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WET COKE QUENCH TOWER EMISSION FACTOR DEVELOPMENT DOMINION FOUNDRIES AND STEEL, LIMITED

Hamilton, Ontario, Canada

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Primary info
on Coke Quenching
Emissions

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SECTION 1

INTRODUCTION

The purpose of this program was to develop total and size-specific emission factors for the No. 1 quench tower at Dominion Foundries and Steel, Limited, (DOFASCO), Hamilton, Ontario, Canada. These emission factors will be used to increase the data base for IP emission factor development, NSPS and enforcement considerations pertaining to wet coke quenching. Total particulate emission rates and particle size distribution were measured simultaneously before and after a baffle array installed in the tower to control quenching emissions. In addition, water samples and process data were obtained.

Total particulate emission rates were measured using a modified EPA Method 5 sampling train. Particle size distribution testing was performed with heated Andersen cascade impactors. The Atmospheric Dilution Sampling System (outlet tests only), and the Inhalable Particulate (IP) dual-cyclone train were also used for particle size determinations. Five tests, each consisting of simultaneous inlet/outlet measurements of total particulate and particle size distribution, were performed using "clean" quench water (510 mg/l total dissolved solids). Three particulate tests were conducted at the outlet only using "semi-dirty" quench water (2270 mg/l total dissolved solids) and four particulate and particle sizing tests were conducted using "dirty" quench water (8850 mg/l total dissolved solids). Composite water samples from the quench spray, the return trough, and the make-up line were obtained for each quench tested.

The coke quenching process is cyclic and poses numerous difficulties when conducting stack tests. Variations in flow, temperature, moisture content, particulate generation, and the quality of the coke quenched sometimes reach orders of magnitude. Droplets are known to affect the particle size results and the stack gas was probably not homogeneous. Typically, a test was completed by sampling 9 to 12 quenches and process conditions pertaining to each of the quenches tested were recorded.

SECTION 2

SUMMARY OF RESULTS

The sampling and analysis program was conducted according to the approved Test Plan. Modified EPA Method 5 and heated Andersen cascade impactor sampling runs were performed simultaneously at the inlet and outlet of the Munters baffle array controlling emissions from the No. 1 wet coke quench tower at DOFASCO.

Three water quality conditions were sampled; "clean" (510 mg/l TDS), "semi-dirty" (2270 mg/l TDS), and "dirty" (8850 mg/l TDS) quench water. Dual cyclone sampling runs were performed nonsimultaneously at the inlet and outlet of the baffles for "clean" and "dirty" water usage. Total particulate tests were performed at the outlet only during "semi-dirty" water usage. Water samples were taken for each quench tested at the quench, return and makeup lines. A summary of the results is presented in Tables 1 through 3 and Figures 1 through 4. In addition, one organic sampling run was conducted simultaneously at the inlet and outlet of the baffles for both "clean" and "dirty" water along with atmospheric dilution tests performed by Southern Research Institute (SORI) personnel at the outlet during "dirty" water usage. The results from the organic sampling portion of this program are presented in the Battelle Laboratories' report shown in Appendix F. The SORI report for the atmospheric dilution testing is shown in Appendix G.

The results of several total particulate and particle size distribution runs are averaged and considered as one test for each water quality. The size specific emission factors shown in Table 2 are calculated by multiplying the "front half" total particulate results by the impactor derived particle size fractions. The results of the total particulate tests show the expected trends for all three water quality phases, and compare well with other available quench tower test data (i.e., Lorain, Gary No. 3, No. 5, DOFASCO '77). The plots of emissions (lb/tons coal charged) versus water quality (TDS mg/l) shown in Figures 1 and 2, are similar to the results of other tests on controlled quench tower emissions from a multi-row baffle system with slow to medium (4-14 fps) exit velocities in the 0 to 10,000 mg/l TDS quench water range. The particle size distribution results presented in this report should be considered as resulting from particles and particles contained in droplets. The results show the expected trends for the dirty water tests. The clean water results show an unexpectedly higher percentage of large particles/droplets in the outlet stream. Since water droplets were present in the stack gas, all the size distribution results are probably biased high since a droplet containing particulate would impact on the appropriate stage

TABLE 1. TOTAL PARTICULATE EMISSION FACTOR SUMMARY, DOFASCO NO. 1 QUENCH TOWER

Test type*	Cyclone (lb/ton coal)[a]	Probe (lb/ton coal)	Filter (lb/ton coal)	Total front half (lb/ton coal)	Total back half (lb/ton coal)	Total train (lb/ton coal)	Quench water quality (mg/l TDS)
Clean Inlet	0.83	0.19	0.11	1.13	0.12	1.25	510
Outlet	0.25	0.03	0.04	0.32	0.17	0.49	
Semi-dirty--Outlet	0.42	0.02	0.04	0.48	0.40	0.88	2,270
Dirty Inlet	3.88	0.33	1.03	5.24	0.56	5.80	8,850
Outlet	0.66	0.42	0.31	1.39	0.77	2.16	

[a] Approximately 3 μm D_{50} lower cut size.

*Format of results based on previous data.

TABLE 2. SIZE SPECIFIC EMISSION FACTORS,[a] DOFASCO NO. 1 QUENCH TOWER

Test type	Total No. of quenches sampled	Cumulative	Particle aerodynamic 50% cut diameter (d_{50})					
			Total	15 μm	10 μm	5 μm	2.5 μm	1.0 μm
Clean Water								
Inlet	36	% mass d_{50}	100	37.4	30.1	19.1	11.1	4.0
		lb d_{50}/ton	1.1	0.4	0.3	0.2	0.1	0.0
Outlet	36	% mass d_{50}	100	15.1	9.8	7.0	6.0	1.2
		lb d_{50}/ton	0.3	0.1	0.0	0.0	0.0	0.0
Dirty Water								
Inlet	39	% mass d_{50}	100	26.4	22.8	21.4	19.3	13.8
		lb d_{50}/ton	5.2	1.4	1.2	1.1	1.0	0.7
Outlet	27	% mass d_{50}	100	49.8	32.3	24.8	20.4	8.5
		lb d_{50}/ton	1.4	0.7	0.5	0.3	0.3	0.1

[a] Based on the assumption that the impactor back-up filter weight gain is invalid.

TABLE 3. WATER ANALYSIS SUMMARY, DOFASCO NO. 1 QUENCH TOWER

Parameter	Clean water			Semi-dirty water			Dirty water		
	Quench	Makeup	Return	Quench	Makeup	Return	Quench	Makeup	Return
Ammonia mg/l	3.4	0.99	2.24	527	3,733	517	2,300	2,928	2,416
Chloride mg/l	138	70	145	1,680	5,437	960	5,955	5,043	6,555
Conductivity µmhos/cm	804	575	859	5,667	24,667	6,050	23,500	21,400	25,400
Cyanide, µg/ml	0.33	0.31	0.34	0.66	1.58	1.0			
Residual, mg/l							0.6	4.3	< 0.4
Amenable, mg/l							3.1	40.1	2.0
pH	8.5	7.5	8.4	7.8	8.55	7.4	8.1	9.0	7.7
Phenol, mg/l	0.336	0.0021	0.461	87.6	808	75.1	284	662	250
Solids, mg/l									
Dissolved	510	337	560	2,270	9,550	2,520	8,858	8,732	9,732
Suspended	57	4.8	273.3	114.2	409.4	284.6	154.5	383	414.5
Sulfate, µg/ml	126	61	138	169.5	266	191	348	68	407
Sulfide, mg/l	<0.4	<0.4	<0.4	2.1	37.2	2.0	23.3	47.8	21.9
Temperature, °C	25.6	21.4	28.6	34.7	38.7	36.3	29	24.6	27.6

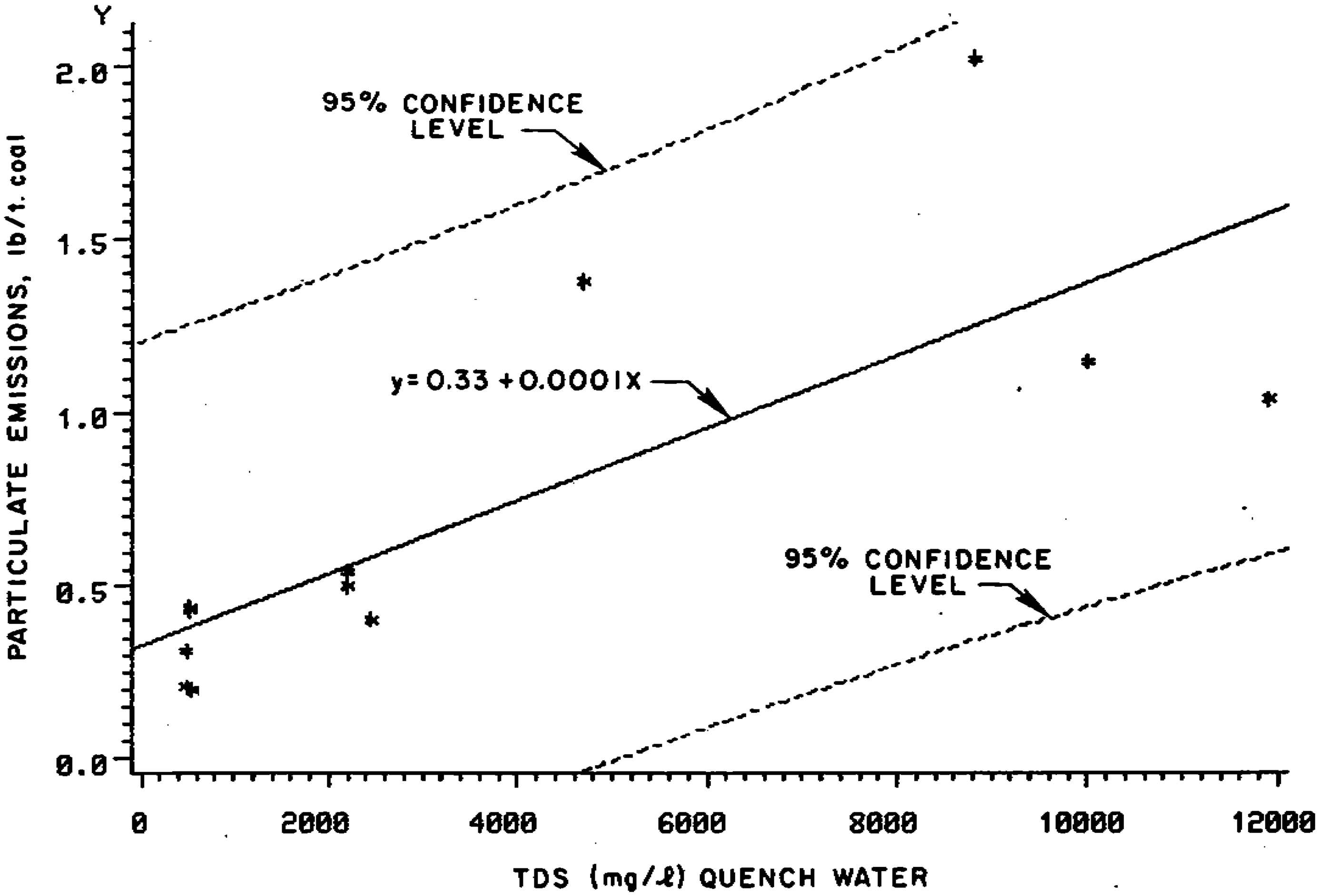


Figure 1. Air emission vs. water quality, outlet to the baffles, DOFASCO No. 1 Quench Tower.

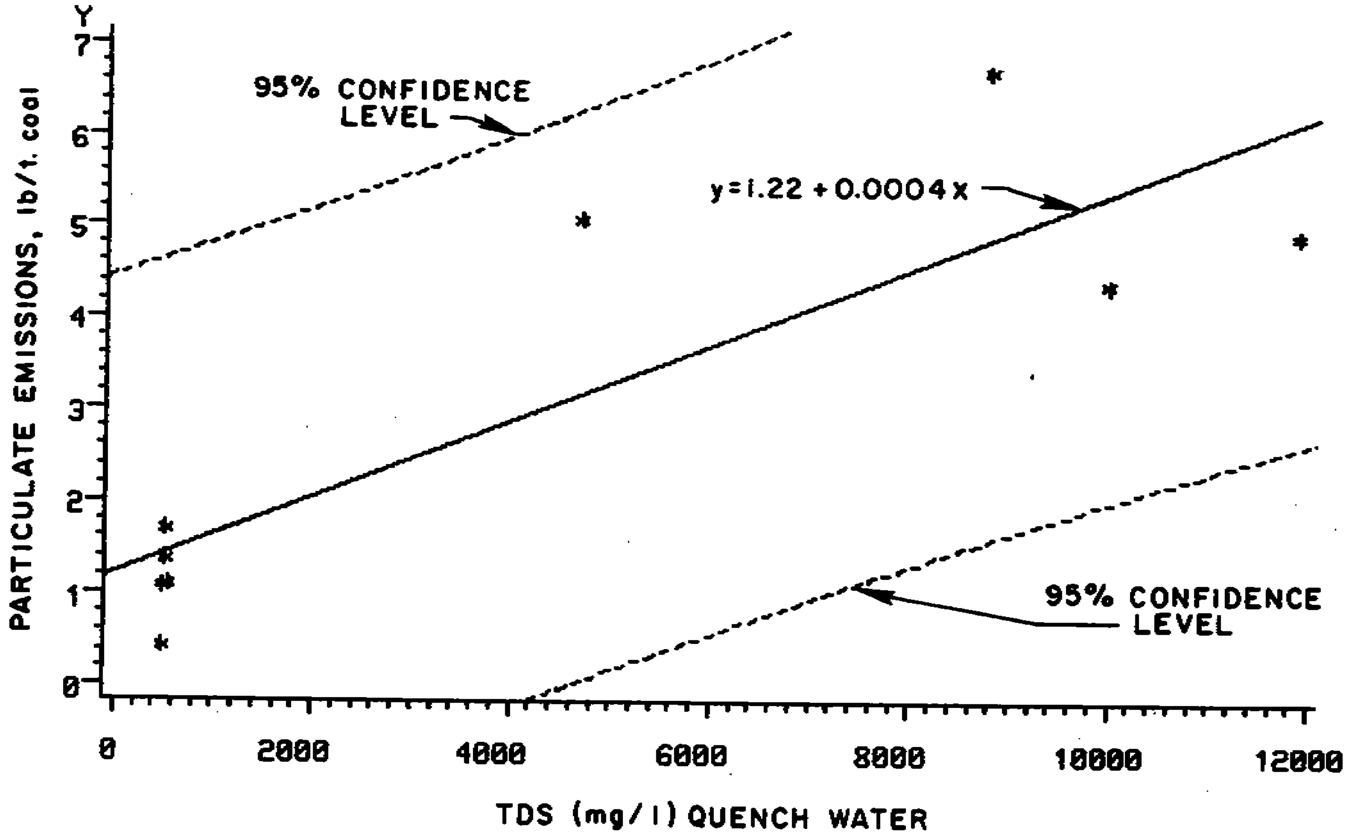


Figure 2. Air emissions vs. water quality, inlet of the baffles, DOFASCO No. 1 Quench Tower.

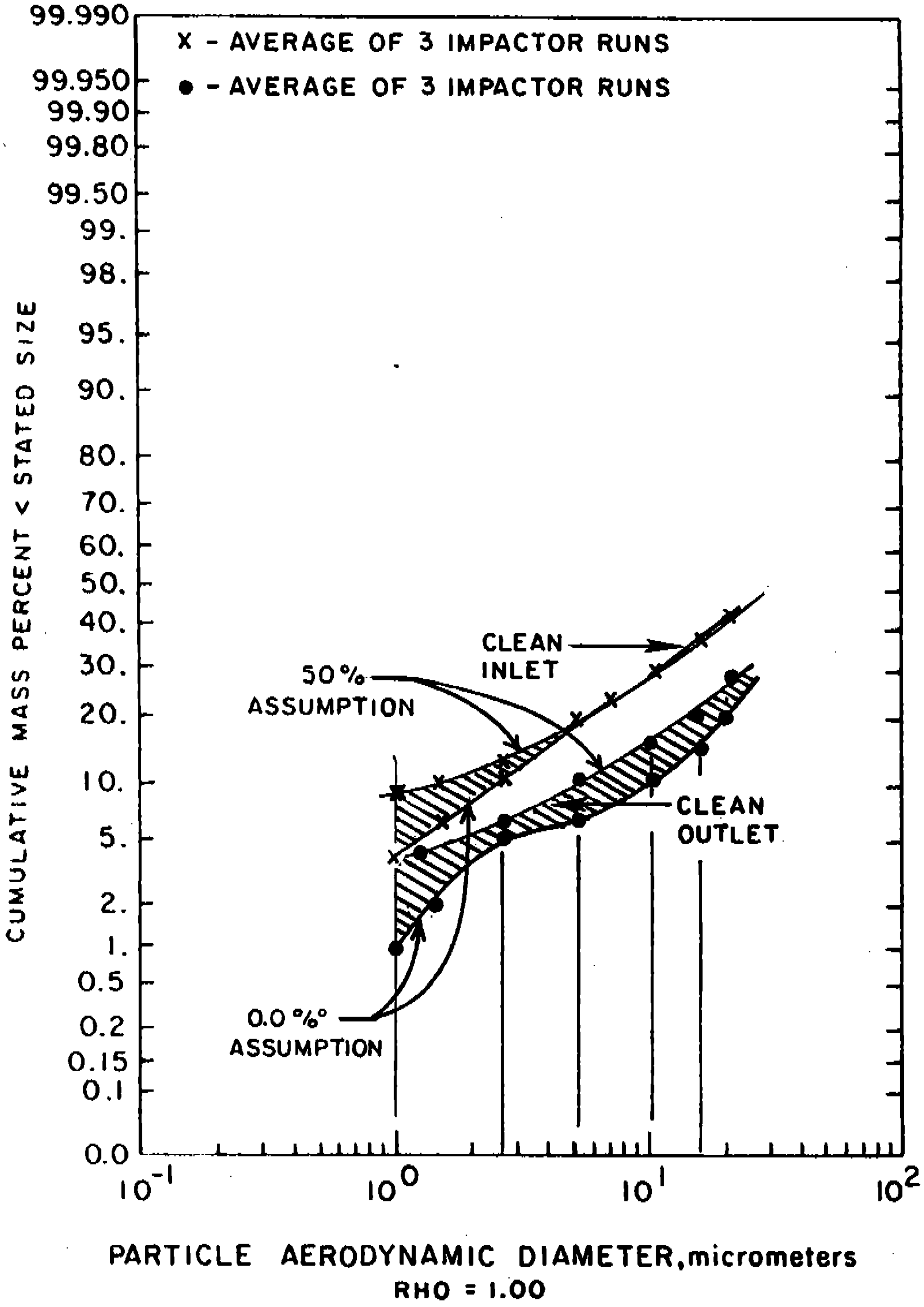


Figure 3. Average results of impactor runs during clean quench water usage, DOFASCO No. 1 Quench Tower.

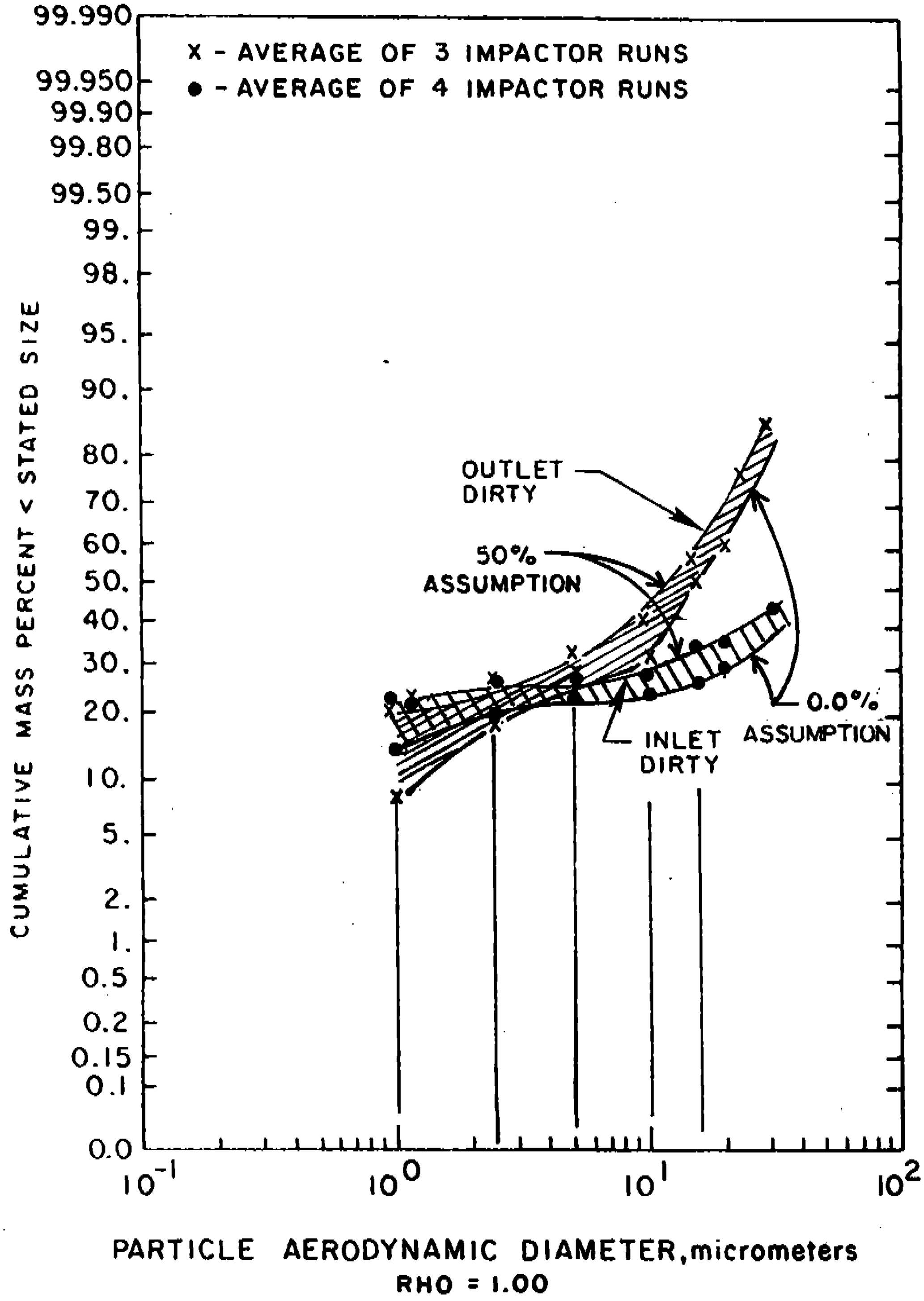


Figure 4. Average results of impactor runs during dirty quench water usage, DOFASCO No. 1 Quench Tower.

and leave a smaller particle. Large quantities of particulate were caught in the cyclone precutter indicating a high percentage of particles (and/or droplets containing smaller particles) that were larger than 15 microns. The impactors were heated to prevent the back-up filter from blinding. The results presented in Table 2 were calculated assuming that the back up filter weight gain was invalid due to particle bounce. Figures 3 and 4 show the results using the above assumption as well as the effect of assuming that 50 percent of the back up filter weight gain is from particles that were smaller than the last impactor stage d_{50}. And 50 percent of the weight gain is invalid due to bounce.

The dual cyclone results are considered less reliable than the above results and will only be presented in Section 5. The results of the water analysis efforts are presented in Table 3. Some of the analyses were performed on site, some by Battelle-Columbus, Ontario Research Foundation and some by Environmental Research & Technology. The remaining sections of this report describe the coke-making process, the sampling and analysis procedures used and the results obtained.

SECTION 3

PROCESS DESCRIPTION

COKE BATTERIES

The number 1 coke plant at DOFASCO consists of three batteries designated nos. 1, 2, and 3 (arranged south to north, respectively). These batteries operate as one complete unit served by two pusher machines, two door machines, and one quench car. All three batteries are Koppers-Becker design, each equipped with gun-flue type heating mechanisms. "Sweetened" blast furnace gas is fired in these flues, and each battery is served by its own combustion stack. Table 4 shows additional design parameters for each battery.

Each oven per battery contains three charge ports and a single standpipe-collector main arrangement located on the coke side. Jumper pipes are used on the push side for charging emission control. Currently, 15.9 tons of coal (with an estimated bulk density of 42 lbs/ft^3; volumetrically controlled) are charged per oven. Coking times average between 14 and 18 hours.

All batteries at DOFASCO use the "Koppers" sequence for scheduling each charge and push; i.e., 1's, 3's, 5's, etc., except where ovens are purposely bypassed (offline or out of service) or contain stickers. This sequence ensures uniform heating; since when an oven is pushed, the oven to its left is 55 percent through the coking cycle while the oven on the right is 45 percent complete.

A coke shed is used to control pushing emissions. The shed is approximately 700 feet long, and is split into two sections: (1) Batteries no. 1 and 2 under one section, and (2) Battery no. 3 under another. Two wet electrostatic precipitators and two 300-hp fans (each rated at 150,000 acfm) operate in parallel to control resulting push and door emissions.

QUENCH TOWER

One quench tower, located approximately 60 feet from the southern end of battery no. 1, serves all three batteries. The tower is constructed of stainless steel and is rectangular in shape measuring approximately 50 ft x 20 ft x 50 ft. See Figure 5 for baffle and sampling locations.

A total of 87 spray nozzles, arranged in three rows of 29, are used to deliver quench water onto the incandescent coke. These spray nozzles are located approximately 18 feet above the quench car tracks.

TABLE 4. SUMMARY OF BATTERY DESIGN PARAMETERS, DOFASCO

				Dimensions			
Battery No.	No. of ovens	Year entered service	Latest rehabilitation	Push side width	Coke side width	Height[b]	Length[c]
1	25	1956	End-flue repair completed March 1981[a]	15-1/4 in.	18-3/4 in.	13 ft	40 ft 3-1/2 in.
2	35	1951					
3	45	1958					

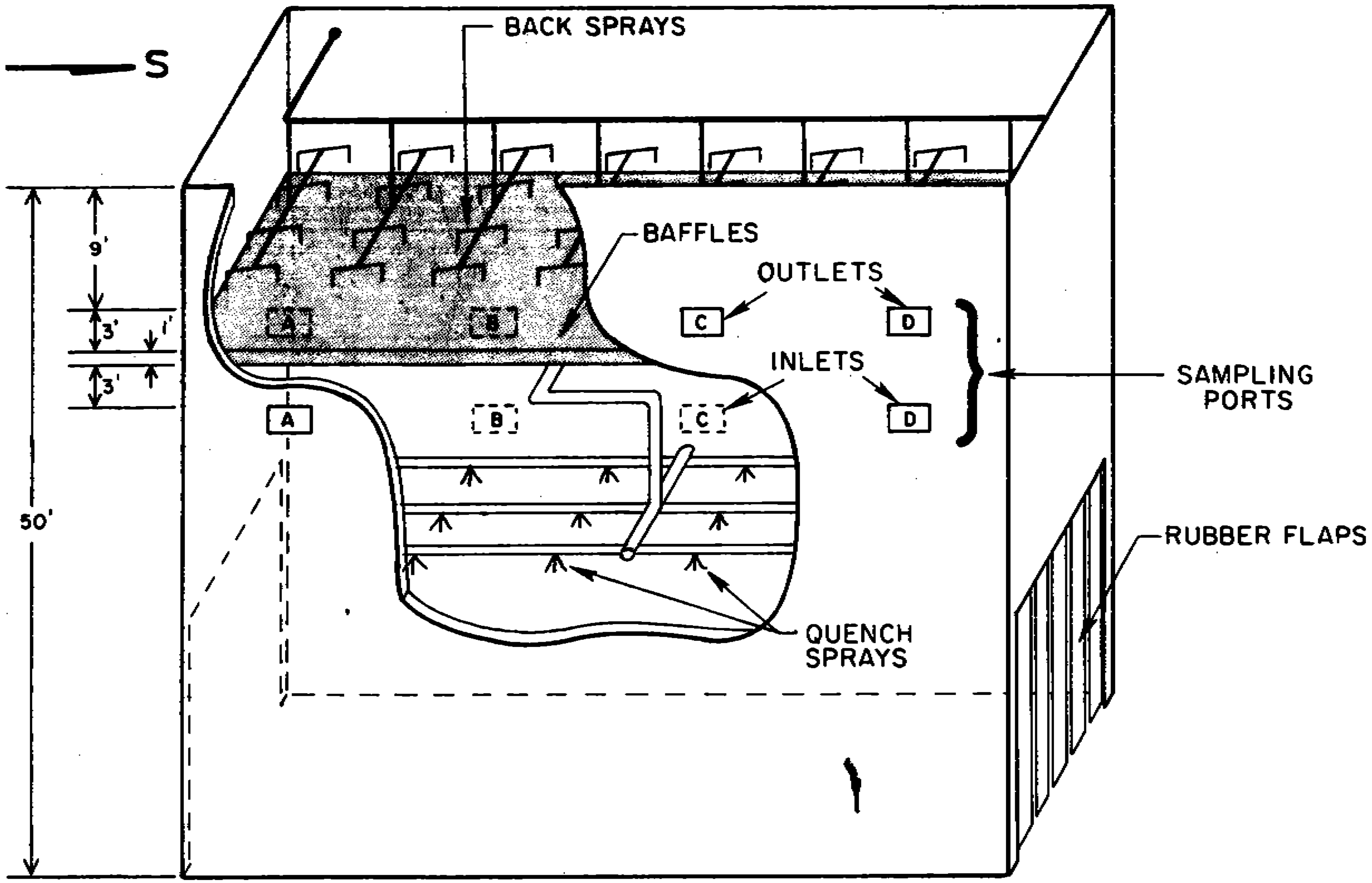


Figure 5. Tower layout, DOFASCO No. 1 Quench Tower.

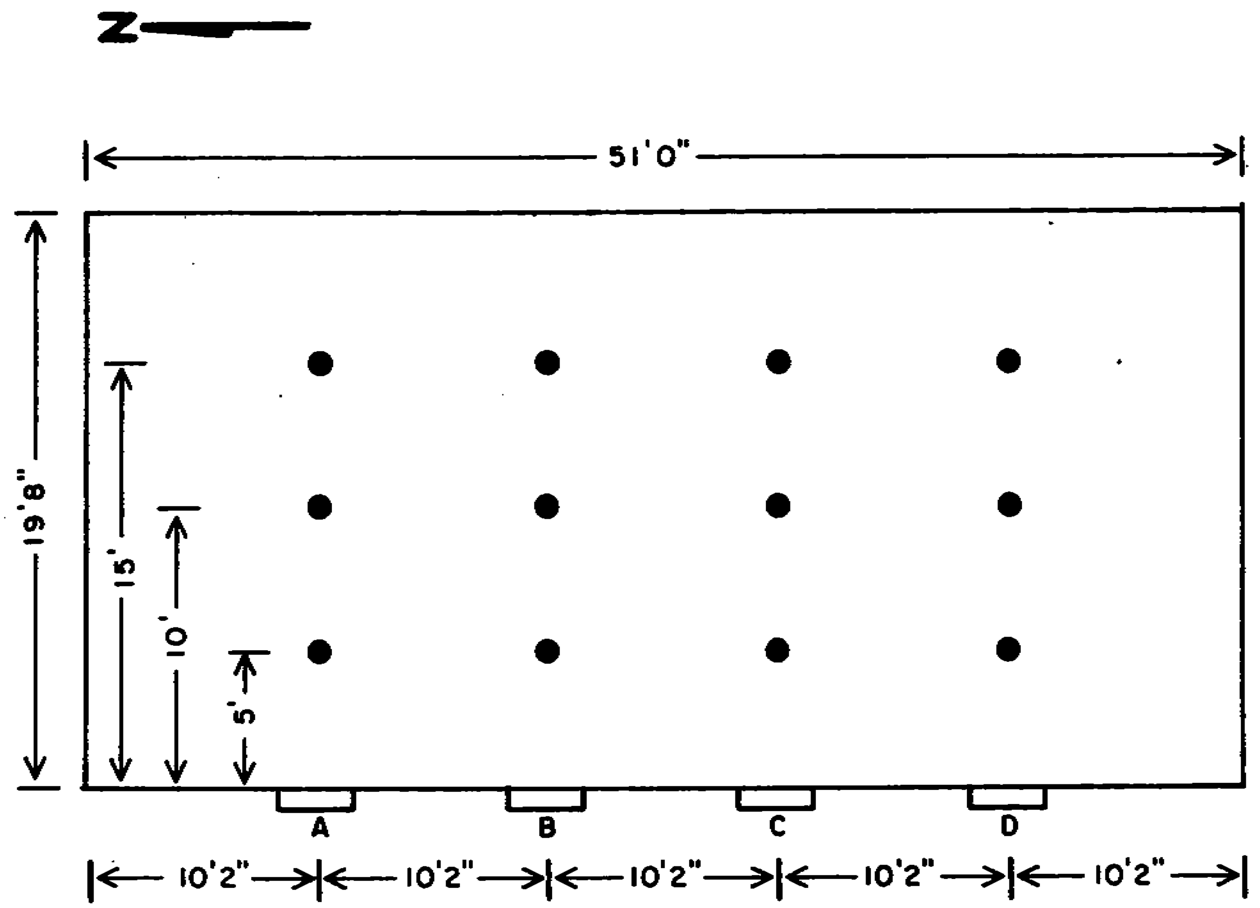


Figure 5A. Sampling prints, DOFASCO Quench Tower.

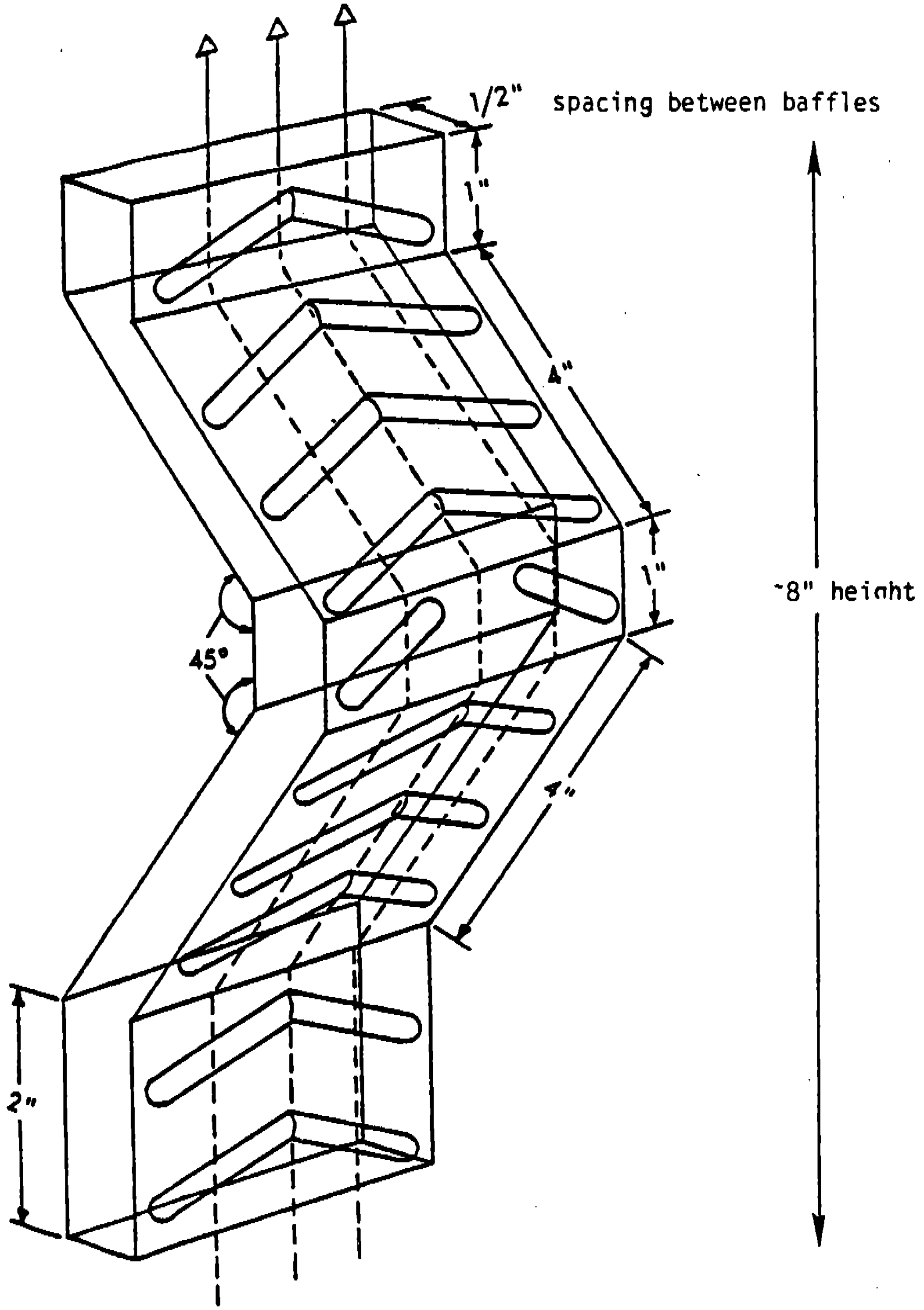
Approximately 6,000 gallons of water are used to quench the hot coke, and between 750 to 1250 gallons is lost up the stack as steam and water droplets. The remaining water is returned to the sump via a trough along side the hot car. Makeup water is added at a rate of 8,000 gallons per hour, with 3,200 gallons of this water being added by the baffle spray cleaning system (normal-"clean" water-operation).

The duration of quenching was preset by a timer at approximately 75 seconds on May 28, 1981. During the pretest evaluation, the average duration for 24 quenches was observed to be approximately 84 seconds. The total quench process, from the time the hot car was completely in the tower to the time completely out, was observed to average 2 minutes, 30 seconds during the presurvey in June, 1981.

The baffles are plastic Munters T-271 mist eliminators, installed approximately 12 ft from the top of the tower. These baffles cover approximately 95 percent of cross-sectional area of the tower. The T-271 is composed of a series of multi-angular shaped separating walls arranged to provide a channel for gas flow. Figure 6 shows the gas/droplet flow through one of the channels of the T-271 mist eliminators. A high pressure sequential spraying system was installed above the baffles and is used to remove particle buildup. Water for this system is taken from Han Hon Harbor/bay and is used as part of the makeup water. The water is applied by spraying one of the eight sections of the system for 4 minutes at a rate of 800 gpm. This is done once per hour.

Baffle plugging was observed during each of the three phases of the sampling program but was more pronounced during the application of dirty water. Figure 7 shows the observed areas of plugging (the center strip is flashing material and does not represent plugging).

Three sections of the baffles were warped during the dirty water phase. It was determined that a load of hot coke was left in the tower for too long a period without being quenched. The areas affected are also shown in Figure 7.



----▷ indicates air flow between baffles

Figure 6. Side view of gas flow through baffle channel, DOFASCO No. 1 Quench Tower.

