

# MRI REPORT

SOURCE TESTING--EPA TASK NO. 9

STANDARD OIL COMPANY  
El Segundo, California

by

E. P. Shea

MIDWEST RESEARCH INSTITUTE  
Kansas City, Missouri 64110

EPA Contract No. 68-02-0228  
(MRI Project No. 3585-C)



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72-PC-10

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## II. INTRODUCTION

Under the Clean Air Act of 1970, as amended, the Environmental Protection Agency is charged with the establishment of performance standards for stationary source categories which may contribute significantly to air pollution. A performance standard is a standard for emissions of air pollutants which reflects emission limitations attainable through the best emission reduction systems that have been adequately demonstrated (taking into account economic considerations).

The development of realistic performance standards requires accurate data on pollution emissions within the various source categories. Sampling and analytical techniques had to be developed to acquire the data. A method for analysis of carbon monoxide (CO) from CO boilers is needed for the petroleum refining industry. The nondispersive infrared analyzer (NDIR) for very low concentrations of carbon monoxide is an instrument that can be used. However, carbon dioxide (CO<sub>2</sub>) interferes in this analysis. This report presents the results of the tests run at Standard Oil of California's El Segundo plant for EPA for its determination of: (1) the applicability of the NDIR to CO analysis, and (2) interference from CO<sub>2</sub> in the range of concentrations normally encountered in a CO boiler stack.

Appendix A presents a proposed method developed by EPA to sample and analyse for CO. This method, with modifications, was applied for these tests. MRI did not attempt to concentrate on comprehensive method refinement. Rather, using mutually accepted modifications, we collected samples

persuant to the method and analyzed them. Our comments are limited to observations in using the method and on potential variations detected between runs.

On Monday, 27 March 1972, the equipment was shipped to California and E. P. Shea (MRI) and W. E. Kelly (EPA) arrived to transport the equipment to the El Segundo refinery and do the test work. Tuesday, the 28th of March, the equipment was delivered to the test site and preparations made for sampling and analysis. A preliminary velocity and temperature profile was obtained for reference with earlier traverse results, and the NDIR was calibrated for use.

Four independent integrated gas samples were collected in Tedlar\* bags on 29 March, and again on 30 March 1972. The samples are identified as Runs 1 through 8. The samples were analyzed in the field on the same dates. An S shaped pitot tube with a thermocouple installed on it was used for velocity and temperature measurements.

Samples were collected from a port 55 ft above the inlet breeching in a stack with an inside diameter of 13 ft 10 in. A 5-ft, glass-lined probe was used to withdraw gas samples from the CO boiler stack into an integrated gas bag. The sampling point was 42 in. from the inside wall of the stack, and was located at 90 degrees from the inlet breeching.

The following sections of the report treat: (1) the summary of results; (2) the description of sampling and analytical procedures; (3) the location of sampling point; and (4) process operating conditions.

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\* Mention of a specific company or product does not constitute endorsement by EPA.

### III. SUMMARY OF RESULTS

Table I presents a summary of results from the CO and CO<sub>2</sub> analysis. There were a total of eight sampling and analytical runs. Table II shows the results of the velocity and temperature profiles. The following discussion presents characteristics of each sample run. Results between runs cannot be accurately compared since process variations are undefined; however, we present variations.

Table I contains the calculated values for gas volume sampled by the NDIR, the volume of CO<sub>2</sub> trapped by the ascarite, total sample volume analyzed, the concentration of carbon monoxide, the percent CO<sub>2</sub> obtained from the absorption of ascarite and by Orsat analysis, and the concentration of CO unscrubbed. The data are presented by run number and by date. The volume analyzed on the first day varied from 0.168 to 0.520 dry standard\* cubic feet. The volume varied according to the length of time for analysis. Run No. 1 only lasted 7 min and 0.168 dscf was analyzed. The other runs lasted from 22 to 31 min and volume varied from 0.405 dscf to 0.520 dscf. The volume of CO<sub>2</sub> varied from 0.0036 dscf on Run No. 1 to 0.0935 dscf on Run No. 3. Run No. 1 was too short and the results for CO<sub>2</sub>, (2.1%) illustrate it. On Run No. 3, water was not put into the ice bath and the ascarite heated up. The results for CO<sub>2</sub> (18.8%) and CO (23.6 ppm) for this run show the need for the ice water bath in removing the heat generated in the absorption of CO<sub>2</sub> by the caustic in the ascarite.

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\* 70°F, 29.92 in. Hg

TABLE I

SUMMARY OF RESULTS WITH SAMPLE CALCULATIONS

Run No.	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>
Date	3/29/72	3/29/72	3/29/72	3/29/72	3/30/72	3/30/72	3/30/72	3/30/72
V <sub>MC</sub> std dcf	0.168	0.515	0.405	0.520	0.278	0.282	0.260	0.198
V <sub>CO<sub>2</sub></sub> std dcf	0.0036	0.0423	0.0935	0.0648	0.039	0.0649	0.0648	0.0202
V <sub>S</sub> std dcf	0.1716	0.5573	0.4985	0.5848	0.3165	0.3469	0.3243	0.2182
C <sub>CO</sub> ppm	12.25	11.6	23.6	11.6	4.4	5.7	7.2	5.4
% CO <sub>2</sub>	2.1	7.6	18.8	11.1	12.3	18.7	12.7	9.3
% CO <sub>2</sub> Orsat	--	--	--	--	12.4	9.4	13.6	13.6
C <sub>CO</sub> (unscrubbed sample) ppm	--	17.6	--	17.4	16.2	12.2	16.0	14.5
Δ wta grams	0.2001	2.4092	5.2301	3.6102	2.1789	3.6140	2.1023	1.124

Sample Calculations, Run No. 2:

Standard conditions 70°F and 29.92 in. Hg (dry).

## 1. Gas volume

$$V_{MC} = V_M \left( \frac{P_M}{P_{STD}} \right) \left( \frac{T_{STD}}{T_M} \right) = 17.71 \frac{^{\circ}R}{\text{in. Hg}} \left( \frac{V_M \text{ cu ft } P_M \text{ in. Hg}}{T_M ^{\circ}R} \right)$$

$$V_{MC} = 17.71 \frac{^{\circ}R}{\text{in. Hg}} \left( \frac{0.5235 \text{ cu ft } 29.97 \text{ in. Hg}}{540^{\circ}R} \right) = 0.515 \text{ dscf}$$

## 2. Volume of carbon dioxide collected

$$V_{CO_2} = 0.01797 \Delta wta$$

$$V_{CO_2} = 0.01797 \frac{\text{cu ft}}{\text{g}} \times 2.4092 \text{ g} = 0.0423 \text{ dscf}$$



TABLE I (Continued)

## 3. Sample volume

$$V_S = V_{MC} + V_{H_2O} + V_{CO_2} \quad \text{Assume } V_{H_2O} = 0$$

$$V_S = 0.515 \text{ dscf} + 0.0423 \text{ dscf} = 0.5573 \text{ dscf}$$

## 4. Concentration of carbon monoxide

$$C_{CO_s} = C_{COM} \left( \frac{V_{MC}}{V_S} \right)$$

$$C_{CO_s} = 12.5 \text{ ppm} \times \frac{0.515 \text{ dscf}}{0.5573 \text{ dscf}} = 11.6 \text{ ppm}$$

## 5. Percent carbon dioxide

$$\% CO_2 = \left( \frac{V_{CO_2}}{V_{MC} + V_{CO_2}} \right) \times 100$$

$$\% CO_2 = \frac{0.0423 \text{ dscf} \times 100}{0.5150 \text{ dscf} + 0.0423 \text{ dscf}} = 7.6\%$$

## 6. Concentration of CO in the unscrubbed sample

$$C_{CO} = C_{COM} \text{ (U.S.)} \times \left( \frac{V_{MC}}{V_S} \right)$$

$$C_{CO} = 19.0 \text{ ppm} \times \frac{0.515 \text{ dscf}}{0.5573 \text{ dscf}} = 17.6 \text{ ppm}$$

- $V_{MC}$  = Dry gas volume through meter at standard conditions cu ft (DSCF)  
 $V_M$  = Dry gas volume measured by meter cu ft (DCF)  
 $P_M$  = Barometric pressure at dry gas meter in. Hg.  
 $P_{STD}$  = Pressure at standard conditions 29.92 in. Hg.  
 $T_{STD}$  = Absolute temperature at standard conditions, 530°R.  
 $T_M$  = Absolute temperature at meter °R.  
 $V_S$  = Volume of sample at standard conditions (DSCF).  
 $C_{CO_s}$  = Concentration of CO in sample ppm by volume.  
 $C_{CO_m}$  = Concentration of CO measured by NDIR Analyzer ppm by volume.  
 $V_{CO_2}$  = Volume of  $CO_2$  collected at standard conditions cu ft dry.  
 $\Delta wta$  = Weight change in ascarite impinger in grams.  
 $C_{COM} \text{ (U.S.)}$  = Concentration of CO measured by NDIR analyzer ppm by volume, unscrubbed.

TABLE II

STACK VELOCITY AND TEMPERATURE\*

<u>Run No.</u>	<u>Date</u>	<u><math>\Delta P</math> Avg. in. H<sub>2</sub>O</u>	<u><math>\sqrt{\Delta P}</math> Avg. in. H<sub>2</sub>O</u>	<u>T<sub>S</sub> Avg. °R</u>	<u>V<sub>S</sub> (ft/min)</u>	<u>Port</u>
Special	3/28/72	0.445	0.676	1237	3,630	W
5 and 6	3/30/72 (a.m.)	0.313	0.555	1233	3,000	N
7 and 8	3/30/72 (p.m.)	0.306	0.554	1225	2,970	N

Equation

$$V_S \text{ Avg (fpm)} = K_p C_p \left( \sqrt{\Delta P \text{ Avg}} \right) \sqrt{\frac{T_S \text{ Avg}}{P_S M_S}} \times \text{sec/min}$$

$$K_p = 85.48 \text{ ft/sec} \left( \frac{\text{lb}}{\text{lb mol } ^\circ\text{R}} \right)^{1/2}$$

$$C_p = 0.85 \text{ (pitot coefficient)}$$

$$M_S = 27.1 \text{ lb/lb-mole}$$

$$P_S = 29.93 \text{ in. Hg}$$

\* Federal Register, 23 December 1971, p. 24884, Method 2.

The values for CO in Runs Nos. 1, 2 and 4 are very close: 12.25, 11.6 and 11.6 ppm. The unscrubbed values for CO in Runs Nos. 2 and 4 show the CO<sub>2</sub> contributed about 6 ppm to the CO reading on the NDIR.

The results for the second day of sampling for CO show a variation of 4.4 ppm to 7.2 ppm CO. The CO<sub>2</sub> results from the absorption of ascarite are close except for Run No. 6 (18.7%); they vary from 9.3% to 12.7%. The unscrubbed CO values are reasonably close for the four runs on the second day with the exception of Run No. 6. They show an average CO<sub>2</sub> contribution to the NDIR reading for CO of about 10 ppm. The values range from approximately 7 to 12 ppm. The Orsat results for CO<sub>2</sub>, with the exception of Run No. 6, are reasonably close. The average CO<sub>2</sub> concentration for Runs Nos. 5 (12.4%), 7 and 8 (13.6%) is 13.2%. While performing the Orsat analysis in Run No. 6, the bag was ruptured by excessive pressure. This bag was discarded and a new one installed in the holder before collecting Samples Nos. 7 and 8.

