WOOD DUST STUDY REPORT

For Three (3) Wood Dust Handling Ducts at

BERNHARDT FURNITURE COMPANY

Hibriten Plant 3

Lenoir, North Carolina

Performed by the Source Testing Staff
of the
North Carolina Department
of Natural & Economic Resources
Division of Environmental Management
Air Quality Section
December 1 & 2, 1976

CONTENTS

INTRODUCTION

It was desired that a study be made of wood dust produced in wood working operations prior to revision of North Carolina Administrative Code, Title 15, Chapter 2, Subchapter 2D, Section .0512, titled, "Particulates From Wood Products Finishing Plants."

Samples of wood dust were taken from three ducts at Bernhardt Furniture Company, Hibriten Plant 3, in Lenoir, North Carolina. The samples were taken on December 1 and 2, 1976.

Personnel involved with taking the samples were J. R. Jernigan and R. E. Wooten from the source testing staff and S. R. Maynard from the South Piedmont Field Office of the North Carolina Division of Environmental Management, Air Quality Section.

Source Description

The three ducts sampled were collecting waste from: (1) a sander line, (2) a machine line, (3) the rough end.

There were a number of pieces of machinery on each line. Some operated for the entire time of a test run, some part of the time, and some none. The machines operating and their approximate schedules are detailed in Appendix C.

In all cases, sampling was done before the wood dust entered a fan or collection device.

Sampling Procedures

Samples were taken with a Rader sampler. This device consists of a probe with a bore of from, say 1 inch to 1.7 inch, depending on what is available. The probe is attached to a filter holder which is sized for an 8 inch by 10 inch high volume ambient particulate sampler filter. The filter is made of glass fibers. A hose connects from the filter holder to an orifice meter. The pressure drop across the orifice is measured as is the gauge pressure of the orifice (in this case with magnehelic gauges and a water filled U-tube manometer, respectively). A thermometer is inserted into the orifice meter. From the discharge side of the orifice meter, a flexible hose connects to the intake port of a centrifugal fan powered by a universal motor. The motor receives power through a variable transformer so that the fan draft can be adjusted. Thus, it is possible to adjust for isokinetic sampling conditions within the limits of the particular sampling equipment. See Appendix D, Figure 1, for a diagram of the equipment.

The three sampling ports were located at points such that dust from a variety of typical industrial wood working machines could be collected. A velocity traverse was made across the duct in each case. The sampling nozzle was then located at the point of mean velocity. It was hoped that, by this method, dust with a representative size distribution would be collected.

Before use, the equipment (which was borrowed) was calibrated using a Roots Meter (see Appendix D). It was determined that, to obtain isokinetic conditions, it was necessary to simultaneously maintain a particular ratio of orifice pressure to stack pressure (P_m/P_s) and a corresponding orifice pressure drop (ΔH) for the velocity at the chosen test point (corresponding to the pitot tube pressure differential Δp).

Families of curves were plotted for each nozzle with each of the two orifice meters provided. These curves were straight line plots of P_m/P_s having constant values of 1, .95, .90, .85, and .80. The abscissa was Δp, the pressure drop across the pitot tube (actually a type S pitot tube with a correction factor of .85). The ordinate was ΔH, the pressure drop across the orifice.

Isokinetic conditions could be reached by a process of iteration. When starting, a P_m/P_s of say .95 would be assumed. The corresponding ΔH was determined from the chart. The fan was set to produce the desired ΔH. Then, ΔH and P_m gauge were used (with barometric pressure, P_b) to calculate actual P_m/P_s. A programmable electronic calculator was used to speed this process. If P_m/P_s was not the initially assumed value, the ΔH for the calculated P_m/P_s was set by adjusting the fan. The resulting P_m/P_s was calculated, the corresponding ΔH was read off the chart and compared to the actual and so forth. When, for the actual P_m/P_s, the corresponding actual ΔH and chart value ΔH were the same, sampling was isokinetic.

In actual practice at Bernhardt's Hibriten Plant 3, the velocities on the sander line and machine line ducts were too high to ever reach isokinetic conditions. On the rough-end duct, isokinetic conditions could be reached and maintained for a half minute or so until loading of the filter reduced the air flow through the sampling equipment.

Therefore, samples were collected below isokinetic rate. There will be a greater proportion of large particles to the total weight collected than would have been the case with exactly isokinetic sampling.

The length of each sampling run was a hit-or-miss situation. It was desired to obtain a sufficiently large sample for accurate size analysis (by screening, Bacho analyzer, etc.). It was not possible to know for sure if enough material was collected until it was actually analyzed. And, while sampling, it was not possible to know just what volume of dust was collected until the Rader sampler nozzle was removed from the duct and the filter holder opened. If it had been easy to reach and maintain isokinetic sampling conditions, then sampling would have been done until such condition could no longer be maintained or until it was obvious from lack of loading of the filter that too little dust was being collected to justify the time involved. As it was, sampling time was determined intuitively with consideration given to drop in achievable ΔH and rise in orifice vacuum.

It should be noted that during these tests at Lenoir, the orifice meter was set up with measurement of the pressure on the down wind or low pressure side of the orifice plate. Conventionally, orifice pressure is measured on the up wind or high pressure side of the plate. Conventionally, calculations involving orifice pressure, P_m, assume that the pressure is determined on the high pressure side of the plate. By adding the drop across the orifice, ΔH, to the pressure on the low pressure side of the plate, which is called P_o in this report, it was possible to find the orifice pressure, P_m.

For later testing, the pressure tap was switched to the conventional location. Smaller nozzles were constructed, too.

Following each sampling run, the collected wood dust was placed in plastic bags along with its filter and sealed. The dust was gotten into the bags by a combination of scooping, picking up with the fingers, and dry brushing. No liquids were used for wash up since the wood dust would have probably clumped as a result.

It was thought that a certain amount of very fine dust would remain behind in the collecting equipment, clinging to any small rough areas in the nozzle or filter holder. Also, the cleanup brushes were expected to acquire a certain amount of fine dust that would remain with them, after which any additional dust could be easily removed. Since the brushes and collection equipment were not pretreated with dust, it is likely that the first samples collected (sander dust) were biased by removal of the finest particles.

The samples, in their plastic bags, were turned over to one of the labs of the U. S. Environmental Protection Agency for analysis. The following paragraph is an edited version of the procedure written by Ray Grote, who did the analysis:

> "The plastic bags were weighed on a triple beam balance as received. The filter paper was brushed to remove as much dust as practical. The filter paper was returned to the bag and reweighed and the difference in weight was taken as the charged weight to a set of sieves. Those samples having in excess of 10 grams were sieved in 8 inch sieves, those having only a small amount were sieved in the Allen Bradley Sonic Sifter. The larger sieves were shaken by hand as the power shaker was unavailable."

Summary of Results

The following emission rates were determined:

