

QUARTERLY REPORT

QUARTERLY PROGRESS REPORT COVERING PERIOD
JULY 1 THROUGH SEPTEMBER 31, 1981
BIOCIDE BY-PRODUCTS IN AQUATIC ENVIRONMENTS

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Period Covered: July 1 - September 31, 1981

Principal Investigator: Roger M. Bean

This quarter's work has involved planning the sampling program to be conducted this coming year and preparing a summary of results from our work at the Millstone, Duane Arnold, and Arkansas Nuclear Power Plants.

A major finding from our analysis of the effluent streams from these locations was that halogenated phenols constituted a significant fraction of the lipophilic nonvolatile organohalogen material found in the discharges at all three locations. We earlier reported the formation of halogenated phenols in our previous studies of chlorinated natural waters.* However, the evidence was that these components were formed in concentrations very much less than $1 \mu\text{g/L}$. We intensified our phenol analyses at the power plant locations. We extracted 2 L samples of intake and discharge water with methylene chloride specifically for quantitative determination of halogenated phenols by electron capture chromatography. We determined the types of phenols present in the water from analysis of samples taken by adsorption of components on XAD-2 resin columns. These samples represented over 100 L of either intake or discharge water, and therefore, contained sufficient phenol concentrations to allow identification by gas chromatography/mass spectrometry (GC/MS).

Using this combination of samples and of analytical techniques, we have identified over thirty different phenols in the discharges. Phenols identified at DAEC (cooling tower, fresh water), Millstone (once-through marine water) and Arkansas Unit #2 (cooling tower, fresh water) are listed in Table I. Arkansas Unit #1, a once-through unit, had less than $20 \mu\text{g/L}$ (parts-per-trillion) halogenated phenols detectable. Table II gives the concentrations of halogenated phenols found in concentrations greater than $0.1 \mu\text{g/L}$ (parts-per-billion). It can be seen that the total concentrations of phenols in the discharges are comparable to the corresponding concentrations of haloforms from the data presented in Table III. At Duane Arnold, the concentrations of trichloro- and bromodichlorophenols exceeded the determined concentration of chloroform.

The halogenated phenols are apparently a significant fraction of the total lipophilic organic halogen adsorbed on XAD-2 resins, as shown

*R. M. Bean, D. C. Mann and R. G. Riley. 1980. Analysis of Organohalogen Products from Chlorination of Natural Waters Under Simulated Biofouling Control Conditions. NUREG/CR-1301. Nuclear Regulatory Commission, Washington, DC.

in Table IV. From the data in Table III, it appears that haloforms and halophenols account for most of the lipophilic organohalogen material trapped on XAD resins.

The results of our phenol analyses was presented orally at the IV Conference on Chlorine: Environmental Impact and Health Effects held at Asilomar Conference Grounds, Pacific Grove, California on October 18-23. A paper has been prepared for publication in the proceedings, and is appended to this report.

We are also submitting for your review a copy of our proposed sampling program for volatile organic compounds in cooling tower atmospheres. The protocol included information which is additional to the previous copy submitted informally.

The next steps to be taken are to determine one additional power station to be sampled, and to work with NRC staff in setting an appropriate schedule for sampling the three nuclear power stations this fiscal year.

TABLE I. Phenols Identified by Cooling Water Discharges of Nuclear Power Stations.

Phenol	DAEC	Millstone	Arkansas #2
Chloro (2)	X	X	X
Dichloro (2)	X	X	X
Trichloro	X	X	X
Bromo (2)		X	X
Dibromo (2)	X	X	X
Tribromo	X	X	X
Bromochloro (2)	X	X	X
Bromodichloro (2)	X		X
Dibromochloro (2)	X		X
Dibromodichloro (3)	X		X
Trichlorobromo (2)			X
Chloromethyl	X		X
Bromomethyl		X	X
Dibromomethyl		X	X
Tribromomethyl			X
Bromodimethyl		X	
Bromodichloromethyl (2)			X
Dibromochloromethyl (2)		X	
Dibromomethoxy		X	
Bromonitro	X		X
Dibromonitro	X		X

TABLE II. Concentrations of Major Phenol Constituents Found in
Chlorinated Power Plant Cooling Water ($\mu\text{g/L} \pm \text{range}$; $n = 2$)

Phenol	Duane Arnold	Millstone	Arkansas	
			Unit #2	Unit #1
2,4,6-Trichloro	0.7 ± 0.1			
Bromodichloro	0.5 ± 0.0			
Dibromochloro			0.3 ± 0.1	
2,4,6-Tribromo		0.4 ± 0.0	0.4 ± 0.1	
Dibromodichloro			0.1 ± 0.0	
Total Phenols Found in Conc. >0.1	1.4	0.5	1.0	-

TABLE III. Trihalomethane Concentrations in Cooling Water Intake and Discharge (Purge and Trap Method, $\mu\text{g/L}$)

	CHCl_3	CHBrCl_2	CHBr_2Cl	CHBr_3
<u>DUANE ARNOLD^a</u>				
Intake	-	-	-	-
Discharge	0.5 ± 0.2	-	-	-
<u>MILLSTONE^a</u>				
Intake	-	-	-	-
Discharge	-	-	~ 0.3	3.7 ± 0.2
<u>ARKANSAS^{b,c}</u>				
Intake	0.2	-	-	-
Unit #1 (Straight-thru)	1.1	1.0	0.6	0.1
Unit #2 (Cooling Twr)	0.7	0.7	0.8	0.3

^a $\bar{X} \pm \text{s.d.}$, $n = 4$

^b Average of duplicates; difference between duplicates ≤ 0.1

^c Trichloroethane and dichloropropene were found in all water samples at the Arkansas facility at $0.2 \mu\text{g/L}$. Tetrachloroethylene was found in all water samples at levels ranging from 2.5 to $3.1 \mu\text{g/L}$.

