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1. INTRODUCTION

Sanders Engineering & Analytical Services, Inc., (SEAS) performed particulate emissions and hydrocarbon testing on the coke battery at Koppers Industries facility located in Dolomite, Alabama. The tests were performed on September 26, 1991. The testing was performed in accordance with the applicable U.S. EPA procedures specified at **40 CFR, Part 60, Appendix A**.

The purpose of the tests was to gain additional information concerning the emission rate of the process.

The tests were conducted by Mr. Jack Covington, Mr. Paul Mathews, and Mr. Tim Kray of Sanders Engineering & Analytical Services, Inc., and were coordinated with Mr. Don Hall of Koppers Industries. Mr. Wayne Studyvin of the Jefferson County Bureau of Environmental Health was also present to observe the testing.

The tests were conducted in accordance with the rules and regulations of the Jefferson County Bureau of Environmental Health. Further discussion of the test methods are included in the report.

2. SUMMARY AND DISCUSSION OF RESULTS

The summary of the particulate emissions and hydrocarbon testing results are presented in Tables I and II, respectively. The completed field data sheets and a copy of the recorder charts are included in Appendix A. The equations used in the calculations, along with the sample calculations are included in Appendix A. The initial and final calibrations of the equipment used in the sampling program are included in Appendix C.

The results of the testing for each pollutant, as required by the Jefferson County Bureau of Environmental Health, are as follows:

Pollutant	Emission Rate LB/HR
Particulate	9.2 ✓
Hydrocarbon	3.7 ✓

No unusual sampling problems were experienced during the performance of the tests. At the completion of each run, the particulate sampling train was removed to a relatively clean, draft-free area for cleanup.

TABLE I
PARTICULATE TEST RESULTS
KOPPERS INDUSTRIES
DOLOMITE PLANT
09-26-91

Title of Run		Run 1	Run 2	Run 3
Static Pressure	IN. H2O	-1.10	-1.10	-1.10
Barometric Pressure	In. Hg.	29.50	29.50	29.50
Average ΔH	In. H2O	1.099	1.073	1.034
Meter Correction		1.012	1.012	1.012
Avg Meter Temp.	DEG F	77.8	89.1	91.5
% O2	%	12.0	15.0	13.0
% CO2	%	6.0	5.0	6.0
Volume Metered	ACF	34.366	34.687	34.895
Volume Water	ML	83.6	88.3	101.4
Sampling Time	MINUTES	60	60	60
Nozzle Diameter	INCHES	0.404	0.404	0.404
Avg. Stack Temp.	DEG F	526.7	527.1	522.7
Area Of Stack	SQ. FEET	50.266	50.266	50.266
Wt. Of Part.	MG	82.8	73.6	76.3
Number Of Points		12	12	12
Avg. Sqrt. ΔP	In. H2O	0.267	0.277	0.273

13.33 Avg.

RESULTS OF COMPUTATIONS

		RUN 1	RUN 2	RUN 3	AVERAGE
Volume of Gas Sampled	SDCF	33.747	33.357	33.404	33.503
Molecular Wt. Of St. Gas	LB/LB-MOLE	28.25	28.14	28.05	28.14
H2O Vapor in Gas Stream	PERCENT	10.4	11.1	12.5	11.3
Avg Stack Gas Velocity	FT/SEC	20.9	21.7	21.4	21.3
Volumetric Flow Rate	SDCFM	29700	30600	29800	30000
Volumetric Flow Rate	ACFM	63100	65400	64500	64300
Particulate Conc.	GRS/SDCF	0.038	0.034	0.035	0.036
Particulate Conc.	GRS/ACF	0.018	0.016	0.016	0.017
Particulate Mass Rate	LB/HR	9.6	8.9	9.0	9.2
Percent of Isokinetic		106.80	102.60	105.60	

SEAS, INC.

$$\frac{0.036\ gr}{d\ FT^3} \times \frac{30{,}000\ FT^3}{min} \times \frac{60\ min}{Hr} \times \frac{\#}{7000\ gr} = 9.26$$

TABLE II: HYDROCARBON TEST RESULTS
KOPPERS INDUSTRIES
COKE BATTERY-DOLOMITE, ALABAMA
SUMMARY OF RUNS

Run	$\bar{C}$	C_o	C_{ma}	C_m	C_A*	lb/hr**
1	29.3	0.40	30	29.25	30.05	6.1
2	17.1	0.65	30	29.65	17.02	3.6
3	7.0	0.25	30	29.60	6.90	1.4
AVG	17.8	0.43	30	29.50	17.99	3.7

WHERE:

$\bar{C}$ = Average Analyses response, dry basis, ppm

C_o = Average Initial and Final zero bias check, ppm

C_m = Average Initial and Final upscale bias check, ppm

C_{ma} = Actual Concentration of the upscale calibration gas, ppm

* $C_A = (\bar{C} - C_o)\, C_{ma} / C_m - C_o$

**lb/hr = (ppm) SDCFM (60m/hr) (1.1421×10^{-7})

3. PROCESS DESCRIPTION

Coke is produced in narrow, slot type ovens constructed of silica brick. A coke oven battery may have a series of 10 to 100 individual ovens, with a heating flue between each oven pair. Ovens are charged with pulverized coal, through ports in the oven top, by a larry car traveling on tracks along the top of each battery. After charging, the ports are sealed, and the coking process begins. Combustion of gases in burners in the flues between the ovens provides heat for the process. Coke oven gas from the by-product recovery plant is the common fuel for underfiring the ovens at most plants, but blast furnace gas and, infrequently, natural gas may also be used.

After a coking time typically between 12 and 20 hours, almost all volatile matter is driven from the coal mass, and the coke is formed. Maximum temperature at the center of the coke mass is usually 1100 to 1150°C (2000 to 2100°F).

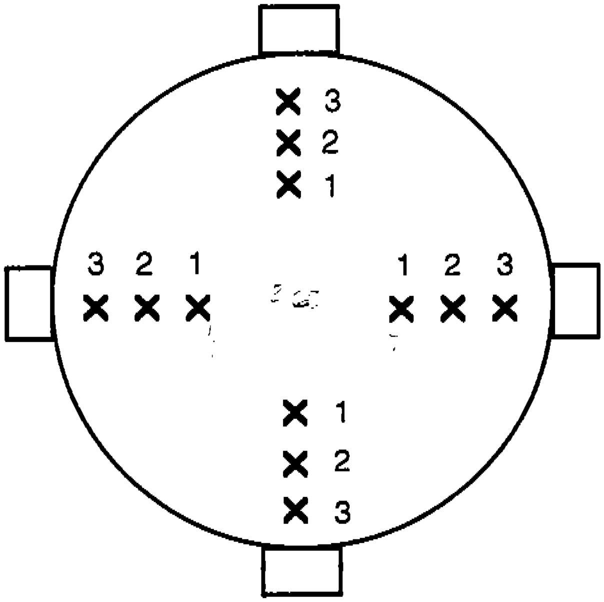
After coking, machinery located on tracks on each side of the battery removes the vertical door on each end of an oven, and a long ram pushes the coke from the oven into a rail quench car, whence it goes to a quench tower, where several thousand gallons of water are sprayed onto the coke mass to cool it. The car then discharges the coke onto a wharf along the battery for further cooling and drainage of water. From here, coke is screened and sent to the blast furnace or to storage in outdoor piles.

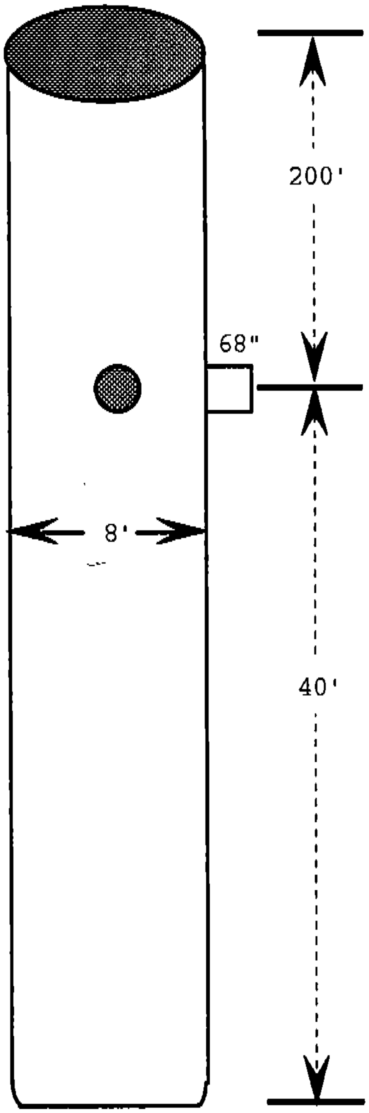
During the coking cycle, volatile matter driven from the coal mass is collected by off-takes located at one or both ends of the oven. A common collector main transports the gases from each oven to the by-product recovery plant. Here, coke oven gas is separated, cleaned and returned to heat the ovens. Only 40 percent of recovered coke oven gas is required for underfiring, and the remainder is used throughout the steel plant. Other coal byproducts also are recovered in the byproduct plant for reuse, sale or disposal.

4. SAMPLING AND ANALYTICAL PROCEDURES

The sample point location and outlet duct schematic for Koppers Industries, Coke Battery, is presented in Figure 1.

FIGURE 1
Sample Point Location
KOPPERS INDUSTRIES
DOLOMITE PLANT





Point Number	Distance From Stack Wall (Inches)
1	28.42
2	14.02
3	4.22

ACCORDING TO METHOD 1:

PT #	DISTANCE FROM STACK WALL (")
1	4.22"
2	14.11"
3	28.32"
4	67.68" (28.32)
5	81.88 (14.11)
6	91.78 (4.22")

5. PARTICULATE SAMPLING PROCEDURES (METHOD 5)

A brief description of the sampling procedure is as follows:

The sample train was prepared in the following manner: 100 milliliters of distilled water were added to the first and second impingers. The third impinger was left empty to act as a moisture trap, and preweighed silica gel was added to the fourth impinger. The train with the probe, as shown in the following schematic, Figure 2, was leak checked by plugging the inlet to the nozzle and pulling a 15 inch mercury vacuum. A leakage rate not in excess of 0.02 cubic feet per minute was considered acceptable.

The inside dimensions of the stack liner were measured and recorded. The number of sampling points, and the location of these points on a traverse, were determined by the guidelines set forth in the **Federal Register, Vol. 36, No. 247, Sec. 60.85, Method 1**. These points were then marked on the probe for easy visibility.

A preliminary traverse was conducted to determine the range of velocity head and the pressure of the stack. From this data, the correct nozzle size and the nomograph multiplication factor were determined.

The probe was attached and the heater was adjusted to provide a temperature of 248 degrees fahrenheit (± 25). Crushed ice was then placed around the impingers. The nozzle was placed on the first traverse point with the tip pointing directly into the gas stream. The pump was started immediately and the flow was adjusted to isokinetic sampling conditions. After the required time interval had elapsed, the probe was repositioned to the next traverse point and isokinetic sampling was re-established. This was done for each point on the traverse until the run was completed. Readings were taken at each point. When changes in stack conditions occurred, adjustments in sampling flow rate were performed. At the conclusion of each run, the pump was turned off and the final readings were recorded.

