/9/79
Time: 1808-1813
Location: Scrubber Stack

Plate Number	Filter Number	Initial Weight (g)	Final Weight (g)	Increase (g)	% of Total	Cum. %	Effective Cut-off Diameter* (microns)
0							
1	II-B25	0.1465	0.1468	0.0003	3.6	96.4	14.5
2	I -B32	0.1354	0.1355	0.0001	1.2	95.2	9.1
3	II-B24	0.1476	0.1479	0.0003	3.6	91.6	6.2
4	I -B31	0.1349	0.1352	0.0003	3.6	88	4.2
5	II-B23	0.1471	0.1472	0.0001	1.2	86.8	2.7
6	I -B30	0.1356	0.1368	0.0012	14.5	72.3	1.35
7	II-B22	0.1463	0.1476	0.0013	15.7	56.6	0.84
8	I -B29	0.1351	0.1366	0.0015	18.1	38.5	0.56
F	83	0.1845	0.1877	0.0032	38.5	0.0	<0.56
			Total	0.0083	100.0		

Particle Density*: 1.00 gm/cm^3
Velocity Head: 0.023 $"H_2O$
Stack Temperature: 97 °F
Molecular Weight: 28.42 lb/lb-mole
Stack Pressure: 29.46 "Hg
Nozzle Diameter: 0.367 inches
Orifice Head: 0.45 $"H_2O$
Sample Volume: 1.922 scf
Meter Temperature: 62 °F
Sampling Rate: 0.444 cfm @ stack conditions
%I: 114.5

* Assumed Particle Density of 1.00 gm/cm^3.

SCRUBBER PARTICLE SIZE DISTRIBUTION, [illegible]



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P. Size

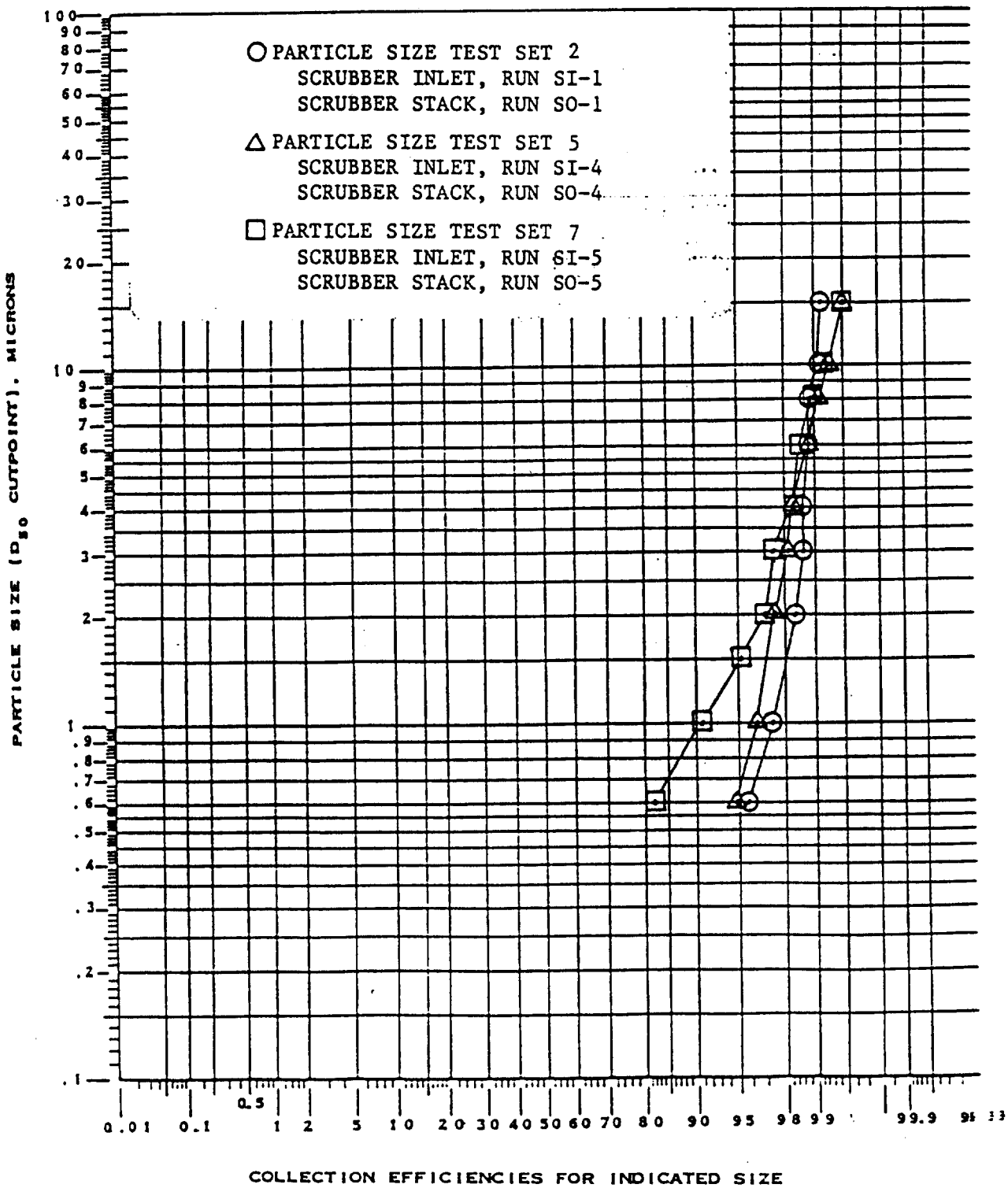


FIGURE 2-1. SLUDGE INCINERATOR SCRUBBER EFFICIENCY VERSUS PARTICLE SIZE DIAMETER

TABLE 2-4

SCRUBBER EFFICIENCY BY PARTICLE DIAMETER

Particle Dia., Microns	Inlet Run SI-1 Cum. % Less Than	Catch, %	Emissions Lbs/Hr*	Cum. > Lb/Hr	Stack Run SO-1 Cum. % Less Than	Catch, %	Emissions Lbs/Hr**	Cum. > Lb/Hr	Collection Efficiency, %
> 15	22.0	78.0	24.4	24.4	95.0	5.0	0.194	0.194	99.2
10	18.5	3.5	1.10	25.5	94.0	1.0	0.039	0.233	99.1
8	18.0	0.5	0.16	25.7	93.0	1.0	0.039	0.272	98.9
6	17.5	0.5	0.16	25.8	92.5	0.5	0.019	0.291	98.9
4	17.0	0.5	0.16	26.0	91.5	1.0	0.039	0.330	98.7
3	16.8	0.2	0.063	26.0	91.0	0.5	0.019	0.349	98.7
2	16.5	0.3	0.094	26.14	89.0	2.0	0.078	0.427	98.4
1	15.2	1.3	0.41	26.55	81.5	7.5	0.291	0.718	97.3
0.6	13.0	2.2	0.69	27.24	70.0	11.5	0.450	1.17	95.7
< 0.6	-	13.0	4.07	31.31	-	70.0	2.72	3.89	87.6

* Based on run I-2 emissions, 31.3 lb/hr

** Based on run O-1 emissions, 3.89 lb/hr

Particle Dia., Microns	Inlet Run SI-4 Cum. % Less Than	Catch, %	Emissions Lbs/Hr*	Cum. > Lb/Hr	Stack Run SO-4 Cum. % Less Than	Catch, %	Emissions Lbs/Hr**	Cum. > Lb/Hr	Collection Efficiency, %
> 15	22.0	78.0	32.6	32.6	97.0	3.0	0.16	0.16	99.5
10	21.0	1.0	0.42	33.0	95.5	1.5	0.078	0.238	99.3
8	19.5	1.5	0.63	33.7	94.0	1.5	0.078	0.316	99.1
6	18.5	1.0	0.42	34.1	92.0	2.0	0.10	0.416	98.8
4	17.8	0.8	0.33	34.4	89.5	2.5	0.13	0.546	98.4
3	17.5	0.3	0.13	34.5	87.5	2.0	0.10	0.646	98.1
2	17.0	0.5	0.21	34.7	84.0	3.5	0.18	0.826	97.6
1	16.5	0.5	0.21	35.0	75.0	9.0	0.47	1.30	96.3
0.6	15.2	1.3	0.54	35.5	65.0	10.0	0.52	1.82	94.9
< 0.6	-	15.2	6.35	41.8	-	65.0	3.39	5.21	87.5

* Based on run I-4 emissions, 41.8 lb/hr

** Based on run O-4 emissions, 5.21 lb/hr

TABLE 2-4

SCRUBBER EFFICIENCY BY PARTICLE DIAMETER

(continued)

Particle Dia., Microns	Inlet Run SI-5 Cum. % Less Than	Catch, %	Emissions Lbs/Hr*	Cum. > Lb/Hr	Stack Run SO-5 Cum. % Less Than	Catch, %	Emissions Lbs/Hr**	Cum. > Lb/Hr	Collection Efficiency, %
> 15	13.8	86.2	23.8	23.8	97.8	2.2	0.11	0.11	99.5
10	13.8	0.0	0.0	23.8	96.2	1.6	0.079	0.189	99.2
8	13.5	0.3	0.083	23.9	95.0	1.2	0.059	0.248	99.0
6	13.0	0.5	0.14	24.0	93.0	2.0	0.098	0.347	98.6
4	12.5	0.5	0.14	24.1	91.0	2.0	0.098	0.446	98.2
3	12.5	0.0	0.0	24.2	88.2	2.8	0.14	0.586	97.6
2	12.0	0.5	0.14	24.3	85.0	3.2	0.16	0.746	96.9
1	10.8	1.2	0.33	24.6	76.0	9.0	0.45	1.20	95.1
0.6	8.0	2.8	0.77	25.4	54.0	22.0	1.09	2.29	91.0
< 0.6	-	8.0	2.21	27.6	-	54.0	2.67	4.95	82.1