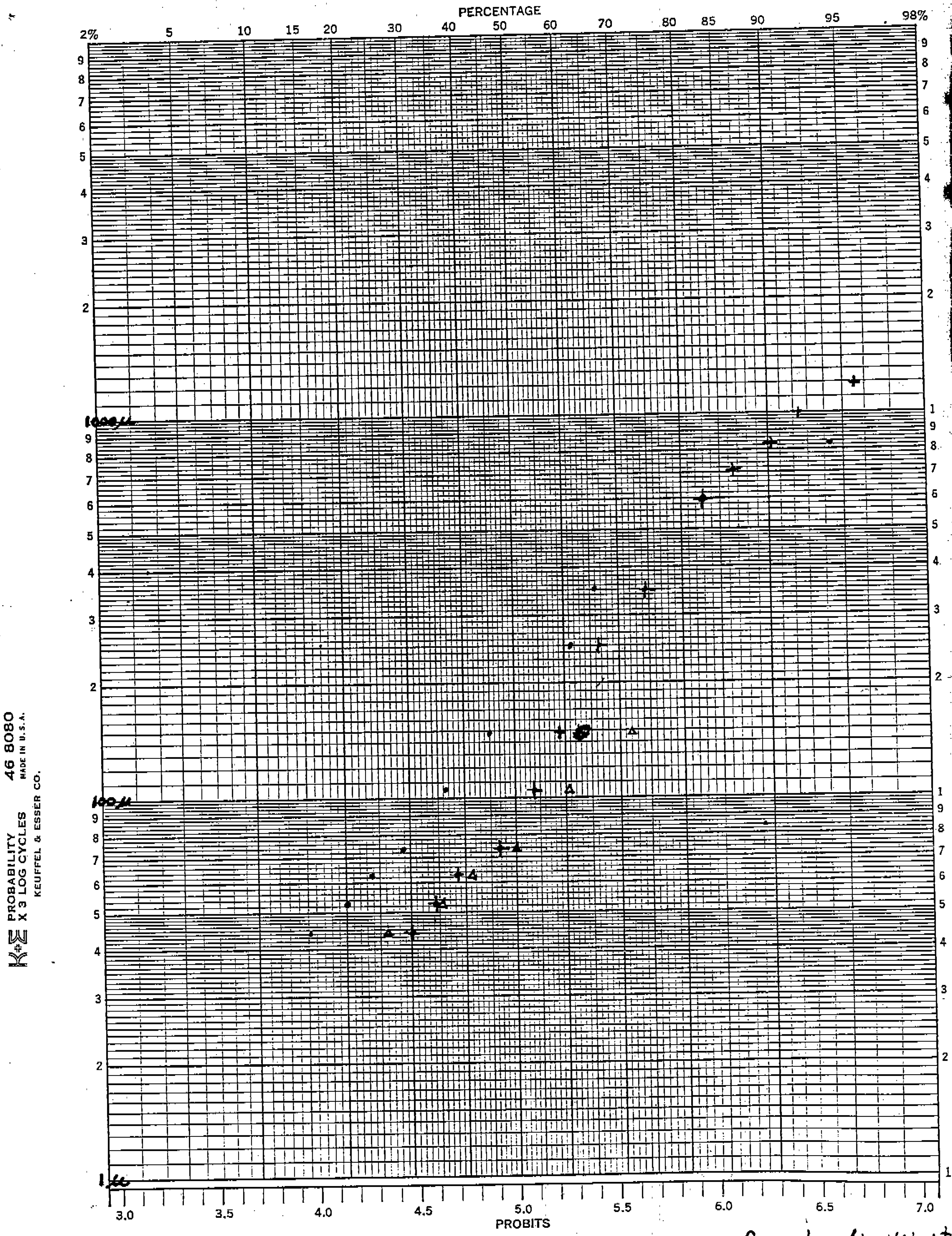
	pmr_c (lb/hr)	pmr_a (lb/hr)	pmr_{avg} (lb/hr)	%I
Sander Line				
Run 1	31.88	31.13	31.51	97.7
Run 2	23.14	20.75	21.95	89.7
Run 3	8.74	8.21	8.48	93.9
Machine Line				
Run 1	51.73	49.84	50.61	96.3
Run 2	65.30	64.14	64.72	98.2
Run 3	22.79	22.29	22.54	97.8
Rough End				
Run 1	661.5	598.7	630.1	90.5
Run 2	860.5	740.9	800.7	86.1
Run 3	534.7	509.7	522.3	95.3

These emission rates should not be considered nearly so accurate as with a properly done EPA Method 5 test.

The following log probability plots show the individual data points for each run and the sum of the data from all runs on each collection system. Notice the list of machines operating during the various runs (Appendix C).

Robert E. Wooten

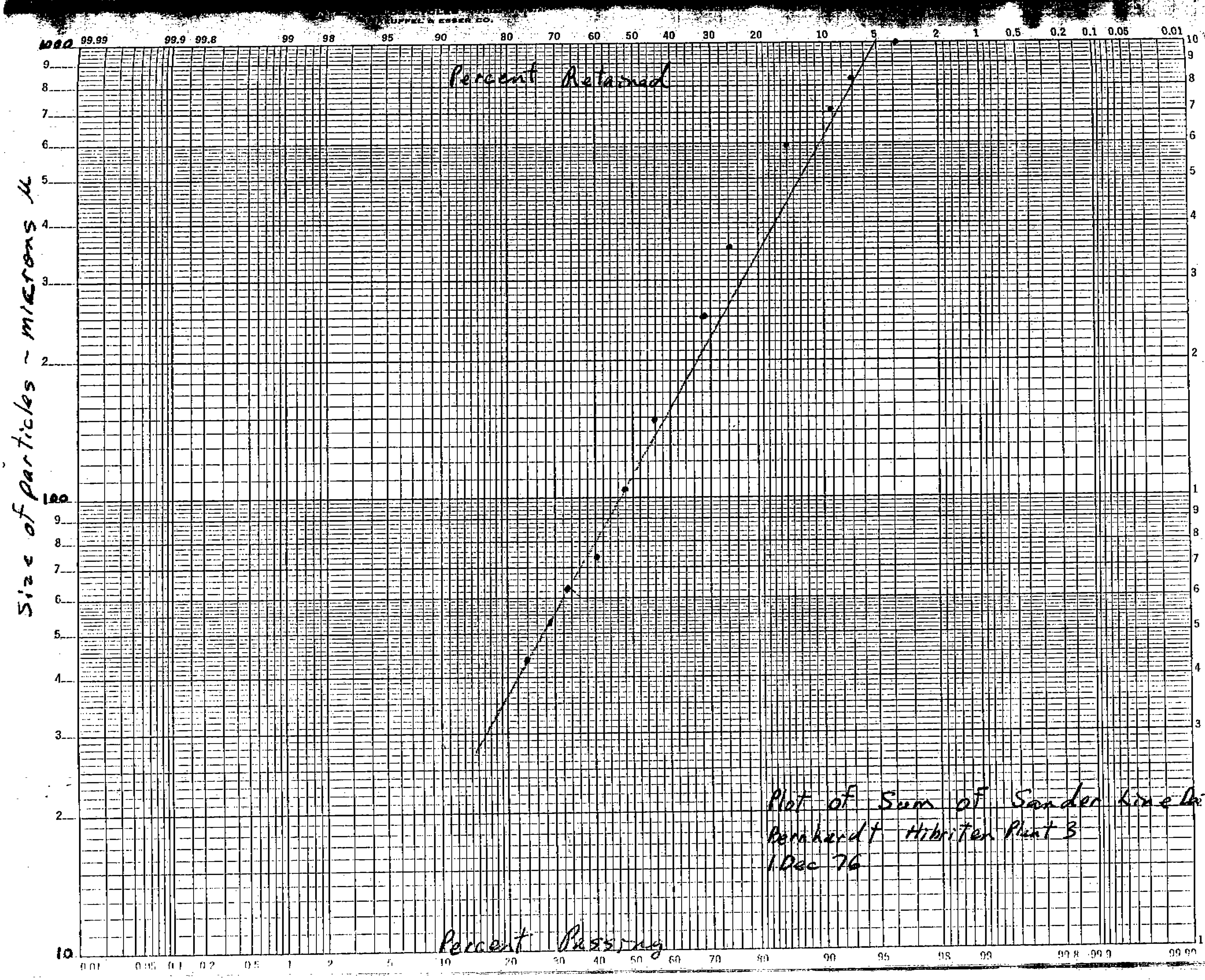
Robert E. Wooten, Engineer
Air Quality Section
January 24, 1977

