AP42 Section:	13.4
Background Chapter	4
Reference:	8
Title:	Cooling Tower Drift Test Report for Unnamed Client of the Cooling Tower Institute, Houston, Texas. Midwest Research Institute (l989).

SUMMARY

The testing services of Midwest Research Institute (MRI) were retained by to conduct a drift test on a 4-cell, mechanical-draft, cross-flow cooling tower located at The work was performed by MRI as an independent test contractor.

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 and 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 droplets and aerosol leaving the stack. Inductively coupled argon plasma spectroscopy (ICP), an extremely sensitive detection technique, was then used to measure the concentration of three selected trace constituents (Na, Ca, Mg,) in the basin water and water collected from the airflow exiting the fan stack. From the measurements of the selected trace constituents in the isokinetic sampling train and the same trace constituents in the basin water, the drift rate was calculated.

The calculated drift rates were between 0.0522% and 0.0543% for fan stack No. 2, depending on which of the three tracers was used. When the results are averaged for all tracers, a drift rate of 0.0535% is obtained for fan stack No. 2. The average drift rate from fan stack No. 2 was representative of the drift rate of the tower.

COOLING TOWER TEST REPORT

DRIFT TEST
ON THE

4-CELL, MECHANICAL-DRAFT, CROSS-FLOW
COOLING TOWER

I. INTRODUCTION

The testing services of Midwest Research Institute (MRI) were retained by to conduct a drift test using modified EPA Method 5 isokinetic sampling techniques on mechanical-draft, cross-flow cooling tower. The cooling tower is located at The work was performed by Mr. Nicholas M. Stich and Mr. George Cobb of MRI. The tower manufacturer was represented by was represented by Mr.

The thermal and drift tests were originally scheduled for the week of

II. TEST SITE DESCRIPTION

is located at in cooling tower provides cooling water to steam condensers. The cooling tower is located in an unobstructed area on the north side of the plant.

The cooling tower consists of four mechanical-draft, cross-flow cells in a continuous straight line with a common cold water basin beneath the tower. Each cell is equipped with a 28-ft diameter fan driven by a 100-hp motor. The hub seal is 96 in. in diameter. The fan stack is 324 in. in diameter at the sample plane location and constructed of fiberglass.

An underground steel conduit returns hot water from the plant to the cooling tower. The main line then tees off to feed two individual 30-in diameter cell risers. Pitot taps for water flow measurement were locate in the 30-in lines.

The cold water from the cooling tower basin is collected in the pump forebay adjacent to the tower where two pumps are used to return cold water to the plant. Taps with temporary standpipes were used for the collection of basin water samples.

III. SAMPLING SEQUENCE

The test sequence for the drift test was as follows:

1. Water flow and fan horsepower measurement were conducted and the tower operations were monitored.
2. Drift sample and airflow measurement locations were calculated.
3. A basin water sample was collected.
4. Isokinetic drift sampling of the selected fan stack was conducted.
5. Isokinetic drift sampling of the fan was completed.
6. A second basin sample was collected at the conclusion of the test. The two basin samples were composited into one basin water sample.
7. The drift samples were recovered from the sample collection system.
8. The basin composite, water blank, and drift impinger samples were acid stabilized and transported to the laboratory for analysis.

IV. DRIFT TEST EQUIPMENT

The drift sampling system used for the test is shown schematically in Figure 1. The key components are described below.

AIR PITOT/DRIFT PROBE:

Since cyclonic flow can bias the drift results, adjustments in the sampling technique must be used to eliminate this bias. A special MRI air pitot/drift probe assembly was developed to allow unbiased sampling. If the sample nozzle is not aligned with the flow, then the effective velocity through the nozzle opening is reduced by the cosine of the angle between the flow and and stack axis. This results in a sample which is not truly isokinetic and thus the alignment approach[1] must be used for the drift test to

[1] 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.

eliminate this bias. Since the sample proportionality could be compromised with the alignment approach, proportional sampling needs must be satisfied by adjusting the nominal base sample time by the cosine of the cyclonic flow angle.

Airflow, fan discharge temperature, and the angle of cyclonic flow were measured with this probe assembly. The air pitot/drift probe assembly was equipped with:

1. S-type primary pitot tips which are connected to a manometer to measure air velocity.

2. Secondary pitot tips which are positioned at 90 degrees from the primary pitot tips. The secondary set of pitot tips are connected to a separate manometer to align the probe and compensate for any cyclonic flow effects.

3. A temperature sensor connected to a digital readout to measure the stack temperature.

4. A protractor attached to the probe assembly to determine the angle that the probe was rotated during the cyclonic flow determination.

5. A stainless steel drift sample nozzle and flexible Teflon sample probe which are connected to the drift collection train.

SAMPLE LOCATIONS:

Since drift is defined as the amount of droplets or aerosols exiting the fan stack, the drift tests must be made at the top of the fan stack. Also, the proximity of the sample locations to the fan required that the station locations be adjusted for the hub effect. Sample locations were determined using the equation for equal annular areas for fan discharge from Chapter 5 of the CTI Manual.

DRIFT COLLECTION TRAIN:

The drift collection train consisted of four high capacity impingers and a filter assembly. Impingers 1 and 2 contained distilled water and were used to scrub out the aerosols and water droplets. The third impinger was used to collect any water droplets that might be carried over from the previous impingers. The filter was used as the final collection medium and was placed between impinger 3 which was dry and impinger 4 which contained silica gel. The sampling train was kept iced during testing to help reduce the water vapor pressure and to further improve collection efficiency.

