

APPENDIX E-16
CEMS RATA Protocol



2011 CEMS Performance Evaluation Test Plan

**To be Conducted for TAPI Puerto Rico, Inc.
at their Facility Located in Guayama, Puerto Rico**

*Protocol No. 3436
February 17, 2011*

Table of Contents

PROJECT OVERVIEW	2
<i>General</i>	2
<i>Methodology</i>	2
Calibration Drift (CD) Test	2
Calibration Error (CE) Test	2
Interference Response Time Methodology	3
RATA Methodology.....	3
<i>RATA Parameters</i>	4
TEST SCHEDULE	5
TEST PROCEDURES	6
<i>Calibration Drift (CD) Test</i>	6
<i>Calibration Error (CE) Test</i>	6
<i>Interference Response Time (RT) Test</i>	7
<i>RATA Method Listing</i>	8
<i>RATA Method Descriptions</i>	8
EPA Methods 3A and 10	8
DESCRIPTION OF INSTALLATION	11
<i>General Description</i>	11
QUALITY ASSURANCE	13
<i>Internal Quality Assurance</i>	13
<i>External Quality Assurance</i>	13
APPENDIX	
Figures	
EPA Approval Letter	
Sample Calculations	
Example Reference Method Data and Process Data	
Actual Calibration Gas Certification Sheets	
Example Data Sheets	
Analyzer Manufacturers Calibration Procedures and Interference Data (Manuals)	

Project Overview

General

Airtech Environmental Services Inc. (Airtech) has been contracted by TAPI Puerto Rico, Inc. (TAPI) to perform an audit of a Continuous Emission Monitoring System (CEMS). The CEMS is used to monitor emissions from the common stack of two Trane liquid incinerators. The evaluation is being performed to satisfy the requirements of 40 CFR Part 63, Subpart EEE and 40 CFR Part 60 Appendix B. The specific objectives of the evaluation are as follows:

- Perform a Calibration Drift (CD) test on the CEMS
- Perform a Calibration Error (CE) test on the CEMS
- Determine the interference Response Time (RT) for each analyzer included in the CEMS
- Perform the annual Relative Accuracy Test Audit (RATA) on the CEMS

Testing will be performed by Airtech Environmental Services Inc. Coordinating the field portion of the test program will be:

Samuel Laguna TAPI Puerto Rico, Inc. P.O. Box 10010 Guayama, PR 00784 Phone: (787) 507-1769 E-mail: Samuel.Laguna@tevausa.com	Patrick Clark, P.E. Airtech Environmental 5776 Lamar St. Arvada, CO 80002 Phone: (303) 670-0530 E-mail: pclark@airtechenv.com
---	---

Methodology

All testing will take place during the seven (7) day calibration drift (CD) period.

Calibration Drift (CD) Test

Calibration data will be collected from the CEMS on each of seven (7) consecutive days. The calibration results will be compared to the actual concentration in the calibration cylinder. The measured value for both the zero and upscale measurement points must not differ from the actual value by more than three (3) percent of the span value for the carbon monoxide (CO) monitor and 0.5 percent of the actual gas value for the oxygen (O₂) monitor. Plant personnel will calibrate and collect the CD data for submittal to Airtech. Airtech will calculate and include the CD data in the final report for the CEMS evaluation.

Calibration Error (CE) Test

A CE test will be performed on the CEMS by measuring the response to EPA Protocol gases at three (3) different concentrations per the requirements found in Performance

Specification 4B, Section 7.1. The gases will be introduced to the CEMS as close to the probe tip as possible. The CEMS will be challenged three non-consecutive times at each concentration and the CEMS response recorded. The mean difference between the CEMS and calibration gas values must be no greater than five (5) percent of the span value for the carbon monoxide (CO) monitor and 0.5 percent of the actual gas value for the oxygen (O₂) monitor.

Interference Response Time (RT) Methodology

The RT test of each CEMS analyzer (both O₂ and CO) will be conducted per the requirements found in Performance Specification 4A, Section 8.3.1. The test will be performed by introducing a zero gas into the CEMS. Once the system output has stabilized (no change greater than one percent of full scale for 30 seconds), an upscale gas will be introduced into the CEMS. The upscale response time is the time required for the output to reach 95 percent of the final stable value. Once a stable value is established for the upscale gas, the zero gas is re-introduced. The downscale response time is the time required for the instrument to reach a stable value. This procedure is repeated three (3) times. The greater of the average upscale response time and downscale response time is the response time of the CEMS. The response time for each monitor in the system must not exceed two (2) minutes.

RATA Methodology

The RATA will be performed on the oxygen (O₂) and carbon monoxide (CO) analyzers used to monitor emissions from the common exhaust stack of the incinerators. The Relative Accuracy (RA) of the CEMS will be determined by comparing the results of reference method (RM) tests to the results of the installed CEMS. EPA Methods 3A and 10 will be used to determine the concentration of O₂ and CO at the test location. Results will be expressed in units of parts per million CO corrected to 7% O₂ (ppm at 7% O₂) on a dry basis and percent O₂ on a dry basis.

It should be noted that Airtech requested and received approval from EPA regarding the use of Methods 3A and 10 for conducting the RATA. In addition, Airtech has requested clarification from EPA that Method 4 does not have to be conducted when both the CEMS and the RM are on a dry basis. A copy of this letter, which grants both requests, can be found in the Appendix of this protocol.

Nine (9) to twelve (12) test runs will be performed with each test run lasting 21 minutes. Each test run will consist of a three (3) point stack traverse with traverse points sampled for seven (7) minutes each. The traverse points will be located at 16.7%, 50.0% and 83.3% of the inside diameter of the stack location. It should be noted that a cyclonic flow check is not required for Method 3A and 10 sampling.

The RA of the O₂ monitor must be no greater than 1.0 percent absolute difference between the average RM result and the average CEMS result. The relative accuracy of the CO monitor must be no greater than 10 percent relative to the average RM value, five (5) percent relative to the applicable standard or within five (5) ppm_{dv} when the RA is

calculated using the absolute average difference between the RM and CEMS plus the 2.5 percent confidence coefficient.

RATA Parameters

The following parameters will be determined at the exhaust of the incinerator stack:

- oxygen concentration
- carbon monoxide concentration

Test Schedule

Testing has been tentatively scheduled for December of 2011.

Day	Location	Activity	Test Method	No. of Runs
1	Guayama, Puerto Rico	Mobilize to job site		
2	Incinerator Stack CEMS	Set up test equipment Perform response time test and calibration error test		
3	Incinerator Stack	Perform RATA	EPA Methods 3A and 10	9-12 (21 minutes each)
4		Demobilize from job site		

Note: RT, CE, and RATA will be conducted during the 7-day drift test period.

Test Procedures

Calibration Drift (CD) Test

The CD test will be conducted while the facility is operating under normal conditions (50 percent of normal load or greater). The CD test will be conducted by determining the monitor response to the injection of zero-level and high-level calibration gas values as outlined in the table below:

Calibration Point	CO Low Range	CO High Range	Oxygen
Low	0-40 ppm	0-600 ppm	0-5 %
High	100-200 ppm	1,500-3,000 ppm	12.5-25 %

The readings will be repeated every 24 hours for seven consecutive days. During this period, no unscheduled maintenance or repairs will take place. If the incinerator is not operated during the test period, the onset and duration of the downtime will be recorded and the CD test will be continued when the unit resumes operation.

The specific procedures for conducting the CD test are as follows: The CEMS test operator will obtain the gas standard concentrations (zero and high level) from the gas cylinders, record the concentrations into the CEMS Data Acquisition System (DAS), and confirm that the concentrations are within the ranges described above for conducting the CD test.

The zero and high level span calibration gases will be injected at the sample probe, and the monitor responses to the gases will be recorded by the plant DAS. If automatic adjustments are made by the CEMS, the CEMS responses will be recorded prior to making any automatic adjustments. The difference between the monitor response and the calibration gas value will be the CD test result, which is recorded by the plant DAS. Once the reading has been recorded, the analyzer may be adjusted if necessary. The measured value for both the zero and upscale measurement points must differ from the actual value by no greater than three (3) percent of the span value for the CO monitor and 0.5 percent for the O₂ monitor on each day. No adjustments will be made to the CEMS during the CD test period. If adjustments are required, the CD period will be extended.

Calibration Error (CE) Test

The CE test will be conducted while the system is operating under normal conditions during the seven day CD test period. The CE test will be conducted by determining the monitor response to the injection of zero, mid, and high-level calibration gases at the sample probe. The concentrations of the gases are summarized in the table found on the following page:

Calibration Point	CO Low Range	CO High Range	Oxygen
1	0-40 ppm	0-600 ppm	0-2 %
2	60-80 ppm	900-1,200 ppm	8-10 %
3	140-160 ppm	2,100-2,400 ppm	14-16 %

During the CE test, the CEMS test operator will obtain the gas standard concentrations from the gas cylinders, record the concentration values on the data sheet (see example data sheet in Appendix), and confirm that the concentrations are within the appropriate ranges.

The low, mid, and high-level calibration gases will be injected non-consecutively at each of the three measurement points. The monitor responses to the gases will be recorded on the data sheet. The difference between the monitor response and the calibration gas value at each level will be calculated and recorded on the data sheet. After completing three runs each of the low, mid, and high-level span ranges, the mean, of the absolute difference, of the readings at the low, mid, and high-level gases will be calculated and entered on the data sheet. The CE result will be presented as a percent of span, which is calculated by dividing the mean difference at each level by the appropriate monitor span. The mean difference between the CEMS and calibration gas values must be no greater than five (5) percent of the span value for the carbon monoxide (CO) monitor and 0.5 percent for the oxygen (O₂) monitor.

Interference Response Time (RT) Test

The RT test of each CEMS analyzer (both O₂ and CO) will be conducted during the CD test period. The system response time will be tested at zero and high-level calibration gas values. The entire CEM system will be checked including the sample extraction, transport, and conditioning apparatus, and the gas analysis and data recording systems.

A zero-level calibration gas will be introduced into the system as close to the sample probe as practical. Once the system has stabilized (no change greater than one percent of full scale for 30 seconds), the high-level calibration gas will be introduced at the same point. The upscale response time is the time required for the output to reach 95 percent of the final stable value.

Once a stable value is established for the upscale gas, the zero gas is re-introduced. The downscale response time is the time required for the instrument to reach a stable value. This procedure is repeated three (3) times. The greater of the average upscale response time and downscale response time is the response time of the CEMS. The response time for each monitor in the system must not exceed two (2) minutes.

RATA Method Listing

The test methods and performance specifications found in the 40 CFR Part 60, Appendix A and B will be referenced during the test program. The following individual methods and Performance Specifications will be referenced:

- Method 3A Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrumental Analyzer Procedure)
- Method 10 Determination of Carbon Monoxide Emissions from Stationary Sources
- PS 4B Specifications and Test Procedures for Carbon Monoxide and Oxygen Continuous Monitoring Systems in Stationary Sources

RATA Method Descriptions

EPA Methods 3A and 10

The oxygen and carbon monoxide concentrations at the test location will be determined using EPA Methods 3A and 10. A sample of the gas stream will be continuously withdrawn from the test location and analyzed using a temporary Reference Method (RM) monitoring system. A diagram of the RM sampling system is shown in Figure 1 of the Appendix.

The sample gas will be withdrawn from the test location at a constant rate through an in-situ 0.3 micron stainless steel sintered frit (optional, used if particulate loading is high), a stainless steel probe, a heated filter (optional, used if particulate loading is high) and a Teflon sample line. The sample line will be operated at a temperature of 250 °F to prevent the condensation of moisture. The sample gas will then pass through a water removal system. The system will consist of two separate stages designed to lower the dewpoint of the sample gas to 35 °F, thus removing the moisture. The dry gas will then be vented to the oxygen and carbon monoxide analyzers. Results from these analyzers are determined on a “dry” basis.

The analyzers that will be used for this project are listed in the following table.

Parameter	Manufacturer	Model Number	Operating Principle	Units Reported	Range to be used
Oxygen	M&C Products	PMA22	Paramagnetic	%	0-14.04
Carbon Monoxide	Thermo Environmental	48	Infrared, Gas Filter Correlation	ppm	0-54.67

Data will be collected every second and averaged into 60 second averages. DASYlab data acquisition software and a Measurement Computing USB-1608FS analog to digital converter will be used. Data will be provided in spreadsheet format.

The RM sampling system will be prepared according to Figure 1 of the Appendix. Prior to sampling, a calibration error test will be performed on each analyzer using EPA Protocol 1 calibration gases (see certification sheets in the Appendix). The calibration gases for each constituent will be introduced directly into each analyzer sequentially (zero, mid and high range gases). In addition to a zero gas, the high range gases to be used will be 14.04 % for O₂ and 54.67 ppm for CO and the mid range gases will be 7.005 % for O₂ and 27.82 ppm for CO. The measured responses will be recorded by the data acquisition system and also recorded on a data sheet (see example datasheet in Appendix). The measured values for each calibration gas will then be compared to the calibration gas values and the differences must be +/- two (2) percent of the calibration span value for the zero, mid, and high level calibration gases.

A sample system bias check will then be performed by introducing the O₂ and CO mid level and zero calibration gases, sequentially, into the sampling system at the base of the probe. The gases will be drawn through the entire sampling system. Once a stable value has been achieved, the measured responses will be recorded by the data acquisition system and also recorded on a data sheet (see example datasheet in Appendix). The sampling system bias must be +/- five (5) percent of the calibration span value for the zero and upscale calibration gas. During the sample system bias check, the system response time will be determined by measuring the time required for each analyzer to reach 95 percent of the mid-range calibration gas value and also the time required to reach within 0.5% O₂ and 0.5 ppm CO or 5.0 percent of the up-scale gas concentration if a zero gas is used or the certified low range gas concentration if a non zero gas is used (whichever is less restrictive). The system response time is the greater of the two values. From the response time data the system bias will be calculated using Eq. 7E-2 of Method 7E of 40 CFR Part 60, Appendix A.

The sampling system probe will be placed at the first sample point and the sample system purged for at least two times the system response time. Sampling will be conducted at the three sample points shown in Figure 2 for a period of seven (7) minutes per point. The sample flow rate will be maintained within 10 percent of the sample flow rate of the bias test (as verified with a flow meter). It should be noted that a cyclonic flow check is not required for Method 3A and 10 sampling.

After each test run the post run system bias check and drift assessment will be performed on each analyzer by introducing the zero and mid-range calibration gases into the sampling system at the base of the probe. No adjustments will be made to the analyzers and the gases will be drawn through the entire sampling system. The measured responses will be recorded by the data acquisition system and also on a datasheet (see example datasheet in Appendix) in order to calculate the low level and mid level bias. The measured responses will then be compared to the values from the previous test run to determine the analyzer drift, using Eq. 7E-4 of Method 7E of 40 CFR Part 60, Appendix A. For all test runs, the analyzer drift must be less than the method requirement of three (3) percent of the span value or the run is invalid. In addition, if a run fails the post run

system bias check and drift assessment, a new calibration error test and a system bias check test will be performed prior to starting any additional runs in conformance with Method 7E, Section 8.5(2). For each test run arithmetic average of all valid O₂ and CO concentrations values will be calculated, then the average will be adjusted bias using equation Eq. 7E-5b of Method 7E of 40 CFR Part 60, Appendix A or Eq. 7E-5a (If you use non-zero gas as your low level calibration gas)

Description of Installation

General Description

TAPI Puerto Rico, Inc. (TAPI) manufactures active pharmaceutical ingredients on a facility located in Guayama, Puerto Rico. TAPI operates two liquid incinerators for the destruction of liquid hazardous waste. The incinerators are Sub-X Liquid Waste Oxidizers, vertical liquid injection systems, manufactured by the Trane Company of Conshohocken, Pennsylvania. They do not have a model number. Trane 1 was installed in 1977 and Trane 2 was installed in 1979. Both incinerators are identical and utilize a submerged quench tank, a high-energy venturi scrubber and a wet electrostatic precipitator for control of air pollution emissions. The two incinerators share a common stack. The CEMS to be evaluated will be located in the common stack of the two incinerators. It is anticipated that the flue gas moisture content will be saturated.

TAPI utilizes a CEMS to monitor the concentration of CO and O₂ on a dry basis. The CEMS includes a heated probe, heated filter, heated sample line, two (2) moisture removal systems and various particulate filters. The moisture removal system consists of four (4) separate chilled impingers designed to lower the dewpoint of the sample gas to 35 °F, thus removing the moisture. The moisture removal systems are manufactured by M&C Products. The overall CEMS was manufactured by Sick Maick and utilizes a Nexxus CEMView Data Acquisition System (DAS).

The CO and O₂ analyzer raw data (high and low range values) is transmitted via serial communication to the DAS Server, which collects and processes the data. The DAS server corrects the carbon monoxide concentration to seven percent oxygen, calculates rolling averages, and processes calibration information. The rolling average for CO is calculated using one-minute averages. The one-minute averages are calculated as the arithmetic average of the six most recent observations taken no more than 10-seconds apart. The one minute averages in the DAS are calculated in order to comply with the MACT requirements of sections 6.5, 6.5.1 and 6.5.3 of 40 CFR Part 63 *Appendix to Subpart EEE of Part 63 – Quality Assurance Procedures for Continuous Emissions Monitors Used for Hazardous Waste Combustors.*

The DAS will communicate to the Digital Control System (DCS) any non-compliance with limits that requires the activation of an alarm or interlock. If there is any parameter condition that puts the Incineration Process out of compliance, then the DAS Server will send a notification to the DCS System to perform an Automatic Waste Cut Off. A diagram of the Air Emission Control Block can be found in the figures section of the Appendix.

CEMS Specifications (MACT)

The sections below summarize the requirements outlined in 40 CFR Part 63, Subpart EEE:

Carbon Monoxide

Low Range Span: 0 to 200 ppmv
High Range Span: 0 to 3000 ppmv
Resolution: 0.5%
Calibration Drift: $\leq 3\%$ of span
Calibration Error: $\leq 5\%$ of span
Response Time: ≤ 2 minutes
Basis: Dry
Relative Accuracy: $\leq 10\%$ when the average RM value is used, 5% of the applicable emission standard, or ≤ 5 ppmv when calculated as the absolute average difference between the RM and CEMS plus the 2.5 percent confidence coefficient

Oxygen

High range Span: 0 to 25%
Resolution 0.5%
Calibration Drift: $\leq 0.5\%$ from the gas reference value
Calibration Error: $\leq 0.5\%$ from the gas reference value
Response Time ≤ 2 minutes
Basis: Dry
Relative Accuracy $\leq 1\%$

Quality Assurance

Pursuant to 40 CFR 63.8(e)(3), the CEMS performance evaluation test plan must include an internal and external quality assurance (QA) program. The internal QA program shall include, at a minimum the activities planned by routine operators and analysts to provide an assessment of CEMS performance. The external QA program shall include, at a minimum, the opportunity for on-site evaluation of instrument calibration, data validation, sample logging, and documentation of quality control data and field maintenance activities.

