Ref. #15.

Rating = C
pg. Back-up data lacking.

15 '78

In Response To The Future

* same unit as ref. #16 / ref. 17 data more complete & will be used.

TRANSMITTAL COVER SHEET

need L+S FR & markup.

ENVIRONMENTAL SCIENCE SERVICES
532 Atwells Avenue
Providence, RI 02909
Fax (401) 421-5731

Date: 31/5/94

From: Dave Adelman

Please deliver the following pages to:

Name: Bob Pollack

Company: EPA

Telecopy Number: (713) 551-0454 Pages: 16 Including cover sheet

Remarks:

Bob,

Attached is a draft of the Engine 5 test. The Appendix (about 25 pages) are not included. Call if you have any questions or comments.

Thanks
Dave

If you do not receive all of the pages or if any are unclear, please notify the sender as soon as possible at (401) 421-0398.

DRAFT

FINAL TEST REPORT FOR:
NORTHEAST LANDFILL
POWER-JOINT VENTURE
ENGINE NO. 5 AT THE
RHODE ISLAND CENTRAL LANDFILL
JOHNSTON, RHODE ISLAND

Prepared By:

Environmental Science Services
532 Atwells Avenue
Providence, RI 02909
(ESS Project #W030)

Author	Reviewer
Calculations Checked by	Air Group Manager

May 31, 1994

TEST PROTOCOL

Facility Name:	Johnston Central Landfill Johnston, Rhode Island
Facility Contact:	Mr. Greg Pawlina (401) 943-5560
Testing Organization:	Environmental Science Services 532 Atwells Avenue Providence, RI 02909 (401) 421-0398
Project Manager:	John DeGirolamo
Test Personnel:	John DeGirolamo Larry McNulty Ken Otis Shiva Prasad
Unit Tested:	Landfill Gas Fueled Engine No. 5 Serial No. 401451
Test Date:	May 25, 1994

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Appendix A Test Data Forms
Appendix B Process Data Forms
Appendix C ESS CEM Specifications

DRAFT

1.0 INTRODUCTION

Environmental Science Services, Inc. (ESS) performed an emissions test program at the Northeast Landfill Power-Joint Venture's Johnston, Rhode Island facility. The objective of this program was to conduct the required compliance tests on the emissions from Engine No. 5 (Serial Number 401451) at the Rhode Island Central Landfill powerhouse. The engine is fired with landfill gas.

Testing included the measurement of a variety of emissions from the engine exhaust stack. The following parameters were tested: carbon monoxide, oxides of nitrogen, and total nonmethane hydrocarbons. All test methods were taken from 40 CFR 60 Appendix A and conformed to the requirements of 40 CFR 86 Subpart D. All testing took place on May 25, 1994.

Engine No. 5 must be re-certified for carbon monoxide (CO) before it can be operated. The Rhode Island Department of Environmental Management (RIDEM) requires, however, that emissions of nitrogen oxides (NO_x) and non-methane hydrocarbons (NMHC) must also be determined in conjunction with emissions of CO.

An emissions test was performed on this engine on May 21, 1993. A roots meter was used to measure engine fuel consumption. This method was employed because of the ease with which fuel consumption can be measured in comparison to direct measurement because of test location restrictions. However, calculating exhaust stack flow from fuel consumption relies on using assumptions in the calculation. For this test, an extension was added and exhaust flow was measured directly using a type "S" pitot tube and inclined manometer. Moisture measurements were also made using US EPA RM 4.

DRAFT

2.0 SUMMARY OF RESULTS

During this test, the engine was maintained at a load of 1,680 to 1,700 KW, which represents full load conditions (over 97% of design).

The emission limits are as follows:

1. NO_X: the emission rate from each engine shall not exceed 1.25 grams/brake horsepower-hour(g/BHP-HR) or a maximum of 6.6 lbs/hr, whichever is more stringent.

2. CO: the emission rate from each engine shall not exceed 2.0 g/BHP-HR or a maximum of 10.58 lbs/hr, whichever is more stringent.

3. NMHC: the emission rate from each engine shall not exceed 0.5 g/BHP-HR or a maximum of 2.6 lbs/hr, whichever is more stringent.

All emission rates were found to be within these limits. Results of the test are summarized in Table 2-1.

DRAFT

Table 2-1

Summary of Measured Pollutant Emissions
Engine No. 5
Northeast Landfill Power - Joint Venture
Johnston, Rhode Island
May 25, 1994

Run No.: Date: Time:	TEST - 1 5/25/94 0900-1000	TEST-2 5/25/94 1025-1125	TEST-3 5/25/94 1330-1430	Avg.
Sample Conditions				
Volume (DSCF)[a]	42.370	42.528	39.220	41.373
Impinger catch (g)	82.3	119.8	114.0	105.4
Stack Conditions				
Flowrate (DSCFM)[b]	4,720	4,530	4,540	4,580
Temperature (°F)	681	684	687	684
Moisture (%)	8.4	11.7	12.0	10.7
Oxygen (%)	8.9	8.7	8.8	8.8
Carbon Dioxide (%)	10.6	10.7	10.7	10.7
Engine Load (KW)	1,680	1,680	1,700	1,686
Pollutant Emissions				
Concentration (ppm)				
CO	393.6	383.2	389.4	388.7
NO_x	64.8	65.8	66.7	65.8
NMHC	< 1.0	5.6	< 1.0	2.5
Emission Rate (lb/hr)[c]				
CO	8.1	7.6	7.7	7.8
NO_x as NO_2	2.2	2.1	2.2	2.2
NMHC as C_3H_8	< 0.03	0.17	< 0.03	0.008
Emission Rate (g/BHP.hour)[d]				
CO	1.5	1.4	1.4	1.4
NO_x as NO_2	0.41	0.39	0.41	0.40
NMHC as C_3H_8	< 0.005	0.032	< 0.005	0.014

[a]) dry standard cubic feet (68°F, 29.92 in Hg)
[b]) dry standard cubic feet per minute
[c]) pounds per hour = concentration (ppm) x molecular weight x DSCFM x 15.58 x 10^{-3}
[d]) grams per brake horsepower hour = (lb/hr)/(horsepower x 0.00225); horsepower = (KW) X (1.4105)

$2.5 ppm\ C_3H_8 \times \frac{3}{5} = 1.25 ppm\ as\ C_6$

$C_6 = C_3 \times 2.5$

DRAFT

3.0 FACILITY DESCRIPTION

The Johnston, Rhode Island Central Landfill powerhouse contains eight engine/generator units whose purpose is to convert the gas produced in the landfill into useful electrical energy. The engine of concern is Engine No. 5. It is a Waukesha 12V-AT25GL lean combustion, low emission engine with 9.8 inch bore x 11.81 inch stroke and 10784 cubic inches displacement. This engine is rated at 1720KWe at 900 RPM. At 96% generator efficiency this is 2400 BHP. The engines are adjusted to run on landfill gas. Specified engine settings are 17 degrees BTDC spark timing and 8.6% +/- 0.2% exhaust oxygen level. Crankcase breather gases are injected into the exhaust stream using compressor bleed air.

Each engine drives a Kato Model A24862001 generator rated at 1700 kilowatts at 4160 volts. Switchgear was manufactured by Point Eight and voltage regulators by Basler.

Fuel gas treatment is accomplished with a modified Bio Gas Development (BGD) and refrigeration system. After leaving the building, each exhaust stream is directed upward through a 60 inch O.D. silencer.

4.0 TEST PROGRAM

The following Reference Methods from 40 CFR 60, Appendix A were used to determine the compliance status of the engine. Both the engine and generator were operated at full load during this test. The sampling duration for all tests was sixty minutes.

EPA Method 1	-	Sample and Velocity Traverses for Stationary Sources.
EPA Method 2	-	Determination of Stack Gas Velocity and Volumetric Flowrate (Type S Pitot Tube, type K thermocouple).
EPA Method 3A	-	Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrumental Analyzer Procedure).
EPA Method 4	-	Determination of Moisture Content in Stack Gases.
EPA Method 7E	-	Determination of Nitrogen Oxide Emissions from Stationary Sources (CEM technique).
EPA Method 10	-	Determination of Carbon Monoxide Emissions from Stationary Sources (CEM technique).
EPA Method 18	-	Determination of Non-methane Hydrocarbons Emissions Using an Semi-Continuous Gas Chromatograph (FID) Technique.
EPA Method 25A	-	Determination of Total Volatile Organic compounds (Continuous FID Analyzer Method).

Continuous monitoring and sample recovery for all testing was performed in the ESS mobile laboratory which was maintained on site during the test.

4.1 Sampling Locations and Flow Rate Determination

Emission concentration measurements were made in the engine exhaust immediately below (upstream from) the exhaust stack muffler. The exit velocity was measured by S type pitot tube down stream from the muffler by adding a stack extension to the top of the stack with two test ports.

The inside diameter of the stack is 24 inches. An extension was flanged to the top of the stack for testing. The extension was made of 16 inch thin wall pipe. This size was used for two reasons. the smaller diameter was used in order to reduce height requirements (in comparison to using a 24" pipe). This size pipe was also used so as not to exceed the back pressure requirements of the engine. The inside diameter of the extension was 15-1/2 inches. The test ports were located 10-1/3 feet from the top of the existing stack which is 8 stack diameters down stream from any flow disturbances. The total length of the added section was 13.5 feet. The test ports were located two stack diameters upstream of any exit flow disturbance. Traverse point locations are presented in Appendix A. Two 2-inch diameter ports were located 90° from each other.

Flow measurements were made during each test run. Flow measurements were made at a total of 12 points in the stack, 6 points per traverse. The test location was checked for cyclonic flow conditions prior to the start of the first test. Cyclonic flow was not present.

4.2 Molecular Weight (Fixed Gas) Determination

The composition of the engine exhaust was determined for oxygen and carbon dioxide during each test run in accordance with EPA Method 3A. Oxygen concentrations were measured using a Horiba Model PMA-200 O_2 analyzer. Carbon dioxide concentrations were made using a Horiba Model PIR-200 CO_2 analyzer.

4.3 Moisture

Stack gas moisture was determined in accordance with EPA Method 4 by drawing exhaust gas through a series of chilled impingers using a Method 4 sampling train. The moisture gain in the impingers was used to calculate the moisture concentration of the exhaust gas.

4.4 Emissions Testing (CO, NO_x, NMHC)

The CEM sample system consists of an in-stack glass fiber filter and heated stainless steel probe. A heated Teflon line connects the probe to the sample conditioner which removes excess moisture and particulate matter for CO and NO_x measurements. A separate sample line heated to 150 °C is used for THC and CH_4 sampling. No moisture removal is performed prior to THC analysis. An in-line particulate matter filter is used to protect the sampling equipment and analyzer. A Teflon line connects the sample conditioner to a pump which supplies the sample gas to the analyzers under positive pressure. The instrument readings were recorded on a Data Acquisition System and strip chart recorder with start and stop times noted. All instruments are housed in an environmentally controlled mobile laboratory that was positioned as close as practical to the sampling location. A schematic of the CEM sampling system is presented in Figures 4.1 and 4.2.

CO and NO_x measurements were made with a TECO Model 48 NDIR Analyzer and TECO Model 42H Chemiluminescent Analyzer respectively. These analyzers are mounted in the mobile laboratory along with the other gas analyzers. All analyzers are guaranteed by the manufacturer to meet applicable EPA performance specifications.

Total hydrocarbon concentrations were measured following EPA Method 25A. A Thermo Electron Corp. (TECO) Model 51 Hydrocarbon analyzer equipped with a heated Flame Ionization detector (FID) was used.

Methane concentrations were measured following EPA Method 18. Periodic injections of stack gas were made to an HNU Model 321 Gas Chromatograph equipped with a flame ionization detector (FID).

Total non-methane hydrocarbons were determined by subtracting total methane determined by Method 18 from total methane equivalents determined by Method 25A.