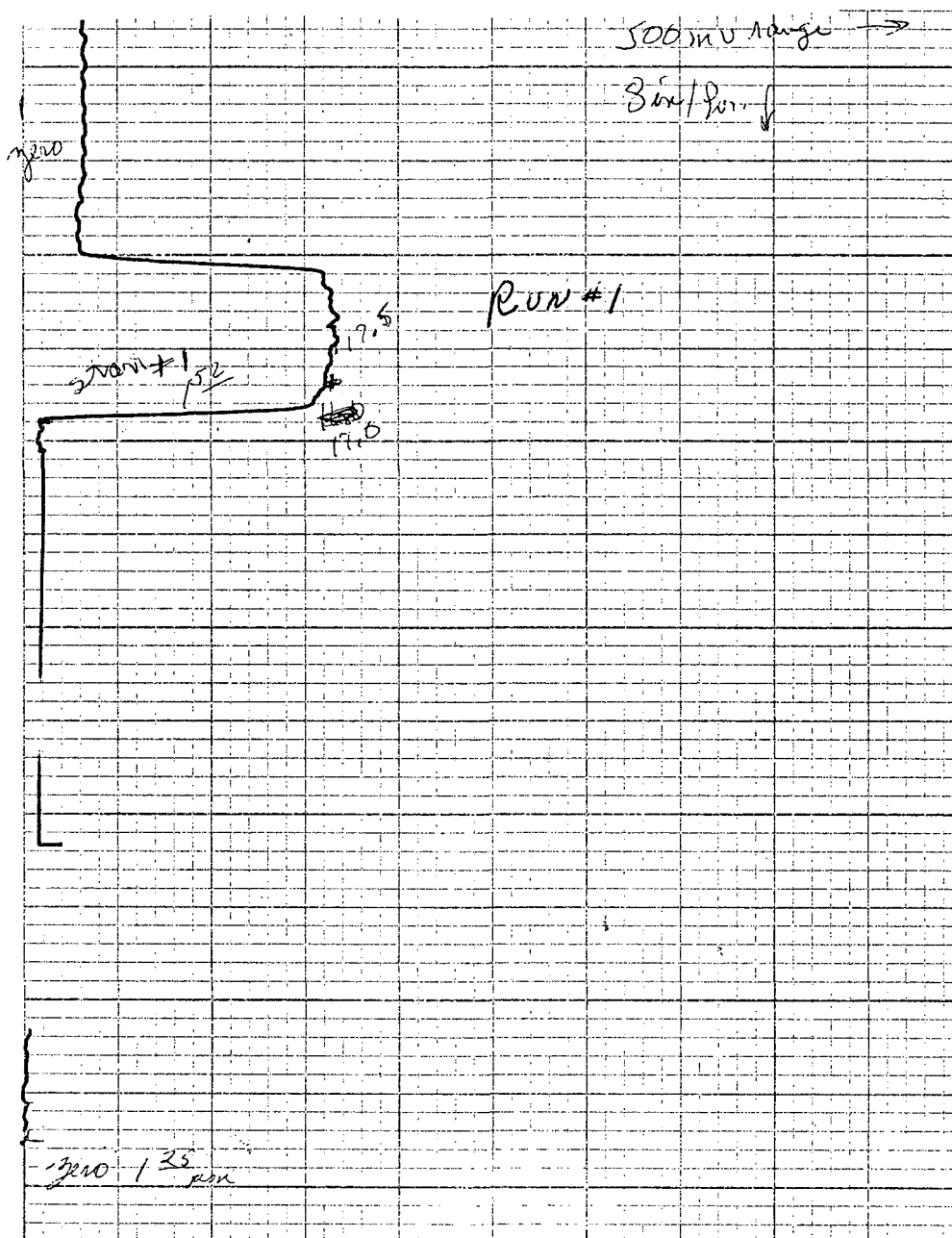
The velocity of the stack gas in Table II varies from 2,970 fpm to 3,630 fpm with an average of 3,200 fpm and the temperature varies from 1225°R to 1237°R with an average of 1232°R.

In Runs Nos. 2 through 8, the ascarite impinger was removed after analyzing the gas stream for CO and the gas passed through the rest of the equipment to assess the effect of CO<sub>2</sub> on the NDIR results. Figures 1 through 8 are the charts from the recorder for each run. The field data sheets

corresponding to the recorder charts are presented in Appendix B. The numbers on the chart (Figure 1), 17.0 and 17.5 are the NDIR readings from the data sheet. The NDIR reading in the field data sheet is taken directly from the indicator on the NDIR. In Run No. 1 the data sheet shows that a steady reading was reached after 3 min and the reading used for calculation of ppm CO was an average taken after steady state was reached.

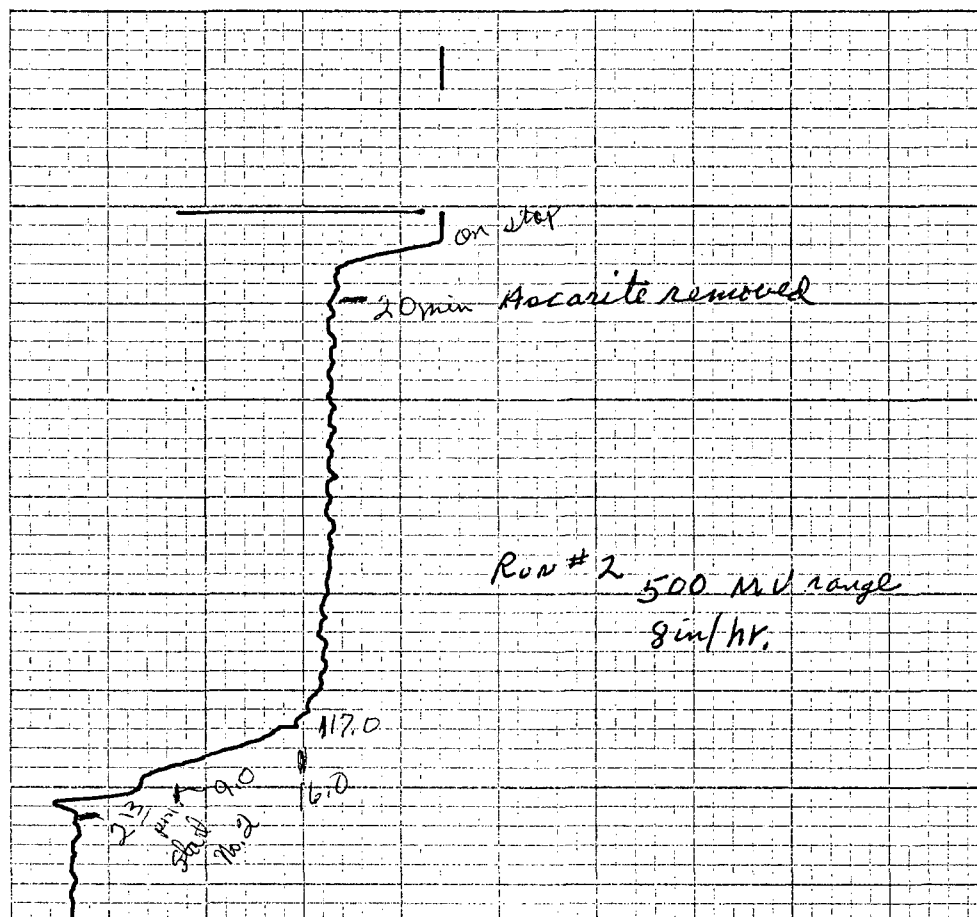
In Runs Nos. 1, 2, 5, 6 and 7, examination of the recorder charts and field data sheets show that a constant reading was obtained after 3 to 5 min. Run No. 8 took about 9 min to reach a constant reading, but the rotameter reading for this run was 8 instead of 14 and less total sample was employed to obtain a steady reading. Run No. 3 was started without purging all lines with nitrogen and with no water in the ice water cooling bath for the ascarite and silica gel. This run, after 7 min, was stopped, everything purged with nitrogen and then restarted. This run gave results that do not correlate with the data from the other runs.

The NDIR value for Run No. 4 steadily increased for 20 min indicating that the ascarite was not doing an efficient job of scrubbing out the CO<sub>2</sub>. The calculated values for CO and CO<sub>2</sub> for Runs Nos. 2 and 4 are comparable. Examination of Figures 2 to 8 and the corresponding field data sheets in Appendix B shows that with the exception of Run No. 3 all readings without ascarite scrubbing reached a steady state after 2 min. The reading was an average after steady state was obtained. The readings for Run No. 3 are unexplainable.