Internal Quality Assurance

The quality of data generated by the system will be assured by implementing internal quality control procedures. TAPI will begin implementation of the routine aspects of the CEMS quality control program immediately after system startup. The routine procedures typically include the following:

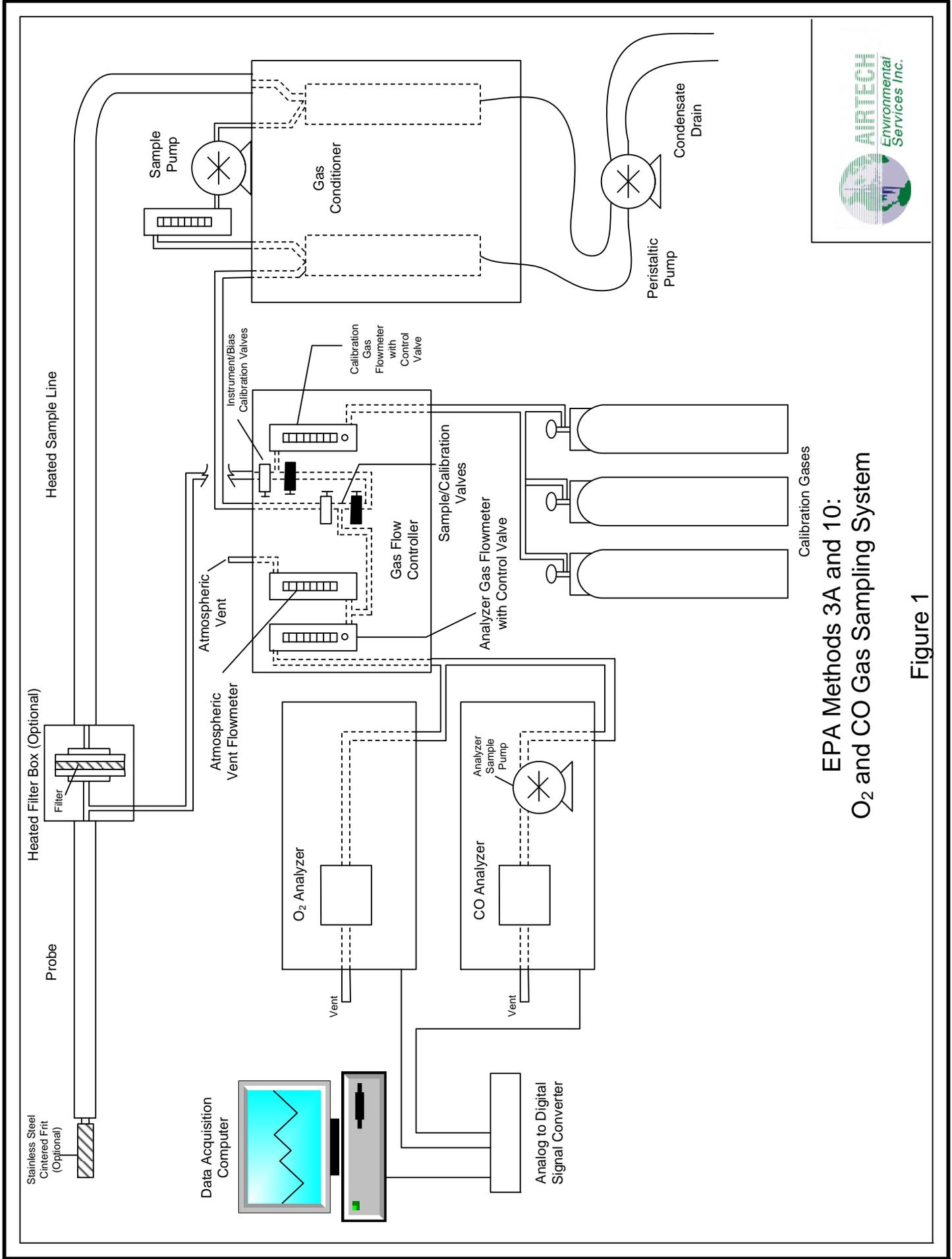
- Field verification of the CEMS instrument location, condition, and installation.
- Daily audit of the CEMS components and operating parameters. Corrective action will be taken as needed to remedy malfunctions or abnormal operating conditions.
- Daily calibration drift checks will be performed on the CEMS with the results recorded by the DAS. The results of the calibration drift check will be reviewed daily and the monitoring instruments will be adjusted for drift as appropriate.

External Quality Assurance

TAPI's QA program includes instrument calibration, data validation, sample logging, and quality control data and field maintenance activities. Documentation of compliance for all of these QA related activities will be available for onsite evaluation during the performance evaluation test. External quality assurance for the RM tests will be via the on-site Puerto Rico EQB observer.

Appendix

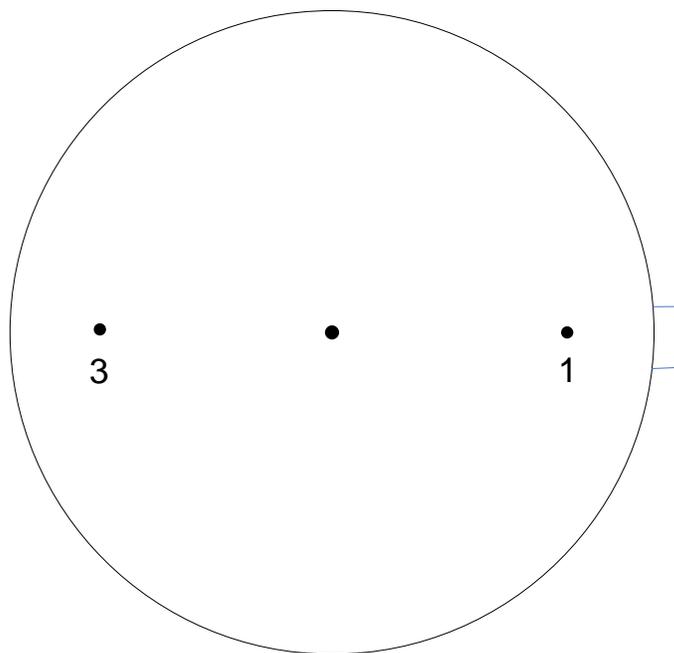
Figures



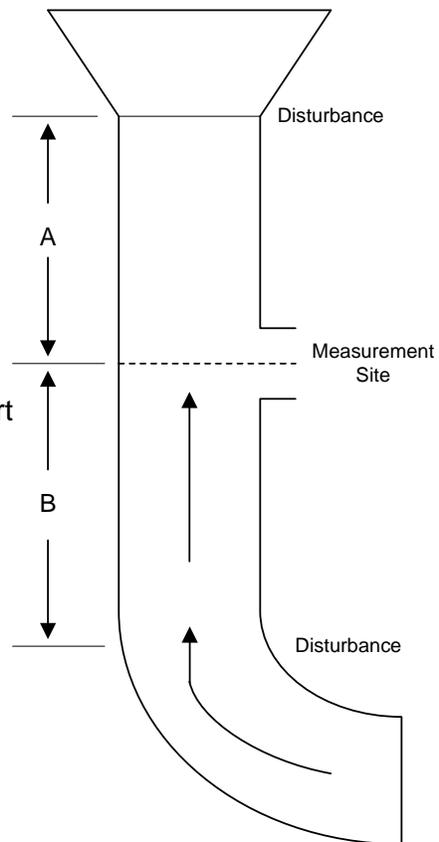
EPA Methods 3A and 10:
O₂ and CO Gas Sampling System



Figure 1



Port
1



Diameter (in.)	24.0
Port Length (in.)	6.0

Point	Distance From Wall (%)
1	4.0
2	12.0
3	20.0

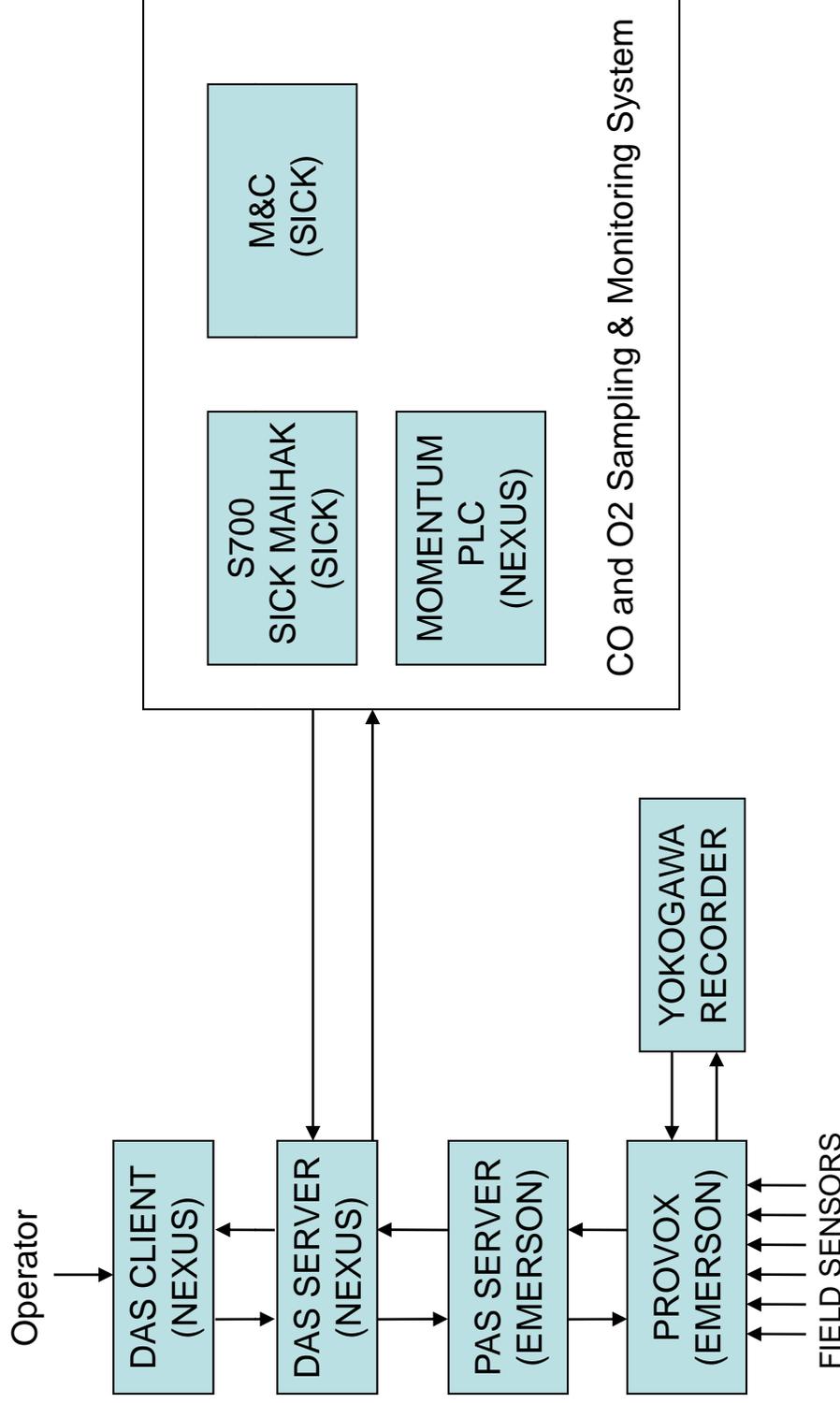
Cross Section of the Stack Test Location
TAPI Puerto Rico, Inc.

Figure 2



AIRTECH
Environmental
Services Inc.

API AIR EMISSION CONTROL DIAGRAM BLOCK



EPA Approval Letter



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

RESEARCH TRIANGLE PARK, NC 27711

MAR 04 2010

OFFICE OF
AIR QUALITY PLANNING
AND STANDARDS

Patrick Clark, P.E.
Airtech Environmental Services Inc.
601A Country Club Drive
Bensenville, IL 60106

Dear Mr. Clark:

This letter is in response to your February 9, 2010, request for approval of an alternative to the requirements to perform Method 3B and Method 4 as specified in 40 CFR Part 63, Subpart EEE (Hazardous Waste Combustor MACT).

The Hazardous Waste Combustor MACT requires Performance Specification (PS) 4B, which then references PS 4A and PS 3. In Section 8.2 of PS 3 it states, "Reference Method. Unless otherwise specified in an applicable subpart of the regulations, Method 3B or other approved alternative is the RM for O₂ or CO₂." You are requesting that Method 3A be accepted as an alternative for this application. Method 3A is an acceptable alternative for Method 3B in this case because Method 3A is more sensitive and has better accuracy and precision than Method 3B. We agree with the reasoning of your request and are approving your request to use Method 3A in lieu of Method 3B.

In Section 6.4.1 of "Appendix to Subpart EEE of Part 63--Quality Assurance Procedures for Continuous Emissions Monitors Used for Hazardous Waste Combustors," it states, "Moisture Correction. Method 4 of Appendix A, part 60 of this chapter, must be used to determine moisture content of the stack gasses." You stated that all three of the required continuous emission monitoring systems (CEMS) use moisture removal systems and read on a "dry" basis, that your reference method system uses a moisture removal system, and that both systems are therefore on a "dry" basis and thus no moisture correction is required. We agree with you that the only reason stack gas moisture needs to be determined during a RATA is in a case where one of the measurements is performed on a "wet" basis and the other measurement is on a "dry" basis. We also agree with you that during compliance monitoring with the CEMS that moisture does not have to be measured continuously because your monitor makes a "dry" measurement. We agree with the reasoning of your request and are approving your request to forego the performance of Method 4 in the "dry" configurations that you have described for either the RATA test or for compliance monitoring.

We believe that this alternative is acceptable for use at any hazardous waste combustor subject to the emission limits under 40 CFR Part 63 Subpart EEE. Therefore, we will announce on EPA's website (www.epa.gov/ttn/emc) that our approval of these alternatives are broadly applicable to all hazardous waste combustors for the purpose of meeting the requirements of Subpart EEE.

If you have any questions or concerns, please feel free to contact Dan Bivins of my staff at (919) 541-5244.

Sincerely,



Conniesue B. Oldham, Ph.D.
Measurement Technology Group

Sample Calculations

1. Analyzer Calibration Error

$$ACE = 100 \times \left(\frac{c_{dir} + c_a}{CS} \right)$$

where:

ACE	= analyzer calibration error (%)
C _{dir}	= measured concentration of calibration gas direct to analyzer (ppm or %)
C _a	= actual span gas value (ppm or %)
CS	= calibration span value (ppm or %)
100	= conversion factor (%)

2. System Bias

$$SB = 100 \times \left(\frac{c_s - c_{dir}}{CS} \right)$$

where:

SB	= system bias (%)
C _s	= measured concentration of calibration gas through the sampling system (ppm or %)
C _{dir}	= measured concentration of calibration gas direct to analyzer (ppm or %)
CS	= calibration span value (ppm or %)
100	= conversion factor (%)

3. Drift Assessment

$$D = |SB_{fin} - SB_{in}|$$

where:

D	= drift (%)
SB _{fin}	= system bias final (%)
SB _{in}	= system bias initial (%)

4. Carbon Monoxide Concentration, Corrected for Analyzer Bias

$$C_{gas} = \left(C_{avg} - \left(\frac{c_{0i} + c_{0f}}{2} \right) \right) \left(\frac{c_{MA}}{\left(\frac{c_{Mi} + c_{Mf}}{2} \right) - \left(\frac{c_{0i} + c_{0f}}{2} \right)} \right)$$

where:

- C_{gas} = average carbon monoxide concentration, corrected for analyzer bias (ppmdv)
- C_{avg} = average unadjusted carbon monoxide concentration (ppmdv)
- C_{0i} = initial system calibration bias value of the zero gas (ppmdv)
- C_{0f} = final system calibration bias value of the zero gas (ppmdv)
- C_{Mi} = initial system calibration bias value of the upscale gas (ppmdv)
- C_{Mf} = final system calibration bias value of the upscale gas (ppmdv)
- C_{MA} = actual concentration of the upscale calibration gas (ppmdv)

5. Carbon Monoxide Concentration, Corrected to 7% O₂

$$C_{@7\%O_2} = C_{gas} \times \left(\frac{20.9 - 7}{20.9 - \%O_2} \right)$$

where:

- $C_{@7\%O_2}$ = concentration of carbon monoxide, corrected to 7% O₂ (ppm)
- C_{gas} = carbon monoxide concentration, corrected for analyzer drift (ppmv)
- $\%O_2$ = concentration of oxygen (%)
- 20.9 = ambient concentration of oxygen (%)
- 7 = correction value (%)

6. Carbon Monoxide Standard Deviation

$$S_d = \left(\frac{\sum_{i=1}^n d_i^2 - \frac{\left(\sum_{i=1}^n d_i \right)^2}{n}}{(n-1)} \right)^{1/2}$$

where:

- S_d = standard deviation
- d_i = difference between the reference method result and the CEM value for a given run (ppm@7%O₂)
- i = run number
- n = number of runs used for calculations

7. Carbon Monoxide Confidence Coefficient

$$CC = \frac{(t_{0.975})(S_d)}{\sqrt{n}}$$

where:

- CC = confidence coefficient
- $t_{0.975}$ = the inverse of the student's t-distribution for the specified degrees of freedom
- S_d = standard deviation
- n = number of runs used for calculations

8. Carbon Monoxide Mean of the Differences

$$d_m = \frac{\sum_{i=1}^n d_i}{n}$$

where:

- d_m = mean of the differences
- d_i = difference between the reference method result and the CEM value for a given run (ppm)
- i = run number
- n = number of runs used for calculations

9. Carbon Monoxide Relative Accuracy, Option 1

$$RA^1 = 100 \times \frac{(|d_m| + |CC|)}{RM}$$

where:

- RA¹ = relative accuracy (%)
- RM = average reference method or the applicable standard (ppm@7% O₂)
- d_m = mean of the differences
- CC = confidence coefficient
- 100 = conversion factor (%)

10. Carbon Monoxide Relative Accuracy, Option 2

$$RA^2 = |d_m| + |CC|$$

where:

- RA² = relative accuracy using the average difference (ppm@7% O₂)
- d_m = mean of the differences
- CC = confidence coefficient

11. Oxygen Relative Accuracy

$$RA = |d_m|$$

where:

- RA = relative accuracy using the average difference (%)
- d_m = mean of the differences

Example Reference Method Data and Process Data

Date
3/31/2009

Time	CO (ppm)
Average	0.00

16:32:59	0
16:33:59	0
16:34:59	0
16:35:59	0
16:36:59	0
16:37:59	0
16:38:59	0.03
16:39:59	0.03
16:40:59	0
16:41:59	0
16:42:59	0
16:43:59	0
16:44:59	0
16:45:59	0
16:46:59	0
16:47:59	0
16:48:59	0
16:49:59	0
16:50:59	0
16:51:59	0
16:52:59	0
16:53:59	0

Multi Component Report - 1 Minute Average

API Industries Inc.
Guayama, Puerto Rico.

Report for the period from 3/31/2009 7:34:00 PM to 3/31/2009 8:16:16 PM

Device: S700

Time Zone: SA Western Standard Time

Interval: 1-min average

Time	CO ppm	CO Corrected ppm	O2 %
19:34	0	0	10.49
19:35	0	0	10.54
19:36	0	0	10.55
19:37	0	0	10.47
19:38	0	0	10.56
19:39	0	0	10.52
19:40	0	0	10.57
19:41	0	0	10.62
19:42	1	1	10.86
19:43	2	2	10.84
19:44	1	1	10.65
19:45	2	3	10.53
19:46	0	0	10.52
19:47	0	0	10.56
19:48	1	1	10.59
19:49	0	0	10.55
19:50	0	0	10.60
19:51	0	0	10.61
19:52	0	0	10.55
19:53	0	0	10.68
19:54	0	0	10.69
19:55	0	0	10.63
19:56	0	0	10.54
19:57	0	0	10.52
19:58	1	1	10.54
19:59	0	0	10.56
20:00	0	0	10.61
20:01	0	0	10.54
20:02	0	0	10.58
20:03	0	0	10.59
20:04	0	0	10.58
20:05	0	0	10.67
20:06	0	0	10.76
20:07	0	0	10.62
20:08	0	0	10.54
20:09	0	0	10.57
20:10	0	0	10.61
20:11	0	0	10.78
20:12	1	1	10.72
20:13	1	1	10.68
20:14	2	3	10.62
20:15	1	2	10.61
20:16	0	0	10.68

Multi Component Report - 1 Minute Average

API Industries Inc.
Guayama, Puerto Rico.