* Based on run I-5 emissions, 27.6 lb/hr

** Based on run O-5 emissions, 4.95 lb/hr

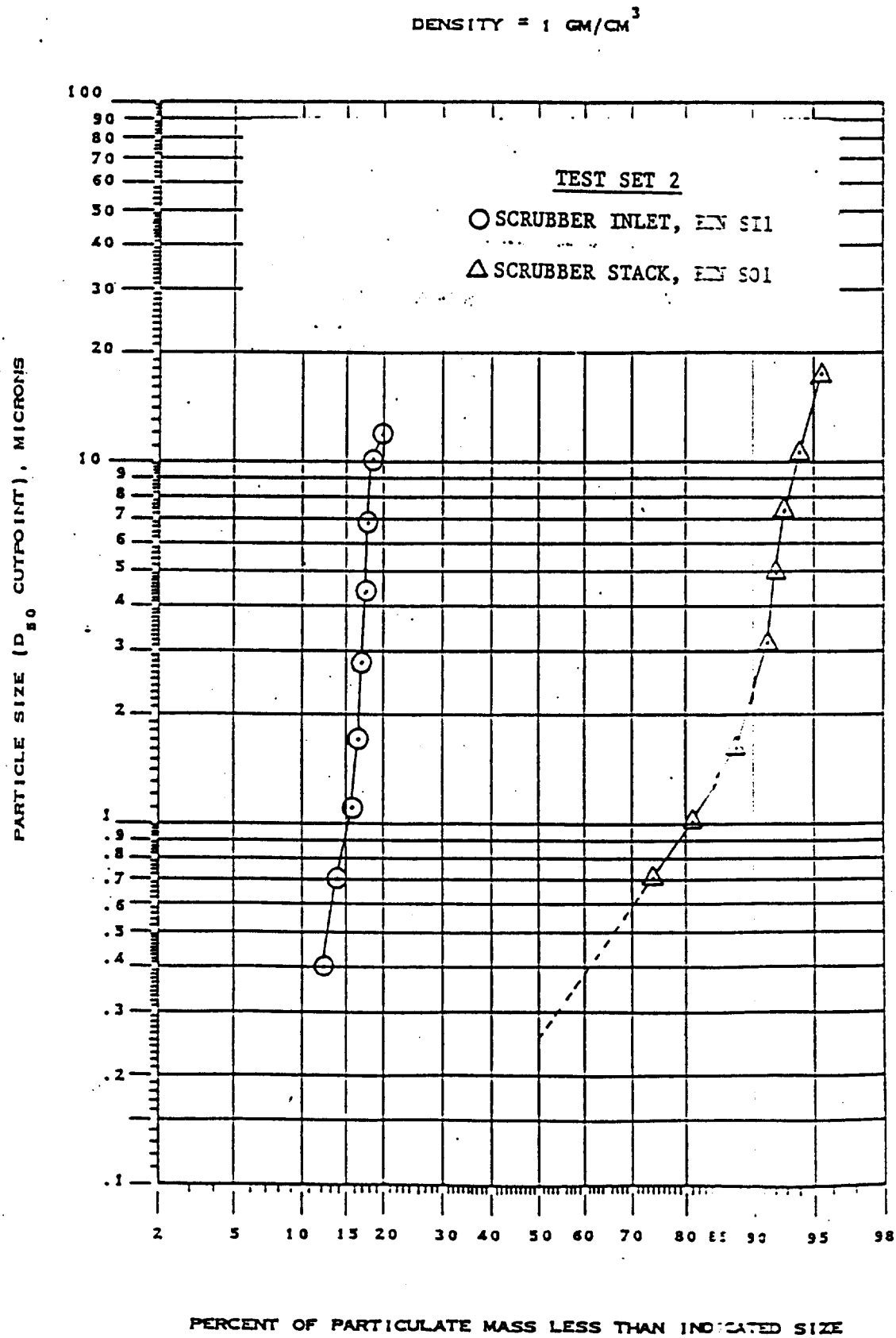


FIGURE 2-2. SLUDGE INCINERATOR PARTICLE SIZE DISTRIBUTION, RUNS S11 AND S01

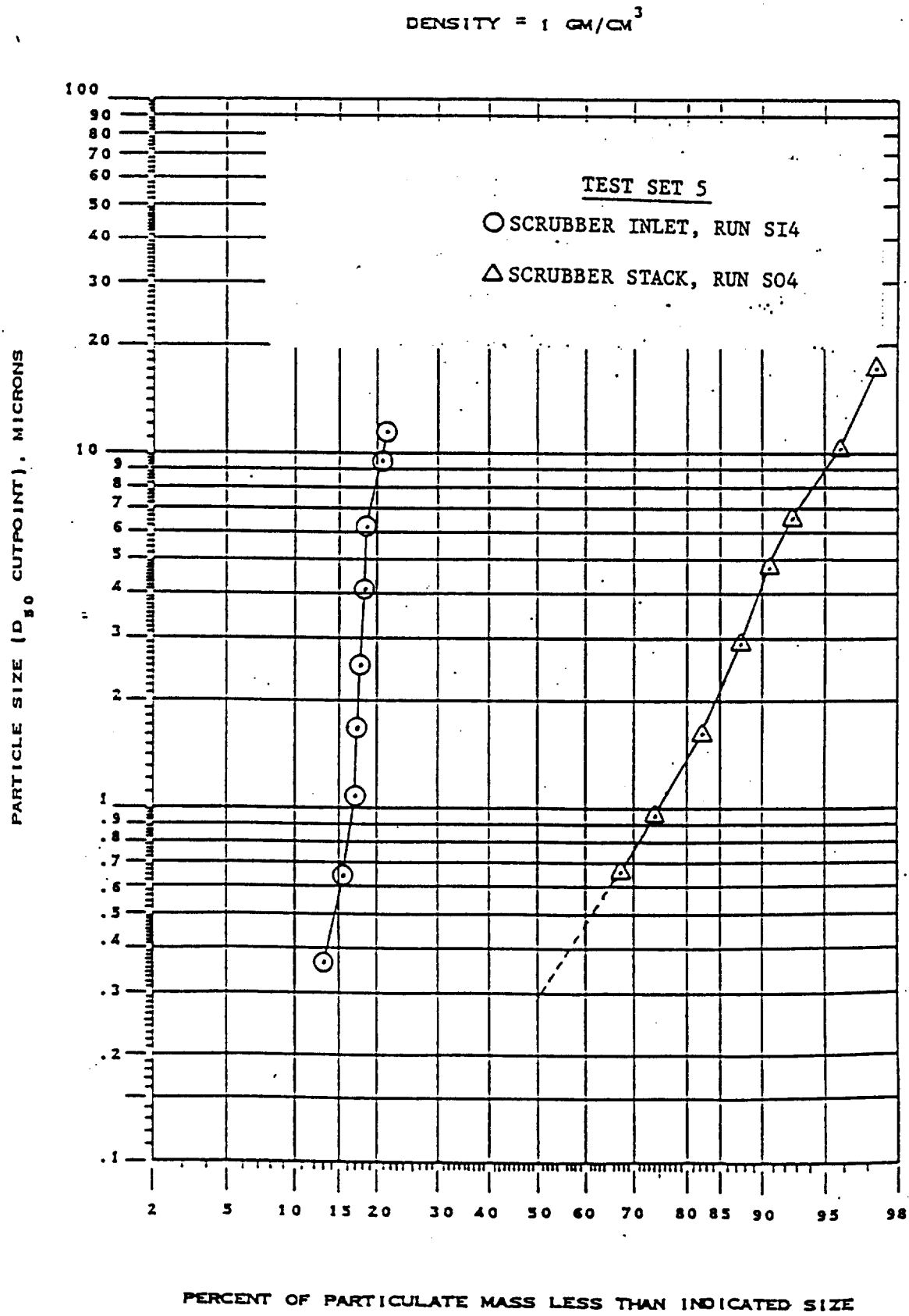


FIGURE 2-3. SLUDGE INCINERATOR PARTICLE SIZE DISTRIBUTION, RUNS SI4 AND SO4

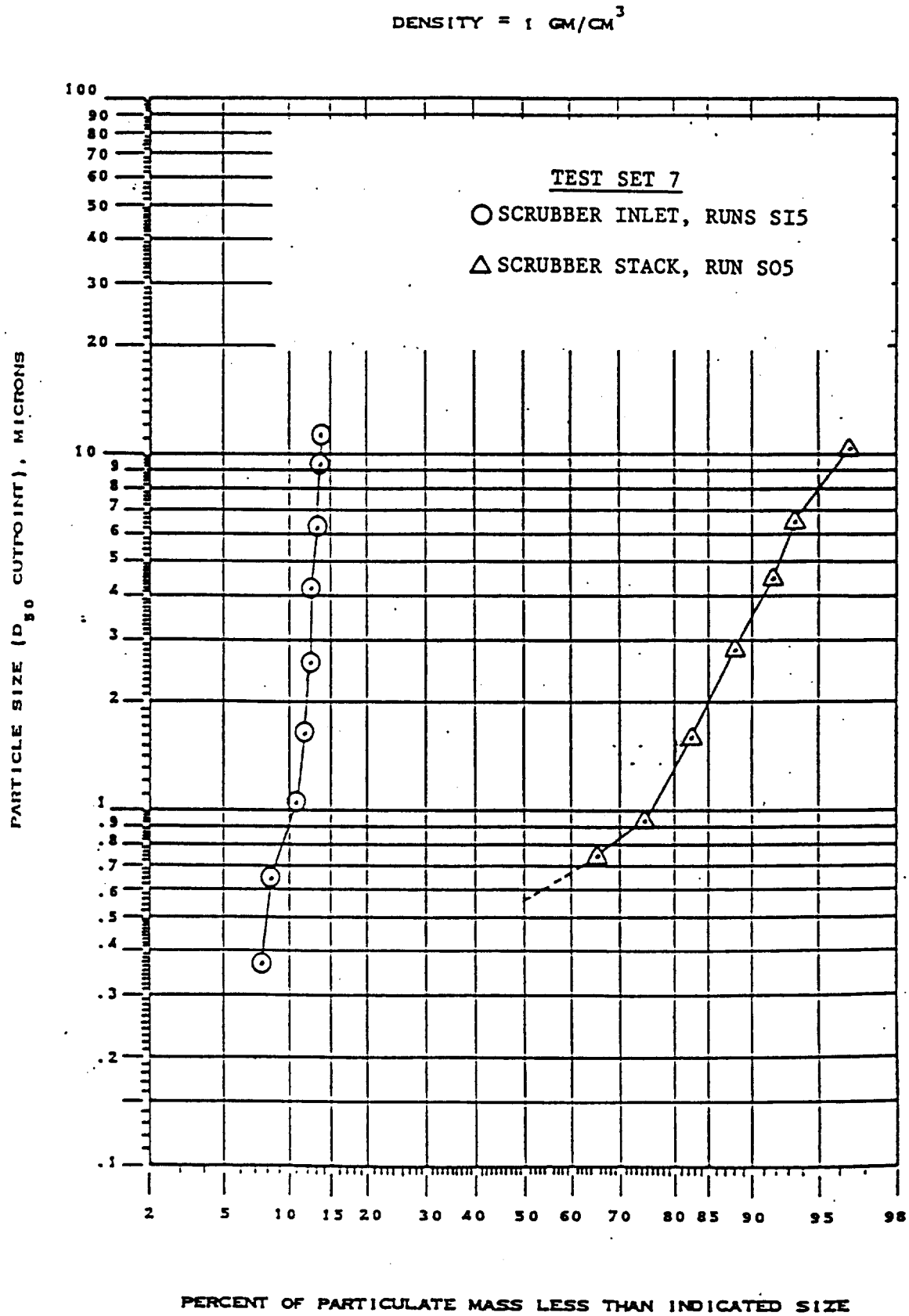


FIGURE 2-4. SLUDGE INCINERATOR PARTICLE SIZE DISTRIBUTION, RUNS SI5 AND SO5

Ref 39
P Size

TABLE 10. PARTICULATE MASS CONCENTRATIONS BY SASS SIZE FRACTION
(g/dscm, 12% O_2)

