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EVALUATION OF CONTINUOUS MONITORS FOR CARBON MONOXIDE IN STATIONARY SOURCES

Environmental Sciences Research Laboratory
Office of Research and Development
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EVALUATION OF CONTINUOUS MONITORS FOR CARBON MONOXIDE IN STATIONARY SOURCES

by

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Contract No. 68-02-1400, Task 20

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ABSTRACT

The performance characteristics of five commercially available continuous carbon monoxide monitors were evaluated in a two part program. This consisted of a laboratory and a field phase. The laboratory phase involved testing each instrument for response characteristics, precision, noise, response times, drifts, variations due to temperature and pressure, and CO_2 and H_2O interferences. The field evaluation phase involved the operation of the monitors on the outlet duct of a carbon monoxide boiler at a petroleum refinery. Data generated in both phases of the program was used as the basis for recommending minimum performance specifications for continuous carbon monoxide monitors at petroleum refineries.

This report was submitted in fulfillment of Contract No. 68-02-1400, Task 20, by Scott Environmental Technology, Inc. under the sponsorship of the U. S. Environmental Protection Agency. This report covers a period from July 1, 1975 to March 1, 1976, and work was completed as of October 14, 1976.

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ACKNOWLEDGEMENTS

Scott Environmental Technology, Inc. is grateful for the assistance and guidance of the EPA Project Officer, Roosevelt Rollins.

SECTION 1

INTRODUCTION

This is the final report describing the results of an evaluation of continuous carbon monoxide monitors for stationary sources. Work was performed by Scott Environmental Technology, Inc. for the U.S. Environmental Protection Agency under task order Contract 68-02-1400, Task No. 20. The evaluation program consisted of both laboratory and field performance phases.

The objectives of the program were to establish the laboratory and field performance characteristics of each of five commercially available instruments. Based on this data, minimum performance specifications for carbon monoxide monitors as applicable to petroleum refineries are recommended. Additionally, recommendations regarding maintenance and calibration of these monitors are made based on the field performance evaluation.

Five commercially available continuous carbon monoxide monitors were selected employing three different detection techniques. The instruments included: two non-dispersive infrared analyzers, a gas chromatographic analyzer with flame ionization detector, an in-situ cross stack analyzer with an infrared source and an instrument employing an electrochemical detector. The specific analyzers selected for the program are presented in Table 1.

The laboratory evaluation phase of the program consisted of a series of performance tests conducted on each instrument. These tests included the response characteristics, precision, noise, response times, drifts, variations due to temperature and flow rates, and CO_2 and H_2O interferences.

The field evaluation phase was performed on the outlet of two carbon monoxide boilers at an east coast oil refinery. The instruments were installed in a trailer parked at the site, and monitoring ran continuously from December 1, 1975 to January 23, 1976. Carbon monoxide emission concentrations from this source averaged about 500 ppm during the program.

TABLE 1. PROGRAM INSTRUMENTATION

Manufacturer	Model	Serial No.	Description
Environmental Research and Technology, Inc.	Stack Gas Analyzer Model 4000		Multi-component in-situ cross stack analyzer using infrared source
Energetics Science Inc.	Ecolyzer Model 3100	31113	Continuous carbon monoxide monitor employing electro-chemical detector
Beckman	Model 6800	1000119	Multi-component automated chromatograph with flame ionization detector
Beckman	Model 865	0100200	Non-dispersive infrared analyzer
Horiba *	A1A-2 and A1A-21AS	30642 45261301	Non-dispersive infrared analyzer

* A1A-2 was replaced by A1A-21AS during field evaluation phase.

SECTION 2

CONCLUSIONS

2.1 DISCUSSION

This evaluation program for continuous carbon monoxide monitors has demonstrated that currently available instrumentation is capable of producing reliable continuous data within reasonable performance specifications. Instrument reliability, however, has been shown to be a weak point in a field monitoring situation over extended periods of time.

The Beckman Model 6800 chromatograph and the Horiba Model A1A-21AS NDIR performed satisfactorily both overall and with respect to the recommended specifications. Failure of the remaining instruments to meet one or more of the recommended specifications was generally related to maintenance problems in the field. However, the maintenance records for the program instruments show that each category of instrumentation whether it be chromatographic, NDIR, cross stack (in situ) or electrochemical had malfunction or maintenance related problems during the field program. In several cases, these malfunctions resulted in a significant amount of down-time and resultant lost data. Considering the maintenance requirements demonstrated by this evaluation program, a regular maintenance program or method of insuring that the instruments are well maintained should be required and considered as important as any of the performance criteria in terms of obtaining reliable continuous data.

Relative accuracy determinations presented in the following section, were made using three instruments as references. Modified Method 10 carbon monoxide determinations using the continuous sampling procedure supplied the reference data. The modifications included elimination of the silica gel and ascarite traps for the NDIR's, as moisture was effectively removed by a refrigerated coil condensor in the sampling system and the NDIR instruments in the program had negligible CO_2 interference (Tables 18 and 21). Relative accuracy determinations using the Beckman 6800 chromatograph as a reference instrument were made. This was done because the Beckman chromatograph has several advantages as a reference instrument over an NDIR including no interference, linear output, insensitivity to sample flow and pressure variations and

its overall superior performance as demonstrated in this program. In light of these advantages, the data produced by using this instrument as a reference in the relative accuracy determination was considered useful.

EPA presently requires daily calibration for continuous monitoring installations and it should be emphasized that these daily calibrations are a must for continuous carbon monoxide instrumentation. This program has demonstrated that several of the instruments are susceptible to significant zero and span drift which should be compensated for daily in order to optimize data quality. In addition to the data quality aspects of daily calibrations, they also serve as an important maintenance indicator and diagnostic tool. This daily calibration data may show up a deteriorating component, for example, thereby avoiding or minimizing needless system downtime.

2.2 PERFORMANCE TEST RESULTS

Summaries of the laboratory and field performance tests are presented in Tables 2 and 3, respectively. Performance test methodologies are described in Section 5.1 for laboratory tests and Section 3.2 for field performance tests.

The specific field performance results for each instrument are presented in the following tables:

Table 4 Relative Accuracy
- A Beckman 865 Reference
- B Horiba A1A-21AS Reference
- C Beckman 6800 Reference

Table 5 Zero and Calibration Drift (24 Hour)

TABLE 2. INSTRUMENT PERFORMANCE SUMMARY - LABORATORY

Parameter	ERT	Ecolyzer	Beckman 6800	Beckman 865	Horiba A1A-2	Horiba A1A-21AS
Range	0-1000	0-1000	0-1000	0-1000	0-1000	0-1000
Calibration Linearity (% Full Scale)	0	5.0	0	9.0	6.0	12.5
Precision (% Full Scale)	*	0.43	0.14	0.22	0.77	0.24
Noise (% Full Scale) zero/span	3.6	0.046 / 0.16	NA	0.06 / 0.094	*	0.05 / 0.2
Rise/Fall Times (Seconds)	*	86 / 83	NA	5.4 / 6.5	10.9 / 9.4	7.9 / 10.0
Zero Drift 24 Hr. (% Full Scale)	*	0.2	0	0.4	1.2	0.18
Zero Drift 12 Hr. Continuous (% Full Scale)	*	0.6	0	0.44	8	0.49
Span Drift 8 Hr./24 Hr. (% Full Scale)	*	* / 0.4	0.7 / 0.8	0.9 / 1.4	* / 0.5	0.7 / 0.98
Interference Equivalent (ppm) 15% CO_2/10% H_2O	20 / 5	0 / *	0 / 0	3.4 / 1.7	40.9 / *	3.4 / 0.5

* Not Tested

NA - Not Applicable

TABLE 3. INSTRUMENT PERFORMANCE SUMMARY (FIELD)

Parameter	ERT	Ecolyzer	Beckman 6800	Beckman 865	Horiba A1A-21AS
Relative Accuracy[1] (Beckman 865 Reference)	3.2	7.4	6.2		2.5
Relative Accuracy[1] (Horiba A1A-21AS Reference)	29.8	6.1	5.1	2.5	
Relative Accuracy[1] (Beckman 6800 Reference)	11.4	4.6		6.5	5.0
Response Time (Minutes)	<1	<2	<6	<1	<1
Zero Drift, 24 Hours[1] (% Full Scale)	*	3.9	0	2.6	0.6
Zero Drift, 2 Hours[1] (% Full Scale)	*	0.7	0	0.3	0.34
Span Drift, 24 Hours[1] (% Full Scale)	*	8.5	0.8	4.5	1.1
Operational Period (Hours)	<168	<168	>168	<168	>168

* Insufficient Data

1. Expressed as sum of absolute mean value plus 95% confidence interval of a series of tests.

TABLE 4A. RELATIVE ACCURACY - BECKMAN 865 REFERENCE

Date	Time (Ending 15 Minute Interval)	Reference Beckman 865 15 Minute Average PPM	ERT 15 Minute Average PPM
12/13	2430	632.0	634.0
	0130	636.6	643.0
	0230	637.7	629.0
	0330	652.0	671.0
	0430	668.5	671.0
	0530	658.0	661.0
	0630	633.5	622.0
	0730	626.3	597.0
	0830	619.0	592.0

Mean Reference Value = 640.5 PPM
Mean Difference = 12
95% Confidence Interval = 8.1
Relative Accuracy = 3.2%

Date	Time (Ending 15 Minute Interval)	Reference Beckman 865 15 Minute Average PPM	Ecolyzer 15 Minute Average PPM
12/13	0630	633.5	622.0
	0730	626.3	605.0
	0830	619.0	590.0
	0930	598.4	567.0
	1030	590.1	567.0
	1130	571.6	500.0
	1230	519.0	470.0
	1330	642.8	627.0
	1430	644.8	622.0

Mean Reference Value = 605.1
Mean Difference = 30.6
95% Confidence Interval = 14.4
Relative Accuracy = 7.4%

Date	Time (Ending 15 Minute Interval)	Reference Beckman 865 15 Minute Average PPM	Beckman 6800 15 Minute Average PPM
12/13	0630	633.5	630.1
	0730	626.3	585.5
	0830	619.0	578.4
	0930	598.4	579.4
	1030	590.1	553.8
	1130	571.6	527.8
	1230	519.0	504.2
	1330	642.8	629.8
	1430	644.8	618.3

Mean Reference Value = 605.1
Mean Difference = 26.5
95% Confidence Interval = 11.2
Relative Accuracy = 6.2%

Date	Time (Ending 15 Minute Interval)	Reference Beckman 865 15 Minute Average PPM	Horiba A1A-21AS 15 Minute Average PPM
12/21	1430	320.0	320.0
	1530	310.0	302.0
	1630	316.0	315.0
	1730	372.0	380.0
	1830	369.0	372.0
	1930	400.0	402.0
	2030	340.0	340.0
	2130	323.0	335.0
	2230	308.0	318.0

Mean Reference Value = 339.8
Mean Difference = 4.9
95% Confidence Interval = 3.6
Relative Accuracy = 2.5%

TABLE 4B. RELATIVE ACCURACY - HORIBA A1A-21AS REFERENCE

Date	Time (Ending 15 Minute Interval)	Ref.-Horiba A1A-21AS 15 Minute Average PPM	ERT 15 Minute Average PPM
12/24	1930	285.0	402.4
	2030	311.0	342.2
	2130	311.0	337.6
	2230	285.0	321.9
	2330	297.o	296.0
	2430	285.0	328.4
	0130	296.0	286.8
	0230	291.0	360.8
	0330	291.0	425.5

Mean Reference Value = 294.7
Mean Difference = 52.2
95% Confidence Interval = 35.6
Relative Accuracy = 29.8%

Date	Time (Ending 15 Minute Interval)	Ref.-Horiba A1A-21AS 15 Minute Average PPM	Ecolyzer 15 Minute Average PPM
12/24	2230	285	310
	2330	297	310
	2430	285	300
	0130	296	305
	0230	291	297
	0330	291	300
	0430	297	292
	0530	299	310
	0630	297	310

Mean Reference Value = 293.1
Mean Difference = 11.8
95% Confidence Interval = 6.1
Relative Accuracy = 6.1%

Date	Time (Ending 15 Minute Interval)	Ref.-Horiba A1A-21AS 15 Minute Average PPM	Beckman 6800 15 Minute Average PPM
12/21	1430	320	336.2
	1530	302	299.8
	1630	315	311.8
	1730	380	360.3
	1830	372	397.3
	1930	402	415.6
	2030	340	335.5
	2130	335	346.7
	2230	318	315.8

Mean Reference Value = 342.7
Mean Difference = 11.0
95% Confidence Interval = 6.5
Relative Accuracy = 5.1%

Date	Time (Ending 15 Minute Interval)	Ref.-Horiba A1A-21AS 15 Minute Average PPM	Beckman 865 15 Minute Average PPM
12/21	1430	320.0	320.0
	1530	302.0	310.0
	1630	315.0	316.0
	1730	380.0	372.0
	1830	372.0	369.0
	1930	402.0	400.0
	2030	340.0	340.0
	2130	335.0	323.0
	2230	318.0	308.0

Mean Reference Value = 342.7
Mean Difference = 4.9
95% Confidence Interval = 3.6
Relative Accuracy = 2.5%

TABLE 4C. RELATIVE ACCURACY - BECKMAN 6800 REFERENCE

Date	Time (Ending 15 Minute Interval)	Reference Beckman 6800 15 Minute Average PPM	ERT 15 Minute Average PPM
12/8	0230	294.1	263.6
	0330	288.9	268.3
	0430	325.1	277.5
	0530	298.7	268.3
	0630	257.5	240.5
	0730	259.8	259.0
	0830	255.2	245.1
	0930	264.4	259.0
	1030	228.8	240.5

Mean Reference Value = 268.0
Mean Difference = 19.3
95% Confidence Interval = 11.5
Relative Accuracy = 11.4%

Date	Time (Ending 15 Minute Interval)	Reference Beckman 6800 15 Minute Average PPM	Ecolyzer 15 Minute Average PPM
12/6	0130	433.0	415.4
	0230	418.3	409.3
	0330	395.9	409.3
	0430	402.6	421.5
	0530	407.0	427.6
	0630	396.0	409.3
	0730	458.7	458.2
	0830	470.1	470.4
	0930	451.4	476.5

Mean Reference Value = 425.9
Mean Difference = 13.2
95% Confidence Interval = 6.6
Relative Accuracy = 4.6%

Date	Time (Ending 15 Minute Interval)	Reference Beckman 6800 15 Minute Average PPM	Beckman 865 15 Minute Average PPM
12/13	0630	630.1	633.5
	0730	585.5	626.3
	0830	578.4	619.0
	0930	579.4	598.4
	1030	553.8	590.1
	1130	527.8	571.6
	1230	504.2	519.0
	1330	629.8	642.8
	1430	618.3	644.8

Mean Reference Value = 578.6
Mean Difference = 26.5
95% Confidence Interval = 11.2
Relative Accuracy = 6.5%

Date	Time (Ending 15 Minute Interval)	Reference Beckman 6800 15 Minute Average PPM	Horiba A1A-21AS 15 Minute Average PPM
12/21	1430	336.2	320.0
	1530	299.8	302.0
	1630	311.8	315.0
	1730	360.3	380.0
	1830	397.3	372.0
	1930	415.6	402.0
	2030	335.5	340.0
	2130	346.7	335.0
	2230	315.8	318.0

Mean Reference Value = 346.6
Mean Difference = 11.0
95% Confidence Interval = 6.5
Relative Accuracy = 5.0%

TABLE 5. ZERO & SPAN DRIFT (24 HOUR)

Ecolyzer			Beckman 6800		
Date	ΔZ PPM	ΔS PPM	Date	ΔZ PPM	ΔS PPM
12/18	0	-30.0	12/2		3.0
12/19	0	52.4	12/3		3.0
12/20	19.4	9.7	12/4		4.0
12/21	-66.9	-28.7	12/5	AUTO ZERO	-9.9
12/22	17.1	128.3	12/6		0
12/23	11.9	67.5	12/7		9.9
12/24	9.0	-16.3	12/8		2.0
Σ	124.3	332.9	Σ		31.8
Mean	17.8	47.5	Mean		4.5
95% Confidence Interval	21.2	37.8	95% Confidence Interval		3.6
Drift (% of Span)	3.9	8.5	Drift (% of Span)		0.8

Beckman 865			Horiba A1A-21AS		
Date	ΔZ PPM	ΔS PPM	Date	ΔZ PPM	ΔS PPM
1/11	-35.0	-65.0	1/11	-8.3	-9.2
1/12	-3.0	-10.1	1/12	-3.3	-13.4
1/13	-12.3	-17.4	1/13	-5.1	+5.0
1/14	+26.7	-26.7	1/14	0	-4.2
1/15	+9.3	+27.8	1/15	-1.7	-6.8
1/16	-13.4	-13.4	1/16	-5.2	-10.4
1/17	-10.0	-36.4	1/17	+1.8	+3.5
Σ	109.7	196.8	Σ	25.4	52.5
Mean	15.7	28.1	Mean	3.6	7.5
95% Confidence Interval	10.3	17.2	95% Confidence Interval	2.6	3.4
Drift (% of Span)	2.6	4.5	Drift (% of Span	0.6	1.1

SECTION 3

RECOMMENDATIONS

3.1 PERFORMANCE SPECIFICATION

Recommended performance specifications for continuous carbon monoxide monitoring systems are presented in Table 3-1 below. These specifications are based on the overall performance demonstrated by the continuous monitors in this program, the results of the specific field performance tests, and a knowledge of the data quality requirements for continuous carbon monoxide monitoring.

TABLE 6. RECOMMENDED PERFORMANCE SPECIFICATIONS FOR CONTINUOUS MONITORS OF CARBON MONOXIDE AS APPLICABLE TO PETROLEUM REFINERIES

Parameters	Specifications
Range	0-1000 ppm
Calibration Linearity[2]	≤2% Span
Relative Accuracy[1]	≤10% Mean Ref. Value
Precision	≤1% Span
Response Time (System)	≤10 Minutes
Output Noise	≤1% Span
Zero Drift, 2 Hours[1]	≤1% Span
Zero Drift, 24 Hours[1]	≤2% Span
Span Drift, 24 Hours[1]	≤2.5% Span
Interference Equiv. 15% CO_2/10% H_2O	≤10 ppm for 15% CO_2 ≤5 ppm for 10% H_2O
Operational Period	168 hours

1. Expressed as summ of absolute mean value plus 95% confidence interval in a series of tests.
2. Based upon Engineering Judgement

The performance parameters specified in Table 6 are defined as follows:

Range - The minimum and maximum measurement levels.

Calibration Linearity - The maximum deviation of the instruments calibration curve from a straight line drawn between the zero and full scale instrument responses. This value is expressed as a percentage of full scale.

Relative Accuracy - The degree of correctness with which the continuous monitoring system yields the value of gas concentration of a sample relative to the value given by a defined reference method.

Precision - Variation about the mean of repeated measurements of the same pollutant concentration, expressed as one standard deviation about the mean.

System Response Time - The time interval from a step change in pollutant concentration at the input to the monitoring system to the time at which 95% of the corresponding value is reached as displayed on the system data recorder.

Output Noise - Spontaneous, short duration deviations in the analyzer output, about the mean output, which are not caused by input concentration changes. Noise is determined as the standard deviation about the mean expressed as a percentage of full scale.

Zero Drift - The change in the continuous monitoring system output over a stated period of time of normal continuous operation when the pollutant concentration at the time of the measurement is zero.

Span Drift - The change in the continuous monitoring system output over a stated period of normal continuous operation when the pollutant concentration at the time of measurement is the same known upscale value.

Interference Equivalent - Positive or negative response caused by a substance other than the one being measured.

Operational Period - A minimum period of time over which a measurement system is expected to operate within certain performance specifications without unscheduled maintenance.

3.2 PERFORMANCE TEST PROCEDURES

The field performance test procedures, which were based on those presented for monitors of SO_2 and NO_x from stationary sources (Federal Register, Volume 40, Number 194 - Monday, October 6, 1975), are presented below.

Procedures for precision, output noise, and interference equivalent are presented in Section 5.1 of this report.

The field performance test data for the five carbon monoxide instruments were selected from periods of representative performance. Periods during which an instrument was known to be malfunctioning were avoided.

Relative Accuracy

For continuous monitoring systems employing extractive sampling the sample for the modified method 10 instrument (NDIR), whenever possible, shall use the same sample delivery system as the continuous monitor being evaluated. In the case of a non-extractive system, or where the sampling system for the continuous monitor cannot be used, the probe for the reference method analyzers and the probe for the continuous monitor should be at adjacent locations in the duct. In the case of an in-situ cross-stack monitor the reference method probe should be centrally located in the duct as close to the measurement path of the continuous monitors as possible.

Determine the average reference method response during one 15 minute segment each hour for 9 hours. For each of these 9 reference test points, determine the average pollutant concentration reported by the continuous monitor being evaluated. These averages shall be concurrent with the reference method time intervals. For each of these 9 test intervals, determine the difference for each pair by subtracting the reference method concentration (15 minute average) from monitoring system concentration (15 minute average). Using these data, compute the mean difference and the 95% confidence interval of the differences using equations 1 and 2 shown below. Relative accuracy is reported as the sum of the absolute value of the mean difference and the 95% confidence interval of the differences expressed as a percentage of the mean reference method value.

Equations

1. The mean difference of a data set is calculated as follows:

$$\bar{X} = \frac{1}{n} \sum_{i=1}^{n} Xi$$

where:

Xi = Absolute value of the measurements

Σ = Sum of all individual values

$\bar{X}$ = Mean value, and

n = Number of data points

2. The 95% confidence interval (two-sided) is calculated as follows:

$$C.I._{95} = \frac{t_{.975}}{n\sqrt{n-1}} \sqrt{n\,(\Sigma\, x_i^2) - (\Sigma\, x_i)^2}$$

where:

$\Sigma\, x_i$ = Sum of all data points

$t_{.975} = t_{1 - x/2}$, and

$C.I._{95}$ = 95% confidence interval estimate of the average mean value

Values For $t_{.975}$

n	$t_{.975}$
2	12.706
3	4.303
4	3.182
5	2.776
5	2.571
7	2.447
8	2.365
9	2.306
10	2.262
11	2.228
12	2.201
13	2.179
14	2.160

Response Time

Introduce zero gas into the continuous monitoring system sampling interface or as close to the sampling interface as possible. When the system output reading has stabilized, switch quickly to a known concentration of pollutant gas. Record the time from concentration switching to 95 percent of final stable response. For non-extractive monitors, the highest available calibration gas concentration shall be switched into and out of the sample path and response times recorded. Perform this test sequence three (3) times. Report the mean of the three upscale test times and the mean of the three downscale test times. The two average times should not differ by more than 15 percent of the slower time. Report the slower time as the system response time.

Zero Drift (2 Hour)

Record the values given by the introduction of zero gas at two hour intervals until 15 data points are obtained. For non-extractive systems, the zero value may be determined by mechanically producing a zero condition that provides a system check on analyzer internal mirrors, electronic circuitry, radiation source and detector assembly. The two hour periods over which the measurements are taken need not be consecutive but may not overlap.

Using this data, calculate the differences between consecutive two hour readings expressed in ppm. Calculate the mean difference and the 95% confidence interval using equations 1 and 2 on page 14. The two hour zero drift is reported as the sum of the absolute mean value and the 95% confidence interval expressed as a percentage of span.

Zero Drift (24 Hour)

Record the zero concentration values every 24 hours during a 168 hour operational field test period. Using the zero values obtained calculate the difference between the zero point after adjustment (if any) and the zero value 24 hours later prior to any adjustment. Calculate the mean value of these points and the 95% confidence interval using equations 1 and 2 on the previous page. Report the zero drift (sum of the absolute mean value and the confidence interval) as a percentage of span.

Calibration Drift (24 Hour)

Record the calibration values measured every 24 hours during a 168 hour operational test period. Using the calibration values obtained calculate the difference between the calibration value after zero and calibration adjustments and the value obtained 24 hours later, after zero but before calibration adjustment. Calculate the mean values of these points and the 95% confidence interval using equations 1 and 2 on the previous page. Report the calibration drift (sum of the absolute mean value and the confidence interval) as a percentage of span.

Operational Test Period

During the 168 hour operational test period, the continuous monitoring system shall not require any corrective maintenance, repair, replacement or adjustment other than that specified, as required by the manufacturer and expected in a one-week period. If the monitoring system performs as above and remains within performance specifications, the test is considered successful.

SECTION 4

DESCRIPTION OF INSTRUMENTATION

4.1 ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC. STACK GAS ANALYZER - MODEL 4000

The Environmental Research and Technology Stack Gas Analyzer Model 4000 is a multi-component in-situ continuous monitor that measures concentrations of component gases based on absorption of infrared energy. For this application, the instrument measured carbon monoxide, although it has the capability for simultaneous measurement of NO, SO_2, CO and CO_2.

The instrument consists of an infrared source and a detector which are mounted on opposite walls of a stack or duct. The concentration of the component gas is based on the attenuation of infrared energy by the gas as the IR beam travels across the duct.

The intensity of this IR beam is attenuated, however, by factors other than CO in its travel across the duct. Variations in particulate concentration, for example, introduce source intensity fluctuations at the detector. These intensity fluctuations, which are independent of CO concentrations, must not be detected as CO. The design of the ERT instrument continuously compensates for these intensity fluctuations by using a gas correlation technique that makes measurement relatively independent of source intensity. This is accomplished through a two phase analysis cycle that alternates between measurement of the source and an internal reference source. Variations in stack temperature affecting concentration measurements are continuously compensated for by a temperature sensor and the instrument's electronics.

Routine calibration of the instrument is controlled by a switch located at the instrument's recorder which directs a calibration IR beam through a reference cell containing CO in the detector. This should produce a pre-established response on the instrument's recorder.

The continuous recorder containing the switches for calibration is remotely located and connected to the detector on the stack or duct by an umbilical cable.

The manufacturer's specifications for the ERT instrument are presented in Table 7.

4.2 ECOLYZER (MODEL 3100), ENERGETICS SCIENCE, INC.

The Ecolyzer senses levels of carbon monoxide by means of an electrochemical detector which produces an electrical current proportional to the concentration of CO in the input sample. This current is produced within the detector by the electro-oxidation of carbon monoxide causing a current flow between two electrodes. The current causes a deflection on a milliammeter indicating the concentration of carbon monoxide relative to calibration. An output is also provided for a continuous recorder. The manufacturers specifications for the Ecolyzer are reproduced in Table 8.

Figure 1 is a flow diagram showing the major components in the instrument. The internal sample pump with associated valve and flow meter maintains constant flow through the instrument which is necessary for accurate response. When using an external sample pump, a bypass must be provided to prevent pressure and flow variation at the instrument.

The following sample conditioning steps were recommended by the manufacturer for the field application at the Sun Oil site:

- Cool the emission gas sample to ambient temperature if possible, but at least down to 100°F.
- Reduce the sample gas pressure to ambient pressure if possible, but at least down to 2 inches of water above ambient.

TABLE 7. MANUFACTURER'S SPECIFICATIONS

ERT STACK GAS ANALYZER

Range of Operating Conditions	
Stack Gas Temperature	$20^{\circ}F$ - $600^{\circ}F$
Source Attenuation (due to combination of stack opacity and window transmission)	0 - 80%
Ambient Temperature Range	$-20^{\circ}F$ - $+105^{\circ}F$
Humidity	0 - 100% relative
Power Requirements	Sensor - 500 Watts at 110 Volts ± 20%, 60 Hz Source - 2000 Watts at 220 Volts ± 20%, 60 Hz
Vibration	No special vibration isolation required.
All Weather Enclosure Provided	
Data Interface	Analog Output - 0 to 10 VDC
	Status Lights - Power ON Window DIRTY
	Remote Control - Span Calibration
Gas Concentration Ranges	
CO - 500 ppm minimum full scale, or greater as required	
Accuracy of Initial Calibration	
CO ± 25 ppm or ± 5% of indicated value, whichever is greater	
Maximum Drift (24 hour)	
CO - Zero ± 25 ppm	Span ± 25 ppm
Weight and Size	
Sensor 23-1/2" x 27-1/2"*x 13-5/8"	112 lbs
Source 15" x 15" x 18"	66 lbs
*31-1/2" with handles and flange	
Windows and Source Purge	
Where required, for example for positive pressure applications, windows and source purge systems can be provided.	

