EPA/600/R-92/003e
March 1992

EMISSIONS OF METALS, CHROMIUM AND NICKEL SPECIES, AND ORGANICS FROM MUNICIPAL WASTEWATER SLUDGE INCINERATORS

Volume V: Site 7 Test Report
CEMS Evaluation

by

A. Laurie Cone
Scott A. Shanklin
Entropy Environmentalists, Inc.
Research Triangle Park, North Carolina 27709

EPA Contract No. 68-C0-0027
Work Assignment No. 0-5

Technical Managers

Harry E. Bostian, Ph.D.
Risk Reduction Engineering Laboratory
U. S. Environmental Protection Agency
Cincinnati, Ohio 45268

Eugene P. Crumpler
Office of Water Regulations and Standards
U. S. Environmental Protection Agency
Washington, D.C. 20460

RISK REDUCTION ENGINEERING LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U. S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The U. S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the research and the user community.

The problem of disposing of primary and secondary sludge generated at municipal wastewater treatment facilities is one of growing concern. Sludge of this type may contain toxics such as heavy metals and various organic species. Viable sludge disposal options include methods of land disposal or incineration. In determining the environmental hazards associated with incineration, the Risk Reduction Engineering Laboratory and the Office of Water Regulations and Standards has sponsored a program to monitor the emissions of metals and organics from a series of four municipal wastewater sludge incinerators. The following document presents the final results from the Site 7 emissions test program.

E. Timothy Oppelt, Director
Risk Reduction Engineering Laboratory

ABSTRACT

The U. S. Environmental Protection Agency (EPA) Office of Water Regulations and Standards (OWRS) has recently revised the risk-based sludge regulations under Section 405d of the Clean Water Act. The revised regulations include a provision for monitoring total hydrocarbon (THC) and/or carbon monoxide (CO) emissions as a surrogate for organic emissions measurements.

With the assistance of EPA's Risk Reduction Engineering Laboratory (RREL), OWRS has implemented a research program to investigate the relationship of CO and hydrocarbon emissions and the viability of the monitoring systems used to continuously measure these emissions. This test report presents the results obtained at the Site 7 municipal wastewater treatment facility.

The Site 7 plant treats 20-50 million gallons a day of municipal and industrial wastewater. The blended primary/secondary sludge is dewatered to approximately 21% solids on filter presses. The dried filter cakes are incinerated in a seven-hearth unit and emissions are controlled with a cyclone separator and a Hydro-Sonic scrubber.

The CO and THC emission levels showed good agreement during the test program, i.e., increases in CO are accompanied by increases in THC. The actual correlation coefficients ranged from .73-.93 using one-minute averaged data from six test runs. Comparisons of CO and THC values corrected to 7% oxygen levels do not provide the same measure of correlation (r-values from .11 to .83). Possible explanation of the apparent change in agreement is being investigated further. This report presents uncorrected and corrected emission data in both tabular and graphic formats.

This report was submitted in fulfillment of Contract No. 68-CO-0027, Work Assignment No. 0-5 by Entropy Environmentalists, Inc. under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from October 28 to November 8, 1989, and work was completed as of August 26, 1991.

DISCLAIMER

The research described in this report has been funded wholly by the United States Environmental Protection Agency's Risk Reduction Engineering Laboratory and Office of Water Regulations and Standards under Contract Nos. 68-02-4442, Work Assignment No. 81; 68-02-4462, Work Assignment No. 90-108; and 68-CO-0027, Work Assignment No. 0-5. It has been subjected to the Agency's required peer and administrative review and it has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute an endorsement of recommendation for use.

CONTENTS

FIGURES

TABLES

SECTION 1
INTRODUCTION

The U. S. Environmental Protection Agency (EPA) Office of Water Regulations and Standards (OWRS) has been developing new regulations for sewage sludge incinerators. EPA's Risk Reduction Engineering Laboratory has been assisting OWRS in the collection of supporting data. There has been particular concern regarding the continuous demonstration of proper control of organic emissions from the incineration of municipal wastewater sludge.

OWRS drafted risk-based sludge regulations under Section 405d of the Clean Water Act which were published for comment in the Federal Register, Volume 54, No. 23, February 6, 1989. The draft regulations were based on the risk incurred by the "most exposed individual" (MEI). The MEI approach involves calculating the risk associated with residing for 70 years at the point of maximum ground level concentration of the emissions from an individual incineration facility. This proposal for regulating sewage sludge incinerators was based on ensuring that the increase in ambient air concentrations of pollutants emitted from sludge incinerators is below ambient air criteria established for the protection of human health.

Because of the large number of comments received on the risk-based proposal, a revised approach for regulating organic emissions was developed and published for comment on November 9, 1990 (54 FR 47242). The revised approach suggests a technology-based total hydrocarbon (THC) standard and/or a carbon monoxide (CO) emissions standard as a surrogate indicator of organic emissions. This technology-based approach addresses the primary concerns of commenters, namely the feasibility of THC monitoring and the risk assessment methodology used in establishing emission limits.

The Site 7 test program was designed to provide: (1) CO and THC monitor performance data during extended operating periods at a sewage sludge incinerator, and (2) comparative emissions data from CO and hydrocarbon monitoring systems. The data obtained during the test program are intended to supplement the existing OWRS emissions data base and assist in preparation of the final regulation, now scheduled for publication in the Federal Register in January 1992.

SECTION 2

SITE 7 TEST SUMMARY AND CONCLUSIONS

The Site 7 test program was conducted to characterize CO and hydrocarbon emissions from a multiple hearth incinerator and to obtain performance data on the instruments used to acquire the emissions data. The emission measurement data collected during the test program supplement data collected at other sewage sludge incinerators. The data support the development of appropriate emission standards for these incinerators.

The incinerator emissions were tested under normal operating conditions. Plant-sponsored testing for particulate matter and metals was performed during the program. Concentrations and emission rates were provided for presentation in this report. Only a limited amount of process data was made available to the field test team during the test program. Testing was performed between October 28 and November 8, 1989.

The following conclusions can be drawn from the Site 7 test.

- Increases in CO emission levels are accompanied by increases in THC levels and decreases in O_2 levels.

- Statistical correlation of the CO and THC data is stronger using pollutant concentrations not corrected to 7% O_2. A possible explanation of this unexpected finding is presented in Section 4.1. The linear regression analyses performed by Entropy have been confirmed by an OWRS statistician. Additional statistical inquiries are being pursued by OWRS.