Max	2	3	10.86
Min	0	0	10.47
Avg	0	0	10.61

'I' - Invalid

'B' - Blowback

'O' - Out-of-Control

'W' - Caution

'H' - Shutdown

'U' - User Data

'E' - Error

'R' - Out-of-Range

'N' - Not Calibrated

'T' - AWFCO Testing

'D' - Process Down

'M' - Maintenance

'L' - Detection Threshold

'S' - Startup

'F' - Frozen FIFO

'C' - Calibration

'P' - Premeasure

'X' - Excess Emission

'Y' - Secondary Startup

'V' - Re-Validated

Actual Calibration Gas Certification Sheets

CERTIFICATE OF ANALYSIS

Grade of Product: EPA Protocol

Part Number: E03NI92E15A091C	Reference Number: 54-124163474-1
Cylinder Number: CC282014	Cylinder Volume: 145 Cu.Ft.
Laboratory: ASG - Chicago - IL	Cylinder Pressure: 2015 PSIG
Analysis Date: Jan 13, 2009	Valve Outlet: 590

Expiration Date: Jan 13, 2012

Certification performed in accordance with "EPA Traceability Protocol (Sept. 1997)" using the assay procedures listed. Analytical Methodology does not require correction for analytical interferences. This cylinder has a total analytical uncertainty as stated below with a confidence level of 95%. There are no significant impurities which affect the use of this calibration mixture. All concentrations are on a volume/volume basis unless otherwise noted.
 Do Not Use This Cylinder below 150 psig.i.e. 1 Mega Pascal

ANALYTICAL RESULTS				
Component	Requested Concentration	Actual Concentration	Protocol Method	Total Relative Uncertainty
CARBON MONOXIDE	28.00 PPM	27.82 PPM	G1	+/- 1% NIST Traceable
OXYGEN	7.000 %	7.005 %	G1	+/- 1% NIST Traceable
NITROGEN	Balance			

CALIBRATION STANDARDS				
Type	Lot ID	Cylinder No	Concentration	Expiration Date
NTRM/CO	080602	CC255431	51.26PPM CARBON MONOXIDE/	Jan 15, 2012
NTRM/O2	980512	SG9166625BAL	7.015% OXYGEN/	Jun 01, 2009

ANALYTICAL EQUIPMENT		
Instrument/Make/Model	Analytical Principle	Last Multipoint Calibration
HORIBA 510	NDIR	Jan 07, 2009
(P-1) CAI-110	Paramagnetic	Dec 07, 2008

Triad Data Available Upon Request

Notes:

 QA Approval

CERTIFICATE OF ANALYSIS

Grade of Product: EPA Protocol

Part Number: E03NI85E15A092C	Reference Number: 54-124163474-2
Cylinder Number: CC281925	Cylinder Volume: 146 Cu.Ft.
Laboratory: ASG - Chicago - IL	Cylinder Pressure: 2015 PSIG
Analysis Date: Jan 13, 2009	Valve Outlet: 590

Expiration Date: Jan 13, 2012

Certification performed in accordance with "EPA Traceability Protocol (Sept. 1997)" using the assay procedures listed. Analytical Methodology does not require correction for analytical interferences. This cylinder has a total analytical uncertainty as stated below with a confidence level of 95%. There are no significant impurities which affect the use of this calibration mixture. All concentrations are on a volume/volume basis unless otherwise noted.
 Do Not Use This Cylinder below 150 psig.i.e. 1 Mega Pascal

ANALYTICAL RESULTS				
Component	Requested Concentration	Actual Concentration	Protocol Method	Total Relative Uncertainty
CARBON MONOXIDE	55.00 PPM	54.67 PPM	G1	+/- 1% NIST Traceable
OXYGEN	14.00 %	14.04 %	G1	+/- 1% NIST Traceable
NITROGEN	Balance			

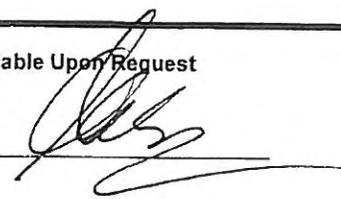
CALIBRATION STANDARDS				
Type	Lot ID	Cylinder No	Concentration	Expiration Date
NTRM/CO	5120408	CC180103	99.49PPM CARBON MONOXIDE/	Feb 02, 2009
NTRM/O2	82658	SG9168304BAL	16.04% OXYGEN/	Jan 01, 2010

ANALYTICAL EQUIPMENT		
Instrument/Make/Model	Analytical Principle	Last Multipoint Calibration
HORIBA 510	NDIR	Jan 07, 2009
(P-1) CAI-110	Paramagnetic	Dec 07, 2008

Triad Data Available Upon Request

Notes:

QA Approval



CERTIFICATE OF BATCH ANALYSIS NITROGEN - CEM-CAL ZERO

Airgas North Central
640 Kimbark Drive
Carol Stream, IL 60188
630-690-3010 FAX 630-690-6287
www.airgas.com

Part Number: NI CZ15A Reference Number: 86-105594717-3
Cylinder Analyzed: CC193251 Cylinder Volume: 142 Cubic Feet
Laboratory: NOC - Carol Stream - IL Cylinder Pressure: 2000 PSIG
Analysis Date: Aug 08, 2008 Valve Outlet: 580
Lot #: 86-105594717-3

ANALYTICAL RESULTS

Component	Requested Purity	Certified Concentration
NitrogenCEM	99.9995%	99.9995%
CARBON DIOXIDE	< 1 PPM	< 1.0 PPM
Moisture	< 1 PPM	0.09 PPM
NOx	< 0.1 PPM	< 0.1 PPM
SO2	< 0.1 PPM	< 0.1 PPM
THC	< 0.1 PPM	< 0.1 PPM
CARBON MONOXIDE	< 0.5 PPM	< 0.5 PPM
Oxygen	< 0.5 PPM	0.18 PPM

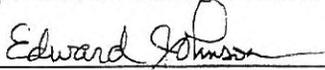
Cylinders in Batch:

CC1008894, CC12813, CC13189, CC13789, CC193251, CC195465, CC195551, CC210601, CC213436, CC222133, CC233446, CC233971, CC235049, CC235350, CC235362, CC235386, CC235400, CC247686, CC247804, CC250835, CC259444, CC259634, CC259649, CC33641, CC34981, CC75172, SG9102233, SG9113294BAL, SG9151433

Notes:

Meets Federal Register specifications Title 40 C.F.R. 72.2

Impurities verified against analytical standards traceable to NIST by weight and/or analysis.



QA Approval

Example Data Sheets

AIRTECH ENVIRONMENTAL SERVICES INC.
CEM ANALYZER I.D. Data Sheet

PROJECT NO. _____

Page		of	
------	--	----	--

Client			
Plant			
Location			
Date		Unit	
Operator/Tech			

Analyzer Type	Model	Notes

Cylinder Contents	Cylinder No.	PPM

	Equipment Description Type/Lengths	USED YES / NO	
Probe			
Filter			
Hsl			
Cold Lines			
Gas Conditioner Type			
Das. Computer			
Flow Panel			

CEM Schematic and Notes

AIRTECH ENVIRONMENTAL SERVICES INC.
Response Time Data Sheet

PROJECT NO. _____

Client	
Plant	
Date	
Unit	
Operator	
Analyzer I.D.	
Analyzer Manufacturer	
Analyzer Model Number	
Date of Most Recent Service	

<i>CEMS Diagram (if applicable)</i>

Oxygen	Trial	Date	Time	Calibration Value (%)	Upscale Response Time (sec)	Downscale Response Time (sec)
	1					
	2					
	3					
Average (sec)						

CO High	Trial	Date	Time	Calibration Value (ppm)	Upscale Response Time (sec)	Downscale Response Time (sec)
	1					
	2					
	3					
Average (sec)						

CO Low	Trial	Date	Time	Calibration Value (ppm)	Upscale Response Time (sec)	Downscale Response Time (sec)
	1					
	2					
	3					
Average (sec)						

Notes:

Table 7E-1 - Analyzer (or System) Calibration Error Data

Source Identification: _____		Analyzer ¹ or System ² calibration error data for sampling runs: _____		
Test personnel: _____		Analyzer Model No. _____		
Date: _____		Serial No. _____		
Time: _____		Calibration Span (CS): _____		
	Manufacturer Certified Cylinder Value (indicate units)	Analyzer calibration response (indicate units)	Absolute difference (indicate units)	Calibration Error (percent of calibration span)
	A	B	A-B	$\frac{A-B}{CS} \times 100$
Low-level (or zero) calibration gas	.....	.....	.....	.....
Mid-level calibration gas.....	.....	.....	.....	.....
High-level calibration gas ....	.....	.....	.....	.....

¹ Refers to data from the analyzer calibration error test of a non-dilution system.

² Refers to data from a 3-point system calibration error test of a dilution system.

Table 7E-2 - System Bias (or System Calibration Error) and Drift Data

Source Identification: _____ Run Number: _____

Test personnel: _____ Calibration Span: _____

Date: _____ Response Time: _____

Analyzer Model No. _____ Serial No. _____

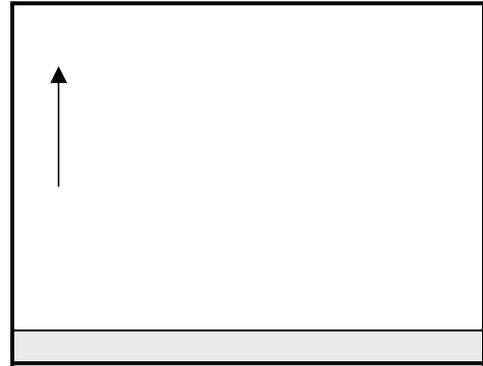
Calibration Gas Level	Initial values			Final values		
	Certified Calibration gas value (indicate units)	System Response (indicate units)	System Bias ¹ or Calibration Error ² (% of calibration span)	System response (indicate units)	System Bias ¹ or Calibration Error ² (% of calibration span)	Drift (% of calibration span)
Low-level gas
Upscale (high- or mid-) level gas

¹ Refers to the pre- and post-run system bias checks of a non-dilution system.² Refers to the pre- and post-run system calibration error checks of a dilution system.

AIRTECH ENVIRONMENTAL SERVICES INC.
 Calibration Drift Data Sheet

PROJECT NO. _____

Client	
Plant	
Date	
Operator	
Analyzer I.D.	
Analyzer Type	
Date of Most Recent Service	



Initial Settings	
Zero	
Span	

Final Settings	
Zero	
Span	

Low-Level Calibration	Day	Date	Time	Calibration Value (%)	Monitor Response (%)	Difference (%)
	0					
	1					
	2					
	3					
	4					
	5					
	6					
7						

High-Level Calibration	Day	Date	Time	Calibration Value (%)	Monitor Response (%)	Difference (%)
	0					
	1					
	2					
	3					
	4					
	5					
	6					
7						

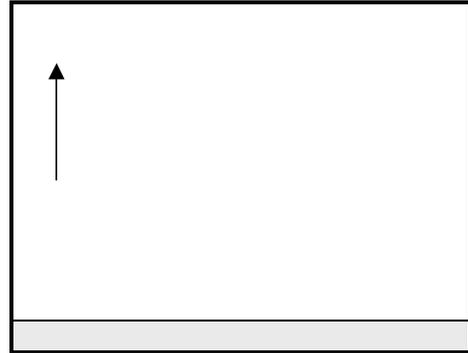
Notes:

AIRTECH ENVIRONMENTAL SERVICES INC.
Calibration Drift Data Sheet

PROJECT NO. _____

Page		of	
------	--	----	--

Client	
Plant	
Date	
Operator	
Analyzer I.D.	
Analyzer Type	
Date of Most Recent Service	



Initial Settings	
Zero	
Span	

Final Settings	
Zero	
Span	

Low-Level Calibration	Day	Date	Time	Calibration Value (ppm)	Monitor Response (ppm)	Difference (ppm)	Percent of Span (%)
	0						
	1						
	2						
	3						
	4						
	5						
	6						
7							

High-Level Calibration	Day	Date	Time	Calibration Value (ppm)	Monitor Response (ppm)	Difference (ppm)	Percent of Span (%)
	0						
	1						
	2						
	3						
	4						
	5						
	6						
7							

Notes:

AIRTECH ENVIRONMENTAL SERVICES INC.
 Calibration Error Data Sheet

PROJECT NO. _____

Page		of	
------	--	----	--

Client	
Plant	
Date	
Operator	
Analyzer I.D.	
Analyzer Type	
Date of Most Recent Service	

↑

Initial Settings	
Zero	
Span	

Final Settings	
Zero	
Span	

Low Level	Trial	Date	Time	Calibration Value (ppm)	Monitor Response (ppm)	Difference (ppm)	Percent of Span (%)
	1						
	2						
	3						

Mid Level	Trial	Date	Time	Calibration Value (ppm)	Monitor Response (ppm)	Difference (ppm)	Percent of Span (%)
	1						
	2						
	3						

High Level	Trial	Date	Time	Calibration Value (ppm)	Monitor Response (ppm)	Difference (ppm)	Percent of Span (%)
	1						
	2						
	3						

Notes:

AIRTECH ENVIRONMENTAL SERVICES INC.
 Calibration Error Data Sheet

PROJECT NO. _____

Client	
Plant	
Date	
Operator	
Analyzer I.D.	
Analyzer Type	
Date of Most Recent Service	



Initial Settings	
Zero	
Span	

Final Settings	
Zero	
Span	

Low Level	Trial	Date	Time	Calibration Value (%)	Monitor Response (%)	Difference (%)
	1					
	2					
	3					

Mid Level	Trial	Date	Time	Calibration Value (%)	Monitor Response (%)	Difference (%)
	1					
	2					
	3					

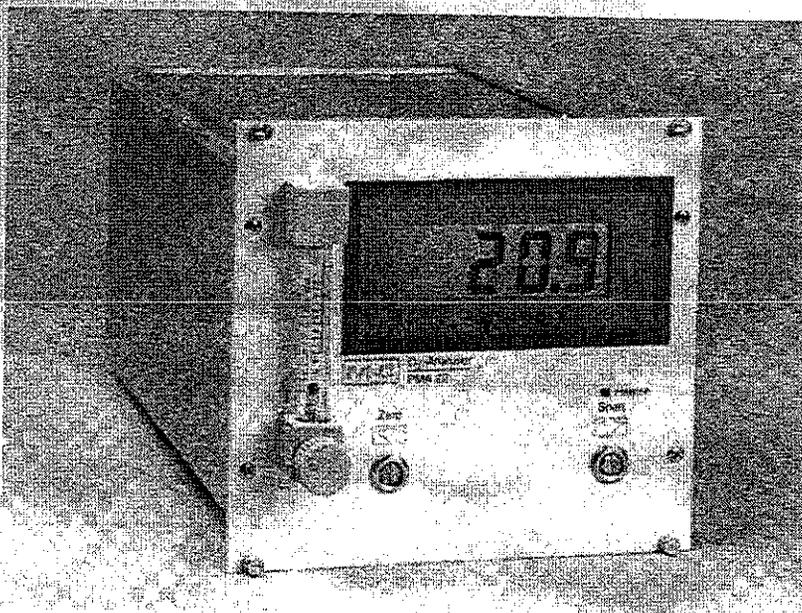
High Level	Trial	Date	Time	Calibration Value (%)	Monitor Response (%)	Difference (%)
	1					
	2					
	3					

Notes:

Analyzer Manufacturers Calibration Procedures and Interference Data (Manuals)



Oxygen Analyser Type PMA 22 INSTRUCTION MANUAL



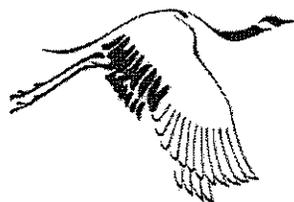
M&C Products Analysentechnik GmbH
Postfach 104224 Renhecke 79
D-40853 Ratingen-Lintorf D-40885
Deutschland



USERS' MANUAL FOR THE TYPE PMA 22 OXYGEN ANALYSER

Document Number : I M 1222 99 01

Issue Number : 3



Published by
M & C Instruments b.v.
Jan v.d. Heydenstraat 24A
2665 JA Bleiswijk
The Netherlands

Copyright © 1999 by M & C Instruments b.v., The Netherlands

No part of this manual may be reproduced or transmitted by any means, electronic or mechanical, including photocopying and recording without written permission from the publisher.



GENERAL SAFETY INFORMATION

ELECTRICAL SAFETY WARNING

The electrical power in this equipment is at a voltage high enough to endanger life.

NOTE

Repair of the analyser should be done by qualified personnel who are familiar with good workshop practice and the requirements for repairing equipment.

WARNING

Any adjustment, maintenance and repair of the opened apparatus under voltage shall be carried out only by a skilled person who is aware of the hazard involved. Printed circuits should not be removed without switching off the power. The circuits can be damaged by accidental short circuits.



TABLE OF CONTENT

<i>Preface</i>		6
Section 1.	GENERAL DESCRIPTION	7
1.1	Product description	7
1.2	Principle of operation	8
1.3	Operating controls	9
1.4	Analyser configuration	10
1.4.1	The controller unit	10
1.4.1.1	The control panel	11
1.4.1.2	Front PCB electronics	11
1.4.1.3	Power supply and heater controller PCB electronics	11
1.4.2	The oxygen transducer	11
1.5	Sample gas flow	11
1.6	Options	12
Section 2.	TECHNICAL SPECIFICATIONS	13
2.1	Supply of mains power	13
2.2	Measuring range	13
2.3	Rang selection	13
2.4	Output signal	13
2.5	Accuracy	13
2.6	Response time	13
2.7	Reproducibility	13
2.8	Barometric pressure effect	13
2.9	Sample gas	13
2.10	Sample gas flow rate	13
2.11	Sample gas flow influence	14
2.12	Gas inlet pressure	14
2.13	Gas outlet pressure	14
2.14	Analyser temperature	14
2.15	Ambient temperature	14
2.16	Storage temperature	14
2.17	Relative humidity	14
2.18	Materials in contact with sample gas	14
2.19	Sample gas connection	14
2.20	Mounting details	14
2.21	Dimension and weight	14
2.22	Protection	14
Section 3.	INSTALLATION INSTRUCTIONS	15
3.1	Pre-installation checks	15
3.2	Installation precautions	15
3.2.1	Mains electricity supply	15
3.2.2	Mains power switch	15
3.2.3	Sample gas	15
3.3	Positioning and location	16
3.4	Installation procedure	17
Section 4.	START-UP AND CALIBRATION	18
4.1	Start-up procedure	18
4.2	Calibration precautions	18
4.2.1	Calibration gases	18
4.2.2	Gas cylinders	18
4.3	Zero calibration	19
4.4	Span calibration	19
4.5	After-calibration	20



<i>Section 5.</i>	MAINTENANCE & REPAIR	21
5.1	Routine maintenance	21
5.2	System check	21
5.3	Repair	22
5.3.1	Repair equipment and tools	22
5.3.2	Replacement of the Measuring cell	23
5.3.3	Mechanical zero adjustment	23
<i>Section 6.</i>	RECOMMENDED SPARE PARTS	26
6.1	Introduction	26
6.2	Parts for analyser unit	26
6.2.1	Parts for the front PCB electronics	26
6.2.2	Parts for the power supply PCB electronics	26
6.3	Parts for oxygen transducer unit	26

LIST OF ILLUSTRATIONS

<i>Figure 1.1.1</i>	The PMA 22 oxygen analyser	7
<i>Figure 1.2.1.</i>	Magnetic susceptibility of gases	8
<i>Figure 1.2.2.</i>	The measuring cell in theory	8
<i>Figure 1.2.3.</i>	Principle of operation	9
<i>Figure 1.3.1.</i>	Overview of the analyser controls	10
<i>Figure 1.5.1</i>	The sample gas flow diagram	11
<i>Figure 3.2.3.1</i>	A typical sample conditioning system	16
<i>Figure 3.4.1</i>	Rear panel of the standard PMA 22	17
<i>Figure 5.3.2.1</i>	Internal front view of the transducer.	23
<i>Figure 5.3.3.1</i>	Internal back view of the transducer.	25

APPENDIXES

<i>Appendix A</i>	: List of used abbreviations
<i>Appendix B</i>	: Cross sensitivity of gases
<i>Appendix C</i>	: Diagrams and drawings :
<i>Appendix D</i>	: Complete overview of the specification of the analyser.



PREFACE

NOTICE.

The information provided in this manual is intended to assist the operator in the efficient and trouble-free operation of our instruments.

ANALYSER MODEL.

This instruction manual covers the rack-mounted industrial type PMA 22 oxygen analyser manufactured by M & C Instruments B.V., Bleiswijk, The Netherlands.

SERIAL NUMBER.

The serial number of this analyser is located on the rear panel of the instrument.

POWER SOURCE.

The analyser should be connected to AC power source of the type as described in this instruction manual and as marked on the rear panel of the instrument.

READ INSTRUCTION BEFORE USE.

The instructions should be read thoroughly before operating the analyser.

FOLLOW INSTRUCTIONS CAREFULLY.

All operating, calibration, installation, and use instructions should be followed carefully in order to obtain the optimum performance of the analyser.

WARNINGS AND CAUTIONS.

This instruction manual includes WARNING and CAUTION text where it is necessary in order to point safety and other important information for the operator of the instrument.

WARNING – Hazards which could result in personal injury or death

CAUTION – Hazards which could result in equipment or property damage as well as to alert the user to pertinent facts and certain conditions

Although WARNING hazards are related to personal injury or death and CAUTION hazards are associated with equipment or property damage, it should be understood that, under certain conditions, the operation of a damaged or defect instrument could result in a degraded process system performance which in turn could also lead to personal injury or death.

RETAIN INSTRUCTIONS.

After reading is finished, the instruction manual of the analyser should be retained in a safe place for future reference.

SECTION 1. GENERAL DESCRIPTION

This instruction manual contains general descriptive information, technical specifications, installation, calibration, operation and maintenance instructions as well as the recommended spare parts for the PMA 22 oxygen analyser. Appendices are also included consisting of used abbreviations, cross sensitivity of gases, circuit diagrams and drawings of the analyser.

The M&C magneto dynamic type measuring cell is patented in Europe and the USA under the following patent numbers:

Netherlands	patent number 188 249
Germany	patent number 36 33 750
France	patent number 87 13 608
United Kingdom	patent number 21 96 127
USA	patent number 4,807,463

§ 1.1 Product description.

The industrial PMA 22 analyser manufactured by M&C Instruments has been designed with simplicity and reliability for continuous measurement of the oxygen content in a clean and dry gas sample with an dew point of 40°C maximum. The operation of the instrument is based upon the principle of the magneto-dynamic cell which is the most accurate and reliable cell for determining the oxygen content of a gas mixture from 0 to 100 volume percent oxygen.

The patented M&C measuring cell, having no dead corner, is unique in its sort, and its design as well as its construction is really a break-through in the world of magneto-dynamic oxygen cells. Although the magneto-dynamic measuring cells has already been applied by other manufacturers of paramagnetic oxygen analysers, the M&C measuring cell has been improved in order to achieve stability, minimum drift of temperature, and extremely fast response time. Due to the extremely fast response time of the analyser and the negligible background cross sensitivity from other gases, the PMA 22 analyser does not normally limit its application for the measurement of the oxygen content in various gas mixtures like for example in flue gases, inert-gas installations, and many other processes.