TABLE 8. CAPABILITIES AND CHARACTERISTICS

ECOLYZER

Item	Characteristics
Power Requirements	
AC	95-130 volts, 50/60 Hz
Battery	One (1) Mercury cell 1.35V Four (4) C size nickel/cadmium 1.25V each
Minimum Detectable Sensitivity	0.5 ppm (0-50 ppm scale)
Readout	Meter (100 divisions full scale)
Range	0-50, 0-100, 0-500 ppm; (0-1000, 0-2000 ppm and dual range option)
Sensor	Electrochemical
Sensor Life	One (1) year in use
Circuitry	Solid State
Operating Temperature Range	Internal temperature controlled (optional) for 0 to 125°F ambient compensation
Temperature Compensation	Built-in thermistor compensation
Calibration	As required
Rise Time	Approximately 90 seconds
Fall Time	Approximately 90 seconds
Zero Drift	Less that ± 0.5% per day
Span Drift	Less than ± 1.0% per day
Accuracy	± 1.0% (full scale)
Noise	± 0.2% (full scale)
Linearity	± 1.0% (full scale)
Relative Humidity Range	5 to 95%

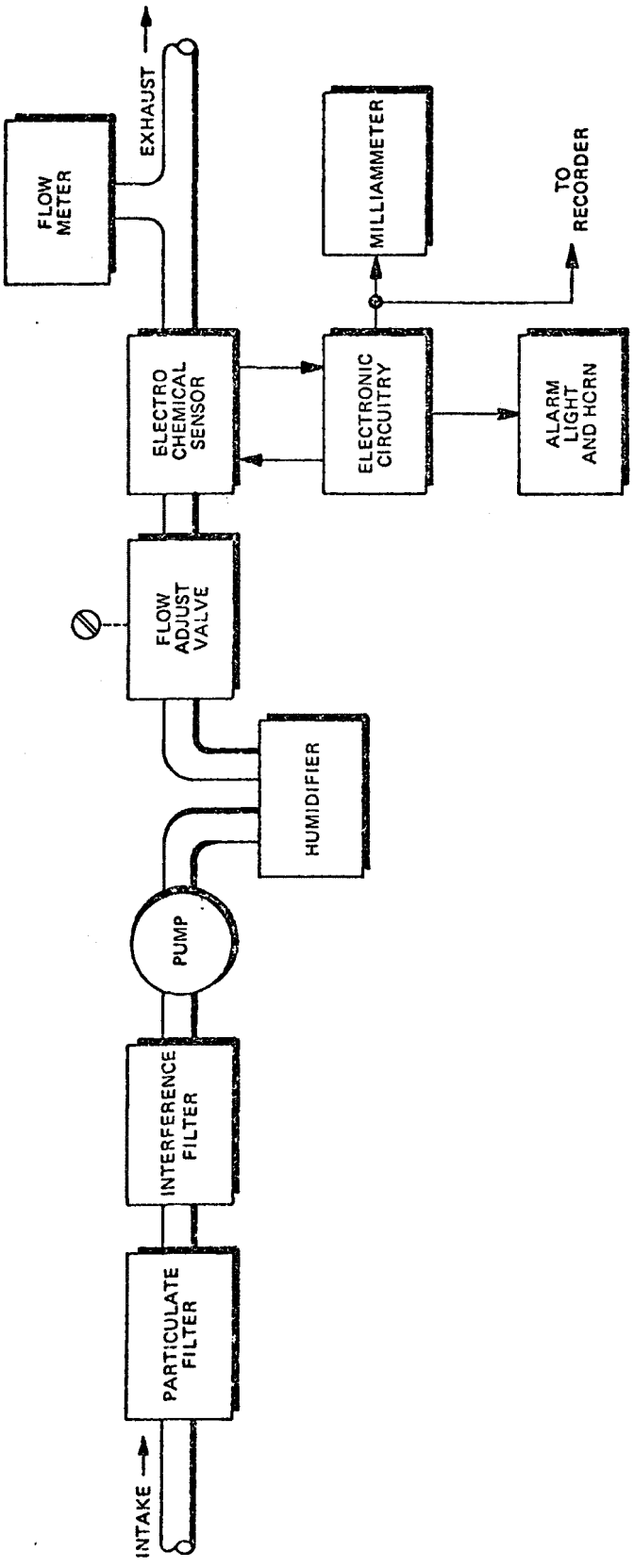


FIGURE 1. 3000 Series Ecolyzer, Flow Diagram

- Remove water condensate in a trap. Ideally, the sample entering the Ecolyzer should have a relative humidity of about 80%.
- Insure that there is a particulate filter in the gas sample line.
- Insure that the Ecolyzer humidity adjustment system is used according to instructions.

4.3 BECKMAN AIR QUALITY CHROMATOGRAPH (MODEL 6800)

The Beckman Chromatograph is a multi-component continuous monitor employing column separation of gaseous components and detection by flame ionization detector (FID). The instrument is totally automated and can be programmed to accommodate a wide variety of applications. Internal automatic functions are performed by solenoid actuated slider valves controlled by a solid state timer.

The basic three component unit used in this program was capable of measuring total hydrocarbons, methane and carbon monoxide. After column separation, a catalytic methanator is used to convert carbon monoxide to methane permitting detection by the flame ionization detector. The Model 6800 is designed as an ambient monitor with a maximum sensitivity of 0-300 ppm, and it was necessary to decrease the size of the sample loop to prevent saturation of the detector in the 0-1000 ppm CO range required for stack gas analysis. The instrument was programmed to perform one analysis every five minutes (12 analysis cycles each hour). The manufacturer's specifications are reproduced in Table 9.

4.4 BECKMAN MODEL 865 NON-DISPERSIVE INFRARED ANALYZER

The Model 865 infrared analyzer continuously measures levels of various infrared absorbing gases based on the differential absorption of infrared energy between a flowing sample cell and a sealed referenced cell. The concentration of the component gas is then proportional to the absorption of infrared energy by that gas in the sample cell relative to

TABLE 9. SPECIFICATIONS

BECKMAN AIR QUALITY CHROMATOGRAPH

Measurements - Standard three-component analysis determines carbon monoxide, methane, and total hydrocarbons. Optional five-component analysis includes determinations of etyhlene and acetylene.

Operation - Automatic, unattended, repetitive analysis of selectable rate of 4, 6, or 12 analyses per hour for three-component system; 4 or 6 analyses per hour for five-component system. Automatic readjustment of electronic zero during each analysis cycle. Automatic daily analysis of calibration standard gas available as an option for three-component system only.

Ranges - Individually selectable, automatically actuated, ranges for each component. Maximum sensitivity, 1 ppm to 300 ppm full scale.

Sample - Ambient air. Integral pump provides sample flow rate of 5 liters per minute at standard temperature and pressure.

Precision - ± 0.5% of full scale or 0.05 ppm, whichever is greater.

Linearity - 1% of full scale.

Zero Drift - Automatic zero adjustment during each analysis cycle compensates for zero drift.

Interference From Other Gases - None

Automatic Timing - Precision digital timing provides one-second resolution for all time-related analysis functions.

Output Signals

1. Individual 0 to 5 volts d.c. outputs for each pollutant for trend recording, computer, telemetry, or other data-acquisition equipment. Output impedance ≈ 0.
2. Zero to 100 millivolts d.c. output for chromatogram and/or bar-graph readout on potentiometric recorder. This output available at both a rear-panel connector for a permanent recorder, and at a front-panel jack for temporary connection of a test recorder.

Ambient Temperature - 35°F to 120°F, 95% relative himidity.

Gases Required - Hydrogen, 70 cc/min at 30 to 150 psig; air, 350 cc/min at 30 to 150 psig.

Dimensions - 17 inches wide x 40 inches high x 20 inches deep.

Shipping Weight - 250 pounds.

Power - 107 to 127 volts a.c., 50/60 Hz, 500 watts.

the reference cell. The instrument's detector has two compartments separated by a diaphram. Each compartment is filled with the component gas to be sampled. The infrared energy passing through the cells excites the molecules in each detector compartment. The difference in excitation between the sample and reference side of the detector causes distention in the diaphram between the detector compartments. This distention causes a capacitance change, which is equivalent to the component concentration in the sample cell, and is amplified for output. The practical range of the instrument is a function of sample cell length. The Beckman 865 used in the program employed a 13-1/2 inch cell accommodating the 0-1000 ppm CO range. The manufacturer's specifications are reproduced in Table 10.

4.5 HORIBA NON-DISPERSIVE INFRARED ANALYZER (MODEL A1A-2 AND A1A-21AS)

The original Horiba NDIR (Model A1A-2) selected for this program was replaced during the field program by a newer model A1A-21AS. Both Horiba instruments are infrared analyzers that measure levels of infrared absorbing gases based on the differential absorption of infrared energy between the flowing sample cell and a sealed reference cell. The concentration of the specific input gas is then proportional to the attenuation of infrared energy by the gas in the sample cell. The basic operating principle is the same as described for the Beckman Model 865 NDIR.

Both Horiba instruments used a 500 mm cell that measured carbon monoxide on the 0-1000 ppm range. The Horiba Model A1A-21AS incorporated optical filters and a new detector designed to reduce interference from water and CO_2. The manufacturer's specifications for the A1A-2 and A1A-21AS are reproduced in Tables 11 and 12.

TABLE 10. SPECIFICATIONS

BECKMAN MODEL 865 NON-DISPERSIVE INFRARED ANALYZER

Accuracy - 1% of full scale.

Span Drift* - ± 1% of full scale in 24 hours.

Zero Drift* - ± 1% of full scale in 24 hours.

Ambient Temperature Range - 30°F to 120°F (-1°C to 49°C)

Line Voltage - 115 ± 15 volts rms.

Line Frequency - 50/60 ± 0.5 Hz

Power Consumption - 400 watts.

Electronic Response Time (0 to 90% of full scale)

Switch selection of fast or slow response.
FAST switch position provides 0.5-second response (optional 1-second response obtainable by clipping jumpers).
SLOW switch position provides 2.5-second response.

Output

Standard (Potentiometric)
0 to 10, 0 to 100 millivolts, o to 1, 0 to 5 volts d.c. (field selectable).
Optional (Current)
4 to 20 and 10 to 50 milliamperes, d.c. (field selectable)
or, Linearized (Potentiometric)
0 to 10, 0 to 100 millivolts, 0 to 1, 0 to 5 volts d.c. (field selectable)

*Performance specifications based on ambient temperature shifts of less than 20 Fahrenheit degrees (11 Centrigrade degrees) at a maximum rate of 20 Fahrenheit degrees (11 Centrigrade degrees) per hour.

TABLE 11. SPECIFICATIONS

HORIBA NON-DISPERSIVE INFRARED ANALYZER MODEL A1A-2

Measuring Method - Infrared analyzer, non-dispersive method, positive filter, double light sources, deflection type.

Accuracy - ± 1%

Drift - ± 1% full scale for 8 hours

Speed of Response - 90% electronic response in 0.5 seconds.

Sensitivity - 0.5% of full scale

Typical Measuring Ranges -

CO (carbon monoxide)
0-1%, 0-3%, 0-5%, 0-10%, 0-12%
0-3000 ppm, 0-250 ppm

All measurement ranges for any one component can be incorporated within a multiple range analyzer but means of an electrical dual or triple range selector or a stacked cell configuration. Flowing reference and filter cells also available.

Output

0-10 mv and 0-100 mv D.C. for recorder and
0-1 V and 0-5 V input to Data Acquisition System.

Ambient Temperature Range - $32^{o}F$ to $105^{o}F$

Power Requirement - 115 V A.C. (60 Hz) or 230 V A.C. (50 Hz) 250 VA

Weight - Analyzer Section: approx. 40 lbs. (18 Kg)
Amplifier Section: approx. 28 lbs. (12.6 Kg)

TABLE 12. SPECIFICATIONS

HORIBA NON-DISPERSIVE INFRARED ANALYZER MODEL A1A-21AS

Measuring Method - NDIR, positive filter, dual source reflection type.

Repeatability - ± 1% of full scale

Sensitivity - 0.5 of full scale

Speed of Response - 90% electronic response in 0.5* seconds.

* A slower response (up to 2 seconds) is required in some applications)

Drift - Zero Drift: 1% of full scale in 8 hours
Span Drift: 1% of full scale in 8 hours

Outputs - 0-1 ma for remote meter readout
0-10 and 0-100 millivolts for pot. recorder
0-1 and 0-5 volts for data acquisition system

(Range indentification outputs are also available on multi-range application.)

Ambient Temperature Range - 0 to 40°C (32 to 105°F)

Sample Temperature Range - 0 to 40°C (32 to 105°F)

Recommended Sample Flow - 1 to 10 liters per minute (2.1 to 21 CFH)

Sample Cell Temperature - 55°C (131°F) regulated

Power Requirement - 115 VAC at 60 Hz

Weight/Unit (approx.) - Analyzer Section (Typical): Version 1 7.7 Kgs. (17 lbs)
Electronics Module Section (Typical):
3-pack 10.3 Kgs (23 lbs)

Sample Connections - 1/8" N.P.T. (inlet and outlet)

SECTION 5

LABORATORY PERFORMANCE EVALUATION

5.1 DESCRIPTION OF TEST PROCEDURES

The laboratory evaluation consisted of a series of performance tests on each instrument. The parameters tested included:

- response characteristics (calibration)
- precision
- noise
- response times (rise and fall)
- H_2O and CO_2 interference
- flow and temperature variation
- zero and span drift

Federal Register Volume 40, Number 33, February 18, 1975, Subpart B, "Procedures for Testing Performance Characteristics of Automated Methods", was used as the basis for the laboratory evaluation tests.

Gas standards used for calibrations and all performance tests were Scott close tolerance cylinder mixtures of carbon monoxide in nitrogen. The mixtures were analyzed against NBS standard reference mixtures containing 100, 500 and 1000 ppm CO. Zero gas used was Scott 99.98% pure nitrogen. Gas for the CO_2 interference tests was a Scott blend of 15% CO_2 in nitrogen.

5.1.1 Response Characteristics (Calibration)

Calibration procedures consisted of introducing several CO calibration gases and nitrogen zero gas into each instrument being tested. Calibration curves were constructed by plotting the instrument responses on the ordinate against the CO concentrations on the abscissa

5.1.2 Precision (Repeatability)

Precision is the standard deviation about the mean of repeated

measurement of the same gas concentration. This value is expressed in concentration units. During the test, measurement of the selected gas is interrupted alternately by the introduction of a higher and a lower gas concentration. Six stable readings of the selected gas are obtained after each injection of the higher or lower standard. These values are then entered into the following equation for precision.

$$P = \sqrt{\frac{1}{5}\left[\sum_{i=1}^{6} Pi^2 - \frac{1}{6}\left(\sum_{i=1}^{6} Pi\right)^2\right]}$$

Where: P = Precision

Pi = Instrument Response (ppm) for the i^{th} measurement

5.1.3 Output Noise

Instrument noise is short-term variations in instrument output not caused by changes in input concentration. This value is expressed in concentration units as the standard deviation about the mean. The recommended procedure is to test for noise using zero and 80% of full scale gas standards.

The test procedure calls for allowing the instrument to stabilize on the gas standard and then take 25 readings within a 60 minute period using a digital voltmeter. These voltages are converted to concentration units and entered into the equation for noise.

$$S = \sqrt{\frac{1}{24}\left[\sum_{r=1}^{25} (ri)^2 - \frac{1}{25}\left(\sum_{r=1}^{25} ri\right)^2\right]}$$

Where: S = Instrument Noise (ppm)

ri = Instrument Response for the i^{th} reading (ppm)

5.1.4 Response Times (Rise and Fall)

Rise Time: Rise time is the time interval between initial instrument response and 95% of the final response after a step increase in input gas concentration. The test procedure involves changing the input from zero gas to a high range span gas. Rise time was calculated from the recorder chart which was run at high speed for this test.

Fall Time: Fall time is the time difference between initial response and 95% of final response after a step decrease in input gas concentration. During this test, the input was changed from a high range span gas to nitrogen zero gas. Times were also measured on the recorder chart.

Figure 2 illustrates the procedure used for measurement of response times.

5.1.5 CO_2 and H_2O Interference

CO_2: CO_2 interference was determined using a Scott blend of 15% CO_2 in nitrogen. The procedure used was to first allow the instrument to stabilize on nitrogen zero gas. The response to the introduction of the 15% CO_2 is then expressed in parts per million as an equivalent CO concentration.

H_2O: H_2O interference was determined by the addition of 10% water vapor while the instrument was sampling nitrogen zero gas. The response to the added water vapor is expressed in parts per million as an equivalent CO concentration. Water vapor was added by passing nitrogen through a flask containing distilled water. The flask was heated sufficiently to introduce 10% water vapor into the flowing sample. This water vapor generator was calibrated using EPA Method 4.

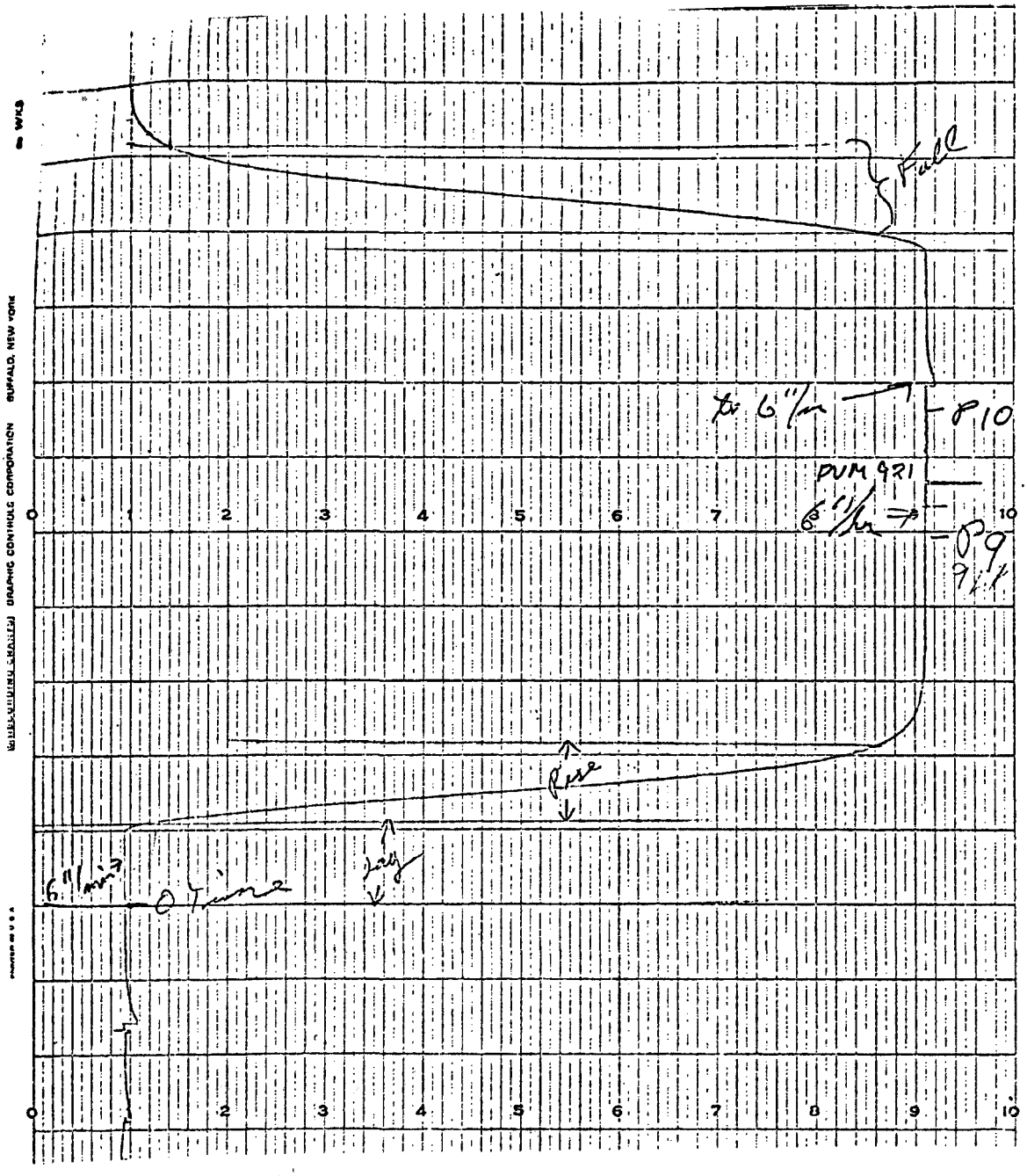


FIGURE 2 RESPONSE TIMES (RISE AND FALL)

5.1.6 Variations Due To Changes In Temperature And Flow Rate

Variations in instrument output caused by short term changes in ambient temperature were measured using nitrogen zero, 163 and 897 ppm CO span gases. The test procedure involved recording stable responses to the three gases at a given temperature then changing the temperature and again recording the stabilized responses. These tests were performed in February and the temperature was varied by regulating heat and opening two large garage doors.

The effects of variation in input flow rate were tested using the 807 ppm CO standard. During the test, the input flow rate was varied from 0-5 liters/minute and responses were monitored with a digital voltmeter. Flows were monitored with a calibrated rotameter.

5.1.7 Zero and Span Drift

12 Hour Continuous Zero Drift: This test involved sampling zero air for 12 consecutive hours. The recorder chart was then examined for the minimum and maximum responses. The maximum minus the minimum response equals the zero drift expressed as parts per million CO.

8 and 24 Hour Zero Drift: For this test the responses to the input of nitrogen zero gas were recorded and entered into the equation $ZD = Z_n - Z_{n-1}$ for the n^{th} test period. This is expressed in parts per million.

Span Drifts: Span drifts were calculated by recording the instrument response at the beginning and end of the time interval being tested. The chart responses are entered into the equation:

$$\text{Span Drift} = \frac{S_n - S_{n-1}}{100}$$

The results are presented as a percent of full scale and as equivalent parts per million.

5.2 LABORATORY TEST RESULTS

5.2.1 Environmental Research & Technology, Inc. Stack Gas Analyzer-Model 4000

Calibration and performance testing of the ERT monitor was conducted at the ERT Laboratories in Concord, Massachusetts on September 15 and October 15, 1975. The second calibration was necessary because the instrument used in the first tests was not the one furnished for this project and the gases used were not comparable to those used on the other instruments. A summary of these test results is shown in Table 13.

Calibration

Calibration of the ERT instrument involves mounting the instrument on a 16 foot test cell that can be evacuated and heated. The equivalent stack concentration is proportional to the ratio of the test cell length to the stack path length.

In the first test series, each calibration point was prepared by adding gas from a cylinder of 2200 ppm CO to a pre-calculated pressure into the evacuated cell. Nitrogen was then added to bring the cell to atmospheric pressure. The concentration of the test cell is a function of the partial pressure at which the calibration gas is introduced.

The following data were recorded:

Equivalent Stack CO Concentration	Interference Gas	Millivolt Output	Cell Temperature (^{o}F)
1100.5	None	77.5	260
680.8	None	42.0	315
282.2	None	20.5	345
0.0	None	1.0	345
0.0	48.22% CO_2 20% H_2O	5.0	345

The second calibration series was made at ERT after the instrument furnished for this project was available. Three Scott standard CO mixtures used for the calibration of the other instruments on this project were transported to ERT. Their concentrations were 100, 321, and 496 ppm.

TABLE 13 PERFORMANCE TEST SUMMARY
ERT MODEL 4000

Range: 0-1000 ppm

Precision: Not Tested

Noise: (Using Internal Cal Mode) 35.5 ppm

Response Times: Not Tested

Interference: 15% CO_2 - 20 ppm

15% CO + 12% H_2O - 25 ppm

Zero and Span Drift: Not Tested

The test cell at ERT was evacuated and filled to atmospheric pressure with each of the Scott gases. The following are the results of the calibration. Figure 3 shows the calibration curve.

Cylinder Concentration	Equivalent Stack Concentration	Millivolt Output	Cell Temperature (^{o}F)
100 ppm CO	195.8 ppm CO	19.5	400
321 ppm CO	495.7 ppm CO	53	400
496 ppm CO	774.5 ppm CO	83	400

Precision

Due to the special nature of the test cell procedure, tests for precision were not practical for the ERT instrument.

Noise

The test for instrument noise was performed on January 22, 1976 while the instrument was at the Sun Oil Company site. The internal calibration mode was used as the source and readings were taken with a digital voltmeter. The test data are shown in Table 14.

Response Times

Response times were not measured during the ERT laboratory checkout.

Interference

Interference tests for H_2O and CO_2 were performed during the ERT laboratory checkout. The instrument's response to 15% CO_2 in N_2 was first recorded, then sufficient water to yield 12% moisture was injected into the heated cell in addition to the 15% CO_2. The responses were as follows:

Cell Concentration	Equiv. Stack Concentration	Response (mv)	Equivalent ppm CO
N_2 (zero gas)	0	0	0
15% CO_2 in N_2	29.4% CO_2	2	20
15% CO_2 + 12% H_2O	29.4% CO_2 + 24% H_2O	2.5	25

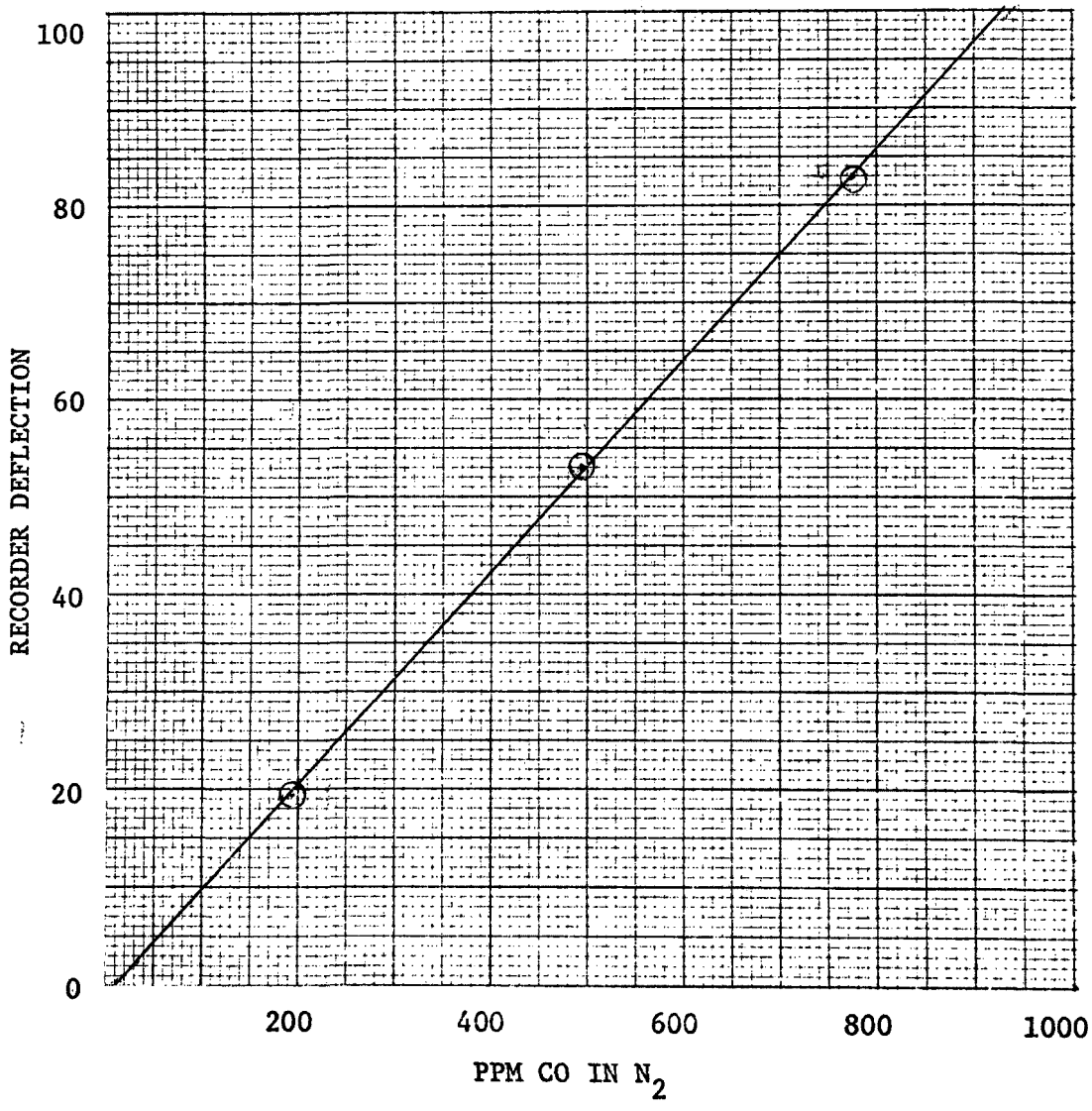


FIGURE 3 ERT MODEL 4000 CALIBRATION CURVE

TABLE 14 NOISE TEST DATA

Applicant _____ Date 11/22/76

Test No. _____

Analyzer FRT - Model 4000 Range 0 - 1000 PPM CO

READING NUMBER (i)	TIME	0% of URL		80% of URL	
		DM READING	r_i, ppm	DM READING	r_i, ppm
1	2			7.45	745
2	4			7.66	766
3	6			7.31	731
4	8			6.95	695
5	10			7.58	758
6	12			7.60	760
7	14			7.02	702
8	16			7.73	773
9	18			7.36	736
10	20			7.18	718
11	22			7.62	762
12	24			7.51	751
13	26			7.58	758
14	28			7.31	731
15	30			7.24	724
16	32			7.79	779
17	34			7.07	707
18	36			8.09	809
19	38			7.57	757
20	40			8.20	820
21	42			7.66	766
22	44			7.48	748
23	46			8.31	831
24	48			8.07	807
25	50			7.30	730
$\sum_{i=1}^{25} r_i$					18864
$\sum_{i=1}^{25} r_i^2$					14264220
S			S_0 =		S_{80} = 35.5

Temperature Variation

Tests for temperature variation were not performed on the ERT during its initial checkout at the ERT laboratories.