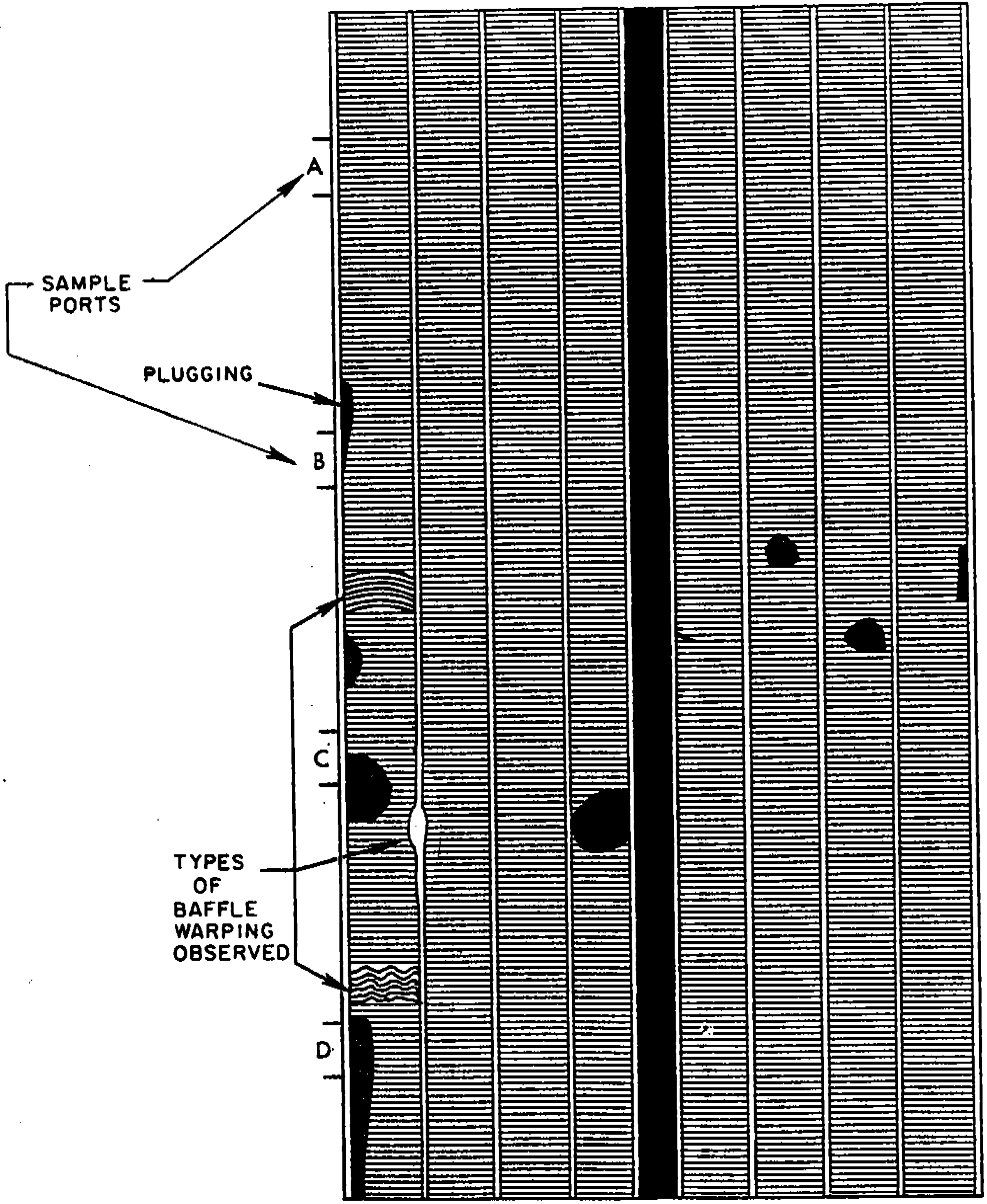


Figure 7. Top view of baffle configuration, DOFASCO No. 1 Quench Tower.

SECTION 4

SAMPLING AND ANALYSIS PROCEDURES

INTRODUCTION

Emissions generated during the quenching process are naturally drafted out of the top of the tower. Prior to initiation of the field sampling program, a pre-survey was conducted to determine:

- whether gas velocities were measurable and consistent over the entire cross-sectional area of the tower;
- the need for heating the cascade impactor to measure particle size distribution;
- sampling sites for particulate and particle sizing tests and water sampling locations.

Upon completion of the presurvey work performed in June, 1981, sampling sites were identified and arrangements were made with DOFASCO personnel and their contractors for construction of the necessary facilities.

PRESAMPLING PREPARATIONS

Glassware and Nalgene sample bottles utilized in this test program were cleaned with an Alconox solution, rinsed with tap water, distilled-deionized (DDI) water and finally rinsed with the appropriate solvents if necessary. The glassware was air-dried and capped with Parafilm except those for the organic tests. All filters were desiccated to constant tare weight (± 0.5 mg).

Pitot tube-thermocouple-probe assemblies used for preliminary velocity traverses were calibrated by the measurement procedure as specified in 40 CFR 60, Appendix A, Method 2. Sampling nozzles were calibrated with a dial vernier micrometer.

Impactors and cyclones were prepared for sampling by cleaning with soap and water, then rinsing with DDI water and finally with acetone. All particle sizing train dry gas meters and orifices were calibrated according to procedures outlined in APTD 0576 prior to sampling.

TOTAL PARTICULATE MATTER

Total particulate matter testing was conducted with a Hi-volume Aerotherm sample train to minimize the amount of time required to collect a sufficient volume of gas and weight of particulate matter. A schematic of the sampling train is provided in Figure 8.

In order to allow a more accurate determination of moisture in the stack gas, to prevent filter plugging, and provide a rough indication of particle sizing, a cyclone was fitted at the nozzle end of the 20 foot probe. The cyclone is designed to have a lower cut size of about 3 μm at the anticipated flow rate. Particulate and gas were drawn through the unheated cyclone where particles and water droplets were collected. The gas then passes through the heated (250°F) probe and a heated (250°F) Spectro grade type AE glass fiber filter where remaining particles are collected. The gas sample then passes through an impinger train-ice bath assembly where additional particulate matter and condensibles are removed. The gas was then further dried prior to entering the flow control module by means of an impinger filled with 300 grams of silica gel.

A continuous strip chart recorder was connected to a Hastings/Raydist flowmeter to record the gas velocity pressure (Δp) and to aid in verifying any uneven flow patterns. The unit operates with air continually purging the pitot lines thus preventing stack gas from entering the meter. Differential pressure across the pitot tube is measured as a change in the pneumatic bridge, formed by the velocity transducer, manifold, and pitot tube. As flow across the tip occurs, a differential pressure develops, imbalancing the bridge and causing a small amount of purge gas to flow through the transducer. The transducer measures this flow which is related to the gas flow at the tip of the pitot tube. Purge gas still exhausts through both openings, but at a slighty unequal rate. The instrument allowed accurate measurement of flow in the steam plume even though large diameter solids (coke breeze) and water droplets were present.

Data from other field tests and the presurvey visit in June, 1981, indicated that velocity head (Δp) was predictable and values for sample rates (ΔH) can be determined based on a preliminary velocity profile taken before each test run. Data from the velocity profile was utilized to determine:

- Absence of erratic flow pattern(s)
- Velocity pressure (Δp)
- Stack gas velocity (feet per minute)
- Required nozzle size
- Predicted sampling rates (ΔH)

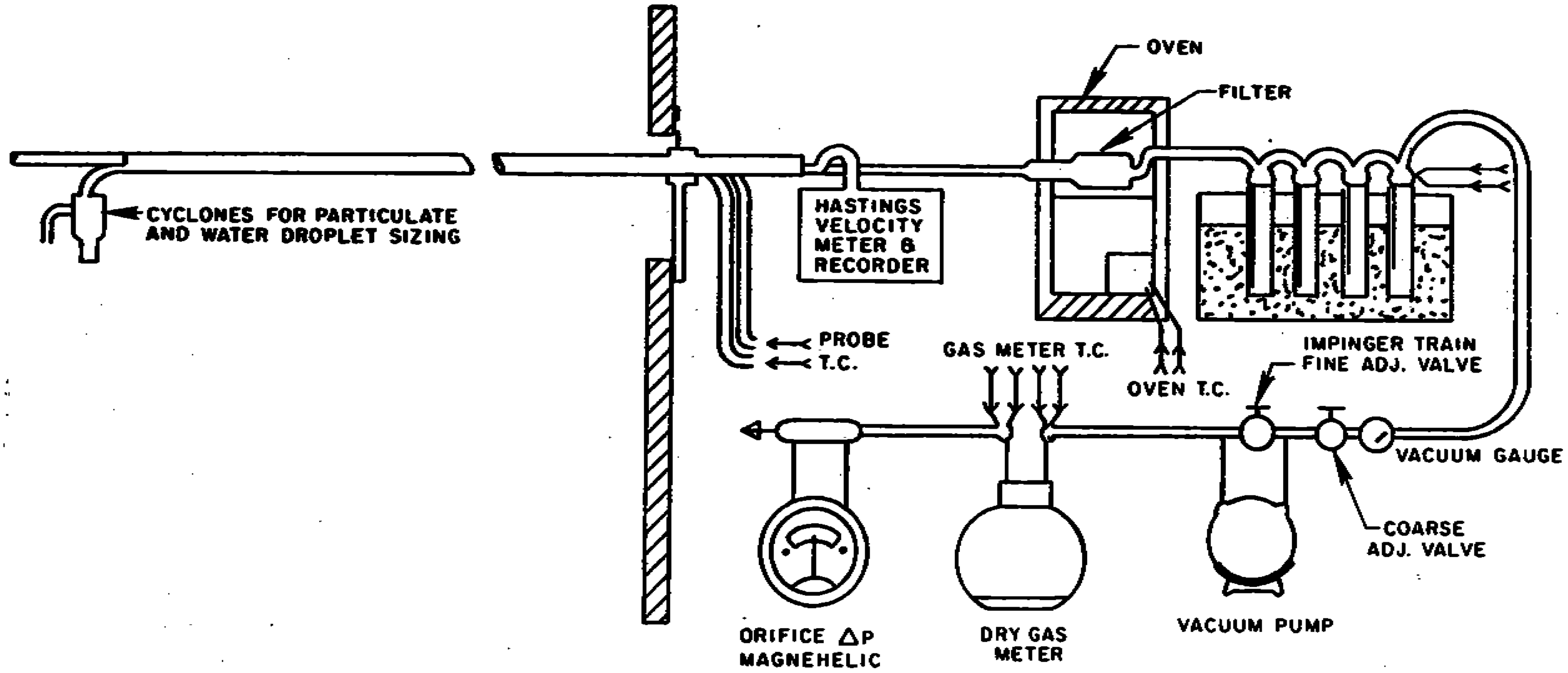


Figure 8. Hi-volume particulate sampling train.

Test Sequence

The initial traverse was used to establish the rate (length of time) of rise of the velocity pressure (Hp), the maximum Δp, and the rate of decline of Δp to an end point greater than zero. For each quench, the sampling rate (ΔH) was gradually increased from the signal CAR-IN over an approximately thirty (30) second period. This maximum sampling rate was maintained until the signal WATER-OFF was given and a ramp down procedure was initiated to a predetermined rate established from the averaging of the ramp down portion of the velocity profile. Sampling was then terminated when the car was completely out of the tower. An example of the velocity profiles obtained during testing is shown in Figure 9.

Due to physical obstructions (i.e., ladders, monorail guidewires, etc.) it was necessary to sample only two (2) ports per test. Therefore, two (2) quenches were sampled for each point until twelve quenches were sampled or, in the case of some of the tests, nine quenches were sampled, due to weather or process conditions.

Sample Recovery

At the completion of each test run, the probe and cyclone assembly was removed from the stack and its exterior wiped clean. Before lowering the train from the test platform, the cyclone cup was removed and its contents poured into a clean labeled container. The cup was then placed back onto the cyclone assembly. The filter holder, umbilical line connecting the filter assembly to the first impinger and the entire impinger unit was disconnected and capped or sealed accordingly. After inspection and recording of any anomalies, the individual units were lowered to the laboratory/trailer for clean-up.

In the laboratory/trailer, clean-up and disassembly of the sampling train was conducted in the following order:

1. The nozzle was carefully removed and the inside surface cleaned by triple rinsing with acetone and brushing between each rinse with a pre-cleaned nylon brush. Brushing was continued until the rinse showed no visible particles, then the inside surface was given a final rinse into the glass sample container.

2. The inside surface of the probe and cyclone were then brushed and rinsed with acetone in a manner similar to the nozzle until the rinse showed no remaining visible particles. The rinsings from the cyclone and probe were placed into labeled glass containers.

3. The filter was then removed from the holder and inspected for tears, punctures and other deformations before being placed in a clean labeled plastic petri dish which was then sealed with tape.

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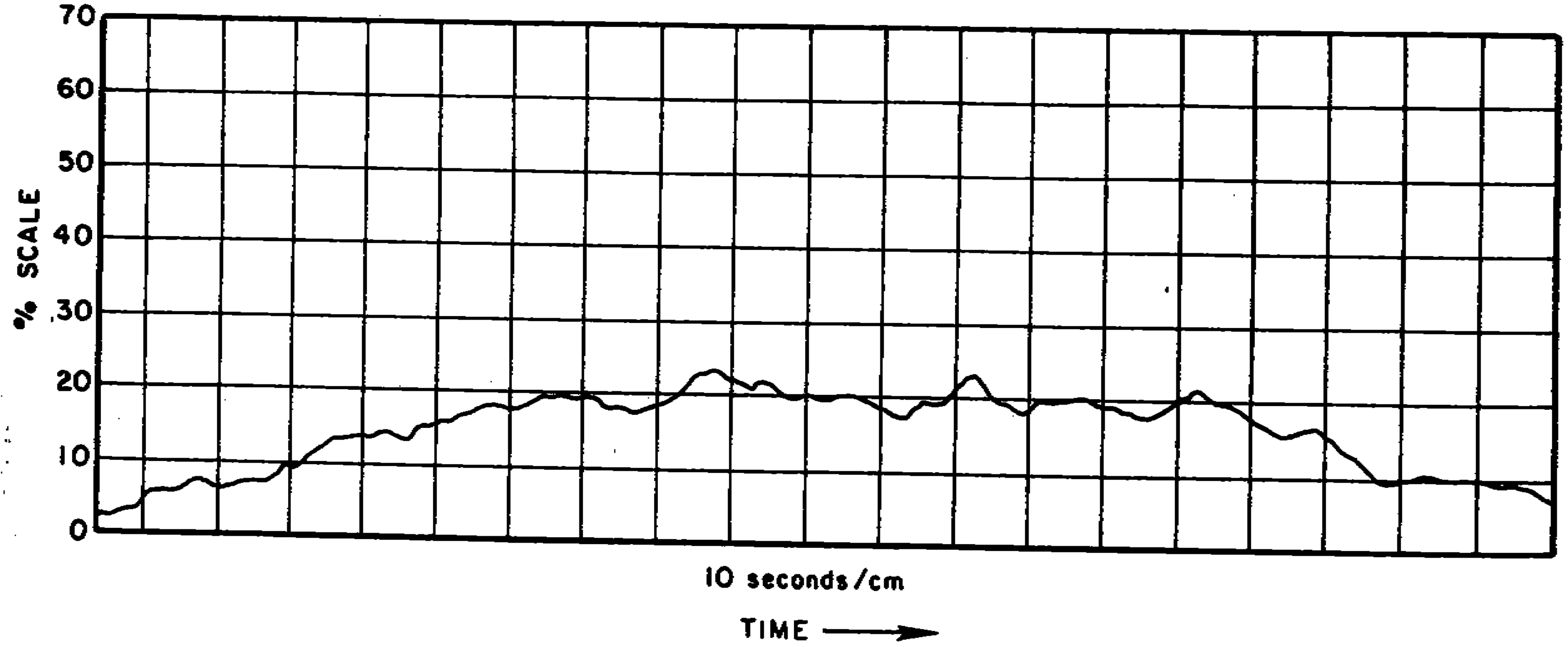

Figure 9. Typical velocity profile, DOFASCO No. 1 Quench Tower.

4. The inside of the front half of the filter holder was cleaned by brushing with a nylon brush and rinsing with acetone at least three times and until all visible particulate was removed. The brush and the inside surface of the front half of the filter holder were then given a final rinse. This rinse was added to the probe sample container.

5. The liquid in the first three impingers and the condensate from the umbilical cord were measured to the nearest ml and recorded. The contents were then placed in a labeled container. Approximately 50 ml of distilled water rinse was poured into each impinger, agitated, and added to the container. The umbilical cord, back half of the filter holder and connecting fittings was rinsed twice with distilled water and added to the wash container. Acetone washes were not performed as Lexan impingers were utilized.

6. The silica gel from the last impinger was transferred to a pretared container, weighed to the nearest 0.1 mg and recorded.

7. The volume of the solution from the cyclone cup was then measured to the nearest ml, recorded, and returned to its separate container.

This sampling recovery scheme resulted in eight samples:

Container No. 1	Cyclone solution	Glass Jar
Container No. 2	Nozzle Wash	Glass Jar
Container No. 3	Cyclone Wash	Glass Jar
Container No. 4	Probe/Filter Front Half Wash	Glass Jar
Container No. 5	Filter	Petri Dish
Container No. 6	Back Half Wash/Impinger Condensate	Glass Jar
Container No. 7	Back Half Wash/Impinger Condensate	Glass Jar
Container No. 8	Silica Gel	Plastic Jar

Sample Analysis

Upon completion of the sample recovery procedures, the samples were labeled, sealed, then liquid levels marked, and the samples carefully packed for shipment to the GCA/Technology Division laboratory for analysis. A Chain of Custody log book that outlined the recovery procedures and documents the history of the samples was kept daily. Upon return to the GCA laboratory, the filter samples were logged in and immediately placed in a desiccator and dried for 24 hours before being weighed. The acetone and wash samples were transferred to pretared beakers, evaporated to dryness at ambient temperatures, desiccated for at least 24 hours and then weighed. After weighing, all samples were placed in the GCA/Technology Division sample bank for storage. The results were calculated by Version 4 of the GCA Particulate Data Reduction System using an IBM 370 computer and the example calculations provided in Appendix A-1.

ANDERSEN IMPACTOR SAMPLING

Particle size fractions in the 0.8 to 15 micron range were determined using Andersen Mark III cascade impactors, preceded by cyclone precollectors. The in-stack fractionating sampler provides eight size range measurements. The preimpactor removed particles greater than 15 microns. The determination of impactor stage cutpoints and particle size distributions was performed with the computerized PADRE data reduction system.

The impactors were loaded with pretared Reeve Angel type 934H-glass fiber substrates in the field trailer. The complete units (impactor, preseparator, and nozzle) were then wrapped with electric heating tape, in order to keep the temperature of the impactor above 212°F and eliminate the problem of water condensation inside the impactor unit.

The sample trains (pictured in Figure 10) were assembled and the heating tape turned on. The trains were then leak checked at a vacuum of 15 in. Hg. A leak rate of less than 0.02 cfm was required to start a test. Once this was achieved, the outlet and inlet trains were placed in the stack such that the nozzles were at the same point in the tower, above and below the baffles.

When the process observer signaled that the quench car was fully into the tower, the isokinetic flow rate was quickly established and monitored as necessary to maintain constant flow. The flow was shut off when the quench car was fully out of the tower, or three minutes had expired. Only twice during the entire program were the inlet and outlet impactors not run simultaneously, once during run 1C, and once during run 2D.

Upon completion of the test, the impactors were removed from the stack and allowed to partially cool. The nozzles were then capped, the impactors removed from the probes and carefully transported back to the trailer. Note that no final leak checks were performed so as not to disturb the particle size distribution within the impactor and preseparator.

Andersen Impactor Gravimetric Analysis

At the conclusion of each test run, each impactor was carefully dissassembled and the nozzle and preseparator section brushed and washed with acetone into a glass sample bottle. Each impactor substrate was placed in its respective petri dish and any particulate adhering to the bottom of the jet plate above it, the crossbar, the gasket, or the top of the jet plate below it was brushed onto the substrate. In all cases, the substrate was carefully placed in a preweighed aluminum foil package to eliminate loss of particulate during handling. On the occasions when the temperature of the impactor fell below 212°F and water condensed inside the impactor, extra care was needed when separating the substrates from the jet plate.

Upon completion of the sample recovery procedures, the samples were labeled, sealed, liquid levels marked, and the samples carefully packed for shipment to the GCA/Technology Division laboratory for analysis. A chain of custody log book that outlines the recovery procedures and documents the history of the samples was kept. Each substrate and weighing jacket, upon

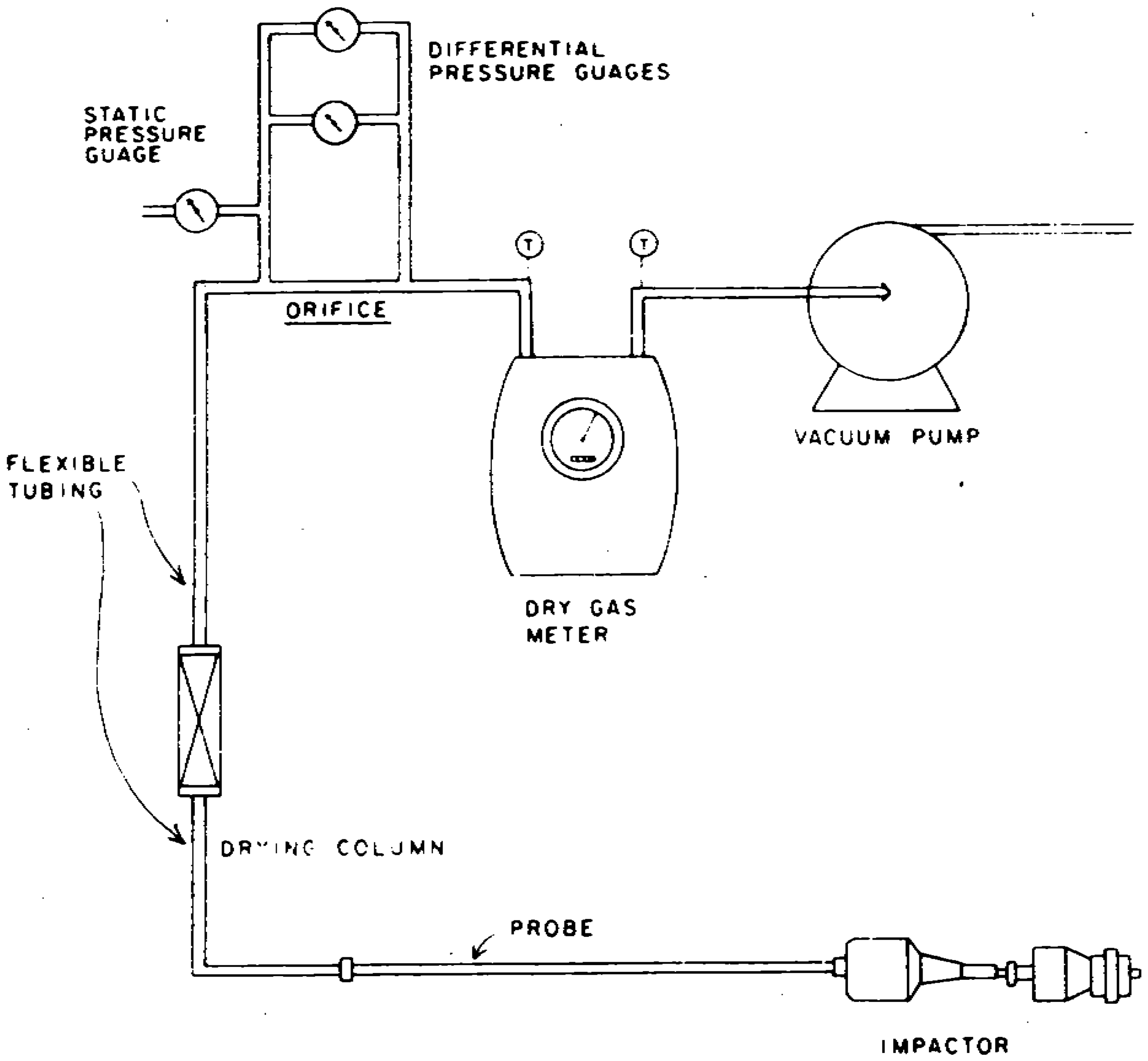

Figure 10. Andersen Sampling Train.

return to the GCA laboratory, was immediately placed in a desiccator and dried for at least 24 hours before being weighed. After weighing, all samples were carefully stored in closed containers. Field and gravimetric analysis data were entered into the interactive data reduction system (PADRE) developed by RTI for EPA. This system checks each inputted variable and warns the user if an error is detected. Example calculations used to determine the cyclone precutter lower cut diameter and a more complete discussion of PADRE is provided in Appendix A-2.

DUAL-CYCLONE SAMPLING

An inhalable particulate sampler, consisting of two cyclones in series and a back-up filter, was developed by Southern Research Institute for size measurement in industrial process streams. Three particle size fractions are determined; greater than 15 microns, 2.5 to 15 microns, and less than 2.5 microns, when operated at a nominal flow rate of 0.8 cfm at 300°F. A schematic of the sampler is provided in Figure 11. For some runs, a backup filter was placed behind a thimble back up filter to collect very fine material which passed through the thimble.

The sampler was attached to a probe, leak-checked to less than 0.02 cfm at 5 inches Hg and inserted into the stack horizontally. The sampler was turned on at the start of a run and allowed to run without interruption, even between quenches. Sample periods ranged from approximately 4 to 10 hours.

The decision to run the dual cyclone sampler continuously was based on the following considerations: it was necessary to sample in the horizontal position, it is necessary for the sampler to be in a position 45° from horizontal before stopping flow, and it is desirable to move the sampler and interrupt flow through it as infrequently as possible. The sampler was left running during the period between quenches and it was assumed that very little sample was collected during this period.

The procedures outlined in the "Procedures Manual for Inhalable Particulate Sampler Operation" (SORI-EAS-79-761), Chapter 5, were followed for recovery of sample from the collector. Brushes and acetone rinses were used to remove all particles adhering to the inside surfaces of the collector. The liquid level in the sample containers were marked, the containers were then sealed and locked up. Chain-of-custody documentation was maintained.

WATER SAMPLING

Water samples were taken at three locations representing three phases of water during the quenching process. Samples were taken at the inlet to the quench spray (labeled the "Quench water" samples), the return to the sump after quenching (labeled "Return water"), and at the makeup to the sump (labeled "Make-up water") which was bay water for the clean water testing and flushing liquor for the semi-dirty and dirty water testing. Sampling locations are shown in Figure 12. These sampling sites were selected to obtain samples which would trace the path of water pollutants through the quenching process. The makeup water samples show the levels of pollutants entering the system as water is added. The quench water samples show levels

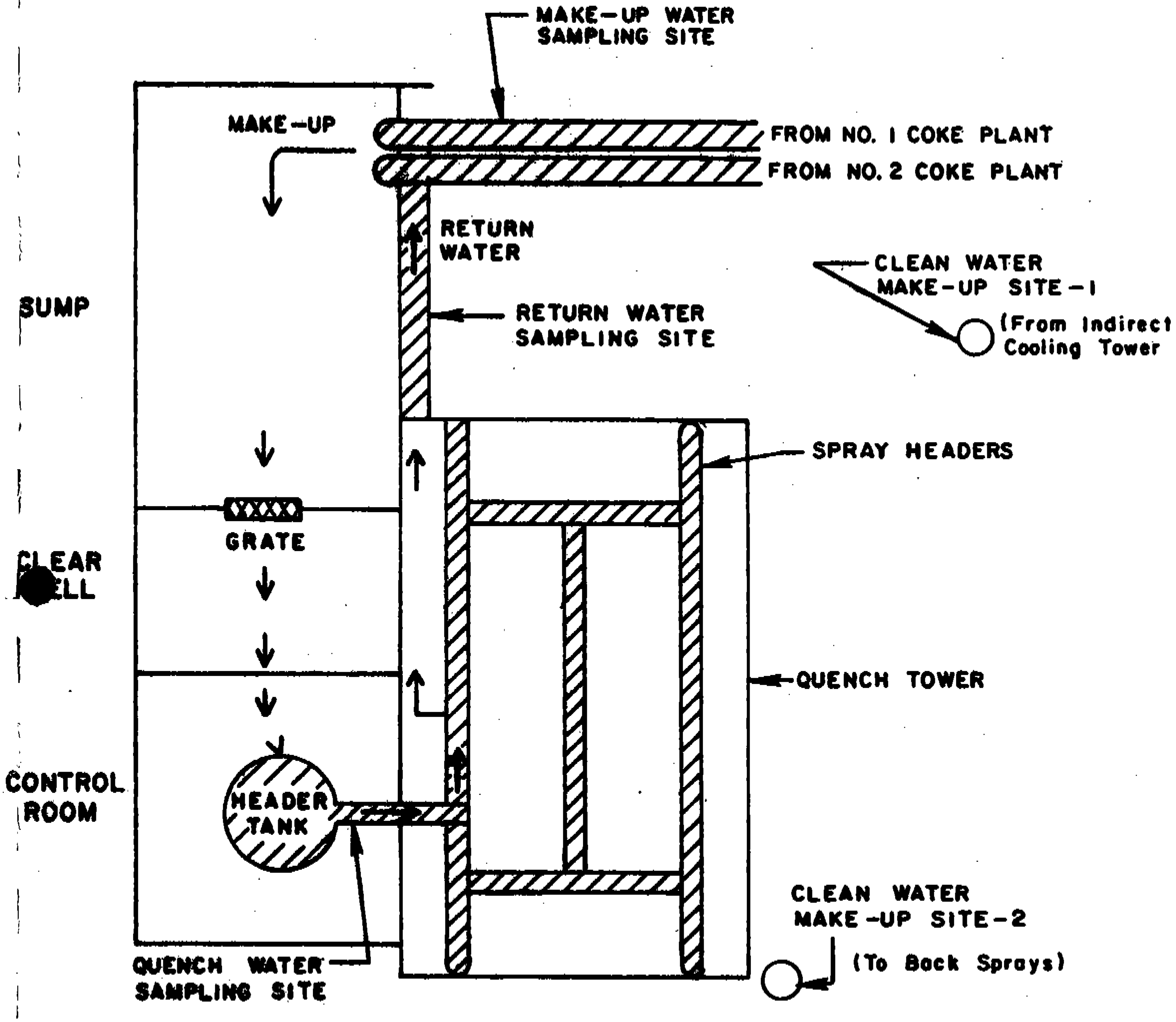

Figure 12. Diagram of water flow and sampling locations, DOFASCO No. 1 Quench Tower.

of pollutants just prior to the quenching and the return water samples show pollutant levels after quenching. Comparing the results obtained at these different points provides an indication of pollutants lost from the water through emissions from the quench tower or, conversely, pollutants gained from contact with the hot coke during quenching.

Water samples were collected as a composite of grab samples taken during each quench of a multi-quench test. During each quench, a grab sample was taken at all three (quench, makeup and return) sample locations. These grabs were composited over the entire test period, 9 to 12 quenches, and treated as one composite sample. Samples were collected in large glass jugs with a total volume of approximately 5 gallons collected during the test period at each location.

The quench water sample was taken from a tap in the water line between the header tank and the spray nozzles. This sample was taken immediately prior to the start of the quench. The return water sample was taken at the return trough between the tower and the sump. This sample consisted of three grab samples from the trough for each quench: one at the beginning of the quench, one in the middle, and one as the car left the tower. The makeup water sample during clean quench water tests was taken at two locations, both of which were sampled during each quench. The first makeup water sample was taken from a tap in the line connecting the final cooler and the trough which drains into the sump. This sample represents the indirect cooling system. The second sample was taken from the line used to clean the baffle array. This water, like the indirect cooling water, comes from the bay. The makeup water samples were taken from 3 in. rubber hoses routed from batteries No. 1 and 2 during semi-dirty and dirty quench water tests. A grab sample was taken from each quench and composited.

Upon completion of a test, the composite water samples were mixed thoroughly and returned to the field trailer for sample recovery and some onsite analysis. Each composite was split into 8 aliquots for further analytical work. Clean, deionized water rinsed glass jars were used as sample containers. In addition to filling eight sample containers, some sample was saved from each composite jug for onsite analysis. For all tests except the clean organic and dirty organic tests, sample containers were prepared for the analyses of the following parameters: ammonia, chloride, cyanide, phenol, solids, sulfate, sulfide and an additional container was filled to serve as an extra sample. For the organic clean water test, samples were collected for phenol and cyanide, and a 1-gallon glass jug was filled from each composite for later analysis of metals and organic compounds. For the organic dirty water test, samples were obtained for ammonia, cyanide, phenol, and solids, as well as the metals and organic compounds. Samples were then preserved according to the specific requirements of the analytical method to be used. A breakdown of the sample split and preservation for each parameter is presented in Table 5.

A portion of each composite sample was analyzed onsite. Temperature, pH, and conductivity were determined for each composite sample, and the values recorded in the water sampling and analysis field notebook. pH was determined using a "mini" analog pH meter with a combination calomel reference electrode. Temperature and conductivity were determined using a Hach model

TABLE 5. WATER SAMPLE HANDLING DATA, DOFASCO NO. 1 QUENCH TOWER

Analysis	Container	Preservation	Holding time	Analyzed by
Ammonia	1 liter glass	Conc. H_2SO_4 to pH2	24 hours	Ontario Research
Chloride	500 ml glass	None	7 days	Battelle
Cyanide	1 liter glass	1.25N NaOH to pH 12	7 days	Battelle Ontario Research
Metals	1 gal glass jug	None	6 months	Battelle
Phenol	1 liter glass	H_3PO_4 to pH 4 1g $CuSO_4$	24 hours	Ontario Research
Solids	500 ml glass	None	None	ERT
Sulfate	1 liter glass	None	7 days	Battelle
Sulfide	500 ml glass	20 drops 2N Zinc Acetate	24 hours	Ontario Research

16300 portable conductivity meter which has a temperature range of 0-100°C, and a conductivity range of 0-20,000 mhos/cm. To obtain conductivity readings higher than 20,000 mhos/cm, dilutions were made of the sample with distilled deionized water.

Following sample recovery and preservation, the water samples were split into three groups, according to which analytical laboratory was to perform the analysis. Due to the extremely short (24 hours) holding time of the ammonia, phenol and sulfide samples, these were driven to Ontario Research Foundation (ORF) for analysis. During the dirty water testing only, cyanide samples were also sent to ORF for analysis, to minimize the difficulties encountered earlier when bringing these samples across the U.S./Canadian border. Sulfide was analyzed in accordance with Standard Methods, 13th ed. 1971 Method No. 228A. Phenolic compounds were analyzed using the automated 4-aminoantipyrene Method A provided by the Ontario Ministry of the Environment. Ammonia was analyzed in accordance with Standard Methods, Standard Methods for the Examination of Water and Wastewater), 14th ed., 1975, Method No. 418 A&B. Cyanides were analyzed by Standard Methods, 14th ed., 1975, Method No. 413 (B, D, and F), and replicate analyses were performed using ASTM, part 31, 1981 edition, Method No. 2036-811B. The complete report detailing methods and results submitted by ORF is included in Appendix E.

Samples for sulfate, chloride, cyanide (during clean water testing), metals and organic compounds, having less restrictive holding times, were sent to Battelle-Columbus Laboratories for analysis. Chloride and sulfate were analyzed using the techniques given in "Methods for Chemical Analysis of Water and Wastes," EPA-600/4-79-020. Organic compounds were analyzed using EPA Methods 624/6235. Priority pollutant metals were analyzed using Atomic Absorption and ICAP. The Draft Final Report from Battelle which includes the analytical methods and results of these water samples is included in Appendix F.

Samples for solids analysis were held for the duration of the sampling trip in the field trailer. Upon return to GCA, these samples were analyzed in-house for suspended (filterable) solids following Standard Methods, 14th ed., 1975, Method 208D. After completion of this analysis, the remainder of the solids samples were sent to the Environmental Research and Technology (ERT) analytical lab for total dissolved solids analysis. This analysis was performed according to Method 160.1 in "Methods for Chemical Analysis of Water and Wastes," EPA-600/4-79-020.

ORGANIC SAMPLING AND ANALYSIS

Organic sampling, consisting of a modification of the total particulate sampling procedure was conducted at the inlet-outlet of the baffles, simultaneously. By placing an XAD adsorbent trap in-line between the filter and the impinger unit of the EPA Method 5 train, organic species in the stack gases are trapped. The tests were run in one sampling port at the inlet and outlet at approximately 0.75 cfm throughout the entire quenching process. Otherwise the same operating procedures discussed in the section on total particulate was adhered to. One test (inlet-outlet) was conducted for clean and one for dirty water quenching wherein nine quenches were sampled during each run. Cleanup procedures were modified to include the use of methylene chloride instead of acetone.

Samples of quench, return, and makeup water were collected in the same manner as were all of the previous water sampling procedures tests. The results of the analysis conducted by Battelle Laboratory for organic species is shown in Appendix F.

CONDENSIBLE EMISSIONS

Measurements of particle sizes after dilution with ambient air were conducted by Southern Research Institute (SORI). The sampling was performed using the EPA Stack Dilultion Sampling System (SDSS) which consists of an instack cyclone precutter (same as the dual-cyclones) followed by a dilution chamber. This unit, its operating procedures and the results of the tests are outlined in the SORI report provided in Appendix G.

GAS ANALYSIS

Stack gas from DOFASCO's coke plant quench tower was analyzed for carbon dioxide, oxygen, and carbon monoxide using an Orsat gas analyzer, and for hydrocarbon content (C_1-C_6) using a Carle GC 9700 FID gas chromatograph.

Grab samples were taken during random quenches during clean, semi-dirty, and dirty water testing using a 1-liter Tedlar bag and squeeze bulb. Samples were taken at the inlet of the baffle array during the clean water quench, and at the outlet during the semi-dirty and dirty water quenches. It was felt that there would be no difference between the inlet and outlet stack gas, however, samples were randomly taken at both locations during the testing. The results of these tests show that the quench tower stack gas had essentially the same carbon dioxide, oxygen and carbon monoxide content as ambient air when measured using an Orsat Analyzer.

Grab samples for gas chromatographic analysis were taken during clean and dirty water quenches only. Prior to each GC analysis , a standard C_1-C_6 gas was run through the GC to obtain a set of standard peaks from which the hydrocarbon content of the sample gas was calculated.

PROCESS OBSERVATIONS

The process observer's role was twofold. Each sampling run in a test was directed by the process observer who also documented all process and test conditions. The process observer's duties included non-Method 9 observations of coke greeness, flames, quench car load distribution, push/quench times, oven numbers, test duration and deviation from normal practices. The process observer also performed a daily door leak inspection, obtained the daily push schedule and was responsible for gathering process information such as average oven temperatures, net coking time, and coal/coke analysis.

The sampling crews on the coke quench tower and in the laboratory were in constant communication with the process observer. It was the observer's responsibility to alert the crews that a load of hot coke was approaching the tower. The signal to begin testing was given by the observer. When the quench car left the quench tower, or 3 minutes had transpired, the observer relayed the signal to stop testing. A series of three commands was used for this process. "Car Coming" alerted the crews to the impending arrival at the quench tower of the quench car. Each crew member verbally responded, signifying that they were prepared to sample. "Car In" was the command to begin the sample run. Each crew responded to assure that normal sampling had begun. At the end of each test the command "Car Out" was used to alert the crews to stop sample train operation. The process observer then relayed the time and duration of the test.

Process observations and test commands were performed from a vantage point midway between the coke shed and the quench tower on the coke side of the batteries. The observer was stationed on a platform approximately 8 meters from the ground. From this point, a clear view of the quench tower was possible. The observer could look down on the quench car prior to arriving in the tower and evaluated the coke greeness, flames, and distribution in the car. Communications were maintained through the use of a headset/intercom system.

The observer, based on his experience in coke plant operations, subjectively rated the "greeness" of each car of coke. A scale of 0-5 was used with a rating of 0 denoting no visible emissions and a rating of 5 denoting 85 to 100 percent opacity emissions emanating from the entire car length. Prior to testing, several quenches were rated by the observer and project coordinator to compare and discuss readings.

The amount and quantity of flaming coke was also noted. Light flames indicated burning coke with a flame height less than 0.3 m (1 ft). Medium flames were greater than 0.3 m (1 ft) but less than 0.6 m (2 ft). Heavy flames were considered greater than 0.6 m (2 ft) and were often disattached from the coke. The location of each area of flames was noted.

Comments were also made on loads of coke which differed from the norm. Excessive amounts of coke, as well as short charges were noted. Any unevenness in the distribution of the coke in the quench car was also recorded.

SECTION 5

TEST RESULTS

INTRODUCTION

The field sampling program was conducted during the last week of September and first 3 weeks of October, 1981. The program objectives were met by completion of five total particulate runs (simultaneous inlet-outlet over 9 to 12 quenches) during clean water (500 mg/l TDS) quenching, three during semi-dirty (2270 mg/l TDS), and four during dirty water (8850 mg/l TDS) quenching. Five impactor runs (inlet-outlet simultaneous) were completed during clean and four during dirty water quenching. Two dual cyclone sampler runs were performed for clean and dirty water quenching. One Modified Method 5 (organic) run was conducted for clean and dirty water usage. Water samples were obtained for each quench sampled. Process conditions were carefully monitored to document that test runs were representative of the normal quenching practices at DOFASCO.

Water samples were analyzed onsite, sent to Battelle Laboratory, Columbus, Ohio; Ontario Research, Mississauga, Ontario; and some samples were driven back to the GCA/Technology Division laboratory and sent to Environmental Research and Technology for analysis. The following sections describe the results of the field sampling and data analysis efforts.

TOTAL PARTICULATE RESULTS

The total particulate measurements were performed simultaneously above and below the baffles (outlet-inlet) using an EPA Method 5 sampling train modified to include an instack cyclone precollector. Tables 6 through 9 summarize the results obtained. Table 6 provides a summary of the average stack gas parameters and sampling conditions for each water quality test series. These results are presented in more detail in Appendix C-1, where particulate concentrations and emission rates are provided in both English and Metric units. Tables 7, 8 and 9 provide emission factors (in English units) based on the amount of coal charged to the coke oven for each water quality test series. In these tables, the distribution of the particulate in the sample train is provided. Typically, 55 to 65 percent of the particulate mass was recovered from the cyclones, 15 to 25 percent was recovered from the probe and filter and 10 to 25 percent in the back half.

