

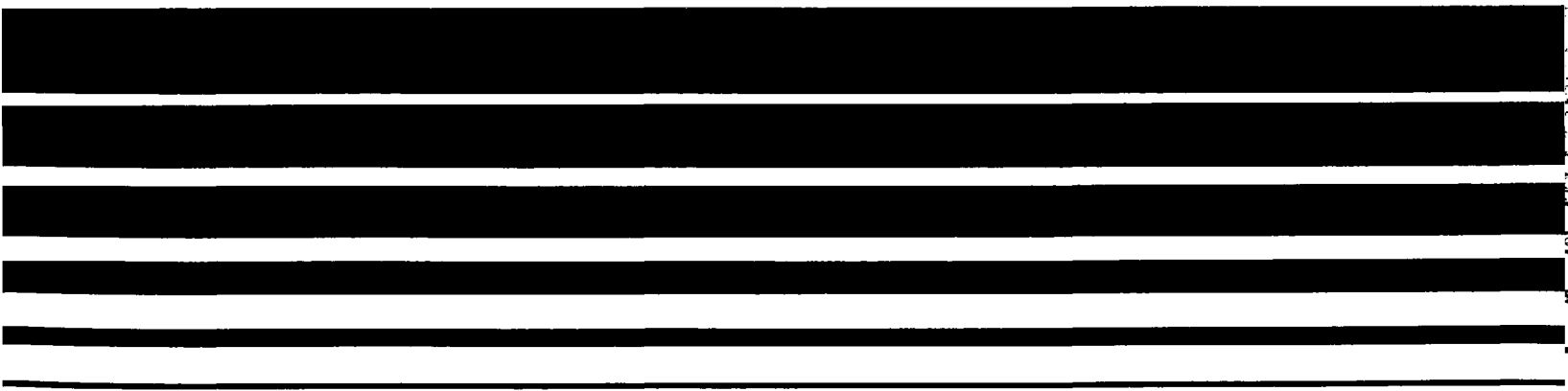
Air



Asphalt Concrete Industry

Emission Test Report T.J. Campbell Company Oklahoma City, Oklahoma

Volume 1



EMISSION TEST REPORT
T.J. CAMPBELL ASPHALT CONCRETE PLANT
OKLAHOMA CITY, OKLAHOMA

Final Report 83-ASP-4
Volume 1

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PREFACE

The work reported herein was performed by personnel from Radian Corporation, Midwest Research Institute (MRI), and the U.S. Environmental Protection Agency (EPA).

Radian's Project Director, Michael Fuchs, directed the field sampling and analytical effort and was responsible for summarizing the test and analytical data presented in this report. Sample analysis was performed by Radian Corporation in Austin, Texas. The test work was performed under EPA Contract No. 68-02-3850, Work Assignment No. 3.

MRI Project Monitor, William Terry, was responsible for monitoring process operations during the emissions testing program, and for reporting those data to EPA. Radian was responsible for incorporating the process data into report form (Section 3.0). The assistance of T.J. Campbell Company personnel contributed substantially to the success of this emission test program. T.J. Campbell Construction Company personnel included Mr. Ted Campbell, President, and Mr. O'Flynn Sewell, Plant Manager.

Mr. Jeffrey Telander, Office of Air Quality Planning and Standards, Industrial Studies Branch, EPA, served as Project Lead Engineer and was responsible for coordinating the process operations monitoring.

Mr. Clyde E. Riley, Office of the Air Quality Planning and Standards, Emission Measurements Branch, EPA, served as Task Manager and was responsible for overall test program coordination.

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SECTION 1

1.0 INTRODUCTION

Section 111 of the Clean Air Act of 1970 charges the Administrator of the U. S. Environmental Protection Agency (EPA) with the responsibility for establishing Federal standards of performance for new stationary sources which may significantly contribute to air pollution. When promulgated, these new source performance standards (NSPS's) are to reflect the degree of emission limitation achievable through application of the best demonstrated emission control technology. Emission data, obtained from selected industrial sources, are used in the development and/or review of NSPS regulations. Information is presently being collected and analyzed for the NSPS review of the asphalt concrete industry.

1.1 BACKGROUND

An NSPS for asphalt concrete plants was promulgated March 8, 1974 and established a particulate limit of 0.04 grains per dry standard cubic foot and a visible emission limit of 20 percent opacity. Following a review of this NSPS in 1979, no revisions to the standard were proposed; however, a second review of the asphalt concrete NSPS was initiated in November of 1982. As part of this review, particulate and opacity limits are being evaluated for plants utilizing recycle asphalt pavement (RAP). The review of the NSPS was requested by the National Asphalt Pavement Association (NAPA). The request was made from the concern that possible higher emissions (particulate and visible) were being generated during asphalt concrete production utilizing RAP. Increased hydrocarbon emissions during RAP utilization are considered to result in greater plume opacity due to the generation of a "blue haze" created by condensed hydrocarbons.

EPA's Office of Air Quality Planning and Standards selected the T. J. Campbell Construction Co. asphalt concrete plant in Oklahoma City, Oklahoma, as an emission test program site. Selection was based upon (1) utilization of RAP, (2) prior results obtained during NSPS compliance testing, and (3) suitability for testing.

1.2 OBJECTIVES

The purpose of the test program was to obtain and evaluate emission data (particulate matter, hydrocarbons, and visible emissions) from an asphalt concrete plant processing RAP. The plant was tested during conventional and recycle operations to provide a basis for comparison of the two operational modes to the promulgated NSPS.

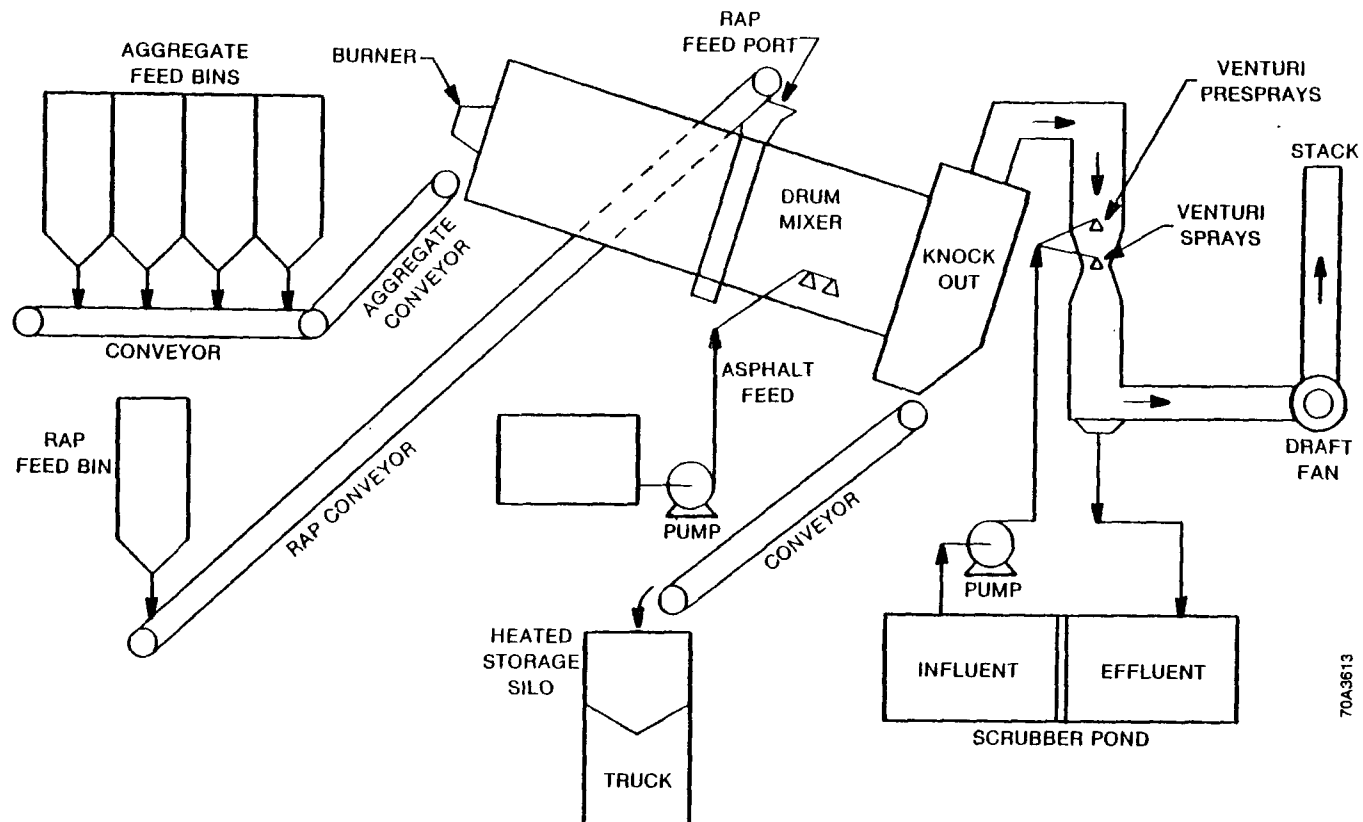
1.3 BRIEF PROCESS DESCRIPTION

Figure 1-1 presents a schematic of the asphalt concrete process. Following are descriptions of conventional and recycle operations at the T. J. Campbell plant.

1.3.1 Conventional Operation

Conventional operation is the term used to denote process operation when feeding only virgin aggregate, i.e., unused aggregate material, to the drum mixer. The virgin aggregate is loaded into the natural gas-fired rotary drum mixer via a belt conveyor. The quantity and mix of virgin aggregate is fed from four bins and controlled by a computer located in the control room. Liquid asphalt is injected into the drum about three-fourths of the distance of the drum from the burner end. The asphalt concrete falls from the drum onto a conveyor and is transported to any of three storage silos for truck load-out.

Gaseous emissions from the drum enter a knockout box which reduces the gas velocity to allow further reduction of particulate matter by settling.



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Figure 1-1. Schematic of asphalt concrete plant process and emission control equipment.

From the knockout box, the emissions are ducted to a wet venturi scrubber. In the duct work between the knockout box and venturi are water sprays to cool the emission gases. Water is also injected at the venturi throat. Additional water is flushed through a collection box below the venturi. Scrubber water is contained in two earthen ponds totaling about 120 feet by 24 feet with an effective depth of 3 to 6 feet. Scrubber effluent flows into the end of one pond while scrubber supply water is pumped from the end of the other pond. The ponds are divided by a dike which serves as a weir to reduce the suspended particulate matter in the scrubber water supply pond.

1.3.2 Recycle Operation

Recycle operation differs from conventional operation in that RAP replaces a portion of the virgin aggregate in the rotary drum mixture. The remainder of the RAP or recycle process is as described in Section 1.3.1. The advantages of recycle operation include use of less virgin aggregate, usually in areas with a limited supply of virgin aggregate, and the use of less asphalt cement due to the inclusion of asphalt material in the RAP.

1.4 EMISSIONS MEASUREMENT PROGRAM

The measurement program was conducted at the T. J. Campbell Construction Co. asphalt concrete plant in Oklahoma City, Oklahoma, November 7-15, 1983. The emission tests were designed to characterize and quantify uncontrolled (venturi scrubber inlet) and controlled (venturi scrubber outlet) emissions from the conventional and recycle asphalt operations.

Radian personnel were responsible for sampling and analyzing process emissions. Midwest Research Institute (MRI) was responsible for coordinating the test program with plant officials and for assuring that operating conditions for process and control equipment were suitable for the test program. MRI was also responsible for monitoring and recording all necessary process and control equipment operating parameters.

1.4.1 Test Parameters of Interest

1.4.1.1 Particulate Mass Loading--

Total particulate loading measurements were performed simultaneously at the scrubber inlet (uncontrolled) and outlet (controlled) using a modified version of EPA Method 5E. Three particulate mass test runs were conducted during conventional operation and three were conducted during recycle operation.

1.4.1.2 Total Organic Carbon and Extractable Organics--

Total organic carbon (TOC) and extractable organics samples were collected at the scrubber inlet and outlet simultaneously during the EPA Method 5E determinations described in Section 1.4.1.1. Each sample consisted of organics that condensed on the glassware downstream of the filter holder and in the first two impingers containing 0.1N NaOH. TOC impinger samples (0.1N NaOH impinger solutions) were analyzed to determine the total organic carbon and the extractable organics content. Three test runs were conducted during both conventional and recycle operation.

1.4.1.3 Trace Metals--

During one recycle and one conventional particulate and TOC/extractable organics test run, a pair of nitric acid (HNO_3) impingers were incorporated in the sampling train to collect volatile trace metals samples. Particulate matter collected during the respective runs was also analyzed for trace metals. Both uncontrolled and controlled emissions were characterized for trace metals.

1.4.1.4 Gas Stream Analysis--

The CO_2 and O_2 concentrations of the inlet and outlet flue gases were determined during recycle and conventional operations using an Orsat O_2/CO_2 apparatus as specified in EPA Method 3.

1.4.1.5 Particle Size Distribution--

Three particle size distribution (PSD) test runs were performed for uncontrolled emissions during conventional operation, and one inlet PSD run was performed during recycle operation. The presence of a water mist in the scrubber outlet gas stream prevented the collection of acceptable PSD data for controlled emissions.

1.4.1.6 Polynuclear Aromatic Hydrocarbons--

One inlet sample and one outlet sample were collected during conventional and recycle operations for polynuclear aromatic hydrocarbons (PAH).

1.4.1.7 Scrubber Water Samples and Operations Monitoring--

The two process waters sampled were scrubber water to the venturi and scrubber water from the venturi. Grab samples of process waters were collected during each recycle and conventional particulate/TOC and PAH run. All samples were composited and analyzed for total dissolved solids, total suspended solids, and total organic carbon. Selected samples were analyzed for polynuclear aromatic hydrocarbons and trace metals.

The temperature and pH of water entering and exiting the scrubber were measured at the respective sampling locations coincident with the conventional and recycle process sampling.

Scrubber water flow rates to the venturi were monitored at two locations: total flow to the venturi and flow to the venturi throat. Flow rate data were recorded during each emission test run.

1.4.1.8 Process Samples and Production Monitoring--

Grab samples of the three process solids streams virgin aggregate, RAP, and asphalt cement were obtained during the test program. Virgin aggregate and RAP were analyzed for moisture content. No analyses were performed on the asphalt cement samples.

MRI monitored and recorded the process operations data presented in this report.

1.5 DESCRIPTION OF REPORT SECTIONS

The remaining sections of this report present the Summary and Discussion of Results (Section 2), Process Description and Operation (Section 3), Location of Sampling Points (Section 4), Sampling and Analytical Methodology (Section 5), and Quality Assurance Procedures (Section 6). Detailed descriptions of methods and procedures, field and laboratory data, and calculations are presented in the various appendices, as indicated in the Table of Contents.

SECTION 2

2.0 SUMMARY AND DISCUSSION OF RESULTS

This section includes a presentation and discussion of the results of emission and process characterization tests conducted at the T. J. Campbell asphalt concrete plant in Oklahoma City, Oklahoma. Uncontrolled and controlled emission streams were tested. Process characterization included testing of scrubber waters and feed materials. Testing was conducted during both conventional and recycle operation.

Particulate mass, total organic carbon, and extractable organics test results are presented in Sections 2.1, 2.2, and 2.3, respectively. A comparison of total organic carbon emissions and extractable organics emissions during conventional and recycle operation is presented in Section 2.4. Sections 2.5 and 2.6 present trace metal and polynuclear aromatic hydrocarbon results, respectively. Particle size distribution data and visible emission results are presented in Sections 2.7 and 2.8. Scrubber characterization results and process sampling results are presented in Sections 2.9 through 2.11.

Difficulties encountered in either sample collection or process control during testing are discussed as applicable to data interpretation. The test results are also discussed and comparisons made, when applicable, to help explain variabilities or discrepancies within the test results.

Additional field data may be found in Appendices A and C. Additional analytical data may be found in Appendix E.

2.1 PARTICULATE EMISSION RESULTS

A modified version of EPA Method 5E was used to collect particulate mass samples during conventional and recycle operation. Particulate emission results, identified in the data tables as the "front-half catch," are presented and discussed in this section.

2.1.1 Conventional Operation Particulate Emission Results

Table 2-1 (English units) and Table 2-2 (metric units) present results of the uncontrolled and controlled particulate emission tests performed during conventional operation. Three uncontrolled and controlled particulate emission sampling runs were conducted simultaneously during conventional operation. The three conventional operation runs are designated as C-1, C-2, and C-3.

Uncontrolled particulate loadings were 7.60, 8.49, and 5.58 grains per dry standard cubic feet (gr/DSCF) for Runs C-1, C-2, and C-3, respectively. The corresponding controlled particulate emissions were 0.0550, 0.0814, and 0.0332 gr/DSCF for Runs C-1, C-2, and C-3, respectively. The average controlled particulate mass loading was 0.0565 gr/DSCF, which is above the present NSPS standard of 0.04 gr/DSCF. The particulate (front-half catch) collection efficiency of the wet venturi scrubber was 99.3, 99.1, and 99.4 percent for Runs C-1, C-2, and C-3, respectively.

2.1.2 Recycle Operation Particulate Emission Results

Table 2-3 (English units) and Table 2-4 (metric units) present results of the uncontrolled and controlled particulate emission tests performed during recycle operation. Three uncontrolled and controlled particulate emission sampling runs were conducted simultaneously during recycle operation. The three recycle operation runs are designated as R-1, R-2, and R-3.

TABLE 2-1. SUMMARY OF PARTICULATE AND TOTAL ORGANIC CARBON EMISSIONS
DURING CONVENTIONAL OPERATION (ENGLISH UNITS)

Date Run Number Type Emissions	11/12		11/13		11/14		Average	
	C-1		C-2		C-1			
	Uncontrolled	Controlled	Uncontrolled	Controlled	Uncontrolled	Controlled	Uncontrolled	Controlled
Scrubber Pressure Drop (in. H ₂ O)	13.5		13.4		13.5		13.5	
Scrubber Water Flow Rate (GPM)	219		219		215		218	
Production Rate (ton/hr)	244		235		213		231	
Process Mix Type	B-Mix		B/C Mix		M-Mix		---	
Average Opacity (Percent) Mean, Range	0 (0-1.5)		0 (-0-)		N/A		0	
<u>Particulate and Total Organic Carbon (TOC) Results</u>								
<u>Front Half Catch - Particulate</u> (probe, cyclone, and filter)								
mg-mass	9360	172	10,800	244	6950	104	9040	173
gr/DSCF	7.60	0.0550	8.49	0.0814	5.58	0.0332	7.22	0.0565
lbs/hr*	762	5.53	910	8.29	599	3.45	757	5.76
lbs/ton production	3.12	0.0226	3.87	0.0353	2.81	0.0162	3.27	0.0247
Collection Efficiency Percent**	99.3		99.1		99.4		99.2	
<u>Back Half Catch - TOC</u> (impinger solutions and rinses)								
mg-mass	253	166	553	417	370	405	392	329
gr/DSCF	0.205	0.0532	0.434	0.139	0.297	0.129	0.312	0.107
lbs/hr*	20.5	5.34	43.6	14.2	31.8	13.4	32.0	11.0
lbs/ton production	0.0840	0.0219	0.186	0.0604	0.149	0.0629	0.139	0.0476
Collection Efficiency Percent**	73.9		67.5		57.8		65.7	
<u>Total Catch</u>								
mg-mass	9610	338	11,400	661	7320	509	9430	502
gr/DSCF	7.80	0.108	8.92	0.220	5.88	0.162	7.53	0.164
lbs/hr*	782	10.9	954	22.5	631	16.8	789	16.7
lbs/ton production	3.20	0.0445	4.06	0.0957	2.96	0.0791	3.41	0.0731
Collection Efficiency Percent**	98.6		97.6		97.3		97.9	

†Average emission rate of concentration and area-ratio methods (Table 2-10)

N/A = not available

*lbs/hr controlled emission rate based on gas flow rate using saturation volume for the moisture content of the gas

**Collection efficiency percent determined using lbs/hr values

TABLE 2-2. SUMMARY OF PARTICULATE AND TOTAL ORGANIC CARBON EMISSIONS
DURING CONVENTIONAL OPERATION (METRIC UNITS)

Date Run Number Type Emissions	11/12 C-1		11/13 C-2		11/14 C-3		Average	
	Uncontrolled	Controlled	Uncontrolled	Controlled	Uncontrolled	Controlled	Uncontrolled	Controlled
Scrubber Pressure Drop (in. H ₂ O)	34.3		34.0		34.3		34.3	
Scrubber Water Flow Rate (GPM)	13.8		13.8		13.6		13.7	
Production Rate (ton/hr)	61.5		59.2		53.7		58.1	
Process Mix Type	B-Mix		B/C Mix		M-Mix		---	
Average Opacity (Percent) Mean, Range	0 (0-1.5)		0 (-0-)		N/A		0	
<u>Particulate and Total Organic Carbon (TOC) Results</u>								
<u>Front Half Catch - Particulate</u> (probe, cyclone, and filter)								
mg-mass	9360	172	10,800	244	6950	104	9040	173
mg/DSCM	17,400	126	19,400	186	12,800	76.0	16,500	129
g/s*	96.1	0.697	115†	1.05	75.5	0.435	95.5	0.726
g/kg production	1.56	0.0113	1.94	0.0177	1.41	0.00810	1.64	0.0125
Collection Efficiency Percent**	99.3		99.1		99.4		99.2	
<u>Back Half Catch - TOC</u> (impinger solutions and rinses)								
mg-mass	253	166	553	417	370	405	392	329
mg/DSCM	470	122	995	319	681	296	715	245
g/s*	2.59	0.673	5.50	1.79	4.01	1.69	4.03	1.39
g/kg production	0.0420	0.0109	0.0931	0.0302	0.0746	0.0315	0.0694	0.0239
Collection Efficiency Percent**	73.9		67.5		57.8		65.6	
<u>Total Catch</u>								
mg-mass	9610	338	11,400	661	7320	509	9430	502
mg/DSCM	17,900	248	20,400	505	13,500	372	17,200	374
g/s*	98.7	1.37	120	2.84	79.5	2.12	99.5	2.12
g/kg production	1.60	0.0222	2.03	0.0479	1.48	0.0396	1.71	0.0364
Collection Efficiency Percent**	98.6		97.6		97.3		97.9	

†Average emission rate of concentration and area-ratio methods (Table 2-10)

N/A = not available

*g/s controlled emission rate based on gas flow rate using saturation volume for the moisture content of the gas

**Collection efficiency percent determined using g/s values

TABLE 2-3. SUMMARY OF PARTICULATE AND TOTAL ORGANIC CARBON EMISSIONS
DURING RECYCLE OPERATION (ENGLISH UNITS)

Date Run Number Type Emissions	11/11 R-1		11/11 R-2		11/12 R-3		Average	
	Uncontrolled	Controlled	Uncontrolled	Controlled*	Uncontrolled	Controlled	Uncontrolled	Controlled
Scrubber Pressure Drop (in. H ₂ O)	13.8		13.8		13.9		13.8	
Scrubber Water Flow Rate (GPM)	223		220		219		221	
Production Rate (ton/hr)	229		250		236		238	
Process Mix Type	Recycle-A		Recycle-A		Recycle-A		--	
Average Opacity (Percent) Mean, Range	1.4 (0-5.8)		0.3 (0-1.7)		N/A		0.85	
<u>Particulate and Total Organic Carbon (TOC) Results</u>								
<u>Front Half Catch - Particulate</u> (probe, cyclone, and filter)								
mg-mass	4380	84.0	5,260	88.2	5570	111	5070	94.5
gr/DSCF	3.24	0.0227	4.37	0.0229	3.75	0.0286	3.79	0.0247
lbs/hr	411	2.72	499†	2.76†	474†	3.42	461	2.97
lbs/ton production	1.79	0.0119	2.00	0.0110	2.01	0.0145	1.94	0.0125
Collection Efficiency Percent**	99.3		99.4		99.3		99.4	
<u>Back Half Catch - TOC</u> (impinger solutions and rinses)								
mg-mass	605	219	788	375	748	618	714	404
gr/DSCF	0.448	0.0592	0.655	0.0975	0.504	0.159	0.536	0.105
lbs/hr	56.8	7.09	69.1	11.1	60.5	19.0	62.1	12.4
lbs/ton production	0.248	0.0310	0.276	0.0445	0.256	0.0805	0.261	0.0520
Collection Efficiency Percent**	87.5		83.9		68.6		80.4	
<u>Total Catch</u>								
mg-mass	4980	303	6050	463	6320	729	5780	498
gr/DSCF	3.69	0.0819	5.02	0.120	4.25	0.188	4.33	0.130
lbs/hr	468	9.81	568	13.8	534	22.4	523	15.3
lbs/ton production	2.04	0.0430	2.28	0.0555	2.27	0.095	2.20	0.0645
Collection Efficiency Percent**	97.9		97.6		95.8		97.1	

†Average emission rate of concentration and area-ratio methods (Table 2-10)

N/A = not available

*lbs/hr controlled emission rate based on gas flow rate using saturation volume for the moisture content of the gas

**Collection efficiency percent determined using lbs/hr values

TABLE 2-4. SUMMARY OF PARTICULATE AND TOTAL ORGANIC CARBON
EMISSION DURING RECYCLE OPERATION (METRIC UNITS)

Date	11/11		11/11		11/12		Average	
Run Number	R-1		R-2		R-3			
Type Emissions	Uncontrolled	Controlled	Uncontrolled	Controlled*	Uncontrolled	Controlled	Uncontrolled	Controlled
Scrubber Pressure Drop (in. H ₂ O)		5.43		5.43		5.47		5.44
Scrubber Water Flow Rate (GPM)		14.1		13.9		13.8		13.9
Production Rate (ton/hr)		57.8		63.1		59.6		60.2
Process Mix Type		Recycle-A		Recycle-A		Recycle-A		---
Average Opacity (Percent) Mean, Range		1.4 (0-5.8)		0.3 (0-1.7)		N/A		0.85
<u>Particulate and Total Organic Carbon (TOC) Results</u>								
<u>Front Half Catch - Particulate</u>								
(probe, cyclone, and filter)								
mg-mass	4380	84.0	5260	88.2	5570	111	5070	94.5
mg/DSCM	7420	51.9	10,000	52.5	8590	65.4	8670	56.6
g/s	51.8	0.343	62.9†	0.348†	59.8†	0.431	58.2	0.374
g/kg production	0.896	0.00593	0.919	0.00550	1.01	0.00726	0.942	0.00622
Collection Efficiency Percent**		99.3		99.4		99.3		99.4
<u>Back Half Catch - TOC</u>								
(impinger solutions and rinses)								
mg-mass	605	219	788	375	748	618	714	401
mg/DSCM	1030	136	1500	224	1160	365	1230	242
g/s	7.16	0.894	8.71	1.40	7.63	2.40	7.83	1.54
g/kg production	0.124	0.0155	0.138	0.0222	0.128	0.0402	0.130	0.0254
Collection Efficiency Percent**		87.5		83.9		68.6		80.4
<u>Total Catch</u>								
mg-mass	4980	303	6050	463	6320	729	5780	498
mg/DSCM	8450	188	11,500	276	9750	430	9900	299
g/s	59.0	1.24	71.6	1.74	67.4	2.83	66.0	1.93
g/kg production	1.02	0.0215	1.06	0.0276	1.14	0.0475	1.07	0.0320
Collection Efficiency Percent**		97.9		97.6		95.8		97.1

†Average emission rate of concentration and area-ratio methods (Table 2-10)

N/A = not available

*gS controlled emission rate based on gas flow rate using saturation volume for the moisture content of the gas

**Collection efficiency percent determined using g/s values

Uncontrolled particulate loadings were 3.24, 4.37, and 3.75 gr/DSCF for Runs R-1, R-2, and R-3, respectively. The corresponding controlled particulate emissions were 0.0227, 0.0229, and 0.0286 gr/DSCF for Runs R-1, R-2, and R-3, respectively. The average controlled particulate mass loading was 0.0247 gr/DSCF which is below the present NSPS standard of 0.04 gr/DSCF. The particulate (front-half catch) collection efficiency of the wet venturi scrubber was 99.3, 99.4, and 99.3, for Tests R-1, R-2, and R-3, respectively.

2.1.3 Discussion of Particulate Emission Test Results

Three topics are discussed in this section. They include:

- o difficulties encountered in collecting particulate mass samples,
- o anisokinetic effect on particulate mass emission calculations, and
- o conventional versus recycle particulate mass emissions.

2.1.3.1 Particulate Mass Sampling Difficulties--

Problems encountered during particulate mass sampling included:

- o source sampling equipment malfunctions, and
- o fluctuations in the moisture content of the process gas streams.

Glassware broke twice during controlled emission sampling Run C-1. When this occurred, sampling was stopped, the broken glassware was replaced, a new leak check was performed, and sampling was resumed. The probe liner heater also shorted out during the same run (C-1). After the liner heater shorted out, the probe was disconnected from the sampling train, the liner end and the nozzle were capped, and the probe was taken to the mobile lab

for cleanup using the procedures outlined in Section 5. The shorted-out liner was then removed and a clean glass liner inserted in the probe. The sampling train was reassembled and after a leak check, sampling was resumed. It is felt that the equipment malfunctions encountered during Run C-1 did not adversely affect or bias the data obtained during the sampling run.

It is believed that fluctuations in the moisture content of the virgin aggregate and recycle asphalt pavement feed caused the moisture content of the uncontrolled emissions gas stream to fluctuate. Two uncontrolled sampling runs conducted on November 11, 1983 using the same mix (Recycle A), had flue gas moisture values that varied by over 7%. To help alleviate this problem, a wet bulb/dry bulb reading was taken prior to and during uncontrolled sampling runs conducted in the latter stages of the testing effort. This procedure provided more accurate data, but the uncontrolled gas moisture content was still observed to fluctuate. In the case of Run C-2, the measured moisture content was 8% higher than the wet bulb/dry bulb value measured immediately prior to the run.

During four of the six controlled particulate emission runs, the moisture values determined from the impinger weight gains exceeded the temperature dependent saturation volume as determined by a psychrometric chart. Sampling runs with impinger moisture values exceeding the saturation volume indicate the presence of water mist. The saturation volume for those four runs was used as the moisture value for all further calculations.

2.1.3.2 Discussion of Anisokinetic Test Results--

Fluctuations in the moisture content of the uncontrolled emissions gas stream and the presence of water mist in the controlled emissions gas stream resulted in anisokinetic sampling rates during four particulate mass runs. These included:

- o Controlled Particulate Emissions Run R-2.
- o Uncontrolled Particulate Emissions Run C-2.

- o Uncontrolled Particulate Emissions Run R-2.
- o Uncontrolled Particulate Emissions Run R-3.

In order to allow a review of possible effects introduced by anisokinetic sampling into the normal mass emission rate calculations, two methods were used to calculate mass emission rates for the particulate mass emission runs. The method normally used to calculate particulate mass emission rates is the concentration method. This method involves multiplying the particulate loading (sample mass divided by gas sample volume) by the volumetric gas flow rate. The second particulate mass emission rate calculation method is the area-ratio method. Based on the area-ratio method, the sample mass is divided by the sampling time and then multiplied by the ratio of the stack area to nozzle area to obtain the particulate mass flow rate.

The difference between the emission rates calculated by these two methods is an estimate of the maximum bias in the measured emission rate due to anisokinetic sampling. Table 2-5 includes particulate emission rates calculated using the concentration method and the area-ratio method. The average particulate emission rate listed in Table 2-5 was used as the true value for the particulate emission runs that were outside of the isokinetic sampling limit of 100 \pm 10 percent

2.1.3.3 Discussion of Particulate Emissions During Conventional and Recycle Operation--

A major objective of this program is to evaluate how the particulate emissions change during conventional asphalt concrete production and production using recycle asphalt pavement. Based on the particulate emissions data presented in Tables 2-1 through 2-4, four general observations were made. These include:

- o The NSPS particulate emission standard (0.04 grains/DSCF) was met during all particulate emission runs except for Runs C-1 and C-2.

TABLE 2-5. COMPARISON OF PARTICULATE EMISSIONS CALCULATED BY THE CONCENTRATION METHOD VS. AREA-RATIO METHOD

Date	Time	Sample Description	Percent Isokinetic	Emission Rate lbs/hr		Average
				Concentration Method	Area-Ratio Method	
Uncontrolled Emissions						
11/12	1151-1243	Run C-1	110	762	837	800
11/13	0956-1050	Run C-2	113	853	967	910
11/14	0827-0936	Run C-3	104	599	622	610
Controlled Emissions						
11/12	1129-1319	Run C-1	102	5.53	5.65	5.59
11/13	0853-1112	Run C-2	96	8.29	8.01	8.15
11/14	0813-1003	Run C-3	99	3.45	3.43	3.44
Uncontrolled Emissions						
11/11	0843-0937	Run R-1	95	411	391	415
11/11	1645-1730	Run R-2	117	460	538	499
11/12	0748-0846	Run R-3	111	451	498	474
Controlled Emissions						
11/11	0839-1433	Run R-1	104	2.72	2.85	2.78
11/11	1515-1704	Run R-2	111	2.61	2.90	2.76
11/12	0713-0900	Run R-3	107	3.42	3.66	3.54
Uncontrolled Emissions ^a						
11/11	1253-1330	PSD R-1	108	486	528	507
11/12	1418-1520	PSD C-1	103	1080	1117	1098
11/14	1014-1143	PSD C-2	103	685	710	698
11/15	1225-1440	PSD C-3	112	1040	1170	1105

^aCalculated particulate size distribution sampling mass emission rate results may not be representative of actual stack mass emission rate.

- o The particulate collection efficiency of the venturi scrubber varied from only 99.1 to 99.4 percent.
- o The data indicate that the type of mix material fed to the drum during each run has a direct effect on the uncontrolled and controlled particulate mass rates, and
- o Over the range tested, the production rate of either conventional mix or recycle mix does not appear to significantly affect the uncontrolled or controlled particulate mass loading.

The controlled particulate mass loadings rates were 0.0550 and 0.0814 gr/DSCF for Runs C-1 and C-2, respectively, which is above the present NSPS standard. Achievement of the NSPS limit during Runs C-3, R-1, R-2, and R-3 was not due to improved performance of the venturi scrubber, but instead due to a decrease in the level of uncontrolled emissions. A major difference between Runs C-1 and C-2 and the rest of the runs is the type of raw materials feed to the drum during each run.