5.1 Particulate Sample Recovery

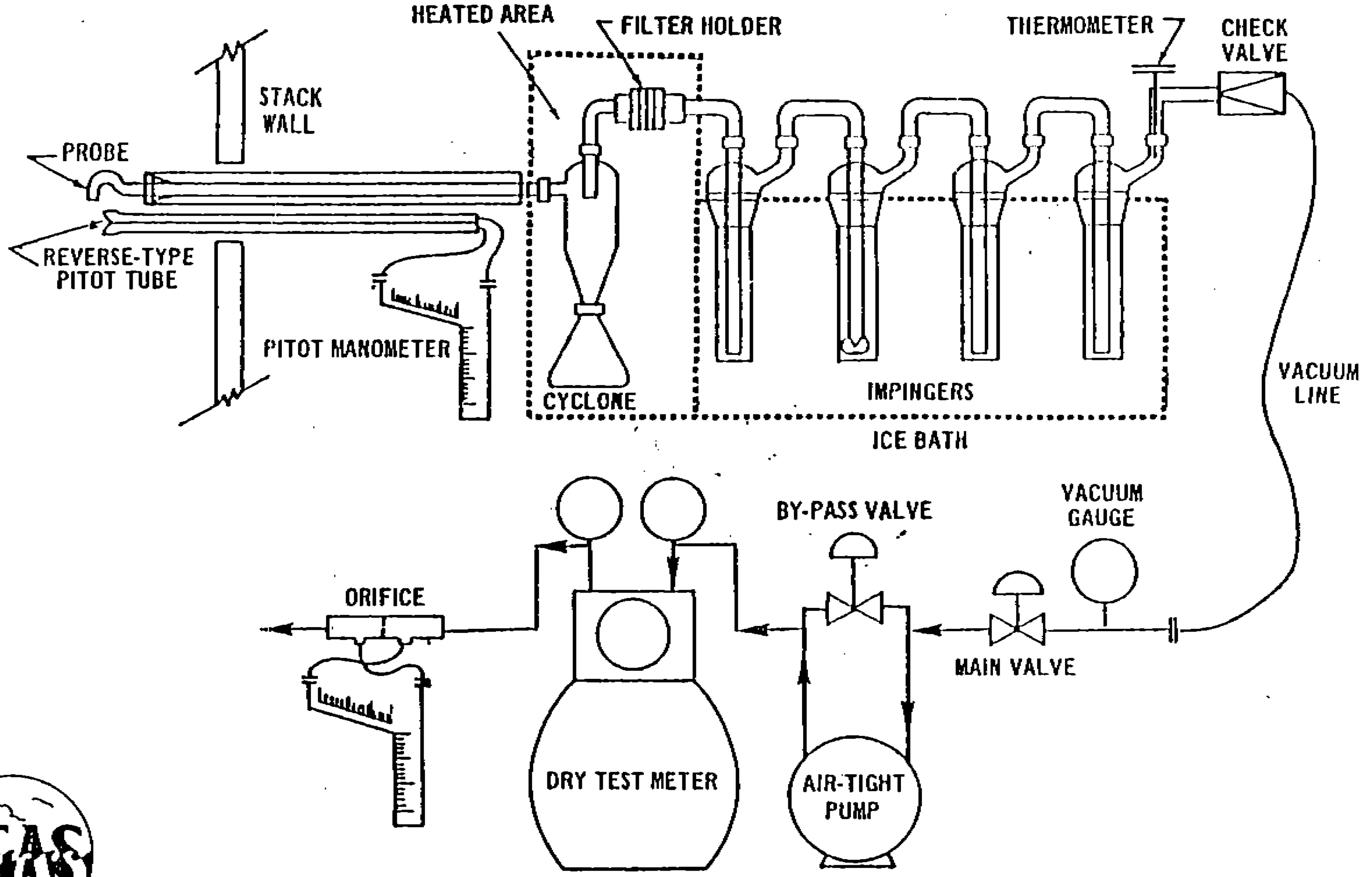
Care was exercised in moving the collection train to the sample recovery area to minimize the loss of collected sample, or the gain of extraneous particulate matter. The volume of water in the first three impingers was measured, the silica gel impinger was weighed and recorded on the field data sheet. The probe, nozzle, and all sample-exposed surfaces were washed with reagent grade acetone and the wash solution was put into a clean sample bottle. A brush was used to loosen any adhering particulate matter and subsequent washings were put into the container. The filter was carefully removed from the fritted glass support and placed in a clean dish. A sample of the acetone used in the washing was saved for a blank laboratory analysis.

5.2 Particulate Analytical Procedures

The filter and any loose particulate matter were transferred from the dish to a clean, tared weighing dish. The filter was placed in a desiccator for a least 24 hours and then weighed to the nearest 0.1 milligram until a constant weight was obtained. The original weight of the filter was deducted, and the weight gain was recorded to the nearest 0.1 milligram.

The wash solution was transferred to a clean, tared beaker. The solution was evaporated to dryness, desiccated to a constant weight, and the weight gain was recorded to the nearest 0.1 milligram.

Figure 2. Particulate Sampling Train.



6. HYDROCARBON SAMPLING PROCEDURES

A Byron Model 30 IHT Methane and Non-Methane Hydrocarbon Analyzer was used to determine the amount of hydrocarbons in stack effluent.

The stack sample is drawn from the stack through a filter, calibration valve and heated teflon line to another filter then through the hydrocarbon analyzer where the sample is analyzed utilizing flame ionization gas chromatography. The results of that analyzation are then recorded on a strip chart recorder. The sample pump is placed on the exhaust of the analyzer to preclude the need to utilize a heated sample pump and minimize the possibility of contaminate being added or hydrocarbons being absorbed within the pump. The analyzed sample is then exhausted to the atmosphere.

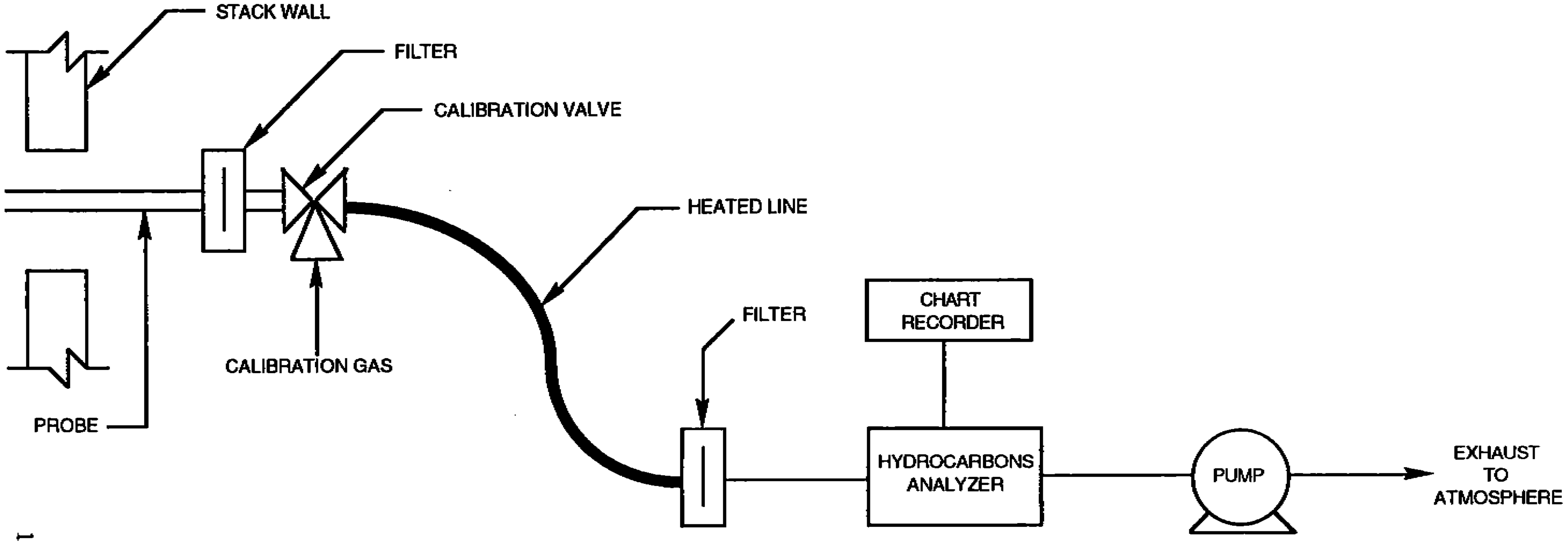


FIGURE 3: HYDROCARBON SAMPLING TRAIN

APPENDIX A: FIELD DATA SHEETS AND RECORDER CHARTS

SANDERS ENGINEERING & ANALYTICAL SERVICES, Inc.
1568 Leroy Stevens Rd.
Mobile, AL 36695
Office: (205) 633-4120
FAX#: (205) 633-2285

FIELD DATA SHEET

COMPANY Koppers DATE 9-25-91 DGM# D-[illegible]

PLANT Woodward R[illegible] OPERATOR Mathews ΔHa .71 cu. ft. /min.

UNIT 1st Battery METHOD 5 PROBE S.S liner 10' length

	RUN 1	RUN 2	RUN 3
NOZZLE CALIBRATION PRE	.404 .404 .406 .404	[illegible] [illegible] [illegible] [illegible]	[illegible] [illegible] .40[illegible] .40[illegible]
POST	.407 [illegible] [illegible] [illegible]	[illegible] [illegible] .4[illegible] .40[illegible]	[illegible] [illegible] [illegible] [illegible]
AVERAGE (PRE / POST)	.404 / [illegible]	[illegible] / [illegible]	[illegible] / [illegible]
FILTER NUMBER	6581 [illegible]	6582	6583
METER READING FINAL	368.913	404.407	443.209
INITIAL	334.577	369.720	408.314
NET	34.366	34.687	34.895
LEAK CHECK SYSTEM Pre	23 in. Hg / .010 cfm	23 in. Hg / .013 cfm	24 in. Hg / .010 cfm
SYSTEM Post	24 in. Hg / .010 cfm	24 in. Hg / .013 cfm	24 in. Hg / .03 cfm
PITOT Pre	impact ✓ / static ✓	impact ✓ / static ✓	impact ✓ / static ✓
PITOT Post	impact ✓ / static ✓	impact ✓ / static ✓	impact ✓ / static ✓

VOLUME OF LIQUID WATER COLLECTED

RUN		IMP. 1	IMP. 2	IMP. 3	IMP. 4
1	FINAL	168 ~~[illegible]~~	~~[illegible]~~ 98		1564.1 ~~[illegible]~~
	INITIAL	100	100		~~1546.5~~ ~~1402.5~~
	NET	~~[illegible]~~ 68	-2		~~[illegible]~~
2	FINAL	168	102	~~1409.3~~	1409.3
	INITIAL	100	100	~~1356.0~~	← 1381.0 ~~[illegible]~~
	NET	68	2	~~53.3~~	18.3
3	FINAL	158	100	1	1446.9
	INITIAL	100	100	0	~~1381.5~~ 1404.5
	NET	58	0	1	~~65.4~~ 42.4

RUN 1: 168 · 3.6 ← TOTAL ~~[illegible]~~ 17.6

RUN 2: TOTAL ~~123.3~~ 88.3

RUN 3: TOTAL ~~124.4~~ 101.4

	RUN 1	RUN 2	RUN 3
GAS ANALYSIS O_2	12	15	13
CO_2	6	5	6
CO			
STATIC in. H_2O	-1.1	-1.1	-1.1
BAROMETRIC in. Hg	29.50	29.50	29.50

~~113.3901~~ ~~113.5535~~ ~~113.4165~~

4/26/91 103.3901 State/County → Wayne Studyvin 100.3535

PAGE 1 OF

03

PORT #	TIME	GAS METER VOL. (cu.ft.)	VEL. HEAD ΔP in.H_2O	ORIFICE HEAD ΔH in. H_2O	TEMPERATURE °F						VAC. in. H_g
POINT #					STACK	PROBE	HOT BOX	IMP.	GAS METER		
									IN	OUT	
1 - 1	908	334.577	.092	1.23	626	—	-	—	76	73	5.5
2	13	337.56	080	1.14	501	-	-	-	78	76	4.5
3	18	340.44	.077	1.23	599	-	-	-	78	76	5.0
2 - 1	923	343.38	.069	1.10	445	—	-	-	75	76	5.0
2	28	346.49	.065	1.04	503	-	—	-	77	77	5.0
3	33	349.25	.060	0.96	505	-	-	-	79	77	4.5
3 - 1	945	351.92	.065	1.04	480	-	-	-	79	77	5.0
2	50	354.63	.060	0.96	568	—	-	-	80	76	4.5
3	55	357.35	.055	0.92	583	-	-	-	81	76	4.0
4 - 1	1004	359.39	.080	1.19	592	-	-	-	79	76	5.0
2	1009	362.34	.085	1.16	617	—	-	-	84	77	5.5
3	1014	365.31	.090	1.32	507	—	-	-	83	80	6.5
		368.913									
									77.75		
		34.336		1.0992							
					526.67						

CHECK INDICATES TEMPERATURES MEET REQUIRED LIMITS.