TABLE IV. Comparison of Halogen in THM's and Halophenols to the Total Organic Halogen Trapped on XAD-2 Resin (Expressed as $\mu\text{g Cl/L}$)

	THM Halogen ^a	Halophenol Halogen ^b	Total Organic Halogen ^b
<u>DUANE ARNOLD</u>			
Intake	-	-	1.0 ± 0.0
Discharge	0.5	0.7 ± 0.1	1.8 ± 0.5
<u>MILLSTONE</u>			
Intake	-	-	0.9 ± 0.5
Discharge	2.8	0.2 ± 0.0	3.9 ± 0.5
<u>ARKANSAS</u>			
Intake	0.2	-	0.5 ± 0.3
Unit #1 Discharge (Once-through)	2.0	-	2.1 ± 0.3
Unit #2 Discharge (Cooling Tower)	1.6	0.4 ± 0.1	3.3 ± 0.9

^a From Table I

^b Average of duplicates \pm range

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ORGANOHALOGENS IN CHLORINATED
COOLING WATERS DISCHARGED FROM
NUCLEAR POWER STATIONS

Roger M. Bean

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ORGANOHALOGENS IN CHLORINATED COOLING WATERS DISCHARGED FROM NUCLEAR POWER STATIONS

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INTRODUCTION

Our previous studies of organic products from the low-level chlorination of natural waters^{1,2} have shown that wide qualitative and quantitative differences in organohalogen products are observed from one water body to another. We have found, as previously reported by Helz and Hsu,³ that bromide content of the chlorinated water profoundly affects the trihalomethane (THM) product distribution. We have also found that the same concentration of added chlorine which produces 2 µg/L chloroform from one fresh water source can generate more than 50 µg/L bromoform from an estuarine water¹. Our previous studies also identified halogenated phenols as products of the chlorination of natural water.

The objective of the present work is to extend our investigations to a study of organohalogen formation during biocide treatment of cooling water facilities at nuclear power stations, using the same methods we previously used to study the chlorination of natural waters. In addition, we wanted to extend our investigations to include a more detailed study of the halogenated phenols produced during chlorination.

POWER STATION COOLING SYSTEMS AND CHLORINATION PRACTICES

Millstone Nuclear Power Station (Millstone) is located in Connecticut on Long Island Sound. Unit #2 uses once-through cooling with sea water. Chlorination (2 ppm) of each condenser is conducted for 15 min at each

each of four condensers in turn, so that products of chlorination are diluted four-fold in the sampled discharge. *Duane Arnold Energy Center* (DAEC) operates a single unit on the Cedar River in Iowa. Mechanical draft cooling is used. During chlorination (5 ppm), the plant is operated in a closed-loop mode, with makeup water added to compensate for evaporation, until the residual chlorine is reduced to 0.1 ppm (8-12 hr). Then water discharge (blowdown) is started, and the cooling unit operated normally until chlorination is again required. *Arkansas Nuclear One, Units #1 and #2* (Arkansas #1, Arkansas #2) is a unique station in that Unit #1 uses once-through cooling with water from the Dardanelle Reservoir (Arkansas River) while Unit #2 is a recirculating natural draft cooling tower facility. Chlorination for Unit #1 (1.5 ppm) is conducted for about 15 min for each of two condenser systems, while Unit #2 is chlorinated for 15 min at 4 ppm. The chlorine contact time for Unit #1 is about 3 min; that in Unit #2 is measured in hours because the chlorinated water is continuously recirculated through the tower. Blowdown from Unit #2 is a discharge stream used to control suspended solids in the tower, and is less than 1% of the recirculation rate. Unit #2 discharge is fed into the much larger volume of Unit #1.

METHODS

Sampling for Chlorinated Organics

Because of the transient nature of the chlorination process, chlorinated discharges were subsampled into 50-gallon drums coated with polyvinyl fluoride resin to preclude iron-chlorine interaction. The drums, baked at 400°C during the coating process, were further cleaned

by methanol washing followed by leaching with flowing river water for several weeks. Sodium sulfite (6-fold excess) was added to the sampled discharge to reduce remaining residual chlorine. Although most samples were subsampled from the barrel, grab samples of discharge were also collected in glass or Teflon[®] containers.

Samples for purge-and-trap analysis were collected by completely filling a 125 mL bottle with discharge and sealing with a Hycar[®] septum. Large volume samples were collected by passing 150-200 L of discharge at ~80 mL/min through stainless steel columns (9" x 1") filled with 80 mL XAD-2 macroreticular resin, precleaned by the method of Junk, et al.⁴

Two liter samples of discharge were brought to pH 1 with sulfuric acid and extracted twice with 50 mL methylene chloride. These samples were used for phenol analysis.

Analytical Procedures

Analysis of purge-and-trap samples for volatile organics by gas chromatography/mass spectrometry (GC/MS) as developed by Bellar and Lichtenberg⁵ has been previously described.^{1,2} Analysis of samples collected on XAD-2 resins were performed on the ether extracts (200 mL). After drying over Na₂SO₄, the ether solutions were analyzed for total organic halogen (TOX) by microcoulometry and trihalomethanes (THM) by gas chromatography.^{1,6} Then the ether extracts were extracted with 50 mL 0.1 N NaOH to remove the phenols. Phenols were also extracted from the methylene chloride samples with 50 mL 0.1 N NaOH. Halogenated phenols were isolated as the phenol acetates by shaking the basic extracts with 0.5 mL redistilled acetic anhydride for ~2 min and extracting with hexane. Identification of halogenated phenols produced in each

discharge was accomplished by capillary GC/MS analysis of the phenol acetates from the XAD-2 extracts.¹ Phenol concentrations were determined by electron capture capillary chromatography of acetates from the corresponding methylene chloride extracts. Quantitation of halogenated phenols was hampered by a lack of standards for many of the compounds identified. Fortunately, standards were available for most of the predominant compound types. The electron capture response of 2,4,6-tribromophenol was about 78% of the response determined for the corresponding trichloro compound. Trisubstituted phenols containing mixtures of chlorine and bromine were assigned a response factor intermediate to those containing only one halogen type. The average extraction efficiency from 2 L water observed for 17 halogenated phenol standards was 90%. Comparable concentrations of phenols were found in grab samples, eliminating the possibility that the sample barrel was a source of phenols.