CONTROL CONSOLE AND PUMP:

The control console and pump used was a High Volume Sampling System (HVSS) consistent with EPA Method 5 requirements. The impinger train was connected to the console via a sample line through the leak free vacuum pump capable of up to 4 cfm. The modular vacuum pump has two control valves to adjust and maintain the desired sampling rate. The console contained a calibrated dry gas meter, digital temperature readout, manometers, and associated controls.

V. DRIFT TEST METHODS

Testing was conducted on The tower's circulating water flow was 103.1% of design and the fan horsepower was 90.7% of design. The test data were acquired in accordance with applicable portions of the CTI ATC-105 (1982) test code. The individual parameters were measured as follows:

- Total circulating water flow was measured with two 20-point pitot traverses of the hot water return riser to the tower. A 42-in Simplex/Leopold-type pitot tube was used to measure the velocity at each point. An air-over-water manometer was used for measuring the differential pressure between the impact and reference orifices of the pitot tube.

- Fan motor power was measured with a clamp-on digital kilowatt meter, using the two watt meter method.

- Air velocity was measured with four 10-point radial traverses of the fan stack using the predetermined sampling locations. At each point the MRI air pitot/drift probe assembly was rotated until the pressure difference across the secondary pitot tips was zero. When this zero differential had been obtained, the primary probe had been aligned with the flow and the protractor was read to determine the cyclonic flow angle. The probe assembly was then used to measure the velocity pressure and temperature at the sample point.

- The previously determined velocity pressure, stack temperature, and cyclonic flow angle were used by a Epson HX-20 computer to calculate the required sample volume, isokinetic rate, and the adjusted base sample time.

- Sampling at each traverse location was commenced after the proper sample rate was determined by turning on the sample pump and simultaneously activating the variable timer function of the HX-20 computer. When each sample time had ended, the pump was shut off, the air pitot/probe assembly was relocated to the next sample location, and the above procedure repeated until all 40 points had been sampled.

* The drift sample recovery was initiated by using distilled deionized water to rinse the stainless steel nozzle and flexible Teflon probe into the contents of the first impinger. The impinger train was sealed and then removed from the cooling tower to the sample recovery location where the remainder of the sample recovery was performed. The impinger volumes and rinse volumes were measured and recorded. The impinger contents along with all rinses were transferred to sample bottles. A distilled deionized water blank was taken. Both the drift impinger samples and water blank were nitric acid stabilized and then returned to MRI for further analysis.

* Basin water samples were taken at the beginning and at the conclusion of the drift test. The basin water sample was taken from a thermal well that was installed on the discharge side of the circulating water flow pump. The samples were collected after the thermal well line was purged. The two samples were collected and then combined into one composite basin water sample. The composite basin sample was stabilized with nitric in the same manner as were the impinger and water blank samples. The composite basin water sample was returned to MRI for further analysis.

VI. SAMPLE ANALYSIS

The samples were returned to MRI where they were logged into a laboratory notebook. Method 3050 was used to prepare the drift and basin water samples for the analysis using Method 6010 as described below.

METHOD 3050:

Method 3050 is an acid digestion procedure used to prepare sediments, sludges, and soil samples for analysis by flame or furnace atomic absorption spectroscopy (FLAA and GFAA, respectively) or by inductively coupled argon plasma spectroscopy (ICP).

A representative sample is digested in nitric acid and hydrogen peroxide. The digestate is then refluxed with either nitric acid or hydrochloric acid. Dilute hydrochloric acid is used as the final reflux acid for (1) the ICP analysis of As and Se, and (2) the flame AA or ICP analysis of Al, Ba, Ca, Cd, Cr, Co, Cu, Fe, Mo, Pb, Ni, K, Na, Tl, V, and Zn. Dilute nitric acid is employed as the final dilution acid for the furnace AA analysis of As, Be, Cd, Cr, Co, Pb, Mo, Se, Tl, and V. A separate sample is dried for a total solids determination.

METHOD 6010:

Method 6010 describes the procedures for inductively coupled argon plasma spectroscopy (ICP) in determining elements including metals in solution. This method is applicable to a large number of metals and wastes. All matrices, including groundwater, aqueous samples, EP extracts, industrial wastes, soils, sludges, sediments, and other solid wastes, require digestion prior to analysis.

The simultaneous, or sequential, multielemental determination of elements by ICP is measured by element-emitted light by optical spectrometry. Samples are nebulized and the resulting emission spectra are produced by a radio-frequency inductively coupled plasma. The spectra are dispersed by a grating spectrometer, and the intensities of the lines are monitored by photomultiplier tubes. Background correction is required for trace element determination.

VII. RESULTS AND CONCLUSIONS

The following equation is used by the MRI drift computer program to calculate the drift results:

% Drift = 100 * (NFA * NWT) / (NZA * WFR * EQT * BTC)

NFA = Net Fan Area (square feet)
NWT = Net Weight of Tracer (µg)
NZA = Nozzle Area (square feet)
WFR = Water flow Rate (grams per minute)
EQT = Equivalent Sample Time (240 minutes)
BTC = Basin Tracer Concentration (µg/g)

The table below summarizes the results of the laboratory analysis and drift calculations.