		Probe and 10 micron Cyclone	3 μm Cyclone	1 μm Cyclone	Filter Catch	Total
Incinerator Outlet						
	Run 1	0.47	0.23	0.012	0.037	0.75
	Run 2	0.43	0.45	0.014	0.034	0.93
	Run 3	0.40	0.30	0.022	0.065	0.79
	Average	0.43	0.33	0.016	0.045	0.82
ESP Outlet						
	Run 1	0.11	0.00	0.00	0.0003	0.11
	Run 2	0.098	0.00	0.00	0.0013	0.10
	Run 3	0.011	0.00	0.00	0.0052	0.012
	Average	0.073	0.00	0.00	0.0023	0.074
Scrubber Outlet						
	Run 1	0.0008	0.00	0.00	0.012	0.013
	Run 2	0.0011	0.00	0.00	0.013	0.014
	Run 3	0.0012	0.00	0.00	0.018	0.019
	Average	0.0010	0.00	0.00	0.014	0.015

TABLE 11. PARTICULATE MASS FLOW RATES BY SASS SIZE FRACTION (lb/hr)

		Probe and 10 micron Cyclone	3 μm Cyclone	1 μm Cyclone	Filter Catch	Total
ESP	Inlet					
	Run 1	0.12	0.06	0.003	0.01	0.20
	Run 2	0.13	0.13	0.004	0.01	0.27
	Run 3	0.14	0.11	0.008	0.02	0.28
	Average	0.13	0.10	0.005	0.013	0.25
	Outlet					
	Run 1	0.017	0.00	0.00	0.0001	0.017
	Run 2	0.017	0.00	0.00	0.0002	0.018
	Run 3	0.0042	0.00	0.00	0.0002	0.0044
	Average	0.013	0.00	0.00	0.0002	0.013
Scrubber	Inlet					
	Run 1	4.62	2.32	0.14	0.40	7.48
	Run 2	3.98	4.18	0.12	0.31	8.59
	Run 3	5.22	3.88	0.28	0.86	10.24
	Average	4.61	3.46	0.18	0.52	8.77
	Outlet					
	Run 1	0.0083	0.00	0.00	0.11	0.12
	Run 2	0.011	0.00	0.00	0.12	0.13
	Run 3	0.015	0.00	0.00	0.23	0.25
	Average	0.011	0.00	0.00	0.15	0.17

TABLE 28. PARTICLE SIZE DISTRIBUTION OF TRACE METALS IN INCINERATOR EMISSIONS

	INCINERATOR OUTLET				
	PROBE + 10 um	3 um CYCLONE	1 um CYCLONE	FILTER CATCH	IMPINGER CATCH
ALUMINUM	33.45	38.46	1.42	26.67	0.00
ANTIMONY	21.01	66.03	1.68	11.28	0.00
ARSENIC	61.57	30.53	2.15	5.75	0.00
BARIUM	50.59	26.74	6.55	16.11	0.00
CADMIUM	28.22	44.37	11.37	16.04	0.00
CALCIUM	24.97	44.12	2.31	28.58	0.02
CHROMIUM	39.59	36.10	1.76	5.35	17.20
COBALT	50.60	39.93	2.19	7.28	0.00
COPPER	43.80	45.79	3.14	7.27	0.00
GOLD	0.00	37.41	0.00	62.59	0.00
IRON	50.95	43.26	2.27	2.71	0.81
LEAD	29.07	47.04	3.25	20.64	0.00
MAGNESIUM	44.56	47.31	2.12	5.98	0.02
MANGANESE	54.20	41.07	2.13	0.64	1.96
NICKEL	33.45	45.30	2.85	0.61	17.80
PHOSPHOROUS	47.88	46.50	1.96	2.71	0.95
SELENIUM	0.00	0.00	0.00	100.00	0.00
SILVER	19.87	67.28	6.31	6.54	0.00
SODIUM	44.33	44.98	1.34	9.36	0.00
SULFUR	0.96	1.38	0.08	0.35	97.23
TIN	26.23	36.15	2.72	34.90	0.00
TITANIUM	51.45	44.32	2.20	2.03	0.00
VANADIUM	44.13	45.75	2.63	7.48	0.00
ZINC	44.46	46.10	2.65	6.78	0.00

TABLE 29 PARTICLE SIZE DISTRIBUTION OF TRACE METALS IN ESP AND SCRUBBER EMISSIONS

	ESP OUTLET				SCRUBBER OUTLET		
	PROBE + 10 um	FILTER CATCH	IMPINGER CATCH		PROBE + 10 um	FILTER CATCH	IMPINGER CATCH
ALUMINUM	5.00	95.00	0.00	ALUMINUM	6.82	93.18	0.00
ANTIMONY	8.58	91.42	0.00	ANTIMONY	1.22	98.78	0.00
ARSENIC	3.14	45.04	51.82	ARSENIC	5.61	84.10	10.29
BARIUM	1.07	98.93	0.00	BARIUM	0.70	99.15	0.15
CADMIUM	31.45	35.38	33.18	CADMIUM	50.98	49.02	0.00
CALCIUM	3.22	96.36	0.42	CALCIUM	6.00	93.88	0.12
CHROMIUM	52.73	0.00	47.27	CHROMIUM	96.81	0.74	2.45
COBALT	3.96	63.14	32.90	COBALT	54.94	0.00	45.06
COPPER	74.55	10.46	14.99	COPPER	67.05	32.95	0.00
GOLD	17.21	82.79	0.00	GOLD	0.00	100.00	0.00
IRON	17.61	63.81	18.58	IRON	91.41	5.32	3.28
LEAD	16.66	83.34	0.00	LEAD	51.05	47.64	1.31
MAGNESIUM	23.75	73.53	2.71	MAGNESIUM	69.01	29.88	1.11
MANGANESE	25.30	0.00	74.70	MANGANESE	93.65	0.00	6.35
NICKEL	64.47	0.00	35.53	NICKEL	96.50	0.00	3.50
PHOSPHOROUS	15.96	1.83	82.21	PHOSPHOROUS	33.22	58.15	8.63
SELENIUM	13.78	3.31	82.91	SELENIUM	99.27	0.73	0.00
SILVER	0.00	100.00	0.00	SILVER	0.00	100.00	0.00
SODIUM	100.00	0.00	0.00	SODIUM	100.00	0.00	0.00
SULFUR	1.79	0.03	98.18	SULFUR	64.54	13.60	21.86
TIN	65.61	4.67	29.72	TIN	72.68	27.32	0.00
TITANIUM	49.24	50.76	0.00	TITANIUM	94.26	5.74	0.00
VANADIUM	11.10	12.96	75.95	VANADIUM	70.92	29.08	0.00
ZINC	54.48	45.52	0.00	ZINC	78.03	21.97	0.00

No metals were caught in the 3 and 1 um cyclones.

represent the percent by weight of each metal captured in the various SASS train size fractions. Each capture point along the SASS train retained particles of a specific size range. The SASS train fractions have the following approximate particle size characteristics:

SASS SIZE FRACTION	SIZE OF PARTICLES RETAINED (d = particle diameter)
Probe and 10-um cyclone	d > 10 um
3 um cyclone	3 um < d < 10 um
1 um cyclone	1 um < d < 3 um
Filter Catch	.1 um < d < 1 um
Impinger Catch	d < .1 um

At the outlets of both control devices, no particulate matter was captured in the 3 um and 1 um cyclones. These size fractions have been omitted from the appropriate tables. Histograms for Nickel, Lead, and Cadmium are presented in Figures 19 through 24 for the inlets and outlets of both control devices. Since the slipstream to the ESP consisted of the flue gas entering the scrubber, the inlet concentrations of both units are assumed to be identical. The three histograms for the inlet concentrations show that in general the majority of particles had diameters greater than 3 um. For Cadmium, 73 percent of the particles were distributed between the 10 um and 3 um cyclones. For Nickel and Lead, 79 percent and 76 percent of the total particles captured were also in the first two cyclones. Sulfur was the exception to this rule in that 97 percent was captured in the impinger catch.

The histograms for the trace metals at the scrubber outlet show that only a small percentage of the total particles were captured in the impinger catch. Nickel, for example, was primarily captured by the probe and 10 um cyclone.

The histograms for the trace metals at the ESP outlet show that the impinger fraction contributed a large percentage of many metals. Cadmium, for example, was distributed evenly among the 10 um cyclone, filter and impinger. No general patterns were apparent for the metals as a whole.

Trace Metals Content of Bottom Ash and ESP Hopper Catch

The trace metals content of incinerator bottom ash and ESP hopper catch samples for each test run are presented in Table 30 and Table 31, respectively. The average trace metals contents of the bottom ash samples were generally similar to that of the dry, volatiles free sludge. Arsenic, iron, phosphorous, and zinc were the only metals to increase significantly in content relative to the sludge concentrations. Enrichment ratios for the metals in the bottom ash and ESP hopper catch are shown in Table 32. Zinc had the highest enrichment ratio with a value of 2.32. The contents of nickel and sulfur descreased sharply relative to the sludge concentrations. The enrichment ratios of these species were .39 and .31, respectively.

In the ESP hopper catch, the content of antimony, cadmium, and lead increased significantly relative to the sludge concentrations. The enrichment ratios of these species were 2.77, 7.58, and 2.13, respectively. Sodium was the only metal in the ESP hopper catch to decrease significantly