TABLE 6. SAMPLING CONDITIONS, DOFASCO NO. 1 QUENCH TOWER

Type	Test No.	Date	No. of Quenches	Average Velocity (fpm)	Average Flow Rate (scfmd)	Moisture Content (% H_2O)	Test Time per Quench (min)	Isokinetic Rate (%)
Clean	1I	10/2-10/3	12	13.28	477,767	29.87	2.45	117.31
	10	10/2-10/3	12	13.10	456,867	32.27	2.45	114.10
	2I	10/3/81	12	14.10	439,651	37.43	2.33	125.71
	20	10/3/81	12	13.87	499,181	30.08	2.33	111.50
	3I	10/5/81	12	13.02	496,507	25.90	2.47	94.90
	30	10/5/81	12	13.43	490,242	29.14	2.47	96.16
	4I	10/5/81	12	12.78	475,079	28.48	2.54	96.15
	40	10/5/81	12	12.51	427,435	34.24	2.54	87.69
	5I	10/6/81	12	13.46	465,712	33.34	2.13	101.27
	50	10/6/81	12	13.49	448,085	36.01	2.13	112.24
Semi-dirty	10	10/9/81	12	13.72	473,696	32.84	2.66	103.67
	20	10/9/81	9	13.57	475,488	31.78	2.59	92.02
	30	10/9/81	9	13.18	440,373	35.00	2.34	107.61
Dirty	1I	10/20/81	12	12.67	415,395	36.11	2.61	87.91
	10	10/20/81	12	12.89	457,544	30.74	2.61	101.74
	2I	10/21/81	12	12.48	466,160	27.66	2.25	88.39
	20	10/21/81	12	13.03	467,849	30.54	2.25	114.50
	3I	10/22/81	6	12.68	457,141	30.01	2.17	105.49
	30	10/22/81	6	12.73	458,286	30.18	2.17	91.07
	4I	10/23/81	9	12.98	455,251	31.73	2.54	94.49
	40	10/23/81	9	12.73	440,602	32.58	2.54	93.92
Average				13.13	461,158	31.71	2.42	101.80[a]
Standard Deviation				0.46	21,534	2.95	0.18	10.93
Range				12.48-14.10	415,395-499,181	25.9-37.43	2.13-2.66	87.69-125.71

[a] 94.54 outlet, 109.06 inlet.

Notes: V_s = fpm
Q_s = scfmd
t/Q = total test time/quench
%I = percent isokinetic

TABLE 7. TOTAL PARTICULATE EMISSION FACTORS - CLEAN WATER, DOFASCO NO. 1 QUENCH TOWER

		lb/ton coal charged					
Test No.	Location	Cyclone[a]	Probe	Filter	Total front half	Total back half	Total train
1	Inlet	0.2743	0.0554	0.0921	0.4218	0.0833	0.5051
	Outlet	0.2248	0.0439	0.0452	0.3139	0.0962	0.4101
2	Inlet	0.9876	0.0397	0.0641	1.0914	0.2013	1.2927
	Outlet	0.1129	0.0332	0.0531	0.1992	0.0669	0.2661
3	Inlet	0.4168	0.4771	0.1855	1.0794	0.0736	1.1530
	Outlet	0.1664	0.0189	0.0283	0.2136	0.1125	0.3261
4	Inlet	1.0501	0.2776	0.0472	1.3749	0.1033	1.4782
	Outlet	0.3531	0.0441	0.0330	0.4302	0.3545	0.7847
5	Inlet	1.3495	0.0355	0.0492	1.6785	0.1403	1.8189
	Outlet	0.3918	0.0215	0.0320	0.4453	0.1398	0.5850
Average	Inlet	0.83	0.19	0.11	0.13	0.12	1.25
	Outlet	0.25	0.03	0.04	0.32	0.17	0.49

[a] Approximately 3 µm D_{50} lower cut size.

TABLE 8. TOTAL PARTICULATE EMISSION FACTORS - SEMI-DIRTY WATER, DOFASCO NO. 1 QUENCH TOWER

				lb/ton coal charged			
Test No.	Location	Cyclone^{a}	Probe	Filter	Total front half	Total back half	Total train
1	Outlet	0.4914	0.0130	0.0326	0.5370	0.2956	0.8326
2	Outlet	0.4604	0.0114	0.0320	0.5038	0.3812	0.8851
3	Outlet	0.3126	0.0467	0.0452	0.4045	0.5462	0.9508
Average	Outlet	0.42	0.002	0.04	0.48	0.40	0.88

[a] Approximately 3 µm D_{50} lower cut size.

TABLE 9. TOTAL PARTICULATE EMISSION FACTORS - DIRTY WATER, DOFASCO NO. 1 QUENCH TOWER

				lb/ton coal charged			
Test No.	Location	Cyclone[a]	Probe	Filter	Total front half	Total back half	Total train
1	Inlet	3.0131	0.2998	1.0409	4.3538	0.7792	5.1330
	Outlet	0.7987	0.2308	0.1145	1.1440	1.6022	2.7462
2	Inlet	3.3506	0.3183	1.2124	4.8813	0.4485	5.3298
	Outlet	0.6320	0.1497	0.2490	1.0307	0.4975	1.5282
3	Inlet	5.6566	0.5684	0.4605	6.6855	0.6324	7.3179
	Outlet	0.7247	0.8208	0.4662	2.0117	0.6039	2.6156
4	Inlet	3.4907	0.1512	1.4002	5.0421	0.3659	5.4080
	Outlet	0.4921	0.4630	0.4151	1.3702	0.3807	1.7509
Average	Inlet	3.88	0.33	1.03	5.24	0.56	5.80
	Outlet	0.66	0.42	0.31	1.39	0.77	2.16

[a] Approximately 3 μm D_{50} lower cut size.

GC/GAS COMPOSITION RESULTS

Stack gas samples were analyzed in the field using a gas chromatograph and an orsat analyzer. The gas composition was determined for the clean and dirty water phases of the program as well as for each of the organic tests. Two methods for obtaining a sample were used, however, only the integrated bag method, similar to the one used in EPA Method 3 was found to give consistent results. In all tests, C-1 was the only hydrocarbon found in an appreciable amount. The levels detected decreased as the hydrocarbon weight increased with C-5 and C-6 not detectable. Gas analysis results for clean, dirty and organic tests are provided in Table 10.

TABLE 10. GAS CHROMATOGRAPHY RESULTS, DOFASCO NO. 1 QUENCH TOWER

	ppm (±10 percent)					
Test	C_1	C_2	C_3	C_4	C_5	C_6
Clean	32.7	0.41	0.33	0.29	-	-
Dirty	30.8	0.10	0.08	-	-	-
Clean-organic	29.4	0.09	-	-	-	-
Dirty-organic	27.0	0.10	0.08	-	-	-

Inorganic gas concentrations were determined by taking a sample from an integrated bag (EPA Method 3) and using an ORSAT analyzer. Concentration levels were determined for O_2, CO_2 and CO. The results from all of these tests (one test per sampling day) were identical and were equal to that of ambient air (i.e., O_2 = 19 percent ± 1.0 percent, CO_2 = 0.0 percent, CO = 0.0 percent).

IMPACTOR SAMPLING

Andersen cascade impactors equipped with cyclone precollectors and glass fiber substrates were used to determine particle size distribution. The impactors were operated at constant flow rates simultaneous with the total particulate runs. Run times on the order 20 to 40 minutes provided adequate particulate loading on the substrate. Each impactor run was conducted at a single sample point, above and below the baffles simultaneously. The impactors were heated to 250°F to prevent moisture problems.

The particle size results were calculated by the interactive computer program developed by RTI for EPA. This Particulate Data Reduction and Entry System or PADRE requires that data be entered in response to specific prompts. PADRE checks each response before storing the data and warns the user if an error is detected. The user enters field data and the gravimetric analysis results and PADRE provides the results using those methods of calculating aerodynamic diameters.

One calculation is required to be done by the user which is determination of the lower cut sizes of the cyclone precollector. This value was calculated using equations provided by Southern Research Institute (SORI) which are shown in Appendix A-2. PADRE also requires a user to make an assumption regarding the validity of the backup filter weight gain. For this section of the report, it was assumed that 50 percent of the backup filter weight gain was actually caused by particles smaller than the last impaction stage cut diameter. It is possible that a higher or lower percentage is caused by particle bounce and other factors. The effect of this assumption on the results is most pronounced for particles smaller than about 2 microns as shown in the summary plots in Section 2. It would be difficult to determine the actual percentage.

PADRE also requires the user to input the maximum particle diameter. This value was determined through microscopic examination of the precutter bulk catch. A calibrated image shearing microscope was used. The largest particles observed were on the order of 400 to 1000 microns and this value was entered into PADRE to be used in the interpolation routines an oscillating polynominal function to curve-fit results and calculate results for standard particle diameters.

The results presented in the tables, figures and size specific emission factors in this report, were calculated by PADRE using the Task Group in Lung Dynamics definition of aerodynamic diameter. This definition assumes that the particles are of unit density and the diameters that result are strictly aerodynamic sizes and do not represent the physical (classical) or impaction (Stokes) diameters. Aerodynamic diameters were also calculated for the Classical and Stokes definitions of size and are only provided in the expanded computer output provided in Appendix C-2.

An overall summary of each series of tests is presented earlier in Section 2. To illustrate the differences between inlet and outlet particle size distributions more clearly, Figures 13 through 16 were prepared. Figures 13 and 14 show the inlet and outlet distributions for the clean water quality tests. Figures 15 and 16 show the results of the dirty water size distribution tests. The dirty water outlet size distribution contains a smaller fraction of large particles than the inlet (i.e. more small particles). This is evidenced by the steeper outlet size distribution curve. The results of the clean water tests are curves of similar shape and steepness however a comparison of these graphs shows the inlet size distribution to contain a smaller percentage of large particles than the outlet. This condition is the opposite of the dirty water results and contrary to the predictions of inertial collection theory. The effect of the baffles on particle size distribution is more evident in Figures 15 and 16 and in the particulate removal plots presented as Figures 17 and 18. Figure 17 is a composite plot of all impactor runs showing the mean change in particle concentration rather than the cumulative percent change. Figure 18 is an efficiency plot by particle size and is obtained by calculating the percent change in the particle concentrations shown in Figure 17. Figure 18 illustrates a trend whereby the baffles do not efficiently remove particles in the 5 to 15 micron size ranges. The negative values indicated for clean water particles greater than 10 microns in figure 18 is caused by the clean water inlet and outlet curves crossing in figure 17. This impossible condition is most likely the result of errors in the gravimetric analysis of the impactors substrates, the small number of runs reduced and the non ideal curve fitting and interpolating routines contained in Padre.

Size specific emission factors are calculated by multiplying the total particulate emission rate (determined by the modified EPA Method 5 procedure), by the impactor derived particle size distribution. These emission factors are presented earlier in Table 2 and were based on the assumption that the back up filter weight gain was invalid. Table 11 was prepared using the assumption that 50 percent of the back-up filter weight gain was valid. Note that the effect of this assumption is to change the emission factors in the 1 to 5 micron range by as much as 50 percent.

DUAL CYCLONE SAMPLING RESULTS

Dual-cyclone sampling was conducted during the clean and dirty quench water phases of the test program. The cyclones were operated without interruption during the Method 5 and impactor tests and also in-between quenches. The operation of the dual cyclone during non quency periods (the need for which has been previously explained) makes any particulate concentration data thus obtained inaccurate due to the large amount of dilution air drawn into the system. For this reason, only the size fractions and emission factors (lb/ton coal) should be compared to the results of the other tests. The cyclone derived particulate concentrations were infact found to be significantly lower than the total particulate (Method 5) concentrations.

Table 7, provided earlier, presents a summary of the range of stack gas conditions encountered during the dual cyclone runs. The data used to calculate the average the lower cut points for the cyclones is provided in Table 12. Example cyclone cut point calculations are provided in Appendix A-3. A summary of the results of the dual cyclone tests is presented in Table 13 and these results are numerically compared to the cascade impactor results in Table 14. The differences in the size fractional results can be seen in Figures 13 through 16 where the dual cyclone derived size fractions are compared to the impactor size fractions. Note that the emission factor scale in Figures 13 through 16 only applies to the impactor runs since, as evidenced by Table 14, the dual cyclone emission factors are, on the average, 50 percent lower.

There are several factors which cause the dual cyclone results for size distribution to be inaccurate. The dual cyclone was designed to be run at a steady flow and constant temperature. The steady flow condition was met but the constant temperature requirement was not due to the cyclic nature of the quench process. The collector would cool between quenches and water would condense inside it during the quench period. The process of condensation agravates the problem of small particles being deposited prematurely due to their entrapment in larger water droplets. The thermal gradient between the hot gas and cool walls of the collectors will also cause the premature

TABLE 11. SIZE SPECIFIC EMISSION FACTORS, 50 PERCENT ASSUMPTION, DOFASCO NO. 1 QUENCH TOWER

Water Type	Location	Cumulative	Particle aerodynmamic 50% cut diameter (d_{50})						
			[a]	15 μm	10 μm	5 μm	2.5 μm	1.0 μm	0.63 μm
Clean	Inlet	% mass < d_{50}	100	38.7	32.2	22.8	15.8	9.9	7.8
		$\frac{\text{lb} < d_{50}}{\text{ton coal}}$	1.13	0.44	0.36	0.26	0.18	0.11	0.09
Clean	Outlet	% mass < d_{50}	100	21.4	15.1	11.0	7.4	4.1	3.34
		$\frac{\text{lb} < d_{50}}{\text{ton coal}}$	0.32	0.07	0.05	0.04	0.02	0.01	0.01
Dirty	Inlet	% mass < d_{50}	100	33.4	29.8	28.5	26.7	22.8	17.2
		$\frac{\text{lb} < d_{50}}{\text{ton coal}}$	5.24	1.75	1.56	1.49	1.40	1.19	0.90
Dirty	Outlet	% mass < d_{50}	100	56.6	40.8	33.6	29.5	20.9	17.4
		$\frac{\text{lb} < d_{50}}{\text{ton coal}}$	1.39	0.79	0.57	0.47	0.41	0.29	0.24

[a] Based on the assumption that very little particle bounce occurred and that 50 percent of back up filter weight gain is valid.

TABLE 12. DUAL CYCLONE DATA, DOFASCO NO. 1 QUENCH TOWER

		Clean Water		Dirty Water	
		Inlet	Outlet	Inlet	Outlet
Date		10/8	10/7	10/20-21	10/22-23
Total Time	(minutes)	343	360	588	504
Meter Temperature	(°F)	55	55	56	61
Meter Calibration Factor	(unitless)	(1.0)	(1.0)	(1.0)	(1.0)
Meter Vacuum	(in. Hg)	1.7	0.9	1.1	0.85
Stack Temperature	°F(°C)	155 (68.33)	155 (68.33)	155 (68.33)	155 (68.33)
Moisture Content	(percent)	3.71	31.71	31.71	31.71
Stack Pressure	(in. Hg)	29.85	29.85	29.85	29.85
Static Pressures (Stack)	(in. H_2O)	0.1	0.1	0.1	0.1
Barometric Pressure	(in. Hg)	29.75	29.75	29.75	29.75
Volume Sampled	(acf)	232	283	74	120.75
Flow Setting (ΔH)	(in. H_2O)	0.75	0.75	0.75	0.75
Volume Sampled	(dscf)	236.85	288.91	75.40	121.10
Sample Flow Rate	(acfm)	0.786	0.939	0.148	0.277
Gas Viscosity	(micropoise)	202.141	202.141	202.141	202.141
Cyclone III Cut Size	(d_{50}, microns)	2.13	1.85	8.48	4.91
Calibrated Flow	(lpm)	17.09	17.09	17.09	17.09
Actual Flow	(lpm)	22.25	26.59	4.19	7.84
Cyclone X Cut Size	(d_{50}, microns)	13.14	12.02	30.29	22.14

TABLE 13. DUAL CYCLONE RESULTS, DOFASCO NO. 1 QUENCH TOWER

	Units	Clean Water		Dirty Water	
		Inlet	Outlet	Inlet	Outlet
<u>Particulate Mass Caught</u>					
Cyclone III and Cannister	(mg)	21.97	89.49	4.20	7.60
Cyclone X	(mg)	687.28	510.34	133.74	143.11
Backup Filter(s)	(mg)	85.14	101.73	234.19	240.09
Total	(mg)	794.39	701.56	372.13	390.80
<u>Sampling Conditions</u>					
Average Gas Temperature	(°F)	155	155	155	155
Average Gas Pressure	(in. Hg)	29.85	29.85	29.85	29.85
Average Viscosity	(micropoise)	202	202	202	202
Average Moisture	(percent)	31.71	31.71	31.71	31.71
Total Time	(hours)	5.7	6.0	9.8	8.4
Number of Quenches Sampled		28	30	49	42
<u>Particulate Emission Rates</u>					
Cyclone III lower cut size	(microns)	2.1	1.8	8.5	4.9
Cyclone X lower cut size	(microns)	13.1	12.0	30.3	22.1
Emissions < Cyclone III cut size	(percent)	10.7	14.6	63.0	61.5
	(gr/dscf)	0.055	0.054	0.480	0.306
Emissions between Cyclone III and X cut size	(percent)	2.8	12.7	1.1	1.9
	(gr/dscf)	0.014	0.048	0.008	0.009
Emissions > Cyclone x cut size	(percent)	86.5	72.7	35.9	36.6
	(gr/dscf)	0.448	0.272	0.273	0.182
TOTAL	(gr/dscf)	0.517	0.374	0.761	0.497

TABLE 14. COMPARISON OF DUAL CYCLONE AND CASCADE IMPACTOR RESULTS, DOFASCO NO. 1 QUENCH TOWER

		Clean Water				Dirty Water			
		Inlet		Outlet		Inlet		Outlet	
	Units	Dual Cyclone[a]	Impactor	Dual Cyclone[a]	Impactor	Dual Cyclone[a]	Impactor	Dual Cyclone[a]	Impactor
Size Fractions									
>15 µm d_{50}	(%)	87	63	80	85	48	74	38	50
>2.5 µm d_{50}	(%)	89	89	85	94	50	81	40	80
<2.5 µm d_{50}	(%)	11	11	15	6	50	19	60	20
Concentrations									
>15 µm d_{50}	(gr/dscf)	0.458	0.06	0.30	0.08	0.13	0.79	0.07	0.03
>2.5 µm d_{50}	(gr/dscf)	0.46	0.08	0.31	0.09	0.14	0.82	0.07	0.05
<2.5 µm d_{50}	(gr/dscf)	0.05	0.01	0.05	0.00	0.14	0.82	0.11	0.01
Total	(gr/dscf)	0.52	0.09	0.37	0.09	0.27	1.64	0.18	0.06
Emission Factors									
>15 µm d_{50}	(lb/ton)	0.42	0.71	0.26	0.27	0.13	3.88	0.07	0.69
>2.5 µm d_{50}	(lb/ton)	0.42	1.01	0.28	0.30	0.14	4.24	0.07	1.11
<2.5 µm d_{50}	(lb/ton)	0.05	0.12	0.05	0.02	0.14	0.99	0.11	0.28
Total	(lb/ton)	0.47	1.13	0.33	0.32	0.29	5.24	0.19	1.39

[a] Calculated cut sizes for cyclone runs were different than 15 and 2.5 microns and these values are estimated through interpolation.

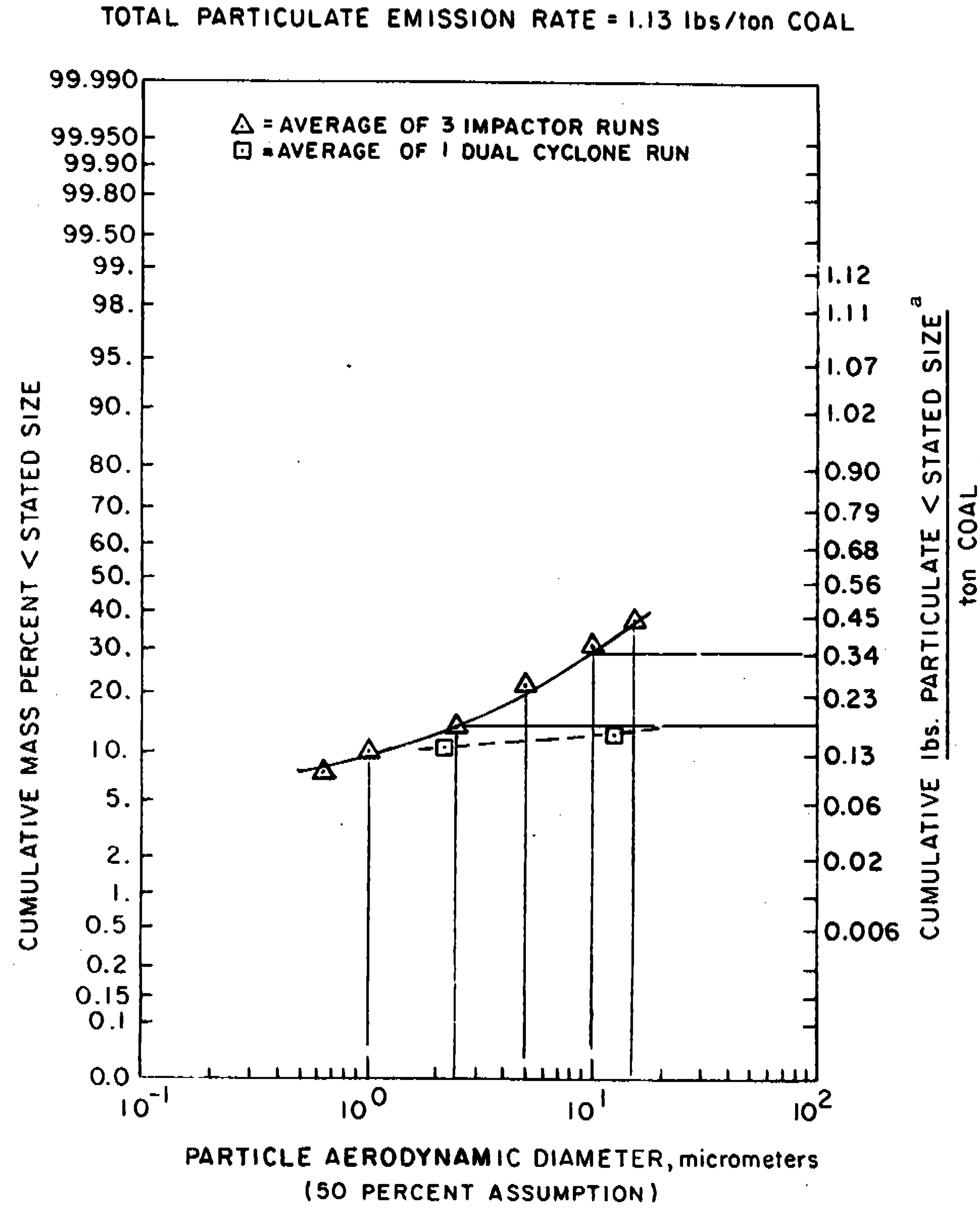

Figure 13. Average inlet size distribution results for runs performed during clean water usage, DOFASCO No. 1 Quench Tower.

[a] E.F. Scale applies only to impactor curve.

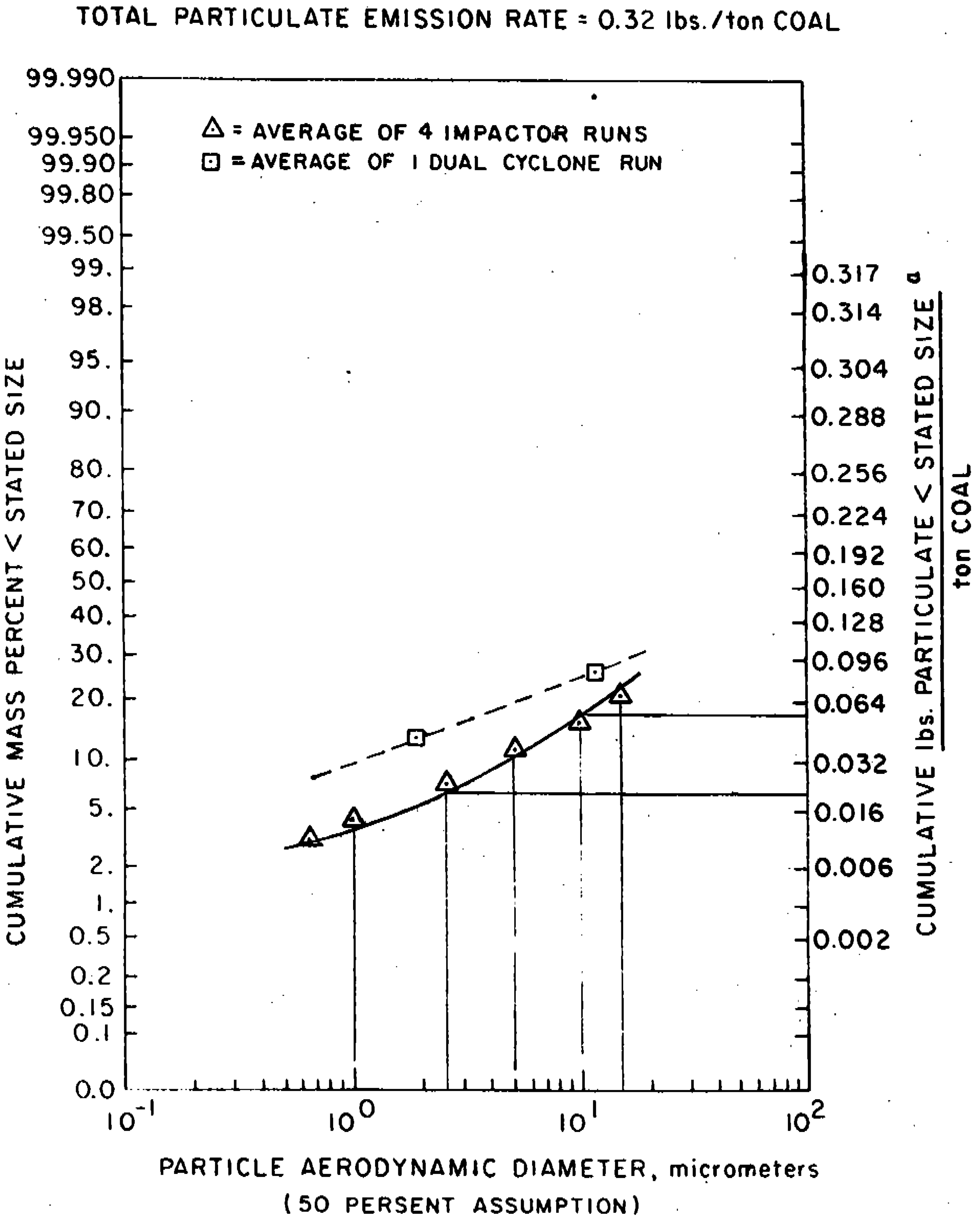

Figure 14. Average outlet size distribution results for runs performed during clean water usage, DOFASCO No. 1 Quench Tower.

[a] E.F. Scale applies only to impactor curve.

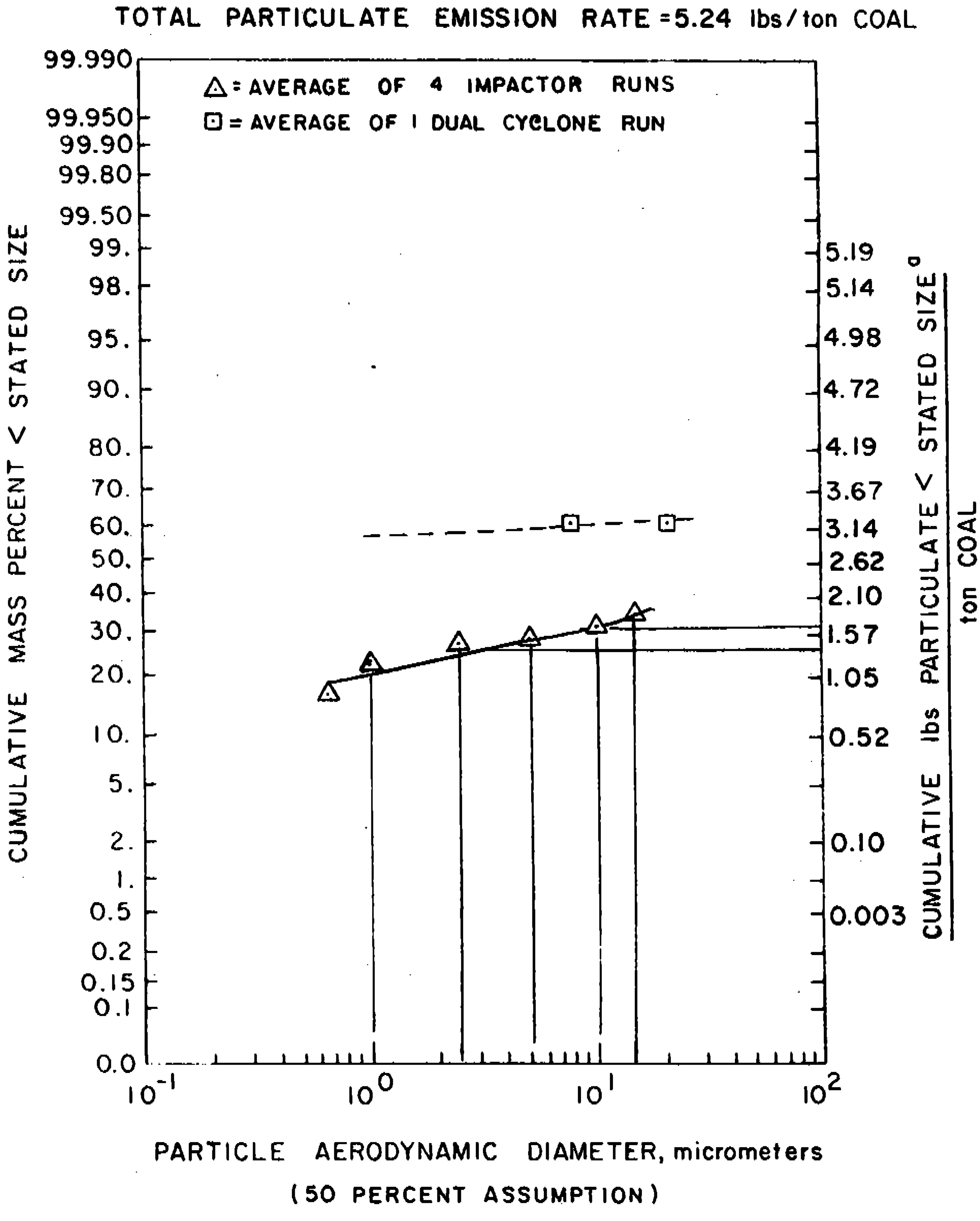

Figure 15. Average inlet size distribution results for runs performed during dirty water usage, DOFASCO No. 1 Quench Tower.

[a] E.F. Scale applies only to the impactor curve.

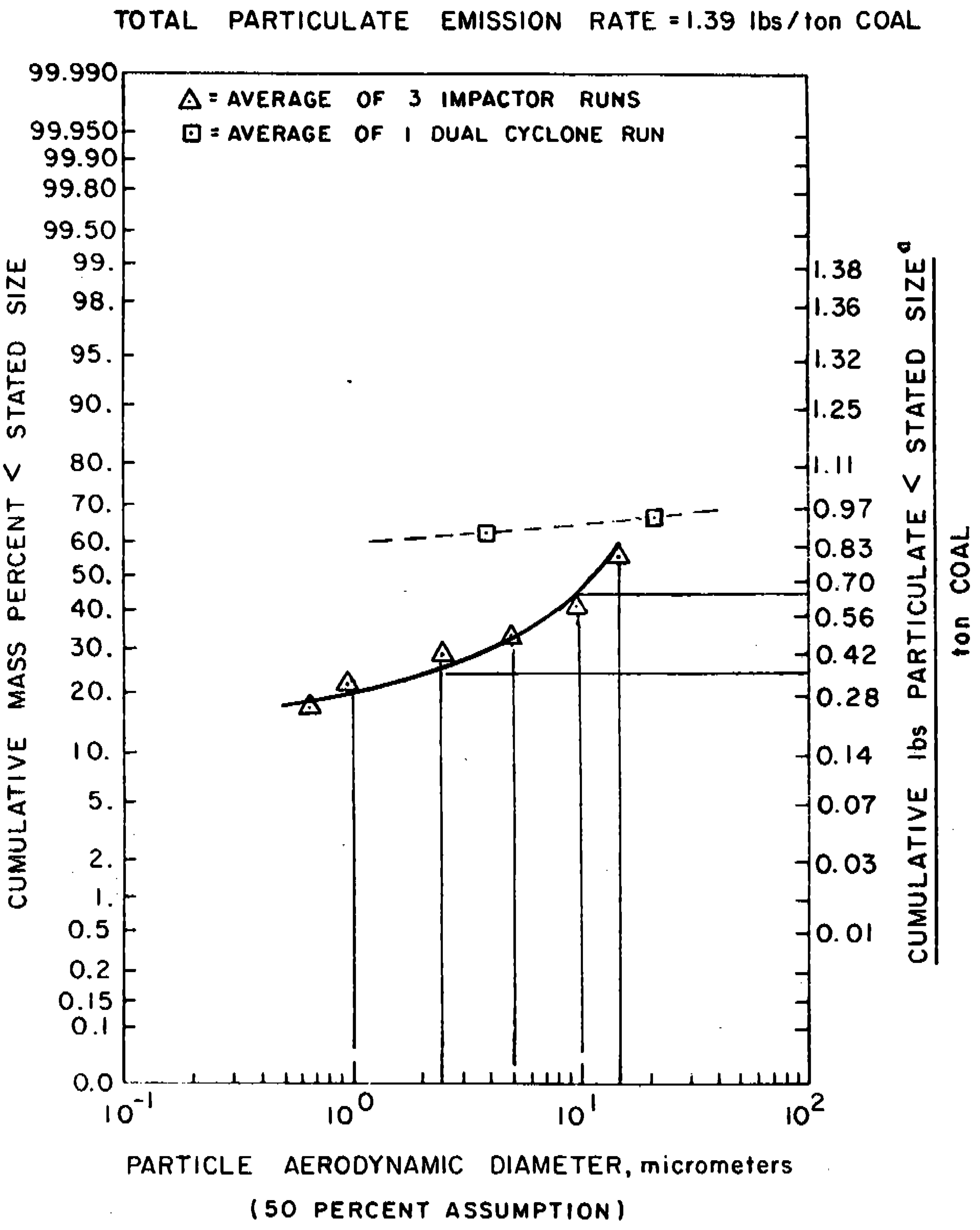

Figure 16. Average outlet size distribution for runs performed during dirty water usage, DOFASCO No. 1 Quench Tower.

[a] E.F. Scale applies only to impactor curve.

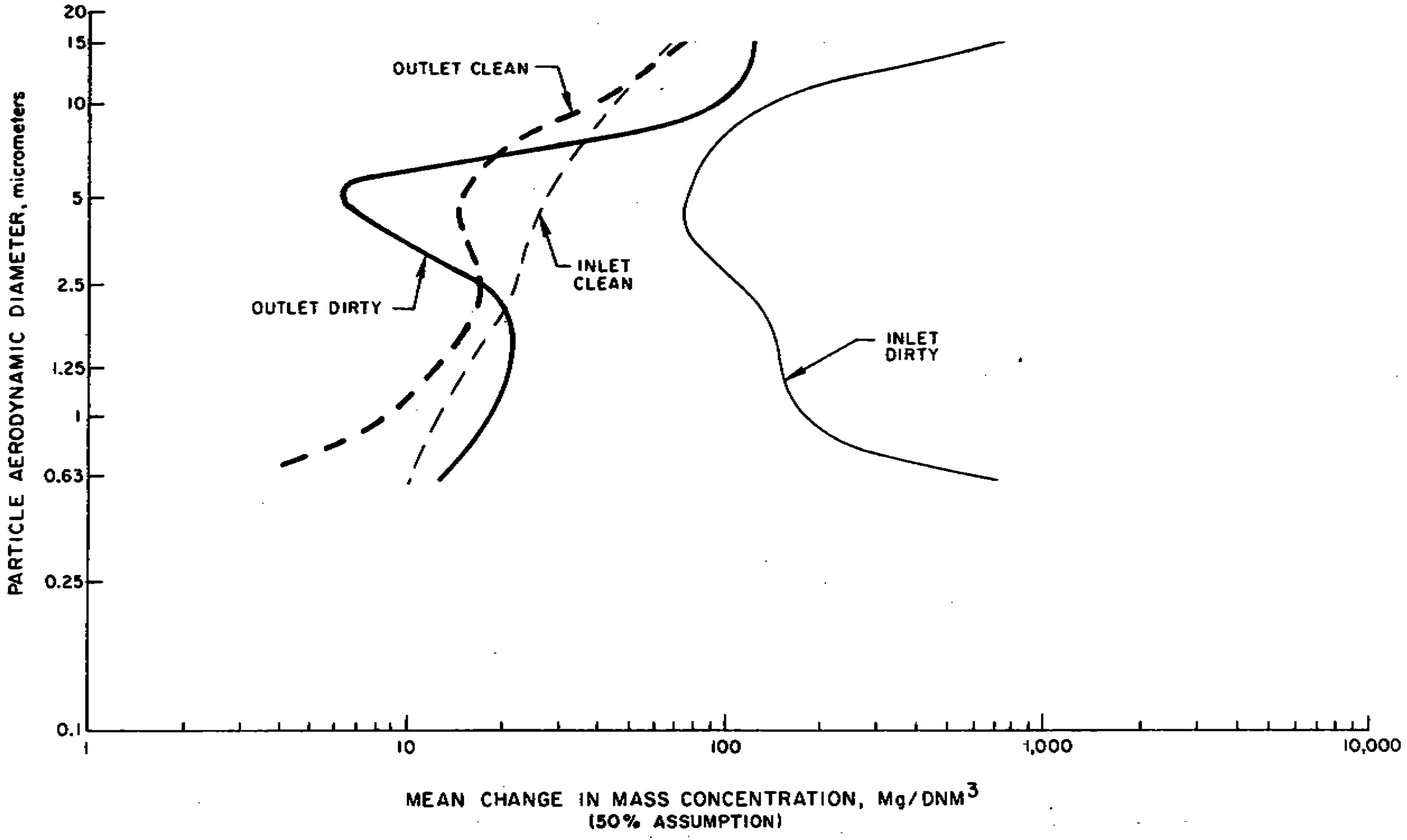

Figure 17. Mean change in concentration by particle size, DOFASCO No. 1 Quench Tower.

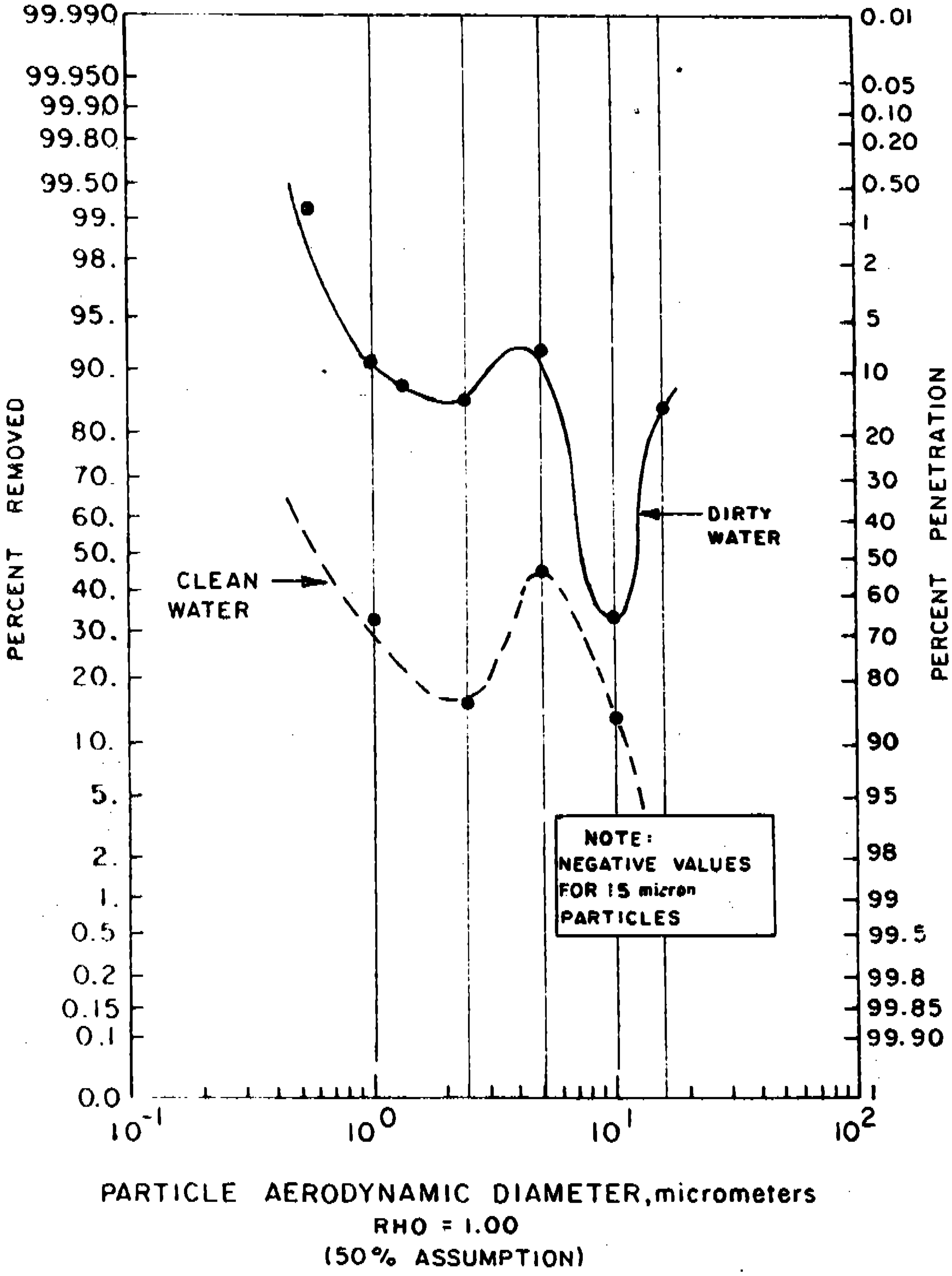

Figure 18. Particulate removal efficiency by particle size, DOFASCO No. 1 Quench Tower.

deposition of particles. Condensed water in the collector can be sucked through the small cyclone carrying with it some of the particulate catch. Aside from the above described physical problems with the use of the dual cyclone it is not possible to accurately determine the stage cut points due to limited calibration data. The equations developed by SoRI were used, however, their validity to the temperature and flow conditions encountered in the quench tower is not known.

