AP42 Section:	13.4
Background Chapter	4
Reference:	2
Title:	Cooling Tower Drift Measurement Position Paper. Performance and Technology Committee, Houston, Texas, October. Cooling Tower Institute (l989).

COOLING TOWER INSTITU 2

IT IS GOOD BUSINESS *TO* CONSERVE WATER

TO: Ben Sherlock

FROM: Bob Fulkerson
Paul Lindahl
Kermit Trout

DATE: October 13, 1989

RE: CTI DRIFT POSITION PAPER

Dear Ben:

Enclosed is the CTI DRIFT POSITION PAPER for the Board's review and approval. This paper was drafted over the last several meetings by the Drift subcommittee, chaired by Toby Daley. A draft was discussed during the meeting at Dana Point and as a result, a "draft" final issue was prepared in August.

That copy was distributed to an Ad-Hoc Review Committee composed of Tony DePalma, Mahendra Doshi, Jan Skold, Mike Wittemore, Toby Daley, Bob Fulkerson, Paul Lindahl and Kermit Trout. The committee reviewed the document for the P&T Committee and provided comments. The revised paper is attached and submitted for approval by the Board of Directors.

Respectfully,

Robert Fulkerson Paul A Lindahl Kermit Trout

Bob Fulkerson
Chairman, P&T Committee
Paul Lindahl
Kermit Trout
Vice-Chairman, P&T Committee

cc: CTI Board of Directors
c/o Dorothy Garrison
Ad-Hoc Review Committee
Tony DePalma
Mahendra Doshi
Jan Skold
Mike Wittemore
Toby Daley
Drift Committee

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COOLING TOWER INSTITUTE
PERFORMANCE AND TECHNOLOGY COMMITTEE
COOLING TOWER DRIFT MEASUREMENT
POSITION PAPER

Prepared by:

The Performance and Technology Committee

Cooling Tower Institute

October, 1989

COOLING TOWER DRIFT MEASUREMENT POSITION PAPER

ABSTRACT

The measurement of cooling tower drift has become increasingly important to users, vendors and regulatory agencies alike over the past decade. Increased concern over environmental impacts and lower guaranteed drift rates have contributed to this increased interest. The purpose of this CTI position paper is two-fold:

- First, to present recommendations on drift measurement based on comparitive results among alternative measurement methods.
- Secondly, to serve as the basis from which a drift test code can be developed.

Drift measurement methods used by cooling tower manufacturers and testing organizations include the following:

- Sensitive paper methods.
- Heated glass bead isokinetic sampling (various methods).
- EPA Method 13A.

The first two methods are considered more "traditional" ones since they have been used the most frequently for drift measurements. Method 13A is gaining popularity, but its results to date have been subject to significant variability. This paper presents comparitive drift measurment results among the methods to substantiate recommendations and conclusions.

BACKGROUND

In the operation of an evaporative cooling system, the circulating water is broken up into droplets in order to enhance the surface area exposed to the air. In this process, droplets are entrained in the air. Those that are not removed and drained by the drift eliminators, are exhausted from the cooling tower into the environment. These droplets, which possess the same components as the circulating water are known as drift.[1]

Cooling tower exit air contains water vapor, drift droplets (which do not necessarily possess the same concentration of chemicals as the circulating water), condensate droplets of pure water, and particulate which originate in the ambient air but not removed by the cooling tower. The proportion of these constituents in the exit air is regulated by a number of factors including, but certainly not limited to, ambient psychrometric and wind conditions, cooling tower heat load, water distribution and fill system design, circulating water chemistry, etc.

Due to the increased use of cooling towers over the last twenty-five years and the enhanced focus on environmental impact, there has been an attendant increase in the measurement and characterization of drift. The impetus behind specific drift measurement programs seems to fall in one of the following categories:

a) Environmental Impact Assessment - Regulatory purview solicits determination of the environmental effects of a cooling tower in terms of such factors as terrestrial impact in the vicinity of the tower. This impact can be caused by any and/or all of the above constituents contained in the cooling tower exit air stream. This is often part of an NPDES (National Pollutant

Discharge Elimination System) permit. Historically, this has been required at all proposed nuclear plants,[3,4,5] however, similar assessments have been solicited at numerous fossil plants.[6]

b) Ambient Air Quality and Emission Limitations - Some regions have imposed lbs/hour limitations on all emission sources such as stack emissions from electric generating plants and include cooling towers. The State of New Jersey and the San Francisco Bay area are two notable areas. Further as part of the National Ambient Air Quality Standards Prevention of Significant Deterioration (PSD) requirements solicit emissions measurements and/or modeling. Specifically based on predictions of ambient air concentrations from a source and the "increment" available to consume based on ambient monitoring, a contemplated source is limited to a specific emission rate.

c) Drift Guarantee Evaluation - Many cooling tower specifications and resultant contracts require drift guarantees. In some cases, drift testing is performed to simply satisfy a "punch list". Specific concerns beyond those alluded to in (a), (b), and (c) above, such as switchyard flashover, water conservation and nuisance problems, may require drift measurements.