Flow Variation

Laboratory tests for flow variation effects could not be conducted with the static test cell used for the ERT laboratory testing.

Zero and Span Drift

Laboratory tests for instrument drift were not conducted on the ERT instrument.

5.2.2 Energetics Science Inc. Ecoylzer - Model 3100 (Serial No. 31113)

Performance tests on the Ecolyzer were conducted both before and after the field program. Some of the tests planned for after the field program were omitted due to the deterioration of the detector cell that occurred during the field program. Figure 4 illustrates the change in response after the detector deterioration. Although the initial response to the input gas was good, it immediately dropped off, after which it took in excess of 1 hour to stabilize. During this stabilization, the response slowly drifted upscale toward the final response.

A summary of the laboratory tests on the Ecolyzer is presented in Table 15.

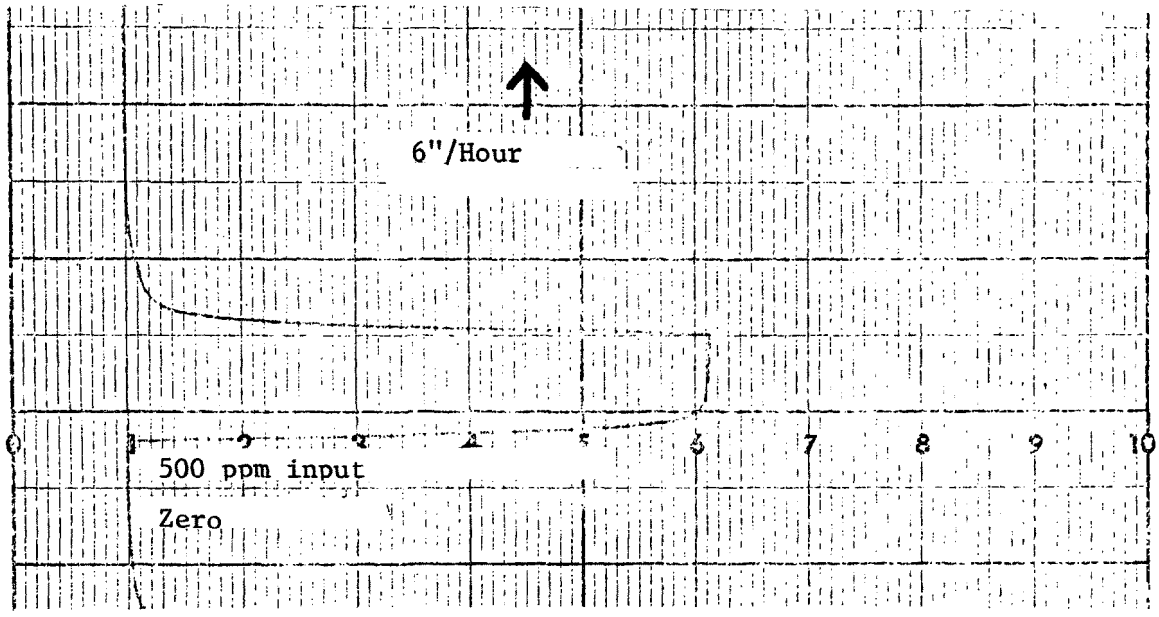
Calibration

Calibration performed on December 1, 1975 is shown below. the calibration curve is shown in Figure 5.

CALIBRATION POINTS 12/1/75

CO Concentration (ppm)	Instrument Response (Chart Units)
0	0
100	10.5
321	34
496	49.5
650	65
807	75.7
925	87

BEFORE DETERIORATION



AFTER DETERIORATION

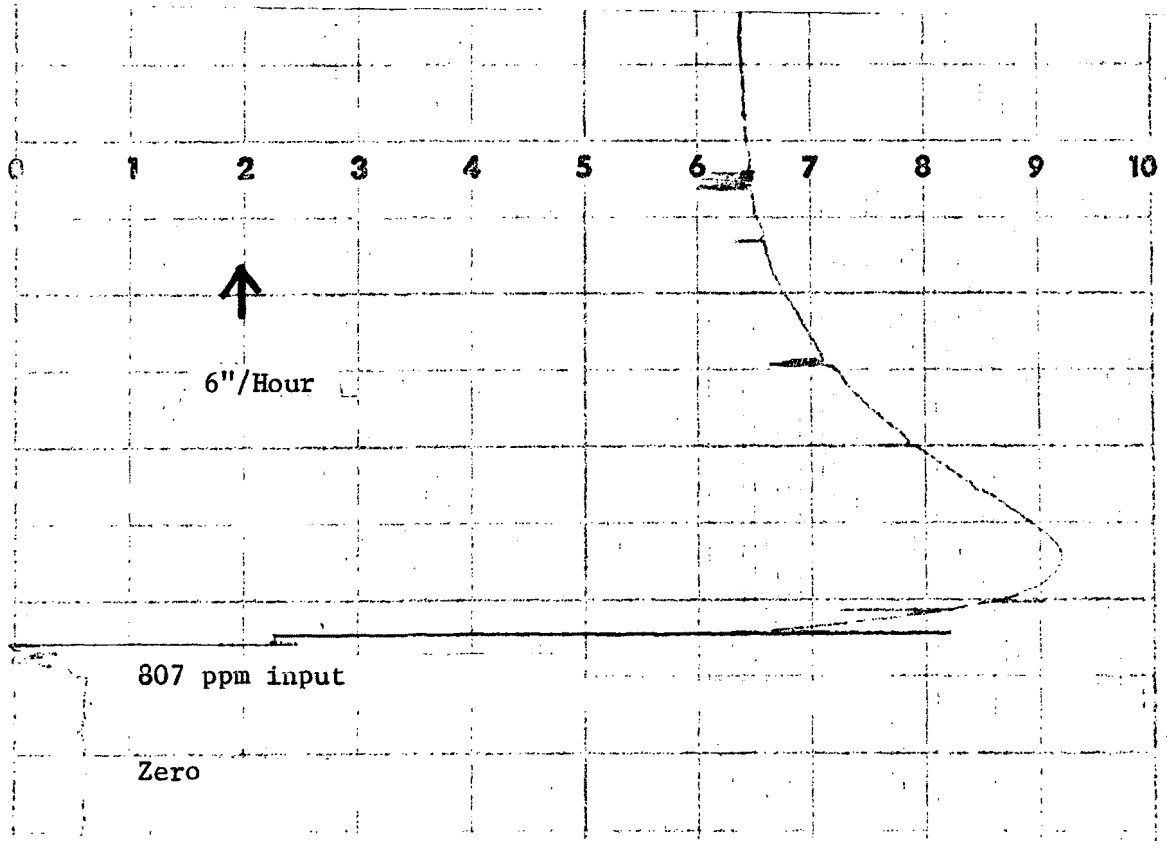


FIGURE 4 ECOLYZER RESPONSE CHANGES (BEFORE AND AFTER DETERIORATION)

TABLE 15. PERFORMANCE TEST SUMMARY

ECOLYZER

Range: 0-1000 ppm CO

Precision: (163 ppm) 4.32 ppm

Noise: Nitrogen Zero - 0.46 ppm
807 ppm CO - 1.6 ppm

Response Times: Rise - 86 seconds
Fall - 83 seconds

Interference: CO_2 - 0 ppm

Zero Drift: (% of Full Scale)
12 hour continuous - 0.6*
24 hour - 0.2*

24 Hour Span Drift: (% of Full Scale)
163 ppm - 0.4*
807 ppm - 0.4

*Average

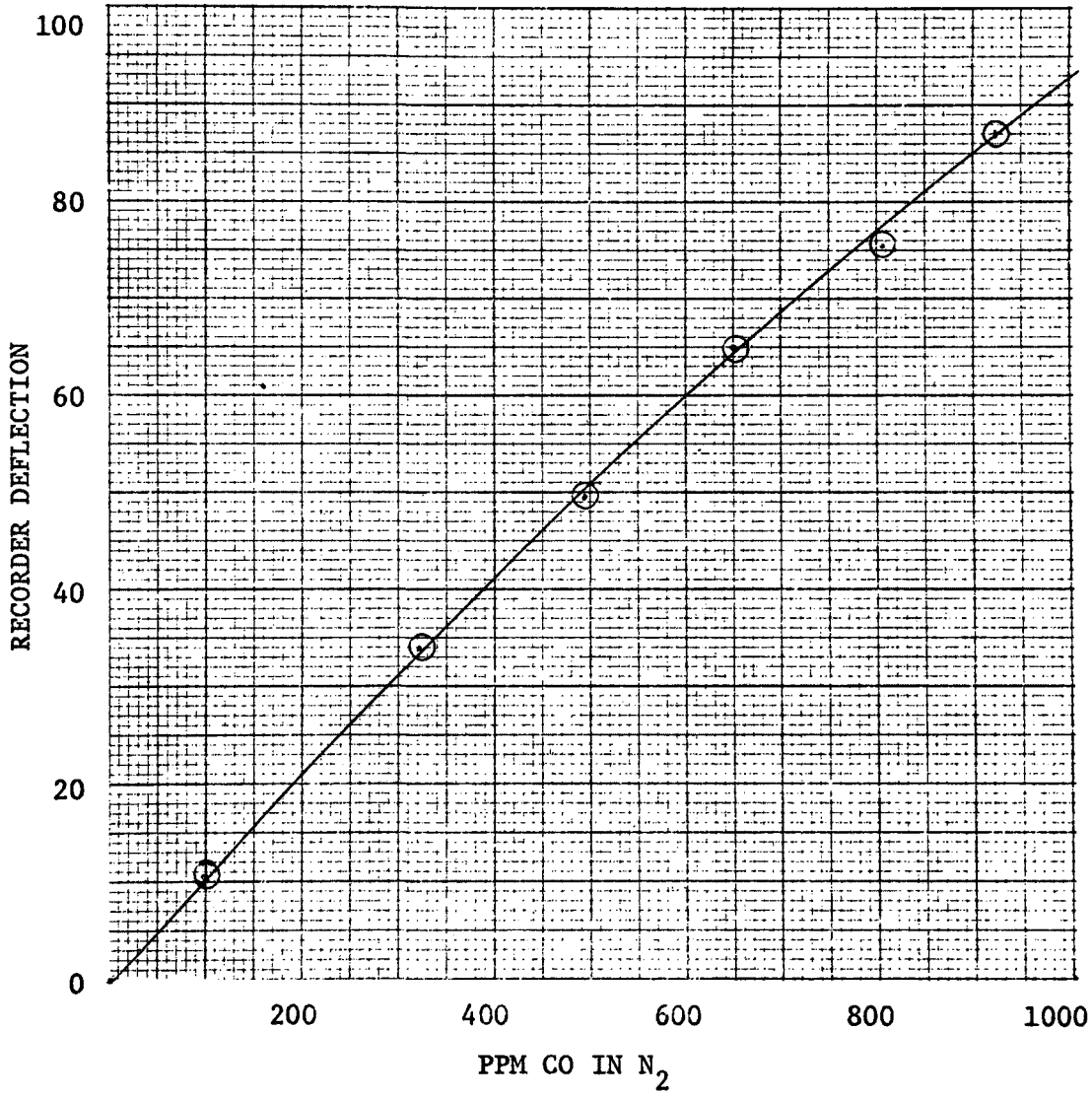


FIGURE 5 ECOLYZER CALIBRATION CURVE

Precision

The test for precision was conducted on February 12 using the 163 ppm calibration standard. The test results are shown below. Precision tests using a higher range gas planned for after the field program were omitted due to the extended response times.

PRECISION TEST 2/12/76

	Calibration Standard (ppm)	Instrument Response (ppm)
P_1	163	163
P_2	163	163
P_3	163	168
P_4	163	163
P_5	163	173
P_6	163	170

P_{163} = 4.32 ppm

Noise

Tests for instrument noise were conducted using nitrogen zero gas and the 807 ppm CO standard. The results are shown on Table 16.

Response Time

The rise and fall times for the Ecolyzer using the 1060 ppm CO standard were 86 and 83 seconds, respectively. This test was performed in October 1975 while the detector was in good condition.

Interference

CO_2 interference was tested on the 0-1000 ppm range using 15% CO_2 in nitrogen. The input changed from nitrogen to 15% CO_2 in nitrogen produced no change in instrument response.

Temperature Variation

Effects of temperature variation on instrument response was tested using zero, 163 ppm and 807 ppm calibration standards.

TABLE 16. NOISE TEST DATA

Applicant _____ Date _____

Test No. _____

Analyzer Ecolyzer Range 0 - 1000

READING NUMBER (i)	TIME	0% of URL		80% of URL	
		DM READING	r_i, ppm	DM READING	r_i, ppm
1	2	29	0	784	807
2	4	28	-1	784	807
3	6	28	-1	785	808
4	8	28	-1	783	806
5	10	29	0	784	807
6	12	28	-1	785	808
7	14	28	-1	786	809
8	16	29	0	786	809
9	18	29	0	787	810
10	20	29	0	787	810
11	22	29	0	787	810
12	24	29	0	787	810
13	26	29	0	786	809
14	28	29	0	787	810
15	30	29	0	786	809
16	32	28	-1	786	809
17	34	29	0	786	809
18	36	29	0	787	810
19	38	29	0	787	810
20	40	29	0	787	810
21	42	29	0	788	811
22	44	28	-1	787	810
23	46	29	0	788	811
24	48	29	0	790	813
25	50	29	0	789	812
$\sum_{i=1}^{25} r_i$			7		20234
$\sum_{i=1}^{25} r_i^2$			7		1637665?
S			$S_0 = 0.46$		$S_{80} = 1.6$

2/11/76

	Time	Temperature	Response
Zero Gas	0900	70°	9.0 ct. units
	1300	60	9.5
			0.5 ct. units = 5.7 ppm
163 ppm	0900	70	15.1 ct. units
	1300	60	13.7
			1.4 ct. units = 16 ppm
807 ppm	0900	70	73 ct. units
	1300	60	70.8
			2.2 ct. units = 25.1 ppm

Flow Variation

Variations in input flow rate, within the manufacturer's recommended range, had negligible effects on instrument output.

Zero and Span Drift

Tests for instrument drift are presented below. These tests include 12 hour and 24 hour zero drift and mid and high range span drifts.

12 Hour Continuous Zero Drift

10/10/75	Maximum	10.3 chart units
	Minimum	9.9
	12 Hr. Drift	0.4 chart units = 4.6 ppm
2/11/76	Maximum	10.0 chart units
	Minimum	9.0
	12 Hr. Drift	1.0 chart units = 11.4 ppm
2/12/76	Maximum	10.2 chart units
	Minimum	9.7
	12 Hr. Drift	0.5 chart units = 5.7 ppm

24 Hour Zero Drift

		Response (% of full scale)			
Date	Temp.	Z_n	Z_{n-1}	Drift (ΔZ)	Equiv. ppm
2/11-12	70	8.3	8.5	-0.3	3.4
2/12-13	60	8.2	8.3	-0.1	1.1

Span Drift

Gas Standard 163 ppm

Date	Temp.	Response (% of full scale) M_n	M_{n-1}	Drift (ΔZ)	Equiv. ppm
24 hour					
2/11-12	70	14.1	14.7	-0.6	6.9
2/12-13	60	13.9	14.1	-0.2	2.3

Gas Standard 807 ppm

Date	Temp.	Response (% of full scale) S_n	S_{n-1}	Drift (ΔZ)	Equiv. ppm
24 hour					
2/11-12	70	73.0	72.6	0.4	4.6

5.2.3 Beckman Air Quality Chromatograph (Model 6800) (Serial No. 1000119)

Performance tests for the Beckman 6800 were conducted both before and after the field program. A summary of the laboratory performance tests is shown in Table 17. Several of the traditional performance tests are not applicable to this instrument due to its operating principles and design. These include zero drift, variations, rise and fall times and noise.

Calibration

Calibrations conducted on February 11, 1976 produced the following points with the curve shown on Figure 6.

CO Concentration (ppm)	Instrument Response (Chart Units)
0	0
163	14.2
321	28.1
496	43.9
650	58.1
807	72.0
925	82.3

TABLE 17. PERFORMANCE TEST SUMMARY
BECKMAN 6800

Range: 0-1000 ppm CO

Precision: 163 ppm standard - 0.69 ppm*
327 ppm standard - 0.08 ppm
807 ppm standard - 1.35 ppm*
1060 ppm standard - 1.17 ppm

Noise: Not Applicable

Interference: CO_2 - None
H_2O - None

Zero Drift: None

Span Drift:

163 ppm standard

8 hr. - 0.1% of full scale

24 hr. - 0.1% of full scale*

807 ppm standard

8 hr. - 0.7% full scale

24 hr. - 0.8% full scale*

*Average

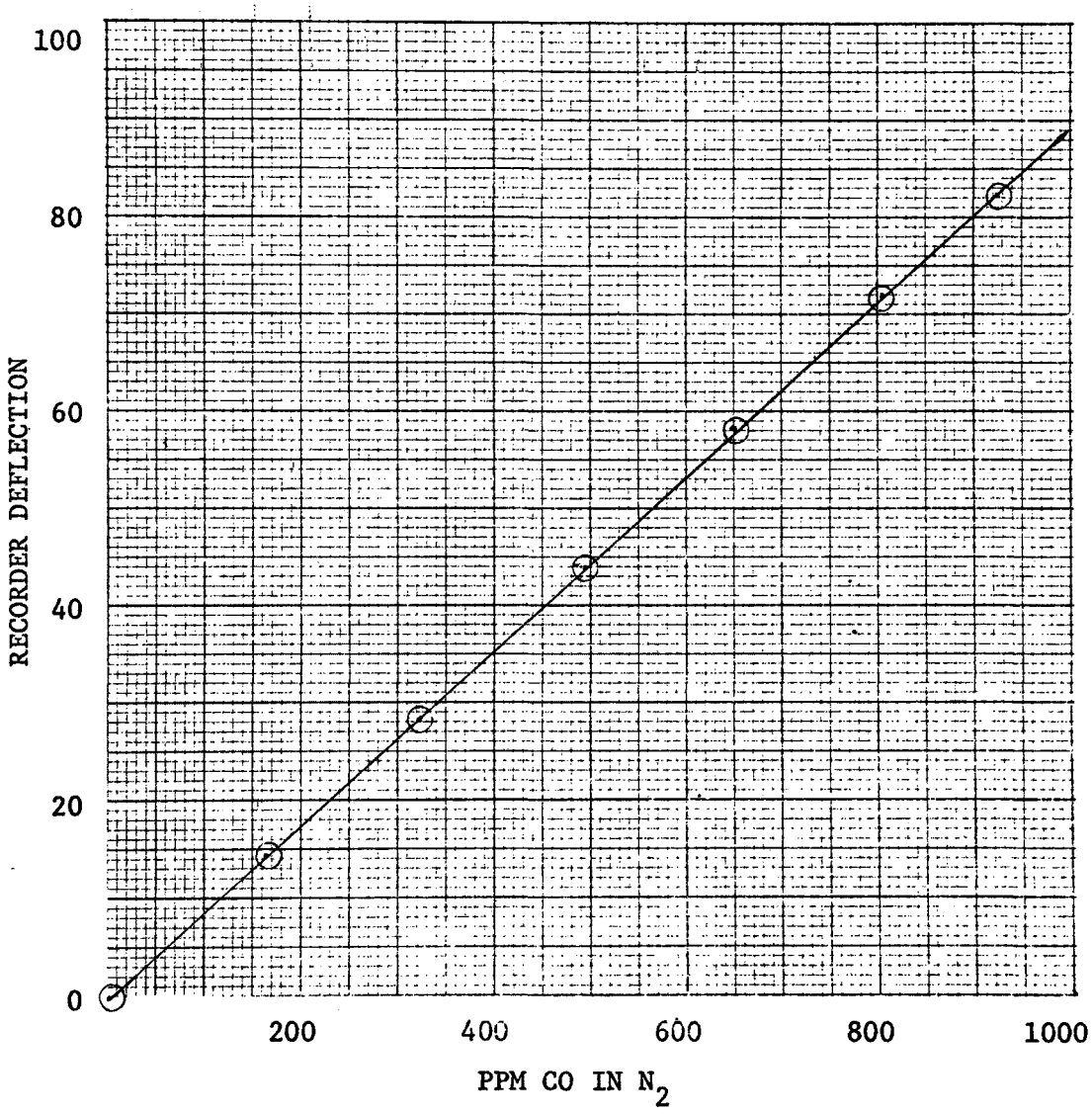


FIGURE 6 BECKMAN 6800 CALIBRATION CURVE

Precision

Tests for precision were performed in November 1975 and February 1976. The results are shown below.

November 1975

Low Concentration (P_L)
Calibration Standard = 327 ppm CO

High Concentration (P_H)
Calibration Standard = 1060 ppm CO

	P_L Instrument Response (ppm)	P_H Instrument Response (ppm)
P_1	327	1060
P_2	327	1059
P_3	327	1060
P_4	329	1059
P_5	329	1058
P_6	328	1057
	P_L = 0.98 ppm	P_H = 1.17 ppm

Low Concentration (P_L)
Calibration Standard = 163 ppm

	Instrument Response (ppm)	
	Test 1	Test 2
P_1	163	163
P_2	161	163
P_3	160	163
P_4	160	163
P_5	160	163
P_6	159	-
P_L	1.38 ppm	0 ppm

High Concentration (P_H)

Calibration Standard = 807 ppm

	Instrument Response (ppm)	
	Test 1	Test 2
P_1	807	807
P_2	807	-
P_3	806	805
P_4	804	808
P_5	807	-
P_6	807	-
P_H	1.2 ppm	1.5 ppm

Noise

Tests for noise are not applicable to this instrument's non-continuous output.

Response Time

Traditional response times do not apply to a chromatographic type instrument. The instrument completes one analysis cycle every 5 minutes.

Interference

There is no CO_2 interference due to the column separation of component gases.

Temperature Variation

The effects of ambient temperature variation are shown below.

2/12/76

		Instrument Response (Chart Units)	
Time	Temp. (^oF)	163 ppm	807 ppm
0930	60	14.1	74.1
1300	70	14.9	74.7
		0.8	0.6
	Equiv. ppm	7.0	5.3

2/13/76

Time	Temp. (^{o}F)	321 ppm
1000	56	31.2
1200	48	31.6
		0.4
	Equiv. ppm	4.1

Flow Variation

The effects of variations in input flow rates are negated by the instrument's internal sample pump and bypass system.

Zero and Span Drift

Zero Drift: Zero drift is corrected by an auto-zero circuit that resets electrical zero during each analysis cycle.

Span Drift: Calibration standard: 163 ppm CO

		Instrument Response (% of full scale)			
Date	Temp. (^{o}F)	S_n	S_{n-1}	Drift (ΔZ)	Equiv. ppm
8 hour					
2/27	68	15.4	15.5	-0.1	-1.1
24 hour					
2/11-12	70	14.1	14.2	-0.1	-1.1
2/25-26	68	15.6	15.5	0.1	1.0
2/26-27	68	15.5	15.6	-0.1	-0.1
Calibration Standard: 807 ppm CO					
8 hour					
2/27	68	75.5	76.2	-0.7	-7.5
24 hour					
2/11-12	70	74	72.2	1.8	19.9
2/25-26	68	76.5	76.8	-0.3	-3.2
2/26-27	68	76.2	76.5	-0.3	-3.2

5.2.4 Beckman NDIR Model 865 (Serial No. 0100200)

The Beckman Model 865 was not obtained until late November and it was immediately placed in field test service. The performance tests presented below were, therefore, conducted after the field program. A summary of the lab performance data is shown in Table 18.

Calibration

Calibration performed by Scott on February 11, 1976 produced the following points with the curve shown in Figure 7.

CO Concentration (ppm)	Instrument Response (Chart Units)
0	0
163	21
321	37.5
496	54.1
650	67
807	78.4
925	86.3

Precision

Tests for precision were performed in February 1976 using both the 163 ppm and 807 ppm calibration standards. The results are shown below.

