AP42 Section:	13.4
Background Chapter	4
Reference:	17
Title:	Cooling Tower Drift Test Report for Unnamed Client of the Cooling Tower institute, Houston, Texas. Midwest Research Institute (1987).

17

4

SUMMARY

The testing services of the Cooling Tower Institute (CTI) were retained by the to conduct drift acceptance tests on a 6-cell, mechanical-draft, counter-flow cooling tower located at The work was performed by Midwest Research Institute (MRI) under contract with CTI as the official CTI test representatives.

The test was conducted on The building was designed to accommodate six cooling tower cells of which four are presently complete and the other two are for future expansion. Cell No. 4 was chosen to be representative of the completed cells. The circulating water flow was measured using a hydraulic pitot tube with an air-over-water manometer. Fan motor power was measured with a clamp-on kilowatt meter. These parameters were within the limits specified by the ATC-105 code for thermal acceptance tests; therefore, the drift test was conducted with representative air and water loadings.

The sampling was conducted using industry-accepted isokinetic sampling techniques. The drift was collected in wet impingers followed by a final teflon filter. The basin water was spiked with sodium bromide prior to sampling. The samples of basin water and drift were analyzed by neutron activation analysis for bromine content. Analytical results were used to calculate a drift rate of 0.007%. This is equivalent to 0.57 gal/min of drift from each cell when operating at a 7,386-gal/min circulation rate.

COOLING TOWER INSTITUTE TEST REPORT

DRIFT ACCEPTANCE TEST
ON A

6-CELL, MECHANICAL-DRAFT, COUNTER-FLOW
COOLING TOWER

I. INTRODUCTION

The testing services of the Cooling Tower Institute (CTI) were retained by the
struction (OFPC) Project No. , to conduct a drift acceptance test on a 6-cell, mechanical-draft, counter-flow cooling tower in accordance with the CTI Acceptance Test Code ATC-105. The cooling tower is located at
campus. The work was performed by Midwest Research Institute (MRI) under contract with the CTI as the official CTI test representative. The CTI test representatives for this test were Mr. Thomas E. Weast, Mr. Kenneth W. Hennon, and Mr. George R. Cobb. The tower manufacturer was not represented. The plant was represented by

Cooling tower drift is defined as the percent of water flow through the tower which exits through the fan in the form of water droplets or aerosols. The amount of drift from the tower was determined by isokinetically sampling a representative fraction of the tower airflow and measuring the amount of aerosol leaving the stack. Sodium bromide (NaBr) was spiked into the basin as a tracer for the analysis. Neutron activation analysis (NAA), an extremely sensitive detection technique, was then used to measure the amount of bromine in the basin water and that exiting from the stack. From measurement of the total bromine collected in the sampler and the concentration of bromine in the basin water, the drift rate was calculated.

II. TEST SITE DESCRIPTION

is located on the north side of the
The cooling
tower provides cooling water to air conditioning equipment. The cooling tower is located on the roof of the building.

The cooling tower consists of six mechanical-draft, counter-flow cells of which four cells are presently complete and two are for future expansion. The cells are in a continuous straight line with a common cold water basin beneath the tower. Each cell is equipped with a 22-ft diameter fan driven by a 75-hp motor.

Twenty-inch diameter, fiberglass conduits feeds hot water from a common manifold to each cell. Pitot taps for water flow and hot water measurement were located in each 20-in. line.

The cold water from the cooling tower basin is collected in the forebay adjacent to the tower, where downcomers return cold water to the plant. Two pumps located two floors below the roof are used to pump water through the system. The tower's makeup water was left in operation but the blowdown discharge was shut off during the drift test.

III. TEST DATA COLLECTION

A. Test Sequence

The test sequence consisted of the following steps:

1. Water flow and fan horsepower measurements were conducted to determine the tower operating conditions.

2. The basin was spiked with a known amount of sodium bromide (NaBr) and a water sample collected.

3. Isokinetic sampling of the selected stack was conducted.

4. A second basin water sample was collected at the conclusion of the test.

5. The samples were recovered from the stack sampling system.

6. The samples were transported to the laboratory and analyzed for bromine content by NAA.

B. Tower Operating Conditions

The applicable test data were acquired in accordance with applicable portions of the CTI ATC-205 (1982) test code. The individual test parameters were measured as follows:

- Total circulating water flow was measured with two 20-point pitot traverses of the hot water return line to the test cell with a Simplex/Leopold-type pitot tube with a 36-in. maximum working length. An air-over-water manometer was used for measuring the differential pressure between the impact and reference orifices of the pitot tube.

- Fan motor input power was measured with a clamp-on, digital-type kilowatt meter using the two watt meter method. The data were taken at the motor control center adjacent to the tower. Power loss between the control center and the tower fan motors was not calculated. A motor efficiency of 0.932 was used to determine the motor output power.

During testing, the tower conditions were in accordance with the CTI Test Code ATC-105 Section I-2.2, and all applicable operating conditions were in accordance with the CTI Test Code ATC-105 Section I-2.3. The operating data are contained in Appendix A.