TRACER ANALYZED	SAMPLE WEIGHT (µg)	WATER BLANK (µg/g)	BASIN CONC. (µg/g)	% DRIFT
Na	7350	0	740	0.0540
Mg	1040	0	104	0.0543
Ca	5040	0	524	0.0522

The results of the drift test conducted for indicate that fan stack No. 2 had an average drift rate of 0.0535%. The drift rate of the the fan tested should be representative of the average drift rate of the tower.

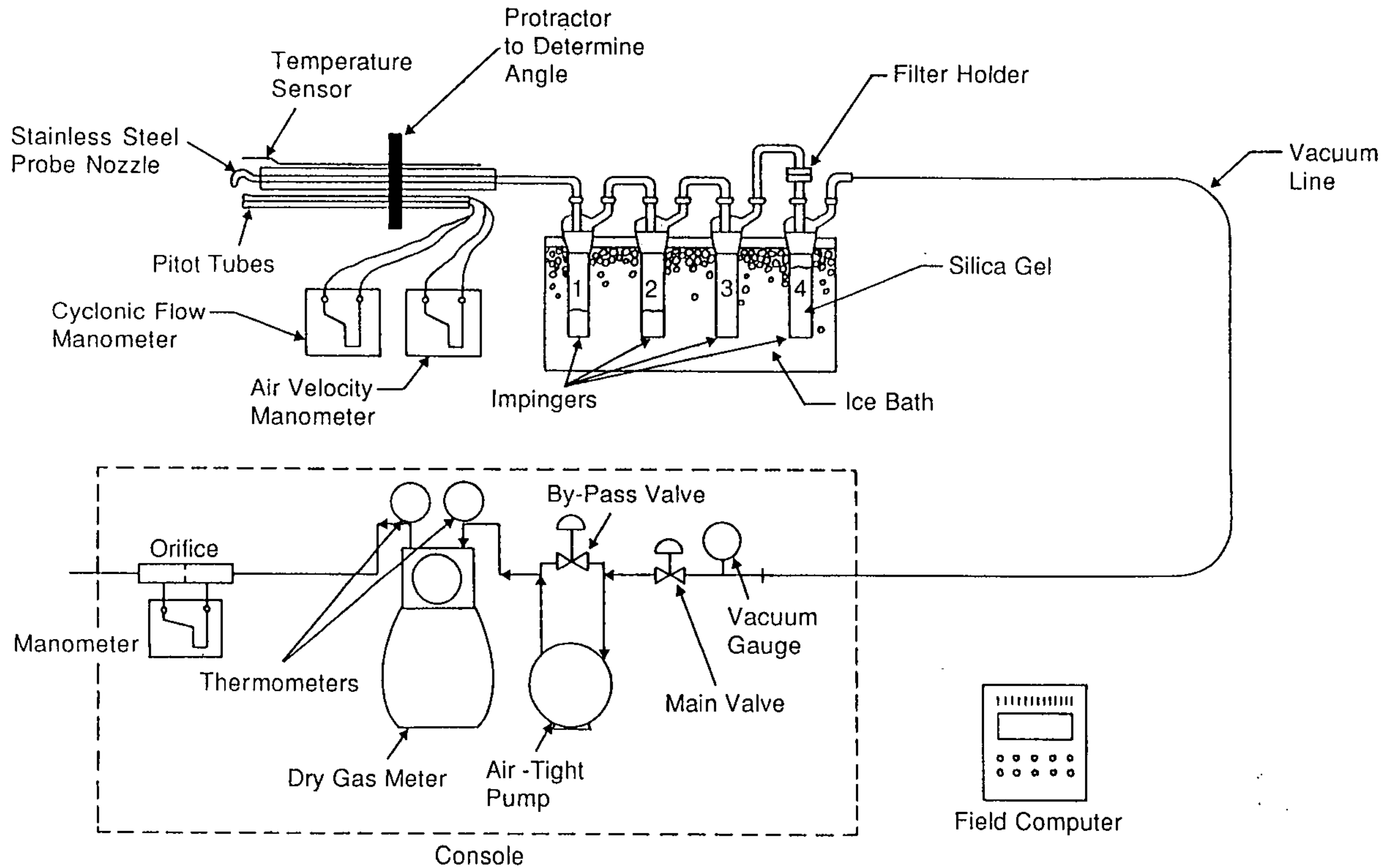


Figure 1 - Air Velocity/Drift Probe, Drift Sample Train and Console System

APPENDIX A

SUMMARY OF RESULTS

DRIFT TEST
ON THE

4-CELL, MECHANICAL-DRAFT, CROSS-FLOW
COOLING TOWER

FILE NAME :
RUN # : FAN #2
LOCATION :
DATE :
PROJECT # :