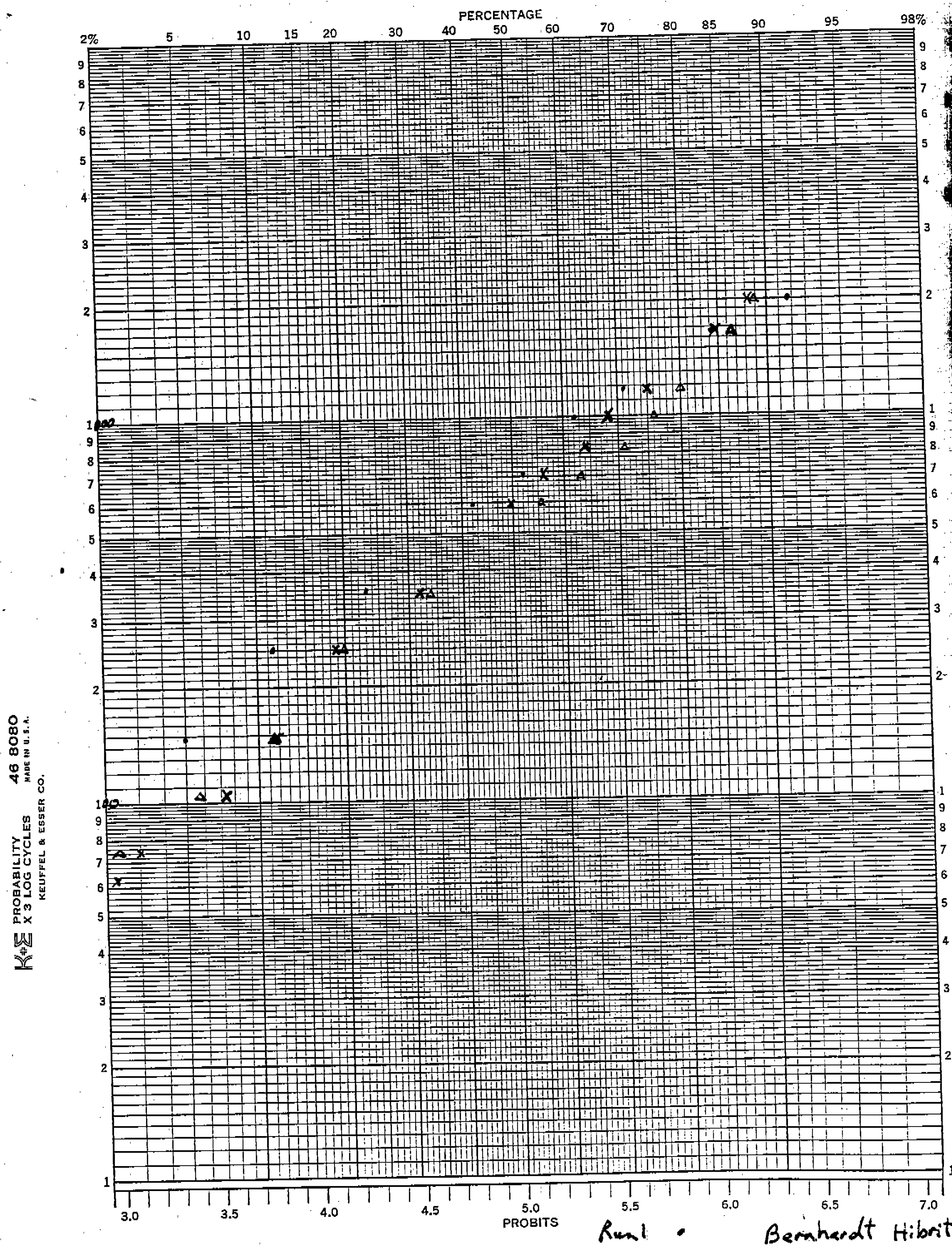


Sander line Runs 1, 2 and 3

Run 1 •
Run 2 +
Run 3 ▲

Bernhardt Hibriten
1 Dec 76

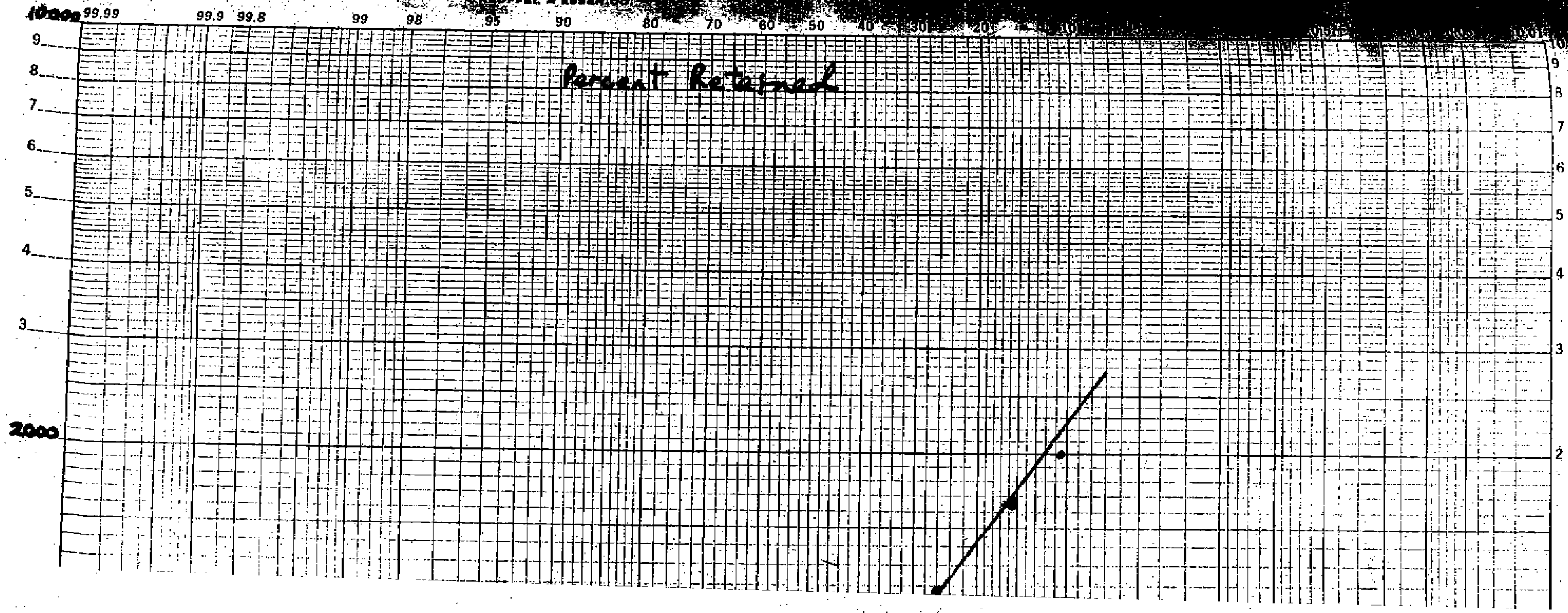

Percent Retained
Percent Passing
Size of particles - microns μ
Plot of Sum of Sander Line Data
Bernhardt Hibriten Plant 3
1 Dec 76
KEUFFEL & ESSER CO.