WATER SAMPLING RESULTS

Water samples were collected at the following locations:

- Quench water: from the header pipe leading to the sprays
- Return water: from the trough to the sump
- Make-up water: lines—"clean" water tests from indirect cooling water and baffle sprays
  "semi-dirty" and "dirty" water tests from the hose(s) from Batteries 1 and 2.

Each of the user samples analyzed for:

- Total dissolved solids
- Cyanides
- Chlorides
- Sulfate
- Sulfide
- Phenol
- Ammonia
- Temperature
- pH
- Conductivity

Results from these tests are shown in Tables 15 through 17. A comparison of these results to other quench tower test results was conducted. A discussion of these findings is provided in Appendix H.

ORGANIC SAMPLING

Samples from the modified Method 5 train and water samples from the quench, return and makeup lines were analyzed by Battelle Laboratories, Columbus, Ohio. Results from this work is shown in Appendix B. Concentration levels are very low, except where field and/or blank contamination is suspected. No correlation was found with existing data.

CONDENSABLE EMISSIONS RESULTS

Results from the SORI sampling program is shown in Appendix G. As no other data exists for quench towers sampled with this equipment, no comparisons are possible.

TABLE 15. DIRTY WATER ANALYSIS RESULTS, DOFASCO NO. 1 QUENCH TOWER

	Quench water					Make-up water					Return water				
Parameter/Run	1-D	2-D	3-D	4-D	1-Org-D	1-D	2-D	3-D	4-D	1-Org-D	1-D	2-D	3-D	4-D	1-Org-D
Ammonia, mg/l	2,770	2,380	2,370	1,860	2,120	3,250	2,670	3,020	2,900	2,800	3,020	2,560	2,450	2,050	2,000
Chloride, g/ml	6,140	6,710	5,660	5,310	-	5,020	5,020	5,240	4,890	-	6,590	7,220	6,610	5,800	-
Conductivity, mhos/cm	23,500	26,500	24,000	22,000	21,500	21,500	13,500	25,000	22,500	24,500	26,000	26,500	28,000	23,000	23,500
Cyanide															
Residual, mg/l	0.8	0.4	1.0	0.3	0.3	2.3	1.7	3.5	6.7	7.5	0.2	0.2	1.0	0.2	0.2
Amenable, mg/l	5.0	2.6	3.2	1.6	2.9	47.0	43.1	42.3	37.6	34.5	4.5	1.2	1.3	0.5	2.6
pH	7.85	8.0	7.7	8.3	8.5	8.75	9.0	8.7	9.0	9.4	7.5	7.75	7.6	7.7	8.0
Phenol, mg/l	318	363	311	213	216	724	732	634	610	612	282	324	266	186	190
Solids															
Dissolved, mg/l	10,000	11,900	8,800	4,690	8,900	9,080	8,930	9,200	7,850	8,600	11,300	12,100	7,560	8,810	8,890
Suspended, mg/l	37.9	146.4	233	136.2	219.2	521.1	203.1	198	434.6	558.6	490.7	278.0	430.5	379.3	493.8
Sulfate, g/ml	336	353	343	360	-	-	63	63	78	-	380	460	386	400	-
Sulfide, mg/l	14.3	28.6	25.6	19.3	28.8	46.4	47.3	58.0	44.6	42.8	15.6	38.5	20.2	19.1	16.2
Temperature, °C	32	33	38	22	20	28	25	26	23	21	28	30	24	32	24

TABLE 17. CLEAN WATER ANALYSIS RESULTS, DOFASCO NO. 1 QUENCH TOWER

Parameter/Run	Quench water						Make-up water						Return water					
	1-C (A/B)	2-C	3-C	4-C	5-C	1-Org-C	1-C (A/B)	2-C	3-C	4-C	5-C	1-Org-C	1-C (A/B)	2-C	3-C	4-C	5-C	1-Org-C
Ammonia, mg/l	1.8 1.6	2.5	3.9	2.1	6.6	-	1.8 1.1	1.3	0.7	0.5	1.0	-	1.4 1.0	2.1	2.6	1.3	4.0	-
Chloride, µg/ml	186 117	127	116	116	164	-	65 59	63	57	84	94	-	129 160	-	182	110	-	-
Conductivity, µmhos/cm	800 825	800	800	800	810	800	565 500	550	520	600	540	550	800 860	880	870	825	880	900
Cyanide total µg/ml	0.33 0.25	0.33	0.33	0.41	-	0.178ᵃ	0.25 0.21	0.17	0.4	-	0.5	0.023ᵃ <0.1	0.17 0.17	0.52	-	-	0.5	0.103ᵃ
pH	8.6 8.4	8.4	8.5	8.3	8.7	8.9	7.0 7.4	7.2	7.2	8.3	7.7	7.5	8.5 8.45	8.3	8.3	8.2	8.7	8.6
Phenol, mg/l	0.300 0.239	0.0372	0.418	0.210	0.711	0.370	0.0012 0.0022	0.0012	0.0058	0.0013	0.0012	0.0016	0.306 0.208	0.550	0.454	0.261	0.783	0.460
Solids																		
Dissolved, mg/l	480 510	540	490	520	520	-	360 320	350	310	330	350	-	510 570	570	550	540	620	-
Suspended, mg/l	34.6 39.0	72.9	70.8	66.8	208.4ᵇ	-	0.0 1.3	8.6	7.0	7.2	4.5	-	230 41.8	381.2	361.7	274.5	351.5	-
Sulfate, µg/ml	116 124	119	-	135	138	-	63 59	62	60	58	62	-	127 136	135	146	-	147	-
Sulfide, mg/l	<0.4 <0.4	<0.4	<0.4	<0.4	<0.4	-	<0.4 <0.4	<0.4	<0.4	<0.4	<0.4	-	<0.4 <0.4	<0.4	<0.4	<0.4	0.6	-
Temperature, °C	19 24	32	28	28	24	24	22 19	20	22	22	23	22	22 32	30	30	34	30	22

[a] mg/l, amenable lost.

[b] Suspected error.

PROCESS DATA RESULTS

The individual process data sheets used by the process observer to note coke and quench process conditions for each quench tested are useful in determining if the process was operating in a normal manner. Observation items such as load positions, hot spots after quenching, etc., are only indicators if a particular test result (i.e., lower/higher than normal emissions) comes into question. Therefore, the process data has been summarized to allow objective comparison between these tests and those previously conducted at other quench towers. No correlation was found to exist between either greenness or coking time and particulate emissions. The coke times, greeness rating and coke-coal analysis are shown in Table 18 through 20. During none of the tests were fugitive emissions (plume flow out of the door openings) excessive.

During both the clean and dirty water phases of the program observations at the outlet of the baffles revealed that large particles were passing through the baffles* during the first 30 to 45 seconds of the quench process. This occurs when the plume consists mainly of steam with little or no water droplets present.

The baffle manufacturer, Munters, asserted that without sufficient wetting of the particles prior to their entry into the baffle array, the particulate removal efficiency of the baffle array is decreased.

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*Buildup of particulate matter on the holders for the spray system used to clean the baffles confirms the findings of the microscopic sizing analysis, wherein particles in excess of 400 microns were found.

TABLE 18. NORMAL COKING TIME--AVERAGE GREENNESS

Test	Net coking time	Average greenness
<u>Particulate tests</u>		
Clean		
1	1663	2.2
2	1603	3.5
3	1622	3.2
4	1627	2.2
5	1685	2.1
Semi-dirty		
1	1919	0.6
2	1893	0.7
3	1884	1.3
Dirty		
1	1638	3.4
2	1716	2.2
3	1616	3.0
4	1619	3.8
<u>Particle Size Tests</u>		
Clean		
1	1674	2.7
2	1602	3.8
3	1625	3.1
4	1625	2.5
5	1680	2.1
Dirty		
1	1640	3.3
2	1719	1.9
3	1614	3.2
4	1619	3.8

TABLE 19. DAILY AVERAGE FLUE TEMPERATURES

Date	No. 1 battery (ovens 1-27)	No. 2 battery (ovens 28-66)	No. 3 battery (ovens 67-116)
Oct. 1	1245°C	1254°C	1254°C
Oct. 2	1253	1260	1259
Oct. 3	1273	1268	1270
Oct. 4	1253	1251	1245
Oct. 5	1257	1257	1250
Oct. 6	1253	1257	1258
Oct. 7	1271	1269	1272
Oct. 8	1275	1268	1270
Oct. 9	1263	1252	1259
Oct. 21	1280	1274	1269
Oct. 22	1286	1278	1279
Oct. 23	1285	1287	1275

TABLE 20. COAL--COKE ANALYSIS

Coal Analysis

Date	% H_2O	% Ash	% V.M.	% F.C.	% S
Oct. 1	8.1	6.0	27.7	66.3	0.82
Oct. 2	8.8	6.1	29.0	64.9	0.82
Oct. 3	10.7	5.5	27.8	66.7	0.81
Oct. 4	5.6	5.6	28.2	66.2	0.82
Oct. 5	6.0	5.7	27.5	66.8	0.83
Oct. 6	6.2	5.4	27.7	66.9	0.78
Oct. 7	7.4	5.3	27.9	66.8	0.75
Oct. 8	6.6	5.3	28.1	66.6	0.75
Oct. 9	5.8	5.5	27.1	67.4	0.76
Oct. 21	7.7	5.4	27.9	66.7	0.77
Oct. 22	7.7	6.4	28.2	65.4	0.82
Oct. 23	8.2	5.8	27.2	67.0	0.82

Coke Analysis

Date	% H_2O	% Ash	% V.M.	% F.C.	% S	% SiO_2	% CaO	%Al_2O_3	% MgO	%Fe_2O_3	%K_2O
Oct. 1	1.5	7.9	0.3	91.8	0.71	3.30	0.28	2.53	0.13	1.27	0.13
Oct. 2	2.0	8.0	0.9	91.1	0.73	3.36	0.30	2.53	0.14	1.17	0.13
Oct. 3	2.4	7.4	0.8	91.8	0.68	3.23	0.27	2.48	0.12	1.02	0.13
Oct. 4	3.0	7.2	0.5	92.3	0.67	3.10	0.25	2.42	0.11	1.13	0.12
Oct. 5	2.5	8.0	0.9	91.1	0.67	3.24	0.27	2.46	0.12	1.66	0.13
Oct. 6	4.0	7.7	0.5	91.8	0.67	3.32	0.31	2.48	0.13	1.05	0.13
Oct. 7	2.9	7.2	0.8	92.0	0.67	3.12	0.27	2.37	0.12	1.09	0.13
Oct. 8	6.0	6.9	0.7	92.4	0.67	2.89	0.28	2.40	0.14	1.11	0.12
Oct. 9	1.1	6.3	0.3	93.4	0.65	2.89	0.25	2.34	0.11	0.82	0.11
Oct. 21	1.9	7.5	1.0	91.5	0.69	3.23	0.27	2.55	0.12	1.05	0.15
Oct. 22	2.9	7.8	1.0	91.2	0.68	3.32	0.28	2.47	0.13	1.35	0.14
Oct. 23	4.2	7.	0.7	91.9	0.68	3.34	0.28	2.54	0.13	0.96	0.16

APPENDIX A-1

TOTAL PARTICULATE EXAMPLE CALCULATIONS

Facility ______________________ Job No. ______________________

Source ______________________ Date ______________________

Run ______________________ Calc/Review ______________________

SAMPLE CALCULATIONS

Particulate Isokinetic Sampling

I. Calculations for stack volume and Isokinetic Ratio

Time	Dry Gas Meter ft^3	Pitot ΔP, in. H_2O	Orifice ΔH, in. H_2O	Dry Gas Temp °F		Stack Static Pressure in. H_2O	Stack Temp °F
				In	Out		
T	VM	ΔP	PM	TMI	TMO	PST	TS

1. DN - Nozzle Diameter, inches ______________ in.
2. PB = Barometric Pressure, inches Hg ______________ in. Hg
3. TT = Net Sampling Time, minutes ______________ min.
4. VM = VM final - VM initial = Sample Gas Volume, ft^3 ______________ ft^3

4A. VML = Use only if any final or intermediate leak check rate is over 0.02 cfm

LI = Leak rate after any given sampling period, cfm

TLI = Total time of sampling period in which leak occurred, min.

VML = VM - [(L1 - 0.02) TL1 + (L2 - 0.02) TL2 + (L3 - 0.02) TL3 + L4 + 0.02) TL4]

= (   ) - [(- 0.02)(   )+(- 0.02)(   )+(- 0.02) (   )+(- 0.02)(   )]

= (   ) - [(   )+(   )+(   )+(   )]

= (   ) - (   ) = ______________ ft^3

5. TM = Average Dry Gas Temperature at Meter, °F

$$TM = \frac{\text{Avg. TMI} + \text{Avg. TMO}}{2} = \_\_\_\_\_\_\_\_\_\_ {}^{\circ}F$$

6. PM = Average Orifice Pressure Drop, inches H_2O

PM = Avg. ΔH = ______ ÷ 13.6 = ______ in.Hg

7. Volume of dry gas sampled at standard conditions,[a] dscf

$$VMSTD = \frac{528\ (Y)(VM)\left(PB + \frac{PM}{13.6}\right)}{29.92\ (TM + 460)}$$

Y = dry gas meter calibration factor ______________

$$\frac{528\ (\qquad)(\qquad)(\qquad)}{29.92\ (\qquad)} = \_\_\_\_\_\_\_\_\_\_ ft^3$$

Job No. ______________________

Run No. ______________________

8. VW = Total Water Collected = gm H_2O Silica gel + ml Imp. H_2O = ml

$$(\qquad\quad) + (\qquad\quad) = \underline{\qquad\qquad}$$

9. Volume of water vapor at standard conditions, scf

$$\text{VW gas} = 0.04715 \times \text{VW} = \text{scf} = 0.04715\,(\qquad\quad) = \underline{\qquad\qquad}\ \text{ft}^3$$

10. Percent moisture in stack gas

$$\%\ \text{M} = \frac{100 \times \text{VW gas}}{\text{VMSTD} + \text{VW gas}} = \frac{100\,(\qquad\quad)}{(\qquad\quad) + (\qquad\quad)} = \frac{(\qquad\quad)}{(\qquad\quad)} =$$

$$= \underline{\qquad\qquad}\ \%$$

11. Mole fraction of dry gas

$$\text{MD} = \frac{100 - \%\text{M}}{100} = \frac{100 - (\qquad\quad)}{100} = \underline{\qquad\qquad}$$

12. Molecular weight of dry stack gas

$$\text{MWD} = (\%CO_2 \times \frac{44}{100}) + (\%O_2 \times \frac{32}{100} + \left[(\%CO + \%N_2) \times \frac{28}{100}\right]$$

$$= (\qquad \times 0.44) + (\qquad \times 0.32) + (\qquad \times 0.28)$$

$$= (\qquad\quad) + (\qquad\quad) + (\qquad\quad) = \underline{\qquad\quad}\ \text{lb/lb mole dry}$$

12A. %EA = % Excess Air =

$$\frac{[(\%\ O_2 - 0.5\ (\%CO))] \times 100}{[(0.264(\%N_2)] - (\%\ O_2) + 0.5\%\ (CO)}$$

$$= \frac{(\qquad - \qquad) \times 100}{[(0.264\ (\qquad\quad)] - (\qquad\quad) + 0.5\ (\qquad\quad)}$$

$$- \frac{(\qquad\quad) - 100}{(\qquad\quad) - (\qquad\quad) + (\qquad\quad)} = \underline{\qquad\quad}\ \%$$

13. Molecular weight of wet stack gas

$$\text{MW} = \text{MWD} \times \text{MD} + 18\ (1 - \text{MD})$$

$$= (\qquad\quad)\ (\qquad\quad) + 18(1 - \qquad\quad)$$

$$= (\qquad\quad) + (\qquad\quad) = \underline{\qquad\qquad}\ \text{lb/lb mole wet}$$

14. AS = Stack Area, square inches

$$\text{Circular}, = \left(\frac{\text{Stack diameter}}{2}\right)^2 \pi = \left(\frac{\qquad}{2}\right)^2 \pi = \underline{\qquad\qquad\qquad}\ \text{sq. in.}$$

$$\text{Rectangular}, = \text{Length} \times \text{width} = (\qquad\quad)(\qquad\quad) = \underline{\qquad\qquad}\ \text{sq. in.}$$

15. PS = Stack Pressure, absolute, inches Hg = PB + AV PST

PST = Stack static pressure

Job No. ______________________

Run No. ______________________

$$\text{PST in. Hg} = \frac{\text{PST in. H}_2\text{O}}{13.6} = \frac{\qquad}{13.6} = \underline{\qquad\qquad}\ \text{in. Hg}$$

$$\text{PS} = \text{PB} + \text{Avg. PST} = (\qquad)\ (\qquad) = \underline{\qquad\qquad}\ \text{in. Hg}$$

16. TS = Average Stack Temperature, ______ °F + 460 = ______ °R

$$\text{TS} = \text{Average TS} \quad \sqrt{\text{TS}_{\text{AV}} + 460} = \underline{\qquad\qquad}$$

17. $\text{SDE}_{\text{AV}} = (\sqrt{\Delta P})_{\text{AV}} \times \sqrt{\text{TS}_{\text{AV}} + 460} = (\qquad)\ (\qquad) = \underline{\qquad\qquad}$

18. Stack gas velocity at stack conditions, afpm

$$\text{VS} = 5130^{(e)} \times \text{Cp} \times \text{Avg. (SDE)} \times \left[\frac{1}{\text{PS} \times \text{MW}}\right]^{\frac{1}{2}} = \text{afpm}$$

Cp = pitot tube coefficient

$$= 5130 \times (\qquad) \times (\qquad) \times \left[\frac{1}{(\qquad)(\qquad)}\right]^{\frac{1}{2}} = \underline{\qquad\qquad}\ \text{afpm}$$

19. Stack gas volumetric flow rate at standard conditions,[c] dscfm

$$Q_s = \frac{528 \times \text{VS} \times \text{AS} \times \text{MD} \times \text{PS}}{(29.92)(144)(\text{TS} + 460)} = \text{dscfm}$$

$$= \frac{528\ (\qquad) \times (\qquad) \times (\qquad) \times (\qquad)}{29.92 \times 144\ (\qquad)} = \underline{\qquad\qquad}\ \text{dscfm}$$

20. Stack gas volumetric flow rate at stack conditions, acfm[d]

$$Q_a = \frac{29.92 \times \text{QS}\ (\text{TS} + 460)}{(528)\ (\text{PS})\ (\text{MD})} = \text{acfm}$$

$$= \frac{29.92\ (\qquad)(\qquad)}{528\ (\qquad)(\qquad)} = \underline{\qquad\qquad}\ \text{acfm}$$

21. Percent isokinetics

$$\%\ \text{I} = \frac{1{,}039^{(f)} \times (\text{TS} + 460) \times \text{VMSTD}}{\text{VS} \times \text{TT} \times \text{PS} \times \text{MD} \times (\text{DN})^2}$$

---

[a] Dry standard cubic feet at 68°F (528R) and 29.92 in. Hg.

[b] Standard conditions at 68°F (528R) and 29.92 in. Hg.

[c] Dry standard cubic feet per minute at 68°F (528) and 29.92 in. Hg.

[d] Actual cubic feet per minute

[e] $5130 = 85.5\ \frac{\text{ft}}{\text{sec}} \left[\frac{(\text{lb/lb mole})(\text{in. Hg})}{(^\circ\text{R})(\text{in. H}_2\text{O})}\right]^{\frac{1}{2}} \times 60\ \text{sec/min}$

[f] $1039 = \frac{29.92\ \text{in. Hg}}{528\ \text{Deg R}} \times \frac{144\ \text{in.}^2}{\text{ft}^2} \times \frac{4}{\pi} \times 100$

Job No. ____________________

Run No. ____________________

$$= \frac{1{,}039 \times (\qquad) \times (\qquad)}{(\qquad) \times (\qquad) \times (\qquad) \times (\qquad) \times (\qquad)^2}$$

= __________ %

II. Calculations for grain loading and emission rates

22. Particulate, gr/dscf

$$gr/dscf = 0.0154 \times \frac{mg}{VMSTD} = \frac{0.0154\ (\qquad)}{(\qquad)} = \underline{\qquad\qquad}\ gr/dscf$$

23. Particulate at stack conditions, gr/acf

$$gr/acf = \frac{528 \times gr/dscf \times PS \times MD}{29.92\ (TS + 460)}$$

$$= \frac{528\ (\qquad) \times (\qquad) \times (\qquad)}{29.92\ (\qquad)} = \underline{\qquad\qquad}\ gr/acf$$

24. Particulate, lb/hr conc. method

$$lb/hr = \frac{60\ min/hr \times gr/dscf \times QS}{7000\ gr/lb} = \frac{60\ min/hr}{7000\ gr/lb} \times (\qquad) \times (\qquad)$$

= ________ lb/hr

25. Particulate lb/hr area method $= 0.132 \times \frac{gms\ particulate \times AS}{\pi \left(\frac{DN}{2}\right)^2 \times TT}$

$$= \frac{0.132 \times (\qquad) \times (\qquad)}{\pi\left(\frac{\quad}{2}\right)^2 \times (\qquad)} = \underline{\qquad\qquad} = \underline{\qquad\qquad}\ lb/hr$$

26. $\frac{lb/hr\ area \times 100}{lb/hr\ conc.} = \frac{(\qquad)}{(\qquad)} \times 100 = \underline{\qquad\qquad}$ % I

27. Particulate combustion $lb/10^6$ Btu heat input method

lb/hr = avg. of area and conc. method = ____________

10^6 Btu from fuel flow, steam generation or heat rate = ____________

$$\frac{lb/hr}{10^6\ Btu\ hr} = \frac{(\qquad)}{(\qquad)} = \underline{\qquad\qquad}\ lb/10^6\ Btu$$

28. $lb/10^6$ Btu F Factor method =

$$\frac{gr/dscf}{7000} \times F \times \frac{20.9}{(20.9 - \%\ O_2)} = \frac{\qquad}{7000} \times (\qquad) \times \frac{20.9}{[20.9 - (\qquad)]}$$

$$= \frac{\qquad}{7000} \times (\qquad) \times \frac{(20.9)}{(\qquad)} =$$

= __________ $lb/10^6$ Btu

Job No.____________________
Run No.____________________

29. Density of stack gas

a. Wet at stack condition $= \text{MW lb/lb mol} \Big/ \left[21.85 \times \left(\frac{TS + 460}{PS}\right)\right]$

$= (\qquad) \Big/ \left[21.85 \times \frac{(\qquad)}{(\qquad)}\right] = (\qquad) \Big/ (\qquad) =$ ______ lb/lb mole wet

b. Dry at 68°F (528R) and 29.92 in. Hg = MWD/385.6

$= (\qquad)/385.6 =$ __________ lb/lb mole dry

30. Exhaust gas flow rate

a. lb/hr dry = QS × 60 × density dry

FRS $= (\qquad) \times 60 \times (\qquad) =$ __________ lb/hr

b. lb/hr wet = QA × 60 × density wet

FRA $= (\qquad) \times 60 \times (\qquad) =$ __________ lb/hr

31. gr/dscf at 12% CO_2 $= \text{gr/dscf} \times \frac{12}{\%\ CO_2}$

$= (\qquad) \times \frac{12}{(\qquad)} =$ __________ gr/dscf

32. gr/dscf at 50% excess air $= \frac{100 + EA}{150} \times \text{gr/dscf}$

$= \frac{(\qquad) + 100}{150} \times (\qquad) =$ ________ gr/dscf

33. lb pollutant/1000 lb flue gas at 12% CO_2

wet or dry $= \frac{\text{lb pollutant/hr}}{\text{FRA or FRS}} \times \frac{12}{\%\ CO_2} \times 1000$

$= \frac{(\qquad)}{(\qquad)} \frac{12}{(\qquad)} \times 1000$

= __________ lb/1000 lb

APPENDIX A-2

SIZE DISTRIBUTION EXAMPLE CALCULATIONS

The field sampling and laboratory analysis data are reduced by an interactive computer program recently developed by RTI. The Particulate Data Reduction and Entry System (PADRE) prompts the user for input of the following parameters:

TEST ID
TEST DATE
TEST COMMENTS
PARTICLE DENSITY
RUN COMMENTS
RUN DATE
STACK TIME
RUN DURATION
CYCLONE CUT POINT

RUN TYPE
GAS COMPOSITION (percent CO_2, etc.)
PERCENT WATER VAPOR
AMBIENT PRESSURE
STACK PRESSURE
STACK TEMPERATURE
IMPACTOR TEMPERATURE
MAXIMUM PARTICLE DIAMETER
IMPACTOR MAKE/MODEL NO.

PRE AND POST WEIGHTS OF EACH SUBSTRATE

The program calculates results using equations that are fully documented in the Southern Research publication EPA 600/7-78-042, March 1978 describing the "Computer Based Cascade Impactor Data Reduction System (CIDRS). PADRE is identical to CIDRS with the following exceptions:

1. Gas Composition--PADRE prints the dry gas composition, which is what users enter. With CIDRS, users enter the dry gas composition, but the wet gas composition is printed.

2. Cut Points--PADRE uses the cyclone cut point entered by the user; CIDRS calculates the cut point for SoRI's cyclone. While this is not as convenient as one would like, we have not been able to locate any cyclone theory which is sufficiently reliable to include in

PADRE. CIDRS assumes that the effective cut point of the filter is half that of the last stage; PADRE prompts the use then indicates this assumption by printing the inputted value in the filter column.

3. Cumulative Masses--PADRE includes only a fraction of the back-up filter mass indicated by the user in the calculation of the cumulative masses. It is not valid to assume, as CIDRS does, that this mass is entirely due to particles with diameters less than the cut point of the last stage. Much, if not most, of this mass is from larger, entrained particles. Note that for a run with no filter, the cumulative values will agree.

4. Interpolated Values at Standard Diameters--This is an addition, available only with PADRE, to facilitate comparison of different runs. The different and cumulative mass distribution values are interpolated and printed for a set of standard diameters. CIDRS uses the same interpolation algorithm, but returns only polynominal coefficients that can later be used to generate curves for graphics or comparison.

The only calculations performed by a user involve determining the lower cut point of the cyclone precutter, if used. The following calculations were provided by Southern Research Institute to determine the cyclone IX d_{50}.

1. Determine Stack Gas Viscosity

$$\mu = 174.4 + 0.406\ (T_s)$$

where T_s = average stack temperature in °C

2. Cyclone IX d_{50}

$$d_{50} = [0.091\mu - 10.136]F^{-0.579}$$

where F = flow rate through cyclone in acfm.

APPENDIX A-3

DUAL CYCLONE EXAMPLE CALCULATIONS

1. Data Sources

a. The following data is obtained as part of each dual cyclone run:

V_M = Volume of gas sampled, dry gas meter conditions, acf

TT = Total sampling time, minutes

T_M = Average dry gas meter temperature, °F

y = Dry gas meter accuracy factor

O_{SP} = Dry gas meter static pressure, inches Hg

b. The following data is obtained from the corresponding total particulate run.

T_S = Average stack gas temperature, °F

%M = Stack gas moisture content, percent

P_S = Stack gas absolute pressure, inches Hg

P_{ST} = Static stack gas pressure, inches Hg

P_B = Barometric pressure.

2. Preliminary Calculations

a. Cyclone flow rate, acfm

$$Q_{DC} = Q_M \left(\frac{TS + 460}{TM + 460}\right)\left(\frac{P_M}{P_S}\right)\left(\frac{\%M}{100} \times VM_{std} \times 0.04715\right)$$

where Q_M = dry gas flow rate = VM_{std}/TT;

P_M = absolute meter pressure = $P_B - O_{SP}$

P_S = absolute stack pressure = $P_B - P_{ST}$

b. Stack gas viscosity, micropoise

$$\mu = 174.4 + 0.406\ T_S\ (°c)$$

3. Cyclone Cut Points

a. Cyclone III cut size, $d_{50} = [0.024\mu - 3.09]\ Q_{DC}^{\ -0.8}$

b. Cyclone X cut size, d_{50} in microns

$$X\ d_{50} = 15\ \sqrt{\frac{Q_{cal}}{Q_{act}}}$$

where $Q_{cal} = 105 \log \mu - 225$ (in lpm)

Q_{act} (lpm) = Q_{act} (acfm) x 28.32 (l/cf)

4. Emission Rates

a. Concentration

$$C = \text{total catch (grains)} \times \frac{1}{VM_{std}}$$

where C = emission rate in grains/dscf

VM_{std} = total volume sampled in dscf.

$$C_{III} = \frac{\text{backup filter net weights (grains)}}{\text{total catch (grains)}} \times C$$

$$C_{III-X} = \frac{\text{cyclone III catch + cannister rinse residue (grains)}}{\text{total catch (grains)}} \times C$$

$$C_X = \frac{\text{cyclone X catch (grains)}}{\text{total catch (grains)}} \times C$$

b. Weight rate

$$E_x = C_x \times Q_s \times 0.00857$$

where E = emission rate in lb/hr.

X = one of three size fractions

Q_s = stack gas volumetric flow rate determined by EPA method 5 tests, dscfm

0.00857 = conversion factor,

$$\frac{1\ \text{gram}}{15.43\ \text{grains}} \times \frac{1\ \text{lb}}{453.6\ \text{grams}} \times \frac{60\ \text{min}}{\text{hr}}$$

c. Emission factor

$$P_x = E_x \times \frac{1}{PWR}$$

where P_x = one of three size specific emission factors, lb/ton poured

PWR = process weight rate - tons of coal charged/quenched.

APPENDIX B

SAMPLE TRAIN CALIBRATION

Note: Sheets to be provided in Final Report.

APPENDIX C-1

COMPUTER PRINTOUTS
TOTAL PARTICULATE DATA REDUCTION

Note: To be provided in Final Report

APPENDIX C-2

COMPUTER PRINTOUTS
IMPACTOR DATA REDUCTION

INLET DIRTY - 50 PERCENT ASSUMPTION

```
DATA COMPARISON FOR    4 INLET  RUNS BY GCA
STD. PT.        CUM. %    CUMULATIVE          DM/DLOGD (MG/DNCM)
(MICRONS)  MASS < D50 MASS < D50    MIN.         MAX.         AVG.      STD. DEV.
 1  30.00       45.98     1.16E+03  8.02E+02  3.01E+03  1.65E+03  1.032E+03
 2  20.00       37.73     9.11E+02  6.65E+02  1.69E+03  1.13E+03  5.193E+02
 3  15.00       33.45     7.93E+02  4.76E+02  1.03E+03  7.79E+02  2.767E+02
 4  10.00       29.82     7.01E+02  5.64E+01  3.31E+02  1.47E+02  1.245E+02
 5   5.00       28.53     6.73E+02  1.84E+01  1.44E+02  8.31E+01  6.379E+01
 6   2.50       26.74     6.39E+02 -1.38E+02  5.49E+02  1.44E+02  2.945E+02
 7   1.25       23.80     5.92E+02 -1.99E+02  6.75E+02  1.64E+02  3.734E+02
 8   1.00       22.79     5.75E+02 -7.33E+01  6.48E+02  2.00E+02  3.172E+02
 9    .63       17.24     4.45E+02  2.27E+02  3.79E+03  1.35E+03  1.642E+03
*** NOTE THAT NEGATIVE VALUES OF DM/DLOGD ARE UNPHYSICAL
THE RUNS MARKED WITH AN * APPEAR TO CONTAIN OUTLIERS

TEST SITE      DOFQ       DOFQ       DOFQ       DOFQ
TEST DATE    102081     102181     102281     102381
RUN NUMBER      1*         1*         1*         1*
RUN DATE     102081     102181     102281     102381
START TIME    1130       1424       1036        916
TOTAL MASS 3.844E+03 1.681E+03 1.614E+03 7.787E+03

DM/DLOGD IN STANDARD INTERVALS (MG/DNCM)
DMDLD( 1)   1.90E+03  8.93E+02  8.02E+02  3.01E+03*
DMDLD( 2)   1.46E+03  6.65E+02  7.20E+02  1.69E+03*
DMDLD( 3)   1.03E+03  4.76E+02* 6.14E+02  9.95E+02
DMDLD( 4)   5.64E+01  1.01E+02  3.31E+02* 9.89E+01
DMDLD( 5)   1.84E+01* 3.87E+01  1.31E+02  1.44E+02
DMDLD( 6)  -1.38E+02  1.46E+01  5.49E+02* 1.53E+02
DMDLD( 7)  -1.99E+02  4.54E+00  6.75E+02* 1.74E+02
DMDLD( 8)  -7.33E+01  3.84E+01  6.48E+02* 1.87E+02
DMDLD( 9)   3.79E+03* 7.73E+02  6.27E+02  2.27E+02

THE VALUES MARKED BY AN * APPEAR TO BE OUTLIERS
DO YOU WISH TO REPEAT THE COMPARISON EXCLUDING SOME RUNS?  ENTER Y OR RETURN
>
DO YOU WISH TO START OVER AT THE BEGINNING OF THE PROGRAM?  ENTER Y OR RETURN
>PP >
```

OUTLET DIRTY - 50 PERCENT ASSUMPTION

```
DATA COMPARISON FOR    3 OUTLET RUNS BY GCA
STD. PT.      CUM. %   CUMULATIVE          DM/DLOGD (MG/DNCM)
(MICRONS) MASS % D50 MASS   D50      MIN.        MAX.       AVG.       STD. DEV.
 1   30.00      85.88     1.09E+02  5.72E+01  1.67E+02  1.04E+02  5.649E+01
 2   20.00      69.23     8.19E+01  4.86E+01  2.38E+02  1.30E+02  9.748E+01
 3   15.00      56.56     6.52E+01  3.54E+01  2.58E+02  1.33E+02  1.137E+02
 4   10.00      40.78     4.40E+01  6.38E+00  2.01E+02  9.93E+01  9.786E+01
 5    5.00      33.62     3.46E+01  4.89E+00  1.17E+01  7.31E+00  3.820E+00
 6    2.50      29.49     3.01E+01  1.35E+01  2.79E+01  2.10E+01  7.235E+00
 7    1.25      22.92     2.32E+01  1.55E+01  3.15E+01  2.27E+01  8.139E+00
 8    1.00      20.90     2.11E+01  1.54E+01  2.80E+01  2.04E+01  6.697E+00
 9     .63      17.44     1.76E+01  9.84E+00  2.06E+01  1.46E+01  5.498E+00
THE RUNS MARKED WITH AN ◆ APPEAR TO CONTAIN OUTLIERS

TEST SITE       DOFO        DOFO        DOFO
TEST DATE      102381      102281      102081
RUN NUMBER        2◆          2◆          2◆
RUN DATE       102381      102281      102081
START TIME        916        1036        1130
TOTAL MASS  1.759E+02  1.078E+02  1.179E+02

DM/DLOGD IN STANDARD INTERVALS (MG/DNCM)
DMDLD( 1)   1.67E+02◆  5.72E+01   8.87E+01
DMDLD( 2)   2.38E+02◆  4.86E+01   1.03E+02
DMDLD( 3)   2.58E+02◆  3.54E+01   1.06E+02
DMDLD( 4)   2.01E+02◆  6.38E+00   9.01E+01
DMDLD( 5)   5.33E+00   4.89E+00   1.17E+01◆
DMDLD( 6)   2.17E+01   2.79E+01   1.35E+01◆
DMDLD( 7)   2.09E+01   3.15E+01◆  1.55E+01
DMDLD( 8)   1.77E+01   2.80E+01◆  1.54E+01
DMDLD( 9)   9.84E+00   2.06E+01◆  1.32E+01

THE VALUES MARKED BY AN ◆ APPEAR TO BE OUTLIERS
```

INLET CLEAN - 50 PERCENT ASSUMPTION

```
~~DATA COM~~PARISON FOR    3 INLET  RUNS BY GCA
STD. PT.      CUM. %    CUMULATIVE          DM/DLOGD (MG/DNCM)
(MICRONS)   MASS < D50 MASS < D50    MIN.         MAX.        AVG.        STD. DEV.
 1 ~~30.00~~       52.79      7.49E+01   2.77E+01   1.71E+02   ~~1.23E+02~~   8.264E+01
 2  20.00       43.99      5.59E+01   3.66E+01   1.27E+02   9.16E+01   4.826E+01
 3  15.00       38.67      4.58E+01   4.29E+01   9.55E+01   7.16E+01   2.663E+01
 4  10.00       32.26      3.55E+01   3.10E+01   5.15E+01   4.46E+01   1.175E+01
 5   5.00       22.78      2.54E+01   8.87E+00   5.77E+01   2.[illegible]E+01   2.616E+01
 6   2.50       15.76      1.79E+01   1.39E+01   3.66E+01   [illegible]E+01   1.279E+01
 7   1.25       11.00      1.23E+01   1.23E+01   2.19E+01   1.56E+01   5.429E+00
 8   1.00        9.88      1.09E+01   1.10E+01   1.79E+01   1.35E+01   3.875E+00
 9    ~~.63~~        7.78      8.43E+00   4.23E+00   2.39E+01   1.15E+01   1.076E+01
THE RUNS MARKED WITH AN ◆ APPEAR TO CONTAIN OUTLIERS

TEST SITE      DOFQ        DOFQ        DOFQ
TAST DATE    100281      100581      100581
RUN NUMBER      2◆          2◆          3
RUN DATE     100281      100581      100581
START TIME    1235        1020        1511
TOTAL MASS 8.968E+01 3.126E+02 2.427E+02

DM/DLOGD IN STANDARD INTERVALS (MG/DNCM)
DMDLD( 1)   2.77E+01◆ 1.71E+02  1.71E+02
DMDLD( 2)   3.66E+01◆ 1.11E+02  1.27E+02
DMDLD( 3)   4.29E+01◆ 7.65E+01  9.55E+01
DADLD( 4)   5.13E+01  3.10E+01◆ 5.15E+01
DMDLD( 5)   5.77E+01◆ 8.87E+00  1.69E+01
DMDLD( 6)   3.66E+01◆ 1.39E+01  1.50E+01
DMDLD( 7)   2.19E+01◆ 1.27E+01  1.23E+01
DMDLD( 8)   1.79E+01◆ 1.10E+01  1.14E+01
DMDLD( 9)   2.39E+01◆ 4.23E+00  6.42E+00
```