22:43:14
PROGRAM V2.1

INITIAL METER VOLUME (CUBIC FEET)=	735.000
FINAL METER VOLUME (CUBIC FEET)=	1075.820
METER FACTOR=	0.9857
FINAL LEAK RATE (CU FT/MIN)=	0.000
NET METER VOLUME (CUBIC FEET)=	335.946
GAS VOLUME (DRY STANDARD CUBIC FEET)=	302.708
BAROMETRIC PRESSURE (IN. HG)=	28.05
STATIC PRESSURE (INCHES H20)=	-0.17
PERCENT OXYGEN=	21.0
PERCENT CARBON DIOXIDE=	0.0
MOISTURE COLLECTED (ML)=	0.0
PERCENT WATER=	3.6
SATURATED STACK	
DRY MOLECULAR WEIGHT=	28.84
WET MOLECULAR WEIGHT=	28.45
AVERAGE METER TEMPERATURE (F.)=	91.6
AVERAGE DELTA H (IN. H20)=	1.69
AVG.SUM of SQR DELTA P (for % ISOKINETIC)=	0.5034
% ISOKINETIC=	102.7
AVERAGE STACK TEMPERATURE (F.)=	79.5
AVG. SUM of SQR DELTA P * COS of ANGLE (IN. H20)=	0.3816
PITOT COEFFICIENT=	0.84
SAMPLING TIME (MINUTES)=	176.1
NOZZLE DIAMETER (INCHES)=	0.4413
STACK AXIS (INCHES)=	324.0
HUB AXIS (INCHES)=	96.0
NET FREE STACK AREA (SQUARE FEET)=	522.29
STACK VELOCITY (ACTUAL, FEET/MIN)=	1,352
FLOW RATE (ACTUAL, CUBIC FT/MIN)=	706,171
FLOW RATE (STANDARD, WET, CUBIC FT/MIN)=	647,664
FLOW RATE (STANDARD, DRY, CUBIC FT/MIN)=	624,225

------------------- DRIFT ANALYSIS -------------------

TRACER ANALYZED	SAMPLE WEIGHT (mcg)	WATER BLANK (mcg/g)	BASIN CONC. (mcg/g)	% DRIFT
NA	7350	0	740	0.0540
MG	1040	0	104	0.0543
CA	5040	0	524	0.0522

AVERAGE PERCENT DRIFT OF ALL TRACERS ANALYZED 0.0535

FILE NAME	:	16:39:52
RUN #	: FAN #2	PROGRAM
LOCATION	:	V2.1
DATE	:	
PROJECT #	:	

* * METRIC UNITS * *

INITIAL METER VOLUME (CUBIC METERS)=	20.812
FINAL METER VOLUME (CUBIC METERS)=	30.463
METER FACTOR=	0.9857
FINAL LEAK RATE (CU M/MIN)=	0.0000
NET METER VOLUME (CUBIC METERS)=	9.513
GAS VOLUME (DRY STANDARD CUBIC METERS)=	8.571
BAROMETRIC PRESSURE (MM HG)=	712
STATIC PRESSURE (MM H20)=	-4
PERCENT OXYGEN=	21.0
PERCENT CARBON DIOXIDE=	0.0
MOISTURE COLLECTED (ML)=	0.0
PERCENT WATER=	3.6
DRY MOLECULAR WEIGHT=	28.84
WET MOLECULAR WEIGHT=	28.45
AVERAGE METER TEMPERATURE (C.)=	33.1
AVERAGE DELTA H (MM H20)=	42.9
AVG. SUM of SQR DELTA P (for % ISOKINETIC)=	2.54
% ISOKINETIC=	102.7
AVERAGE STACK TEMPERATURE (C.)=	26.4
AVG. SUM of SQR DELTA P * COS of ANGLE (MM H20)=	1.92
PITOT COEFFICIENT=	0.84
SAMPLING TIME (MINUTES)=	176.1
NOZZLE DIAMETER (MM)=	11.21
STACK AXIS #1 (METERS)=	8.230
STACK AXIS #2 (METERS)=	2.438
CIRCULAR STACK	
STACK AREA (SQUARE METERS)=	48.522
STACK VELOCITY (ACTUAL, M/MIN)=	412
FLOW RATE (ACTUAL, CUBIC M/MIN)=	19,997
FLOW RATE (STANDARD, WET, CUBIC M/MIN)=	18,340
FLOW RATE (STANDARD, DRY, CUBIC M/MIN)=	17,676

FILE NAME :
RUN # : FAN #2
LOCATION :
DATE :
PROJECT # :

16:41:39
PROGRAM
V2.1

POINT #	DELTA P (IN. H2O)	DELTA H (IN. H2O)	STACK T (F.)	METER T. IN(F.)	METER T. OUT(F.)	ANGLE (DEG)
1	0.100	0.600	83	63	63	20
2	0.140	0.800	81	68	93	15
3	0.150	0.900	82	72	92	15
4	0.250	1.600	70	72	100	38
5	0.400	2.600	74	82	105	38
6	0.380	2.400	70	75	96	38
7	0.370	2.200	65	75	96	46
8	0.320	2.000	74	70	87	57
9	0.310	1.900	78	91	98	65
10	0.230	1.400	84	93	98	78
11	0.130	0.800	79	89	88	50
12	0.150	0.900	77	89	89	43
13	0.250	1.500	72	90	89	35
14	0.310	1.900	74	90	88	22
15	0.370	2.300	77	91	88	18
16	0.430	2.700	76	92	88	17
17	0.410	2.600	78	94	89	33
18	0.390	2.500	74	97	89	39
19	0.310	2.000	72	94	89	52
20	0.250	1.500	73	95	90	64
21	0.050	0.300	87	96	97	84
22	0.070	0.400	90	96	97	60
23	0.150	0.900	93	96	97	32
24	0.300	1.900	92	96	96	25
25	0.350	2.200	92	96	96	17
26	0.370	2.400	89	98	94	12
27	0.360	2.300	91	99	93	25
28	0.390	2.400	90	99	95	41
29	0.320	2.000	91	100	96	38
30	0.200	1.300	91	100	97	73
31	0.060	0.400	76	94	95	50
32	0.110	0.700	72	94	95	60
33	0.140	0.900	78	95	95	40
34	0.300	1.900	80	94	94	35
35	0.340	2.200	78	94	94	28
36	0.350	2.300	72	96	94	22
37	0.370	2.400	78	97	95	24
38	0.360	2.400	72	96	95	33
39	0.320	2.100	73	96	95	43
40	0.160	1.000	81	94	92	55