COMPANY Koppers DATE 9-26-91

SITE Woodward / 3' barn RUN # 1 PAGE 1 OF 1

WS
9/26/91

CΔH: 1.0992 ~~1.0271~~
CΔP: .2674

103.2336%

PORT # POINT #	TIME	GAS METER VOL. (cu.ft.)	VEL. HEAD ΔP in.H_2O	ORIFICE HEAD ΔH in. H_2O	TEMPERATURE °F STACK	PROBE	HOT BOX	IMP.	GAS METER IN	GAS METER OUT	VAC. in. H_g
1-1	1126	369.72	.080	1.05	450	–	–	–	84	81	4.0
2	1131	372.41	.035	1.23	500	–	–	–	86	82	4.0
3	1136	375.29	.031	1.18	503	–	–	–	88	84	4.0
2-1	1144	378.23	.080	1.17	507	–	–	–	87	84	4.0
2	49	381.23	.070	.9736	553	–	–	–	90	87	3.5
3	54	384.05	.065	.891	573	–	–	–	92	89	3.0
3-1	1202	386.76	.075	1.03	529	–	–	–	91	89	3.0
2	07	389.62	.080	1.07	613	–	–	–	93	90	3.0
3	12	392.72	.070	0.92	620	–	–	–	95	92	3.0
4-1	1220	395.36	.075	1.01	473	–	–	–	93	90	3.0
2	25	398.22	.073	1.03	500	–	–	–	93	90	3.0
3	30	401.23	.036	1.27	500	–	–	–	95	93	4.0
		404.407									
									89.	0833	
		34.687									
					527.0833						
				1.0729							

CHECK INDICATES TEMPERATURES MEET REQUIRED LIMITS.

COMPANY Koppers DATE 9-26-91

SITE Woodward / D'ham RUN # 2 PAGE 1 OF 1

CΔH = ~~1.1??~~ 1.0729

CΔP = 0.2767

106.3584

JS 9/26/91

PORT # POINT #	TIME	GAS METER VOL. (cu.ft.)	VEL. HEAD ΔP in.H_2O	ORIFICE HEAD ΔH in. H_2O	TEMPERATURE °F STACK	PROBE	HOT BOX	IMP.	GAS METER IN	OUT	VAC. in. H_g
1 - 1	1306	408.314	.086	1.07	589	-	-	-	86	85	4.0
2	11	411.32	.088	1.11	530	-	-	-	90	87	4.0
3	16	414.33	.082	1.21	501	-	-	-	91	88	4.0
2 - 1	1323	417.43	.072	1.06	474	-	-	-	88	86	4.0
2	1328	420.77	.065	0.96	497	-	-	-	92	89	4.0
3	1333	423.04	.06	0.83	499	-	-	-	92	90	4.0
3 - 1	1346	425.39	.067	0.99	536	-	-	-	93	90	4.0
2	1351	428.84	.063	0.85	569	-	-	-	93	90	3.5
3	1356	431.56	.061	0.82	580		-	-	95	92	3.5
4 - 1	1404	434.19	.085	1.12	508	-	-	-	96	94	4.5
2	09	437.11	.090	1.19	610	-	-	-	99	95	5.0
3	14	440.15	.099	1.15	579	-	-	-	100	96	5.0
		443.204									
		—									
		34.895		1.0342					91.	5417	
					522.667						

CHECK INDICATES TEMPERATURES MEET REQUIRED LIMITS.

COMPANY Koppers DATE 9-26-91

SITE Woodward / B'ham RUN # 3 PAGE 1 OF 1

K 26/91

<ΔP = .2727
<ΔH = ~~1.1233~~ 1.0342

109.4755

SANDERS ENGINEERING & ANALYTICAL SERVICES, Inc.
1568 Leroy Stevens Rd.
Mobile, AL 36695
Office: (205) 633-4120
FAX#: (205) 633-2285

CHAIN of CUSTODY & LABORATORY ANALYSIS

COMPANY Koppers

PLANT B'ham

UNIT

DATE of TEST 9-26-91

TEST: ☑ M-5 ☐ M-17

☐ OTHER M-25A

SAMPLE NO.	WASH	RETURNED BY	RECEIVED BY	TIME	DATE	REASON FOR CHANGE
3	3			AM	9-27-9	N. chg

UNIT:

RUN #	FILTER # 6581	BEAKER. # 30
	F 651.5	F 64.6021
	I 583.3	I 64582.5
	D ~~[illegible]~~ 63.2	D .0196
	TOTAL	82.8
RUN #	FILTER # 6582	BEAKER. # 37
	F 648.3	F 67.8056
	I 587.1	I 67793.2
	D 61.2	D 12.4
	TOTAL	73.6
RUN #	FILTER # 6583	BEAKER. # 38
	F 662.0	F 63.4156
	I 596.4	I 63404.9
	D 65.6	D 10.7
	TOTAL	76.3
RUN #	FILTER #	BEAKER. #
	F	F
	I	I
	D	D
	TOTAL	

UNIT:

RUN #	FILTER #	BEAKER. #
	F	F
	I	I
	D	D
	TOTAL	
RUN #	FILTER #	BEAKER. #
	F	F
	I	I
	D	D
	TOTAL	
RUN #	FILTER #	BEAKER. #
	F	F
	I	I
	D	D
	TOTAL	
RUN #	FILTER #	BEAKER. #
	F	F
	I	I
	D	D
	TOTAL	

Koppers Industries ; Montgomery, Alabama 07-08-97
Non-Methane Hydrocarbons

Calibration Data

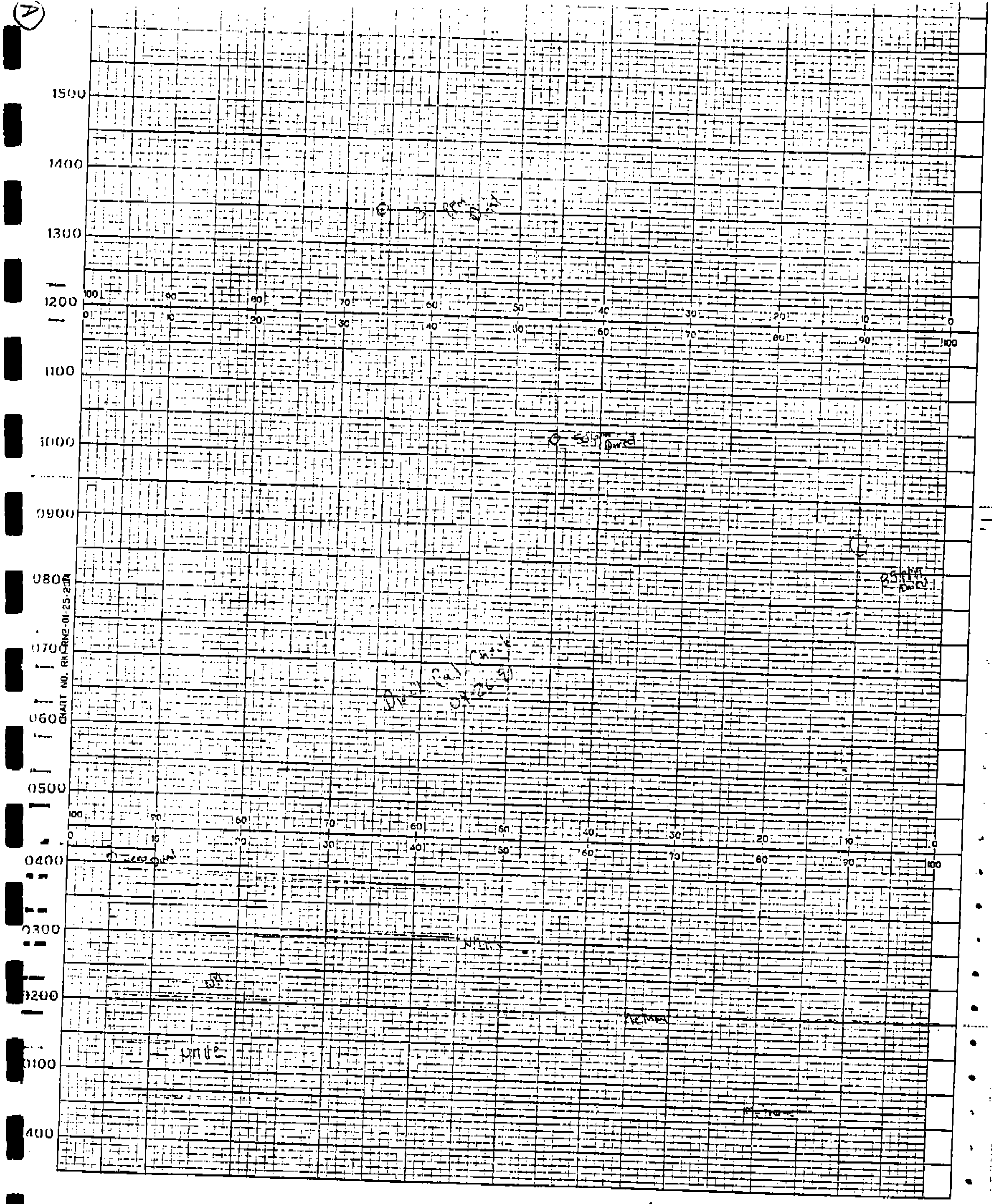
Beginning Calibration

	Admitted	Indicated
Direct :	85 ppm Admitted	85.2 PPM
	50 ppm	49.8 PPM
	30 ppm	29.5 PPM
	0 PPM	0.0 PPM
System	30 ppm	29.0 ppm
	0 ppm	0 ppm
2nd	30 ppm	29.5 ppm
	0 ppm	0.8 ppm
3rd	30 ppm	29.8 ppm
	0 ppm	0.5 ppm
4th	30 ppm	29.2 ppm
	0 ppm	0.0 ppm
Direct	0 ppm	0 ppm
	30 ppm	28.8 ppm
	50 ppm	49.9 ppm
	85 ppm	84.5 ppm