RESULTS

Trihalomethanes

The results of analysis of intake and discharge streams for the four power units sampled are given in Table I. The chloroform concentration in the DAEC discharge is very low when the high chlorine levels and long residence time used in the biofouling treatment are considered. In previous studies with chlorination of natural waters,^{1,2} we have found that 2-5 ppm chlorine addition results in between 2 and 25 µg/L of chloroform, produced in one hour. At DAEC, under similar chlorine concentrations and longer residence time, very little THM is observed. This observation is consistent with the postulation by Jolley et al.⁷ that much of the THM formed during the chlorination of

recirculating cooling tower is lost to the atmosphere. In contrast, the bromoform concentration measured in the Millstone discharge is consistent with those found in previous studies with sea water¹ (about 15 µg/L) when the four-fold dilution of the discharge is considered. When Arkansas Unit #1 is compared with Unit #2, concentrations of THM are found to be comparable, even though chlorination conditions were more severe in Unit #2. Concentrations of di- and tribromo THM's were found to be higher in the cooling tower discharge than in the straight-through discharge.

Halogenated Phenols

The halogenated phenols were easily identified as the acetate derivatives because principle ions in the mass spectra are the molecular ion, M^+ and the $M-42^+$ ion from the loss of a ketene moiety.¹ Number and type of halogen substituents are determined from M^+ and isotope ratios. Table II gives a list of halophenols identified in the four chlorinated discharge streams sampled, using the concentrated XAD-2 extract samples. Detection levels for these components correspond to the 1 µg/L level because of the large water sample taken. Comparison of concentration determined by XAD-2 extraction with the electron capture analysis of methylene chloride extracts indicate that more than 50% of the phenols in the water at the µg/L level were trapped on the XAD-2 resin. The identification of tetrahalogenated phenols is more tentative and is based mostly on consideration of molecular weight and loss of mass 42. Isotope ratios for these components were not good enough to be certain of their identity. Nitrohalophenols were identified by comparing their

spectra to the nonhalogenated nitrophenols given in the EPA/NIH Data Base.⁸ Fragment losses and relative ion abundances were strikingly similar.

Table III gives the concentrations of halogenated phenols determined by electron capture capillary gas chromatography of the acetylated methylene chloride extracts. 2,4,6-Tribromophenol was the predominant halophenol constituent found in the Millstone discharge, while chlorine was the predominant substituent in the DAEC discharge. Halosubstitution in the Arkansas Unit #2 discharge strongly favored bromine.

Contribution of THM's and Halophenols to TOX

Analyses of XAD-2 extracts for total organic halogen, together with the values determined for trihalomethane halogen and halophenol halogen are presented in Table IV. The data in Table IV indicate that in the cooling tower discharges, halophenols contribute substantially to the determined increase in TOX over intake water TOX. For the straight-through cooling units, THM's were the largest contributors to the increase in TOX found in the discharge.

CONCLUSIONS

As we have previously reported,¹ organic halogen constituents formed from low-level chlorination of natural waters which are sufficiently lipophilic to be absorbed on XAD-2 resins are found in µg/L concentrations. For the power plant discharges we have studied to date, measured concentrations of THM are lower than might be expected from our previous studies, particularly in the cooling tower water which can lose THM's to the atmosphere. In the cooling towers, where chlorine was

added in higher concentrations and for longer residence times, halogenated phenols can contribute significantly to the total organic halogen content of the discharge. The way in which cooling towers are operated may also be a factor in the production of halogenated phenols, since they concentrate the incoming water by a factor of four or five. For example, Arkansas Unit #2 tower concentrated the bromide ion in the incoming water five-fold to 1.0 ppm, which explains the high contribution of bromine to the halogenated phenol content. In addition, the phenols which act as a substrate for the halogenating agent are also likely concentrated by the cooling tower operation and may be prevented from being biodegraded by the same biocide addition producing the halogenated phenols.

ACKNOWLEDGMENTS

The authors are pleased to acknowledge the support of the Nuclear Regulatory Commission for the conduct of this work. Brand names and suppliers are given to assist in replication of the analyses, and their use does not constitute endorsement by Battelle Memorial Institute.

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TABLE I. Trihalomethane Concentrations in Cooling Water Intake and Discharge (Purge and Trap Method, $\mu\text{g/L}$)

	CHCl_3	CHBrCl_2	CHBr_2Cl	CHBr_3
<u>DUANE ARNOLD^a</u>				
Intake	-	-	-	-
Discharge	0.5 ± 0.2	-	-	-
<u>MILLSTONE^a</u>				
Intake	-	-	-	-
Discharge	-	-	~ 0.3	3.7 ± 0.2
<u>ARKANSAS^{b,c}</u>				
Intake	0.2	-	-	-
Unit #1 (Straight-thru)	1.1	1.0	0.6	0.1
Unit #2 (Cooling Twr)	0.7	0.7	0.8	0.3

^a $\bar{X} \pm \text{s.d.}$, $n = 4$

^b Average of duplicates; difference between duplicates ≤ 0.1

^c Trichloroethane and dichloropropene were found in all water samples at the Arkansas facility at $0.2 \mu\text{g/L}$. Tetrachloroethylene was found in all water samples at levels ranging from 2.5 to $3.1 \mu\text{g/L}$.

TABLE II. Phenols Identified by Cooling Water Discharges of Nuclear Power Stations.