APPENDIX B

FIELD DATA SHEETS

DRIFT TEST
ON THE

4-CELL, MECHANICAL-DRAFT, CROSS-FLOW
COOLING TOWER

FIELD DATA

RUN NO. 1

PROJECT NO. ______

PLANT ______

DATE ______

SAMPLING LOCATION ______

SAMPLE TYPE Drift

OPERATOR Stich / Cobb

FILTER NO. NA

RECORD DATA EVERY VAR MIN.

UMBILICAL/SAMPLER HOOKUP NA

PROBE NO. Drift

PROBE LENGTH AND TYPE NA

SAMPLE BOX NO. Drift

METER BOX NO. Drift

TEMP. CONTROLLER NO. NA

TEMP. METER NO. —

THERMOCOUPLE I.D. NO. —

UMBILICAL CORD I.D. NO. —

UMBILICAL CORD I.D. NO. —

NOZZLE NO. 7-1

NOZZLE DIA. .443

ASSUMED MOISTURE % Sat

METER ΔH @ .293 using .250 orifice

METER CORRECTION .9857

PITOT NO. Drift

PITOT COEFFICIENT .84

BAROMETRIC PRESSURE 28.05

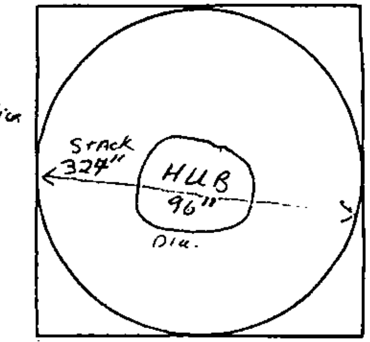
SITE TO BARO. ELEVATION (ft.) –0–

CORRECTED B.P. (0.1 in./100 ft.) 28.05

STATIC PRESSURE – .17

Stack Area (ft²) = 572.555

Hub Area (ft²) = 50.265



SCHEMATIC OF TRAVERSE POINT LAYOUT

Net Area (ft²) = 522.290

PITOT LEAK CHECK ≥3" H_2O

	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL
TIME (24 hr)						
PASS/FAIL						

PITOT LEAK CHECK ≥3" H_2O

	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL
TIME (24 hr)						
PASS/FAIL						

SAMPLE TRAIN LEAK CHECKS

	INITIAL	FINAL	INITIAL	FINAL	INITIAL
TIME (24 hr)	8:00	15:40			
VACUUM, In. Hg	≥15"	7.5"	≥15"		≥15"
CFM	.017	.018			
VOLUMES					
FINAL					
INITIAL					
DIFFERENCE					

SAMPLE TRAIN LEAK CHECKS

	FINAL	INITIAL	FINAL	INITIAL	FINAL
TIME (24 hr)					
VACUUM, In. Hg		≥15"		≥15"	
CFM					
VOLUMES					
FINAL					
INITIAL					
DIFFERENCE					

INITIAL VOLUME 735.00

FINAL VOLUME 1075.82

LEAK CHECK VOLUME —

ADJUSTED FINAL VOLUME 340.82

COMMENTS

Revision 11/18/85

RUN NO. 1 SAMPLING LOCATION Fan Stack #2 p. 1 of 2

DATE PROJECT NO. OPERATOR Strch / Cobb

TRAVERSE POINT NUMBER	SAMPLING TIME, min (Start)	CLOCK TIME (24-hr.) (Start time)	GAS METER READING (V_m), ft³ INITIAL 735.00 DESIRED	ACTUAL	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in H_2O DESIRED	ACTUAL	STACK TEMP. (T_s), °F	DRY GAS METER TEMPERATURE INLET ($T_{m_{in}}$), °F	OUTLET ($T_{m_{out}}$), °F	PUMP VAC., in. Hg	IMPINGER TEMP., °F	SAMPLE BOX TEMP., °F	PROBE TEMP., °F	FILTER TEMP., °F	Cos θ	
S-1	8:56	338	741.28	741.68	.10	.60	.6	83	63	63	5	NA	NA	NA	NA	20	
S-2	[illegible]	685	749.19	749.45	.14	.88	.80	81	68	93	6					15	
S-3		932	757.38	757.65	.15	.94	.90	82	72	92	6					15	
S-4		1315	766.17	766.74	.25	1.62	1.6	70	72	100	10					38	
S-5		1598	777.40	777.97	.40	2.6	2.6	74	82	105	15					38	
S-6		1881	789.23	789.11	.38	2.4	2.4	70	75	96	13					38	
S-7		2131	797.71	798.33	.37	2.4	2.2	65	75	96	12					46	
S-8		2327	804.48	805.19	.32	2.0	2.0	74	70	87	10					57	
S-9		2479	809.78	810.45	.31	2.0	1.9	78	91	98	10					65	
S-10		2553	811.99	812.60	.23	1.5	1.4	84	93	98	7					78	
—	Changed		Ports														
W-1	11:08	2784	817.14	817.60	.13	.83	.80	79	89	88	6					50	
W-2		3047	823.47	823.60	.15	.96	.90	77	89	89	6					43	
W-3		3341	832.64	832.50	.25	1.6	1.5	72	90	89	10					35	
W-4		3674	844.18	843.71	.31	2.0	1.9	74	90	88	10					22	
W-5		4016	857.10	856.73	.37	2.4	2.3	77	91	88	13					18	
W-6		4360	871.13	870.60	.43	2.8	2.7	76	92	88	15					17	
W-7		4661	883.14	882.80	.41	2.7	2.6	78	94	89	15					~~33~~	33
W-8		4940	894.07	894.19	.39	2.5	2.5	74	97	89	15					39	
W-9		5161	901.75	902.10	.31	2.0	2.0	72	94	89	13					52	
W-10	1220	5318	906.67	906.99	.25	1.5	1.5	73	95	90	8					64	
									~~98~~	~~96~~							
	Continued	next	Sheet														