HEWLETT-PAC

Figure 1 - Run No. 1

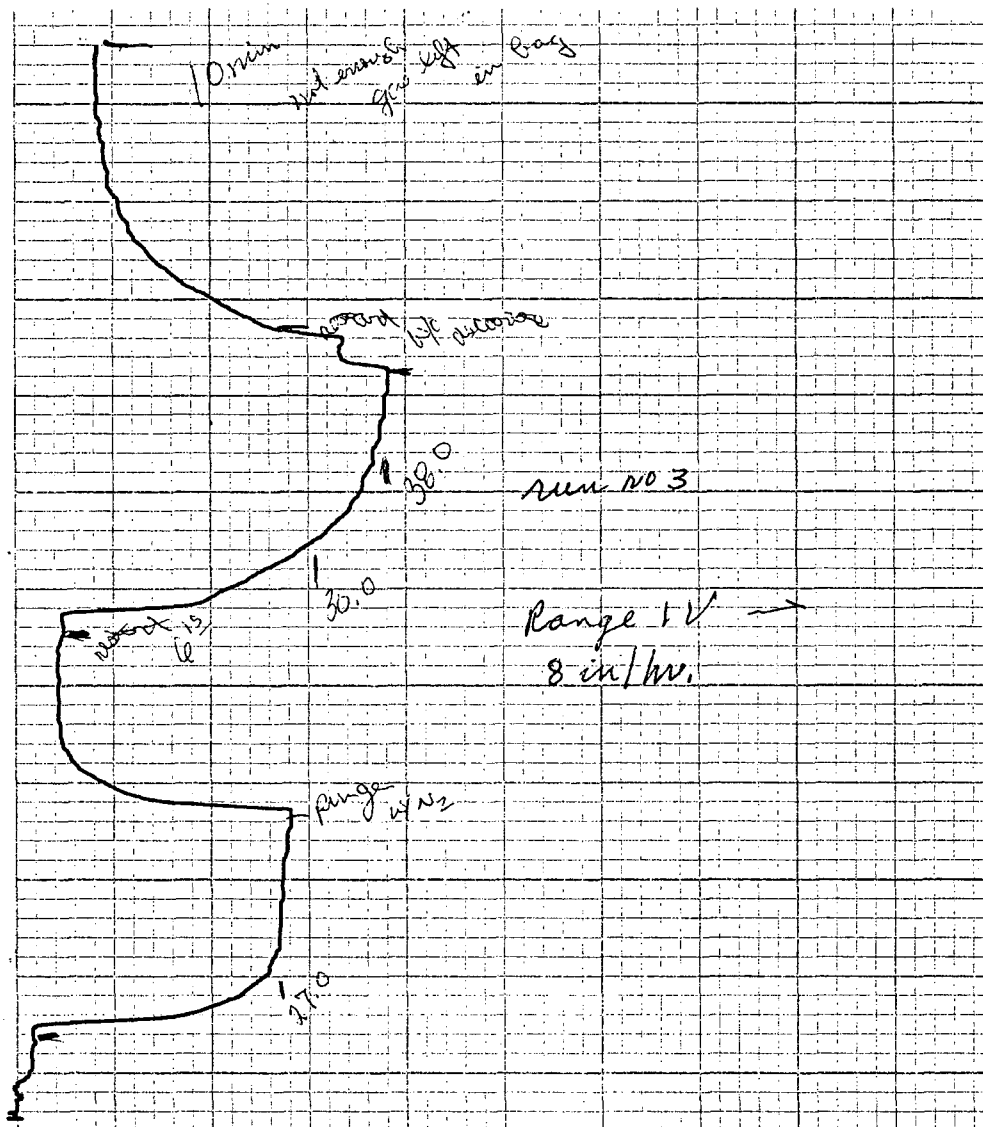


910

S27C-1012

KARD/MOSELEY DIVISION

Figure 2 - Run No. 2



910

5270.1012

WILETT-PACKARD/MOSELEY DIVISION

Figure 3 - Run No. 3

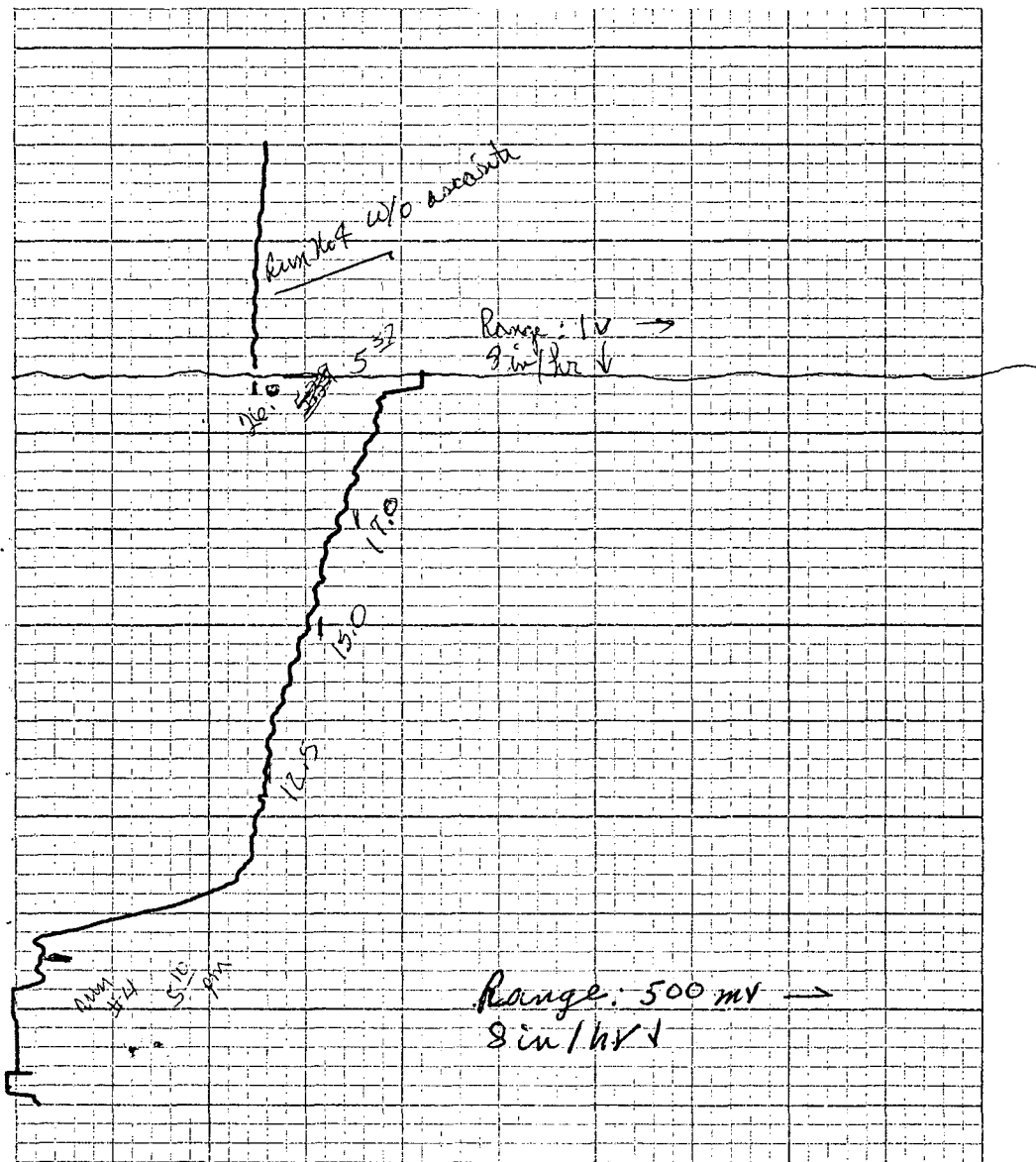


Figure 4 - Run No. 4



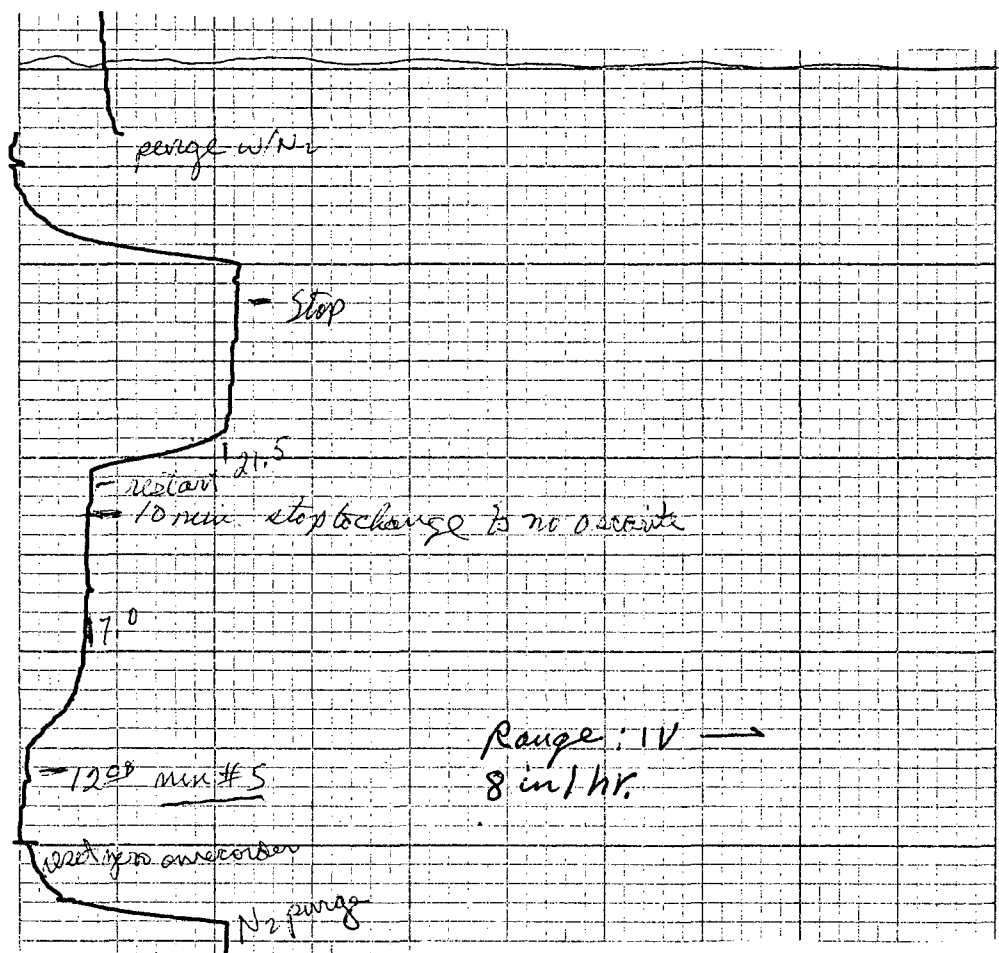
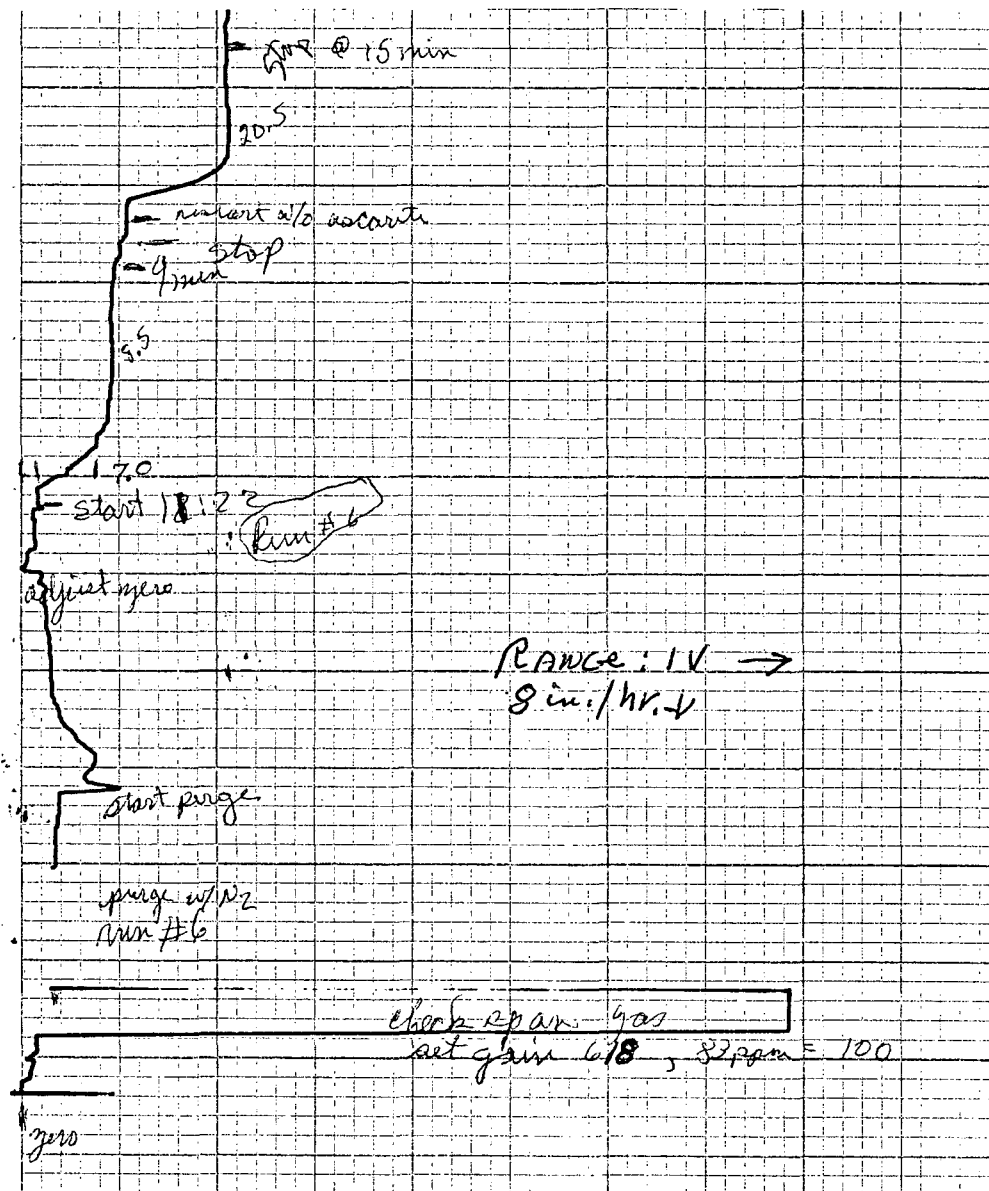


Figure 5 - Run No. 5



910

9270-1012

HEWLETT-PACKARD/MOSELEY DIVISION

Figure 6 - Run No. 6

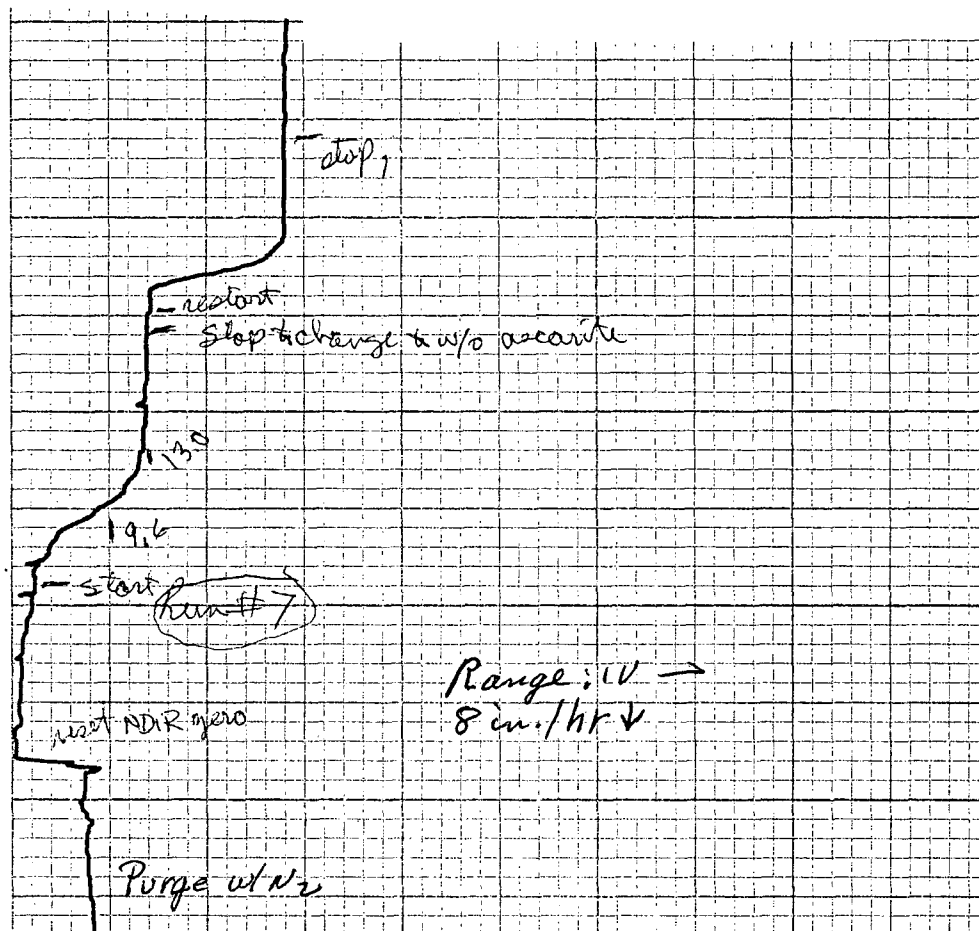
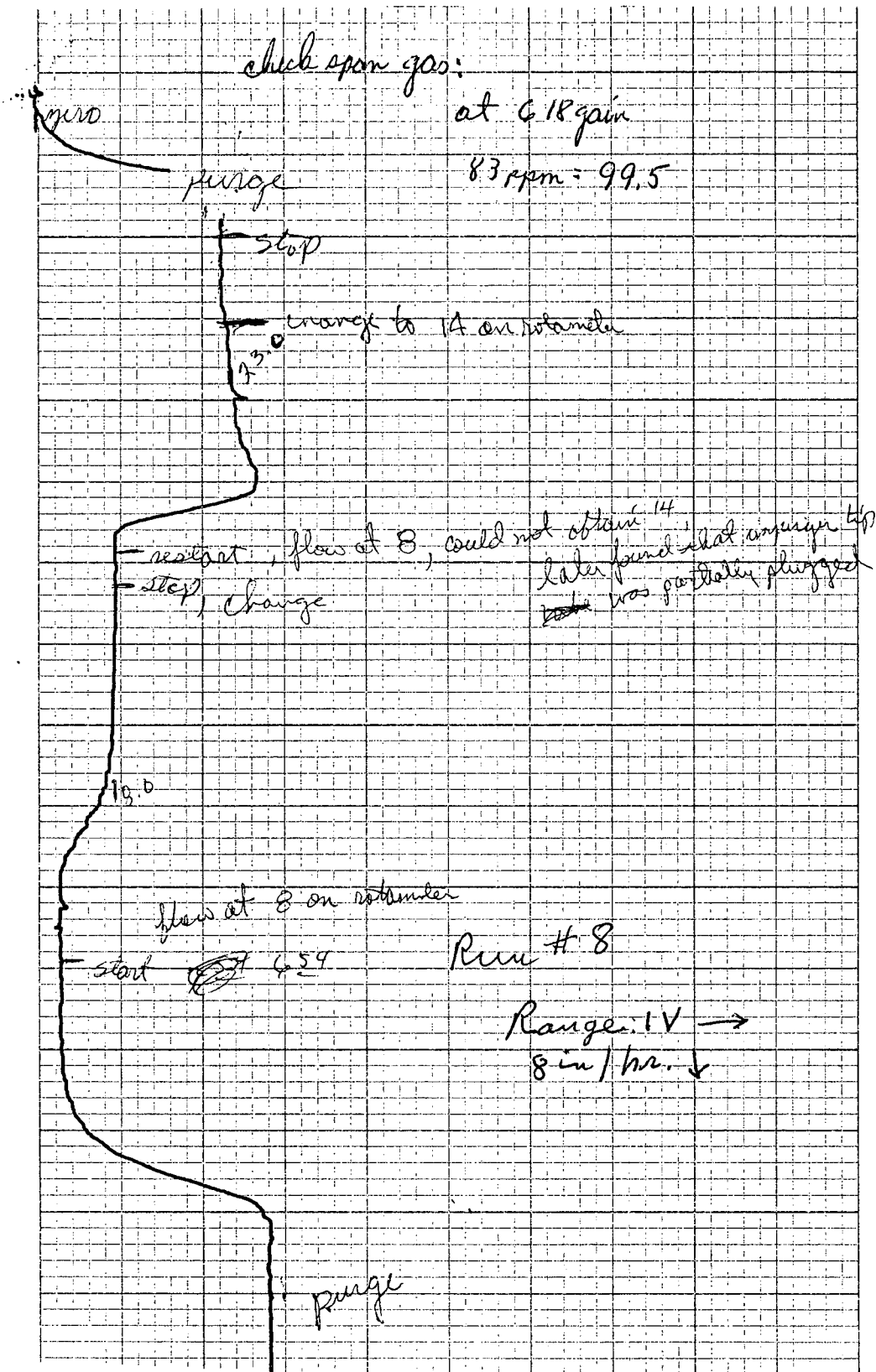