B. Basin Water Spike

When the type and quantity of elements in the basin water which are suitable for analysis are unknown, a surrogate (i.e. tracer) compound may be added to ensure that a sufficient quantity of known material will be collected for analysis. Therefore, 110 lb of NaBr was added to the tower basin prior to testing. This brought the concentration of Br (the element chosen as a tracer for this test) to a sufficient concentration that excessive sampling times could be avoided. Before testing, a sample of the basin water was taken. This was combined with a second sample taken at the completion of the test (approximately 8 hr later). An average value of 55.2 μg/mL was obtained and used for the calculations described below.

C. Sampling Procedures

The sampling equipment and procedures used on the test are briefly described below. Some test results are also provided in this section where appropriate.

1. Airflow measurements: The tower's airflow, exit air temperature, and angle of cyclonic flow were measured prior to the sampling of each point using a standard pitot tube. The sample plane was located across the top of the fan stack. The sampling point locations were computed using the following equation:

$$D_n = \frac{d}{2} - \sqrt{\left(\frac{2N - 2n - 1}{8N}\right)\left(d^2 - d_h^{\,2}\right) + \left(\frac{dh}{2}\right)^2}$$

where:

D_n = nozzle distance from the edge of the stack

d = diameter of the stack (278.75 in.)

n = point number being sampled

N = total number being sampled (10)

d_h = hub diameter (72.75 in.)

This procedure was used to divide the outlet into 10 of equal areas. Four radial traverses of 10 points each were made at 90 degrees to each other along the horizontal plane of the stack as shown in Figure 1. These procedures were adapted from those specified by EPA.[1] The total volume of airflow from the cell was found to be 666,444 dscfm.

2. Collection of stack sample

a. Sampling equipment: The sample train used for the test is shown in Figure 2. Impingers 1 and 2 contained distilled water. Impinger 3 was dry. Impinger 4 was deleted. The filter was a 47-mm millipore Teflon filter with a pore size of 5 μm.

An airtight pump was used to draw the sample through the train. The actual volume sampled was measured with a standard dry gas meter. The probe was Teflon with a stainless steel nozzle.

b. Sampling procedures: Sampling of the stack was conducted at the same points used for the airflow measurements (see Figure 1). Samples were drawn isokinetically through the nozzle and Teflon probe and into the impingers. The first two impingers were used to scrub out particulate and water droplets. The third impinger was used to collect water droplets which might be carried over from the first two impingers. The millipore filter then served as a backup for any particulate which might have passed through the impingers.

Since cyclonic flow can bias the drift results, adjustments in the sampling technique were used to eliminate this bias. If the nozzle is not aligned with the flow, then the effective velocity through the nozzle opening with respect to the cross-sectional area of the fan stack is reduced by the cosine of the angle between the flow and stack axis. This results in a flow sample which is not truly isokinetic. To eliminate this bias, the alignment approach[2] was used during the drift test. The angle of the flow to the stack axis for each point was determined prior to sampling that point. It was assumed that the airflow direction and velocity for each point remained stable through these measurements and the sampling period. The nozzle was aligned with the airflow and the samples were collected isokinetically. Proportional sampling needs were then satisfied by adjusting the sampling time at each point by the cosine of the angle. This related the volume collected to the axial velocity by a constant according to:

[1] Federal Register, Vol. 42, No. 160, August 18, 1977.

[2] Peeler, J. W., F. J. Phoenix, and D. J. Grove, "Characterization of Cyclonic Flow and Analysis of Particulate Sampling Approaches at Asphalt Plant," Entropy Environmentalists, Inc.