Phenol	DAEC	Millstone	Arkansas #2
Chloro (2)	X	X	X
Dichloro (2)	X	X	X
Trichloro	X	X	X
Bromo (2)		X	X
Dibromo (2)	X	X	X
Tribromo	X	X	X
Bromochloro (2)	X	X	X
Bromodichloro (2)	X		X
Dibromochloro (2)	X		X
Dibromodichloro (3)	X		X
Trichlorobromo (2)			X
Chloromethyl	X		X
Bromomethyl		X	X
Dibromomethyl		X	X
Tribromomethyl			X
Bromodimethyl		X	
Bromodichloromethyl (2)			X
Dibromochloromethyl (2)		X	
Dibromomethoxy		X	
Bromonitro	X		X
Dibromonitro	X		X

TABLE III. Concentrations of Major Phenol Constituents Found in
Chlorinated Power Plant Cooling Water ($\mu\text{g/L} \pm \text{range}$; $n = 2$)

Phenol	Duane Arnold	Millstone	Arkansas	
			Unit #2	Unit #1
2,4,6-Trichloro	0.7 ± 0.1			
Bromodichloro	0.5 ± 0.0			
Dibromochloro			0.3 ± 0.1	
2,4,6-Tribromo		0.4 ± 0.0	0.4 ± 0.1	
Dibromodichloro			0.1 ± 0.0	
Total Phenols Found in Conc. >0.1	1.4	0.5	1.0	-

TABLE IV. Comparison of Halogen in THM's and Halophenols to the Total Organic Halogen Trapped on XAD-2 Resin (Expressed as $\mu\text{g Cl/L}$)

	THM Halogen ^a	Halophenol Halogen ^b	Total Organic Halogen ^b
<u>DUANE ARNOLD</u>			
Intake	-	-	1.0 ± 0.0
Discharge	0.5	0.7 ± 0.1	1.8 ± 0.5
<u>MILLSTONE</u>			
Intake	-	-	0.9 ± 0.5
Discharge	2.8	0.2 ± 0.0	3.9 ± 0.5
<u>ARKANSAS</u>			
Intake	0.2	-	0.5 ± 0.3
Unit #1 Discharge (Once-through)	2.0	-	2.1 ± 0.3
Unit #2 Discharge (Cooling Tower)	1.6	0.4 ± 0.1	3.3 ± 0.9

^a From Table I

^b Average of duplicates \pm range

SAMPLING VOLATILE ORGANICS FROM
POWER PLANT COOLING TOWERS

Roger M. Bean
Donald W. Glover
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Cooling Tower Sampling Protocol

I. Overview

The task of identifying and quantitatively measuring the atmospheric release of gaseous material during cooling tower operation represents a significant departure from routine source characterization. General operational features of natural and forced draft towers have been considered in designing a general protocol which will be subject to modification imposed by specific design and operating features associated with individual test sites. As opposed to more typical source sampling tasks, the following considerations, unique to the cooling tower problem, must be recognized and explored in terms of the specific towers to be sampled.

- Tower dimensions and the relative upstream distance between vapor release from the cooling water and the top of the tower suggest that vapor concentration may vary across the effluent stream. The cooling tower therefore represents a source in which effluent concentration is non-uniform.
- Vapor concentration will undoubtedly change dramatically with time. Peak release is expected to occur during or soon after the chlorination process and decay in an exponential manner to near zero within a period of 1-2 hours.
- Unlike stack effluent characterization, sampling must be conducted at the top of the tower rather than through upstream ports. Although there may be access to a lower region, several problems are expected with respect to personnel and equipment operation within the tower. Additionally, since sampling will be conducted at the top of the tower, ambient conditions (wind speed and direction) must be selected to minimize impact.
- Significant levels of liquid water will be encountered in the test environment. This must be recognized in selecting pumps and installing them for the sampling task. The impact of liquid water on the vapor adsorption column must also be considered and a sampling head employed to separate liquid water from the vapor stream being sampled.

II. Characterization and Sampling Tasks

a. Characterization

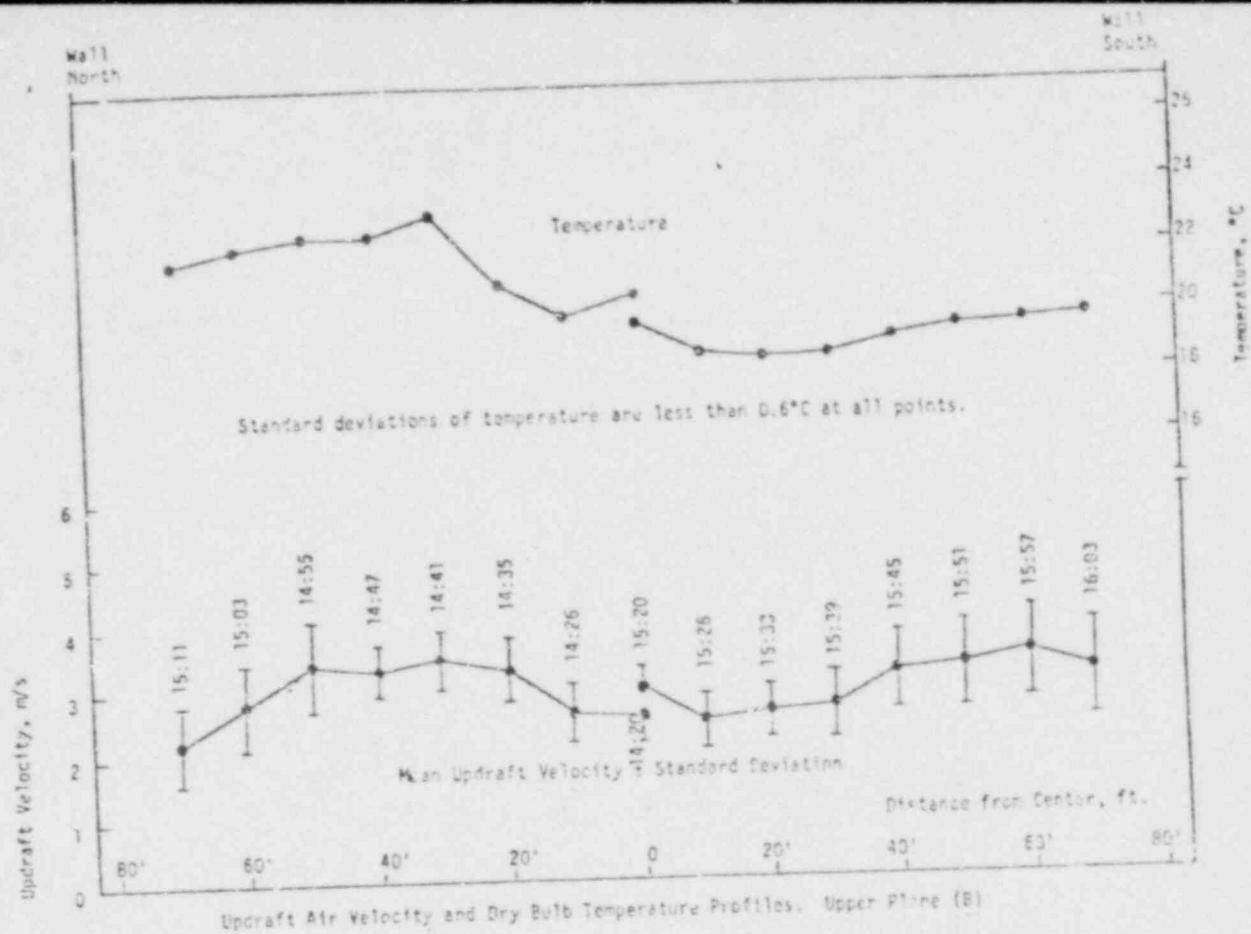
Natural and forced draft cooling towers present distinctive sampling problems. The updraft velocity in a natural draft tower is indicated by the profile measurements displayed in Figure 1. Although the flow velocity is fairly uniform, the size of the opening to be sampled may impose sampling limitations depending on the extent to which materials must be fabricated to support and house sampling equipment, the presents of work space at the tower exit and tower access. Forced draft towers present a different set of problems including a more complex flow pattern (Figure 2) and the need to focus on a single cell in a battery of units as a practical limitation imposed by equipment, personnel and time constraints. In either case a complete description of the tower and the cooperation of plant personnel is vital to the planning process. In the absence of a site visit prior to the measurement program, a description of the tower including engineering drawings and photographs is essential.