Figure 7 - Run No. 7



910

270-1012

Figure 8 - Run No. 8

Figure 9 is the calibration curve for the NDIR, that relates the NDIR reading to ppm CO. It was calibrated using nitrogen, 22 ppm CO, 41 ppm CO and 83 ppm CO for full scale deflection.

Beckman NDIR Calibration (By MRI)

Date: 3-15-72  
Calibrated by: N. Stich  
Cells: 15 1/2 in.  
Zero Gas: Nitrogen

Tune: 61  
Gain: 618 Range 3  
Full Scale Deflection: 83 ppm  
Application: CO

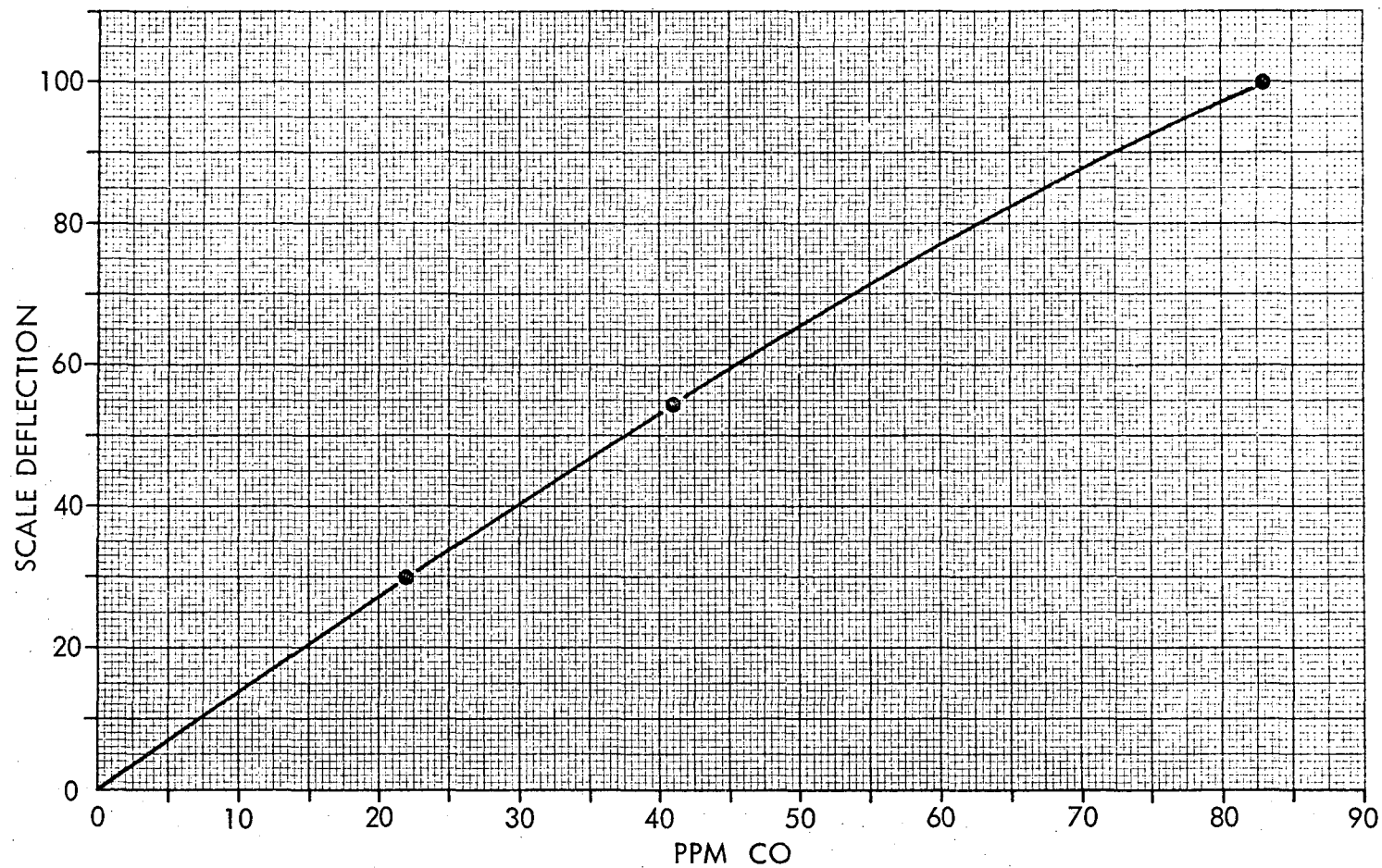


Figure 9

#### IV. SAMPLING AND ANALYTICAL EQUIPMENT AND PROCEDURES

The CO boiler stack at Standard Oil of California's El Segundo plant was the site chosen for sampling the stack gas to determine the applicability of the analytical method for CO using the nondispersive infrared analyzer (NDIR).

##### A. Sampling Equipment and Procedure

Figure 10 is a schematic of the equipment used to obtain an integrated gas sample. A glass-lined heated probe was inserted through a cover plate fastened to the port. The probe was connected with Tygon\* tubing to an air cooled condenser, a rate meter and the Tedlar\* gas bag. Flow was controlled by use of a micrometer adjusted needle valve. A vacuum pump was connected to the bag holder and the resulting vacuum used to withdraw the sample from the stack. The bag was leak checked prior to obtaining a sample.

Figures 11 through 14 are colored photographs showing the equipment and arrangement of this equipment in sampling. Figure 11 shows the probe inserted through the port cover into the stack. The probe and the method of connecting with the Tygon\* tubing is shown in Figure 12. The condenser and gas bag holder appear in Figure 13. The flowmeter, micrometer needle valve, the gas bag holder, and the vacuum pump are displayed in Figure 14.

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\* Mention of a specific company or product does not constitute endorsement by EPA.