With this backdrop, the cooling tower owner/operator is potentially faced with the prospect of determining drift emissions. However, there are no existing standards or codes for such determinations. In cases where EPA guidelines form the impetus for measurements, regulatory groups may suggest or impose methods for drift emissions determinations. These include stack sampling methods and specialized source sampling methods such as Method 13A.[7] In other situations, historically recognized methods such as those compared and evaluated in references 2, 6, and 8, have been used. These include devices such as those listed in Table 3 from the EPRI/MIT study.[8]

Table 3

LIST OF PARTICIPATING ORGANIZATIONS AND MEASUREMENT TECHNIQUES REPRESENTED IN THE MIT/EPRI COMPARATIVE DRIFT MEASUREMENT METHODS ANALYSIS PROJECT

Participating Organization	Measurement Method	Droplet Size Measurement Capability	Droplet Velocity Measurement Capability
HAMON SOBELCO Brussels, Belgium	coated slide	yes	no
ECODYNE Santa Rosa, CA, USA	cyclone separator	no	no
CALFRAN INDUSTRIES Springfield, MA, USA	droplet photography	yes	no
Prof. G. Ernst and Associates University of Karlsruhe Karlsruhe, Federal Republic of Germany	a) sensitive paper	yes	no
	b) double calorimeter	no	no
	c) heating psychrometer	no	no
	d) condensing apparatus	no	no
	e) cyclone separator	no	no
ENVIRONMENTAL SYSTEMS CORPORATION Knoxville, TN, USA	a) laser light scattering	yes	no
	b) sensitive paper	yes	no

CURRENT STATUS OF DRIFT MEASUREMENTS

Most of the drift testing in the United States, both in laboratory and field situations, has been conducted using heated glass bead isokinetic or Sensitive Paper techniques. The data base resulting from these measurements has formed the basis for drift rate specifications and associated guarantees. Although it has long been recognized that the Sensitive Paper method can yield lower numbers (see Table 4 from reference 9), than concurrent determinations of drift with isokinetic sampling, it has been relied on for the following reasons:

a) the Sensitive Paper method yields droplet size data necessary for modeling of drift transport,

b) it provides an indication of drift eliminator effectiveness as a function of droplet size, and

c) it is unaffected by entrained ambient minerals which can bias isokinetic sampling methods.

Unfortunately, the Sensitive Paper method cannot provide data on droplet sizes below about 20-30 μm, and it cannot delineate between condensate and drift droplets. Further, there is no way to assess the individual droplet chemistry and thereby afford a direct comparison between isokinetic and Sensitive Paper methods.

Drift Droplet Size Distribution

The following paragraph, excerpted from reference 2, addresses some of the factors, but certainly not all, that can influence drift droplet evaporation and chemical constituency and thus cooling tower emissions measurements interpretations.

The difference between droplets surface vapor pressure and the ambient vapor pressure determines the rate of droplet growth by condensation or evaporation. Salt concentration and the radius of curvature of the droplet effect surface pressure and thus growth rate. The curvature effect decreases as the drop radius increases and is negligible for drops larger than several microns. The salt content is an important factor for concentration greater than 10^3 to 10^4 ppm. The time required for a droplet to grow from 1μ to $10\text{-}20\mu$ in the diffusion process just outlined is on the order of a few seconds. The effect of salt concentration in towers where sea water with a salt content of about 30,000 ppm is used for coolant may be sufficient for drift droplets to grow at the expense of evaporative fog. (Salt nuclei have been used for fog dispersal at airports.) This discussion should demonstrate that caution must be exercised in considering fog and drift as separate phenomena or that drift has the same concentration of dissolved minerals as the circulating water. All drift measurement methods reviewed in reference 2 lack the ability to simultaneously discern drop size and chemical concentration.

It has long been felt that the bulk of the drift leaving an evaporative cooling tower is in the range of about 10-20 μm. Table 5a and 5b provide example droplet spectra from older vintage and more state-of-the-art cooling tower drift elimination systems.[10,11]

Table 4

Ratio of Sensitive Paper Drift Fraction
to Isokinetic Drift Rates

LOCATION & TIME OF TEST		SP%	IK% Δ_k	Ratio
Homer City Counterflow Natural Draft	8/16/72	0.00024	0.0011	4.6
Hornaing, France Crossflow Natural Draft	10/5/72	0.00034	0.0011	3.2
K-25 Crossflow Mechanical Draft	6/73	0.09	0.11	1.2
Turkey Point Crossflow Mechanical Draft	2-3/74	0.00027	0.00078	2.9
Chalk Point #3 Crossflow Natural Draft Cooling Tower				
	12/15-19/75	0.00033	0.0013	3.9
	6/22/76	0.00056	0.00068	1.2

Average $\frac{IK}{SP} = 2.8$

Table 5a

Drift Mass Emission Percentages
For Single Fan Stacks of Specific Towers
Based on Sensitive Paper Tests