Table 2-6 includes a summary of the asphalt concrete mixes typically produced by the T. J. Campbell Construction Company. During Run C-1, Type B mix was being produced. Type B mix was also produced during most of Run C-2, with some production of Type C mix near the end of Run C-2. Type M mix was produced during Run C-3 and Type A recycled asphalt mix was produced during Runs R-1, R-2, and R-3.

Type B, C, and M mixes are top mixes that contain about 20 to 24 percent sand. The Type M mix uses washed sand while Type B and C mixes use unwashed sand. The washed sand is believed to contain less fines and adhered dissolved salts. Type A recycled asphalt mix is a base mix and contains about 9.8 percent sand. Run results indicate that the type (washed/

TABLE 2-6. AGGREGATE ADDITIONS FOR TYPICAL MIXES AT T. J. CAMPBELL
 CONSTRUCTION COMPANY, OKLAHOMA CITY, OKLAHOMA

Type Mix	Asphalt Cement Added (Percent)	Bin No.	Percent of Aggregate	Bin Contents	Moisture Content Estimated By Plant Personnel (Percent)
Type B (virgin)	4.9	1	45	Screenings	2.5
		2	22	Sand	12.0
		3	8	3/4 in. rock	1.5
		4	25	5/8 in. rock	2.0
Type C	5.0	1	43	Screenings	1.5
		2	24	Sand	12.0
		3	33	3/8 in. rock	1.5
		4	0	--	---
Type M	5.0	1	53	Screenings	2.0
		2	20	Sand (washed)	11.0
		3	0	--	---
		4	27	5/8 in. rock	2.0
Type A (recycle)	3.9 (4.6) ^a	1	18	Screenings	2.5
		2	9.8	Sand	12.0
		3	0	--	---
		4	47.2	1.5 in. rock	2.0
		RAP	25	RAP	2.0
Hot Sand (recycle)	4.5 (4.6) ^a	1	15	Screenings	2.0
		2	60	Sand	11.0
		3	--	--	--
		4	--	--	--
		RAP	25	RAP	2.0

^aAsphalt cement in the RAP.

unwashed) and quantity (9.8%/20-24%) of sand in the mix feed materials affect the concentration of particulate matter entrained in the emission gases.

2.2 TOTAL ORGANIC CARBON RESULTS

Controlled and uncontrolled total organic carbon (TOC) mass samples were collected simultaneously with particulate mass samples using the modified EPA Method 5E sampling train. The TOC content of the 0.1 N NaOH impinger and rinse solutions were analyzed directly using an instrumental technique. TOC results, identified in the data tables as the "back-half catch," are presented and discussed in this section.

2.2.1 Conventional Operation TOC Emission Results

Uncontrolled and controlled TOC results for conventional operation are presented in Table 2-1 (English units) and Table 2-2 (metric units). Uncontrolled TOC loadings were 0.205, 0.434, and 0.297 gr/DSCF for Runs C-1, C-2, and C-3, respectively. The controlled TOC loadings were 0.0532, 0.139, and 0.129 gr/DSCF for Runs C-1, C-2, and C-3, respectively. The TOC (back-half catch) collection efficiency of the wet venturi scrubber was 73.9, 67.5, and 57.8 percent for Runs C-1, C-2, and C-3, respectively.

2.2.2 Recycle Operation TOC Emission Results

Table 2-3 (English units) and Table 2-4 (metric units) present results of the uncontrolled and controlled TOC measurements performed during recycle operation. Uncontrolled TOC loadings were 0.448, 0.655, and 0.504 gr/DSCF for Runs R-1, R-2, and R-3, respectively. The controlled TOC loadings were 0.0592, 0.0975, and 0.159 gr/DSCF for Runs R-1, R-2, and R-3, respectively. The TOC collection efficiency of the wet venturi scrubber was 87.5, 83.9, and 68.6 percent for Runs R-1, R-2, and R-3, respectively.

2.2.3 Discussion of TOC Test Results

The uncontrolled TOC loadings varied from 0.205 to 0.434 gr/DSCF during conventional operation and from 0.448 to 0.655 gr/DSCF during recycle operation. The controlled TOC loadings varied from 0.0532 to 0.139 gr/DSCF during conventional operation and from 0.0592 to 0.159 gr/DSCF during recycle operation. Based on the limited data available, it is difficult to develop any correlations between process operation and the degree of variability in the uncontrolled and controlled TOC emissions during conventional and recycle operation.

The average uncontrolled TOC loading was approximately 72 percent greater during recycle operation (0.0536 gr/DSCF) as compared to conventional operation (0.0312 gr/DSCF). But the average controlled TOC loading during recycle operation (0.105 gr/DSCF) approximated the average controlled TOC loading during conventional operation (0.107 gr/DSCF). These data indicate that although the average uncontrolled TOC emissions increased during recycle operation, they did not result in an increase in controlled TOC emissions when compared to conventional TOC data. The average removal efficiency of the venturi scrubber increased from 65.7 percent during conventional operation to 80.4 percent during recycle operation.

2.3 EXTRACTABLE ORGANICS EMISSION RESULTS

Extractable organics analysis was performed on the same 0.1 N NaOH impinger solutions and rinses that TOC analysis was performed on (modified EPA Method 5E samples) with the addition of the inclusion of results of a trichloroethane rinse. An aliquot of the 0.1N NaOH samples were extracted with chloroform and diethyl ether. After evaporation at room temperature, the mass of extractable organics was determined gravimetrically. The trichloroethane rinses were also evaporated at room temperature to determine the mass of extractable organics gravimetrically. Tables 2-7 and 2-8 contain a summary of uncontrolled and controlled extractable organics and particulate emission results. Extractable organics are identified as the

TABLE 2-7. SUMMARY OF UNCONTROLLED PARTICULATE AND EXTRACTABLE ORGANICS EMISSIONS

DATE	11/12	11/11	11/13	11/11	11/14	11/12		
RUN NO.	C-1	R-1	C-2	R-2	C-3	R-3		
PROCESS OPERATION	CONVENTIONAL	RECYCLE	CONVENTIONAL	RECYCLE	CONVENTIONAL	RECYCLE	CONVENTIONAL	RECYCLE
VOLUME GAS SAMPLED (DSCF)	19.0	20.8	19.6	18.6	19.2	22.9	19.3	20.8
STACK GAS FLOW RATE (DSCFM)	11,700	14,800	11,700	12,300	12,500	14,000	12,000	13,700
STACK TEMPERATURE (°F)	298	296	289	314	304	317	297	309
PERCENT MOISTURE BY VOLUME	38.0	24.4	39.6	31.5	36.7	27.7	38.1	27.9
PERCENT ISOKINETIC	110	95	113	117	104	111	109	108
PRODUCTION RATE (tons/hr)	244	229	235	250	213	236	231	238
PARTICULATE - EXTRACTABLE ORGANICS RESULTS								
<u>FRONT HALF CATCH - PARTICULATE</u> (probe, cyclone, and filter)								
mg-mass	9360	4380	10,800	5260	6950	5570	9040	5070
gr/DSCF	7.60	3.24	8.49	4.37	5.58	3.75	7.22	3.79
lbs/hr	762	411	910†	499†	599	474†	757	461
lbs/ton production	3.12	1.79	3.87	2.00	2.81	2.01	3.28	1.94
<u>BACK HALF CATCH - EXTRACT- ABLE ORGANICS</u> (impinger solutions & rinses)								
mg-mass	217	208	72.3	169	163	113	151	163
gr/DSCF	0.176	0.154	0.0568	0.140	0.131	0.076	0.121	0.123
lbs/hr	17.6	19.5	5.70	14.7	14.0	9.12	12.4	14.4
lbs/ton production	0.0721	0.0852	0.0243	0.0588	0.0657	0.0386	0.0537	0.0605
PERCENT EXTRACTABLE ORGANICS*	2.26	4.54	0.62	2.86	2.28	1.88	1.61	3.02

† Average emission rate of concentration and area-ratio methods (Table 2-10).

* Percent Extractable Organics determined using lbs/hr values and is the percentage of extractable organics of the total catch.

TABLE 2-8. SUMMARY OF CONTROLLED PARTICULATE AND EXTRACTABLE ORGANICS EMISSIONS

DATE	11/12	11/11	11/13	11/11	11/14	11/12		
RUN NO.	C-1	R-1	C-2	R-2	C-3	R-3		
PROCESS OPERATION	CONVENTIONAL	RECYCLE	CONVENTIONAL	RECYCLE	CONVENTIONAL	RECYCLE	CONVENTIONAL	RECYCLE
VOLUME GAS SAMPLED (DSCF)	48.2	57.1	46.2	59.3	48.5	60.1	47.6	58.8
STACK GAS FLOW RATE (DSCFM)	11,700* (11,400)	14,000	11,900 (11,400)	13,300 (12,700)	12,100 (11,800)	14,000	11,900 (11,500)	13,800 (13,600)
STACK TEMPERATURE (°F)	159	147	155	152	153	143	156	147
PERCENT MOISTURE BY VOLUME	32.0 (32.3)	21.3	29.0 (32.3)	26.6 (30.6)	27.5 (29.7)	20.7	29.5 (32.1)	22.9 (24.2)
PERCENT ISOKINETIC	102 (105)	104	96 (100)	111 (116)	99 (102)	107	99 (102)	107 (109)
PRODUCTION RATE (tons/hr)	244	229	235	250	213	236	231	238
PARTICULATE - EXTRACTABLE ORGANICS RESULTS								
FRONT HALF CATCH - PARTICULATE (probe, cyclone, and filter)								
mg-mass	172	84.0	244	88.2	104	111	173	94.5
gr/DSCF	0.0550	0.0227	0.0814	0.0229	0.0332	0.0286	0.0565	0.0247
lbs/hr	5.53 (5.36)	2.72	8.29 (7.95)	2.76† (2.49)	3.45 (3.36)	3.42	5.76 (5.56)	2.97 (2.88)
lbs/ton production	0.0227 (0.0220)	0.0119	0.0353 (0.0338)	0.0110 (0.0100)	0.0162 (0.0158)	0.0145	0.0247 (0.0239)	0.0125 (0.0123)
BACK HALF CATCH - EXTRACT- ABLE ORGANICS (impinger solutions & rinses)								
mg-mass	245	86.8	81.1	229	87.7	130	138	149
gr/DSCF	0.0786	0.0235	0.0271	0.0596	0.0279	0.0334	0.0445	0.0388
lbs/hr	7.88 (7.65)	2.81	2.71 (2.65)	6.79 (6.46)	2.89 (2.82)	4.00	4.49 (4.37)	4.53 (4.42)
lbs/ton production	0.0323 (0.0314)	0.0123	0.0115 (0.0113)	0.0272 (0.0258)	0.0136 (0.0132)	0.0169	0.0191 (0.0186)	0.0188 (0.0183)
PERCENT EXTRACTABLE ORGANICS‡	58.8 (58.8)	50.8	24.6 (25.0)	71.1 (72.2)	45.6 (45.6)	53.9	43.8 (44.0)	60.4 (60.5)

NOTE: Top number based on saturation volume for moisture content of gas; (bottom number) is moisture content calculated using impinger catch indicating the presence of water mist.

† Average emission rate of concentration and area-ratio methods (Table 2-10).

‡ Percent Extractable Organics determined using lbs/hr values and is the percentage of extractable organics of the total catch.

"back-half catch" in Tables 2-7 and 2-8. The extractable organics results are presented and discussed in this section.

2.3.1 Conventional Operation Extractable Organics Emission Results

Uncontrolled extractable organics loadings were 0.176, 0.0568, and 0.131 gr/DSCF for Runs C-1, C-2, and C-3, respectively. The controlled extractable organics loadings were 0.0786, 0.0271, and 0.0279 gr/DSCF for Runs C-1, C-2, and C-3, respectively.

2.3.2 Recycle Operation Extractable Organics Emission Results

Uncontrolled extractable organics loadings were 0.154, 0.140, and 0.076 gr/DSCF for Runs R-1, R-2, and R-3, respectively. Controlled extractable organics loadings were 0.0235, 0.0596, and 0.0334 gr/DSCF for Runs R-1, R-2, and R-3, respectively.

2.3.3 Discussion of Extractable Organics Emission Test Results

The uncontrolled extractable organics loadings varied from 0.0568 to 0.176 gr/DSCF during conventional operation and from 0.076 to 0.154 gr/DSCF during recycle operation. The controlled extractable organics loadings varied from 0.0271 to 0.0786 gr/DSCF during conventional operation and from 0.0235 to 0.0596 gr/DSCF during recycle operation. Based on the limited data available, it is difficult to develop any correlations between process operation and the degree of variability in the uncontrolled and controlled extractable organics emissions during conventional and recycle operation.

The average uncontrolled extractable organics loading during conventional operation (0.121 gr/DSCF) approximated the average uncontrolled extractable organics loading during recycle operation (0.123 gr/DSCF). The average controlled extractable organics loading was approximately 15 percent greater during conventional operation (0.0445

gr/DSCF) as compared to recycle operation (0.0388 gr/DSCF). It is believed that the variability between the controlled extractable organics loadings is within the variability of the sampling and analytical techniques.

2.4 COMPARISON OF TOC AND EXTRACTABLE ORGANICS EMISSION RESULTS

Two analytical procedures were used during this program to quantify the concentration of uncontrolled and controlled organic emissions generated during conventional and recycle operation. An instrumental technique was used to determine the concentration of TOC present in the 0.1N NaOH impinger and rinse solutions generated during EPA Method 5E testing. The same samples were also analyzed using a gravimetric technique to determine the concentration of extractable organics. The main objective of performing both analyses on the same samples was to provide data that could be used to help assess the utility of both procedures in characterizing organic emissions from asphalt concrete plants.

2.4.1 Comparison of Uncontrolled TOC and Extractable Organic Emissions Results

Table 2-9 presents a comparison of uncontrolled TOC and extractable organics emissions during conventional and recycle operation. The average uncontrolled TOC loadings indicate that the uncontrolled organic emissions were about 72 percent greater during recycle operation (0.536 gr/DSCF) as compared to conventional operation (0.312 gr/DSCF). On the other hand the average uncontrolled extractable organics loadings indicate that the uncontrolled organic emissions were essentially the same during both recycle (0.123 gr/DSCF) and conventional (0.121 gr/DSCF) operations.

TABLE 2-9. COMPARISON OF UNCONTROLLED TOC AND EXTRACTABLE ORGANICS EMISSIONS

RUN NUMBER	C-1		C-2		C-3		R-1		R-2		R-3		AVERAGE			
PROCESS OPERATION	CONVENTIONAL		CONVENTIONAL		CONVENTIONAL		RECYCLE		RECYCLE		RECYCLE		CONVENTIONAL		RECYCLE	
DATE	11/12		11/13		11/14		11/11		11/11		11/12					
VOLUME GAS SAMPLES (DSCF)	19.0		19.6		19.2		20.8		18.6		22.9		19.3		20.8	
STACK GAS FLOW RATE (DSCFM)	11,700		11,700		12,500		14,800		12,300		14,000		12,000		13,700	
STACK TEMPERATURE (°F)	298		289		304		296		314		317		297		309	
PERCENT MOISTURE BY VOLUME	38.0		39.6		36.7		24.4		31.5		27.7		38.1		27.9	
PERCENT ISOKINETIC	110		113		104		95		117		111		109		108	
PRODUCTION RATE (TONS/HR)	244		235		213		229		250		236		231		238	
BACK HALF CATCH - ORGANICS RESULTS (impinger solutions & rinses)	EXT**		EXT.		EXT.		EXT.		EXT.		EXT.		EXT.		EXT.	
	TOC*	ORG.	TOC	ORG.	TOC	ORG.	TOC	ORG.	TOC	ORG.	TOC	ORG.	TOC	ORG.	TOC	ORG.
mg-mass	253	217	553	72.3	370	163	605	208	788	169	748	113	392	151	714	163
gr/DSCF	0.205	0.176	0.434	0.0568	0.297	0.131	0.448	0.154	0.655	0.140	0.504	0.076	0.312	0.121	0.536	0.123
lbs/hr	20.5	17.6	43.6	5.70	31.8	14.0	56.8	19.5	69.1	14.7	60.5	9.12	32.0	12.4	62.1	14.4
lbs/ton production	0.0840	0.0721	0.186	0.0243	0.149	0.0657	0.248	0.0852	0.276	0.0588	0.256	0.0386	0.139	0.0537	0.261	0.0605

*TOC - Total Organic Carbon

**EXT. ORG. - Extractable Organics

2.4.2 Comparison of Controlled TOC and Extractable Organics Emissions Results

Table 2-10 presents a comparison of controlled TOC and extractable organics emissions during conventional and recycle operation. The average controlled TOC loadings indicate that the controlled organic emissions were essentially the same during conventional (0.107 gr/DSCF) and recycle (0.105 gr/DSCF) operations. The average controlled extractable organics loadings indicated that the controlled organic emissions were about 15 percent greater during conventional operation (0.0445 gr/DSCF) as compared to recycle operations (0.0388 gr/DSCF).

2.4.3 Discussion of TOC and Extractable Organics Emissions Results

Because of the limited quantity of available data, it is difficult to develop an accurate comparison between the TOC and extractable organics analytical procedures. In formulating an opinion about the two procedures, it is important that several factors be kept in mind. First, the TOC analysis results are indicative of the mass of carbon present in all of the organic species in a sample. The extractable organics analysis results are indicative of the mass of organic compounds (not just carbon) having a boiling point greater than 300°C. Also, the TOC analysis procedure is a direct instrumental technique requiring a minimal amount of sample preparation (refer to Section 5.2). On the other hand, the extractable organics analysis procedure does require sample preparation (refer to Section 5.2) by means of extraction with chloroform and diethyl ether. The remaining extract is then evaporated to dryness at room temperature before weighing.

It is believed that the TOC analysis procedure is more suitable than the extractable organics procedure for characterizing organic emissions from asphalt concrete plants.

TABLE 2-10. COMPARISON OF CONTROLLED TOC AND EXTRACTABLE ORGANICS EMISSIONS

RUN NUMBER	C-1		C-2		C-3		R-1		R-2		R-3		AVERAGE			
PROCESS OPERATION	CONVENTIONAL		CONVENTIONAL		CONVENTIONAL		RECYCLE		RECYCLE		RECYCLE		CONVENTIONAL		RECYCLE	
DATE	11/12		11/13		11/14		11/11		11/11		11/12					
VOLUME GAS SAMPLES (DSCF)	48.2		46.2		48.5		57.1		59.3		60.1		47.6		58.8	
STACK GAS FLOW RATE (DSCFM)	11,700* (11,400)		11,900 (11,400)		12,100 (11,800)		14,000		13,300 (12,700)		14,000		11,900 (11,500)		13,800 (13,600)	
STACK TEMPERATURE (°F)	159		155		153		147		152		143		156		147	
PERCENT MOISTURE BY VOLUME	32.0 (34.3)		29.0 (32.3)		27.5 (29.7)		21.3		26.6 (30.6)		20.7		29.5 (32.1)		22.9 (24.2)	
PERCENT ISOKINETIC	102 (105)		96 (100)		99 (102)		104		111 (116)		107		99 (102)		107 (109)	
PRODUCTION RATE (TONS/HR)	244		235		213		229		250		236		231		238	
BACK HALF CATCH - ORGANICS RESULTS (Impinger solutions & rinses)	EXT.***		EXT.		EXT.		EXT.		EXT.		EXT.		EXT.		EXT.	
	TOC**	ORG.	TOC	ORG.	TOC	ORG.	TOC	ORG.	TOC	ORG.	TOC	ORG.	TOC	ORG.	TOC	ORG.
mg-mass	166	245	417	81.1	405	87.7	219	86.8	375	229	618	130	329	138	404	149
gr/DSCF	0.0532	0.0786	0.139	0.0271	0.129	0.0279	0.0592	0.0235	0.0975	0.0596	0.159	0.0334	0.107	0.0445	0.105	0.0388
lbs/hr	5.34	7.88	14.2	2.71	13.4	2.89	7.09	2.81	11.1	6.79	19.0	4.00	11.0	4.49	12.4	4.53
lbs/ton production	0.0219	0.0323	0.0604	0.0115	0.0629	0.0136	0.0310	0.0123	0.0445	0.0272	0.0805	0.0169	0.0476	0.0191	0.052	0.0188

*NOTE: Top number based on saturation volume for moisture content of gas; (bottom number) is moisture content calculated using Impinger catch results indicating the presence of water mist.

** TOC - Total Organic Carbon

*** EXT. ORG. - Extractable Organics

2.5 TRACE METAL EMISSION RESULTS

During this program the concentration of uncontrolled and controlled trace metals were derived from the analysis of "front-half" and "back-half" catches of the trace metal sampling train described in Section 5.1. The front-half catch is the sum of the analytical results of the acetone and trichloroethane probe and glassware washes, the cyclone solids (if applicable), and the filter solids. The back-half catch is the sum of the analytical results of the NaOH impingers and HNO₃ impingers. One set of trace metal samples (uncontrolled/controlled) was collected during conventional and recycle operation.

2.5.1 Conventional Operation Trace Metals Emission Results

Table 2-11 includes a summary of uncontrolled and controlled trace metals emissions during conventional operation. The collection efficiency of the wet venturi scrubber for each element during conventional operation, is presented in Table 2-11.

2.5.2 Recycle Operation Trace Metals Emission Results

Table 2-12 includes a summary of uncontrolled and controlled trace metals emissions during recycle operation. The collection efficiency of the wet venturi scrubber for each element during recycle operation is also presented in Table 2-12.

2.5.3 Discussion of Trace Metals Emission Results

During both conventional and recycle operations, the uncontrolled and controlled concentrations of calcium, iron, magnesium and aluminum comprised greater than 99 percent of the trace metals analyzed in the samples. Each of these elements are non-volatile, according to their elemental boiling point, and are predominantly associated with the particulate ("Front-half Catch"). The wet venturi scrubber removed greater than 99 percent of the

TABLE 2-11. SUMMARY OF TRACE METAL EMISSIONS DURING CONVENTIONAL OPERATION

Date	11/12				11/12				
Sampled Emissions	Uncontrolled				Controlled				
Production Rate (Ton/Hr)					244				
Trace Metal Results	Mass Front Half (µg)	Mass Back Half (µg)	Mass Total (µg)	Concentration (µg/DSCM)	Mass Front Half (µg)	Mass Back Half (µg)	Mass Total (µg)	Concentration (µg/DSCM)	Removal Efficiency (%)
<u>Element</u>									
Aluminum	29,500	66	29,600	55,000	453	98	551	404	99.3
Beryllium	2.33	0.90	3.23	6.0	0.187	2.6	2.8	2.0	66.7
Calcium	2,654,000	1260	2,660,000	4,930,000	41,000	1283	42,300	31,000	99.4
Cadmium	14.7	5.4	20.1	37	28	13	41	30	18.9
Chromium	138	<1.47	138	255	7.2	12	19	14	14.5
Iron	57,700	53	57,800	107,000	650	61	711	521	99.5
Mercury	<273	<20	<293	<544	<90	<56	<146	<107	--
Magnesium	42,900	50	43,000	79,600	1234	230	1460	1070	98.7
Manganese	911	1.8	913	1700	42.7	5.1	48	35	97.9
Nickel	104	<4.4	104	193	16.4	<5.6	16	12	93.8
Lead	118	<118	118	219	4.7	<152	4.7	3.4	98.4
Vanadium	<540	<88	<628	<1170	<115	<113	<228	<167	--
Zinc	194	13	207	385	42.2	9.6	52	38	90.1

TABLE 2-12. SUMMARY OF TRACE METAL EMISSIONS DURING RECYCLE OPERATION

Date	11/11				11/11				
Sampled Emissions	Uncontrolled				Controlled				
Production Rate (Ton/Hr)					250				
Trace Metal Results	Mass Front Half (µg)	Mass Back Half (µg)	Mass Total (µg)	Concentration (µg/DSCM)	Mass Front Half (µg)	Mass Back Half (µg)	Mass Total (µg)	Concentration (µg/DSCM)	Removal Efficiency (%)
<u>Element</u>									
Aluminum	13,300	69	13,300	22,500	201	<70	201	124	99.4
Beryllium	0.91	1.37	2.28	3.9	0.22	<0.70	0.22	0.14	96.4
Calcium	1,154,000	751	1,150,000	1,960,000	18,400	730	19,100	11,800	99.4
Cadmium	13.7	6.6	20.3	34	5.8	<2.8	5.8	3.6	89.4
Chromium	111	6.25	117	199	8.4	<1.4	8.4	5.2	97.4
Iron	24,600	64	24,600	41,800	320	9.8	330	204	99.5
Mercury	<136	<40	<176	<298	<60	<41	<101	<62	--
Magnesium	22,600	121	22,700	38,500	500	<47	500	309	99.2
Manganese	362.3	3.2	366	620	18.1	<1.4	18.1	11	98.2
Nickel	63.6	2.8	66	112	12	4.8	16.8	10	91.1
Lead	89	<113	89	150	4.2	<118	4.2	2.6	98.3
Vanadium	<141	<82	<223	<378	<120	<84	<204	<126	--
Zinc	230	14	244	414	67.3	7.6	74.9	46	88.9

calcium, iron, and aluminum during both conventional and recycle operation. Magnesium was removed at an efficiency of about 98.7.

Several "more volatile" elements were also detected in the trace metal samples. These elements included beryllium, cadmium, and zinc. Because of the greater volatility of these elements, a greater percentage of the volatile elements were found in the "back-half" portion of the trace metal sample than the above mentioned nonvolatile elements.

2.6 POLYNUCLEAR AROMATIC HYDROCARBONS EMISSION TEST RESULTS

Polynuclear aromatic hydrocarbon (PAH) samples were collected in the uncontrolled and controlled air emissions, during this program, using an adaption of EPA Method 5E. The technique, described in Section 5, includes the use of Method 5E front-half (filter) and back-half (XAD-2 resin) for adsorption of organic compounds. One set of PAH samples (uncontrolled/controlled) was collected during conventional and recycle operation. The PAH emission results are presented and discussed in the following section.

2.6.1 Conventional Operation PAH Emission Results

A summary of the uncontrolled and controlled PAH emissions during conventional operation are presented in Table 2-13. Included in Table 2-13 are the front- and back-half concentrations of both active and nonactive carcinogenic PAH species. The activity of the PAH species was determined using a reference book entitled "Polycyclic Aromatic Hydrocarbons in Water Systems."¹ The removal efficiency of the wet venturi scrubber for each of the PAH compounds is included in Table 2-13. The removal efficiency of the venturi scrubber ranged from 1 percent for benzo(b)fluoranthene to 100 percent for benzo(a)pyrene during conventional operation.

TABLE 2-13. SUMMARY OF POLYNUCLEAR AROMATIC HYDROCARBON EMISSIONS
DURING CONVENTIONAL OPERATION

Sampled Emissions	Uncontrolled						Controlled						
Date	11/14						11/14						
Volume Gas Sampled - DSCF (DSCM)	12.3 (0.3472)						42.2 (1.1963)						
Stack Gas Flow Rate - DSCFM (M ³ /Min)	10,200 (289)						11,700 (331)						
Stack Temperature (°F)	313						158						
Scrubber Pressure Drop (in. H ₂ O)	13.4						13.4						
Scrubber Water Flow Rate (GPM)	220						220						
Percent Moisture by Volume	42.2						32.2						
Percent Isokinetic	111						103						
Production Rate (tons/hr)	196						196						
CONCENTRATIONS AND MASS EMISSION RATES													
Polynuclear Aromatic Hydrocarbon Results	Front Half		Back Half		Total		Front Half		Back Half		Total		Removal Efficiency (Percent)
Active Carcinogenic ^a Species	(µg/DSCM)	(mg/hr)	(µg/DSCM)	(mg/hr)	(µg/DSCM)	(mg/hr)	(µg/DSCM)	(mg/hr)	(µg/DSCM)	(mg/hr)	(µg/DSCM)	(mg/hr)	
Benz(a)anthracene	1.1	19	0.28	4.9	1.4	24	<0.10	<2.0	0.22	4.4	0.22	4.4	82
Chrysene	6.2	110	1.1	19	7.3	130	0.15	3.0	1.0	20	1.2	24	82
Benzo(b)fluoranthene	0.58	10	<0.10	<1.7	0.58	10	0.50	9.9	ND		0.50	9.9	1
Benzo(j)fluoranthene	ND		ND		ND		ND		ND		ND		
Benzo(e)pyrene	2.6	45	0.86	15	3.5	61	0.17	3.4	ND		0.17	3.4	94
Benzo(a)pyrene	1.4	24	ND		1.4	24	ND		ND		ND		100
Indeno(1,2,3-c,d)-pyrene	1.4	24	0.29	5.0	1.7	29	0.084	1.7	ND		0.084	1.7	94
Nonactive Carcinogenic Species													
Phenanthrene	20	350	120	2100	140	2400	0.66	13	100	2000	100	2000	17
Anthracene	2.6	45	17	290	20	350	ND		7.1	140	7.1	140	60
Fluoranthene	5.4	94	7.4	130	13	230	0.29	5.8	2.5	50	2.5	56	76
Pyrene	16	280	20	350	36	620	0.97	19	6.4	130	6.4	150	76
Benzo(k)fluoranthene	0.58	10	ND		0.58	10	0.50	9.9	ND		0.50	9.9	1
Perylene	0.29	5.0	0.29	5.0	0.58	10	0.17	3.4	ND		0.17	3.4	66
Benzo(g,h,i)perylene	ND		ND		ND		ND		ND		ND		

ND = not detected.

^aFutoma, David, et al. Polycyclic Aromatic Hydrocarbons in Water Systems. Boca Raton, FL, CRC Press, Inc., 1981 - Reference used to determine if PNA species were active or nonactive carcinogens.

2.6.2 Recycle Operation PAH Emission Test Results

Table 2-14 includes a summary of uncontrolled and controlled PAH emissions during recycle operations. The controlled concentrations of benzo(b)fluoranthene, indeno(1,2,3-c,d)-pyrene, anthracene, and benzo(K)fluoranthene was greater than the uncontrolled concentrations for these compounds. The removal efficiency of the wet venturi scrubber for the remaining PAH compounds ranged from 31 percent for pyrene to 73 percent for benzo(e)pyrene and 41 percent for benzo(a)pyrene.

2.6.3 Discussion of PAH Emission Test Results

Based on the limited amount of available data, it is difficult to develop correlations between PAH concentrations and conventional or recycle operations. For most of the PAH compounds analyzed, the concentrations of the controlled emissions were less than the concentrations of the uncontrolled emissions. However, during recycle operation, there were several PAH compounds for which the controlled emissions were greater than the uncontrolled emissions. It is believed that these results are most probably caused by sampling and analytical error.

2.7 PARTICLE SIZE DISTRIBUTION RESULTS

An Andersen High Capacity Stack Sampler (AHCSS) was used during this program to determine the particle size distribution (PSD) of uncontrolled emissions. The AHCSS sizes particles aerodynamically and is designed to determine the PSD of gas streams with high grain loadings without overloading or using short sampling periods.

¹Futoma, David, et al. Polycyclic Aromatic Hydrocarbons in Water Systems. Boca Raton, FL, CRC Press, Inc., 1981.

TABLE 2-14. SUMMARY OF POLYNUCLEAR AROMATIC HYDROCARBON EMISSIONS DURING RECYCLE OPERATION

Sampled Emissions		Uncontrolled				Controlled			
Date		11/15				11/15			
Volume Gas Sampled - DSCF (DSCM)		16.2 (0.4590)				45.2 (1.2789)			
Stack Gas Flow Rate - DSCFM (M ³ /Min)		10,400 (294)				9,900 (280)			
Stack Temperature (°F)		299				173			
Scrubber Pressure Drop (in. H ₂ O)		12.7				12.7			
Scrubber Water Flow Rate (GPM)		214				214			
Percent Moisture by Volume		48.0				43.4			
Percent Isokinetic		105				113			
Production Rate (tons/hr)		166				166			

Polynuclear Aromatic Hydrocarbon Results		CONCENTRATIONS AND MASS EMISSION RATES												Removal Efficiency (Percent)
		Front Half		Back Half		Total		Front Half		Back Half		Total		
Active Carcinogenic ^a Species		(ug/DSCM)	(mg/hr)	(ug/DSCM)	(mg/hr)	(ug/DSCM)	(mg/hr)	(ug/DSCM)	(mg/hr)	(ug/DSCM)	(mg/hr)	(ug/DSCM)	(mg/hr)	
Benz(a)anthracene		0.64	11	1.1	19	1.8	32	0.75	13	0.0010	0.02	0.75	13	59
Chrysene		3.6	64	4.8	85	8.4	150	0.15	2.5	2.4	40	2.6	44	71
Benzo(b)fluoranthene		ND		0.087	1.5	0.087	1.5	ND		0.24	4.0	0.24	4.0	-170
Benzo(j)fluoranthene		ND		ND		ND		ND		ND		ND		
Benzo(e)pyrene		1.3	23	0.57	10	1.9	34	0.078	1.3	0.47	7.9	0.55	9.2	73
Benzo(a)pyrene		0.41	7.2	0.087	1.5	0.50	8.8	ND		0.31	5.2	0.31	5.2	41
Indeno(1,2,3-c,d)-pyrene		ND		0.15	2.6	0.15	2.6	ND		0.31	5.2	0.31	5.2	-100
Nonactive Carcinogenic Species														
Phenanthrene		8.3	150	210	3700	220	3900	1.0	17	86	1400	87	1500	62
Anthracene		1.5	26	15	260	16	280	ND		18	300	18	300	-7
Fluoranthene		1.9	34	18	320	20	350	0.30	5.0	13	220	13	220	37
Pyrene		3.4	60	33	580	36	640	0.83	14	25	420	26	440	31
Benzo(k)fluoranthene		ND		0.11	1.9	0.11	1.9	ND		0.24	4.0	0.24	4.0	-110
Perylene		ND		0.33	5.8	0.33	5.8	0.078	1.3	0.078	1.3	0.16	2.7	53
Benzo(g,h,i)perylene		ND		ND		ND		ND		ND		ND		

ND - not detected

^a Futoma, David, et al. Polycyclic Aromatic Hydrocarbons in Water Systems. Boca Raton, FL. CRC Press, Inc., 1981 - Reference used to determine if PNA species were active or nonactive carcinogens.

Attempts were made at determining the PSD of the controlled emissions using an Andersen Mark III cascade impactor. The attempts were unsuccessful because of the presence of water mist in the controlled emissions stream. As a result, no controlled PSD data are present.