In its basic version the analyser already includes the following standard features:

- ✓ lowest measuring range of 0-3 vol.% oxygen preset ;
- ✓ non isolated 0-1 volt output for 0-100% reading.

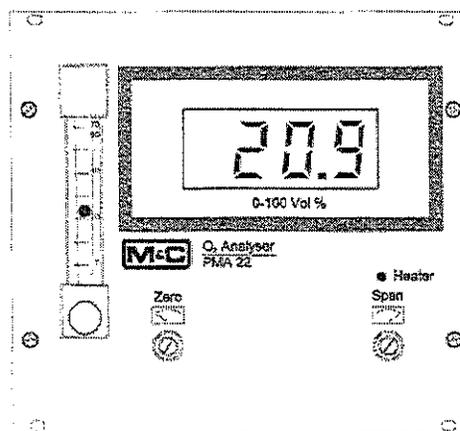
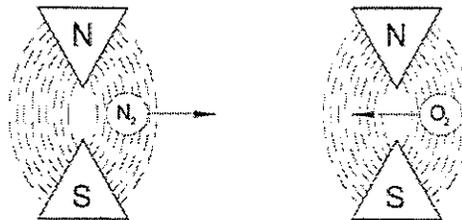


Figure 1.1.1. The PMA 22 oxygen analyser.

§ 1.2 Principle of operation.

The paramagnetic susceptibility of oxygen is significantly greater than that of other common gases, and for this reason the molecules of oxygen are attracted much more strongly by a magnetic field than the molecules of other gases. Most of the other gases are slightly diamagnetic, i.e. the molecules are then repelled by a magnetic field.

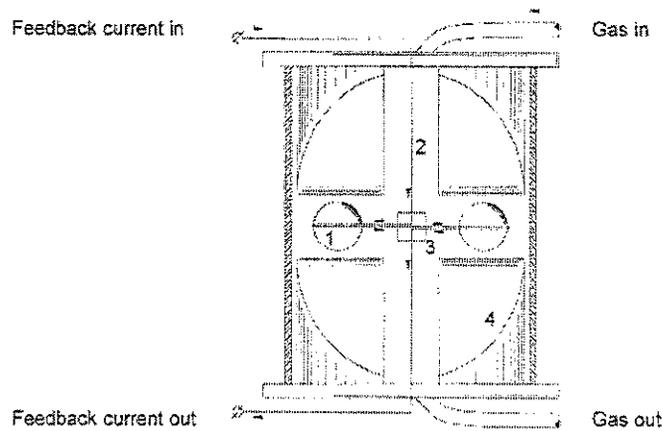


Nitrogen = Diamagnetic

Oxygen = Paramagnetic

Figure 1.2.1. Magnetic susceptibility of gases.

The principle of the magneto-dynamic cell is based upon Faraday's method of determining the magnetic susceptibility of gas. The cell consists of two nitrogen-filled quartz spheres arranged in the form of a dumb-bell. A single turn of platinum wire is placed around the dumb-bell which is suspended in a symmetrical non-uniform magnetic field. When the surrounding gas contains oxygen, the dumb-bell spheres are pushed out of the magnetic field by the change in the field which is caused by the relatively strong paramagnetic oxygen. The torque acting on the dumb-bell will be proportional to the paramagnetism of the surrounding gas and consequently it can be used as a measure of the oxygen concentration.

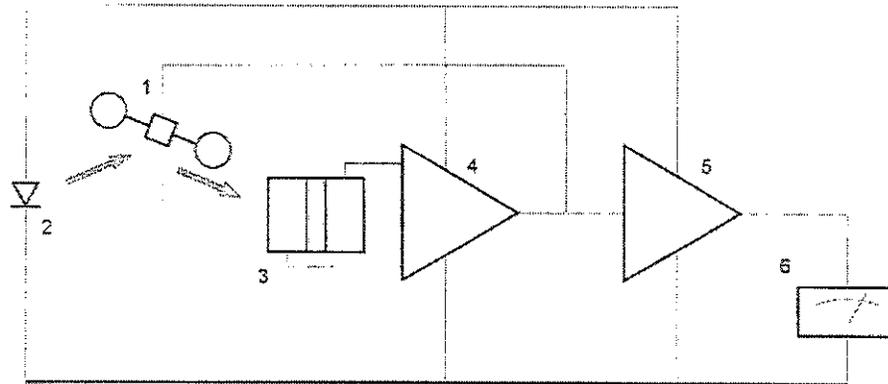


- 1 : Quartz sphere dumb-bell.
- 2 : Platinum feedback coil.

- 3 : Mirror.
- 4 : Magnet pole pieces.

Figure 1.2.2. The measuring cell in theory.

The distortion of the dumb-bell is sensed by a light-beam and projected on a mirror attached to the dumb-bell whereof it is reflected to a pair of photo-cells. When both photo-cells are illuminated equally the output will be zero. The output from the photo-cells is connected to an amplifier, which in turn is fed to the feedback coil of the measuring cell. If the oxygen content of the gas sample changes, the corresponding output of the amplifier, which is a current and also proportional to the oxygen content, produces a magnetic field in the feedback coil opposing the forces and thereby causing the dumb-bell to rotate.



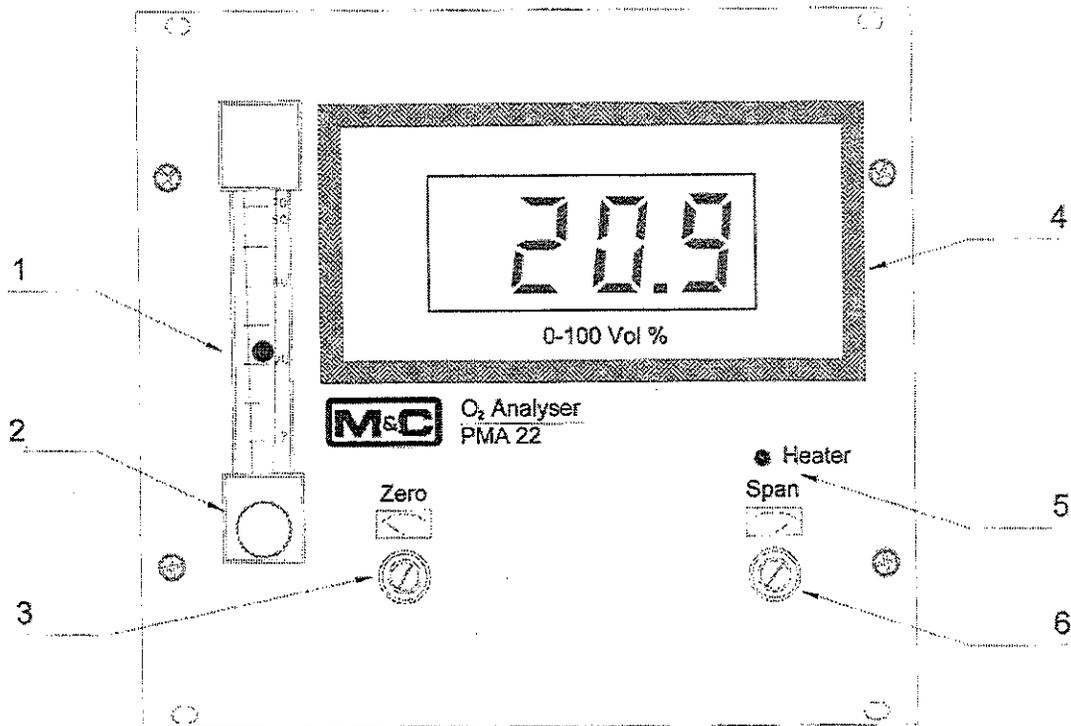
- | | | |
|------------------------|----------------------|-----------------------|
| 1 : Measuring cell | 2 : "led" light beam | 3 : Photo cell |
| 4 : Feedback amplifier | 5 : Output amplifier | 6 : Meter indication. |

Figure 1.2.3. Principle of operation.

Since the feedback current from the amplifier is proportional to the oxygen content of the gas sample, the output signals produced by the amplifier will be accurate and linear. The paramagnetic susceptibility of oxygen varies inversely as the square of the absolute temperature. Therefore, a temperature sensitive element in contact with the measuring cell assembly is included in the feedback current circuit in order to provide compensation for changes in analyser temperature.

§ 1.3 Operating controls.

The PMA 22 analyser is provided with a digital meter with an range of 0-100% to indicate the oxygen content of the gas sample. The output range of the analyser is internal pre-selectable for the range 0-3%, 0-10%, 0-30%, and 0-100%. A flow-meter with needle valve is fitted at the front panel to control the sample gas flow through the measuring cell of the analyser. The needle valve may be used to adjust the required flow-rate. The PMA 22 analyser is a thermostated instrument which is adjusted to operate at a constant temperature of 50°C. Therefore, a heater flashing LED is fitted at the front panel to indicate the proper functioning of the operating temperature control circuit of the analyser. Controls for calibration adjustment of zero and span points are conveniently accessible at the control panel.



- | | |
|---------------------------|----------------------------|
| 1 : Flow-tube | 2 : Needle valve ; |
| 3 : Zero control analyser | 4 : Digital panel meter ; |
| 5 : Heater LED | 6 : Span control analyser. |

Figure 1.3.1. Overview of the analyser controls.

§ 1.4 Analyser configuration.

The paramagnetic PMA 22 oxygen analyser is primarily designed for 19-inch rack mounting, and for this reason the instrument is installed in the 19-inch cassette. The cassette, made from an aluminium alloy, consists a control panel, a rear panel, two side plates, a bottom plate, and a top cover plate.

In general, the basic configuration of the PMA 22 oxygen analyser comprises two main units which are installed in the cassette. The two main units of the analyser may be described as follows:

- a The controller unit comprising the electronics as well as the mechanical parts of the unit.
- b The oxygen transducer unit including the measuring cell and its signal processing electronics.

§ 1.4.1 The controller unit.

The controller unit of the PMA 22 analyser comprises the control panel, the front PCB electronics, the power supply and heater control electronics, and an adjustable flowmeter which forms a part of the sample system.

§ 1.4.1.1 The control panel

The control panel of the PMA 22 analyser is provided with a liquid crystal display indicator which enables the operator to read the oxygen value. The required flow rate of the sample gas may be adjusted by means of the flow control needle valve located on the flow-meter. For calibration of the analyser the controls for adjustment of zero and are easily accessible.

As the PMA 22 analyser is a thermostated instrument which is adjusted to operate at a constant temperature of 50°C, a heater flashing LED is fitted at the control panel to indicate the proper functioning of the operating temperature control circuit of the analyser.

§ 1.4.1.2. Front PCB electronics

The front printed circuit board electronics, being another part of the controller unit, is attached at the back side of the control panel. On this board the setting of the range can be chosen by mean of an soldering link. The lowest range is 0 - 3 % oxygen.

§ 1.4.1.3. Power supply and heater controller PCB electronics.

In its standard version the PMA 22 is provided with output signals for 0/4-20 mA and 0-1 Volt. The non-isolated 0-1 Volt signal is for the range of 0-100 volume percent oxygen, can only be used for an external recording instrument with a load of more than 100 KOhms. The mA output can be ordered as an isolated or non-isolated signal and it is selectable for 0-20 or 4-20 mA with a maximum load of 500 Ohms.

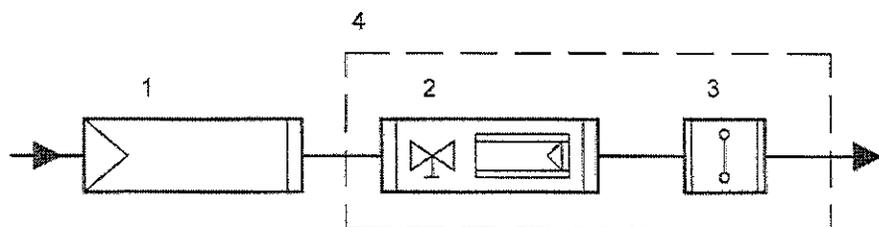
§ 1.4.2 The oxygen transducer unit.

The transducer unit of the PMA 22 oxygen analyser comprises the patented M&C magneto-dynamic type measuring cell and its signal processing PCB electronics. A circuit diagram of the transducer unit is included in Appendix C of this manual.

§ 1.5 Sample gas flow.

The sampling system of the PMA 22 analyser must include an external filter to prevent the entrance of foreign matter into the measuring cell.

The sample gas enters the analyser through the inlet connector, mounted at the rear panel, after which the gas flows through the flow-meter with needle valve where it can be adjusted at the required flow-rate for entrance into the measuring cell.



1 : External fine-filter.

2 : Flow-meter with needle valve.

3 : Measuring cell.

4 : Analyser PMA 22.

Figure 1.5.1. The sample gas flow diagram.



§ 1.6 Options.

A single or double oxygen alarm, isolated or non-isolated 0/4-20 mA output for the selected range and the type of housing in which the PMA 22 is to be installed may be ordered as option.

Remark : as this mA output is no separate PCB but an integrated part of the transducer we advice to order it together with the analyser. Later ordering will give double work.



SECTION 2. TECHNICAL SPECIFICATIONS

§ 2.1 Supply of mains power.

The PMA 22 oxygen analyser is normally designed with an internal power unit which requires an AC mains supply of 115/230 Volts, selectable, operating on a frequency between 40 and 60 Hertz.

Voltage tappings are selected via soldered wire links for 115 or 230 Volts. Mains power supply variations of plus or minus 15% does not affect the normal operation of the analyser.

§ 2.2 Measuring range.

The four pre-selectable linear measuring ranges are 0-3, 0-10, 0-30, and 0-100 volume percent oxygen. A digital display indicating the oxygen content from 0-100%. This digital meter indicates the oxygen content of the sample gas stream through the analyser.

§ 2.3 Range selection.

Selection of the measuring ranges can be made internally by means of 4 soldering links on the front PCB board.

§ 2.4 Output signals.

The 0-1 Volt output is a non-isolated signal designed for the range of 0-100 volume percent oxygen, and may be used for recording instruments with a load of more than 100 K ohms. A non-isolated 0-20 or 4-20 mA output signal with a maximum load of 300 Ohms for each selected range is available as an option. Also an isolated output mA signal is available as an option.

§ 2.5 Accuracy.

After correct calibration the accuracy of the analyser $\pm 1\%$ of the span.

§ 2.6 Response time.

The response time of the analyser for 90% FSD is less than three seconds at a sample gas flow of 60 l/hr.

§ 2.7 Reproducibility.

Less than 1% of the span

§ 2.8 Barometric pressure effect.

The oxygen reading will vary in direct proportion to changes of the barometric pressure.

§ 2.9 Sample gas.

Sample gas temperature should be between -10°C and $+40^{\circ}\text{C}$. Sample gas should be desaturated and dust free.

§ 2.10 Sample gas flow rate.

The sample gas flow rate is adjustable between 6 and 60 l/hr.



§ 2.11 Sample gas flow influence.

Variations between 0 and 60 NI/hr. air will show a difference of less than 0.1 volume percent oxygen.

§ 2.12 Gas inlet pressure.

Minimum 0.1 barg. Maximum 1 barg.

§ 2.13 Gas outlet pressure.

Outlet of analyser must always discharged freely in the open atmosphere.

§ 2.14 Analyser temperature.

The analyser is set to operate at a temperature of 50°C.

§ 2.15 Ambient temperature.

The analyser operates between -10°C and +55°C.

§2.16 Storage temperature.

Minimum -20°C. Maximum +55°C.

§ 2.17 Relative humidity.

0-90%RH.

§ 2.18 Materials in contact with sample gas.

Platinum, Glass, Stainless Steel 316, Epoxy resin, Polypropylene, and Viton.

§ 2.19 Sample gas connections.

Hose nipple for DN 4/6 mm tube.

§ 2.20 Mounting details.

The analyser is primarily designed as a cassette for 19-inch rack mounting. Three analyser can be installed in one 19-inch rack. However, it is also possible to install the PMA 22 analyser in a portable housing.

§ 2.21 Dimensions and weight.

The dimensions of the 19-inch cassette are: height = 3U, Width = 28HP, depth = 230mm (+60mm installation space) Net weight of the analyser is ±2 Kg.

§ 2.22 Protection.

Dependent on type of housing.



SECTION 3. INSTALLATION INSTRUCTIONS

§ 3.1 PRE-INSTALLATION CHECKS

After unpacking the analyser, the instruments must be inspected for signs of damage which may have occurred during transport or shipment. Make a visual inspection of the analyser for loose, broken or missing parts, and if any damage is evident, inform M&C or the official sales agency in your area as soon as possible.

§ 3.2 INSTALLATION PRECAUTIONS

To maintain accuracy as well as to minimize possible damage which could result in improper functioning of the instrument, the following precautions should be taken before installation.

These precautions are to ensure that the existing features of the analyser will not be degraded during installation.

§ 3.2.1 Mains electricity supply.

A suitable source of electric power, supplying the required voltage and frequency, must be available at the location where the analyser is to be installed. Make certain that the requirements for a safety earth and ground are met.

WARNING

Under all circumstances the metal case of the PMA 22 analyser must be connected to earth.

§ 3.2.2 Mains power switch.

As the PMA 22 analyser is not provided with a mains power switch, the instrument has to be connected to a mains electricity supply which has a suitable power switch in order to turn the analyser ON and OFF.

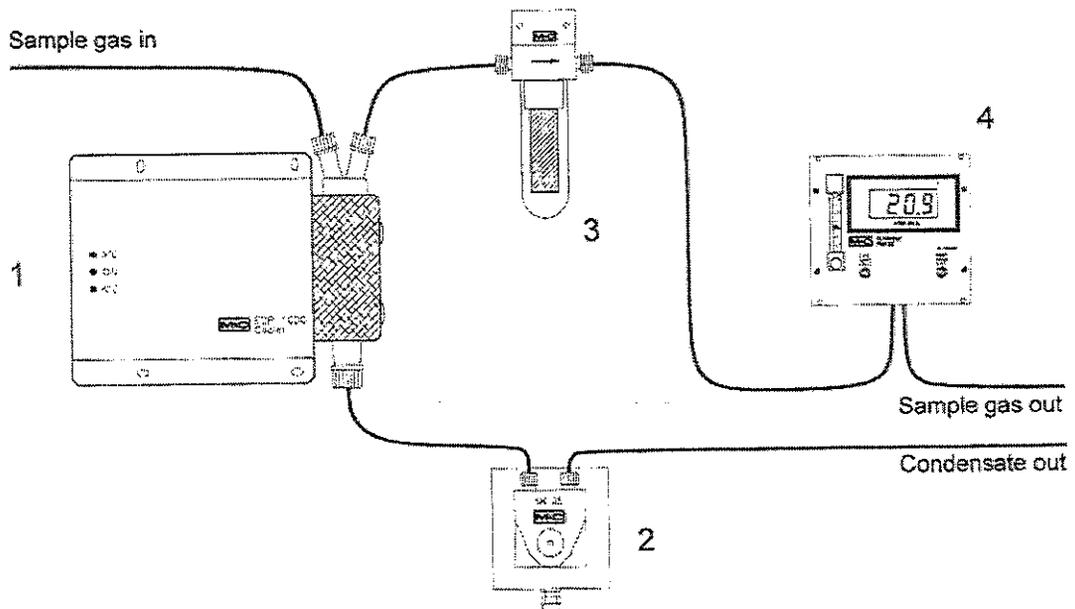
§ 3.2.3 Sample gas.

The sample gas must be desaturated and dust, and its temperature should not exceed 40°C.

WARNING

Under all circumstances an external fine filter must be used at the gas inlet of the analyser in order to prevent that foreign matter will enter into the measuring cell of instrument.

If it is to be expected that the sample gas temperature will exceed 40°C, a sample conditioning system incorporating a cooler and condensation drain will be one of the solutions.



- | | |
|------------------------------|--------------------------|
| 1 : Gas cooler (ECP 1000) | 3 : Fine-filter (FT- 2T) |
| 2 : Peristaltic pump (SR 25) | 4 : Analyser (PMA 22) |

Figure 3.2.3.1 A typical sample conditioning system.

§ 3.3 Positioning and location.

Accurate and proper installation of the PMA 22 analyser will not only minimize instrument breakdown, but it will also result in reliable operation of the analyser.

The operator must be satisfied that the analyser installation and positioning is safe for extremes of conditions which could occur in the operating environment of the analyser.

Choose installation sites which are reasonable free from vibration sources, and which are not subjected to large temperature fluctuations outside the analyser specification.

Without any precautions avoid any back-pressure different from barometric pressure at the gas outlet of the analyser.

WARNING

Note that the PMA 22 analyser is only suitable for measuring of nonhazardous gas or gas mixtures in non-hazardous areas.

§ 3.4 Installation procedure.