Koppers Industries Montgomery Ala 09·26·91

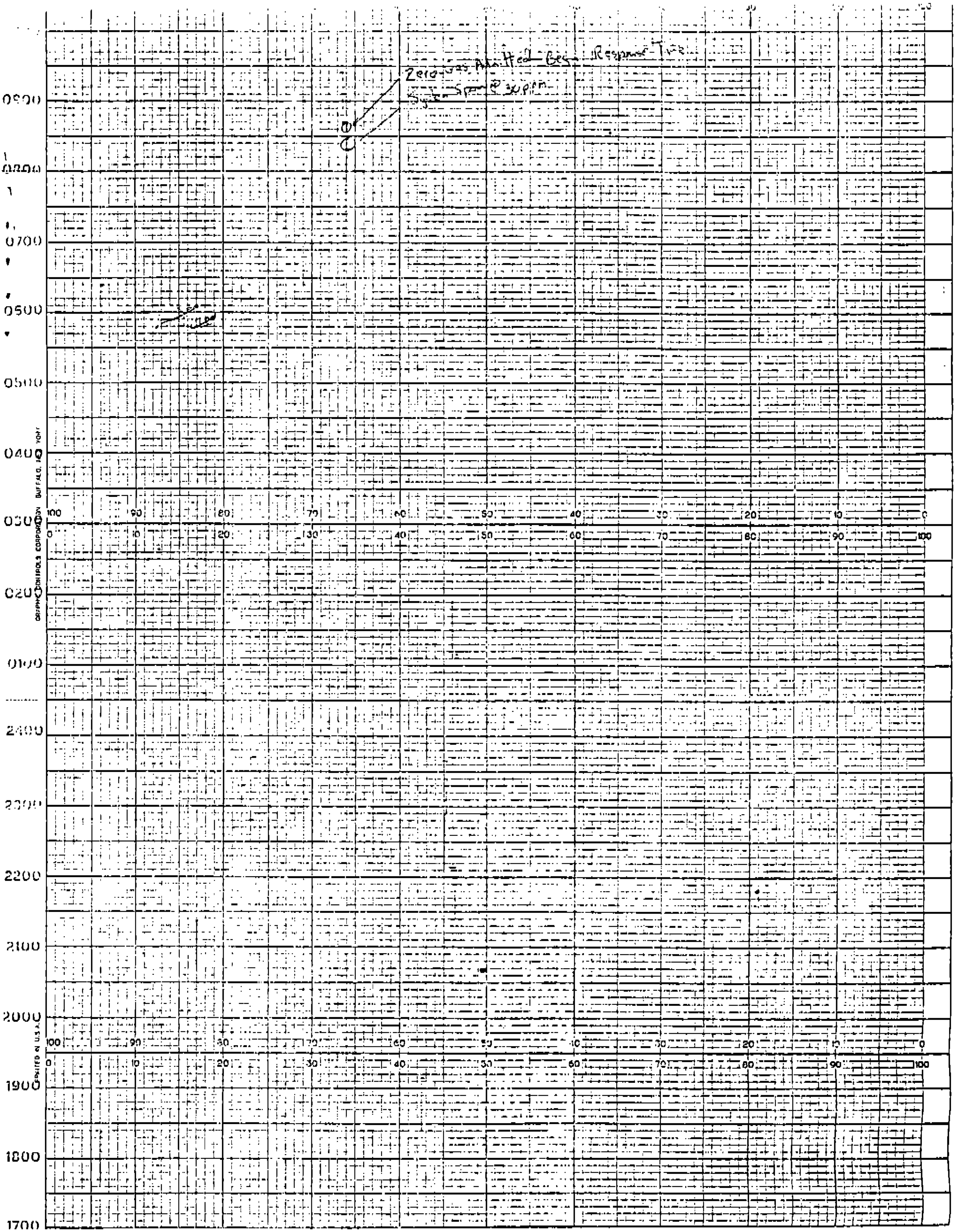
Run #1	Run #2	Run #3	
32.5	21.0	6.8	
22.5	32.0	7.5	
17.7	33.8	7.0	
14.8	31.6	6.0	
13.2	25.0	7.7	
12.5	21.0	7.4	
12.0	16.9	7.8	
11.8	13.4	8.0	
12.0	12.1	8.5	
13.1	10.9	8.3	
15.2	10.0	8.5	
19.8	9.6	8.6	
40.0	9.0	9.0	
4.0	9.6	6.3	
100.0	10.0	5.8	
98.0	10.9	6.1	
60.0	12.1	6.1	
35.8	13.2	5.0	
26.3	14.8	4.6	
25.7	26.2	4.2	
Total: 586.9	343.1	139.2	
Average: 29.345	17.155	6.96	→ 17.82

Non-Methane Hydrocarbons



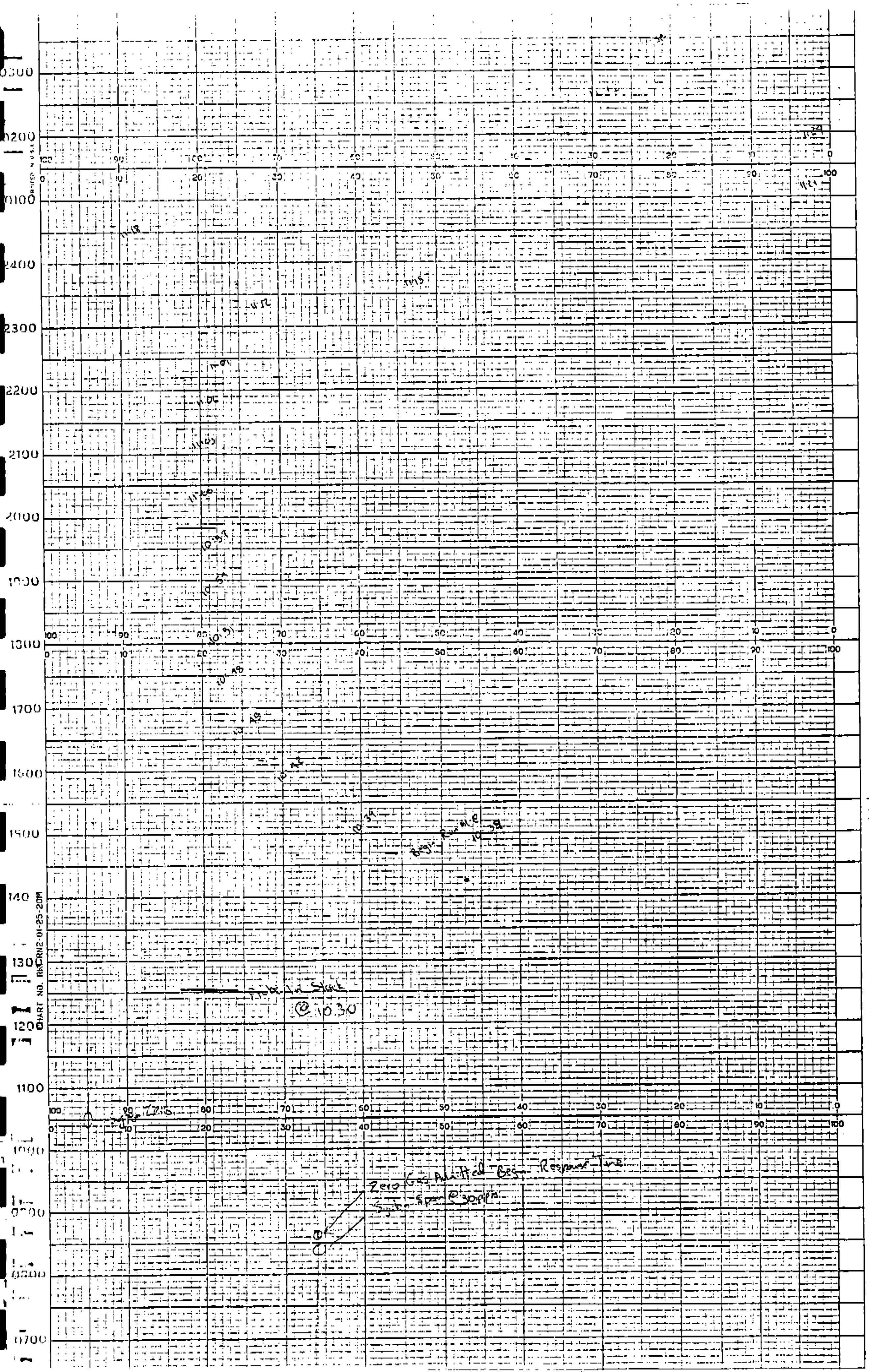
Koppers Industries
Non-Methane Hydrocarbons
09-26-1991
Range 0 to 100 ppm w/5% Zero Offset
Chart Speed 30 mm/hr

Ⓑ



Zero gas Admitted Begin Response Time
Sys. Span @ 30 ppm
①
②
0900
0800
0700
0600
0500
0400
0300
0200
0100
2400
2300
2200
2100
2000
1900
1800
1700
100 90 80 70 60 50 40 30 20 10 0
0 10 20 30 40 50 60 70 80 90 100
GRAPHIC CONTROLS CORPORATION BUFFALO, NEW YORK
PRINTED IN U.S.A.