2.7.1 Conventional Operation Uncontrolled Emissions PSD Results

Three uncontrolled PSD sampling runs were performed during conventional operation. The results of these runs are presented graphically in Figure 2-1 and tabularly in Table 2-15. During Run C-1 aggregate mix B was produced. During Run C-2 aggregate mix B and C were produced while aggregate mix M was produced during Run C-3. It should be noted that mix M contains washed sand.

2.7.2 Recycle Operation Uncontrolled Emissions PSD Results

A total of three PSD samples were scheduled for collection during recycle operation, but only one uncontrolled PSD sampling run was performed during recycle operation. The results of the single PSD recycle run (R-1) are presented graphically in Figure 2-1 and tabularly in Table 2-15. RAP mix A was produced during the sampling period.

2.7.3 Discussion of Uncontrolled Emissions PSD Results

The three PSD curves of uncontrolled emissions during conventional operation (Figure 2-1) are similar in shape. The mass mean diameter for Runs C-1, C-2, and C-3 are 10.5 μm , 6.0 μm , and 8.0 μm respectively.

The mass mean diameter for the single PSD test performed during recycle operation is approximately 16 μm .

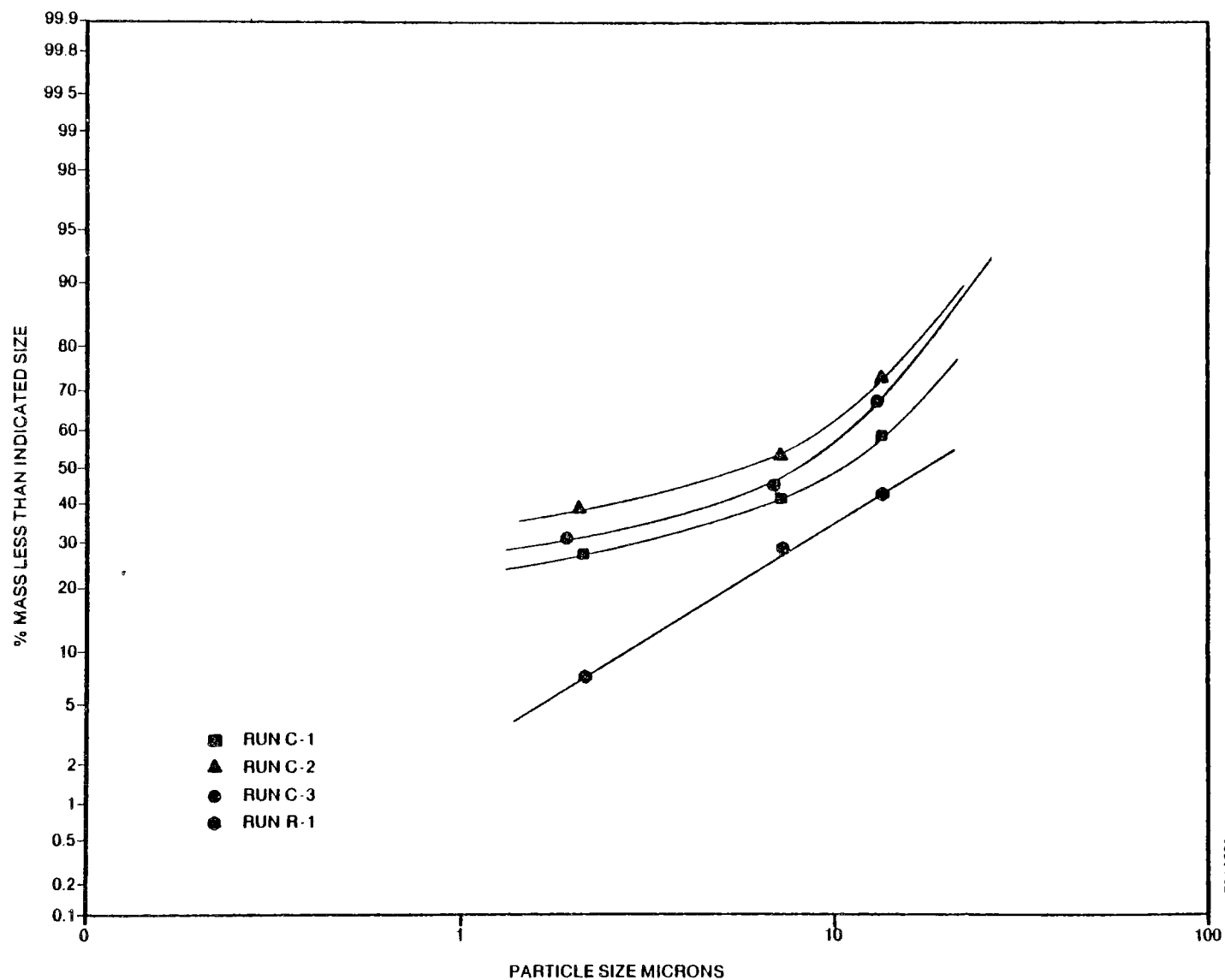


Figure 2-1. Particle size distribution curves of uncontrolled emissions collected during recycle and conventional operation.

TABLE 2-15. SUMMARY OF UNCONTROLLED PARTICLE SIZE
DISTRIBUTION TESTS

Date	Time	Run In	Flow Rate (ACFM ¹)	Stage	Mass Collected (g)	% in Size Range	Cumulative % less than Size Range	Size Range (µm)	DP ₅₀ (µm)	% Isokinetic
RECYCLE										
1111	1253-1330	1	0.439	1	1.1838	57.5	42.6	>13.3	13.3	108
			0.439	2	0.2831	13.8	28.8	7.2-13.3	7.2	
			0.439	Cyclone	0.4340	21.1	7.7	2.1-7.2	2.1	
			0.439	Filter	0.1581	7.7	0	>0-2.1	-	
CONVENTIONAL										
1112	1418-1520	C-1	0.430	1	2.9926	41.0	58.9	>13.3	13.3	103
			0.430	2	1.2359	16.9	42.0	7.2-13.3	7.2	
			0.430	Cyclone	1.0506	14.4	27.6	2.2-7.2	2.2	
			0.430	Filter	2.0152	27.6	0	>0-2.2	0	
1114	1014-1143	C-2	0.442	1	1.5725	27.3	72.7	>13.3	13.3	103
			0.442	2	1.0991	19.1	53.6	7.2-13.3	7.2	
			0.442	Cyclone	0.8769	15.2	38.4	2.1-7.2	2.1	
			0.442	Filter	2.2131	38.4	0	>0-2.1	-	
1115	1225-1440	C-3	0.456	1	3.2178	32.2	67.8	>13.0	13.0	112 ²
			0.456	2	2.3035	23.1	44.7	6.9-13.0	6.9	
			0.456	Cyclone	1.3990	14.0	30.7	1.9-6.9	1.9	
			0.456	Filter	3.0625	30.7	0	>0-1.9	-	

¹ACFM = actual cubic feet per minute

²Wet bulb/dry bulb indicated 35% moisture; 42.5% moisture measured which caused super isokinetic run

2.8 VISIBLE EMISSIONS RESULTS

Visible emissions were measured by a certified reader during most testing periods when a clear, blue sky was available. The blue sky background was required for detection of emissions caused by condensed hydrocarbons in the plume. Opacity readings taken during emission tests are presented and discussed in this section. Additional measurements were performed and are included in Appendix G.

2.8.1 Conventional Operation Visible Emissions Results

Opacity readings performed during conventional operation are presented in Table 2-16. The opacity readings are graphically represented in Figure 2-2. The average measured opacity reading during conventional operation test periods was 0 percent.

2.8.2 Recycle Operation Visible Emissions Results

Table 2-17 presents opacity measurements performed during recycle tests. These results are graphically represented in Figures 2-3 and 2-4. The average opacity measurement was 1.4 and 0.3 percent during Runs R-1 and R-2. The maximum six minute opacity measurement was 5.8 and 1.7 percent during Runs R-1 and R-2 respectively. During the recycle PAH sample collection period the average opacity measurement was zero percent.

2.8.3 Discussion of Visible Emission Results

One objective of this program was to investigate the "blue haze" plume caused by condensible hydrocarbons. On the afternoon of November 10, 1983 the water flow to the presprays was turned off for over an hour in an effort to generate "blue haze" by eliminating the prespray cooling. No "blue haze" was observed during this period. With concurrence of the EPA Industrial Studies Branch (ISB) and Emission Measurements Branch (EMB) representatives, testing under reduced water flow conditions was cancelled.

TABLE 2-16. SUMMARY OF VISIBLE EMISSION OBSERVATIONS DURING CONVENTIONAL OPERATION

Date	Run No.	Time	Average Opacity for 6 Minutes	Date	Run No.	Time	Average Opacity for 6 Minutes
11/12/83	T.M.Part/ Cond.Hyd. (C-1)	1130-1135 1136-1141 1142-1147 1148-1153 1154-1159 1200-1205 1206-1211 1212-1217 1218-1223 1224-1229 1230-1235 1236-1241 1242-1247 1248-1253 1254-1259 1300-1305 1306-1311 1312-1317 1318-1323 1318-1323	0 0	11/13/83	Part/ Cond./ Hyd. (C-2)	0848-0853 0854-0859 0900-0905 0906-0911 0912-0917 0918-0923 0924-0929 0930-0935 0936-0941 0942-0947 0948-0953 0954-0959 1000-1005 1006-1011 1012-1017 1018-1023 1024-1029 1030-1035 1036-1041 1042-1047 1048-1053 1103-1108 1109-1114	0 (ave.)
11/12/83	N/A*	1324-1329 1330-1335 1336-1341 1342-1347 1348-1353 1354-1359 1400-1405 1406-1411 1412-1417 1418-1423 1424-1429	0 0 0 0 0 0 0 0.6 1.5 0.2 0 0.21 (ave.)				

*No source sampling performed during this visible emissions measurement period.

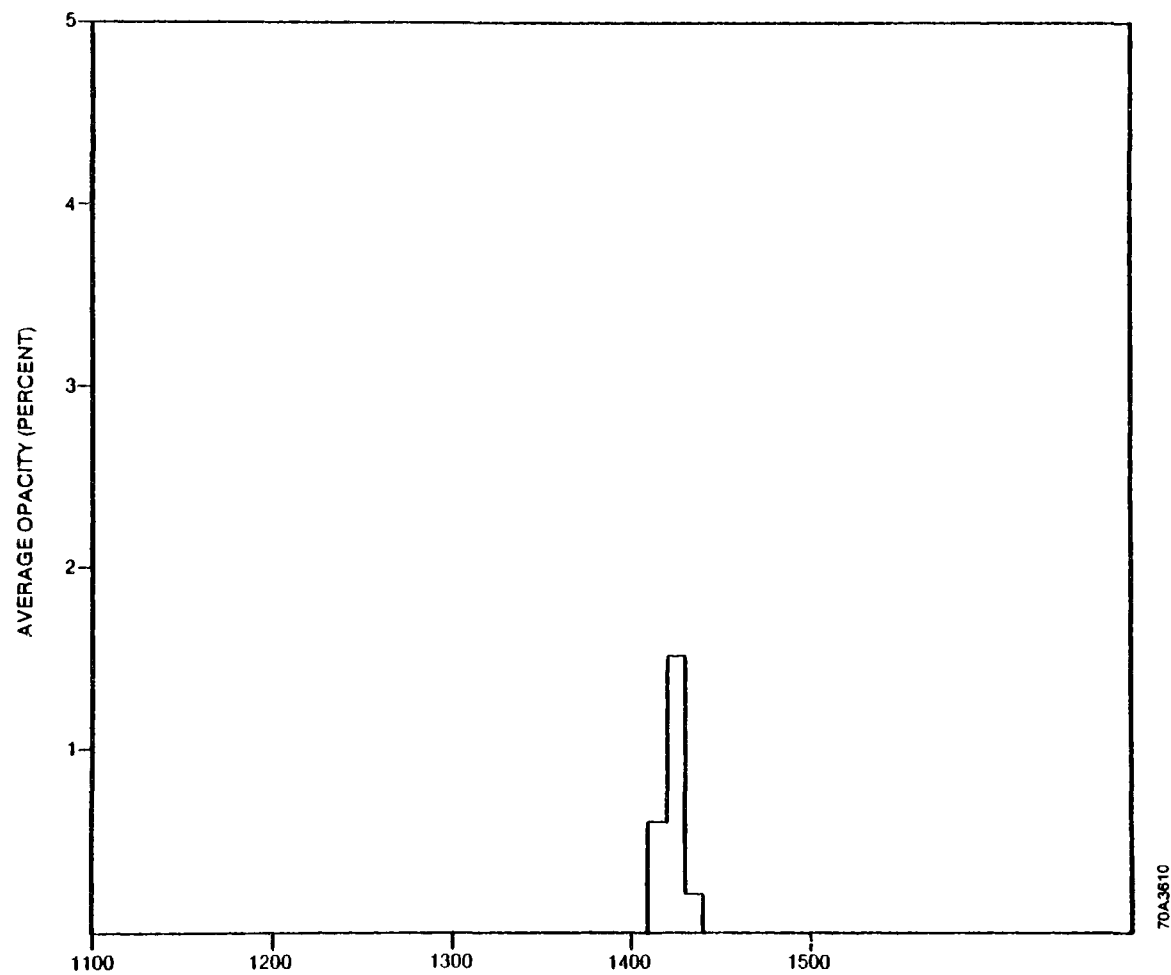


Figure 2-2. Six-minute averages of November 12, 1983. Opacity readings on the venturi scrubber stack during conventional operation.

TABLE 2-17. SUMMARY OF VISIBLE EMISSION OBSERVATIONS
 DURING RECYCLE OPERATION

Date	Run No.	Time	Average Opacity for 6 Minutes	Date	Run No.	Time	Average Opacity for 6 Minutes
11/11/83	T.M.Part/ Cond.Hyd. (R-1)	0837-0842	0	11/15/83	PAH R-1	0855-0900	0
		0843-0848	0			0901-0906	0
		0849-0854	0			0907-0912	0
		0855-0900	.2			0913-0918	0
		0901-0906	0			0919-0924	0
		0907-0912	0			0925-0930	0
		0913-0918	0			0931-0936	0
		0919-0924	0			0937-0942	0
		0925-0930	0			0943-0948	0
		0931-0936	0			0949-0954	0
		0937-0942	0			0955-1000	0
		0943-0948	0			1001-1006	0
		0949-0954	0			1007-1012	0
		0955-1000	.8			1013-1018	0
						1019-1024	0
		1009-1014	.8			1025-1030	0
						1031-1036	0
		1104-1109	.4			1037-1042	0
		1110-1115	0			1043-1048	0
		1116-1121	.6			1049-1054	0
		1122-1127	0				
		1128-1133	0			Average	0
		1308-1313	3.8				
		1314-1319	2.3				
		1320-1325	2.3				
		1326-1331	4.6				
		1332-1337	4.0				
		1400-1405	1.5				
		1406-1411	2.3				
		1412-1417	5.0				
		1418-1423	3.5				
		1424-1429	2.3				
		1430-1435	2.1				
		1436-1441	5.2				
		Average	1.4				
11/11/83	Part/Cond. Hyd. (R-2)	1530-1535	0				
		1536-1541	0				
		1545-1550	1.7				
		1551-1556	.4				
		1557-1602	0				
		1603-1608	1.3				
		1609-1614	1.0				
		1615-1620	0				
		1621-1626	0				
		1627-1632	0				
		1633-1638	0				
		1639-1644	0				
		1645-1650	0				
		1651-1656	0				
		1657-1702	0				
		1703-1708	0				
		1709-1714	0				
		Average	0.3				

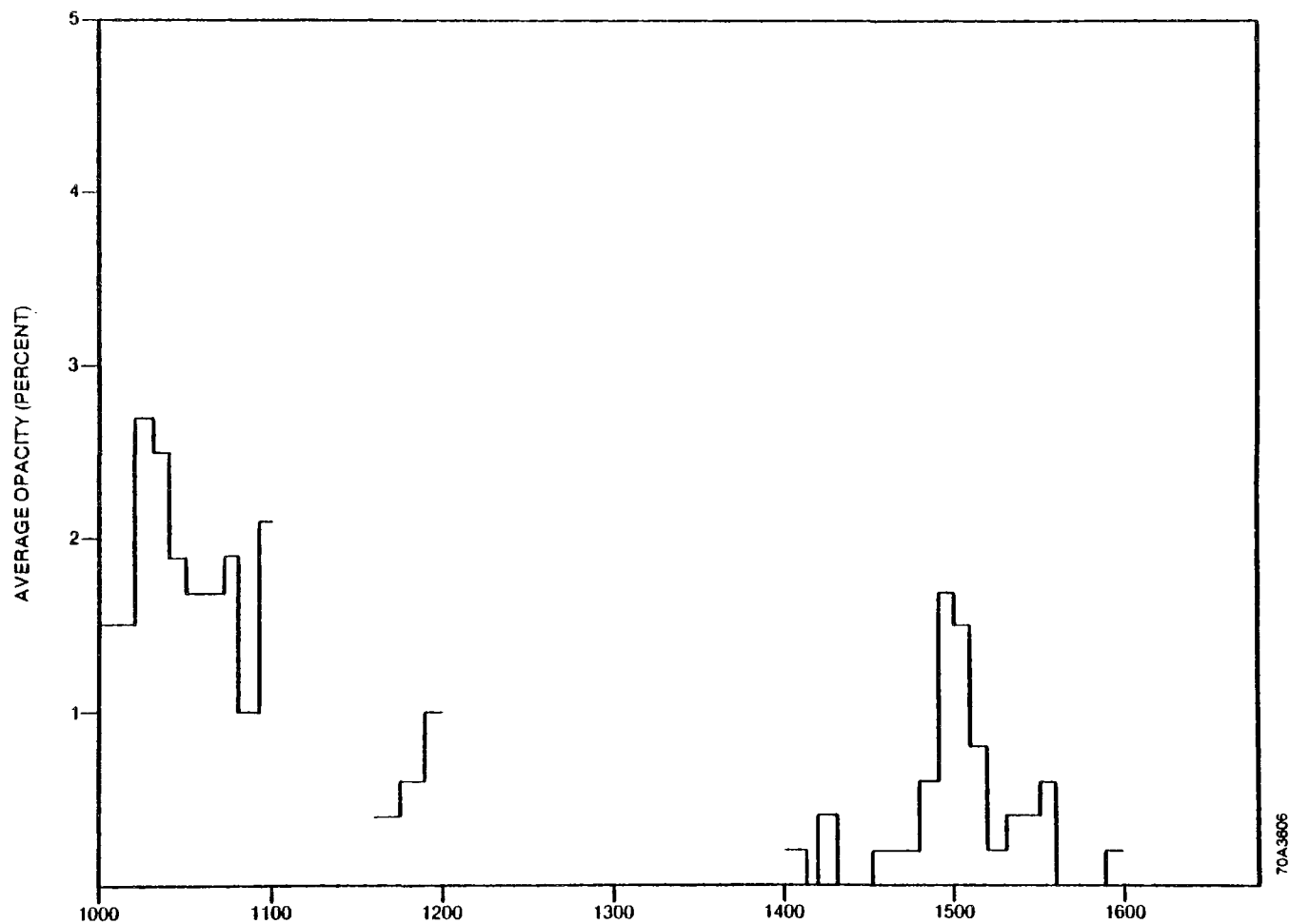
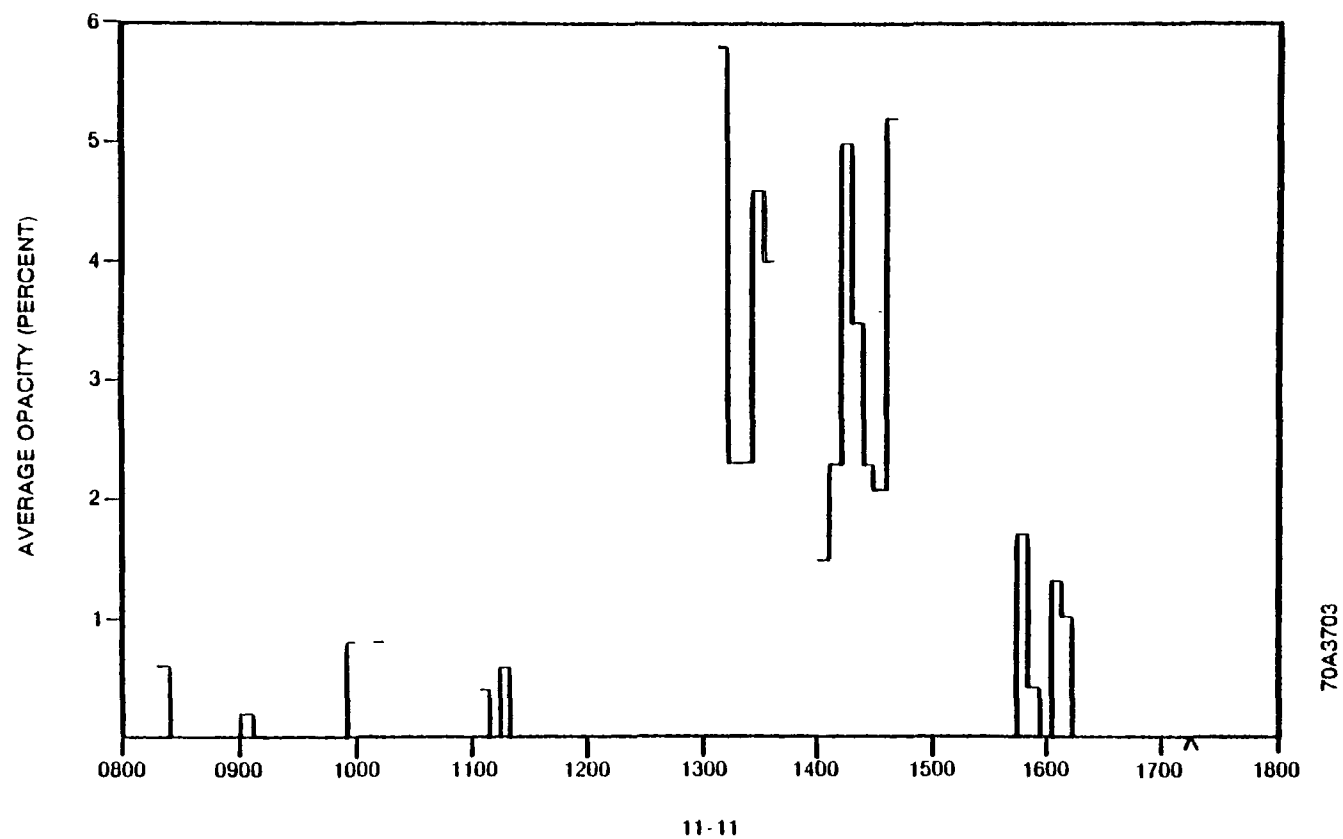


Figure 2-3. Six-minute averages of November 10, 1983. Opacity readings on venturi scrubber stack during recycle operation.



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Figure 2-4. Six-minute averages of November 11, 1983. Opacity readings on venturi scrubber stack during recycle operation.

2.9 SCRUBBER WATER GRAB SAMPLE MEASUREMENTS

Periodically during each sampling run, grab samples were taken of the venturi scrubber water influent (pond water) and venturi scrubber water effluent. The pH and temperature were measured for all grab samples (see Section 2.11 for analytical results). This section presents results of pH and temperature measurements performed on scrubber water samples.

2.9.1 Conventional Operation Scrubber Water pH and Temperature Results

Scrubber water pH and temperature results during conventional operation are presented in Table 2-18. Average pH results for the venturi scrubber influent were 7.30, 7.30, and 7.36 for Runs C-1, C-2, and C-3, respectively. Average venturi scrubber effluent pH's were 7.17, 7.18 and 7.17 for Runs C-1, C-2, and C-3, respectively.

The average venturi scrubber water influent temperatures for Runs C-1, C-2, and C-3 were 132°F, 126°F and 118°F, respectively. Two main factors affect pond temperature, ambient temperature and length of scrubber operation for each day.

The average venturi effluent temperature is a direct function of the flue gas temperature. Since water has a much higher capacity for heat transfer than air the flue gas can be cooled substantially with a relatively small increase in the scrubber water temperature. The average scrubber water effluent temperatures for Runs C-1, C-2, and C-3 were 156°F, 151°F, and 152°F, respectively. The average venturi inlet flue gas temperatures corresponding to the above sampling runs were 298°F, 289°F, and 304°F, respectively.

2.9.2 Recycle Operation Scrubber Water pH and Temperature Results

Results of pH and temperature measurements during recycle operation are presented in Table 2-19. The average pH measurements for the venturi scrub-

TABLE 2-18. SUMMARY OF SCRUBBER WATER pH AND TEMPERATURE MEASUREMENTS FOR CONVENTIONAL OPERATION

Run No.	Date	Time	Water to Venturi		Venturi Exit Water		Pond Water ¹		
			pH	Temperature, °F	pH	Temperature, °F	Time	Temperature, ² °F	
Part/C1	11/12	1140	7.28	127	7.18	153	1130	134	142
		1240	7.30	133	7.15	154	1230	137	143
		1340	7.31	136	7.18	160	1430	139	145
		Average		7.30	132		7.17	156	
Part/C2	11/13	0920	7.31	124	7.24	149	0929	130	139
		1020	7.29	129	7.12	153	1030	134	143
		Average		7.30	126		7.18	151	
Part/C3	11/14	0850	7.43	99	7.12	145	0830	104	110
		0945	7.36	115	7.18	147	0900	114	124
		1230	7.31	127	7.15	156	0930	121	130
		1400	7.34	129	7.22	160	1000	128	136
		Average		7.36	118		7.17	152	
PAH/C1	11/14	0850	7.43	99	7.12	145	0830	104	110
		0945	7.36	115	7.18	147	0900	114	124
		1230	7.31	127	7.15	156	0930	121	130
		1400	7.34	129	7.22	160	1000	128	136
		Average		7.36	118		7.17	152	

¹Data collected by MRI personnel

²Temperatures expressed as inlet temperature - outlet temperature

TABLE 2-19. SUMMARY OF SCRUBBER WATER pH AND TEMPERATURE MEASUREMENTS DURING RECYCLE OPERATION

Run No.	Date	Time	Water to Venturi		Venturi Exit Water		Pond Water ¹		
			pH	Temperature, °F	pH	Temperature, °F	Time	Temperature, ² °F	
Part/R1	11/11	0900	7.46	91	7.18	131	0901	99	110
		0945	7.32	108	7.10	131	0930	107	114
		1440	7.25	129	7.22	149	1430	132	138
		Average		7.34	109	7.17	137		
Part/R2	11/11	1605	7.28	131	7.20	153	1602	136	140
		1650	7.28	131	7.22	154	1700	137	142
		Average		7.28	131	7.21	154		
Part/R3	11/12	0830	7.46	109	7.22	142	0830	114	121
		0900	7.40	111	7.11	145	0900	118	128
		Average		7.43	110	7.16	144		
PAH/R1	11/15	0915	7.44	118	7.11	176	0903	124	132
		1000	7.46	129	7.10	171	0957	136	145
		1050	7.49	135	7.15	174	1055	143	151
		Average		7.46	127	7.12	174		

¹Data collected by MRI personnel

²Values expressed as inlet temperature - outlet temperature

ber water influent were 7.34, 7.28, 7.43, and 7.46 for particulate sampling Runs R-1, R-2, R-3, and PAH sampling Run R-1, respectively. The average venturi scrubber water effluent pH readings corresponding to the above sampling runs were 7.17, 7.21, 7.16, and 7.12, respectively.

The average venturi scrubber water influent temperatures were 109°F, 131°F, 110°F, and 127°F for Method 5E Runs R-1, R-2, R-3, and PAH Run R-1, respectively. The average corresponding water effluent temperatures were 137°F, 154°F, 144°F, and 174°F. The average venturi scrubber inlet gas temperatures for those sampling runs were 296°F, 314°F, 317°F, and 299°F.

2.9.3 Discussion of Scrubber Water Grab Sample Measurement Results

The scrubber water influent and effluent temperature and pH values did not vary significantly during conventional and recycle operations.

2.10 SCRUBBER WATER ANALYTICAL RESULTS

During each sampling run at least two venturi scrubber water influent and effluent samples were collected. The grab samples during each run were composited and then filtered to determine total suspended solids. An aliquot of the filtrate was then analyzed for dissolved solids. The remaining filtrate was analyzed for TOC, trace metals, and/or polynuclear hydrocarbons.

2.10.1 Conventional Operation Scrubber Water Analytical Results

Table 2-20 presents the scrubber water analytical results during conventional operation. Total suspended solids (TSS) concentrations for the venturi scrubber water influent samples were 161 mg/l, 23.9 mg/l, and 23.5 mg/l for sampling Runs C-1, C-2, and C-3. The corresponding total dissolved solids (TDS) concentrations were 1860 mg/l, 1780 mg/l, and 1770 mg/l. TSS concentrations for the venturi scrubber water effluent samples were 6710

TABLE 2-20. SUMMARY OF SCRUBBER WATER ANALYTICAL RESULTS
DURING CONVENTIONAL OPERATION

Run No. Date	C1 11/12		C2 11/13		C3 11/14		PAH C1 11/15		Average	
Sample Type	Water to Venturi	Venturi Exit Water	Water to Venturi	Venturi Exit Water	Water to Venturi	Venturi Exit Water	Water to Venturi	Venturi Exit Water	Water to Venturi	Venturi Exit Water
pH	7.30	7.17	7.30	7.18	7.36	7.17	7.36	7.17	7.33	7.17
Temperature, °F	132	156	126	151	118	152	118	152	124	153
Total Organic Carbon Results										
mg/l (as C)	160	160	180	250	186	230	180	200	176	210
Trace Metals Results										
Element (ug/ml.)										
Aluminum	<0.05	<0.05								
Beryllium	0.001	<0.005								
Calcium	290	300								
Cadmium	0.007	<0.002								
Chromium	0.004	<0.001								
Iron	0.026	<0.008								
Mercury	<0.03	<0.03								
Magnesium	54	54								
Manganese	0.047	0.053								
Nickel	<0.003	0.005								
Lead	<0.08	<0.084								
Vanadium	0.069	<0.003								
Zinc	<0.003	<0.003								
Polyaromatic Hydrocarbon Results										
Active Carcinogenic Species (ug/L)										
Benz(a)anthracene							<0.1	<0.1		
Chrysene							0.1	0.1		
Benzo(b)fluoranthene							ND	ND		
Benzo(j)fluoranthene							ND	ND		
Benzo(e)pyrene							ND	ND		
Benzo(a)pyrene							ND	ND		
Indeno(1,2,3-c,d)pyrene							ND	ND		
Nonactive Carcinogenic Series (ug/L)										
Phenanthrene							10	6.8		
Anthracene							0.4	ND		
Fluoranthene							0.6	0.3		
Pyrene							1.4	0.6		
Benzo(k)fluoranthene							ND	ND		
Perylene							ND	ND		
Benzo(g,h,i)perylene							ND	ND		
Total Solids Results										
Suspended Solids mg/l	161	6710	23.9	6530	23.5	5180	ND	5240	69.5	5920
Dissolved Solids mg/l	1860	1850	1780	1760	1770	1770	1790	1810	1800	1800

mg/l, 6530 mg/l, and 5180 mg/l for sampling Runs C-1, C-2, and C-3. The corresponding TDS concentrations were 1850 mg/l, 1760 mg/l, and 1770 mg/l.

There are no significant differences between the venturi scrubber influent and effluent trace metals concentrations. Calcium and magnesium were the only species found in excess of 100 ppb. The concentrations were 290 mg/l and 54 mg/l for the influent and 300 mg/l and 54 mg/l for the effluent for calcium and magnesium respectively.

Polynuclear aromatic hydrocarbons were found in trace amounts in the scrubber water during conventional operation. Phenathrene and pyrene were found in levels in excess of 1 ppb. Three other species anthracene, fluoranthrene, and chrysene were detected in levels of less than 1 ppb. Benz(a)anthracene was detected, but not at a quantifiable level.

2.10.2 Recycle Operation Scrubber Water Analytical Results

Table 2-21 presents the scrubber water analytical results during recycle operation. TSS concentrations for the venturi scrubber water influent were 77.8 mg/l, 144 mg/l and 179 mg/l for Runs R-1, R-2, and R-3, respectively. The corresponding TDS concentrations were 1960 mg/l, 1970 mg/l, and 1890 mg/l. TSS concentrations for the venturi scrubber water effluent were 3090 mg/l, 4690 mg/l, and 3010 mg/l for Runs R-1, R-2, and R-3, respectively. The corresponding TDS contents were 1950 mg/l, 1970 mg/l, and 1900 mg/l.

No significant differences were seen between the venturi scrubber influent and effluent trace metals concentrations. As with conventional operation calcium and magnesium were the only soluble species found in excess of 100 ppb. Their concentrations were 300 mg/l and 54 mg/l for the influent and 300 mg/l and 53 mg/l for the effluent for calcium and magnesium respectively.

TABLE 2-21. SUMMARY OF SCRUBBER WATER ANALYTICAL RESULTS DURING RECYCLE OPERATION

Run No. Date	R1 11/11		R2 11/11		R3 11/12		PAH R1 11/15		Average	
	Water to Venturi	Venturi Exit Water	Water to Venturi	Venturi Exit Water	Water to Venturi	Venturi Exit Water	Water to Venturi	Venturi Exit Water	Water to Venturi	Venturi Exit Water
Sample Type										
pH	7.34	7.17	7.28	7.21	7.43	7.16	7.46	7.12	7.38	7.16
Temperature, °F	109	137	131	154	110	144	127	174	119	152
Total Organic Carbon Results										
mg/l (as C)	170	170	180	190	170	170	190	190	178	180
Trace Metals Results										
Element (µg/ml.)										
Aluminum	0.05	0.05								
Beryllium	0.005	0.005								
Calcium	300	300								
Cadmium	0.002	0.002								
Chromium	0.001	0.001								
Iron	0.008	0.008								
Mercury	0.03	0.03								
Magnesium	54	53								
Manganese	0.060	0.061								
Nickel	0.003	0.003								
Lead	0.084	0.084								
Vanadium	0.003	0.003								
Zinc	0.003	0.003								
Polyaromatic Hydrocarbon Results										
Active Carcinogenic Species (µg/l.)										
Benz(a)anthracene							0.1	0.1		
Chrysene							0.1	0.1		
Benzo(b)fluoranthene							ND	ND		
Benzo(j)fluoranthene							ND	ND		
Benzo(e)pyrene							ND	ND		
Benzo(a)pyrene							ND	0.4		
Indeno(1,2,3-c,d)pyrene							ND	ND		
Nonactive Carcinogenic Series (µg/l.)										
Phenanthrene							7.0	5.0		
Anthracene							ND	ND		
Fluoranthene							0.7	0.5		
Pyrene							1.3	0.8		
Benzo(k)fluoranthene							ND	ND		
Perylene							ND	0.5		
Benzo(g,h,i)perylene							ND	ND		
Total Solids Results										
Suspended Solids mg/l.	77.8	3090	144	4690	179	3010	60	1150	115	2980
Dissolved Solids mg/l.	1960	1950	1970	1970	1890	1900	1860	1820	1920	1910

Polynuclear aromatic hydrocarbons were found in trace amounts in the scrubber water during recycle operation. Phenanthrene and fluoranthrene were the only species found in excess of 1 ppb. Four other species anthracene, perylene, chrysene, and benzo(a)pyrene were detected in levels less than 1 ppb. The presence of benz(a)anthracene was detected but not quantified.