- All instruments operated during the test achieved expected performance levels on calibration drift and linearity tests.

SECTION 3

FACILITY DESCRIPTION

Site 7 provides treatment for municipal and industrial wastewater. It has the capacity to treat an average flow of 20 million gallons per day (MGD), and peak rates of up to 50 MGD during wet weather. The plant operates continuously 24 hours per day, 7 days per week.

All wastewater entering the plant is screened to remove trash and pumped to a series of treatment units. Figure 1 is a schematic flow diagram of the treatment plant. The first stage of the treatment process includes aeration tanks designed to remove odorous and corrosive gases from the wastewater, and settling tanks which remove settleable solid materials from the flow stream. Soluble material and solids which do not settle out require biological conversion to a solid residue which is then removed. Biological conversion is done in the second stage of the process using bacteria in aerated tanks. Solid material resulting from the aerobic treatment is removed in settling tanks. The wastewater is chlorinated and aerated before discharge.

The sludge removed from the various treatment units is pumped to receiving and blending tanks. It is pumped from the blending tanks to a thickening tank and then dewatered on filter presses. The dewatered sludge mixture, or sludge cake, contains approximately 21 % dry solids and is conveyed to an incinerator where it is burned at approximately 1400°F.

The incinerator consists of seven vertically stacked hearths. Dewatered sludge cake is fed into the top (No. 1) hearth, and is moved through successive hearths by a center shaft with arms on each hearth. The arms have teeth which continue the flow of material across each hearth and then down through the incinerator, hearth by hearth. The incinerator is equipped with fuel oil-fired burners which ignite the volatile components of the sludge feed. Combustion air is supplied through auxiliary air fans into hearth Nos. 2 through 6. The upper hearths are used for final drying of the sludge, intermediate hearths are used for combustion, and the bottom hearth is used

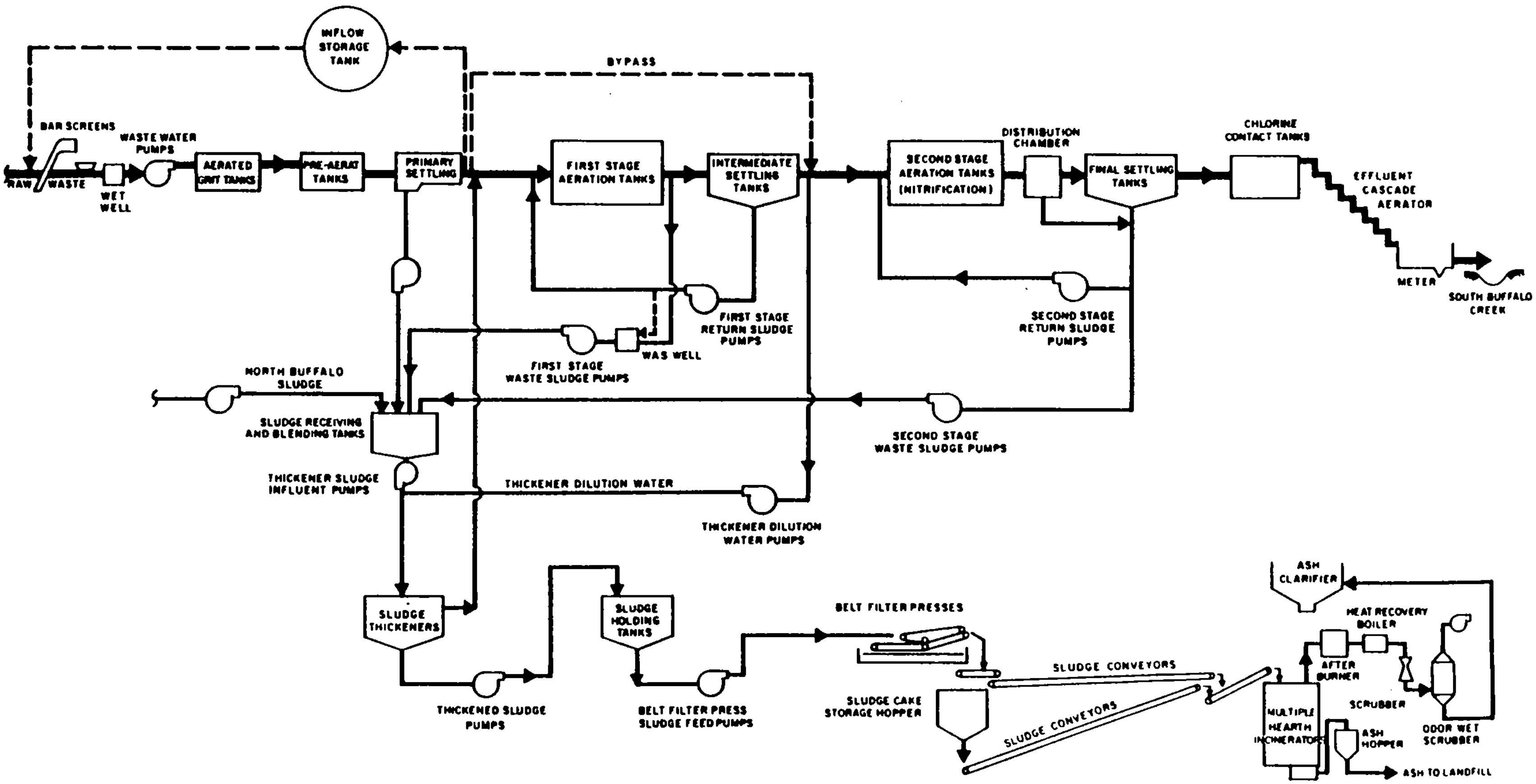


Figure 1. Site 7 plant schematic

for ash cooling. Ash is discharged to the ash handling system. The combustion gases leave the hearths and enter a quench chamber for cooling. The gases then pass through a two-stage Hydro-Sonic scrubber and cyclone separator for emissions control before being exhausted to the atmosphere via the stack.

SECTION 4

TEST RESULTS

CONTINUOUS EMISSION MONITORING RESULTS

Continuous emission monitoring (CEM) was performed at the stack location of Site 7. The monitoring system included CO, THC, and O_2 monitors. Emissions were measured on a dry basis. On November 8, 1989, a heated hydrocarbon sampling system was included to provide comparative THC data using heated and unheated systems. The hot THC data were corrected to dry-basis using moisture values determined during the particulate matter and metals testing on October 31 and November 2, 1989. The consistent relationship between moisture and O_2 values on these two days is used in selecting the proper moisture corrections for different periods on November 8. Calculations for moisture correction are shown in Appendix A.