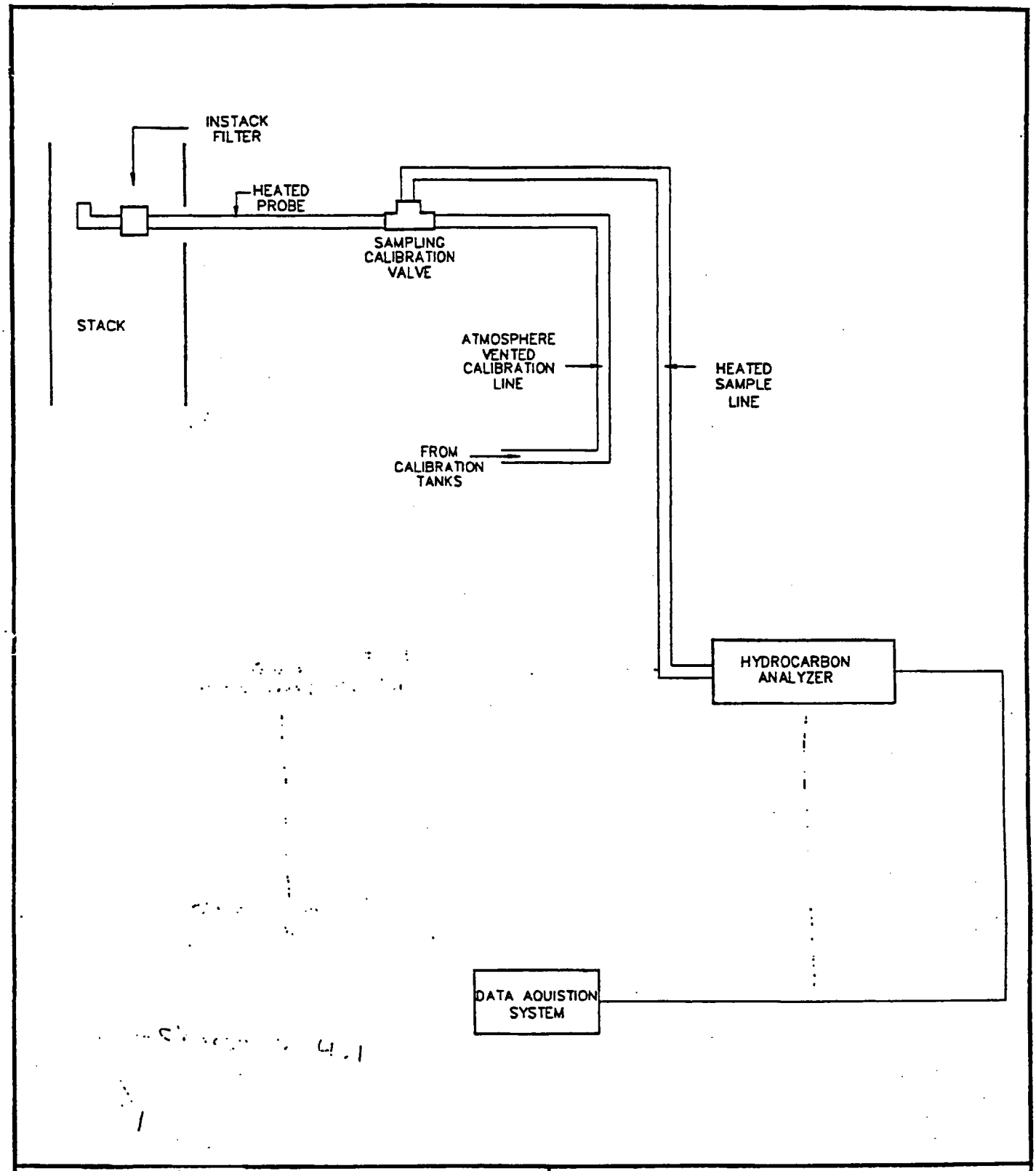

Figure 3.1

ESS CEM Sampling
Hot/Wet Train Schematic

ENVIRONMENTAL SCIENTISTS, ENGINEERS, AND ANALYTICAL LABORATORY

ENVIRONMENTAL SCIENCE SERVICES

PROVIDENCE, RHODE ISLAND 02909 (401) 421-0398

SCALE: None DATE: January, 1994

CEMB

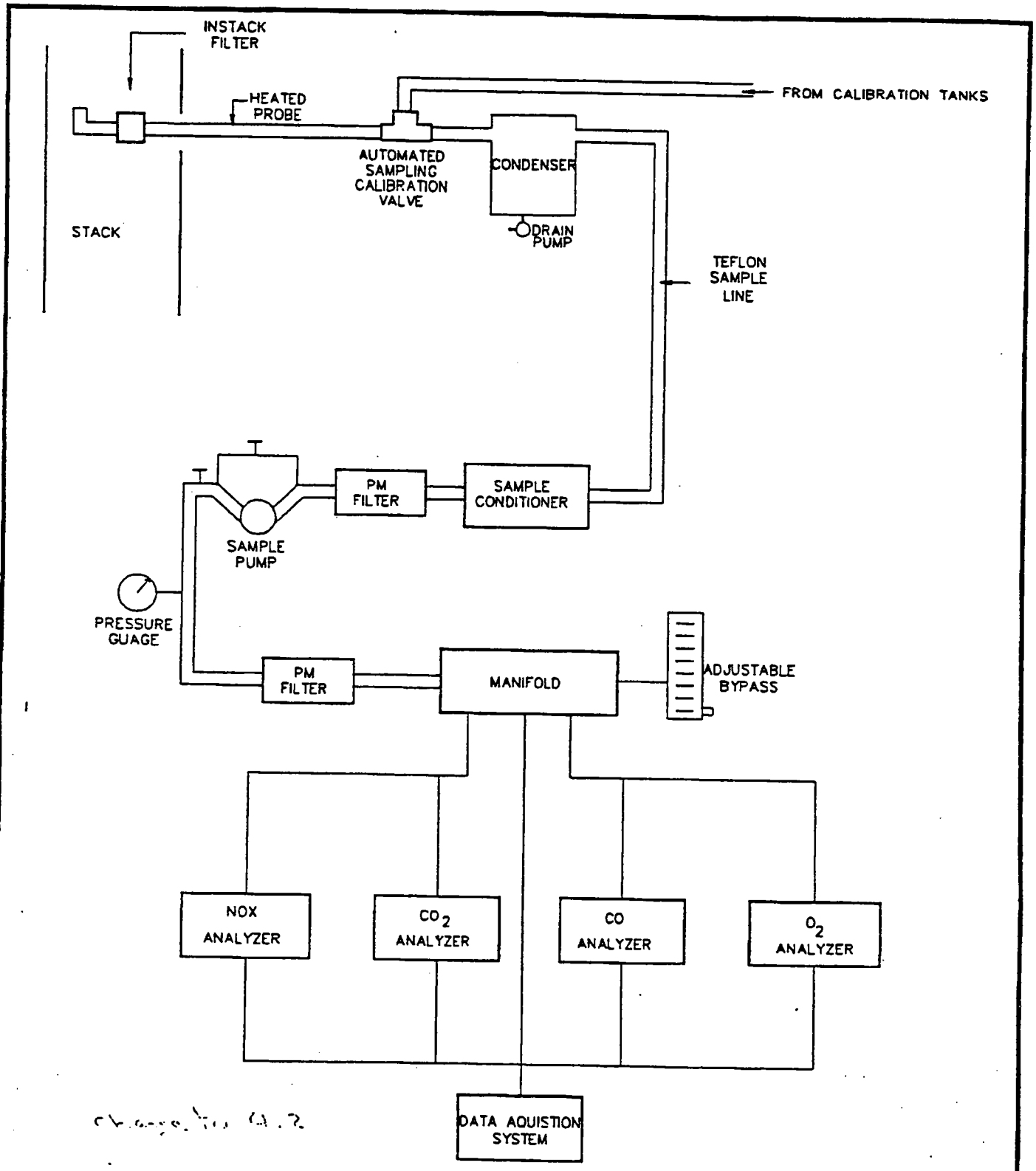

Figure 3.2

ESS CEM Sampling

Cold/Dry Train Schematic

ENVIRONMENTAL SCIENTISTS, ENGINEERS, AND ANALYTICAL LABORATORY

ENVIRONMENTAL SCIENCE SERVICES

PROVIDENCE, RHODE ISLAND 02909 (401) 421-0398

Not to Scale

DATE: October, 1993
REVISED: February, 1994

CDMC

5.0 QA/QC MEASURES

Environmental Science Services is committed to providing high quality testing services. To meet this commitment, ESS follows EPA sampling procedures and implements QA/QC procedures with all test programs. Each team member is qualified and has experience conducting the tests assigned to him.

All reports undergo a two tier review. The initial review of the report and calculations is performed by the project manager or the originator of the calculations. A second detailed review is then performed by a senior engineer or group manager not affiliated with the project.

The calibration of all applicable manual sampling equipment follows the QA/QC procedures in 40 CFR 60, the EPA "Quality Assurance Handbook", Volume III, APTA0576, and all applicable equipment manufacturers procedures. Where sampling procedures differ from standard EPA Methods, these variations are noted.

5.1 Test Methods

The sampling equipment associated with the manual source sampling methods are calibrated at the ESS equipment laboratory before transport to the field. Calibrations are checked in the laboratory after the test at field operated rates and highest field operating vacuums.

Calibration documentation is provided prior to testing. The following specific Quality Control measures are used:

CEM calibration gases are traceable to the NIST in accordance with EPA Protocol 1.

Orsat measurements for CO_2 and O_2 are made in triplicate.

5.2 Data Reporting

All data is reported in clear easy to read tables. The results are reported in the units given in the permit. Any variations from a test protocol are not made without proper authorization from the Division.

Ref #16

Rating = A

Engines: CO
NOx
NMOC.

Same Unit tested
in ref. #15

TEST REPORT FOR:
NORTHEAST LANDFILL POWER
JOINT VENTURE
AT THE
RHODE ISLAND CENTRAL LANDFILL
JOHNSTON, RHODE ISLAND

Prepared By:

Environmental Science Services
532 Atwells Avenue
Providence, RI 02909
(ESS Project #W014)

June 11, 1993

Good Sampling Calcs.

TEST PROTOCOL

Facility Name:	Johnston Central Landfill Johnston, Rhode Island
Facility Contact:	Mr. Robert Wilson (401) 943-5560
Testing Organization:	Environmental Science Services 532 Atwells Avenue Providence, RI 02909 (401) 421-0398
Project Manager:	Dave Adelman
Test Personnel:	John DeGirolamo Shiva Prasad
Unit Tested:	Landfill Gas Fueled Engine #5
Test Date:	May 21, 1993

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APPENDICES

Appendix A: Process and Test Data

Appendix B: ESS CEM Output and Calibration

Appendix C: Calculations

Appendix D: CEM Specifications

1.0 INTRODUCTION

Environmental Science Services, Inc. (ESS) was retained by Northeast Landfill Power Joint Venture to perform an emission test program at their Johnston, Rhode Island facility. The objective of this program was to conduct the required compliance tests on the emissions from Engine No. 5 (Serial No. 401451) at the Rhode Island Central Landfill powerhouse. The engine is fired with landfill gas.

The test program involved the measurement of a variety of emissions from the engine exhaust stack. The following parameters were tested: oxygen, carbon monoxide, carbon dioxide, oxides of nitrogen, methene, and total nonmethane hydrocarbons. All test methods were taken from 40 CFR 60 Appendix A and conformed to the requirements of 40 CFR 86 Subpart D. A test protocol was submitted to the Rhode Island DEM on April 8, 1993 and the protocol was approved on May 3, 1993. All testing took place on May 21, 1993. Tests were observed by Mr. Richard Evans of DEM.

Facility Description

The Johnston, Rhode Island Central Landfill powerhouse contains eight engine/ generator units whose purpose is to convert the gas produced in the landfill into useful electrical energy. The engine of concern, Engine No. 5., is a Waukesha 12V-AT25GL lean combustion, low emission engine with 9.8 inch bore x 11.81 inch stroke and 10784 cubic inches displacement. This engine is rated at 1720 KWe at 900 RPM. At 96% generator efficiency this is 2400 BHP. The engines are adjusted to run on landfill gas. Specified engine settings are 17 degrees BTDC spark timing and 8.6% +/- 0.2% exhaust oxygen level. Crankcase breather gases are injected into the exhaust stream using compressor bleed air.

Each engine drives a Kato Model A24862001 generator rated at 1700 kilowatts at 4160 volts. Switchgear was manufactured by Point Eight and voltage regulators by Basler.

Fuel gas treatment is accomplished with a modified Bio Gas Development (BGD) unit and refrigeration system. After leaving the building, each exhaust stream is directed upward through a 60 inch O.D. silencer.

Engine No. 5 must be re-certified for carbon monoxide (CO) before it can be operated. The Rhode Island Department of Environmental Management (RIDEM) requires, however, that nitrogen oxides (NOx) and non-methane hydrocarbons (NMHC) also be monitored.

The emission limits are as follows:

1. NOx: The emission rate from each engine shall not exceed 1.25 grams/brake horsepower-hour(g/BHP-HR) or a maximum of 6.6 lbs/hr, whichever is more stringent.
2. CO: The emission rate from each engine shall not exceed 2.0 g/BHP-HR or a maximum of 10.58 lbs/hr, whichever is more stringent.
3. NMHC: The emission rate from each engine shall not exceed 0.5 g/BHP-HR or a maximum of 2.6 lbs/hr, whichever is more stringent.

2.0 RESULTS

The emission test on engine No. 5 was conducted on May 21, 1993. The results for the test are summarized in Table 2.1 and shows that the engine is in compliance with the permit emission limits for the three specified parameters. The emission rate calculations are shown in detail in Appendix C along with a sample calculation. Table 2.2 shows the various precursor data.

TABLE 2.1

Summary of Engine No. 5 Emission Rates.
Rhode Island Central Landfill Powerhouse
Johnston, Rhode Island
May 21, 1993

Compound	Units	Test #1 9:20 – 10:20	Test #2 11:20 – 12:20	Test #3 13:00 – 14:00	Average	Permit Limit
NOx as NO2	g / bhp–hr	0.40	0.41	0.41	0.40	1.25
	lbs / hr	2.09	2.15	2.16	2.14	6.61
CO	g / bhp–hr	2.0	1.9	1.8	1.9	2.0
	lbs / hr	10.83	10.16	9.36	10.11	10.58
NMHC	g / bhp–hr	<0.02	<0.02	<0.02	<0.02	0.5
	lbs / hr	0.09	0.08	0.08	0.08	2.65

fuel flow = 199 CFM.
(199 ft³/min)(.5441 CH_4) = 108.3 ft^3 CH_4/min.

TABLE 2.2

Summary of Engine No. 5 Emission Concentrations.
Rhode Island Central Landfill Powerhouse
Johnston, Rhode Island
May 21, 1993

Parameters	Test No. 1	Test No. 2	Test No. 3	
Test Time:	9:20 – 10:20	11:20 – 12:20	13:00 – 14:00	Avg
Exhaust Conc				
CO (ppm)	390.9	385.4	370.8	
NOx (ppm)	46.0	49.7	52.2	
O2 (%)	10.2	9.5	9.0	
CO2 (%)	9.9	9.9	10.1	
THC (ppm)	10.6	53.4	871.9	
NMHC (ppm)	<5.0	<5.0	<5.0	
Exhaust Flow (lb/hr)	31810.4	30221.5	28950.7	30,327.5

Note: CO and NOx Conc are quantified as ppm dry.
THC and NMHC Conc are quantified as ppm wet.
CO2 and O2 Conc are quantified as % dry.

$$\text{NMOC eff.} = \frac{53.6\ \text{lb/hr} - 0.08\ \text{lb/hr}}{53.6\ \text{lb/hr}} = 99.85\%.$$

see calcs. for determ. of NMOC Input.

FFR = 2664.5 lb/hr.

3.0 SAMPLING AND ANALYSIS METHODS

The following Reference Methods from 40 CFR 60, Appendix A were used to determine the compliance status of the facility. The sampling duration for each of the three tests conducted was sixty minutes.

Positive Displacement Rootsmeter	-	Determination of Inlet Gas Volumetric Flow Rate
EPA Method 3A	-	Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrumental Analyzer Procedure).
EPA Method 7E	-	Determination of Nitrogen Oxides Emissions from Stationary Sources (Instrumental Analyzer Procedure).
EPA Method 10	-	Determination of Carbon Monoxide Emissions from Stationary Sources (Instrument technique).
EPA Method 18	-	Measurement of gaseous organic compound emissions by Gas Chromatography.

Instrumentation for all tests was housed in the ESS mobile laboratory.

3.1 Sampling Locations and Flow Rate Determination

Emission concentration measurements were made in the engine exhaust immediately below (upstream from) the exhaust stack muffler. As in past tests on these engines, volumetric flowrate measurements cannot be directly made at this location. The exhaust gas flowrate was instead measured indirectly. A Rootsmeter was installed in-line as during the June 4-7, 1991, test program to measure the fuel gas volumetric flowrate. The exhaust flowrate was then calculated by mass balance, using the known

fuel gas composition and the measured exhaust concentrations of CO_2, CO, O_2. These calculations are shown in Appendix C.

3.2 Molecular Weight (Fixed Gas) Determination

The composition of the engine exhaust was determined by analyzing continuous samples of stack gas for oxygen and carbon dioxide collected during each test run in accordance with EPA Method 3A.

3.3 CEM Testing (CO, NOx, NMHC)

The CEM sampling system consisted of an in-stack glass fiber filter and heated stainless steel probe. A heated Teflon line connected the probe to a sample conditioner which removed excess moisture and particulate matter (the conditioner was by-passed for NMHC measurement). A Teflon line connecting the sample conditioner to a pump supplied the sample gas to the CO, NOx, and NMHC analyzers under positive pressure. The instrument readings were recorded on a data acquisition system and strip chart recorder with start and stop times noted.