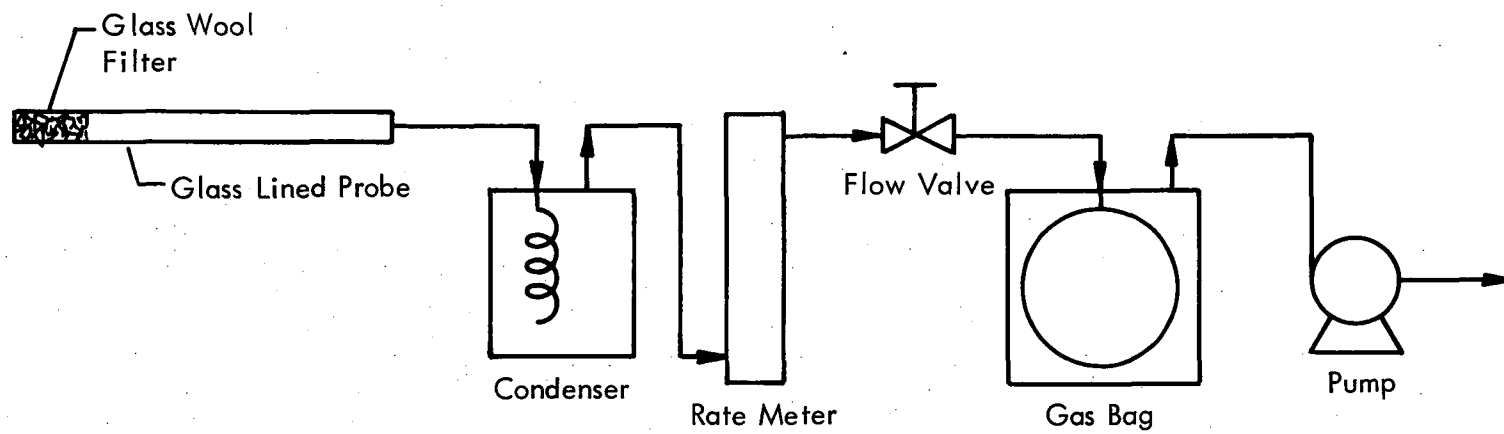


Figure 10 - Sampling Apparatus For Carbon Monoxide



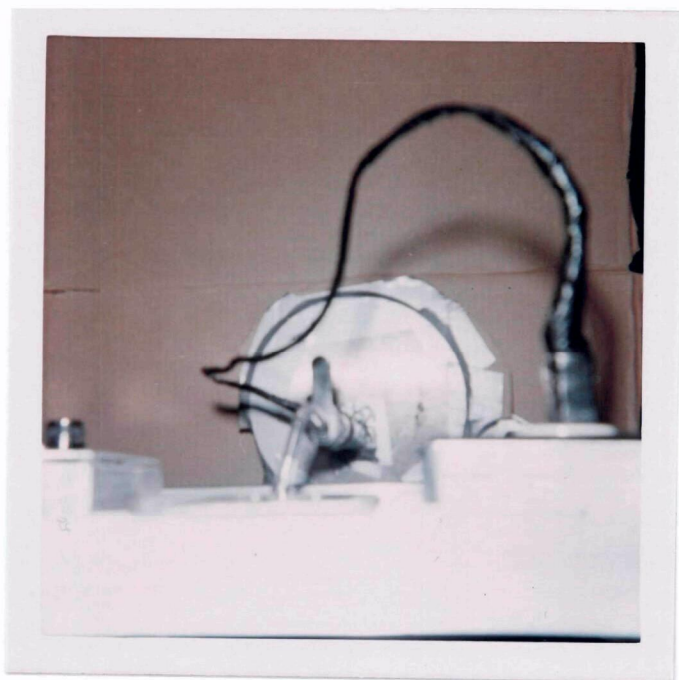


Figure 11 -  
Port Cover - Probe  
Heater Cord



Figure 12 -  
Probe and Connector

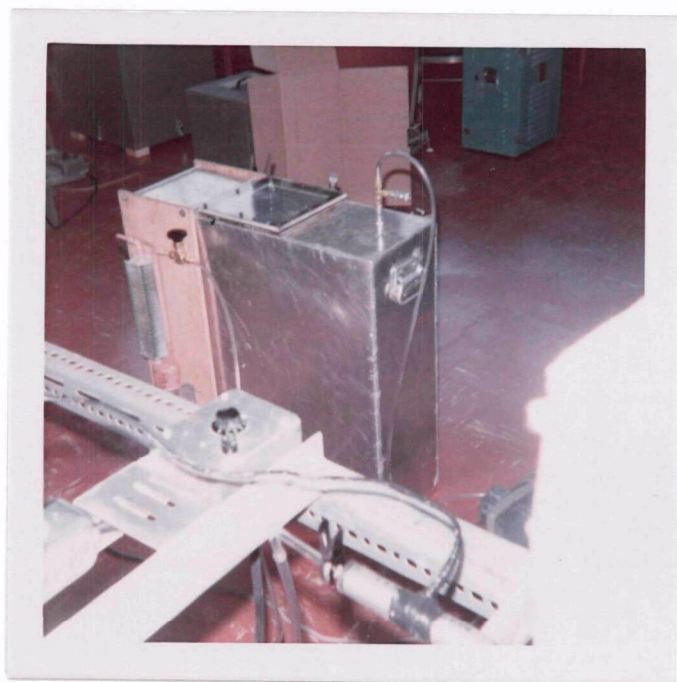


Figure 13 -  
Condensor - Bag Holder

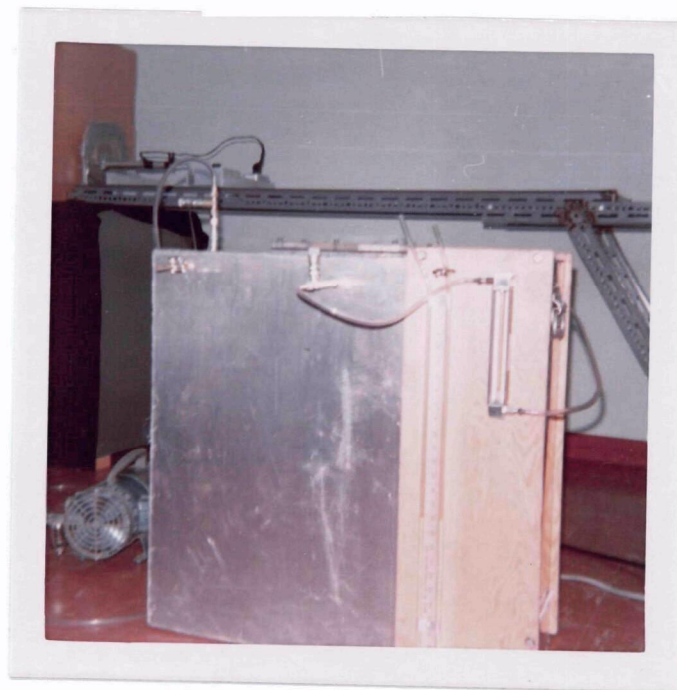


Figure 14 -  
Rate Meter - Micrometer Valve -  
Bag Holder - Vacuum Pump

## B. Analytical Procedure and Equipment

The schematic of the equipment used in analyzing the stack gas for CO and CO<sub>2</sub> is shown in Figure 15. Everything but the gas bag was purged with nitrogen before and after sampling. Purging with nitrogen sweeps out entrained air or other gases. A Bechman\* Infrared Analyzer (NDIR) Model 215°A with a 15.25 in. CO sample cell and a 15.25 in. reference cell with optical filters (for removal of interference from NH<sub>3</sub>) was used. The range of the instrument is from 0-150 ppm CO. A Hewlett Packard\* Model No. 680 strip chart recorder was used with the NDIR. The NDIR was zeroed by using 100% nitrogen and the span was set by using an 83 ppm CO in nitrogen.

Figures 16 through 20 are colored photographs of the setup used in the analytical procedure. Figure 16 shows the nitrogen cylinder being used to purge the tubing and the equipment and to zero the NDIR. Figure 17 shows the 83 ppm CO (span gas) used to establish the upper limit of the analytical instrument. Figure 18 is an overall view of the equipment used in analyzing the stack gas. Figure 19 is a close-up of the impingers containing silica gel and ascarite in the ice water bath with the NDIR and dry gas meter in the background. Figure 20 is a close-up showing more details of the hookup with the Tygon\* tubing from the gas bag to the impinger, through the flowmeter, the drying tube, the filter, the NDIR with recorder and the dry gas meter. Figure 21 shows the Orsat being used to analyze for CO<sub>2</sub> and O<sub>2</sub>.

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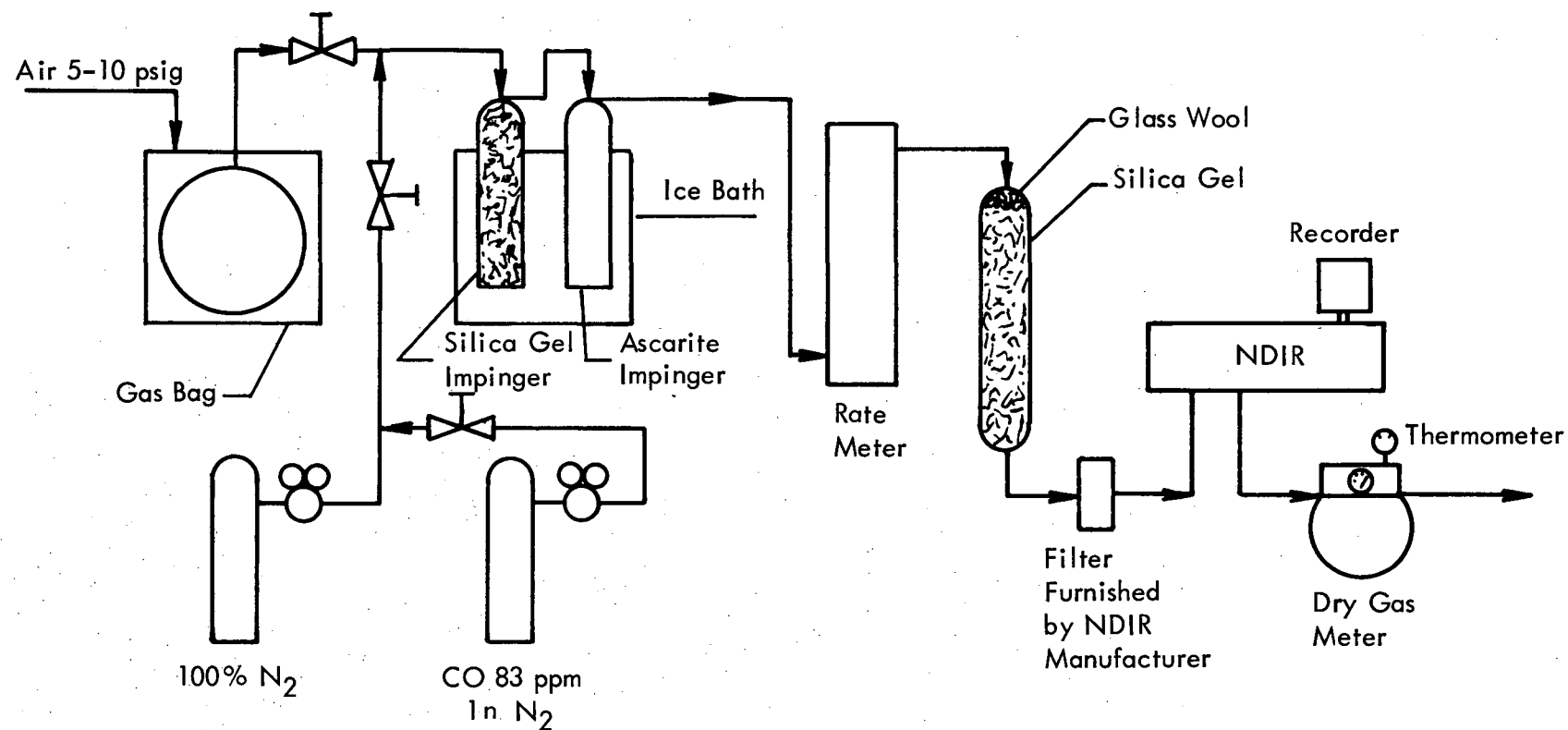