Flow characteristics (updraft velocity and temperature) should be determined prior to and during sample collection. These measurements will be made using Gill propeller anemometers located at points defined by an Equal Area Traverse (EAT). Using this technique the tower cross section to be sampled is divided into annular rings of equal area. Anemometers will be located along perpendicular traverses of the sampling plane midway between the inner and outer diameter of the respective rings. The number of sampling points will be dependent on tower dimensions and practical limitations such as available sampling units. A minimum of six points, determined in accordance with methods published in the Federal Register (Vol. 36, No. 247, Thursday, December 23, 1971) will be used to define tower characteristics.

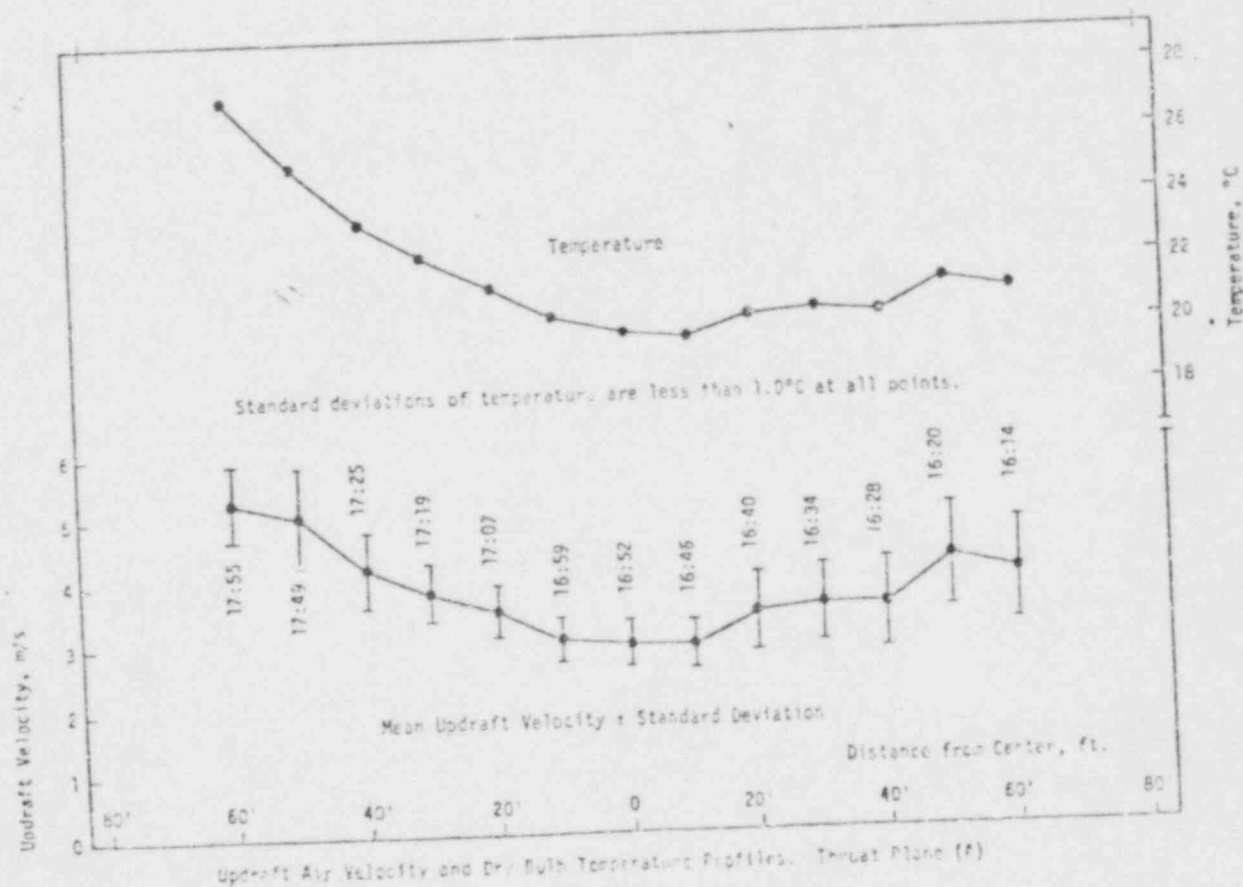
b. Sample Collection

Sample collection will be conducted at points corresponding to flow and temperature measurement. It will be initiated prior to chlorination and continue for a minimum of one hour following termination of the