CO and NO_x concentrations were continuously measured during three 60-minute time periods. Stack gas was withdrawn from the centroid of the stack.

NO_x concentration was measured in accordance with EPA Method 7E. A Thermo Environmental (TECO) Model 42H Chemiluminescent Analyzer measured the concentration of nitric oxide (NO) and total oxides of nitrogen (NOx) in the gas sample, by the chemiluminescent reaction between NO and ozone. Instrument calibrations were performed with EPA Protocol 1 certified gases at concentrations of zero and approximately 50 and 90 percent of a predetermined operation range.

Carbon monoxide concentrations were measured in accordance with EPA Method 10. A TECO Model 48 CO analyzer which uses a non-dispersive infrared (NDIR) method and a gas filter correlation (GFC) technique was used. Calibration of the CO analyzer was performed as per the description for NOx Method 7E using EPA Protocol 1 certified gases.

EPA Method 18 was used for the determination of non-methane hydrocarbons. With this method, a gas tight syringe was used to inject gas into a heated sample loop on a HNU 321 gas chromatograph (GC). The column on the GC was a 5% SP-1200/1.75% Bentone 34 on 100/120 SUPELCOPORT. The injector/detector temperature was 110°C and the temperature of the column was 90°C. The carrier gas used was nitrogen at a flowrate of 35 ml/min. Periodic (approximately every 5 minutes) injections into the GC were made from the CEMS continuous stream. The GC was equipped with a heated injection valve and a flame ionization detector (FID), and was calibrated with Protocol 1 propane-in-air compressed gas standards. The methane concentration in the exhaust gas was specifically quantified, and all other peaks eluting from the GC column were summed together and quantified as methane. This calculation was done by using a multiplication factor of 3 for the peak concentration observed. Output from the GC went to a strip chart recorder and a computer (for accurate integration of peak areas).

A schematic representation of the CEM sampling system is presented in Figure 3.1.

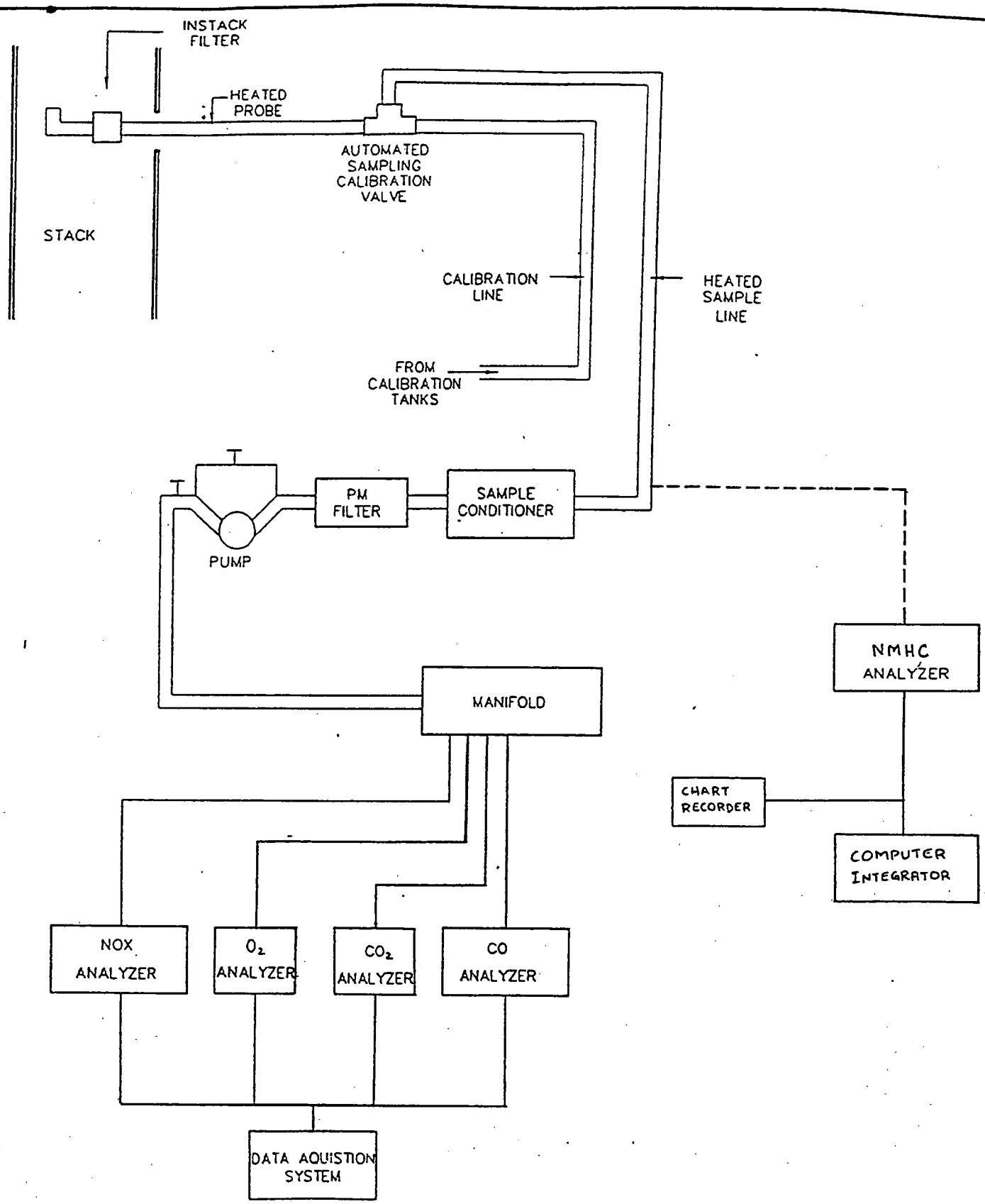


Figure 3.1

ESS CEM Sampling Train Schematic

ENVIRONMENTAL SCIENTISTS, ENGINEERS, AND ANALYTICAL LABORATORY

ENVIRONMENTAL SCIENCE SERVICES

PROVIDENCE, RHODE ISLAND 02909 (401) 421-0199

4.0 QA/QC MEASURES

Environmental Science Services is committed to providing high quality testing services. To meet this commitment, ESS follows EPA sampling procedures and implements QA/QC procedures with all test programs. Each team member is qualified and has experience conducting the test(s) assigned to them.

All reports have undergone a three tier review. The initial review of the report and calculations were performed by the project manager or the originator of the calculations and a second detailed review was then performed by a second senior staff member not involved with the project. A final review was then performed by the Air Group manager prior to issuing this final report.

The calibration of all applicable manual sampling equipment generally follow the QA/QC procedures in 40 CFR 60, the EPA "Quality Assurance Handbook", Volume III, APTA0576, and all applicable equipment manufacturers procedures. Where sampling procedures differ from standard EPA Methods, these variations have been noted.

The sampling equipment associated with the manual source sampling methods were calibrated at the ESS equipment laboratory before transporting them to the field. Calibrations were checked in the laboratory after the tests at field operating rates and the highest field operated vacuums. The following specific Quality Control measures were followed:

CEM calibration gases are traceable to the NIST in accordance with EPA Protocol 1. All instruments were calibrated in the field prior to and following the tests.

Calibration documentation for the Rootsmeter was provided by the supplier of the Rootsmeter. The calibration document is provided in Appendix B.

Inlet gas analysis was performed by Atlantic Analytical Labs.

APPENDIX A

PROCESS AND TEST DATA

FIELD DATA RECORDING SHEET
WPI TESTING

READING										
SPEED - RPM	900	900	900	900	900					
LOAD - KWc	1600	1610	1600	1616	1610					
BHP @ 96%										
GAS TEMP - °F	75	76	76	76	77					
GAS PRESSURE PSIG	45	45	45	45	45					
OBS FT^3	-			200	200					
OBS TIME MIN.	1:13	1:14	1:13	1:13	1:12.4					
SLHV										
BSFC BTU / BHP-HR										
ENGINE EXH, TEMP. - °F	1047	1045	1045	1045	1045					
FUEL G/A "Hg										
INTAKE MANIF/PRESS - PSIG	20	20	20	20	20					
OIL PRESS. PSIG	43	43	43	43	43					
OIL TEMP. °F	185	185	185	185	185					
WATER TEMP °F	220	220	220	220	220					
AUX. WATER TEMP. - °F	115	115	115	115	115					
INTAKE MANIF. TEMP. - °F	121	121	122	122	122					
FUEL RATE LO/MIN										
TIME	9:20	9:35	9:50	10:05	10:20					

Observer(s)_____ Room No._____ Barometer_____ Date 5/21/93
Subject_____ Sheet No. _____

FDRS/WPI

FIELD DATA RECORDING SHEET
WPI TESTING

READING										
SPEED - RPM	902	902	902	902	902					
LOAD - KWc	1635	1675	1660	1649	1690					
BHP @ 96%										
GAS TEMP - °F	84°	84°	83°	81	83					
GAS PRESSURE PSIG	44.4	44.4	44.5	44.5	44.5					
OBS FT³	200	200	200	200	200					
OBS TIME MIN	1.13	1.28	1.14.2	1.13	1.13.9					
SLHV										
BSFC BTU / BHP-HR										
ENGINE EXH, TEMP. - °F	908°	910°	908°	908°	905°					
FUEL G/A "Hg										
INTAKE MANIF/PRESS - PSIG	19	21	19	20	19					
OIL PRESS. PSIG	43	43	43	43	43					
OIL TEMP. °F	180°	180°	180°	180°	180°					
WATER TEMP °F	222°	222°	222°	223°	223°					
AUX. WATER TEMP. - °F	119°	119°	119°	115°	117°					
INTAKE MANIF. TEMP. - °F	120	122	118	129	121					
FUEL RATE LO/MIN										
TIME	11.20	11.35	11.50	12.05	12.20					

Observer(s) E.A.G. Room No._____ Barometer_____ Date 5/21/93

Subject_____ Sheet No._____

FDRS/WPI

FIELD DATA RECORDING SHEET
WPI TESTING

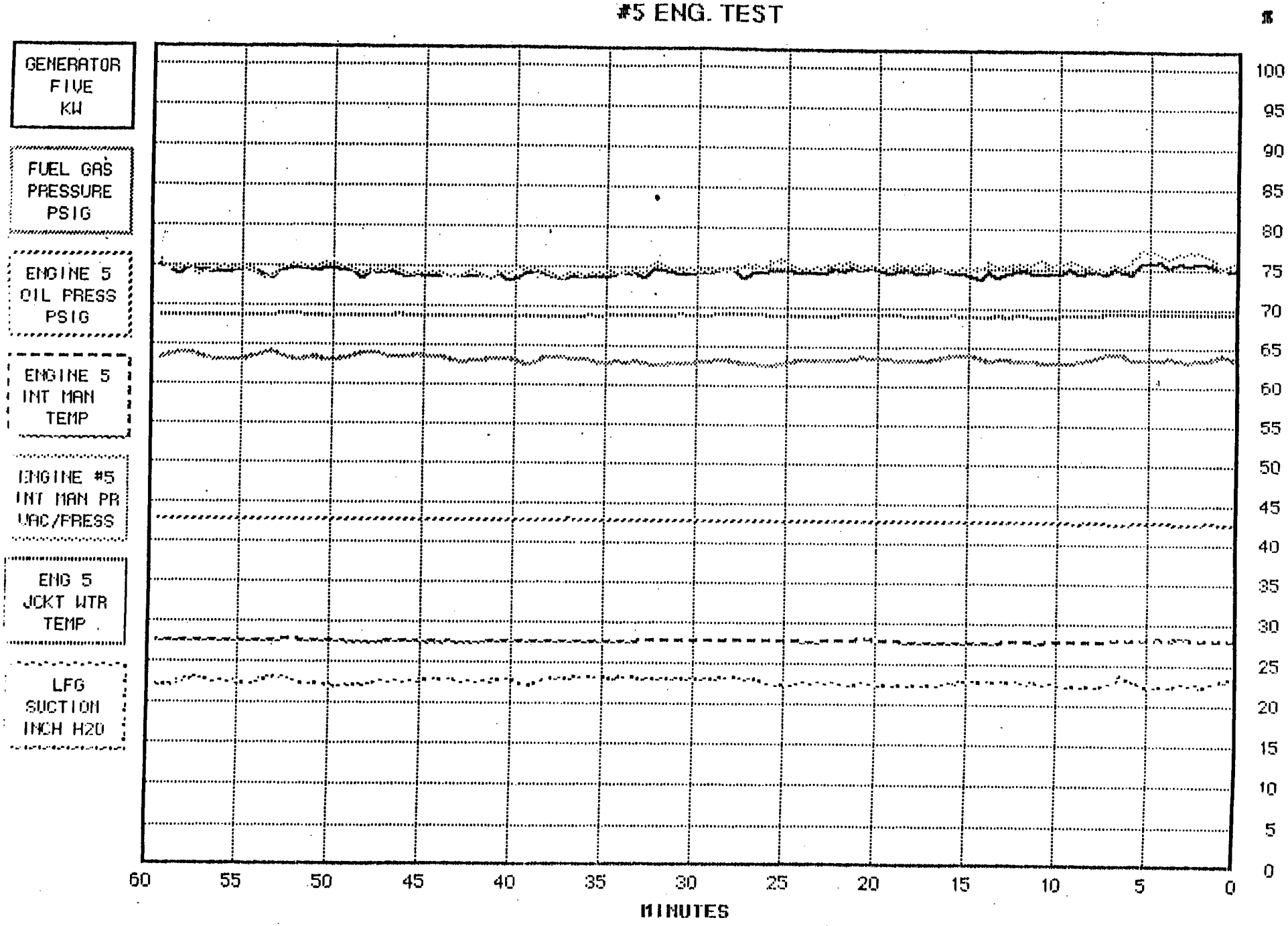
READING										
SPEED - RPM	902	902	902	902	902					
LOAD - KWc	1630	1654	1630	1653	1670					
BHP @ 96%										
GAS TEMP - °F	84°	84°	83°	85°	84°					
GAS PRESSURE PSIG	44.4	44.7	44.3	44.4	44.5					
OBS FT³	200	200	200	200	200					
OBS TIME MIN	1128	113.47	113.1	1.14.1	113.39					
SLHV										
BSFC BTU / BHP-HR										
ENGINE EXH, TEMP. - °F	910	910	910	910	910					
FUEL G/A "Hg										
INTAKE MANIF/PRESS - PSIG	18	19	19	19	19					
OIL PRESS. PSIG	43	43°	43°	43°	43°					
OIL TEMP. °F	185°	185°	185°	185°	185°					
WATER TEMP °F	222°	222°	222°	223	224					
AUX. WATER TEMP. - °F	115°	115°	115°	115°	115°					
INTAKE MANIF. TEMP. - °F	119°	119°	119°	120	121					
FUEL RATE LO/MIN										
TIME	1:00	1:15	1:30	1:45	200					