2.10.3 Discussion of Scrubber Water Analytical Results

Fluctuations in the TSS concentrations of influent scrubber water samples occurred during both conventional and recycle operations. The exact cause for the TSS fluctuations is not known at this time. Flocculant was added to the ponds to help reduce TSS after dredging operations on November 7 and 14, 1984. It is believed that the fluctuations in TSS concentrations of the influent scrubber water samples were not caused by the addition of flocculant on November 7 and 14, 1983.

The average TSS concentration of scrubber water effluent samples was approximately 70 percent greater during conventional operation (5920 mg/L) as compared to recycle operation (2980 mg/L). The higher TSS concentrations in the scrubber effluent water during conventional operation are due to the high uncontrolled particulate emissions observed during conventional operations as compared to recycle operation. The particulate removal efficiency of the venturi scrubber was basically the same during both modes of production.

The average TDS concentration of influent scrubber water samples was 1800 mg/l during conventional operation and 1920 mg/l during recycle operation. The average TDS concentration of effluent scrubber water samples was 1800 mg/l during conventional operation and 1910 mg/l during recycle operation. Based on the above data, the average concentration of TDS did not vary significantly in the scrubber water influent and effluent samples.

The concentration of trace metals and PAH's present in scrubber water influent and effluent samples were essentially the same during conventional and recycle operation.

2.11 PROCESS SAMPLING RESULTS

During each conventional and recycle operation test period, samples of virgin aggregate and recycled asphalt pavement (during recycle operation) were collected and analyzed for percent moisture. Care was taken to obtain a representative sample including collecting very large samples (approximately 10 pounds) and riffing the sample to the 500-700 grams used for analysis.

2.11.1 Conventional Operation Grab Sampling Results

Table 2-22 presents moisture values of the virgin aggregate during conventional operation. The percent moisture by weight values were 2.68%, 2.32%, and 2.63% for Runs C-1, C-2, and C-3. These moisture values are slightly lower than the 3-4% estimated by plant personnel.

2.11.2 Recycle Operation Grab Sampling Results

Table 2-23 presents moisture values of the virgin aggregate and recycle asphalt pavement used during recycle operation. The percent moisture by weight values were 1.46%, 1.83%, 1.20%, and 6.88% for the virgin aggregate and 1.48%, 1.40%, 2.12%, and 4.88% for the recycled asphalt pavement, for particulate Runs R-1, R-2, R-3 and polynuclear aromatic hydrocarbons Run R-1, respectively. Plant operators estimated 3-4% moisture for the virgin aggregate and 2% moisture for the recycled asphalt pavement during the particulate runs. During PAH Run R-1, plant estimates were 8% for the virgin aggregate and 3.5% for the recycled asphalt pavement.

TABLE 2-22. SUMMARY OF PROCESS SAMPLE MEASUREMENTS
 FOR CONVENTIONAL OPERATION

Run No.	Date	Time	Virgin Aggregate	
			Sample amount (g)	Percent Moisture by Weight
Part/C1	11/12	1345	666	2.68
Part/C2	11/13	0920	676	2.32
Part/C3	11/14	0850	669	2.64
		1235	717	2.62
			693 (ave.)	2.63 (ave.)
PAH/C1	11/14	0850	669	2.64
		1235	717	2.62
			693 (ave.)	2.63 (ave.)

TABLE 2-23. SUMMARY OF PROCESS SAMPLE MEASUREMENTS FOR RECYCLE OPERATION

Run No.	Date	Time	Virgin Aggregate		Recycle Asphalt Pavement	
			Sample Amount (g)	% Moisture by Weight	Sample Amount (g)	% Moisture by Weight
Part/R1	11/11	0900	607	1.46	456	1.48
Part/R2	11/11	1400	924	1.83	846	1.40
Part/R3	11/12	0835	734	1.20	517	2.12
PAH/R1	11/15	0915	638	6.88	573	4.88

2.11.3 Discussion of Process Sampling Results

The average moisture content of the virgin aggregate was 2.54% during conventional operation and 1.50% during recycle Runs R-1, R-2, and R-3. The moisture content of the virgin aggregate increased to 6.88% during PAH Run R-1. The average moisture content of the RAP was 1.67% during recycle Runs R-1, R-2, and R-3. The moisture content of the RAP increased to 4.88% during Run R-1.

SECTION 3

PROCESS DESCRIPTION AND OPERATION

This section provides a brief description of the asphalt concrete plant operated by the T. J. Campbell Construction Co. in Oklahoma City, Oklahoma. The procedures used to monitor the operation of the asphalt concrete plant during both conventional and recycle testing are also presented in this section.

3.1 PROCESS DESCRIPTION

A description of the T. J. Campbell asphalt plant (including the emissions control system) is presented in this section.

3.1.1 Process Equipment Description

T. J. Campbell Construction Company operates a CMI drum-mix asphalt plant in Oklahoma City, Oklahoma (refer to Figure 1-1). Plant operation began in 1979 and was modified in March 1983 to include a new, larger capacity drum which was designed to handle recycled asphalt pavement (RAP). Primary design changes for utilization of RAP were an injection system for the RAP in the center area of the drum and a heat shield between the RAP injection point and the burner. The modifications were designed to reduce the temperature to which the RAP is exposed. Table 3-1 presents a summary of technical data on the asphalt concrete plant.

The CMI drum at T. J. Campbell is 36 feet long and has expanded front and back ends. The expanded ends are 8.5 feet in diameter, and the mid-section is 7 feet in diameter. The expanded front end allows for greater heat transfer near the burner flame, while the expanded back end causes the

TABLE 3-1. TECHNICAL DATA ON THE ASPHALT CONCRETE PLANT OPERATED BY THE
T. J. CAMPBELL CONSTRUCTION COMPANY, OKLAHOMA CITY, OKLAHOMA

Type:	Drum-mix
Manufacturer:	CMI
Model Number:	UVM-1200RS-162
Dated Installed:	March 1983
Capacity: rated	250-350 tons/h
typical	240 tons/h
Dryer: fuel	Natural gas
capacity	109 million BTUs
firing rate	80-90 million BTUs/h
Drum Size: diameter	ends--8.5 ft
	middle--7 ft
length	36 ft
Drum Slope:	0.75 in. per ft
Product Temperature:	275° to 325°F
RAP Entry Position:	Center feed
Asphalt Heater:	Fuel--Natural gas
	Storage capacity--35,000 gal
Storage Silos (3):	Capacity--235 tons each
	Heating--Heat transfer oil

exhaust gas velocity to decrease to allow the larger particles to settle out in this region. The drum is natural gas-fired. The burner at T. J. Campbell is a Hauck power flame burner with a 109 million BTU rating. Virgin aggregate is stored in four cold feed bins and RAP is stored in a separate cold feed bin. The liquid asphalt is stored in a heated 35,000 gallon tank on site. The asphalt storage container is maintained at 300°F. The finished asphalt concrete mix is stored in one of three heated storage silos.

3.1.2 Emission Control System Description

Figure 3-1 illustrates the emission control system (venturi scrubber) used by T. J. Campbell. Process emissions from the drum-mixer exit the discharge end of the drum and enter a knockout box to remove some of the larger particles by reducing the air velocity. After the knockout box, the emissions are ducted to a wet venturi scrubber. Specifications for the venturi scrubber are listed in Table 3-2. In the duct work between the knockout and venturi are water sprays, two nozzle bars with 13 nozzles per bar, to cool the emission gases. Water is also injected at the venturi throat through a 12-nozzle spray bar. Additional water is flushed through a collection box below the venturi.

Scrubber water is contained in two adjacent earthen ponds that are interconnected by means of a dike. One pond is approximately 55 feet x 24 feet and the other is approximately 65 feet x 24 feet with an effective depth of 3 to 6 feet. Scrubber effluent flows into the end of one pond while scrubber supply water is pumped from the other pond. The dike dividing the two ponds serves as a weir to reduce the suspended particulate matter in the scrubber supply pond. Silt is cleaned from the ponds weekly and is landfilled. Pond make-up water is supplied from a well. The pH of the ponds is controlled by addition of lime; flocculant is occasionally added to the ponds to aid settling. The venturi pressure drop is variable (12.5 to 18 inches of water column).

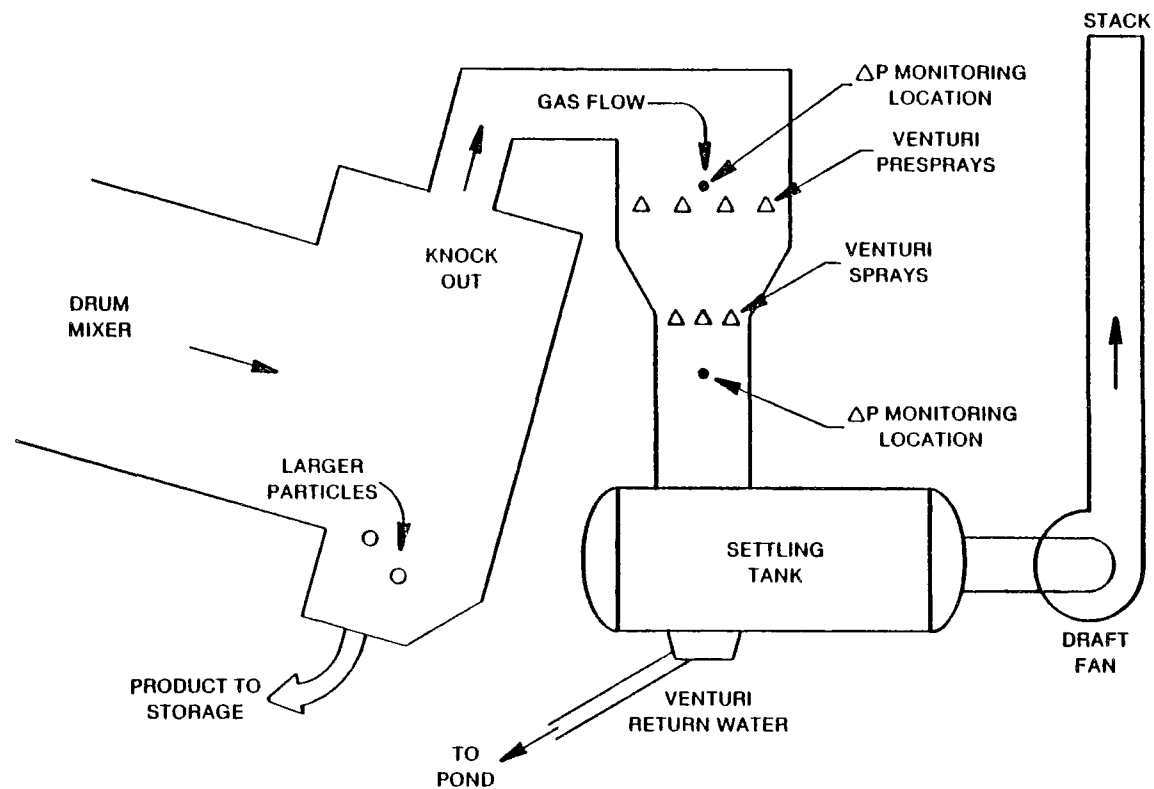


Figure 3-1. Wet venturi emissions control scrubber operated by the T.J. Campbell Construction Company, Oklahoma City, Oklahoma

TABLE 3-2. TECHNICAL DATA ON THE WET VENTURI SCRUBBER AT THE T. J.
CAMPBELL CONSTRUCTION COMPANY, OKLAHOMA CITY, OKLAHOMA

Type:	Venturi scrubber
Manufacturer:	CMI
Date Installed:	Spring 1979
Total Air Flow:	35,000-36,000 acfm
Water Circulation Rate:	300 gpm (design)
Makeup water:	Well water as needed
Pressure Drop:	12.5 to 14.5 inches w.c.
Scrubber Inlet Temperature:	300°F
Scrubber Motor	60 hp
Pressure in Venturi Nozzle:	100 lbs
Fan Motor:	150 hp
Ponds - number	2
sizes (approx)	55 ft x 24 ft and 65 ft x 24 ft; both approx. 3 to 6 ft deep
capacity (approx)	70,000 gal and 100,000 gal
Scrubber Outlet:	Rectangular steel stack with sampling ports
Scrubber Sludge: quantity	2 percent of the No. 200 and less fines run through drum
disposal	Fill

3.2 PROCESS OPERATION

Operation of the T. J. Campbell plant is typical of other drum-mix plants. The T. J. Campbell plant operates about 10 hours per day, typically 8:00 AM to 6:00 PM, and does not operate on weekends unless requested by a customer. The rate of asphalt concrete production is dependent upon the temperature of the product and the moisture content of the raw feed material. The maximum rated capacity of the T. J. Campbell plant is 350 tons per hour at a product temperature of 240°F and 1-2 percent feed moisture. The T. J. Campbell plant operates at a product temperature higher than normal for the industry (300°F as opposed to 275 to 285°F) to produce a more workable mix for smaller paving jobs. With a product temperature of 300°F and a feed moisture content of 5 to 6 percent, the rated capacity of the plant is 250 tons per hour. A daily production of 2,000 tons is considered very good. The T. J. Campbell plant produces a variety of commercial and recycle mixes. A brief description of the process operating procedures used during conventional and recycle operation is presented below.

3.2.1 Conventional Process Operation

During conventional operation, virgin aggregate is added to the burner end of the rotating drum. The virgin aggregate is stored in four cold feed bins. Aggregate from each bin is metered onto a conveyor according to the desired commercial mix. Table 3-3 includes a description of the various commercial mixes produced by T. J. Campbell during the test program.

The liquid asphalt is injected into the dryer about 2 feet downstream from the center of the drum. The liquid asphalt is stored in a heated 35,000 gallon (gal) tank on site, maintained at a temperature of 300°F. The grade of asphalt used during the test period is designated AC-20, which has a 60 to 100 penetration grade. Campbell has two suppliers of liquid asphalt, Kerr McGee (Wynnewood, Oklahoma) and Allied Chemical (Stroud, Oklahoma). No recycling agents are used by Campbell. The finished asphalt concrete mix drops out the end of the drum and is lifted by bucket conveyor

TABLE 3-3. AGGREGATE ADDITIONS FOR TYPICAL CONVENTIONAL MIXES PRODUCED AT THE T.J. CAMPBELL CONSTRUCTION COMPANY, OKLAHOMA CITY, OKLAHOMA

Type Mix	Asphalt Cement Added (Percent)	Bin No.	Percent of Aggregate	Bin Contents	Moisture Content Estimated By Plant Personnel (Percent)
Type B (virgin)	4.9	1	45	Screenings	2.5
		2	22	Sand	12.0
		3	8	3/4 in. rock	1.5
		4	25	5/8 in. rock	2.0
Type C	5.0	1	43	Screenings	1.5
		2	24	Sand	12.0
		3	33	3/8 in. rock	1.5
		4	0	--	---
Type M	5.0	1	53	Screenings	2.0
		2	20	Sand (washed)	11.0
		3	0	--	---
		4	27	5/8 in. rock	2.0

TABLE 3-4. AGGREGATE ADDITIONS FOR TYPICAL RAP MIXES PRODUCED AT THE T. J. CAMPBELL CONSTRUCTION COMPANY, OKLAHOMA CITY, OKLAHOMA

Type Mix	Asphalt Cement Added (Percent)	Bin No.	Percent of Aggregate	Bin Contents	Moisture Content Estimated By Plant Personnel (Percent)
Type A (recycle)	3.9 (4.6) ^a	1	18	Screenings	2.5
		2	9.8	Sand	12.0
		3	0	---	---
		4	47.2	1.5 in. rock	2.0
		RAP	25	RAP	2.0
Hot Sand (recycle)	4.5 (4.6) ^a	1	15	Screenings	2.0
		2	60	Sand	11.0
		3	--	--	--
		4	--	--	--
		RAP	25	RAP	2.0

^aAsphalt cement in the RAP

to one of three storage silos. These silos are heated with heat transfer oil and are insulated. The asphalt concrete is then loaded onto trucks on a scale. The truck used by Campbell to haul the product are owned and operated by independent truckers.

3.2.2 Recycle Progress Operation

RAP is predominantly used in base course mixes. Table 3-4 includes a description of the various RAP mixes produced by T. J. Campbell during the test program. During recycle operation, RAP was added to the center of the rotating drum and the quantity of virgin aggregate added to the rotating drum was reduced. Typical RAP percentages are 25 to 30 percent. The remaining recycle process operating procedures are similar to the conventional process operating procedures presented in Section 3.2.1.

3.3 PROCESS MONITORING DURING THE EMISSION TEST PROGRAM

The operation of the drum-mix asphalt plant was monitored by MRI personnel during both the conventional and recycle test periods. Table 3-5 contains a summary of the process data collected during the emissions testing program. The test period included the company's peak production week of over 9,000 tons and its peak production day, November 11, 1983, when 2,354 tons were sold.

3.4 EMISSION CONTROL SYSTEM MONITORING DURING THE EMISSION TEST PROGRAM

The operation of the venturi scrubber emission control system was monitored by MRI personnel during both the conventional and recycle test periods. Emission control system parameters that were monitored during testing included:

- o venturi scrubber pressure drop,
- o total scrubber water flow to the venturi, and
- o scrubber water flow to the venturi throat.

TABLE 3-5. PROCESS INFORMATION DURING EMISSION TESTING,
T.J. CAMPBELL CONSTRUCTION COMPANY, OKLAHOMA CITY, OKLAHOMA

Date	Time	Production rate, tph ^a	Virgin, tph ^a	RAP ^a tph	Aphalt, tph ^b	Mix temp., °F	Burner setting, %	Operator estimate moisture content		Drum internal pressure, ΔP	Mix design	Comment
								Virgin	RAP			
11/10/83	9:30	201.3	191.1	--	10.2	270	30	5	--	-0.25	C mix	
	(a.m.) 10:00	219.2	208.3	--	10.9	290	40	5	--	-0.09	C mix	
	10:33	232.4	221.0	--	11.4	290	40	5	--	-0.10	C mix	
	11:00	228.5	217.5	--	11.0	310	40	5	--	-0.09	C mix	
	11:30	219.2	208.7	--	10.5	310	40	5	--	-0.10	C mix	
	11:50	217.4	206.7	--	10.7	290	40	5	--	-0.01	C mix	
	(p.m.) 2:01	209.1	150.8	52.5	5.8	290	30	4-5	3	-0.34	Recycle-A ^C	
	2:31	248.3	177.3	64.1	6.9	290	35	4-5	2	-0.30	Recycle-A	Turned off prespray water flow at 2:41 p.m.
	2:57	250.7	179.3	64.5	6.8	290	40	4-5	2	-0.33	Recycle-A	
	3:31	262.8	192.5	62.9	7.4	285	40	4-5	2	-0.32	Recycle-A	
	3:52	274.3	195.5	71.4	7.4	285	40	4-5	2	-0.17	Recycle-A	Turned on prespray water flow at 3:44 p.m.
	4:12	248.1	181.9	59.1	7.1	305	45	4-5	2	-0.16	Recycle-A	
	4:28	231.2	167.4	57.6	6.2	290	35	4-5	2	-0.25	Recycle-A	
	11/11/83											
(a.m.)	8:37	226.7	164.1	56.4	6.3	295	30	3-4	2	-0.19	Recycle-A	
	9:01	208.2	161.7	40.1	6.2	295	30	3-4	2	-0.18	Recycle-A	
	9:30	214.6	157.4	51.2	6.0	290	30	3-4	2	-0.15	Recycle-A	9:45-9:50 RAP bin clog reduced production rate
	10:01	231.5	167.1	58.2	6.2	295	35	3-4	2	-0.12	Recycle-A	
	10:30	245.6	173.7	65.2	6.7	295	40	3-4	2	-0.05	Recycle-A	
	11:00	262.2	191.8	63.3	7.1	290	40	3-4	2	-0.04	Recycle-A	
	11:30	279.2	198.3	73.4	7.5	260	40	3-4	2	-0.04	Recycle-A	
	(p.m.) 12:10	213.8	157.1	50.8	5.9	325	30	3-4	2	-0.13	Recycle-A	Reduced production rate due to loader problems
	12:30	215.4	153.9	55.3	6.2	295	30	3-4	2	-0.09	Recycle-A	
	1:00	223.7	157.6	60.2	5.9	305	30	3-4	2	-0.11	Recycle-A	
	1:30	212.4	151.0	55.8	5.6	310	30	3-4	2	-0.10	Recycle-A	
	2:00	218.3	157.3	55.0	6.0	290	30	3-4	2	-0.14	Recycle-A	
	2:30	205.3	139.9	58.9	6.5	300	20	3-4	2	-0.14	Recycle-A	
	3:01	238.3	171.4	60.4	6.5	290	35	3-4	2	-0.06	Recycle-A	
	3:31	254.2	180.3	67.9	6.0	285	40	3-4	2	-0.02	Recycle-A	Stopped operation 3:41 to 3:44; drag slot clogged
	4:02	208.5	165.3	36.1	7.1	255	30	3-4	2	-0.02	Recycle-A	
	4:30	265.4	188.9	69.8	6.7	270	45	3-4	2	-0.01	Recycle-A	
	5:00	267.8	189.8	71.7	6.3	285	45	3-4	2	-0.01	Recycle-A	
	5:26	264.8	197.0	60.8	7.0	280	50	3-4	2	0	Recycle-A	Stopped process at 5:30 to switch to C mix (virgin)

(continued)

TABLE 3-5 (continued)

Date	Time	Production rate, tph ^a	Virgin, tph ^a	RAP, tph ^a	Asphalt, tph ^b	Mix temp., °F	Burner setting, %	Operator estimate moisture content		Drum internal pressure, ΔP	Mix design	Comment
								Virgin	RAP			
11/12/83 (a.m.)	7:10	215.6	155.0	55.4	5.2	290	40	3-4	2	0.09	Recycle-A	
	7:30	237.8	173.5	58.1	6.2	290	35	3-4	2	0.08	Recycle-A	
	8:01	238.1	174.1	57.4	6.6	295	35	3-4	2	0.11	Recycle-A	8:05 to 8:10--drum off; switching to load different storage silo
	8:30	234.1	171.6	56.5	6.0	290	35	3-4	2	0.11	Recycle-A	
	9:00	253.5	183.4	63.6	6.5	270	40	3-4	2	0.03	Recycle-A	At 9:20 stopped adding RAP to drum; switching to B mix
	11:00	256.8	244.2	--	12.6	275	60	~3	--	0	B mix	
	11:30	247.6	235.1	--	12.5	270	60	~3	--	0	B mix	
	12:00	250.8	238.5	--	12.3	280	60	~3	--	0	B mix	11:55 took asphalt cement sample--
	12:30	248.8	236.8	--	12.0	290	55	~3	--	0	B mix	Source Allied, Stroud, Oklahoma
	1:01	235.0	223.3	--	11.7	280	50	~3	--	0	B mix	
	1:30	235.4	223.6	--	11.8	280	50	3-4	--	0	B mix	
	2:00	222.2	211.5	--	10.7	285	50	3-4	--	0	B mix	Reduced production rate; not enough trucks to haul the asphalt concrete
	2:30	215.7	205.3	--	10.4	290	35	3-4	--	0.01	B mix	
	3:01	209.7	199.4	--	10.3	285	35	3-4	--	0.02	B mix	
11/13/83 (a.m.)	8:01	212.8	202.9	--	9.9	295	35	3-4	--	0.13	B mix	
	8:29	256.9	244.3	--	12.6	275	50	3-4	--	0	B mix	
	8:58	236.7	225.1	--	11.6	275	60	3-4	--	0	B mix	
	9:29	238.3	226.7	--	11.6	285	50	3-4	--	0	B mix	
	9:59	241.1	229.0	--	12.1	285	45	3-4	--	0.02	B mix	
	10:30	243.4	231.7	--	11.7	280	45	3-4	--	0	B mix	10:54 stopped operation to switch to C mix
	11:05	230.1	218.1	--	11.4	280	60	3-4	--	0	C mix	
	11:29	222.8	211.6	--	11.2	255	60	3-4	--	0	C mix	11:52 stopped operation to switch to M mix
	11/14/83	185.1	176.2	--	8.9	305	40	3-4	--	0.01	M mix	
	8:30	209.1	198.4	--	10.7	305	45	3-4	--	0	M mix	
11/14/83 (a.m.)	9:00	219.9	208.9	--	11.0	290	45	3-4	--	0	M mix	
	9:30	218.9	207.9	--	11.0	290	50	3-4	--	0	M mix	
	10:00	224.6	213.3	--	11.3	285	50	3-4	--	0	M mix	
	10:30	219.3	208.5	--	10.8	275	50	3-4	--	0	M mix	
	11:08	201.5	191.2	--	10.3	280	50	3-4	--	0	C mix	10:55 stopped operation to switch to C Mix

(continued)

TABLE 3-5 (continued)

Date	Time	Production rate, tph ^a	Virgin, tph ^a	RAP, tph ^a	Asphalt, tph ^b	Mix temp., °F	Burner setting, %	Operator estimate moisture content		Drum internal pressure, ΔP	Mix design	Comment
								Virgin	RAP			
	11:30	206.8	196.5	--	10.3	295	35	3-4	--	0	C mix	
(p.m.)	12:00	182.6	173.4	--	9.2	300	40	3-4	--	0	M mix	11:43 plant shut off to switch to M mix
	12:30	199.7	189.8	--	9.9	285	40	3-4	--	0	M mix	
	1:00	202.5	192.4	--	10.1	300	35	3-4	--	0.03	M mix	1:18 plant shut down; silo filled; slow laydown operation
	2:06	204.5	194.5	--	10.1	270	55	3-4	--	0	C mix	
	2:25	190.1	180.5	--	9.6	290	50	3-4	--	0	C mix	
11/15/83 (a.m.)	7:38	222.1	211.0	--	11.1	255	50	3-4	--	0	M mix	
	8:00	215.6	204.8	--	10.8	285	45	3-4	--	0	M mix	
	8:30	241.5	229.4	--	12.1	290	50	3-4	--	0	M mix	Stopped operation at 8:44 to switch to hot sand RAP mix
	9:03	178.6	134.2	37.9	6.5	285	55	8	3.5	0	Recycle-HS ^d	8:56 started recycle mix; hot hot sand mix typically runs at lower production rate
	9:30	157.7	116.0	36.4	5.3	310	65	8	3.5	0	Recycle-HS	
	9:57	170.7	126.5	38.1	6.1	255	60	8	3.5	0	Recycle-HS	
	10:30	156.1	119.8	30.8	5.5	255	65	8	3.5	0	Recycle-HS	
	10:55	166.6	117.1	43.9	5.6	265	65	8	3.5	0	Recycle-HS	11:00 shut off operation to switch to M mix
(p.m.)	12:07	245.6	233.3	--	12.3	280	60	3-4	--	0	M mix	
	12:30	241.1	229.1	--	12.0	285	60	3-4	--	0	M mix	
	1:00	237.4	225.3	--	12.1	265	60	3-4	--	0	M mix	1:21 stopped to switch to C mix
	1:35	226.7	215.5	--	11.2	270	60	3-4	--	0	C mix	1:38 to 1:41 shut off water to prespray and venturi throat
	1:55	223.8	212.8	--	11.0	295	65	3-4	--	0	C mix	

^aMeasured by weigh bridge on feed conveyors.

^bMeasured by flow meter at asphalt storage tank.

^cRecycle-A = recycle A mix.

^dRecycle-HS = recycle hot sand mix.

Tables 3-6 and 3-7 contain a summary of the venturi scrubber operating data collected during the test program.

3.5. SUMMARY OF PERTINENT PLANT OPERATION INFORMATION DURING THE EMISSION TEST PROGRAM

This section includes a summary of pertinent information concerning the operation and monitoring of the asphalt concrete plant and venturi scrubber.

3.5.1 Asphalt Concrete Production Summary

Table 3-8 presents a summary of the average asphalt concrete production and mix type produced during each test period.

3.5.2 Blue Haze Production

The water flow to the presprays was turned off for over an hour on the afternoon of November 10, 1983 in an effort to generate blue haze by eliminating the prespray cooling. No blue haze was observed during this period. With the concurrence of the EPA Industrial Studies Branch (ISB) and Emission Measurements Branch (EMB) representatives, testing under reduced water flow conditions was cancelled.

TABLE 3-6. SUMMARY OF VENTURI SCRUBBER OPERATING DATA COLLECTED
DURING CONVENTIONAL OPERATION AT T. J. CAMPBELL
CONSTRUCTION COMPANY, OKLAHOMA CITY, OKLAHOMA

Run No.	Date	Time	Pressure Drop (In. H ₂ O)	Scrubber Water Flow Rates (GPM)	
				Total to System	Venturi Throat
Part C1	11/12	1100	13.5	215	41
		1200	13.5	220	41
		1230	13.5	220	41
		1301	13.5	220	42
		1330	13.5	220	42
			13.5 (avg)	219 (avg)	41 (avg)
Part C2	11/13	0801	13.5	215	41
		0829	13.5	220	42
		0858	13.5	215	42
		0929	13.5	220	42
		0959	13.5	220	42
		1030	13.5	220	42
		1105	13.5	220	42
		1129	13.0	220	42
			13.4 (avg)	219 (avg)	42 (avg)
Part C3	11/14	0803	13.5	215	42
		0830	13.5	215	42
		0900	13.5	215	41
		0930	13.5	215	41
		1000	13.5	215	42
		1030	13.5	215	42
			13.5 (avg)	215 (avg)	42 (avg)
PAH C1	11/14	1200	13.5	220	43
		1230	13.5	220	42
		1300	13.5	220	42
		1406	13.0	220	42
			13.4 (avg)	220 (avg)	42 (avg)

TABLE 3-7. SUMMARY OF VENTURI SCRUBBER OPERATING DATA COLLECTED DURING RECYCLE OPERATION AT T. J. CAMPBELL CONSTRUCTION COMPANY, OKLAHOMA CITY, OKLAHOMA

Run No.	Date	Time	Pressure Drop (In. H ₂ O)	Scrubber Water Flow Rates (GPM)	
				Total to System	Venturi Throat
Part R1	11/11	0837	12.5	235	40
		0901	12.5	235	40
		0930	12.5	225	40
		1001	14.5	220	38
		1030	14.5	220	41
		1100	14.5	220	41
		1130	14.5	220	41
		1210	14.0	220	41
		1230	14.0	220	42
		1300	14.0	220	41
		1332	14.0	220	42
		1400	14.0	220	42
		1430	14.0	220	41
			13.8 (avg)	223 (avg)	41 (avg)
Part R2	11/11	1501	14.0	220	41
		1531	13.5	220	41
		1602	13.5	220	41
		1630	14.0	220	42
		1700	14.0	220	41
		1726	14.0	220	41
			13.8 (avg)	220 (avg)	41 (avg)
Part R3	11/12	0700	14.0	215	42
		0730	14.0	220	42
		0801	14.0	220	41
		0830	14.0	220	42
		0900	13.5	220	41
			13.9 (avg)	219 (avg)	42 (avg)
PAH R1	11/15	0903	13.0	225	30
		0930	13.0	210	30
		0957	12.5	215	30
		1030	12.5	210	30
		1055	12.5	210	30
			12.7 (avg)	214 (avg)	30 (avg)

TABLE 3-8. AVERAGE PRODUCTION AND MIX TYPE DURING TESTING PERIOD---
 T.J. CAMPBELL CONSTRUCTION COMPANY, OKLAHOMA CITY, OKLAHOMA

Date	Test period time (beginning-end)	Average production rate, tph	Product type
11/11/83	08:39-14:33 ^a	229.3	Recycle A mix
11/11/83	15:15-17:04 ^a	249.8	Recycle A mix
11/12/83	07:13-09:00 ^a	235.8	Recycle A mix
11/12/83	11:39-13:19 ^a	243.5	Virgin B mix
11/12/83	14:18-15:20 ^b	215.9	Virgin B mix
11/13/83	08:53-11:12 ^a	235.4	Virgin B&C mix
11/14/83	08:13-10:03 ^a	212.8	Virgin M mix
11/14/83	10:14-11:43 ^b	209.2	Virgin M&C mix
11/15/83	12:25-14:00 ^b	232.3	Virgin M&C mix

^aControlled emission test periods - uncontrolled emission tests
 conducted sometime during the indicated time periods.

^bUncontrolled particle size test periods.

SECTION 4

SAMPLING LOCATIONS

A schematic diagram of the asphalt concrete process is presented in Figure 4-1. The general location of each sampling point and the parameters measured at each sampling location are also presented in Figure 4-1. Section 4 contains a brief description of each of the sampling locations used at T. J. Campbell during the emissions testing program.

4.1 VENTURI SCRUBBER INLET SAMPLING LOCATIONS

Uncontrolled emissions samples were collected in the duct work between the drum mixer and the wet venturi scrubber. A side view and top view of the duct work immediately upstream and downstream of the uncontrolled emissions sampling location is illustrated in Figure 4-2. Flue gas exiting the rotating drum enters the knockout duct that carries the flue gas upward about 10 to 12 feet where the flue gas then flows horizontally in a triangular duct. The triangular duct funnels the gas to a 90° downward bend into the wet venturi scrubber. Uncontrolled emissions samples were collected in the triangular duct.