The PMA 22 analyser is designed for 19-inch rack mounting and consequently the installation provisions for the mechanical as well the electrical connections are made at the rear panel of the instrument. Sample gas connectors are suitable for 4/6 mm tube.
 For connection of the AC mains supply a 3-pin receptacle with line filter, marked X1, is fitted in the centre of the rear panel, and F1 and F2 are fuses for protection of the AC mains supply. X2 is a seven-pin female connector for the mA and mV output signals.

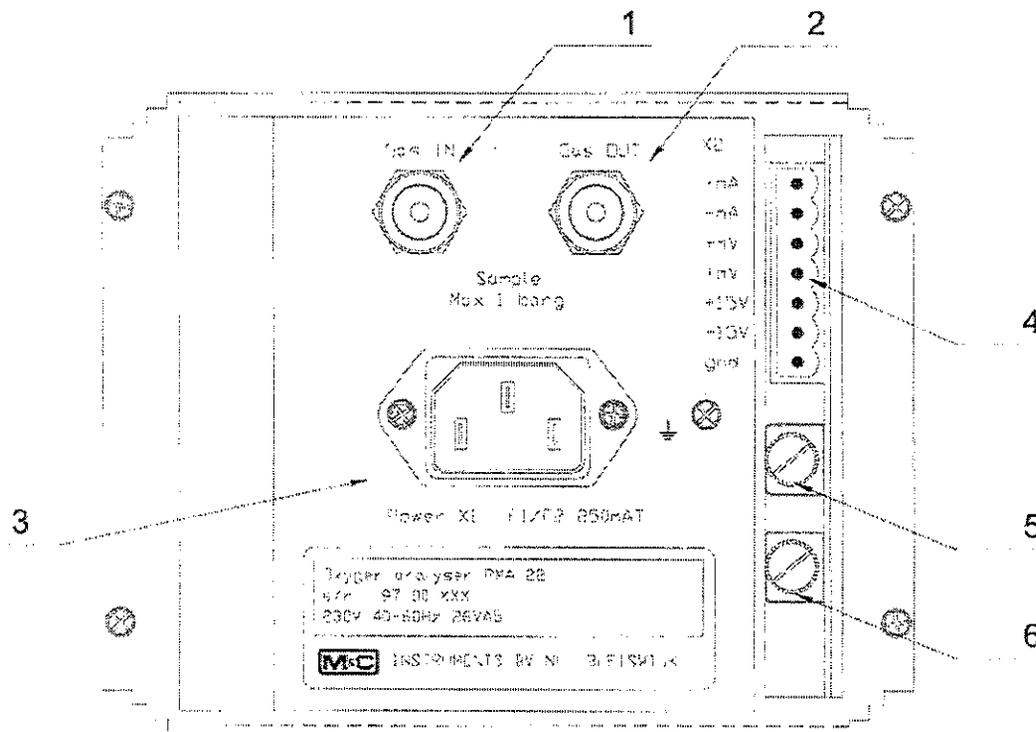


Figure 3.4.1. Rear panel of the standard PMA 22.

- | | |
|-----------------------------------|-----------------------------------|
| 1 : Sample gas inlet connection. | 4 : 7-pole male connector. |
| 2 : Sample gas outlet connection. | 5 : Fuse holder mains. (250-mA T) |
| 3 : Three-pole power connector. | 6 : Fuse holder mains. (250-mA T) |



SECTION 4. START - UP AND CALIBRATION

§ 4.1 Start - up procedure.

- X Make certain that the analyser is properly installed before switching on the electricity supply and introducing the sample gas into the instrument.
- X Switch on the AC mains supply.

Normally, the digital meter will indicate less than 21% if the measuring cell of the analyser is filled with normal ambient air.

The heater LED indicator will remain fully on, but after approximately 30 minutes the LED starts to flash to indicate that the analyser has reached its operating temperature.

CAUTION

After 3 hours the analyser is ready for calibration, but after another 24 hours re-calibration of the instrument is necessary in order to ensure that the analyser has been totally stabilized.

§ 4.2 Calibration precautions.

To maintain accuracy of the PMA 22 analyser as well as to prevent improper functioning of the instrument, the following precautions should be taken:

- X Once the analyser is in continuous use calibration should be performed regularly.
- X The oxygen reading is directly proportional to the barometric pressure and depending on the measuring range of the sample gas, the span should be calibrated daily for changes of barometric pressure. However, if maximum accuracy is required, zero as well as span may be calibrated daily, or otherwise weekly.

CAUTION

For a fast and continuous response time of the analyser, the flow-rate of the sample gas should be adjusted at maximum flow of 60 NI/hr.

§ 4.2.1 Calibration gases.

Normally, calibration of the analyser may be performed with high purity nitrogen for the zero point and clean dry air for the span point.

§ 4.2.2 Gas cylinders.

The gas cylinders which are used to be used in conjunction with the calibration procedure of the analyser must be fitted with a suitable pressure regulator as well as an appropriate output pressure gauge in order to prevent over-pressure in the measuring cell of the analyser.



§ 4.3 Zero calibration.

Perform the zero point setting of the analyser carefully and accurately as outlined in the following steps:

- X Make a suitable viton hose connection between the analyser and the pressure regulator of the gas bottle.
- X Adjust the pressure regulator of the gas bottle to a minimum of 0.2 barg., but do not exceed the maximum pressure of 1 barg in order to prevent over-pressure in the instrument.
- X Introduce the zero gas (high purity nitrogen) from the gas bottle into the analyser, and adjust the gas flow to a maximum rate of 60 NI/hr.
- X Wait for a certain period to ensure that the analyser is totally filled with the zero gas.
- X Make certain that the reading stands still.

CAUTION

As a flow-rate between 0 and 60 NI/hr shows a difference of less than 0.1 volume percent oxygen, it is recommended to shut off the supply of zero gas before adjusting the zero control.

- X If high purity nitrogen is not available as the zero gas, an equivalent zero gas may be used. Adjust the zero control with a suitable screwdriver to obtain the indication determined by the magnetic susceptibility of the used zero gas.
- X When the required zero setting has been obtained, the hose connection between analyser and gas bottle can be removed. Otherwise, the preceding steps should be repeated until the correct zero indication has been obtained.

§ 4.4 Span calibration.

Normally clean dry air may be used to perform the span calibration.

CAUTION

A correct span calibration cannot be performed until a successful zero calibration has been accomplished.

- X Introduce the span gas into the analyser and adjust the flow-rate of the gas to the maximum of 60 NI/hr.
- X Wait for about 30 seconds and make certain that the reading stands still before making any adjustment.
- X Adjust the span control with a suitable screwdriver to obtain the corresponding indication of the used span gas, which is 21.0 % for clean dry air.
- X When the required span indication has been obtained, the supply of span can be stopped, otherwise the preceding steps should be repeated.



§ 4.5 After-calibration.

If span calibration is finished successfully disconnect the calibration gas. Connect the gas inlet of the analyser to the process and the analyser is ready for use.

NOTE:

In case deviations > 2% oxygen have to be calibrated by the zero and span potentiometers a re- calibration should take place following the above-mentioned procedure.

SECTION 5. MAINTENANCE AND REPAIR

WARNING:

Before carrying out any maintenance or service activities, the engineer concerned must ensure that the analyser is disconnected from the electrical supply of power.

Maintenance of the analyser should be performed by qualified personnel, and the frequency of maintenance may vary as a result of operating experience.

Any used spare parts must be specified as M&C spare parts.

§ 5.1 Routine maintenance.

- X Routine maintenance of the PMA 22 oxygen analyser is limited to frequently checking the zero and span point calibration. If the values are not correct, the instrument should be re-calibrated according the procedure as outlined in this instruction manual.
- X In case of a temporary shut-down of the process control systems around the analyser, the AC mains supply of the analyser must remain "ON".
- X In case of a temporary shut-down of the analyser itself, there are no special precautions required.
- X In case of a shut-down of the analyser for a longer period, it is recommended to flush the analyser with clean air in order to prevent that harmful gases will be left in the instrument and damage the measuring cell.

§ 5.2 System check.

- X In the event of an incorrect reading of the analyser or a system failure make certain that the sampling system is in a good condition and that all sample handling components are working properly.
- X Check that gas cooler, filters, condensate drain or other components are not blocked with dirt or any foreign matter. Ensure that the sample gas is connected correctly and is flowing properly through the system, and make a visual inspection of the analyser for loose or leaking connections.

A list of recommended spare parts for the PMA 22 oxygen analyser is specified in section six of this manual.



§ 5.3 Repair.

In the event of a failure of the analyser, make certain that the other components of the sampling system are in good condition.

Check that the gas cooler, gas filter and condensate drain are not blocked with dirt or any foreign matter.

Ensure that the sample gas is connected correctly and is flowing properly through the system, and make a visual inspection of the analyser for loose or leaking connections.

WARNING

It is strictly recommended that the repair of the analyser should be performed by high qualified as well as experienced personnel, and that any spare part which is used should be specified as M&C spare part.

§ 5.3.1 Repair equipment and tools.

The following equipment and tools should be available to personnel responsible for maintenance and repair of the analyser.

- A volt / ohm / milliamp meter of high input impedance ;
- Soldering iron 25 W ;
- Flat bladed screw driver, 3 mm width ;
- Flat bladed screw driver, 8 mm width ;
- Nut driver, 5,5 mm ;
- Crosspoint screw driver, point size 1 ;
- Crosspoint screw driver, point size 2 ;
- Calibration gases : Clean dry nitrogen with an oxygen concentration of 0,0% O₂
Pure oxygen with a concentration of 100 % O₂

§ 5.3.2 Replacement of the measuring cell.

Refer to figure 5.3.2.1.

1. Take the oxygen analyser out of its 19" rack by using the flat bladed screw driver, 3 mm width, and place it on an clear workbench.
2. Put the analyser in front of you, with the display aiming front.

WARNING :

Before proceeding further, remove your wristwatch unless it is antimagnetic. There is a strong magnetic field inside the oxygen transducer.

3. Use the crosspoint screw driver, point size 1, to open the top panel of the analyser, by removing the two screws. Be sure not to lose them.
4. Put the analyser upside down, now remove the next two screws also. Don't take out this bottom panel because it is holding the transducer.



5. Now turn the analyser up right again. Use the crosspoint screwdriver again to remove the right panel of the analyser, it is fixed with four screws. Two on the front panel and two on the back panel.
6. The right panel can now be removed and put aside.
7. Pull out the 2 pole, 3 pole and 4 pole green plugs on the main board, disconnect the earth connection of the transducer (green / yellow wire). Also disconnect the 18 pole blue ribbon cable going from the transducer to the main board.
8. Pull the black inlet and outlet viton tube (2/4 mm and 4/6 mm) from the transducer.
9. The transducer and bottom plate can be moved away from the rest of the analyser.
10. Remove carefully the black foam insulation cap of the transducer, pulling it out by the corners.

CAUTION :

Temperatures up to 50°C may exist on the transducer.

11. Put the transducer in front of you with the tubing of the cell aiming front see also figure 5.3.2.1. The 18 pole connector must be on the right.
12. Unsolder the brown and yellow wire from the terminal pins on the back of the measuring cell see figure 5.3.2.1 mark 1. Remark : do not overheat the terminals because they might come loose. Remember where brown and yellow were connected
13. Loosen the cell clamp using the 5.5mm nut driver see figure 5.3.2.1 mark 4.
14. Grip the measuring cell firmly and pull it out of the magnet frame.

CAUTION :

Do not pull out the cell by its gas connections.

15. Change the measuring cell with the same type of cell.
16. Now follow the instruction 11 - 14 in reverse order.

Because this is a new cell the dumb-bell of the cell may have a different angle. To correct this the photocells have to be set right again. The next section is the description to get the transducer working in the right way.

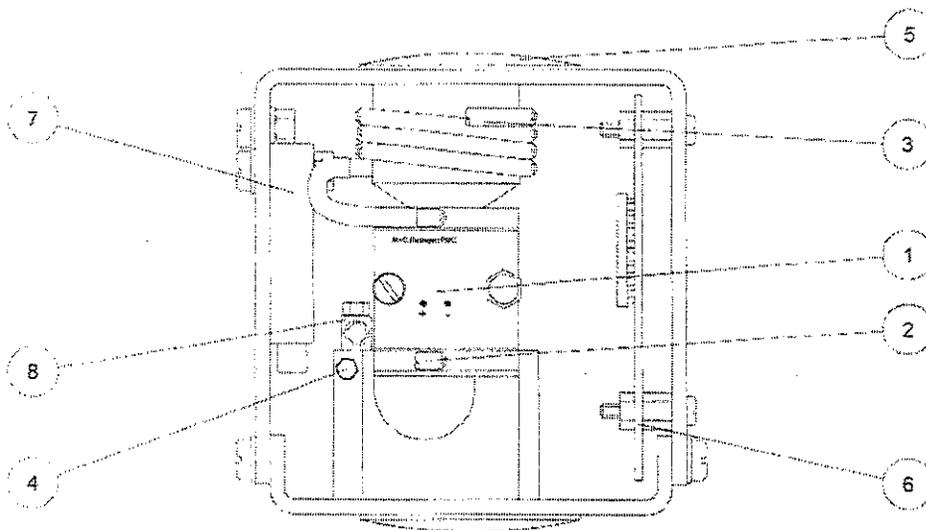


Figure 5.3.2.1. Internal front view of the transducer.

- | | |
|---|----------------------------------|
| 1 : Electrical connection measuring cell. | 5 : Heater pad. |
| 2 : Output measuring cell. | 6 : Transducer PCB. |
| 3 : Input Measuring cell | 7 : Temperature cut out at 72°C. |
| 4 : Cell clamp screw 5.5 mm nut. | 8 : Temperature sensor. |

§ 5.3.3 Mechanical zero adjustment.

Refer to figure 5.3.3.1.

After following section 5.3.2 the transducer mechanical zero has to be set right. To do this follow the next steps.

1. Turn the transducer around with the cell connection aiming to the back.
2. You can see the photocell and the IR led. The photocell's are connected with the white and grey wire and the IR led with an black and red wire. See also figure 5.3.3.1.

CAUTION :

The photo-cells are fragile. Take care not to damage them.

3. For testing the transducer mechanical zero it has to be connected again to the electrical connection of the main PCB. So position the transducer and bottom plate next to the rest of the analyser.
4. Connect the 2 pole, 3 pole and 4 pole green plugs to the main board, connect the earth connection of the transducer (green / yellow wire). Also connect the 18 pole blue ribbon cable going from the transducer to the main board.
5. Place the inlet and outlet viton tube (2/4 mm and 4/6 mm) to the measuring cell.
6. Next place carefully the black foam insulation cap back again.



Leave the right and top plate of the 19" cassette away from the analyser. Make sure there are no loose screws around the analyser so that the analyser can be switched on safely. Use an mains three pole euro connector power cable for testing the analyser, *check the supply voltage of the analyser it must be 115 or 230 volts*.

1. Now switch the AC mains electrical supply on. Normally, the digital meter will indicate about 21.0 % oxygen because the cell is filled with normal ambient air.
2. Allow the analyser to warm up, the heater indication led will remain fully on, but after approximately 30 minutes the led starts to flash to indicate that the analyser has reached its operation temperature.
3. Set the multi turn pot-meter of the zero and span in the mid-position. You can do this by turning the controls fully to the left then turning them five full turns to the right. Use the flat bladed screw driver, 8 mm width.
4. Pass nitrogen as a zero gas through the analyser at a cell flow rate of about 40 l/h.
5. The analyser display must now indicate around 0.0% oxygen.
6. Pull the the black foam insulation cap of the transducer carefully just so you can see all screws on the photo-cells assembly. See also figure 5.3.3.1.
7. Loosen the hex screw using the nut driver, 5,5 mm. The photocell assembly can now be moved freely to the left and right. See also figure 5.3.3.1 mark 4.
8. Now turn the screw mark 6 figure 5.3.3.1 with the flat bladed screw driver, 8 mm width clock wise or counter clock wise to get the reading as close to the 0% reading. Take some time doing this.
9. After moving the photo-cells in the correct position, secure the assembly with the hex screw using the nut driver, 5,5 mm. See also figure 5.3.3.1 mark 4.
10. The analyser mechanical zero has now been set. Next follow the steps 1 - 10 in reverse order see section 5.3.2.

It is necessary that the analyser is re-calibrated again, see also the section "STARTUP AND CALIBRATION".

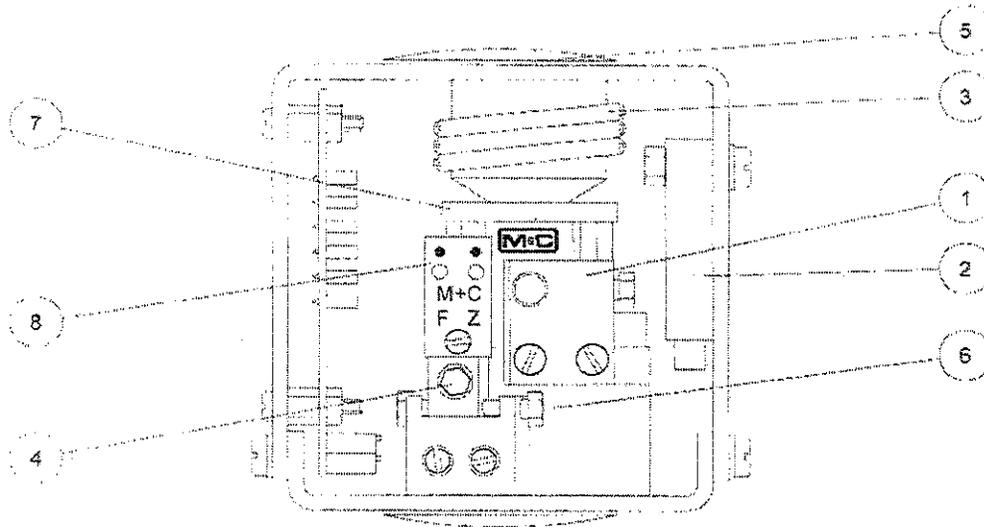


Figure 5.3.3.1. Internal back view of the transducer.

- | | |
|---|-------------------------------|
| 1 : IR led assembly. | 5 : Heater pad. |
| 2 : Temperature cut out at 72°C. | 6 : Moving screw photo-cells. |
| 3 : Stainless steel coil. | 7 : Measuring cell. |
| 4 : Clamp screw photo-cells 5.5 mm nut. | 8 : Photocell assembly. |



SECTION 6. RECOMMENDED SPARE PARTS

§ 6.1 Introduction.

Depending on the number of PMA 22 oxygen analysers as well as their intensive use, it is recommended to have the most important parts and components in stock in order to overcome unexpected failure or defect of the instrument.

As described in the preceding part of this manual the analyser comprises two main units, which are the controller unit including control panel and printed circuit boards and the oxygen transducer unit including the measuring cell. Consequently, the recommended parts list in this section of the manual is also divided in two separate paragraphs.

The list comprises a brief selection of parts and components, and the quantity of the items to be held in stock depends on the number of analysers as well as their frequency of use. For this reason the items are marked as follows:

- ① 1 item required for 1 to 4 analysers,
- ② 1 item required for 5 or more analysers.

§ 6.2 Parts for the analyser unit.

The analyser unit can be divided into the, the front PCB electronics, the power supply PCB electronics, and the transducer unit.

§ 6.2.1 Parts for the front PCB electronics.

Mark and description	Part number
① Zero potentiometer 5K 10-turn	90 A 0020
① Span potentiometer 1K 10-turn	90 A 0025
② Digital panel meter	90 A 1000

§ 6.2.2 Parts for the power supply PCB electronics.

Mark and description	Part number
② mA/mV isolated convertor (in case it has an iso-mA option)	90 A 0215
② blue DIL-plug 18-pole type 609-M185H	99 A 1220
② blue DIL-plug 8-pole type 609-M085H	99 A 1225
② TR1 - Transformer 2 x 115 V / 2x15 V.	90 A 0095
① Fuse 400 mA slow-blow	90 A 0180
② Solid state relay A3P-202N	90 A 3010

§ 6.3 Parts for the oxygen transducer unit.