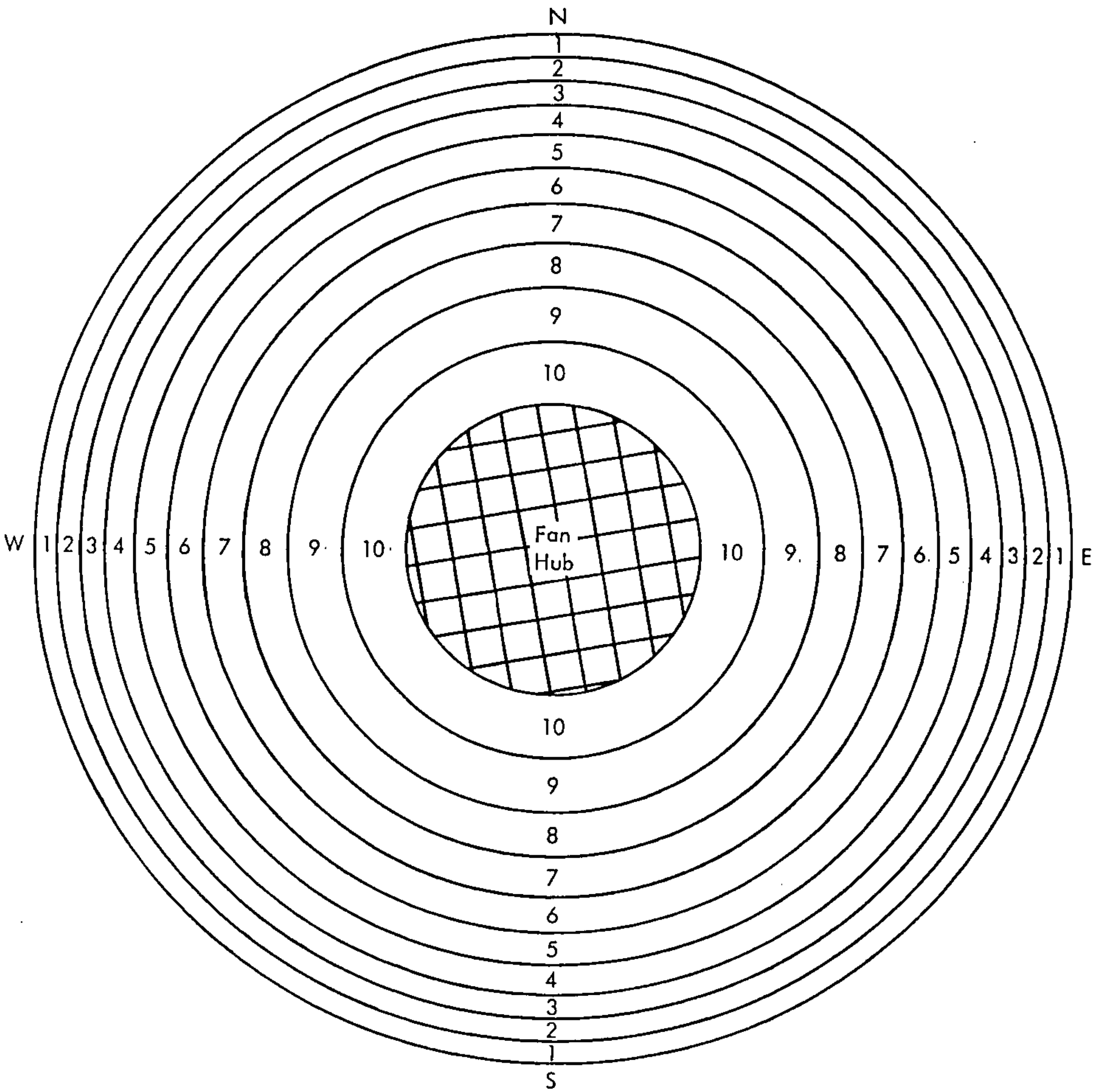


Figure 1 - Sampling Points were Located in the Center of Each of the Equal Area Zones. Numbers 1 to 10 indicate the distances from the fans inside wall to the respective sampling points.