Figure 4-3 presents the location of the four 3-inch ports that were used to measure the gas flow rate and collect particulate mass, TOC, extractable organics, trace metals, and polynuclear aromatic hydrocarbon samples at the venturi inlet. The four sampling ports were located about two feet upstream from the water sprays in the triangular duct. These co-current sprays, used to cool flue gases prior to venturi entry, did not interfere with the sampling activities. Figure 4-3 includes a description of the 16 sampling points used to characterize the inlet duct.

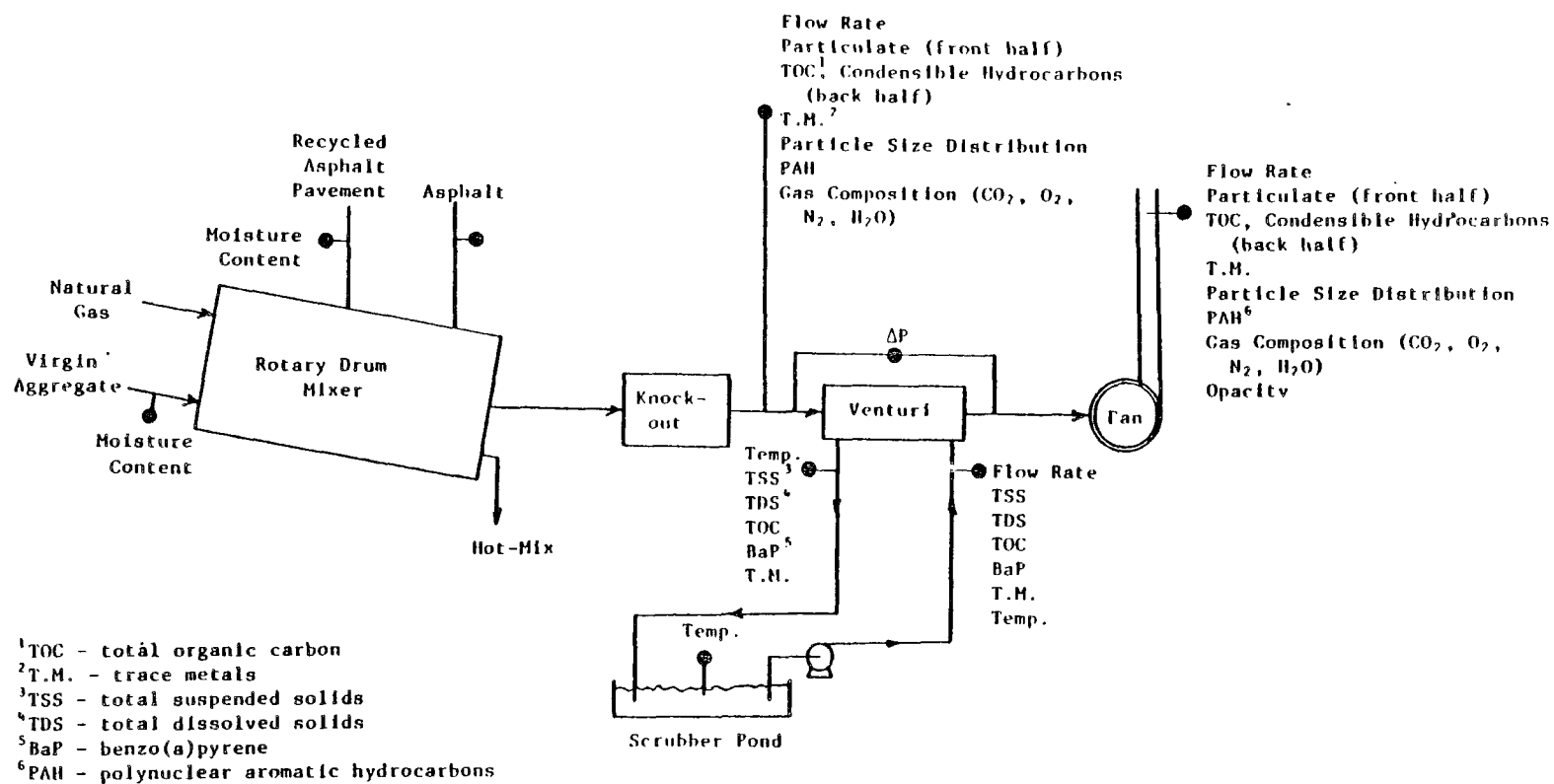


Figure 4-1. Schematic of asphalt concrete process including sampling point locations and sampling matrix.

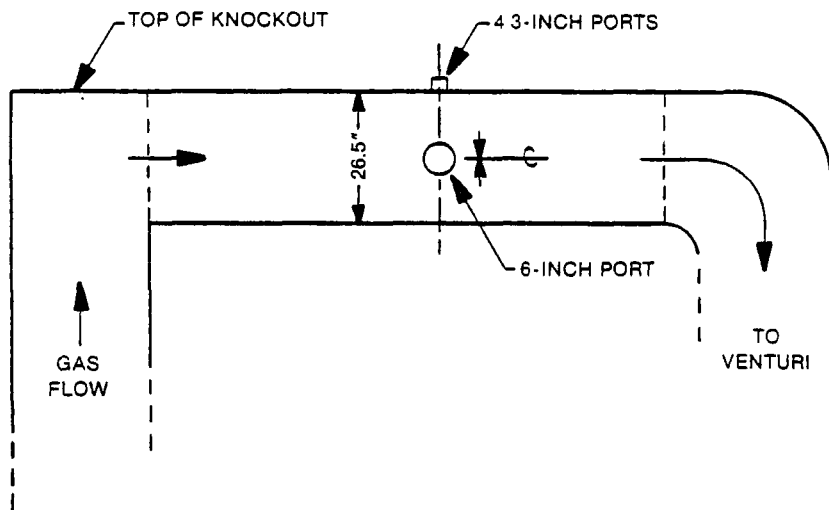


Figure 4-2A. Side View of Inlet Duct Sampling Ports.

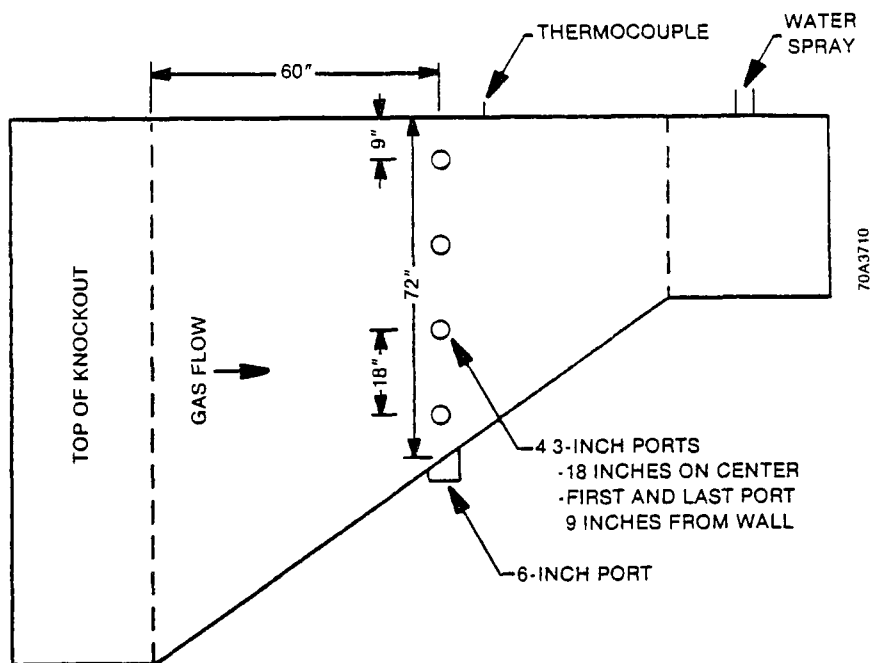


Figure 4-2B. Top View of Inlet Duct Sampling Ports.

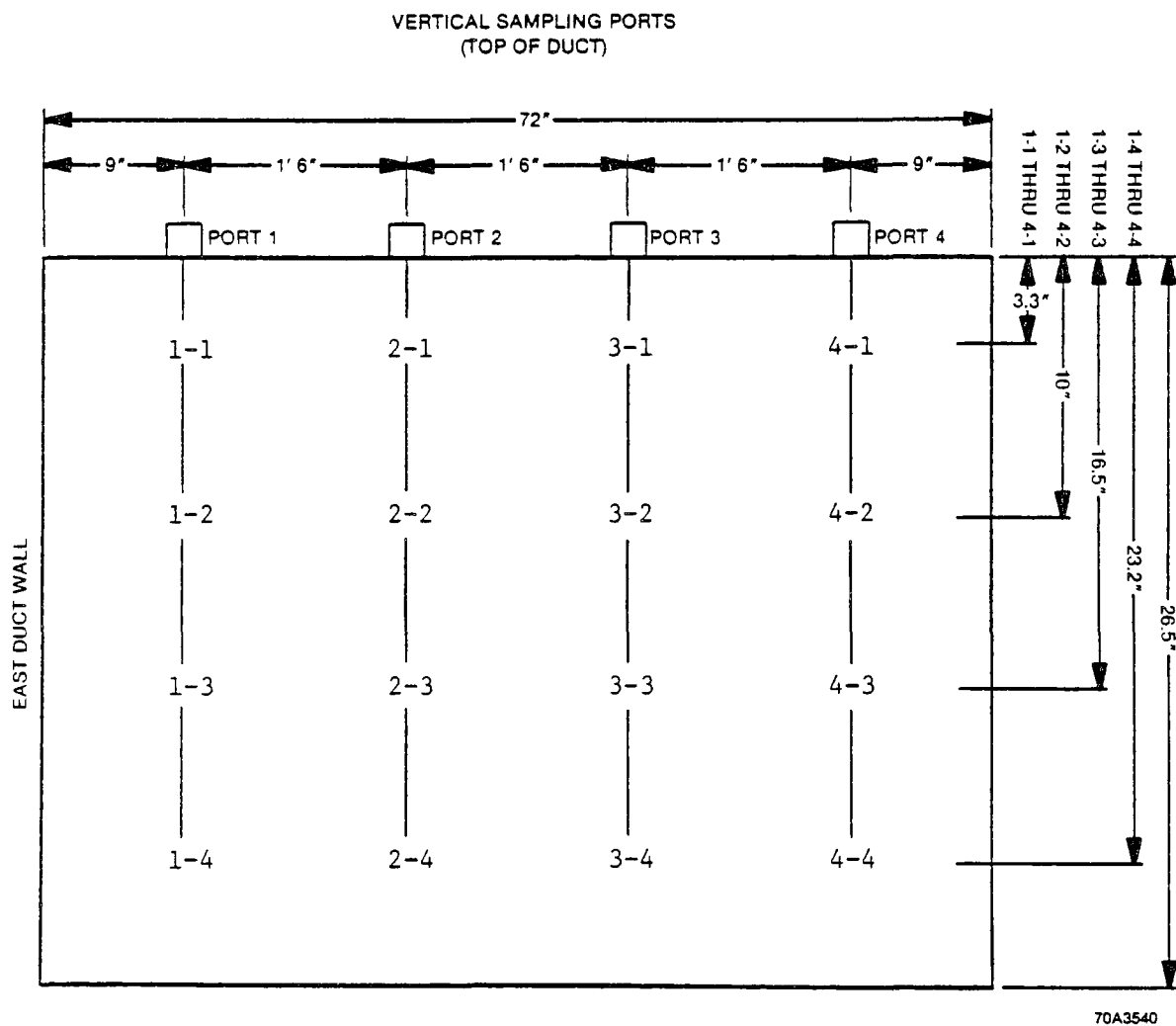


Figure 4-3. Venturi scrubber inlet sampling location for gas flow rate, particulate mass, condensible hydrocarbons, trace metals, and polyaromatic hydrocarbons emissions sampling.

Uncontrolled flue gas samples for O₂ and CO₂ analysis were collected at sampling point 2-2 as illustrated in Figure 4-3.

Particle size distribution (PSD) samples were collected through the single 6-inch port (Port 5 illustrated in Figure 4-4) mounted on the east side of the triangular duct. The center of Port 5 is situated 13.25 inches from the top of the duct. PSD samples were collected 27 inches from the east duct wall (Point 5-1).

4.2 VENTURI SCRUBBER OUTLET SAMPLING LOCATIONS

Controlled emissions samples were collected at the outlet of the venturi scrubber. Flue gas exiting the venturi scrubber entered the exhaust fan and then passed through a flow control damper. The flue gas then exited through a rectangular stack. Controlled emissions samples were collected from two sets of sampling ports on the stack.

The first set of ports consisted of three 3-inch ports located about eight feet downstream of the control damper. The second set of ports consisted of six 3-inch ports located about six feet further downstream from the first set of ports.

Particle size distribution tests were unsuccessfully attempted through the three ports located immediately downstream of the control damper. Figure 4-5 illustrates the location of the port and point used for the particle size distribution tests on controlled emissions.

Gas flow rate measurements and particulate mass, TOC, extractable organics, trace metals, and polynuclear aromatic hydrocarbon samples were collected using the set of six 3-inch ports. Figure 4-6 illustrates the location of the six ports and the locations of the twenty-four sampling points used to collect controlled emissions samples.

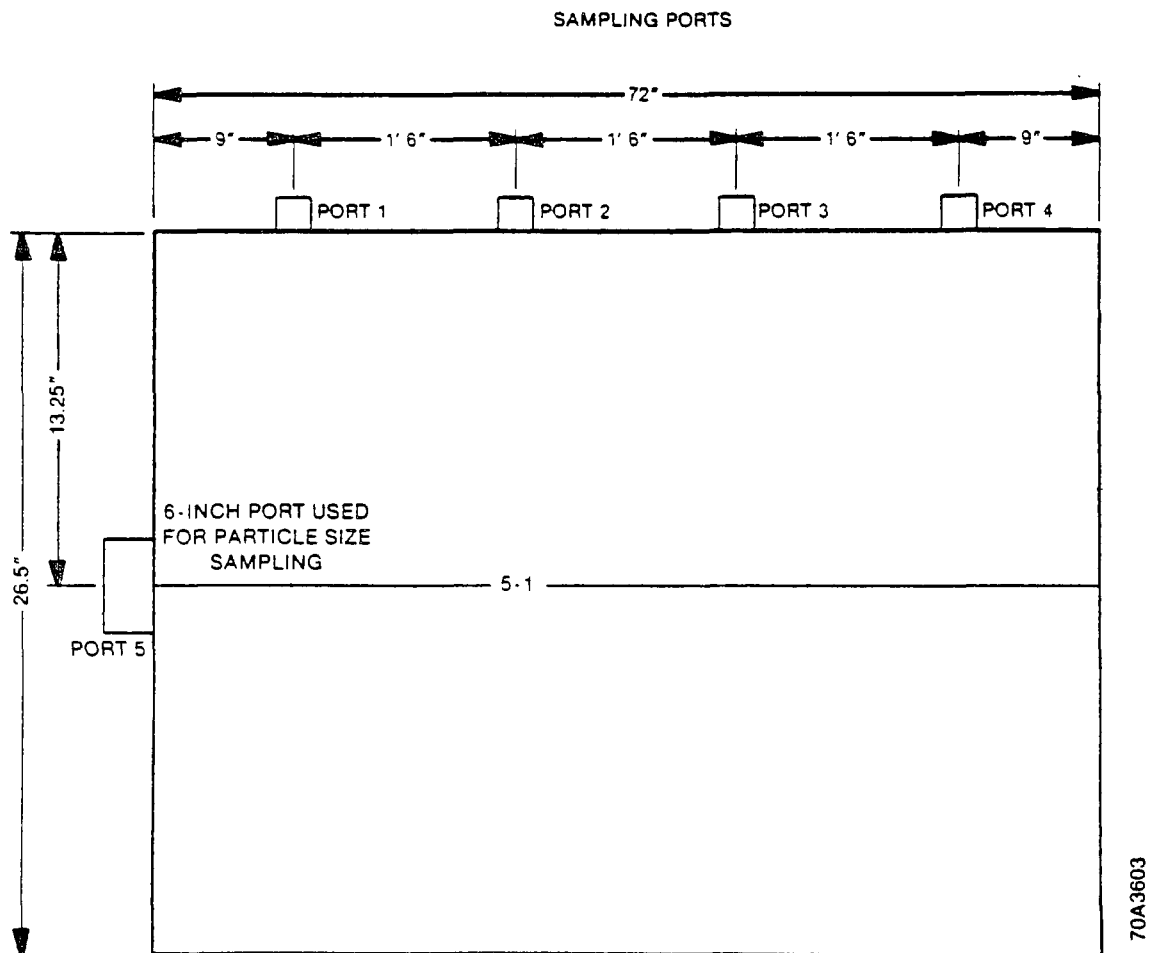


Figure 4-4. Venturi scrubber inlet sampling location for the collection of particle size distribution samples.

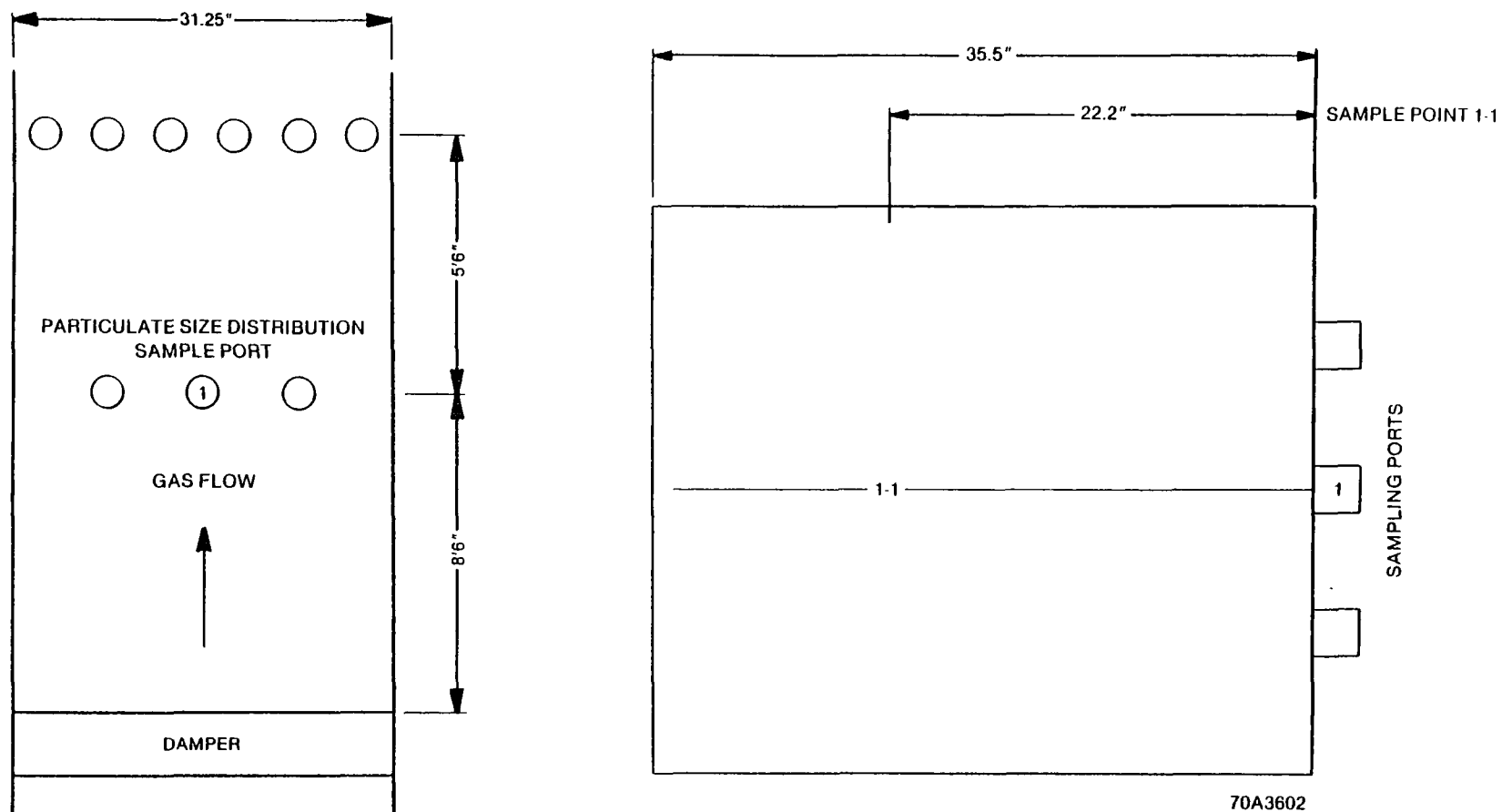
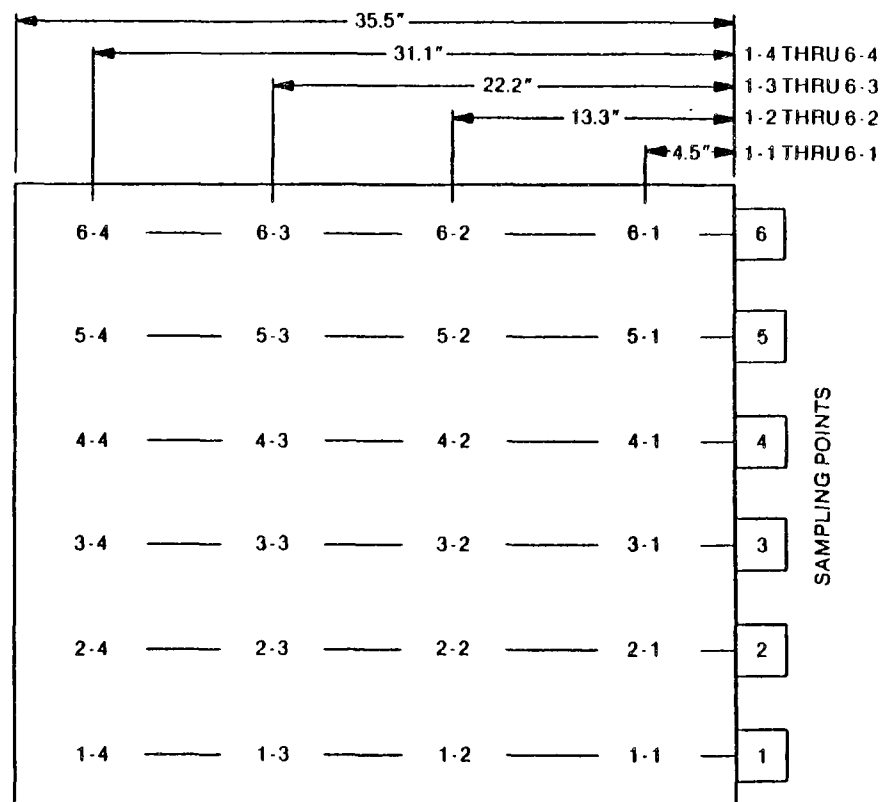
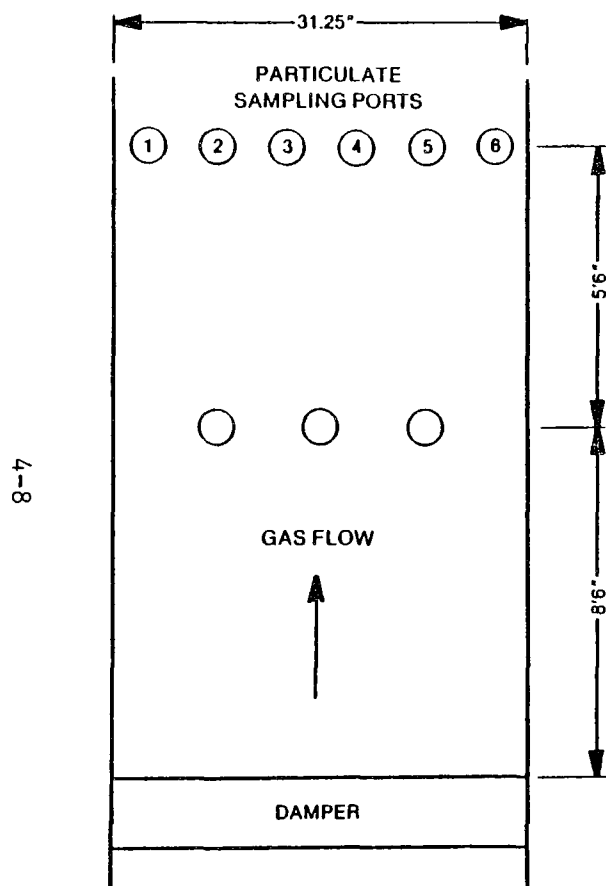


Figure 4-5. Venturi scrubber outlet sampling location for particle size distribution sampling.



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Figure 4-6. Venturi scrubber outlet sampling location for gas flow, particulate mass, condensable hydrocarbons, trace metals, and polyaromatic hydrocarbons emission sampling.

4.3 VISIBLE EMISSION OBSERVATION LOCATIONS

Visible opacity observations were made of the plume exiting the stack. A total of six locations were used to make the opacity observations during this program. Figure 4-7 presents the layout of the T. J. Campbell asphalt plant and the approximate location of the observer with respect to the stack at each position during visible emissions measurements.

4.4 VENTURI SCRUBBER WATER SAMPLING LOCATIONS

Samples of water supplied to the venturi scrubber and samples of venturi scrubber effluent water were collected during emissions testing. Samples of pond water being supplied to the venturi scrubber spray nozzles were collected at the floating pump intake (refer to Figure 4-8). The intake line floats out in the pond and access to the intake is by means of a wooden plank. Water samples were collected near the pump intake by dipping a sample container into the pond at the intake position.

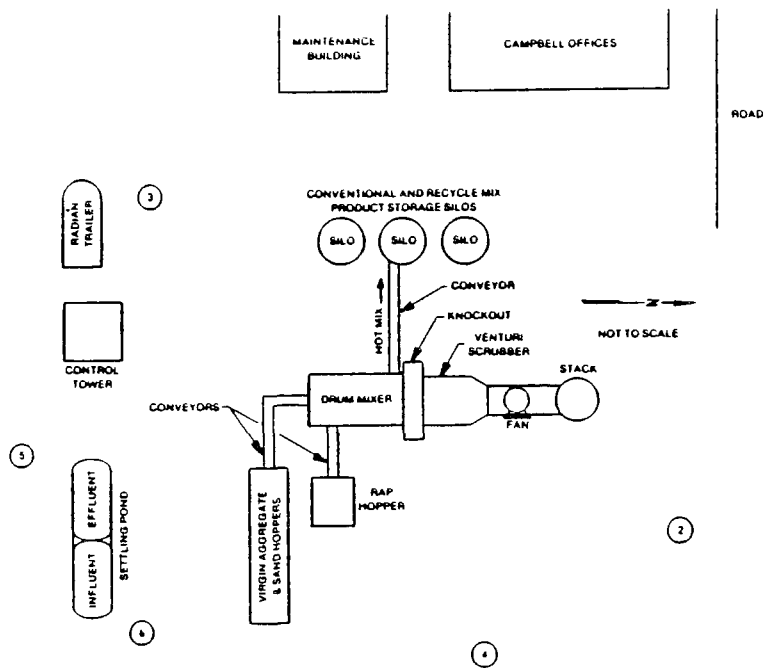
Venturi scrubber water drains into a collection box below the venturi. The scrubber water then drains back to the settling pond by means of an 8-inch diameter plastic pipe. Samples of the scrubber effluent water were collected from the collection box below the venturi scrubber.

4.5 VENTURI SCRUBBER PROCESS MONITORING LOCATIONS

The venturi scrubber pressure drop and venturi scrubber water flow rates were monitored during the emissions test program.

4.5.1 Venturi Scrubber Pressure Drop Monitoring

Figure 4-9 illustrates the locations used to monitor the venturi pressure drop. Swagelok® connectors were installed in the duct work immediately upstream and downstream of the venturi scrubber. Tygon® tubing was used to



Position No.	Date	Time	Approximate Distance from Stack (ft)	Direction of Observer from Discharge Point	Plant Mode ¹
1	11-10-83	1000-1625	1000	SE	R
2	11-11-83	0819-1126	125	NE	R
3	11-11-83	1308-1718	100	SW	R
4	11-12-83	0722-1429	200	E	C&R
5	11-13-83	0800-1150	80-100	S-SE	C
6	11-15-83	0815-1054	250	E-SE	R

¹C - conventional operation
R - recycle operation

Figure 4-7. Locations of visible emission observations at the T.J. Campbell asphalt plant, Oklahoma City, Oklahoma.

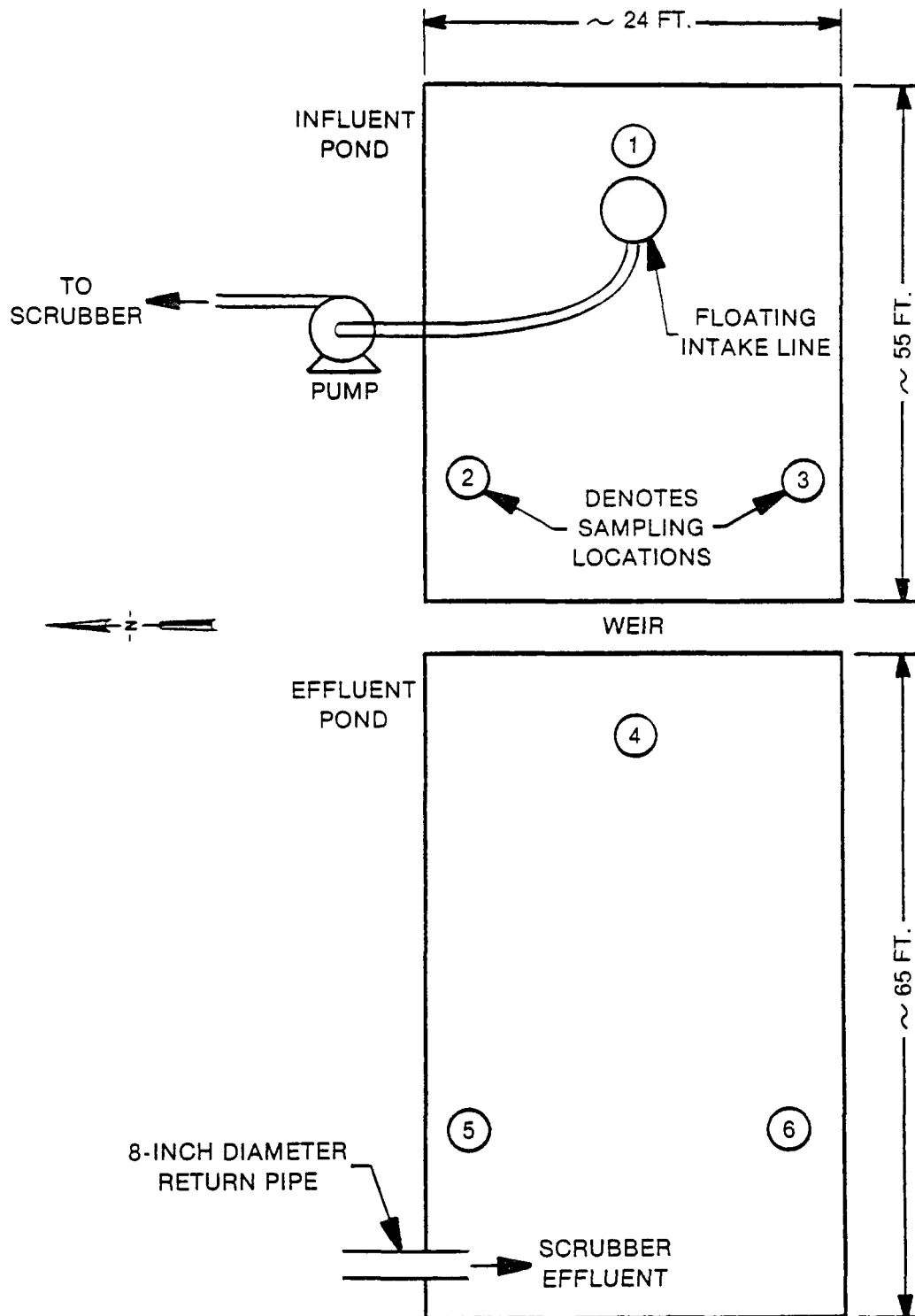


Figure 4-8. Layout of effluent and influent scrubber ponds including sampling locations.

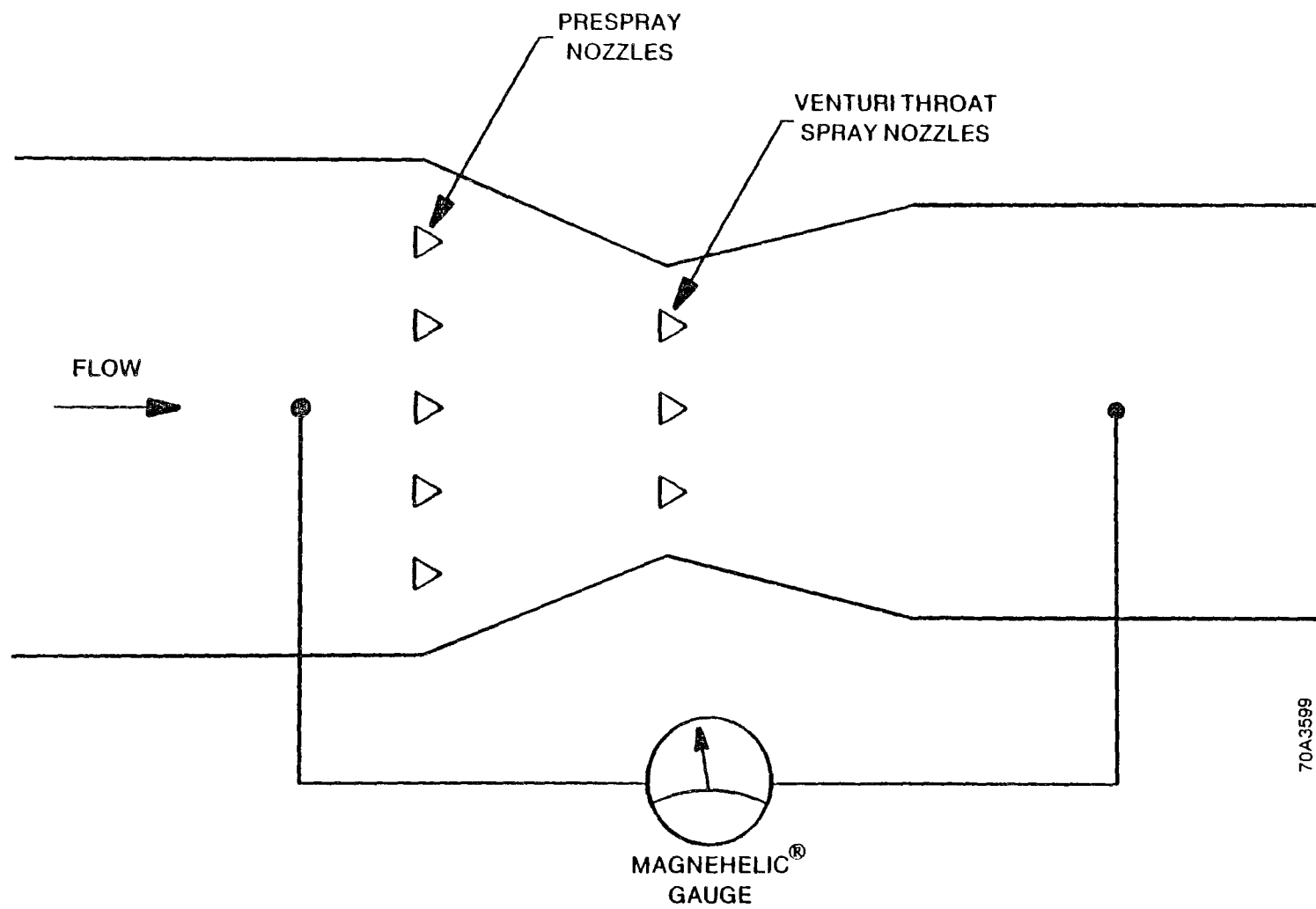


Figure 4-9. Venturi scrubber pressure drop monitoring location.

connect the sample taps to a Magnehelic® differential pressure gauge for use in monitoring the scrubber differential pressure.