Mark and description	Part number
② M&C Oxygen measuring cell Type PMC-1	90 A 0010
① Temperature fuse 72°C not re-set able	90 A 3015
② Temperature sensor	90 A 3020
② Heater elements 50 x 40 mm 12W / 115V	90 A 3030
② IR led for PMA 1.02.0 transducer	90 A 0035



**LIST OF USED ABBREVIATIONS IN
M&C - DOCUMENTS AND DRAWINGS**

A	Ampère	MC	Measuring Cell
AC	Alternating Current	Min	Minute
AOT	Adjustable On Terminal	mm	milli meter
B	Bridge rectifier	mV	milli Volt
C	Common or Capacitor	N	Neutral
°C	°Celsius	n	nano
D	Diode	NC	Normally Closed
DC	Direct Current	NC	Not Connected
DIL	Dual In Line	NI/hr	Normal litre per hour
F	Fuse or Farad	NO	Normally Open
FS	Flow Sensor	NTC	Negative Temperature Coefficient
FSD	Full Scale Deflection	P	Potentiometer
GND	GrouND	TP	Test Point
H	Heater	PC	Photo-Cell
HFL	dutch guilders	PCB	Printed Circuit Board
Hz	Hertz	PE	Positive Earth
I	Indicator	PMA	ParaMagnetic Analyser
IC	Integrated Circuit	PTC	Positive Temperature Coefficient
IP	Internal Protection	R	Resistor
IPA	Infra-red Paramagnetic Analyser	RE	RElais
IR	Infra-Red	SW	SWitch
Kg	Kilogram	T	Transistor
L	Line	TF	Thermal Fuse
LAIR	Light Absorption Infra-red Radiation	TR	TRansformer
LCD	Liquid Crystal Display	TS	Temperature Sensor
LED	Light Emitting Diode	VA	Volt-Ampère
l/hr	litre per hour	VAC	Voltage Alternating Current
M	Mega	VDC	Voltage Direct Current
mA	milli Ampère	X	electrical connector
		Z	Zener Diode



CROSS-SENSITIVITIES; SOMETHING TO TAKE INTO ACCOUNT

The paramagnetic measuring principle is based on the very high magnetic susceptibility of oxygen.

In comparison to oxygen other gases have such a minor susceptibility, most of them are not even worth mentioning.

Exception to this are the nitrogen oxides. However, as this gas is in most cases present in a very low concentration, the error is still negligible.

EXAMPLE 1

The residual oxygen percentage should be measured in a closed 100% carbon dioxide (CO₂) atmosphere. The "zero-calibration" is done by means of Nitrogen (N₂).

According to the list of cross-sensitivities the error for CO₂ at 20°C is -0,27%. In order to obtain a higher accuracy this means for the calibration that the reading should be adjusted at +0,27% with N₂, in order to compensate the error of CO₂.

Since the values of cross-sensitivities are based on 100 vol % of that particular gas, the error at 50 vol % CO₂ and 50 vol % N₂ is -0,135%.

EXAMPLE 2

Following gas composition at a temperature of 20°C:

5 vol % oxygen (O ₂)	+ 100,00x10 ⁻² x5	= + 5,0000
40 vol % carbon dioxide (CO ₂)	- 0,27x10 ⁻² x40	= - 0,1080
1 vol % ethane (C ₂ H ₆)	- 0,43x10 ⁻² x1	= - 0,0043
54 vol % nitrogen (N ₂)	+ 0,00x10 ⁻² x54	= + 0,0000
		+ _____ +
gives a reading of		+ 4,8877 vol. %

As this example shows, the total error is 5,0000 minus 4,8877 is -0,1123.



LIST WITH CROSS-SENSITIVITIES

all values based on nitrogen 0% / oxygen 100%

GAS	Formula	20°C	50°C
Argon	Ar	- 0,23	- 0,25
Acetylene	C ₂ H ₂	- 0,26	- 0,28
Acetone	C ₃ H ₆ O	- 0,63	- 0,69
Acetaldehyde	C ₂ H ₄ O	- 0,31	- 0,34
Ammonia	NH ₃	- 0,17	- 0,19
Benzene	C ₆ H ₆	- 1,24	- 1,34
Bromine	Br ₂	- 1,78	- 1,97
Butadiene	C ₄ H ₆	- 0,85	- 0,93
Isobutylene	(CH ₃) ₂ CH=CH ₂	- 0,94	- 1,06
n-Butane	C ₄ H ₁₀	- 1,10	- 1,22
Chlorine	Cl ₂	- 0,83	- 0,91
Hydrogen chloride	HCL	- 0,31	- 0,34
Nitrous oxide	N ₂ O	- 0,20	- 0,22
Diacetylen	(CHCl) ₂	- 1,09	- 1,20
Ethane	C ₂ H ₆	- 0,43	- 0,47
Ethylene oxide	C ₂ H ₄ O ₂	- 0,54	- 0,60
Ethylene	C ₂ H ₄	- 0,20	- 0,22
Ethylene glycol	CH ₂ OHCH ₂ OH	- 0,78	- 0,88
Ethylbenzene	C ₈ H ₁₀	- 1,89	- 2,08
Hydrogen fluoride	HF	+ 0,12	+ 0,14
Furan	C ₄ H ₄ O	- 0,90	- 0,99
Helium	He	+ 0,29	+ 0,32
n-Hexane	C ₆ H ₁₄	- 1,78	- 1,97
Krypton	Kr	- 0,49	- 0,54
Carbonmonoxide	CO	- 0,06	- 0,07
Carbon dioxide	CO ₂	- 0,27	- 0,29
Methane	CH ₄	- 0,16	- 0,17
Methanol	CH ₃ O	- 0,27	- 0,31
Methylene chloride	CH ₂ Cl ₂	- 1,00	- 1,10
Neon	Ne	+ 0,16	+ 0,17
n-Octane	C ₈ H ₁₈	- 2,45	- 2,70
Phenol	C ₆ H ₅ O	- 1,40	- 1,54
Propane	C ₃ H ₈	- 0,77	- 0,85
Propylene	C ₃ H ₆	- 0,57	- 0,62
Propene	CH ₃ CH=CH ₂	- 0,58	- 0,64
Propyleneoxide	C ₃ H ₆ O	- 0,90	- 1,00
Propylene chloride	C ₃ H ₇ Cl	- 1,42	- 1,44
Silane	SiH ₄	- 0,24	- 0,27
Styrene	C ₇ H ₆ =CH ₂	- 1,63	- 1,80
Nitrogen	N ₂	0,00	0,00
Nitrogen monoxide	NO	+ 42,70	+ 43,00
Nitrogen dioxide	NO ₂	+ 5,00	+ 16,00
Oxygen	O ₂	+100,00	+100,00
Sulphur dioxide	SO ₂	- 0,18	- 0,20
Sulphur fluoride	SF ₆	- 0,98	- 1,05
Hydrogen sulphide	H ₂ S	- 0,41	- 0,43
Toluene	C ₇ H ₈	- 1,57	- 1,73
Trichloroethylene	C ₂ HCl ₃	- 1,56	- 1,72
Vinyl chloride	C ₂ H ₃ Cl	- 0,68	- 0,74
Vinyl fluoride	CH ₂ F	- 0,49	- 0,54
Water	H ₂ O	- 0,03	- 0,03
Hydrogen	H ₂	+ 0,23	+ 0,26
Xenon	Xe	- 0,95	- 1,02



DIAGRAMS AND DRAWINGS

The next part of this instruction manual consists of diagrams and drawings of the analyser. These diagrams and drawings may be useful information for the operator of the instrument as well as for the maintenance and service engineer. In case of any doubt, please feel free to contact M&C Instruments or the official sales agency in your area. For addresses of official sales agencies contact M&C Instruments.

Oxygen Transducer Unit Type PMA 1.02.0 consisting of the following parts and components:

C 1	1 uF	16V	
C 2	1 uF	16V	
C 3	0,68 nF	32V	
C 4	100 uF	10V	
C 5	22 uF	25V	
C 6	47 uF	16V	
C 7	47 nF	32V	
C 8	1 uF	16V	
C 10	1,5 nF	32V	
C 11	1,5 nF	32V	
D 1 (transistor)	BC 517		
D 2	1N4148		
D 3	1N4148		
D 4	1N4148		
IC 1	LM 317		
IC 2	LM 337		
IC 3	OP 77	alternate	AD 707 JN
IC 4	OP 07	alternate	AD 707 JN
IC 5	OP 07	alternate	AD 707 JN
IC 6	OP 77	alternate	AD 707 JN
IC 7	OP221		
P 1	20 K		
P 2	10 K		
P 3	100 K		
T 1	BC 517		
T 2	BC 212		
T 3	2N2905		
R 1	470 E		
R 2	3,9 K		
R 3	3,9 K		
R 4	470 E		
R 5	560 E		
R 6	22 M		
R 7	100 K		
R 8	1 K		
R 9	330 E		
R 10	22 E		

Subject : Component list circuit diagram

M & C Instruments B.V.

Jan v/d Heijdenstraat 24a

2665 JA Bleiswijk

Tel. 01892-18566 Telefax. 01892-18994

Date: 05-01-94

Issue nr. : 1

Drawing nr. : 99 12122 05

Checked : B.V.D.

R 11	1 K	
R 12	22 E	
R 13	160 E	
R 14	22 E	
R 15	10 K	
R 16	10 K	
R 17	150 E	
R 18	4 K 7	
R 19	470 E	
R 20	10 K	
R 21	10 K	
R 22	1 K 5	0,1%
R 23	1 K 5	0,1%
R 24	49,9 K	0,1%
R 25	15 K	0,1%
R 26	49,9 K	0,1%
R 27	150 K	0,1%
R 28	1 K	
R 30	8 K 2	
R 32	100 K	
R 33	1 M	
R 34	100 K	
R 35	43,2 K	
R 36	100 K	
R 37	49,9 K	0,1%
R 38	2 K 2	0,1%
R 39	49,9 K	0,1%
R 40	2 K 2	
R 41	10 K	
R 42	10 K	
R 43	10 K	
R 44	47 E	
R 45	22 E	
R 46	27 E	
R 47	47 E	NTC

MC	Measuring Cell
PC	Photo-cells
LED	Light Emitting Diode
TS	Temperature Sensor KTY 11
H 1	Heater 110V 12W
H 2	Heater 110V 12W
TF	Thermal Fuse

Subject : Component list circuit diagram

M & C Instruments B.V.

Jan v/d Heijdenstraat 24a

2665 JA Bleiswijk

Tel. 01892-18566 Telefax. 01892-18994

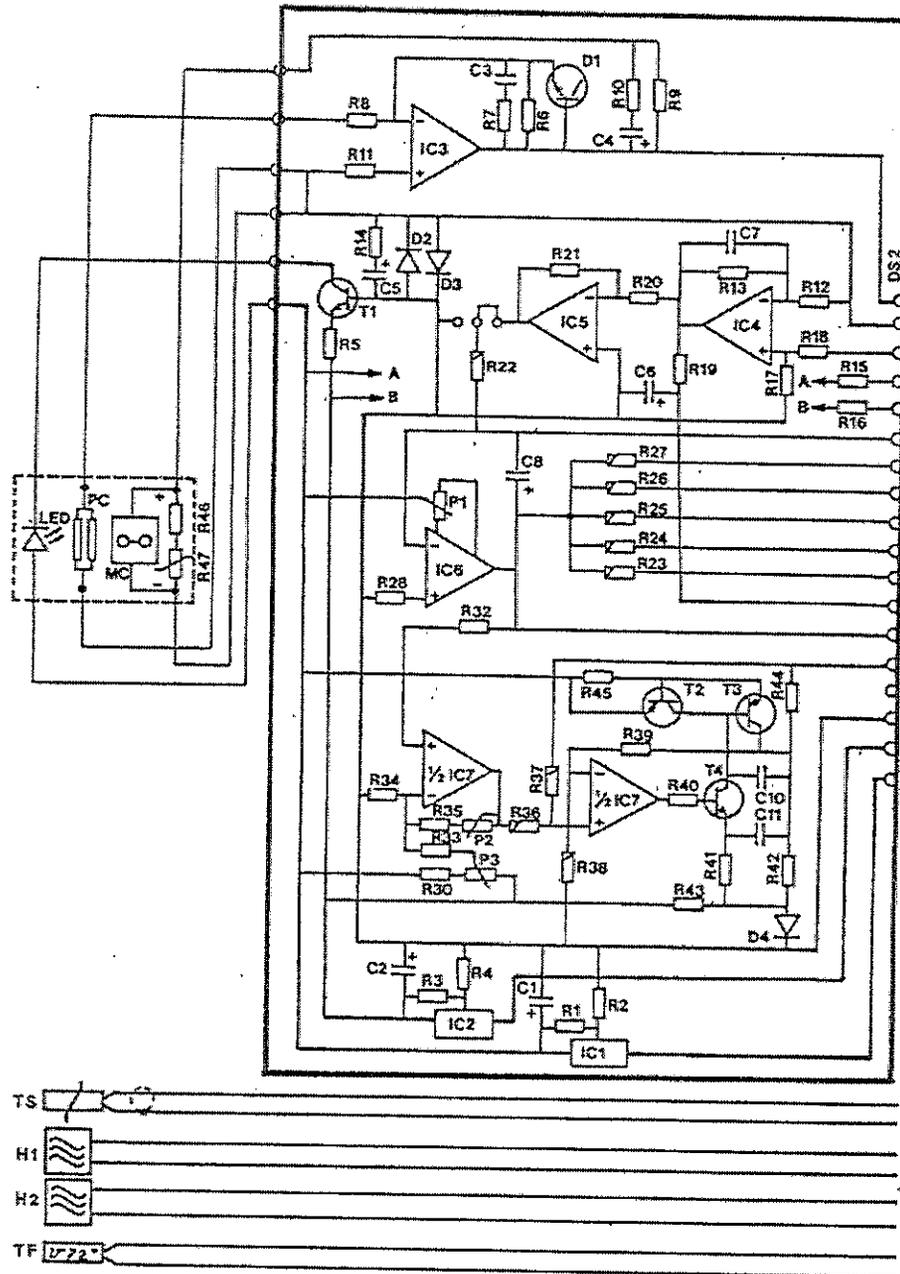
Issue nr.	Change	Date

Date: 05-01-94

Issue nr. : 1

Drawing nr. : 99 1222 06

Checked : B.V.D.



Subject : Circuit diagram oxygen transducer unit

M & C Instruments B.V.

Jan v/d Heijdenstraat 24a

2665 JA Bleiswijk

Tel. 01892-18566 Telefax. 01892-18994

Issue nr.

Change

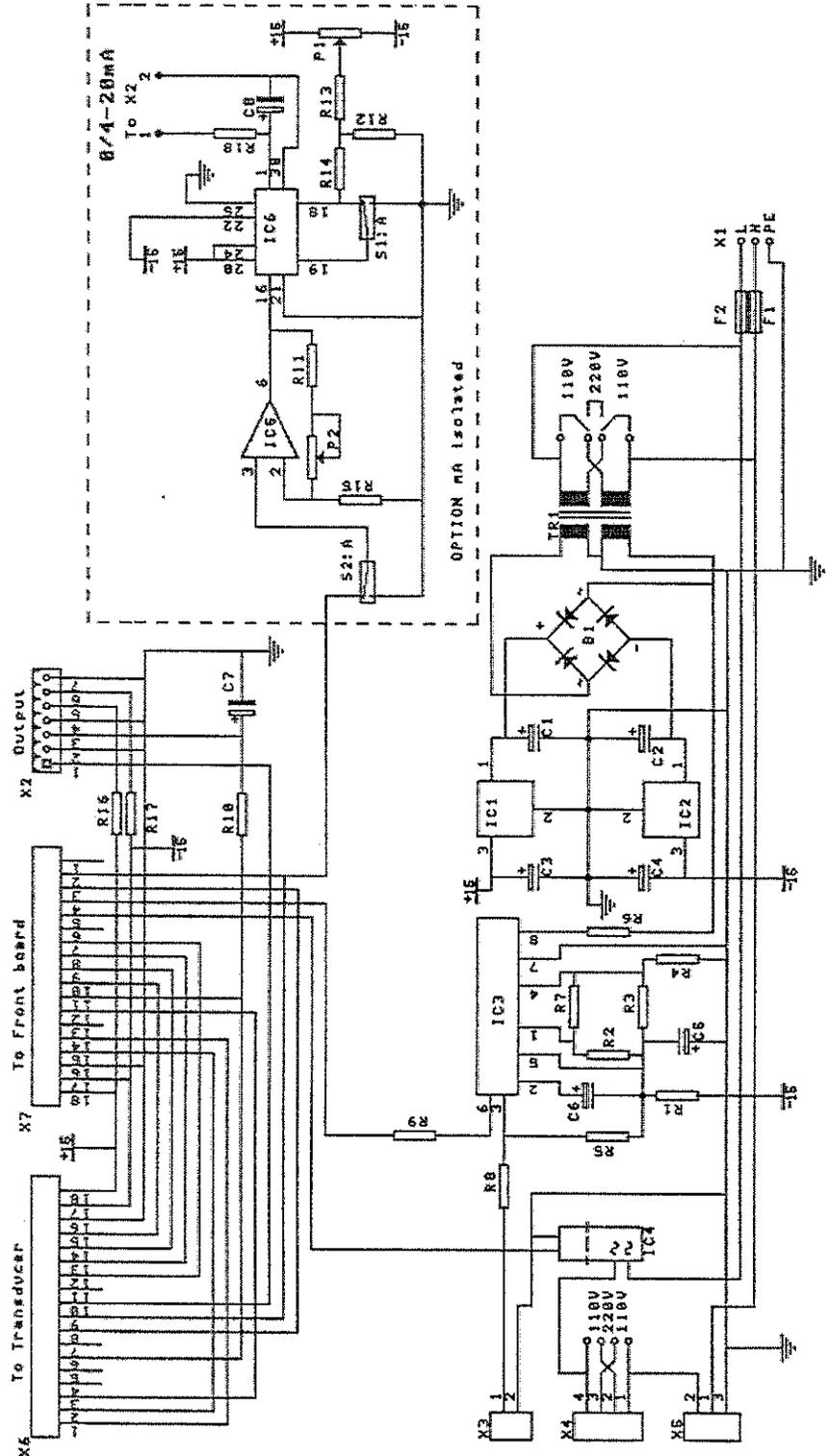
Date

Date: 05-01-94

Issue nr. : 1

Drawing nr. : 99 1222 04

Checked : B.V.D.

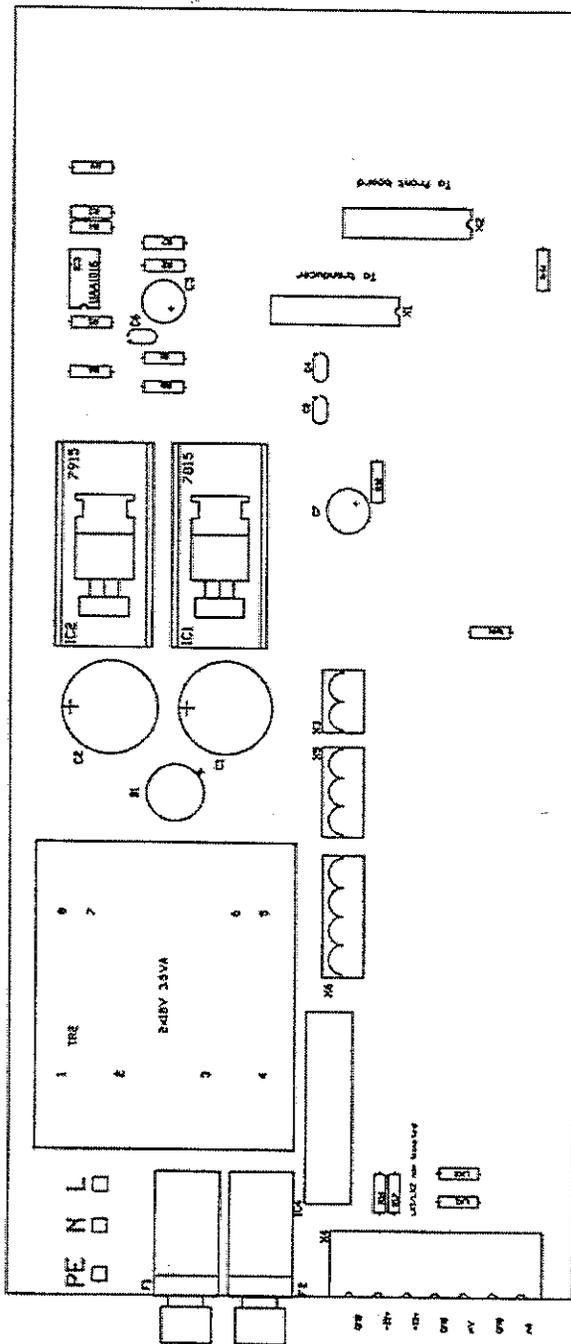


Subject : Electrical drawing of the main PCB of the PMA 22 oxygen analyser.

M & C Instruments B.V.
 Jan v/d Heijdenstraat 24a
 2665 JA Bleiswijk
 Tel. 01892-18566 Telefax. 01892-18994

Issue nr.	Change	Date

Date: 06-01-95 Issue nr. : 1
 Drawing nr. : 99 1222 03 Checked : BVD



Subject : Component layout power supply board PMA 22

M & C Instruments B.V.

Jan v/d Heijdenstraat 24a

2665 JA Bleiswijk

Tel. 01892-18566 Telefax. 01892-18994

Issue nr.