The CEM data are presented in several formats:

- Extended emissions characterization periods depicting continuous CO and hydrocarbon measurements are illustrated in Figure 2.
- CO and THC measurement data obtained during the particulate matter and metals testing are presented as measured and corrected to 7% O_2, in Table 1 and Figures 3 and 4.
- A 3-hour period of concurrent hot and cold hydrocarbon measurements are presented in Figure 5. Emissions data from all monitoring systems are separated into three shorter periods and summarized in Table 2.

The extended measurement periods, portions of which are shown in Figure 2, provide an indication of the wide range of emissions possible from this facility. Typical O_2 levels accompanying the CO and THC data shown are 5 to 9%, with extremes ranging from 0.3 to 14% O_2.

Continuous emissions data obtained during the particulate matter and metals testing provide a more in-depth examination of CO, hydrocarbon, and O_2 relationships. The graphs and run summaries using uncorrected data indicate

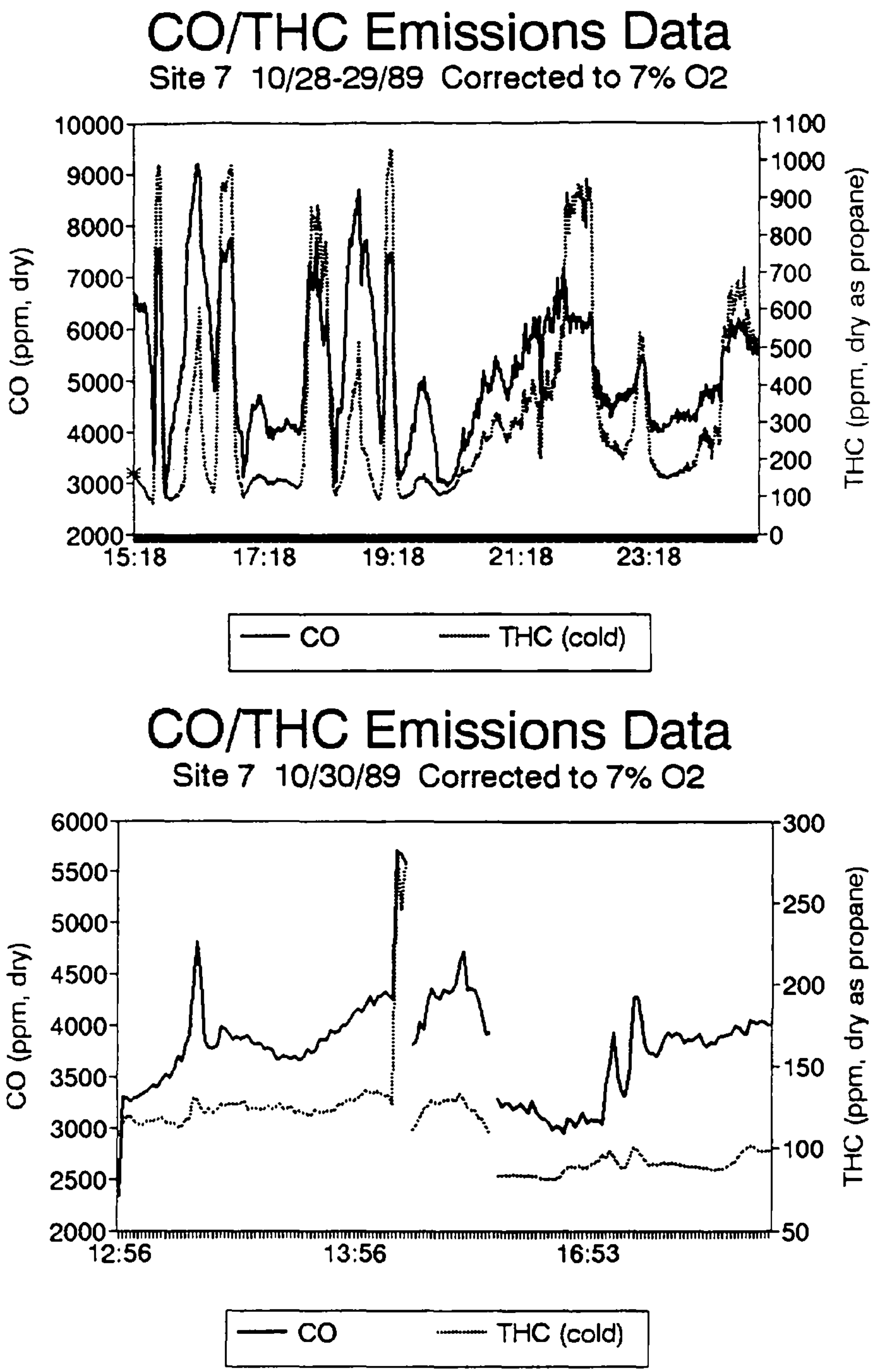


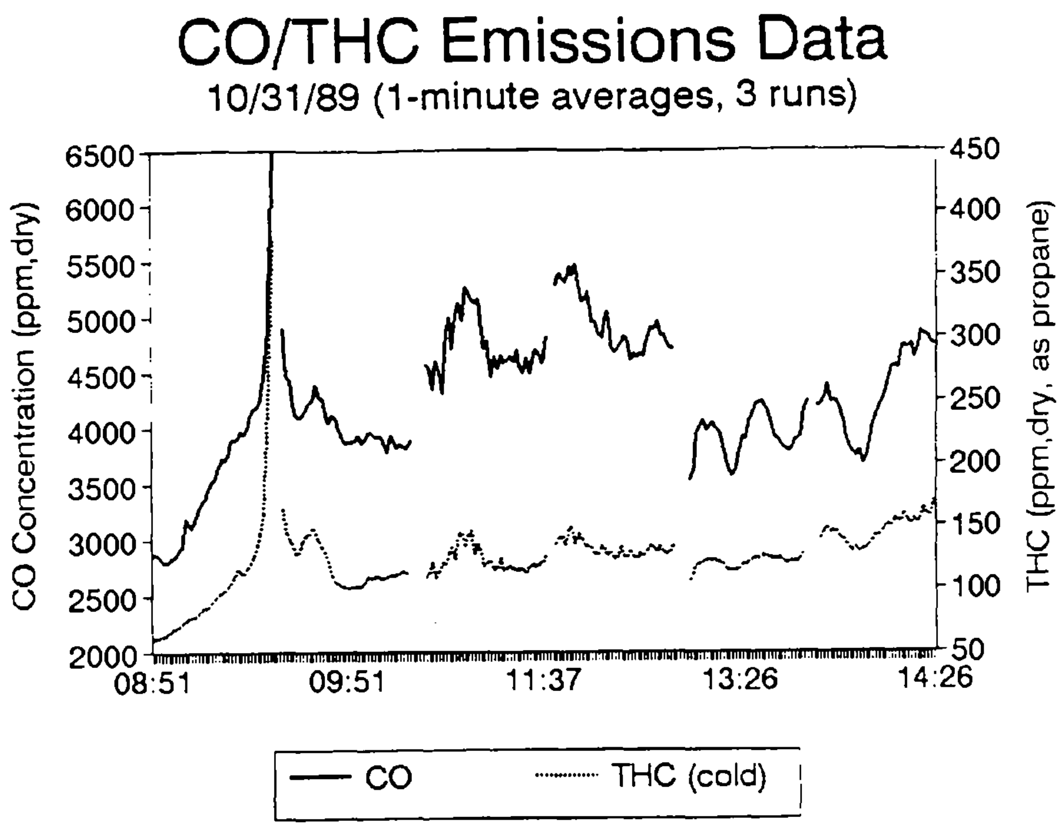
Figure 2. Extended periods of CO and THC CEM data.

TABLE 1. CEM DATA SUMMARIES
October 31 and November 2, 1989

Date	Run No.	Thermox % O2	TECO 48 ppm CO	Beckman ppm C3	Ratfisch ppm C3	TECO 48 ppm CO @7% O2	Beckman ppm THC @7% O2
10/31	1	8.4	3846.8	113.6	118.8	4291.5	123.1
	2	8.1	4833.7	126.8	127.4	5253.3	137.7
	3	8.1	4122.1	133.0	120.7	4467.0	144.0
11/2	1	5.6	4191.3	241.3	259.0	3837.9	218.1
	2	7.5	2854.3	87.8	93.3	2973.0	91.0
	3	5.8	4678.0	182.4	193.7	4320.5	168.2

TABLE 2. LINEAR REGRESSION SUMMARIES

Date	Run No.	Uncorrected Data	Data @ 7% O_2
		R-Values Using 1-Minute Averages	
10/31	1	.927	.413
	2	.799	.567
	3	.877	.294
11/2	1	.890	.825
	2	.737	.110
	3	.778	.605
		R-Values Using Run Averages	
10/31		.491	.201
11/2		.461	.387
ALL SIX RUNS COMBINED		.796	.724



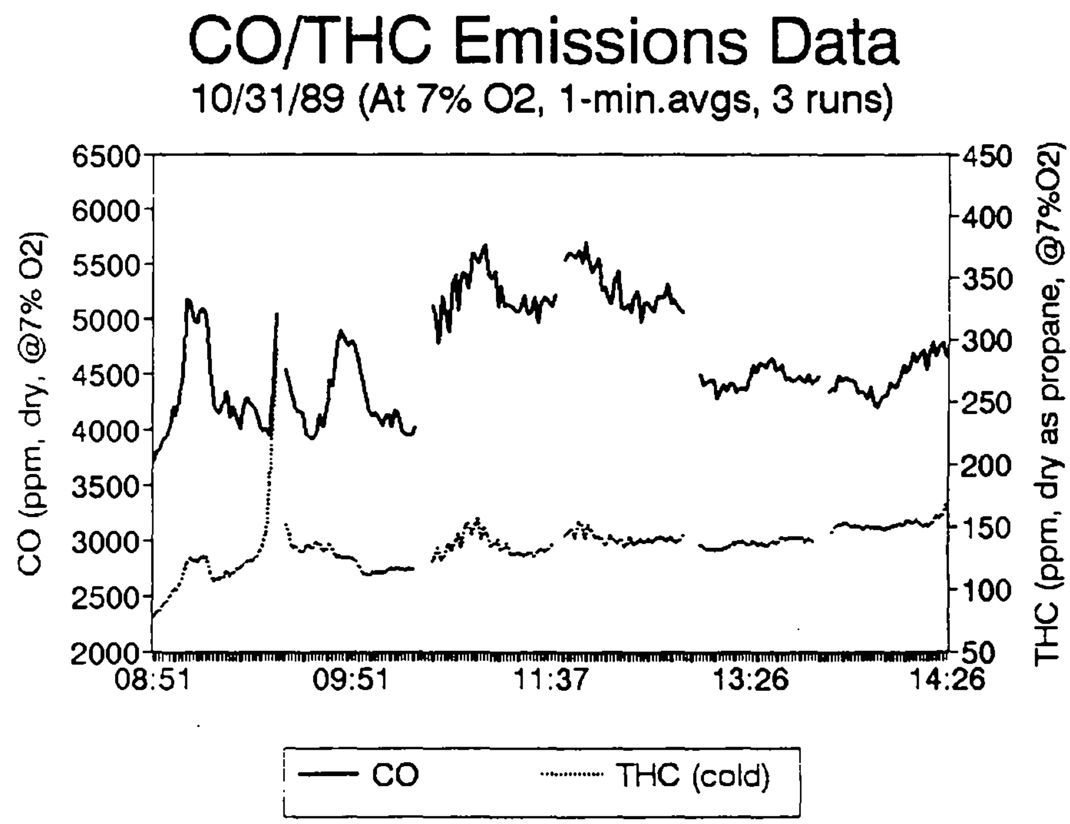
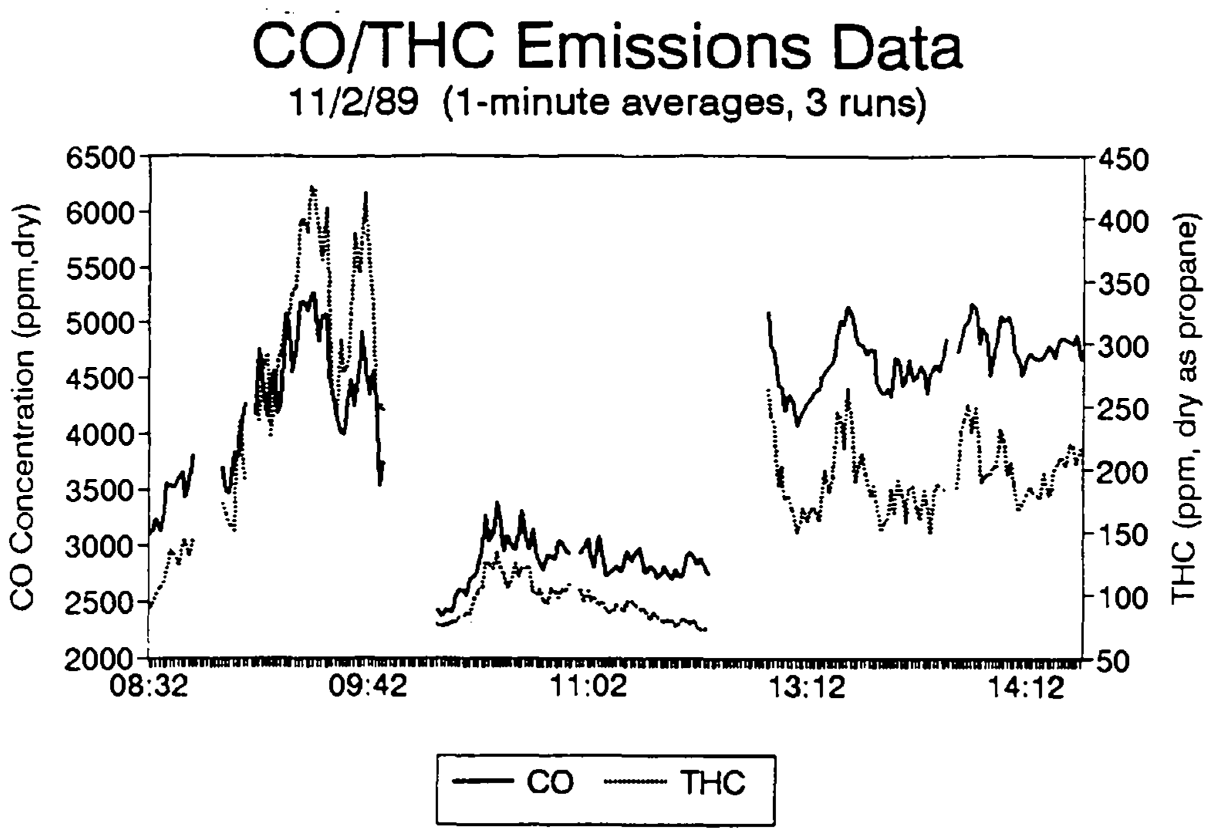