Droplet Size Interval		Tower A[a]		Tower B[b]	Tower C[c]	
d_l	d_u	Low	High		Low	High
μm	μm	%	%	%	%	%
10	20	0.1	0.03	1.2	0.4	0.2
20	20	1.9	0.7	2.9	6.2	2.7
30	40	3.0	1.2	2.8	11.2	4.9
40	50	2.9	0.9	2.8	11.2	3.2
50	60	3.3	1.1	2.4	10.7	1.6
60	70	3.4	1.1	2.6	8.3	1.0
70	90	5.9	1.8	5.9	9.2	0.7
90	110	6.5	1.8	5.8	7.2	0.5
110	130	4.6	1.6	5.3	1.9	0.6
130	150	4.3	2.0	3.7	0.7	0.5
150	180	5.6	2.7	4.4	1.2	0.6
180	210	5.0	2.7	3.3	1.2	1.0
210	240	5.6	3.3	2.4	1.0	1.7
240	270	4.4	3.1	2.0	1.1	2.2
270	300	2.9	6.4	1.8	0.8	3.7
300	350	5.5	8.6	2.6	0.7	7.1
350	400	6.7	8.6	2.3	0.9	6.8
400	450	3.3	6.8	2.1	0.9	7.1
450	500	1.7	5.3	2.0	0.7	3.1
500	600	0.5	5.3	3.0	1.2	1.3
600	700	1.1	1.4	3.1	2.0	6.7
700	800	1.6	1.9	1.7	1.5	5.8
800	900	1.7	1.3	2.8	1.2	2.1
900	1000	2.2	0.7	1.9	1.4	1.2
1000	1200	3.8	1.3	3.3	2.3	1.1
1200	1400	3.5	0.4	2.4	0.9	1.4
1400	1600	1.4	1.8	4.5	1.4	2.3
1600	1800	2.3	1.5	1.7	0	0.9
1800	2000	1.7	2.4	1.5	0	0.4
2000	2200	1.5	2.4	3.8	0	6.0
2200	2400	2.3	2.2	2.1	0	0
2400	2600		0.9	0	0	0
2600	2800		2.7	0	0	7.6
2800	3000		2.8	0	0	0
3000	3200		4.4	0	12.1	3.8
3200	3400			0		
3400	3600		7.0	7.5		
	100.2*	100.13*	100.2*	100.0	99.8*	
Drift Fraction (%)		0.00544	0.0158	0.00167	0.000339	0.00107

[a]Counterflow +20 yrs old Chevron Drift Eliminators
[b]Crossflow 1978 vintage Honeycomb Drift Eliminators
[c]Crossflow 1980 vintage Honeycomb Drift Eliminators

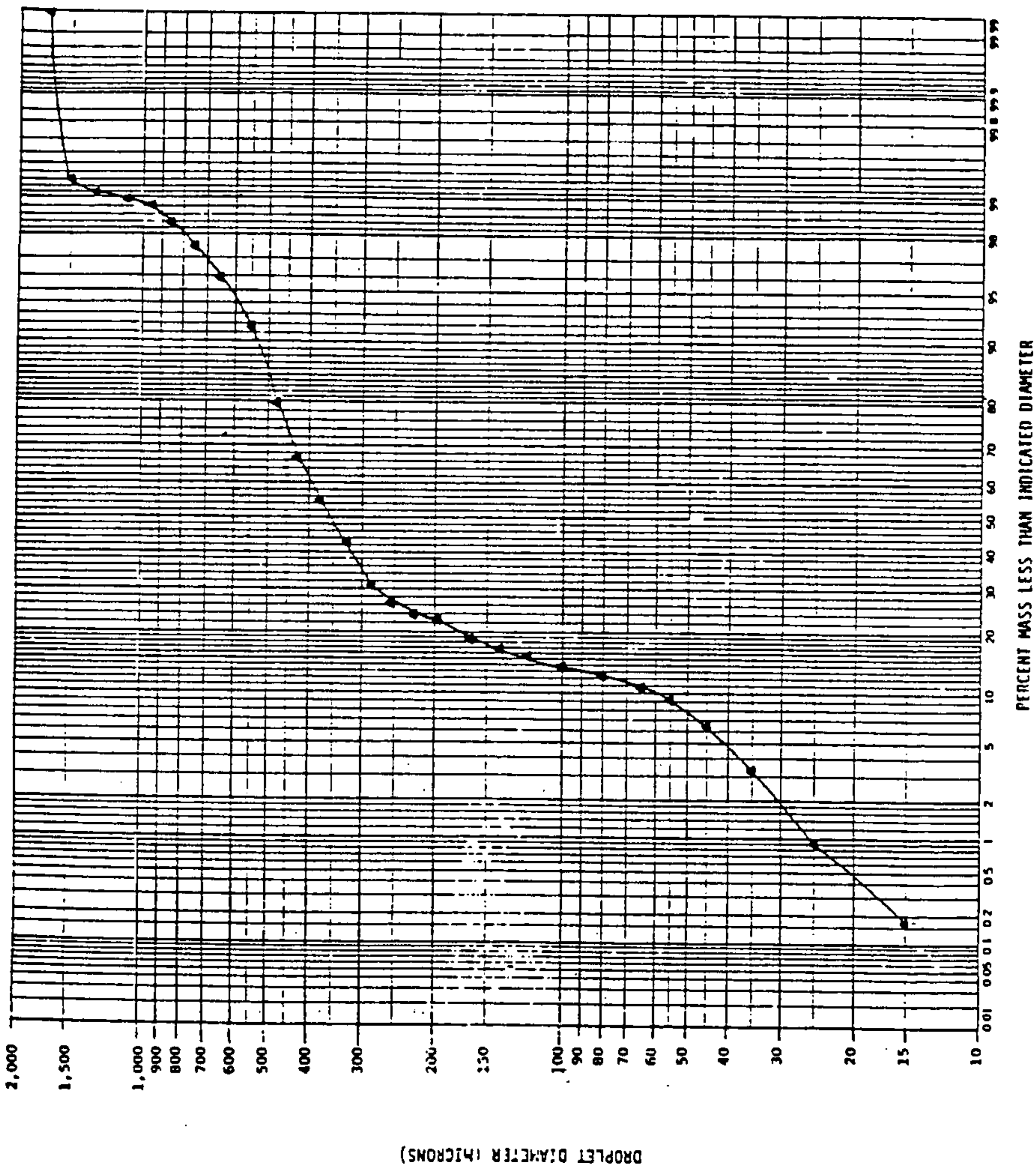
Table 5b

PALO VERDE NUCLEAR GENERATING STATION
COOLING TOWER C
SUMMARY DROP-SIZE DISTRIBUTION
EXIT PLAN AREA = 1539.98 M2
COMPOSITE OF 4 CELLS