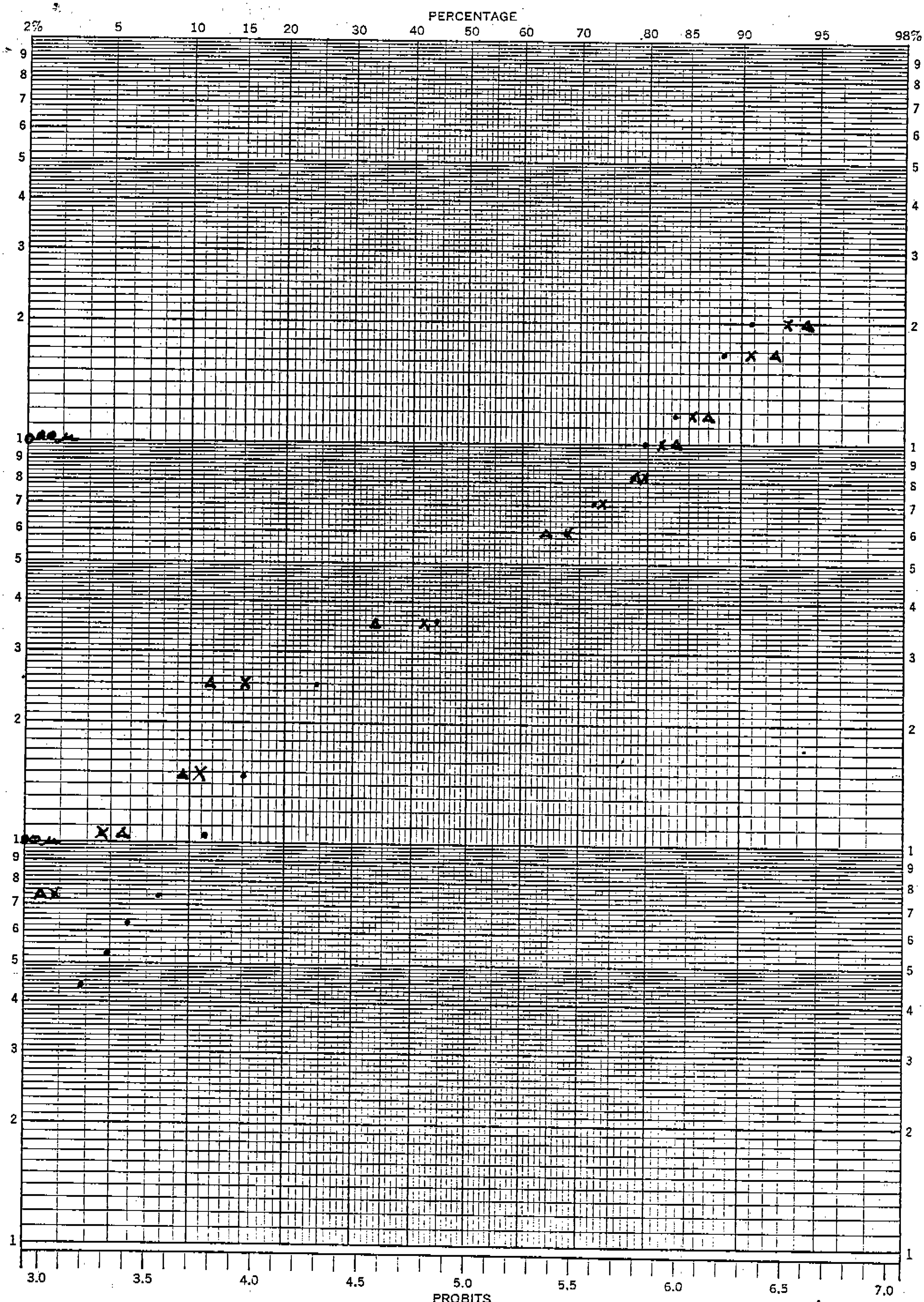
Machine Line Runs 1, 2, and 3

Run1 •
Run2 X
Run3 Δ

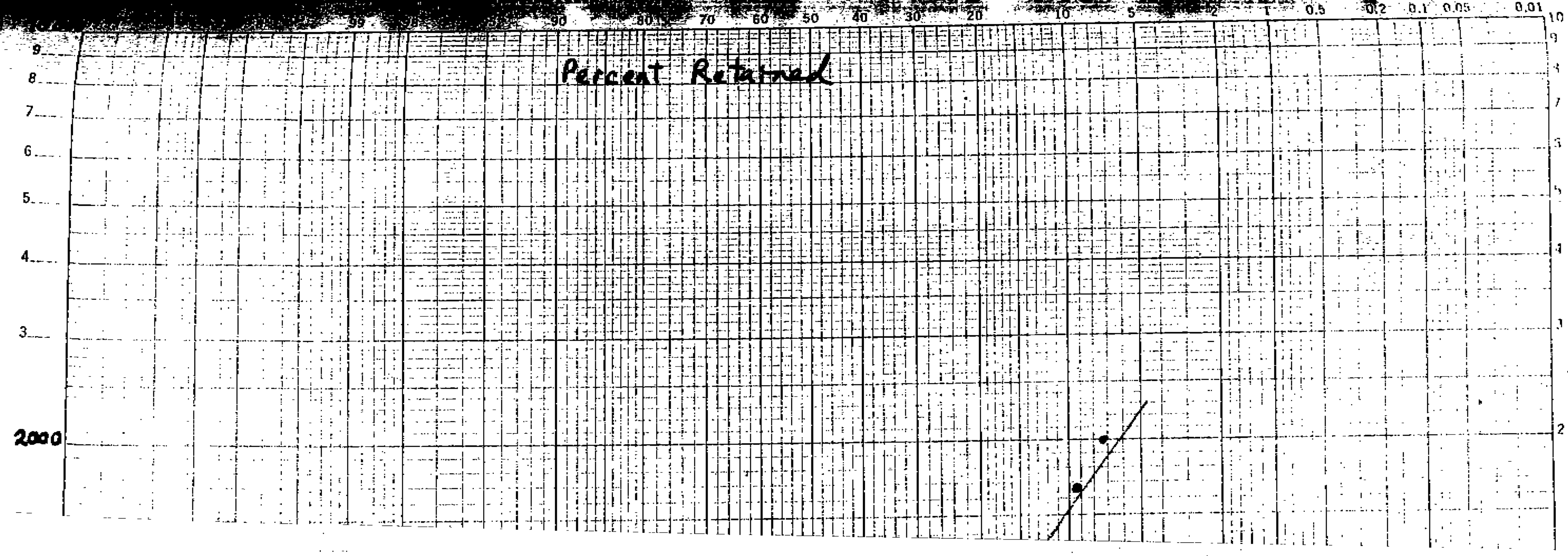
Bernhardt Hibriten
2 Dec 76



Percent Retained
10000
2000



Rough End   Runs 1, 2, and 3   Run 1 •   Run 2 X   Run 3 Δ   Bernhardt Hibriten Plant 3   2 Dec 76.


Percent Retained
2000
99
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.2
0.1
0.05
0.01

NOMENCLATURE

A_n	(in.^{2}), Cross sectional area of nozzle
A_s	(in.^{2}), Cross sectional area of stack
A'_s	(ft^2), Cross sectional area of stack
$\overline{B}$	(ft^2), Mean value of calibration coefficients for a particular orifice, (Orifice 1 = .006796, Orifice 2 = .003616)
C_p	Pitot tube calibration coefficient
ΔH	(in. H_2O), Average orifice meter reading (also used for individual orifice meter readings when taking data)
%I	Percent Isokineticity
M	(lb/lb mole), Molecular weight of gas
$n_{\Delta p}$	Number of Δp readings
P_b	(in. Hg), Local atmospheric pressure
P_m	(in. H_2O), Orifice meter pressure, an absolute pressure
P_o	(in. H_2O), mean pressure on low pressure side of orifice plate, a gauge pressure.
P_{sg}	(in. H_2O), Gauge static pressure in stack
P_s	(in. Hg), Absolute static pressure in stack
P_{std}	(29.92 in. Hg), Standard pressure
pmr_a	(lb/hr), Pollutant mass rate based on ratio of areas
pmr_{avg}	(lb/hr), Average pollutant mass rate
pmr_c	(lb/hr), Pollutant mass rate based on concentrations
Δp	(in. H_2O), Velocity pressure measured with pitot tube
Q_o	(ft^3/min), Orifice meter flow, actual
$Q_{o\ std}$	(ft^3/min), Orifice meter flow at standard conditions
Q_s	(ft^3/min), Actual stack volume flow rate
Q_{std}	(ft^3/min), Stack volume flow at standard conditions

(10) Pollutant mass rate based on particulate concentration — pmr_c (lb/hr)

$$pmr_c = K_3 \frac{Wt \quad Q_{std}}{V_{std}} \qquad K_3 = 0.1323 \text{ (units conversion)}$$

(11) Pollutant mass rate based on the ratio of the cross sectional area of the stack and the sampling nozzle — pmr_a (lb/hr)

$$pmr_a = K_3 \frac{Wt \quad A_s}{\theta \quad A_n} \qquad K_3 = 0.1323 \text{ (units conversion)}$$

(12) Percent Isokineticity — %I

$$\%I = \frac{pmr_a}{pmr_c} \times 100$$

(13) Average pollutant mass rate — pmr_{avg} (lb/hr)

$$pmr_{avg} = \frac{pmr_a + pmr_c}{2}$$

Calculation Summary

Sander Line

	Run 1	Run 2	Run 3
ΔH, in. H_2O	16	30	26
P_o, in. H_2O	-34.53	-34.79	-35.62
T_m, ^oR	535	534	535
θ, min	16	30	26
P_b, in. Hg	29.22	29.22	29.22
P_m, in. H_2O	367	366	365
Q_o, ft^3/min	54.81	50.27	52.68
$Q_{o\ std}$, ft^3/min	53.02	48.72	50.96
V_{std}, ft^3	848	1462	1325
$\Sigma\sqrt{\Delta p}/n\Delta p$	1.47	1.47	1.47
P_{sg}, in. H_2O	-8.8	-8.8	-8.8
P_s, in. Hg	28.57	28.57	28.57
C_p	.85	.85	.85
M	28.84	28.84	28.84
v_s, ft/sec	86.07	85.99	86.07
D_s, in.	37	37	37
A'_s, ft^2	7.47	7.47	7.47
Q_s, ft^3/min	38,575	38,539	38,575
Q_{std}, ft^3/min	36,490	36,524	36,490
Wt, grams	5.6	7.0	2.4
pmr_c, lb/hr	31.88	23.14	8.74
A_s, $in.^2$	1075	1075	1075
D_n, in.	1.427	1.427	1.427
A_n, $in.^2$	1.599	1.599	1.599
pmr_a, lb/hr	31.13	20.75	8.21
%I	97.7	89.7	93.9
pmr_{avg}, lb/hr	31.51	21.95	8.48

Calculation Summary

Machine Line

	Run 1	Run 2	Run 3
ΔH, in. H_2O	3.58	3.73	3.69
P_o, in. H_2O	-35.10	-34.76	-35.03
T_m, ^oR	531	534	534
θ, min	24	26	30
P_b, in. Hg	28.86	28.86	28.86
P_m, in. H_2O	361	362	361
Q_o, ft^3/min	54.16	55.36	55.14
$Q_{o\ std}$, ft^3/min	52.13	52.99	52.78
V_{std}, ft^3	1251	1378	1583
$\Sigma\sqrt{\Delta p}/n\Delta p$	1.47	1.47	1.47
P_{sg}, in. H_2O	-8.8	-8.8	-8.8
P_s, in. Hg	28.21	28.21	28.21
C_p	.85	.85	.85
M	28.84	28.84	28.84
v_s, ft/sec	86.29	86.53	86.53
D_s, in.	36	36	36
A'_s, ft^2	5.59	5.59	5.59
Q_s, ft^3/min	36,604	36,707	36,707
Q_{std}, ft^3/min	34,447	34,350	34,350
Wt, grams	14.2	19.8	7.94
pmr_c, lb/hr	51.73	65.30	22.79
A_s, $in.^2$	1018	1018	1018
D_n, in.	1.427	1.427	1.427
A_n, $in.^2$	1.599	1.599	1.599
pmr_a, lb/hr	49.84	64.14	22.29
%I	96.3	98.2	97.8
pmr_{avg}, lb/hr	50.61	64.72	22.54