4.5.2 Venturi Scrubber Water Flow Rate Monitoring

The total water flow rate to the venturi scrubber system and the flow rate of water to the venturi spray nozzles were monitored using paddle wheel type sensors. Flosensors® were used to monitor the water flow rate at the two locations. Figure 4-10 depicts the locations of the two Flosensors® in the scrubber system. One Flosensor® was installed in the 4-inch main line to monitor the total flow of water to the scrubber system. A second Flosensor® was installed in the 2-inch line that supplies water to the venturi spray nozzles. Both Flosensors® were installed in vertical sections of pipe to ensure full-pipe flow of water during monitoring.

4.6 ASPHALT CONCRETE PROCESS SAMPLING LOCATIONS

During emissions testing samples of the virgin aggregate and recycled asphalt pavement were collected from the conveyor belts that transport the raw materials to the drum mixer from the storage bins.

Samples of the liquid asphalt cement were obtained from a vendor truck that transported the asphalt cement to the plant.

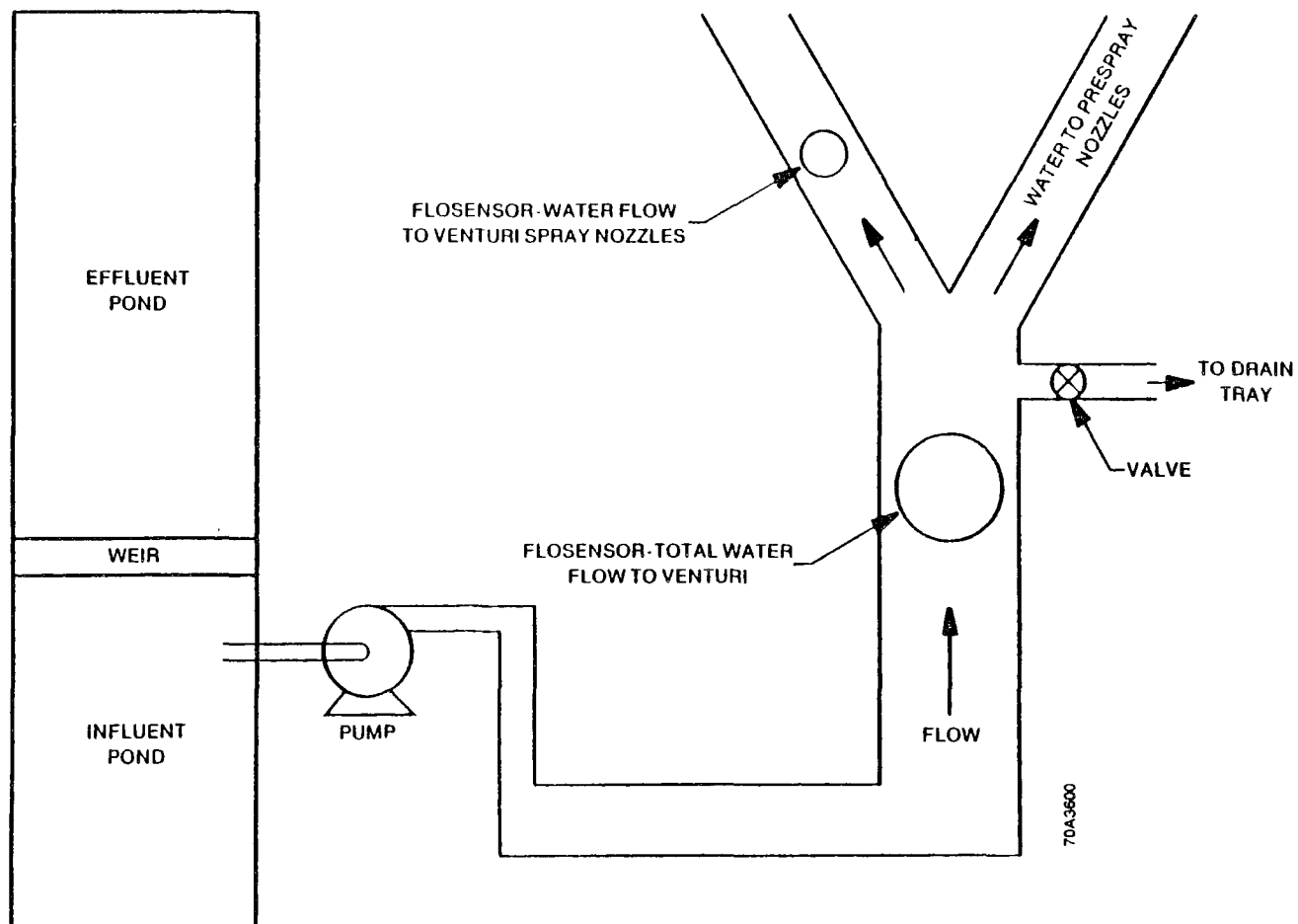


Figure 4-10. Location of flosensors used to monitor the flow rate of water to the T.J. Campbell wet venturi scrubber.

SECTION 5

SAMPLING AND ANALYSIS

This section contains general descriptions of sampling equipment, sample collection techniques, and sample recovery techniques used during the emissions testing program at the T.J. Campbell asphalt concrete plant. Also included are analytical preparation techniques and analytical methodology used to analyze the samples collected during sampling. Additional information is provided in Appendix J.

5.1 SAMPLING PROCEDURES

This section provides a description of the sampling procedures that were used to collect samples of the flue gas, scrubber waters, and process solids for analysis.

5.1.1 Source Sampling Procedures

Included in Table 5-1 is a list of the various parameters that were measured at the inlet and outlet of the venturi scrubber and the sampling methodology that was used during source sampling. Each of the sampling methods listed in Table 5-1 are described in this section. Whenever possible, EPA referenced source sampling methods were used. The EPA reference methods were taken from the Environmental Reporter, Volume I - Federal Regulations, Section 121, "Air," Appendix A. If an EPA reference method did not exist, a detailed description of the methodology is provided.

5.1.1.1 Gas Phase Composition--

Following are discussions of the methods which were used to measure gas phase composition.

TABLE 5-1. SUMMARY OF SOURCE SAMPLING PARAMETERS AND METHODOLOGY

Parameter Measured	Test Location	Methodology	Sample Frequency ¹			
			Conventional		Recycle	
			Uncontrolled	Controlled	Uncontrolled	Controlled
Number and location of sampling points, gas velocity and volumetric gas flow	Inlet/outlet	EPA Methods 1 & 2	6	6	4	4
Gas phase composition/dew point	Inlet/outlet	Wet bulb/dry bulb	8	3	1	2
Gas phase composition and molecular weight	Inlet/outlet	EPA Method 3	5	1	4	0
Gas phase composition moisture content	Inlet/outlet	EPA Method 4	4	4	4	4
Particulate loading	Inlet/outlet	Modified EPA Method 5E	3	3	3	3
TOC/Extractable hydrocarbons	Inlet/outlet	Modified EPA Method 5E with 0.1N NaOH impinger solutions	3	3	3	3
Trace metals	Inlet/outlet	Modified EPA Method 5E with acid/base impingers	1	1	1	1
Polynuclear Aromatic hydrocarbons	Inlet/outlet	Modified EPA Method 5E with XAD-2 resin canister	1	1	1	1
Particle size distribution	Inlet	Andersen High Capacity Stack Sampler	3	-	1	-
Particle size distribution	Outlet	Andersen Mark III cascade Impactor	-	3 ²	-	2 ²

¹Number of valid sampling runs performed

²Number of attempted sampling runs

Moisture Determination--The moisture content of the outlet gas stream was determined using a modified version of the methodology described in EPA Method 4. This method requires that a known volume of particle free gas be pulled through a chilled impinger train. The quantity of condensed water is determined gravimetrically and then related to the volume of gas sampled to determine the moisture content.

The moisture content of the gas stream was determined simultaneously during each EPA Method 5E test and each particle size distribution determination. The absolute filter in the EPA Method 5E and particle sizing trains removed the particulate matter from the gas stream, allowing condensed water to collect in the impinger train.

The moisture content of the gas stream is required to calculate the molecular weight of the gas (wet) and the isokinetic gas sampling rate.

Relative Humidity--A wet bulb/dry bulb apparatus was used in conjunction with a psychrometric chart to determine the relative humidity of the scrubber gas streams. The wet bulb/dry bulb apparatus consists of two thermocouples strapped together. The front end of the first thermocouple extended out about three inches further than the second thermocouple. A cloth sock was placed tightly over the front two inches of the first thermocouple (wet bulb). Prior to sampling, the cloth sock was saturated with water. The thermocouples were then inserted into the center of the duct and the temperature of the wet bulb thermocouple monitored. After the temperature of the wet bulb thermocouple stabilized (reached equilibrium), the temperature of the dry thermocouple was measured. The wet bulb and dry bulb temperatures were used with a psychrometric chart to determine the relative humidity and moisture content of the gas stream. A high temperature psychrometric chart (dry bulb temperature ~500°F) was used during this program because of the high temperature (~300°F) of the uncontrolled emissions gas stream. The wet bulb/dry bulb temperatures were determined at least once during each test run to verify the moisture content of the gas streams.

Molecular Weight Determination--The dry molecular weight of the gas stream was determined using the grab sampling technique described in EPA Method 3. The dry molecular weight of the gas was calculated based upon the O₂, CO₂, and N₂ concentration. CO₂ and O₂ concentrations were determined using an Orsat apparatus. N₂ was determined by difference.

A small diaphragm pump with a stainless steel probe were used to extract a small volume (~10 liters) of the gas sample which was collected in a Tedlar® bag. Collection of the gas sample in the Tedlar® bag required 15 to 20 minutes and was performed immediately following a source sampling run (ex. EPA Method 5E). A specific volume of gas is then transferred to the Orsat. During analysis, the gas sample is passed through two absorbing solutions designed to selectively remove CO₂ and then O₂. The decrease in the gas volume in the Orsat container is proportional to the dry concentration of the absorbed species. The balance of the gas mixture was assumed to be N₂. If more than six passes were required to obtain a constant (0.3% difference, absolute) reading for either O₂ or CO₂, the appropriate absorbing solution was replaced.

5.1.1.2 Volumetric Gas Flow Rate Determinations--

Total gas flow rates at the scrubber inlet and outlet were determined using procedures described in EPA Method 2. The volumetric gas flow rate was determined by measuring the cross sectional area of the inlet duct and the stack and the average velocity of the gas stream. The area of the inlet duct and the stack was determined by direct measurement.

The number of sampling points required to statistically measure the average gas velocity in the stack was determined using the procedures outlined in EPA Method 1. The number of sampling points and their distance from the duct wall is a function of the proximity of the sampling location to its nearest upstream and downstream flow disturbance. A total of 24 sampling points (4x6 matrix) were used at the stack sampling location.

The inlet sampling location (refer to Section 4) did not meet EPA Method 1 criteria but represented the best possible location available for collecting uncontrolled emission samples. The number of inlet sampling points were limited to 16 (4x4 matrix) because of the high particulate loading and limited sample collection time.

The gas stream velocity was calculated from the average gas velocity pressure (ΔP), the average flue gas temperature, wet molecular weight, and absolute pressure. ΔP and temperature profile data were measured at each of the sampling points using an S-type pitot tube and type-K thermocouple. A Magnehelic® gauge was used to measure the pressure drop (ΔP) across the S-type pitot.

Barometric pressure readings were obtained daily by phoning Tinker Air Force Base. The static pressure was measured by inserting a stainless steel probe into the duct. A Magnehelic® gauge attached to the probe was used to measure the static pressure within the duct.

5.1.1.3 Particulate Loading Determination--

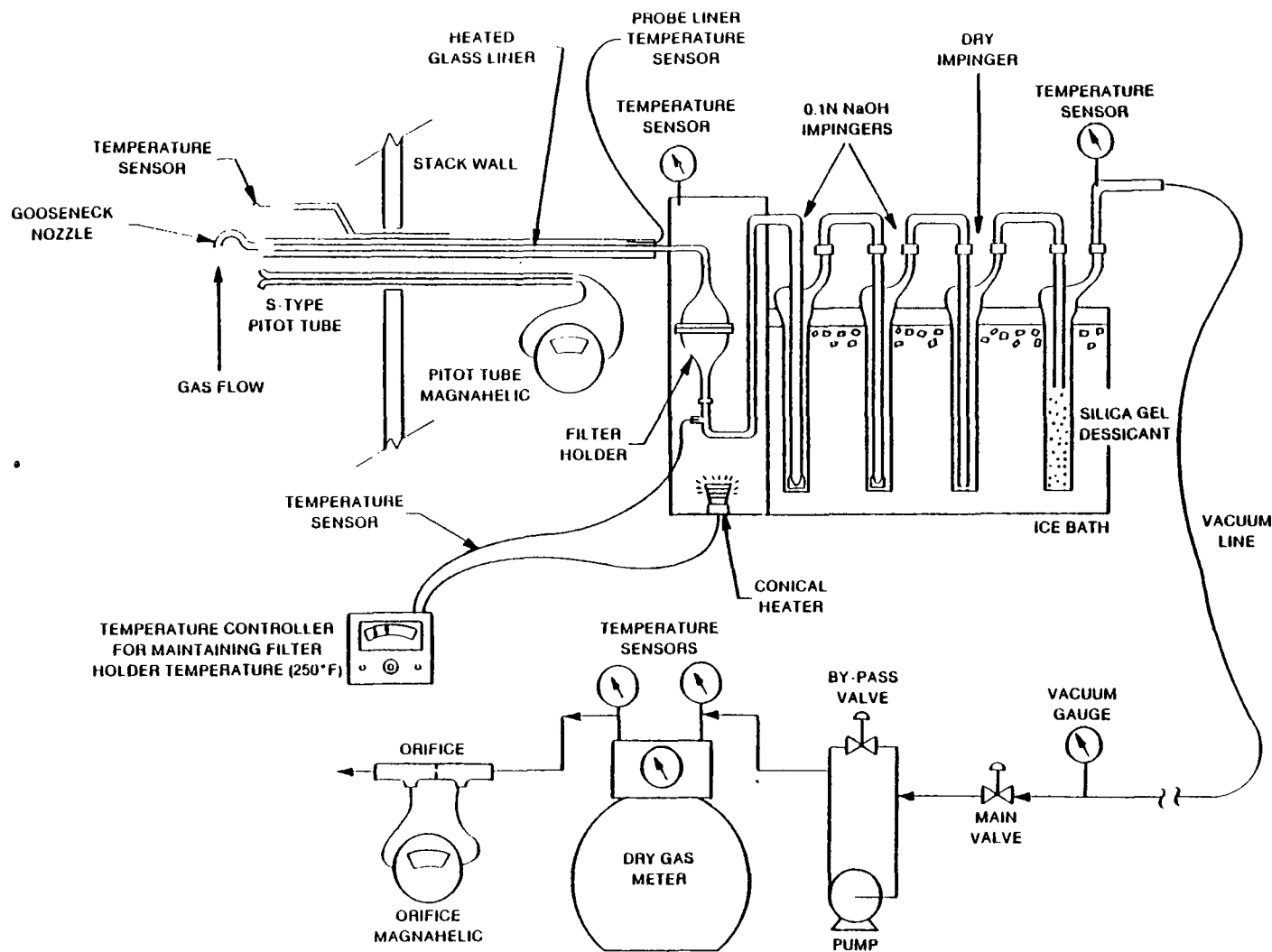
A modified version of the sampling procedure specified in EPA Method 5E was used to measure the particulate and condensible hydrocarbon loadings. The primary modifications to the standard procedure include:

- o impinger train configuration and impinger contents depending upon the chemical specie(s) of interest,
- o the sample recovery procedure(s),
- o performing an acetone probe rinse prior to the trichloroethane probe rinse, and
- o maintaining the filter temperature at $250^{\circ}\text{F} \pm 10^{\circ}\text{F}$.

Figure 5-1 illustrates the EPA Method 5E sampling train. A sample of particulate-laden flue gas was collected isokinetically through a stainless steel gooseneck nozzle. A stainless steel or glass-lined heat traced probe transported the flue gas from the duct to the hot box. Problems were encountered with glass liners breaking during the runs. To eliminate this problem a stainless steel probe was used during later runs. The trace metal samples were collected using a glass liner. The probe temperature was closely monitored and controlled at $250^{\circ}\text{F} \pm 10^{\circ}\text{F}$. After entering the hot box, the particulate matter was removed from the gas stream by means of a glass filter housed in a glass holder. The temperature of the sampled gas was monitored and controlled at the filter using a time proportioning temperature controller to a temperature of $250^{\circ}\text{F} \pm 10^{\circ}\text{F}$.

The filtered gas stream then entered a series of impingers immersed in an ice bath. The configuration and contents of the impingers depended on the type of chemical specie(s) of interest. The impinger train used during condensible hydrocarbons and particulate determinations consisted of four impingers situated in an ice bath. The first two impingers were of the Greenburg-Smith design and contained 250 ml of 0.1 N sodium hydroxide (NaOH) for hydrocarbon collection. The third and fourth impingers were of the modified Greenburg-Smith design. The third impinger was dry and the fourth impinger contained about 250 grams of silica gel for final moisture removal. Section 5.1.1.4 provides a description of the trace metals impinger train configuration that was used simultaneously with the particulate loading determination. All impingers were weighed before and after sampling using a top loader balance. The impinger weight gain data was used to calculate the moisture content of the flue gas.

During sampling, the flue gas velocity was monitored by an S-type pitot tube attached to a Magnehelic® gauge. The isokinetic sampling rate was maintained through a system of valves and a leakless pump. The sampling rate was monitored using a calibrated orifice with a Magnehelic® gauge and



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Figure 5-1. Modified EPA Method 5E sampling train designed to collect particulate and condensible hydrocarbon samples at the venturi scrubber inlet and outlet.

the total sample volume was measured using a calibrated dry gas meter. The gas stream temperature was monitored using a type-K thermocouple and a pyrometer.

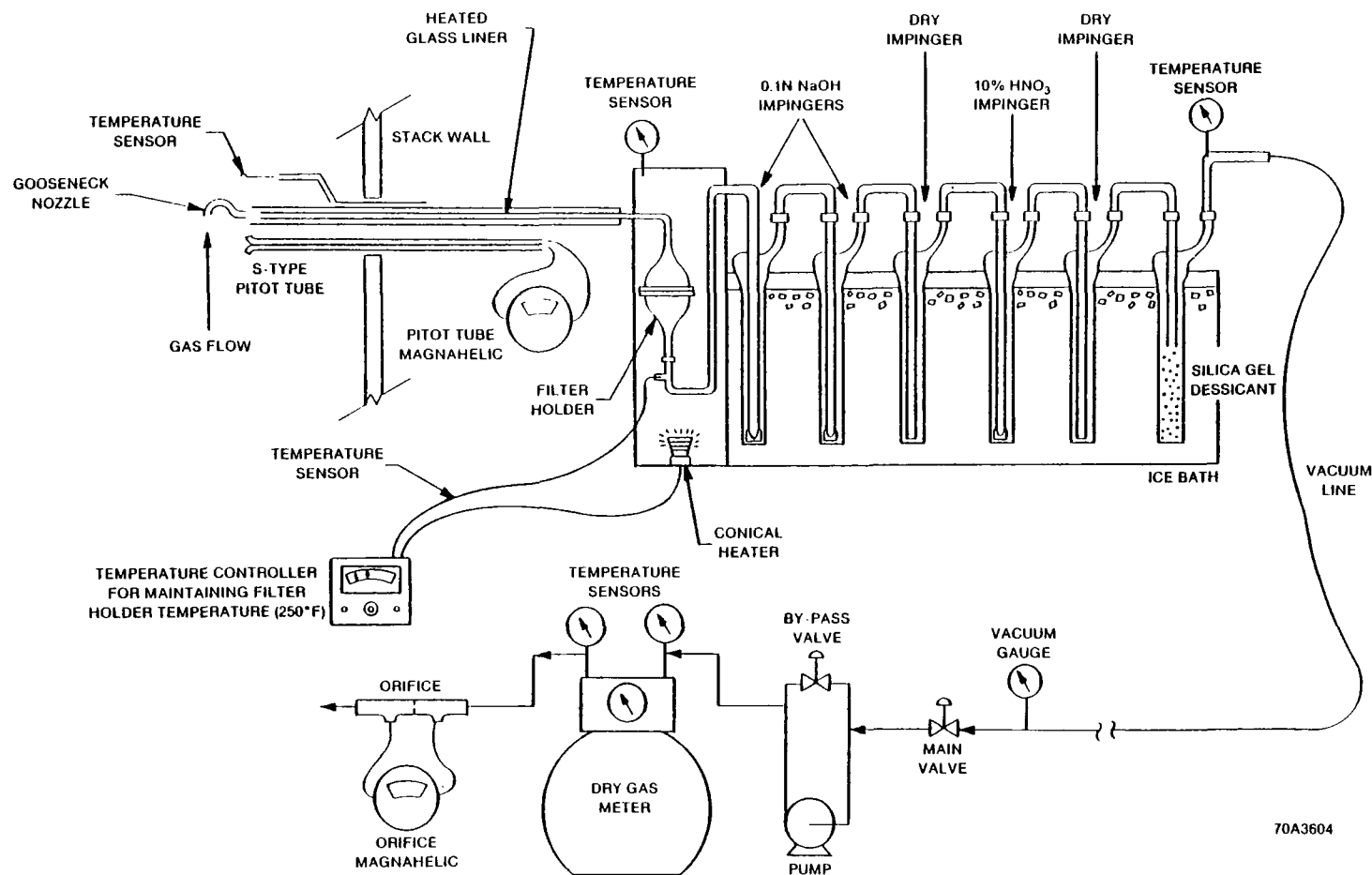
When sampling was completed, the nozzle, probe, and interconnecting glass pieces prior to the filter were brushed and washed, first with three volumes of acetone and then with a volume of 1,1,1-trichloroethane. The dual solvent rinse was requested by EPA to relate results to comparative Method 5 data and collect samples within the protocol of Method 5E. The acetone and trichloroethane "front-half" rinses were stored separately in individual 500 ml glass bottles with teflon lid inserts. The filter was transferred to the filter's original petri dish along with any particles or loose filter material in the holder.

After weighing, the impinger contents were quantitatively transferred to individual 500 ml glass bottles with teflon lid inserts. All of the glassware from the filter to the silica gel impinger was rinsed, first with two aliquots of 0.1 N NaOH and then with a volume of trichloroethane. The trichloroethane "back-half" rinses were stored separately in individual 500 ml glass bottles with teflon lid inserts.

The filters, impinger solutions, and acetone, trichloroethane, and NaOH rinses were carefully packaged for shipment back to Radian for weighing and other analyses.

5.1.1.4 Trace Metals Sample Collection--

Samples of the gas streams were collected during this program for trace metals analysis. Collection of the volatile trace metals samples was achieved by incorporating an acid impinger into the impinger train described in Section 5.1.1.3. The impinger, containing 250 ml of 10% ultrex nitric acid (HNO_3), was placed immediately downstream of the two 0.1 N NaOH impingers used for hydrocarbons collection. Sample collection was similar to the procedure described in Section 5.1.1.3. Figure 5-2 graphically illustrates the trace metals sampling train.



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Figure 5-2. Sampling train designed to collect trace metals samples at the venturi scrubber inlet and outlet.

Upon completion of sampling, the particulate and TOC/extractable hydrocarbon sample recovery procedure described in Section 5.1.1.3 was used. The HNO_3 impinger solution was stored in a 500 ml Nalgene bottle. The HNO_3 impinger was rinsed with an aliquot of 10% HNO_3 and the rinse added to the sample bottle.

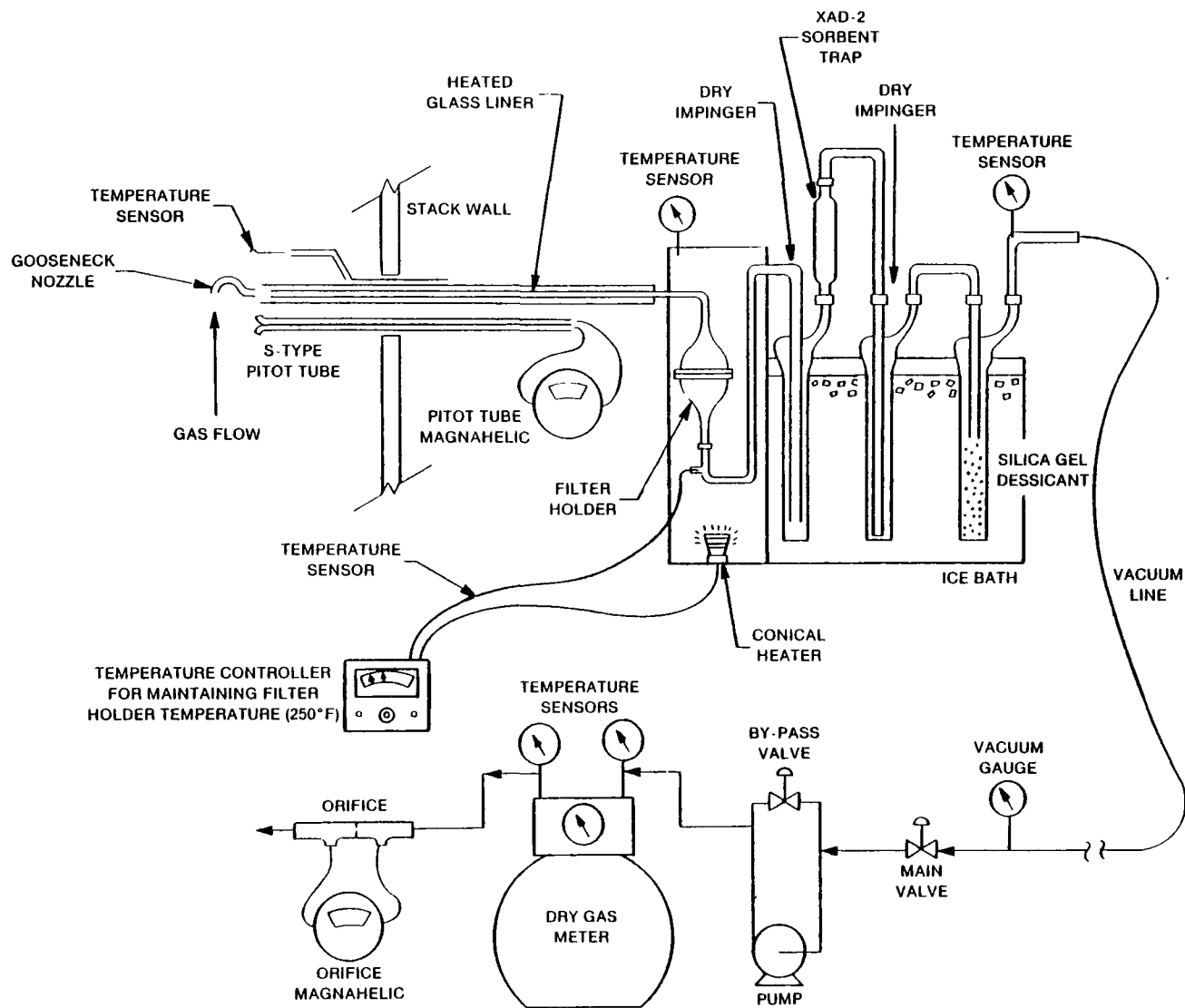
The filter, acid and base impinger solutions, and the acetone and trichloroethane rinse solutions were shipped back to Radian for trace metals analysis using procedures described in Section 5.2.

5.1.1.5 Polynuclear Aromatic Hydrocarbons Sample Collection--

Figure 5-3 illustrates the sampling train that was used to collect samples of the gas stream for PAH analysis. The PAH sample collection procedure is similar to the particulate loading procedure described in Section 5.1.1.3. The major differences between the two systems include impinger configuration, contents, and sample recovery procedures.

The PAH impinger train consisted of a dry impinger for cooling down the gas before entering the glass canister containing XAD-2 resin for PAH adsorption. The temperature of the gas entering the resin canister was monitored using a thermocouple. Following the XAD-2 resin canister was a second dry impinger for collection of any condensate occurring downstream of the XAD-2 resin. The third impinger contained silica gel for final moisture removal. The glassware in the hot box, the two dry impingers, and the XAD-2 resin canister were wrapped with aluminum foil to reduce sample exposure to ultraviolet radiation, which can cause possible photodegradation of the PAH's.

Upon completion of sampling, the sampling train was returned to the mobile laboratory for sample recovery. Incandescent lights were used in the mobile laboratory during sample recovery to minimize PAH photodegradation. The nozzle and glass probe liner were brushed and rinsed with methylene chloride. All interconnecting glassware in the hot box and impinger train



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Figure 5-3. Sampling train designed to collect polynuclear aromatic hydrocarbon samples at venturi scrubber inlet and outlet.

(except the silica gel impinger) were also rinsed with methylene chloride. The methylene chloride rinses were stored in amber glass bottles with teflon lid inserts. The filter was transferred to a glass petri dish and wrapped with aluminum foil to protect it from direct light during storage and shipment. The XAD-2 resin was transferred from the canister to a pint Ball jar and wrapped with aluminum foil for storage. Methylene chloride was used to rinse the resin into the jar. A lid with a teflon insert was used to seal the jar. The PAH sample was analyzed at Radian using the procedure described in Section 5.2.

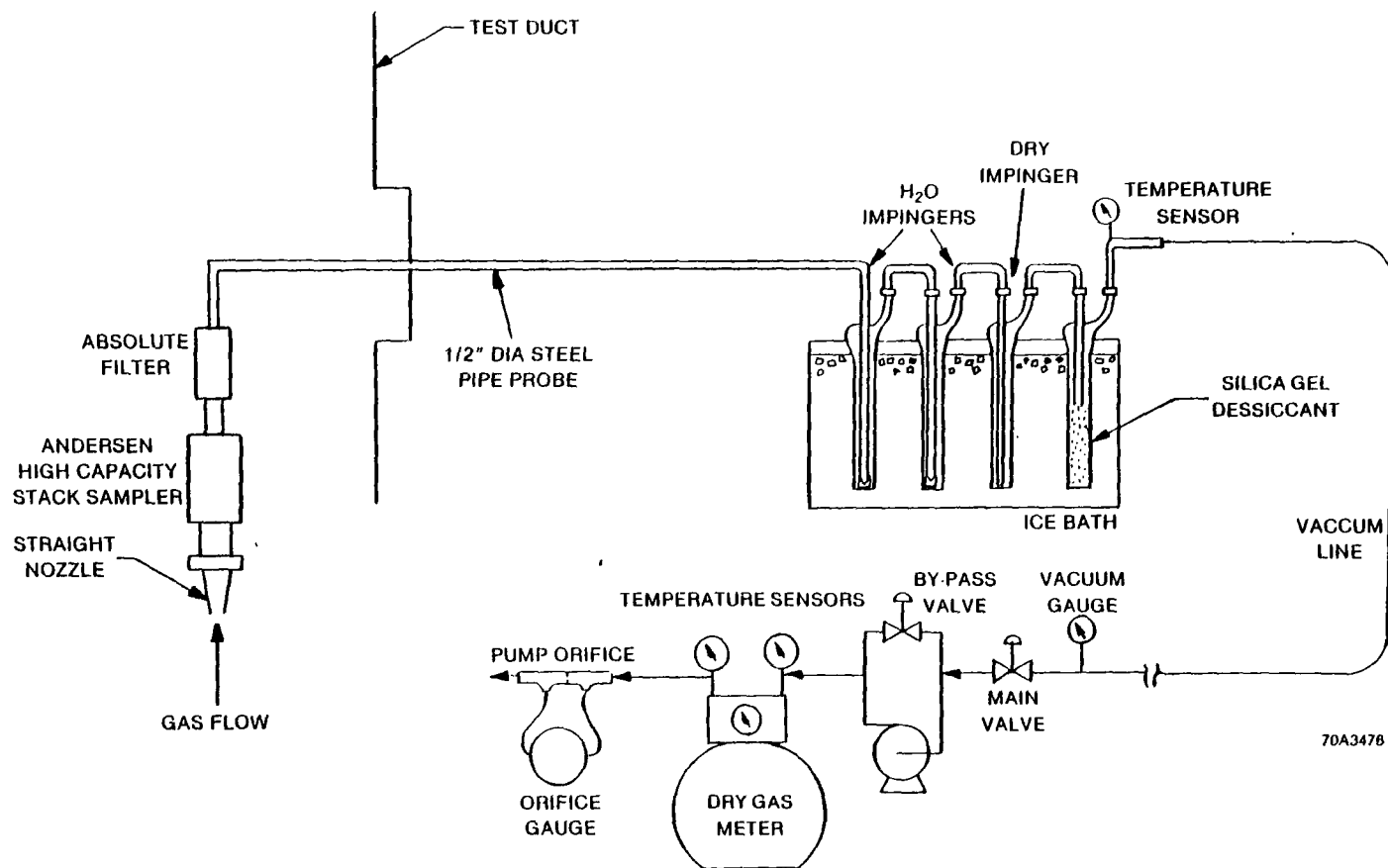
5.1.1.6 Particle Size Distribution Determination--

During this project the particle size distribution at the inlet and outlet of the scrubber was determined using the sampling trains illustrated in Figures 5-4 and 5-5, respectively. Both sampling trains were similar in design and used equipment designed to classify particles present in the gas stream with respect to their aerodynamic size.