Figure 15 - Analytical Apparatus For Carbon Monoxide

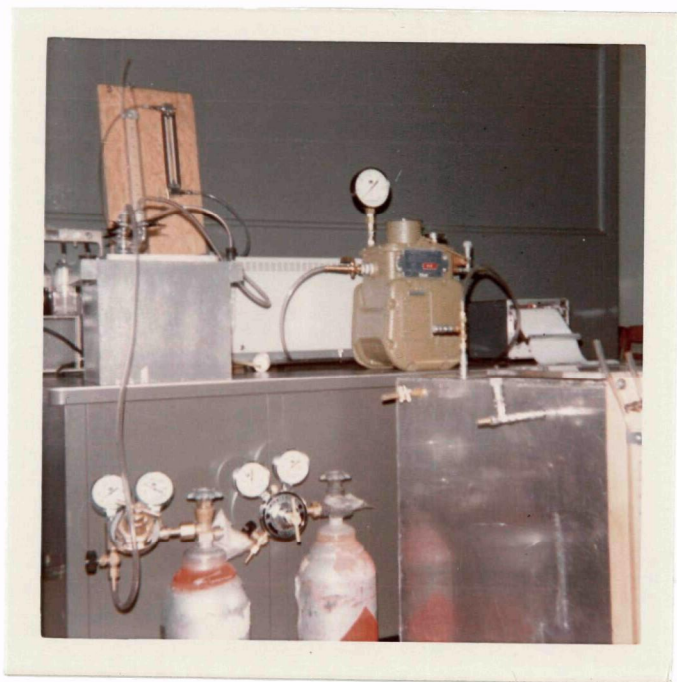


Figure 16 -  
Setup With N<sub>2</sub> Cylinder

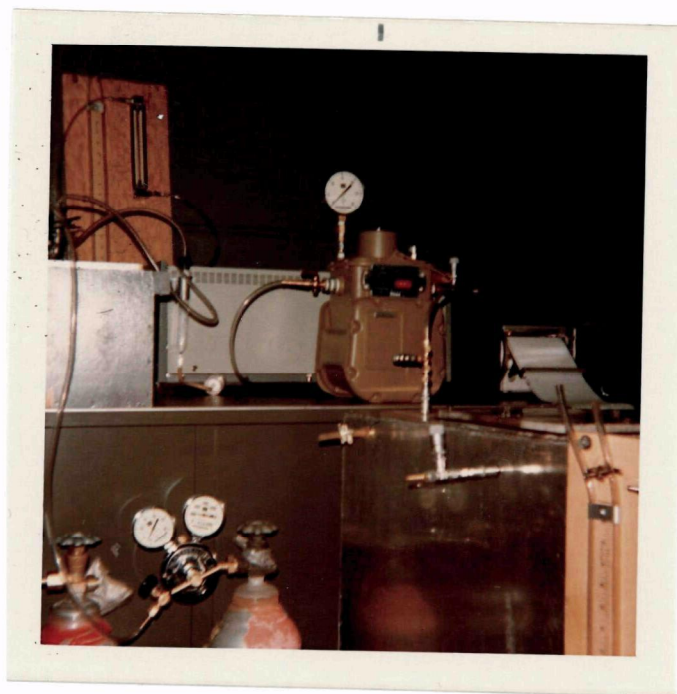


Figure 17 -  
Analytical Setup With CO<sub>2</sub>  
Span Gas

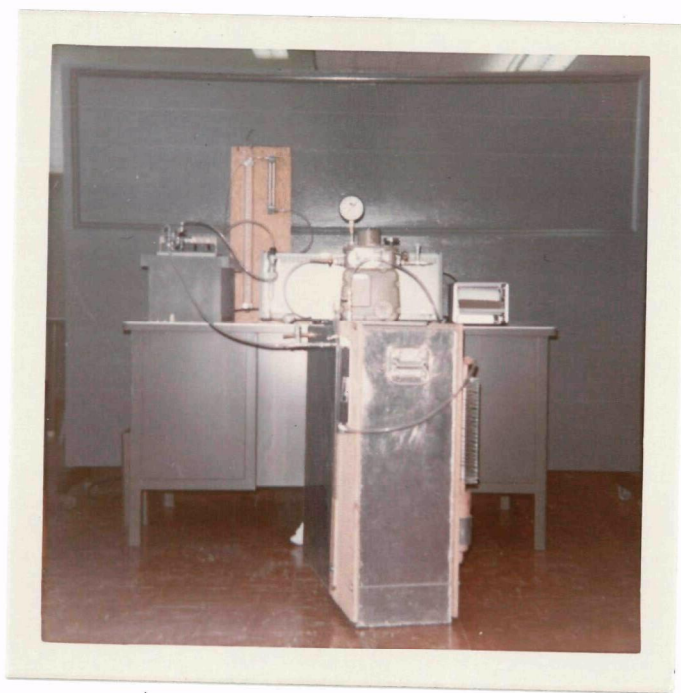


Figure 18 -  
Overall View of Equipment  
Analytical Setup



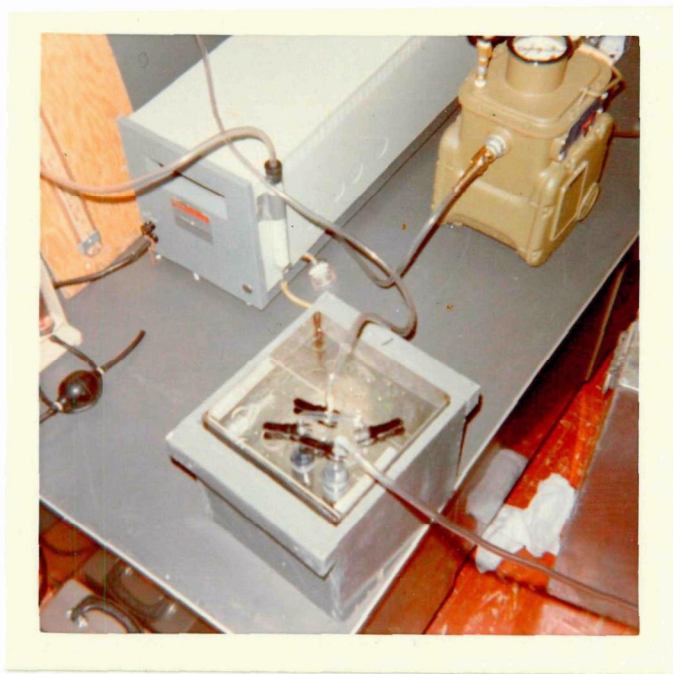


Figure 19 -  
Impingers in Ice Water Bath

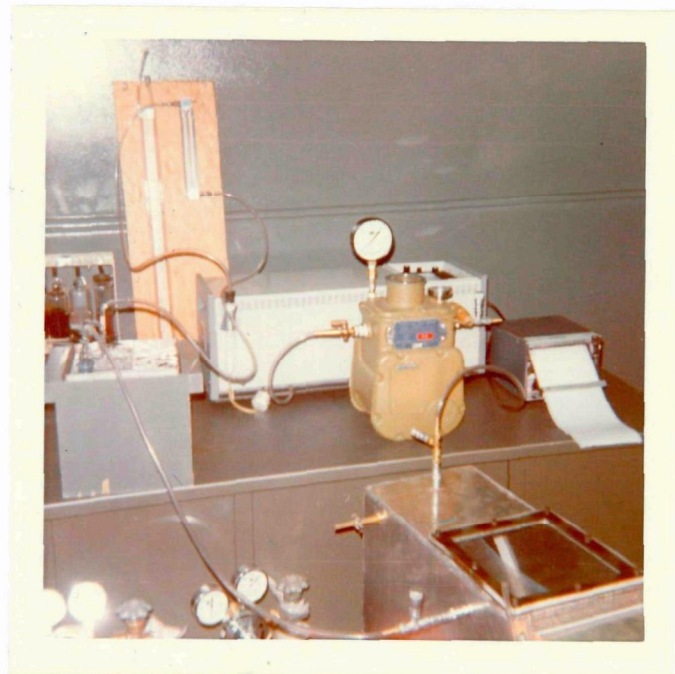


Figure 20 -  
Close-Up of Analytical Setup

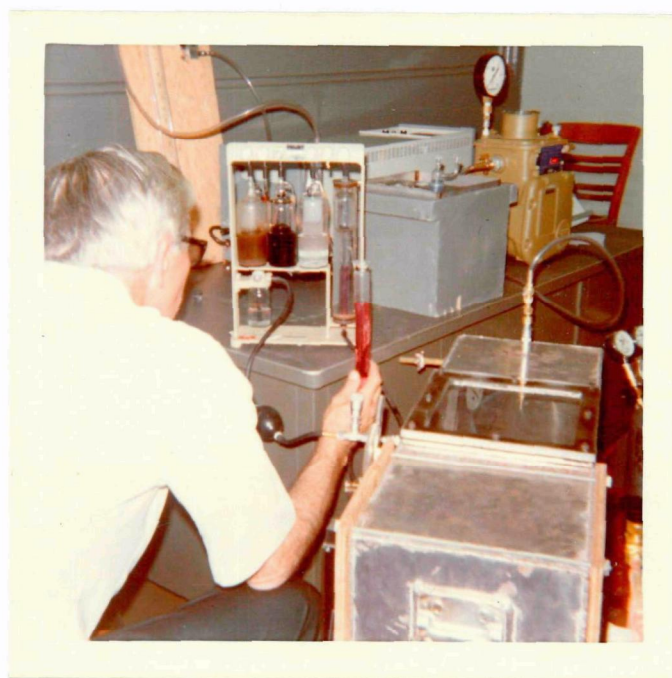


Figure 21 -  
Orsat Analysis

After purging all lines with nitrogen, the line to the gas bag was connected to the impinger containing silica gel. Air pressure was bled into the gas bag holder forcing the sample gas out of the bag through the impingers containing silica gel and ascarite; through the flowmeter (the rotameter reading for the test was set at 14 on a Matheson\* Model No. 620PBW603 flowmeter with an R-2-15B tube) a drying tube containing glass wool and silica gel; a filter, furnished with the NDIR; the NDIR, equipped with an external recorder, and finally through the dry gas meter (an American Meter Company\* Charcoal test meter Model No. AL-110, where temperature and total flow were measured). The sample gas was run through the system until a steady reading was obtained on the NDIR. After the reading stabilized on the NDIR, the flow was stopped and the ascarite removed for weighing. The weight gain provides CO<sub>2</sub> collected volume. The flow of sample gas was restarted and continued until a steady reading was again obtained on the NDIR. This reading is the effect of interference (primarily CO<sub>2</sub>) and CO.

#### C. Observations

The geometry of the stack must be carefully considered in selecting a single sample point. The carrier gas must be thoroughly mixed at the sample point, otherwise a sample traverse would be necessary. On negative pressure stacks, sealing of the port around the probe is essential. If the opening is not properly sealed, there is a possibility of

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\* Mention of a specific company or product does not constitute endorsement by EPA.

diluting the sample with air. A single-point sample should be located well into the stack.

Since the method does not allude to sample point criteria, the above observations were incorporated to project a sample point 42 in. from the inside wall and at 90 degrees from the inlet breeching at approximately 4 diameters downstream from the breeching.

In the analytical procedure there are two very important precautions that must be taken.

All of the equipment and tubing used in the analysis must be purged with nitrogen before the sample is introduced to ensure that none of the tubing or equipment is contaminated with the previous sample. The silica gel and ascarite impingers must be in an ice water bath, or the caustic in the ascarite might react with other components of the gas stream, particularly  $\text{SO}_2$  and  $\text{SO}_3$ , if present. Also, excess heat causes water to be formed from the reaction between  $\text{CO}_2$  and  $\text{NaOH}$ .

The procedure "Gas Analysis for Carbon Monoxide" (dated 10 February 1972), as furnished by EPA is included in this report as Appendix A. We made some changes and additions to this procedure for this test.

These changes are:

5.3.5 - Used 25-30 grams of preweighed ascarite instead of 200 grams to improve the accuracy in determining the weight change of the ascarite.

7.3 - The silica gel tube was not weighed because this would only give the percent moisture in the bag. The sample was passed through a condenser

before filling the Tedlar\* bag. The volume of the water condensed from the sample and the volume of gas sampled would have to be measured before the stack moisture could be determined. The percent moisture was not a test objective.

9.4 - Assume  $V_{H_2O} = 0$ .

The additions are:

5.3.6 - Ice water bath for ascarite and silica gel.

5.3.7 - Needle valve to adjust and maintain constant flowrate.

5.3.8 - Span gas for NDIR.

5.3.9 - Flowmeter to measure flow rate.

5.4.0 - Dry gas meter with thermometer.

5.4.1 - Recorder for NDIR.

7.3 - The lines and equipment must be purged with nitrogen before the gas is analyzed.

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## V. LOCATION OF SAMPLING POINTS

Figure 22 shows the location of the two ports used in sampling for CO analysis and for temperature and velocity profiles at the boiler stack. The samples were collected at an elevation of 55 ft (about four stack diameters) above the inlet breeching. The inside diameter of this stack is 13 ft 10 in. The CO samples and the first velocity profile were taken from the port at 90 degrees from the inlet breeching. The other two velocity profiles were taken from the port above the inlet breeching.

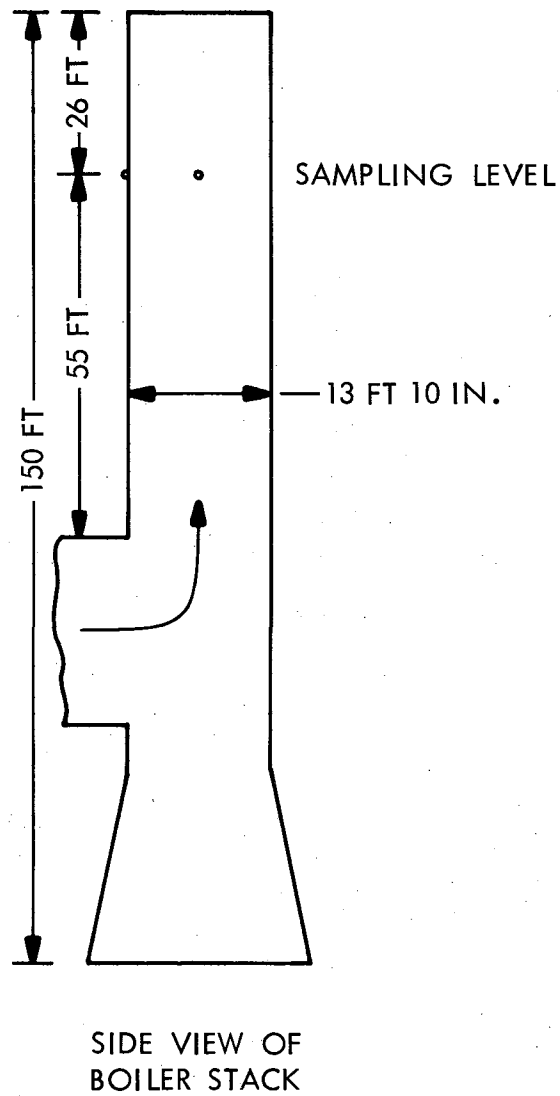


Figure 22 - Location of Sampling Station

VI. PROCESS OPERATING CONDITIONS

This section is to be furnished by EPA.

#### APPENDIX A

The following represents the suggested method of sampling and analyzing for carbon monoxide. This method was furnished by EPA. Observations on the method are tabulated in Section IV-C.

## Gas Analysis for Carbon Monoxide

1. Principle and Applicability

- 1.1 Principle. An integrated or grab gas sample is extracted from a sampling point and analyzed for carbon monoxide content using a nondispersive infrared analyzer or equivalent.
- 1.2 Applicability. This method should be applied only when specified by the test procedures for determining compliance with the new source performance standards. The test procedure will indicate whether a grab or an integrated sample will be used.

2. Range and Sensitivity.

- 2.1 Range. 0-100 p.p.m.
- 2.2 Sensitivity. Minimum detectable sensitivity is 4 p.p.m.

3. Interferences

- 3.1 Any substance having a strong absorption of infrared energy will interfere to some extent. For example, discrimination ratios for water and carbon dioxide are 3.5% H<sub>2</sub>O/7 p.p.m. CO and 10% CO<sub>2</sub>/10 p.p.m. CO, respectively, for devices measuring in the 1500 to 3000 p.p.m. range. For devices measuring in the 0-100 p.p.m. range, interference ratios can be as high as 3.5% H<sub>2</sub>O/25 p.p.m. CO and 10% CO<sub>2</sub>/50 p.p.m. CO. The use of silica gel and ascarite traps will alleviate the major interference problems. The measured gas volume must be corrected if these traps are used.

4. Precision and Accuracy

- 4.1 Precision. The precision of most NDIR analyzers is approximately  $\pm 2\%$  of span. The precision of the overall method is unknown.
- 4.2 Accuracy. The accuracy of most NDIR analyzers is approximately  $\pm 5\%$  of span after calibration. The accuracy of the overall method is unknown.

5. Apparatus

- 5.1 Grab sample (Figure 3-1) Federal Register, 36, 24886, Dec. 23, 1971.
- 5.1.1 Probe. Stainless steel or Pyrex glass, equipped with a filter to remove particulate matter.
- 5.1.2 Pump. One-way squeeze bulb, or equivalent, or leakless diaphragm pump or equivalent, to transport gas sample to analyzer.

5.2 Integrated sample (Figure 3-2) Federal Register, 36, 24886, Dec. 23, 1971.

- 5.2.1 Probe. Stainless steel or Pyrex glass, equipped with a filter to remove particulate matter.
- 5.2.2 Air cooled condenser or equivalent - to remove any excess moisture.
- 5.2.3 Needle valve - to adjust flow rate.
- 5.2.4 Pump. Leak-free diaphragm type, or equivalent to pull gas.
- 5.2.5 Rate meter. To measure a flow range from 0 to 0.035 C.F.M.
- 5.2.6 Flexible bag. Tedlar, or equivalent, with a capacity of 2 to 3 cubic feet. Leak test the bag in the laboratory before using.
- 5.2.7 Pitot tube. Type S, or equivalent, attached to the probe so that the sampling rate can be regulated proportional to the stack gas velocity when velocity is varying with time or a sample traverse is conducted.

5.3 Analysis.

- 5.3.1 Nondispersive infrared analyzer, or equivalent.
  - (a) range-0-100 p.p.m.
  - (b) output (minimum)-0-10 mv.
  - (c) minimum detectable sensitivity-4 p.p.m.
  - (d) rise time (maximum)-30 seconds to 90% response.
  - (e) fall time (maximum)-30 seconds.
  - (f) zero drift (maximum)-10% in 8 hours.
  - (g) span drift (maximum)-10% in 8 hours.
  - (h) precision-± 2%.
  - (i) noise (maximum)-± 1%.
  - (j) linearity-2% of scale.
  - (k) Interference rejection ratio-CO<sub>2</sub> - 1000/1, H<sub>2</sub>O - 500/1.
- 5.3.2 Drying tube. Approximately 200 g. of dry preweighed silica gel.
- 5.3.3 Calibration gas.
- 5.3.4 Particulate filter. As recommended by NDIR manufacturer.
- 5.3.5 CO<sub>2</sub> removal tube. Approximately 200 g. of preweighed ascarite. (2)

## 6. Reagents

6.1 Calibration gas. Known concentration of CO in N<sub>2</sub> for instrument span, prepurified grade of N<sub>2</sub> for zero. Three concentrations corresponding to span, 60% span, 30% span. The span concentration shall not exceed 1.5 times the applicable source performance standard.