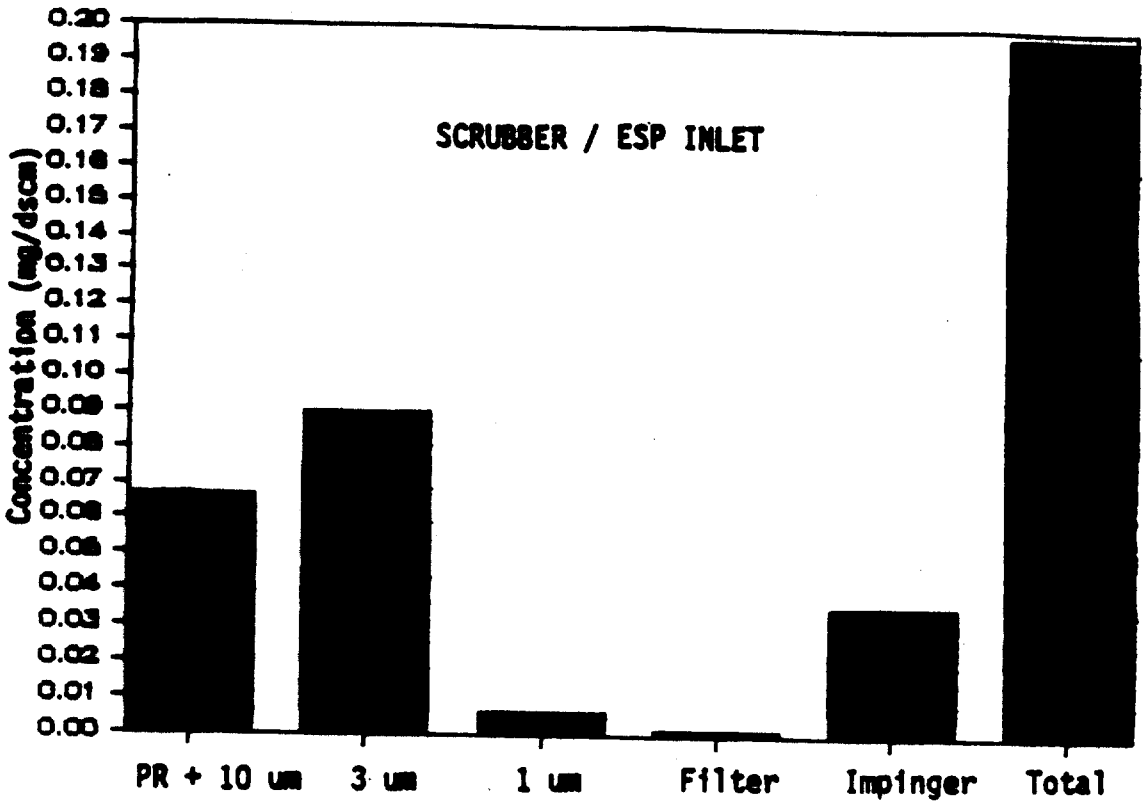


Figure 19. Particle Size Distribution of Nickel in the Uncontrolled Incinerator Emissions.

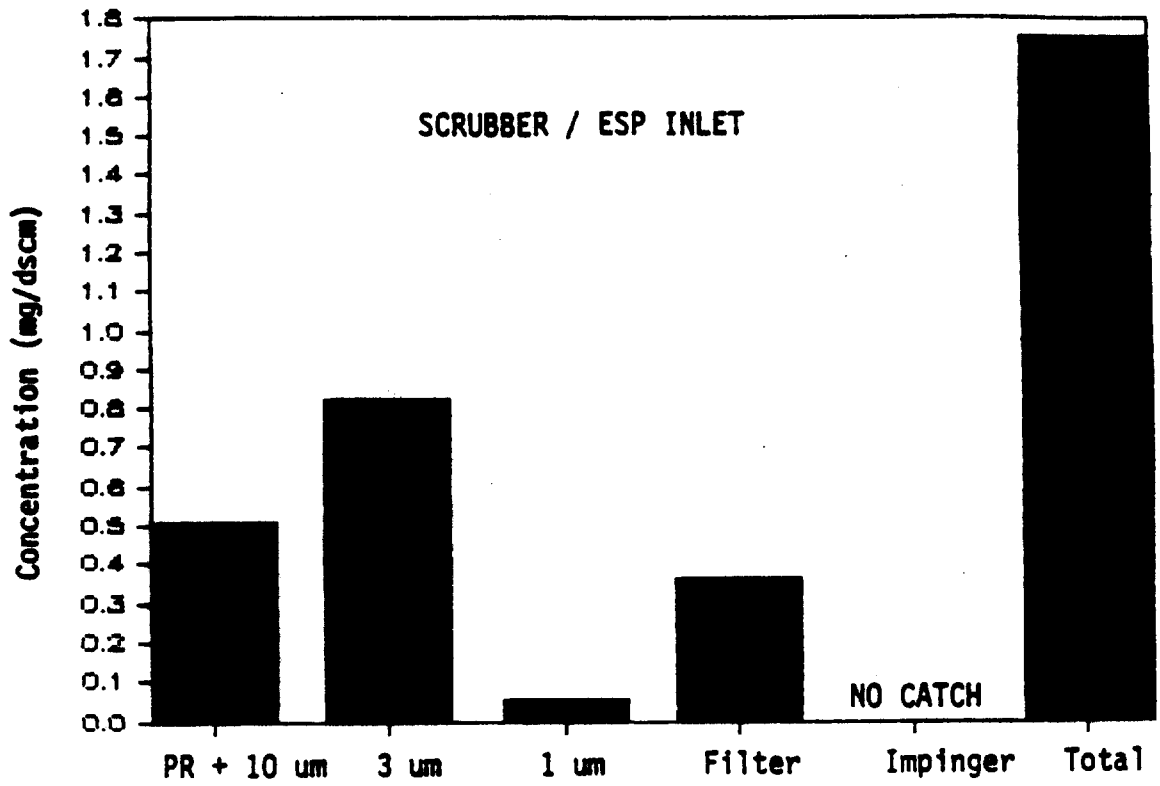


Figure 20. Particle Size Distribution of Lead in the Uncontrolled Incinerator Emissions.

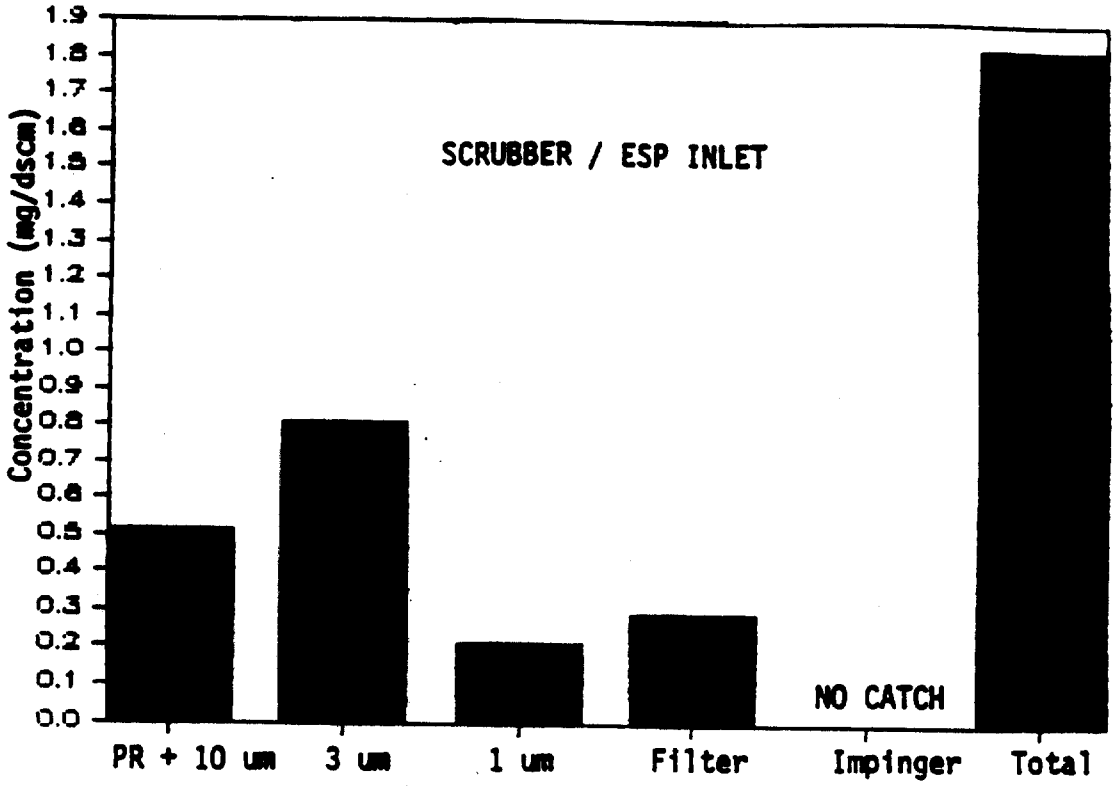
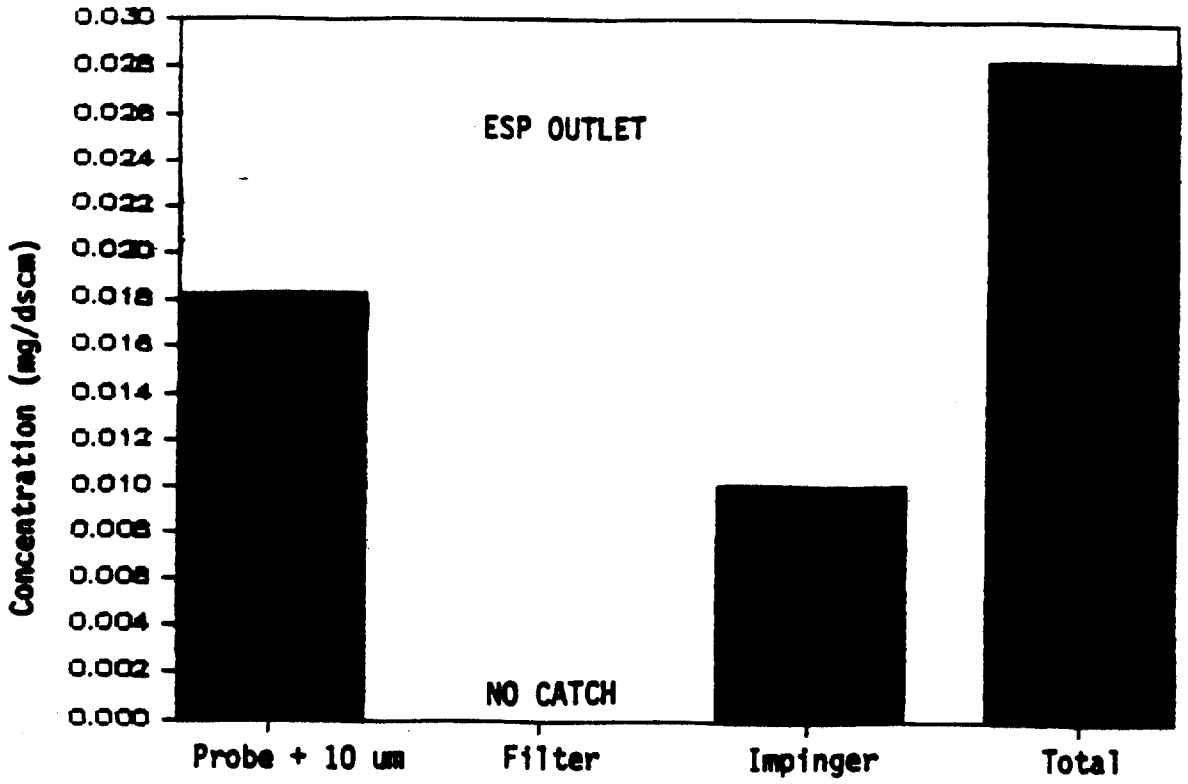


Figure 21. Particle Size Distribution of Cadmium in the Uncontrolled Incinerator Emissions.