OUTLET CLEAN - 50 PERCENT ASSUMPTION

```
DATA COMPARISON FOR     4 OUTLET RUNS BY GCA
STD. PT.         CUM. %    CUMULATIVE          DM/DLOGD (MG/DNCM)
(MICRONS)  MASS < D50 MASS < D50     AVG.      STD. DEV.    MIN.        MAX.
 1   20.00        27.98     4.52E+01   1.01E+02   2.31E+01   8.83E+01   1.36E+02
 2   15.00        21.42     3.43E+01   7.55E+01   2.66E+01   5.40E+01   1.12E+02
 3   10.00        15.07     2.39E+01   3.86E+01   2.68E+01   1.46E+01   7.07E+01
 4    5.00        11.03     1.76E+01   1.52E+01   1.18E+01   2.89E+00   3.11E+01
 5    2.50         7.41     1.20E+01   1.83E+01   6.28E+00   9.07E+00   2.27E+01
 6    1.25         4.65     7.38E+00   1.19E+01   5.37E+00   6.87E+00   1.91E+01
 7   P1.00         4.08     6.36E+00   9.09E+00   5.71E+00   2.87E+00   1.67E+01
 8     .63         3.34     4.99E+00   4.84E+00   6.42E+00   8.27E-02   1.43E+01
THE RUNS MARKED WITH AN ◆ APPEAR TO CONTAIN OUTLIERS

TEST SITE      DOE0       DOE0       DOE0       DOE0
TEST DATE     100281     100381     100581     100681
RUN NUMBER       3◆         2◆         4◆         3◆
RUN DATE      100281     100381     100581     100681
START TIME     1235       1545       1511       1314
TOTAL MASS 2.282E+02 1.854E+02 1.730E+02 1.391E+02

DM/DLOGD IN STANDARD INTERVALS (MG/DNCM)
 1   20.00  8.86E+01   8.83E+01   1.36E+02◆ 9.27E+01
 2   15.00  5.40E+01   5.78E+01   1.12E+02◆ 7.82E+01
 3   10.00  1.84E+01   1.46E+01   7.07E+01◆ 5.05E+01
 4    5.00  2.89E+00◆  1.52E+01   1.15E+01   3.11E+01◆
 5    2.50  9.07E+00◆  2.27E+01   2.01E+01   2.16E+01
 6    1.25  8.84E+00   1.91E+01◆  1.27E+01   6.87E+00
 7    1.00  7.72E+00   1.67E+01◆  9.13E+00   2.87E+00◆
 8     .63  1.69E+00   1.43E+01◆  3.30E+00   8.27E-02
```

INLET DIRTY - ZERO PERCENT ASSUMPTION

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THE RUNS MARKED WITH AN * APPEAR TO CONTAIN OUTLIERS

TEST SITE      DOEO        DOEO        DOEO        DOEO
TEST DATE     102081      102181      102281      102381
RUN NUMBER       1*          1           1*          1*
RUN DATE      102081      102181      102281      102381
START TIME     1130        1424        1036         916
TOTAL MASS 3.844E+03 1.681E+03 1.614E+03 7.787E+02

STD. DIAM.  CUM. % MASS < D50  *
 1  20.00      36.84       24.08       53.31*       7.91*
 2  15.00      32.11       19.60       47.71*       6.03*
 3  10.00      28.57       16.07       41.65*       4.74*
 4   5.00      28.20       14.68       38.38*       4.29*
 5   2.50      27.88       13.56       31.91        3.70*
 6   1.25      27.56*      12.57       17.38        3.06*
 7   1.00      27.44*      12.27       12.81        2.83*
 8    .63      27.19*      11.68        5.51        2.29

THE VALUES MARKED BY AN * APPEAR TO BE OUTLIERS

DATA COMPARISON FOR    4 INLET  RUNS BY GCA
STD. DIAM.   NO.   DM/DLOGD   CUMULATIVE          CUM. % MASS < D50
(MICRONS)   RUNS  (MG/DNCM)   MASS < D50    AVG.     STD. DEV.     MIN.       MAX.
 1  20.00     4    9.85E+02   6.74E+02     30.54     19.25         7.91      53.31
 2  15.00     4    6.81E+02   5.71E+02     26.36     17.78         6.03      47.71
 3  10.00     4    1.47E+02   4.89E+02     22.76     15.92         4.74      41.65
 4   5.00     4    8.00E+01   4.62E+02     21.39     14.97         4.29      38.38
 5   2.50     4    2.02E+02   4.21E+02     19.26     13.02         3.70      31.91
 6   1.25     4    2.39E+02   3.51E+02     15.14     10.19         3.06      27.56
 7   1.00     4    2.26E+02   3.29E+02     13.84     10.16         2.83      27.44
 8    .63     4    1.69E+02   2.88E+02     11.66     11.06         2.29      27.19
DO YOU WISH TO REPEAT THE COMPARISON EXCLUDING SOME RUNS?  ENTER Y OR N
 Y
```

OUTLET DIRTY - ZERO PERCENT ASSUMPTION

```
TEST SITE      DOFO       DOFO       DOFO
TEST DATE    102081     102281     102381
RUN NUMBER      2◆         2◆         2◆
RUN DATE     102081     102281     102381
START TIME    1130       1036        916
TOTAL MASS 1.178E+02 1.078E+02 1.753E+02

STD. DIAM.   CUM. % MASS < D50
 1  20.00      62.52      58.52      73.36◆
 2  15.00      45.98◆     50.10      53.16
 3  10.00      26.01      43.52◆     27.41
 4   5.00      14.85      42.12◆     17.48
 5   2.50      11.86      34.71◆     14.65
 6   1.25       6.42      16.67◆     10.51
 7   1.00       4.66◆     11.56       9.35
 8    .63       1.83       4.23       7.64◆

THE VALUES MARKED BY AN ◆ APPEAR TO BE OUTLIERS

DATA COMPARISON FOR    3 OUTLET RUNS BY GCA
STD. DIAM.   NO.   DM/DLOGD  CUMULATIVE          CUM. % MASS < D50
(MICRONS)   RUNS  (MG/DNCM)  MASS < D50    AVG.     STD. DEV.     MIN.        MAX.
 1  20.00     3    1.43E+02  7.11E+01     64.80        7.68       58.52       73.36
 2  15.00     3    1.39E+02  5.33E+01     49.75        3.60       45.98       53.16
 3  10.00     3    9.88E+01  3.17E+01     32.31        9.73       26.01       43.52
 4   5.00     3    5.77E+00  2.25E+01     24.82       15.04       14.85       42.12
 5   2.50     3    2.22E+01  1.85E+01     20.41       12.47       11.86       34.71
 6   1.25     3    2.41E+01  1.10E+01     11.20        5.16        6.42       16.67
 7   1.00     3    2.08E+01  8.84E+00      8.52        3.52        4.66       11.56
 8    .63     3    1.10E+01  5.57E+00      4.57        2.92        1.83        7.64
DO YOU WISH TO REPEAT THE COMPARISON EXCLUDING SOME RUN ?  ENTER Y OR N
 N
```

INLET CLEAN - ZERO PERCENT ASSUMPTION

```
THE RUNS MARKED WITH AN * APPEAR TO CONTAIN OUTLIERS

TEST SITE      DOFO       DOFO       DOFO
TEST DATE    100281     100581     100581
RUN NUMBER      2*         2          3
RUN DATE     100281     100581     100581
START TIME    1235       1020       1511
TOTAL MASS 8.968E+01 3.126E+02 2.427E+02

STD. DIAM.   CUM. % MASS < D50
 1  20.00      99.47*     11.43       19.39
 2  15.00      90.32*      7.95       13.79
 3  10.00      76.80*      4.98        8.38
 4   5.00      48.34*      3.65        5.37
 5   2.50      26.95*      2.80        3.47
 6   1.25      13.23*      1.01        1.52
 7   1.00      10.32*       .57         .99
 8    .63       6.01*       .10         .27

THE VALUES MARKED BY AN * APPEAR TO BE OUTLIERS

DATA COMPARISON FOR.    3 INLET  RUNS BY GCA
STD. DIAM.   NO.  DM/DLOGD  CUMULATIVE          CUM. % MASS < D50
(MICRONS)   RUNS (MG/DNCM)  MASS < D50    AVG.     STD. DEV.    MIN.        MAX.
 1  20.00     3   8.93E+01  4.85E+01     43.43      48.69      11.43       99.47
 2  15.00     3   7.03E+01  3.86E+01     37.35      45.97       7.95       90.32
 3  10.00     3   4.45E+01  2.84E+01     30.05      40.52       4.98       76.80
 4   5.00     3   2.59E+01  1.84E+01     19.12      25.32       3.65       48.34
 5   2.50     3   2.33E+01  1.14E+01     11.07      13.76       2.80       26.95
 6   1.25     3   1.72E+01  5.10E+00      5.25       6.91       1.01       13.23
 7   1.00     3   1.37E+01  3.60E+00      3.96       5.52        .57       10.32
 8    .63     3   6.15E+00  1.63E+00      2.13       3.36        .10        6.01
DO YOU WISH TO REPEAT THE COMPARISON EXCLUDING SOME RUNS?  ENTER Y OR N
N
```

OUTLET CLEAN - ZERO PERCENT ASSUMPTION

```
K=              3  X=  .00000000       .00000000       .00000000
THE RUNS MARKED WITH AN ◆ APPEAR TO CONTAIN OUTLIERS

TEST SITE      DOFO       DOFO       DOFO
TEST DATE    100581     100381     100281
RUN NUMBER      4◆         2◆         3◆
RUN DATE     100581     100381     100281
START TIME    1511       1545       1235
TOTAL MASS 1.730E+02 1.854E+02 2.282E+02

STD. DIAM.  CUM. % MASS < D50
 1  20.00      32.08◆     20.57       9.90
 2  15.00      22.69      16.24       6.45◆
 3  10.00      12.79      12.79       3.76◆
 4   5.00       7.49      10.50       3.07◆
 5   2.50       5.14       7.33◆      5.63
 6   1.25       1.47       3.49◆       .90
 7   1.00        .80       2.51◆       .16
 8    .63        .15       1.06◆       .00

THE VALUES MARKED BY AN ◆ APPEAR TO BE OUTLIERS

DATA COMPARISON FOR    3 OUTLET RUNS BY GCA
STD. DIAM.   NO.   DM/DLOGD  CUMULATIVE          CUM. % MASS < D50
(MICRONS)   RUNS  (MG/DNCM)  MASS < D50    AVG.     STD. DEV.    MIN.       MAX.
 1  20.00     3    9.71E+01  3.77E+01     20.85      11.10       9.90      32.08
 2  15.00     3    7.12E+01  2.73E+01     15.12       8.18       6.45      22.69
 3  10.00     3    3.54E+01  1.77E+01      9.78       5.22       3.76      12.79
 4   5.00     3    4.60E+00  1.28E+01      7.02       3.74       3.07      10.50
 5   2.50     3    1.70E+01  1.15E+01      6.03       1.15       5.14       7.33
 6   1.25     3    2.07E+01  3.60E+00      1.95       1.36        .90       3.49
 7   1.00     3    1.14E+01  2.08E+00      1.16       1.21        .16       2.51
 8    .63     3    3.81E+00  7.21E-01       .40        .57        .00       1.06
DO YOU WISH TO REPEAT THE COMPARISON EXCLUDING SOME RUNS?  ENTER Y OR N
```

1 INLET DIRTY

```
DATA FOR TEST BY CONTRACTOR GCA . AT SITE DOFQ, ON DATE 102081. RUN NO.    1
TEST COMMENTS        TCOMM= DOFASCO WET QUENCH TOWER IP TESTING
PARTICLE DENSITY (GM/CC): RHO=     1.000

RUN COMMENTS:          RCOMM= 1ID
DATE OF RUN:           JDATE= 102081 AMBIENT PRESSURE (IN HG)           PAMBNT=  29.73
START TIME:           ISTART=   1130 STACK PRESS WRT AMBIENT (IN H2O):DPSTK=    .00
RUN DURATION (MIN):    DUR=    31.5 STACK TEMPERATURE (DEG F):         TSTACK=  155.0
RUN TYPE:             RTYPE= I      IMPACTOR TEMPERATURE (DEG F):        TIMP=  250.0
% CARBON DIOXIDE:      CO2=      .3 MAX. PARTICLE DIAM. (MICRONS):       DMAX= 1000.0
% CARBON MONOXIDE:      CO=      .0 CYCLONE CUT POINT (MICRONS):         CYCL=   12.7
% NITROGEN:             N2=    78.8 BACKUP FILTER USED?                    BF= YES
% OXYGEN:               O2=    20.9 % FILTER MASS < D50 LAST STAGE   PCTINY=   50.0
% WATER VAPOR:         H2O=    36.1 FLOW RATE DETERMINATION:
IMPACTOR TYPE:     IMPNAM=ANDERSENIMPACTOR FLOW RATE (ACFM):           FLOW=   .550
IMPACTOR MODEL:    IMPMOD=MARK 3
IMP. PLATE SET ID:IPLATE=       7 SUBSTRATES ID:                       IDSUBS=    491
NO. IMP. STAGES USED  NS=       8 DESCR=1ID
NO. JETS  DIAM.   CUMDP  CALIB        CYCLONE      530.609 MG
  264    .1640  .0000   .3808        STAGE  1       1.479 MG
  264    .1250  .0000   .3808        STAGE  2       1.490 MG
  264    .0950  .0000   .3808        STAGE  3       1.570 MG
  264    .0760  .0000   .3808        STAGE  4       1.200 MG
  264    .0670  .0000   .3808        STAGE  5       1.780 MG
  264    .0360  .1760   .3808        STAGE  6       2.280 MG
  264    .0260  .2940   .3808        STAGE  7       2.160 MG
  156    .0250 1.0000   .3808        STAGE  8     203.070 MG
IMPACTOR DP SCALING FACTOR      1.287  FILTER       283.890 MG

1ID
TOTAL MASS  9.1851-001  1.6798+000  2.1019+003  3.8439+003        DMAX=1000.0
               GR/ACF      GR/DCNF     MG/ACM      MG/DNCM              MICRONS

 STAGE      MASS       MASS      % CUM.       D50       GEO. MEAN DM/DLOGD   DN/DLOGD
            (MG)    (MG/DNCM)    MASS     (MICRONS)  (MICRONS)  (MG/DNCM)  (NO/DNCM)
CYCLONE    530.61    1981.11     40.22       12.68      112.61    1.04+003   1.40+006
    1        1.48       5.52     40.05       12.24       12.46    3.63+002   3.59+008
    2        1.49       5.56     39.88        8.41        9.97    3.11+001   6.00+007
    3        1.57       5.86     39.71        5.64        6.58    3.23+001   2.16+008
    4        1.20       4.48     39.57        3.79        4.50    3.01+001   6.32+008
    5        1.78       6.65     39.37        3.12        3.44    7.86+001   3.69+009
    6        2.28       8.51     39.11        1.17        1.91    1.99+001   5.48+009
    7        2.16       8.06     38.87         .68         .89    3.42+001   9.30+010
    8      203.07     758.19     15.99         .46         .56    4.50+003   4.95+013
FILTER     283.89    1059.95                                .32    3.52+003   1.96+014
INTERPOLATED TO STD. INTERVALS:
                                 57.32       30.00                 1.90+003
                                 48.23       20.00                 1.46+003
                                 43.56       15.00                 1.03+003
                                 40.03       10.00                 5.64+001
                                 39.67        5.00                 1.84+001
                                 40.21        2.50                -1.38+002
                                 41.92        1.25                -1.99+002
                                 42.39        1.00                -7.33+001
                                 33.82         .63                 3.79+003
```

2 INLET DIRTY

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DATA FOR TEST I BY CONTRACTOR GCA , AT SITE DOFQ, ON DATE 102181, RUN NO.    1
TEST COMMENTS         TCOMM= DOFASCO WET QUENCH TOWER IP TESTING
PARTICLE DENSITY (GM/CC): RHO=     1.000

RUN COMMENTS:         RCOMM= 2ID
DATE OF RUN:          JDATE= 102181 AMBIENT PRESSURE (IN HG)          PAMBNT=  29.92
START TIME:          ISTART=   1424 STACK PRESS.WRT AMBIENT (IN H2O):DPSTK=     .00
RUN DURATION (MIN):    DUR=   20.4 STACK TEMPERATURE (DEG F):         TSTACK=  155.0
RUN TYPE:             RTYPE= I      IMPACTOR TEMPERATURE (DEG F):       TIMP=  250.0
% CARBON DIOXIDE:       CO2=     .3 MAX. PARTICLE DIAM. (MICRONS):      DMAX= 1000.0
% CARBON MONOXIDE:       CO=     .0 CYCLONE CUT POINT (MICRONS):        CYCL=   13.0
% NITROGEN:              N2=   78.8 BACKUP FILTER USED?                   BF= YES
% OXYGEN:                O2=   20.9 % FILTER MASS < D50 LAST STAGE  PCTINY=   50.0
% WATER VAPOR:          H2O=   27.7 FLOW RATE DETERMINATION:
IMPACTOR TYPE:      IMPNAM=ANDERSENIMPACTOR FLOW RATE (ACFM):           FLOW=   .520
IMPACTOR MODEL:     IMPMOD=MARK 3
IMP. PLATE SET ID:IPLATE=       7 SUBSTRATES ID:                      IDSUBS=    171
NO. IMP. STAGES USED  NS=       8 DESCR=2ID
NO. JETS   DIAM.    CUMDP   CALIB         CYCLONE      187.980 MG
  264     .1640   .0000    .3808          STAGE  1       1.930 MG
  264     .1250   .0000    .3808          STAGE  2       2.000 MG
  264     .0950   .0000    .3808          STAGE  3       1.390 MG
  264     .0760   .0000    .3808          STAGE  4       1.310 MG
  264     .0670   .0000    .3808          STAGE  5       1.910 MG
  264     .0360   .1760    .3808          STAGE  6       2.060 MG
  264     .0260   .2940    .3808          STAGE  7       1.600 MG
  156     .0250 1.0000     .3808          STAGE  8      26.880 MG
IMPACTOR DP SCALING FACTOR       1.287   FILTER         87.840 MG

2ID
TOTAL MASS   4.5766-001  7.3451-001  1.0473+003  1.6808+003      DMAX=1000.0
                GR/ACF      GR/DCNF     MG/ACM      MG/DNCM            MICRONS

 STAGE        MASS       MASS       % CUM.       D50     GEO. MEAN  DM/DLOGD  DN/DLOGD
              (MG)    (MG/DNCM)     MASS      (MICRONS) (MICRONS)  (MG/DNCM)  (NO/DNCM)
CYCLONE      187.98    1003.37      30.63       13.05     114.24   5.32+002  6.82+005
    1          1.93      10.30      29.92       12.84      12.95   1.47+003  1.30+009
    2          2.00      10.68      29.18        8.51      10.45   5.97+001  9.99+007
    3          1.39       7.42      28.67        5.60       6.90   4.09+001  2.37+008
    4          1.31       6.99      28.18        3.98       4.72   4.70+001  8.54+008
    5          1.91      10.19      27.48        3.28       3.61   1.21+002  4.90+009
    6          2.06      11.00      26.72        1.23       2.00   2.58+001  6.11+009
    7          1.60       8.54      26.13         .71        .94   3.63+001  8.48+010
    8         26.88     143.47      16.21         .49        .59   8.58+002  8.04+012
FILTER        87.84     468.86                               .34   1.56+003  7.36+013
 INTERPOLATED TO STD. INTERVALS:
                                    47.99       30.00              8.93+002
                                    38.34       20.00              6.65+002
                                    33.45       15.00              4.76+002
                                    29.66       10.00              1.01+002
                                    28.50        5.00              3.87+001
                                    27.90        2.50              1.46+001
                                    27.78        1.25              4.54+000
                                    27.68        1.00              3.94+001
                                    23.10         .63              7.27+002
```

3 INLET DIRTY

```
DATA FOR TEST BY CONTRACTOR GCA , AT SITE DOFQ, ON DATE 102281, RUN NO.    1
TEST COMMENTS       TCOMM= DOFASCO WET QUENCH TOWER IP TESTING
PARTICLE DENSITY (GM/CC): RHO=     1.000

RUN COMMENTS:          RCOMM= 3ID
DATE OF RUN:           JDATE= 102281 AMBIENT PRESSURE (IN HG)          PAMBNT=  29.87
START TIME:           ISTART=   1036 STACK PRESS WRT AMBIENT (IN H2O):DPSTK=      .00
RUN DURATION (MIN):    DUR=     21.4 STACK TEMPERATURE (DEG F):         TSTACK=  155.0
RUN TYPE:              RTYPE= I      IMPACTOR TEMPERATURE (DEG F):        TIMP=  250.0
% CARBON DIOXIDE:       CO2=      .3 MAX. PARTICLE DIAM. (MICRONS):       DMAX= 1000.0
% CARBON MONOXIDE:       CO=      .0 CYCLONE CUT POINT (MICRONS):         CYCL=    12.9
% NITROGEN:              N2=    78.8 BACKUP FILTER USED?                    BF= YES
% OXYGEN:                O2=    20.9 % FILTER MASS < D50 LAST STAGE  PCTINY=    50.0
% WATER VAPOR:          H2O=    30.0 FLOW RATE DETERMINATION:
IMPACTOR TYPE:     IMPNAM=ANDERSENIMPACTOR FLOW RATE (ACFM):              FLOW=    .530
IMPACTOR MODEL:    IMPMOD=MARK 3
IMP. PLATE SET ID:IPLATE=        7 SUBSTRATES ID:                     IDSUBS=     208
NO. IMP. STAGES USED  NS=        8 DESCR=3ID
NO. JETS  DIAM.   CUMDP  CALIB          CYCLONE     154.400 MG
  264    .1640  .0000   .3808           STAGE  1      9.450 MG
  264    .1250  .0000   .3808           STAGE  2      4.580 MG
  264    .0950  .0000   .3808           STAGE  3      3.090 MG
  264    .0760  .0000   .3808           STAGE  4      4.260 MG
  264    .0670  .0000   .3808           STAGE  5     22.030 MG
  264    .0360  .1760   .3808           STAGE  6     34.710 MG
  264    .0260  .2940   .3808           STAGE  7     27.520 MG
  156    .0250 1.0000   .3808           STAGE  8     19.360 MG
IMPACTOR DP SCALING FACTOR      1.287  FILTER        32.090 MG

3ID
TOTAL MASS  4.2442-001  7.0551-001  9.7122+002  1.6145+003        DMAX=1000.0
               GR/ACF      GR/DCNF      MG/ACM      MG/DNCM               MICRONS

 STAGE      MASS      MASS      % CUM.       D50     GEO. MEAN DM/DLOGD   DN/DLOGD
            (MG)   (MG/DNCM)    MASS     (MICRONS) (MICRONS) (MG/DNCM)  (NO/DNCM)
CYCLONE    154.40    800.26     47.74      12.92    113.67   4.24+002   5.51+005
      1      9.45     48.98     44.54      12.65     12.78   5.35+003   4.89+009
      2      4.58     23.74     42.99       8.38     10.30   1.33+002   2.32+008
      3      3.09     16.02     41.95       5.52      6.80   8.82+001   5.35+008
      4      4.26     22.08     40.50       3.92      4.65   1.49+002   2.82+009
      5     22.03    114.18     33.05       3.23      3.56   1.35+003   5.74+010
      6     34.71    179.90     21.30       1.21      1.97   4.21+002   1.05+011
      7     27.52    142.64     11.98        .70       .92   6.06+002   1.48+012
      8     19.36    100.34      5.43        .48       .58   5.98+002   5.90+012
 FILTER     32.09    166.32                            .34   5.53+002   2.75+013
 *** WARNING  CUT POINTS FOR STAGES  0  1 ARE SIMILAR OR INVERTED
 *** WARNING  CUT POINTS FOR STAGES  4  5 ARE SIMILAR OR INVERTED
  INTERPOLATED TO STD. INTERVALS:
                                64.97      30.00              8.02+002
                                56.08      20.00              7.20+002
                                50.65      15.00              6.14+002
                                44.83      10.00              3.31+002
                                41.68       5.00              1.31+002
                                35.14       2.50              5.49+002
                                22.45       1.25              6.75+002
                                18.26       1.00              6.42+002
                                 9.75        .63              6.32+002
```

4 INLET DIRTY

```
DATA FOR TEST BY CONTRACTOR GCA , AT SITE DOFCO, ON DATE 102381, RUN NO.     1
TEST COMMENTS        TCOMM= DOFASCO WET QUENCH TOWER IP TESTING
PARTICLE DENSITY (GM/CC): RHO=     1.000

RUN COMMENTS:          RCOMM= 4ID
DATE OF RUN:           JDATE= 102381 AMBIENT PRESSURE (IN HG)         PAMBNT=  29.74
START TIME:          ISTART=    916 STACK PRESS WRT AMBIENT (IN H2O):DPSTK=     .00
RUN DURATION (MIN):  DUR=    22.9 STACK TEMPERATURE (DEG F):         TSTACK=  155.0
RUN TYPE:              RTYPE= I       IMPACTOR TEMPERATURE (DEG F):     TIMP=  250.0
% CARBON DIOXIDE:       CO2=      .3 MAX. PARTICLE DIAM. (MICRONS):    DMAX= 1000.0
% CARBON MONOXIDE:       CO=      .0 CYCLONE CUT POINT (MICRONS):      CYCL=   12.7
% NITROGEN:              N2=    78.8 BACKUP FILTER USED?                 BF= YES
% OXYGEN:                O2=    20.9 % FILTER MASS < D50 LAST STAGE  PCTINY=   50.0
% WATER VAPOR:          H2O=    31.7 FLOW RATE DETERMINATION:
IMPACTOR TYPE:     IMPNAM=ANDERSENIMPACTOR FLOW RATE (ACFM):         FLOW=   .550
IMPACTOR MODEL:    IMPMOD=MARK 3
IMP. PLATE SET ID:IPLATE=        7 SUBSTRATES ID:                   IDSUBS=    291
NO. IMP. STAGES USED  NS=        8 DESCR=4ID
NO. JETS   DIAM.    CUMDP   CALIB          CYCLONE    1513.580 MG
  264    .1640  .0000   .3808           STAGE  1       2.260 MG
  264    .1250  .0000   .3808           STAGE  2       1.630 MG
  264    .0950  .0000   .3808           STAGE  3       4.500 MG
  264    .0760  .0000   .3808           STAGE  4       5.030 MG
  264    .0670  .0000   .3808           STAGE  5       5.210 MG
  264    .0360  .1760   .3808           STAGE  6      11.330 MG
  264    .0260  .2940   .3808           STAGE  7       9.530 MG
  156    .0250 1.0000   .3808           STAGE  8       8.280 MG
IMPACTOR DP SCALING FACTOR      1.287  FILTER        59.850 MG

4ID
TOTAL MASS  1.9890+000  3.4030+000  4.5516+003  7.7872+003       DMAX=1000.0
              GR/ACF       GR/DCNF      MG/ACM       MG/DNCM              MICRONS

 STAGE       MASS       MASS      % CUM.        D50     GEO. MEAN  DM/DLOGD   DN/DLOGD
             (MG)    (MG/DNCM)    MASS      (MICRONS)  (MICRONS)  (MG/DNCM)  (NO/DNCM)
CYCLONE    1513.58    7270.28      4.88       12.68     112.61    3.83+003   5.13+006
    1         2.26      10.85      4.74       12.37      12.52    1.00+003   9.77+008
    2         1.63       7.83      4.64        8.19      10.07    4.38+001   8.20+007
    3         4.50      21.62      4.36        5.39       6.65    1.19+002   7.73+008
    4         5.03      24.16      4.04        3.83       4.55    1.62+002   3.30+009
    5         5.21      25.03      3.71        3.15       3.47    2.96+002   1.35+010
    6        11.33      54.42      3.00        1.18       1.93    1.27+002   3.40+010
    7         9.53      45.78      2.40         .68        .90    1.94+002   5.12+011
    8         8.28      39.77      1.88         .46        .56    2.36+002   2.52+012
FILTER       59.85     287.48                               .33    9.55+002   5.17+013
 INTERPOLATED TO STD. INTERVALS:
                                  13.64       30.00                3.01+003
                                   8.27       20.00                1.69+003
                                   6.13       15.00                9.95+002
                                   4.74       10.00                9.89+001
                                   4.29        5.00                1.44+002
                                   3.70        2.50                1.53+002
                                   3.06        1.25                1.74+002
                                   2.93        1.00                1.87+002
                                   2.28         .63                2.27+002
```

1 OUTLET DIRTY

```
DATA FOR TEST BY CONTRACTOR GCA , AT SITE DOFO, ON DATE 102081, RUN NO.   2
TEST COMMENTS        TCOMM= DOFASCO WET QUENCH TOWER IP TESTING
PARTICLE DENSITY (GM/CC): RHO=     1.000

RUN COMMENTS:         RCOMM= 10D
DATE OF RUN:          JDATE= 102081 AMBIENT PRESSURE (IN HG)         PAMBNT=  29.73
START TIME:         ISTART=   1130 STACK PRESS WRT AMBIENT (IN H2O):DPSTK=     .00
RUN DURATION (MIN):  DUR=     31.5 STACK TEMPERATURE (DEG F):        TSTACK=  155.0
RUN TYPE:             RTYPE= 0      IMPACTOR TEMPERATURE (DEG F):      TIMP=  250.0
% CARBON DIOXIDE:      CO2=      .3 MAX. PARTICLE DIAM. (MICRONS):     DMAX=  450.0
% CARBON MONOXIDE:      CO=      .0 CYCLONE CUT POINT (MICRONS):       CYCL=   12.7
% NITROGEN:             N2=    78.8 BACKUP FILTER USED?                  BF= YES
% OXYGEN:               O2=    20.9 % FILTER MASS < D50 LAST STAGE  PCTINY=   50.0
% WATER VAPOR:         H2O=    30.7 FLOW RATE DETERMINATION:
IMPACTOR TYPE:      IMPNAM=ANDERSENIMPACTOR FLOW RATE (ACFM):          FLOW=   .550
IMPACTOR MODEL:     IMPMOD=MARK 3
IMP. PLATE SET ID:IPLATE=        7 SUBSTRATES ID:                    IDSUBS=    317
NO. IMP. STAGES USED  NS=        8 DESCR=10D
NO. JETS  DIAM.   CUMDP  CALIB           CYCLONE       16.439 MG
  264    .1640  .0000    .3808           STAGE  1       5.500 MG
  264    .1250  .0000    .3808           STAGE  2        .200 MG
  264    .0950  .0000    .3808           STAGE  3        .930 MG
  264    .0760  .0000    .3808           STAGE  4        .390 MG
  264    .0670  .0000    .3808           STAGE  5        .800 MG
  264    .0360  .1760    .3808           STAGE  6       1.280 MG
  264    .0260  .2940    .3808           STAGE  7       1.040 MG
  156    .0250 1.0000    .3808           STAGE  8        .610 MG
IMPACTOR DP SCALING FACTOR       1.287   FILTER         7.000 MG

10D
TOTAL MASS  3.0503-002  5.1458-002  6.9801+001  1.1775+002       DMAX= 450.0
              GR/ACF       GR/DCNF      MG/ACM      MG/DNCM              MICRONS

 STAGE        MASS       MASS      % CUM.        D50      GEO. MEAN DM/DLOGD  DN/DLOGD
              (MG)    (MG/DNCM)    MASS      (MICRONS)  (MICRONS) (MG/DNCM) (NO/DNCM)
CYCLONE      16.44      56.62      46.43        12.68       75.54  3.65+001  1.62+005
   1          5.50      18.94      28.51        12.40       12.54  1.93+003  1.87+009
   2           .20        .69      27.86         8.21       10.09  3.85+000  7.16+006
   3           .93       3.20      24.83         5.41        6.66  1.76+001  1.14+008
   4           .39       1.34      23.56         3.84        4.56  9.03+000  1.82+008
   5           .80       2.76      20.95         3.16        3.48  3.26+001  1.47+009
   6          1.28       4.41      16.78         1.18        1.93  1.03+001  2.73+009
   7          1.04       3.58      13.39          .69         .90  1.52+001  3.98+010
   8           .61       2.10      11.40          .46         .56  1.24+001  1.32+011
FILTER        7.00      24.11                                 .33  8.01+001  4.31+012
 INTERPOLATED TO STD. INTERVALS:
                                   80.47        30.00              8.87+001
                                   64.20        20.00              1.03+002
                                   51.75        15.00              1.06+002
                                   34.97        10.00              9.01+001
                                   24.53         5.00              1.17+001
                                   21.35         2.50              1.35+001
                                   17.12         1.25              1.55+001
                                   15.70         1.00              1.54+001
                                   12.90          .63              1.33+001
```

3 OUTLET DIRTY

```
DATA FOR TEST BY CONTRACTOR GCA , AT SITE DOFQ, ON DATE 102281, RUN NO. [illegible]
TEST COMMENT:      TCOMM= DOFASCO WET QUENCH TOWER IP TESTING
PARTICLE DENSITY (GM/CC): RHO=    1.000

RUN COMMENTS:        RCOMM= 30D
DATE OF RUN:         IDATE= 102281 AMBIENT PRESSURE (IN HG)          PAMBNT=  29.87
START TIME:         ISTART=   1036 STACK PRESS WRT AMBIENT (IN H2O):DPSTK=     .00
RUN DURATION (MIN):   DUR=    21.4 STACK TEMPERATURE (DEG F):        TSTACK=  155.0
RUN TYPE:            RTYPE= 0      IMPACTOR TEMPERATURE (DEG F):       TIMP=  250.0
% CARBON DIOXIDE:      CO2=     .3 MAX. PARTICLE DIAM. (MICRONS):      DMAX=  450.0
% CARBON MONOXIDE:      CO=     .0 CYCLONE CUT POINT (MICRONS):        CYCL=   12.8
% NITROGEN:             N2=   78.8 BACKUP FILTER USED?                  BF= YES
% OXYGEN:               O2=   20.9 % FILTER MASS < D50 LAST STAGE  PCTINY=   50.0
% WATER VAPOR:         H2O=   30.2 FLOW RATE DETERMINATION:
IMPACTOR TYPE:     IMPNAM=ANDERSENIMPACTOR FLOW RATE (ACFM):           FLOW=   .540
IMPACTOR MODEL:    IMPMOD=MARK 3
IMP. PLATE SET ID:IPLATE=        7 SUBSTRATES ID:                    IDSUBS=     19
NO. IMP. STAGES USED  NS=        8 DESCP=30D
NO. JETS   DIAM.    CUMDP   CALIB        CYCLONE       6.390 MG
  264     .1640   .0000    .3808        STAGE  1       .280 MG
  264     .1250   .0000    .3808        STAGE  2       .001 MG
  264     .0950   .0000    .3808        STAGE  3       .060 MG
  264     .0760   .0000    .3808        STAGE  4       .100 MG
  264     .0670   .0000    .3808        STAGE  5       .950 MG
  264     .0360   .1760    .3808        STAGE  6      2.020 MG
  264     .0260   .2940    .3808        STAGE  7      1.190 MG
  156     .0250 1.0000     .3808        STAGE  8       .630 MG
IMPACTOR DP SCALING FACTOR       1.287  FILTER        9.530 MG

30D
TOTAL MASS   2.8285-002   4.7113-002   6.4727+001   1.0781+002        DMAX= 450.0
                GR/ACF        GR/DCNF       MG/ACM       MG/DNCM                MICRONS

 STAGE       MASS       MASS       % CUM.       D50      GEO. MEAN  DM/DLOGD   DN/DLOGD
             (MG)    (MG/DNCM)     MASS     (MICRONS)  (MICRONS)  (MG/DNCM)  (NO/DNCM)
CYCLONE      6.39      32.57       61.01      12.80      75.89    2.11+001   9.20+004
    1         .28       1.43       59.29      12.53      12.66    1.53+002   1.44+008
    2         .00        .01       59.29       8.00      10.20    2.85-002   5.13+004
    3         .06        .31       58.92       5[illegible]       6.73    1.68+000   1.05+007
    4         .10        .51       58.31       3.88       4.60    3.43+000   6.71+007
    5         .95       4.84       52.51       3.19       3.52    5.73+001   2.51+009
    6        2.02      10.30       40.19       1.19       1.95    2.41+001   6.18+009
    7        1.19       6.07       32.92        .69        .91    2.57+001   6.51+010
    8         .63       3.21       29.08        .47        .57    1.91+001   1.95+011
FILTER       9.53      48.58                               .33    1.61+002   8.33+012
 INTERPOLATED TO STD. INTERVALS:
                                   82.31      30.00                5.72+001
                                   71.19      20.00                4.86+001
                                   64.94      15.00                3.54+001
                                   59.95      10.00                6.38+000
                                   58.85       5.00                4.89+000
                                   52.48       2.50                2.79+001
                                   41.16       1.25                2.15+001
                                   37.66       1.00                2.90+001
                                   31.80        .63                2.06+001
```

4 OUTLET DIRTY

```
DATA FOR TEST BY CONTRACTOR GCA , AT SITE DOFQ, ON DATE 102
TEST COMMENTS:      TCOMM= DOFASCO WET QUENCH TOWER IP TESTING
PARTICLE DENSITY (GM/CC): RHO=     1.000

RUN COMMENTS:          RCOMM= 40D
DATE OF RUN:           JDATE= 102381 AMBIENT PRESSURE (IN HG)           PAMBNT=  29.74
START TIME:           ISTART=    916 STACK PRESS WRT AMBIENT (IN H2O):DPSTK=    .00
RUN DURATION (MIN):     DUR=    22.9 STACK TEMPERATURE (DEG F):        TSTACK=  155.0
RUN TYPE:             RTYPE= 0       IMPACTOR TEMPERATURE (DEG F):       TIMP=  250.0
% CARBON DIOXIDE:       CO2=      .3 MAX. PARTICLE DIAM. (MICRONS):      DMAX=  450.0
% CARBON MONOXIDE:       CO=      .0 CYCLONE CUT POINT (MICRONS):        CYCL=   12.7
% NITROGEN:              N2=    78.8 BACKUP FILTER USED?                   BF= YES
% OXYGEN:                O2=    20.9 % FILTER MASS < D50 LAST STAGE    PCTINY=   50.0
% WATER VAPOR:          H2O=    32.6 FLOW RATE DETERMINATION:
IMPACTOR TYPE:      IMPNAM=ANDERSENIMPACTOR FLOW RATE (ACFM):            FLOW=   .550
IMPACTOR MODEL:     IMPMOD=MARK 3
IMP. PLATE SET ID:IPLATE=        7 SUBSTRATES ID:                     IDSUBS=    378
NO. IMP. STAGES USED  NS=        8 DESCR=40D
NO. JETS   DIAM.   CUMDP   CALIB          CYCLONE       17.740 MG
  264     .1640   .0000    .3808          STAGE  1       9.980 MG
  264     .1250   .0000    .3808          STAGE  2        .001 MG
  264     .0950   .0000    .3808          STAGE  3        .030 MG
  264     .0760   .0000    .3808          STAGE  4        .170 MG
  264     .0670   .0000    .3808          STAGE  5        .890 MG
  264     .0360   .1760    .3808          STAGE  6       1.440 MG
  264     .0260   .2940    .3808          STAGE  7        .760 MG
  156     .0250 1.0000    .3808           STAGE  8        .270 MG
IMPACTOR DP SCALING FACTOR       1.287   FILTER         4.750 MG

40D
TOTAL MASS   4.4207-002   7.6586-002   1.0116+002   1.7526+002        DMAX= 450.0
                GR/ACF        GR/DCNF       MG/ACM       MG/DNCM             MICRONS

 STAGE        MASS       MASS        % CUM.       D50      GEO. MEAN  DM/DLOGD   DN/DLOGD
              (MG)    (MG/DNCM)      MASS      (MICRONS)  (MICRONS)  (MG/DNCM)  (NO/DNCM)
CYCLONE      17.74      86.29       47.29       12.68       75.54    5.57+001   2.47+005
      1       9.98      48.54       17.64       12.34       12.51    4.17+003   4.06+009
      2        .00        .00       17.63        8.18       10.05    2.72-002   5.12+004
      3        .03        .15       17.54        5.38        6.64    8.04-001   5.25+006
      4        .17        .83       17.04        3.82        4.54    5.56+000   1.14+008
      5        .89       4.33       14.40        3.15        3.47    5.12+001   2.34+009
      6       1.44       7.00       10.12        1.18        1.92    1.64+001   4.40+009
      7        .76       3.70        7.86         .68         .90    1.57+001   4.16+010
      8        .27       1.31        7.06         .46         .56    7.78+000   9.37+010
FILTER        4.75      23.10                                 .33    7.67+001   4.18+012
 INTERPOLATED TO STD. INTERVALS:
                                    94.87       30.00                1.67+002
                                    72.30       20.00                2.38+002
                                    52.99       15.00                2.58+002
                                    27.43       10.00                2.01+002
                                    17.47        5.00                5.33+000
                                    14.64        2.50                2.17+001
                                    10.50        1.25                2.09+001
                                     9.34        1.00                1.77+001
                                     7.64         .63                9.84+000
```