Ⓐ

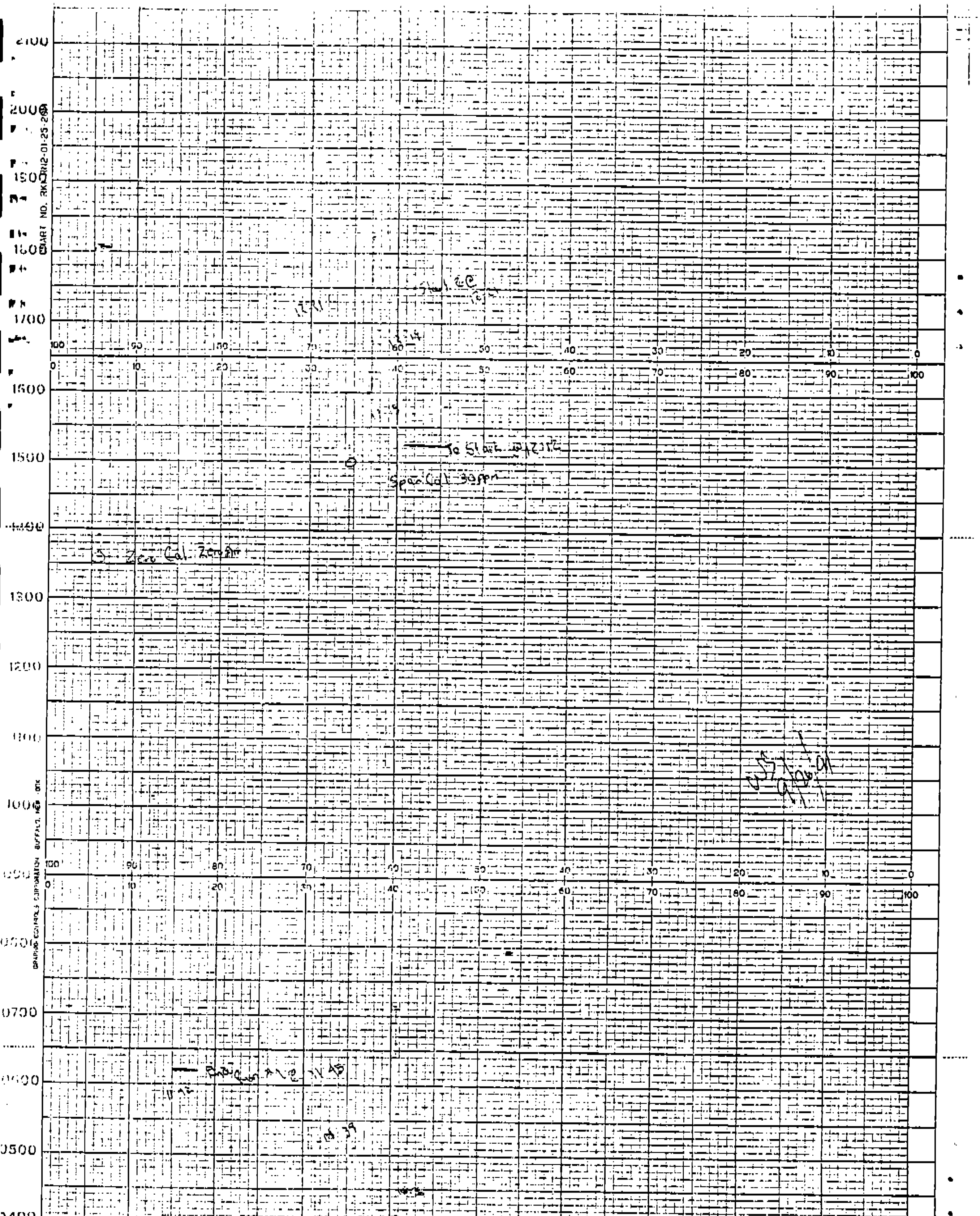


Begin Run #1 @ 10:39

Probe in Stack @ 10:30

Zero Gas Admitted Begin Response Time

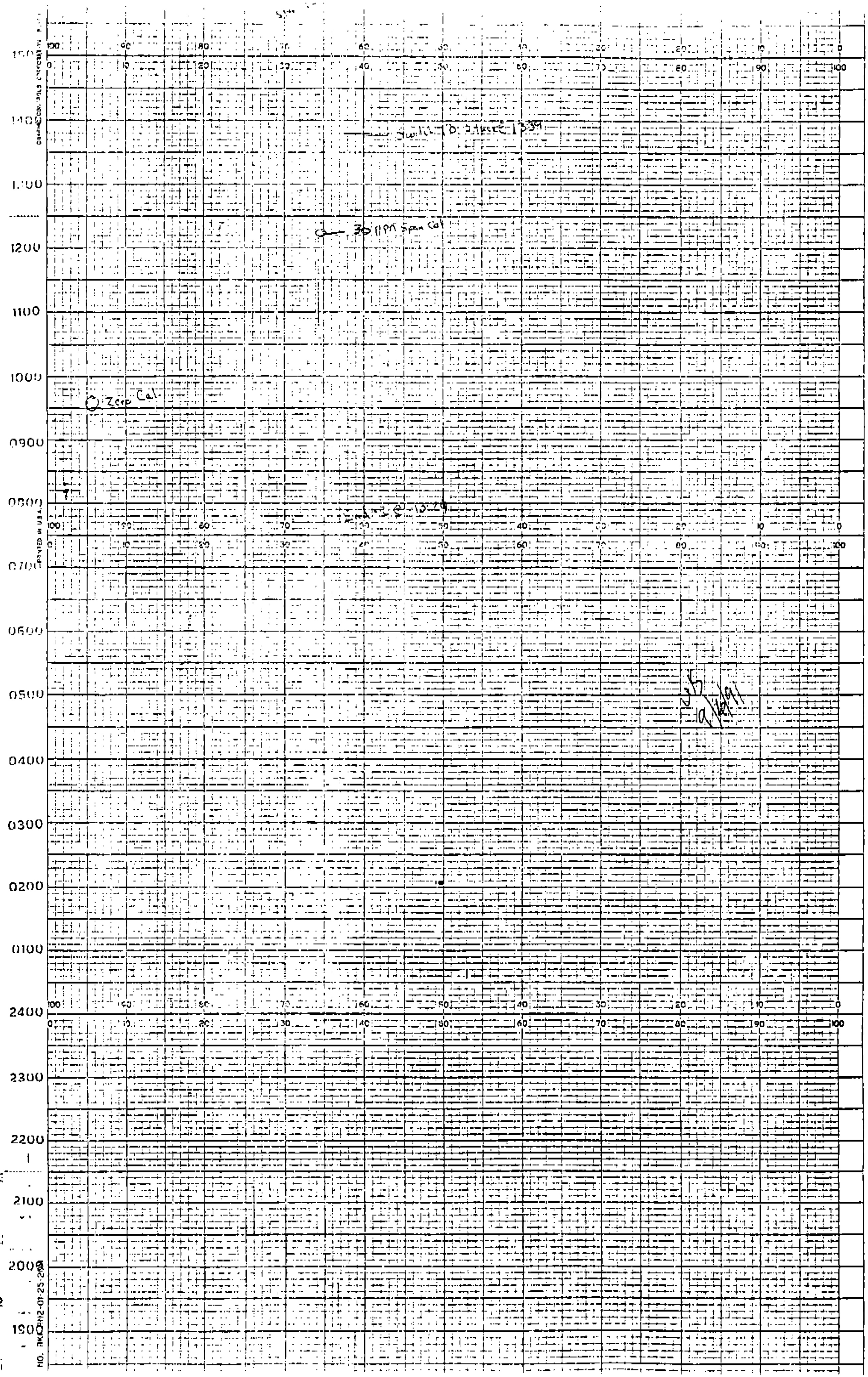
System Span @ 30ppm

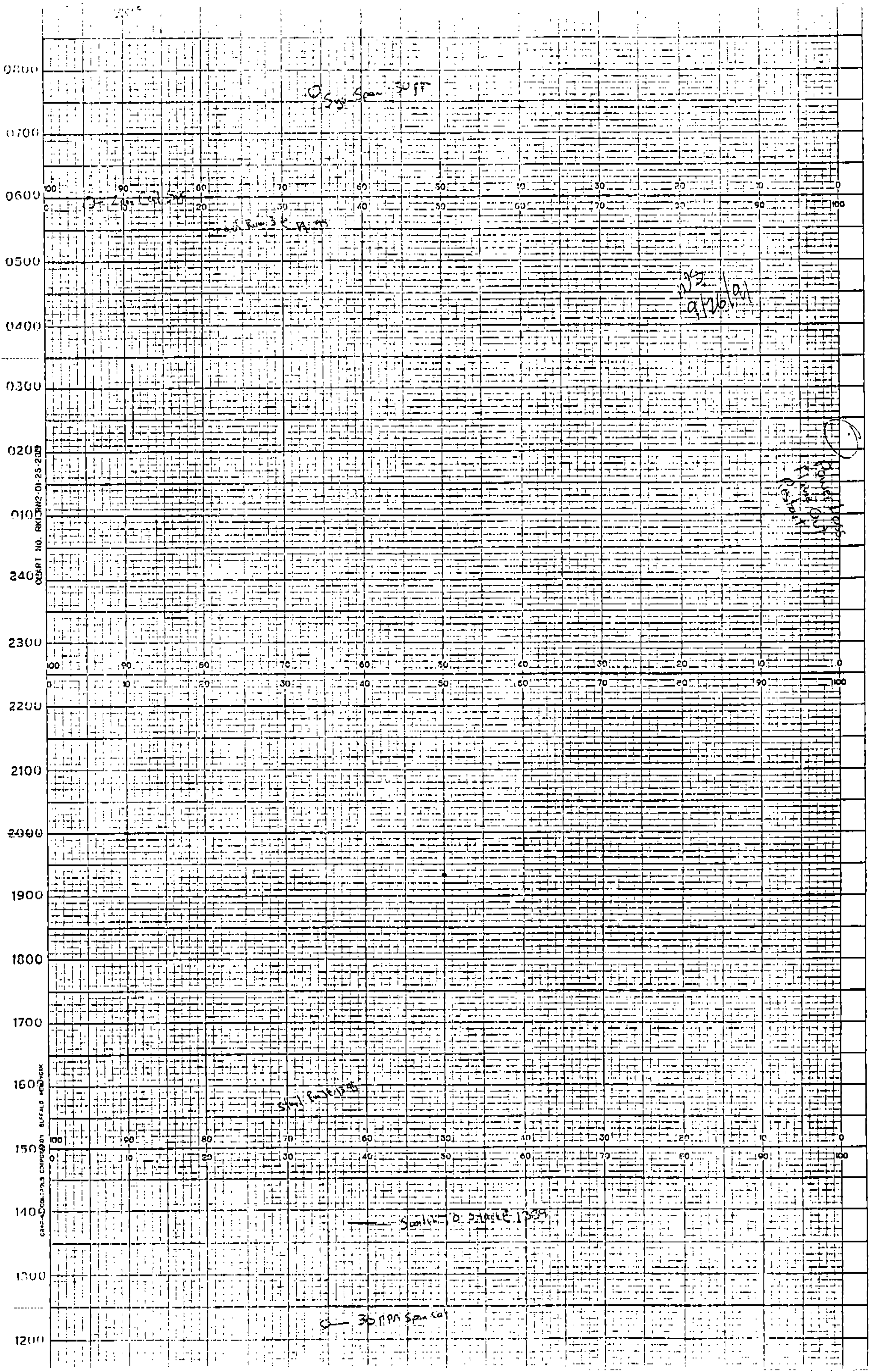

2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
0900
0800
0700
0600
0500
0400
100 90 80 70 60 50 40 30 20 10 0
0 10 20 30 40 50 60 70 80 90 100
CHART NO. RK0R12-01-25-260
GRAPHIC CONTROLS CORPORATION BUFFALO NEW YORK
Start CC
1221
1214
11:19
To Start
Span Cal 30ppm
Zero Cal Zero Air
Resume Air @ 11:45
11:42
10:39
JS 9/26/01

Ⓓ

Ⓒ

①


1500
1400
1300
1200
1100
1000
0900
0800
0700
0600
0500
0400
0300
0200
0100
2400
2300
2200
2100
2000
1900
100 90 80 70 60 50 40 30 20 10 0
0 10 20 30 40 50 60 70 80 90 100
Switch To Stack 1339
30 PPM Span Cal
Zero Cal
End Run 3 @ 13:29
JS 10/16/91
E
D
5