I	D(LOW) UM *****	D(HI) UM *****	MASS FLUX UG/M2/SEC *********	% MASS SMALLER *******
1	10.	20.	2.91E+01	0.178
2	20.	30.	1.18E+02	0.904
3	30.	40.	4.02E+02	3.367
4	40.	50.	5.31E+02	6.620
5	50.	60.	4.18E+02	9.185
6	60.	70.	2.52E+02	10.733
7	70.	90.	2.70E+02	12.390
8	90.	110.	2.26E+02	13.776
9	110.	130.	2.52E+02	15.318
10	130.	150.	2.54E+02	16.876
11	150.	180.	3.38E+02	18.946
12	180.	210.	4.05E+02	21.426
13	210.	240.	4.14E+02	23.965
14	240.	270.	5.00E+02	27.032
15	270.	300.	7.98E+02	31.922
16	300.	350.	1.60E+03	41.721
17	350.	400.	2.03E+03	54.181
18	400.	450.	2.19E+03	67.631
19	450.	500.	1.98E+03	79.762
20	500.	600.	1.94E+03	91.639
21	600.	700.	6.77E+02	95.789
22	700	800.	2.67E+02	97.428
23	800.	900.	1.65E+02	98.438
24	900.	1000.	6.18E+01	98.817
25	1000.	1200.	2.43E+01	98.966
26	1200.	1400.	2.41E+01	99.113
27	1400.	1600.	3.70E+01	99.340
28	1600.	1800.	1.08E+02	100.000

TOTAL MASS FLUX = 1.63E+04 UG/M2/SEC
MASS MEAN DIAMETER = 376. UM

MASS EMISSION RATE = 2.51E+01 GRAMS/SEC



COOLING TOWER C - DROPLET SIZE DISTRIBUTION
PERCENT MASS LESS THAN INDICATED DIAMETER

Note that the ratio of IK to SP inferred drift rates ranged from approximately 1-5 with an average of slightly over 3. Similar, but more comprehensive tests conducted on a state-of-the-art circular crossflow mechanical draft cooling tower indicated IK to SP ratios averaging approximately 6.[10] High volume samples of air entering the tower revealed high concentrations of the same minerals as existed in the circulating water and exit plane. Accordingly, the IK/SP ratio could have been biased due to entrained and unscrubbed particulate. In short, the <u>inference</u> of the SP and IK data is that (a) the droplets have greater concentrations of minerals than does the circulating water and/or (b) there exists a significant component of mineral bearing drift in the less than 30μm range.

Pursuant to the above-referenced differences, size distribution data were acquired by EPA on a mechanical draft cooling tower.[12] These measurements were part of a series of tests in support of developing a possible chromium standard under the National Emission Standards for Hazardous Air Pollutants (NESHAPS). A "disc train" and an "aligned nozzle train" were used and "cut-off" diameters were calculated. The data from this effort suggests the possibility that, at least in the case of the chromium tracer used, a significant portion of the chromium mass was associated with particles less than 15μm. Further, absorbent paper results with a calculated "aerodynamic cut off" suggest that only a small portion (ie <15%) of the chromium bearing aerosol mass is <u>greater than</u> 30μm. Clearly, more data is needed in this area before definitive conclusions can be made.

Additional data taken by EPA (contractor Entropy Environmentalists Inc.) and ESC using method 13A[12,13] Isokinetic and Sensitive Paper methods are summarized in Table 6.

Table 6

Summary of EPA Chromium Emission Tests as
Contrasted to ESC Sensitive Paper Results

TEST	TYPE OF TOWER	DRIFT ELIMINATOR	DRIFT RATE (percent) METHOD 13A RESULTS	RATIO OF HIGH TO LOW (13A)	DRIFT RATE (percent) SP RESULTS	RATIO OF 13A TO SP
1	Crossflow	Herringbone Blade-Type	0.484 0.0574 0.0205	23.6	0.0045	8.6[A]
2	Crossflow	PVC Honeycomb	0.0452 0.0045	10	0.0009	5[A]
3	Counterflow	PVC Honeycomb	0.0068 0.0022	3.09	0.0006	7.5
4	Counterflow	PVC Honeycomb	0.0749 0.0031	24.2	0.0005	6.0
5	Crossflow	PVC Honeycomb	0.0130 0.0019	6.8	0.0002	9.5[A]
6	Crossflow	PVC Honeycomb	0.002 0.001	2	0.0004	3.75
7	Crossflow	PVC Honeycomb	0.0823 0.0019	43	0.0008	2.37[A]
8	Crossflow	PVC Honeycomb	0.0012 0.0014	1.1	0.0002	6.5

[A]High 13A reading omitted

ADDITIONAL TESTS

9A Cell	Crossflow	Herringbone	0.344 0.068 0.0089 0.0039	N/A	0.0047 0.0103 0.0072 0.0042	73.2 6.6 1.2 0.98
10A Cell	Counterflow	PVC Herringbone	0.0087 0.0122	N/A	0.0037 0.0042	2.4 2.9

The data presented in Table 6 are all taken from mechanical draft cooling towers. In contrast, the only data available on a natural draft tower taken by ESC indicates very close agreement between SP and Method 13A tests. This is based on three, essentially simultaneous tests on a natural draft salt water cooling tower.