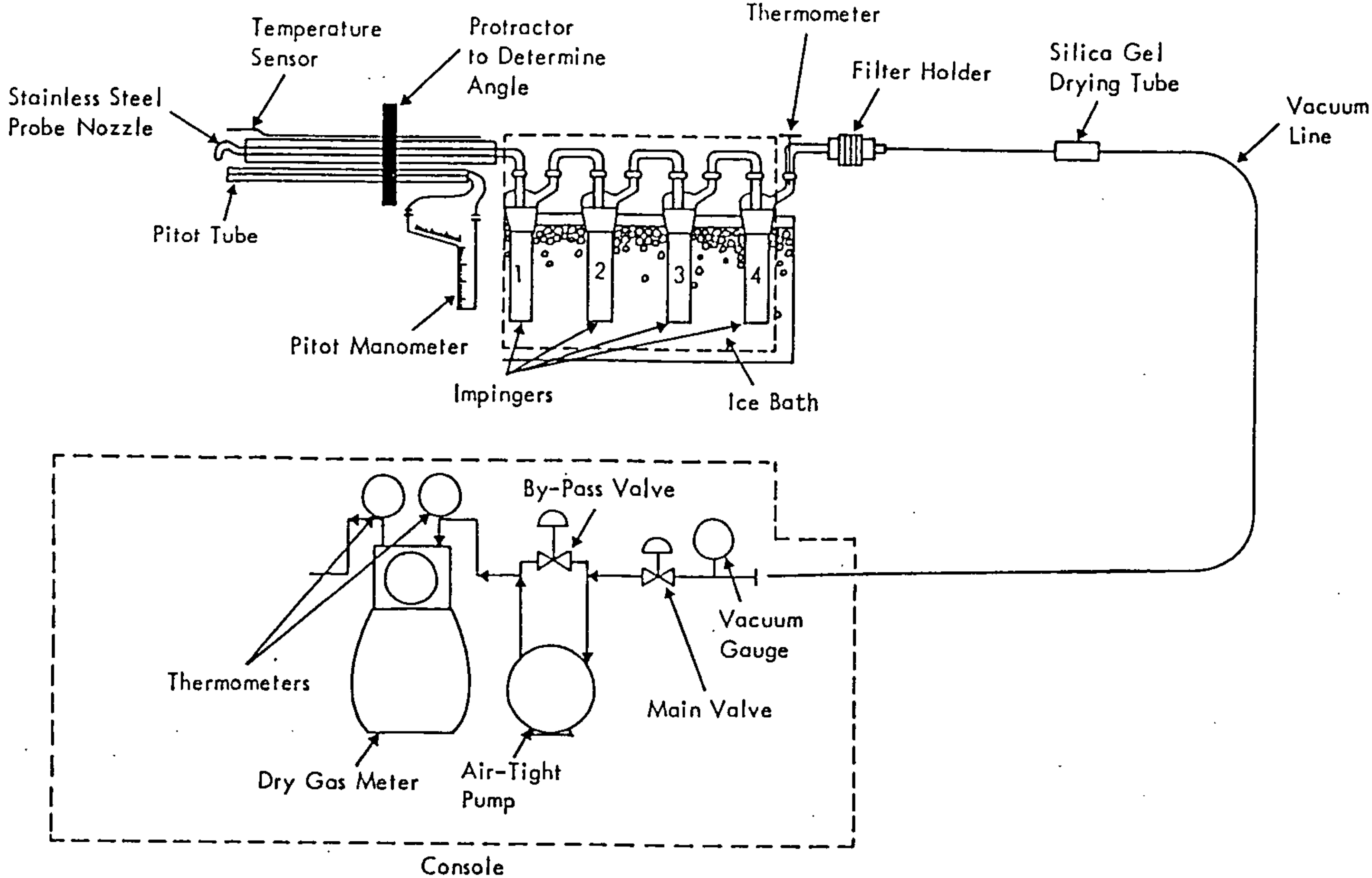


Figure 2 - Typical Drift Sample Train

$$t_2 = t_1 \cos \theta$$

where:

t_1 = nominal sampling time per point = 5 min

t_2 = actual sampling time per point

θ = angle between flow direction and stack axis

The total volume of the sample was 551.1 dscf. The raw data are provided in Appendix A.

D. Sample Recovery

The sample train was recovered by the following procedure: the filter was removed from the filter holder and stored in a petri dish; the impinger contents were quantitatively transferred to a sample bottle; all areas between the probe opening and the filter holder which came in contact with the sample were rinsed with distilled deionized water; and the rinse was added to the impinger contents.

E. Analysis Method

NAA was performed on the samples by the University of Missouri, Columbia. This process involves exposure of the samples to a neutron source where the following nuclear reaction occurs:

$${}^{79}_{35}Br + {}^{1}_{0}n \rightarrow {}^{80}_{35}Br$$

The ${}^{80}_{35}Br$, which is radioactive, decays according to the reaction:

$${}^{80}_{35}Br \rightarrow {}^{80}_{36}Kr + \beta^- + \text{gamma radiation (616 Kev)}$$

The characteristics of the gamma radiation were then used to determine the amount of bromine in the sample. The lower detection limit for the method is 0.0001 µg. This is well below the amount of bromine collected by the sampler. The analysis data are shown in Table 1.

TABLE 1

SAMPLE ANALYSIS

Sample No.	Description	Sample Volume (mL)	Sample Concentration (μg/mL)	Total Br (μg)
102	Basin water	-	55.2	-
104	Impinger contents	425	0.24	102.00
106	Water blank	425	0.006	2.55
107	Filter	-	-	0.24
108	Filter blank	-	-	0.07

All samples, except the filters, are run in triplicate. The average of the three values is recorded in Table 1 and was used in the calculation.

V. CALCULATION PROCEDURE AND RESULTS

The calculation of correction factors needed to determine drift are relatively complex. The calculation procedure, without indicating the corrections, is presented in this section. The purpose is to provide a clear picture of the principles underlying the calculation of the drift rate. The actual calculations with all the correction factors have been provided in Appendix B. The sampling data used in the calculations are shown in Table 2.

TABLE 2

SAMPLING DATA

Description	
Corrected total Br in sample	99.62 μg[a]
Sample volume	551.1 dscf
Stack airflow rate	666,444 dscfm
Basin water Br concentration	55.2 μg/mL
Water flow rate through the cell	7,386 gpm

[a] See calculations in Appendix B.

The calculation of the drift rate requires several steps. First, the concentration of bromine in the air from the stack is calculated from the equation:

$$\text{Conc. Br in stack air } (\mu g/ft^3) = \frac{\text{Corrected total Br in sample } (\mu g)}{\text{Sample volume } (ft^3)}$$

Next, the total stack emission of Br is obtained by multiplying the stack concentration by the stack flow rate:

$$\text{Total Br emissions } (\mu g/min) = \text{Conc. Br in stack air } (\mu g/ft^3) \times \text{Stack airflow rate } (ft^3/min)$$

The bromine emissions are then related to the basin water lost, by the equation:

$$\text{Vol. of basin water lost } (mL/min) = \frac{\text{Total Br emissions } (\mu g/min)}{\text{Basin water conc. } (\mu g/mL)}$$

The drift then is calculated as a percent of the total flow through the tower according to the equation:

$$\%\text{ Drift} = \frac{\text{Vol. of basin water lost } (mL/min)}{\text{Water flow through tower } (mL/min)} \times 100$$

Blank corrections were applied for the water used in the rinse. Complete calculations with the appropriate corrections have been provided in Appendix B.

When the calculations were completed, the drift for the cell was found to be 0.007%. For the measured water flow rate of 7,386 gpm, the drift rate equals 0.57 gal/min or 34.2 gal/hr of basin water discharged by the tower cell as drift.

VI. DISCUSSION AND CONCLUSIONS

The definition of drift as used in this report is "the percentage of the water flowing through the tower which is discharged through the fan in the form of water droplets or aerosols." Under the conditions of this test, the drift rate was found to be 0.007% or 0.57 gal/min. The percent drift measured is 0.002% above the 0.005% specified in the design parameters.