Low Concentration: 163 ppm Standard

	Instrument Response (ppm CO)	
	Test 1	Test 2
P_1	163	163
P_2	164	164
P_3	163	164
P_4	164	165
P_5	163	160
P_6	163	165
	P_L = 0.52 ppm	P_L = 1.9 ppm

TABLE 18. PERFORMANCE TEST SUMMARY

BECKMAN 865

Range: 0-1000 ppm CO

Precision: Calibration Standard 163 ppm CO - 1.21 ppm*
Calibration Standard 807 ppm CO - 3.25 ppm*

Noise: Nitrogen Zero - 0.6 ppm
807 ppm CO - 0.94 ppm

Response Times: Rise - 5.4 seconds
Fall - 6.5 seconds

Interference: 15% CO_2 - 3.4 ppm
10% H_2O - 1.7 ppm

Zero Drift: 12 hour continuous - 4.4 ppm*
24 hour - 0.4% of full scale*

Span Drift: Calibration Standard - 163 ppm CO
8 hour - 0% of full scale
24 hour - 0.38% of full scale*
Calibration Standard - 807 ppm CO
8 hour - 0.9% of full scale
24 hour - 1.4% of full scale*

*Average

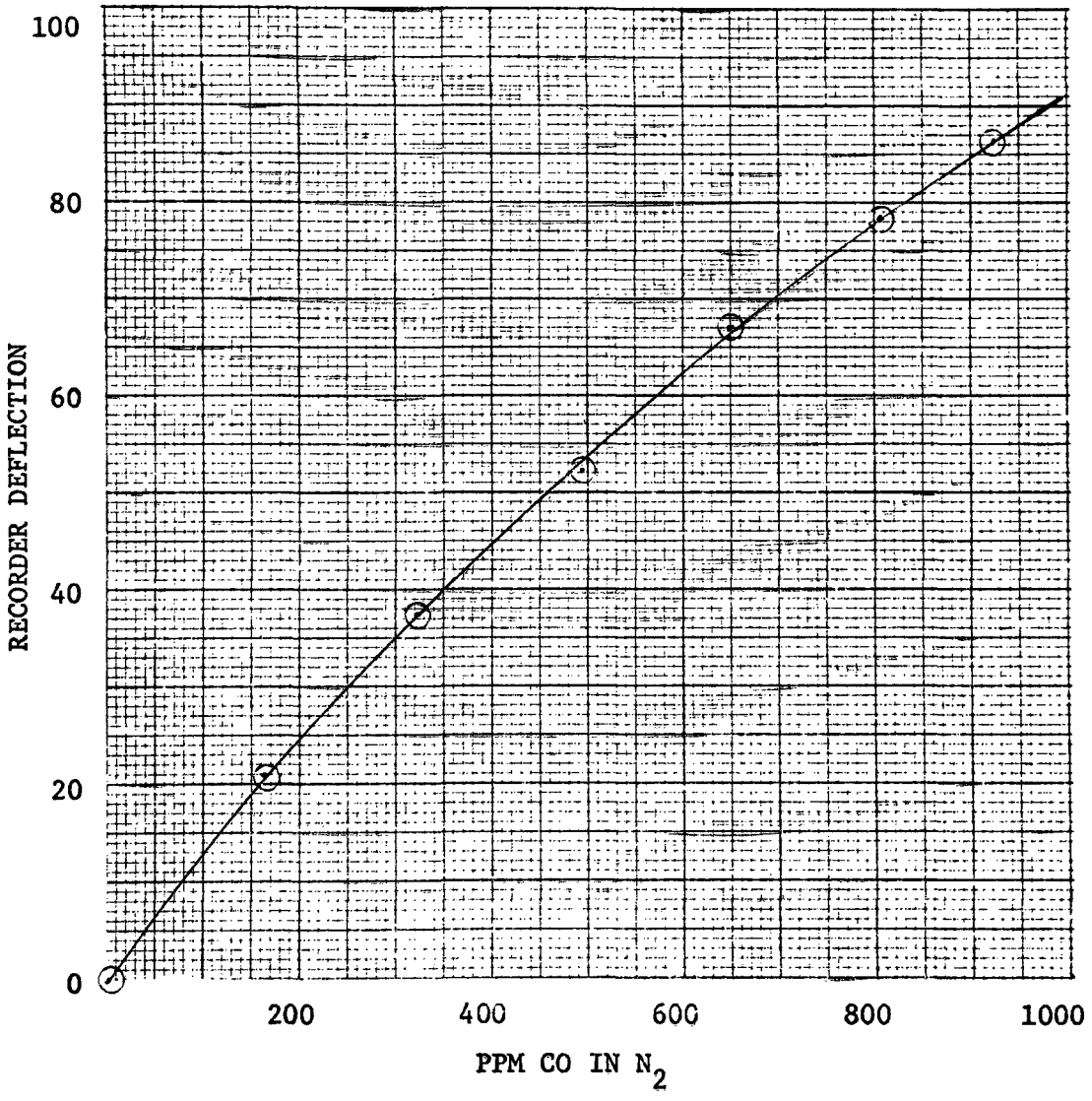


FIGURE 7 BECKMAN 865 CALIBRATION CURVE

High Concentration: 807 ppm Standard

	Instrument Response (ppm CO)	
	Test 1	Test 2
P_1	807	807
P_2	810	814
P_3	807	815
P_4	811	817
P_5	810	809
P_6	813	817
	P_L = 2.3 ppm	P_L = 4.2 ppm

Noise

Tests for instrument noise were conducted on February 10, 1976 using nitrogen zero gas and the 807 ppm standard. The data are shown on Table 19.

Response Time

The response characteristics of the Beckman NDIR were tested using the 807 ppm CO standard. The following results were obtained.

Rise Time = 5.4 seconds

Fall Time = 6.5 seconds

Interference

CO_2 interference was tested on the 0-1000 ppm CO range using 15% CO_2 in nitrogen. Response as measured with a digital volt meter was 3.36 ppm. Instrument response to the input of 10% water vapor was 1.7 ppm as measured with a digital voltmeter.

Temperature Variation

The effects of variations in ambient temperature on instrument response are shown below. Responses to the new temperatures were measured shortly after a stable reading was obtained to minimize the effects of instrument drift.

TABLE 19. NOISE TEST DATA

Applicant Beckman '865' Date 2/10/76

Test No. 1

Analyzer Temp 69° Range 0-1000

READING NUMBER (i)	1423-0 1503-80 TIME	0% of URL N2		80% of URL	
		DM READING	r_i, ppm	DM READING	r_i, ppm
1	02	67 mv	0 PPM	875	807
2	04	67	0	873	805
3	06	66	-1	875	807
4	08	66	-1	875	807
5	10	66	-1	874	806
6	12	66	-1	874	806
7	14	66	-1	874	806
8	16	66	-1	874	806
9	18	66	-1	872	804
10	20	66	-1	872	804
11	22	65	-2	874	806
12	24	66	-1	874	806
13	26	66	-1	872	804
14	28	66	-1	873	805
15	30	67	0	873	805
16	32	66	-1	873	805
17	34	65	-2	874	806
18	36	66	-1	875	807
19	38	65	-2	873	805
20	40	65	-2	874	806
21	42	66	-1	874	806
22	44	66	-1	875	807
23	46	66	-1	873	805
24	48	65	-2	874	806
25	50	65	-2	873	805
$\sum_{i=1}^{25} r_i$			28		20142
$\sum_{i=1}^{25} r_i^2$			40		16229028
S			S_0 = 0.6		S_{80} = 0.94

Date/Time	Temperature	Instrument Response (Chart Units)		
		Zero	163 ppm	807 ppm
2/12/76 @ 0900	70°	0	20.2	78.2
@ 1300	60°	0	20.8	80
Response Change (Chart Units)		0	+0.6	+1.8
Equivalent ppm		0	+6.1	+18.4
2/13/76 @ 0900	56°	0	20.5	79.2
@ 1150	48°	0	20.8	79.2
Response Change (Chart Units)		0	+0.3	0
Equivalent ppm		0	+3.1	0

Flow Variation

The effects of sample flow rate variations were measured with the digital voltmeter. Flows were varied from 0 to 5.0 liters per minute. The recommended flow is 0.5-1.0 liters/minute. The results are as follows:

Flow Rate (Liter/Minute)	Instrument Response (ppm)
0	806
0.84	807
1.45	808
2.65	812
5.00	819

Zero and Span Drifts

Zero and span drifts for the Beckman 865 are presented below. Included are 12 and 24-hour zero drifts, mid-range span drift (163 ppm) and high-range span drift (807 ppm).

12-Hour Continuous Zero Drift

	2/10/76	2/11/76	2/12/76
Maximum	9.3 ct. units	10.1 ct. units	10.2 ct. units
Minimum	8.9	9.7	9.7
12 Hour Drift	0.4 ct. units = 4.1 ppm	0.4 ct. units = 4.1 ppm	0.5 ct. units = 5.0 ppm

24-Hour Zero Drift

Date	Temp.	Instrument Response (% of Full Scale) Z_n	Z_{n-1}	Drift (ΔZ)	Equiv. ppm
2/11-2/12	70	9.8	9.6	0.2	2.1
2/12-2/13	60	9.9	9.8	0.1	1.0
2/24-2/25	68	7.0	7.2	-0.2	-2.1
2/25-2/26	68	6.1	7.0	-0.9	-9.3
2/26-2/27	68	5.5	6.1	-0.6	-6.2

Span Drift

Calibration Standard - 163 ppm CO

Date	Temp.	Instrument Response (% of Full Scale) M_n	M_{n-1}	Drift (ΔZ)	Equiv. ppm
8-Hour Drift					
2/27		19.5	19.5	0	0
24-Hour Drift					
2/11-2/12	70	20.2	20.3	-0.1	-1.0
2/12-2/13	60	20.4	20.2	0.2	2.1
2/24-2/25	68	21.0	21.1	-0.1	-1.0
2/25-2/26	68	20.2	21.0	-0.8	-8.3
2/26-2/27		19.5	20.2	-0.7	-7.2

Calibration Standard - 807 ppm CO

8-Hour Drift					
2/27		73.9	74.8	-0.9	7.8
24-Hour Drift					
2/11-2/12	70	79.9	78.3	1.6	16.3
2/12-2/13	60	79.1	99.9	-0.8	-8.2
2/24-2/25	68	68.5	79.5	-1.0	-11.2
2/25-2/26	68	76.7	78.5	-1.8	-18.4
2/26-2/27	68	75.0	76.7	-1.7	-18.2

5.2.5 Horiba NDIR - Model A1A-2 (Serial No. 30642)

Laboratory performance evaluation of the Horiba Model A1A-2 was performed prior to the field program. A summary of the laboratory results is shown in Table 20.

Calibration

Calibration of the Horiba instrument on the 0-1000 ppm CO range produced the following data points. The calibration curve is shown in Figure 8.

CO Concentration (ppm)	Instrument Response (Chart Units)
0	0
100	8.5
321	33.5
496	52.0
650	67.0
1060	100.0

Precision

The test for precision using the 650 ppm CO standard produced the following data:

	Instrument Response (ppm)
P_1	650
P_2	655
P_3	650
P_4	655
P_5	669
P_6	664

$P_H = 7.73$ ppm

Noise

Tests for noise were not conducted on the Horiba A1A-2.

Response Time

The rise and fall using 1060 ppm CO standard were 10.9 and 9.4 seconds, respectively.

TABLE 20. PERFORMANCE TEST SUMMARY

HORIBA NDIR MODEL A1A-2

Range: 0-1000 ppm CO

Precision: Calibration standard - 650 ppm CO - 7.73 ppm

Noise: Not Tested

Response Times: Rise - 10.9 seconds
Fall - 9.4 seconds

Interference: 15% CO_2 - 40.9 ppm
H_2O - Not Tested

Zero Drift: 24 hour - 11.7 ppm

Span Drift: 24 hour - 0.5% of full scale*

*Average

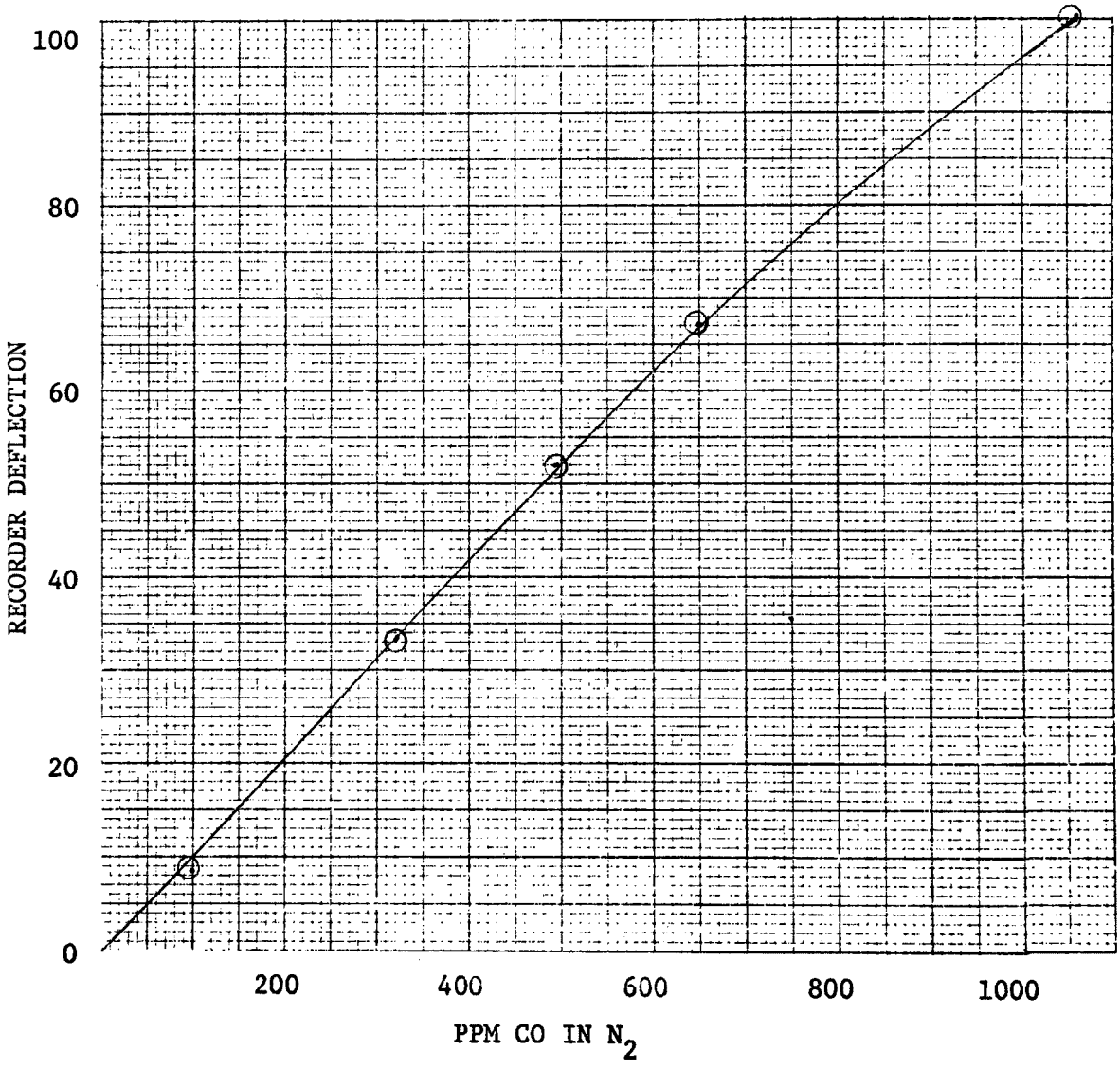


FIGURE 8 HORIBA A1A-2 CALIBRATION CURVE

Interference

The results of the CO_2 interference test are shown below.

Response to 15% CO_2 = 40.9 ppm CO

Tests for H_2O interference were not conducted on this instrument.

Temperature

Tests for temperature variation were not conducted on the Horiba A1A-2.

Flow Variation

Tests for flow variation were not conducted on the Horiba A1A-2.

Zero and Span Drifts

Zero Drift

The zero drift was measured over a period of 25 hours. A 11.7 ppm drift was measured on the 1000 ppm range. Test data is shown below.

Date	Time		Output
10/9/75	1400 hrs.	=	0.522 volts
10/10/75	1500 hrs.	=	0.576 volts
Zero Drift (25 hours)		=	+0.054 volts
		=	11.7 ppm

Span Drift

Span drift obtained from records of daily span checks with 650 ppm CO.

Range 0-1000 ppm CO

Date	Response (Chart Units)	Drift (% of Full Scale)
12/11	70	0
12/12	70	0
12/13	69	-1.0
12/14	69	0
12/15	69 (adj. to 66.5)	0
12/16	66	+0.5
12/17	67	+1.0
12/18	66	-1.0

5.2.6 Horiba NDIR Model A1A-21AS (Serial No. 45261301)

The Horiba Model A1A-2 was replaced during the field program by the newer model A1A-21AS. Laboratory testing of the model A1A-21AS was, therefore, conducted after the field program. A summary of these performance tests is shown in Table 21.

Calibration

Calibration performed on February 2, 1976 on the 0-1000 ppm CO range produced the following data with the curve presented on Figure 9.

CO Concentration (ppm)	Instrument Response (Chart Units)
0	0
163	23.2
321	40.6
496	56.6
650	68.8
807	79.0
925	85.6

Precision

Tests for instrument precision using the 163 ppm and 807 ppm standards are shown below.

Calibration Standard: 163 ppm

	Instrument Response (ppm)	
	Test 1	Test 2
P_1	163	163
P_2	166	161
P_3	165	160
P_4	166	159
P_5	165	159
P_6	167	158
	P_L = 1.4 ppm	P_L = 1.8 ppm

TABLE 21. PERFORMANCE TEST SUMMARY

HORIBA NDIR MODEL A1A-21AS

Range: 0-1000 ppm CO

Precision: Calibration Standard 163 ppm CO - 1.6 ppm*
Calibration Standard 807 ppm CO - 3.2 ppm*

Noise: Nitrogen Zero - 0.47 ppm
Calibration Standard 807 ppm CO - 2.1 ppm

Response Times: Rise - 7.9 seconds
Fall - 10.0 seconds

Interference: 15% CO_2 - 3.4 ppm
10% H_2O - 0.5 ppm

Zero Drift: 12-hour continuous - 4.9 ppm*
8-hour - 0.4% of full scale
24-hour - 0.18% of full scale*

Span Drift: Calibration Standard 163 ppm CO
8 hour - 0% of full scale
24 hour - 0.36% of full scale*
Calibration Standard 807 ppm CO
8 hour - 0.7% of full scale
24 hour - 0.98% of full scale*

*Average

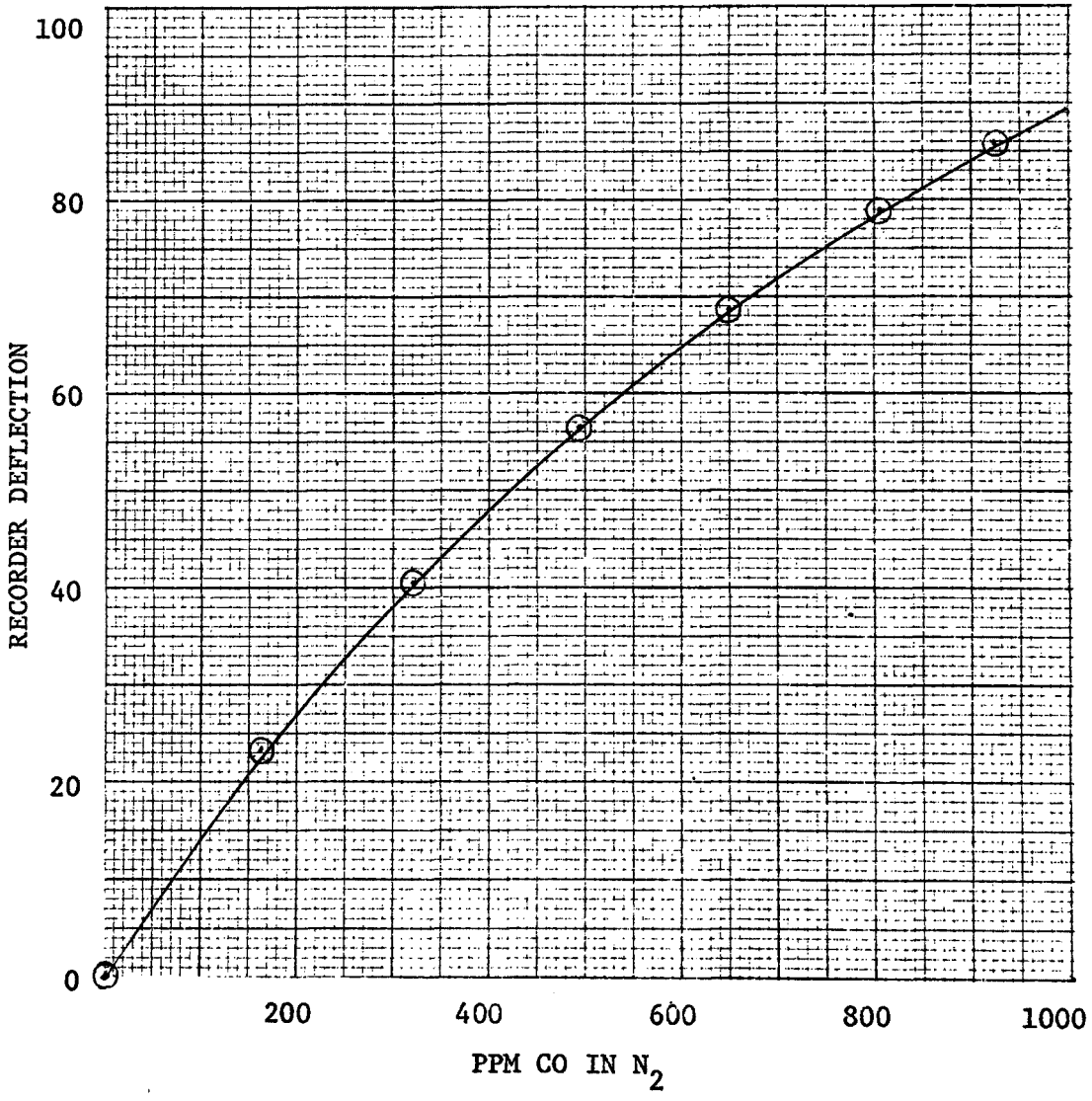


FIGURE 9 HORIBA A1A-21AS CALIBRATION CURVE

Calibration Standard: 807 ppm

	Instrument Response (ppm)	
	Test 1	Test 2
P_1	807	807
P_2	803	807
P_3	807	806
P_4	807	807
P_5	812	809
P_6	815	812
	P_H = 4.2 ppm	P_H = 2.2 ppm

Noise

The test for instrument noise was conducted using nitrogen zero gas and the 807 ppm standard. The results are shown in Table 22.

Response Time

Response time for the Horiba AlA-21AS using the 807 ppm calibration standard are shown below.

2/11/76

Rise Time = 8.1 Seconds

Fall Time = 10.0 Seconds

2/12/76

Rise Time = 7.8 Seconds

Fall Time = 10.0 Seconds

Interference

H_2O and CO_2 interferences were measured using a digital voltmeter. The response to the addition of 10% water vapor was equivalent to -0.5 ppm CO, and the response to the addition of 15% CO_2 in N_2 was equivalent to +3.4 CO ppm.

TABLE 22. NOISE TEST DATA

Applicant Hanlon Date 2/10/76

Test No. #1

Analyzer Temp. 68° Range 0 - 1000 PPM

READING NUMBER (i)	1423-0 1603-80 TIME	0% of URL N2		80% of URL	
		DM READING	r_i, ppm	DM READING	r_i, ppm
1	02	87 mer	0	702	807
2	04	87	0	902	807
3	06	87	0	901	806
4	08	87	0	902	807
5	10	87	0	902	807
6	12	87	0	901	806
7	14	87	0	902	807
8	16	87	0	903	808
9	18	87	0	902	807
10	20	87	0	903	808
11	22	87	0	903	808
12	24	87	0	903	808
13	26	88	1	904	809
14	28	87	0	903	808
15	30	87	0	904	809
16	32	87	0	904	809
17	34	87	0	905	810
18	36	87	0	905	810
19	38	86	1	905	810
20	40	86	1	906	811
21	42	86	1	906	811
22	44	87	0	907	812
23	46	86	1	907	812
24	48	86	1	907	812
25	50	87	0	907	807
$\sum_{i=1}^{25} r_i$			46		20922
$\sum_{i=1}^{25} r_i^2$			6		1635 7272
S			$S_0 = 1.47$		$S_{80} = 2.1$

Temperature Variation

Variations in instrument response due to temperature changes are shown below.

		Instrument Response (Chart Units)		
Time	Temp.	Zero	163 ppm	807 ppm
2/12/76				
0900	70°	8.7	24.0	80.8
1300	60°	9.8	24.2	82.1
		1.1 =	0.2 =	2.3 =
		10.8 ppm	2.0 ppm	22.6 ppm
2/13/76				
0845	56°	10.1	24.6	83.3
1150	48°	10.1	25.0	84.4
		0	0.4 =	1.1 =
			3.9 ppm	10.8 ppm

Flow Variation

The effects of flow variation as measured by the digital voltmeter were as follows: The recommended range for the instrument is 1-10 liter/minute.

Flow (Liter/Minute)	MV Response	Equiv. ppm
0	847	807
0.84	846	806
1.45	847	807
2.6	847	807
5.0	850	810

Zero and Span Drifts

Tests for instrument drift are presented below. Included are hourly zero drift and mid-range and high-range span drifts.

Zero Drift

12-Hour Continuous Zero Drift

	12/10/75	12/11/75	12/12/75
Maximum	9.5 ct. units	9.0 ct. units	10.1 ct. units
Minimum	9.0	8.6	9.6
12 Hour Drift	0.5 ct. units = 5.0 ppm	0.4 ct. units = 4.6 ppm	0.5 ct. units = 5.2 ppm

8 and 24-Hour Zero Drift

		Instrument Response (% of Full Scale)			
Date	Temp.	Z_n	Z_{n-1}	Drift (ΔZ)	Equiv. ppm
8-Hour					
2/27	68	5.4	5.8	-0.4	-4.2
24-Hour					
2/11-2/12	70	8.7	8.7	0	0
2/12-2/13	60	10.1	9.9	0.2	2.0
2/24-2/25	68	6.0	6.6	-0.6	-6.3
2/25-2/26	68	6.0	6.0	0	0
2/26-2/27	68	5.9	6.0	-0.1	-1.0

Span Drift

Calibration Standard: 163 ppm CO

		Instrument Response (% of Full Scale)			
Date	Time	S_n	S_{n-1}	Drift (ΔS)	Equiv. ppm
8-Hour					
2/27		22.5	22.5	0	0
24-Hour					
2/11-2/12	70	23.7	23.2	0.4	4.0
2/12-2/13	60	24.6	24.1	0.5	5.0
2/24-2/25	68	22.9	23.4	-0.5	-5.0
2/25-2/26	68	22.8	22.9	-0.1	-1.0
2/26-2/27		22.5	22.8	-0.3	-3.0

Calibration Standard: 807 ppm CO

Date	Temp.	Instrument Response (% of Full Scale) S_n	S_{n-1}	Drift (ΔS)	Equiv. ppm
8-Hour					
2/27		75.3	76.0	-0.7	- 7.4
24-Hour					
2/11-2/12	70	80.7	78.8	1.9	19.2
2/12-2/13	60	83.2	82.2	1.0	10.1
2/24-2/25	68	71.7	78.0	-1.3	- 13.3
2/25-2/26		76.0	76.7	-7.0	-7.3
2/26-2/27		76.0	76.0	0	0

SECTION 6

FIELD PERFORMANCE EVALUATION

6.1 SITE SELECTION, DESCRIPTION AND PREPARATION

Site selection was based on the following criteria:

- o Availability of a continuous carbon monoxide source in the range of 500 - 1000 ppm.
- o Accessibility of site for equipment and testing.
- o Availability of instrument housing.
- o Proximity of site to Scott's Plumsteadville laboratory.

The source chosen for the field program was the outlet duct from an electrostatic precipitator exhausting flue gas from two carbon monoxide boilers. These are waste heat boilers that receive flue gas from the catalyst regenerator section of the catalytic cracking unit. These input flue gases contain high concentrations of carbon monoxide and are at very high temperatures. The CO boilers recover heat from the hot regenerator gases, convert CO contained in these gases to CO_2 and take advantage of the heat created by this conversion, as well as the heat recovered to generate steam.

The boilers are controlled by a Buell electrostatic precipitator and a Lodge-Cottrell precipitator ducting to a common stack. The configurations of the precipitators and stack is shown in Figure 10.