6.2 Silica gel. Indicating type, 6-16 mesh, dried at 175°C (350°F) for 2 hours.

6.3 Ascarite<sup>(R)</sup> (ascarite / NaOH catalyst)

## 7. Procedure

### 7.1 Grab sampling.

7.1.1 Set up the equipment as shown in Figure 3-1 (Federal Register, 36, 24886, Dec. 23, 1971) making sure all connections are leak free. Place the probe in the stack at a sampling point and purge the sampling line. Connect the analyzer and draw sample into the analyzer. Allow five minutes for the system to stabilize and record the analyzer reading. (See Sections 7.3 and 8.)

### 7.2 Integrated sampling.

7.2.1 Evacuate the flexible bag. Set up the equipment as shown in Figure 3-2 (Federal Register, 36, 24886, Dec. 23, 1971) with the bag disconnected. Place the probe in the stack and purge the sampling line. Connect the bag, making sure that all connections are tight and that there are no leaks. Sample at a rate proportional to the stack velocity.

7.3 Analysis. Assemble the apparatus, calibrate the instrument, and perform other required operations as described in Section 8. Direct the sample stream through the instrument for the test period, recording the readings. Check the zero and span again after the test to insure that any drift or malfunction is detected. Record the sample volume passed through the system. Remove and carefully weigh the silica gel and ascarite tubes.

8. Calibration. Assemble the apparatus according to Figure 1. Carefully weigh the silica gel and ascarite tubes before assembly. Generally an instrument which is started up cold requires a warm-up period before stability is obtained. Follow the manufacturer's instructions for specific procedure. Allow a minimum time of one hour for warm-up. During this time check the sample conditioning apparatus, i.e., filter, converter, drying tube, CO<sub>2</sub> removal tube to insure that each component is in good operating condition. Zero and calibrate the instrument according to the manufacturer's procedures using nitrogen and the calibration gases respectively.

## 9. Calculations

### 9.1 Volume of water vapor collected.

$$V_{H_2O} = \Delta wt_a \left( \frac{\rho_{H_2O}}{M_{H_2O}} \right) \left( \frac{RT_{STD}}{P_{STD}} \right)$$

$$= 0.0474 \frac{\text{cu. ft.}}{\text{g.}} (\Delta wt_a)$$

where:

$V_{H_2O}$  = Volume of water vapor collected at standard conditions, cu. ft.

$\Delta wt_a$  = Weight increase in silica gel tube + weight of liquid water collected in air-cooled condenser, g.

$\rho_{H_2O}$  = Density of water, 1 g./ml.

$M_{H_2O}$  = Molecular weight of water, 18 lb./lb.-mole.

$R$  = Ideal gas constant, 21.83 inches Hg-cu.ft./lb. mole-°R.

$T_{STD}$  = Absolute temperature at standard conditions, 530°R.

$P_{STD}$  = Absolute pressure at standard conditions, 29.92 inches Hg.

### 9.2 Volume of carbon dioxide collected.

$$V_{CO_2} = (\Delta wt_a) \frac{22.4 \text{ l./g. mole}}{44 \text{ g./mole}} \frac{1}{28.32 \text{ l./cu.ft.}}$$

$$= 0.01797 \Delta wt_a$$

where:

$V_{CO_2}$  = Volume of  $CO_2$  collected at standard conditions, cu. ft.

$\Delta wt_a$  = Weight increase in ascarite tube, g.

### 9.3 Gas volume.

$$V_{MC} = V_M \left( \frac{P_M}{P_{STD}} \right) \left( \frac{T_{STD}}{T_M} \right)$$

$$= 17.71 \frac{^{\circ}R}{\text{in. Hg}} \left( \frac{V_M P_M}{T_M} \right)$$



where:

$V_{MC}$  = Dry gas volume through meter at standard conditions, cu. ft.

$V_M$  = Dry gas volume measured by meter, cu. ft.

$P_H$  = Barometric pressure at dry gas meter, inches Hg.

$P_{STD}$  = Pressure at standard conditions, 29.92 inches Hg.

$T_{STD}$  = Absolute temperature at standard conditions, 530°R.

$T_M$  = Absolute temperature at meter, °R.

#### 9.4 Sample volume.

$$V_{SAMPLE} = V_{MC} + V_{H_2O} + V_{CO_2}$$

where:

$V_{SAMPLE}$  = Volume of sample at standard conditions.

#### 9.5 Concentration of CO.

$$C_{CO_{STACK}}^{sample} = C_{CO_M} \left( \frac{V_{MC}}{V_{SAMPLE}} \right)$$

where:

$C_{CO_{STACK}}$  = Concentration of CO in stack, p.p.m. by volume.

$C_{CO_M}^{sample}$  = Concentration of CO measured by NDIR analyzer, p.p.m. by volume.

#### 10. Bibliography.

The Intech NDIR-CO Analyzer by Frank McElroy. Presented at the 11th Methods Conference in Air Pollution, University of California, Berkeley, California, April 1, 1970.

Jacobs, M. B. et al., J.A.P.C.A. 9, No. 2, 110-114, August 1959.

MSA LIRA Infrared Gas and Liquid Analyzer Instruction Book, Mine Safety Appliances Co., Pittsburgh, Pa.

Beckman Instruction 1635B, Models 315A., 315A and 415A Infrared Analyzers, Beckman Instrument Company, Fullerton, California.

Continuous CO Monitoring System, Model A 5611, Intertech Corp.,  
Princeton, N. J.

Bendix--UNOR Infrared Gas Analyzers. Ronceverte, W. Va.

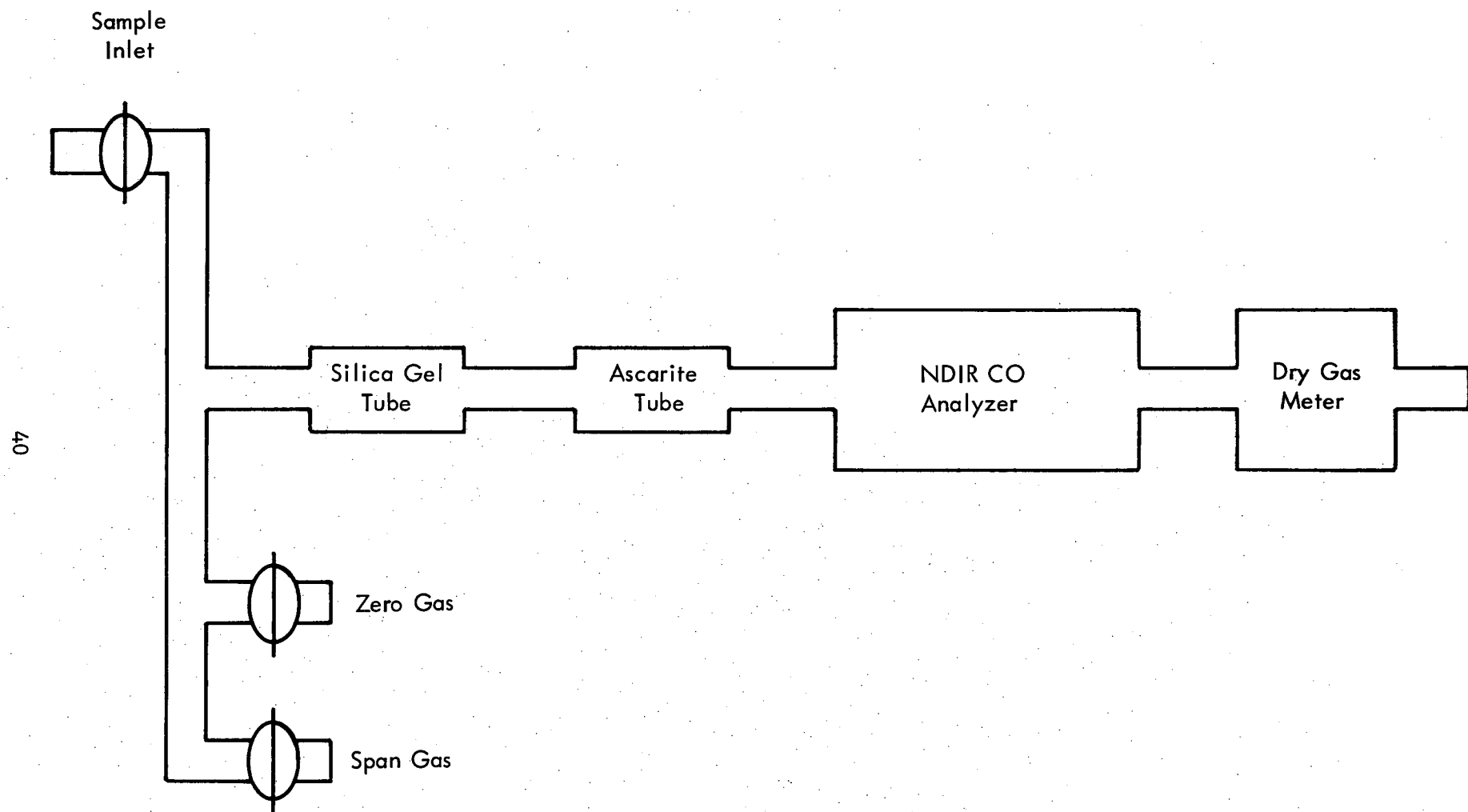


Figure A-1

## APPENDIX B

The Field Data Sheets are contained in this appendix.

# VELOCITY TRAVERSE FIELD DATA

Plant Std oil EL SECUNDO

Test SPECIAL

Location CO Boiler STATION W. PORT

Date 3/28/72

Operator SHEA + KELLEY

Meter All



Clock Time	Point	(1) $\Delta P$ , in. $H_2O$	(1) $\sqrt{\Delta P}$ , in. $H_2O$	(2) $\Delta P$ , in. $H_2O$	(2) $\sqrt{\Delta P}$ , in. $H_2O$	Stack Temp. °F	
						(1)	(2)
3 PM	2"	.43	.655			778	
	5"	.46	.678			779	
	8"	.48	.692			779	
	11"	.50	.706			778	
	17"	.49	.700			780	
	34"	.45	.67			776	
	46"	.44	.664			774	
	88"	.41	.64			769	

(1)  $\Delta P$ , in.  $H_2O$  Average 0.445

(2)  $\Delta P$ , in.  $H_2O$  Average 0.676

Comments:

$T_s$  Avg 777 °F  
+ 460  
1237 °R

III. SAMPLE DATA TEST	Project <u>CORRAL</u> Sample Date <u>3/29/72</u> Test Team <u>KELLY-SHEH</u> Test NO. <u>1</u>
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III. SAMPLE DATA TEST	Project <u>CORRAL</u> Sample Date <u>3/29/72</u> Test Team <u>KELLY-SHEH</u> Test NO. <u>1</u>
--------------------------	---

GAIN - 6.20  
SPAN GAS - 83 ppm CO      ASCARITE WT.

GAIN - 6.20  
SPAN GAS - 83 ppm CO      ASCARITE WT.