Observer(s) EG Room No. _____ Barometer _____ Date 5/21/93

Subject _____ Sheet No. _____

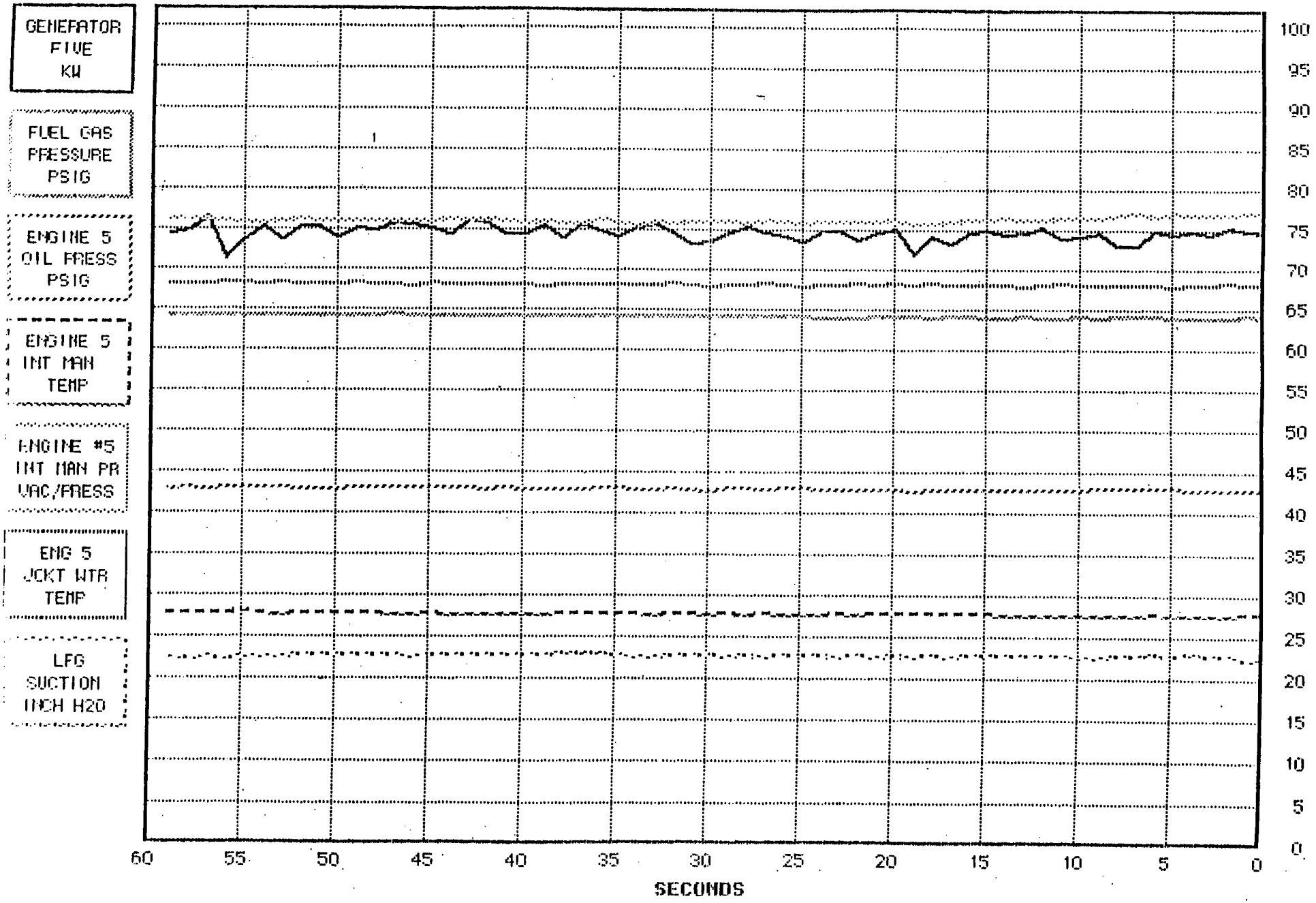
FDRS/WPI

#5 ENG. TEST



Cyl. Temp. Avgs. & Eng. Comparisons	Fri, May 21, 1993	2:01:58 PM

#5 ENG. TEST



Cyl. Temp. Avgs. & Eng. Comparisons	Fri, May 21, 1993	9:40:32 AM

ATLANTIC
ANALYTICAL
LABORATORY

Mr. Charles Zhang
Environmental Science Services
532 Atwells Avenue
Providence, RI 02909

Report No. AAL-9194
Date Requested 05-24-93
Date Reported 06-01-93
P.O. No. 01314

Material Submitted: One Landfill Gas Sample in a 500cc Stainless Steel Cylinder

Information Requested: Gas Chromatography Analysis

Notebook: SS101,p72-73;SS097,p132-133

Results are reported on the following page.

k0601

Bruce J. Gollob

FAX: 401-421-5731

Environmental Science Services Report No. AAL-9194

Results of Analysis

Constituent	Concentration % by Volume
Methane	54.4100
Ethane	0.011 = 110 ppm
Propane	0.0083 = 83 ppm
Isobutane	ND 0.0020
n Butane	ND 0.0020
Isopentane	ND 0.0020
n Pentane	ND 0.0020
Hexane	0.0078 = 78 ppm
Carbon dioxide	40.67
Nitrogen	4.89
Net BTU/CuFt	497
Gross BTU/CuFt	552
Specific Gravity	0.971

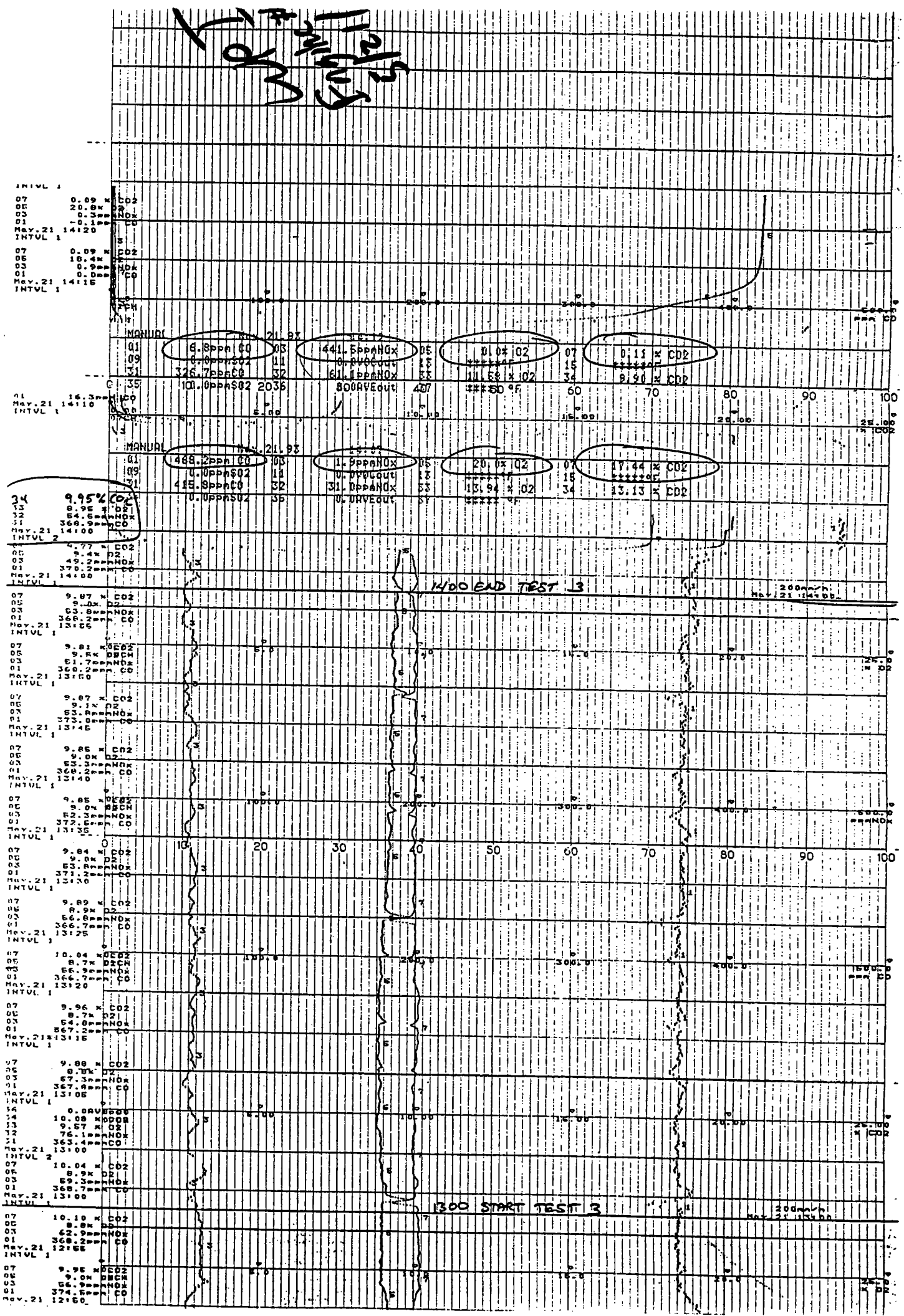
0.037 balance is assumed NMOC

BTU values at 60 F and 14.73 psia.

NMOC = Cannot be determined from the above analysis.

ATLANTIC ANALYTICAL LABORATORY, INC.
P.O. BOX 220 • SALEM INDUSTRIAL PARK • BUILDING #4 • WHITEHOUSE, N.J. 08888
PHONE 908-534-5600 • FAX 908-534-2017

ATLANTIC ANALYTICAL LABORATORY


1400 END TEST 3
1300 START TEST 3
MANUAL
6.8ppm CO
0.0ppmSO2
326.7ppmCO
100.0ppmSO2 2036
441.5ppmNOx
0.0VOCout
61.1ppmNOx
800AVEout
0.10% O2
11.5% x O2
50 °F
0.11 % CO2
9.90 % CO2
MANUAL
488.2ppm CO
0.0ppmSO2
415.8ppmCO
0.0ppmSO2
1.9ppmNOx
0.0VOCout
31.0ppmNOx
0.0AVEout
20.0% O2
13.94 % O2
17.44 % CO2
13.13 % CO2
9.95% CO2

215-691-2474
FAX # 215-758-8384

LIQUID CARBONIC
SPECIALTY GAS CORPORATION
EAST COAST REGION
145 SHIMERSVILLE RD., BETHLEHEM, PA 18015

CERTIFICATE OF ANALYSIS / EPA PROTOCOL GAS

CUSTOMER S/T SLATERSVILLE P.O NUMBER

REFERENCE STANDARD

COMPONENT	NIST SRM NO.	CYLINDER NO.	CONCENTRATION
NITRIC OXIDE	1684B	CLH-002038	94.7 PPM

ANALYZER READINGS

R=REFERENCE STANDARD *Z=ZERO GAS* *C=GAS CANDIDATE*

1. COMPONENT NITRIC OXIDE ANALYZER MAKE-MODEL-S/N THERMO ENV 14A SN/14A-35387-250

ANALYTICAL PRINCIPLE CHEMILUMINESCENCE LAST CALIBRATION DATE 06/30/92

FIRST ANALYSIS DATE 6/16/92				SECOND ANALYSIS DATE 6/30/92			
Z 0.0 PPM	R 88.8 PPM	C 79.2 PPM	CONC. 87.5 PPM	Z 0.0 PPM	R 81.6 PPM	C 72.8 PPM	CONC. 87.5 PPM
R 88.6 PPM	Z 0.0 PPM	C 79.1 PPM	CONC. 87.6 PPM	R 81.3 PPM	Z 0.0 PPM	C 72.5 PPM	CONC. 87.5 PPM
Z 0.0 PPM	C 79.0 PPM	R 88.6 PPM	CONC. 87.5 PPM	Z 0.0 PPM	C 72.1 PPM	R 80.9 PPM	CONC. 87.4 PPM
U/M PPM		MEAN TEST ASSAY	87.5 PPM	U/M PPM		MEAN TEST ASSAY	87.5 PPM

THIS CYLINDER NO. SA-1144
HAS BEEN CERTIFIED ACCORDING TO SECTION 3.0.4
OF TRACEABILITY PROTOCOL NO. 1
PROCEDURE G1
CERTIFIED ACCURACY ± 1.0 % NIST TRACEABLE
CYLINDER PRESSURE 2000 PSIG
CERTIFICATION DATE 06/30/92
EXPIRATION DATE 12/30/93

CERTIFIED CONCENTRATION
NITRIC OXIDE 87.5 PPM
NITROGEN BALANCE

ANALYZED BY KEVIN BRADY

CERTIFIED BY BILL CAFFERTY

215-691-2474
FAX # 215-758-8384

LIQUID CARBONIC
SPECIALTY GAS CORPORATION
EAST COAST REGION
145 SHIMERSVILLE RD., BETHLEHEM, PA 18015

CERTIFICATE OF ANALYSIS / EPA PROTOCOL GAS

CUSTOMER S/T SLATERSVILLE

P.O NUMBER

REFERENCE STANDARD

COMPONENT	NIST SRM NO.	CYLINDER NO.	CONCENTRATION
NITRIC OXIDE	1686b	CLM000851	489 PPM

ANALYZER READINGS

R=REFERENCE STANDARD *Z=ZERO GAS* *C=GAS CANDIDATE*

1. COMPONENT NITRIC OXIDE ANALYZER MAKE-MODEL-S/N THERMO ENV 14A SN:14A-35387-250

ANALYTICAL PRINCIPLE CHEMILUMINESCENCE LAST CALIBRATION DATE 07/09/92

FIRST ANALYSIS DATE 07/01/92 SECOND ANALYSIS DATE 07/09/92

Z	0.0	R	432.0	C	373.8	CONC.	428.3	Z	0.0	R	379.0	C	329.5	CONC.	430.3
R	431.0	Z	0.0	C	377.2	CONC.	433.2	R	378.6	Z	0.0	C	328.8	CONC.	429.9
Z	0.0	C	376.8	R	429.9	CONC.	433.9	Z	0.0	C	329.5	R	378.8	CONC.	429.9
U/M	PPM			MEAN TEST ASSAY			431.8	U/M	PPM			MEAN TEST ASSAY			430.0

THIS CYLINDER NO. SA-3988
HAS BEEN CERTIFIED ACCORDING TO SECTION 3.0.4
OF TRACEABILITY PROTOCOL NO. 1
PROCEDURE G1
CERTIFIED ACCURACY ± 1.0 % NIST TRACEABLE
CYLINDER PRESSURE 2000 PSIG
CERTIFICATION DATE 7/ 9/92
EXPIRATION DATE 1/ 9/94