O Sys Span 30 ff

O = Zero Cal Sys

Start Run 3 @ 12:45

NS 9/26/01

Power Loss Flame Out Restart

Stop Run 2 @ 1545

Switch to Stack 1339

G — 30 ppm Span Cal

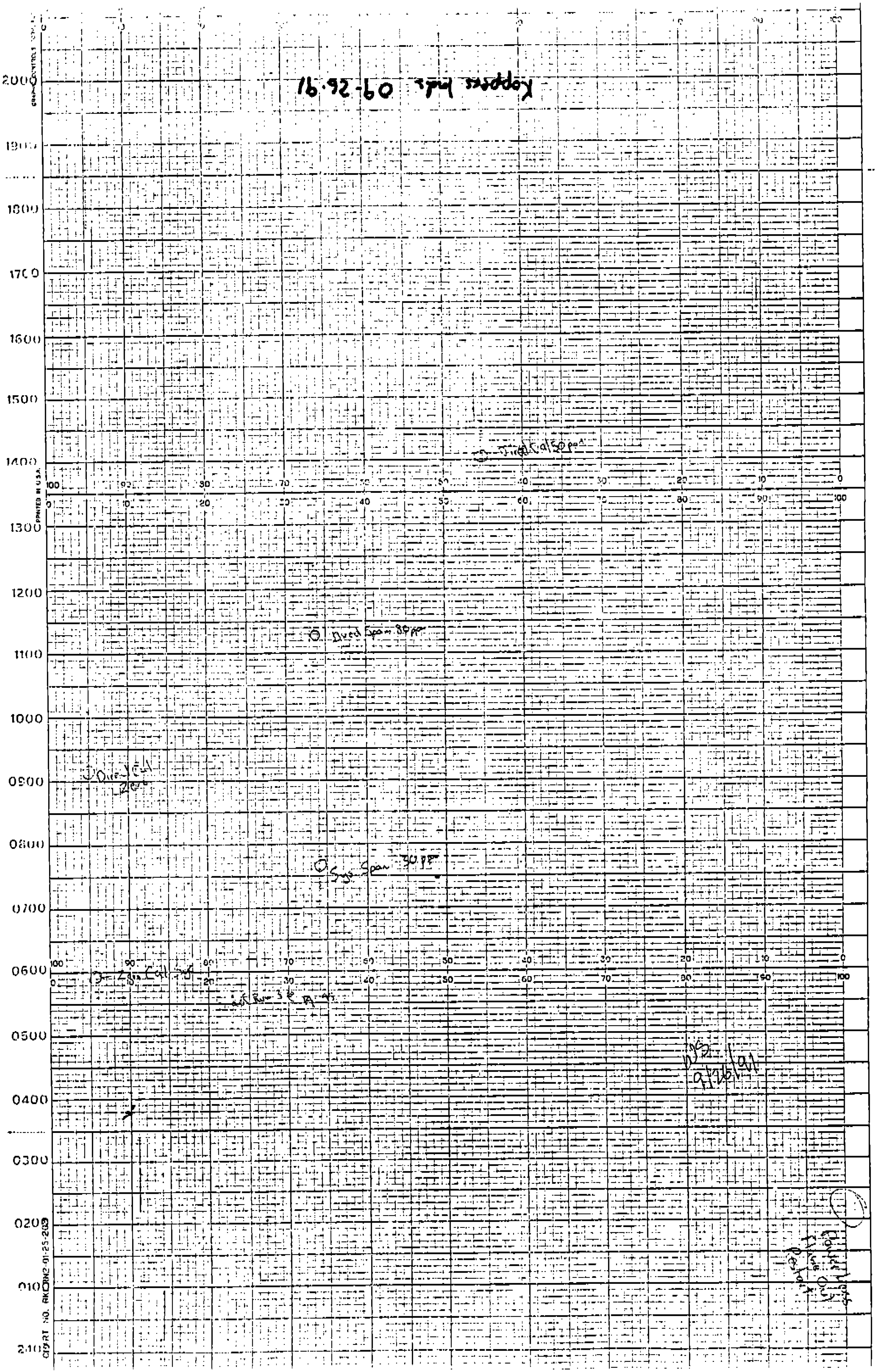
(F)

(F)

(G)

(E)

Koppers Ind. 09-26-91



⑦

Ⓕ

APPENDIX B: EQUATIONS AND SAMPLE CALCULATIONS

EQUATIONS

1. $P_s = P_{bar} + \frac{P_g}{13.6}$

2. $P_m = P_{bar} + \frac{\overline{\Delta H}}{13.6}$

3. $v_s = K_p C_p \sqrt{\overline{\Delta p}} \sqrt{\frac{\overline{T}_s}{M_s P_s}}$

4. $V_{m(std)} = 17.64\ V_m Y \left[\frac{P_{bar} + \frac{\overline{\Delta H}}{13.6}}{\overline{T}_m}\right]$

5. $V_{mc} = V_m - (L_p - L_a)\Theta$

6. $V_{w(std)} = 0.04707\ V_{lc}$

7. $B_{ws} = \frac{V_{w(std)}}{V_{m(std)} + V_{w(std)}}$

8. $M_d = 0.44(\%CO_2) + 0.32(\%\ O_2) + 0.28(\%\ N_2 + \%\ CO)$

9. $M_s = M_d(1 - B_{ws}) + 18(B_{ws})$

10. $EA = \left[\frac{\%O_2 - 0.5(\%CO)}{0.264(\%N_2) - (\%O_2) + 0.5(\%CO)}\right] 100$

11. $Q_a = (v_s)(A_s)(60)$

12. $Q_s = Q_a(1 - B_{ws})\left(\frac{528}{\overline{T}_s}\right)\left(\frac{P_s}{29.92}\right)$

13. $W_a = \frac{m_a\ V_{aw}}{V_a}$

14. $$c_s = 0.0154 \left(\frac{m_n}{V_{m(std)}}\right)$$

15. $$c_{50} = \frac{c_B}{1 - \left[\frac{(1.3)(\%O_2) - 0.133(\%N_2) - 0.75(\%CO)}{21}\right]}$$

16. $$c_{12} = c_B \left(\frac{12}{\%\ CO_2}\right)$$

17. $$PMR = (c_s)(Q_B)\left(\frac{60}{7000}\right)$$

18. $$V_n = \frac{\overline{T_s}}{\overline{P_s}} \left[(0.002669)(V_{lc}) + \frac{Vm\ Y}{\overline{T_m}}\left(P_{bar} + \frac{\overline{H}}{13.6}\right)\right]$$

19. $$I = \frac{100\ \overline{T_s}\left[(0.002669)\ V_{lc} + \frac{Vm\ Y}{\overline{T_m}}\left(P_{bar} + \frac{\overline{H}}{13.6}\right)\right]}{60\ 0\ v_s P_s A_n}$$

$$= \frac{100\ V_n}{60\ 0\ v_s A_n}$$

20. $$C_{SO_2} = \frac{7.061 \times 10^{-5}\ (V_t - V_{tb})\ N\ \frac{V_{soln}}{Va}}{V_{m(std)}}$$

21. $$C_{H_2SO_4} = \frac{1.081 \times 10^{-4}(V_t - V_{tb})\ N\ \frac{V_{soln}}{V_a}}{V_{m(std)}}$$

22. $V_{m(std)} = K_1 Y \frac{V_m P_{bar}}{T_m}$

23. $V_{sc} = \frac{T_{std}}{P_{std}} (V_f - V_a) \left[\frac{P_f}{T_f} - \frac{P_i}{T_i}\right] = K_1 (V_f - 25ml) \left[\frac{P_f}{T_f} - \frac{P_i}{T_i}\right]$

24. $F = \sum_{i=1}^{n} X_i F_i$ or $F_c = \sum_{i=1}^{n} X_i (F_c)_i$

25. $C_{TRS\ as\ H2S}\ (ppm) = K_2 \frac{(Vt - V\ tb)\ N\ (Vsoln/Va)}{Vm}$

26. $C_{TRS\ as\ H2S}\ (lbs/sdcf) = C_{SO2} \frac{34.02}{64.06}$

SANDERS ENGINEERING & ANALYTICAL SERVICES, INC.

NOMENCLATURE

A_n = Cross-sectional area of nozzle, ft^2

A_s = Area of stack, ft^2

B_{ws} = Water vapor in the gas stream, proportion by volume (dimensionless)

C_p = Pitot tube coefficient (dimensionless)

C_s = Particulate concentration, grains/SDCF

I = Percent of isokinetic sampling

K_m = Orifice correction factor (dimensionless)

K_p = Pitot tube constant,

85.49 ft/sec $[(lb/lb\text{-}mole)\ (in.\ Hg)\ /\ (°R)\ (inc.\ H_2O)]^{1/2}$

M_n = Total amount of particulate matter collected, mg

M_d = Molecular weight of stack gas; dry basis, lb/lb-mole

M_s = Molecular weight of stack gas; wet basis, lb/lb-mole

P_{bar} = Barometric pressure at the sampling site, in. Hg

P_m = Meter pressure, in. Hg

P_s = Absolute stack pressure, in. Hg

P_g = Stack static pressure, in H_2O

P_{std} = Standard absolute pressure, 29.92 in. Hg

PMR = Particulate mass rate, lb/hr

Q_a = Volumetric flow rate, ACFM

Q_s = Volumetric flow rate, SDCFM

Input and Constants

```
              3
     9820 ft
f := --------
      mm btu

pg := -(1.1 in. H2O)

pbar := 29.5 in. Hg.

Δhavg := 1.009 in. H2O

y := 1.012

tm := 77.8 °F

o2 := 12.

co2 := 6.

                 3
vm := 34.366 ft

vlc := 83.6 ml

theta := 60 min

nozdia := 0.404 in.

ts := 526.7 °F

                 2
as := 50.266 ft

mn := 82.8 mg

numberofpoints := 12

                        0.5
sqrtΔp := 0.267 in. H2O

                         lb in. Hg.     0.5
      85.49 1 ft 1 (------------------)
                     lb-mole °R in. H2O
kp := ------------------------------------
                     1 sec

cp := 0.84

      17.64 °R
k1 := --------
      in. Hg.
```

$$ts = \frac{(ts + 460\ {}^\circ F)\ {}^\circ R}{{}^\circ F}$$

$986.7\ {}^\circ R$

$$tm = \frac{(tm + 460\ {}^\circ F)\ {}^\circ R}{{}^\circ F}$$

$537.8\ {}^\circ R$

$$n2 = 100 - o2 - co2$$

82.

$$an = \frac{nozdia^2\ 3.1416}{4\left(\frac{12\ in.}{ft}\right)^2}$$

$0.000890207\ ft^2$

Calculations

Equation 1

$$ps = pbar + \frac{pg}{\dfrac{13.6\ \text{in. H2O}}{1\ \text{in. Hg.}}}$$

29.4191 in. Hg.

Equation 2

$$pm = pbar + \frac{\Delta havg}{\dfrac{13.6\ \text{in. H2O}}{\text{in. Hg.}}}$$

29.5742 in. Hg.