Calculation Summary

Rough End

	Run 1	Run 2	Run 3
ΔH, in. H_2O	2.60	2.35	2.90
P_o, in. H_2O	-38.88	-38.48	-38.10
T_m, ^oR	534	536	531
θ, min	8	8	8
P_b, in. Hg	28.86	28.86	28.86
P_m, in. H_2O	356	356	357
Q_o, ft^3/min	46.61	44.39	49.01
$Q_{o\ std}$, ft^3/min	44.61	42.33	47.17
V_{std}, ft^3	357	339	377
$\Sigma\sqrt{\Delta p}/n\Delta p$	1.34	1.34	1.34
P_{sg}, in. H_2O	-7.8	-7.8	-7.8
P_s, in. Hg	28.29	28.29	28.29
C_p	.85	.85	.85
M	28.84	28.84	28.84
v_s, ft/sec	78.77	78.92	78.55
D_s, in.	32	32	32
A_s', ft^2	5.59	5.59	5.59
Q_s, ft^3/min	26,419	26,469	26,344
Q_{std}, ft^3/min	24,793	24,747	24,863
Wt, grams	72.5	89.1	61.3
pmr_c, lb/hr	661.5	860.5	534.9
A_s, $in.^2$	804	804	804
D_n, in.	1.427	1.427	1.427
A_n, $in.^2$	1.599	1.599	1.599
pmr_a, lb/hr	598.7	740.9	509.7
%I	90.5	86.1	95.3
pmr_{avg}, lb/hr	630.1	800.7	522.3

Sample	ID	Charge in grams	Recovered grams	Recovered %	D50 microns	Explanat[ion]
0089	S 1	5,6	5,09	90.8	180	SANDER RUN 1
0090	RE 1	72,5	65,19	89,9	450	ROUGH E[…] RUN 1
0091	ML 1	14,2	12,15	85,6	700	MACHINE L[…] RUN 1
0092	S 2	7.0	6,7	95.7	100	SANDE[R] RUN 2
0093	ML 2	19,8	18,37	92.8	580	MACHINE L[…] RUN 2
0094	RE 2	89,1	87.94	98.7	450	ROUGH E[…] RUN 2
0095	S 3	2,4	1,65	68.8	80	SANDE[R] RUN 3
0096	RE 3	61.3	59.53	97.1	420	ROUGH E[…] RUN 3
0097	ML 3	7,94	5,37	67.7	560	MACHINE L[…] RUN 3

Note how the D50 increases in size from run 3 to 2 to 1.

LABORATORY REPORT OF SIEVE ANALYSIS

Material WOOD Dust

Description Run I SANDER 1 Dec 76

Test No. 1

Sample 0089

Time

Minutes

Test Particle

Remarks D 50 = 180μ

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Special Sieves			Weights on or Between Sieves		Total Percentage	
Opening	Tyler Mesh	U.S. No.	~~Opening~~ μ	Tyler Mesh	U.S. No.	Grams	Per Cent	Greater	Fall
	9	10	2000			0	0		
	10	12	1680						
	14	16	1190						
	16	18	1000						
	20	20	833			.295	5.79	5.79	94.21
	24	25	710			—	—	—	—
	28	30	595			.57	11.19	16.98	83.02
	42	45	354			.86	17.08	34.06	65.94
	60	60	250			.24	4.71	38.77	61.23
	100	100	149			.81	15.9	54.67	45.33
	150	140	105			.46	9.03	63.70	36.30
	200	200	74			.38	7.46	71.16	28.84
	250	250	63			.25	4.91	76.07	23.93
	270	270	53			.19	3.73	79.82	20.20
	325	325	44			.26	5.1	84.90	15.10
Pan	-325					.78	15.31	100.21	0
Total						5.095	100.21	100.21	100

PLEASE MENTION ABOVE WHEN ORDERING

LABORATORY REPORT OF SIEVE ANALYSIS

Test No. 2

NAME

Material WOOD DUST

Description Rough END Run # 1 2 Dec 76

Sample 0090

Largest Particle

Time

Minutes

Remarks D 50 = 450

Tyler Standard Screen Scale, Sieves 2 or 1.414			Special Sieves			Weights on or Between Sieves		Total Percentage	
Opening In.	Tyler Mesh	U.S. No.	~~Opening In.~~ μ	Tyler Mesh	U.S. No.	Grams	Per Cent	~~On~~ Greater	Passing
1.050									
.742									
.525									
.371	9	10	2000			6.2	9.17	9.17	90.83
.263	10	12	1680			1.6	2.37	11.54	88.46
.185	14	16	1190			3.5	5.18	16.72	83.28
.131	16	18	1000			2.5	3.70	20.42	79.58
.093	20	20	850			1.2	1.78	22.2	77.8
.065	24	25	710			3.8	5.63	27.83	72.17
.046	28	30	590			3.0	4.44	32.27	67.73
.0328	42	45	350			15.7	23.24	55.61	44.39
.0232	60	60	250			13.5	19.99	75.6	24.4
.0164	100	100	149			6.3	9.33	84.93	15.07
.0116	150	140	[illegible]			2.53	3.75	88.68	11.32
	200	200	[illegible]			2.40	3.55	92.23	7.77
	250	250	[illegible]			1.24	1.84	94.07	5.93
	270	270				0.66	0.98	95.05	4.95
	[illegible]	325	[illegible]			0.81	1.20	96.25	3.75
		-325				~~2.51~~	3.72	99.97	.03
Totals						65.19 67.45	99.97	99.97	100

By

THE W. S. TYLER COMPANY, CLEVELAND, OHIO

LABORATORY REPORT OF SIEVE ANALYSIS

Test No. 3

Material: WOOD DUST

Description: MAchine Line Run 1, 2 Dec 76

Sample: 0091

Time ... Minutes

Largest Particle

Remarks: D50 = 700 μ

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414 Tyler Mesh	U.S. No.	Special Sieves (μ)	Tyler Mesh	U.S. No.	Weights on or Between Sieves Grams	Per Cent	Total Percentage Greater	Passing
9	10	2000			1	8.23	8.23	91.77
10	12	1680			0.9	7.41	15.64	84.36
14	16+	1190			1.6	13.17	29.81	71.19
16	18+	1000			1.1	9.05	37.86	62.14
20	20+	[illegible]			0.28	2.30	40.16	59.84
24	25+	[illegible]			0.94	7.74	47.90	52.1
28	30+	[illegible]			1.25	10.29	58.19	41.81
[illegible]	45+	[illegible]			2.23	18.35	76.64	23.36
[illegible]	60+	[illegible]			1.46	12.02	88.56	11.44
[illegible]	100+	[illegible]			0.78	6.42	94.98	5.02
[illegible]	140+	[illegible]			0.39	3.21	98.19	1.21
[illegible]	200+	[illegible]			0.17	1.40	99.59	0.41
[illegible]	250−	[illegible]			0.03	0.247	99.84	0.16
[illegible]	270−				0.01	0.08	99.92	0.08
[illegible]	325	[illegible]			0.01	0.08	100.0	0
Total					12.15	99.997	99.997	100

By

LABORATORY REPORT OF SIEVE ANALYSIS

NAME

Material WOODDUST

Description SANDER RUN 2 1 DEC 76

Test No. 4

Sample 0092

Largest Particle

Time

Minutes

Remarks D50 = 100 μ

Tyler Standard Screen Scale Sieves 2 or 1.414			Special Sieves			Weights on or Between Sieves		Total Percentage	
Opening Ins.	Tyler Mesh	U. S. No.	~~Opening Ins.~~ μ	Tyler Mesh	U. S. No.	Grams	Per Cent	~~Or~~ Greater	Passing
1.050									
.742									
.525									
.371	9	10	2000			0	0		
.263	10	12	1680			0	0		
.185	14	16	1190			0.294	4.39	4.39	95.61
.131	16	18	1000			0.224	3.34	7.63	92.37
.093	20	20	833			0.134	2.00	9.63	90.37
.065	24	25	710			0.251	3.75	13.38	86.62
.046	28	30	590			0.248	3.70	17.08	82.92
.0328	42	45	355			0.564	8.42	25.5	74.5
	60	60	250			0.526	7.85	33.35	66.65
						0.247	3.74	37.09	62.91
.0164	100	100	149			0.236	3.60	40.78	59.22
	150	140	105			0.353	5.27	46.05	53.95
	200	200	74			0.480	7.16	53.21	46.79
	250	250	[illegible]			0.574	8.57	61.79	38.22
	270	270	[illegible]			0.273	4.07	65.87	34.13
	[illegible]	325	[illegible]			0.251	3.75	69.62	30.38
	Pan	Pan				2.049	30.63	100.25	0
	Totals					6.70	100.05	100.25	100