chlorination process. The vapor collection device will consist of two tubes in series packed with an adsorbent material, Tenax-GC. The packed columns are preceded by an impinger to capture liquid water droplets which would interrupt sample flow by altering the pressure drop across the columns. Effluent sample will be pulled through the sampling device using pumps located at the perimeter of the tower in order to minimize contact with moisture laden air. The pumps will be battery operated units designed to sample personnel exposure in workplace environments. They offer adequate flow while eliminating electrical hazards associated with the use of AC power lines. Flowmeters should be placed in the sampling lines, downstream of the adsorption tubes, to permit monitoring of sample flow rates. All measured parameters, updraft velocity, temperature and sample flow rate, will be recorded at five minute intervals throughout the sampling period. In addition to sample collection at the time of chlorination, samples exposed during a day when the cooling water is not treated will serve as blanks.



Updraft Air Velocity and Dry Bulb Temperature Profiles, Upper Plane (B)



Updraft Air Velocity and Dry Bulb Temperature Profiles, Throat Plane (F)

Figure 1. Nature Draft Cooling Tower

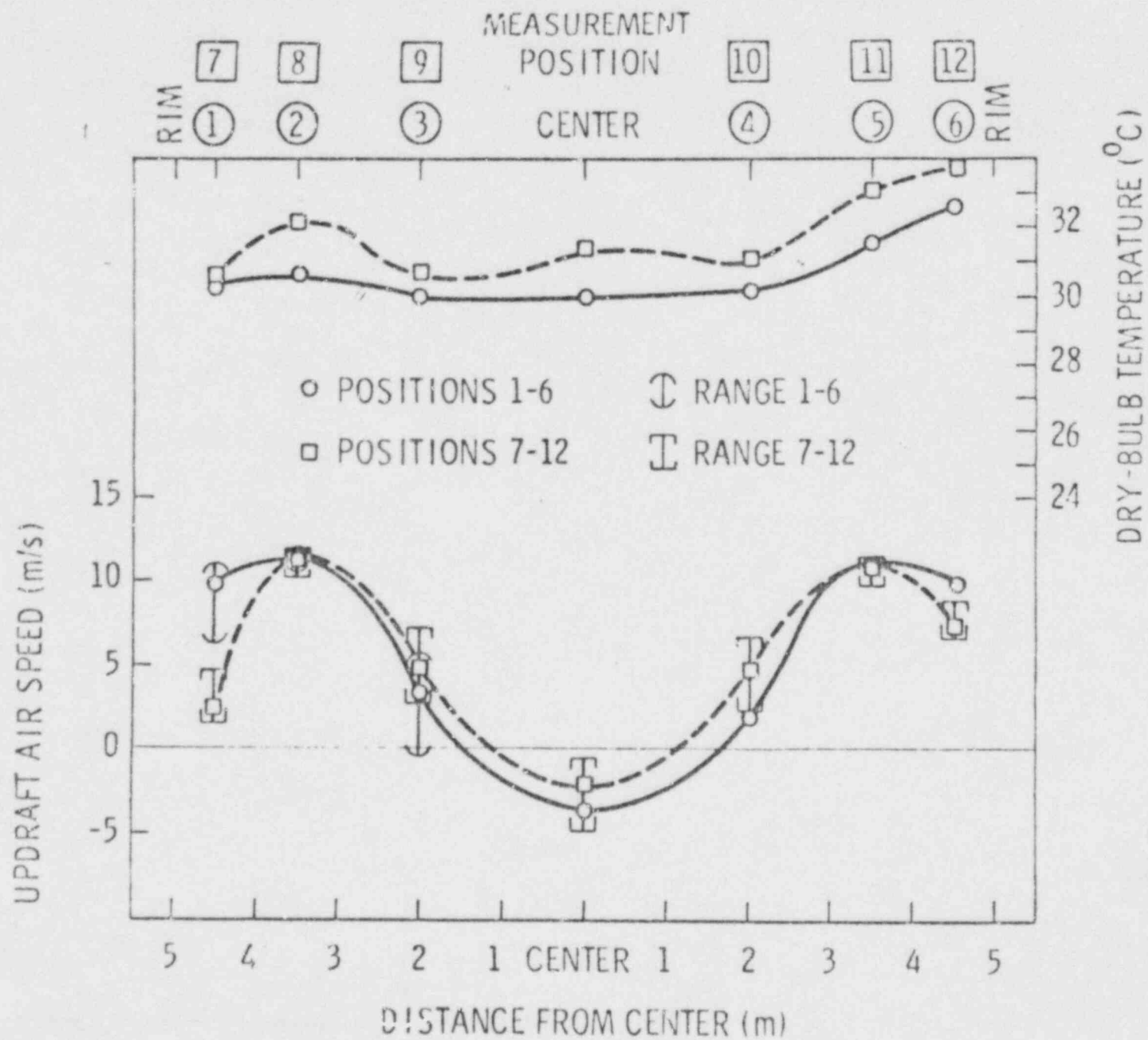


Figure 2. Forced Draft Cooling Tower

III. Sample Analysis

Adsorption sampling tubes are 1/4" stainless steel containing Tenax resin and are purchased from Envirotech, Inc. These columns have been used successfully for purge and trap analysis of volatiles in chlorinated waters during the course of the program.¹ Sampling and analysis of air pollutants using Tenax Resin columns have been extensively documented by Pellizzari for the USEPA.²

Prior to taking the sampling tubes out in the field, each will be heated to 200°C in a stream of inert gas for 30 minutes and transferred to a sealed teflon-lined vial containing nitrogen. The tubes will be kept sealed in the vials until immediately before use, and replaced in the vials immediately after sample collection.