Equation 3

$$vmstd = \frac{k1\ vm\ y\ \left(pbar + \dfrac{\Delta havg}{\dfrac{13.6\ \text{in. H2O}}{\text{in. Hg.}}}\right)}{tm}$$

$33.7365\ ft^3$

Equation 4

$$vwstd = \frac{0.04707\ ft^3\ \ vlc}{ml}$$

$3.93505\ ft^3$

Equation 5

$$bws = \frac{vwstd}{vmstd + vwstd}$$

0.104457

Equation 6

$$md = \frac{(0.44\ co2 + 0.32\ o2 + 0.28\ n2)\ lb}{lb\text{-}mole}$$

$$\frac{29.44\ lb}{lb\text{-}mole}$$

Equation 7

$$ms = md\ (1 - bws) + \frac{bws\ 18\ lb}{lb\text{-}mole}$$

$$\frac{28.245\ lb}{lb\text{-}mole}$$

Equation 8

$$vs = kp\ cp\ \mathrm{sqrt}\Delta p \left(\frac{ts}{ms\ ps}\right)^{0.5}$$

$$\frac{20.8936\ ft}{sec}$$

Equation 9

$$qa = \frac{vs\ as\ 60\ sec}{min}$$

$$\frac{63014.2\ ft^{3}}{min}$$

Equation 10

$$qs = \frac{qa\ (1 - bws)\ 528\ ^{\circ}R\ ps}{ts\ 29.92\ in.\ Hg.}$$

$$\frac{29692.2\ ft^{3}}{min}$$

Equation 11

$$cs = \frac{0.0154\ gr\ mn}{mg\ vmstd}$$

$$\frac{0.0377964\ gr}{ft^{3}}$$

Equation 12

$$pmr = \frac{cs\ qs\ 60\ min}{hour\ \frac{7000\ gr}{lb}}$$

$$\frac{9.61935\ lb}{hour}$$

Equation 13

$$e = \frac{cs\ f\ 20.9\ 1\ lb}{(20.9 - o2)\ 7000\ gr}$$

$$\frac{0.124515\ lb}{mm\ btu}$$

Equation 14

$$vn = \frac{ts\ \left(\frac{0.002669\ in.\ Hg.\ ft^{3}\ vlc}{ml\ {}^{\circ}R} + \frac{vm\ y\ pm}{tm}\right)}{ps}$$

$$71.6277\ ft^{3}$$

Equation 15

$$i = \frac{100\ \%\ vn}{\frac{60\ sec\ theta\ vs\ an}{min}}$$

106.973 %

Equation 16

$$hi = \frac{pmr}{e}$$

$$\frac{77.2547\ mm\ btu}{hour}$$

APPENDIX C: CALIBRATIONS

INITIAL
METER CALIBRATION FORM - DGM

DATE: 08-12-91 Box No. D-460

Ref. DGM Ser. # 1044453 Calibrated By JACK COVINGTON

RUN #	1	2	3	4	5
DELTA H (DGM)	0.50	1.00	1.50	2.00	3.00
Y (Ref. DGM)	1.00	1.00	1.00	1.00	1.00
Reference DGM					
Gas Vol. Initial	130.000	139.200	166.200	173.900	180.300
Gas Vol. Final	138.300	165.500	173.000	179.400	186.000
Meter Box DGM					
Gas Vol. Initial	345.275	354.595	382.075	389.900	396.375
Gas Vol. Final	353.675	381.360	388.995	395.465	402.082
Reference DGM					
Temp.	Avg.	Avg.	Avg.	Avg.	Avg.
Deg F Initial	86	87	88	88	90
Deg F Final	87	88	88	89	90
Meter Box DGM					
Temp. Initial In	94	100	107	110	111
Temp. Initial Out	92	97	104	104	105
Temp. Final In	100	107	108	110	111
Temp. Final Out	97	104	104	105	105
P Bar IN. Hg	30.17	30.17	30.17	30.17	30.17
Time (sec.)	1221	2783	594	416	354
Meter Calibration Factor (Y)	1.004	1.006	1.011	1.017	1.024
Qm (C.F.M.)	0.397	0.551	0.667	0.770	0.935
Km (Std Pressure)	0.706	0.689	0.679	0.678	0.673
DELTA Ha	1.70	1.75	1.78	1.78	1.81
Average Y (Meter Calibration Factor				1.012	
Average Km (Standard Pressure)				0.685	
Average DELTA Ha of Orifice				1.76	

FINAL
METER CALIBRATION FORM - DGM

DATE: 09-26-91 Box No. D-460

Ref. DGM Ser. # 1044456 Calibrated By PAUL MATTHEWS

RUN #	1	2	3
DELTA H (DGM)	1.0	1.0	1.0
Y (Ref. DGM)	1.000	1.000	1.000
Reference DGM			
Gas Vol. Initial	50.000	56.000	62.000
Gas Vol. Final	56.000	62.000	68.000
Meter Box DGM			
Gas Vol. Initial	456.970	462.980	468.990
Gas Vol. Final	462.980	468.990	475.030
Reference DGM			
Temp.	Avg.	Avg.	Avg.
Deg F Initial	74	74	74
Deg F Final	74	74	74
Meter Box DGM			
Temp. Initial In	81	85	86
Temp. Initial Out	77	81	82
Temp. Final In	85	86	87
Temp. Final Out	81	82	84
P Bar IN. Hg	29.90	29.90	29.90
Time (sec.)	628	630	630
Meter Calibration Factor (Y)	1.009	1.014	1.011
Qm (C.F.M.)	0.567	0.565	0.565
Km (Std Pressure)	0.718	0.714	0.713
DELTA Ha	1.71	1.71	1.71

Average Y (Meter Calibration Factor)	1.011
Initial Y (Meter Calibration Factor)	1.012
Percent Error	0.10%
Average Km (Standard Pressure)	0.715
Average DELTA Ha of Orifice	1.71

MAGEHELIC CALIBRATION

SER. NO.	10720-AB68	R1061-6AG48	R5031-SEB76	R1062-9JA82	R1051-3MR42	R1071-JA8
RANGE	0-.25	0-.50	0-2	0-5	0-10	0-25
REFERENCE READING	BOX #1	FIELD DEVICE READING				
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.05	0.05					
0.10	0.110	0.11				
0.200	0.210	0.210				
0.400		0.400				
0.500			0.500			
1.000			0.990	1.000		
1.500			1.490			
2.000				2.000	2.000	
3.500				3.490		
5.000					4.800	5.000
8.00					7.80	
10.00						10.00
20.00						19.95

DATE: 07-08-91 **SIGNATURE:** Robert Richman

MAGNEHELIC CALIBRATION

Ser. No.	10819-DR2	R1090-2AG18	R50315-EB93	R1062-9TA87	30830-AM79	R1072-2MC5	
Range	0-.25	0-.5	0-2	0-5	0-10	0-25	
Reference Reading	**Box #2**	**Field Device Reading**					
0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.05	0.05						
0.10	0.10	0.10					
0.20	0.20	0.20					
0.40		0.40					
0.50			0.50				
1.00			1.00	0.92			
1.50			1.49				
2.00				1.90	2.00		
3.50				3.40			
5.00					4.95	4.80	
8.00					8.05		
10.00						10.20	
20.00						20.20	

Date: 7-8-91 **Signature:** Robert Richman

MAGNEHELIC CALIBRATION
BOX #3

SERIAL NO.	R10831CF30		R01126TC2		R10608CF14	
RANGE	0 - 0.5		0 - 2		0 - 10	
* REFERENE READING TAKEN FROM OIL GAGE MANOMETER						
	* REF.	ACTUAL	* REF.	ACTUAL	* REF.	ACTUAL
	0.50	0.50	2.00	1.99	10.0	10.0
	0.30	0.29	1.50	1.49	8.00	8.00
	0.20	0.20	1.00	0.99	5.00	5.00
	0.10	0.09	0.50	0.49	2.00	2.00
	0.00	0.00	0.00	0.00	0.00	0.00

DATE: 7-8-91

SIGNATURE: Robert Richman

MAGNEHELIC CALIBRATION
BOX #5

SERIAL NO.	R900723MRR1		R901003CD87		R901119RR106	
RANGE	0 - 0.5		0 - 5		0 - 25	
* REFERENE READING TAKEN FROM OIL GAGE MANOMETER						
	*REF.	ACTUAL	*REF.	ACTUAL	*REF.	ACTUAL
	0.50	0.49	5.00	5.00	20.0	20.0
	0.30	0.30	3.00	2.95	15.0	15.0
	0.20	0.20	2.00	1.95	10.0	10.0
	0.10	0.09	1.00	1.00	5.00	5.00
	0.00	0.00	0.00	0.00	0.00	0.00

DATE: 7-8-91

SIGNATURE: Robert Richman

MAGNEHELIC CALIBRATION
BOX #4

SERIAL NO.	R900723MRR40		R900516GT21		R901015CD102	
RANGE	0 - 0.5		0 - 5		0 - 25	
* REFERENE READING TAKEN FROM OIL GAGE MANOMETER						
	* REF.	ACTUAL	* REF.	ACTUAL	* REF.	ACTUAL
	0.40	0.40	3.50	3.45	20.0	20.0
	0.20	0.20	2.00	1.98	10.0	10.0
	0.10	0.10	1.00	1.03	5.00	5.05
	0.000	0.000	0.00	0.00	0.00	0.00
	0.000	0.000	0.00	0.00	0.00	0.00

DATE: 7-8-91

SIGNATURE: Robert Richman

MAGNEHELIC CALIBRATION

BOX #	D-460 R01123TC2		C-133		C-173 R10608CF14		C-175 R10831CF80	
SER. NO.	91127WW137		91126AM91		R20208A617		R01126YC2	
RANGE	0-2	0-5	0-2	0-5	0-2	0-4	0-2	0-4
REFERENCE READING	FIELD DEVICE READING							
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.50	0.50	0.00	0.50	0.00	0.51	0.00	0.00	0.00
1.00	0.99	0.00	0.99	0.00	1.01	0.00	0.00	0.00
1.75	1.74	0.00	1.77	0.00	1.73	0.00	0.00	0.00
3.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DATE: 07-08-91

SIGNATURE: Robert Richman

TEMPERATURE CALIBRATIONS - DEGREES FAHRENHEIT

REFERENCE DEVICE READING*	Date Calibrated	0 DEG. F	210 DEG.	420 DEG.	630 DEG.	840 DEG.	1050 DEG.	1260 DEG.	1470 DEG.	1680 DEG.	1900 DEG.
METER BOX C-133 11580	07-09-91	0	209	412	626	836	1048	1260	1467	1680	1905
METER BOX C-175 15962	06-16-91	0	208	415	622	831	1041	1251	1457	1674	1901
METER BOX C-173 S11-24	06-15-91	2	211	419	627	836	1047	1258	1465	1680	1906
METER BOX D-460 15751	06-16-91	0	208	418	624	834	1046	1256	1463	1675	1901
METER BOX 2879	06-21-91	0	211	421	631	840	1050	1260	1471	1681	1901
PORTABLE THERMOCOUPLE # 1 249662	07-08-91	-2	209	418	631	839	1049	1258	1469	1680	1900
PORTABLE THERMOCOUPLE # 2 T-05792	07-08-91	2	211	419	630	847	1060	1284	1489	1707	1918
PORTABLE THERMOCOUPLE #3 T-61422	07-08-91	1	208	415	625	840	1057	1272	1482	1685	1894

SIGNATURE: Robert Richman

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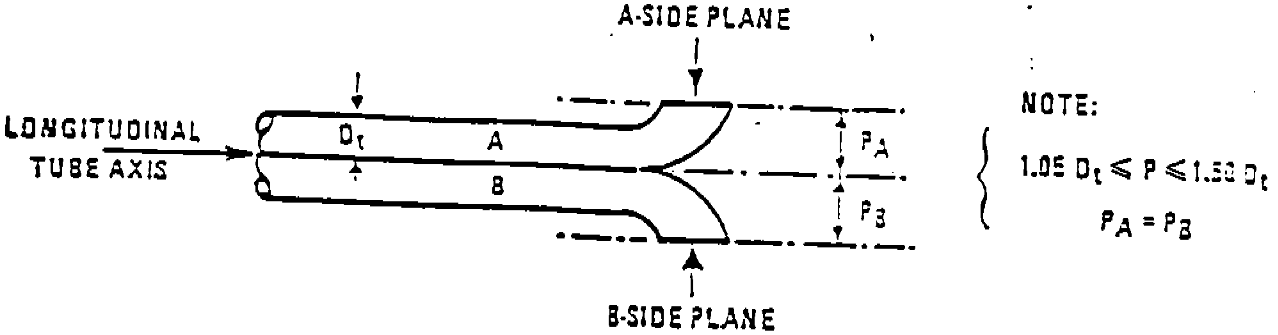
* Reference Device is an Omega Engineering CL505-A calibrated reference thermocouple-potentiometer system.