CERTIFIED CONCENTRATION

NITRIC OXIDE	430.9 PPM
NITROGEN	BALANCE

ANALYZED BY KEVIN BRADY

CERTIFIED BY BILL CAFFERTY

Scott Specialty Gases

2330 Hamilton Blvd South Plainfield NJ
PHONE 908-754-7700 FAX 908-754-7303

CERTIFICATION OF ANALYSIS-EPA PROTOCOL

Date Shipped 11-24-1992 Our Project 0718135 Your P.O. 01773
Certified per Protocol#1 Procedure 3.0.4-G1 Top Pressure 2000psig
Cylinder # ALM015730 REFERENCE STD GAS ANALYZER

MINOR comp.	CERT. conc.	CRM/SRM num	CYL. num	STD conc.	MAKE/ model	LAST cal.	ANAL prin.
Carbon Dioxide	17.9%+/-1%	1675	ALM1140	14.02 %	Varian 3700-31608928-9/3/92-GC TCD		
Carbon Monoxide	475ppm+/-1%	1681	ALM010486	967 ppm	Ecolyzer 2000-1709-11/1/92- Electrochemical		
Oxygen	20.0%+/-1%	2659	AAL18592	20.66 %	Varian 3700-31608928-9/14/92- GC TCD		

BALANCE Nitrogen EXPIRES 5-24-1993

ANALYZER READINGS

Component	*First Analysis*	*Second Analysis*
Carbon Dioxide	*Date: 11-24-1992 Mean test assay 17.9*	
all values as %	*Zero= 0 Ref.= 14.02 Test=17.9*	
	Ref.= 14.02 Zero= 0 Test=17.9	
	Zero= 0 Test=17.8 Ref.= 14.02	
Carbon Monoxide	*Date: 11-16-1992 Mean test assay 475*	*Date: 11-24-1992 Mean test assay 475*
all values as ppm	*Zero= 0 Ref.= 967 Test=475*	*Zero= 0 Ref.= 967 Test=475*
	Ref.= 967 Zero= 0 Test=475	*Ref= 967 Zero= 0 test=475*
	Zero= 0 Test=475 Ref.= 967	*Zero= 0 Test= 475 Ref.= 967*
Oxygen	*Date: 11-24-1992 Mean test assay 20*	
all values as %	*Zero= 0 Ref.= 20.66 Test=20.0*	
	Ref.= 20.66 Zero= 0 Test=20.0	
	Zero= 0 Test=19.9 Ref.= 20.66	

ANALYST adela sy APPROVED BY john o'shea

CONTINUOUS EMISSION MONITORING DATA SHEET
EPA Methods 3A, 6C, 7E, 10, and 25A

Firm Name Waukesha Pierce
Site Location Johnston RI
Test Number Test 3
Source Engine #5 exhaust
Date 5/21/93

Testers JDD, SP
Ambient Temp. 75
Bar. Press. 30.24
Sample Press. 9" H_2O
Time 1300-1400

Analyzer	Range		Rack Cal.	Pre Test Sys. Cal	Cal. Bias % of span	Post Test Sys. Cal.	Cal. Bias % of span	Drift % of span
CO	0-500 ppm	zero	0.0	8.3	1.7	6.8	1.4	0.3
		upscale	472.3	472.7	0.1	468.2	0.8	0.9
NO_x	0-500 ppm	zero	0.5	2.9	0.4	1.9	0.3	0.1
		upscale	436.4	423.7	1.5	441.5	1.0	2.5
O_2	0-25%	zero	0.0	0.1	0.4	0.0	0.0	0.4
		upscale	19.9	19.5	1.6	20.0	0.4	2.0
CO_2	0-25%	zero	0.03	0.15	0.9	0.11	0.3	0.6
		upscale	17.76	17.76	0.0	17.44	1.3	1.3
		zero						
		upscale	CO	NO_x	O_2	CO_2		
AVERAGES		zero	7.6	2.4	0.05	0.13		
		upscale	470.4	432.6	19.75	17.60		
					+/- 5%		+/- 5%	+/- 3%

Average Analyzer Response	Actul Gas Conc.
368.9	370.8
54.5	52.2
8.95	9.0
9.95	10.1

Actual Gas Conc.= (Cavg−Co)(Ctk/(Cup−Co))
Cavg= average analyzer response
Co = average zero response
Cup =average upscale response
Ctk =actual tank conc.

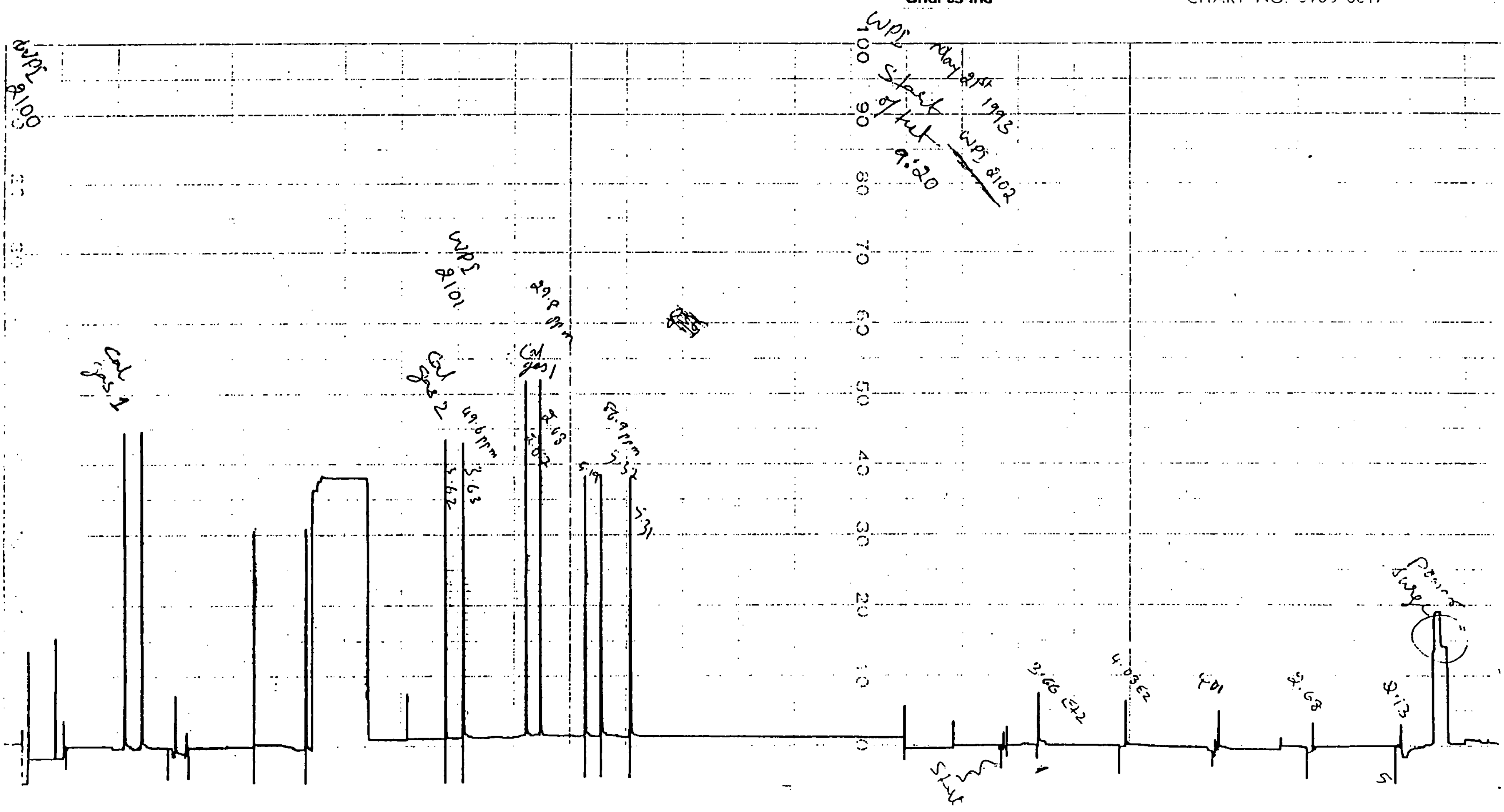
Leak Check = oxygen zero <0.5% O2
Cal. Bias < 5%

Calibration Gasses

Gas	Conc.	Tank NO.
	See Test #1	

Gas	Conc.	Tank NO.

Charts-Inc CHART NO. 0100-0017



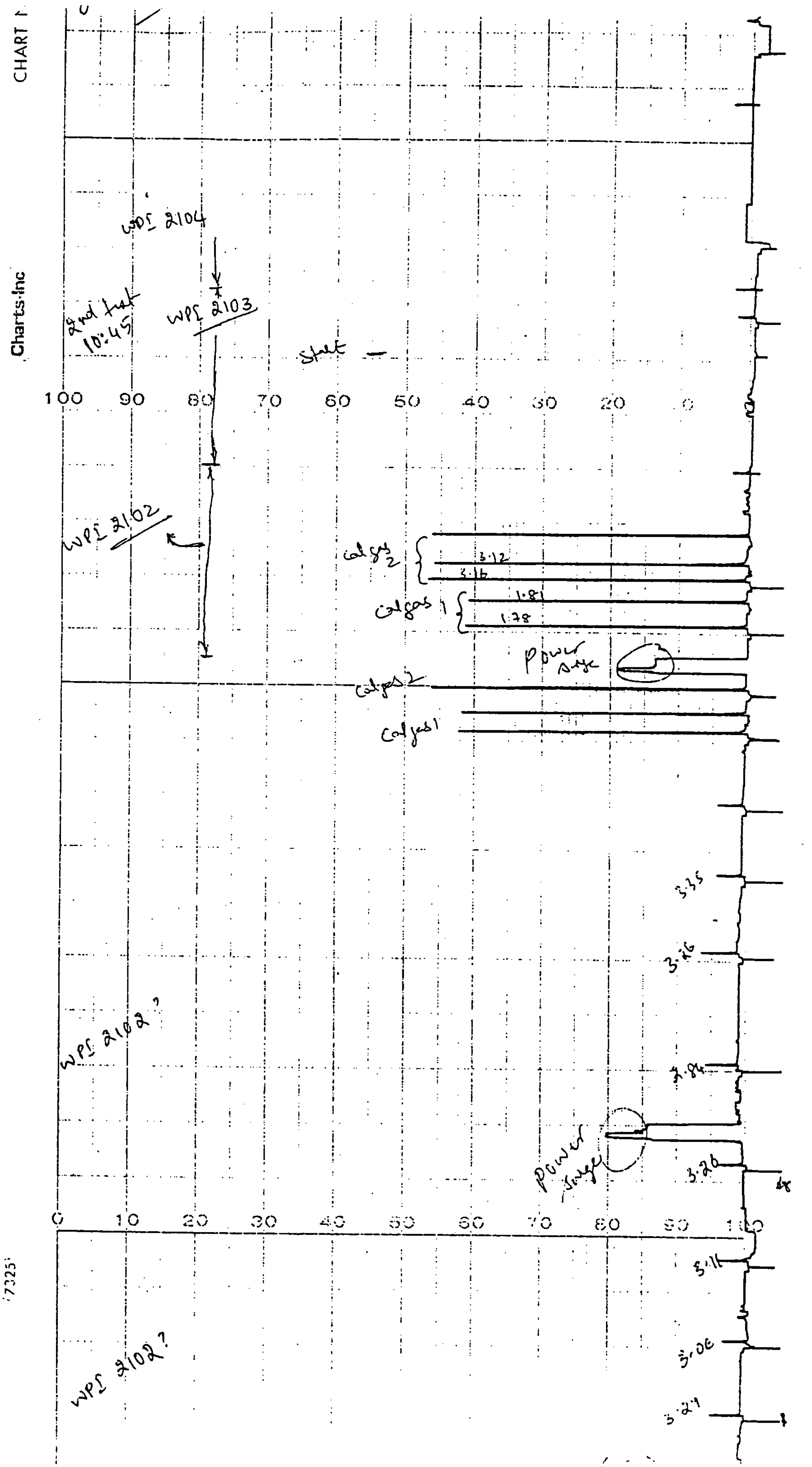
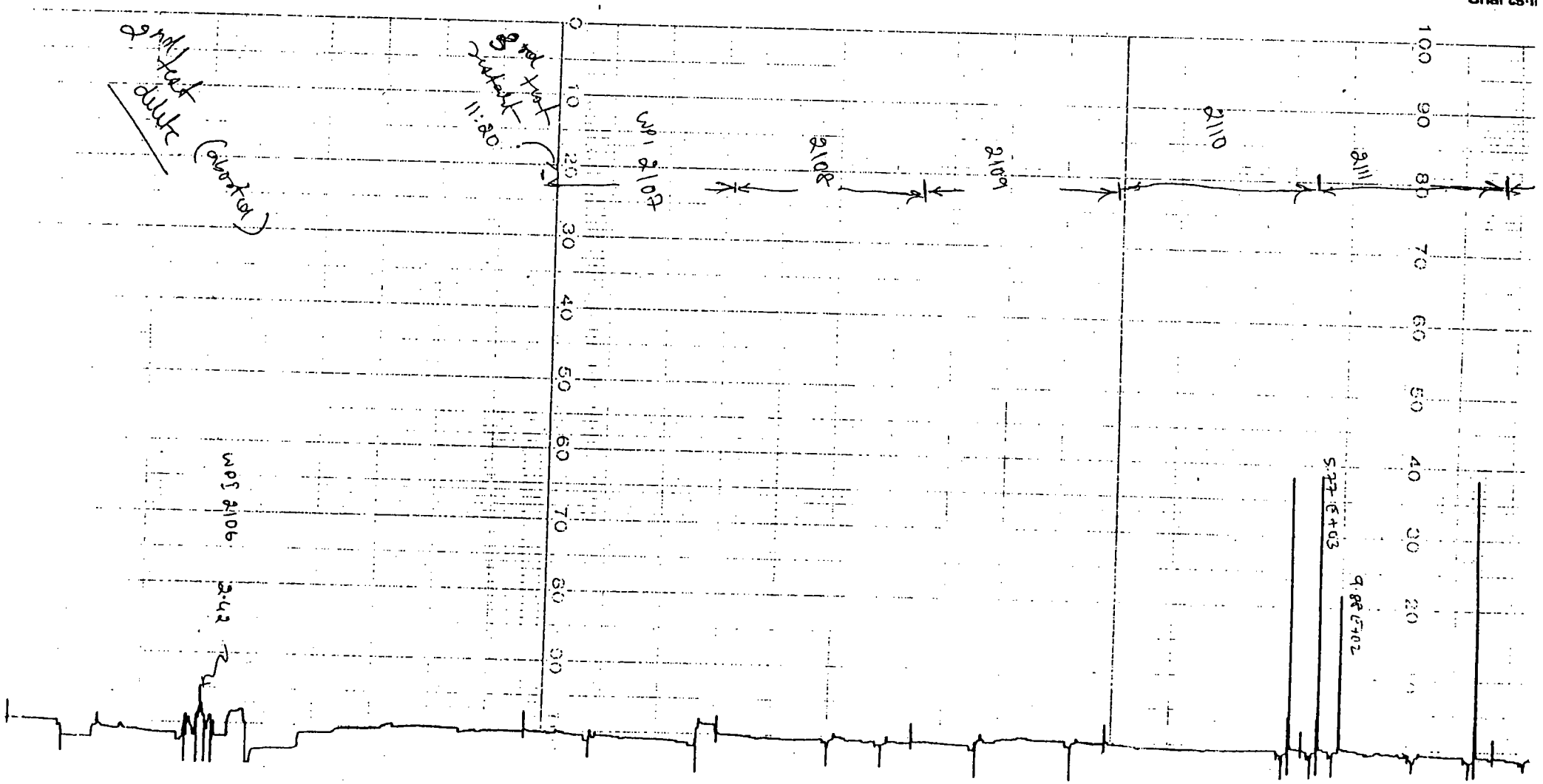


CHART
Charts-Inc
7325
100 90 80 70 60 50 40 30 20 10
0 10 20 30 40 50 60 70 80 90 100
WPI 2104
2nd test
10:45
WPI 2103
Start
WPI 2102
Cal gas 2
3.12
3.16
Cal gas 1
1.81
1.78
power surge
Cal gas 2
Cal gas 1
3.35
3.26
3.84
3.26
WPI 2102?
3.11
3.06
3.29
WPI 2102?