Figure 3. CEM data during 10/31/89 particulate sampling.



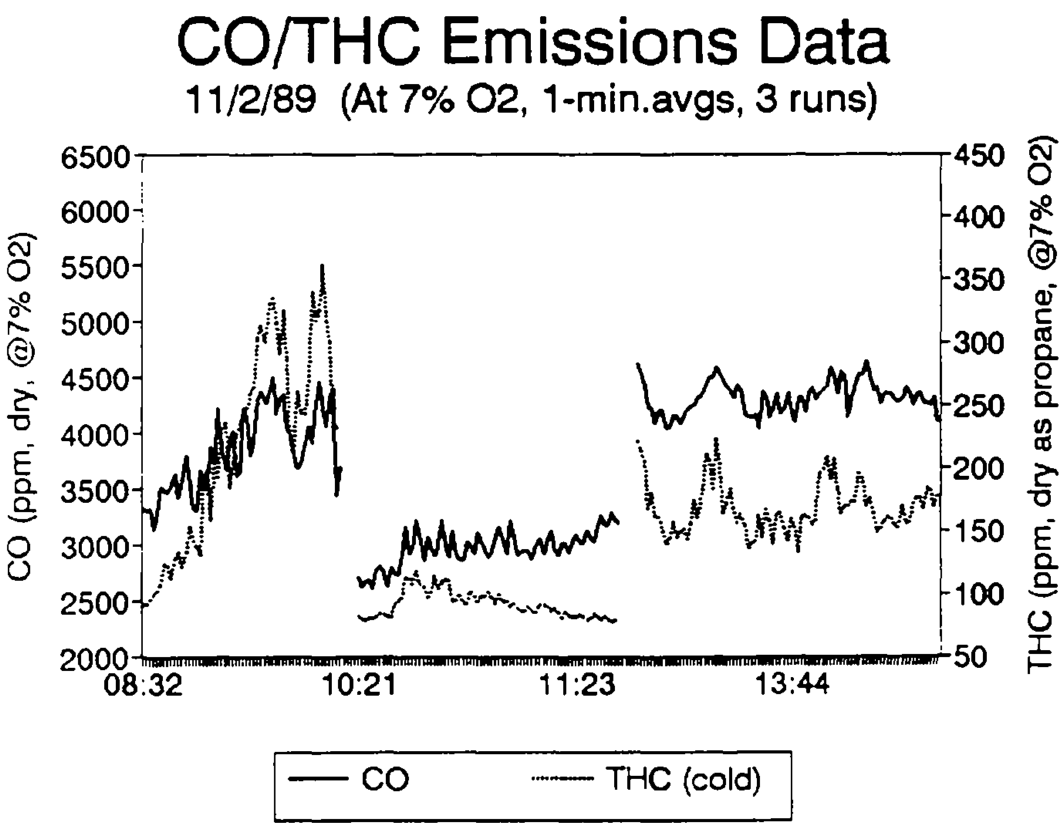


Figure 4. CEM data during 11/2/89 particulate sampling.