Port No.	Point No.	RAC Filter No.	Sample Time Min.	Start Time	Rotometer	NDIR	Vacuum in. Hg	Meter ft <sup>3</sup>	Meter Temp. °F		Stack Temp. °F	S. Cel	Probe	Comment
					Pitot in. H <sub>2</sub> O	Probe in. H <sub>2</sub> O			Left	Right		Temp. °F	Temp. °F	
W	8		0	1:52	14.0	1		10.9/98		80		108.2021	108.6028	0.2001
	42" IN.		1			2								
			2			17								
			3			17.5								
			4			17.5								
			5			17.5								
			7	1:59	✓	16.0		11.0905						
								0.1707						
BAROMETRIC PRESSURE														
10:00 AM - 30.00														
1:00 PM 29.97														
4:00 PM 29.92														

Project CO AWAL Sample Data 3/29/72  
Test Team KELLY-Shea Test NO. 2

44

Project C.O. ANA/ Sample Data 3/29/72  
Test Team Kelly-Shea Test NO. 3

45



III. SAMPLE DATA  
EMISSION TEST

Project CO ANAL. Sample Data 3/29/72  
Test Team Shea+Kelly Test NO. 4

ASCARITE WT

Port No.	Point No.	RAC Filter No.	Sample Time Min.	Start Time	Rate meter Pitot in. H <sub>2</sub> O	NDIR Probe in. H <sub>2</sub> O	Vacuum in. Hg	Meter ft <sup>3</sup>	Meter Temp. °F Left	Meter Temp. °F Right	Stack Temp. °F	S. Gel Temp. °F FINAL	Probe Temp. °F INIT	Comment DIFF
W			0	5 <sup>10</sup> <del>0</del>	14	0		12.1855	79			114.223	110.612	3.602
H <sub>2</sub> O P			1			3.0								
440 P			2			8.5								
			3			11.2								
			4			12.0								
			6			12.8								
			7			12.5								
			8			12.5								
			9			13.0								
			10			13.5								
			12			14.2								
			14			15.0								
			16			16.0								
			18			17.0								
			20	5 <sup>30</sup> PM		18.0		12.7140	0.5285					
No Ascrite			0	"	14	18.0								
			1			23.0								
			2			26.0								
			3			26.5								
			4			26.4								
			5			26.1								
			6			26.5								
			8			26.1								
			9			26.1								
			10			26.5								
			11			27.0								

P<sub>B</sub> = 29.92

### III. SAMPLE DATA

#### EMISSION TEST

Project CO. ANAL. Sample Data 3/30/72  
Test Team Kelly + Shari Test NO. 5

ASCARITE WT

Port No.	Point No.	RAC Filter No.	Sample Time Min.	Start Time	Rotometer	NDIR	Vacuum in. Hg	Meter ft <sup>3</sup>	Meter Temp. °F		Stack Temp. °F	S. Cal	Probe	Comment
					Pitot in. H <sub>2</sub> O	Probe in. H <sub>2</sub> O			Left	Right		Temp. °F FINAL	Temp. °F INIT	
W	8		0	12:08	14.0	0		16H160	78°F			102.1227	104.9458	2.1789
	42"		1			1.0								
	1N		2			3.0								
			3			5.5								
			4			6.1								
			5			7.0								
			6			6.8								
			7			7.0								
			8			6.8								
			9			7.0								
			10			7.0		16.6960	0.2800					
No Ascarite			10			7.0								
			12			19.0			P <sub>B</sub>		10:00 AM = 30.04			
			14			22.0			P <sub>B</sub>		1:00 PM = 30.04			
			16			22.6			P <sub>B</sub>		4:00 PM = 29.98			
			17			22.5								

# ORSAT FIELD DATA

Location Standard El Segundo

Comments:

Date 3/30/72

Time 1<sup>40</sup> P

Operator Shea & Kelly

Test	(CO <sub>2</sub> ) Reading 1	(O <sub>2</sub> ) Reading 2	(CO) Reading 3
# 5 ①	<del>11.2</del>	<del>16.0 4.8</del> <del>11.2</del>	<del>0</del>
②	12.1	16.1 4.0 <del>12.1</del>	0
③	12.7	17.5 4.8 <del>12.7</del>	0

III. SAMPLE DATA EMISSION TEST	Project <u>CO ANAL</u> Sample Date <u>3/30/72</u> Test Team <u>Kelly-Shea</u> Test NO. <u>6</u>
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III. SAMPLE DATA EMISSION TEST	Project <u>CO ANAL</u> Sample Date <u>3/30/72</u> Test Team <u>Kelly-Shea</u> Test NO. <u>6</u>
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ASCARITE WT															
Port No.	Point No.	RAC Filter No.	Sample Time Min.	Start Time	Rotometer	NDIR	Vacuum in. Hg	Meter ft <sup>3</sup>	Meter Temp. °F		Stack Temp. °F	S. Gel	Probe	Comment	
					Pitot in. H <sub>2</sub> O	Probe in. H <sub>2</sub> O			Left	Right		Temp. °F	Temp. °F		
W	8		0	1122	14	1		15.7281		77			107.5825	103.8681	3.6144
925	42"		1			4.1									
1000			2			7.0									
			3			8.2									
			4			8.8									
			5			8.8									
			6			8.3									
			7			8.5									
			8			8.5									
			9			9.0									
			10	1132		10.0		16.0131	0.2850						
No ASCARITE			10			10.5									
			12			20.5									
			14			20.5									
			15	1137		20.5									
										PB	30.04				

# ORSAT FIELD DATA

Location Local, El Segundo

Comments:

Date 3/30/72

Time 1:50 P

Operator Shea & Kelly

AIR LEAK HOLE IN GAS BAG DURING

Test	(CO <sub>2</sub> ) Reading 1	(O <sub>2</sub> ) Reading 2	(CO) Reading 3
#6 ①	9.4	18.0 8.6	0
②	9.4	18.0 8.6	0
③	9.2		

ORSAT  
RUN

# VELOCITY TRAVERSE FIELD DATA

Plant EP Segundo Std Oil

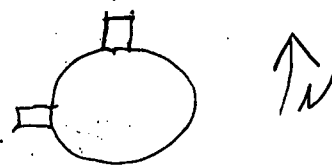
Test # 546

Location Co Boiler Stack North Port

Date 3/30/72

Operator SHEA/KELLY

Meter All



Clock Time	Point	(1) $\Delta P$ , in. $H_2O$	(1) $\sqrt{\Delta P}$ , in. $H_2O$	(2) $\Delta P$ , in. $H_2O$	(2) $\sqrt{\Delta P}$ , in. $H_2O$	Stack Temp. °F	
						(1)	(2)
9:45	5"	.19	<del>.765</del> .36			765	
	8"	.28	.53			771	
	11"	.30	.548			771	
	17"	.34	.583			775	
	34"	.33	.562			778	
	46"	.34	.583			779	
	88"	.41	.64			775	

(1)  $\Delta P$ , in.  $H_2O$  Average 0.303

(2)  $\sqrt{\Delta P}$ , in.  $H_2O$  Average 0.555

Comments:

$T_{sAvg}$  773 °F  
+ 460  
1233 °R

III. SAMPLE DATA  
EMISSION TEST

Project CO ANAL. Sample Date 3/30/72  
Test Team Shea-Kelly Test NO. 7

ASCARITE Wt.

Port No.	Point No.	RAC Filter No.	Sample Time Min.	Start Time	Roto Meter Pitot in. H <sub>2</sub> O	NDIR Probe in. H <sub>2</sub> O	Vacuum in. Hg	Meter ft <sup>3</sup>	Meter Temp. °F		Stack Temp. °F	S. Gel Probe Temp. °F		Comment
									Left	Right		FINAL	INITIAL	
W	8		0	6:14	14	1		18.1648	70			106.3406	104.2383	2.1023
325	42" IN		1			—								
4.00			2			4.8								
			3			9.6								
			4			12.0								
			5			13.0								
			6			13.3								
			7			13.2								
			8			13.6								
			9			13.3								
			10	6:24		13.3		18.4240	0.2592					
No ASCARITE			10			14.0								
			12			28.0								
			14			28.0								
			15			28.1								
			17	6:41		28.0								
PB = 29.98														

# ORSAT FIELD DATA

Location STP. 0.1 El. SEGUNDO Comments: LO Boiler  
STACK  
WEST PORT  
 Date 3/30/72  
 Time 6:50 PM  
 Operator Shea & Kelley

#

Test	(CO <sub>2</sub> ) Reading 1	(O <sub>2</sub> ) Reading 2	(CO) Reading 3
7	12.6	<u>16.4</u> 3.8 <u>12.6</u>	0
7a	13.6	<u>16.9</u> 3.3 <u>13.6</u>	0
7b	13.6	<u>16.9</u> 3.3 <u>13.6</u>	0



III. SAMPLE DATA EMISSION TEST	Project <u>Shera-Kelly</u> Sample Data <u>3/30/72</u> <del>Test Room</del> <u>CO</u> Test NO. <u>8</u>
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Port No.	Point No.	RAC Filter No.	Sample Time Min.	Start Time	Rotameter	NDIR	Vacuum in. Hg	Meter ft <sup>3</sup>	Meter Temp. °F		Stack Temp. °F	S. Gel Probe Temp. °F		Comment
					Pitot in. H <sub>2</sub> O	Probe in. H <sub>2</sub> O			Left	Right		IN. TWT.	FW. T.	
W	42"	4.30 4.32P	0	6 <sup>54</sup>	8	2.0		18.723	70°			<del>108.88</del>	<del>107.7</del>	
	1N		1			2.0						107.7263	108.88	1.1244
	8		2			-								
			3			2.0								
			4			2.1								
			5			4.0								
			6			5.5								
			7			-								
			8			-								
			9			8.1								
			10			8.2								
			12			8.5								
			14			8.5								
			16	7:10	✓	8.5		18.9206						
No ASCARITE			1		8	8.5								
			2			17.5								
			3			26.5								
			4			25.5								
			6			23.8								
			8			23.0								
			10	7:20	✓	23.0								
			11		14	22.1								
			12			22.0								
			13			22.0								
			14	7:20		22.0		54						

PB = 29.98

# ORSAT FIELD DATA

Location Sto. I. El Segundo.

Date 3/30/72

Time 7:30 PM

Operator Shea & Kelly

Comments: CO Boiler Stack  
WEST PORT  
GLASS LINED PROBE  
INSERTED ABOUT  
44" IN STACK.

Test	(CO <sub>2</sub> ) Reading 1	(O <sub>2</sub> ) Reading 2	(CO) Reading 3
8	13.8	17.6 13.8 3.8	0
8a	13.4	17.4 13.4 4.0	0
			0

## VELOCITY TRAVERSE FIELD DATA

Plant Socal., Ec Segundo

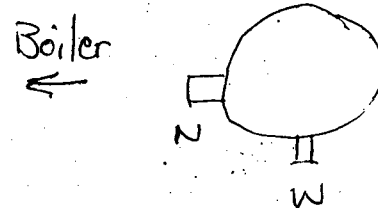
Test 748

Location Co Boiler stack N-port

Date 3/30/72

Operator Shea + Kelly

Meter All \_\_\_\_\_

[illegible]

(1)  $\Delta P$ , in.  $H_2O$  Average 306

(1)  $\Delta P$ , in.  $H_2O$  Average 554

**Comments :**

$$\begin{array}{r} T_{s \text{ Avg}} \quad 765^{\circ} \text{F} \\ + 460 \\ \hline 1225^{\circ} \text{R} \end{array}$$

## APPENDIX C

The sampling and analytical logs make up this appendix.

<u>Run</u>	<u>Analytical Log</u>				<u>Elapsed Time (min)</u>
	<u>Pollutant</u>	<u>Date</u>	<u>Began</u>	<u>Ended</u>	
1	CO, CO <sub>2</sub>	3/29/72	1:52 p.m.	1:59 p.m.	7
2	CO, CO <sub>2</sub>	3/29/72	2:13 p.m.	2:40 p.m.	27
3	CO, CO <sub>2</sub>	3/29/72	5:45 p.m. 6:15 p.m. 6:27 p.m.	5:52 p.m. 6:25 p.m. 6:32 p.m.	22
4	CO, CO <sub>2</sub>	3/29/72	5:10 p.m. 5:31 p.m.	5:30 p.m. 5:42 p.m.	31
5	CO, CO <sub>2</sub>	3/30/72	12:08 p.m. 12:20 p.m.	12:18 p.m. 12:27 p.m.	17
5	CO <sub>2</sub> , O <sub>2</sub>	3/30/72	1:40 p.m.	1:50 p.m.	10
6	CO, CO <sub>2</sub>	3/30/72	11:22 p.m.	11:37 p.m.	15
6	CO <sub>2</sub> , O <sub>2</sub>	3/30/72	1:50 p.m.	2:00 p.m.	10
7	CO, CO <sub>2</sub>	3/30/72	6:14 p.m.	6:41 p.m.	27
7	CO <sub>2</sub> , O <sub>2</sub>	3/30/72	6:50 p.m.	7:00 p.m.	10
8	CO, CO <sub>2</sub>	3/30/72	6:54 p.m.	7:24 p.m.	30
8	CO <sub>2</sub> , O <sub>2</sub>	3/30/72	7:30 p.m.	7:40 p.m.	10

<u>Run</u>	<u>Sampling Log</u>					<u>Elapsed Time (min)</u>
	<u>Location</u>	<u>Pollutant</u>	<u>Date</u>	<u>Began</u>	<u>Ended</u>	
1A	Stack (W)	Velocity and Temp.	3/28/72	3:00 p.m.	3:30 p.m.	30
1	Stack (W)	CO, CO <sub>2</sub>	3/29/72	9:30 a.m.	10:15 a.m.	45
2	Stack (W)	CO, CO <sub>2</sub>	3/29/72	10:15 a.m.	11:00 a.m.	45
3	Stack (W)	CO, CO <sub>2</sub>	3/29/72	3:00 p.m.	4:00 p.m.	60
4	Stack (W)	CO, CO <sub>2</sub>	3/29/72	4:00 p.m.	5:00 p.m.	60
5	Stack (W)	CO, CO <sub>2</sub> , O <sub>2</sub>	3/30/72	9:00 a.m.	9:45 a.m.	45
5 and 6	Stack (N)	Velocity and Temp.	3/30/72	9:45 a.m.	10:00 a.m.	15
6	Stack (W)	CO, CO <sub>2</sub> , O <sub>2</sub>	3/30/72	9:45 a.m.	10:45 a.m.	60
7	Stack (W)	CO, CO <sub>2</sub> , O <sub>2</sub>	3/30/72	3:00 p.m.	4:15 p.m.	75
7 and 8	Stack (N)	Velocity and Temp.	3/30/72	3:45 p.m.	4:00 p.m.	15
8	Stack (W)	CO, CO <sub>2</sub> , O <sub>2</sub>	3/30/72	4:15 p.m.	5:30 p.m.	75