CHART NO. 0100-0017



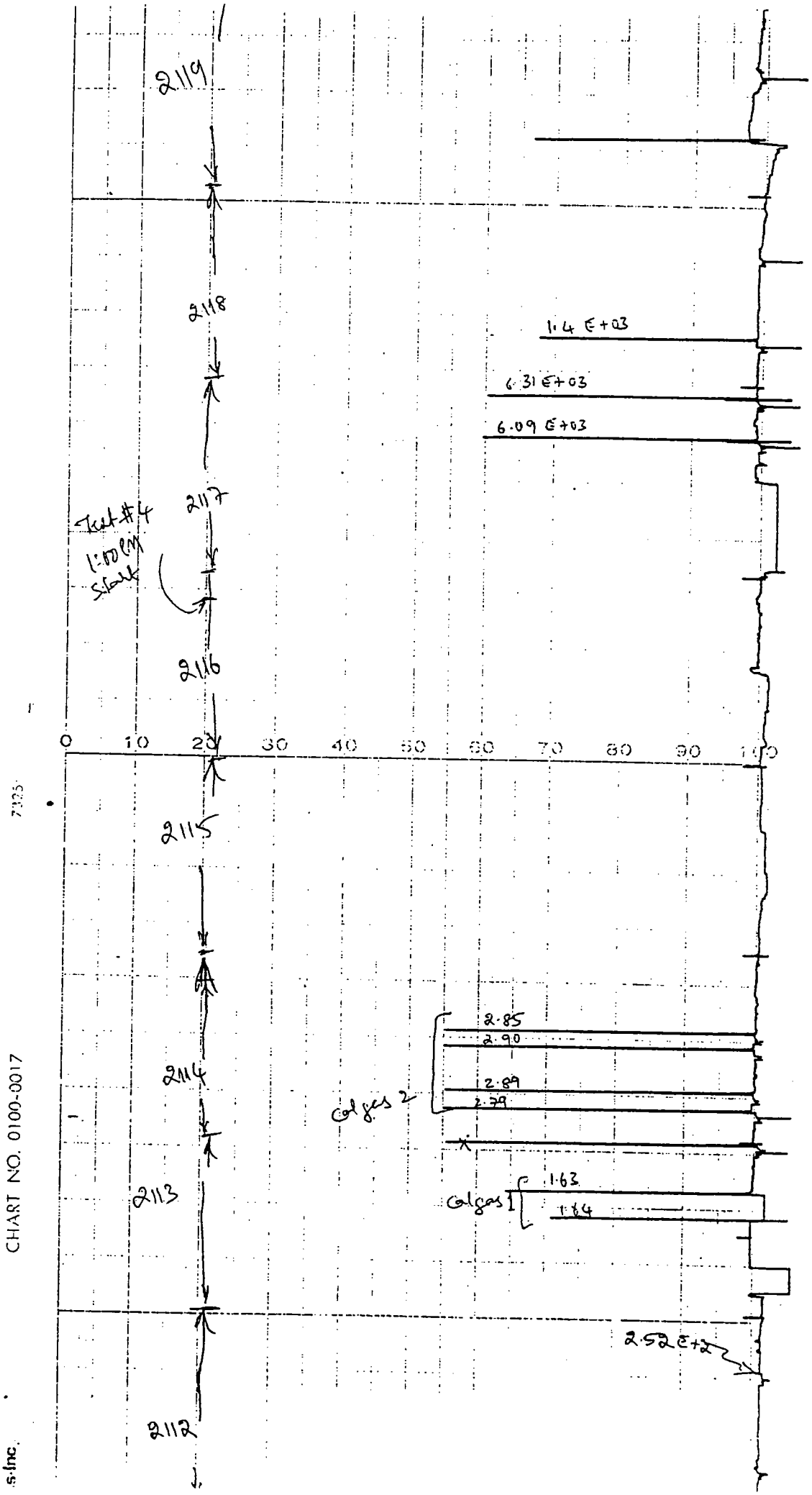
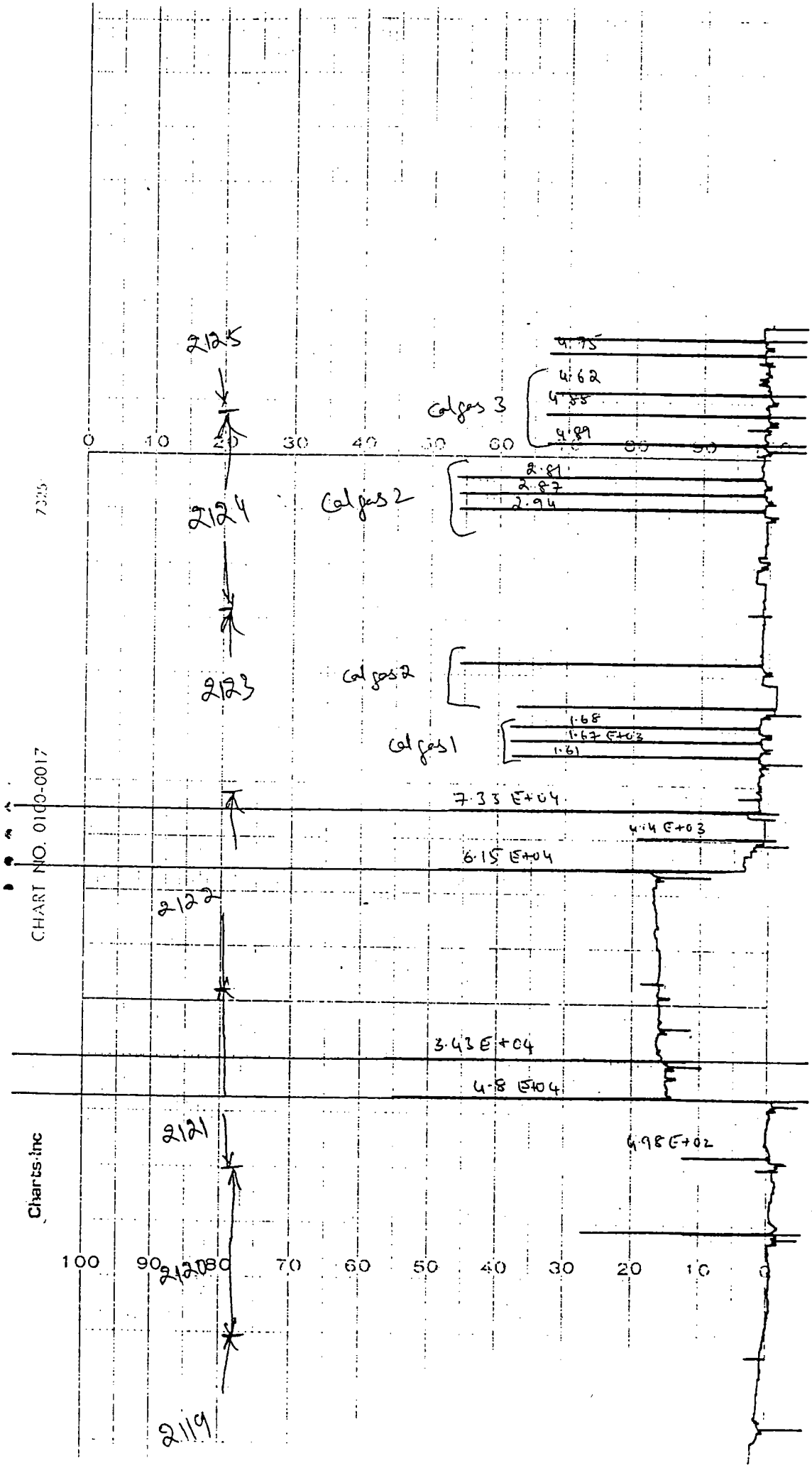


CHART NO. 0100-0017


2125
4.75
4.62
4.55
4.89
Calgas 3
0 10 20 30 40 50 60 80 90
2124
2.81
2.87
2.94
Calgas 2
2123
Calgas 2
1.68
1.67 E+03
1.61
Calgas 1
7.33 E+04
4.4 E+03
6.15 E+04
2122
3.43 E+04
4.8 E+04
4.98 E+02
2121
100 90 80 70 60 50 40 30 20 10 0
2120
2119
CHART NO. 0100-0017
Charts inc

213 585-2154
FAX # 213 585-0582

LIQUID CARBONIC
SPECIALTY GAS CORPORATION
5700 SOUTH ALAMEDA STREET • LOS ANGELES, CALIFORNIA 90058

CERTIFICATE OF ANALYSIS / EPA PROTOCOL GAS

CUSTOMER ENVIRONMENTAL SCIENCE SVS P.O NUMBER

REFERENCE STANDARD

COMPONENT	NIST SRM NO.	CYLINDER NO.	CONCENTRATION
PROPANE	1667b	CLM-005042	47.3 ppm

ANALYZER READINGS

R=REFERENCE STANDARD *Z=ZERO GAS* *C=GAS CANDIDATE*

1. COMPONENT PROPANE ANALYZER MAKE-MODEL-S/N HP 5890 Series II S/N 3108A34409

ANALYTICAL PRINCIPLE GC/ Thermal Conductivity LAST CALIBRATION DATE 06/11/92

FIRST ANALYSIS DATE 07/06/92 SECOND ANALYSIS DATE

Z 0	R 452	C 286	CONC. 29.9 ppm	Z	R	C	CONC.
R 454	Z 0	C 285	CONC. 29.7 ppm	R	Z	C	CONC.
Z 0	C 284	R 451	CONC. 29.8 ppm	Z	C	R	CONC.
U/M uV		MEAN TEST ASSAY	29.8 ppm	U/M uV		MEAN TEST ASSAY	

THIS CYLINDER NO. SA 5122
HAS BEEN CERTIFIED ACCORDING TO SECTION 3.0.4
OF TRACEABILITY PROTOCOL NO. 1
PROCEDURE G1
CERTIFIED ACCURACY ± 1 % NIST TRACEABLE
CYLINDER PRESSURE 2000 PSIG
CERTIFICATION DATE 07/06/92
EXPIRATION DATE 01/06/94

CERTIFIED CONCENTRATION

PROPANE	29.8 ppm
ZERO AIR	BALANCE

ANALYZED BY DOUG GRANT

CERTIFIED BY KWAN YOUNG

213 585-2154
FAX # 213 585-0582

LIQUID CARBONIC

SPECIALTY GAS CORPORATION
5700 SOUTH ALAMEDA STREET • LOS ANGELES, CALIFORNIA 90058

CERTIFICATE OF ANALYSIS / EPA PROTOCOL GAS

CUSTOMER ENVIRONMENTAL SCIENCE SVS

P.O NUMBER

REFERENCE STANDARD

COMPONENT	NIST SRM NO.	CYLINDER NO.	CONCENTRATION
PROPANE	1668	CAL-4623	94.8 ppm

ANALYZER READINGS

R=REFERENCE STANDARD *Z=ZERO GAS* *C=GAS CANDIDATE*

COMPONENT PROPANE

ANALYZER MAKE-MODEL-S/N HP 5890 Series II S/N 3108A34409

ANALYTICAL PRINCIPLE GC/ Thermal Conductivity

FIRST ANALYSIS DATE 06/15/92

LAST CALIBRATION DATE 06/11/92

SECOND ANALYSIS DATE

Z 0	R 895	C 821	CONC. 87.0 ppm	Z	R	C	CONC.
R 896	Z 0	C 820	CONC. 86.8 ppm	R	Z	C	CONC.
Z 0	C 820	R 894	CONC. 87.0 ppm	Z	C	R	CONC.
U/M uV		MEAN TEST ASSAY	86.9 ppm	U/M uV		MEAN TEST ASSAY	

THIS CYLINDER NO. SA 4581
HAS BEEN CERTIFIED ACCORDING TO SECTION 3.0.4
OF TRACEABILITY PROTOCOL NO. 1
PROCEDURE G1
CERTIFIED ACCURACY ± 1 % NIST TRACEABLE
CYLINDER PRESSURE 2000 PSIG
CERTIFICATION DATE 06/15/92
EXPIRATION DATE 12/15/93

CERTIFIED CONCENTRATION

PROPANE	86.9 ppm
ZERO AIR	BALANCE

ANALYZED BY DOUG GRANT

CERTIFIED BY KWAN YOUNG

213 585-2154
FAX # 213 585-0582

LIQUID CARBONIC

SPECIALTY GAS CORPORATION

5700 SOUTH ALAMEDA STREET • LOS ANGELES, CALIFORNIA 90058

CERTIFICATE OF ANALYSIS / EPA PROTOCOL GAS

CUSTOMER ENVIRONMENTAL SCIENCE SVS P.O NUMBER

REFERENCE STANDARD

COMPONENT	NIST SRM NO.	CYLINDER NO.	CONCENTRATION
PROPANE	1667b	CLM-005042	47.3 ppm

ANALYZER READINGS

R=REFERENCE STANDARD *Z=ZERO GAS* *C=GAS CANDIDATE*

1. COMPONENT PROPANE ANALYZER MAKE-MODEL-S/N HP 5890 Series II S/N 3108A34409

ANALYTICAL PRINCIPLE GC/ Thermal Conductivity LAST CALIBRATION DATE 06/11/92

FIRST ANALYSIS DATE 07/06/92 SECOND ANALYSIS DATE

Z 0	R 455	C 475	CONC. 49.4 ppm	Z	R	C	CONC.		
R 453	Z 0	C 476	CONC. 49.7 ppm	R	Z	C	CONC.		
Z 0	C 474	R 452	CONC. 49.6 ppm	Z	C	R	CONC.		
U/M uV		MEAN TEST ASSAY	49.6 ppm	U/M uV			MEAN TEST ASSAY		