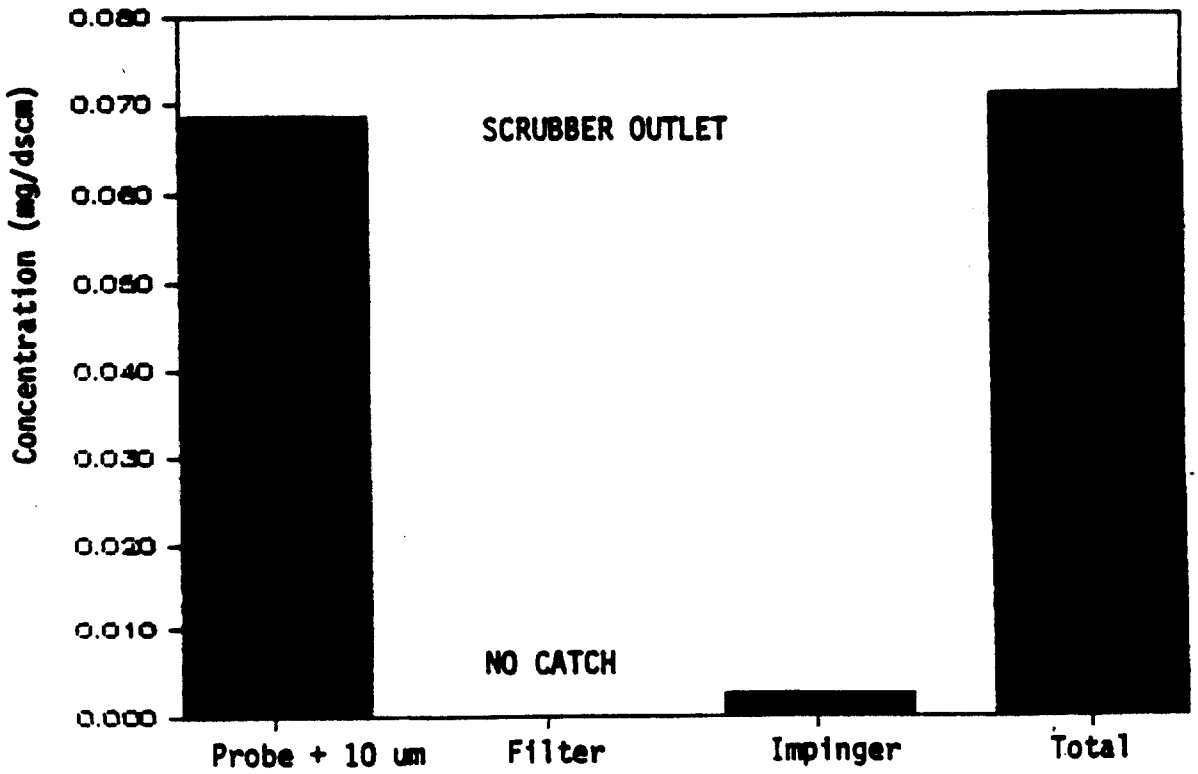
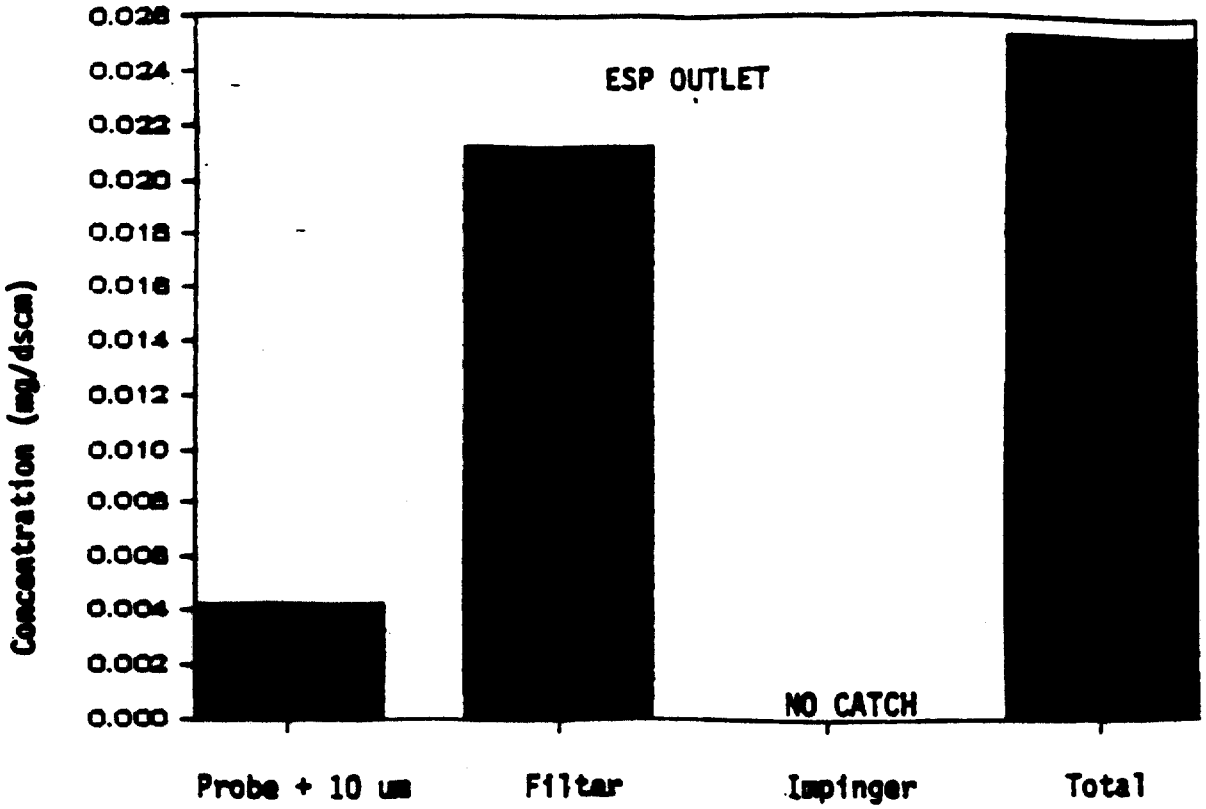


Figure 22. Particle Size Distributions of Nickel in the Controlled ESP and Scrubber Emissions.



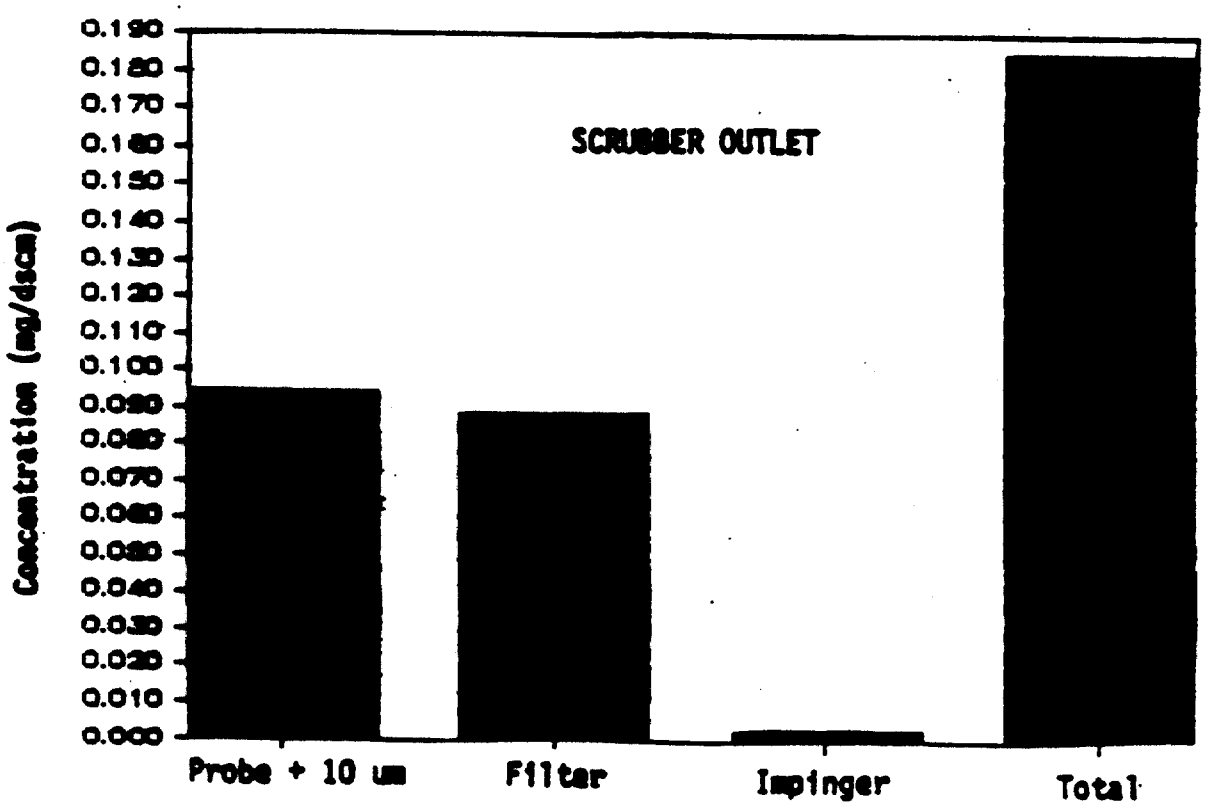
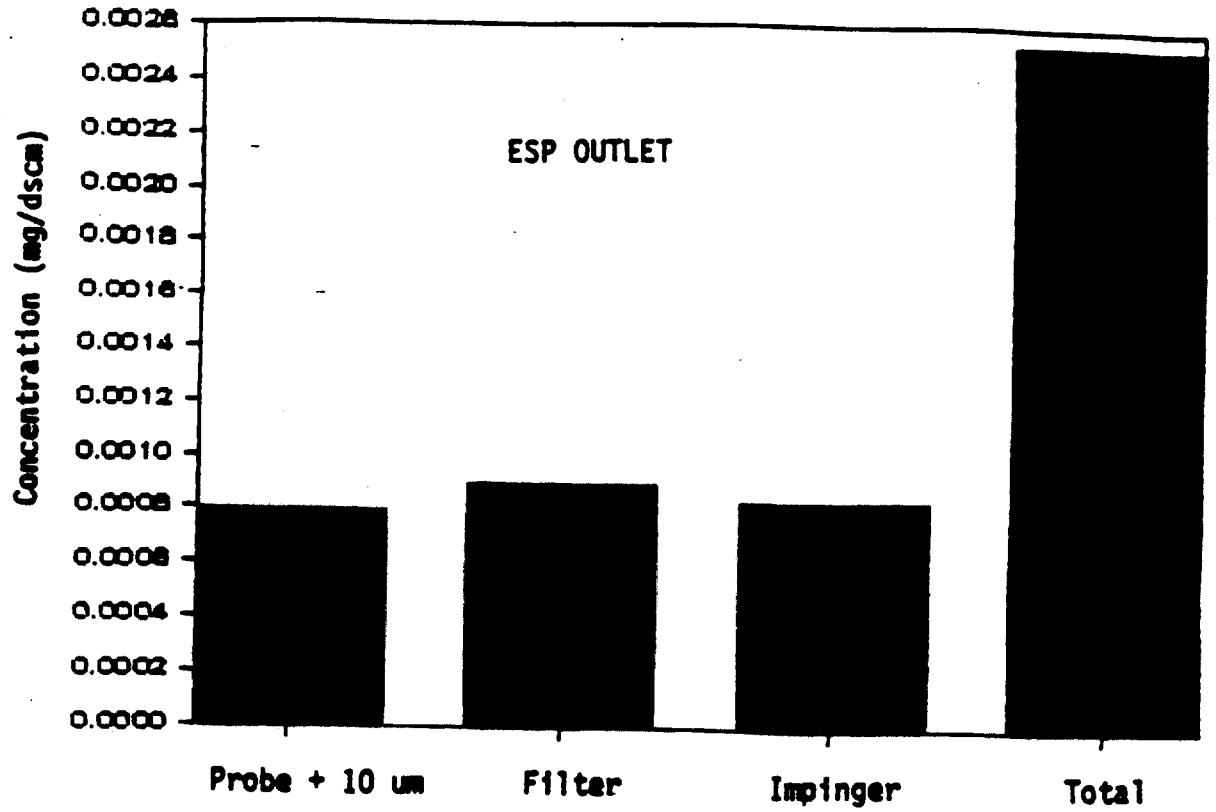


Figure 23. Particle Size Distributions of Lead in the Controlled ESP and Scrubber Emissions.