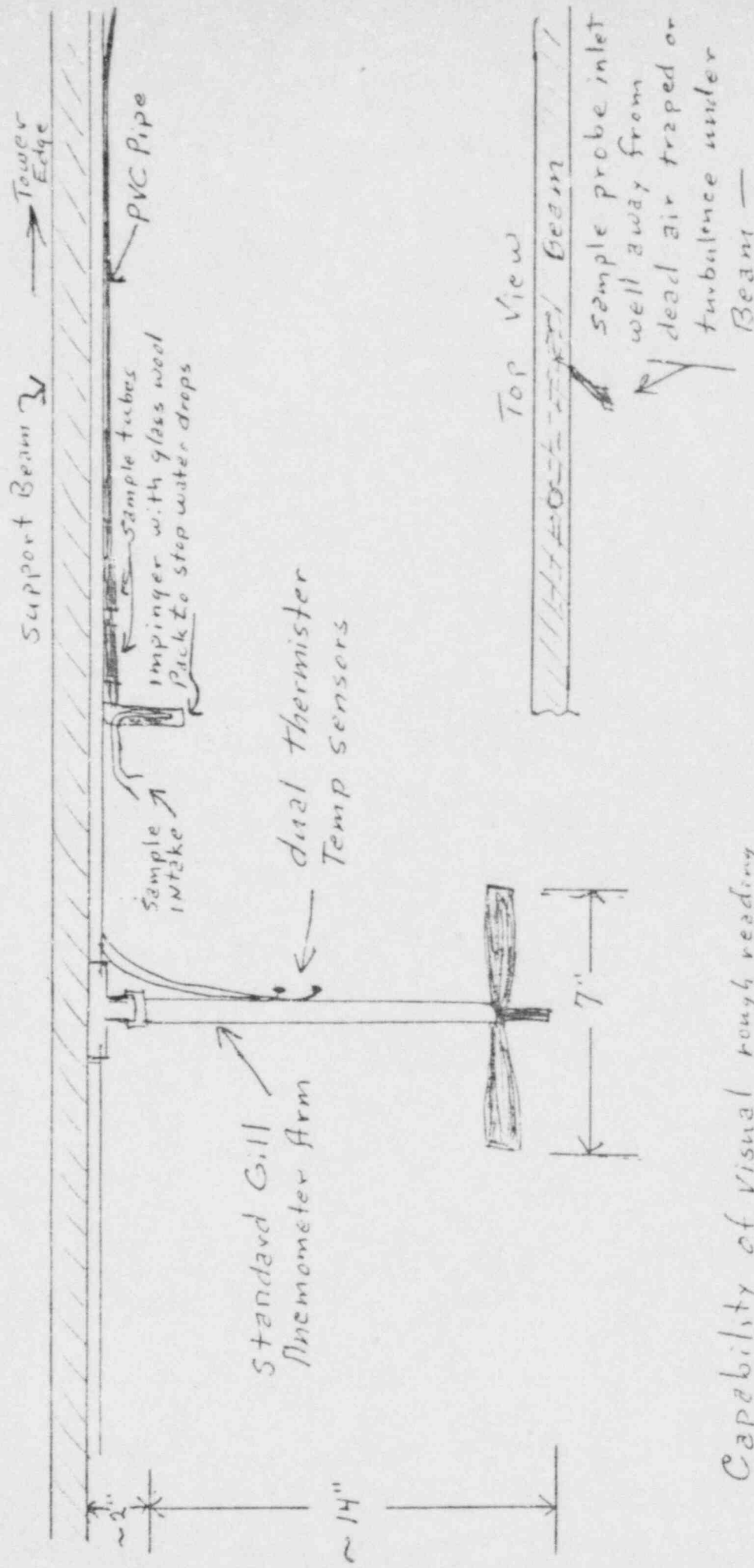
The samples will be analyzed by heating the Tenax column to 200°C in a stream of carrier gas which will force the sample onto a 6-ft. long, 2 mm ID glass chromatographic column packed with 0.2% Carbowax 1500 on Carbowax. Analysis of sample components for volatile components will be by Mass Spectrometry. Components analyzed will be principally the four trihalomethanes (THM). However, selected samples will be analyzed in detail for other volatile chemicals containing halogen. This list of chemicals is described in NUREG/CR-1301.

¹R. M. Bean, D. C. Mann, R. G. Riley. Analysis of Organohalogen Products from Chlorination of Natural Waters Under Simulated Biofouling Control Conditions. NUREG/CR-1301.

²E. D. Pellizzari. 1977. Analysis of Organic Air Pollutants by Gas Chromatography and Mass Spectroscopy, EPA-600/2-77-100.