THIS CYLINDER NO. SA 4999
HAS BEEN CERTIFIED ACCORDING TO SECTION 3.0.4
OF TRACEABILITY PROTOCOL NO. 1
PROCEDURE G1
CERTIFIED ACCURACY ± 1 % NIST TRACEABLE
CYLINDER PRESSURE 2000 PSIG
CERTIFICATION DATE 07/06/92
EXPIRATION DATE 01/06/96

CERTIFIED CONCENTRATION

PROPANE	49.6 ppm
ZERO AIR	BALANCE

ANALYZED BY DOUG GRANT

CERTIFIED BY KWAN YOUNG

Table No. B1 GC FID Calibration data

Calibration No. 1

Propane Conc. ppm	GC Response Peak Ht.	Regression Conc. ppm	
0	0	0.0	106.3
29.8	1945	30.1	1929.6
49.6	3365	53.3	3141.0
86.9	5290	84.7	5423.1

Calibration No. 2

Propane Conc. ppm	GC Response Peak Ht.	Regression Conc. ppm	
0	0	0.0	−40.0
29.8	1720	28.8	1780.6
49.6	2990	49.6	2990.3
86.9	5290	87.2	5269.1

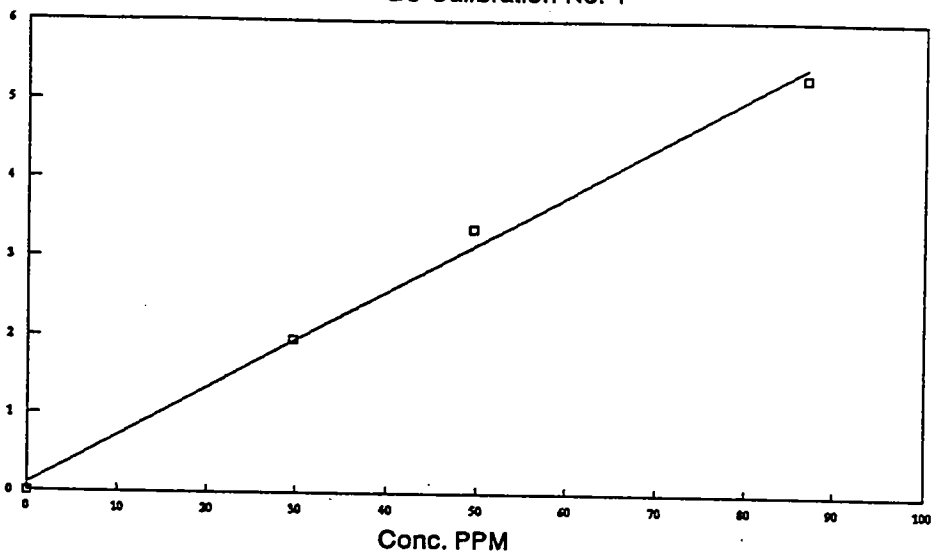
Calibration No. 3

Propane Conc. ppm	GC Response Peak Ht.	Regression Conc. ppm	
0	0	0.0	20.4
29.8	1650	29.4	1675.0
49.6	2860	51.1	2774.3
86.9	4805	86.2	4845.3

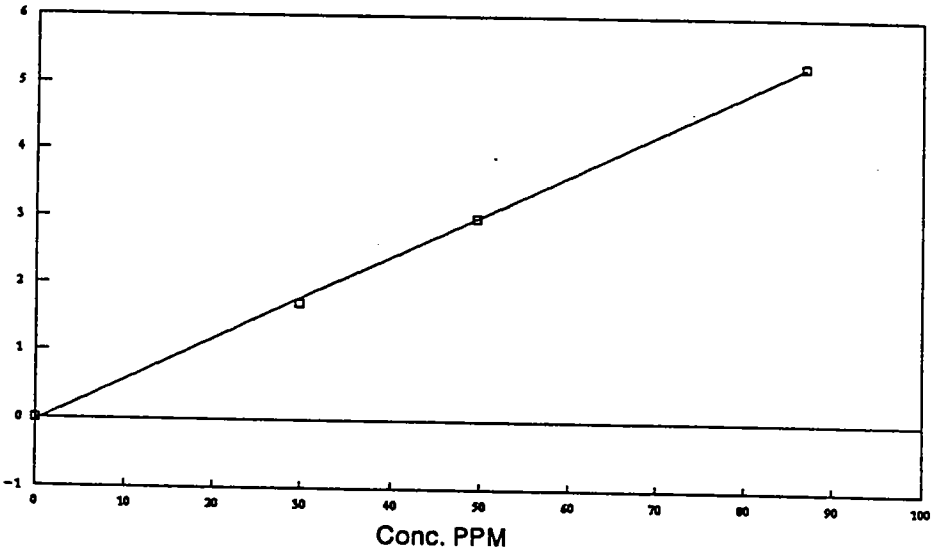
Figure No. B1 GC. FID Calibration Curves using Propane in air.

WPI Compliance Testing for Gen No. 5, 21st March 1993.

GC Calibration No. 1



GC Calibration No. 2



GC Calibration No. 3

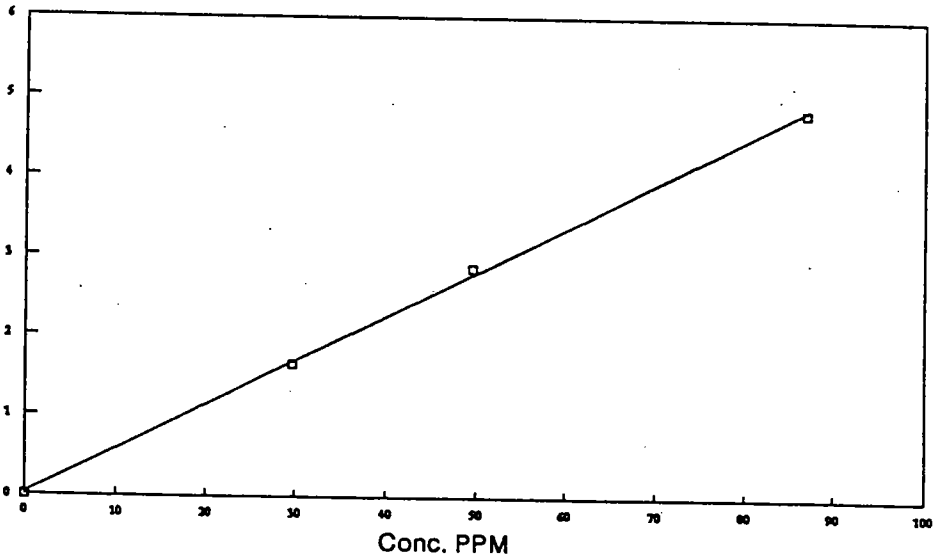


Table No. B2, Peak data with sample injection time and concentration

Test Run #1, start time 9:20 AM

Sl No.	Time of Injection	Peak Height	Conc. in PPM Methane	Conc. in PPM NMHC
1	9:21	366	12.7	<5.0
2	9:26	408	14.8	<5.0
3	9:31	401	14.5	<5.0
4	9:36	268	7.9	<5.0
5	9:41	213	5.2	<5.0
6	9:45	329	10.9	<5.0
7	9:49	306	9.8	<5.0
8	9:53	311	10.0	<5.0
9	9:59	326	10.8	<5.0
10	10:03	284	8.7	<5.0
11	10:09	326	10.8	<5.0
12	10:13	335	11.2	<5.0
13	10:17	315	10.2	<5.0
		Average Conc:	10.6	

Test Run #2, start time 11:20 AM

Sl No.	Time of Injection	Peak Height	Conc. in PPM as Methane Methane	Conc. in PPM as Methane NMHC
1	11:23	105	7.1	<5.0
2	11:28	138	8.7	<5.0
3	11:35	<5.0	<5.0	<5.0
4	11:38	164	10.0	<5.0
5	11:43	131	8.4	<5.0
6	11:48	191	11.3	<5.0
7	11:58	<5.0	<5.0	<5.0
8	12:00	5770	285.3	<5.0
9	12:01	988	50.5	<5.0
10	12:06	183	10.9	<5.0
11	12:09	5560	275.0	<5.0
12	12:12	183	10.9	<5.0
13	12:17	252	14.3	<5.0
		Average Conc:	53.3	

Test Run #3, start time 1:00 PM

Sl No.	Time of Injection	Peak Height	Conc. in PPM as Methane Methane	Conc. in PPM as Methane NMHC
1	1:01	149	6.9	<5.0
2	1:08	6100	328.5	<5.0
3	1:10	6310	339.8	<5.0
4	1:13	1410	75.1	<5.0
5	1:18	109	4.8	<5.0
6	1:24	1400	74.5	<5.0
7	1:28	186	8.9	<5.0
8	1:38	4610	248.0	<5.0
9	1:42	498	25.8	<5.0
10	1:45	48100	2597.8	<5.0
11	1:47	34300	1852.2	<5.0
12	1:49	142	6.6	<5.0
13	1:58	61600	3327.2	<5.0
14	1:59	4140	222.6	<5.0
15	2:01	73300	3959.4	<5.0
		Average Conc:	871.9	

Note: All concentrations reported are as methane equivalent

Waukesha Engine Div. Service Operations
Fax: 414-549-2804

To: Bob Wilson
Date: 06/09/93
From: Jeff Balls
Subject: Roots Meter Calibration Report
CC: R P Jelinek

Co.: WPI - Rhode Island
Fax No.: 401-943-8156
File:

We have received the Roots Meter that you sent back on 2 June 1993. Attached is the latest Roots Meter calibration report for this fuel flow meter, S/N 8460783. It is dated 7 January 1993 which was after it was returned from Rhode Island the last time. Review of the data shows the calibration accuracy varied from 100.3% to 100.7% across the range of flow from 1000 CFH to 10,000 CFH.

If you have any questions feel free to contact me at 414-549-2607.

Regards,

Jeff Balls

dlm

/BWSJUNE3.DOC/

ROOTS DRESSER

ROOTS® PROVER DATA SHEET

DMP-184

LOCATION CELL 12 (LAB)
FIELD METER SIZE 11M
FIELD METER SERIAL 2460783

RECALIBRATION AFTER TRIP FROM RHODE ISLAND

ROOTS PROVER SERIAL 11M
OPERATOR SA
DATE 1-7-93

RUN NUMBER	TIME OF DAY	MASTER METER PRESET	INDICATED FLOW RATE CFH	AVERAGE FLOW RATE CFH	% PRESS. CORR.	% TEMP. CORR.	% PROOF. UNCORR.	% PROOF. CORR.	% ACCURACY CORR.	COMMENTS
		22	1000	1045	-0.1	+0.2	99.5	99.6	100.4	
		"	"	1065	-0.1	+0.3	99.5	99.7	100.3	
		"	"	1066	-0.1	+0.3	99.5	99.7	100.3	
		19	2500	2600	-0.2	+0.3	99.6	99.7	100.3	
		"	"	2580	-0.2	+0.2	99.6	99.6	100.4	
		"	"	2593	-0.2	+0.2	99.6	99.6	100.4	
		18	5000	4945	-0.5	+0.1	99.9	99.5	100.5	
		"	"	4921	-0.5	+0.0	99.9	99.4	100.6	
		"	"	4897	-0.4	-0.1	99.9	99.3	100.7	
		17	7500	7548	-0.9	-0.1	100.4	99.4	100.6	
		"	"	7548	-0.9	-0.1	100.4	99.4	100.6	
		"	"	7556	-0.9	-0.1	100.5	99.5	100.5	
		17	10,000	10202	-1.5	-0.2	101.0	99.3	100.7	
		"	"	10202	-1.5	-0.1	101.0	99.4	100.6	
		"	"	10202	-1.5	-0.2	101.0	99.3	100.7	

APPENDIX C

CALCULATIONS

EMISSION CALCULATIONS

1) Brake Specific Fuel Consumption (BSFC) (BTU/BHP-HR)

$$BSFC = 1040.0\left(\frac{SLHV}{BHP}\right)\left(\frac{FT^3}{MIN}\right)\left(\frac{P_B + P_{GAS}}{T_{GAS} + 460^o}\right)$$

WHERE:

1040.0	Conversion factor for standard conditions of 60°F and 29.92 inches Hg
SLHV	Saturated low heat value - fuel analysis (BTU/FT^3)
BHP	Average Horse Power - Process Data
FT^3/MIN	Measured cubic feet of fuel gas per minute (Rootsmeter)
P_B	Barometric pressure (inches Hg)
P_{GAS}	Measured fuel gas pressure (inches Hg)
T_{GAS}	Measured fuel gas temperature (°F)

2) Fuel Flow (FF) (lb/hr)

$$FF = (BSFC)(BHP)\left(\frac{1}{SLHV}\right)(FGD)$$

WHERE:

FGD = Fuel gas density = SG x 0.0765 lb/ft^3

3) Air-Fuel Ratio (AFR)

$$AFR=F_b[11.492F_c(\frac{1+R/2+Q}{1+R})+(\frac{120F_{H2}}{3.5+R})]$$

Modified for fuels containing CO_2

$$AFR=F_b[(11.492F_C+3.136F_{CO2})(\frac{1+R/2+Q}{1+R})+(\frac{120F_{H2}}{3.5+R})-3.136F_{CO2}]$$

WHERE:

F_c	Carbon weight fraction in fuel
F_{H2}	Hydrogen weight fraction in fuel
F_{CO2}	Carbon dioxide weight fraction in fuel
R	= %CO / $\%CO_2$
Q	= $\%O_2$ / $\%CO_2$
F_b	= (%CO + $\%CO_2$) / (%CO + $\%CO_2$ + %THC)

4) Air Flow (lb/hr)

$$AF=(FF)(AFR)$$

5) Exhaust Flow (lb/hr)

$$EF=AF+FF$$

EMISSION

6) Brake Specific Emission Rates (grams/BHP-HR)

$$Ei=(\frac{(EF)(WMF_x)}{BHP})(\frac{453.6grams}{1b})$$

WHERE:

WMF_x = Wet mass fraction of pollutant x

ENVIRONMENTAL SCIENCE SERVICES
532 Atwells Avenue
PROVIDENCE, RHODE ISLAND 02909
(401) 421-0398

JOB WPI Compliance test for Gen #5
SHEET NO. 1 OF 6
CALCULATED BY Prasad DATE 6/2/93
CHECKED BY _____ DATE _____
SCALE _____

Sample Calculation for Test Run No 1

1) Brake Specific Fuel Consumption:

$$BSFC = 1040 \left[\frac{SLHV}{BHP}\right]\left[\frac{FT^3}{min}\right]\left[\frac{P_B + P_{GAS}}{T_{GAS}+460^\circ}\right]$$