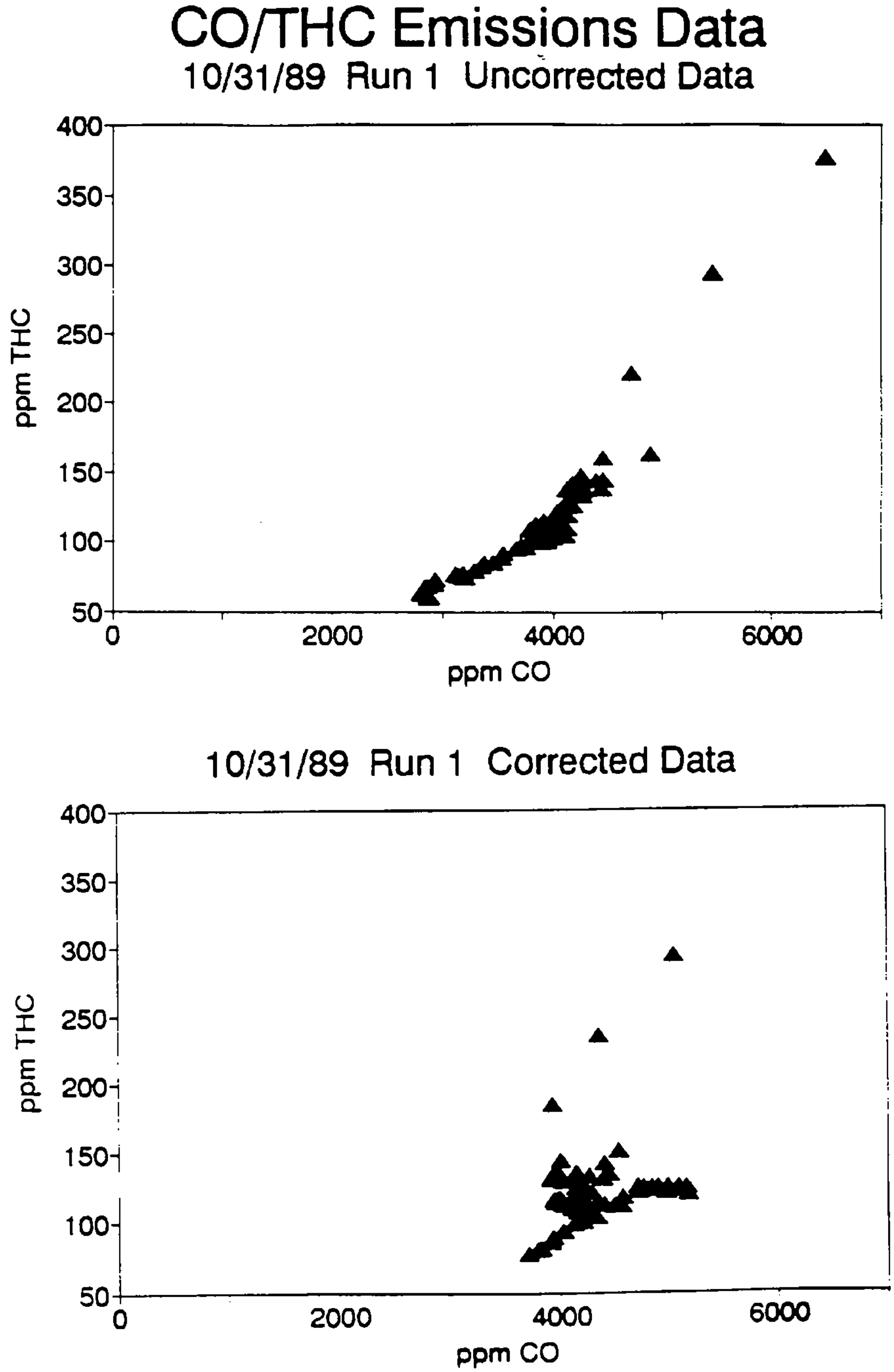


Figure 5. CO/THC emissions comparison.

that increases in CO are accompanied by increases in THC levels and decreases in O_2 levels. Following correction to 7 % O_2, the relationship between CO and THC trends becomes less pronounced. (See Figures 3 and 4, and Table 1.) Further investigation using linear regression analysis verified the decreased correlation but did not validate the consistent relationship suggested in the graphs between uncorrected CO and THC values. Regression analysis was performed both on 1-minute averages obtained during the runs and on each run average. Table 2 provides the r-values obtained and Appendix A contains the regression output for each comparison. One-minute averages of all monitoring data obtained during the six particulate test runs are in Appendix B.

The most likely explanation involves the effect of the correction to 7% O_2 on individual data points. Under normal operation, emission levels of CO and THC vary inversely with O_2 levels. In other words, high levels of CO and THC occur during periods of low O_2 and low levels of CO and THC occur under high excess O_2 conditions. As shown in Table 2, the wide range of uncorrected CO and THC emission measurements demonstrate good correlation and low variability. The correction to 7% O_2 essentially lowers the high CO and THC values and raises the low CO and THC values, removing the extremes which define the linear regression line (see Figure 5).

Measurements of hot and cold hydrocarbons were fairly close, as shown in Figure 6. The relatively low stack gas temperature of 160-170°F and the wet scrubber design possibly contributed to the similarity in measured emissions. Using the relative accuracy criterion of agreement within 20% from Performance Specification 2 (40 CFR 60, Appendix B) the data acquired with the two separate sampling systems can be considered the same. No reference organic measurement method nor performance criterion is available against which these instrument can be evaluated as correct or incorrect. Averages for O_2, CO, and cold and hot THC values are shown in Table 3.

The original intent of the testing on this day was to raise the top hearth temperature to 1100°F (measured during previous multiple hearth testing). However, as the furnace was being brought up to that temperature over the morning, it became apparent that keeping the temperature and O_2 elevated required too great a decrease in the sludge feed rate. With 25% less sludge being fired, conclusions could not be drawn as to the cause of the lower emissions. In spite of the difficulties, the experiment still produced