By

MENTION ABOVE WHEN ORDERING

LABORATORY REPORT OF SIEVE ANALYSIS

Test No. 5

Name of Material WOOD DUST Description Machine Line Run 2 2 Dec 16 Sample 0093

Largest Particle ...... Time ...... Minutes

Remarks D50 = 580 µ

Opening Ins.	Tyler Mesh	U. S. No.	Special Sieves ~~Opening Ins.~~ µ	Tyler Mesh	U. S. No.	Weights on or Between Sieves Grams	Per Cent	Total Percentage ~~On~~ Greater	Passing
.050									
.742									
.525									88.24
.371	9	10	2000			2.16	11.76	11.76	~~76.48~~
.263	10	12	1680			0.685	3.73	15.49	84.51
.185	14	16	1190			1.79	9.75	2524	74.76
.131	16	18	1000			1.18	6.42	31.66	68.34
	20	20	850			0.81	4.41	36.07	63.93
.065	24	25	710			1.52	8.28	44.35	55.65
	28	30	590			1.13	6.15	50.5	49.5
	42	45	354			326	17.75	68.25	31.75
	60	60	210			2.42	13.18	81.43	18.57
	100	100	149			1.24	6.75	88.18	11.82
	150	140	105			0.85	4.63	92.81	7.19
	200	200	74			0.76	4.14	96.95	3.05
	250	250	[illegible]			0.16	0.87	97.82	2.18
	270	270	53			0.04	0.22	98.04	1.96
	[illegible]	325	[illegible]			0.155	0.84	98.88	1.12
Pan		-325				0.208	1.13	100.01	0
Totals						18.368	100.01	100.01	100

By

W. S. TYLER COMPANY, CLEVELAND, OHIO, U.S.A.

PLEASE MENTION ABOVE WHEN ORDERING

LABORATORY REPORT OF SIEVE ANALYSIS

Test No. 6

NAME

Material WOOD DUST

Description ROUGH END RUN 2 2 DEC 76

Sample 0099

Time

Minutes

Largest Particle

Remarks D50 = 450µ

Tyler Standard Screen Scale Sieves √2 or 1.414			Special Sieves			Weights on or Between Sieves		Total Percentage	
Opening Ins.	Tyler Mesh	U.S. No.	~~Opening Ins.~~ µ	Tyler Mesh	U.S. No.	Grams	Per Cent	~~Or~~ Greater	Passing
1.050									
.742									
.525									
.371	9	10	2000			6.00	6.82	6.82	93.18
.263	10	12	1680			2.02	2.30	9.12	90.88
[illegible]	14	16	1190			4.89	5.56	14.68	85.32
[illegible]	[illegible]	18	1000			3.13	3.56	18.24	81.76
[illegible]	[illegible]	20	833			2.04	2.31	20.55	79.45
[illegible]	[illegible]	25	710			5.16	5.88	26.42	73.58
[illegible]	[illegible]	30	590			5.09	5.79	32.21	67.79
[illegible]	[illegible]	45	354			22.74	25.86	58.07	41.93
[illegible]	[illegible]	60	[illegible]			23.52	26.74	84.81	15.19
[illegible]	100	100	149			3.75	4.26	89.07	10.93
[illegible]	150	140	105			5.53	6.29	95.36	4.64
	[illegible]	200	74			1.60	1.82	97.18	2.82
	[illegible]	250	63			0.90	1.02	98.2	1.8
	[illegible]	270	53			0.29	0.33	98.52	1.48
	[illegible]	325	44			0.31	0.35	98.87	1.13
	Pan	-325				0.97	1.10	99.7	0.3
Totals						87.94	99.98	99.97	100

By

THE W. S. TYLER COMPANY, CLEVELAND, OHIO, U.S.A.

LABORATORY REPORT OF SIEVE ANALYSIS

Test No. 7

Material: WOOD DUST

Description: SANDER RUN 3 1 DEC 76

Sample: 0095

Time ______ Minutes

Particle: D50 = 80 µ

Tyler Standard Screen Scale Sieves √2 or 1.414		Special Sieves			Weights on or Between Sieves		Total Percentage	
Tyler Mesh	U.S. No.	~~Opening In.~~ µ	Tyler Mesh	U.S. No.	Grams	Per Cent	On	Passing
9	10	2000						
10	12	1680						
14	16	1190						
16	18	1000						
20	20	833						
24	25	710						
28	30	590						
42	45	354						
60	60	250						
100	100	149			0.460	27.8	27.8	72.2
150	140	105			0.195	11.78	39.58	60.42
200	200	74			0.176	10.63	50.21	49.79
250	250	63			0.144	8.70	58.91	41.09
270	270	53			0.094	5.68	64.59 ~~[illegible]~~	35.41 ~~[illegible]~~
325	325	44			0.155	9.36	73.95	26.05
Pan	-325				0.431	26.04	99.99	0.01
Total					1.655	99.99	99.99	100.0

By ______

TYLER COMPANY, CLEVELAND

LABORATORY REPORT OF SIEVE ANALYSIS

NAME .... Test No. 8

Material WOOD DUST Description ROUGH END RUN 3 2 DEC 76 Sample 009

Largest Particle .... Time .... Minutes

Remarks D50 = 420µ

Tyler Standard Screen Scale Sieves √2 or 1.414			Special Sieves			Weights on or Between Sieves		Total Percentage	
Opening Ins.	Tyler Mesh	U.S. No.	~~Opening In.~~	Tyler Mesh	U.S. No.	Grams	Per Cent	~~On~~	Passing
			µ					Greater	
1.050									
.742									
.525									
.371	9	10	2000			3.34	5.60	5.6	94.4
.263	12	12	1680			1.07	1.80	7.4	92.6
.185	14	16	1190			3.36	5.64	13.04	86.96
[illegible]	16	18	1000			2.06	3.46	16.5	83.5
.093	20	20	833			3.09	5.20	21.7	78.3
[illegible]	24	25	710						
[illegible]	28	30	590			8.36	14.04	35.74	64.26
[illegible]	[illegible]	45	350			18.39	30.90	66.64	33.36
[illegible]	[illegible]	60	250			12.87	21.62	88.26	11.74
[illegible]	100	100	149			1.40	2.36	90.62	9.38
[illegible]	[illegible]	140	105			2.20	3.70	94.32	5.68
	[illegible]	200	74			1.90	3.20	97.52	2.48
	[illegible]	250	63			0.518	0.87	98.39	1.61
	[illegible]	270	53			0.159	0.27	98.66	1.34
	[illegible]	325	44			3.32	0.56	99.22	0.78
Pan		−325				0.482	0.81	100.0	0
Totals						59.53	100.0	100	100

62.52

By

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Material: WOOD DUST

Description: MACHINE LINE RUNS 2 DEC 76

Test No. 9

Sample 0097

Time .... Minutes ....

Largest Particle ....

Remarks: D50 = 560

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414 Tyler Mesh	U.S. No.	Special Sieves µ	Tyler Mesh	U.S. No.	Weights on or Between Sieves Grams	Per Cent	Total Percentage Greater	Passing
9	10	2000			0.599	11.14	11.14	88.86
10	12	1680			0.119	2.21	13.35	86.65
14	16	1190			0.356	6.62	19.97	80.03
16	18	1000			0.221	4.11	24.08	75.92
20	20	833			0.264	4.91	28.99	71.01
24	25	710			0.413	7.67	36.68	63.32
28	30	590			0.428	7.96	44.64	55.36
42	45	354			1.16	21.6	66.24	33.77
60	60	250			0.752	13.99	80.23	19.77
100	100	149			0.441	8.21	88.44	11.56
150	140	105			0.310	5.77	94.21	5.79
200	200	74			0.183	3.41	97.62	2.38
250	250	63						
270	270	53						
	325	— —			0.128	2.38	100	0
Pan	-325							
Total					5.374	100	100	100

By ....

W. S. TYLER COMPANY CLEVELAND 14 OHIO U.S.A.

FIELD DATA

Sander Line data for velocity traverse and static pressure are missing. However, it was remembered that the values recorded were very close to the data for the Machine Line. Therefore, it was decided that the machine line data would be used for the sander line.

Machine Line

Duct diameter = 36 in.

Static pressure = -8.8 in.

Insertion of Pitot tube into stack (in.)	Pressure drop Δp (in. H_2O)	
34	.65	mean Δp if .65 is thrown out as extranious is 2.18 in. H_2O
30	2.0	
26	2.0	
22	2.2	
18	2.2	Probe was placed 18 in. into the duct
14	2.2	
10	2.4	
6	2.2	
2	2.2	

Rough End

Duct diameter = 32 in.