SLHV	:	Saturated low heat value - fuel analysis	= 497 Btu/ft³
BHP	:	Average Brake Horse Power	= 2400
FT^3	:	Measured cubic feet of fuel gas (roots meter)	= 200
		Calibration factor of roots meter	= 0.995
min	:	Observed flow time for 200 ft³	= 1.2167
P_B	:	Barometric Pressure (in Hg)	= 30.24
P_{GAS}	:	Measured fuel gas pressure (psi)	= 45
		Conversion factor from psi to in Hg	= 0.4897
T_{GAS}	:	Measured fuel gas temperature	= 75°F
1040	:	Conversion factor for std conditions ie 60°F and 29.92 in Hg	

$$BSFC = 1040 \times \frac{497}{2400} \times \frac{200 \times 0.995}{1.2167} \times \frac{30.24 + 45/0.4897}{75 + 460^\circ}$$

$$= 8041.5 \text{ Btu/BHP-HR}$$

2) Fuel Flow:

$$FF = (BSFC)(BHP)\left[1/SLHV\right](FGD)$$

SG_{gas} = 0.971 (fuel analysis)
FGD = SG x 0.0765 lb/ft³

$$\therefore FF = 8041.5 \times 2400 \times \frac{1}{497} \times (0.971 \times 0.0765)$$

$$= 2884.5 \text{ lb/hr}$$

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JOB WPI Compliance test for Gen #5
SHEET NO. 2 OF 6
CALCULATED BY Prasad DATE 6/2/93
CHECKED BY _____ DATE _____
SCALE _____

3) Air Fuel Ratio :

[Eqn modified for fuels containing CO_2]

$$AFR = F_b\left[(11.492\,F_c + 3.136\,F_{CO_2})\left(\frac{1+\frac{R}{2}+Q}{1+R}\right) + \left(\frac{120\,F_{H_2}}{3.5+R}\right) - 3.136\,F_{CO_2}\right]$$

$$F_b = (\%CO + \%CO_2)/(\%CO + \%CO_2 + \%THC)$$

$$= (0.039 + 9.9)/(0.039 + 9.9 + 0.00106) = 0.9999$$

F_c = Carbon weight fraction in fuel (Refer Table C1) = 0.2305

F_{CO_2} = Carbon dioxide weight fraction in fuel (table C1) = 0.6307

$$R = (\%CO / \%CO_2)$$

$$= 0.039/9.9 = 0.0039$$

$$Q = \%O_2/\%CO_2$$

$$= 10.2/9.9 = 1.03$$

F_{H_2} = Hydrogen weight fraction in fuel (table C1) = 0.0768

$$AFR = 0.9999\left[(11.492 \times 0.2305 + 3.136 \times 0.6307)\left(\frac{1+\frac{0.0039}{2}+1.03}{1+0.0039}\right) + \left(\frac{120 \times 0.0768}{3.5+0.0039}\right) - 3.136 \times 0.6307\right]$$

$$= 10.07$$

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JOB WPI Compliance test for Gen # 5
SHEET NO. 3 OF 6
CALCULATED BY Prasad DATE 6/2/93
CHECKED BY _____ DATE _____
SCALE _____

4) Air Flow:

AF = Fuel Flow (FF) x Air-Fuel Ratio (AFR)

= 2884.5 lb/hr x 10.07

= 29054.1 lb/hr

5) Exhaust Flow:

EF = Air Flow (AF) x Fuel Flow (FF)

= 29054.1 lb/hr x 2884.5 lb/hr

= 31938.6 lb/hr

6) Brake Specific Emission Rate:

$$E_i = \frac{(EF)(WMF_x)}{(BHP)} \times 453.6 \frac{\text{grams}}{\text{lb}}$$

WMF_x = Wet Mass fraction for pollutant x.

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JOB WPI Compliance test for Gen #5
SHEET NO. 4 OF 6
CALCULATED BY Prasad DATE 6/2/93
CHECKED BY _____ DATE _____
SCALE _____

Pollutant

NO_x	= 46 ppm	dry measure	=	0.0046 %
CO	= 390.9 ppm	dry measure	=	0.03909 %
THC	= 10.6 ppm	wet measure	=	0.00106 %
NMHC	= 5 ppm	wet measure	=	0.0005 %

$\% O_2 = 10.2\%$
$\% CO_2 = 9.9\%$

$$\% \text{ Excess Air} = \frac{(\% O_2 - 0.5\% CO)}{(0.264 \times \% N_2) - (\% O_2 - 0.5\% CO)}$$

$\% N_2 = 79.9\%$ in air

$$= \frac{(10.2 - 0.5 \times 0.03909)}{(0.264 \times 79.9) - (10.2 - 0.5 \times 0.03909)}$$

$$= 0.933$$

From graph of effect of air/fuel ratio on flue gas analysis
H_2O content = 12%

$\therefore$ wet/dry ratio = $1/1.12 = 0.8929$

percent water vapor = $1 - 0.8929 = 0.1071$
= 10.71 % water vapour

Converting the pollutants to wet basis

			volume fraction
NO_x	$= 46/1.12 = 41.07$ ppm	$= 0.004107\%$	$= 0.00004107$
CO	$= 390.9/1.12 = 349.02$ ppm	$= 0.034902\%$	$= 0.00034902$
CO_2	$= 9.9/1.12$	$= 8.839287\%$	$= 0.0839286$
O_2	$= 10.2/1.12$	$= 9.107143\%$	$= 0.0910714$

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JOB WPI Compliance test for Gen # 5
SHEET NO. 5 OF 6
CALCULATED BY Prasad DATE 6/2/93
CHECKED BY DATE
SCALE

To Calculate MW of exhaust stream:

Pollutant	Vol fraction A	Pollutant MW B	MW fraction C	Specific MW / Actual MW D	Wet mass fraction E (A·D)
NO_x as NO_2	0.00004107	46.0055	0.00188944	1.60190	0.0000 6579
CO	0.00034902	28.0106	0.00977624	0.97531	0.0003404
THC as CH_4	0.0000106	16.0430	0.00017006	0.55861	0.00000592
CO_2	0.0839286	44.0099	3.8901627	1.53240	0.1354526
O_2	0.0910714	31.9988	2.9141755	1.11418	0.1014694
H_2O	0.107143	18.0153	1.9302176	0.62728	0.0672087
Balance as N_2	0.7129921	28.0134	19.973333	0.97541	0.6954569
	1.0000000		28.719724		0.9999998

$$E_i = \frac{EF \times WMF_x}{BHP} \times 453.6 \frac{g}{lb}$$

a) $E_{NO_x} = \frac{31810.4 \text{ lb/hr} \times 0.00006579}{2400} \times 453.6 \frac{g}{lb} = 0.3955 \text{ g/BHP-HR}$

b) $E_{CO} = \frac{31810.4 \text{ lb/hr} \times 0.0003404}{2400} \times 453.6 \frac{g}{lb} = 2.0465 \text{ g/BHP-HR}$

c) $E = \frac{31810.4 \text{ lb/hr} \times 0.00000592}{2400} \times 453.6 \frac{g}{lb} = 0.0356 \text{ g/BHP-HR}$

$2260 \text{ ppmv} \times \frac{1 \text{ MOC}}{86.2 \text{ MOC}} \times \frac{16 \text{ CH}_4}{1 \text{ MOC}} \times \frac{1}{6}$

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JOB WPI Compliance test for Gen #5
SHEET NO. 6 OF 6
CALCULATED BY Prasad DATE 6/2/93
CHECKED BY _____ DATE _____
SCALE _____

For Non Methane Hydrocarbon:

10.6 ppm − 5 ppm = 5.6 ppm Volume fraction = 0.0000056

Wet mass fraction = Vol fraction × $\frac{\text{Species MW}}{\text{Actual MW}}$

= 0.0000056 × 0.55861

= 0.000000 31282

$$E_{NMHC} = E_{THC} - \left[\frac{31810.4 \text{ lb/hr} \times 0.000000 31282}{2400} \times 453.6 \frac{g}{lb}\right]$$

= ~~0.0358~~

= 0.0356 − 0.0188072

= 0.0168 g/BHP-HR.

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(401) 421-0398

JOB WPI Compliance test for Gen #5
SHEET NO. 1 OF 1
CALCULATED BY Dave Adelman DATE 6/1/93
CHECKED BY _____ DATE _____
SCALE _____

Table No. C1

Constituent	Mole fraction	Carbon		Hydrogen
CH_4	0.5441	1 x 0.5441	= 0.5441	4 x 0.5441 = 2.1764
C_2H_6	0.00011	2 x 0.00011	= 0.00022	6 x 0.00011 = 0.0007
C_3H_8	0.000083	3 x 0.000083	= 0.00025	8 x 0.000083 = 0.0007
C_6H_{14}	0.000078	6 x 0.000078	= 0.00047	14 x 0.000078 = 0.0011
			0.5450	2.1789

	Moles	MW	Weight	Weight fraction
Carbon in fuel	0.5450	12	6.54	0.2305
Hydrogen in fuel	2.1789	1	2.179	0.0768
Carbon dioxide (CO_2)	0.4067	44	17.894	0.6307
Nitrogen (N_2)	0.0489	28	1.369	0.0482
Oxygen ($N_2/4$)	0.0122	32	0.391	0.0138
			28.373	1.0000

Table No. C2

BSFC: Brake Specific Fuel Consumption
FF: Fuel Flow
AFR: Air Fuel Ratio
AF: Air Flow
EF: Exhaust Flow
Ei:Brake Specific Emission rate

Fuel Analysis: Net BTU/cft = 497
Gross BTU/cft = 552
Specific Gravity of fuel = 0.971

SL No.	BSFC btu/bhp–hr	Fuel Flow lb/hr	Air Fuel Ratio	Air Flow lb/hr	Exhaust Flow lb/hr	Brake Spec Emis Rate Ei grams/bhp–hr
	8041.5	2884.5	10.1	29054.1	31938.6	0.3955 NOx
	7918.1	2840.2	10.1	28608.0	31448.3	2.0465 CO
Test Run #1	8026.5	2879.1	10.1	28999.9	31879.0	0.0356 THC
	8026.5	2879.1	10.1	28999.9	31879.0	0.0168 NMHC
	8033.6	2881.7	10.1	29025.4	31907.1	
					31810.4	
	7829.2	2808.3	9.7	27355.4	30163.7	0.4066 NOx
	7923.2	2842.1	9.7	27684.1	30526.2	1.9197 CO
Test Run #2	7747.2	2778.9	9.7	27068.9	29847.8	0.1705 THC
	7880.5	2826.8	9.7	27534.7	30361.4	0.0160 NMHC
	7840.7	2812.5	9.7	27395.8	30208.3	
					30221.5	
	7923.2	2842.1	9.3	26565.7	29407.8	0.4089 NOx
	7785.3	2792.6	9.3	26103.2	28895.8	1.7683 CO
Test Run #3	7828.5	2808.1	9.3	26248.2	29056.4	2.6672 THC
	7690.1	2758.5	9.3	25784.2	28542.7	0.0153 NMHC
	7773.2	2788.3	9.3	26062.6	28850.8	
					28950.7	

NOTE: Air Fuel Ratio is calculated as one hour average.

APPENDIX D

CEM SPECIFICATIONS

TECO MODEL 42 NITROGEN OXIDES (NO_X - NO_2 - NO) ANALYZER

SPECIFICATIONS

Ranges	: 0-10, 20, 50, 100, 200, 500, 1,000, 2,000, 5,000 ppm
Noise	: 25 ppb
Detection Limit	: 50 ppb
Zero Drift (24 hour)	: 50 ppb
Span Drift (24 hour)	: +/- 1% Full Scale
Rise, Fall Times (0-95%)	: 2.5 seconds NO or NO_x mode
Linearity	: +/- 1% Full Scale
Sample Flow Rate	: 25 cc/min.
Vacuum	: 28.5" Hg
Power Requirements	: 500 Watts : 115 ± 10 Volts : 220 ± 20 Volts : 50/60 HZ
Physical Dimensions	: 17" W x 8 3/4" H x 23" D
Weight	: 70 lbs. (including external pump)
Outputs	: NO, NO_2, NO_x Selectable Voltage 4-20 ma

D&S

HNU Systems, Inc.
Model 321 Gas Chromatograph
System Specifications

Table 1-1. System Specifications

Component	Description
Oven	
Size:	296 cubic inch interior 6.5 W x 6.5 L x 7 D inches
Capacity:	2 packed or 1 capillary column
Temperature Range:	ambient to 300° C
Heat-Up:	50° C to 300° C in approx. 12 minutes
Cool-Down:	300° C to 70° C in less than 10 minutes
Temperature Control:	proportional control in 1° C increments with accuracy to ± 0.1° C
Injectors	
Packed Column Injector	
Type:	direct on-column injection port, heated block, cool septum holder with needle guide, pre-heated carrier gas accommodates 1/4 inch O.D. glass or metal columns, adapters for other column sizes; septum size: 3/8 inch or 9.5 mm
Split/Splitless Capillary Column Injector	
Type:	split/splitless
Splitless Injection:	max. sample capacity 5 µl replaceable glass liner
Split Injection:	linear ±2% for sample injection and up to 8 µl and adjustable splitting flow rate, replaceable glass liner or packed pre-column
Split Mode:	linear ±2% for sample injection up to 8 µl; splitting flow rate up to 300 ml/min
Pneumatics	
Range:	0-100 psi
Carrier Gas:	diffusion-proof regulator with gauge, flow controller with gauge
Gases	air and hydrogen controller with flow restrictors—30 psi H_2 = 30 ml/min flow, air = 300 ml/min flow
Microcontroller	
Bus:	Versalogic™ on-board STD bus architecture
Software:	Software Model 321.01
Version:	1.0

Table 1-1. System Specifications (continued)	
Component	**Description**
Electrometers (PID or FID)	
Input Attenuation:	1, 10, 100
Maximum Sensitivity:	5 x E-12 amp full scale
Output (recorder) Attenuation:	1-1024 (binary step)
Noise:	0.5 x E-14 amp
Response Time:	<0.3 seconds for 90% full scale
Outputs:	1) 0-1mV (for recorder)
	2) 0-1 V (for integrator)
System Requirements	
Power:	Fixed 100, 115/120, 230/240 VAC, ±10% of rated line voltage, 50/60 Hz, 400 Watts, 600 Watts max, 300 Watts average
Environment:	20% to 80% ambient relative humidity up to 40° C maximum ambient temperature
Physical Dimensions	
Gas Chromatograph	
Height:	10.5 inches (26.7 cm)
Width:	13.75 inches (34.9 cm)
Depth:	11 inches (27.9 cm)
Weight:	25 lb (11.3 kg)
Other:	1) Autozero provided for both PID and FID on common control 2) PID equipped with LAMP ON switch, FID with IGNITE switch
Microcontroller	
Height:	5.5 inches (13.97 cm)
Width:	9.25 inches (23.49 cm)
Depth:	10.75 inches (27.30 cm)
Weight:	8.8 lb (4.0 kg)