COMMENTS

Revision 9-4-84

RUN NO. 1 SAMPLING LOCATION FAN #2 p. 2 of 2

DATE PROJECT NO. OPERATOR Stich Kobb

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr.)	GAS METER READING (V_m), ft³ INITIAL 906.99 DESIRED	ACTUAL	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in H_2O DESIRED	ACTUAL	STACK TEMP. (T_s), °F	DRY GAS METER TEMPERATURE INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F	PUMP VAC., in. Hg	IMPINGER TEMP., °F	SAMPLE BOX TEMP., °F	PROBE TEMP., °F	FILTER TEMP., °F	COS θ
N-1	13:05	5355	907.19	907.35	.05	.30	.30	87	96	97	1	NA	NA	NA	NA	84
N-2		5534	910.13	910.00	.07	.45	.40	90	96	97	3					60
N-3		5839	917.45	917.01	.15	.95	.90	93	96	97	6					32
N-4		6165	928.52	927.98	.30	1.9	1.9	92	96	96	12					25
N-5		6509	941.13	940.80	.35	2.2	2.2	92	96	96	13					17
N-6		6853	954.14	954.05	.37	2.4	2.4	89	98	94	14					12
N-7		7179	966.27	966.31	.36	2.3	2.3	91	99	93	14					25
N-8		7450	976.80	976.90	.39	2.5	2.4	90	99	95	15					41
N-9	↓	7733	986.77	987.11	.32	2.0	2.0	91	100	96	14					38
N-10	14:10	7838	989.70	990.10	.20	1.3	1.3	91	100	97	8					73
—																
—	Changed Points															
E-1	14:33	8069	993.25	993.31	.06	.39	.4	76	94	95	2					50
E-2		8248	996.98	997.0	.11	.72	.7	72	94	95	4					60
E-3		8523	1003.43	1003.40	.14	.91	.9	78	95	95	5					40
E-4		8817	1013.49	1013.05	.30	1.94	1.9	80	94	94	10					35
E-5		9134	1025.05	1024.56	.34	2.2	2.2	78	94	94	12					28
E-6		9467	1037.47	1037.16	.35	2.3	2.3	72	96	94	13					22
E-7		9795	1050.00	1050.00	.37	2.4	2.4	78	97	95	14					24
E-8		10096	1061.39	1060.81	.36	2.4	2.4	72	96	95	13					33
E-9	↓	10359	1070.77	1070.60	.32	2.1	2.1	73	96	95	13					43
E-10		10565	1075.90	1075.82	.16	1.03	1.0	81	94	92	6					55
	Fan Data	H2		Volts	Amps	KW										
				469	88.8	21.6										
	@ 14:15			470	89.4	42.1										
												↓	↓	↓	↓	

COMMENTS Sample Time = 176.08 min. Total Kwr = 63.7

Revision 9-4-86

MIDWEST RESEARCH INSTITUTE

Drift Sample Recovery

File ______ Date ______

	1st Impinger Probe Rinse	2nd Impinger	3rd Impinger
Final Volume (includes rinses)	406	222	98
Rinse Volume	136	60	66
Initial Volume	150	100	—
Net Volume	120	62	32

==

No. of Bottles	Description
1	Basin Composite (No. of Comps. 2)
1	Probe Rinse & 1st Impinger (Vol.= 406 ml)
1	2nd & 3rd Impinger (Sample Vol. = 320 ml)
1	Filter
1	Water Blank
1	Filter Blank

MIDWEST RESEARCH INSTITUTE

FILE NO.: ____ TEST DATE: ____

DATA SHEET "C"

MEAS. OF: FAN DRIVER INPUT HORSEPOWER — UNIT: HP

INSTRUMENT IDENTIFICATION: SPERRY — DATE CALIBR.:

TIME: START — END

FAN NO.	VOLTS	AMPS	P.F.	KW_1	KW_2	KW_T	MOTOR EFF.	HP
4	468 / 469	88.6 / 87.8		41.7	21.3	63.0	.95	80.23
2	468 / 467	89.5 / 89.5		21.7	42.1	63.8	.95	81.25
3	467 / 469	90.6 / 90.3		42.8	21.6	64.4	.95	82.01
		92.0						
1	469 / 470	92.0 / 92.1		43.5	22.7	66.2	.95	84.30
	wire size 2/0							
	AVG	(90.05)				(64.35)		