Several points should be noted relative to the drift rate measured on this test.

- The water flow rate during the test was 5.5% above the design flow rate. This may increase the initial formation of drift size droplets.

- A small gap between the tower drift eliminators and a portion of the north wall of the test cell was observed. This may have allowed some drift particles to by-pass the drift eliminators.

- The accuracy of the drift sampling technique used has not been fully proven for colling tower testing, however, it is based on generally accepted sampling procedures.

Appendix A contains the raw data collected during the testing of the stack (including airflow measurements) and the basin water flow. Appendix B contains the calculations used to calculate the drift rate.

APPENDIX A

TEST DATA

DRIFT ACCEPTANCE TEST
ON A

6-CELL, MECHANICAL-DRAFT, COUNTER-FLOW
COOLING TOWER

FOR USE WITH CTI
TEST CODE ATC 105

COOLING TOWER INSTITUTE

ACCEPTANCE TEST PROCEDURE

DATA SHEET "E"
WATER FLOW MEASUREMENT

PITOT TUBE

FILE NO.: [illegible]

TEST DATE: [illegible]

PITOT TUBE MAKE, MODEL	SERIAL NO	PIPE SIZE, INCHES
Simplex - 1/2"		NOM = 20 ID = 20 3/8
DATE CALIBR. Mar ' 85	TUBE COEFFICIENT C = .82333	AREA = .00545 ID², SQ FT A = 2.26424

Fiberglass

PIPE ID RDG NO	IN DIA X	RDG NO	DIA X	LOCATION DECIMAL INCHES CALCULATED	CORRECTED*	STA DESC. #4 H d, in	$\sqrt{d}$	TIME V d, in.	$\sqrt{d}$	STA DESC d, in.	$\sqrt{d}$	TIME d, in.	$\sqrt{d}$
1	.013			1/4		14		12					
2	.039			13/16		14.5		12.25					
3	.067			1 3/8		16		14.5					
4	.097			1 15/16		17.25		15.5					
5	.129			2 5/8		18.5		16					
6	.165	1	.026	3 3/8		18.75		16.25					
7	.204	2	.082	4 1/8		19.25		15.5					
8	.250	3	.146	5 1/16		18		17					
9	.306	4	.226	6 1/4		17		16.75					
10	.388	5	.342	7 15/16		16		15.5					
11	.612	6	.658	12 7/16		15.75		16					
12	.694	7	.774	14 1/8		16.5		16.75					
13	.750	8	.854	15 5/16		15		16					
14	.796	9	.918	16 1/4		14.75		15					
15	.835	10	.974	17		14		13.25					
16	.871			17 3/4		13.5		12.75					
17	.903			18 7/16		12		12					
18	.933			19		11.5		11.25					
19	.961			~~20 7/16~~	19 9/16	10.75		9.25					
20	.987			20 1/8		9		9					
						TOTAL	77.381	TOTAL	74.998	TOTAL		TOTAL	
						AVG	3.8691	AVG	3.7499	AVG		AVG	
						TRAVERSE AVG $\sqrt{d}$			3.8095	TRAVERSE AVG $\sqrt{d}$			
						US GPM	7386			US GPM			

(Rows 1–10 left margin: CALCULATED; under DIA columns: UNDER 18 IN DIAM)

RDG NO	TIME	d
A		
B		
C		

$Q_{gpm} = \sqrt{d}\,(1040 \times C \times A) = \sqrt{d}\,(1938.72)$

BASIS: AIR WATER MANOMETER

* CALCULATED VALUE DECREASED BY DISTANCE FROM END OF PITOT TUBE TO CENTER LINE OF IMPACT HOLE.

Sampling Locations

OD = 23' 2 3/4" HUB D = 72 3/4"

= 278.75" = 72.75"

	X - in from radius
1	3.286
2	10.108
3	17.310
4	24.965
5	33.171
6	42.065
7	51.860
8	62.898
9	75.823
10	92.171

Area = 394.93 ft^2

22.424' equivalent Ø

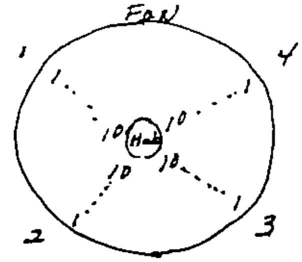
1/1../87	9:55 am	dumped 110 lbs NaBr in sump # 4
	9:10	Initial basin Sample
	9:15-11:05	Pitot Traverse
	4:45p	Final basin Sample

FIELD DATA

PLANT Univ. of Texas
DATE 1-20-87
SAMPLING LOCATION Fan # 4
SAMPLE TYPE Drift
RUN NUMBER 1
OPERATOR Weast/Henwood/Cobb
BAROMETRIC PRESSURE 29.67
SITE TO BARO. ELEVATION (ft) 0
CORRECTED B.P. 29.67
STATIC PRESSURE (P_s) +.06
FILTER NUMBER(s) —

LEAK CK: Initial at ≥15" Hg, CFM ok.
Final at 12 " Hg, CFM .035
Pitot at ≥3" H_2O ok