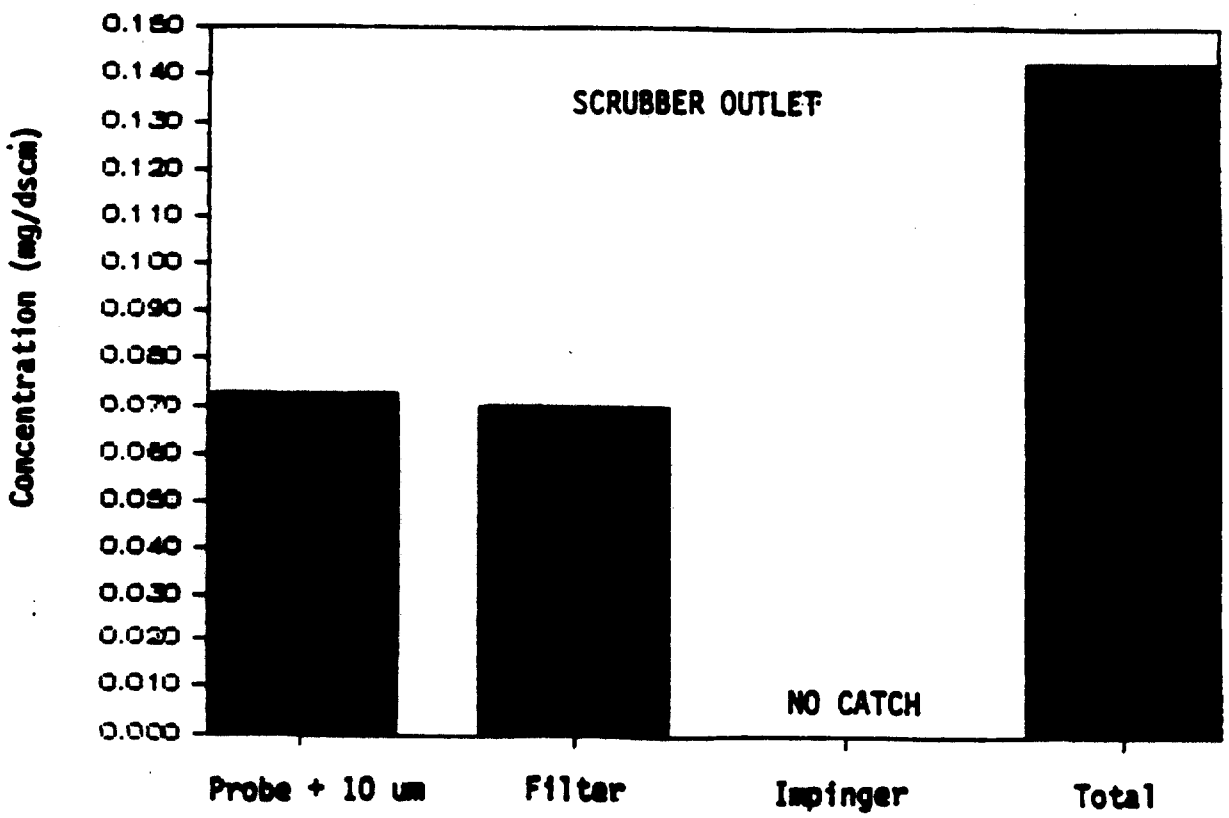


Figure 24. Particle Size Distributions of Cadmium in the Controlled ESP Emissions and Scrubber Emissions.

Ref 40 page

TABLE 10. TOTAL PARTICULATE CONCENTRATIONS BY SASS SIZE FRACTION

Sampling Location	Total Particulate Concentration Corrected to 12% O_2 (g/dscm)				
	Probe Rinse/ 10 Micron Cyclone	3 Micron Cyclone	1 Micron Cyclone	Filter	Total
Uncontrolled Emissions					
Run 02	0.18	0.068	0.0032	0.029	0.28
Run 03	0.22	0.086	0.0149	0.035	0.35
Run 04	0.20	0.079	0.0047	0.034	0.32
Run 06	0.25	0.126	0.0136	0.031	0.42
Run 07	0.33	0.189	0.0283	0.040	0.58
Run 08	0.27	0.137	0.0245	0.041	0.47
Average	0.24	0.114	0.0145	0.035	0.40
Scrubber Emissions					
Run 02	0.0093	0.0	0.0	0.013	0.022
Run 03	0.0024	0.0	0.0	0.013	0.015
Run 04	0.0014	0.0	0.0	0.014	0.016
Average	0.0044	0.0	0.0	0.013	0.018
Baghouse Emissions					
Run 06	0.0013	0.0	0.0	0.0006	0.0019
Run 07	0.0019	0.0	0.0	0.0004	0.0023
Run 08	0.0070	0.0	0.0	0.0002	0.0072
Average	0.0034	0.0	0.0	0.0004	0.0038

TABLE 11. TOTAL PARTICULATE REMOVAL EFFICIENCY

Baghouse		Scrubber	
Run 6	99.4660	Run 2	91.9460
Run 7	99.4300	Run 3	95.7600
Run 8	98.4180	Run 4	95.1390
Average	99.1050	Average	94.2820

TABLE 12. PARTICULATE REMOVAL EFFICIENCY BY SASS SIZE FRACTION

	Probe + 10 µm	3 µm Cyclone	1 µm Cyclone	Filter Catch	TOTAL
Baghouse					
Run 6	99.3760	100.0000	100.0000	97.7570	99.4660
Run 7	99.1470	100.0000	100.0000	98.7090	99.4300
Run 8	97.3230	100.0000	100.0000	99.4260	98.4180
Average	98.6150	100.0000	100.0000	98.6310	99.1050
Scrubber					
Run 2	94.7800	100.0000	100.0000	54.6930	91.9460
Run 3	98.9140	100.0000	100.0000	64.2670	95.7600
Run 4	99.3110	100.0000	100.0000	58.3740	95.1460
Average	97.6680	100.0000	100.0000	59.1110	94.2820

The particle size distribution data shown in Table 10 for the uncontrolled incinerator emissions are summarized graphically in Figures 9 and 10. These data show that particulate matter was captured in all SASS train size fractions for each test run. The particle size distributions were similar for the various runs. The probe rinse and 10 micron cyclone catch accounted for approximately 60 percent of the total catch; the 3 micron cyclone, 28 percent; the 1 micron cyclone, 3 to 4 percent; and the filter catch, 8 to 9 percent.

Scrubber Outlet Location

SASS train sampling was performed at the scrubber exhaust stack location during test runs 02, 03, and 04 (i.e., scrubber test runs). The emissions data in Table 9 show that the total particulate concentration at the scrubber exhaust stack location was fairly consistent between runs. The controlled total particulate emissions concentration at the scrubber outlet averaged 0.0065 g/dscm on an as-measured O_2 basis and 0.018 g/dscm when corrected to 12% O_2. The maximum percentage deviation of the scrubber outlet concentration for any individual scrubber test run from the mean for all scrubber test runs was approximately 25 percent. The total particulate mass emission rate for the scrubber averaged 0.089 kg/hr for the three scrubber test runs. As shown in Table 11, the average total particulate removal efficiency for the scrubber system was 94.3 percent, with a range for individual runs of 91.9 to 95.8 percent.

The SASS train particle size distribution data in Table 10 for the scrubber particulate emissions are shown graphically in Figure 11. The data show that particulate emissions from the scrubber were captured only in the probe rinse/10 micron cyclone fraction and the filter fraction of the SASS train catch, with no particulate matter captured in the 3 micron and 1 micron cyclones. The filter catch was the largest contributor to the total particulate mass for each test run. The average percentages of the total particulate emissions contributed by the probe rinse/10 micron cyclone catch and filter catch were 25 percent and 75 percent, respectively. Run 02 had a considerably higher percentage of the total particulate emission contributed from the probe rinse/10 micron cyclone catch (42 percent) than Runs 03 and 04 (12 percent). This anomaly could not be explained by a consideration of potential sampling uncertainties.

Particulate removal efficiencies for the scrubber system are shown by SASS size fraction in Table 12. The removal efficiency for the probe rinse/ 10 micron catch averaged 97.7 percent for the test runs, with a range for individual runs of 94.8 percent to 99.3 percent. Removal efficiencies for the 3 micron and 1 micron cyclone catches were 100 percent for all test runs, since no particulate was captured in these cyclones at the scrubber exhaust stack. The removal efficiency for particulate matter in the SASS train filter catch was low for all three scrubber test runs, with an average of 59.1 percent. The range for individual runs was 54.7 percent to 64.3 percent.