The Pitot used was within the following geometric specifications:

$C_p = 0.84$



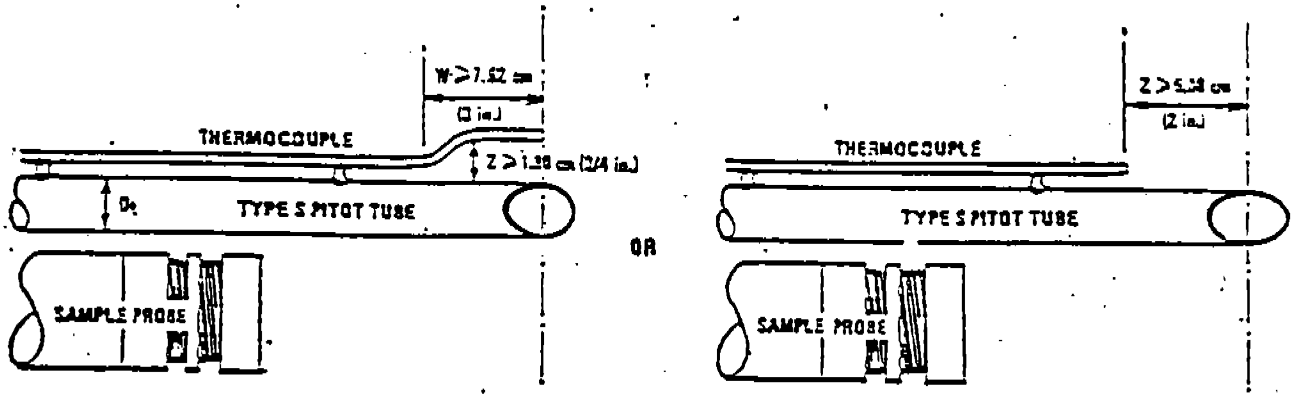


Figure 2-7. Proper thermocouple placement to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

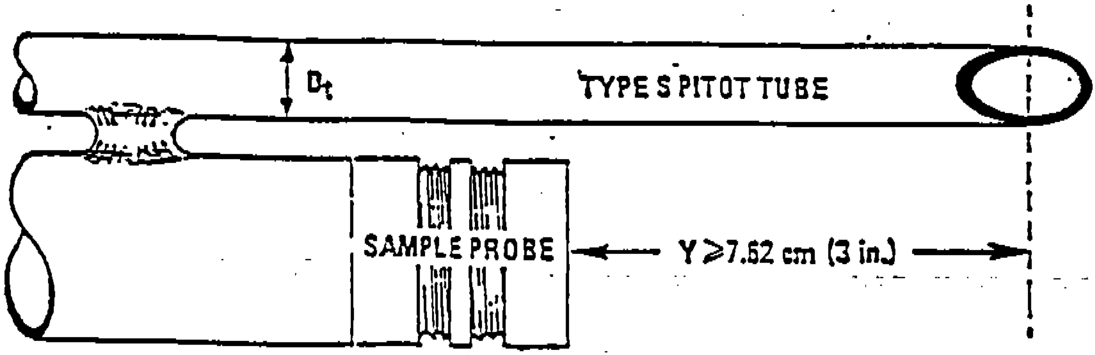
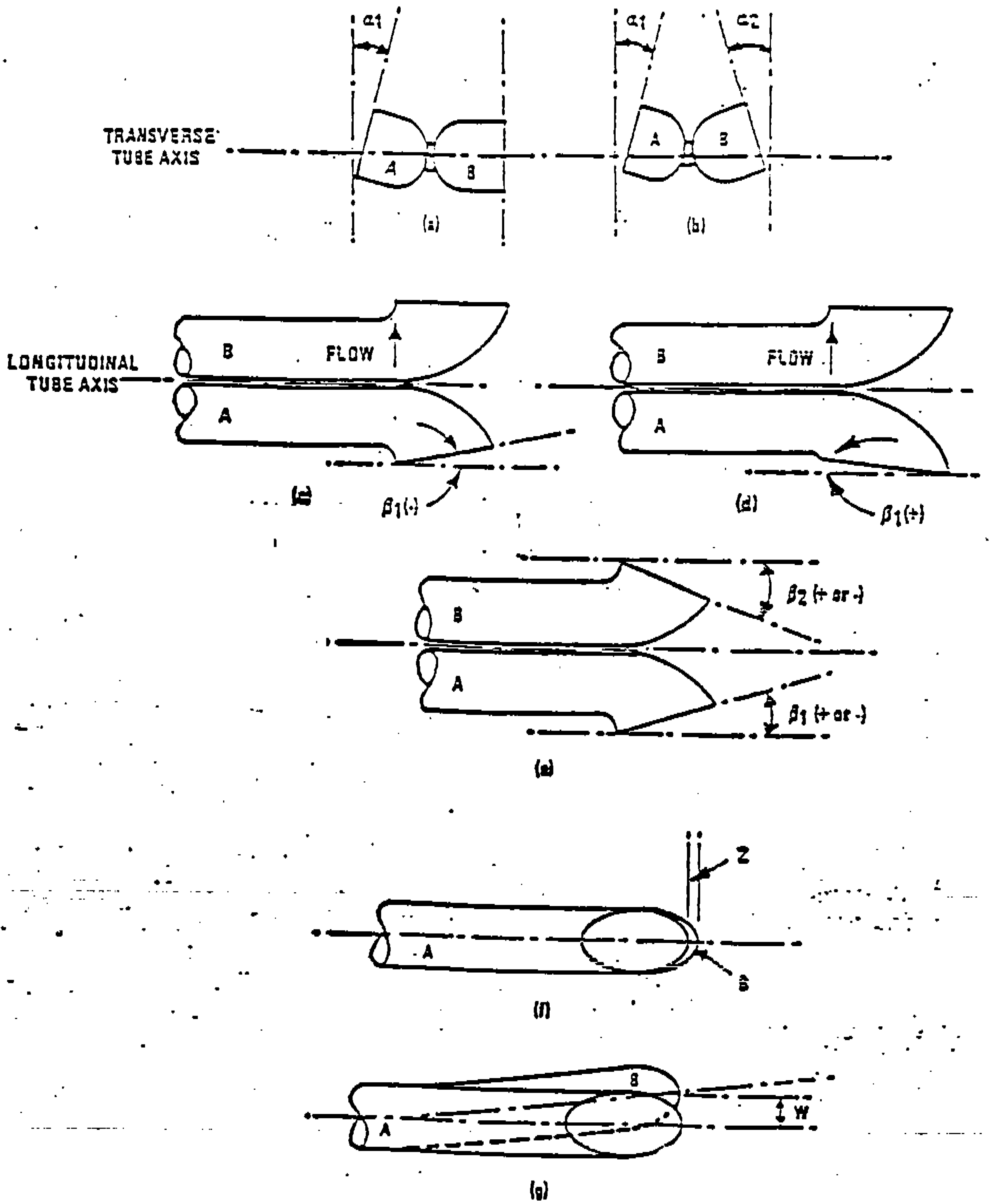
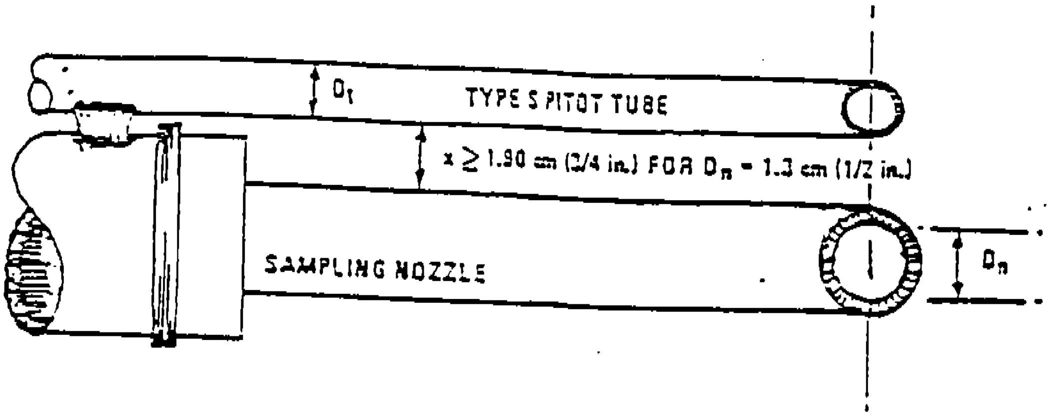


Figure 2-8. Minimum pitot-sample probe separation needed to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

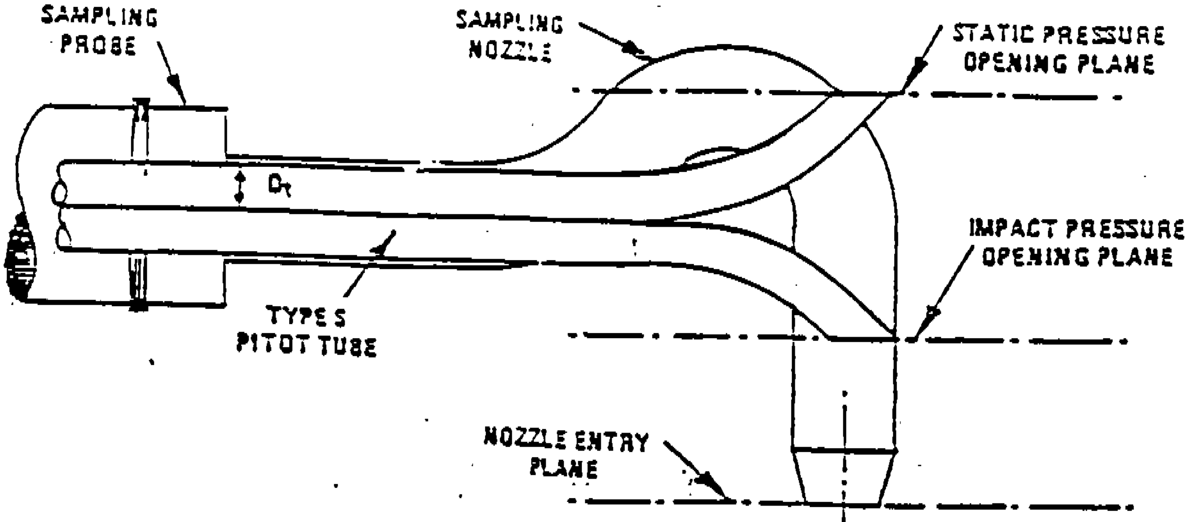
PITOT CALIBRATIONS



Types of face-opening misalignment that can result from field use or improper construction of Type S pitot tubes. These will not affect the baseline value of $\bar{C}_p(s)$ so long as α_1 and $\alpha_2 < 10°$, β_1 and $\beta_2 < 5°$. $z < 0.32$ cm (1/8 in.) and $w < 0.08$ cm (1/32 in.) (citation 11 in Section 6).



A. BOTTOM VIEW: SHOWING MINIMUM PITOT-NOZZLE SEPARATION.



B. SIDE VIEW: TO PREVENT PITOT TUBE FROM INTERFERING WITH GAS FLOW STREAMLINES APPROACHING THE NOZZLE, THE IMPACT PRESSURE OPENING PLANE OF THE PITOT TUBE SHALL BE EVEN WITH OR ABOVE THE NOZZLE ENTRY PLANE.

Proper pitot tube - sampling nozzle configuration to prevent aerodynamic interference; buttonhook - type nozzle; centers of nozzle and pitot opening aligned; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).