1 INLET CLEAN

```
DATA FOR TEST BY CONTRACTOR GCA , AT SITE DOFQ, ON DATE 100281, RUN NO.    2
TEST COMMENTS        TCOMM= DOFASCO WET QUENCH TOWER IP TESTING
PARTICLE DENSITY (GM/CC): RHO=     1.000

RUN COMMENTS:        RCOMM= 1IC
DATE OF RUN:         JDATE= 100281 AMBIENT PRESSURE (IN HG)         PAMBNT=   29.76
START TIME:         ISTART=   1235 STACK PRESS WRT AMBIENT (IN H2O):DPSTK=      .00
RUN DURATION (MIN):   DUR=   42.1 STACK TEMPERATURE (DEG F):        TSTACK=   155.0
RUN TYPE:           RTYPE= I       IMPACTOR TEMPERATURE (DEG F):      TIMP=   250.0
% CARBON DIOXIDE:     CO2=      .3 MAX. PARTICLE DIAM. (MICRONS):     DMAX=  1000.0
% CARBON MONOXIDE:     CO=      .0 CYCLONE CUT POINT (MICRONS):       CYCL=    12.8
% NITROGEN:            N2=    78.8 BACKUP FILTER USED?                  BF= YES
% OXYGEN:              O2=    20.9 % FILTER MASS < D50 LAST STAGE  PCTINY=    50.0
% WATER VAPOR:        H2O=    29.9 FLOW RATE DETERMINATION:
IMPACTOR TYPE:     IMPNAM=ANDERSENIMPACTOR FLOW RATE (ACFM):          FLOW=    .540
IMPACTOR MODEL:    IMPMOD=MARK 3
IMP. PLATE SET ID:IPLATE=       7 SUBSTRATES ID:                     IDSUBS=     488
NO. IMP. STAGES USED  NS=       8 DESCR=1IC
NO. JETS  DIAM.   CUMDP  CALIB          CYCLONE        3.960 MG
  264    .1640  .0000   .3808           STAGE  1       2.521 MG
  264    .1250  .0000   .3808           STAGE  2        .930 MG
  264    .0950  .0000   .3808           STAGE  3       4.860 MG
  264    .0760  .0000   .3808           STAGE  4       2.920 MG
  264    .0670  .0000   .3808           STAGE  5       3.550 MG
  264    .0360  .1760   .3808           STAGE  6       3.390 MG
[illegible]  .0260  .2940   .3808           STAGE  7       1.450 MG
[illegible]  .0250 1.0000   .3808           STAGE  8       1.720 MG
IMPACTOR DP SCALING FACTOR       1.287  FILTER         9.410 MG

1IC
TOTAL MASS  2.3546-002  3.9189-002  5.3881+001  8.9679+001       DMAX=1000.0
              GR/ACF        GR/DCNF      MG/ACM       MG/DNCM              MICRONS

 STAGE       MASS       MASS       % CUM.        D50      GEO. MEAN  DM/DLOGD   DN/DLOGD
             (MG)    (MG/DNCM)     MASS       (MICRONS)  (MICRONS)  (MG/DNCM)  (NO/DNCM)
CYCLONE      3.96      10.23       86.80        12.80      113.14   5.41+000   7.13+003
    1        2.52       6.51       78.40        12.54       12.67   7.21+002   6.77+008
    2         .93       2.40       75.30         8.31       10.20   1.34+001   2.42+007
    3        4.86      12.56       59.10         5.47        6.74   6.91+001   4.31+008
    4        2.92       7.54       49.37         3.88        4.61   5.07+001   9.91+008
    5        3.55       9.17       37.54         3.20        3.52   1.08+002   4.74+009
    6        3.39       8.76       26.24         1.19        1.95   2.05+001   5.25+009
    7        1.45       3.75       21.41          .69         .91   1.59+001   4.02+010
    8        1.72       4.44       15.68          .47         .57   2.64+001   2.70+011
FILTER       9.41      24.31                                  .33   8.08+001   4.17+012
 INTERPOLATED TO STD. INTERVALS:
                                  104.73        30.00                2.77+001
                                   97.46        20.00                3.66+001
                                   91.03        15.00                4.29+001
                                   80.43        10.00                5.13+001
                                   56.38         5.00                5.77+001
                                   38.60         2.50                3.66+001
                                   27.37         1.25                2.19+001
                                   24.88         1.00                1.79+001
                                   19.91          .63                2.39+001
```

3 INLET CLEAN

```
DATA FOR TEST BY CONTRACTOR GCA , AT SITE DOFQ, ON DATE 100581, RUN NO.    2
TEST COMMENTS        TCOMM= DOFASCO WET QUENCH TOWER IP TESTING
PARTICLE DENSITY (GM/CC): RHO=     1.000

RUN COMMENTS:        RCOMM= 3IC
DATE OF RUN:         JDATE= 100581 AMBIENT PRESSURE (IN HG)          PAMBNT=  29.86
START TIME:         ISTART=   1020 STACK PRESS WRT AMBIENT (IN H2O):DPSTK=     .00
RUN DURATION (MIN):   DUR=    36.8 STACK TEMPERATURE (DEG F):        TSTACK=  155.0
RUN TYPE:           RTYPE= I       IMPACTOR TEMPERATURE (DEG F):       TIMP=  250.0
% CARBON DIOXIDE:     CO2=      .3 MAX. PARTICLE DIAM. (MICRONS):      DMAX= 1000.0
% CARBON MONOXIDE:     CO=      .0 CYCLONE CUT POINT (MICRONS):        CYCL=    13.0
% NITROGEN:            N2=    78.8 BACKUP FILTER USED?                   BF= YES
% OXYGEN:              O2=    20.9 % FILTER MASS < D50 LAST STAGE  PCTINY=    50.0
% WATER VAPOR:        H2O=    25.9 FLOW RATE DETERMINATION:
IMPACTOR TYPE:    IMPNAM=ANDERSENIMPACTOR FLOW RATE (ACFM):            FLOW=    .520
IMPACTOR MODEL:   IMPMOD=MARK 3
IMP. PLATE SET ID:IPLATE=        7 SUBSTRATES ID:                    IDSUBS=     489
NO. IMP. STAGES USED  NS=        8 DESCR=3IC
NO. JETS  DIAM.   CUMDP  CALIB          CYCLONE        96.229 MG
  264    .1640  .0000   .3808           STAGE  1        1.890 MG
  264    .1250  .0000   .3808           STAGE  2         .520 MG
  264    .0950  .0000   .3808           STAGE  3         .500 MG
  264    .0760  .0000   .3808           STAGE  4         .420 MG
  264    .0670  .0000   .3808           STAGE  5        1.060 MG
  264    .0360  .1760   .3808           STAGE  6        1.330 MG
  264    .0260  .2940   .3808           STAGE  7         .870 MG
  156    .0250 1.0000   .3808           STAGE  8         .180 MG
IMPACTOR DP SCALING FACTOR      1.287   FILTER          4.900 MG

3IC
TOTAL MASS  8.7016-002  1.3661-001  1.9912+002  3.1261+002       DMAX=1000.0
              GR/ACF       GR/DCNF      MG/ACM      MG/DNCM              MICRONS

 STAGE        MASS       MASS       % CUM.        D50      GEO. MEAN  DM/DLOGD   DN/DLOGD
              (MG)    (MG/DNCM)      MASS      (MICRONS)  (MICRONS)  (MG/DNCM)  (NO/DNCM)
CYCLONE      96.23      278.80        8.74        13.05     114.24   1.48+002   1.90+005
     1        1.89        5.47        6.95        12.89      12.97   1.04+003   9.07+008
     2         .52        1.51        6.46         8.54      10.49   8.43+000   1.39+007
     3         .50        1.45        5.98         5.62       6.93   7.98+000   4.58+007
     4         .42        1.22        5.59         3.99       4.74   8.19+000   1.47+008
     5        1.06        3.07        4.58         3.29       3.62   3.63+001   1.46+009
     6        1.33        3.85        3.32         1.23       2.01   9.03+000   2.12+009
     7         .87        2.52        2.49          .72        .94   1.07+001   2.47+010
     8         .18         .52        2.32          .49        .59   3.12+000   2.89+010
FILTER        4.90       14.20                                 .34   4.72+001   2.21+012
  INTERPOLATED TO STD. INTERVALS:
                                     22.33        30.00              1.71+002
                                     14.18        20.00              1.11+002
                                     10.38        15.00              7.65+001
                                      7.22        10.00              3.10+001
                                      5.85         5.00              8.87+000
                                      4.68         2.50              1.39+001
                                      3.32         1.25              1.27+001
                                      2.94         1.00              1.10+001
                                      2.40          .63              4.23+000
```

4 INLET CLEAN

```
DATA FOR TEST BY CONTRACTOR GCA , AT SITE DOFO, ON DATE 100581, RUN NO.    3
TEST COMMENTS       TCOMM= DOFASCO WET QUENCH TOWER IP TESTING
PARTICLE DENSITY (GM/CC): RHO=     1.000

RUN COMMENTS:        RCOMM= 4IC
DATE OF RUN:         JDATE= 100581 AMBIENT PRESSURE (IN HG)           PAMBNT=  30.11
START TIME:         ISTART=   1511 STACK PRESS WRT AMBIENT (IN H2O):DPSTK=     .00
RUN DURATION (MIN):   DUR=   38.2 STACK TEMPERATURE (DEG F):        TSTACK=  155.0
RUN TYPE:            RTYPE= I      IMPACTOR TEMPERATURE (DEG F):      TIMP=  250.0
% CARBON DIOXIDE:     CO2=     .3 MAX. PARTICLE DIAM. (MICRONS):      DMAX= 1000.0
% CARBON MONOXIDE:     CO=     .0 CYCLONE CUT POINT (MICRONS):        CYCL=   13.0
% NITROGEN:            N2=   78.8 BACKUP FILTER USED?                   BF= YES
% OXYGEN:              O2=   20.9 % FILTER MASS < D50 LAST STAGE  PCTINY=   50.0
% WATER VAPOR:        H2O=   28.5 FLOW RATE DETERMINATION:
IMPACTOR TYPE:      IMPNAM=ANDERSENIMPACTOR FLOW RATE (ACFM):         FLOW=   .520
IMPACTOR MODEL:     IMPMOD=MARK 3
IMP. PLATE SET ID:IPLATE=       7 SUBSTRATES ID:                    IDSUBS=    480
NO. IMP. STAGES USED  NS=       8 DESCR=4IC
NO. JETS   DIAM.   CUMDP   CALIB          CYCLONE        73.671 MG
  264     .1640  .0000    .3808          STAGE  1        2.940 MG
  264     .1250  .0000    .3808          STAGE  2        1.040 MG
  264     .0950  .0000    .3808          STAGE  3         .930 MG
  264     .0760  .0000    .3808          STAGE  4        1.080 MG
  264     .0670  .0000    .3808          STAGE  5        1.270 MG
  264     .0360  .1760    .3808          STAGE  6        1.190 MG
  264     .0260  .2940    .3808          STAGE  7         .930 MG
  156     .0250 1.0000    .3808          STAGE  8         .340 MG
IMPACTOR DP SCALING FACTOR      1.287    FILTER          1.340 MG

4IC
TOTAL MASS   6.5742-002  1.0605-001  1.5044+002  2.4267+002        DMAX=1000.0
                GR/ACF      GR/DCNF      MG/ACM      MG/DNCM               MICRONS

 STAGE        MASS        MASS      % CUM.        D50      GEO. MEAN DM/DLOGD   DN/DLOGD
              (MG)    (MG/DNCM)     MASS      (MICRONS)  (MICRONS)  (MG/DNCM)  (NO/DNCM)
CYCLONE      73.67      210.99      12.36       13.05      114.24   1.12+002   1.43+005
     1        2.94        8.42       8.86       12.82       12.93   1.08+003   9.57+008
     2        1.04        2.98       7.63        8.49       10.44   1.67+001   2.80+007
     3         .93        2.66       6.52        5.59        6.89   1.47+001   8.56+007
     4        1.08        3.09       5.23        3.97        4.71   2.08+001   3.80+008
     5        1.27        3.64       3.72        3.27        3.60   4.31+001   1.76+009
     6        1.19        3.41       2.31        1.22        2.00   7.99+000   1.90+009
     7         .93        2.66       1.20         .71         .93   1.13+001   2.65+010
     8         .34         .97        .80         .49         .59   5.83+000   5.47+010
FILTER        1.34        3.84                                .34   1.27+001   6.03+011
 INTERPOLATED TO STD. INTERVALS:
                                    31.30       30.00                1.71+002
                                    20.34       20.00                1.27+002
                                    14.60       15.00                9.55+001
                                     9.13       10.00                5.15+001
                                     6.10        5.00                1.69+001
                                     4.00        2.50                1.50+001
                                     2.29        1.25                1.23+001
                                     1.82        1.00                1.14+001
                                     1.04         .63                6.47+000
```

1 OUTLET CLEAN

```
DATA FOR TEST BY CONTRACTOR GCA , AT SITE DOFQ, ON DATE 100281, RUN NO.    3
TEST COMMENTS        TCOMM= DOFASCO WET QUENCH TOWER IP TESTING
PARTICLE DENSITY (GM/CC): RHO=     1.000

RUN COMMENTS:        RCOMM= 10C
DATE OF RUN:         JDATE= 100281 AMBIENT PRESSURE (IN HG)         PAMBNT=  29.76
START TIME:         ISTART=   1235 STACK PRESS WRT AMBIENT (IN H2O):DPSTK=     .00
RUN DURATION (MIN):   DUR=   42.1 STACK TEMPERATURE (DEG F):       TSTACK=  155.0
RUN TYPE:           RTYPE= D      IMPACTOR TEMPERATURE (DEG F):      TIMP=  250.0
% CARBON DIOXIDE:     CO2=     .3 MAX. PARTICLE DIAM. (MICRONS):     DMAX=  450.0
% CARBON MONOXIDE:     CO=     .0 CYCLONE CUT POINT (MICRONS):       CYCL=   12.7
% NITROGEN:            N2=   78.8 BACKUP FILTER USED?                  BF= YES
% OXYGEN:              O2=   20.9 % FILTER MASS < D50 LAST STAGE  PCTINY=   50.0
% WATER VAPOR:        H2O=   32.3 FLOW RATE DETERMINATION:
IMPACTOR TYPE:      IMPNAM=ANDERSENIMPACTOR FLOW RATE (ACFM):        FLOW=    .550
IMPACTOR MODEL:     IMPMOD=MARK 3
IMP. PLATE SET ID:IPLATE=       7 SUBSTRATES ID:                   IDSUBS=    471
NO. IMP. STAGES USED  NS=       8 DESCR=10C
NO. JETS  DIAM.    CUMDP  CALIB          CYCLONE      80.950 MG
  264     .1640  .0000   .3808          STAGE  1      1.591 MG
  264     .1250  .0000   .3808          STAGE  2       .010 MG
  264     .0950  .0000   .3808          STAGE  3       .001 MG
  264     .0760  .0000   .3808          STAGE  4       .240 MG
  264     .0670  .0000   .3808          STAGE  5       .660 MG
  264     .0360  .1760   .3808          STAGE  6      1.000 MG
  264     .0260  .2940   .3808          STAGE  7       .700 MG
  156     .0250 1.0000   .3808          STAGE  8       .001 MG
IMPACTOR DP SCALING FACTOR      1.287   FILTER        1.730 MG

10C
TOTAL MASS  5.7864-002  9.9722-002  1.3241+002  2.2820+002      DMAX= 450.0
              GR/ACF      GR/DCNF     MG/ACM      MG/DNCM              MICRONS

 STAGE      MASS      MASS      % CUM.       D50      GEO. MEAN  DM/DLOGD   DN/DLOGD
            (MG)   (MG/DNCM)    MASS     (MICRONS)  (MICRONS)  (MG/DNCM)  (NO/DNCM)
CYCLONE    80.95    212.62      5.89       12.68      75.54    1.37+002   6.08+005
    1       1.59      4.18      4.04       12.35      12.52    3.68+002   3.59+008
    2        .01       .03      4.03        8.18      10.06    1.47-001   2.76+005
    3        .00       .00      4.03        5.39       6.64    1.45-002   9.43+004
    4        .24       .63      3.75        3.83       4.54    4.24+000   8.65+007
    5        .66      1.73      2.98        3.15       3.47    2.05+001   9.37+008
    6       1.00      2.63      1.82        1.18       1.92    6.14+000   1.65+009
    7        .70      1.84      1.01         .68        .90    7.79+000   2.06+010
    8        .00       .00      1.01         .46        .56    1.56-002   1.68+008
FILTER      1.73      4.54                                .33    1.51+001   8.20+011
 INTERPOLATED TO STD. INTERVALS:
                                20.57       30.00                 1.49+002
                                11.50       20.00                 8.86+001
                                 7.63       15.00                 5.40+001
                                 4.76       10.00                 1.84+001
                                 3.98        5.00                 2.89+000
                                 3.09        2.50                 9.07+000
                                 1.84        1.25                 8.84+000
                                 1.48        1.00                 7.72+000
                                 1.02         .63                 1.69+000
```

2 OUTLET CLEAN

```
DATA FOR TEST BY CONTRACTOR GCA , AT SITE DOFO, ON DATE 100381, RUN NO.
TEST COMMENTS        TCOMM= DOFASCO WET QUENCH TOWER IP TESTING
PARTICLE DENSITY (GM/CC): RHO=    1.000

RUN COMMENTS:         RCOMM= 20C
DATE OF RUN:          JDATE= 100381 AMBIENT PRESSURE (IN HG)          PAMBNT=  29.34
START TIME:          ISTART=   1545 STACK PRESS WRT AMBIENT (IN H2O):DPSTK=     .00
RUN DURATION (MIN):    DUR=    29.3 STACK TEMPERATURE (DEG F):       TSTACK=  155.0
RUN TYPE:            RTYPE= 0       IMPACTOR TEMPERATURE (DEG F):      TIMP=  250.0
% CARBON DIOXIDE:      CO2=      .3 MAX. PARTICLE DIAM. (MICRONS):     DMAX=  450.0
% CARBON MONOXIDE:      CO=      .0 CYCLONE CUT POINT (MICRONS):       CYCL=   12.7
% NITROGEN:             N2=    78.8 BACKUP FILTER USED?                  BF= YES
% OXYGEN:               O2=    20.9 % FILTER MASS < D50 LAST STAGE  PCTINY=   50.0
% WATER VAPOR:         H2O=    30.1 FLOW RATE DETERMINATION:
IMPACTOR TYPE:      IMPNAM=ANDERSENIMPACTOR FLOW RATE (ACFM):          FLOW=   .550
IMPACTOR MODEL:     IMPMOD=MARK 3
IMP. PLATE SET ID:IPLATE=         7 SUBSTRATES ID:                   IDSUBS=    308
NO. IMP. STAGES USED  NS=         8 DESCR=20C
NO. JETS  DIAM.   CUMDP   CALIB          CYCLONE     42.150 MG
  264    .1640  .0000    .3808          STAGE  1       .579 MG
  264    .1250  .0000    .3808          STAGE  2       .180 MG
  264    .0950  .0000    .3808          STAGE  3       .670 MG
  264    .0760  .0000    .3808          STAGE  4       .620 MG
  264    .0670  .0000    .3808          STAGE  5      1.220 MG
  264    .0360  .1760    .3808          STAGE  6      1.830 MG
  264    .0260  .2940    .3808          STAGE  7       .960 MG
  156    .0250 1.0000    .3808          STAGE  8       .620 MG
IMPACTOR DP SCALING FACTOR      1.287  FILTER        1.220 MG

20C
TOTAL MASS  4.7848-002  8.1020-002  1.0949+002  1.8540+002       DMAX= 450.0
              GR/ACF      GR/DCNF      MG/ACM      MG/DNCM              MICRONS

 STAGE       MASS       MASS      % CUM.        D50     GEO. MEAN DM/DLOGD  DN/DLOGD
             (MG)    (MG/DNCM)    MASS      (MICRONS) (MICRONS) (MG/DNCM) (NO/DNCM)
CYCLONE     42.15     156.14      14.74       12.68     75.54   1.01+002  4.46+005
    1         .58       2.15      13.57       12.41     12.55   2.33+002  2.25+008
    2         .18        .67      13.21        8.22     10.10   3.73+000  6.90+006
    3         .67       2.48      11.85        5.41      6.67   1.37+001  8.78+007
    4         .62       2.30      10.60        3.84      4.56   1.54+001  3.11+008
    5        1.22       4.52       8.13        3.16      3.49   5.34+001  2.41+009
    6        1.83       6.78       4.43        1.18      1.93   1.58+001  4.19+009
    7         .96       3.56       2.49         .69       .90   1.50+001  3.95+010
    8         .62       2.30       1.23         .46       .56   1.36+001 PLZ5+011
FILTER       1.22       4.52                              .33   1.50+001  8.12+011
 INTERPOLATED TO STD. INTERVALS:
                                  32.80       30.00              1.28+002
                                  22.51       20.00              8.83+001
                                  17.60       15.00              5.78+001
                                  13.86       10.00              1.46+001
                                  11.59        5.00              1.52+001
                                   8.34        2.50              2.27+001
                                   4.78        1.25              1.91+001
                                   3.84        1.00              1.67+001
                                   2.15         .63              1.43+001
```

4 OUTLET CLEAN

```
DATA FOR TEST BY CONTRACTOR GCA , AT SITE DOFO, ON DATE 100581. RUN NO.   4
TEST COMMENTS       TCOMM= DOFASCO WET QUENCH TOWER IP TESTING
PARTICLE DENSITY (GM/CC): RHO=     1.000

RUN COMMENTS:          RCOMM= 40C
DATE OF RUN:           JDATE= 100581 AMBIENT PRESSURE (IN HG)              PAMBNT=  30.11
START TIME:           ISTART=   1511 STACK PRESS WRT AMBIENT (IN H2O):DPSTK=      .00
RUN DURATION (MIN):    DUR=     38.2 STACK TEMPERATURE (DEG F):          (TSTACK=  155.0
RUN TYPE:             RTYPE= 0        IMPACTOR TEMPERATURE (DEG F):        TIMP=  250.0
% CARBON DIOXIDE:        CO2=      .3 MAX. PARTICLE DIAM. (MICRONS):       DMAX=  450.0
% CARBON MONOXIDE:        CO=      .0 CYCLONE CUT POINT (MICRONS):         CYCL=   12.7
% NITROGEN:               N2=    78.8 BACKUP FILTER USED?                    BF= YES
% OXYGEN:                 O2=    20.9 % FILTER MASS < D50 LAST STAGE  PCTINY=    50.0
% WATER VAPOR:           H2O=    34.2 FLOW RATE DETERMINATION:
IMPACTOR TYPE:       IMPNAM=ANDERSENIMPACTOR FLOW RATE (ACFM):            FLOW=    .550
IMPACTOR MODEL:      IMPMOD=MARK 3
IMP. PLATE SET ID:IPLATE=        7 SUBSTRATES ID:
NO. IMP. STAGES USED  NS=        8 DESCR=40C                          IDSUBS=     266
NO. JETS  DIAM.    CUMDP   CALIB           CYCLONE        46.400 MG
  264     .1640   .0000    .3808           STAGE  1        5.181 MG
  264     .1250   .0000    .3808           STAGE  2         .080 MG
  264     .0950   .0000    .3808           STAGE  3        1.060 MG
  264     .0760   .0000    .3808           STAGE  4         .320 MG
  264     .0670   .0000    .3808           STAGE  5        2.620 MG
  264     .0360   .1760    .3808           STAGE  6         .670 MG
  264     .0260   .2940    .3808           STAGE  7         .600 MG
  156     .0250  1.0000    .3808           STAGE  8         .120 MG
IMPACTOR DP SCALING FACTOR         1.287   FILTER          1.680 MG

40C
TOTAL MASS   4.3083-002   7.5583-002   9.8589+001   1.7296+002        DMAX= 450.0
               GR/ACF        GR/DCNF      MG/ACM        MG/DNCM               MICRONS

 STAGE        MASS       MASS       % CUM.        D50      GEO. MEAN  DM/DLOGD   DN/DLOGD
              (MG)    (MG/DNCM)     MASS       (MICRONS)  (MICRONS)  (MG/DNCM)  (NO/DNCM)
CYCLONE      46.40     136.65      19.85        12.68       75.54    8.82+001   3.91+005
    1         5.18      15.26      10.90        12.30       12.49    1.15+003   1.13+009
    2          .08        .24      10.76         8.15       10.01    1.32+000   2.51+006
    3         1.06       3.12       8.93         5.36        6.61    1.72+001   1.14+008
    4          .32        .94       8.38         3.81        4.52    6.34+000   1.31+008
    5         2.62       7.72       3.85         3.14        3.46    9.13+001   4.22+009
    6          .67       1.97       2.69         1.17        1.92    4.62+000   1.25+009
    7          .60       1.77       1.66          .68         .89    7.50+000   2.01+010
    8          .12        .35       1.45          .46         .56    2.10+000   2.27+010
FILTER        1.68       4.95                                 .33    1.64+001   8.98+011
 INTERPOLATED TO STD. INTERVALS:
                                   48.10        30.00                1.55+002
                                   32.91        20.00                1.36+002
                                   23.81        15.00                1.12+002
                                   14.20        10.00                7.07+001
                                    8.83         5.00                1.15+001
                                    5.96         2.50                2.01+001
                                    2.93         1.25                1.27+001
                                    2.30         1.00                9.13+000
                                    1.59          .63                3.20+000
```

5 OUTLET CLEAN

```
DATA FOR TEST BY CONTRACTOR GCA , AT SITE DOFQ, ON DATE 100681, RUN NO.    3
TEST COMMENTS        TCOMM= DOFASCO WET QUENCH TOWER IP TESTING(TORN SUBSTRATES)
PARTICLE DENSITY (GM/CC): RHO=     1.000

RUN COMMENTS:          RCOMM= 50C(UNTORN)
DATE OF RUN:           JDATE= 100681 AMBIENT PRESSURE (IN HG)            PAMBNT=  30.08
START TIME:           ISTART=   1314 STACK PRESS WRT AMBIENT (IN H2O):DPSTK=     .00
RUN DURATION (MIN):     DUR=   25.1 STACK TEMPERATURE (DEG F):           TSTACK=  155.0
RUN TYPE:             RTYPE= 0      IMPACTOR TEMPERATURE (DEG F):          TIMP=  250.0
% CARBON DIOXIDE:       CO2=      .3 MAX. PARTICLE DIAM. (MICRONS):        DMAX=  450.0
% CARBON MONOXIDE:       CO=      .0 CYCLONE CUT POINT (MICRONS):          CYCL=   12.5
% NITROGEN:              N2=    78.8 BACKUP FILTER USED?                     BF= YES
% OXYGEN:                O2=    20.9 % FILTER MASS < D50 LAST STAGE  PCTINY=    50.0
% WATER VAPOR:          H2O=    36.0 FLOW RATE DETERMINATION:
IMPACTOR TYPE:      IMPNAM=ANDERSENIMPACTOR FLOW RATE (ACFM):            FLOW=    .570
IMPACTOR MODEL:     IMPMOD=MARK 3
IMP. PLATE SET ID:IPLATE=        7 SUBSTRATES ID:                      IDSUBS=      18
NO. IMP. STAGES USED  NS=        8 DESCR=50C
NO. JETS   DIAM.   CUMDP   CALIB         CYCLONE      19.600 MG
  264     .1640   .0000   .3808          STAGE  1      1.800 MG
  264     .1250   .0000   .3808          STAGE  2       .520 MG
  264     .0950   .0000   .3808          STAGE  3       .920 MG
  264     .0760   .0000   .3808          STAGE  4      1.260 MG
  264     .0670   .0000   .3808          STAGE  5      1.630 MG
  264     .0360   .1760   .3808          STAGE  6       .510 MG
  264     .0260   .2940   .3808          STAGE  7       .010 MG
  156     .0250 1.0000    .3808          STAGE  8       .001 MG
 IMPACTOR DP SCALING FACTOR      1.287   FILTER        4.940 MG

 50C(UNTORN)
 TOTAL MASS  3.3670-002  6.0765-002  7.7050+001  1.3905+002       DMAX= 450.0
                GR/ACF      GR/DCNF      MG/ACM      MG/DNCM              MICRONS

  STAGE        MASS       MASS      % CUM.        D50     GEO. MEAN  DM/DLOGD  DN/DLOGD
               (MG)    (MG/DNCM)    MASS       (MICRONS) (MICRONS) (MG/DNCM)  (NO/DNCM)
 CYCLONE      19.60      87.38      31.76        12.45     74.85    5.61+001   2.55+005
    1          1.80       8.02      25.49        12.03     12.24    5.37+002   5.60+008
    2           .52       2.32      23.68         7.97      9.79    1.30+001   2.64+007
    3           .92       4.10      20.48         5.25      6.47    2.26+001   1.60+008
    4          1.26       5.62      16.09         3.72      4.42    3.78+001   8.35+008
    5          1.63       7.27      10.41         3.07      3.38    8.59+001   4.25+009
    6           .51       2.27       8.64         1.14      1.87    5.32+000   1.54+009
    7           .01        .04       8.60          .66       .87    1.89-001   5.43+008
    8           .00        .00       8.60          .45       .55    2.63-002   3.08+008
 FILTER        4.94      22.02                                 .32    7.32+001   4.33+012
  INTERPOLATED TO STD. INTERVALS:
                                    58.54        30.00               1.03+002
                                    45.01        20.00               9.27+001
                                    36.66        15.00               7.82+001
                                    27.46        10.00               5.05+001
                                    19.70         5.00               3.11+001
                                    12.26         2.50               2.16+001
                                     9.06         1.25               6.87+000
                                     8.69         1.00               2.87+000
                                     8.60          .63               8.27-002
```

APPENDIX D-1

TOTAL PARTICULATE FIELD DATA

(Note: Sheets to be provided in Final Report).

APPENDIX D-2

IMPACTOR FIELD DATA SHEETS

Note: Sheets to be provided in Final Report.

APPENDIX D-3

DUAL CYCLONE FIELD DATA SHEETS

Note: Sheets to be provided in Final Report.

ONTARIO**RESEARCH**
FOUNDATION

SHERIDAN PARK RESEARCH COMMUNITY
MISSISSAUGA, ONTARIO, CANADA L5K 1B3 • (416) 822-4111 • TELEX 06-982311

GCA Corporation,
Technology Division,
213 Burlington Road,
Bedford, Mass. 01730.

November 20, 1981

Attention: Mr. John Jeffery.

REPORT NUMBER	ACS5-81820
IDENTIFICATION	P.O. No. 31442 ORF Quote No. ACS5-81-1
SPECIFICATIONS OF ORDER	Analyse: 42 samples for sulphide 45 samples for phenol 42 samples for ammonia 18 samples for total cyanide 16 samples for cyanides amenable to chlorination

---

RESULTS

Shown on attached Tables 1 and 2.

GENERAL

The samples were refrigerated (4°C) immediately upon receipt and analysed within the time limit described under Procedures.

PROCEDURES

Sulphide

Because of possible interferences using the direct iodometric procedure, all samples were analysed in accordance with Standard Methods, 13th ed., 1971, Method No. 228A, involving acidifaction of a known aliquot of the sample followed by purging with nitrogen to evolve sulphides, and subsequently collect the sulphides in a train of impingers containing zinc acetate solution. The sulphide in the impingers was then determined using the iodine titrimetric method (Standard Methods, 13th ed., Method No. 228A.

Precision: At ORF using industrial effluent samples at concentrations of 2.3 and 48 mg/L sulphide, the standard deviation was ±0.2 mg/L and ±2.4 mg/L respectively.

Accuracy: Recoveries from the acidified and purged standards, when compared with direct iodometric measurement of sulphides, were 96% sulphide.

Phenolic Compounds

Phenol analyses were carried out within forty eight hours of receipt. The method of analysis used was an automated distillation, 4AAP colorimetric method using Technicon equipment (Appendix I) in a procedure provided by the Ontario Ministry of the Environment.

Precision: At ORF using surface water at 0.5 µg/L pehnol and industrial effluent at 34.3 µg/L phenol the standard deviation was ±0.2 µg/L phenol and ±1.1 µg/L phenol respectively.

Accuracy: Various recoveries depending on the type of phenol present. Phenol distilled from reagent grade crystals yield 88-100% recoveries. Phenol from pentachlorophenol (PCP) at 103 µg/L PCP yielded 25% recovery. of phenol.

Ammonia

Ammonia analysis was performed within seven days of receipt of sample. All samples were distilled to pH 9.5 prior to Nesslerization and spectrophotometric measurement (Standard Methods, 14th ed., 1975, Method No. 418 A&B).

Precision: At ORF using surface water at 0.32 mg/L N and industrial effluent at 2.51 mg/L N the standard deviation was ±0.02 and ±0.04 respectively.

Accuracy: At ORF using surface water and waste water at 0.51 mg/L N and 1.81 mg/L N the recoveries were 98.8% and 90.5%* respectively.

---

* used steel mill waste as spiked sample

Cyanides (Total and Amenable to Chlorination)

All samples were originally analysed within seven days of receipt, but because of interferences with the method (Standard Methods, 14th ed., 1975, Method No. 413 B, D and F), both in the Total CN analyses and in the chlorinated analyses, all samples were repeated using procedures outlined in ASTM, Part 31, 1981 edition, Method No. 2036-81B. The reported cyanide analyses were completed within fourteen days of receipt of samples.

The interferences encountered appeared to arise from organo-sulphur compounds which formed sulphides on acidification and heating, during the reflux-distillation procedure. These sulphides interfered with subsequent titrimetric measurement of the total cyanide evolved and trapped in the absorption solution. Colour interferences with the pyridine barbituric acid colorimetric method were also encountered from organic compounds on chlorination of the sample.

To remove these interferences, the following procedures were used:

Total Cyanides

Sulphides were removed from the samples by precipitation with lead carbonate followed by immediate filtration.

For total cyanides an aliquot was reflux-distilled for two hours using magnesium chloride as a catalyst in 5% H_2SO_4. The HCN evolved was trapped in an NaOH absorption solution containing lead carbonate to remove H_2S liberated from organo-sulphur compounds during the acid digestion, reflux-distillation procedure. The absorption solution was then filtered, made up to a known volume and analyzed for CN^- content by titration with standardized $AgNO_3$ using Rhodamine dye as an indicator solution.

Cyanides Amenable to Chlorination

For cyanides amenable to chlorination, an aliquot was taken from the initial sample which had been treated with lead carbonate and filtered. This sample was treated with calcium hypochlorite under alkaline conditions (pH >11) until there was a measurable excess of chlorine for one hour. After one hour of chlorination, ascorbic acid was added to remove excess chlorine. Analysis for cyanide remaining was conducted by the reflux-distillation method for total cyanides exactly as described above.

Precision and accuracy data are unavailable for the ASTM method, but six sets of duplicate samples were run with two levels of KCN and two levels of $K_3Fe(CN)_6$ and $K_4Fe(CN)_6$ (see Tables 3 and 4).

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TABLE I

Samples received week of October 2, 1981

Sample	Date Sampled	Date Received	Sulphide mg/L	Phenol mg/L	Ammonia mg/L	CN⁻ (mg/L)	
						Total	Amen. to Cl_2
1-CM-A	Oct. 2	Oct. 4	<0.4	0.0012	1.8		
1-CQ-A	Oct. 2	Oct. 4	<0.4	0.300	1.8		
1-CR-A	Oct. 2	Oct. 4	<0.4	0.306	1.4		
1-CM-B	Oct. 3	Oct. 4	<0.4	0.0022	1.1		
1-CQ-B	Oct. 3	Oct. 4	<0.4	0.239	1.6		
1-CR-B	Oct. 3	Oct. 4	<0.4	0.208	1.0		
2-CM	Oct. 3	Oct. 4	<0.4	0.0012	1.3		
2-CQ	Oct. 3	Oct. 4	<0.4	0.0372	2.5		
2-CR	Oct. 3	Oct. 4	<0.4	0.550	2.1		
3-CM	Oct. 5	Oct. 7	<0.4	0.0058	0.7		
3-CQ	Oct. 5	Oct. 7	<0.4	0.418	3.9		
3-CR	Oct. 5	Oct. 7	<0.4	0.454	2.6		
4-CM	Oct. 5	Oct. 5	<0.4	0.0013	0.5		
4-CQ	Oct. 5	Oct. 5	<0.4	0.210	2.1		
4-CR	Oct. 5	Oct. 5	<0.4	0.261	1.3		
5-CM	Oct. 8	Oct. 9	<0.4	0.0012	1.0		
5-CQ	Oct. 8	Oct. 9	<0.4	0.711	6.6		
5-CR	Oct. 8	Oct. 9	0.6	0.783	4.0		
1-ORG-C-M	Oct. 8	Oct. 9	-	0.0016	-	0.023**	<0.1
1-ORG-C-Q	Oct. 8	Oct. 9	-	0.370	-	0.178**	Lost
1-ORG-C-R	Oct. 8	Oct. 9	-	0.460	-	0.103**	Lost
1-SD-M	Oct. 9	Oct. 10	45.9	870	3750		
1-SD-Q	Oct. 9	Oct. 10	1.8	85.3	486		
1-SD-R	Oct. 9	Oct. 10	1.3	80.2	465		
2-SD-M	Oct. 9	Oct. 10	31.1	768	3900		
2-SD-Q	Oct. 9	Oct. 10	2.8	86.9	486		
2-SD-R	Oct. 9	Oct. 10	3.2	69.1	525		
3-SD-M	Oct. 9	Oct. 10	34.7	787	3550		
3-SD-Q	Oct. 9	Oct. 10	1.8	90.5	610		
3-SD-R	Oct. 9	Oct. 10	1.5	76.1	560		

**Used pyridine - barbituric acid colorimetric measurement

TABLE 2

Samples received week of October 20, 1981

Sample	Date Sampled	Date Received	Sulphide mg/L	Phenol mg/L	Ammonia mg/L	Cyanide, mg/L		
						Total	After Chlorination	Amenable to Chlorination
1-D-M	Oct. 20	Oct. 20	46.4	724	3250	49.3	2.3	47.0
1-D-Q	Oct. 20	Oct. 20	14.3	318	2770	5.8	0.8	5.0
1-D-R	Oct. 20	Oct. 20	15.6	282	3020	4.5	ND<0.2	4.5
2-DM	Oct. 21	Oct. 22	47.3	732*	2670	44.8	1.7	43.1
2-DQ	Oct. 21	Oct. 22	28.6*	363	2380	3.0	0.4	2.6
2-DR	Oct. 21	Oct. 22	38.5	324	2560	1.2	ND<0.2	1.2
3-DM	Oct. 22	Oct. 22	58.0	634	3020	45.8	3.5	42.3
3-DQ	Oct. 22	Oct. 22	25.6	311	2370	4.2	1.0	3.2
3-DR	Oct. 22	Oct. 22	20.2	266	2450	2.3	1.0	1.3
4-DM	Oct. 23	Oct. 23	44.6	610	2900	44.3	6.7	37.6
4-DQ	Oct. 23	Oct. 23	19.3	213	1860	1.9	0.3	1.6
4-DR	Oct. 23	Oct. 23	19.1	186	2050	0.5	ND<0.2	0.5
1-ORG-DM	Oct. 23	Oct. 23	42.8	612	2800	42.0	7.5	34.5
1-ORG-DQ	Oct. 23	Oct. 23	28.8	216	2120	3.2	0.3	2.9
1-ORG-DR	Oct. 23	Oct. 23	16.2	190	2000	2.8	0.2	2.6

* received Oct. 23

TABLE 3

Quality Control Data for Cyanides

Standard	CN^- Total		CN^- After Chlorination	
	Amount found mg/L	% Recovery	Amount found mg/L	% Recovery
3.72 mg/L CN^- from KCN	3.7) 3.6)	98.5	<0.005* <0.2	0
18.1 mg/L CN^- from KCN	19)	105	<0.2	0
36.2 mg/L CN^- from KCN	36)	99.4	<0.2	
9.49 mg/L CN^- from $K_3Fe(CN)_6$	9.4	99	-	-
7.39 mg/L CN^- from $K_4Fe(CN)_6$	7.04	95.3	-	-
0.237 mg/L CN^- from $K_3Fe(CN)_6$	0.25	105.5	0.23	97
0.369 mg/L CN^- from $K_4Fe(CN)_6$	0.40	108.4	0.37	100

* used pyridine barbituric acid colorimetric measurement

TABLE 4

Range Data on Duplicate Samples

Sample	CN^- Total mg/L			CN^- after Chlorination mg/L		
	1st	2nd	Range	1st	2nd	Range
2DR	1.0	1.5	±0.5			
2DQ	3.1	2.9	±0.2	0.4	0.4	-
4DM	43.4	45.3	±1.9			
4DR	0.4	0.6	±0.2			
3DM				3.6	3.5	±0.1
4DQ				0.3	0.4	±0.1
1-ORG-DR				0.3	<0.2	±0.3

APPENDIX I

PHENOLIC COMPOUNDS

AUTOMATED 4-AMINOANTIPYRINE METHOD A

SUMMARY	
Substance determined.	Phenol and substituted phenolics other than those para substituted phenols in which the substitution is alkyl, aryl, nitro, benzoyl, nitroso, or aldehyde group.
Interpretation of results.	Since the recovery of phenolics is non-uniform, the choice of phenol as a standard for the colorimetric procedure provides that any color produced by the reaction of other phenolics is reported as phenol. Substitution usually reduces recovery and the reported value represents the minimum concentration of phenolic compounds present in the sample.
Principle of method.	After distillation of the sample from acidic medium to remove interferences, the distillate is buffered to *pH 9.2* and reacted with 4-Aminoantipyrine. In the presence of an alkaline oxidizing agent, potassium ferricyanide, a red antipyrene dye is formed and measured colorimetrically at *505 nm*.
Time required for analysis.	Approximately *20* analyses can be performed in an hour. Operation of the AutoAnalyzer equipment can be maintained for as long as *18 hours* a day performing upwards of *200* tests.
Range of application.	Range on undiluted sample *0.5 - 50 μg/l* phenol. Minimum *0.5 μg/l*. Higher levels are determined by dilution of the original sample.
Standard deviation.	*0.7 μg/l* phenol in the normal operating range.
Accuracy.	Recoveries vary with types of phenolics present in sample. Analysis result represents minimum quantity of phenolics present in the sample.