CONCLUSIONS AND RECOMMENDATIONS

Cooling Tower Drift measurements are required for laboratory research and field validation of drift emissions rates. The impetus behind such measurements usually fall into one of three categories.

1) lbs/hr emissions required - (regulatory based)
2) environmental impact assessment and modeling required, and
3) drift specifications and guarantees solicit verification of compliance.

A significant body of data exists on cooling tower drift measurement results. The majority of these data were acquired with either heated glass bead isokinetic or Sensitive Paper. It is upon this data base that a number of drift specifications and performance guarantees have been based.

Recent data acquired by the Environmental Protection Agency as part of the development of hexavalent chromium emissions calls into question the accuracy of SP measurements and possibly heated glass bead isokinetic measurements. These data suggest that a significant portion of the mineral bearing mass of drift are less than 30μm and are not captured by the Sensitive Paper. It is also possible, that even with a back up filter with 0.45μm porosity, the heated glass bead isokinetic sampler may not capture all the mineral bearing effluent from a cooling tower.

Unfortunately, much of the EPA efforts concentrated on hexavalent chromium and the results are extremely variable. To a lesser degree, surrogate compounds were used, which provided greater repeatability. In some cases, however, Method 13A results indicated drift rates of greater than 0.2%, a rate which testing agencies have not encountered with any methods, even with drift eliminators in disrepair.

The Cooling Tower Institute has no code on drift measurements. However, they are looked to for direction in this area. It is therefore the Performance and Technology Committee's position that CTI adopt the following stance for drift measurement guidelines.

1) Use Heat Glass Bead Isokinetic (HBIK) system with demonstrated performance for drift guarantee assessment.

2) Use a sensitive surface method, such as Sensitive Paper (SP), where previous benchmark data were acquired with SP and/or where droplet size is solicited, and if it is mutually acceptable to the parties to the test.

3) Support (and contribute technically) additional research into the size distribution of mineral bearing particulate exiting the cooling towers. Seek out and participate in additional comparative studies using Method 13A, Heated Glass Bead Isokinetic and other isokinetic systems. As the knowledge base expands, revise the CTI position and/or test codes as required.

4) Develop a specific test code for total drift measurements.

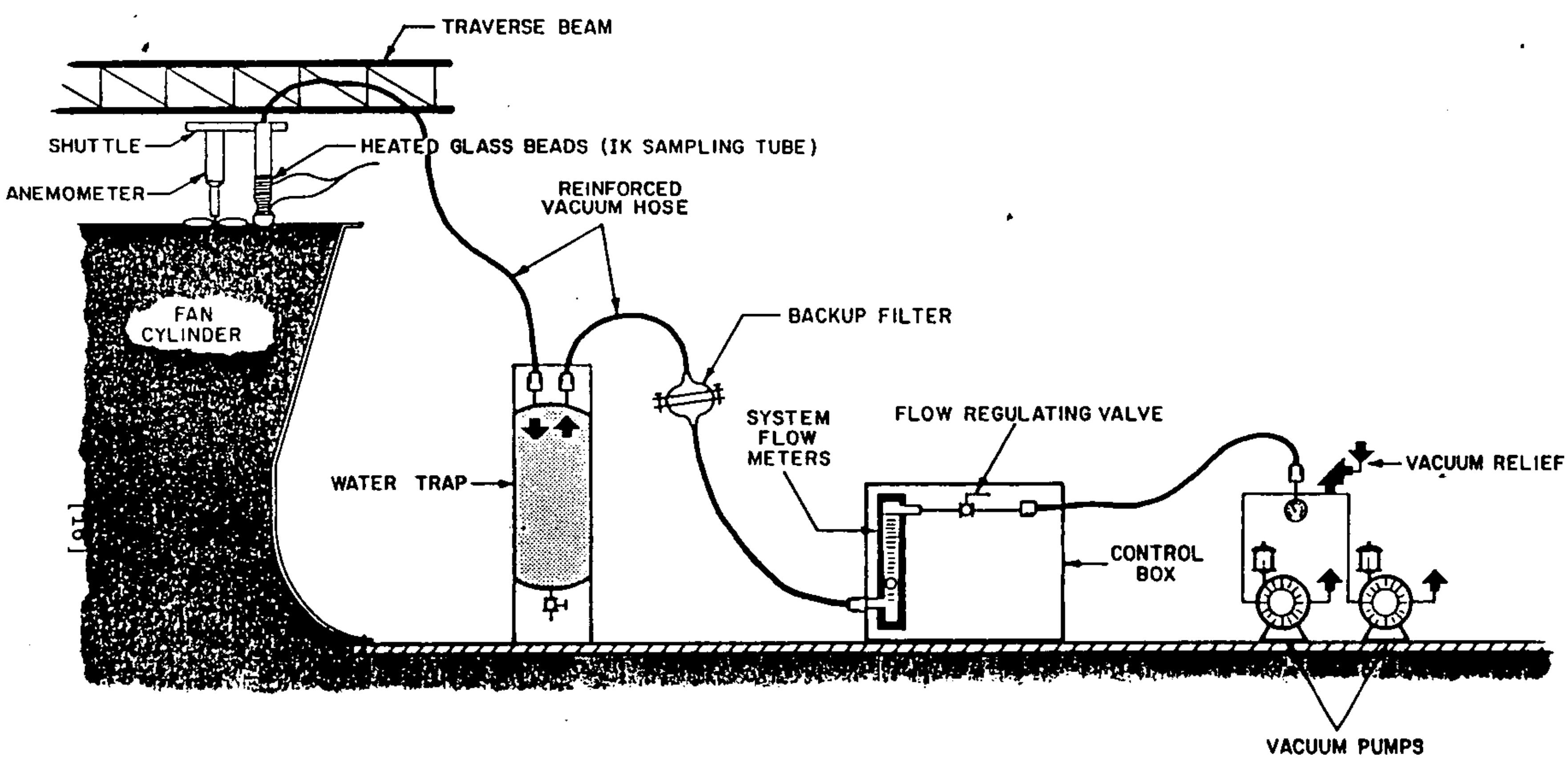
5) Use a sensitized surface system with demonstrated performance for drop size characterization.