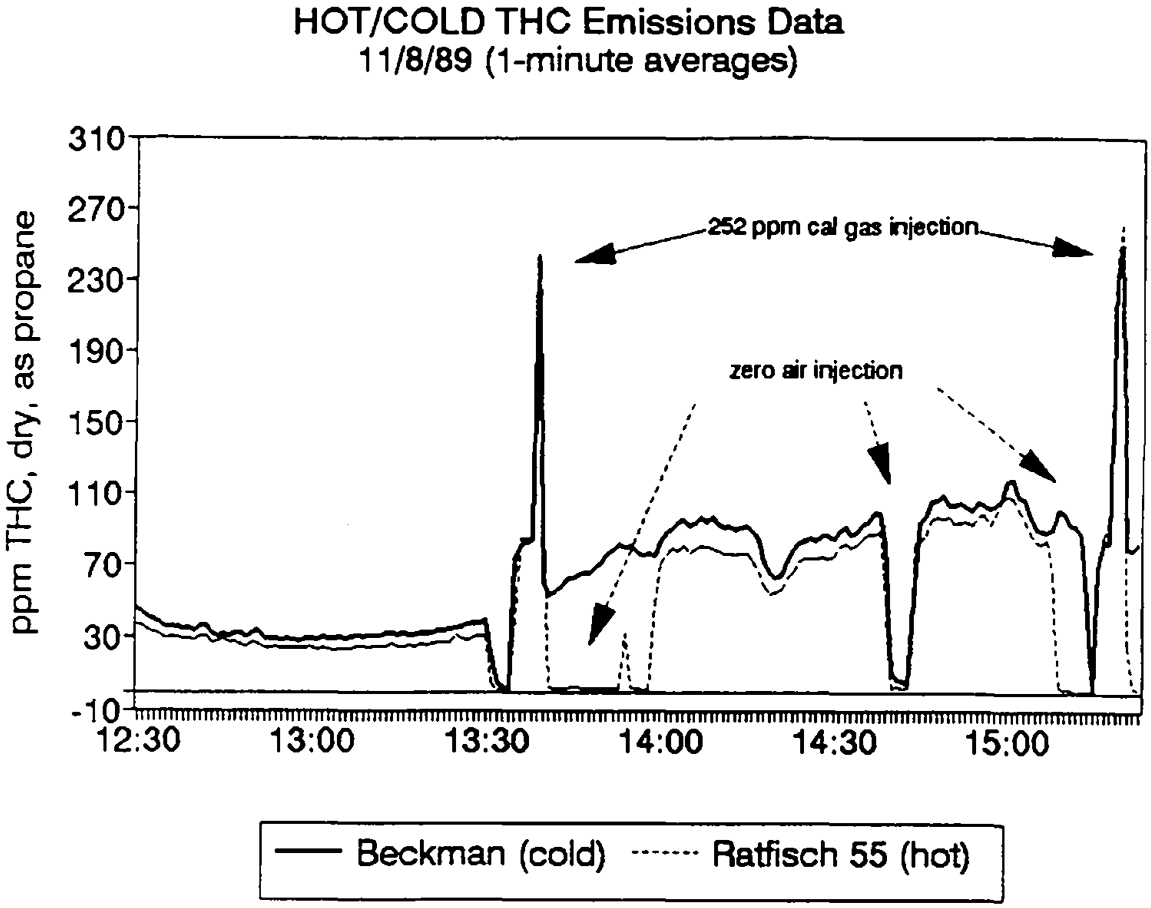


Figure 6. Hot/cold THC emissions data.

TABLE 3. CEM DATA SUMMARY

(Removing Calibration Gas Responses)

Time Period	Thermox % O2	TECO 48 ppm CO	Beckman ppm C3	Ratfisch ppm C3	TECO 48 ppm CO @7% O2	Beckman ppm THC @7% O2	Ratfisch ppm THC @ 7% O_2
12:30-13:30	9.7	1198.0	33.1	27.3	1486.8	41.1	33.9
14:00-14:38	5.8	2224.7	87.0	74.8	2047.9	80.1	68.9
14:47-15:07	4.5	2504.5	103.4	95.4	2122.7	87.6	80.9

the lowest emission levels observed during the Site 7 test program. At 13:00 hrs, the plant operator began bringing the sludge feed rate back to normal levels. Unexpectedly, emissions remained low compared to previous observations, even after the feed rate and temperature had returned to normal levels.

PARTICULATE MATTER AND METALS TESTING

Plant personnel conducted particulate matter and metals testing during the CO and THC monitoring to provide concurrent data under normal operating conditions. The results of this testing are presented in terms of emission rates in Table 4 and in concentration units in Table 5. Plant personnel experimented with hearth temperatures, nozzle pressures, and scrubber pressure drop to determine whether the same or lower emissions could be obtained in a more economical operating mode. The CO and THC emissions data do not suggest conclusive results.

TABLE 4. SUMMARY OF PARTICULATE AND METALS MASS EMISSION RATES

	10/31/1989			11/2/1989		
	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
Particulate Mass Rate (kg/hr)	0.20	0.15	0.25	0.57	0.56	0.39
Flue Gas Metal Mass Emission Rate (mg/hr)						
Arsenic	30	64	140	185	141	128
Beryllium	<100	<111	<105	< 96	<660	< 97
Cadmium	2670	2452	2942	9171	6401	4631
Chromium	<205	<223	<210	<192	<200	<193
Copper	247	279	315	577	522	328
Lead	205	223	210	2311	1598	386
Mercury	1317	1657	1448	2320	1653	1439
Molybdenum	<205	<223	<210	<192	<200	<193
Nickel	<205	<223	<210	<192	<200	<193
Selenium	14	20	16	36	29	21
Zinc	1090	1026	1575	11168	5720	1930

TABLE 5. SUMMARY OF PARTICULATE AND METALS CONCENTRATIONS

	10/31/1989			11/2/1989		
	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
Particulate Mass Rate (mg/dscm)	17.7	13.1	21.8	53.5	52.9	38.7
Flue Gas Metals Concentration (ug/dscm)						
Arsenic	2.7	5.6	12.0	17.3	13.4	12.6
Beryllium	<9.2	<9.8	<9.3	<9.0	<9.5	<9.5
Cadmium	238	214	258	858	606	458
Chromium	<18.3	<19.5	<18.6	<18.1	<19.0	<19.1
Copper	21.9	24.5	27.9	54.2	49.4	32.5
Lead	18.3	19.5	18.6	217	152	38.2
Mercury	117	145	127	217	156	143
Molybdenum	<18.3	<19.5	<18.6	<18.1	<19.0	<19.1
Nickel	<18.3	<19.5	<18.6	<18.1	<19.0	<19.1
Selenium	1.2	1.7	1.4	3.4	2.7	2.1
Zinc	97.0	89.9	139	1048	540	191

SECTION 5

SAMPLING LOCATION AND TEST PROCEDURES

SAMPLING LOCATION

Continuous monitoring was performed at the incinerator exhaust stack using various instruments to measure THC, CO, and O_2. The sampling location was at the roof-level of the incinerator stack downstream of the emissions control equipment. The inside diameter of the stack is 32 inches. The distance from the sample port to the nearest upstream flow disturbance is nine feet; the top of the stack is 15 feet above the sample port.

CEMS DESCRIPTION

The measurement system consisted of a sampling system and analyzers for the measurement of THC, CO, and O_2. The analyzers used in this test program had various gas sample conditioning requirements. Two of the THC analyzers were heated internally so that the only sample gas conditioning necessary was filtration of particulate. These hot THC measurement systems must maintain the temperature of all components of the sampling system at a minimum of 150°C. Particulate and water vapor were removed from the gas sample prior to injection into the unheated analyzers. The condensers used in the system to remove the water vapor lowered the sample gas temperature to approximately 5°C; this system is operated as a cold measurement system.