Fan



SCHEMATIC OF TRAVERSE POINT LAYOUT
Read and Record All Data
Every ______ Minutes

PROBE LENGTH AND TYPE Teflon
NOZZLE I.D. 8-3 .5016
ASSUMED MOISTURE, % Sat.
SAMPLE BOX NUMBER Huss
METER BOX NUMBER Huss
TEMPERATURE METER NO. Huss
THERMOCOUPLE I.D. NO. —
METER ΔH@ .293
METER CORRECTION .9869
C FACTOR —
REFERENCE Δp —
UMBILICAL CORD I.D. NO. —

$$\cancel{V_{m_i} = \_\_\_\_ (T_m + 460)\sqrt{\frac{\Delta P_s}{T_s + 460}}}$$

TRAVERSE POINT NUMBER	SAMPLING TIME, sec.	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft^3 676.314		VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		Angle of flow degrees
			Desired	Actual		DESIRED	ACTUAL		INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F	
1-1	225	1040	688.12	687.65	.34	3.55	3.4	63	45	45	40
2	359	1049	703.36	702.94	.33	3.46	3.5	64	48	47	4
3	359	1101	720.46	719.83	.415	4.35	4.35	65	49	48	4
4	354	1111	737.58	736.89	.425	4.46	4.5	66	52	49	10
5	354	1121	754.89	754.09	.43	4.54	4.5	66	55	51	10
6	346	1131	771.78	770.75	.43	4.52	4.5	68	55	51	16
7	347	1141	788.61	787.51	.425	4.46	4.5	69	55	52	15
8	[illegible]	1150	804.83	803.64	.42	4.41	4.4	70	56	53	21
9	140	1157	810.16	809.11	.26	2.74	2.7	70	58	55	67
10	0	—	810.16	809.11	0	0	0	70	55	55	90
2-1	326	1230	821.13	821.31	.25	2.6	2.6	65	48	49	25
2	338	1238	835.25	835.38	.32	3.34	3.3	65	49	49	20
3	346	1248	850.79	850.74	.37	3.85	3.8	67	51	49	16
4	350	—	866.50	—	.37	3.85	3.85	66	50	49	13
5	350	1309	883.48	882.92	.43	4.49	4.4	65	51	49	13
6	340	1318	899.76	899.15	.42	4.37	4.4	67	52	49	19
7	352	1327	916.43	915.81	.41	4.28	4.3	66	52	49	12
8	336	1335	932.92	932.25	.44	4.59	4.6	67	53	49	21
9	263	1344	943.75	943.37	.31	3.23	3.3	68	53	50	43
10	146	1351	946.97	946.85	.09	0.93	0.9	68	50	49	66

COMMENTS

Traverse Point Number	Sampling Time sec	Clock Time (24 hr clock)	Gas Meter Reading (V_m), ft³ Desired	Gas Meter Reading (V_m), ft³ Actual	Velocity Head (Δp_s), in H_2O	Orifice Pressure Differential (ΔH), in H_2O Desired	Orifice Pressure Differential (ΔH), in H_2O Actual	Stack Temperature (T_s), °F	Dry Gas Meter Temperature Inlet ($T_{m\,in}$), °F	Dry Gas Meter Temperature Outlet ($T_{m\,out}$), °F	Angle of Flow degrees
3-1	338	1405	958.41	958.54	.21	2.19	2.2	64	49	48	20
2	359	1413	973.66	973.63	.33	3.45	3.45	64	50	49	4
3	355	1421	989.85	989.68	.38	3.96	3.9	66	52	49	9
4	355	1429	1006.28	1005.93	.39	4.07	4.0	67	54	50	9
5	350	1437	1024.00	1023.48	.465	4.87	4.9	67	56	50	13
6	347	1445	1041.59	1040.69	.465	4.87	4.9	67	56	51	15
7	347	1453	1058.37	1057.27	.425	4.43	4.4	68	56	50	15
8	338	1501	1074.10	1073.23	.395	4.11	4.1	69	55	50	20
9	174	1510	1079.70	1079.90	.19	1.97	2.0	70	53	50	61
10	0	-	1079.70	1079.90	0	0	0	70	49	49	90
4-1	301	1525	1090.69	1091.00	.245	2.55	2.5	66	49	49	33
2	347	1533	1104.73	1105.32	.30	3.13	3.2	65	50	49	15
3	354	1541	1120.81	1121.31	.375	3.92	3.9	66	54	50	10
4	356	1548	1138.08	1138.41	.425	4.46	4.4	67	57	51	8
5	356	1556	1155.46	1155.60	.43	4.51	4.5	67	57	52	8
6	355	1609	1173.35	1173.24	.455	4.78	4.8	68	61	52	9
7	358	1620	1190.77	1190.56	.43	4.49	4.5	68	55	51	5
8	347	1629	1207.45	1207.13	.42	4.39	4.4	68	55	51	15
9	311	1638	1220.50	1220.25	.32	3.34	3.35	69	56	51	30
10	0	-	1220.50	1220.25	0	0	0	68	55	51	90

Run Number 1   Date 1-20-87   Sampling Location Stack

Comments:

EPA (Dur) 236
4 72

[illegible]
[illegible] # [illegible]-1
[illegible] -- FAN-4
[illegible] 1/20/87
[illegible] # - 8143-04

PROG.=VER 01/06/87 V1
01-23-1987 04:05:15

[illegible] Meter Volume (Cubic Feet)=	676.314	
[illegible] Meter Volume (Cubic Feet)=	1220.250	
[illegible] Factor=	0.987	
[illegible] Leak Rate (cu ft/min)=	0.035	Leak Correction= 3.6000
[illegible] Volume (Cubic Feet)=	533.258	
[illegible] Volume (Dry Standard Cubic Feet)=	550.469	
[illegible] Pressure (in Hg)=	29.67	
[illegible] Pressure (Inches H2O)=	0.06	
[illegible] Oxygen=	20.9	
[illegible] Carbon Dioxide=	0.0	
[illegible] Collected (ml)=	0.0	
[illegible] Water=	2.2	
[illegible] Meter Temperature (F)=	51	
[illegible] Delta H (in H2O)=	3.53	
[illegible] Delta P (in H2O)=	0.299	
[illegible] Stack Temperature (F)=	67	
[illegible] Molecular Weight=	28.84	
[illegible] Molecular Weight=	28.59	
[illegible] Square Root of Delta P (in H2O)=	0.5116	
[illegible]=	99.0	
[illegible] Coefficient=	0.84	
[illegible] Time (Minutes)=	240.0	
[illegible] Diameter (Inches)=	0.502	
[illegible] Axis #1 (Inches)=	269.1	
[illegible] Axis #2 (Inches)=	269.1	
[illegible] Stack		
[illegible] Area (Square Feet)=	394.93	
[illegible] Velocity (Actual, Feet/min)=	1,737	
[illegible] Rate (Actual, Cubic ft/min)=	686,056	
[illegible] (Standard, Wet, Cubic ft/min)=	681,748	
[illegible] Rate (Standard, Dry, Cubic ft/min)=	666,444	

[illegible] Loading - Front Half

		Corr. to 7% O2
[illegible] Weight (g)=	0.0000	
[illegible] Loading, Dry Std. (gr/scf)=	0.0000	0.0000
[illegible] Loading, Actual (gr/cu ft)=	0.0000	
[illegible] Rate (lb/hr)=	0.00	

[illegible] Half Analysis

* * METRIC UNITS * *

[illegible] NAME
[illegible] # - UOT-1
[illegible] FAN-4
[illegible] 1/20/87
[illegible] # - 8143-04

PROG.=VER 01/06/87 V1
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[illegible] Meter Volume (Cubic Meters)=	19.151		
[illegible] Meter Volume (Cubic Meters)=	34.553		
[illegible] Factor=	0.987		
[illegible] Leak Rate (cu m/min)=	0.0010	Leak Correction=	0.1019
[illegible] Meter Volume (Cubic Meters)=	15.100		
[illegible] Volume (Dry Standard Cubic Meters)=	15.587		
[illegible] Pressure (mm Hg)=	754		
[illegible] Pressure (mm H2O)=	2		
[illegible] Oxygen=	20.9		
[illegible] Carbon Dioxide=	0.0		
[illegible] Collected (ml)=	0.0		
[illegible] Water=	2.2		
[illegible] Meter Temperature (C)=	11		
[illegible] Delta H (mm H2O)=	89.7		
[illegible] Delta P (mm H2O)=	7.6		
[illegible] Stack Temperature (C)=	19		
[illegible] Molecular Weight=	28.84		
[illegible] Molecular Weight=	28.59		
[illegible] Square Root of Delta P (mm H2O)=	2.5786		
[illegible]=	99.0		
[illegible] Coefficient=	0.84		
[illegible] Time (Minutes)=	240.0		
[illegible] Diameter (mm)=	12.74		
[illegible] Axis #1 (Meters)=	6.835		
[illegible] Axis #2 (Meters)=	6.835		
[illegible] Stack			
[illegible] Area (Square Meters)=	36.690		
[illegible] Velocity (Actual, m/min)=	529		
[illegible] rate (Actual, Cubic m/min)=	19,427		
[illegible] rate (Standard, Wet, Cubic m/min)=	19,305		
[illegible] rate (Standard, Dry, Cubic m/min)=	18,872		

[illegible] Loading - Front Half

[illegible] Weight (g)=	0.0	Corr. to 7% O2
[illegible] Loading, Dry Std. (mg/cu m)=	0.0	0.0
[illegible] Loading, Actual (mg/cu m)=	0.0	
[illegible] Rate (kg/hr)=	0.00	

[illegible] Back Half Analysis

[illegible] NAME -
[illegible] OUT-1
[illegible] - FAN-4
[illegible] 1/20/87
[illegible] # - 8143-04