6) Seek and participate in research into the drop size distribution of drift droplets exiting cooling towers.

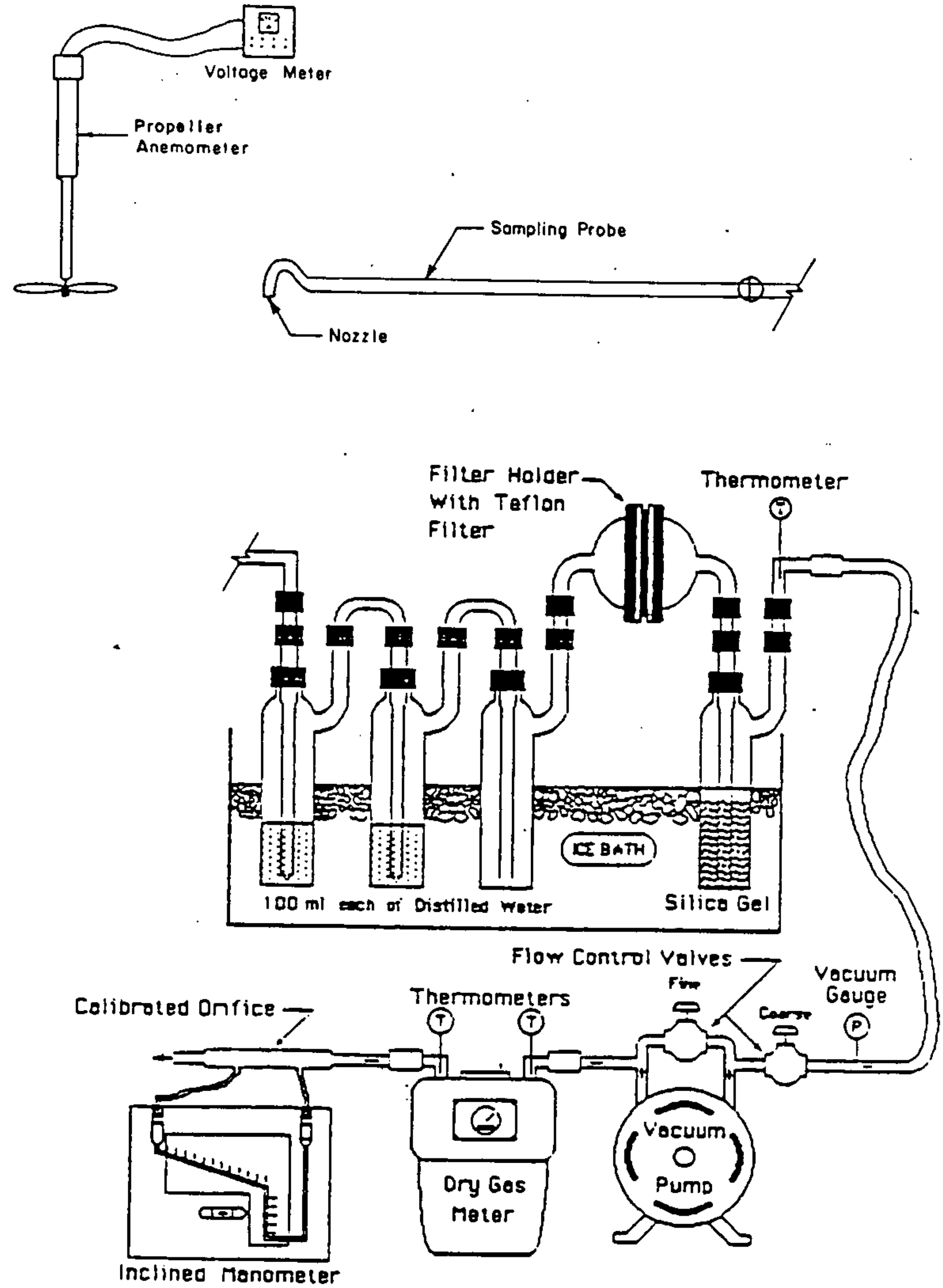
7) Develop a specific test code for drop size distribution measurement.

It should be emphasized that the drift guarantee basis is <u>drift only</u> as defined in the first paragraph of this position paper and is independent of the influence of inlet air constituents. This requires that the solution analysis method be independent of significant influence of elements found in the inlet airstream. Background constituent levels cannot be subtracted from outlet levels since the scrubbing effect of the cooling tower is unknown.

(The attached diagrams provide schematics of the SP, HBIK, and Method 13A sampling devices.)