TEST AVERAGE INPUT HP — HP with Line Loss (81.17)

MEAS. OF: — UNIT:

INSTRUMENT IDENTIFICATION:

TIME			WIND, MPH	WIND DIREC

TEST AVERAGE:

MEAS. OF: — UNIT:

INSTRUMENT IDENTIFICATION: — DATE CALIBR.:

RUN	TIME					
1						
2		wire Run ≈ 300 ft				
3		wire size 2/0				
4						
5		Reliance XE Motor				
6		100 HP 3/60/460				
7		1785 RPM				
8		Guar. EFF 95% Full Load				
		Amps 111				
		1.15 SF				
		KW Loss = .60				
		HP Loss = .76				
		HP with Line Loss 81.17				

TEST AVERAGE

MEAS. OF: — UNIT:

INSTRUMENT IDENTIFICATION: — DATE CALIBR.:

RUN	TIME	Pump 1	pump 2		
1	8-30-88				
2	8:30	25.4	25.0		
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

TEST AVERAGE:

MIDWEST RESEARCH INSTITUTE

FILE NO.: ____________

DATA SHEET "E"
WATER FLOW MEASUREMENT
PITOT TUBE

TEST DATE: ____________

PITOT TUBE MAKE, MODEL	SERIAL NO.	PIPE SIZE, INCHES
MRI - Simplex	MRI - 8842	NOM = 30 I.D. = 29 1/4 (29 1/2)
DATE CALIBR.:	TUBE COEFFICIENT C = .7948	AREA = .00545 ID², SQ FT A = 29 1/4 = 4.6664; 29 1/2 = 4.7465

PIPE I.D.			IN.	LOCATION DECIMAL INCHES		~~South~~ East STA. DESC. ~~West~~ South Pit. ~~North~~		TIME Riser East ~~South~~		29 1/4 STA. DESC. South ~~West~~ Trav. ~~North~~ West		29 1/2 TIME East ~~South~~	
RDG NO.	DIA. X (18 IN. DIAM AND OVER)	RDG NO.	DIA. X (UNDER 18 IN. DIAM)	CALCULATED (29 1/2)	CORRECTED* (29 1/4)	d, in.	√d	d, in.	√d	d, in.	√d	d, in.	√d
1	.013			3/8	3/8	23 3/4		26 1/4		24 1/4		21 3/4	
2	.039			1 1/8	1 1/8	26 3/4		28 1/2		27 -		22 3/4	
3	.067			2 -	1 15/16	28 1/2		32 -		26 1/2		24 1/2	
4	.097			2 7/8	2 13/16	29 1/4		32 1/4		27 1/2		23 1/2	
5	.129			3 13/16	3 3/4	29 1/2		32 -		24 3/4		24 1/2	
6	.165	1	.026	4 7/8	4 13/16	31 1/2		32 -		25 1/2		24 1/2	
7	.204	2	.082	6 -	5 15/16	30 -		32 1/2		25 3/4		25 -	
8	.250	3	.146	7 3/8	7 5/16	31 1/2		32 1/2		26 -		26 1/2	
9	.306	4	.226	9 1/16	8 15/16	31 1/4		31 3/4		27 1/4		26 -	
10	.388	5	.342	11 7/16	11 3/8	31 1/2		31 1/2		27 1/2		28 1/4	
11	.612	6	.658	18 1/16	17 7/8	30 1/4		29 1/2		28 1/2		29 1/4	
12	.694	7	.774	20 7/16	20 5/16	30 -		29 1/2		27 1/2		30 1/4	
13	.750	8	.854	22 1/8	21 15/16	30 -		28 3/4		28 1/2		30 -	
14	.796	9	.918	23 1/2	23 5/16	28 1/2		28 -		27 1/2		29 3/4	
15	.835	10	.974	24 5/8	24 7/16	28 -		26 1/2		27 -		29 1/2	
16	.871			25 11/16	25 1/2	26 -		25 1/4		24 3/4		27 1/2	
17	.903			26 5/8	26 7/16	23 3/4		23 3/4		23 1/2		27 1/4	
18	.933			27 1/2	27 7/16	23 1/2		22 1/2		24 -		25 1/2	
19	.961			28 3/8	28 1/4	20 1/4		19 1/2		20 -		24 3/4	
20	.987			29 1/8	28 7/8	21 1/2		17 -		10 3/4		23 1/2	
						TOTAL	105.16	TOTAL	105.61	TOTAL	100.08	TOTAL	
						AVG	5.258	AVG	5.280	AVG	5.000	AVG	4.974
						TRAVERSE AVG √d				TRAVERSE AVG √d			

RDG NO	TIME	d
A		
B		
C		

West Trav. = 20629
South Trav = 20364
US GPM East Riser = 20497

South = 19284
West = 19515
US GPM West Riser = 19400

Q, gpm = √d (1040 x C x A) = √d (________)

BASIS, AIR/WATER MANOMETER

Total Tower Flow = 39897

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

APPENDIX C

LABORATORY ANALYSIS

DRIFT TEST
ON THE

4-CELL, MECHANICAL-DRAFT, CROSS-FLOW
COOLING TOWER

Table 1. Summary of Sample Analysis Results for Project

Project:
Lotus File: 92888A
Jarrell-Ash Data File: 92888A
Analyst: M. Greene
Analysis Date:
Data Analyst: E. McClendon
Date:
Sample Matrix: 10% HNO_3
Analytes: Ca, Mg, Na