Because of the high particulate loading encountered at the scrubber inlet, an Andersen High Capacity Stack Sampler (AHCSS) was used to determine the inlet particle size distribution. A cut-away view of the AHCSS is illustrated in Figure 5-6. The AHCSS contains two impaction chambers followed by a cyclone and a backup absolute thimble. Particles were automatically fractionated into four size ranges and the results were then plotted to represent the size distribution (see Figure 2-3).

A right angle probe was used at the scrubber inlet to allow the AHCSS to be pointed into the gas stream. A straight-neck sampling nozzle was attached to the AHCSS to minimize the impaction of larger particles that might otherwise occur using a gooseneck nozzle at the inlet.

PSD sampling at the scrubber outlet was attempted using an Andersen Mark III cascade impactor. The impactor classifies aerosols aerodynamically into nine size fractions. Glass fiber impactor substrates were used to collect the particles from the gas stream. The substrates decrease the



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Figure 5-4. In-stack Andersen high capacity stack sampler sampling train used to determine the particle size distribution at the venturi scrubber inlet.

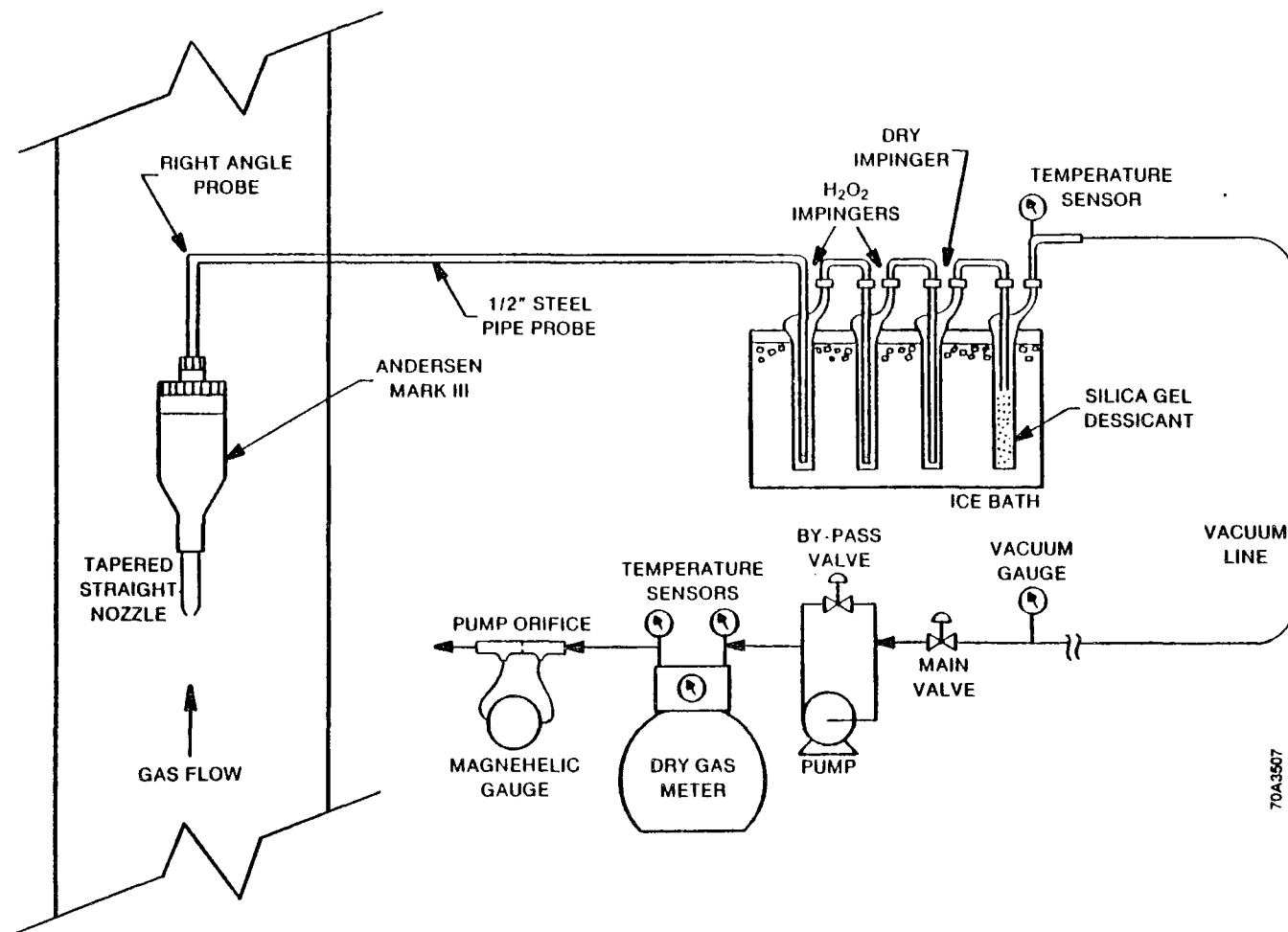


Figure 5-5. In-stack Andersen Mark III Cascade impactor sampling train used to determine the particle size distribution at the venturi scrubber outlet.

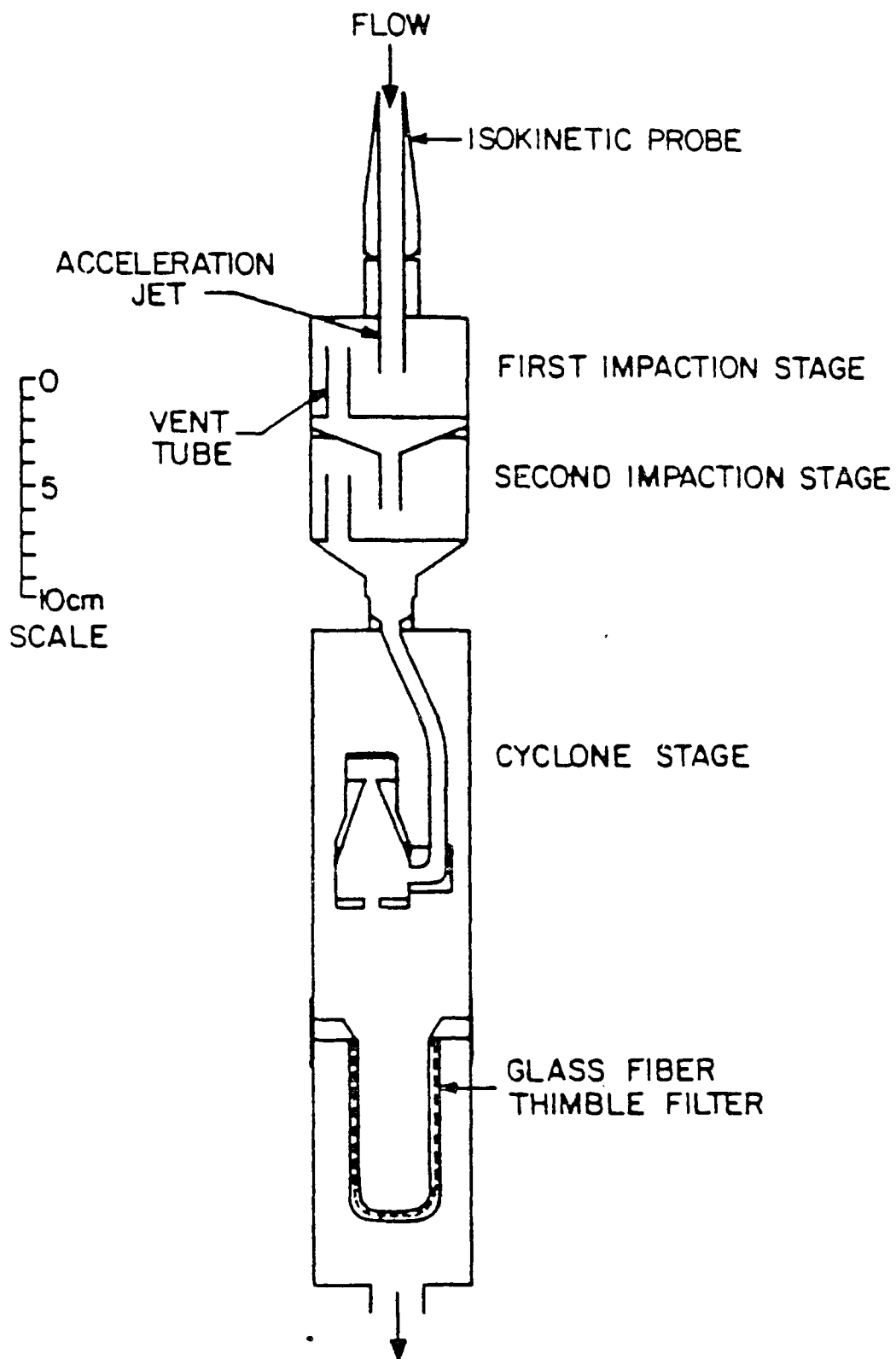


Figure 5-6. Schematic of the Andersen Model HCSS High Grain-Loading Impactor

errors that are encountered in weighing the large metal plates. The substrates were pretreated before use by baking the filters at 500°F for two hours. The substrates were then desiccated and weighed using a Mettler AE163 analytical balance. Prewighed sets of substrates were stored in polyethylene petri dishes until use in the field.

The Andersen impactor was oriented horizontally and a straight-neck nozzle used. Because of the high moisture content of the outlet flue gas, an auxiliary heating system (heating tape and insulation) was required to elevate the operating temperature of the Andersen. An elevated temperature was used to try to evaporate water droplets present in the gas stream. A discussion of the problems encountered during this sampling is presented in Section 2. To assist in this evaporation process, a ten- to twelve-inch heated extension (0.5-inch ID stainless steel tube) was used between the nozzle and impactor. A thermocouple mounted in the gas stream directly behind the Andersen was used to monitor the Andersen operation. A variac was used to control the heating tape, and thereby the exit gas temperature of the impactor.

Impactor sampling at the inlet and outlet was performed at a point of average velocity in the gas stream. The isokinetic flow rate through the nozzle was precalculated based on velocity data obtained during earlier sampling (modified Method 5E). Operation of both the AHCSS and Andersen Mark III required that the flow rate through the impactor be kept constant. This requirement eliminated the possibility of adjusting the flow rate if variations in gas velocity occurred.

Prior to sampling at the inlet the AHCSS was allowed to preheat in the duct for at least 45 minutes to allow ample time for the unit to reach the flue gas temperature. After sampling, the AHCSS and the Andersen Mark III were carefully unloaded and the solids and/or substrates desiccated and weighed. The majority of the Andersen Mark III substrates lost weight due to the moisture droplets wetting the substrates and making sample recovery impossible. The individual weight gains of the stages and filters were used

along with the impactor operating conditions to calculate the particle size distribution of the scrubber inlet. The impingers were weighed before and after sampling to determine the moisture content of the gas stream.

5.1.1.7 Visible Determination of Opacity--

The visible opacity of the outlet stack plume was determined by visual observation using the procedure described in EPA Method 9. When meteorological conditions permitted, observations were performed during stack gas sampling runs for particulate and TOC/extractable hydrocarbons loading, trace metals, and polynuclear aromatic hydrocarbons. Readings were performed when there was a clear blue sky background. The clear blue sky background was required for detection of emissions caused by condensed hydrocarbons in the plume.

5.1.2 Process Water Sampling

Scrubber water influent and effluent samples were collected during the field testing program. Scrubber water was contained in two ponds located near the venturi scrubber. Water supplied to the scrubber was pumped from the end of one pond through a floating intake line. Water from the scrubber flows by gravity to the opposite end of the second pond. A dike across the two ponds served as a weir to facilitate settling of solids. Following are descriptions of sampling methods for the scrubber water streams.

Scrubber Water Sample Collection--Samples of the process water pumped to the venturi scrubber were collected at the floating intake pump. The venturi scrubber return water samples were collected at the bottom of the venturi as the water was gravity fed to the settling pond. Samples were collected in 500 ml amber glass bottles with Teflon® liners. An attempt was made to collect at least three samples during each particulate and TOC/extractable hydrocarbons loading, trace metals, and polynuclear aromatic hydrocarbons run.

Scrubber Water Flow Rate--The total flow rate of water to the venturi and to the venturi throat was monitored using Signet Scientific paddle-wheel Flosensors®. The Flosensors® were installed in vertical sections of pipe on the discharge side of the pump. Installation of the sensors in this manner was necessary to ensure that flow of water covers the entire cross-sectional area of the pipes for an accurate measure of flow rate which is based upon stream velocity. The Flosensors® were coupled with analog read-out devices which include flow accumulators. Flow rate data was recorded several times during each particulate and TOC/extractable hydrocarbons loading, trace metals, and PAH run. The data was recorded by MRI personnel.

Scrubber Water Temperature and pH--At the times of collection of venturi scrubber water samples, the temperature and pH of the stream were measured. Temperature was measured by direct insertion of a mercury thermometer into the water stream at the collection point. pH measurements were performed using an Orion digital hand-held pH meter. The pH meter was standardized with pH 7 and pH 10 buffers just prior to each set of measurements. The pH of the venturi influent water was measured by direct insertion of the pH probe into the pond at the collection point. Effluent scrubber water pH was measured at the sampling location in a collected beaker of the water.

MRI measured the temperature of the pond water at the location of the scrubber water intake pump and at the scrubber water return location. These measurements were taken using a mercury thermometer.

5.1.3 Process Solids Sampling

Three process solids streams were sampled:

- o virgin aggregate,

- o recycled asphalt pavement, and
- o asphalt.

The sampling and analytical requirements for virgin aggregate and recycled asphalt pavement were the same. The two streams are belt-conveyed individually from storage hoppers to the drum mixer. Samples were collected from the belt conveyors in a large collection tray. The samples were riffled to obtain a representative sample and taken directly to the mobile laboratory for moisture analysis. At least one sample was collected and analyzed for moisture during each particulate and TOC/extractable hydrocarbons loading, trace metals, and polynuclear aromatic hydrocarbons run. Additional samples of the virgin aggregate and recycled asphalt pavement were collected for storage.

Samples of the asphalt were collected during the testing program in one-gallon metal cans. No analyses have as yet been performed.

5.1.4 Process Parameters

MRI was responsible for monitoring the venturi pressure drop across the venturi scrubber. Radian installed connections in the ductwork just before and after the venturi. Tubes were fitted to the two locations and connected to a Magnehelic® differential pressure gauge. MRI was also responsible for monitoring the water flow rate to the venturi throat and total flow to the venturi scrubber.

5.2 ANALYTICAL METHODOLOGY

The previous section described sampling procedures. This section describes the analytical procedures and points out where samples for analysis were retrieved from the various sample streams.

The majority of analyses for this project were performed at Radian's Austin laboratories. Samples for analysis resulted from the following:

- o particulate, TOC/extractable hydrocarbons sampling train for controlled and uncontrolled air emissions;
- o particulate, TOC/extractable hydrocarbons, and trace metals sampling train for controlled and uncontrolled air emissions;
- o polynuclear aromatic hydrocarbons sampling train for controlled and uncontrolled air emissions;
- o scrubber water to and from the venturi; and
- o virgin aggregate and recycled asphalt pavement.

Figures 5-7 through 5-10 present analytical schemes for the three sampling trains and scrubber waters. These figures indicate where samples were retrieved from the various systems and the analyses performed. The following analyses were performed:

- o gravimetric analysis of solvent rinses,
- o gravimetric analysis of ether chloroform extract of impingers,
- o total organic carbon,
- o major organics and benzo(a)pyrene,
- o trace metals,
- o total solids,

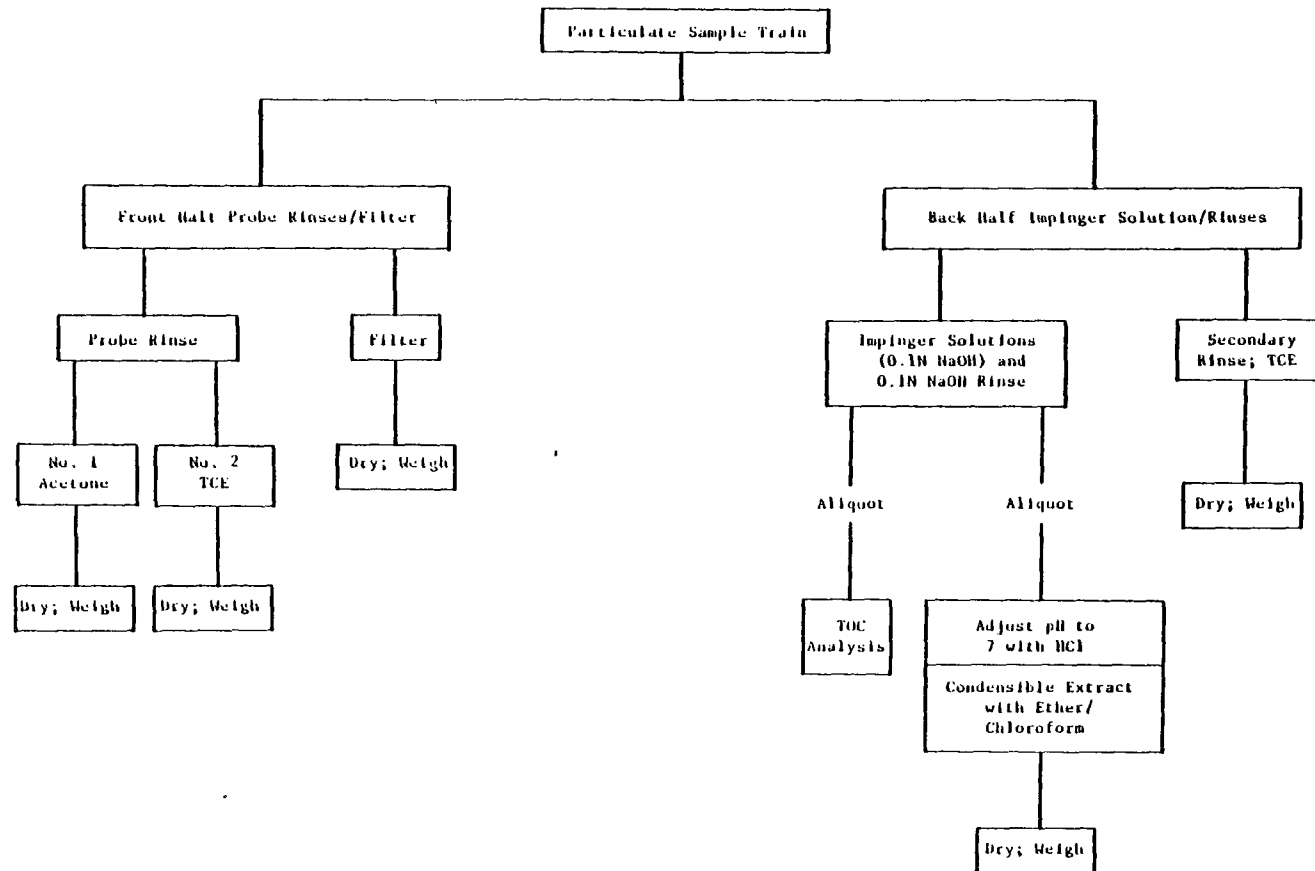


Figure 5-7. Particulate and condensible hydrocarbons sample recovery analytical matrix.

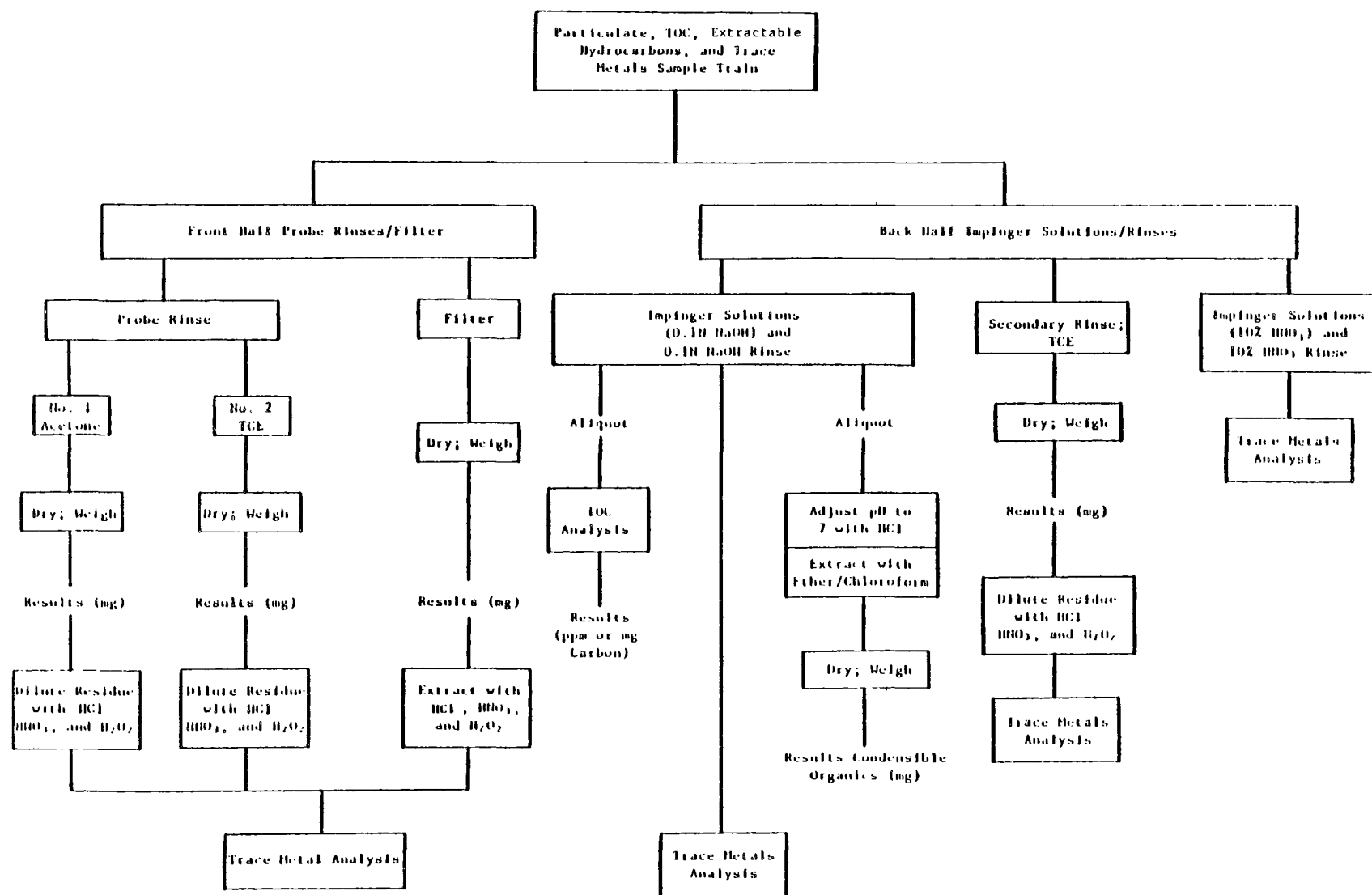


Figure 5-8 Particulate, extractable hydrocarbons, and trace metals sample recovery analytical matrix.

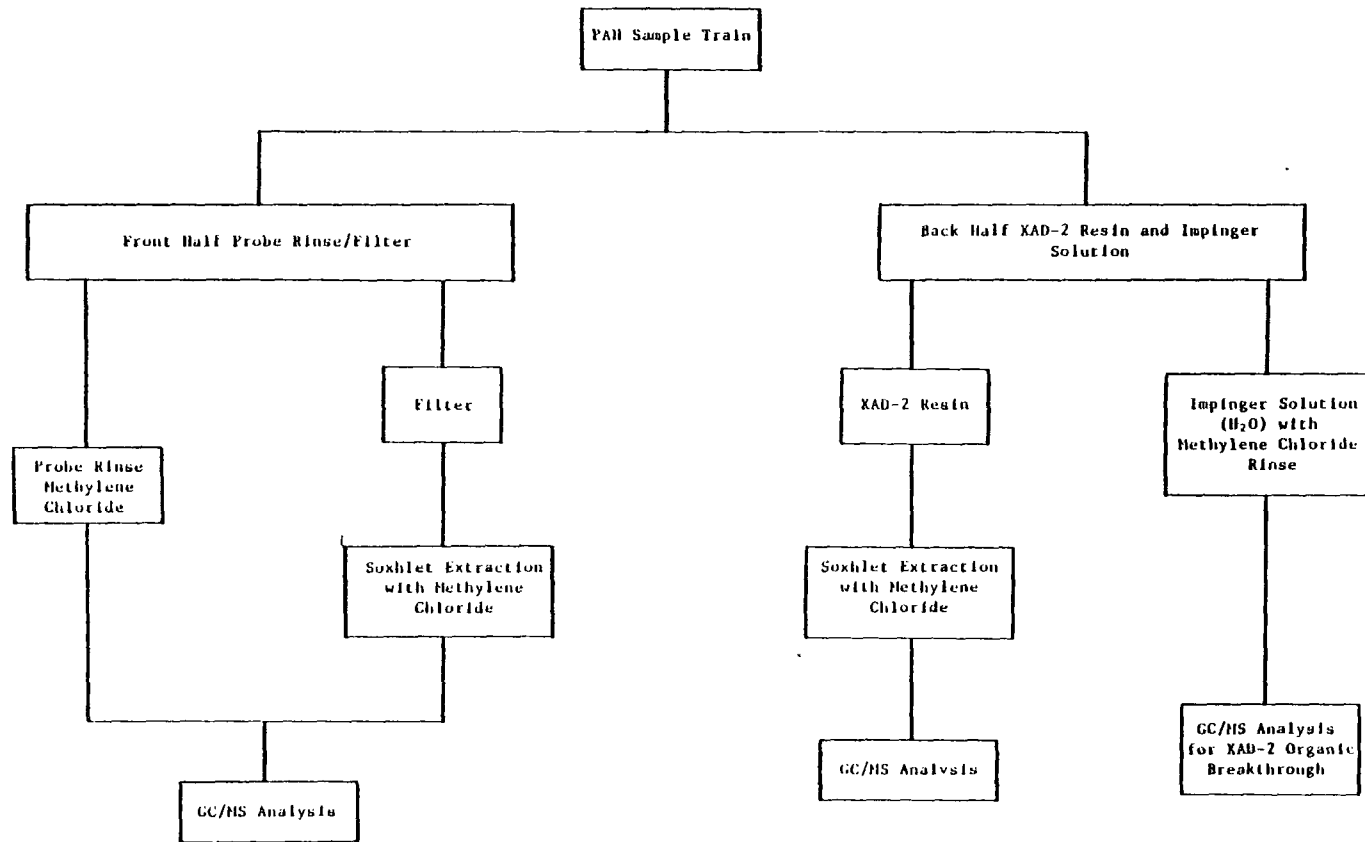


Figure 5-9. Polynuclear aromatic hydrocarbons sample recovery analytical matrix.

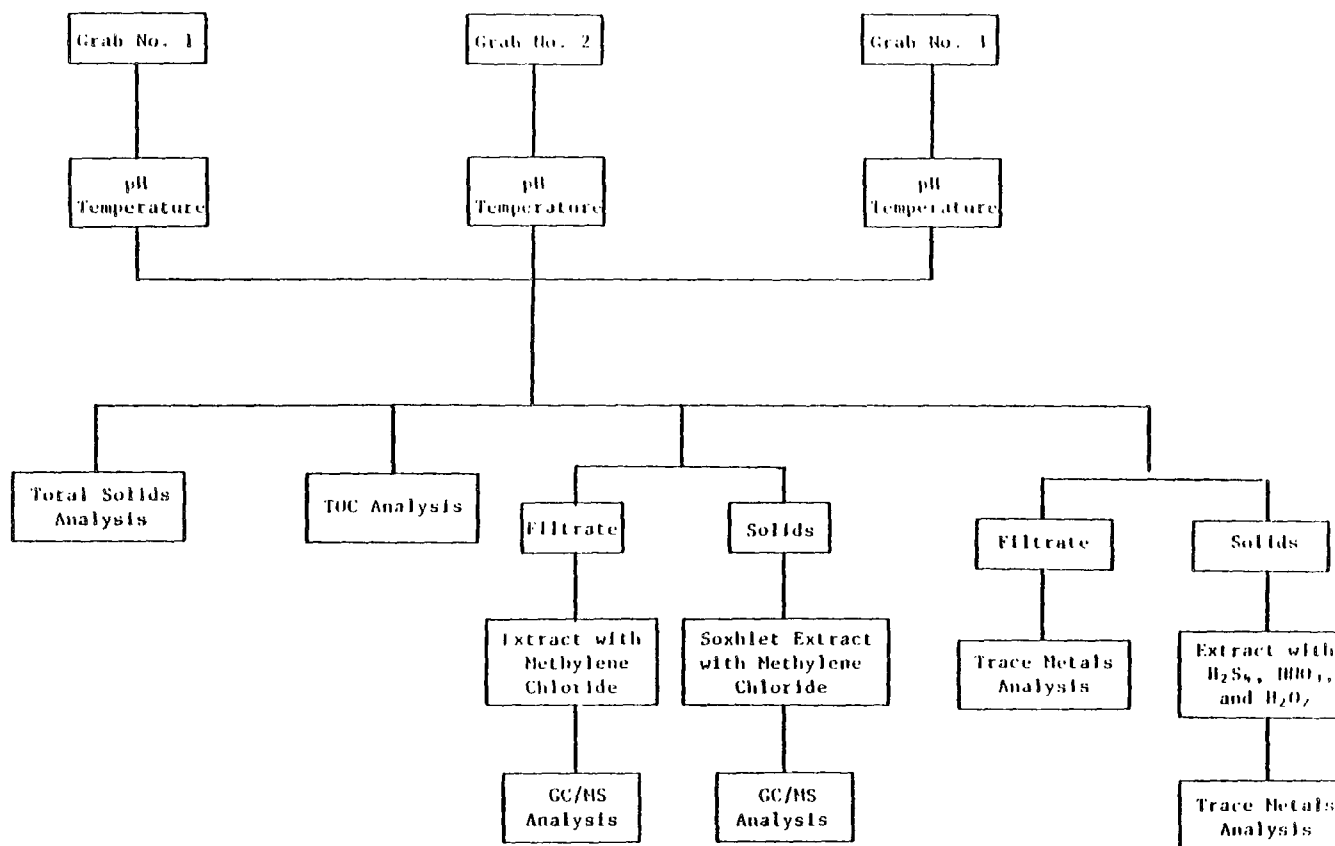


Figure 5-10. Scrubber water samples analytical matrix.

- o pH and temperature, and
- o moisture.

Gravimetric Analysis of Solvent Rinses--The sampling train for particulate and TOC/extractable organics and the train which combined trace metals with particulate and TOC/extractable organics produced several solvent rinses requiring gravimetric analysis. The solvent rinses included:

- o acetone probe rinse,
- o trichloroethane probe rinse, and
- o trichloroethane rinse of impingers and associated glassware.

The rinse samples were placed in glass bottles and transported to Radian's Austin laboratories for analysis. The volume of solvent in each sample was determined gravimetrically and then the entire sample was evaporated at room temperature. The sample could not be dried at elevated temperatures because of the potential loss of hydrocarbons. When dry, the sample was desiccated and weighed to a constant weight.

The residue in the solvent rinses collected during the trace metals runs was dissolved in HCl, HNO₃, and H₂O₂ and was analyzed by Inductively Coupled Argon Plasma Emissions Spectroscopy (ICAPES).

Gravimetric Analysis of Extractable Organics--The extractable organics sample consisted of the EPA Method 5E "back-half" trichloroethane rinse and 0.1N NaOH impinger solution and rinse described in Section 5.1.1.

Analysis of the trichloroethane "back-half" rinse consisted of several steps. First, the volume of each rinse sample was determined gravimetrically. Each rinse sample was then transferred to a clean and preweighed beaker. The rinse samples were then allowed to evaporate to dryness at room

temperature. The beakers were dessicated for 24 hours and then weighed to a constant weight. A constant weight is defined as two weighings that agree within 0.5 mg or 1 percent of the residue mass.

Each trichloroethane rinse sample was corrected for the solvent blank. The actual magnitude of the solvent blank correction was dependent upon the volume of trichloroethane present in each sample. To determine the magnitude of the trichloroethane blank, a known volume of unused trichloroethane solvent was evaporated using the above procedure. The mass of residue remaining after evaporation was then correlated to the volume of trichloroethane to generate a blank correction factor (mg of blank residue/volume of trichloroethane in the sample).

The extractable organics content of the NaOH impinger samples was determined using the following procedure. First, a 400 ml sample aliquot was adjusted to pH 7 using HCl to improve extraction efficiency. The sample was then extracted with three portions of a 3:1 mixture of chloroform and diethyl ether for a total of 200 mls. The solvent was then filtered. The filtrate was evaporated to dryness at room temperature (70-75°) and weighed to a constant weight following desiccation. The trichloroethane rinse of the impingers and associated glassware was also evaporated to dryness and weighed and the mass of residue added to the ether/chloroform extraction mass. The summed results were related to the gas sample volume to determine the gas phase concentration of extractable organics.

The TOC content of the EPA Method 5E sodium hydroxide impinger solution was determined instrumentally during this program. A 20 ml aliquot of the NaOH impinger solution was acidified with H_2SO_4 and then sparged with nitrogen gas to remove any inorganic carbon.

The sample was then analyzed using a Beckman 915B Total Carbon Analyzer. The TOC concentration of the sample was determined by comparing the

sample results with the results of standards prepared with potassium hydrogen phthalate. Blank TOC corrections were not required because of insignificant TOC blank values.