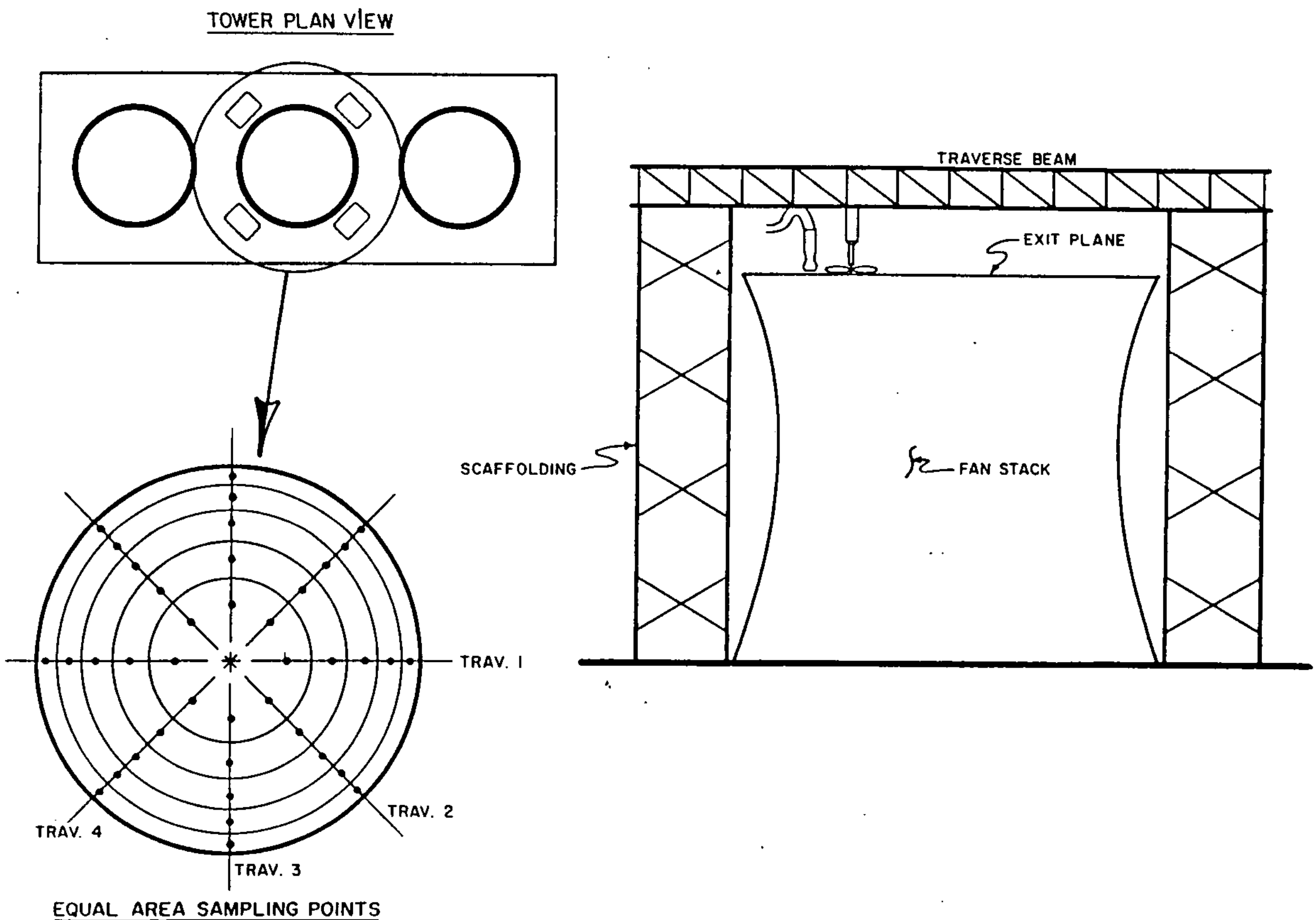


CONSTITUENTS OF AND DEPLOYMENT OF THE
HEATED GLASS BEAD ISOKINETIC SAMPLER

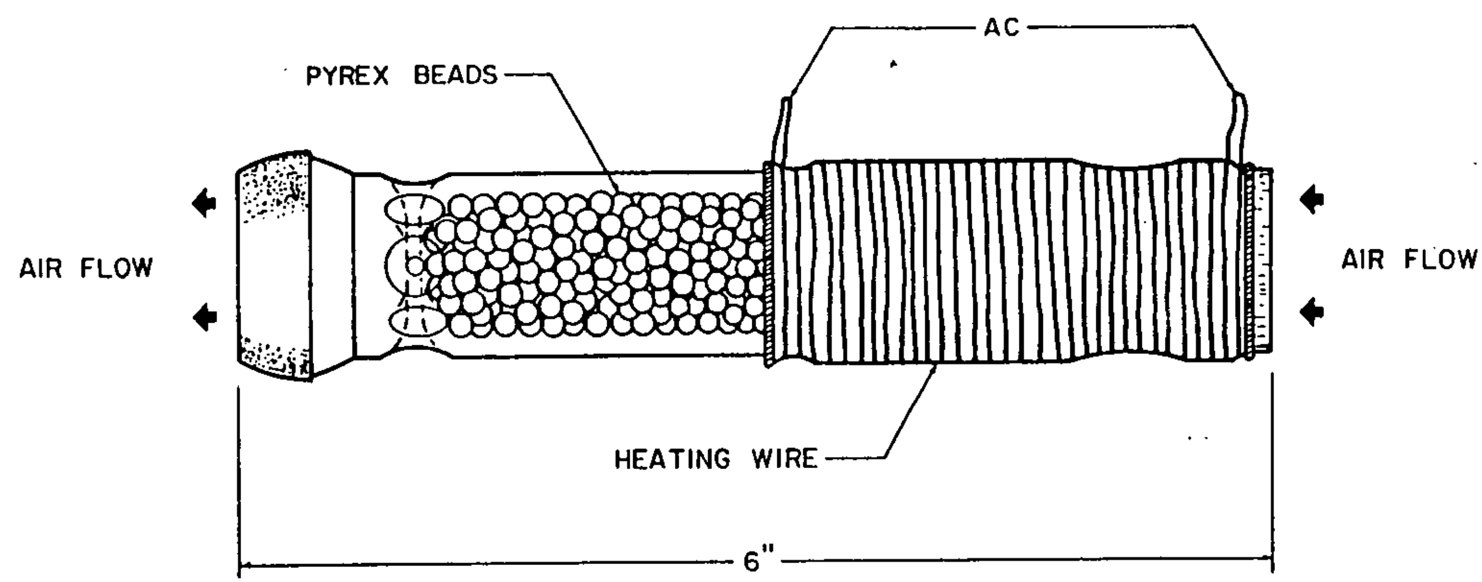


SAMPLING TRAIN FOR MEASURING COOLING TOWER EMISSIONS