Figure 12 gives a graphic representation of the average scrubber system particulate removal efficiency data. The parameter (1-scrubber efficiency) is plotted in bar graph form for each SASS train size fraction. This parameter is equivalent to the ratio of the scrubber inlet mass emissions rate divided by the scrubber outlet mass emission rate (i.e., "relative emissions"). The

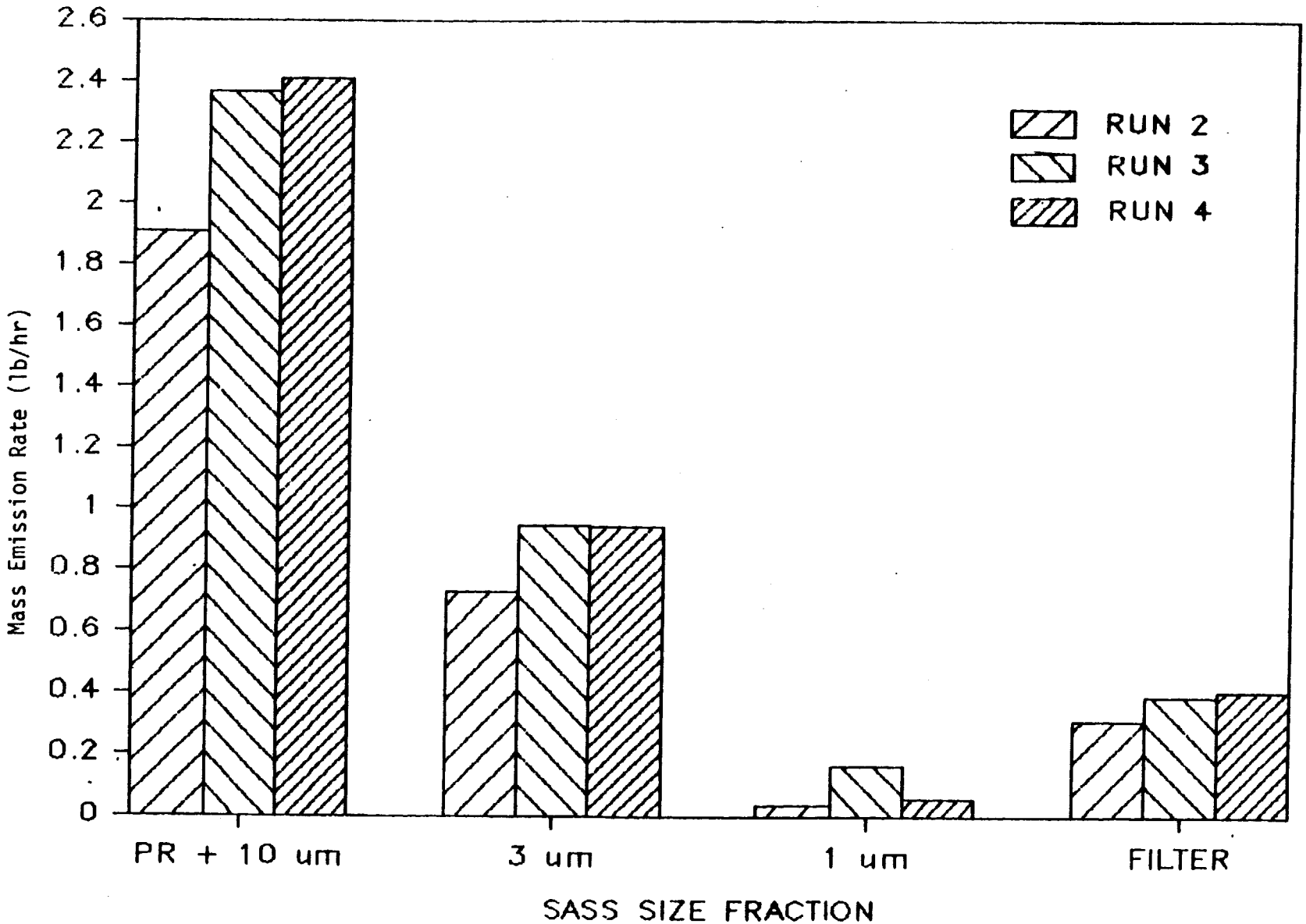


Figure 9. Particle Size Distribution of the Uncontrolled Particulate Emissions from the Incinerator (Scrubber Test Runs)

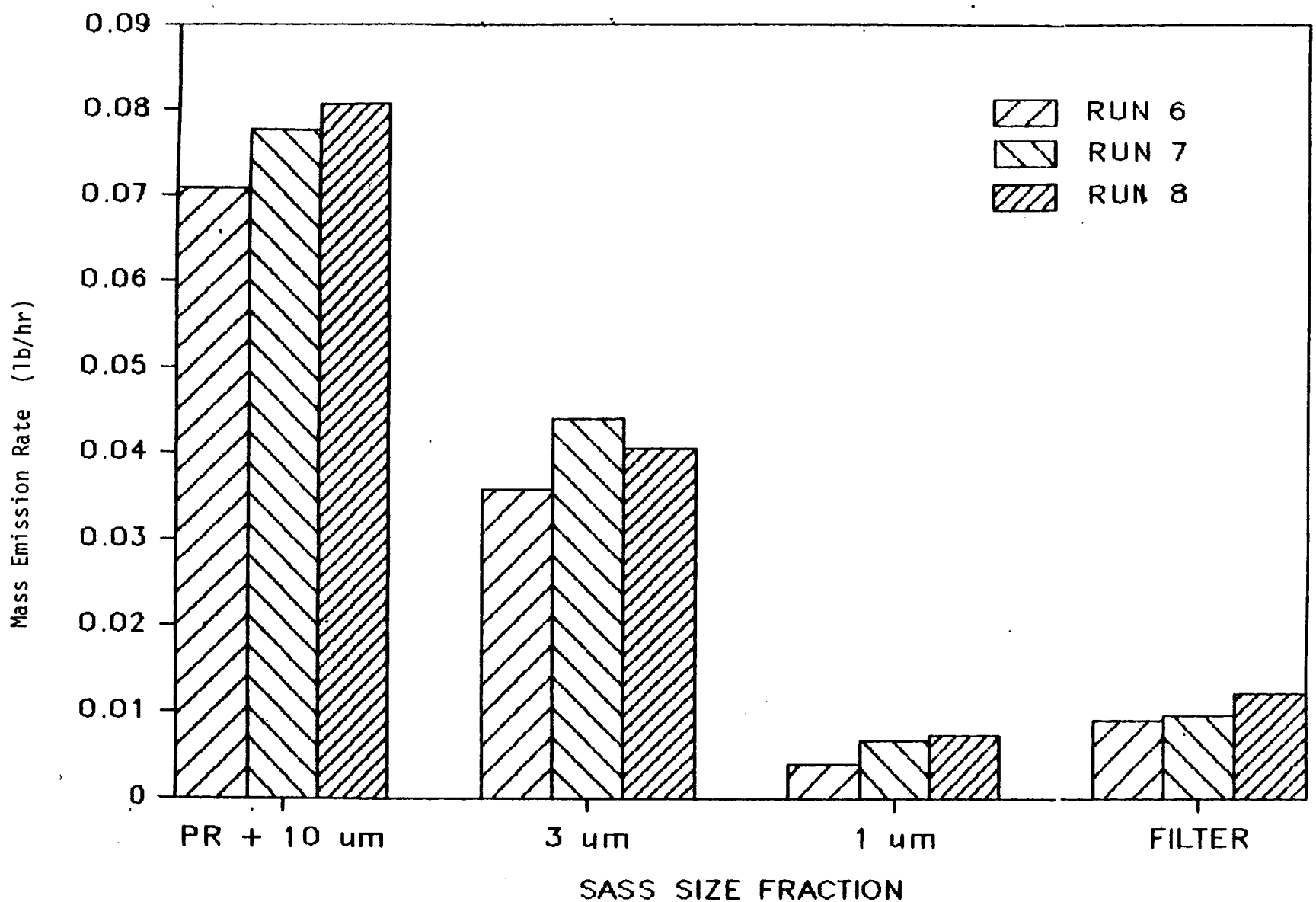


Figure 10. Particle Size Distribution of the Uncontrolled Particulate Emissions from the Incinerator (Baghouse Test Runs)