Change

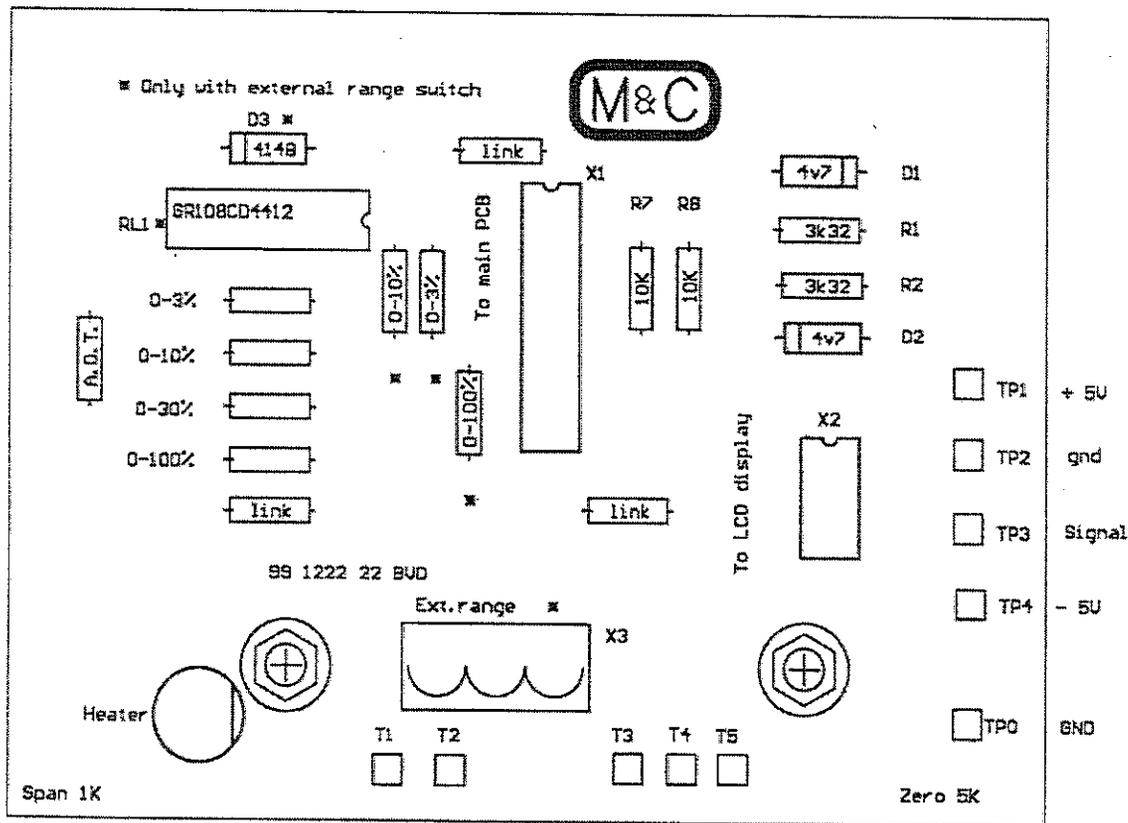
Date

Date: 02-11-94

Issue nr. : 1

Drawing nr. : 99 1222 02

Checked : B.V.D.



Subject : Component layout front board PMA 22 with option range switch.

M & C Instruments B.V.

Jan v/d Heijdenstraat 24a

2665 JA Bleiswijk

Tel. 01892-18566 Telefax. 01892-18994

Issue nr.

Change

Date

Date: 02-11-94

Issue nr. : 1

Drawing nr. : 99 1222 01

Checked : B.V.D.

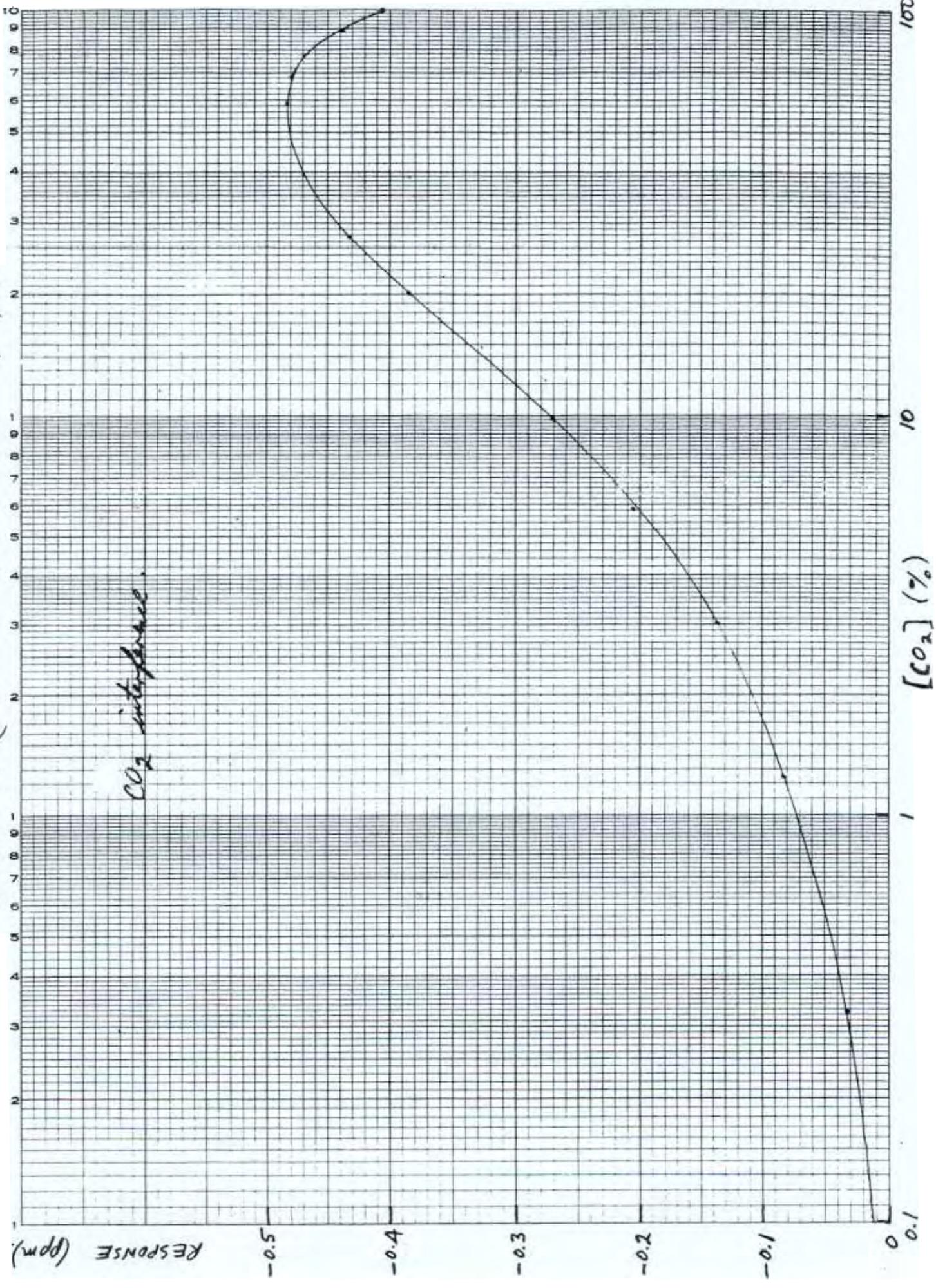
**Complete overview of the specification of the analyser.**

Measuring output range	: Pre-setable for 0-3, 0-10, 0-30 or 0-100 volume % oxygen, linear.
Indication	: 3 ½ digit 18 mm. high, LCD indicator for 0-100 % oxygen reading.
Output signals	: Standard; 0-1 VDC., non-isolated, load > 100 KOhm Option; 0/4-20 mA, non-isolated, max. load 300 Ohm for the chosen range. 0/4-20 mA, isolated, max. load 300 Ohm for the chosen range.
Response time for 90% FSD	: < 3 seconds at 60 NI/hr. air.
Accuracy after calibration	: ± 1 volume % of span.
Reproducibility	: < 1 volume % of span.
Influence of barometric pressure	: The oxygen reading will vary in direct proportion to changes of the barometric pressure.
Influence of sample gas flow	: Variations in gas flow between zero and 60 NI/hr. air will show a difference of < 1 vol. % oxygen (analyser output to atmosphere).
Gas inlet pressure	: Minimum 0.01 barg, maximum 1 barg.
Gas outlet pressure	: Outlet of analyser must always discharged freely in the open atmosphere.
Flow rate of sample gas	: Adjustable between 7 and 70 l/hr with the needle valve on the flow-meter. Maximum flow is 60 NI/hr.
Gas temperature	: Between -10°C and +40°C.
Analyser temperature	: +50°C.
Operating temperature	: Between -10°C and +55°C.
Storage temperature	: Between -20°C and +55°C, relative humidity is 0-90% RH.
Power supply	: Internal power unit for 115/230 VAC., selectable (+/-10%), 40-60 Hz., 26,5 VA. AC mains supply by 3 pole chassis plug with internal filter.
Materials in contact with sample gas	: Platinum, Glass, Polypropylene, Viton, Stainless Steel 316 and Epoxy resin.
Sample gas connection	: Hose nipple for DN 4 / 6 mm. tube.
Dimensions	: Height = 3U, Width = 28HP and Length = 230 mm. (+ 60 mm. installation space).
Protection	: IP 20.
Weight	: ± 2 Kg.

MODEL 48 (Baseline unit).

4/29/87.

CO₂ interference.



INSTRUCTION MANUAL

MODEL 48

GFC AMBIENT CO ANALYZER

**Thermo Environmental Instruments Inc.
8 West Forge Parkway
Franklin, Massachusetts 02038
Telephone: (508) 520-0430
Facsimile: (508) 520-1460**

P/N 7700

This Manual Issued For:

Serial No. _____

Program _____

Options _____

Date _____

The Thermo Environmental Instruments Inc. Model 48 has been designated by the United States Environmental Protection Agency (EPA) as a Reference Method for the measurement of ambient concentrations of Carbon Monoxide pursuant with the requirements defined in 40 CFR Part 53.

DESIGNATION REFERENCE METHOD NUMBER RFCA-0981-054
EPA DESIGNATION DATE Sept. 23, 1981

The Thermo Electron Model 48 CO Analyzer meets the EPA designation method requirements when operated with the following parameters:

RANGE:	0 - 50 PPM
LINE VOLTAGE RANGE:	105 - 125 VAC
TEMPERATURE RANGE:	20 - 30 DEGREES CELSIUS
TIME CONSTANT	30 SECONDS

With or without the following options:

48-001	Particulate Filter
48-002	19" Rack Mountable Configuration
48-003	Remote Activation of Zero and Span

The analyzer must be operated and maintained according to the Operation and Service Manual to conform to the EPA designation requirements.

TABLE OF CONTENTS

	PAGE
CHAPTER I INTRODUCTION	I-1
A. PRINCIPLE OF OPERATION OF THE GAS FILTER CORRELATION SPECTROMETER	I-4
B. INSTRUMENT DESCRIPTION	I-5
1. Optical Bench	I-6
2. Correlation Wheel and Chopper Motor	I-6
3. Source and Power Supply	I-6
4. Detector, Preamplifier, and Bias Supply	I-6
5. Input Signal Conditioning Board	I-6
6. DC Power Supplies	I-6
7. Microcomputer	I-6
8. Temperature Controller	I-7
9. Flow Components	I-7
10. Temperature and Pressure Transducers	I-7
C. SPECIFICATIONS	I-10
CHAPTER II INSTALLATION	II-1
A. UNPACKING	II-1
B. ASSEMBLY	II-1
C. OPTIONAL EQUIPMENT	II-4
1. Rack Mounting	II-4
2. Teflon Particulate Filter	II-4
3. Remote Activation of Zero, Span, and Sample	II-4

TABLE OF CONTENTS (Continued)

	PAGE
CHAPTER III OPERATION	III-1
A. DESCRIPTION OF CONTROLS	III-1
1. Power Switch	III-1
2. Sample Flow Meter	III-1
3. LED Display	III-1
4. CO Run and Test Mode Entry Pushbuttons	III-1
5. Zero Thumbwheels	III-4
6. Span Thumbwheels	III-4
7. Range Thumbwheels	III-5
8. Time Thumbwheels	III-6
B. START UP	III-7
C. SHUTDOWN	III-8
D. LOSS OF POWER	III-8
E. INTERNAL SWITCHES	III-8
F. HOURLY AVERAGE	III-10
CHAPTER IV CALIBRATION	IV-1
A. EQUIPMENT REQUIRED	IV-1
1. CO Concentration Standard	IV-1
2. Dilution Gas (Zero Air)	IV-1
3. Flowmeter(s) and Controller(s)	IV-2
4. Pressure Regulator for CO Standard Cylinder	IV-2
5. Mixing Chamber	IV-2
6. Output Manifold	IV-2
B. CHECKOUT OF THE MODEL 48 GFC AMBIENT CO ANALYZER	IV-2

TABLE OF CONTENTS (Continued)

	PAGE
C. STEP-BY-STEP CALIBRATION OF THE MODEL 48	IV-2
1. Connecting Instrument	IV-2
2. Zero Adjust	IV-4
3. Span Adjust	IV-4
4. Additional Concentration Standards	IV-5
5. Calibration Curve	IV-5
6. Frequency of Calibration	IV-5
D. PERIODIC ZERO AND SPAN CHECKS	IV-5
CHAPTER V PERIODIC MAINTENANCE AND SERVICE CHECKS	V-1
A. CLEANING OF THE OPTICS.....	V-1
B. SOURCE REPLACEMENT	V-1
C. DETECTOR FREQUENCIES	V-3
D. PRESSURE TRANSDUCER	V-3
E. TEMPERATURE TRANSDUCER	V-3
F. SYSTEM LEAKS AND PUMP CHECK OUT	V-5
G. DIGITAL TO ANALOG CONVERTER TESTS	V-5
CHAPTER VI DESCRIPTION OF ELECTRONICS AND SOFTWARE OF THE MODEL 48	VI-1
A. ELECTRONICS	VI-1
1. DC Power Supplies	VI-1
2. Bias, Source, and Cooler Power Supplies	VI-1
3. Detector and Preamplifier	VI-1
4. Input Signal Conditioning Board	VI-2
5. Microcomputer System	VI-3

TABLE OF CONTENTS (Continued)

	PAGE
a. Microprocessor Board	VI-3
b. Memory Board	VI-4
c. Counter Board	VI-4
d. Peripheral Interface Board	VI-4
e. Display Driver	VI-4
f. Digital/Analog Board	VI-5
g. Switch Board	VI-5
h. Span/Zero Buffer Board	VI-5
6. Temperature Controller	VI-5
B. SOFTWARE	VI-5
CHAPTER VII TROUBLESHOOTING	VII-1
A. TROUBLESHOOTING MODE	VII-1
B. TROUBLESHOOTING CHART	VII-2
CHAPTER VIII CORRECTIVE MAINTENANCE	VIII-1
A. SOURCE REPLACEMENT	VIII-1
B. CORRELATION WHEEL REPLACEMENT	VIII-1
C. CHOPPER MOTOR REPLACEMENT	VIII-4
D. OPTICAL BENCH REPLACEMENT	VIII-4
E. OPTICAL SWITCH REPLACEMENT	VIII-4
F. BENCH HEATER AND BENCH HEATER POWER SUPPLY REPLACEMENT	VIII-5
G. PREAMPLIFIER - DETECTOR ASSEMBLY REPLACEMENT ..	VIII-5
H. PUMP REBUILDING	VIII-5

TABLE OF CONTENTS(Continued)

	PAGE
I. PUMP REPLACEMENT	VIII-7
J. PRESSURE TRANSDUCER REPLACEMENT	VIII-7
K. MICROCOMPUTER ASSEMBLY REPLACEMENT	VIII-7
L. INPUT SIGNAL CONDITIONING BOARD REPLACEMENT ...	VIII-9
M. DC AND BIAS POWER SUPPLY BOARDS REPLACEMENT ...	VIII-9
N. CAPILLARY REMOVAL	VIII-9
O. SOLENOID VALVE REPLACEMENT	VIII-10

Appendices

A. WARRANTY OF MODEL 48	A-1
B. SPARE PARTS AND SERVICING LOCATION	B-1
C. RETURN OF MERCHANDISE	C-1
D. RECOMMENDED SPARE PARTS	D-1
E. SCHEMATICS	E-1
F. REMOTE ACTIVATION OF ZERO, SPAN, AND SAMPLE SOLENOIDS	F-1

LIST OF FIGURES

FIGURE		PAGE
I-1	PHOTO OF MODEL 48	I-2
I-2	BLOCK DIAGRAM OF GAS FILTER CORRELATION SPECTROMETER	I-3
I-3	COMPONENT LAYOUT OF MODEL 48	I-8
I-4	FLOW SCHEMATIC OF MODEL 48	I-9
II-1	REAR VIEW OF MODEL 48	II-2
II-2	RACK MOUNT OPTION ASSEMBLY	II-5
II-3	GENERAL DIMENSIONAL OUTLINE	II-6
III-1	MODEL 48 FRONT PANEL CONTROLS	III-2
III-2	HOURLY AVERAGE OUTPUTS	III-9
IV-1	FLOW SCHEMATIC FOR CALIBRATION OF MODEL 48	IV-3
V-1	ASSEMBLY DRAWING OF MODEL 48 OPTICAL BENCH	V-2
V-2	PRESSURE TRANSDUCER	V-4
V-3	MICROCOMPUTER ELECTRONICS	V-7
VIII-1	OPTICAL BENCH	VIII-2
VIII-2	CHOPPER ASSEMBLY CLOSEUP	VIII-3
VIII-3	PUMP ASSEMBLY DIAGRAM	VIII-6
VIII-4	MICROCOMPUTER ELECTRONICS AND POWER SUPPLY REMOVAL	VIII-8
E-1	DC POWER SUPPLY SCHEMATIC	E-2
E-2	BIAS POWER SUPPLY SCHEMATIC	E-3
E-3	PREAMPLIFIER SCHEMATIC	E-4
E-4	INPUT SIGNAL CONDITIONING SCHEMATIC	E-5
E-4	OSCILLOSCOPE TRACINGS OF TEST POINTS	E-6
E-5	MOTHER BOARD SCHEMATIC	E-7

LIST OF FIGURES (Continued)

FIGURE		PAGE
E-6	PROCESSOR BOARD SCHEMATIC	E-8
E-7	MEMORY BOARD SCHEMATIC	E-9
E-8	COUNTER BOARD SCHEMATIC	E-10
E-9	PERIPHERAL INTERFACE BOARD SCHEMATIC	E-11
E-10	DISPLAY BOARD SCHEMATIC	E-12
E-11	DIGITAL/ANALOG BOARD SCHEMATIC	E-13
E-12	SWITCH BOARD SCHEMATIC	E-14
E-13	BENCH HEATER POWER SUPPLY SCHEMATIC	E-15
E-14	SPAN ZERO BUFFER BOARD SCHEMATIC	E-16
E-15	SIGNAL PROCESSING SYSTEM	E-17
F-1	REAR PANEL BARRIER STRIP	F-3
F-2	INTERFACE/OUTERFACE BOARD INSTALLATION	F-4

CHAPTER I INTRODUCTION

Thermo Environmental Instruments Inc. Model 48 (Figure I-1) Gas Filter Correlation (GFC) CO Ambient Analyzer meets the need for a self-contained analytical instrument capable of measuring ambient CO on a continuous real time basis.

Compared to other types of NDIR (non-dispersive infrared) techniques for measuring ambient levels of CO, the Model 48 offers the following significant advantages:

- Highly specific to CO (high interference rejections)
- Lower ranges with wide dynamic range (suitable for both lower ambient and source applications)
- Linear output through all ranges
- Increased sensitivity
- Long term zero and span stability
- Vibration and shock resistant
- Self-aligning optics
- Dual fully independent analog outputs
- Standard hourly average outputs
- Automatic microcomputer compensation for changes in temperature and pressure
- Powerful internal diagnostics made possible by the microcomputer

The microcomputer circuitry upon which the Model 48 is based eliminates many disadvantages inherent in analog systems and provides for increased stability, accuracy, and flexibility. Digital computations are insensitive to drift with time or temperature, therefore sources of instrument drift or error due to the electronics are minimized.

Because infrared absorption is a non-linear measurement technique, it is necessary for the instrument electronics to transform the basic analyzer signal into a linear output. In instruments employing analog electronics, this is accomplished with an additional circuit which generates a function approximating the basic analyzer's calibration curve over a limited range of gas concentrations. With the Model 48, approximations are not necessary since the exact calibration curve is stored in the computer's memory and is used to accurately linearize the instrument output over any desired range. The Thermo Environmental Instruments Inc. Model 48 is linearized in this way up to a CO concentration of 1000 PPM.