Preliminary information indicated the following stack conditions:

- o Carbon Monoxide - 500-1000 ppm
- o Carbon Dioxide - 10-12%
- o Moisture - Approximately 10%
- o Temperature - 500^{o}F

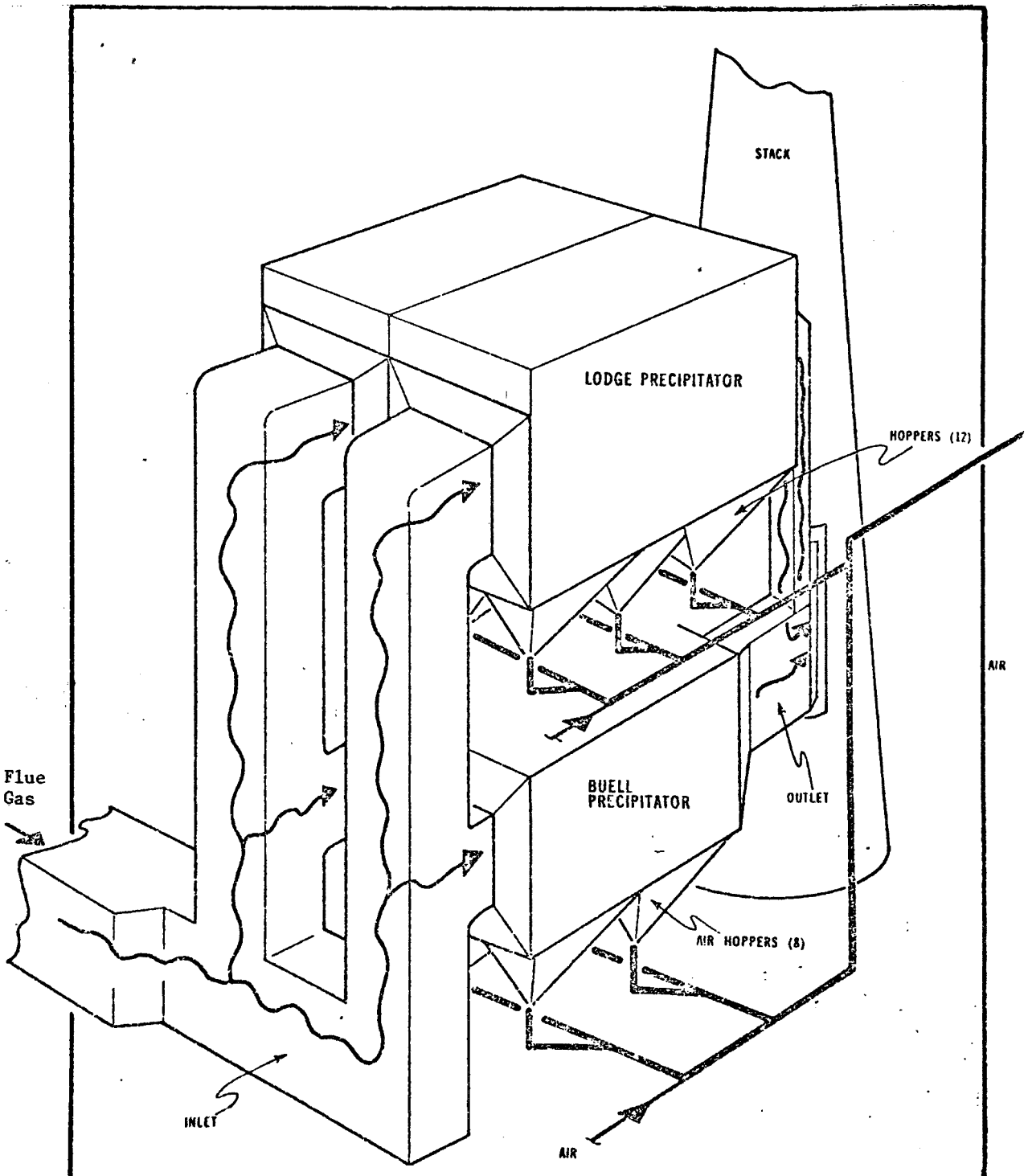


FIGURE 10 CONFIGURATIONS OF PRECIPITATORS AND STACK

- Pressure - Approximately Atmospheric
- Flow - Approximately 160,000 ACFM
- Particulate (EPA Method 5) - 3 gr/SCF
- SO_x - 500 ppm (maximum)

Arrangements were made to install the sampling system and instrumentation during a routine outage for maintenance. At this time, the ERT monitor was mounted on the duct and the extractive sampling system was installed. A compact trailer was provided for instrument housing with provisions for power and lighting.

The catalytic cracker became operational during the first week in November; however, normal operating conditions were not achieved until the following week. During this period, the necessary probe placement and instrument check-out were performed.

During the field program, several process upsets occurred. This was usually the result of #2 boiler being shut down although at one time both #1 and #2 boilers were down.

When #2 boiler was in upset condition, the flow of input gas from the hot regenerator would be bypassed to a secondary stack and exhausted combustion air to #2 boiler would remain on. Therefore, the boiler effluent discharging through the precipitators and past the sampling ports would be diluted and the CO concentrations decreased along with the stack temperature. These periods are indicated in the field data summary.

6.2 FIELD SAMPLING SYSTEM

The sampling system designed by Scott for the field evaluation phase of the project provided for the continuous operation of the five CO monitors at the refinery site. In addition, flow rates, duct and instrument trailer temperatures and moisture levels were monitored periodically along with the continuous recording of CO_2 by NDIR.

Four of the monitors being evaluated required sample extraction and conditioning. These instruments were located in a compact trailer 25

meters below the sample ports. The fifth instrument was an in-situ cross-stack infrared analyzer with only its recorder located in the trailer.

A schematic diagram of the sample ports and delivery system is shown in Figure 11.

6.2.1 Sample Port Location

The optimum location for sampling was on the outlet duct from one site of the Lodge-Cottrell precipitator. This duct had existing platforms, was easily accessible, and posed minimum problems regarding the installation of the ERT cross-stack monitor. Also, five ports were available on this duct for sample probe placement, velocity traverses, moisture determinations, and ancillary testing.

6.2.2 Probe

The probe was fabricated from 3/8" stainless steel tubing. The end of the tubing was capped and five inlet holes were drilled so that sample would be drawn from the centers of five equal areas across the duct. The probe was inserted through a 4" port cap using a swage-lock fitting and oriented with the inlet holes facing downstream. A three-way valve and blower were installed at the outlet of the probe for daily purging of particulate matter.

6.2.3 Stack-Mounted Water Trap

Immediately following the probe assembly was a water trap to prevent condensed water from freezing in the sample line. The trap originally consisted of four 500 ml glass impingers in a water bath. The last impinger contained glass wool for filtering particulate. Water collected in these impingers was emptied during routine field visits.

This impinger water trap was replaced on December 23 with refrigeration coils immersed in a water bath. This version was automated so that collected water would be purged hourly while the instruments below were in the hourly zero mode. These functions along with the purging of a second condenser system in the trailer and the purging of the probe were controlled by solenoids activated by a master timer in the trailer.

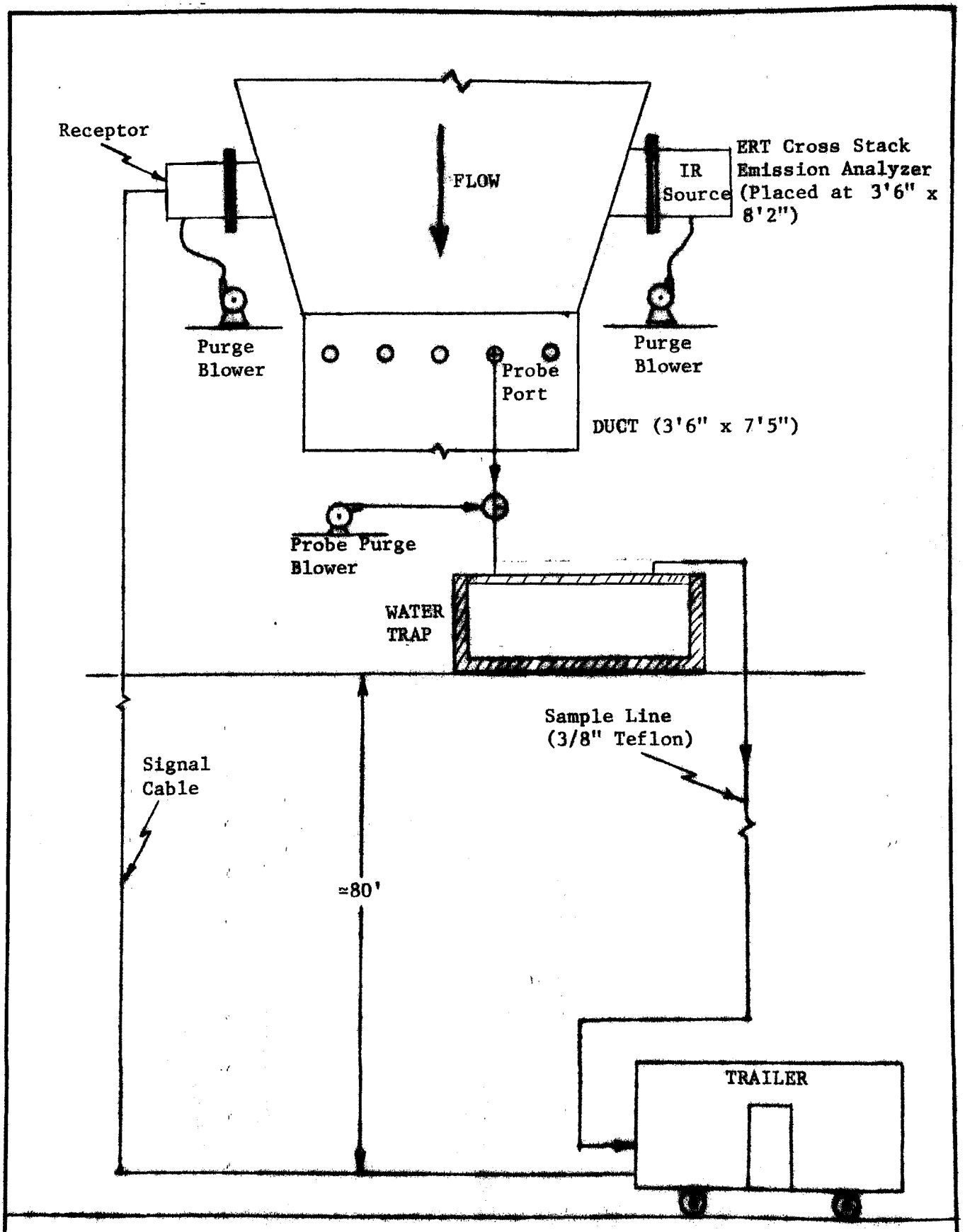


FIGURE 11 SAMPLING LOCATION AND SAMPLE FLOW TO INSTRUMENT TRAILER

A refrigeration type of condenser was not permitted at the probe location due to safety requirements and, therefore, the moisture level in the sample gas was derived by the water bath temperature. Since this was partially warmed by stack radiation, enough moisture was present in the sample to freeze in the sample line during very cold periods.

6.2.4 Sample Transport System

Sample was transported from the stack to the instrument trailer through a 3/8" teflon line. A diaphram pump with a free capacity of 4.0 CFM was used, providing a sample transport time of approximately 5 seconds. Sample in excess of that required for the instruments was bypassed to minimize transport time.

6.2.5 Sample Conditioning Components

Sample conditioning involved particulate and moisture removal. Figure 12 shows the arrangement of the sample conditioning components in the trailer.

Filtration was accomplished by a heated 3" diameter fiberglass filter located before the sample pump and condensor unit and an unheated 3" fiberglass filter after the condensor.

Water vapor was reduced to approximately 0.5% by a refrigerated condensor. This condensor was automatically purged hourly while the instruments were in the zero mode.

6.2.6 Auto-Zero Solenoid and Master Timer

Following the conditioning components sample was routed to the auto-zero solenoid. This solenoid interrupted sample flow and routed nitrogen zero gas through the instruments in the trailer for three minutes every hour. This solenoid was activated by a master timer that also controlled the purging of both water condensors and the probe.

6.2.7 Sample Manifold and Control Console

The sample manifold and control console is shown in Figure 12. The manifold, which received sample from the auto-zero solenoid had five

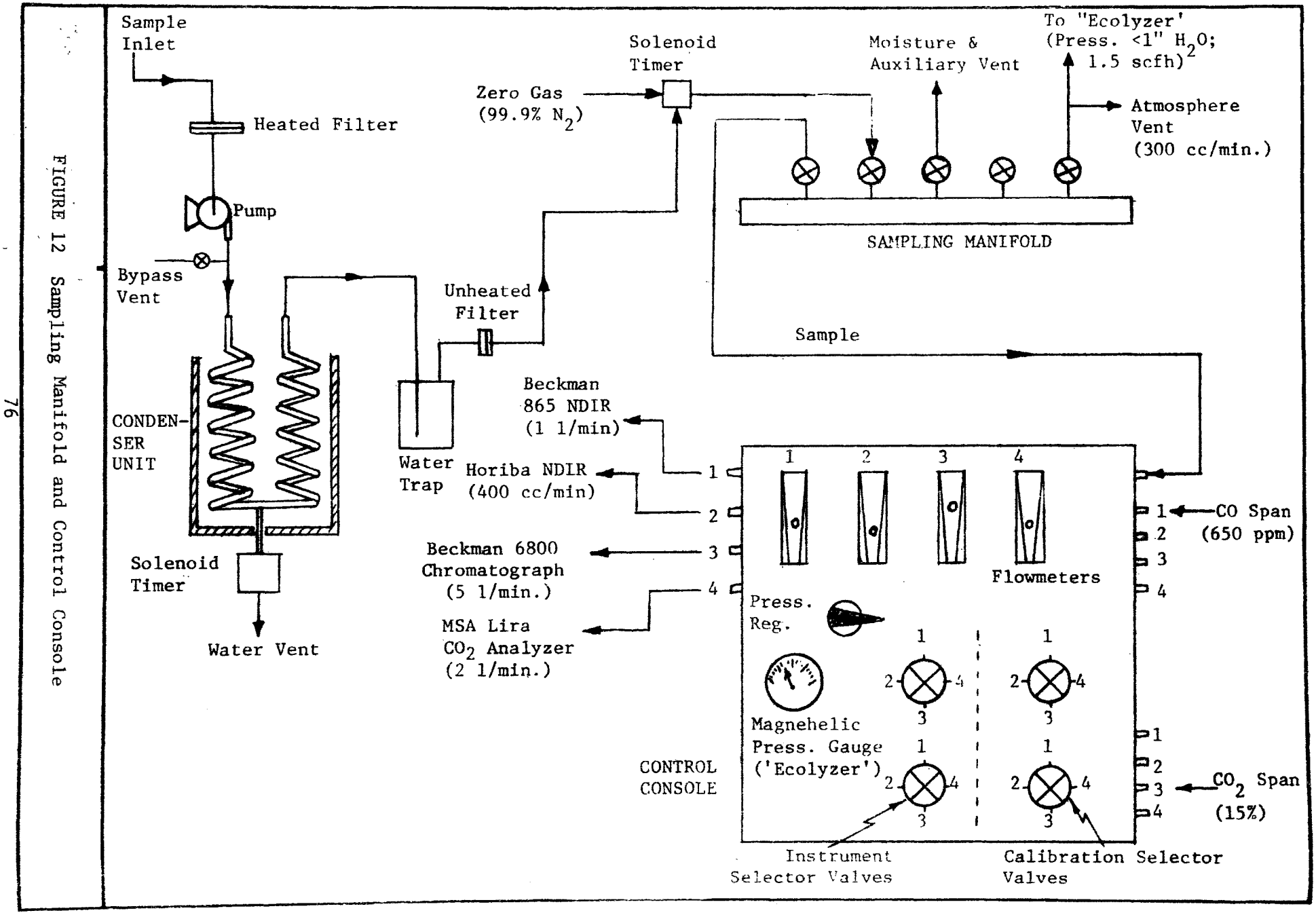


FIGURE 12 Sampling Manifold and Control Console

ports for sample distribution to the instruments and for any ancillary testing. One port on the manifold was used to supply sample to the control console for distribution to the Horiba NDIR, Beckman NDIR, Beckman chromatograph and MSA CO_2 monitor. A second manifold port was used to provide sample to the Ecolyzer which was controlled independently in order to maintain a sample pressure of less than 1" H_2O as per instructions. Another port was used to measure sample moisture content.

The control console was used to distribute both sample and calibration gas flow to each instrument. The console contained flow meters and selector valves for convenient selection and regulation of gas flow to each instrument.

6.2.8 Calibration Gases

All instruments, except the ERT, were spanned with Scott "close tolerance" (±2% analysis) blends of carbon monoxide in nitrogen. The following six concentrations covering the 0-1000 ppm range were available in the instrument trailer: 100 ppm, 321 ppm, 496 ppm, 650 ppm, 807 ppm and 925 ppm. The MSA CO_2 monitor was spanned with a Scott blend of 15% CO_2 in nitrogen. Zero gas used for both routine calibrations and automatic hourly zeroes was Scott 99.98% pure nitrogen. All of these gases were connected to the gas inputs on the control console for convenient selection and control.

The Ecolyzer, however, due to its sample pressure sensitivity, was spanned by filling Tedlar bags with the appropriate gas at the control console and allowing the instrument to draw gas, at its own rate, into the detector cell.

6.2.9 System Performance

The sample delivery/conditioning system performed adequately throughout the program with the exception of several sample line freeze-ups. This freezing condition was often due to the simultaneous occurrence of near zero ambient temperatures and a process upset in #2 boiler.

Other minor problems like broken filters and dirty solenoids

caused brief interruptions in sample flow.

Table 23 outlines all sample flow interruptions to the instruments. During periods where a leak resulted in a diluted sample flow to the instruments comparative evaluation of all but the ERT in situ monitor is still valid.

6.2.10 Data Acquisition

All instrument responses were recorded on individual, continuous strip chart recorders. This includes the stack-mounted ERT instrument recorder in the trailer.

In addition, the Horiba NDIR, Beckman NDIR, Ecolyzer and ERT responses were recorded on magnetic tape using Westinghouse environmental data loggers. These loggers convert instrument outputs to pulses which are recorded on tape. The pulse frequency recorded is proportional to the input voltage. Additionally, each recorder has a time channel which receives a pulse every 15 minutes for subsequent computer correlation.

Data presented in the Field Data Summary (Section 6.7) for the Horiba NDIR, Beckman NDIR, Ecolyzer and ERT were computed from data logged on the tapes. Data for the Beckman 6800 and MSA CO_2 monitor were obtained from strip charts.

6.3 FIELD VISITS

Throughout the field program, daily maintenance and calibration visits were required. During each visit, a schedule of procedures, along with any required maintenance, would be followed.

Figure 13 shows the log sheet used for recording calibration and maintenance data during the program.

6.3.1 Daily Calibration

All instruments except the ERT were calibrated daily using the 650 ppm calibration standard and nitrogen zero gas. The ERT was calibrated with its internal calibration cell. The zero and span responses were then recorded on the log sheet along with any adjustments that were required.

In addition to the CO instrument, the MSA CO_2 monitor was calibrated daily using 15% CO_2 in nitrogen.

TABLE 23. SAMPLE FLOW INTERRUPTIONS

Date/Time	Reason	Notes
12/18 1300-4130	Clogged Probe	No Sample
12/22 0900-1600	Clogged Line	No Sample
12/24 0615-1230	Clogged Line	No Sample
12/29 1100-1600	Solenoid Stuck	No Sample
1/2 0600-1415	Frozen Sample Line	No Sample
1/5 @ 1200- 1/6 1330	Frozen Sample Line	Diluted Sample (Partial Flow)
1/9 0300-1400	Solenoid Frozen Open	Diluted Sample (Flow but no CO)
1/10 @ 1200- 1/11 1300	Frozen Sample Line	No Sample
1/12 @ 1430- 1/13 1200	Filter Leak	Diluted Sample
1/14 @ 2200- 1/15 1330	Broken Filter	Diluted Sample
1/16 0500-1200	Broken Filter	Diluted Sample
1/17 @ 1100- 1/20 1200	Leak In Reefer System	Diluted Sample
1/18 @ 1200- 1/20 1400	Frozen Sample Line	Sample Intermittant
1/20 @ 2200- 1/21 1300	Leak in Reefer System	Diluted Sample

DAILY LOG PROJECT 1519

DATE 1/15/76 TIME IN 1030 NAME(S) MR

TRAILER COND. - Ambient Temp. 70 Line Volt. 116

Flowrates O.K. - (Notes) ✓

Change 2 Filters-(Notes) ✓

CYLINDERS N_2 1350 Air 1100 H_2 975 65060 550

Notes:

MOISTURE (Every Day): At Manifold (.58%)

Start Time: 1230 Start Meter: 269.7 Meter Temp. 58

Stop Time: 1300 Stop Meter: 276.8 Meter Temp. 62

Silica gel: Initial wt. 38.0 Final wt. 38.9

INSTRUMENTS: All readings in recorder chart units. Always get zero and span readings before and after any adjustments. Check with lab before adjusting spans.

ERT (Switch to Cal.): Time: 1030 Recorder: out of range

Cal. Reading 70 Notes: Recommended

BECKMAN 6800: Time: 1045 Recorder: OK

Baseline: 6 Cal. (Cal. std. switch, set flowrate in rear to 9.0) 77

Notes: Working OK - No Calibration

BECKMAN 865: Time: 1040 Recorder: OK

Zero 4 Gain 500, New Zero _____ Gain _____

Span 77 Gain 798, New Span _____ Gain _____

Notes:

HORIBA: Time: 1035 Recorder: OK

Zero 0.8 Gain 720, New Zero _____ Gain _____

Span 76 Gain 961, New Span _____ Gain _____

Notes:

MSA (CO_2): Time: 1100 Recorder ink skipped 3-4 hrs ago

Zero 10 Gain 605, New Zero ~~5~~ 5 Gain 1.51

(15% CO_2) Span offscale Gain 60.5, New Span ~~94~~ 89 Gain same

Notes:

ECOLYZER: Time: 1230 Recorder OK

Zero (switch) 7.5, New Zero _____

Span (Tedlar bag) 55.5, New Span _____

Check H_2O Bottle Inside: ✓

Condition of Pre-filter: ✓

Bypass Flow (Outside Trailer) _____ cc/min.

FIGURE 13. SAMPLE OF DAILY LOG SHEET

STACK CHECK-OUT

* Moisture and flows must be done on Tuesday and Thursday unless planned otherwise: (Obtain ice for moisture check from lab.)

PLANT CONTROL ROOM: Time 1130 Baro. Press. (Ext. 300) 30.20

Flow in Brick Stack ✓

Boiler Status OK

STACK COND.

Condenser: (Notes) OK; filter changed

Check filter (change if necessary): changed filter & cleaned nozzle

MOISTURE: Set up probe, 2 impingers, silica gel tube, pump and flowmeter on middle port. (Sample ~ 10 ft.^{3})

Start Time — Start Meter 418.005 Temp. In 40 Out 46

Stop Time _____ Stop Meter 428.87 Temp. In 49 Out 62

Initial wt. 53.5 Final wt. 56.4

Impinger vol. - initial ~~203~~ 100 ml final 115

9.1% H_2O

Fyrite: Sample Middle Port 12 % CO_2

Traverse: Use pitot bridge and monometer. Static 0.4

Point	Port A (on left)		Port B		Port C		Port E	
1	1.25 in.	°F	.80 in.	°F	.99 in.	°F	1.2 in.	°F
2	1.3 in.	°F	1.1 in.	°F	1.0 in.	°F	1.35 in.	°F
3	1.25 in.	400 °F	1.15 in.	450 °F	1.05 in.	444 °F	1.14 in.	420 °F
4	1.3 in.	°F	1.1 in.	°F	1.05 in.	°F	1.14 in.	°F
5	1.1 in.	°F	1.0 in.	°F	1.0 in.	°F	1.02 in.	°F

REMARKS: _____

Time Leaving Site: 1315

Return form, silica gel tubes, charts (every 3-4 days) to Scott.

Supplies Needed: new filter ½ - WK5, WK7 paper

Problems Unsolved Upon Leaving:

None

FIGURE 13. (Continued) SAMPLE OF DAILY LOG SHEET (Page 2)

6.3.2 Weekly Calibrations

On Monday of each week, a comprehensive calibration was conducted using all six span gases available in the trailer. These gases included 100, 321, 496, 650, 807 and 929 ppm CO.

6.3.3 System Maintenance

Maintenance activities required on a daily basis included emptying the condensed water from the impinger water trap at the stack, purging the probe and changing the filters in the instrument trailer. Daily maintenance on the stack was eliminated by the installation of the automated condenser system on December 23. The remaining components of the sampling system would be checked and maintained as necessary.

Other routine maintenance items included recording gas cylinder pressures and making any necessary replacements and maintaining the continuous recorders on the instruments.

6.3.4 Ancillary Data Acquisition

During each field visit, the trailer temperature, line voltage, barometric pressure and sample moisture level would be recorded. Moisture was determined using a pre-weighed silica gel tube and dry test meter. Sample was obtained from a vacant port on the sample manifold.

Twice per week the flow rate, temperatures, pressure, moisture and CO_2 level in the duct would be measured. This involved a complete traverse using a type "S" pitot tube and thermocouple along with the CO_2 check using a fyrite. Moisture determinations were made using a pre-weighed silica gel tube with a dry gas meter and pump.

6.4 INSTRUMENT PERFORMANCE AND MAINTENANCE

The following section presents each instrument's overall performance and maintenance records for the field evaluation program. Included are service calls, routine maintenance, malfunctions and resultant down times for each instrument. The daily zero and span responses along with zero and span drifts are also included as an indication of overall performance.

6.4.1 Environmental Research & Technology, Inc. - Stack Gas Monitor (Model 4000)

A review of both the calibration and maintenance log and the field data show that the ERT had chronic problems resulting in a significant amount of lost and questionable data throughout the field program.

Instrument responses were often intermittant, reading correctly at times and then switching suddenly to completely irrational responses. The ERT representative was called three times spending a total of five days at the site repairing the various malfunctions.

Beginning with the November instrument check-out, the ERT service representative was called to replace a defective recorder and replace a power supply apparently caused by the shorting out of a blower used to purge the optics on the IR source unit. This blower remained inoperative for the entire program.

ERT was called again on December 2 and 3 to repair problems caused by overheating when the blower for the IR detector failed. These repairs were apparently unsuccessful because the responses were still intermittant afterward although the blower itself was repaired.

The ERT serviceman returned on December 18 to work on the intermittant response problems but could not effect repairs.

Also, in approximately 50% of the calibration attempts, the instrument would either not respond at all or respond erratically.

Table 24 is the calibration and maintenance log for the ERT instrument.

6.4.2 Energetics Science Inc., Ecolyzer (Model 3100)

The initial check-out of the Ecolyzer at the Sun Oil Company site revealed serious SO_2/NO_x interference despite the internal filter incorporated in the instrument. This interference was remedied with a heavy-duty pre-filter supplied by Energetics Science Inc. and installed on December 1, 1975. This filter, which was designed to last over a month, had to be replaced every 2 weeks during the program.

TABLE 24. ERT CALIBRATION AND MAINTENANCE

Date	Time	Calibration Response (% of Full Scale)	Maintenance Notes
12/1	1337	40-97	
12/2	1130	2	ERT Rep. to repair damage caused by shorted blower
12/3	1300	30-50	
12/4	1230		No Cal. Response
12/5	1100		No Cal. Response
12/6	1100	6	Sample Responses Intermittant
12/7	1200		No Cal. Response
12/8	1130	65-70	
12/9	1230	65-72	ERT put on mag. tape
12/10	1200	65-70	
12/11	1530	65-70	
12/12	1400		No Cal. Response
12/13	1705	∿6	Erratic Response Intermittant
12/14	1200		No Cal. Response
12/15	1108		No Cal. Response
12/16	1300	65-70	
12/17	1800		No Cal. Response
12/18	1200		No Cal. Response - ERT to repair intermittant response problems
12/19	1414	70	
12/20	1520		No Cal. Response
12/21	1200	60-70	Erratic
12/22	1200		No Cal. Response - Sample Responses Intermittant
12/23	1315	50-60	
12/24	1058	35	
12/25		NO ROUTINE VISIT	
12/26	1157		Erratic Calibration Response
12/27		NO ROUTINE VISIT	
12/28	1330		No Cal. Response

TABLE 24(CONT'D) ERT CALIBRATION AND MAINTENANCE

Date	Time	Calibration Response (% of Full Scale)	Maintenance Notes
12/29	1200	20-50	Erratic Cal. Response
12/30	1140		No Cal. Response
12/31	1100		No Cal. Response
1/1		NO ROUTINE VISIT	
1/2	1030	65	
1/3		NO ROUTINE VISIT	
1/4	1515	68	
1/5	1330	34-45	
1/6	1200	50-60	
1/7	1215	35	
1/8	1230	8	
1/9	1305	17	
1/10			
1/11	1113	65	
1/12	1235	60	
1/13	1130	60-70	
1/14	1115	70	
1/15	1230	70	
1/16	1125		No Cal. Response
1/17	1005	65	
1/18		NO ROUTINE VISIT	
1/19	1245	70	
1/20	1245	67	Stuck at 40 for 1st 20 Minutes
1/21	1142	67	
1/22	1200	70-80	
1/23			No Calibration

The Ecolyzer had no malfunctions resulting in lost data throughout the field program. It's response to both sample and calibration gas was initially very good. Starting with the second week in January, however, performance began to deteriorate until, by the end of the program, sluggish responses made calibration and performance checks difficult.

Figure 14 is a comparison of routine calibrations showing the difference in response towards the end of the program. The figure shows that the January trace did not flatten out or replicate in the same manner as in early December.

This problem appeared to result from deterioration and/or contamination of the electrochemical detector cell in the instrument. This may have resulted from exposure to the stack gas prior to the installation of the heavy-duty SO_2/NO_x filter. The Ecolyzer was purchased new for this program and its detector is specified to last 1 year in use.