Limit of detection.	*0.5 µg/l* phenol.
Interferences and shortcomings.	Potential colorimetric interferences are removed during automated distillation. $FeSO_4$ should be added to samples known to contain oxidizing agents. Manual solvent extraction and distillation techniques may be required for oil and tar laiden samples. Certain para substituted phenolics do not react with 4-AAP, therefore analysis represents a minimum phenolic concentration.
Minimum volume of sample.	*150 ml* of preserved sample.
Preservation and sample containers.	Special glass sample bottles containing copper sulfate and phosphoric acid are provided by the laboratory. Unpreserved samples lose phenolics in storage. Due to the corrosive nature of the preservatives, sample bottles should be stored in an upright position to prevent acidic corrosion of foil liners in bottle caps.
Safety considerations.	Preservative solution is strongly acidic. Flush any spilled preservative with copious quantities of water. Phenolic standards are prepared from pure phenol which is extremely hydroscopic and can be absorbed through the skin. Phenol crystals and burns should be flushed with methanol (keep away from eyes) followed by copious quantities of cold water.

3. Apparatus

a) Instrument:

   i) sampler

   ii) proportioning pump

   iii) heating bath with distillation head and modified condensing system as shown in Figure I.

   iv) colorimeter equipped with 505 nm filters and a 5 cm flow cell.

   v) voltage regulator

   vi) range expander

   vii) chart recorder

b) Pump tubing manifold and associated manifold glassware as shown in Figure II for AAII systems.

c) Culture tubes: 25 X 100 nm

d) Culture tube racks of 20 tube capacity.

e) Dilution tubes, 50 ml capacity

f) Nessler or dilution tubes, 100 ml capacity.

g) Reagent bottles, 170 ml, exterior coated with black paint.

h) Reagent bottles, 1 liter

i) Reagent reservoir bottles, 9 liter

4. Reagents

a) Sodium hydroxide, $NaOH$, reagent grade pellets.

b) Ethylenediaminetetra-acetic acid disodium salt, $(CH_2N)_2(CH_2COOH)_2(CH_2COONa)_2.2H_2O$, reagent grade powder.

c) Phenol, C_6H_5OH, reagent grade crystals.

d) Acetone, C_3H_6O, reagent grade.

e) Phosphoric acid, H_3PO_4 reagent grade, concentrated (85%).

f) Copper sulfate, $CuSO_4.5H_2O$; reagent grade powder.

g) di-Sodium tetraborate, $Na_2B_4O_7.10H_2O$; reagent grade crystals.

h) Sodium potassium tartrate, $NaKC_4H_4O_6.4H_2O$; reagent grade crystals.

i) 4-Aminoantipyrine, (4-Aminophenazone) $CH_3CC(NH_2)CON(C_6H_5)NCH_3$; reagent grade powder.

j) Potassium ferricyanide, $K_3Fe(CN)_6$; reagent grade powder.

k) <u>Phosphoric Acid Reagent</u>

Add 100 ml of 85% phosphoric acid to approximately 800 ml of deionized distilled water. Dilute to 1 liter when cool.

l) <u>Buffer Reagent</u>

Add 50 g of $Na_2B_4O_7.10H_2O$ and 25 g of $NaKC_4H_4O_6.4H_2O$ to approximately 900 ml of deionized distilled water. Add 10 ml of acetone and stir until dissolved. Dilute to 1 liter and filter if necessary.

m) <u>4-AAP Reagent</u>

Dissolve 0.20 g of 4-aminoantipyrine in 200 ml of deionized distilled water and transfer to a darkened storage bottle before use. Prepare a fresh solution daily.

n) <u>Potassium Ferricyanide Reagent</u>

Dissolve 1.0 g of $K_3Fe(CN)_6$ in deionized distilled water and dilute to 200 ml. Transfer to a darkened storage bottle before use. Prepare a fresh solution daily.

o) Copper Sulfate-Phosphoric Acid Preservative

Carefully and with continuous stirring add *50 ml* of concentrated phosphoric acid to approximately *900 ml* of phenol free distilled water. Dissolve *96 g* of anhydrous copper sulfate in deionized distilled water and after dissolution is complete, dilute to a final volume of *1 liter*.

p) Concentrated Stock Standard Phenol Solution

Dissolve *1.00 g* of reagent grade phenol crystals in phenol free distilled water and dilute to *1 liter* in a volumetric flask. Mix well and store in a tightly stoppered container. Concentration of phenol; *1000 mg/l*.

CAUTION: PHENOL CAUSES SEVERE BURNS WITHOUT CAUSING ANY IMMEDAITE PAIN. DO NOT UNDERESTIMATE THIS DANGER. MAINTAIN A QUANTITY OF METHANOL (IN THE WORK AREA AS A RINSING AGENT FOR ALL PHENOL SPILLS). IN CASE OF FACIAL CONTACT USE WATER ONLY.

q) Dilute Stock Standard Phenol Solution

Transfer a *1.0 ml* aliquot of the concentrated stock standard phenol solution to a liter flask containing approximately *800 ml* of distilled water. Dilute to *1 liter* with phenol free distilled water. Mix well before using. Prepare a fresh solution daily. Concentration of phenol; *1000 μg/l*.

r) Working Stock Standard Phenol Solution

Transfer a *50 ml* aliquot of the dilute stock standard phenol solution to a liter flask containing approximately *800 ml* of phenol free water. Add *5 ml* $CuSO_4$ solution and dilute to *1 liter*. Mix well before using. Prepare a fresh solution daily. Concentration of phenol; *50 μg/l*.

s) Working Standard Solution

Calibration standards are prepared by diluting the following aliquots to *50 ml*.

Using Working Stock Standard Phenol Solution *50 μg* phenol/*l*.

Working Stock *ml*	*50.0*	*40.0*	*30.0*	*20.0*	*10.0*	*5.0*
Working Standards µg phenol/*l*.	*50*	*40*	*30*	*20*	*10*	*5*

t) Quality Control Samples

Prepare Quality Control *A* and *B* solutions, *QC-A* and *QC-B* respectively, that will provide test solution for at least *20 days* of analysis. The concentration of the *QC-A* and *-B* should be chosen such that they fall within the normal concentration range of samples being routinely analyzed. These quality control checks are used to detect systematic errors such as blank or calibration changes from day to day and must be included in each run of standards and samples on a day to day basis. Prepare a new *QC-A* and *QC-B* and monitor their concentration for at least *3 days* prior to adopting them.

u) Daily Sensitivity Checks

AAII Systems

In order that sensitivity changes within a run can be monitored, prepare solutions that will provide *50%* (high) and *10%* (low) of full scale response.

v) Basic Cleaning Solution *(NaOH-EDTA)*.

Cautiously and with continuous stirring, dissolve *250 g* of reagent grade sodium hydroxide pellets in approximately *1000 ml* of distilled water. Add approximately *60 g* of ethylenediaminetetra-acetic acid, disodium salt.

w) Preservation Solution

Precharged sample containers are provided by the laboratory for phenol samples.

i) *170 ml* Prince of Wales bottles
Add *1.0 ml* of the $CuSO_4$-H_3PO_4 solution (Reagent o) to each sample bottle. Store containers in an upright position.

ii) *25 X 150 mm* Screw Cap Culture tube.
Add *0.3 ml* of the $CuSO_4$-H_3PO_4 solution (Reagent o) to each sample tube. Store in upright position.

5. Procedure

a) After collecting the samples, group samples by classification and maintain the numerical sample order within each group.

b) List the samples on the bench sheets designed for *10 samples* each. Use separate bench sheets for different sample classifications.

MAINTENANCE OF SEQUENTIAL SAMPLE ORDER IN COLLECTION AND RETURN OF SAMPLES TO THEIR PROPER STORAGE POSITION, AND IN LISTING, PREPARATION AND ANALYSIS, GREATLY ASSISTS IN ENSURING THAT BENCH SHEETS AND SAMPLES ARE PROPERLY CORRELATED AND ALSO FACILITATES THE REPORTING OF RESULTS AND AN ORDERLY LABORATORY WORK RECORD.

c) Rinse each sample tube at least twice with *15 ml* portions of sample prior to accepting a third portion for analysis.

d) Place the culture tube containing the sample into a test tube rack in such a position that it may easily be correlated with the sample number on the bench sheet, i.e. the *4th* sample on the *2nd* sheet is located in the *4th* space in the *2nd* row of the test tube rack. Where empty spaces occur on the bench sheet, leave the corresponding space in the test tube rack vacant. Write the appropriate sample number on the first and last sample tube in each row.

e) Set the AutoAnalyzer into operation using cleaning, set-up and checking procedures appropriate to the manifold and modules in use.

f) When loading the samples into the AutoAnalyzer sampler module, ensure that bench sheets are retained in the proper order by clipping them in order, one at a time, on a clipboard as each row of samples is loaded.

g) Complete Sampler Loading Sequences.

Each run of samples will include all of the following units:

6. Calculation and Reporting

Multiply the reading by the dilution factor

$$\frac{\text{diluted volume}}{\text{aliquot volume}}$$

and record the result in the answer space opposite each sample number. Report the results according to the following schedule:

High and Low range:	A maximum of *two* significant figures are shown when reporting to *one* decimal place with a minimum reporting value of: less than *0.5* µg/*l*.

7. Precision and Accuracy

Standard Deviation in µg/*l*	Duplicates	Concentration in µg/*l* phenol
0.36	Within-run	*5*
0.65	Within-run	*18*
1.29	Within-run	*35*

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v) Mohler, E.F. Jr.; Jacob, L.N.; *Determination of Phenolic-Type Compounds in Water and Industrial Waste Waters: Comparison of Analytical Methods*, Anal. Chem., 29, 1369 (1957).

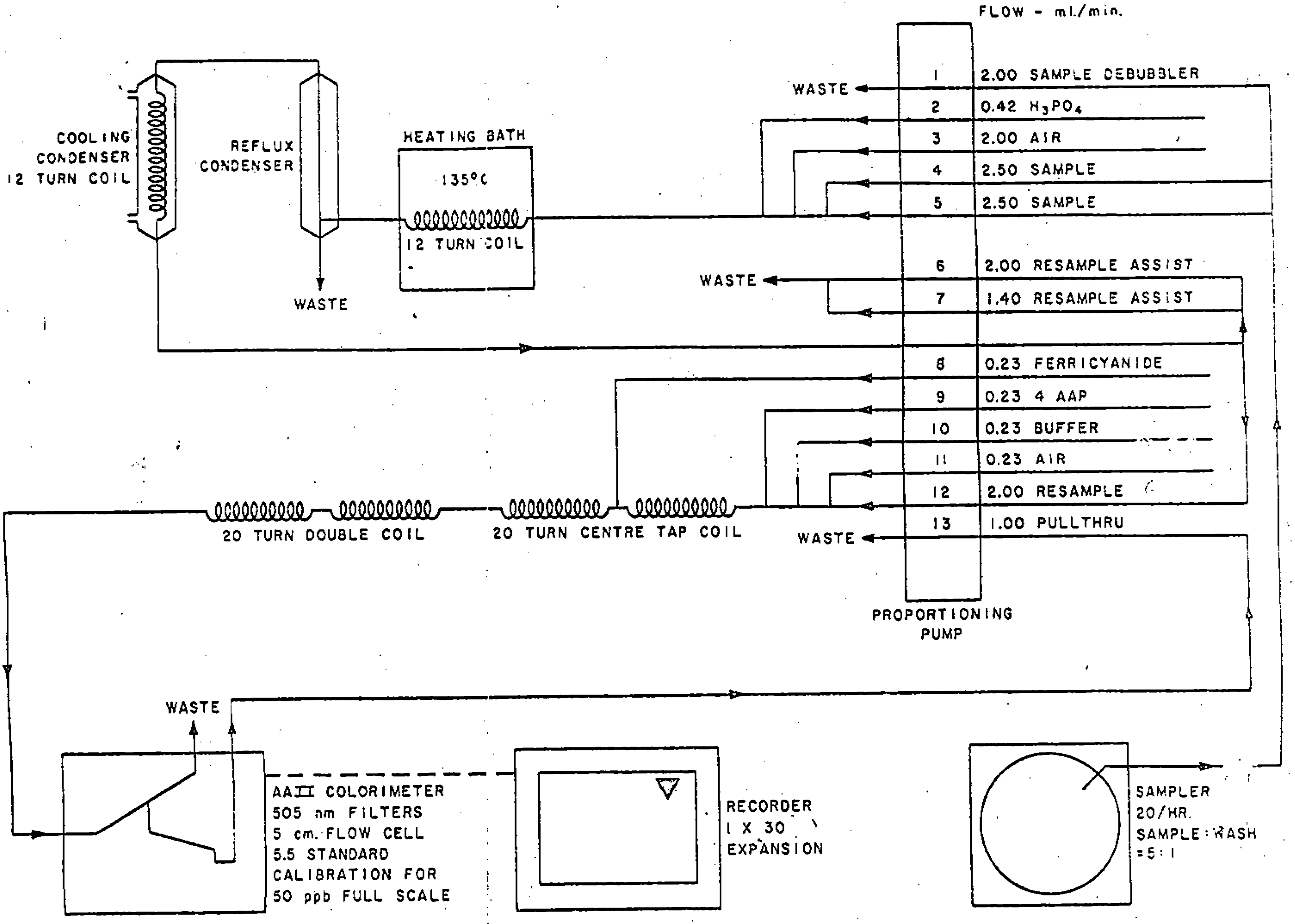

FIGURE 1 - AUTOANALYSER AAII SYSTEM FOR PHENOLIC COMPOUNDS

APPENDIX F

ORGANIC AND WATER ANALYSIS REPORT FROM BATTELLE LABORATORIES

DRAFT FINAL REPORT

on

ANALYSIS OF AIR AND WATER SAMPLES FROM WET COKE QUENCHING

to

U.S. ENVIRONMENTAL PROTECTION AGENCY

February 11, 1982

by

M. P. Miller and P. E. Strup

Contract Number 68-02-3169
Work Assignment 22.0

EPA Task Officer: Robert C. McCrillis, IERL
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SECTION I

INTRODUCTION

The purpose of this work assignment was to investigate the potential relationship between coke quench water priority pollutant content and coke quench air emissions and the effectiveness of the quench tower baffles to control these air emissions. Battelle was to conduct analysis for priority pollutant compounds in two different quench waters clean (Lake Erie) water and coke byproduct wastewater. In addition, air emission samples were to be analyzed for selected priority pollutants found in the quench water. Chloride, sulfate, and cyanide analyses were also to be conducted on a number of water samples.

The priority pollutant analyses for organic compounds were conducted by GC-MS using EPA Method 625. Metal priority pollutants were determined using inductively coupled argon plasma spectroscopy, graphite furnace atomic absorption spectroscopy, and cold vapor atomic absorption spectroscopy.

The analytical methods and the results of analyses are given in this report, along with a discussion of the results obtained.

SECTION II

CONCLUSIONS

On the basis of the results of the analysis performed during the execution of this work assignment, the following conclusions were made:

- The concentration of sulfate and chloride in samples taken during the clean quench water test were generally lower than the concentrations found during the dirty water test, but the differences were generally small.

- Small amounts of cyanide were present in samples taken during the clean quench water test.

- The dirty quench water exhibits higher concentrations of the elements analyzed than the clean quench water, with calcium, iron, magnesium, and sodium being the predominate elements. Selenium was found in the dirty quench water at 1740 μg/l.

- Metals analysis of the sample train filters demonstrated levels of iron, manganese, and titanium above the filter blank.

- Metals analysis of the baffle grit samples showed that the grit found after the clean and dirty quench water tests were essentially identical.

- The clean quench water contained detectable levels of phenol, 2,4 dimethylphenol, napthalene, fluoranthene, and bis-2-ethylhexylphthalate, with 2,4-dimethylphenol at the highest concentration (140 μg/l)

- The dirty quench water contained eleven detectable semi-volatile organic priority pollutants including phenols and PAHs. Phenol was present at 36,000 μg/l and naphthalene was found at 2,200 μg/l.

- All filters were found to contain low levels of bis-2-ethylhexylphthalate. The filter from the dirty quench water test used in the outlet sampling train contained 1,2-dichlorobenzene and three phthalates.

SECTION III

RECOMMENDATIONS

Observations, encountered problems, and conclusions made during the performance of this work assignment have lead to the following recommendations:

- For future work involving sampling with XAD traps, the resin should be cleaned and shipped to the sampling site immediately prior to sampling. After sampling, the traps should be immediately sent to the analysis laboratory and extracted as soon as possible.
- For future sampling efforts involving quench water, the sample collection apparatus should be geared toward efficient collection of phenols and PAHs, since these are the predominate forms found in the quench water.

SECTION IV

EXPERIMENTAL

PROJECT DESCRIPTION AND WORK PLAN

As originally conceived, the program to be conducted was to include the following work elements.

(1) Preparation of XAD resin cartridges

  (a) A total of approximately 12 XAD resin cartridges will be prepared and sent to the sampling site

(2) Priority pollutant analysis of water samples

  (a) Inorganic analysis. Two water samples will be analyzed by Atomic Absorption and ICAP for the 13 priority pollutant metals.

  (b) Organic analysis. Two water samples will be analyzed for volatile and semivolatile organics using EPA Methods 624/625.

(3) Organic analysis of absorbents. For each of the four sampling trains to be run by GCA, the probe filter and absorbent module extracts will be combined and analyzed by GC-MS for the presence of semivolatile organics.

(4) Analysis of chloride, sulfide, and sulfate.

  (a) Approximately 40 samples each will be analyzed for chloride, sulfide, and sulfate using techniques given in "Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020".

Due to changes in the sampling plan and other considerations to be discussed below, several of the work elements were changed as the task progressed.

The first task, preparation and shipment of the XAD sampling cartridges, was completed on schedule, i.e. October 1, 1981. These cartridges were shipped directly to the sampling team at the test facility in Canada.

During the month of October, all samples were received for chemical analysis. Since the samples received differed considerably from that initially expected, a detailed breakdown is given.

The first shipment of samples was received on October 16, 1981. The shipment consisted of samples for the following analyses:

- Sulfate, 24 shipped, 2 broken in shipment
- Chloride, 25 shipped, all intact
- Cyanide, 22 shipped, 2 broken in shipment
- Priority pollutants, 3 shipped, all intact.

All of the above samples were taken during the clean water quench test.

The above shipment differed from the original work plan in two respects. First, the work plan called for Battelle to conduct analysis for chloride, sulfide, and sulfate. However, it was decided by the sampling team to have the sulfide analyses conducted by a local lab, and to ship the samples for cyanide analysis to Battelle. Second, the quench water sample was to be analyzed for priority pollutant metals and organics, both volatile and semi-volatile. No sample was taken for volatile analysis (using sealed, 40 ml vials) thus, no volatile analyses were possible on the quench water sample.

Two additional water samples were received, labeled make-up and return water. As per discussions with the EPA Task Officer, these samples were not analyzed.

The samples taken during the dirty water trial were received by Battelle on October 30. This shipment consisted of 12 samples for sulfate and chloride analysis; quench, make-up, and return water samples for priority pollutant analysis (excluding volatile organics, since no sample for volatiles analysis was received) and samples taken from four separate sampling trains. No samples for cyanide analysis were received. A breakdown of the train subsamples is given in Table 1.

Initially, it was planned to combine subsamples taken as part of the sample train prior to organic analysis for semivolatile priority pollutants. The fractions that were to be combined are indicated in Table 1. Approximately one-eighth of the filter paper was to be taken for metals analysis. The remaining seven-eighths was to be extracted with methylene chloride and the extract combined with the other fractions. Impingers 2 and 3 were located after the XAD trap in the sampling train, thus, it is unlikely any organic compounds were present. These impinger solutions (when available) were analyzed for metals. A grit material was observed on the baffles during both clean and dirty water sampling episodes. This material was screened for metals content using inductively coupled argon plasma.

Upon closer examination of the methylene chloride rinse samples, a problem was noted with the sample containers. No teflon liners had been inserted into any of the bottle caps at the time of the sampling. The paraffin liners in these commercial caps had been, therefore, in direct contact with the methylene chloride. In addition, all samples taken during the clean water quench test had been sealed with black electrical tape. There is a possibility that the methylene chloride came in contact with this black tape. After discussions with the Task Officer, it was decided that these rinse samples would not be combined with the extracts of the filter and XAD traps in order to avoid contamination of the filter and trap samples. The organic priority pollutant analyses was therefore to be conducted only upon the extracts of the filters and the XAD traps.

INORGANIC ANALYSIS

Sulfate

All sulfate analyses were conducted by the gravimetric procedure as given in EPA Method 375.3 (1). In this method, the sulfate is precipitated as barium sulfate in a hydrochloric acid medium by the addition of barium chloride. After digestion, the precipitate is filtered, washed, ignited, and weighed as barium sulfate.

A 100 ml aliquot of the sample was taken for analysis. The pH of the solution was adjusted to 4.5 using 1:1 HCl, then an additional 1 ml of HCl was added. The solution was heated to boiling, at which time the barium chloride solution was added slowly until precipitation appeared to be complete. An excess of 2 ml barium chloride was then added. The solution was digested for two hours, filtered using ashless paper and pulp, and washed until free of chloride residue. The filtrate was dried and ignited at 800°C for one hour, cooled and weighed. The results are reported as μg/ml of sulfate.

TABLE 1. SUBSAMPLES RECEIVED FOR PRIORITY POLLUTANT ANALYSIS

Sample Designation	Clean Water	Dirty Water	Analysis
MC Rinse	I, O	N.R.	Org., comb.
Impinger Rinse	N.R.	I, O	Org., comb.
Cyclone Cupcatch	I, O	I, O	Org., comb.
Impinger 1	I, O	I, O	Org., comb.
Filter	I, O	I, O	Metals, Org., Comb.
Impinger 2	I, O	N.R.	Metals
Impinger 3	I, O	N.R.	Metals
Probe/Filter Rinse	I, O	I, O	Org., comb.
Cyclone Rinse	I, O	I, O	Org., comb.
Nozzle Wash	I, O	I, O	Org., comb.
XAD Trap	I, O	I, O	Org., comb.
Blank $MeCl_2$	X	X	Metals, org.
Blank XAD	X	X	Metals, org.
Baffle Grit	X	X	Metals

I = Inlet sample train

O = Outlet sample train

N.R. = Not received

X = One sample received for inlet and outlet

Org., comb. = Semivolatile organic analysis of combined extract

Metals = ICAP metals screening analysis

Chloride

Chloride analyses were conducted using an Amico-Cotlove Automatic Chloride Titrator. To 5 ml of the sample, 0.5 ml of 1 N NaOH and 0.5 ml of 30 percent H_2O_2 was added. The solution was heated for 15 minutes or until foaming ceased. The sample was cooled and neutralized with nitric acid. To this solution, 7.5 ml of a mixture of 40 percent acetic acid and 0.4 N ammonium nitrate was added and diluted to 30 ml with deionized water. Four drops of indicator, (a 60:1:1 ratio of gelatin, thymol blue, and thymol) was added. The solution was then titrated coulimetrically with the auto titrator. The titrator was standardized using known concentrations of chloride. Results are reported in μg/ml of sample.

Cyanide

For cyanide analysis, EPA Method 335.2 was used. An interference was found to occur when using the colorimetric method, thus the titrimetric part of the method was used for all analyses.

A 400 ml-500 ml aliquot of the sample (depending upon the amount available) was taken for the analysis and placed in a one liter boiling flask. The absorbing tube was filled with 50 ml of 1.25 N NaOH, and a slow stream of air was initiated. To the boiling flask, 25 ml of concentrated sulfuric acid was added slowly, and the inlet tube was rinsed with deionized water. After addition of 20 ml of $MgCl_2$ the solution was heated to boiling and refluxed for one hour. The solution was cooled, transferred to a 100 ml volumetric flask, and diluted to volume.

A 50 ml aliquot was taken of the distillate for analysis. To the aliquot, ten drops of benzalrhodamine indicator solution was added and titrated to the pink endpoint with standardized 0.0192 N $AgNO_3$ solution. A blank solution containing equivalent amounts of NaOH and indicator was titrated and sample results were corrected for the blank. All results are reported in μg/ml.

Metals Analysis

For the metals analyses, several different sample preparation procedures were used, dependent upon the nature of the sample and the element of interest. All samples were prepared using acid digestion procedures and analyzed by either ICAP, graphite furance AAS, or cold vapor AAS.

For the analysis of solutions, including the two quench water samples and the impinger solutions, preparation was conducted according to EPA Method 4.1.3 (1) for all ICAP analyses, and by a HNO_3-H_2O_2 digestion for graphite furnace analyses. Method 4.1.3 consists of a HNO_3 digestion, taking the sample to near dryness on a hotplate several times until digestion is deemed complete. However, since many of the more volatile elements can be lost during this vigorous digestion, samples to be analyzed for arsenic, antimony, selenium, silver, and thallium were prepared using a less vigorous digestion, as approved by EPA (1) and given in Reference 2. This digestion involves heating the sample gently with addition of HNO_3 and H_2O_2, filtering, and diluting to a known volume. The volatile elements were analyzed by graphite furnace atomic absorption, while an additional 21 elements were determined by ICAP.

For mercury analyses, a separate sample preparation was conducted, as described by EPA Method 245.1. The sample was digested with concentrated H_2SO_4 and HNO_3, then oxidized with potassium permanganate and potassium persulfate. The mercury was then reduced to elemental mercury with stannous sulfate just prior to analysis using cold vapor atomic absorption spectroscopy.

For the filter sample, an alternate digestion was used in order to ensure a more complete dissolution of the particulate. Since the filter had to be used for both inorganic and organic analyses, a portion of the filter (one eighth) was cut out to use for metals analysis. The sample was placed in a 100 ml beaker, and 5 ml of aqua regia was added. The beaker was placed on a hot plate and heated for one hour. To the beaker, 5 ml of deionized water was added, and the solution was heated for an additional hour. The solution was then cooled, filtered through white ribbon filter paper into a 50 ml volumetric flask, washed, and diluted to volume. The samples were then analyzed by ICAP. The results reported are given in total μg per filter, assuming that the section removed was a representative sample of the entire filter.

Two additional samples were analyzed by ICAP for metals content, referred to as baffle grit material. For these samples, a 1.0 g portion was taken and digested with concentrated HNO_3 on a hot plate for two hours. The samples were filtered through white ribbon paper into a 50 ml volumetric flask and diluted to volume. All results are reported in μg/g.

ORGANIC ANALYSES

The analysis of the semivolatile organic priority pollutants was to be conducted on the combined sample train extracts, filters, and XAD sampling cartridges and on the quench water samples. As described above potential contamination of the sample extracts from bottle liners and electrical tape necessitated the elimination of these fractions. Only the filters and the XAD traps were extracted for analysis, as were the quench water samples. The samples were extracted with different procedures.

Sample Preparation of XAD and Filters

The XAD and filter samples were soxhlet extracted using methylene chloride for a period of 12 hours. Prior to extraction 15 μg of a surrogate internal standard of hexaethylbenzene (HEB) was added to each sample. The percent recovery of the HEB indicates the efficiency and precision of the extraction, sample preparation and analytical procedure.

Following extraction, sample volumes were reduced to 1.0 ml using Kuderna-Danish evaporation on a water bath at 50°C. These samples were then analyzed by GC and/or GC-MS. Samples to be analyzed by GC-MS were spiked with 50 ppm of d_{10}-phenanthrene as an internal standard.

Sample Preparation: Water

The two quench water samples were extracted following EPA Method 625 guidelines. One-half liter of water was adjusted to pH 2 and extracted in a separatory funnel using 3 x 60 ml aliquots of methlylene chloride. The pH of the remaining aqueous phase was adjusted to pH 12 and extracted with 3 x 60 ml aliquots of methylene chloride. The extracts were then dried using a column of anahydrous sodium sulfate and combined. The extracts were reduced in volume to 1.0 ml using Kuderna-Danish evaporation as described above. Analysis of these samples were performed using GC and GC-MS. These samples were spiked with 50 ppm of d_{10}-phenanthrene as an internal standard.

GC Analysis

A preliminary screening of the above extracts was performed by GC. This screening was undertaken to obtain a general profile of the individual samples and to provide information as to the concentration of the various components in each sample. This screening allows any sample which is found to be too concentrated for GC-MS analysis to be diluted by an appropriate amount prior to analysis. Only one sample, the dirty quench water, needed to be diluted 100 fold prior to GC-MS analysis.

GC analysis was performed using a Carlo Erba Model 2150 gas chromatograph with FID detector and capillary column under the following conditions:

Column:	Fused Silica Capillary 30 m x 0.25 mm Phase SE-30
Flow Velocity:	Hydrogen 50 cm/sec
Injector Temperature:	275°C
Detector Temperature:	300°C
Temperature Program:	Ambient for 5 min to 270° @ 8°/min
Injection:	2 μl splitless

GC-MS Analysis of Semivolatile (Extractable) Organics

Instrumentation--

The sample extracts were analyzed using an advanced analytical system consisting of (1) a Finnigan Model 9610 GC equipped with a 30 m x 0.2 mm ID fused silica capillary column coated with SE-52 methyl silicone (2) a Finnigan Model 4000 quadrupole mass spectrometer, scanning the range of 42 to 450 a.m.u. during data acquisition; and (3) a Hewlett-Packard Model 7672A automatic sample injection system (autosampler).

The mass spectrometer and autosampler were controlled by an INCOS 2300 data system. A command from the data system to the Hewlett-Packard autosampler starts the injection cycle and stops the split flow of the capillary injector. At the moment of injection the autosampler signals the computer to start the data acquisition in a suspended mode, signals the microprocessor of the 9610 GC to begin the column temperature program sequence, and signals the injector split flow control timer to begin the 55 seconds timing sequence for the splitless injection. After 55 seconds the split flow is restarted. At 5.5 minutes the 9610 microprocessor turns on the filament and electron multiplier of the mass spectrometer. The data system, at 6.0 minutes, starts the data acquisition for the 70 minutes of analysis time. During this 70 minutes a reverse-library search of the acquired data is performed by the data system. Each of the 89 compounds in the library was searched in a time window of ±60 seconds around expected retention time as determined by analysis of the calibration standards. If a compound is found in the window, the area of a selected ion in the mass spectrum is recorded so that a quantification value is determined by the ratio of the compound area to that of the internal standard times a response factor for the compound.

At the end of the search routine a list of the found compounds ("hits") and their amounts are printed along with the numerical difference between their expected and found scan numbers. A hard copy of the enhanced (background subtracted) mass spectrum of each of the "hits" is also automatically printed for manual confirmation or refutation of the mass spectra.

At the end of the data acquisition and reverse-library search, the data system prepares for analysis of the next sample. Once the data system receives a signal from the 9610 GC microprocessor that the GC oven temperature has cooled to the starting temperature, the data system injects the next sample in 25 minutes. This delay allows the GC oven temperature and the column temperature to equilibrate which greatly enhances the reproducibility of the retention times.

The GC-MS parameters used during autosampler analysis of all samples for semivolatiles are summarized below:

- Autosampler Injection Volume 2.0 µl
- Injection Mode Splitless for 55 sec
  - Split Flow 20 ml/min
  - Sweep Flow 4 ml/min
- Injector Temperature 290°C
- Separator Oven Temperature 300°C
- Transfer Line Temperature 295°C
- Ionizer Temperature 250°C
- Manifold Temperature 120°C

the priority pollutant "hits" was hard-copied and manually inspected to confirm the identification.

Once a calibration standard was analyzed and the concentrations of each of the calibration standard components entered into the computer program, the response factors were determined by the computer according to the equation:

$$\text{Response Factor} = RF = \frac{A_s C_{is}}{A_{is} C_s}$$

where A_s = the integrated peak area of the characteristic fragmentation ion for the priority pollutant

A_{is} = the integrated peak area of the characteristic fragmentation ion for the reference internal standard

C_{is} = the concentration of the reference internal standard in the calibration standard (μg/l or μg/g)

C_s = the concentration of the pollutant standard in the calibration standard (μg/l or μg/g)

The response factors were updated following the analysis of a calibration standard. Because of the relatively small number of samples, two calibration standards were analyzed and interspersed with the samples.

The concentration of each compound in each sample was determined according to the equation:

$$C_s = \frac{A_s C_{is}}{A_{is} RF} \times DF$$

where the terms are defined as in the response factor equation above and DF is the dilution factor.

SECTION V

RESULTS AND DISCUSSION

INORGANIC ANALYSIS

Sulfate, Chloride, and Cyanide Analysis

The results for the analysis of sulfate, chloride, and cyanide conducted on samples taken during the clean and the dirty quench water tests are given in Tables 2 and 3, respectively. As noted above, no samples were received for cyanide analysis form the dirty quench water test. The range of concentrations found for each of these determinations is as follows:

Analyte	Clean Water (μg/ml)	Dirty Water (μg/ml)
Sulfate	60-250	60-460
Chloride	570-5,500	4,900-7,200
Cyanide	0.17-1.8	Not Received

The dirty quench water samples generally exhibited a higher level of sulfate and chloride, although some of the samples taken during the clean water test were nearly as high.

Replicate analyses were run for sulfate, chloride, and cyanide analyses, as shown in Table 4. For sulfate analyses, the relative percent difference (RPD) varied from 0-3.2 percent, indicating excellent precision of analysis. For chloride anlaysis, the RPD ranged from 0.2 percent to 22 percent, with the high percent difference occurring on a sample with a low concentration of chloride. In general, the precision was quite good. For cyanide analyses, only two samples could be run in duplicate due to the

TABLE 2. RESULTS OF ANALYSIS FOR SULFATE, CHLORIDE, AND CYANIDE FOR CLEAN WATER QUENCH TEST

Sample	$SO_4^=$ μg/ml	Cl^- μg/ml	CN^- μg/ml
1-CM	N.R.(a)	N.R.	0.25
1-CM-A	63	65	N.R.
1-CM-B	59	59	0.21
1-CQ-A	116	186	0.33
1-CQ-B	124	117	0.25
1-CR	N.R.	129	N.R.
1-CR-A	127	160	0.17
1-CR-B	136	N.R.	0.17
1-SD-M	254	5380	Broken
1-SD-Q	167	1850	0.91
1-SD-R	184	1290	0.62
2-CM	62	63	0.17
2-CQ	119	127	0.33
2-CR	135	N.R.	0.52
2-SD-M	Broken(b)	5490	1.40
2-SD-Q	172	1520	0.41
2-SD-R	198	1450	Broken
3-CM	60	57	0.41
3-CQ	N.R.	116	0.33
3-CR	146	182	N.R.
3-SD-M	278	5440	1.75
3-SD-Q	Broken	1670	N.R.
3-SD-R	N.R.	140	1.37
4-CM	58	84	N.R.
4-CQ	135	116	0.41
4-CR	N.R.	110	N.R.
5-CM	62	94	0.50
5-CQ	138	164	N.R.
5-CR	147	N.R.	0.50

(a) N.R. = not received.

(b) Broken; four sample bottles were broken during shipment from the sampling site.

TABLE 3. RESULTS OF ANALYSIS FOR SULFATE AND CHLORIDE FOR DIRTY WATER QUENCH TEST

Sample	$SO_4^=$ (μg/ml)	Cl^- (μg/ml)
1-DM	N.R.(a)	5020
1-DQ	336	6140
1-DR	380	6590
2-DM	63	5020
2-DQ	353	6710
2-DR	460	7220
3-DM	63	5240
3-DQ	343	5660
3-DR	386	6610
4-DM	78	4890
4-DQ	360	5310
4-DR	400	5800
Make-Up Water	83	N.R.

(a) N.R. = not received.

TABLE 4. REPLICATE ANALYSES FOR SULFATE, CHLORIDE, AND CYANIDE

	Sulfate (μg/ml)				Chloride (μg/ml)				Cyanide (μg/ml)		
Sample	Rep 1	Rep 2	Rel. % Diff.(a)	Sample	Rep 1	Rep 2	Rel. % Diff.	Sample	Rep 1	Rep 2	Rel. % Diff.
1-SD-R	183	185	1.1	1-CM-A	62	68	9.4	1-CM-B	0.21	0.21	0.0
2-SD-R	198	199	0.5	1-SD-M	5330	5420	1.7	3-CM	0.41	0.41	0.0
4-CM	58	57	1.7	2-CQ	120	130	8.0				
5-CM	63	63	0.0	3-SD-Q	1600	1740	8.5				
2-DM	64	62	3.2	3-SD-R	120	150	22				
				3-DM	5230	5240	0.2				
				4-DQ	5270	5360	1.7				
				4-DR	5740	5850	1.9				

(a) Rel. % Diff. = Relative Percent Difference, defined as $\frac{\text{Rep 1 - Rep 2}}{\text{Avg}}$ X 100%.

limited volume of sample available in most cases. In both cases, the replicates were identical.

An estimate of the method accuracy can be gained by analysis of samples spiked with known concentrations of the analyte. A poor spike recovery is indicative of a matrix effect in the analysis. Spike recovery studies were conducted for sulfate and chloride analyses, with the results given in Table 5. No spiked samples were run for cyanide analysis. The results given in Table 5 demonstrate a spike recovery for sulfate analysis ranging from 93-113 percent, indicating good accuracy. For chloride analysis, spike recoveries ranged from 93-104 percent, indicating very good accuracy for this analysis.

Metals Analysis

The results for metals analysis of the quench waters, the impinger solutions, the filters, and the baffle grit are given in Table 6. Twenty-one elements were determined by inductively coupled argon plasma. Five elements (As, Sb, Se, Ag, and Tl) were determined by graphite furnace atomic absorption, and mercury was analyzed by cold vapor atomic absorption spectroscopy. Only the quench waters were analyzed for the volatile elements.

The results of the quench water analyses show that the dirty quench water does exhibit higher concentrations of detectable elements, however, the elements of highest concentration (Ca, Fe, Mg, Na) are of little concern environmentally. A small amount of Be was found in the dirty quench water, however, this could likely be an interference from the high level of iron in this sample. The dirty water was also found to contain 1740 μg/l of selenium, which may be of concern. However, no selenium analysis was conducted on the impinger and filter samples, in accordance with the work plan.

Analysis of the impinger solutions demonstrate only low concentrations of metals present, reported as total micrograms present in the impinger. Elements detected include Al, Ba, Ca, Co, Cu, Fe, Mg, and Zn. Comparison of the concentratins found in the clean and dirty water outlet impingers shows similar concentrations, with the exception of Fe and Zn. No impinger was received from the inlet sample train taken during the dirty water test.