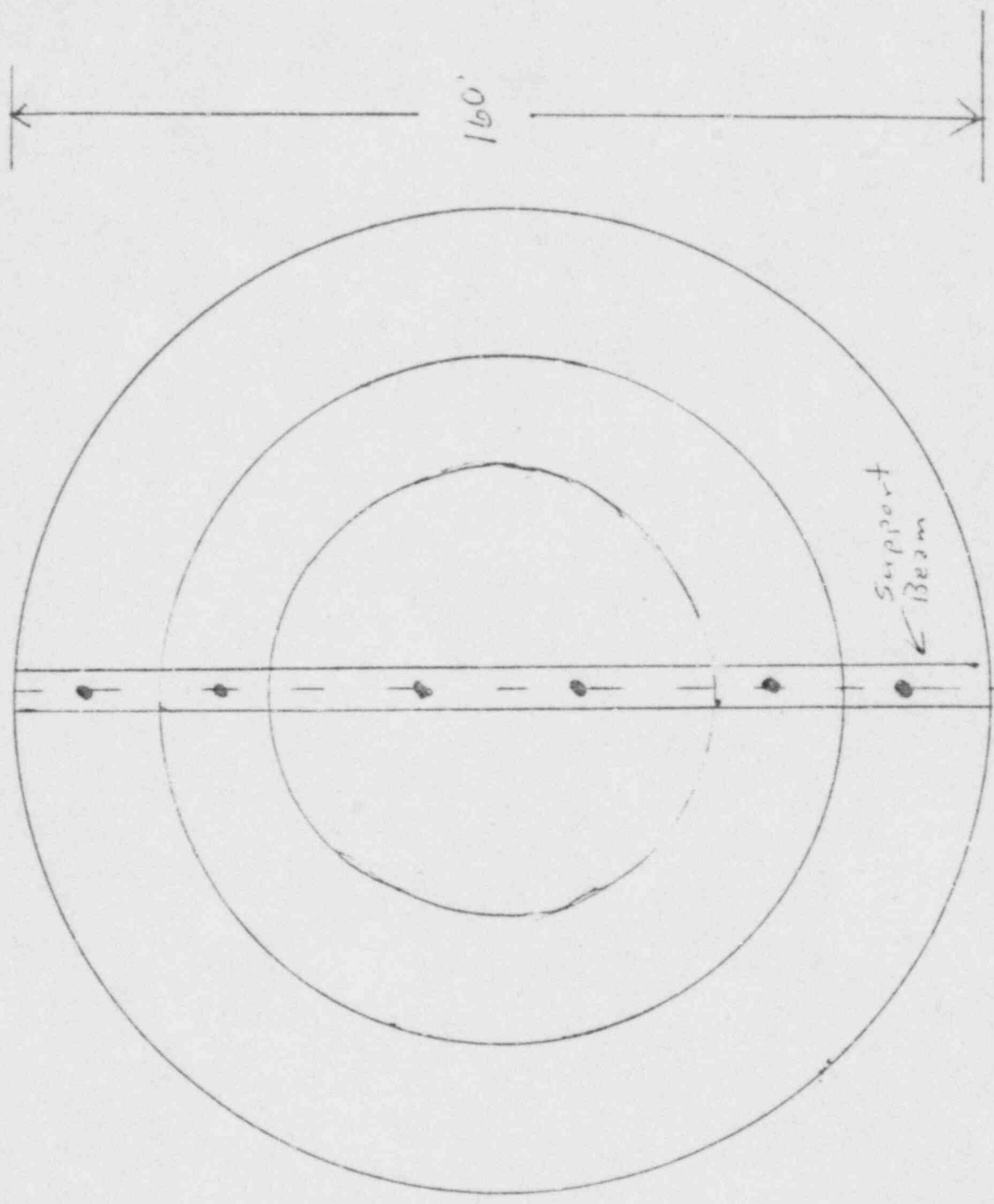
Prior to analysis of samples, calibration curves will be prepared by (1) injecting known quantities of THM's on the Tenax resins, purging with moist air for the sampling time (1-2 hr) and comparing the THM before and after purging, (2) purging known quantities of THM from water onto the trap for the sampling time and comparing with the same quantities of THM directly injected onto the trapping column. These experiments will confirm: (a) the detection limits (200 ng/m^3 are estimated by Pellizzarai²), (b) the capacity of the columns and (c) the efficiency. These measurements will allow us to apply appropriate corrections and give estimates of minimum and maximum discharges by the cooling towers which can be detected by our methods.

Individual Sample Station



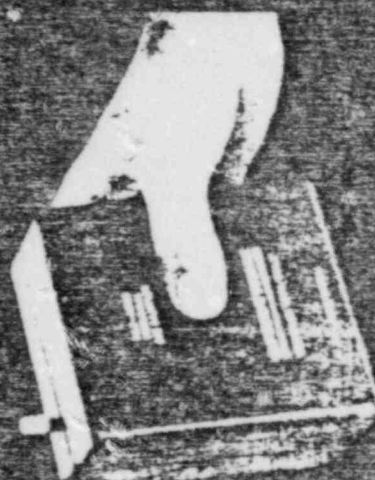
Capability of visual rough reading on all Temp. and Velocity sensors and 7099 track may tape record of both-continuous throughout sample period

Cooling Tower Top View



- 6 sample stations each one drawing an air sample plus temp. and Air Velocity

OPERATING MANUAL



PAS-3000 PERSONAL AIR SAMPLER

SPOTREX
CORPORATION

3841 HAVEN AVENUE, REDWOOD CITY,
CALIFORNIA 94063, (415) 386-9967

PURPOSE

The PAS-3000 is a personal air sampler for moving air through an external collection device, such as charcoal tube or gravimetric filter, or for filling sample bags. It automatically provides constant flow for 1-5% in spite of changes of pressure drops as high as 10 inches of water.

CONTENTS

The PAS-3000 sampling kit consists of:

- Constant flow sampler, with built-in rechargeable battery pack
- 110V 60 Hz battery charger
- Screws for removing sampler cover and setting flow
- Volume indicator (for setting 10⁻³ l/min at 2 LPM for flow calibration)
- Carrying case



STANDARD FEATURES

1. Seven flow control for constant flow for a changing input vacuum load up to 10⁻³ H₂O
2. Flow rates from 5 cc to 2.7 LPM set by combination of mechanically adjustable pump stroke and potentiometer control
3. Pulsation dampener
4. 2 LPM flow for over 16 hours across 80mm filter and over 12 hours across 40mm filter on one battery charge
5. 100 cc per minute flow for over 30 hours on one battery charge
6. Dependable, 10,000 hour operating life

7. Full battery charge indicator
8. Audible low flow detector for duration of restriction plus electronic memory to indicate at end of sampling period if there has been a restriction beyond preset time
9. All controls are internal and are protected from tampering during sampling period

OPTIONAL FEATURES

1. Humming time indicator
2. Preprogrammable timing timer
3. Air outlet port for bag sampling
4. Variable flow meter
5. External on/off switch or external retrievable on/off jack
6. Small portable rotameter, self standing, to set 2 LPM flow

STEP-BY-STEP OPERATING INSTRUCTIONS

1. CHARGE BATTERIES

Plug battery charger cord into receptacle on left side of pump and plug three prong adapter into any standard 110 V AC outlet. When the red light emitting diode on the battery charger lights up the pump is being charged. A full charge is obtained after 16 hours. The batteries cannot be overcharged.

2. OPEN CASE

A. Open pump by unscrewing 4 corner screws on the back case of the pump, using the screwdriver provided. The screws are locked in and cannot fall out of the rear case.