Table 25 is the calibration and maintenance log for the Ecolyzer. Although there was no lost data due to malfunction there was a few problems with drifts as can be seen from the data.

Although zero drift in most cases was not a problem, the span drift was consistantly very high resulting, during periods of inordinately high drift, in erroneous and unreliable data. The deterioration of the instrument response towards the end of the program, especially to calibration gas input, aggrevated this span drift problem because the responses to calibration gas inputs would not replicate or stabilize.

6.4.3 Beckman Air Quality Chromatograph (Model 6800)

The Beckman chromatograph performed very well for most of the field program exhibiting excellent stability and reliability. There was one malfunction, however, that began intermittantly on December 19, 1975 resulting in several flame-outs and resultant lost data. This problem was difficult to diagnose initially due to its intermittant nature and because variations in H_2 fuel and air carrier pressure settings would temporarily remedy the problem. A faulty multi-functional injector valve was finally isolated and repaired by Beckman on January 21.

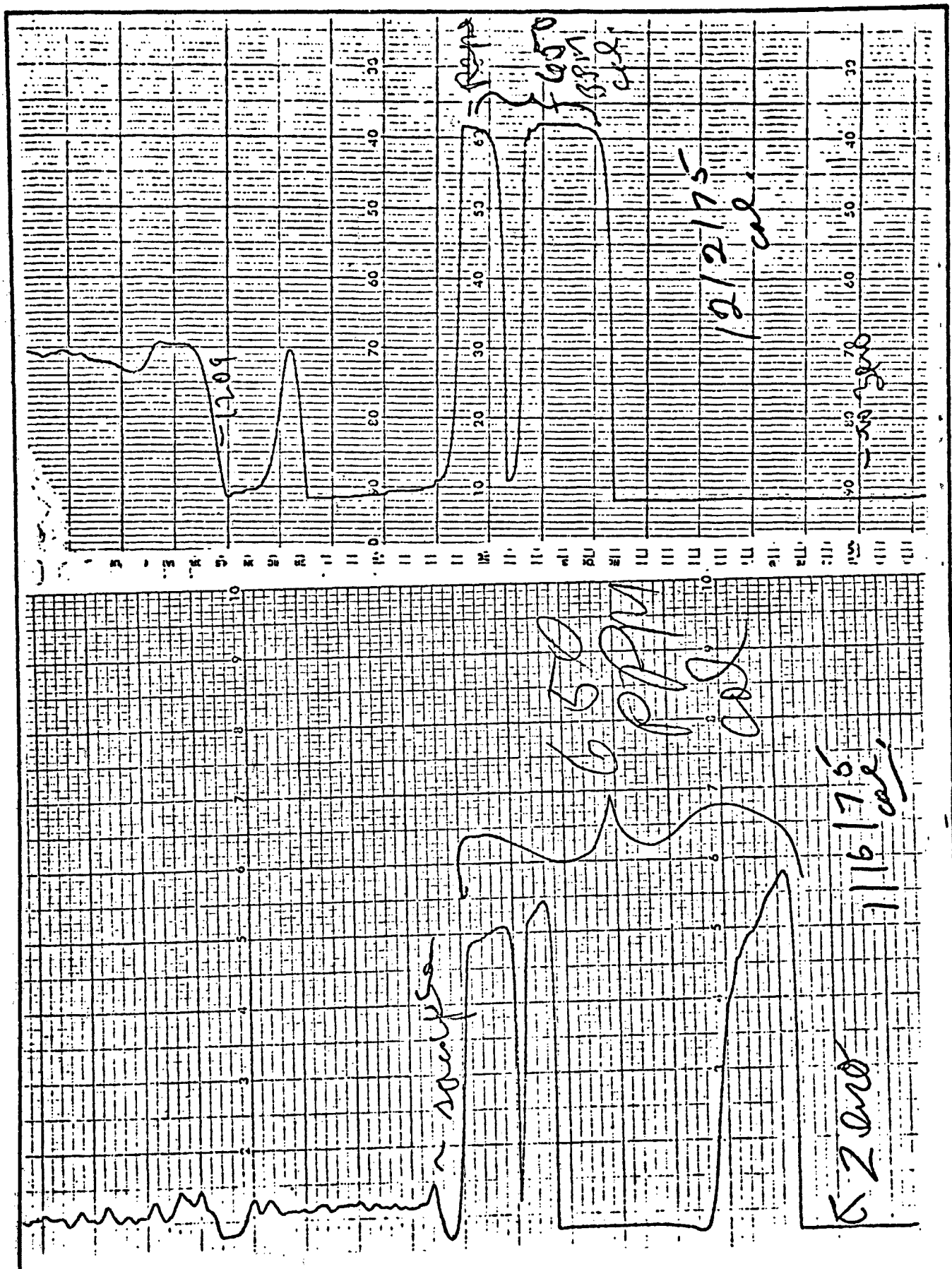


FIGURE 14 COMPARISON OF ROUTINE CALIBRATIONS OF ECOLYZER

TABLE 25. ECOLYZER
CALIBRATION AND MAINTENANCE

Date	Time	Zero (Chart Units)	Zero Drift (% of Full Scale)	Span (Chart Units)	Span Drift (% of Full Scale)	Maintenance Notes
12/1	1300	8		64.5		Heavy Duty SO_2/ NO_x filter installed
12/2	1130	8	0	54.0	-10.5	
12/3	1300	7	-1	61.0	+7.0	
12/4	1230	8	+1	55.0	-6.0	
12/5	1100	8	0	54.0	-1.0	
12/6	1100	10	+2	53.0	-1.0	
12/7	1200	10	0	40	-13.0	
12/8	1130	9	-1	59	+19.0	
12/9	1230	14	+5	45	-14.0	
12/10	1200	19/10*	+5	81/65	+36.0	Span Off Scale Refill Humidifier Bottle
12/11	1530	21/10*	+11	79/65*	+14.0	
12/12	1400	9	-1	64	-1.0	
12/13	1705	15	+6	58	-6.0	
12/14	1200	7	-8	-		
12/15	1108	6/9*	-1	36/65*	-22.0	Replaced Heavy Duty Filter Media (Zero Unstable)
12/16	1300	9	0	72	-7.0	
12/17	1800	10	+1	65	-7.0	
12/18	1200	10	0	62	-3.0	
12/19	1345	10	0	67	+5.0	
12/20	1400	12	+2	68	+1.0	
12/21	1215	5	-7	38	-3.0	
12/22	1145	6/6.8*	+1	45.5/65.5*	+7.5	
12/23	1230	8	+1.2	71.8	+6.8	
12/24	1045	9	+1	70	-1.8	
12/25			NO ROUTINE VISIT			
12/26	1230	16	+7	69	-1.0	
12/27			NO ROUTINE VISIT			
12/28	1315	8	-8	63	-6.0	
12/29	1215	6.8	-1.2	60.2	-2.8	Replaced Heavy Duty Filter Media
12/30	1115	7.5	+0.7	55	-5.2	
12/31	1110	7.8	+0.3	57.2	+2.2	

TABLE 25(CONT'D) ECOLYZER

CALIBRATION AND MAINTENANCE

Date	Time	Zero (Chart Units)	Zero Drift (% of Full Scale)	Span (Chart Units)	Span Drift (% of Full Scale)	Maintenance Notes
1/1			NO ROUTINE VISIT			
1/2	1110	5	-2.8	59	+1.8	
1/3			NO ROUTINE VISIT			
1/4	1430	9.5	+4.5	41.5	-17.5	
1/5	1305	15	+15.5	39	-2.5	
1/6	1200	7.5	-7.5	44.5	+5.5	Replaced Heavy Duty Filter Media
1/7	1200	5	-2.5	45	+0.5	
1/8	1245	5.8	+0.8	50.2	+5.2	
1/9	1248	6	+0.2	47	-3.2	
1/10			NO ROUTINE VISIT			
1/11	1125	6	0	49	+2.0	
1/12	1230	6	0	48	-1.0	
1/13	1110	7	+1.0	47.5	-0.5	
1/14	1120	9	+2.0	53	+5.5	
1/15	1040	7.5	-1.5	48	-5.0	
1/16	1100	7	-0.5	48	0	
1/17	1025	6	-1.0	51.5	+3.5	
1/18			NO ROUTINE VISIT			
1/19	1300	8	+2.0	46	-5.5	
1/20	1300	7.8	-0.2	40.2	-5.8	
1/21	1125	7.5	-0.3	46	+5.8	
1/22	1200	8	+0.5	45	-1.0	
1/23	1610	8	0	43.2	-1.8	

* Adjustment Made

Note: All span and zero drifts based on 0-1000 ppm full scale.

Table 26 is a summary of daily calibrations and maintenance notes. The excellent stability is shown by the almost negligible span drift during the times not affected by the valve malfunction. The instrument has an automatic zero that sets the baseline every five minute cycle thereby eliminating any zero drift.

6.4.4 Beckman NDIR (Model 865)

The Beckman 865 had several problems in the field. From the beginning of the field program, difficulties with the source balance on this instrument were resulting in negative deflections with CO concentrations less than 100 ppm while responses to higher concentrations were non-linear.

Although the sources were brought into balance by Scott personnel on two occasions early in the program, the sources would rapidly drift out of balance.

Significant zero and span drifts necessitated frequent adjustments. Increases in gain, compensating for span drifts, resulted in maximum gain control towards the end of December and proper span responses could not be maintained.

On January 5, a Beckman service representative was called in at which time the temperature control circuit board and detector were replaced. The instrument performed well afterward with the exception of minor zero and span drift.

Table 27 is the calibration and maintenance log for the Beckman 865.

This table illustrates the zero and span drift problems apparently resulting from the temperature controller and detector being faulty from the beginning of the program. The temperature controller and detector are principle components in an NDIR and the fact that they could be faulty without the obvious need for service illustrates the need for regular service by the manufacturer to insure reliable data.

TABLE 26. BECKMAN 6800

CALIBRATION AND MAINTENANCE

Date	Time	Span (650 ppm)	Span Drift (% Full Scale)	Maintenance Notes
12/1	1300	65.3		
12/2	1130	65.6	+0.3	
12/3	1300	65.9	+0.3	
12/4	1230	66.3	+0.4	
12/5	1100	65.3	-1.0	
12/6	1100	65.3	0	Replaced Carrier Air Cyl.
12/7	1200	66.3	+1.0	
12/8	1130	66.5	+0.2	
12/9	1230	65.3	-1.2	
12/10	1200	63.3	-1.0	
12/11	1530	64.3	+1.0	
12/12	1400	64.3	0	
12/13	1705	64.3	0	
12/14	1200	65.3	+1.0	
12/15	1108	63.3	-2.0	Replaced H_2 Cyl. @ 1200
12/16	1300	63.3	-	Replaced H_2 Cyl. due to Leaky Regulator Valve
12/17	1800	63.3	0	
12/18	1200	63.3	0	
12/19	1345	66.8	+3.5	
12/20	1400	64.3	-2.5	
12/21	1215	64.3	0	
12/22	1145	63.3	-1.0	
12/23	1230			Adjust Slope
12/24	1045	66.8	+3.5	
12/25		NO ROUTINE VISIT		
12/26	230	63.8	-3.0	
12/27		NO ROUTINE VISIT		
12/28	1315	66.3	+2.5	
12/29	1215	67.1	+0.8	
12/30	1115	67.3	+0.2	
12/31	1110	64.3	-3.0	

TABLE 26 (CONT'D) BECKMAN 6800

CALIBRATION AND MAINTENANCE

Date	Time	Span (650 ppm)	Span Drift (% Full Scale)	Maintenance Notes
1/1		NO ROUTINE VISIT		
1/2	1110	68.3	+4.0	
1/3		NO ROUTINE VISIT		
1/4	1430	67.3-74.3	-1.0 - +6.0	
1/5	1305	75.8	+8.1 - +1.5	Erratic Cal. Flow Slider Valve Problem
1/6	1200	75.8	0	
1/7	1200	85.3	+9.5	Flame Out, No Data 0100-2400
1/8	1245	69.3	-1.6	Flame Out
1/9	1248	70.3	+1	Flame Out, No Data 0000-1300, 1700-2400
1/10		NO ROUTINE VISIT		Flame Out, No Data All Day
1/11	1125	67.8	-2.5	Flame Out, No Data
1/12	1230	68.3	-0.5	Flame Out, No Data
1/13	1110	71	+2.7	Flame Out, No Data
1/14	1120	68.3	-2.7	Flame Out, No Data 0000-1200
1/15	1040	71.3	+3.0	
1/16	1100	69.3	-2.0	Erratic Cal. Flow, Slider Valve Problem Flame Out 1400-2400
1/17	1025	59.3	-10.0	Flame Out, No Data
1/18		NO ROUTINE VISIT		Flame Out
1/19	1300	64.3	+5.0	Flame Out 0000-1300
1/20	1300	63.3	-1.0	Not Responding Well, Flame Out 0700-2400
1/21	1125	66.3	+3.0	Beckman Rebuilt Faulty Valve
1/22	1200	66.5	+0.2	Working Well
1/23	1610	67.3	+0.8	Working Well

NOTE: Zero readings maintained at 5.0-6.0 chart units by automatic zero mechanism.

Span drifts based on 0-1000 ppm full scale.

TABLE 27. BECKMAN 865

CALIBRATION AND MAINTENANCE

Date	Time	Zero (Chart Units)	Zero Drift (% of Full Scale)	Span (Chart Units)	Span Drift (% of Full Scale)	Maintenance Notes
12/1	1300	4		69.5		
12/2	1130	-2/5.5*	-6	65/69.5*	-4.5	Zero Adjust Control At Maximum
12/3	1300	12.5/7*	+7	53/70.5*	-16.5	Adjustment Of Source Balance
12/4	1230	8.2	+1.2	63.8	-6.7	
12/5	1000	8.5	+0.3	61.5	-2.3	
12/6	1100	7.5	-1.0	57.5	-4.0	Negative Response to Low Concentration
12/7	1200	14.2	+6.7	49.8	-7.7	
12/8	1130	8/7*	-6.2	55/69.5*	+5.2	Adjustment Of Source Balance
12/9	1230	10	+3	69	-0.5	
12/10	1200	11	+1	65.2	-3.8	
12/11	1530	-1	-12	63	-2.2	
12/12	1400	-1/10*	-	58/64*	-5.0	
12/13	1705	5	-5	63	-1	
12/14	1200	3.5	-1.5	65	+2	
12/15	1108	5.8/6*	2.3	63.7/70*	-1.3	Routine Cal. Adj.
12/16	1300	7	+1	67	-3.0	
12/17	1800	7	0	69	+2.0	
12/18	1200	5	-2	71	+2.0	
12/19	1345	7.5	+2.5	64.5	-6.5	
12/20	1400	20	+12.5	71.5	+7.0	
12/21	1215	32/10*	+12	68/73	-3.5	Adjust Zero
12/22	1145	10	0	71.5	-1.5	
12/23	1230	10.5	+0.5	70.3	-1.2	
12/24	1045	16/10*	+5.5	69.8/71.5*	-0.5	Adjust Zero
12/25			NO ROUTINE VISIT			
12/26	1230	11	+1	65.5	-6.0	
12/27			NO ROUTINE VISIT			
12/28	1315	21	+10	66.5	+1.0	
12/29	1215	22/10*	+11	66.8/67.2*	+0.3	Adjust Zero
12/30	1115	13.2	+2.2	68	+0.8	
12/21	1110	15.2	+2.0	64	-4.0	

TABLE 27 (CONT'D) BECKMAN 865

CALIBRATION AND MAINTENANCE

Date	Time	Zero (Chart Units)	Zero Drift (% of Full Scale)	Span (Chart Units)	Span Drift (% of Full Scale)	Maintenance Notes
1/1			NO ROUTINE VISIT			
1/2	1110	18.5	+3.3	68.5	+4.5	
1/3			NO ROUTINE VISIT			
1/4	1430	19.5	+1	68.5	0	
1/5	1305	-/10*		-/73*		Beckman Replaced Temp. Controller And Detector
1/6	1200	7.2/7.5*	-2.8	66.3/72.7*	-6.7	
1/7	1200	5.5	-2.0	69.5	-3.2	
1/8	1245	5.7	+0.2	62.8	-6.7	
1/9	1248	5	-0.7	71	+8.2	
1/10			NO ROUTINE VISIT			
1/11	1125	1.5	-3.5	64.5	-6.5	
1/12	1230	1.2	-0.3	63.5	-1.0	
1/13	1110	0/4*	-1.2	61.8/73*	-1.7	Adj. Both Zero And Span
1/14	1120	3	+3	70	-3.0	
1/15	1040	4	+1	73	+3.0	
1/16	1100	2.5	-1.5	71.5	-1.5	
1/17	1025	1.4	-1.1	67.5	-4.0	
1/18			NO ROUTINE VISIT			
1/19	1300	0.7	-0.7	69.3	+1.8	
1/20	1300	0.2	-0.5	67.8	-1.5	
1/21	1125	0.4/14.2*	+0.2	63.6/60*	-4.2	Adjust Zero
1/22	1200	12.8	-2.4	61.7	+1.7	
1/23	1610	12.2	-0.6	60.8	-0.9	

* Adjustment Made

NOTE: Zero and span based on 1000 ppm full scale.

6.4.5 Horiba NDIR (Model A1A-2, 12/1-12/19; Model A1A-21AS, 12/19-1/23)

The original Horiba NDIR (Model A1A-2) was replaced with a newer model (A1A-21AS) on December 19 because the newer instrument is claimed to have negligible CO_2 and H_2O interference. Performance comparisons between the two instruments can be seen both in the lab evaluation results and in the field data summary.

Both Horiba instruments performed very well in the field. There had been no malfunction or lost data throughout the field or lab programs with either Horiba instrument. Both have exhibited very good zero and span stability requiring only a few routine calibration adjustments.

Table 28 is the daily calibration and maintenance log for the Horiba instruments. This table shows that except for warm-up periods at the program start and when the new Horiba NDIR was installed, both zero and span drifts were very low.

6.5 ANCILLARY INSTRUMENTATION

6.5.1 Mine Safety Appliances (NDIR) CO_2 Monitor

The MSA monitor was included in the program in order to continuously record levels of CO_2 as an interferent. Four of the five instruments under evaluation were susceptible to CO_2 interference.

The MSA instrument ran continuously for the entire program without malfunction or resultant lost data. Continuous CO_2 data is included in the field data summary.

In addition to a record of CO_2 for interference purposes, the MSA monitor proved invaluable in isolating small leaks in the sample delivery system.

6.5.2 Fyrite: CO_2 Measurement

Levels of CO_2 in the duct at the sampling ports were checked periodically using a Fyrite. A Fyrite operates on the same principle as an Orsat in that the specific gas is absorbed in a chemical solution indicating the proportion of that gas in the sample.

These checks were also useful in isolating leaks in the sampling system.

TABLE 28. HORIBA INSTRUMENTS

CALIBRATION AND MAINTENANCE

Date	Time	Zero (Chart Units)	Zero Drift (% of Full Scale)	Span (Chart Units)	Span Drift (% of Full Scale)	Maintenance Notes
12/1	1300	7		67.5		
12/2	1130	0/6*	-7	56/66.2*	-11.5	Zero Adjust
12/3	1300	4.5	-1.5	64.5	-2.3	
12/4	1230	7	+2.5	66.5	+2.0	
12/5	1100	9.7	+2.7	68.3	+1.8	
12/6	1100	9	-0.7	67	-1.3	
12/7	1200	8	-1.0	68	+1.0	
12/8	1130	7.5/4.5	-0.5	67.7/68.2*	-0.3	Zero Adjust
12/9	1230	2.8	-1.7	63.7	-4.5	
12/10	1200	3	+0.2	63.2	-0.5	
12/11	1530	7	+4.0	70	+6.8	
12/12	1400	7	0	70	0	
12/13	1705	6.5	-0.5	69.5	-0.5	
12/14	1200	6	-0.5	69	-0.5	
12/15	1108	6/6*	0	69/66.5*	0	Span Adjust
12/16	1300	6	0	66	-0.5	
12/17	1800	6	0	67	+1.0	
12/18	1200	6	0	66	-1.0	
12/19	1345	5/6.7*	-1.0	65/75.3*	-1.0	Horiba Model A1A-21AS Installed
12/20	1400	5.5	-1.2	69.5	-5.8	
12/21	1215	5.5	0	69.5	0	
12/22	1145	5/6*	-0.5	68/75*	-1.5	Span Adjust
12/23	1230	5	-1.0	75.5	+0.5	
12/24	1045	5	0	76.5	+1.0	
12/25			NO ROUTINE VISIT			
12/26	1230	5.5	+0.5	74.5	-2.0	
12/27			NO ROUTINE VISIT			
12/28	1315	4.5	-1.0	74	-0.5	
12/29	1215	4	-0.5	73.5	-0.5	
12/30	1115	4/4	0	71.8/83	-1.7	Span Adjust
12/31	1110	3.6	-0.4	77.4	-5.6	

TABLE 28 (CONT'D) HORIBA INSTRUMENTS

CALIBRATION AND MAINTENANCE

Date	Time	Zero (Chart Units)	Zero Drift (% of Full Scale)	Span (Chart Units)	Span Drift (% of Full Scale)	Maintenance Notes
1/1			NO ROUTINE VISIT			
1/2	1110	3	-0.6	75	-2.4	
1/3			NO ROUTINE VISIT			
1/4	1430	3	0	75	0	
1/5	1305	2.5	-0.5	76	+1.0	
1/6	1200	2.5	0	78	+2.0	
1/7	1200	2.6	+0.1	75.6	-2.4	
1/8	1245	2.0	-0.6	76.5	+0.9	
1/9	1248	3.0	+1.0	79	+2.5	
1/10			NO ROUTINE VISIT			
1/11	1125	2.0	-1.0	77.9	-1.1	
1/12	1230	1.6	-0.4	76.3	-1.6	
1/13	1110	1.0	-0.6	76.5	+0.2	
1/14	1120	1.0	0	76	-0.5	
1/15	1040	0.8	-0.2	75.2	-0.8	
1/16	1120	0.2	-0.6	74	-1.2	
1/17	1025	0.4	+0.2	74.4	+0.4	
1/18			NO DATA			
1/19	1300	0.2	-0.2	76.3	+1.9	
1/20	1300	0.3	+0.1	25.7	-0.6	
1/21	1125	0.5	+0.2	71.5	-4.2	
1/22	1200	0	-0.5	72.5	+1.0	
1/23	1610	0.2	+0.2	72.5	0	

* Adjustment Made

NOTE: Zero and span based on 1000 ppm full scale.

6.5.3 Flow Measuring Equipment

Duct flow rates were determined periodically using a calibrated type "S" pitot tube and magnehelic differential pressure gauge. Temperatures were measured with chrome-alumel thermocouple and pyrometer.

6.5.4 Moisture Determination Equipment

Moisture levels were usually determined twice weekly in the stack and daily in the instrument trailer. Equipment used at the stack consisted of a stainless steel probe, pre-weighed silica gel tube, calibrated dry test meter and sample pump. Equipment used in the trailer was identical with the exception that a pump was unnecessary because the sample was under pressure at this point.

Moisture data is included with the field data summary.

6.6 DATA LOGGER TRANSLATION

Each Westinghouse data logger contained two data channels and one time channel. The circuitry converted the output voltage of each analyzer to a continuous record of data pulses. Translation of these pulses into parts per million carbon monoxide was done by computer, utilizing two factors which had to be calculated and entered into the tape translation program. These factors are referred to as "multiplier" and "zero adjust" factors.

Multiplier factors were used to convert raw pulses to ppm. These factors are equal to the range of the instrument in ppm divided by the range of the data logger which was 1500 pulses per 15 minute interval. Zero adjust factors allow for a positive voltage output from the instrument equalling 0 ppm CO to be translated as 0 ppm rather than some value analogous to the pulse rate for that positive voltage. This condition was maintained in order to record negative zero drifts. These zero adjust factors would then be a function of the 0 ppm instrument output and the multiplier factor.

Due to instrument drift affecting the full scale range of each instrument, these values were computed daily based on each day's span results. Therefore, span or zero drifts occurring after the entrance of multiplier and zero adjust factors was not compensated for until the next day's factors were entered. The most accurate data comparisons can therefore be made shortly after the entrance of new zero and multiplier factors.

All logger data presented is based on an average of the last three quarters of every hour. This was necessary because during the first quarter of every hour the sampling system automatically routed nitrogen zero gas to each instrument for 3 minutes. The first quarterly segment is, therefore, biased because 3 minutes of zero were included in that quarter's average.

In making data comparisons, it is also important to note that data logger translation was based on daily instrument responses to calibration with 650 ppm CO. Based on this single point, the computer translates all data over the 0-1000 ppm range linearly. Therefore, non-linearity in an instrument's calibration curve is not accounted for. This is illustrated by the typical NDIR calbration curve shown in Figure 15. This discrepancy could have been minimized by using linearizing circuits which are available as optional accessories for both NDIRs in the program.

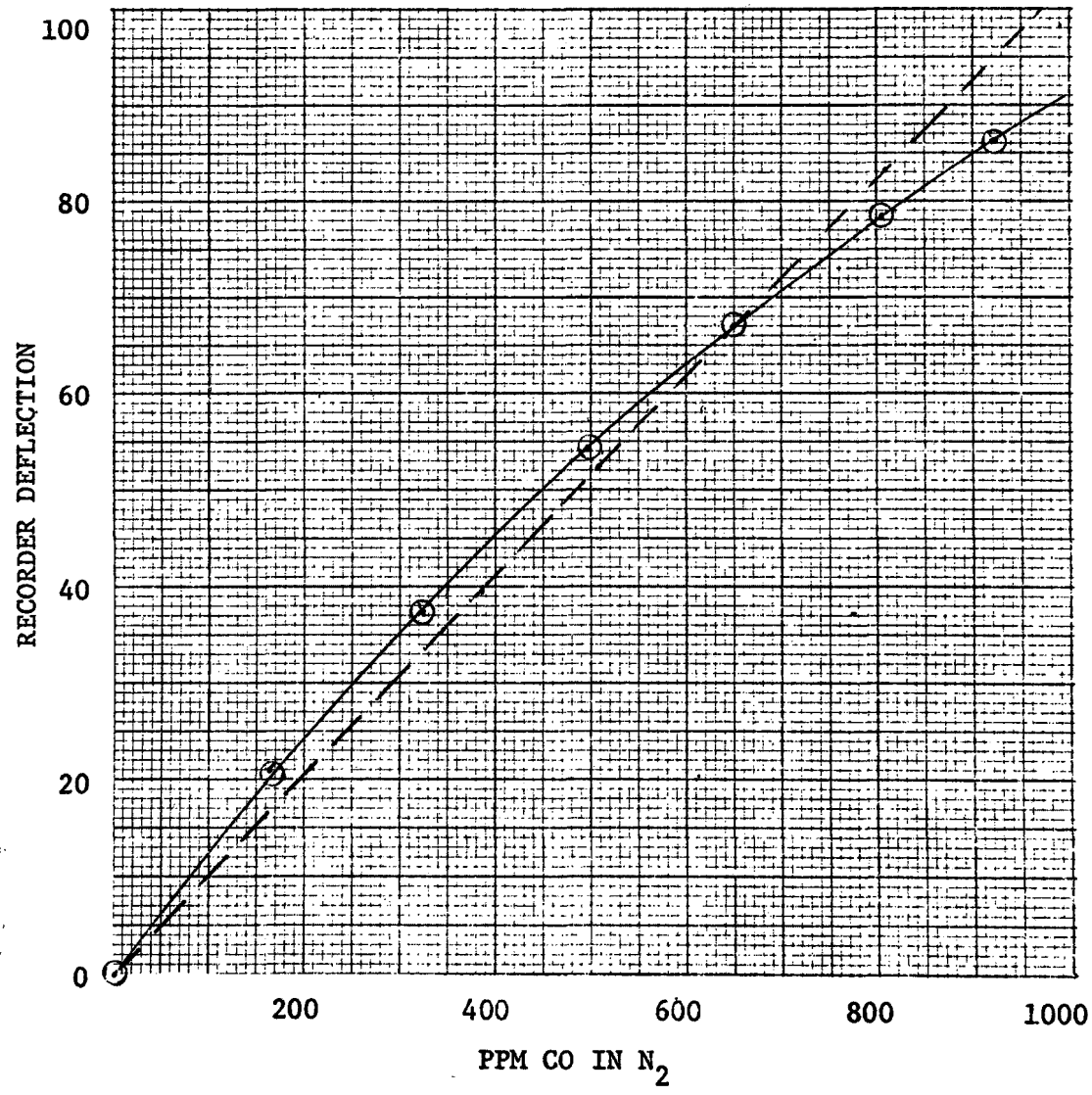


FIGURE 15 BECKMAN 865 CALIBRATION CURVE

6.7 FIELD DATA SUMMARY

The following data summary sheets contain hourly averages of the continuous field data for each instrument in the program. In addition, a continuous record of CO_2 levels and all ancillary data collected including sample and duct moistures, duct flows, temperatures and pressures and sample and process upset notes are presented.