Summary of Sample Analysis Results:

Verified by: E. McClendon 10-14-88

Project Sample Name	ASF Sample Bar Code(s)	Sample Units	Element Ca	Element Mg	Element Na
Impingers	06354	mcg	5040	1040	7350
Basin Water	06355/06356	mcg/g	524	104	740
Water Blank	06359	mcg/g	<0.00723	<0.00026	<0.0504

Comments:
The samples were analyzed on a Jarrell-Ash Model 1155A ICP-AES.
The final sample concentrations are as received in the units listed.

INTEROFFICE COMMUNICATION

MIDWEST RESEARCH INSTITUTE

To: D. Cobb

From: E. McClendon

Subject: ICAP Analysis Results for Project

Enclosed are the results of the ICAP analysis performed for Project Drift samples.

I. Introduction and Request for Analysis

These samples were submitted for . The analytes of interest were Ca, Mg and Na. Analyses were performed on the Jarrell-Ash Model 1155A ICP-AES.

II. Submission of Samples for Analysis and Sample Preparation

Four samples (Impinger contents in two containers, a filter, a container with basin water and a conatiner with "blank" water) were received in the Atomic Spectroscopy Facility from D. Cobb. The samples were prepared according to EPA SW-846 Method 3050, as per the memo from D. Cobb dated September 15, 1988.

III. Standard Preparation

Standards for this analysis were prepared at appropriate concentrations from Spex Industries Multielement Custom Plasma Standard Analytical Reference Materials. The standards were prepared in 10% (v/v) nitric acid (Baker Instra-analyzed Lot B04C58) and the upper instrumental calibration limit was 10 mcg/mL for Ca, 5 mcg/mL for Mg and 150 mcg/mL for Na. A calibration blank consisting of the stock 10% nitric acid was used.

An instrumental check standard was prepared at a 1 mcg/mL level from custom prepared multielement standards from Inorganic Ventures, Inc..

IV. Instrumental Analysis

The samples were analyzed on the Jarrell-Ash Model 1155A ICP-AES. The instrumental parameters are recorded on the appropriate sheet in the data packet and the instrument was profiled and standardized according to the manufacturer's instructions.

V. Sample Analysis Results and Discussion

The samples were analyzed by EPA SW-846 Method 6010. The tables listed below contain the analytical data for this study.

Table No.	Description
1	Summary of Sample Analysis Results
2	Sample Weighing Data
3	ICAP Sample Raw and Calculated Data
4	Instrumental Check Standard, Duplicate and Spike Data

Table 1 contains the analytical results of the analysis. Table 2 contains the sample weighing data generated during the digestion of the samples. Table 3 contains the ICAP sample raw data along with the blank corrected calculated sample data and table 4 instrumental check standard data, the resulting percent instrumental drift and duplicate determination and spike recovery data.

The cell formulas used in these tables are included for completeness.

VI. Internal Quality Control

The detection limit was determined by direct output from the Jarrell-Ash Model 1155A ICP-AES. This detection limit was determined from the calibration blank data generated throughout the sample run and is defined as two times the largest standard deviation of the calibration blank data.

Analytical quality check samples were prepared from Custom Multielement Plasma Standard Analytical Reference Materials manufactured by Inorganic Ventures, Inc.. The concentration (mcg/mL) found for this solution did not deviate from the stated value by more than 4 percent.

Midpoint instrumental check standards were analyzed throughout the sample analysis run. The percent drift calculated from the instrumental check determinations is appended in the Instrumental Check Standard, Duplicate and Spike Data Table (Table 4). Instrument drift was less than 3 percent, indicating that the instrument was fairly stable throughout the entire sample analysis.

No interference check standard was prepared as the analysis was for what could be considered major components. The duplicate determinations showed percent differences of less than 3 percent, except for the Ca. The sample had high levels of all analytes and could be considered "hard" water, presumably from contact with limestone. The large duplicate difference could have occurred from inhomogeneity due to calcium carbonate precipiate, which forms readily with hard water sources. Most of the spiking levels were less than one-fourth of the native level and the remaining spike recovery was 77 percent for a spike at one-fourth the native level. Recovery of the analytes of interest at the concentrations of the magnitude which the samples exhibited is not considered difficult.

VII. Additional Information

The following raw data accompanies this report. This information is coded by Project Number 9150L29 and also contains a part number identifier.

Project

Part Number	Description
1	ICP-AES Data Reporting Sheet
2	Control Table Editor Output
3	DEC Command Files Used
4	ICAP Sample Raw Data
5	Sample Weighing Sheet - Initial Weights
6	Sample Weighing Sheet - Final Weights
7	Photocopy of MRI Laboratory Generated Sample Inventory
8	Photocopies of Notebook 1357:98-100

With the exception of part number 8, the photocopies of the notebook 1357:98-100, this file contains the only record of the analysis. This file should therefore be archived as required by the project or as required by MRI policy.

This data has undergone one level of senior review within the Analytical Chemistry Section. The MRI Quality Assurance Unit has not reviewed this data.

Approved,

John Stanley, Head
Analytical Chemistry Section