This procedure differed from that proposed in EPA Reference Method 5E in that Method 5E specifies analyzing for inorganic carbon total carbon and subtracting inorganic carbon from total carbon to give total organic carbon.

Major Organics and Benzo(a)Pyrene--Major organics and benzo(a)pyrene were analyzed by gas chromatography-mass spectrometry (GC-MS) in samples retrieved from the polynuclear aromatic hydrocarbons sampling train and scrubber water samples. The analytical scheme quantifies benzo(a)pyrene (BaP) and a group of isomers of BaP, several major polynuclear aromatic hydrocarbons (PAH), and several major organic compounds. The PAHs and major organic compounds which were analyzed were selected based upon relative peak heights of the GC-MS scan.

The samples produced in the PAH sampling train were the methylene chloride (MeCL_2) probe rinse, the filter, the condensate, the XAD-2 resin, and resin trap MeCL_2 rinse. The filter and XAD-2 resin were extracted individually in soxhlet extractors for 24 hours each with MeCL_2 . The MeCL_2 rinses of the probe and resin were incorporated in the soxhlet extractions.

Scrubber water samples were collected and filtered on-site and the filtrate stored in amber glass bottles with Teflon® liners, and kept cold prior to analysis.

Organic analyses were performed by GC-MS for both benzo(a)pyrene (BaP) and related polynuclear aromatic hydrocarbons (PAH). Table 5-2 lists the PAH compounds which were quantified.

Isotopically labeled benzo(a)pyrene- d_{12} was added to all samples prior to extraction as a check on extraction efficiency. Table 5-3 summarizes the analytical conditions which were employed for the GC-MS analyses.

TABLE 5-2. POLYCYCLIC AROMATIC HYDROCARBONS DETERMINED BY GC-MS

<u>Phenanthrenes</u> (178)	<u>Benzopyrenes</u> (252)
Phenanthrene	Benzo(a)pyrene
Anthracenes	Benzo(e)pyrene
	Perylene
<u>Pyrenes</u> (202)	Benzo(b)fluoranthrene
Pyrene	Benzo(j)fluoranthrene
Fluoranthene	Benzo(k)fluoranthene
	<u>Benzoperylene</u> s (276)
<u>Chrysenes</u> (278)	Benzo(g,h,i)perylene
Chrysene	Indeno(1,2,3-c,d)pyrene
Benz(a)anthracene	
Triphenylene	

Note: The molecular weight of each group is shown in parentheses.

TABLE 5-3. GC-MS CONDITIONS

Operating Parameter	Experimental Condition
Instrument	Hewlett Packard 5985A
Ionization voltage	70eV
Scan rate	1 scan/second
Scan range	40 → 450 amu
Column	SE54 fused silica capillary
H ₂ flow rate	30 cm/sec
Initial temp	25°
Initial hold	2.0 min
Program rate	8°/min
Final temp	300°C
Final hold	20 min
Injector temp	25°C
Injection	Cool on-column
Sample size	1 µL

Trace Metals--The concentrations of the following trace metals were determined in the controlled and uncontrolled air emissions and influent and effluent scrubber waters.

nickel	lead	vanadium
calcium	manganese	iron
chromium	magnesium	zinc
cadmium	beryllium	aluminum
mercury		

The analysis for trace metals was performed using Inductively Coupled Argon Plasma Emission Spectroscopy (ICAPES). The technique combines the multielemental capabilities of emission spectroscopy with a radio-frequency generated argon plasma source.

The sample is aspirated into the argon plasma which may reach temperatures of 10,000°K. The emission is focused onto a grating which diffracts the light according to the Paschen Runge theory. The diffracted light bands are passed through slits selected for each element of interest and measured by photomultiplier tubes. The system is computer-controlled which allows for simultaneous multielement determinations by comparing the electrical charge of each photomultiplier tube to the current measured during standardization. ICAPES also provides automatic background correction to adjust for matrix interferences.

The Radian system is an ARL Model 34000B which is capable of analyzing up to 40 elements simultaneously with detection limit of 1 to 5 ppmv.

Solid samples were dissolved into an acidic solution of HCl, HNO₃, and H₂O₂ for analysis.

Scrubber Water TOC Analysis--The TOC content of scrubber water filtrate samples was determined instrumentally during this program. A 20 ml sample

aliquot was acidified with H_2SO_4 and then sparged with nitrogen gas to remove any inorganic carbon. The sample was then analyzed using a Beckman 915B Total Carbon Analyzer. The TOC concentration of the sample was determined by comparing the sample results with the results of standards prepared using potassium hydrogen phthalate.

Total Solids--Total solids in the scrubber waters were determined by the analysis of total suspended solids (TSS) and total dissolved solids (TDS) on-site. During each test run, samples of the influent and effluent venturi scrubber waters were collected. Samples were filtered through one filter to determine a composite TSS concentration by measuring the residue collected on the filter and relating the mass to the volume of scrubber water determined gravimetrically. The TDS concentration in the resulting composite sample was determined by measuring a 50 milliliter aliquot of the sample into a tared 100 milliliter beaker and evaporating to dryness at $105^\circ C$, desiccating the sample, and weighing. The concentration of TDS is the mass of residue remaining related to the volume of the aliquot.

pH and Temperature--Samples of the influent and effluent venturi scrubber waters were collected during each particulate and TOC/extractable hydrocarbons loading and PAH runs. pH measurements were performed at the sampling location during sample collection with a hand-held pH meter.

Scrubber water temperatures were monitored at the sampling location during sample collection using a mercury thermometer.

Moisture--During each particulate and TOC/extractable hydrocarbons loading, trace metals, and/or polynuclear aromatic hydrocarbon run, at least one sample of the virgin aggregate and recycled asphalt pavement were collected for moisture analysis. The samples were collected in a large tray, riffled to obtain a representative sample and taken directly to the on-site mobile laboratory for moisture analysis. In the mobile lab, approximately 600 grams of the material was weighed into an aluminum pan and dried overnight at $105^\circ C$. The sample was then weighed to within ± 0.1 gram.

5.3 DATA REDUCTION

This section provides a discussion of the data reduction procedures used to process the raw data generated during this sampling program. EPA referenced data reduction procedures were used whenever possible. When an EPA referenced data reduction procedure was not available, a detailed description of the data reduction procedure is provided. Further information is given in Appendix B.

5.3.1 Gas Stream Sampling Data Reduction

Data reduction procedures and equations used for gas stream sampling data reduction were taken from applicable parts of 40 CFR 60, Appendix A. Raw field data were reduced to engineering units using Radian's Source Sampling Data Reduction Computer Program. Copies of the data reduction printouts are presented in Appendix A. As a verification check of the computer reduction, several runs were hand calculated using the equations outlined in Appendix B. No significant differences were found.

Particulate Mass Emission Rate Data Reduction

In order to allow a review of possible effects introduced by anisokinetic sampling into the normal mass emission rate calculations, two methods were used to calculate mass emission rates for the particulate mass emission runs. The method normally used to calculate particulate mass emission rates is the concentration method. This method involves multiplying the particulate loading (sample mass divided by gas sample volume) by the volumetric gas flow rate. The second particulate mass emission rate calculation method is the area-ratio method. Based on the area-ratio method, the sample mass is divided by the sampling time and then multiplied by the ratio of the stack area to nozzle area to obtain the particulate mass flow rate.

Equation:

$$(m/t) \times (A_s/A_n) = \text{MER}$$

where: m = mass of particulate matter collected during sampling (pounds)
 t = elapsed sampling time (hours)
 A_s = area of stack (square feet)
 A_n = area of nozzle (square feet)
 MER = mass emission rate (pounds per hour)

The difference between the emission rates calculated by these two methods is an estimate of the maximum bias in the measured emission rate due to anisokinetic sampling. Table 2-5 includes particulate emission rates calculated using the concentration method and the area-ratio method. The average particulate emission rate listed in Table 2-5 was used as the true value for the particulate emission runs that were outside of the isokinetic sampling limit of 100 ± 10 percent.

Total Organic Carbon (TOC) Emissions Data Reduction

Equation:

$$\text{TOC}_{(g)} = \frac{(\text{TOC}_{(L)} \times V_I) - (\text{TOC}_{(B)} \times V_I)}{\text{DGV}}$$

Nomenclature:

$\text{TOC}_{(g)}$ = Total organic carbon in gas phase, mg/dscm
 $\text{TOC}_{(L)}$ = Total organic carbon in impinger catch, mg/l
 $\text{TOC}_{(B)}$ = Total organic carbon in the impinger blank,
mg/l
 V_I = Total volume of impinger catch, l
 DGV = Volume of gas sampled, standard conditions
dry standard cubic meters, dscm

Trace Metals Emission Data Reduction

Equation:

$$TM_{(E)} = \frac{A + T + (C \times C_T) + F + (S \times S_T) + N \times N_T}{DGV}$$

Nomenclature:

 $TM_{(E)}$ = Total trace metal specie mass concentration, $\mu\text{g/dscm}$ A = Total concentration of trace metal specie in acetone probe wash, μg T = Total concentration of trace metal specie in trichloroethane probe wash, μg C = Concentration of trace metal in the cyclone catch, $\mu\text{g/g}$ C_T = Total weight of cyclone solids, gF = Total concentration of trace metal specie in the filter, μg S = Concentration of trace metal in the NaOH impinger, $\mu\text{g/ml}$ S_T = Total volume of NaOH impinger catch, mlN = Concentration of trace metal in the nitric acid impinger, $\mu\text{g/ml}$ N_T = Total volume of the nitric acid impinger, ml

DGV = Dry gas volume, standard conditions, dry standard cubic meters (dscm)

Particle Size Distribution Data Reduction (AHCSS)

The procedure for calculating the particle size distribution of the particulate caught by the AHCSS was taken directly from the operating manual for the AHCSS.

Add up the weight gains for the four stages to obtain the total particulate collected.

Divide the amount collected in an individual stage by the total amount collected to determine the percentage of the total collected in each stage.

Starting with stage 4 (backup filter) compute the cumulative percent less than the staged size range. The cumulative percent less than stage 3 (the cyclone) is equal to the percent caught in stage 4. The cumulative percent less than stage 2 is the sum of the percent caught on stage 3 and the percent caught on stage 4. The cumulative percent less than stage 1 is the sum of the percents caught on stages 4, 3, and 2.

Particle density is considered to be 1.0 gm/cm^3 and the particles are considered to be spherical. Particle sizes are reported as equivalent aerodynamic diameters.

Using Figure 5-11 with gas flow rate at stack conditions and stack temperature, determine the d_{50} (50% Effective Cut Off Diameter) for each stage.

Plot the results on log probability graph paper with the particle diameter (d_{50}) as the ordinate and the cumulative percent less than the stated size range by weight as the abscissa.

Polynuclear Aromatic Hydrocarbon (PAH) Emissions Data Reduction

Equation:

$$PAH_{(G)} = \frac{P_T - B}{DGV}$$

Nomenclature:

$PAH_{(G)}$ = Concentration of PAH specie in flue gas, $\mu\text{g/dscm}$

P_T = Total concentration of PAH specie, μg

B = Specie blank, μg

DGV = dry gas volume, standard conditions, dscm

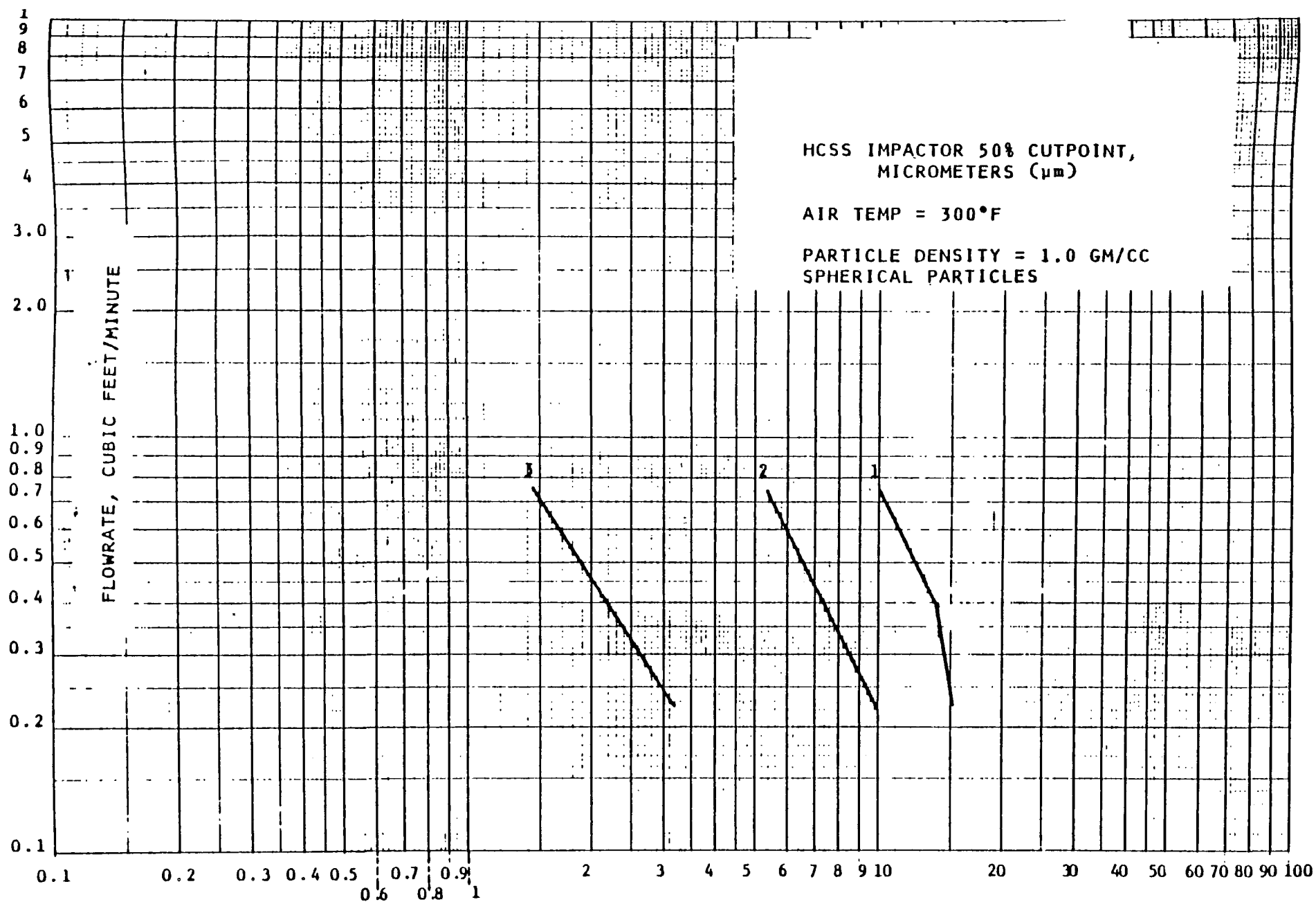


Figure 5-11. Gas flow rate at stack conditions and stack temperature.

5.3.2 Process Sampling Data Reduction

PAH in Scrubber Water Data Reduction

Equation:

$$PAH_{(W)} = \frac{P_{(T)}}{0.4}$$

Nomenclature:

$PAH_{(W)}$ = Concentration of PAH in the scrubber water, $\mu\text{g/liter}$

$P_{(T)}$ = Total concentration of PAH specie, μg

0.4 = Volume of scrubber water extracted, liter

PAH in Scrubber Solids Data Reduction

Equation:

$$PAH_{(S)} = \frac{P_{(T)}}{S}$$

Nomenclature:

$PAH_{(S)}$ = Concentration of PAH specie in scrubber solids, $\mu\text{g/gram}$

$P_{(T)}$ = Total concentration of PAH specie, μg

S = Weight of scrubber solids extracted, g

Weight Percent Solids Data Reduction

Equation:

$$S_{(WT)} = \frac{F_{(F)} - F_{(T)}}{W_{(T)}} \times 100$$

Nomenclature:

$S_{(WT)}$ = Weight % solids

$F_{(F)}$ = Final filter weight, g

$F_{(T)}$ = Filter tare weight, g

$W_{(T)}$ = Weight of scrubber water filtered, g

100 = conversion from fraction to percent

Total Dissolved Solids Data Reduction

Equation:

$$\text{TDS} = \frac{W_{(F)} - W_{(T)}}{0.05}$$

Nomenclature:

TDS = Total dissolved solids, mg/l

$W_{(F)}$ = Weight of beaker and residue after evaporation, mg

$W_{(T)}$ = Beaker tare weight, mg

0.05 = Volume of solution evaporated, liter

SECTION 6

QUALITY ASSURANCE

Quality assurance/quality control guidelines outline pertinent steps during the production of analytical and emission data to ensure the acceptability and reliability of the data generated. The measures outlined in this segment were followed to ensure the production of quality data from the sampling and analytical efforts.

6.1 STANDARD QUALITY ASSURANCE PROCEDURES

QA/QC procedures are followed during sampling and analysis to ensure that the data generated are of acceptable quality. These quality control and quality assurance procedures are used during EPA reference method sampling and/or routine analysis. Additional QA/QC procedures may be called for on a site-specific basis. This section describes QA/QC procedures applicable to the methods used, as well as specific procedures used during this test program.

6.1.1 Sampling Equipment Preparation

The checkout and calibration of source sampling equipment is vital to maintaining data quality. Referenced calibration procedures were strictly adhered to when available, and all results were documented and retained. If a referenced calibration technique for a particular piece of apparatus is not available, then a state-of-the-art technique was documented and followed. Table 6-1 summarizes the parameters of interest and the types of sampling equipment that were used to measure each parameter. The techniques used to calibrate the equipment are as follows:

TABLE 6-1 SUMMARY OF CALIBRATED EQUIPMENT USED IN PERFORMING SOURCE SAMPLING

Parameter		Calibrated Equipment Used in Measuring Parameters					
		Type-S Pitot Tube	Differential Pressure Gauge	Temperature Measuring Device	Gas Metering System	Orsat	Isokinetic Nozzles
Volumetric Gas Flow Rate	EPA-1, EPA-2	*	*	*			
Gas Phase Composition							
Moisture	EPA-4		*	*	*		
Molecular Weight	EPA-3					*	
Particulate Mass & TOC/ Extractable Hydrocarbons	Modified EPA-5E	*	*	*	*	*	*
Trace Metals	Modified EPA-5	*	*	*	*	*	*
Polynuclear Aromatic Hydrocarbons	Modified EPA-5	*	*	*	*	*	*
Particle Size Distribution		*	*	*	*	*	*

- o Prior to sampling all equipment was cleaned and checked to ensure operability.
- o Equipment requiring pretest calibration (Table 6-1) was calibrated in accordance with "Quality Assurance Handbook for Air Pollution Measurements Systems, Volume III, Stationary Source Specific Methods," (EPA 600 4-77-027b).
- o Equipment calibration forms were reviewed for completeness to ensure acceptability of the equipment required for each specific application.
- o The Andersen Mark III Impactor and AHCSS were cleaned and visually inspected.
- o Each component of the various sampling systems was carefully packaged for shipment.
- o Upon arrival on site--the equipment was unloaded, inspected for possible damage, assembled for use, and checked for operability.

6.1.2 Collection of Samples

The most important aspect of sample collection is obtaining a valid sample. This section focuses on measures taken to obtain valid samples. Those measures were:

- o Pretest and posttest leak checks of the sampling trains were made.
- o The sampling systems were visually inspected prior to sampling to ensure proper assembly and operability.

- o The S-type pitot tubes were leak checked before and after sampling and inspected for damage.
- o The Magnehelic® gauges were leveled and zeroed prior to sampling.
- o Temperature measurement systems were visually checked for damage and operability by measuring the ambient temperature prior to each sampling run.
- o The nozzles were visually inspected for damage before and after each sampling run.
- o The Andersen Mark III Impactor and AHCSS were preheated to minimize condensation of water in the particle sizing device.
- o Data requirements were reviewed prior to each sampling run.
- o Ice was maintained in the icebaths during all sampling runs.
- o Number and location of sampling ports were checked prior to each sampling run.
- o Sampling ports were sealed to help prevent possible air inleakage.

The molecular weight of the flue gas was determined using EPA Reference Method 3 (4). Quality control for Method 3 focused on the following:

- o The sampling train was purged prior to sample collection.
- o The Orsat analyzer was leveled and the fluid levels zeroed prior to use.

- o The Orsat analyzer was leak-checked prior to use.
- o The Orsat analyzer was thoroughly purged with sample prior to analysis.
- o Analyses were repeated until the analysis agreed within 0.3% absolute.
- o The Orsat absorbing solutions were changed when more than six passes were required to obtain a stable reading of any component.

The moisture determinations were made simultaneous with the modified EPA Reference Method 5E. Quality control procedures for Method 4 focused on the following:

- o Before and after sampling each impinger was carefully weighed to the nearest 0.02 g. Care was taken to see the impingers were dry and the stopcock grease was removed from the ball joints prior to each weighing.

The particulate loading determinations were performed using a modified EPA Reference Method 5E. Quality control procedures for this method focused on the following:

- o Prior to particulate sampling preliminary velocity, temperature, and moisture determinations were made. This aided in calculating isokinetic flow rates.
- o Prior to sampling, particulate filters were baked, desiccated and weighed. They were then placed in clean petri dishes until used.
- o Particulate filters were handled with tweezers.

The visible opacity of controlled emissions were observed using EPA Reference Method 9. Quality control procedures for this method focused on the following:

- o The visible emissions observer was certified within six months of the test program.
- o The location of the observer was independently verified.
- o A clear blue sky was required to ensure valid visible emission observations.

6.1.3 Sample Recovery

To ensure data integrity careful sample recovery techniques must be adhered to. This section outlines quality control procedures followed to ensure data integrity. These include:

- o Particulate filters were handled out of drafts and transferred with treezers.
- o Sample trains were disassembled and the samples recovered in clean areas to prevent contamination.
- o The nozzle was capped prior to and following sampling.
- o The samples were transferred to appropriate storage containers and clearly labeled. Liquid levels were noted.
- o Field blanks were included for each method. These consisted of (i.e. unused) sampling trains which were assembled, disassembled, recovered, and analyzed in the same manner as actual sampling trains and samples.

- o Samples were carefully labeled, logged into the field logbook and assigned a unique identification code immediately after collection.
- o The impingers were rinsed three times with aliquots of fresh impinger solution.

6.1.4 Preparation of Samples for Analysis

Prior to sample analysis each sample must be properly prepared. This section outlines quality control procedures used to ensure proper sample preparation. Included are:

- o Each sample identification code was crosschecked for accuracy against the sample logbook.
- o The analytical requirements of each sample were reviewed.
- o The samples were checked for leakage or damage and any anomalies were noted.

6.1.5 Sample Analysis

The exact quality assurance/quality control procedures taken during analysis were dependent on the specific analysis. One or more of the following steps were taken:

- o Duplicate analyses were performed on 5-15% of the samples.
- o Internal QC samples were analyzed to verify instrument or procedural variance.
- o Blind QC samples were submitted to the analytical lab along with the field generated samples.

- o Blanks were analyzed to correct for background and/or matrix interferences.
- o The samples were spiked with known additions of the species of interest.

6.1.6 Data Reduction

Several steps were taken to verify the correctness of the data reduction. Steps routinely used include:

- o Alternate procedures were used to reduce the data. A common example is reducing source sampling data by using Radian's Source Sampling Data Reduction Program and comparing selected results against hand calculations.
- o A certain percentage (approximately 10%) of the results were recalculated from raw data by someone unassociated with the original data reduction.
- o The data was carefully checked for unexplained variance and internal consistency, i.e. are the results consistent with expected and/or other results).

6.1.7 Data Documentation and Verification

Several measures were taken to verify the completeness and accuracy of the data generated. These include:

- o All sampling data was recorded on preformatted data sheets.
- o Analytical results and calculations were recorded in bound laboratory notebooks.

- o Data tables were made and reviewed for completeness and accuracy.
- o All data that appeared to be outside expected ranges were carefully scrutinized for process upsets and reanalyzed as necessary.
- o Data generated were compared to process operation and system upsets.

6.2 TEST PROGRAM SPECIFIC QUALITY CONTROL/QUALITY ASSURANCE PROCEDURES

Each sampling site presents its own individual problems and peculiarities. Because of this any QA/QC program must be custom tailored to each specific site. This section presents the procedures that were specific to the T.J. Campbell asphalt concrete sampling program.

6.2.1 Sampling Equipment Preparation

This section outlines equipment modifications that were used during this program to ensure the sample data produced were valid. These measures are in addition to the standard equipment calibration and checkout procedures outlined in Section 6.1.1. These include:

- o Variacs were used to control the probe heater temperature.
- o Inline thermocouples were installed to monitor the gas stream temperature as it exited the filter holder.
- o A time-proportioning temperature controller was used to control the hot box temperature to within $\pm 10^{\circ}\text{F}$.

- o A heated twelve-inch extension was placed between the nozzle and Andersen Mark III impactor. This was to evaporate flue gas moisture and prevent impaction of droplets on the substrates.

Hydrocarbons in the gas stream condense as a function of temperature. As the temperature decreases more hydrocarbons condense as particulate. For this program it was important to have very strict control of the collection temperature since the collection temperature "defined" the particulate. If temperature fluctuations were encountered an increase or decrease in the amount of particulate collected could be observed depending on temperature.

An inline thermocouple positioned directly after the filter holder, coupled to a time proportioning temperature controller, was used to control the hot box so the gas temperature would remain at $250^{\circ}\text{F} \pm 10^{\circ}\text{F}$. The vast majority of the time temperature was controlled at $250^{\circ}\text{F} \pm 5^{\circ}\text{F}$. A variac was used to control the probe heat temperature. The constant voltage output kept a more constant temperature and avoided the temperature fluctuations encountered with standard oven heaters.

6.2.2 Sample Collection

The sampling program presented some special problems in sample collection. This section outlines special QC steps that were taken to aid in reliable and representative sample collection. These are in addition to such measures as visual inspection of sampling trains and equipment, leak checks, and other measures outlined in Section 6.1.2.

6.2.2.1 Sampling Preparation--

Certain non-equipment items such as the filters and glassware required special preparation. This section outlines that preparation. The measures include:

- o Particulate filters were baked at 500°F prior to use.

- o Particulate filters used during polynuclear aromatic hydrocarbon sampling were methylene chloride extracted prior to use and stored in glass petri dishes.
- o All glassware used during sampling was specially cleaned.

All particulate mass collection filters were baked at 500°F prior to use. They were then desiccated, weighed, and placed in clean petri dishes. The particulate filters used during polynuclear aromatic hydrocarbon sampling were extracted with methylene chloride, baked at 500°F, and stored after weighing in methylene chloride rinsed glass petri dishes.

All glassware used during sampling was cleaned as follows:

- o The glassware was first washed thoroughly with laboratory soap and water.
- o The glassware was kiln-fired at 500°C for 18 hours.
- o After the glassware cooled, it was rinsed with methylene chloride and all the ball joints were capped with aluminum foil.

6.2.2.2 Preliminary Measurements--

This section outlines QC checks and measurements performed prior to sampling to assist in the calculation of anisokinetic sampling rate. These include:

- o A check for cyclonic or turbulent flow was performed prior to sampling at the uncontrolled emissions sampling location.
- o Preliminary velocity, temperature and moisture determinations were performed to aid in conducting isokinetic sampling.

- o Wet bulb/dry bulb moisture determinations were performed prior to individual sampling runs.

It was discovered early into the sampling program that the moisture content of the scrubber inlet could vary drastically from run to run. For this reason preliminary moisture determinations were performed to calculate accurate isokinetic sampling rates prior to each sampling run.

6.2.2.3 Sampling Procedures--

This section outlines measures taken to ensure that valid and representative samples were collected. The measures include:

- o Approximately 10 pound aggregate samples were taken. The samples were riffled to produce the 600 gram sample used to determine the moisture content.
- o Two to four scrubber water samples were taken during each sampling run. The samples were composited and all subsequent analyses were performed on the composite sample.
- o All glassware except the silica gel impinger was wrapped with aluminum foil during the polynuclear aromatic hydrocarbon sampling runs to help prevent photodegradation of the organic species.

6.2.3 Sample Recovery

This section outlines special QA/QC measures taken during sample recovery. These measures are in addition to particulate filter handling, performance of field blanks, labeling and logging in of samples and other steps outlined in Section 6.1.3. Measures taken to further ensure the integrity of the samples during recovery include:

- o Incandescent lighting was used during recovery of the

polynuclear aromatic hydrocarbon sampling trains. This was to reduce the chance of photodegradation of the organic species by ultraviolet light.

- o Polynuclear aromatic hydrocarbon samples were stored in amber glass bottles with teflon lid inserts to prevent photodegradation and/or contamination of the sample during storage and transport.
- o Particulate filters used during the polynuclear aromatic hydrocarbon sampling runs were stored after use in glass petri dishes. The petri dishes were wrapped in aluminum foil to prevent possible photodegradation of the sample.

6.2.4 Preparation of Samples for Analysis

Quality control procedures incorporated during the preparation of the samples for analysis are outlined in this section. These were in addition to visually checking the samples for damage and ensuring proper labeling and other procedures outlined in Section 6.1.4. These measures include:

- o Sample matrix sheets were developed as an aid in analytical preparation and as a flow diagram for the actual analysis.
- o Each polynuclear aromatic hydrocarbon sample was spiked with deuterated benzo(a)pyrene-d¹² prior to sample extraction as a QC check on extraction efficiency.
- o Particulate filters and impactor substrates were desiccated for at least 24 hours prior to their first weighing.
- o The particulate filters were weighed at 24-hour intervals to a constant weight.

6.2.5 Sample Analysis

This section outlines additional QC procedures employed during the program to evaluate the quality of the analytical data. These procedures are in addition to such measures as duplicate analysis, blank analysis, internal QC samples, and other measures outlined in Section 6.1.5. Included are:

- o Immediately prior to sample analysis each polynuclear aromatic hydrocarbon sample was spiked with benzo(a)pyrene-d¹² as an internal QC standard.
- o Total organic carbon audit samples were submitted to the analytical laboratory prior to the submission of the field samples.
- o Field blanks were evaluated to determine species background and possible contamination problems.

The results of the total organic carbon audit samples are presented in Table 6-2. A statistical evaluation of the audit samples is presented in Appendix I.3.3.3.

The results of the field blanks are presented in Table 6-3. The clean-up results were used to correct the analytical results for background.

TABLE 6-2. SUMMARY OF TOTAL ORGANIC CARBON
 AUDIT SAMPLE MEASUREMENTS

EPA Prepared Sample Results (9/9/83)

Sample No.	Date of Analysis	(A) Actual Values	(R) Radian Analysis Values (mg/L)	Percent Error R-A/A x 100
EPA 1	10-28-83	4.1	4.5	9.76
EPA 2	thru	61.2	70	14.4
EPA 3	11-02-83	61.2	69	12.7
EPA 5		4.1	3	-26.8

Radian Prepared Sample Results

Sample No.	Date of Analysis	(A)	(R)	Percent Error R-A/A x 100
		Actual Values	Radian Analysis Values (mg/L)	
Set 1 - Submitted 11-30-83				
Radian #1		80	85	6.25
Radian #2		40	45	12.5
Radian #3		80	81	1.2
Radian #4		4	4	0
Radian #5		4	3	-25.0
Radian #6		40	41	2.5
Set 2 - Submitted 12-12-83				
Radian #1 ¹		80 ¹	85	6.25
Radian #2		20 ²	21	5.0
Radian #3		20 ¹	19	-5.0
Radian #4		80 ²	84	5.0
Radian #5		80 ¹	77	-3.75
Radian #6		20 ¹	21	5.0

¹Sample in 0.1 in NaOH matrix

²Sample in distilled water

TABLE 6-3. SUMMARY OF CLEANUP RESULTS

Particulate and Condensible Organic Sample Blanks		Train 1 Uncontrolled		Train 2 Controlled		Average	
Front Half (mg) Probe rinses		31.7* 20.1**		11.9*		21.8	
Back Half (mg) Condensible hydrocarbons Total organic carbon (mg/L)		1.4 <1		1.4 2		1.4 ¹ 1	
Trace Metals Sample Blanks		Train 1			Train 2		
Element	Filter Blank	NaOH Blank	HNO ₃ Blank	Filter Blank	NaOH Blank	HNO ₃ Blank	
Al	<.5	<.05	<.05	<.5	<.05	<.05	
Be	<0.5	<0.0005	<0.0005	<0.5	<0.005	<0.0005	
Ca	<3	<0.04	<0.04	<3	<0.04	<0.04	
Cd	<0.2	<0.002	<0.0002	<0.2	<0.0002	<0.0002	
Cr	<0.1	<0.001	<0.001	<0.1	<0.001	<0.001	
Fe	<0.8	<0.008	<0.008	<0.8	<0.008	<0.008	
Hg	<3	<0.03	<0.03	<3	<0.03	<0.03	
Mg	<3	<0.034	<0.034	<3	<0.034	<0.034	
Mn	<0.1	<0.001	<0.001	<0.1	<0.001	<0.001	
Ni	<0.3	<0.003	<0.003	<0.3	<0.003	<0.003	
Pb	<8	<0.084	<0.084	<8	<0.084	<0.084	
V	<6	<0.003	<0.003	<6	<0.003	<0.003	
Zn	<0.6	<0.003	<0.003	<0.3	<0.003	<0.003	

Polyaromatic Hydrocarbon Blanks (µg)	Train 3 Uncontrolled			Train 4 Controlled			Average		
	Front Half	Back Half	Total	Front Half	Back Half	Total	Front Half	Back Half	Total
<u>Active carcinogenic species</u>									
Benz(a)anthracene	ND	0.02	0.02	ND	0.04	0.04	ND	0.03	0.03
Chrysene	ND	0.05	0.05	ND	0.11	0.11	ND	0.08	0.08
Benzo(b)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(j)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(e)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-c,d)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND
<u>Nonactive carcinogenic species</u>									
Phenanthrene	0.07	0.65	0.72	0.10	0.79	0.89	0.08	0.72	0.80
Anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	0.03	0.24	0.27	0.06	0.40	0.46	0.04	0.32	0.36
Pyrene	0.07	0.49	0.56	0.19	0.85	1.04	0.13	0.67	0.80
Benzo(k)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Perylene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	ND	ND	ND	ND	ND	ND	ND	ND	ND

* glass probe

** stainless steel probe

¹ based on an average of five blank values