Data for the Beckman 6800 and MSA CO_2 monitors were read from continuous strip charts. The Horiba NDIR, Beckman NDIR, ERT and Ecolyzer data were obtained from two Westinghouse data loggers. The ERT and Horiba NDIR were on one logger and the Ecolyzer and Beckman NDIR were on the other. Each logger could record a month of data on a tape cartridge. Tape cartridges were installed on December 1 and on December 31. Each tape also had a time channel that received a pulse every 15 minutes. The time coordination of these loggers remained within one 15-minute segment throughout the program.

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/1/75

Trailer Temperature: 80°
Sample Moisture: 0.56%

Barometric Pressure: 30.04
Ambient Temperature: 48°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100								
0200								
0300								
0400								
0500								
0600								
0700								
0800								
0900								
1000								
1100								
1200								
1300						13-14%		
1400								
1500	0	559	575	618	618			
1600	0	527	585	607	579			
1700	0	511	565	591	552			
1800	0	511	555	584	539			
1900	0	509	560	576	526			
2000	0	530	580	594	543			
2100	0	526	595	591	536			
2200	0	514	592	580	519			
2300	0	514	582	578	515			
2400	0	511	572	574	507			

Note: Routine calibration times are underlined.

Duct Flow (acfm): 145,579
Duct Moisture: 9.3%

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/2/75

Trailer Temperature: 78°
Sample Moisture: 0.60%

Barometric Pressure: 30.14
Ambient Temperature: 48°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	0	508	572	577	512	13-14%		
0200	0	396	572	569	510			
0300	0	432	573	418	483			
0400	0	472	562	533	476			
0500	0	462	537	525	471			
0600	0	465	555	518	461			
0700	0	453	544	511	461			
0800	0	445	548	503	457			
0900	0	437	554	499	457			
1000	0	417	544	472	430			
1100	0	387	474	445	398			
1200								
1300	0	336	481	509	553			
1400	0	476	456	497	536			
1500	0	513	492	539	586			
1600	0	524	512	538	590			
1700	0	516	502	521	580			
1800	0	528	502	525	589			
1900	o	731	711	694	776			
2000	0	740	741	691	780			
2100	0	758	799	700	796			
2200	0	745	759	680	786			
2300	0	725	717	668	763			
2400	0	680	700	629	721			

Note: Routine calibration times are underlined.

Duct Flow (acfm): 151,591
Duct Moisture: 9.2%

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/3/75

Trailer Temperature: 80°
Sample Moisture: 0.64%

Barometric Pressure: 30.11
Ambient Temperature: 36°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	0	661	651	611	706	13-14%		
0200	0	657	706	619	720			
0300	0	592	679	597	702			
0400	0	591	639	573	680			
0500	0	587	609	570	678			
0600	0	591	654	581	691			
0700	0	556	639	565	677			
0800	0	517	619	559	679			D
0900	0	436	421	278	402			
1000	0	177	123	95	193	13		
1100	0	648		484	614	12		
1200	0	74		124	112	13-14%		
1300								
1400								
1500	0	217	223	220	278			
1600	0	251	223	223	284			
1700	0	220	213	193	253			
1800	0	318	242	306	368			
1900	0	351	331	335	398			
2000	0	403	360	385	453			
2100	0	360	322	340	407			
2200	0	341	312	321	386			
2300	0	344	312	331	395			
2400	0	345	342	330	396			

Note: Routine calibration times are underlined.

Duct Flow (acfm): 141,779
Duct Moisture: 9.0%

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/4/75 Trailer Temperature: Barometric Pressure: 30.40
Sample Moisture: 0.47 Ambient Temperature: 32°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	0	350	320	340	404	13-14%		
0200	0	358	319	350	416			
0300	0	364	349	324	424			
0400	0	330	310	320	385			
0500	0	337	309	327	393			
0600	0	320	320	311	378			
0700	0	328	331	322	391			
0800	0	342	330	336	411			
0900	0	335	341	326	408			
1000	0	309	311	293	381			
1100	0	269	251	249	344			
1200	0							
1300	0							D2
1400	0	465	432	464	533	11		
1500	0	426	412	430	498	11		
1600	0	460	478	454	530	11		
1700	0	319	236	300	393	13-14		
1800	0	362	303	348	445			
1900	0	165	117	123	236			
2000	0	189	226	149	258			
2100	0	138	79	86	199			
2200	0	201	139	168	282			
2300	0	275	273	254	359			
2400	0	285	206	270	375			

Note: Routine calibration times are underlined.

Duct Flow (acfm): 145,405
Duct Moisture: 8.7%

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/5/75

Trailer Temperature:
Sample Moisture: 0.47%

Barometric Pressure: 30.38
Ambient Temperature: 42°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	0	286	253	288	395	13-14%		D2
0200	0	335	291	325	430			
0300	0	348	283	333	437			
0400	0	390	291	373	467			
0500	0	231	273	197	306			
0600	0	261	263	227	332			
0700	0	171	224	139	255			
0800	0	265	214	238	352			
0900	0	322	214	293	410			
1000	0	335	271	304	423			
1100	0	353	251	311	-			
1200	0							
1300	0							
1400	0							
1500	0	258	213	172	278			
1600	0	430	303	351	444			
1700	0	463	383	393	482			
1800	0	452	383	380	474			
1900	0	444	383	371	468			
2000	0	447	383	373	472			
2100	0	457	393	381	479			
2200	0	469	403	392	492			
2300	0	492	423	416	511			
2400	0	490	423	415	510			

Note: Routine calibration times are underlined.

Duct Flow (acfm): 115,862
Duct Moisture: 9.6%

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/6/75

Trailer Temperature: 80°
Sample Moisture: -

Barometric Pressure: 30.17
Ambient Temperature: 45°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	0	481	403	406	501	13-14%		
0200	0	459	413	386	484			
0300	0	461	413	388	486			
0400	0	461	403	387	485			
0500	0	463	403	388	488			
0600	0	469	413	396	496			
0700	0	461	413	389	490			
0800	0	505	453	436	534			
0900	0	503	463	439	538			
1000	0	513	473	437	541			
1100	0							
1200	0							
1300	0							D2
1400	0	672	585	558	646			
1500	0	354	244	275	378			
1600	0	767	544	485	547			
1700	0	326	274	244	360			
1800	0	322	283	244	360			
1900	0	327	275	250	376			
2000	0	325	284	246	370			
2100	0	342	273	261	381			
2200	0	340	273	260	378			
2300	0	333	263	267	368			
2400	0	260	215	188	315			

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/7/75

Trailer Temperature: -
Sample Moisture: -

Barometric Pressure: 30.32
Ambient Temperature: 37°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	0	324	275	257	370	13-14%		
0200	0	330	273	267	379			
0300	0	328	295	265	377			
0400	0	346	293	285	397			
0500	0	343	305	284	393			
0600	0	350	315	327	401			
0700	0	373	334	322	425			
0800	0	353	324	302	408			
0900	0	367	357	325	426			
1000	0	380	345	336	433			
1100	0	357	324	311	415			
1200	0	351	323	309	415			
1300	0							
1400	0							
1500	0	364	265	180	349			
1600	0	305	283	997	482			
1700	0	320	264	170	331			
1800	0	357	273	181	336			
1900	0	375	273	205	356			
2000	0	408	303	240	379			
2100	0	431	323	264	398			
2200	0	429	333	262	397			
2300	0	441	343	275	407			
2400	0	396	293	221	369			

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/8/75

Trailer Temperature: 74°
Sample Moisture: 0.71%

Barometric Pressure: 30.22
Ambient Temperature: 34°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	0	391	303	222	371	13-14%		
0200	0	390	303	219	369			
0300	0	390	293	220	371			
0400	0	389	303	224	376			
0500	0	399	313	231	379			
0600	0	379	303	204	362			
0700	0	332	273	153	330			
0800	0	326	263	146	326			
0900	0	321	253	137	320			D2
1000	0	326	253	144	326			
1100	0	309	263	122	311			
1200	0							
1300	0							
1400	0	335	153	274	243			
1500	0	180	136	173	168			
1600	0	190	136	180	164			
1700	0	168	116	171	140			
1800	0	187	96	168	128			
1900	0	158	116	180	131			
2000	0	153	96	179	124			
2100	0	155	106	185	124			
2200	0	843	480	670	603			
2300	0	451	390	366	371	12		
2400	0	153	96	181	105	12		

Note: Routine calibration times are underlined.

Duct Flow (acfm): 150,853
Duct Moisture: 9.5%

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/9/75

Trailer Temperature: 75°
Sample Moisture: 1.60%

Barometric Pressure: 29.89
Ambient Temperature: 45°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	0	142	96	183	104	12%		D2
0200	0	184	96	207	128	↓		↓
0300	0	206	136	239	155			
0400	0	230	126	263	170			
0500	0	222	146	260	160			
0600	0	272	204	311	209			
0700	0	371	323	403	293			
0800	0	250	185	280	178			
0900	0	263	243	296	196			
1000	0	274	223	305	207			
1100	0	272	243	286	188			
1200	0	258	217	297	206			
1300								
1400	251	233	236	313	319			
1500	230	227	217	267	251	↓		
1600	554	503	447	491	521	13-14%		
1700	335	371	427	355	348			
1800	404	470	357	441	46			
1900	406	1475	327	463	552			
2000	242	951	267	291	316			
2100	594	647	207	238	245			
2200	59	532	177	225	214			
2300	59	488	177	240	219			
2400	60	426	147	224	189	↓		

Note: Routine calibration times are underlined.

Duct Flow (acfm): 125,915
Duct Moisture: 9.1%

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/10/75

Trailer Temperature: 82°
Sample Moisture: 0.61%

Barometric Pressure: 29.70
Ambient Temperature: 43°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	59	406	146	228	184	13-14%		
0200	60	397	127	227	179	↓		
0300	90	377	137	221	173	↓		
0400	164	362	127	204	173	↓		
0500	167	350	147	211	197	↓		
0600	177	371	147	221	179	↓		
0700	174	297	127	210	162	↓		
0800	167	323	117	204	168	↓		D2
0900	375	754	147	335	381	↓		↓
1000	277	693	367	260	254	↓		↓
1100	241	823	257	286	255	↓		↓
1200						↓		↓
1300	184	303	193	232	215	13		↓
1400	149	193	140	153	130	11		↓
1500	180	214	193	228	202	11		↓
1600	359	258	253	391	429	11		↓
1700	313	220	253	296	313	13-14%		↓
1800	494	495	396	538	616	↓		↓
1900	560	634	503	551	649	↓		2
2000	630	362	460	419	507	↓		↓
2100	691	649	560	561	684	↓		↓
2200	604	577	553	564	699	↓		↓
2300	712	664	586	637	784	↓		D2
2400	459	390	356	410	553	↓		↓

Note: Routine calibration times are underlined.

Duct Flow (acfm): 122,310
Duct Moisture: 9.4%

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/11/75

Trailer Temperature: 82°
Sample Moisture: 0.73%

Barometric Pressure: 30.07
Ambient Temperature: 40°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	774	687	536	595	818	13-14%		D2
0200	911	808	506	628	808	↓		↓
0300	552	439	440	360	526			
0400	1038	850	1000+	848	1126			
0500	892	843	936	756	1019			
0600	822	848	873	704	968			
0700	778	854	833	684	961			
0800	794	855	853	680	967			
0900	449	852	833	657	953			
1000	613	845	813	642	948			
1100	808	836	798	619	927			
1200	819	836	774	608	924			
1300	806	827	764	584	901			
1400	796	818	745	571	897			
1500	789	817	725	546	872			
1600								
1700	762	687	693	644	723			
1800	746	756	703	681	746			
1900	775	756	713	691	758			
2000	769	756	723	693	765			
2100	784	756	723	686	760			
2200	759	755	723	685	759			
2300	764	752	703	673	745			
2400	765	754	713	678	748			

Note: Routine calibration times are underlined.

Duct Flow (acfm): 152,292
Duct Moisture: 8.4%

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/12/75

Trailer Temperature: 82°
Sample Moisture: 0.86%

Barometric Pressure: 30.38
Ambient Temperature: 42°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	108	753	713	673	743	13-14%		
0200	60	753	683	658	729			
0300	571	752	692	659	735			
0400	602	753	693	664	740			
0500	735	746	651	629	701			
0600	217	726	621	599	671			
0700	61	732	652	620	698			
0800	214	717	622	604	682			
0900	257	667	612	584	667			
1000	638	627	582	558	651			
1100	415	598	571	531	628			
1200	321	585	550	522	617			
1300	48	564	541	572	604			
1400								
1500	59	515	525	512	548			
1600	61	549	525	551	587			
1700	504	622	575	607	649			
1800	720	633	595	614	661			
1900	739	650	625	623	674			
2000	728	643	625	622	669			
2100	721	634	615	619	667			
2200	703	611	596	603	650			
2300	693	597	575	604	644			
2400	699	599	595	612	647			

Note: Routine calibration times are underlined.

Duct Flow (acfm): 152,027
Duct Moisture: 8.1%

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/13/75

Trailer Temperature: 86°
Sample Moisture: -

Barometric Pressure: 30.57
Ambient Temperature: 46°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	705	596	595	615	651	13-14%		
0200	719	611	615	628	666			
0300	735	618	615	630	674			
0400	751	631	635	633	688			
0500	746	633	645	629	690			
0600	722	605	625	605	663			
0700	680	576	595	582	646			
0800	662	566	585	571	642			
0900	661	559	575	562	638			
1000	546	566	595	570	651			
1100	173	528	556	533	620			
1200	139	425	476	447	524			
1300	263	478	506	506	592			
1400	557	581	625	587	682			
1500	478	571	616	578	677			
1600	657	580	586	563	688			
1700	390	670	647	598	687			
1800								
1900	343	774	709	691	753			
2000	68	767	699	671	732			
2100	154	737	608	606	656			
2200	90	696	588	601	642			
2300	64	626	588	598	639			
2400	63	580	568	588	628			

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/14/75 Trailer Temperature: 80° Barometric Pressure: 30.44
Sample Moisture: - Ambient Temperature: 46°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	62	490	517	539	572	13-14%		
0200	62	467	506	538	572			
0300	62	445	496	529	570			
0400	63	441	496	535	579			
0500	64	429	506	536	578			
0600	64	415	496	534	575			
0700	63	408	506	532	580			
0800	61	400	506	530	577			
0900	59	394	526	538	580			
1000	56	373	506	538	567			
1100	57	349	498	527	551			
1200								
1300								
1400								
1500	55	349	422	471	505			
1600	55	337	421	470	510			
1700	55	331	431	477	518			
1800	54	324	431	478	522			
1900	55	314	431	473	521			
2000	55	316	441	483	529			
2100	54	311	441	489	534			
2200	54	300	441	490	533			
2300	54	292	441	491	529			
2400	54	281	441	491	525			

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: F = Frozen Sample Line
(does not apply to ERT) L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/15/75

Trailer Temperature: 80°
Sample Moisture: 0.5%

Barometric Pressure: 29.97
Ambient Temperature: 51°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	55	267	421	485	518	13-14%		
0200	55	263	421	487	520			
0300	54	253	421	481	511			
0400	53	240	401	472	500			
0500	52	233	401	473	497			
0600	46	231	401	481	502			
0700	44	229	421	489	504			
0800	44	224	412	497	509			
0900	44	222	421	497	513			
1000	47	207	394	478	494			
1100	43	192	382	453	472			
1200								
1300								
1400	53	485	394	494	482			
1500	44	491	384	486	476			
1600	44	473	379	470	467			
1700	43	469	374	460	464			
1800	43	460	351	449	454			
1900	43	462	351	440	454			
2000	43	467	356	431	455			
2100	44	471	362	422	456			
2200	43	479	367	439	460			
2300	45	480	368	456	456			
2400	43	473	364	460	456			

Note: Routine calibration times are underlined.

Duct Flow (acfm): 153,414
Duct Moisture: 8.8%

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/16/75

Trailer Temperature: 85°
Sample Moisture: 0.55%

Barometric Pressure: 29.97
Ambient Temperature: 43°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	44	459	353	450	448	13-14%		
0200	44	441	343	434	434			
0300	44	453	353	443	440			
0400	44	452	348	441	437			
0500	138	455	348	445	444			
0600	292	455	353	443	444			
0700	160	448	353	438	434			
0800	134	454	353	432	439			
0900	269	494	374	450	469			
1000	291	469	364	425	450			
1100	278	450	353	409	436			
1200	266	462	364	422	444			
1300								
1400								
1500	253	390	350	441	443	No Ink		
1600	259	392	350	434	449			
1700	272	403	365	429	462			
1800	216	409	369	439	469			
1900	130	414	377	450	475			
2000	83	425	388	459	482			
2100	74	424	389	466	483			
2200	265	425	388	479	489			
2300	277	434	410	496	498			
2400	292	444	421	508	506			

Note: Routine calibration times are underlined.

Duct Flow (acfm): 151,700
Duct Moisture: 8.5%

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/17/75 Trailer Temperature: 80° Barometric Pressure: 30.10
Sample Moisture: - Ambient Temperature: 39°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	159	454	432	521	516	No Ink		
0200	78	444	422	515	509			
0300	226	441	422	521	513			
0400	99	437	423	524	515			
0500	110	442	442	534	522			
0600	167	456	474	550	538			
0700	116	470	484	560	555			
0800	43	489	504	574	572			
0900	43	551	545	623	626			
1000	43	548	525	613	622			
1100	43	535	525	590	610			
1200	49	537	534	581	610			
1300	43	536	514	575	607			
1400	44	513	493	554	587			
1500	43	497	472	536	572			
1600	44	489	473	530	568			
1700	44	480	473	532	569	13-14%		
1800								
1900	62	503	477	482	575			
2000	279	543	487	580	566			
2100	143	553	499	524	574			
2200	256	531	477	511	557			
2300	241	505	456	497	541			
2400	216	492	446	486	531			

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: F = Frozen Sample Line
(does not apply to ERT) L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/18/75

Trailer Temperature: -
Sample Moisture: 0.41%

Barometric Pressure: 29.88
Ambient Temperature: 30°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	209	489	446	490	519	13-14%		
0200	198	485	446	491	524			
0300	224	483	436	491	521			
0400	191	480	436	490	516			
0500	85	472	435	483	510			
0600	17	463	426	474	593			
0700	4	465	436	471	509			
0800	0	481	446	481	513			
0900	0	511	477	503	544			
1000	0	523	486	512	551			
1100	0	529	498	520	562			
1200								
1300							I	
1400							I	
1500	380	652	549	585	627		I	
1600	634	658	529	565	619			
1700	655	578	489	515	559			
1800	662	583	492	523	564			
1900	690	571	492	515	561			
2000	671	523	504	518	566			
2100	688	588	520	532	585			
2200	655	590	520	536	593			
2300	660	597	532	545	598			
2400	653	593	532	546	604			

Note: Routine calibration times are underlined.

Duct Flow (acfm): 149,053
Duct Moisture: 7.76%

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/19/75

Trailer Temperature: 60°
Sample Moisture: -

Barometric Pressure: 30.23
Ambinet Temperature: 22°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	623	594	531	551	605	13-14%		
0200	652	621	613	605	662	↓		
0300	622	594	633	511	677	↓		
0400	619	560	613	609	679	↓		
0500	623	531	592	586	651	↓		
0600	608	537	592	571	637	↓		
0700	635	460	603	570	636	↓		
0800	636	508	633	594	663	↓		
0900	625	634		588	676	↓		
1000	659	617		568	662	↓		
1100	641	603		564	663	↓		
1200	644	476		517	645	↓		
1300						↓		
1400						↓		
1500	649	699	544	690	563	↓		
1600	643	711	552	685	582	↓		
1700	640	730	563	697	587	↓		
1800	631	441	562	471	321	↓		
1900	571	56	563	180	83	0%		D2
2000	593			54	3	↓		↓
2100	580			49	3	↓		↓
2200	244	2	514	89	15	↓		↓
2300	74		495	64	14	↓		↓
2400	89	106	580	381	220	13%		↓

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/20/75 Trailer Temperature: 72° Barometric Pressure: 30.21
Sample Moisture: - Ambient Temperature: 32°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	114	-30		81	7	0%		D2
0200	167	-32		83	6			
0300	484	-34		87	6			
0400	450	-35		93	4			
0500	560	-36		100	4			
0600	556	-37		106	4			
0700	553	-38		112	3			
0800	544	-39	514	118	3			
0900	541	81	484	584	419	13%		
1000	553	24	514	406	238	0-13%		
1100	444	335	514	592	412	13-14%		
1200	354	651	474	767	549			
1300	330	692		763	545			
1400								
1500	376	548		561	547			
1600	20	57		6	17	0%		
1700	29	-		5	14			
1800	26	-		11	14			
1900	29	-		17	15			
2000	31	-		24	15			
2100	51	-		29	16			
2200	45	-		33	17			
2300	40	-		38	17			
2400	41	-		43	16			

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: F = Frozen Sample Line
(does not apply to ERT) L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/21/75

Trailer Temperature: 72°
Sample Moisture: -

Barometric Pressure: 30.10
Ambient Temperature: 31°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	28	-		47	16	0%		D2
0200	46	-		54	19			
0300	42	-		60	19			
0400	29	-		65	19			
0500	26	-		70	17			
0600	357	-		74	16			
0700	20	-		80	15			
0800	21	-		85	13			
0900	427	-		89	12			
1000	461	-		93	13			
1100	461	-		97	13			
1200	447	60		212	145			
1300						13-14%		
1400	193	415	355	391	462			
1500	182	387	335	378	453			
1600	169	341	315	346	414			
1700	427	339	315	361	434			
1800	450	373	376	407	483			
1900	425	361	376	405	480			
2000	477	368	396	422	498			
2100	538	316	345	376	448			
2200	530	292	335	359	431			
2300	554	275	315	350	426			
2400	564	258	315	345	421			

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/22/75

Trailer Temperature: 76°
Sample Moisture: -

Barometric Pressure: 29.83
Ambient Temperature: 28°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	565	250	315	348	423	13-14%		
0200	548	246	325	356	434			
0300	506	260	376	386	466			
0400	451	255	416	407	496			
0500	422	256	406	437	521			D2
0600	388	227	366	404	477			
0700	365	206	366	391	464			
0800	342	185	376	392	468			
0900	321	114		405	479	321	I	
1000	297	270		566	608			
1100	336	167		407	426			
1200								
1300								
1400	321	124		47	8			
1500	363	40		75	61	13-14%		
1600	350	136		161	152			
1700	420	164	127	79	172			
1800	434	180	127	11	173			
1900	412	183	127	28	172			
2000	411	194	137	64	182			
2100	419	202	137	94	187			
2200	415	201	127	108	183			
2300	476	201	137	125	183			
2400	486	203	147	138	184			

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/23/75

Trailer Temperature: 74°
Sample Moisture: 0.63%

Barometric Pressure: 29.96
Ambient Temperature: 31°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	474	214	147	159	196	13-14%		
0200	476	214	137	165	193			
0300	463	221	147	177	198			
0400	462	220	147	177	192			
0500	466	221	147	186	198			
0600	476	220	136	188	197			
0700	501	223	157	192	197			
0800	504	226	147	190	196			
0900	521	234	157	196	205			
1000	493	237	147	201	207			
1100	495	241	159	209	211			
1200	482	248	147	213	213			
1300								
1400	167	133		147	148			
1500	32	134		165	158			
1600	0	166		200	185			
1700	5	166		197	182			
1800	72	166		199	183			
1900	203	162		197	178			
2000	238	152		196	172			
2100	72	162		205	197			
2200	131	155		199	168			
2300	188	155		206	169			
2400	75	282		339	336			

Note: Routine calibration times are underlined.

Duct Flow (acfm): 141,094
Duct Moisture: 7.9%

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/24/75 Trailer Temperature: 75° Barometric Pressure: 30.40
Sample Moisture: 0.71% Ambient Temperature: 22°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	12	348		379	372	13-14%		
0200	67	358		380	375	↓		
0300	0	365		385	377			
0400	0	360		380	375			
0500	8	368		385	382			
0600	63	363		384	382		I	
0700	249	51		90	7	0%	↓	
0800	371	19		62	6	0%		
0900	378	106		256	213	13-14%		
1000	279	213		379	354	↓		
1100	277							
1200	291	275	292	312	326			
1300	355	214	294	262				
1400	399	364	304	362	389			
1500	439	381	304	357	389			
1600	467	369	293	352	388			
1700	518	345	292	354	391			
1800	409	336	294	356	394			
1900	442	244	304	358	390			
2000	458	165	304	362	395			
2100	382	203	314	371	401			
2200	370	321	304	372	402			
2300	347	373	304	374	396			
2400	338	385	314	381	405			

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/25/75

Trailer Temperature: -
Sample Moisture: -

Barometric Pressure: 30.38
Ambient Temperature: 26°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	355	377	314	377	399	13-14%		
0200	337	376	304	375	402	↓		
0300	427	372	294	369	398			
0400	476	376	294	372	402			
0500	472	359	304	370	399			
0600	427	382	314	377	405			
0700	360	382	304	376	404			
0800	316	379	314	376	406			
0900	361	385	314	379	409			
1000	388	385	314	375	407	↓		D2
1100	408	151	314	185	119	0%		↓
1200	460	20		44	7	↓		
1300	482	9		22	6			
1400	477	9		34	30			
1500	463	7		37	19			
1600	448	3		31	9			
1700	436	7		57	32			
1800	488	2		40	9	↓		
1900	446	299	294	380	380	13-14%		
2000	404	351	305	386	392	↓		
2100	376	371	305	385	395			
2200	375	364	395	376	384			
2300	380	372	305	382	389			
2400	376	381	395	386	392	↓		

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/26/75

Trailer Temperature: -
Sample Moisture: 0.64%

Barometric Pressure: 29.75
Ambient Temperature: 43°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	379	377	305	380	385	13-14%		
0200	321	380	305	379	388			
0300	566	384	395	379	395			
0400	790	400	315	385	401			
0500	783	413	315	392	401			
0600	636	403	325	399	418			
0700	416	284	315	385	417			
0800	41	299	382	441	471			
0900	43	468	362	434	477			
1000	43	508	382	426	476			
1100	43	303	217	277	308			
1200	48	261	198	260	294			
1300								
1400	50	114	217	249	273			
1500	44	177	197	255	273			
1600	42	168	197	259	275			
1700	42	154		253	264			
1800	42	165		247	257			
1900	42	167		248	254			
2000	42	130		216	216			
2100	42	150		239	241			
2200	42	150		246	245			
2300	42	147		255	246			
2400	42	149	175	259	245			

Note: Routine calibration times are underlined.