TABLE 5. SPIKE RECOVERIES FOR SULFATE AND CHLORIDE ANALYSES

Sulfate					Chloride				
Sample	Amount in Sample (μg/ml)	Amount Added (μg/ml)	Sample + Spike (μg/ml)	Percent Recovery	Sample	Amount in Sample (μg/ml)	Amount Added (μg/ml)	Sample + Spike (μg/ml)	Percent Recovery
1-CR-A	127	500	632	101	1-CM-A	65	113	176	97
1-SD-M	254	200	488	113	1-SD-M	5380	1130	6560	104
1-SD-Q	167	500	680	103	2-CQ	127	284	391	93
5-CR	147	200	350	102	3-SD-Q	1670	2840	4600	103
3-DQ	343	100	443	93	4-DQ	5310	1130	6420	98
					4-DR	5800	4540	10200	97

TABLE 6. METALS ANALYSIS BY ICAP AND AAS

Element	Solutions					Filters					Grit	
	Reported in μg/l		Reported in Total μg			Reported in Total μg/Filter					Reported in μg/g	
	Quench 1-Org-C-Q	Quench 1-Org-C-D	1-D-O-Org	IMP 3 1-Org-C-O	IMP 3 1-Org-C-I	1-D-O-F-Org	1-D-I-F-Org	1-Org-C-O-F	1-Org-C-I-F	(Filter Blk) 1-D-O-Org	1-C-BG-Org	1-D-BG-Org
Al	410	950	4.9	2.5	4.1	690	960	1,100	2,070	1,080	390	360
B	220	745	<2.6	3.0	<2.2	380	660	760	1,260	740	7.8	7.0
Ba	240	930	1.7	1.2	1.1	71	76	82	110	77	16	12
Be	<1	3.7	<0.1	<0.1	0.1	<0.4	<0.4	<0.4	<0.4	<0.4	<0.1	<0.1
Ca	64,900	110,000	52	52	41	2,380	3,400	3,700	5,580	3,500	200	250
Cd	5.3	20	<0.7	<0.6	<0.6	<2	<2	<2	<2	<2	0.66	1.1
Co	<5	<5	<0.7	1.0	6.0	<2	<2	<2	<2	<2	0.78	0.62
Cr	<10	<10	<1.3	<1.1	<1.1	6.5	<4	<4	5.1	<4	30	8.3
Cu	<10	65	<1.3	<1.1	3.6	20	20	18	20	19	5.3	5.2
Fe	1,030	7,770	14	3.7	12	140	120	88	120	62	1,990	1,890
Pb	<50	<50	<6.6	<6.0	<6.0	<20	<20	<20	<20	<20	<2.5	<2.5
Mg	15,300	22,200	5.9	4.7	5.9	840	1,260	1,400	2,230	1,300	72	84
Mn	32	430	<1.3	<1.1	<1.1	4.8	5.1	<4	5.2	<4	16	17
Mo	14	<10	<1.3	<1.1	<1.1	<4	<4	<4	<4	<4	1.2	1.1
Ni	<50	<50	<6.6	<6.0	<6.0	<20	<20	<20	<20	<20	15	3.6
Na	58,600	52,400	<260	<220	<220	19,500	18,200	17,900	22,000	18,400	<100	<100
Sn	<30	<30	<4	<3.4	<3.4	<12	<12	<12	<12	<12	<1.5	<1.5
Ti	30	52	<0.7	<0.6	<0.6	3.5	2.9	3.2	3.8	<2	19	20
V	<5	<5	<0.7	<0.6	<0.6	<2	<2	<2	<2	<2	1.8	1.6
Y	<5	<5	<0.7	<0.6	<0.6	<2	<2	<2	<2	<2	0.54	0.55
Zn	16	120	5.9	1.7	7.6	61	65	62	80	61	20	16
As	<150	<150										
Sb	<100	<100										
Se	<50	1740										
Ag	<10	<10										
Tl	<100	<100										
Hg	<1	<1										

As described above, one-eighth of the total filter was taken for metals analysis, with the results given in Table 6 reported as the total mass present in the entire filter. A filter blank was also received and analyzed. The results reported in Table 6 have not been corrected for the filter blank. In the samples, detectable levels of Al, B, Ba, Ca, Cr, Cu, Fe, Mg, Mn, Na, Ti, and Zn were found. However, the levels of these elements found in the blank were comparable for all cases except Fe, Mn, and Ti. Even for these three elements, the concentration found in the sample is no more than twice that found in the blank. Therefore, the concentration of elements found in the filters is in all cases minimal.

Two grit samples were analyzed, one taken following the clean quench water test. The ICAP analyses (Table 6) show iron to be the element of highest concentration, at approximately 2000 μg/g in both samples. Aluminum, calcium, chromium, magnesium, manganese, nickel, titanium, and zinc were also found at levels above 10 μg/g. A comparison of the results from the two grits indicates close agreement for all elements except chromium and nickel, both found at higher levels in the clean water test grit.

Quality control procedures conducted during these analyses included the analysis of duplicate samples of the dirty quench water, and the clean baffle grit. An aliquot of the clean quench water was spiked with known concentrations of 21 elements and analyzed by ICAP. The results of the quality control analyses are given in Table 7.

For replicate analysis of the dirty quench water, the relative percent difference is in all cases less than ten percent. For many elements, the concentration was found to be below detection limit, thus no relative percent difference is reported. For the replicate analyses of the clean baffle grit, the relative percent differences are much higher, with the poorest precision found for nickel and chromium. Examination of these results indicates that there is no real difference between the clean and dirty water baffle grit samples considering the variation found for replicate analyses. This variation is indicative of an inhomogeneous sample, since the better precision of the ICAP analysis is demonstrated in the replicate analysis of the quench water.

TABLE 7. METALS ANALYSIS — DUPLICATES AND SPIKE RECOVERIES

	Solutions - Duplicates Reported in µg/l			Solutions - Spikes Reported in µg/l				Grit - Duplicates Reported in µg/g		
Element	Quench 1-Org-D-Q-A	Quench 1-Org-D-Q-B	Rel. % Diff.	1-Org-C-Q	1-Org-C-Q + Spike	Amount of Spike	Percent Recovery	1-C-BG-Org-A	1-C-BG-Org-B	Rel. % Diff.
Al	910	990	8.4	410	1,370	1,000	96	430	350	21
B	730	760	4.0	220	600	400	95	7.2	8.5	17
Ba	920	940	2.2	240	440	200	100	20	13	42
Be	3.6	3.8	5.4	<1	99	100	98-99	<0.1	<0.1	NA
Ca	108,800	111,800	2.7	64,900	67,800	2,000	145(a)	180	230	24
Cd	20	21	5.0	5.3	210	200	102	0.49	0.82	50
Co	<5	<5	NA	<5	950	1,000	94-95	0.95	0.60	45
Cr	<10	<10	NA	<10	420	400	102-105	48	12	120
Cu	62	68	6.2	<10	500	500	98-100	5.2	5.4	3.8
Fe	7,420	8,120	9.0	1,030	2,120	1,000	109	1800	2180	19
Pb	<50	<50	NA	<50	950	1,000	90-95	3.8	<2.5	NA
Mg	21,900	22,600	3.2	15,300	17,500	2,000	110	70	73	4.2
Mn	420	440	4.6	32	240	200	104	11	20	58
Mo	<10	<10	NA	14	210	200	98	1.3	1.1	17
Ni	<50	50	NA	<50	1,010	1,000	96-101	26	4.8	138
Na	51,300	53,600	4.4	58,600	82,100	20,000	118(a)	<100	<100	NA
Sn	<30	<30	NA	<30	870	1,000	84-87	<1.5	<1.5	<1.5
Ti	50	53	5.8	30	230	200	100	18	20	10
V	<5	<5	NA	<5	98	100	93-98	1.9	1.8	5.4
Y	<5	<5	NA	<5	100	100	95-100	0.53	0.55	3.7
Zn	110	120	8.9	16	1,050	1,000	103	16	25	44
As	100	120	9.1							
Sb	<100	<100	NA							
Se	1,740	1,730	0.6							
Ag	<10	<10	NA							
Tl	<100	<100	NA							

NA = not applicable since values are less than detection limit.
(a) Spike concentration too low to be seen above inherent sample concentration.

To determine the accuracy of the metals analyses, the clean quench water was spiked with known concentrations of 21 elements. The percent recovery data in Table 6 indicate excellent accuracy, with the recovery falling between 90-110 percent for 19 elements. For two elements (Ca and Na) the amount of spike added was too low to be quantitatively determined above the inherent sample concentration. If an element was found to be below the detection limit, then the percent recovery is reported as a range, since the concentration in the unspiked sample could be anything between zero and the detection limit.

ORGANIC ANALYSIS

As was previously discussed, the analysis of organics was limited to semivolatile compounds on the two quench waters and on a combined extract of the filters and the XAD traps. All rinse solutions (probe, impinger, cyclone, nozzle) and impinger solutions from upstream of the XAD trap were not included in the composite due to suspected contamination from the cap liners and black electrical tape used for sealing the bottles.

The quench water samples were analyzed by EPA Method 625 (GC-MS) for all semivolatile priority pollutants. The results of these analyses are given in Table 8. Because of the nature of the sample, the extract from the dirty quench water (1-Org-D-Q) had to be diluted 100 fold prior to injection to pervent saturation of the GC-MS electronics. For this reason, detection limits estimated for this sample are a factor of 100 greater than those given for the clean quench water sample (1-Org-C-Q).

For the clean quench water, five compounds were found at concentrations greater than the detection limit; phenol (5.6 μg/1), 2,4-dimethylphenol (140 μg/1), napthalene (4.0 μg/1), fluoranthene (17 μg/1), and bis-2-ethylhexylphthlate (34 μg/1). All remaining priority pollutant compounds were not found above the method detection limit, as indicated in Table 8.

A total of eleven compounds were found at concentrations above the detection limits in the dirty quench water, with phenol having the highest concentration (36,000 μg/1). Naphthalene was found at 2,200 μg/1, and several other PAHs were also present at levels from 94-440 μg/1.

TABLE 8. ANALYSIS OF SEMIVOLATILE ORGANICS BY METHOD 625

	Quench Waters (µg/l)		Filters (total µg)				
	1-Org-C-Q	1-Org-D-Q	1-Org-C -I-F	1-Org-C -O-F	1-D-I -F-Org	1-D-O -F-Org	1-D-Org-BF Blank
GC-MS - Acid Compounds							
1A. 2-Chlorophenol	<0.3	<30	<1	<1	<1	<1	<1
2A. 2,4-Dichlorophenol	<0.3	<30	<1	<1	<1	<1	<1
3A. 2,4-Dimethylphenol	140	240	<1	<1	<1	<1	<1
4A. 4,6-Dinitro-o-Cresol	<2	<200	<4	<4	<4	<4	<4
5A. 2,4-Dinitrophenol	<4	<400	<8	<8	<8	<8	<8
6A. 2-Nitrophenol	<0.5	<50	<1	<1	<1	<1	<1
7A. 4-Nitrophenol	<1	<100	<2	<2	<2	<2	<2
8A. P-Chloro-M-Cresol	<0.4	<40	<1	<1	<1	<1	<1
9A. Pentachlorophenol	<0.9	<90	<2	<2	<2	<2	<2
10A. Phenol	5.6	36,000	<1	<1	<1	<1	<1
11A. 2,4,6-Trichlorophenol	<0.4	<40	<1	<1	<1	<1	<1
GC-MS - Base/Neutral Compounds							
1B. Acenaphthene	<0.1	<10	<1	<1	<1	<1	<1
2B. Acenaphtylene	<0.1	400	<1	<1	<1	<1	<1
3B. Anthracene	<0.1	150	<1	<1	<1	<1	<1
4B. Benzidine	(a)	(a)	(a)	(a)	(a)	(a)	(a)
5B. Benzo(a)Anthracene	<0.1	94	<1	<1	<1	<1	<1
6B. Benzo(a)Pyrene	<0.2	<20	<1	<1	<1	<1	<1
7B. 3,4-Benzofluranthene	<0.2	<20	<1	<1	<1	<1	<1
8B. Benzo(g,h,i)Perylene	<0.2	<20	<1	<1	<1	<1	<1
9B. Benzo(k)Fluoranthene	<0.2	<20	<1	<1	<1	<1	<1
10B. Bis(2-Chloroethoxy)Methane	<0.2	<20	<1	<1	<1	<1	<1
11B. Bis(2-Chloroethyl)Ether	<0.3	<30	<1	<1	<1	<1	<1
12B. Bis(2-Chloroisopropyl)Ether	<0.1	<10	<1	<1	<1	<1	<1
13B. Bis(2-Ehtylhexyl)Phthalate	34	<10	120	3.9	29	29	1.8
14B. 4-Bromophenyl Phenyl Ether	<0.5	<50	<1	<1	<1	<1	<1
15B. Butyl Benzyl Phthalate	<0.2	<20	<1	<1	<1	7.0	<1
16B. 2-Chloronaphthalene	<0.1	<10	<1	<1	<1	<1	<1

Footnotes appear on the last page of the table.

TABLE 8. (Continued)

	Quench Waters (μg/l)		Filters (total μg)				
	1-Org-C-Q	1-Org-D-Q	1-Org-C -I-F	1-Org-C -O-F	1-D-I -F-Org	1-D-O -F-Org	1-D-Org-BF Blank
GC-MS - Pesticides							
1P. Aldrin	<0.4	<40	<1	<1	<1	<1	<1
2P. α-BHC	<0.8	<80	<1	<1	<1	<1	<1
3P. β-BHC	<2	<200	<4	<4	<4	<4	<4
4P. γ-BHC	<0.9	<90	<2	<2	<2	<2	<2
5P. δ-BHC	<3	<300	<6	<6	<6	<6	<6
6P. Chlordane	<1	<100	<2	<2	<2	<2	<2
7P. 4,4'DDT	<0.3	<30	<1	<1	<1	<1	<1
8P. 4,4'DDE	<0.3	<30	<1	<1	<1	<1	<1
9P. 4,4'-DDD	<0.5	<50	<1	<1	<1	<1	<1
10P. Dieldrin	<0.3	<30	<1	<1	<1	<1	<1
11P. α-Endosulfan	<1	<100	<1	<1	<1	<1	<1
12P. β-Endosulfan	<1	<100	<2	<2	<2	<2	<2
13P. Endosulfan	<1	<100	<2	<2	<2	<2	<2
14P. Endrin	<5	<500	<10	<10	<10	<10	<10
15P. Endrin Aldehyde	<1	<100	<2	<2	<2	<2	<2
16P. Heptachlor	<1	<100	<2	<2	<2	<2	<2
17P. Heptachlor Epoxide	<1	<100	<2	<2	<2	<2	<2
18P. PCB-1242	<1	<100	<2	<2	<2	<2	<2
19P. PCB-1254	<1	<100	<2	<2	<2	<2	<2
20P. PCB-1221	<1	<100	<2	<2	<2	<2	<2
21P. PCB-1232	<1	<100	<2	<2	<2	<2	<2
22P. PCB-1248	<1	<100	<2	<2	<2	<2	<2
23P. PCB-1260	<1	<100	<2	<2	<2	<2	<2
24P. PCB-1016	<1	<100	<2	<2	<2	<2	<2
25P. Toxaphene	<1	<100	<2	<2	<2	<2	<2
Tetrachlorobiphenyl(c)	<0.4	<40	<1	<1	<1	<1	<1
Hexachlorobiphenyl(c)	<0.3	<30	<1	<1	<1	<1	<1

(a) Method 625 not applicable for benzidene analysis.
(b) Compound not stable in water.
(c) Tetrachlorobiphenyl and hexachlorobiphenyl represent common components of polychlorinated biphenyl mixtures.

contamination. For the filter from the outlet sample train during the dirty quench water test, a total of four compounds were found; 200 μg of 1,2-dichlorobenzene, 4 μg of diethylphthalate, 7 μg of butylbenzylphthalate, and 29 μg of bis-2-ethylhexylphthalate. Of these four compounds, only bis-2-ethylhexylphthalate was found in the quench waters, but then only in the clean quench water. There appears to be little correlation between the compounds found on the filter and those present in the quench water samples.

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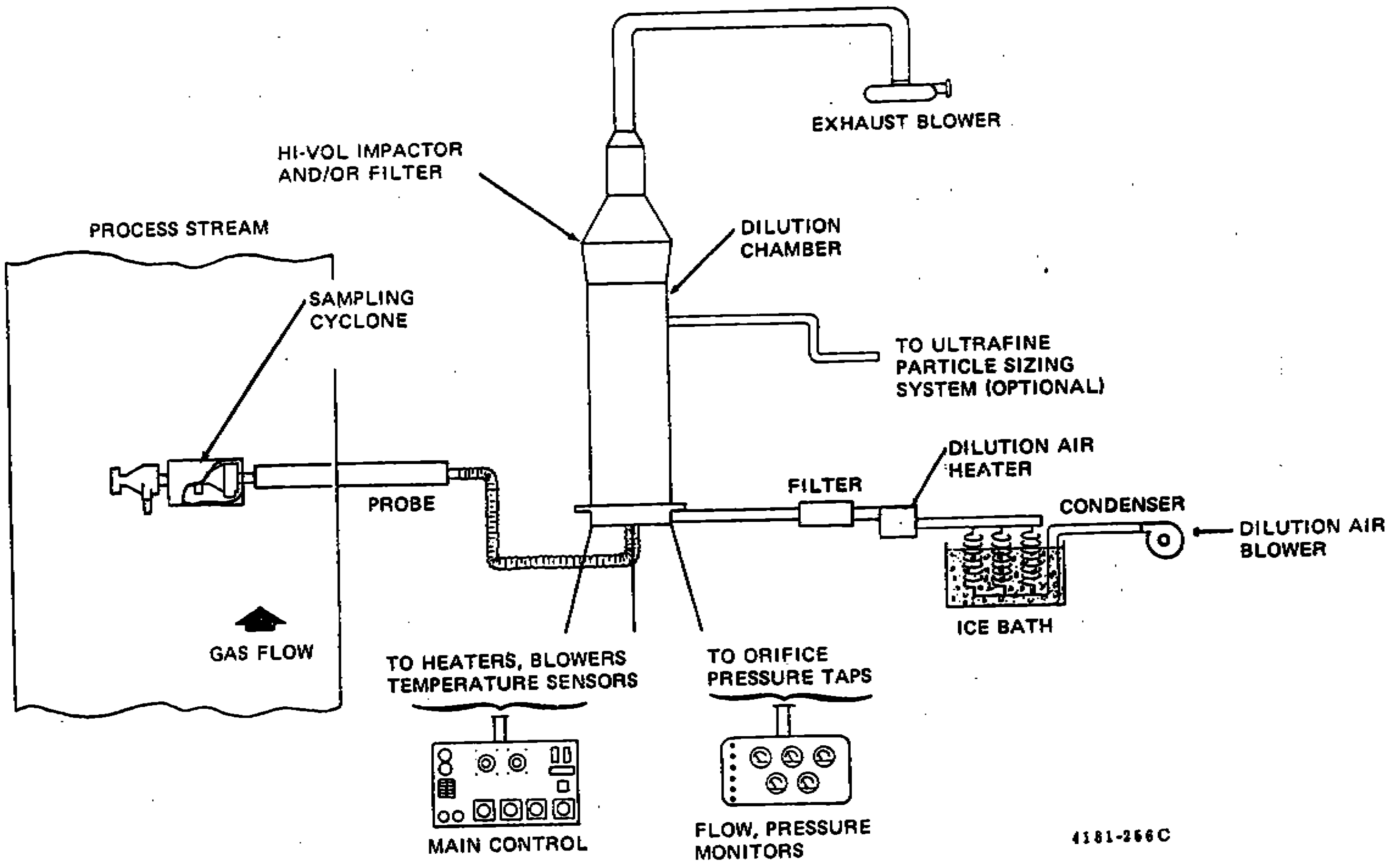


Figure 1. Diagram of stack dilution sampling system.

SDSS Specifications

The geometric and flow specifications have been set by several constraints. The sample flow rate is set by the flow requirements of the IP Cyclone Sampler. Ideally, to approximate the conditions found in actual plumes, the dilution ratio should be high (approaching 10^3-10^4) and the mixing times long (tens of seconds). The actual dilution conditions represent a compromise dictated by limitations on the size of a portable field instrument. Geometric and flow specifications are given in Table 1.

Since the effect of varying dilution air temperature and humidity cannot be easily predicted for all typical process streams, standard conditions of 0.57% moisture by volume at 21.1°C (corresponding to about 24% RH at 70°F) were chosen. This relatively dry dilution air should not be subject to water condensation for normal stack samples, yet is more realistic than totally dry air.

Operating Procedure

The in-stack IP Dual Cyclone Train is the intended precutter for the Dilution Stack Sampling System. This device is fully described in the Procedures Manual For Inhalable Particulate Sampler Operation, Report SoRI-EAS-79-761. The flowrate of stack gas entering the dilution system is determined by the necessity to obtain a D_{50} of 15 μm (50% collection efficiency at 15 μm) for the initial IP cyclone (SRI-X). This flowrate, which varies with temperature, can be determined from the experimental calibration data for the cyclone train. Nominally 23 ℓ/min (0.8 ft^3/min) is required for standard air at 150°C (300°F). Over the entire operating temperature range of the sampler, Cyclone SRI-III obtains 50% collection efficiency at 2.5 $\pm$ 0.5 μm for the flow rate determined by SRI-X. Particulate with aerodynamic diameter smaller than 2.5 μm (The Fine Particulate fraction) passes into the Dilution Stack Sampling System and provides centers for the accumulation of condensable material in the dilution/cooling process.

Since the fine particulate fraction of the instack particulate is collected along with the condensable emissions, a second Dual Cyclone IP train with a standard instack filter is used to simultaneously measure the instack particulate without condensation effects. The setup and operating procedures for both cyclone trains is essentially identical and is described in full in the Procedures Manual for Inhalable Particulate Sampler Operation, Report SoRI-EAS-79-761. In brief, the stack gas temperature, velocity, and composition are measured, and the gas viscosity calculated. Using calibration data for Cyclone X of the Dual Cyclone IP sampler, a flow rate is selected to obtain a D_{50} of 15 μm for this device. Nozzles are selected for isokinetic sampling, and the sampling trains, after warmup, are inserted at different points in the stack which are demonstrated not to have dramatically different loadings due to stratification of

Table 1. Specifications for Dilution Sampling System

GEOMETRIC

• Active length of dilution chamber:	122 cm
• Diameter of dilution chamber:	21.3 cm
• Diameter of sample inlet tube:	4.27 cm
• Active dilution volume:	43600 cm^3

FLOW

• Sample flow (determined by IP cyclone train):	∿17 ℓ/min
• Sample velocity:	∿27 cm/sec at 150°C
• Dilution air flow:	425 ℓ/min
• Dilution air velocity:	20 cm/sec
• Dilution ratio:	∿25:1 (up to 40:1 possible)
• Residence time:	6.2 sec

GAS CONDITIONS

- Sample gas: T<250°C; particles >2.5 μm removed by cyclones
- Dilution air: T=21.1°C; relative humidity 24%; filtered ambient air

SAMPLE COLLECTION

- Particulate collected on glass fiber filter
- Optional impactor gives cuts at 0.5, 1.0, 2.0, 4.0 μm
- Optional extraction of diluted stream for sizing by optical counter, electrical mobility analyzer, CN counter, etc.

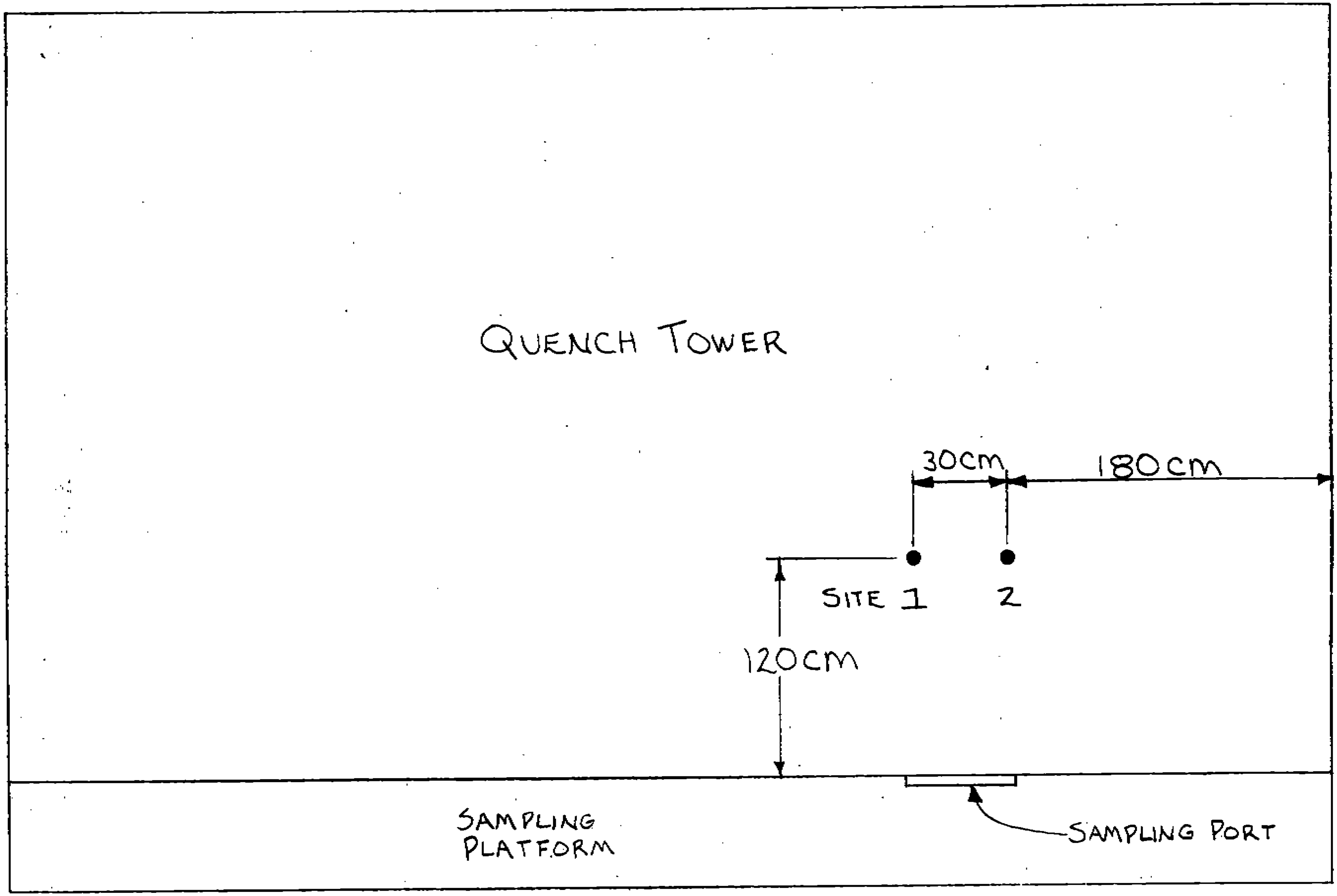


FIGURE 2. CROSS SECTION OF QUENCH TOWER AT DOFASCO, INC. ALL DIMENSIONS APPROXIMATE.

RESULTS

The weights of the cyclone and filter catches along with other associated data are shown in Table 2. Due to an unfortunate miscommunication, two filters run in the SDSS were not preweighed. Techniques used to obtain the sample weights for these filters are described in Appendix A.

CONCLUSIONS

The total concentration of mass runs from instack IP ranged from 55 to 72 percent of the total concentration obtained in parallel SDSS runs. The difference between IP and SDSS concentrations increases in the Inhalable Particulate range (<15 µm) and increased further still in the Respirable Particulate range (<2.5 µm). The concentration of mass indicated for the SDSS runs two and three are extremely conservative since these were obtained from extraction of the catch from the filters as described in the Appendix.

Table 2. Test Results from Coke Quench Operation at Dofasco Inc.

Run Number	Date	Run Type	Sample Duration (min)	No. of Quench Cycles Sampled	Sample Gas Vol. DNM³	Catch Weights (mg)					Mass Concentration mg/DNM³							
						Cyc. X	Cyc. III	Probe	Hose	Filter	Cyc X	Cyc III	Probe	Hose	Filter	I.P.C.^a)	R.P.C.^b)	Total
1	10/21/81	SDSS	66	18	.459	27.14	2.69	24.8	39.0	51.3	59.12	5.86	54.02	84.95	111.75	256.58	250.72	315.70
		IP	44	12	.306	20.18	5.30	-	-	44.2	65.94	17.32	-	-	144.42	161.74	144.42	227.68
2	10/22/81	SDSS	49	16	.481	23.67	5.53	15.3	29.5	49.9*	49.25	11.51	31.83	61.38	103.82	208.54	197.33	257.79
		IP	49	16	.481	15.73	4.12	-	-	52.6	32.73	8.57	-	-	109.44	118.01	109.44	150.74
3	10/23/81	SDSS	33	12	.324	11.14	5.42	14.2	22.9	31.1*	34.42	16.74	43.87	70.75	96.08	227.44	210.70	261.86
		IP	33	12	.324	9.97	3.41	-	-	47.4	30.80	10.53	-	-	146.43	156.96	146.43	187.76
4†	10/24/81	SDSS	70	21	.687	13.85	5.07	7.0	32.7	20.1	20.17	7.38	10.19	47.62	29.27	94.46	87.08	114.63
		IP	70	21	.687	14.09	4.12	-	-	24.7	20.52	6.00	-	-	35.97	41.97	35.97	62.49

*Filter catch weight obtained by extraction (see Appendix A for details)
†Make-up of Quench Water changed
a) Inhalable Particulate Component $\leq$ 15 µm
b) Respirable Particulate Component $\leq$ 2.5 µm

APPENDIX A

Filter Extraction Methodology

SRI has had prior experience in removal of particulate matter from filter material. (For a complete description see A Study to Determine an Optimized Filter Cleaning Procedure for Obtaining Bioassay Samples, Report SoRI-EAS-81-355) as previously mentioned two of four SDSS runs were made with filters having no preweights. Several test extractions were run in order to determine the most effective solvent for removing the Dofasco catches from the filters with no preweights. For these tests, the two filters with valid sample weights were quartered and individually weighed.

Quarters of the filter from SDSS Run #1 were spent in the determination of the most suitable solvent of those tried (acetone, dichloromethane, naptha, and carbon tetrachloride). The grade of carlon tetrachloride used leaves virtually no residue when evaporated (~.0003%), which was confirmed by the evaporation of 500 ml in an aluminum collection pan with no measurable weight gain. The 500 ml evaporated was substantially more than the total volume of carbon tetrachloride utilized during extraction of the catch from each filter quarter, hence solvent residue did not contribute to the weight of the sample removed by extraction.

Filter Extraction

Each filter quarter was immersed in approximately 50 ml of carbon tetrachloride, aggetated manually, then removed. The solvent was then transferred to a preweighed evaporation/collection dish and allowed to evaporate at room temperature. This step was performed in order to remove any material soluble in carbon tetrachloride from the filter segments. Each filter quarter was then placed in a clean glass container with approximately 50 ml of solvent and floated in an ultrasonic bath for approximately 20 minutes. The ultrasonic cleaning process was repeated for each filter quarter until there was no increase in the weight of the collection pan after the solvent had been evaporated. Placing the filter quarters in an ultrasonic bath capaided in physically removing insoluable particular matter captured on the filter membrane and backing.

Data obtained from one filter with a known weight gain and from the two filters of unknown weight gain are shown in Table 3. The fraction of surface was determined by the ratio of the weight of the segment to the total weight of the filter before quartering. The amount of sample present on each segment of SDSS run #1 filter was approximated by proportioning the total catch using each quarter's surface area. To obtain correct weights from an extraction the amount of gain in a collection container should equal the initial amount of sample present on the filter material in question. Retrival efficiency of 100% is obtained when these two amounts are equal. The average retrieval efficiency of the extraction test (preweighed) filter was ~79%.

Table 3

Filer ID	Fraction of Filter Surface Area	Wt. Lost from Filter Segment	Wt. Gain in Collection Pan	Amount of* Sample on Seg.	Total* Filter Gain	Total Lost from Filter	Total Gain in Collection Pan	Retrieval Efficiency (%)
SDSS 10/24/81								
A	.25	4.3	3.9	5.1	20.1	17.1	15.5	76
B	.26	4.5	4.0	5.2				77
C	.25	4.3	3.9	5.0				78
D	.24	4.0	3.7	4.8				83
SDSS 10/23/81								
A	.22	8.3	7.4	-	-	34.9	31.1	-
B	.26	8.9	8.0	-				-
C	.28	9.0	8.0	-				-
D	.24	8.7	7.7	-				-
SDSS 10/22/81								
A	.25	12.9	11.5	-	-	56.3	49.9	-
B	.25	15.2	13.7	-				-
C	.27	15.4	13.5	-				-
D	.23	12.8	11.2	-				-

*Filter weight known for Run #4 SDSS 10/24/81.

APPENDIX H

COMPARISONS WITH WATER QUALITY DATA FROM OTHER QUENCH TOWER TESTS

Water quality data from the DOFASCO 1981 quench tower testing, for clean and dirty water quenching, were compared with data from three steel mill quench tower tests:

- USS/Gary--clean and dirty water quenching
- USS/Lorain--clean and dirty water quenching
- DOFASCO (1977)--clean water quenching.

Data comparisons are shown in Tables H-I and H-II for clean water and dirty water, respectively.

The data comparisons presented indicate that for the water quality parameters shown, the DOFASCO 1981 data are within the ranges established by the USS/Loraine data for both clean and dirty water quenching. The only noticable exceptions are the higher solids (dissolved and suspended) and higher phenol and lower sulfate concentrations for DOFASCO makeup water (dirty water analysis).

A direct comparison of DOFASCO 1981 clean water analysis data with DOFASCO 1977 data showed the following:

- roughly a 60 percent reduction in 1981 makeup water total solids concentration;
- phenols concentration considerably lower in 1981 makeup water while quench and recycle water showed higher levels of phenols; and
- cyanides concentration for 1981 were high for quench, makeup and recycle waters.

MASS BALANCE ANALYSIS OF SELECTED QUENCH WATER PARAMETERS

Mass balance calculations for TSS, TDS, chlorides, phenols, and ammonia were performed to illustrate the quantities of each of these parameters emitted from or retained within the quench tower and quench water sump. Mass balance analysis for these parameters is shown in Table H-III.

H-I. COMPARISONS WITH WATER QUALITY DATA FROM OTHER QUENCH TOWER TESTS

Parameter (ppm)	Clean Water Analysis									
	USS/Gary		USS/Lorain			DOFASCO (1977)			DOFASCO (1981)		
	Quench	Makeup	Quench	Makeup	Return	Quench	Makeup	Return	Quench	Makeup	Return
pH	8.0-8.1	7.5-7.6	-	-	-	7.4-7.8	7.1-11.4	7.0-7.7	8.5	7.5	8.4
TSS	29.2-52.8	3.3-5.5	34-88	5.2-42	103-1245	517-692[a]	895-899[a]	585-956[a]	57	4.8	273.3
TDS	488-494	390-506	110-325	318-1037	837-1261				510	337	560
Sulfate	101-155	21-22	273-340	139-170	237-326	43-65	69-95	41-69	126	61	138
Chlorides	64-230	13-13.4	660-3200	130-2400	720-1325	163-181	68-91	116-125	138	70	145
Phenols	0.5-25	0.03	0.4-0.16	0.1-0.2	0.4-1.8	0.03	0.08-0.12	0.03	0.34	0.002	0.46
Cyanide	2.0-2.7	<1.0-2.0	0.2-0.3	0.0-0.1	0.2-0.4	0.025	0.025	0.025	0.33	0.31	0.34
Ammonia	14-86	0.6-1.6	18-30	0.1-2.1	13-32	0.12-0.92	0.6-2.0	0.86-0.92	3.4	0.99	2.24

[a] Quantities listed as total solids (TSS and TDS).

H-II. COMPARISONS WITH WATER QUALITY DATA FROM OTHER QUENCH TOWER TESTS

Parameter (ppm)	DIRTY WATER ANALYSIS							
	USS/Gary		USS/Lorain			DOFASCO (1981)		
	Quench	Makeup	Quench	Makeup	Return	Quench	Makeup	Return
pH	8.3-8.7	9.1-9.4	-	-	-	8.1	9.0	7.7
TSS	83-126	75-104	120-279	60-338	122-765	155	383	415
TDS	1752-3300	1627-1904	9143-13263	3405-6426	8478-11168	8,858	8,732	9,732
Sulfate	487-1721	809-936	269-319	137-247	206-298	348	68	407
Chlorides	414-696	606-992	6575-14150	5525-9950	7700-11425	5,955	5,043	6,555
Phenols	89-210	255-346	265-390	133-174	231-410	284	662	250
Cyanide	6.3-103	3.6-63	7.2-12.4	6.2-8.6	4.4-7.3	3.7	44.4	2.0
Ammonia	1246-1849	2905-3760	853-2891	873-1216	456-1268	2,300	2,928	2,416

TABLE H-III. MASS BALANCE ANALYSIS OF SELECTED QUENCH WATER PARAMETERS FOR CLEAN WATER, SEMI-DIRTY WATER, AND DIRTY WATER QUENCHING AT DOFASCO (1981) (ppm)

	TSS	TDS	Chlorides	Phenols	Ammonia
<u>Clean Water Analysis</u>:					
Quench	57	510	138	0.336	3.4
Makeup	4.8	337	70	0.0021	0.99
Return	273.3	560	145	0.461	2.24
Tower Loss	NONE	260	103	NONE	9.2
Sump Loss	1,720	465	15	0.5	NONE
<u>Semi-Dirty Water Analysis</u>:					
Quench	114.2	2,270	1,680	87.6	527
Makeup	409.4	9,550	5,437	808	3,733
Return	284.6	2,520	960	75.1	517
Tower Loss	NONE	1,020	5,280	150	577
Sump Loss	2,231	23,767	5,699	1,904	8,993
<u>Dirty Water Analysis</u>:					
Quench	154	8,858	5,955	284	2,300
Makeup	338	8,732	5,043	662	2,928
Return	414	9,732	6,555	250	2,416
Tower Loss	NONE	4,488	2,955	454	1,720
Sump Loss	2,930	15,805	8,523	1,009	4,941

Flow Balance

The flow diagram and balance calculations for the quench tower system are shown in Figure H-I. Information supplied to GCA by DOFASCO was as follows:

- quench water at 6000 gallons per quench;
- makeup water at 8000 gallons per hour with five quenches per hour; and
- return water at 5000 gallons per quench.

TSS Balance

Two noticeable increases in TSS occured as the water quality decreased (clean to dirty):

- increases in return water TSS; and
- increases from sump loss.

The mass gain in return water may be attributed to coke thermal shaffer and/or tower fallout. The percent of Mass increases in the return water for each water quality category were as follows:

- clean - 300%
- semi-dirty - 108%
- dirty - 124%

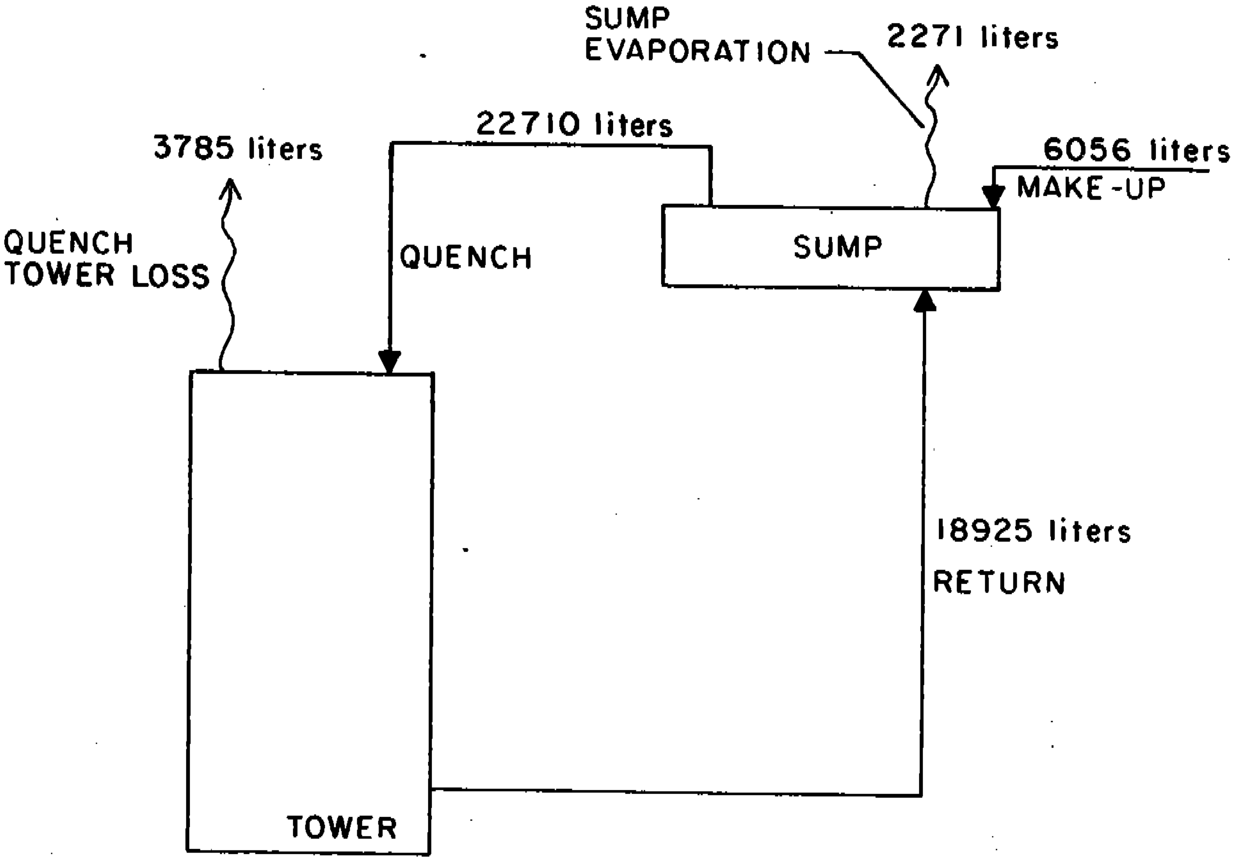
Increases in sump loss TSS are probably due to settlement and sludge formation.

TDS Balance

Contrary to what was found for the TSS balance, there is a mass loss from quench water to return water for all three water qualities. However, this increase attributed to tower loss may not be entirely an atmospheric discharge. Other tower losses include coke attachment and side wall and baffle impingement.

Chlorides Balance

Sump losses of chlorides increased with decreases in water quality possibly due to sludge fixation or volatization of chloride compounds (HcE).



NOTE: All numbers in liters/quench

Figure H-1. Water flow/mass balance.