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[illegible] #	Delta P (in. H2O)	Delta H (in. H2O)	Stack T (F)	Meter T In(F)	Meter T Out(F)
[illegible]	0.200	3.40	63	45	45
[illegible]	0.328	3.50	64	48	47
[illegible]	0.413	4.35	65	49	48
[illegible]	0.412	4.50	66	52	49
[illegible]	0.417	4.50	66	55	51
[illegible]	0.397	4.50	68	55	51
[illegible]	0.397	4.50	69	55	52
[illegible]	0.366	4.40	70	56	53
[illegible]	0.040	2.70	70	58	55
[illegible]	0.000	0.00	70	55	55
[illegible]	0.205	2.60	65	48	49
[illegible]	0.283	3.30	65	49	49
[illegible]	0.342	3.80	67	51	49
[illegible]	0.351	3.85	66	50	49
[illegible]	0.408	4.40	65	51	49
[illegible]	0.375	4.40	67	52	49
[illegible]	0.392	4.30	66	52	49
[illegible]	0.383	4.60	67	53	49
[illegible]	0.166	3.30	68	53	50
[illegible]	0.015	0.90	68	50	49
[illegible]	0.185	2.20	64	49	48
[illegible]	0.328	3.45	64	50	49
[illegible]	0.371	3.90	66	52	49
[illegible]	0.380	4.00	67	54	50
[illegible]	0.441	4.90	67	56	50
[illegible]	0.434	4.90	67	56	51
[illegible]	0.397	4.40	68	56	50
[illegible]	0.349	4.10	69	55	50
[illegible]	0.045	2.00	70	53	50
[illegible]	0.000	0.00	70	49	49
[illegible]	0.172	2.50	66	49	49
[illegible]	0.280	3.20	65	50	49
[illegible]	0.364	3.90	66	54	50
[illegible]	0.417	4.40	67	57	51
[illegible]	0.422	4.50	67	57	52
[illegible]	0.444	4.80	68	61	52
[illegible]	0.427	4.50	68	55	51
[illegible]	0.392	4.40	68	55	51
[illegible]	0.240	3.35	69	56	51
[illegible]	0.000	0.00	68	55	51

[illegible] NAME -
[illegible] # - UOT-1
[illegible] - FAN-4
[illegible] 1/20/87
[illegible] # - 8143-04

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[illegible]tion	Final Wt. (g)	Tare Wt. (g)	Blank Wt. (g)	Net Wt. (g)
[illegible]	0.0000	0.0000	0.0000	0.0000
[illegible]	0.0000	0.0000	0.0000	0.0000

[illegible]tion	Final Wt. (g)	Tare Wt. (g)	Vol. (ml)	Net Wt. (g)
[illegible] RINSE	0.0000	0.0000	0.0	0.0000
[illegible]	0.0000	0.0000	0.0	0.0000

[illegible] Rinse Blank (mg/ml)= 0.0000
[illegible] Blank (mg/ml)= 0.0000

APPENDIX B

CALCULATIONS

DRIFT ACCEPTANCE TEST
ON A
6-CELL, MECHANICAL-DRAFT, COUNTER-FLOW
COOLING TOWER

COMPLETE CALCULATIONS

This appendix provides the calculations for this test, complete with all correction factors applied. All numbers have been rounded to three significant figures. The data used were taken from Tables 1 and 2 in the report.

The total weight of Br in the sample train (Br_T) is the sum of the Br found in the impinger content and the water rinse (Br_I), and on the filter (Br_F).

$$Br_T = Br_I + Br_F$$

$$= 102.00 + 0.24 = 102.24\ \mu g\ Br$$

Corrections (B_T) for the water blank (W_B) must be applied to the weight of bromine collected in the sample train. In this test, 425 mL of water were used in the impingers and water rinse. A blank filter (F_B) was also analyzed.

$$(B_T) = (W_B) + (F_B)$$

$$= 2.55 + 0.07 = 2.62\ \mu g\ Br$$

The net corrected weight of bromine in the sample train due to drift (Br_C) is:

$$(Br_C) = (Br_T) - (B_T)$$

$$= 102.24 - 2.62 = 96.62\ \mu g\ Br$$

After obtaining the corrected Br weight (Br_C) for the sample train, the concentration of Br (in µg/dscf) in the stack air is calculated from the sample volume, V_S:

$$\text{Conc. Br in stack} = \frac{Br_C}{V_S} = \frac{99.62\ \mu g\ Br}{551.1\ dscf}$$

$$= 0.18\ \mu g\ Br/dscf$$

Since the total stack flow rate was measured as 666,444 dscfm, the total Br emissions from the stack (Br_S) is calculated by:

$$\text{Total Br from stack} = 666{,}444\ dscfm \times \frac{0.18\ \mu g\ Br}{dscfm}$$

$$= 119{,}960\ \mu g\ Br/min$$

The volume of basin water, W_V, required to deliver 119,960 μg of Br is calculated by:

$$W_V = \frac{\text{Total Br from stack}}{\text{Conc. Br in basin}}$$

$$= \frac{119{,}960\ \mu g\ Br/min}{55.2\ \mu g\ Br/mL} = 2{,}173\ mL/min$$

Converting to gallons per minute gives:

$$gpm = \frac{2{,}173\ mL/min}{3{,}784\ mL/gal.} = 0.57\ gpm$$

or 192 gal/hr.

The percent drift, % D, can now be calculated according to the equation:

$$\%\ D = \frac{\text{Vol. basin water from stack } (W_V)}{\text{Total water vol. through basin}} \times 100$$

$$= \frac{0.57\ gpm}{7{,}386\ gpm} \times 100 = 0.007\%$$