Static pressure = -7.8 in. H_2O

Insertion of Pitot tube into stack (in.)	Pressure drop Δp (in. H_2O)
30	2.0
26	2.2
22	2.2
18	1.90
14	1.45
10	1.20
6	1.20
2	2.4

mean Δp = 1.82 in. H_2O

probe was placed 17 1/4 in. into duct

Bernhardt Furniture, Hibriten Furniture, Plant #3

Sander Line
Orifice #1
Probe - stainless steel 1.427 in. diameter
Barometric Pressure 29.22
Chosen Sampling Point 18 in. from near wall

37 in. diameter duct
Date December 1, 1976

Run 1 $\Delta p = 2.2$	Filter No. 54847			Run 2 $\Delta p = 2.2$	Filter No. 54844			Run 3 $\Delta p = 2.2$	Filter No. 54845		
ΔH in. H_2O	P_o in. H_2O	θ	T_m ^oF	ΔH in. H_2O	P_o in. H_2O	θ	T_m ^oF	ΔH in. H_2O	P_o in. H_2O	θ	T_m ^oF
4	34.8	2	72	3.8	35	2	72	3.8	34.3	2	72
3.8	34.7	4	72	3.4	35	4	72	3.5	34.6	6	72
3.8	34.5	6	74	3.3	35	6	72	3.5	35.2	8	74
3.6	34.4	10	76	3.2	34.7	8	72	3.4	35.3	10	74
3.6	34.2	12	76	3.2	34.6	10	74	3.4	35.5	12	74
3.6	34.5	14	76	3.3	35	12	74	3.4	36	14	74
3.6	34.7	16	74	3.2	34.9	14	74	3.4	36.4	16	76
				3.2	34.9	16	74	3.4	36.5	18	76
				3.1	35.1	18	74	3.3	36.1	20	76
				3.1	35	20	74	3.2	35.9	22	76
				3.1	35.2	22	74	3.2	36.4	24	76
				3.0	35.4	24	74	3.2	36.2	26	76
				2.8	34.9	26	74				
				2.6	33.9	28	74				
				2.4	33.2	30	74				

Bernhardt Furniture, Hibriten Furniture, Plant #3

Machine Line
Orifice #1
Probe - stainless steel 1.427 in. diameter
Barometric Pressure 28.86 in. Hg
Chosen Sampling Point 18 in. from near wall
Δp = 2.18

36 in. diameter duct
Date December 2, 1976

Run 1				Run 2				Run 3			
Filter No. 54846				Filter No. 54848				Filter No. 54849			
ΔH in. H_2O	P_o in. H_2O	θ	T_m °F	ΔH in. H_2O	P_o in. H_2O	θ	T_m °F	ΔH in. H_2O	P_o in. H_2O	θ	T_m °F
3.8	34.7	2	72	4.1	35	2	74	3.9	35.1	2	74
3.8	35.2	4	72	4	34.8	4	74	3.8	34.9	4	74
3.7	35.3	6	72	4	34.8	6	74	3.8	34.8	6	74
3.7	35.7	8	72	3.9	34.6	8	74	3.8	35	8	74
3.7	36	10	72	3.8	34.7	12	74	3.7	35.1	10	74
3.6	34.8	12	70	3.7	34.6	14	74	3.7	35	12	74
3.5	34.9	14	70	3.7	34.7	16	74	3.7	35.1	14	74
3.5	35	16	70	3.6	34.6	18	74	3.7	35	16	74
3.4	35	18	70	3.6	34.9	20	74	3.7	35.1	18	74
3.4	35	20	70	3.4	34.5	22	74	3.6	35.1	20	74
3.4	34.9	22	70	3.5	35	24	72	3.6	35.2	22	74
3.4	34.7	24	70	3.4	35	26	72	3.6	34.6	24	74
								3.6	34.8	26	74
								3.6	35.3	28	74
								3.6	35.3	30	74

filter mutilated by particulate

Bernhardt Furniture, Hibriten Furniture, Plant #3

Rough End — 32 in. diameter duct
Orifice #1
Probe - stainless steel 1.427 in. diameter
Barometric Pressure 28.86 in. Hg
Chosen Sampling Point - 17 1/4 in. from near wall
Δp = 1.82 in. H_2O

Run 1				Run 2				Run 3			
Filter No. 54850				Filter No. 54851				Filter No. 54852			
ΔH in. H_2O	P_o in. H_2O	θ	T_m °F	ΔH in. H_2O	P_o in. H_2O	θ	T_m °F	ΔH in. H_2O	P_o in. H_2O	θ	T_m °F
3.6	38	2	74	3.6	36.2	2	76	3.6	36	2	72
2.6	38.7	4	74	2.2	38	4	76	3.2	38.2	4	70
2.2	39	6	74	2.0	39.4	6	76	2.6	38.9	6	70
2.0	39.6	8	74	1.60	40.3	8	76	2.2	39.3	8	70

Approximate Machine Operation During Test Runs

		Portion of Time
SANDER LINE		
Run 1	1 string sander	100%
	2 side stroke sanders	100%
	2 side stroke sanders	50%
	1 triple drum sander	100%
	2 horizontal string sanders	100%
Run 2	1 string sander	100%
	2 side stroke sanders	50%
	2 side stroke sanders	100%
	1 triple drum sander	50%
	2 horizontal string sanders	100%
Run 3	1 spool sander	100%
	3 horizontal string sanders	75%
	2 string sanders	75%
	1 triple drum sanders	50%
	1 Heasman sander	50%
MACHINE LINE		
Run 1	Not Taken	
Run 2	2 band saws	100%
	1 band saw	75%
	2 hand shapers	75%
	1 trim & bore machine	100%
	1 profile shaper	75%
	1 hand shaper	20%
Run 3	2 band saws	75%
	1 hand shaper	100%
	1 profile shaper	50%
ROUGH END		
Run 1	3 rip saws	100%
	2 cut-off saws	100%
	1 strato planer	100%
	2 moulders	100%
Run 2	4 rip saws	100%
	2 cut-off saws	100%
	1 strato planer	100%
	2 moulders	100%
Run 3	3 rip saws	100%
	2 cut-off saws	100%
	1 strato planer	100%
	2 moulders	100%

Sampling Train Calibration and Operation

Terms:

v_s (ft/sec), Velocity in stack

V_n (ft/sec), Velocity in nozzle

C_p pitot tube calibration coefficient, the type-s tube used was assumed to have a coefficient of .85

Δp (in. H_2O), Pressure drop across pitot tube

R $(53.34 \frac{ft\ lbf}{lbm\ ^oR})$, Gas constant

T_s (^oR), Stack temperature

g_c $(32.17 \frac{lbm\ ft}{lbf\ sec^2})$, Gravitational acceleration correction factor

P_s (in. H_2O), Absolute stack static pressure

Q_n (ft^3/sec), Flow through nozzle

A_n (ft^2), Area of nozzle

Q_m (ft^3/sec), Flow through orifice meter

T_m (^oR), Orifice meter temperature

P_m (in. H_2O), Absolute pressure in orifice meter measured on high pressure side of orifice plate

K Orifice meter correction factor

A_m (ft^2), Orifice area

ρ $(\frac{in.\ H_2O\ lbm}{ft\ lbf})$, Density of gas

P_1 (in. H_2O), Pressure on high pressure side of orifice

P_2 (in. H_2O), Pressure on low pressure side of orifice

ΔH (in. H_2O), Orifice pressure drop

d (in.), Diameter of nozzle

B (ft^2), Calibration coefficient for orifice meter

Theory

A sketch showing the general sampling train arrangement is shown in Figure 1. For calibration, the fan was replaced by a Roots Meter (lobed rotor) followed by a fan with variable transformer. The vacuum in the Roots Meter was measured with a manometer.

To have isokinetic sampling, it is necessary that the velocity of stack gas going into the nozzle be the same as the velocity in the stack (or duct).

$$v_s = V_n$$

The velocity in the stack is measured by a pitot tube. The equation for velocity based on pitot tube pressure drop is:

$$v_s = C_p \sqrt{\frac{2 \, \Delta p \; R \; T_s \; g_c}{P_s}}$$

The volumetric flow through the nozzle is related to the nozzle velocity and size and is equal to the flow through the orifice meter on a mass basis. On a volume basis, adjustments for pressure and temperature are required. So:

$$Q_n = V_n A_n = v_s A_n$$

$$v_s A_n = Q_m \frac{T_s}{T_m} \frac{P_m}{P_s}$$

The flow through the orifice meter is found from the equation:

$$Q_m = K A_m \sqrt{\frac{2 g_c}{\rho}} \sqrt{P_1 - P_2}$$

where,

$$\rho = \frac{P_m}{R \, T_m}$$

$$\sqrt{P_1 - P_2} = \sqrt{\Delta H}$$

so,

$$Q_m = K \; A_m \sqrt{\frac{2 \; g_c \; R \; T_m \; \Delta H}{P_m}}$$

Therefore, at isokinetic conditions, we can say:

$$A_n \; C_p \sqrt{\frac{2 \; \Delta p \; R \; T_s \; g_c}{P_s}} = K \; A_m \sqrt{\frac{2 \; g_c \; R \; T_m \; \Delta H}{P_m}} \left(\frac{T_s}{T_m}\right) \left(\frac{P_m}{P_s}\right)$$

As a further simplification, for any given orifice meter, the value of A_m will be constant so we can define a calibration factor:

$$B = K \, A_m$$

The equation for isokinetic sampling can thus be simplified to:

$$\Delta H = .4457 \; \frac{d^4}{B^2} \; \frac{P_s}{P_m} \; \Delta p \quad \text{having noted that } T_s \simeq T_m$$

For a given orifice, nozzle, and point in a duct, d, B, and Δp would be known. To have isokinetic sampling requires that:

$$\Delta H \; \frac{P_m}{P_s} = .4457 \; \frac{d^4}{B^2} \; \Delta p$$

The value of P_m/P_s will change as ΔH changes. Thus, isokinetic conditions can be reached by a process of iteration.