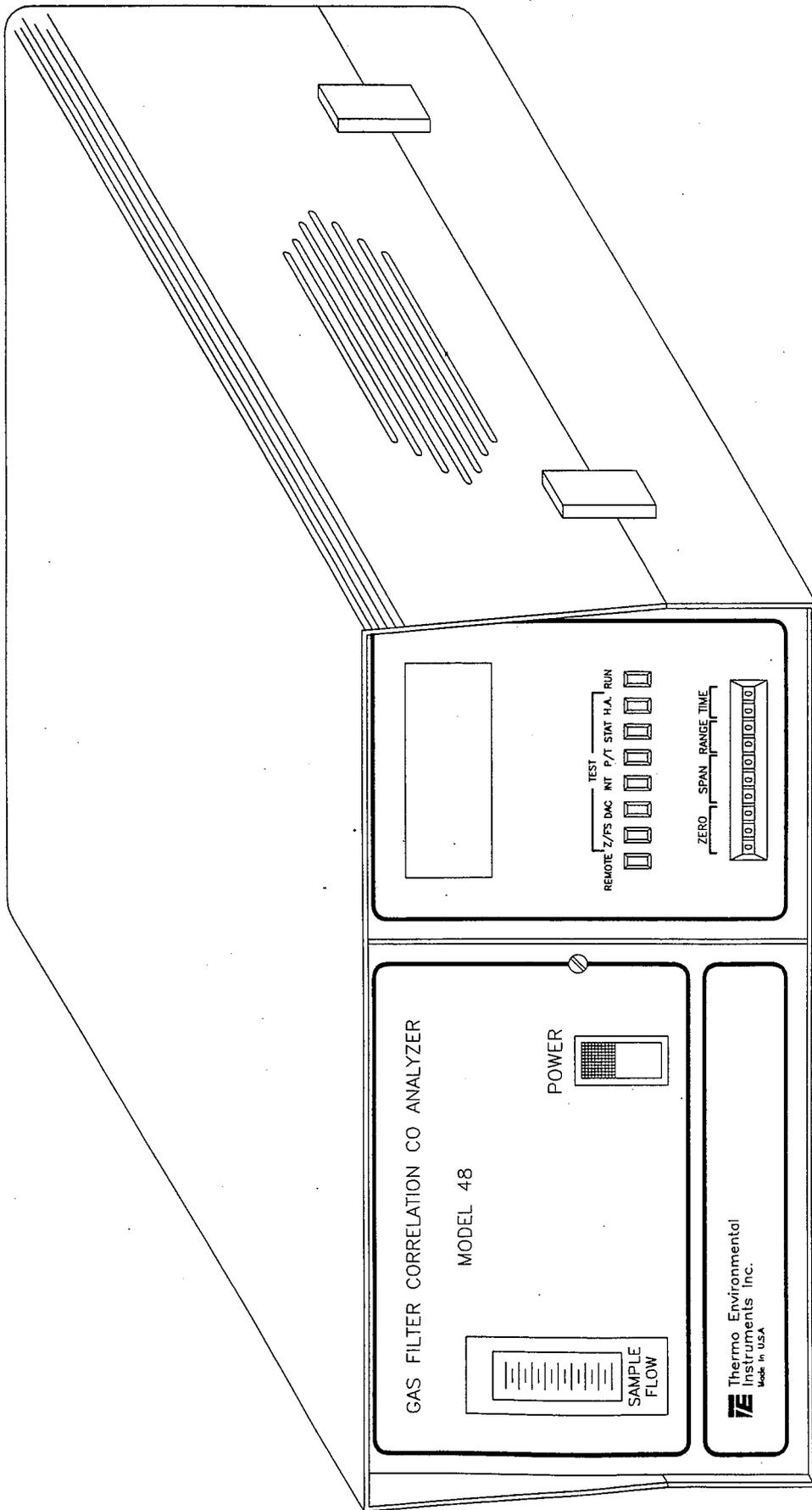


Figure I-1
 Model 48 GFC Ambient CO Analyzer

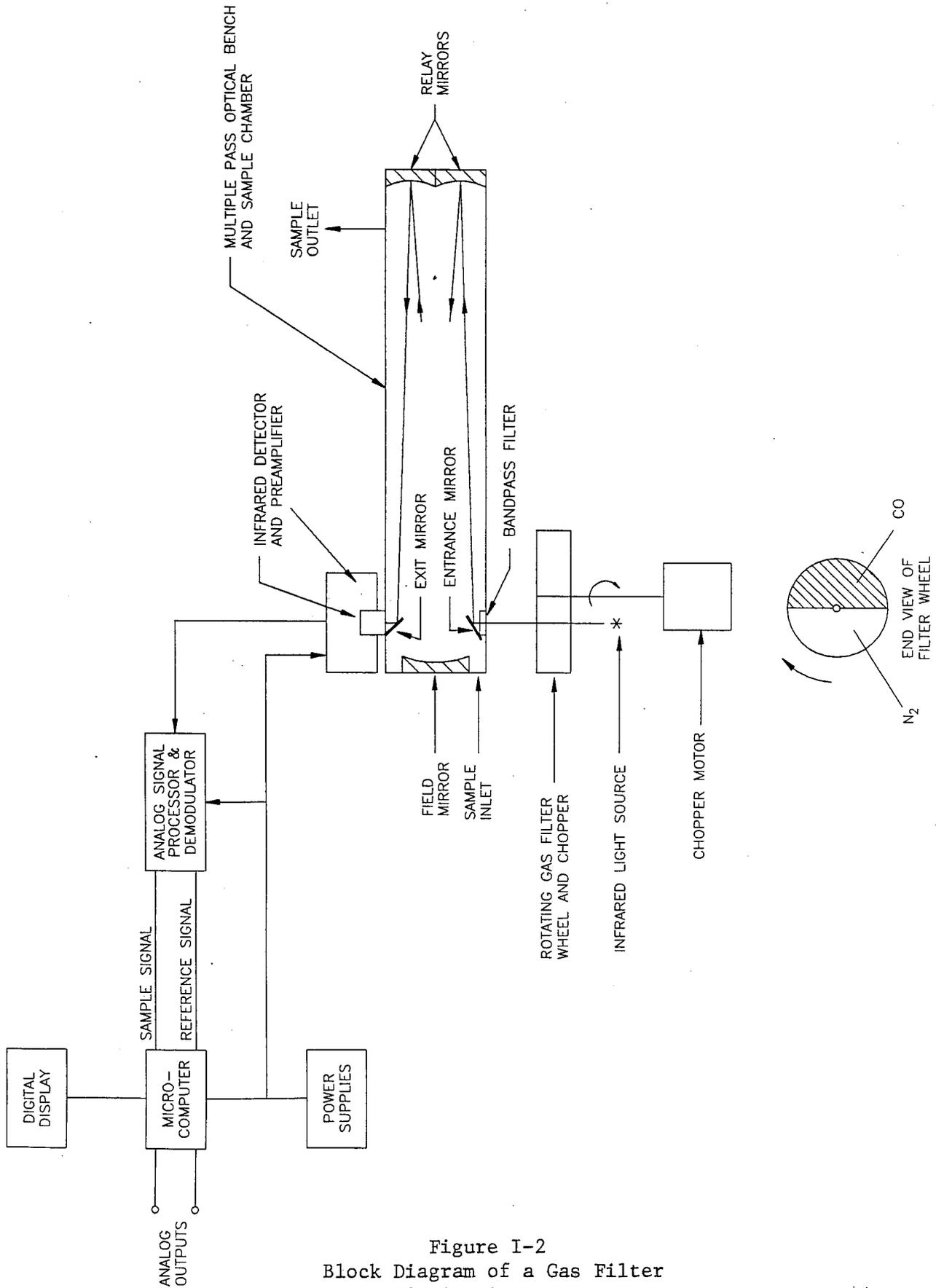


Figure I-2
Block Diagram of a Gas Filter
Correlation Spectrometer

The advantages of the Model 48 are appreciable when compared to analog systems where each correction made to the instrument output requires not only the appropriate transducer, but also a compensation circuit which may need to have a particular non-linear circuit which may need to have a particular non-linear characteristic (as is the case for the effect of pressure and temperature changes on infrared absorption measurements). Analog diagnostic functions also require more circuitry thereby increasing both complexity and cost while decreasing reliability. Data averaging in analog systems is usually done at considerable extra cost with a separate instrument connected to the output of the basic analyzer.

In contrast, the Model 48 has been designed to perform a large variety of tasks by utilizing appropriate information stored in the system's program memory. For example, the micro-computer is used to process signals from both a pressure and temperature transducer to make corrections to the instrument output, resulting in CO concentration measurements which are unaffected by changes in the temperature or pressure of the gas being sampled. Both linear and non-linear corrections are handled with equal ease. In addition, many diagnostic functions can be selected through the use of front panel pushbutton switches (Figure I-1). User selectable program options include: settable time response for data smoothing; one hour averaged value which may be set for continuous output at a standard secondary pair of output terminals, or can be set to interrupt the primary output briefly every hour, or can be de-activated. These options are standard with every instrument and are selected by setting switches on the front panel of the instrument.

Thermo Environmental Instruments Inc. is pleased to have supplied you with a Model 48. We are committed to the manufacture of instruments exhibiting high standards of quality performance, and workmanship. We are prepared and eager to be of service to you in the use of this instrument.

A. PRINCIPLE OF OPERATION OF THE GAS FILTER CORRELATION SPECTROMETER

The technique of Gas Filter Correlation (GFC) offers improved specificity and sensitivity over conventional non-dispersive infrared (NDIR) techniques. GFC spectroscopy is based upon comparison of the detailed structure of the infrared absorption spectrum of the measured gas to that of other gases also present in the sample being analyzed. The technique is implemented by using a high concentration sample of the measured gas, i.e., CO, as a filter for the infrared radiation transmitted through the analyzer, hence the term GFC.

The basic components of the GFC CO spectrometer are shown in Figure I-2. Radiation from an IR source is chopped and then passed through a gas filter alternating between CO and N₂ due to rotation of the filter wheel. The radiation then passes through a narrow bandpass interference filter and enters a multiple optical pass cell where absorption by the sample gas occurs. The IR radiation then exits the sample cell and falls on an IR detector.

The CO gas filter acts to produce a reference beam which cannot be further attenuated by CO in the sample cell. The N₂ side of the filter wheel is transparent to the IR radiation and therefore produces a measure beam which can be absorbed by CO in the cell. The chopped detector signal is modulated by the alternation between the two gas filters with an amplitude related to the concentration of CO in the sample cell. Other gases do not cause modulation of the detector signal since they absorb the reference and measure beams equally. Thus the GFC system responds specifically to CO.

With the improved rejection of interferences afforded by the GFC technique, it is possible to increase the sensitivity of the analyzer. This is achieved by the multiple pass optics (White Cell) used in the sample cell which leads to a large path length, and thus an improved sensitivity, in a small physical space. This allows full scale sensitivity down to 1 PPM with a lower detectable limit (LDL) of 0.1 PPM to be achieved.

B. INSTRUMENT DESCRIPTION

The instrument can be most conveniently discussed by separating it into the following operational components (Figure I-3):

1. Optical bench
2. Correlation wheel and chopper motor
3. Source and source power supply
4. Detector, preamplifier, and bias supplies
5. Input signal conditioning board
6. DC power supply
7. Microcomputer
8. Temperature controller
9. Flow components (pump, valves, flowmeter, and plumbing)
10. Temperature and pressure transducers

1. Optical Bench (Figures I-2 and 3) - The optical bench is of the White Cell design. The use of the White Cell multipass optical bench allows one to achieve a long path length, with a large acceptance angle, in a small physical package. The bench has been designed for easy disassembly for cleaning. The source, detector, correlation wheel, and chopper motor mount rigidly to the bench. No realignment should be necessary after routine cleaning.

2. Correlation Wheel and Chopper Motor - The correlation wheel consists of two hemispherical cells, one filled with CO and the other with N₂. Integral with the correlation wheel is the chopper pattern necessary to produce the high frequency (360 Hz) chop necessary for the infrared detector. The correlation wheel is rotated by a synchronous motor.

3. Source and Power Supply - The infrared source is a special wire wound resistor. It is heated by passing a highly regulated DC voltage through the resistor. Replacement, when necessary, is straightforward.

4. Detector, Preamplifier, and Bias Supply - The detector used on the Model 48 is a solid state device with an integral cooler. It is mounted directly onto the optical bench. The output of the detector is fed into a preamplifier (Figure I-3) prior to its transmission to the input signal conditioning board. The bias voltage necessary to operate the detector is generated by a separate bias voltage power supply.

5. Input Signal Conditioning Board - The input signal conditioning board takes the output signal from the preamplifier, and separates the signal into two components, one component being the signal coming from the CO half of the correlation cell, the other due to the N₂ half of the correlation cell. This board includes the sensors and associated circuitry for determination of the wheel position, as well as an AGC (automatic gain control) circuit. Finally, it contains two V-F's (voltage to frequency) converters to digitize the two signals.

6. DC Power Supplies - The DC power supply board generates the necessary regulated DC voltages. In addition, it contains the driving circuitry for the solenoids.

7. Microcomputer - The microcomputer on the Thermo Environmental Instruments Inc. GFC CO Ambient Analyzer is based upon the Motorola 6800 family. The pulse train outputs of the input signal conditioning board feed directly into computer controlled counters. In addition, the pulse train output of the pressure transducer and the temperature transducer system are fed directly to the same computer controlled counter.

The software operates on this information to determine the CO concentration, to output diagnostic data, and to output the computed CO concentration to the front panel digital display and rear panel analog recorder jacks. The software contains sophisticated algorithms to minimize noise, increase sensitivity, insure that the output is linear, to correct for changes in ambient temperature and pressure, and to check for malfunctions.

8. Temperature Controller - The Model 48 contains a temperature transducer to measure the temperature and to correct for ambient temperature changes. However, in order to insure that the optical bench is above the dew point to avoid water condensation, the optical bench is operated at a temperature slightly above ambient. Meaningful output data will be generated even if the bench has not stabilized.

9. Flow Components - The Model 48 operates at normal atmospheric pressure. Figure I-4 summarizes the flow schematic. A downstream pump and capillary control the sample flow through the optical bench, which is monitored by a rotameter. The nominal flow is 1 liter per minute, with values between 1/2 - 2 liters per minute acceptable.

The span, zero, and sample solenoids are operated by successive engagements of the RUN pushbutton on the front panel. The control signals for the solenoids go through the microcomputer.

10. Temperature and Pressure Transducer - Temperature and pressure must be measured if one wants to compensate for changes in ambient values. The pressure is measured by a strain gauge pressure transducer. The temperature is measured by a thermistor.

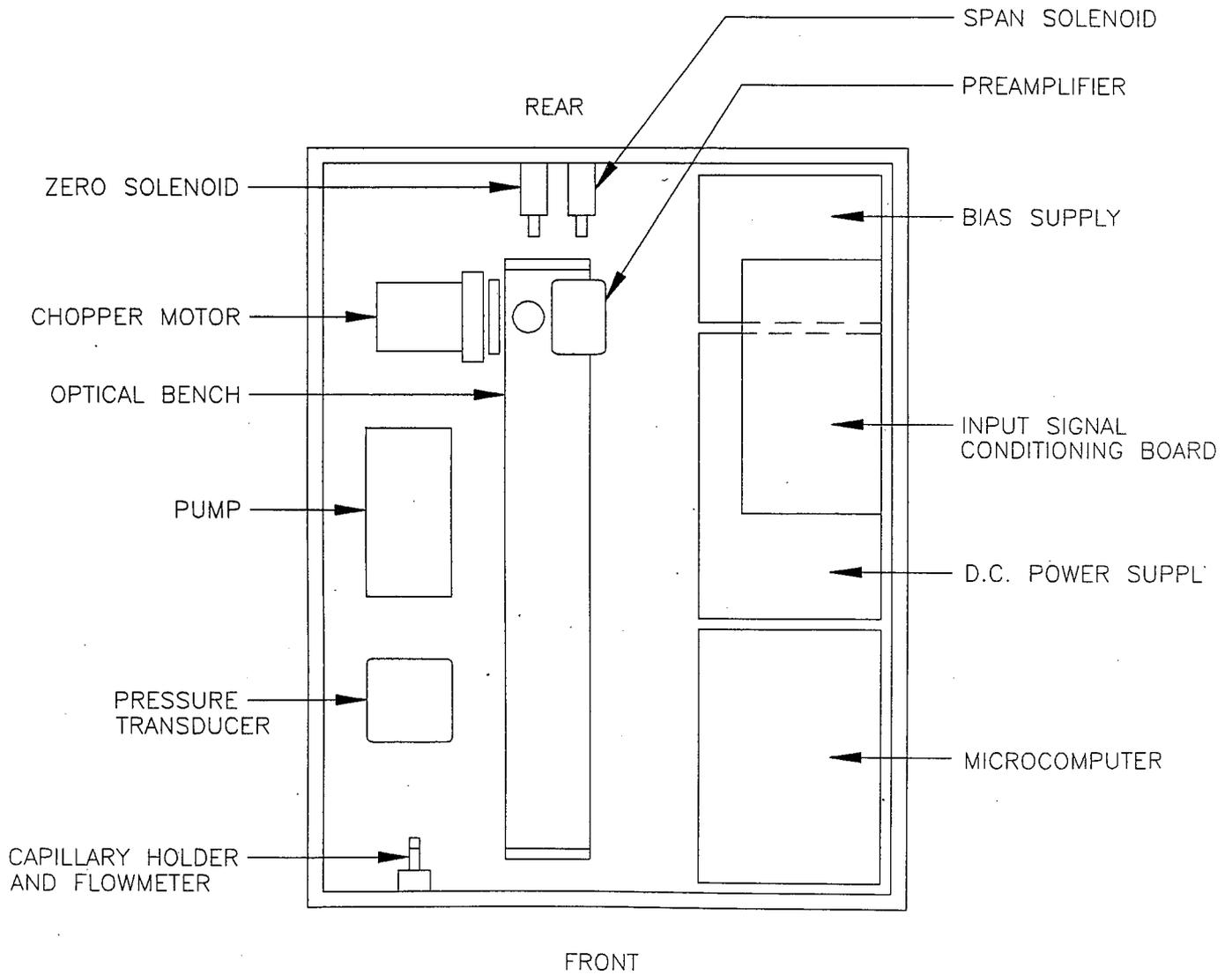


Figure I-3
Component Layout

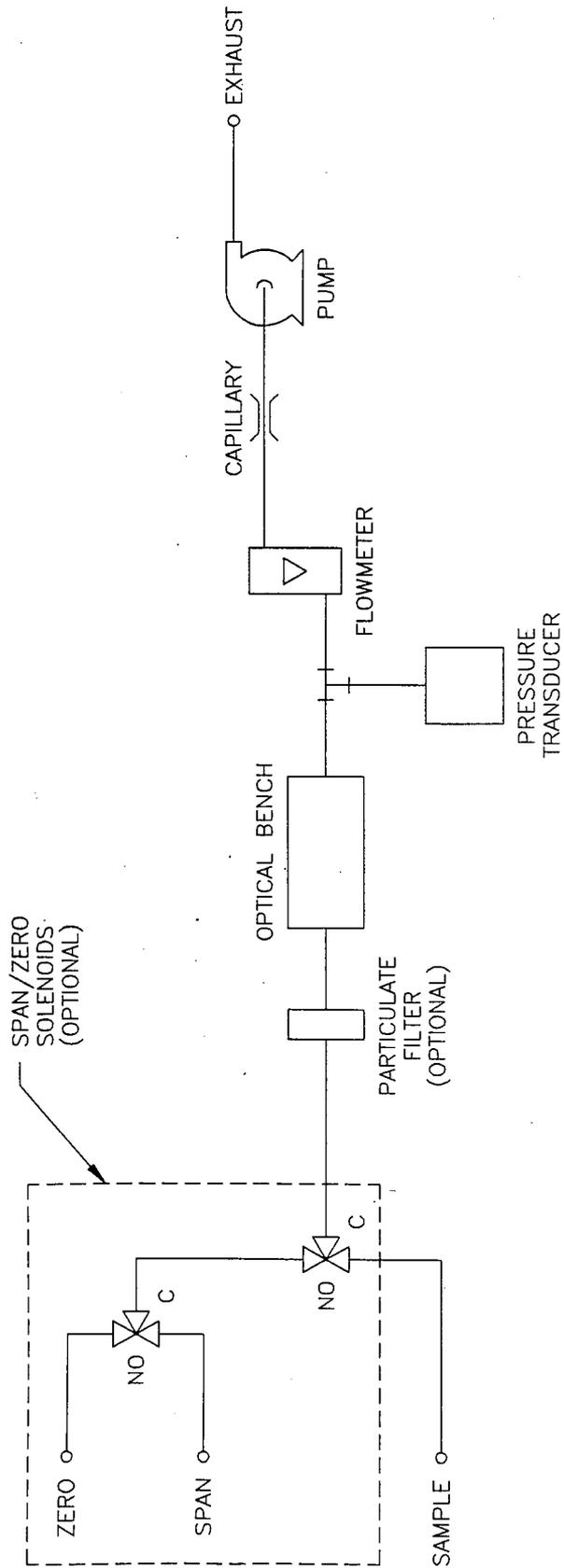


Figure I-4
Flow Schematic of Model 48