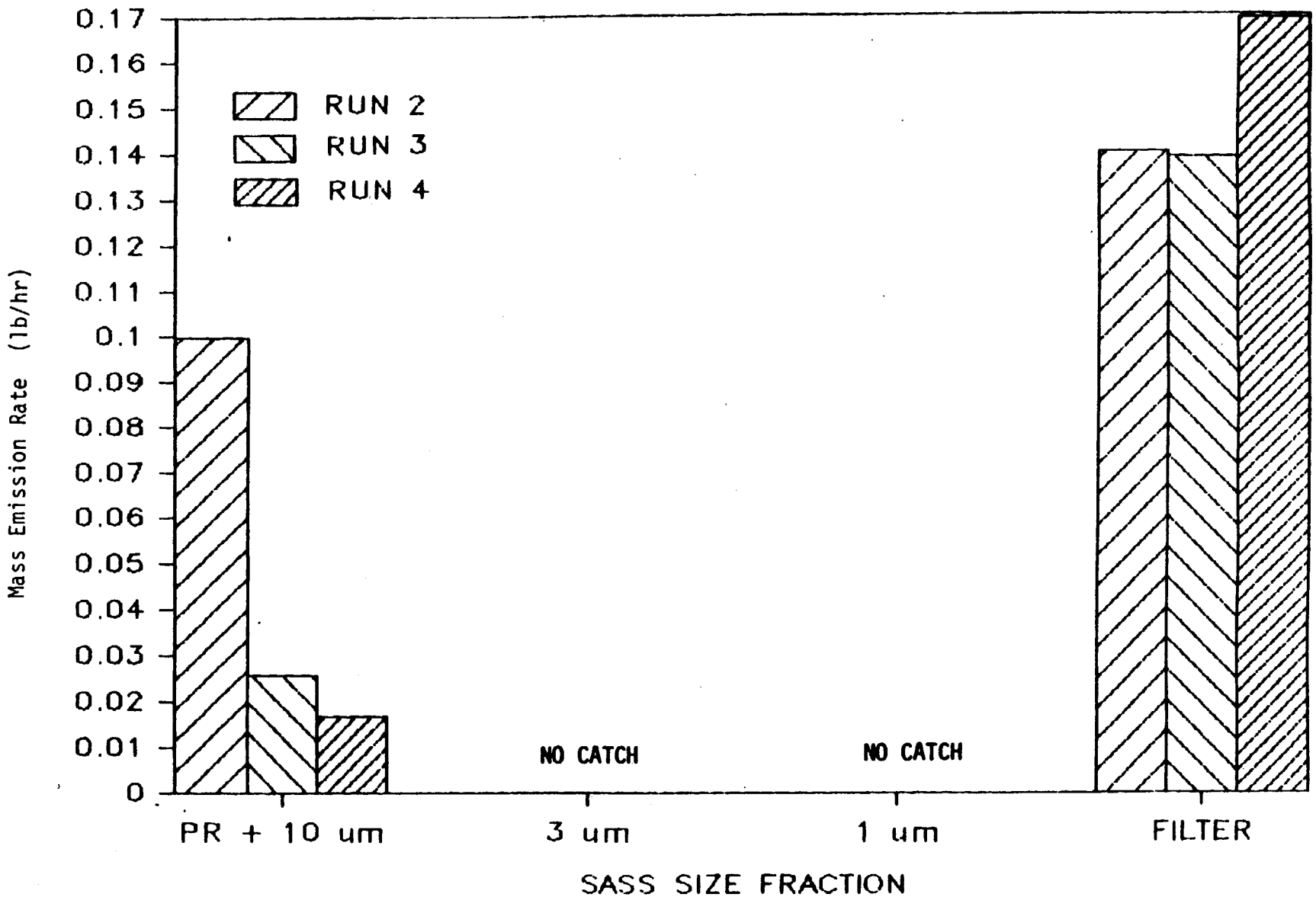


Figure 11. Particle Size Distribution of Particulate Emissions from the Scrubber

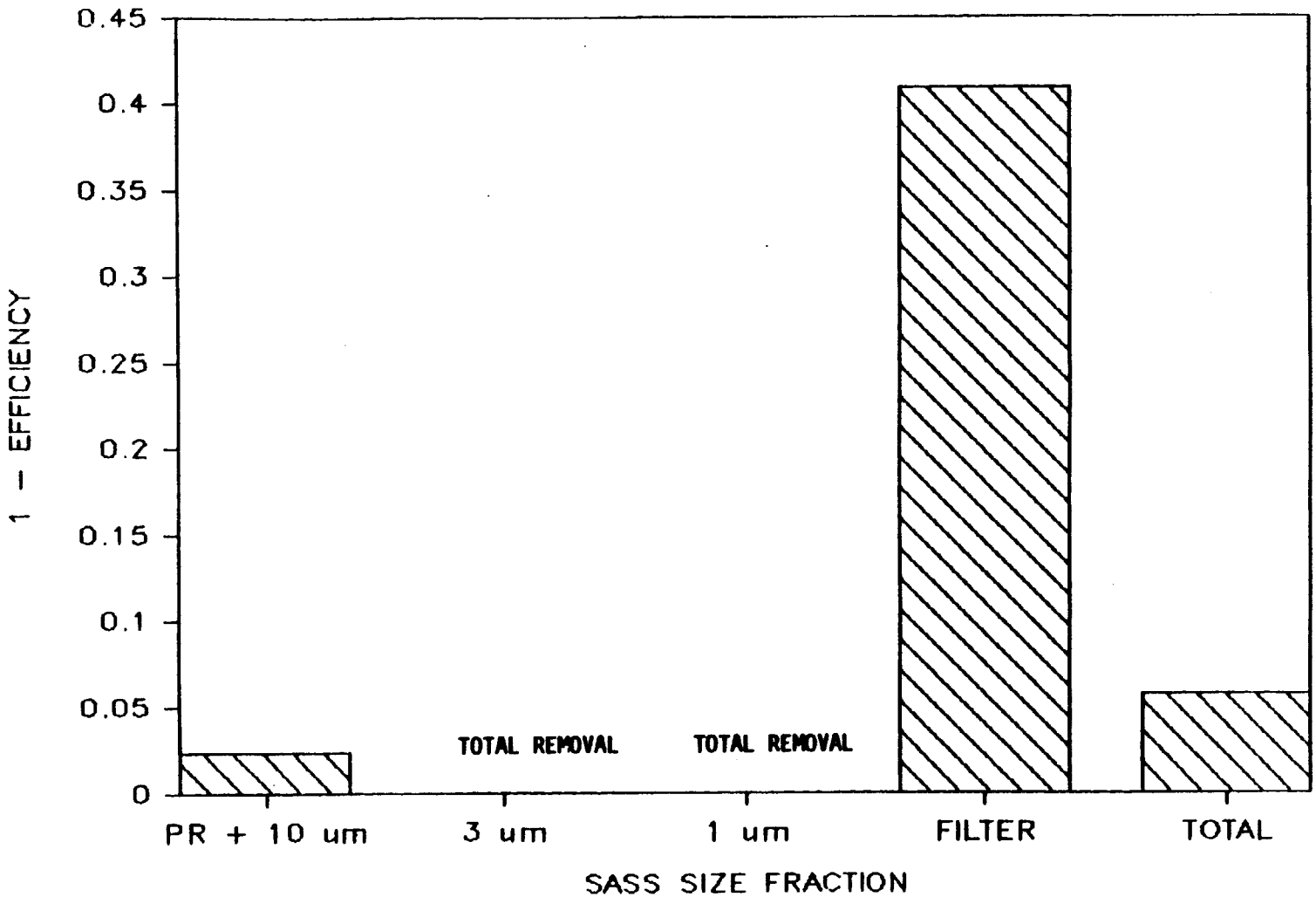


Figure 12. Particulate Removal Efficiency by SASS Train Size Fraction for the Scrubber

TABLE 18. AVERAGE TRACE METALS PARTICLE SIZE DISTRIBUTION IN THE UNCONTROLLED INCINERATOR EMISSIONS (Scrubber Test Runs)

	Percent of Metal in Size Fraction				
	PROBE + 10 um	3 um CYCLONE	1 um CYCLONE	FILTER CATCH	IMPINGER CATCH
ALUMINUM	11.90	6.54	10.94	70.62	0.00
ANTIMONY	58.34	22.65	1.80	17.21	0.00
ARSENIC	61.20	24.03	2.65	5.20	6.92
BARIUM	19.41	9.08	4.04	67.46	0.00
CADMIUM	17.30	19.72	4.51	58.34	0.12
CALCIUM	88.00	9.37	1.09	1.47	0.06
CHROMIUM	3.54	1.17	0.26	0.64	94.39
COBALT	12.73	5.55	0.52	2.39	78.82
COPPER	51.95	23.20	2.91	21.60	0.33
GOLD	75.63	12.53	0.00	11.84	0.00
IRON	46.46	16.85	1.86	1.20	33.63
LEAD	20.58	18.52	3.88	57.02	0.00
MAGNESIUM	66.78	29.78	1.61	1.73	0.09
MANGANESE	21.44	8.55	0.81	0.86	68.34
NICKEL	3.71	2.11	0.41	3.04	90.73
PHOSPHOROUS	65.03	27.21	2.72	2.00	3.04
SELENIUM	0.00	44.36	0.00	55.64	0.00
SILVER	30.60	43.65	4.08	21.67	0.00
SODIUM	61.24	14.85	1.95	21.96	0.00
SULFUR	3.84	2.64	0.35	1.99	91.18
TIN	17.63	13.05	2.80	66.52	0.00
TITANIUM	68.05	27.34	2.81	1.81	0.00
VANADIUM	31.23	21.66	3.07	44.03	0.00
ZINC	52.85	24.86	2.89	18.82	0.58

TABLE 19. AVERAGE TRACE METALS PARTICLE SIZE DISTRIBUTION IN THE UNCONTROLLED INCINERATOR EMISSIONS (Baghouse Test Runs)

	Percent of Metal in Size Fraction				
	PROBE + 10 um	3 um CYCLONE	1 um CYCLONE	FILTER CATCH	IMPINGER CATCH
ALUMINUM	21.30	12.59	16.87	49.24	0.00
ANTIMONY	56.65	24.92	2.67	15.76	0.00
ARSENIC	54.83	34.25	5.77	5.15	0.00
BARIUM	23.04	11.14	5.34	60.48	0.00
CADMIUM	17.89	31.75	9.45	40.48	0.44
CALCIUM	50.07	37.77	5.76	6.30	0.10
CHROMIUM	15.07	9.19	1.51	1.64	72.59
COBALT	8.90	5.00	0.84	1.41	83.85
COPPER	45.35	34.49	6.63	13.25	0.28
GOLD	45.93	30.99	6.94	16.14	0.00
IRON	52.20	33.83	5.31	1.29	7.36
LEAD	19.62	24.14	7.93	48.31	0.00
MAGNESIUM	52.14	40.32	5.07	2.40	0.07
MANGANESE	42.37	26.19	4.34	2.09	25.01
NICKEL	13.60	10.65	2.18	6.70	66.86
PHOSPHOROUS	48.39	41.83	6.45	2.04	1.28
SELENIUM	0.00	0.00	0.00	3.52	96.48
SILVER	12.84	55.05	16.79	15.32	0.00
SODIUM	37.07	32.42	7.30	22.29	0.91
SULFUR	2.80	3.17	0.71	1.79	91.53
TIN	15.69	18.79	5.28	57.91	2.34
TITANIUM	58.47	34.75	4.91	1.87	0.00
VANADIUM	25.97	51.94	4.45	16.96	0.67
ZINC	47.35	34.99	6.32	11.11	0.22

TABLE 25. AVERAGE TRACE METALS PARTICLE SIZE DISTRIBUTIONS FOR THE CONTROLLED SCRUBBER EMISSIONS

	Percent of Metal in Size Fraction		
	PROBE + 10 um	FILTER CATCH	IMPINGER CATCH
ALUMINUM	1.19	98.81	0.00
ANTIMONY	46.40	53.60	0.00
ARSENIC	3.53	96.47	0.00
BARIUM	5.67	94.33	0.00
CADMIUM	15.98	83.72	0.30
CALCIUM	46.80	47.88	5.32
CHROMIUM	43.35	1.49	55.16
COBALT	0.00	0.00	100.00
COPPER	1.18	86.92	11.90
GOLD	ND	ND	ND
IRON	27.81	26.85	45.34
LEAD	1.68	98.32	0.00
MAGNESIUM	97.63	0.00	2.37
MANGANESE	19.32	8.58	72.10
NICKEL	6.63	3.97	89.40
PHOSPHOROUS	29.90	70.10	0.00
SELENIUM	100.00	0.00	0.00
SILVER	6.88	93.12	0.00
SODIUM	8.63	89.94	1.43
SULFUR	8.69	20.87	70.45
TIN	0.20	99.80	0.00
TITANIUM	16.95	83.05	0.00
VANADIUM	13.23	85.88	0.88
ZINC	63.34	31.23	5.44

TABLE 31. AVERAGE TRACE METALS PARTICLE SIZE DISTRIBUTIONS FOR THE CONTROLLED BAGHOUSE EMISSIONS

	Percent of Metal in Size Fraction		
	PROBE + 10 um	FILTER CATCH	IMPINGER CATCH
ALUMINUM	1.53	98.47	0.00
ANTIMONY	34.67	8.10	57.23
ARSENIC	25.61	74.39	0.00
BARIUM	15.19	84.81	0.00
CADMIUM	73.47	15.81	10.72
CALCIUM	83.69	0.00	16.31
CHROMIUM	41.14	0.00	58.86
COBALT	28.31	0.00	71.69
COPPER	68.23	31.77	0.00
GOLD	0.00	100.00	0.00
IRON	33.38	9.09	57.52
LEAD	17.14	82.86	0.00
MAGNESIUM	59.96	34.76	5.29
MANGANESE	4.00	1.10	94.90
NICKEL	37.55	2.87	59.58
PHOSPHOROUS	10.39	7.94	81.67
SELENIUM	3.72	0.36	95.92
SILVER	82.17	17.83	0.00
SODIUM	58.90	41.10	0.00
SULFUR	0.14	0.02	99.83
TIN	0.00	3.76	96.24
TITANIUM	35.26	64.74	0.00
VANADIUM	91.59	8.41	0.00
ZINC	89.43	2.91	7.66