Calibration

The orifice meter was calibrated using the equation:

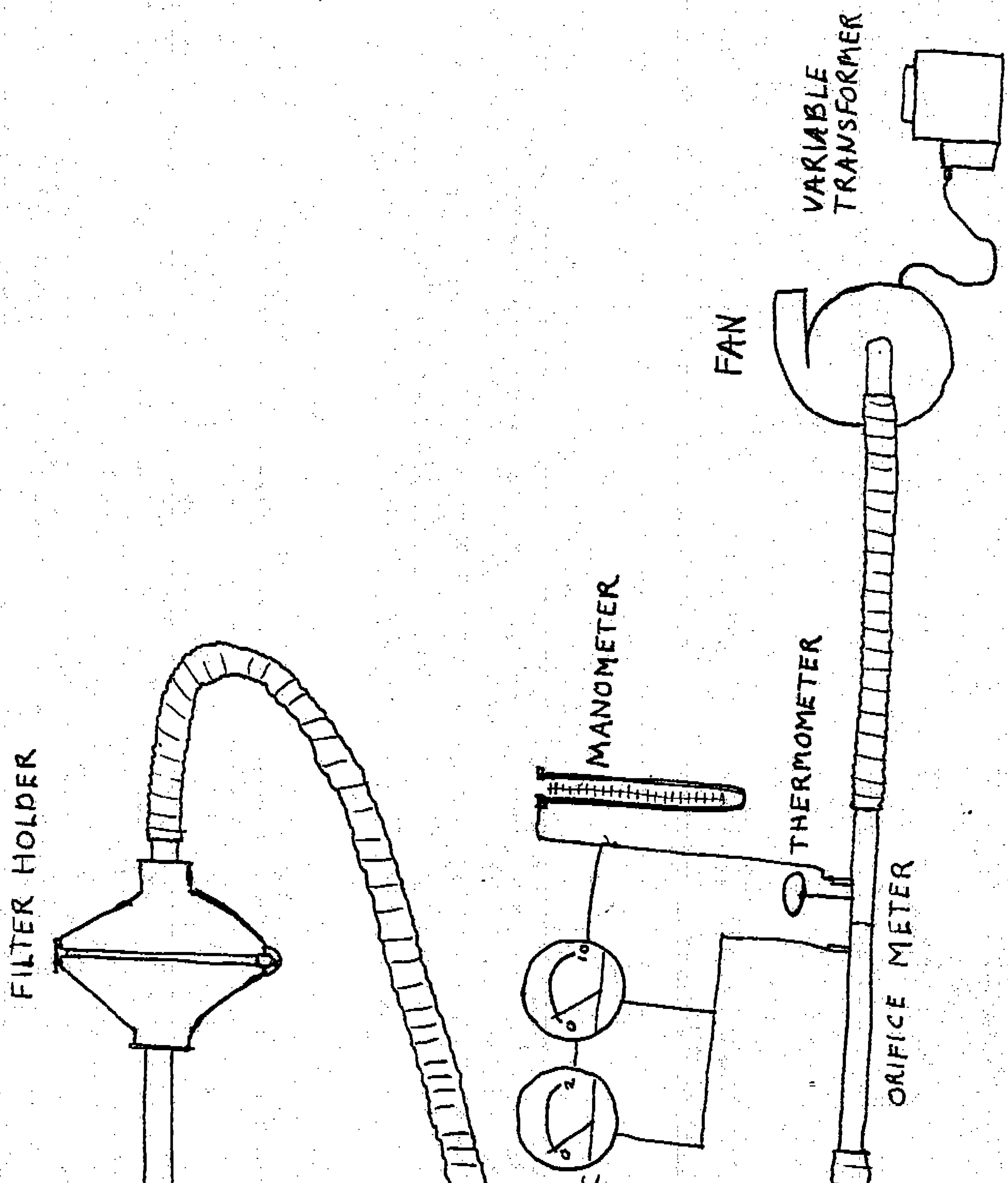
$$Q_m = B\sqrt{\frac{2\ g_c\ R\ T_m\ \Delta H}{P_m}}$$

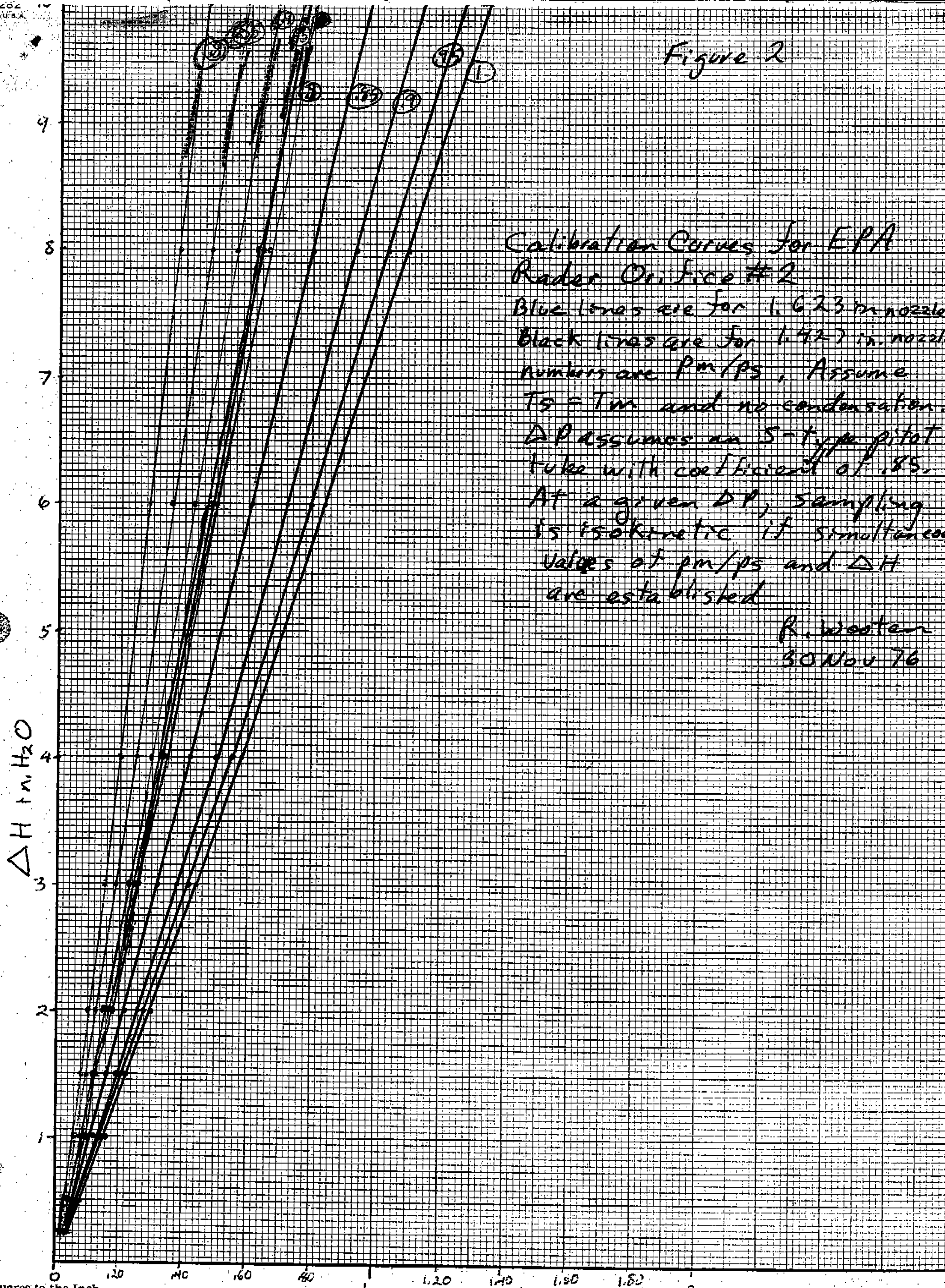
The flow through the train was set at various values of ΔH and held at that value while the Roots Meter was timed as it measured off a particular volume of air. The values of barometric pressure, orifice meter temperature, orifice pressure, Roots Meter pressure, time, Roots Meter volume, and orifice pressure drop were recorded. For each ΔH, the corresponding B was calculated.

The equation:

$$\Delta p = \frac{\Delta H}{.4457}\ \frac{B^2}{d^4}\ \frac{P_m}{P_s}$$

was then used to calculate values of Δp for each ΔH used in calibration, with P_m/P_s taking values of 1, .95, .9, .85, and .8. The resulting numbers were then plotted to provide a family of curves which could be used to establish isokinetic sampling conditions. One of the plots is shown as Figure 2.


FILTER HOLDER
NOZZLE
MANOMETER
THERMOMETER
MAGNEHELIC GAUGES
ORIFICE METER
FAN
VARIABLE TRANSFORMER



20 Squares to the Inch