Duct Flow (acfm): 143,352
Duct Moisture: 10.4%

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/27/75

Trailer Temperature: -
Sample Moisture: -

Barometric Pressure: 29.88
Ambient Temperature: 37°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	42	143	165	257	241	13-14%		
0200	42	151	175	263	245	↓		
0300	42	155	174	268	255			
0400	42	150	174	262	248			
0500	42	143	175	255	244	No Ink		
0600	42	106	164	256	243			
0700	42	89	163	253	230			
0800	42	81	155	246	221			
0900	42	44	155	234	209			
1000	42	61	154	246	227			
1100	42	102	153	243	219			
1200	48	72	154	236	221			
1300	58	61	145	226	212			
1400	60	72	145	225	213			
1500	35	87	133	221	203			
1600	41	84	135	228	204			
1700	51	56	135	226	196			
1800	48	57	130	227	200			
1900	49	77	130	216	187			
2000	50	82	135	218	188			
2100	50	49	125	210	178			
2200	49	39	125	222	182			
2300	45	30	125	229	182			
2400	43	28	135	238	187	↓		

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/28/75

Trailer Temperature: -
Sample Moisture: -

Barometric Pressure: 30.23
Ambient Temperature: 31°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	47	21	125	234	178	No Ink		
0200	43	23	119	235	171			
0300	48	15	114	231	164			
0400	48	25	125	242	175			
0500	35	25	119	237	171			
0600	37	32	114	243	168			
0700	36	26	119	246	169			
0800	50	26	114	246	167			
0900	45	11	124	245	166			
1000	42	-	124	233	167			
1100	47	1	125	254	171			
1200	48	7	129	260	180			
1300	21	14	134	269	168			
1400						6.3%		
1500	11	69	69	94	120	8		
1600	15	54	89	119	147	10		
1700	43	48	104	111	163	12		
1800	53	36	99	115	163	12		
1900	42	41	118	137	184	No Ink		
2000	22	55	119	107	186			
2100	46	56	118	156	179			
2200	50	58	119	163	177			
2300	39	58	121	163	174			
2400	18	64	120	170	178			

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/29/75 Trailer Temperature: 80° Barometric Pressure: 30.40
Sample Moisture: - Ambient Temperature: 34°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	22	57	120	168	176	No Ink		
0200	23	57	115	164	172	↓		
0300	33	77	189	247	259			
0400	46	81	194	264	270			
0500	44	85	214	290	293			
0600	48	72	204	278	278			
0700	157	88	115	286	283			
0800	111	86	110	275	278			
0900	31	71	120	281	289			
1000	22	71	115	276	285		I	
1100	59	72	110	275	388		↓	
1200	46	93	130	293	307			
1300	156							
1400	11							
1500	28	22	25	18	11			
1600	46	28	66	34	27			
1700	44	59	60	75	61			
1800	13	63	50	83	70			
1900	41	62	50	80	68			
2000	48	63	50	80	65			
2100	47	61	50	78	64			
2200	46	59	50	80	63			
2300	37	59	50	85	61			
2400	40	59	50	90	62			

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: F = Frozen Sample Line
(does not apply to ERT) L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/30/75

Trailer Temperature: 76°
Sample Moisture: 1.1%

Barometric Pressure: 30.19
Ambient Temperature: 36°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	44	56	50	90	59	No Data		
0200	45	57	50	91	61			
0300	34	59	50	89	58			
0400	32	59	50	94	62			
0500	46	58	50	97	63			
0600	20	58	50	98	61			
0700	28	58	50	101	63			
0800	29	58	50	100	60			
0900	27	57	49	96	58			
1000	45	56	50	92	59			
1100	50	53	45	88	56			
1200	52							
1300	45	76	55	80	74			
1400	49	80	65	85	75			
1500	54	86	65	94	81			
1600	41	87	65	98	82			
1700	46	87	65	100	80			
1800	40	85	65	101	80			
1900	44	55	29	53	37			
2000	46	49	29	52	37			
2100	26	45	29	47	36			
2200	37	44	29	50	39			
2300	50	44	29	52	40			
2400	50	43	29	55	41			

Note: Routine calibration times are underlined.

Duct Flow (acfm): 131,577
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/31/75

Trailer Temperature: 82°
Sample Moisture: 0.86%

Barometric Pressure: 29.85
Ambient Temperature: 40°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	50	42	29	56	40	No Data		
0200	53	43	29	61	42			
0300	52	45	29	65	43			
0400	50	42	29	64	39			
0500	49	44	29	65	42			
0600	45	43	29	64	41			
0700	42	43	29	64	39			
0800	42	45	29	67	43			
0900	11	44	29	65	43			
1000	34							
1100	49							
1200								
1300	25	55	31	78	51			
1400	5	74	82	110	97			
1500	13	71	51	76	57			
1600	4	64	51	82	73			
1700	9	53	41	71	53			
1800	4	42	41	63	43			
1900	23	45	41	66	47			
2000	56	49	41	74	51			
2100	58	53	51	79	53			
2200	59	55	51	87	58			
2300	189	70	51	114	80			
2400	631	61	31	105	61			

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/1/76

Trailer Temperature: -
Sample Moisture: -

Barometric Pressure: 29.91
Ambient Temperature: 34°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	565	64	51	111	60	No Data		
0200	556	70	62	118	63			
0300	541	70	51	119	65			
0400	530	77	51	130	81			
0500	514	88	51	140	91			
0600	529	85	61	137	86			
0700	526	95	61	149	91			
0800	576	109	82	164	103			
0900	589	97	82	146	94			
1000	603	114	72	173	119			
1100	602	123	112	176	121			
1200	604	125	61	173	119			
1300	604	118	83	168	115			
1400	599	104	73	148	94			
1500	613	162	102	206	153			
1600	611	104	92	145	103			
1700	601	99	62	146	98			
1800	609	88	52	136	84			
1900	468	82	72	132	81			
2000	296	99	73	154	105			
2100	483	91	83	147	92			
2200	601	90	62	148	89			
2300	591	108	73	171	109			
2400	585	124	103	190	131			

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/2/76

Trailer Temperature: 60°
Sample Moisture: .6

Barometric Pressure: 30.26
Ambient Temperature: 38°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	557	175	113	231	170	No Data		
0200	561	193	143	253	189	↓		
0300	567	191	123	248	181	↓		
0400	569	155	113	209	142	↓		
0500	575	152	133	208	143	↓		
0600	535	156	113	215	148	↓	F	
0700	542	43	10	74		↓	↓	
0800	552	17	10	49		↓	↓	
0900	548	12	10	44		↓	↓	
1000	527	112	113	183	121	↓	↓	
1100	492	24	-	185	122	↓	↓	
1200						↓	↓	
1300						9%	F	
1400	73	90	77	61	53	↓		
1500	94	130	87	127	119	↓		
1600	114	158	97	150	141	↓		
1700	120	166	117	146	139	↓		
1800	91	124	87	107	94	↓		
1900	96	125	69	111	102	↓		
2000	101	135	87	121	114	↓		
2100	88	139	107	126	119	↓		
2200	74	157	107	148	136	↓		
2300	111	165	77	156	144	↓		
2400	114	161	108	148	136	↓		

Note: Routine calibration times are underlined.

Duct Flow (acfm): 119.117
Duct Moisture: 11.6

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/3/76

Trailer Temperature: -
Sample Moisture: -

Barometric Pressure: 29.90
Ambient Temperature: 35°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	112	157	87	147	139	9%		
0200	108	148	87	135	126			
0300	109	155	108	142	139			
0400	94	143	98	123	122			
0500	88	153	98	134	135			
0600	48	164	118	125	146			
0700	31	171	108	147	162			
0800	62	173	128	99	156			
0900	6	166	118	124	148			
1000	9	179	108	160	172			
1100	14	175	127	143	150			
1200	33	154	87	126	132			
1300	57	139	77	109	116			
1400	8	141	97	113	116			
1500	16	146	86	121	125			
1600	109	147	96	121	128			
1700	119	150	106	123	133			
1800	104	140	87	104	116			
1900	109	138	68	92	111	7%		
2000	105	122	68	64	92	6%		
2100	90	107	39	40	61			
2200	80	105	50	44	59			
2300	86	103	45	48	56			
2400	88	105	50	51	58			

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: F = Frozen Sample Line
(does not apply to ERT) L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/4/76

Trailer Temperature: 72°
Sample Moisture: -

Barometric Pressure: 30.02
Ambient Temperature: 28°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	87	99	40	44	47	6%		
0200	88	101	40	47	49			
0300	101	107	40	57	59			
0400	103	126	50	90	88	9%		
0500	73	109	69	72	58			
0600	60	104	40	65	51			
0700	56	110	40	75	59			
0800	42	109	40	53	51			
0900	47	-18	50	73	68			
1000	37	114	50	76	64			
1100	52	120	60	85	71			
1200	52	116	69	76	58			
1300	56	121	50	89	75			
1400								
1500								
1600	245	92	-	76	74	11%		
1700	48	83	46	65	64			
1800	59	88	46	92	94			
1900	123	90	63	111	114			
2000	562	91	90	125	125			
2100	536	88	90	142	140			
2200	527	78	100	136	139	10%		
2300	550	61	80	78	75			
2400	556	66	63	105	106			

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/5/76 Trailer Temperature: 68° Barometric Pressure: 30.41
Sample Moisture: - Ambient Temperature: 23°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	541	64	63	105	110	10%		
0200	517	63	73	108	115	↓		
0300	537	56	74	74	79	↓		
0400	567	57	56	79	86	↓		
0500	588	50	64	51	54	↓		
0600	614	53	73	72	76	↓		
0700	594	44	46	45	50	↓		
0800	571	45	26	56	58	↓		
0900	585	48	36	65	67	↓		
1000	595	45	36	59	61	13-14%		
1100	488	46	46	55	52	↓		
1200	384	34	36	19	190	↓		
1300						↓		
1400						↓		
1500	185	-	35	27	48	↓	F	
1600	0	-	35	30	53	↓	↓	
1700	0	-	45	26	53	↓	↓	
1800	0	-	35	26	53	↓	↓	
1900	0	-	45	34	60	↓	↓	
2000	0	-	55	36	61	↓	↓	
2100	0	-	55	33	58	↓	↓	
2200	0	-	45	30	58	↓	↓	
2300	0	-	25	-	9	↓	↓	
2400	0	-	35	25	53	↓	F	

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: F = Frozen Sample Line
(does not apply to ERT) L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/6/76

Trailer Temperature: 68°
Sample Moisture: .57

Barometric Pressure: 30.49
Ambient Temperature: 24°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	3	-	45	24	54	13-14%	F	
0200	3	-	35	21	53			
0300	19	-	35	22	58			
0400	8	-	45	18	60			
0500	9	-	45	22	57			
0600	29	-	55	26	68			
0700	30	14	45	30	70			
0800	34	23	62	37	76			
0900	37	8	55	38	76			
1000	36	14	55	42	79			
1100	62	2	-	41	75			
1200								
1300						10%	F	
1400	57		34	46	45			
1500	54	77	34	46	44			
1600	63	69	34	53	51			
1700	91	104	54	94	93			
1800	70	68		47	45			
1900	73	71		53	53			
2000	74	73		55	54			
2100	75	72		53	51			
2200	64	62		45	41			
2300	66	61	34	42	46			
2400	66	58	34	42	43			

Note: Routine calibration times are underlined.

Duct Flow (acfm): 123.229
Duct Moisture: 9.3

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/7/76 Trailer Temperature: 71° Barometric Pressure: 30.10
Sample Moisture: - Ambient Temperature: 29°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	69	61	34	45	49	No Ink		
0200	63	56	Flame Out	40	45	↓		
0300	66	59	↓	43	51	↓		
0400	66	52	↓	35	43	↓		
0500	68	49	↓	30	38	↓		
0600	70	48	↓	30	38	↓		
0700	72	47	↓	30	40	↓		
0800	68	45	↓	28	35	↓		
0900	60	43	↓	26	31	↓		
1000	36	45	↓	27	32	↓		
1100	42	40	↓	23	26	↓		
1200			↓			↓		
1300			↓			↓		
1400	72	86	↓	40	27	10%		
1500	73	80	↓	36	26	↓		
1600	81	95	↓	51	45	↓		
1700	73	91	↓	35	31	↓		
1800	78	85	↓	38	37	↓		
1900	86	99	↓	42	41	↓		
2000	70	76	↓	28	28	↓		
2100	75	77	↓	31	29	↓		
2200	81	87	↓	40	36	↓		
2300	80	85	↓	38	36	↓		
2400	86	79	↓	30	30	↓		

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/8/76

Trailer Temperature: 76°
Sample Moisture: .72

Barometric Pressure: 29.81
Ambient Temperature: 36°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	79	82	Flame Out	36	38	Jammed		
0200	81	79	↓	30	32	↓		
0300	83	84		35	37			
0400	65	68		20	19			
0500	63	76		29	28			
0600	66	78		30	30			
0700	73	101		53	58			
0800	75	104		57	65			
0900	83	113		62	72			
1000	102	111		58	66			
1100	658	128		77	86			
1200	649	123		68	77			
1300			↓					
1400						↓		
1500	687	89	49	53	63	7%		
1600	725	71	29	39	49	6		
1700	700	51	19	17	25	3		
1800	722	54	Flame Out	25	32	5		
1900	736	66	↓	43	45	7		
2000	742	86		57	66	9		
2100	750	99		84	79	↓		
2200	725	113		107	105			
2300	688	129		109	105			
2400	735	125	↓	109	108	↓		

Note: Routine calibration times are underlined.

Duct Flow (acfm): 122,793
Duct Moisture: 5.8

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/9/76

Trailer Temperature: 64
Sample Moisture: -

Barometric Pressure: 30.22
Ambient Temperature: 18°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	733	110	Flame Out	95	95	9%		
0200	738	112	↓	101	98	↓		
0300	750	116	↓	114	111	↓	I	
0400	757	50	↓	6	7	↓	↓	
0500	768	42	↓	3	8	↓	↓	
0600	749	40	↓	4	6	↓	↓	
0700	765	38	↓	3	5	↓	↓	
0800	794	37	↓	3	6	0%	↓	
0900	735	37	↓	2	7	↓	↓	
1000	706	37	↓	2	7	↓	↓	
1100	666	38	↓	8	8	↓	↓	
1200	676	39	↓	8	10	↓	↓	
1300			↓			7-8%	↓	
1400			↓			↓	I	
1500	121	107	↓	85	79	↓		
1600	130	118	↓	100	98	↓		
1700	120	120	↓	98	94	↓		
1800	112	116	↓	92	87	↓		
1900	108	113	↓	87	85	↓		
2000	110	116	↓	87	84	↓		
2100	116	117	↓	87	84	↓		
2200	111	113	↓	82	81	↓		
2300	109	109	↓	80	81	↓		
2400	115	112	↓	80	84	↓		

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/10/76

Trailer Temperature: -
Sample Moisture: -

Barometric Pressure: 30.46
Ambient Temperature: 20°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	120	111	Flame Out	80	84	7-8%		
0200	118	110		80	83			
0300	112	106		73	78			
0400	113	105		72	77			
0500	117	105		69	78			
0600	114	101		64	74			
0700	118	101		63	74			
0800	115	101		64	71			
0900	114	99		61	72			
1000	104	90		49	63		F	
1100	133	103		44	74			
1200	117	96		18	62			
1300	106	87		21	51			
1400	119	90		46	57			
1500	122	84		29	51			
1600	115	81		2	45			
1700	116	88		34	51			
1800	110	82		38	47	0%		
1900	108	59		-	11			
2000	108	39		-	-			
2100	104	35		-	-			
2200	101	35		-	-			
2300	84	34		-	-			
2400	79	33		-	-		F	

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/11/76

Trailer Temperature: 68°
Sample Moisture: -

Barometric Pressure: 30.17
Ambient Temperature: 30°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	78	33	Flame Out	-	-	0%	F	
0200	82	33		-	-			
0300	87	33		-	-			
0400	87	34		-	-			
0500	83	34		-	-			
0600	92	34		-	1			
0700	92	35		-	1			
0800	91	34		-	-			
0900	90	34		-	-			
1000	95	34		-	-			
1100	103	34		-	-			
1200						6-7%		
1300							F	
1400	105	72		58	48			
1500	112	81		71	61			
1600	78	75		61	53			
1700	75	73		57	46			
1800	92	73		58	47			
1900	99	77		63	51			
2000	92	72		58	46			
2100	88	71		58	45			
2200	93	75		63	51			
2300	92	78		66	56			
2400	93	79		66	57			

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/12/76

Trailer Temperature: 75°
Sample Moisture: .83

Barometric Pressure: 30.07
Ambient Temperature: 30°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	102	84	Flame Out	70	61	6-7%		
0200	105	90	↓	77	68	↓		
0300	103	91		77	68			
0400	110	90		74	66			
0500	106	95		76	67			
0600	98	87		68	58			
0700	92	81		62	52			
0800	92	82		63	52			
0900	101	92		73	66			
1000	113	99		83	72			
1100	112	98		24	68			
1200	111	94		75	64			
1300								
1400							L	
1500	71	77		51	46		↓	
1600	90	74		51	49			
1700	81	68		44	44			
1800	78	66		44	43	6%		
1900	82	60		39	34	6%		
2000	80	58		38	32	5%		
2100	77	53		34	28	↓		
2200	78	59		39	32			
2300	69	53		32	27		↓	
2400	77	56	↓	35	31	↓	L	

Note: Routine calibration times are underlined.

Duct Flow (acfm): 120,145
Duct Moisture: 7.4

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/13/76

Trailer Temperature: 77°
Sample Moisture: .5

Barometric Pressure: 30.09
Ambient Temperature: 36°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	76	54	Flame Out	34	29	5%	L	
0200	74	55		35	30			
0300	74	55		33	28			
0400	74	55		33	27			
0500	74	59		34	26			
0600	76	57		35	32			
0700	74	59		35	32			
0800	77	58		34	30			
0900	70	62		37	32			
1000	67	61		35	34			
1100								
1200						10-11%	L	
1300	96	81		95	93			
1400	66	84		97	98			
1500	99	90		101	101			
1600	98	92		99	98			
1700	98	95		104	104			
1800	102	99		104	108			
1900	103	105		110	114			
2000	88	109		110	117			
2100	36	110		110	118			
2200	82	139		142	153			
2300	120	151		148	158			
2400	61	119		113	121			

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/14/76 Trailer Temperature: 80° Barometric Pressure: 29.89
Sample Moisture: .57 Ambient Temperature: 13°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	43	122	Flame Out	115	121	10-11%		
0200	42	116	↓	104	111	↓		
0300	0	108		97	104			
0400	34	127		121	129			
0500	101	132		124	129			
0600	100	131		122	126			
0700	96	128		114	116			
0800	92	127		119	125			
0900	112	167		150	154			
1000	110	162		141	150			
1100	114	168		142	151	13-14%		
1200								
1300	101	60	↓	101	98			
1400	97	81	60	112	107			
1500	96	98	68	128	121			
1600	81	85	58	112	108			
1700	82	79	77	108	103			
1800	80	73	67	106	97			
1900	81	75	58	107	97			
2000	85	75	67	108	96			
2100	78	70	58	103	91			
2200	77	66	58	98	85		L	
2300	76	64	58	99	83		L	
2400	74	62	0	96	81	↓	L	

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/15/76

Trailer Temperature: 70°
Sample Moisture: 5.8

Barometric Pressure: 30.20
Ambient Temperature: 32°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	65	52	0	84	65	13-14%	L	
0200	60	47	28	82	63			
0300	76	55	48	94	72			
0400	73	51	48	92	69			
0500	69	42	48	88	69			
0600	67	39	48	88	71	No Ink		
0700	66	33	48	86	69			
0800	63	30	39	78	62			
0900	58	28	29	77	59			
1000	51	25	29	75	53			
1100								
1200								
1300						12-13%	L	
1400	48	33	27	51	45			
1500	45	31	27	48	44			
1600	50	35		51	50			
1700	55	36		51	53			
1800	59	39		51	55			
1900	65	38		51	55			
2000	67	39		51	55			
2100	40	44		54	60			
2200	12	44		53	59			
2300	62	53		64	65			
2400	69	53		64	65			

Note: Routine calibration times are underlined.

Duct Flow(acfm): 121,734
Duct Moisture: 9.1

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/16/76

Trailer Temperature: 72°
Sample Moisture: .68

Barometric Pressure: 29.90
Ambient Temperature: 34°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	68	51	Flame Out	62	63	12		
0200	67	48		58	57	12		
0300	64	36		40	38	9		
0400	72	45		57	58	10		
0500	69	40		49	50	9	L	
0600	68	24		26	28	5	↓	
0700	71	7		7	8	2		
0800	37	3		5	5	2		
0900	17	2		6	7	2		
1000	46	-		2	1	2		
1100	32	-		110		13-14%	L	
1200								
1300	47	78		76	69			
1400	28	79		76	75			
1500	54	83		78	78			
1600	51	80		73	75			
1700	42	79		72	75			
1800	42	78		69	73			
1900	29	80		70	77			
2000	66	87		76	82			
2100	76	92		77	87			
2200	73	86		70	81			
2300	56	80		65	76			
2400	16	76		60	70			

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/17/76 Trailer Temperature: 80° Barometric Pressure: 29.83
Sample Moisture: .80 Ambient Temperature: 24°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	66	85	Flame Out	71	83	13-14%		
0200	76	91		74	89			
0300	71	95		75	91			
0400	62	88		65	81			
0500	58	85		62	77			
0600	49	75		55	67			
0700	47	69		51	62			
0800	46	48		53	61			
0900	44	66		49	56			
1000	46	67		51	58			
1100							L	
1200	52	46		52	44	9%		
1300	47	35		53	42			
1400	45	34		50	39			
1500	38	33		49	37			
1600	49	33		55	42			
1700	50	34		57	43			
1800	50	35		56	40			
1900	46	35		54	35			
2000	49	36		52	30			
2100	43	37		53	32			
2200	387	37		55	33			
2300	1346	37		54	34			
2400	158	35		56	38		L	

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: F = Frozen Sample Line
(does not apply to ERT) L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/18/76

Trailer Temperature: -
Sample Moisture: -

Barometric Pressure: 30.32
Ambient Temperature: 14°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	701	35	Flame Out	53	38	9%	L	
0200	1376	35	↓	56	43	↓	↓	
0300	1348	36		51	39			
0400	402	38		52	41			
0500	1075	42		52	41			
0600	41	46		48	38			
0700	61	51		46	38	↓		
0800	795	56		44	37	7%		
0900	285	54		36	30	6%		
1000	35	57		43	36	9%		
1100	35	56		43	34	9%	↓	
1200	35	49		21	9	0%	L,F	
1300	30	43		20	8	↓	↓	
1400	32	40		20	7			
1500	31	37		20	3			
1600	34	35		20	2			
1700	34	35		20	4			
1800	38	36		20	5			
1900	38	36		20	5			
2000	44	36		20	4			
2100	54	37		20	6			
2200	47	38		20	7			
2300	44	38		20	6		↓	
2400	41	38	↓	20	6	↓	L,F	

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: F = Frozen Sample Line
(does not apply to ERT) L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/19/76 Trailer Temperature: 65° Barometric Pressure: 30.58
Sample Moisture: - Ambient Temperature: 17°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	45	38	Flame Out	20	8	0%	L,F	
0200	39	44		32	27			
0300	44	47		27	18			
0400	42	41		20	8			
0500	35	40		20	9			
0600	36	40		20	9			
0700	35	41		20	11			
0800	37	42		20	11			
0900	24	42		20	7			
1000	18	41		22	9			
1100	33	42		21	7	-		
1200	44	39		20	3	-		
1300						-		
1400						-		1,2
1500	41	42	7			3		
1600	26	11	0	26		2		
1700	34	13	0	26	4	3		
1800	27	10	0	26	2	3		
1900	24	8	0	26	0	3		
2000	27	8	5	26	-	0		
2100	19	7	10	26	-	0		
2200	21	6	10	26	-	0		
2300	26	7	10	26	0	0		
2400	25	7	10	26	1	0	L,F	

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/20/76

Trailer Temperature: 60°
Sample Moisture: .4

Barometric Pressure: 30.25
Ambient Temperature: 20°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	28	7	10	26	3	0	L,F	1,2
0200	35	8	10	26	4	0	↓	↓
0300	31	8	10	26	3	0	↓	↓
0400	34	9	0	26	6	3	↓	↓
0500	333	103	20	210	215	3	↓	↓
0600	243	53	10	85	82	3	↓	↓
0700	61	15	Flame Out	26	4	0	↓	↓
0800	75	17	↓	30	23	0	↓	↓
0900	35	15	↓	26	3	0	↓	↓
1000	72	11	↓	26	4	0	↓	↓
1100	61	11	↓	26	5	0	↓	↓
1200	100	10	↓	189	↓	-	L,F	↓
1300	↓	↓	↓	↓	↓	7	F	↓
1400	↓	↓	↓	↓	↓	↓	F	↓
1500	75	72	↓	45	40	↓	↓	↓
1600	48	53	↓	38	29	↓	↓	↓
1700	18	51	↓	40	30	↓	↓	↓
1800	50	50	↓	40	32	↓	↓	↓
1900	50	53	↓	43	35	↓	↓	↓
2000	58	60	↓	50	44	↓	↓	↓
2100	74	58	↓	47	40	↓	↓	↓
2200	69	55	↓	43	36	↓	L	↓
2300	57	43	↓	32	23	↓	L	↓
2400	55	40	↓	32	20	↓	L	↓

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: F = Frozen Sample Line
(does not apply to ERT) L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/21/76

Trailer Temperature: 70°
Sample Moisture: .46

Barometric Pressure: 29.84
Ambient Temperature: 30°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	57	39		32	20	7	L	
0200	55	37		32	18			
0300	42	36		32	16			
0400	35	36		32	17			
0500	34	36		32	19			
0600	52	36		32	19			
0700	42	35		32	19			
0800	37	35		32	17			
0900	22	35		32	15			
1000	24	33		32	12			
1100	24	33		32	12			
1200								
1300							L	
1400								
1500	55	39	22	32	28	13-14%		
1600	55	42	30	39	30			
1700	54	42	23	36	29			
1800	47	43	23	33	28			
1900	53	43	23	30	26			
2000	58	44	30	31	26			
2100	51	44	25	31	26			
2200	53	44	32	31	25			
2300	52	44	23	32	26			
2400	51	42	23	31	25			

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/22/76

Trailer Temperature: 68°
Sample Moisture: -

Barometric Pressure: 29.75
Ambient Temperature: 21°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	50	42	23	31	28	13-14%		
0200	43	43	23	30	28	↓		
0300	43	44	23	30	28	↓		
0400	44	43	24	29	26	↓		
0500	51	42	24	29	27	↓		
0600	47	44	24	31	30	↓		
0700	38	42	24	27	26	↓		
0800	36	41	24	26	25	↓		
0900	36	40	23	25	24	↓		
1000	37	41	23	26	25	↓		
1100	41	42	24	27	24	-		
1200						13-14%		
1300						↓		
1400	24	111	42	116	85	↓		
1500	55	94	72	106	95	↓		
1600	48	92	62	91	80	↓		
1700	44	87	62	85	75	↓		
1800	35	79	62	85	74	↓		
1900	40	68	62	83	72	↓		
2000	39	63	57	79	67	↓		
2100	64	61	57	80	69	↓		
2200	44	56	57	78	66	↓		
2300	774	53	57	77	68	↓		
2400	792	51	52	76	69	↓		

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/23/76

Trailer Temperature: -
Sample Moisture: -

Barometric Pressure: 30.01
Ambient Temperature: 13°

Hour Ending	ERT	Ecolyzer	Beckman 6800	Beckman NDIR	Horiba NDIR	MSA CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0100	18	49	52	78	73	13-14%		
0200	339	45	52	47	69	↓		
0300	773	45	46	74	67			
0400	561	51	52	79	72			
0500	579	57	52	75	68			
0600	1096	54	47	71	66			
0700	67	40	47	61	60			
0800	237	37	42	61	60			
0900	77	36	42	61	62			
1000	75	37	47	64	65			
1100	92	37	47	67	68			
1200	108	37	48	67	67			
1300	108	37	53	69	69			
1400	128	42	72	88	88			
1500	110	34	53	72	68			
1600	67	38	62	81	95			
1700								
1800								
1900								
2000								
2100								
2200								
2300								
2400								

Note: Routine calibration times are underlined.

Duct Flow (acfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to ERT)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
D = #2 Boiler Flow Diverted From Sample Duct

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-600/2-77-063		

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

The performance characteristics of five commercially available continuous carbon monoxide monitors were evaluated in a two part program consisting of laboratory and field phases. The laboratory phase involved testing each instrument for response characteristics, precision, noise, response times, drifts, variations due to temperature and pressure, and CO_2 and H_2O interferences. The field evaluation phase involved the operation of the monitors on the outlet duct of a carbon monoxide boiler at a petroleum refinery. Data generated in both phases of the program were used as the basis for recommending minimum performance specifications for continuous carbon monoxide monitors at petroleum refineries.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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