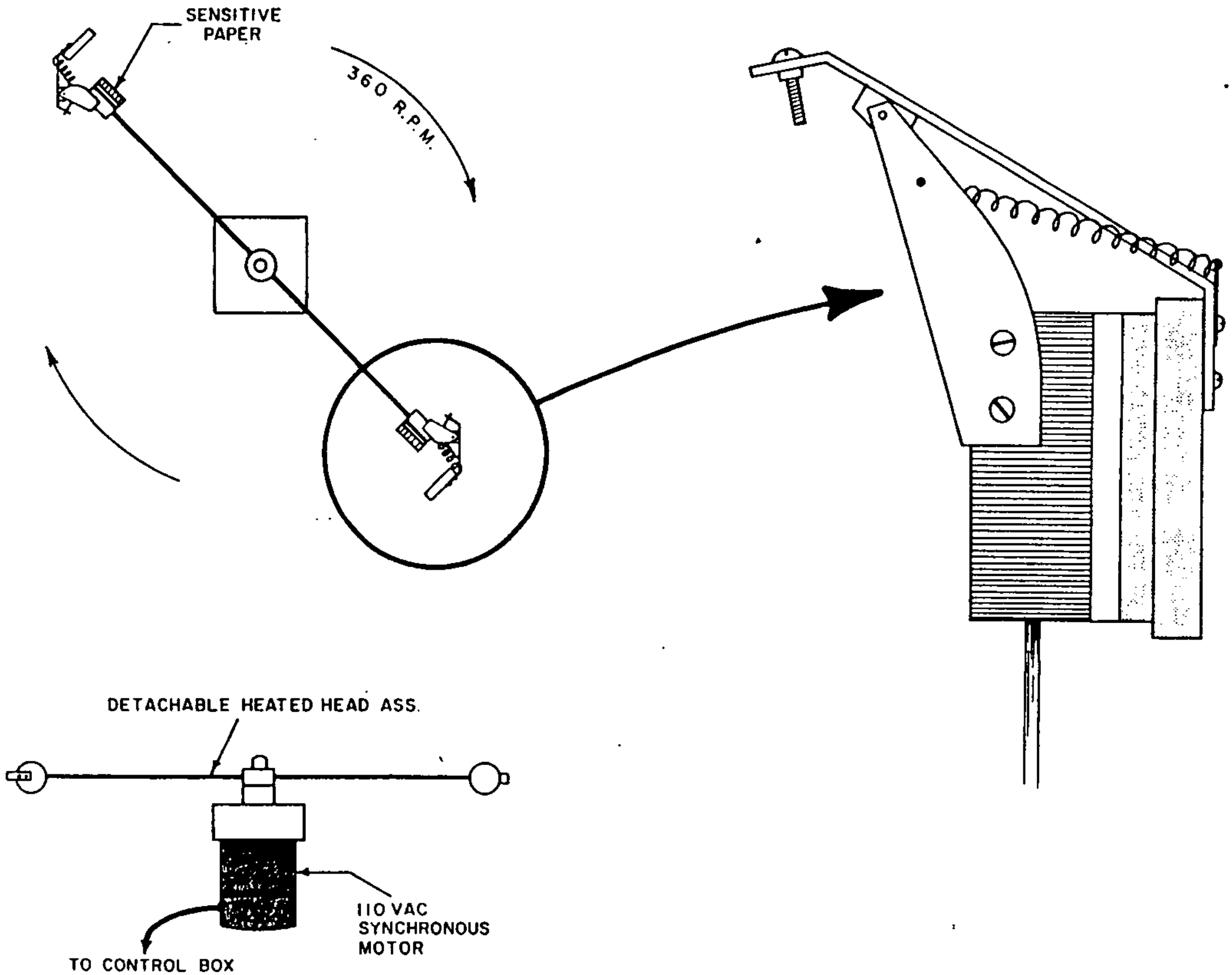
EPA METHOD 13



ISOKINETIC DRIFT SAMPLING



SCHEMATIC OF THE HEATED GLASS BEAD ISOKINETIC SAMPLING TUBE



ROTATING SENSITIVE PAPER MACHINE

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