A simplified schematic of the extractive measurement system is depicted in Figure 7. (The ACS CO instruments illustrated were not used because the measurement ranges were too low. The JUM THC instrument had been returned to Entropy without the requested service and therefore was not included in the test.) Effluent gas sample was drawn from the stack via a heated sampling system and delivered to the gas analyzers located in a shelter on the ground. All components of the sampling system were made of Type 316 stainless steel, Teflon, and glass. A heated sample probe was installed on the stack. The gas

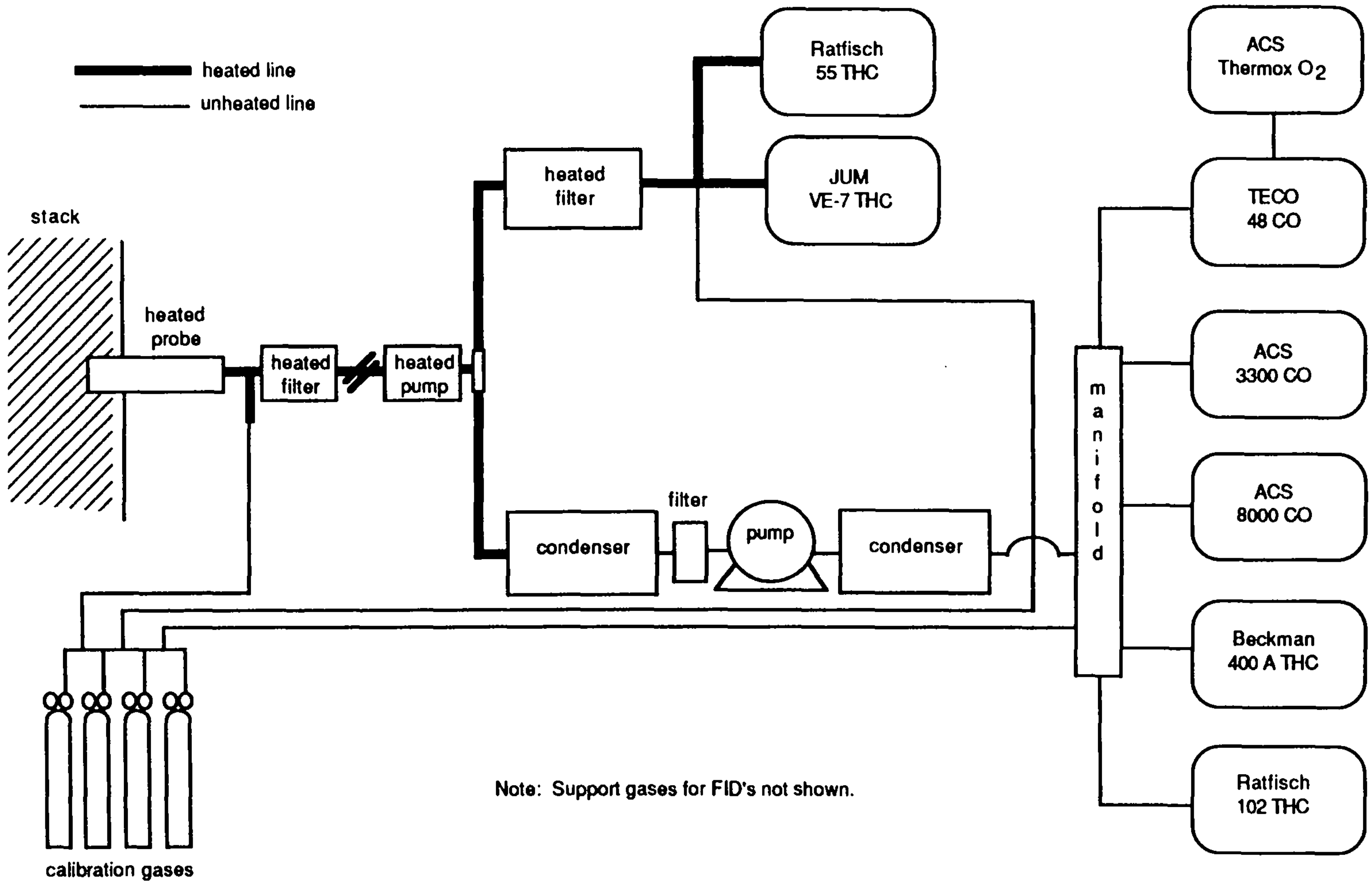


Figure 7. CO/THC sampling system configuration.

was filtered and transported through 100 feet of heated Teflon tubing via a heated sample pump. The gas sample was split into two streams at the exit of the pump. One stream was passed through a chilled condenser to remove moisture and was then delivered to Beckman Model 400A THC, Ratfisch Model 102 THC, TECO Model 48 CO, and Thermox O_2 analyzers. The temperature of the second sample stream was maintained at 150°C and passed through a secondary particulate filter and then delivered to JUM VE-7 and Ratfisch Model 55 THC analyzers.

The collected condensate was removed continuously from the condenser in the cold measurement system to minimize condensate contact with the sample gas. (See Figure 8.) A 2-micron glass fiber filter was placed downstream of the condenser. The manifold used in the cold system allowed sample pressures and flowrates to be controlled individually for each analyzer. A zero air generator was used to provide zero-level calibration gas and combustion air for the THC analyzers. Ultra-pure carrier grade air was used to verify the quality of the generated zero air.

Calibration gas injection points were located both at the probe and at the inlet to each analyzer. A calibration gas manifold was used to distribute the various gases to the proper locations.

A portable Compaq computer and an Entropy-designed data acquisition system was used to record emissions and calibration data from the analyzers. Strip chart recorders were also used to display the trends of the emissions during the testing.

Total Hydrocarbon Analyzers

The hydrocarbon instruments used in this study continuously measure the concentration of total organic hydrocarbons in a gaseous sample. This measurement is obtained by using a flame ionization detector (FID). Operation of the FID is based on a burner in which a small flame is sustained by carefully regulated flows of air and fuel gas (40% hydrogen (H_2) and 60% helium (He) or pure H_2). The burner jet is used as an electrode and is connected to the negative side of a power supply. Also in the burner is a "collector" electrode which is connected to an electrical amplifier. These polarized electrodes establish an electrostatic field in the vicinity of the burner flame. When a sample of gas is passed into the burner, it is ionized

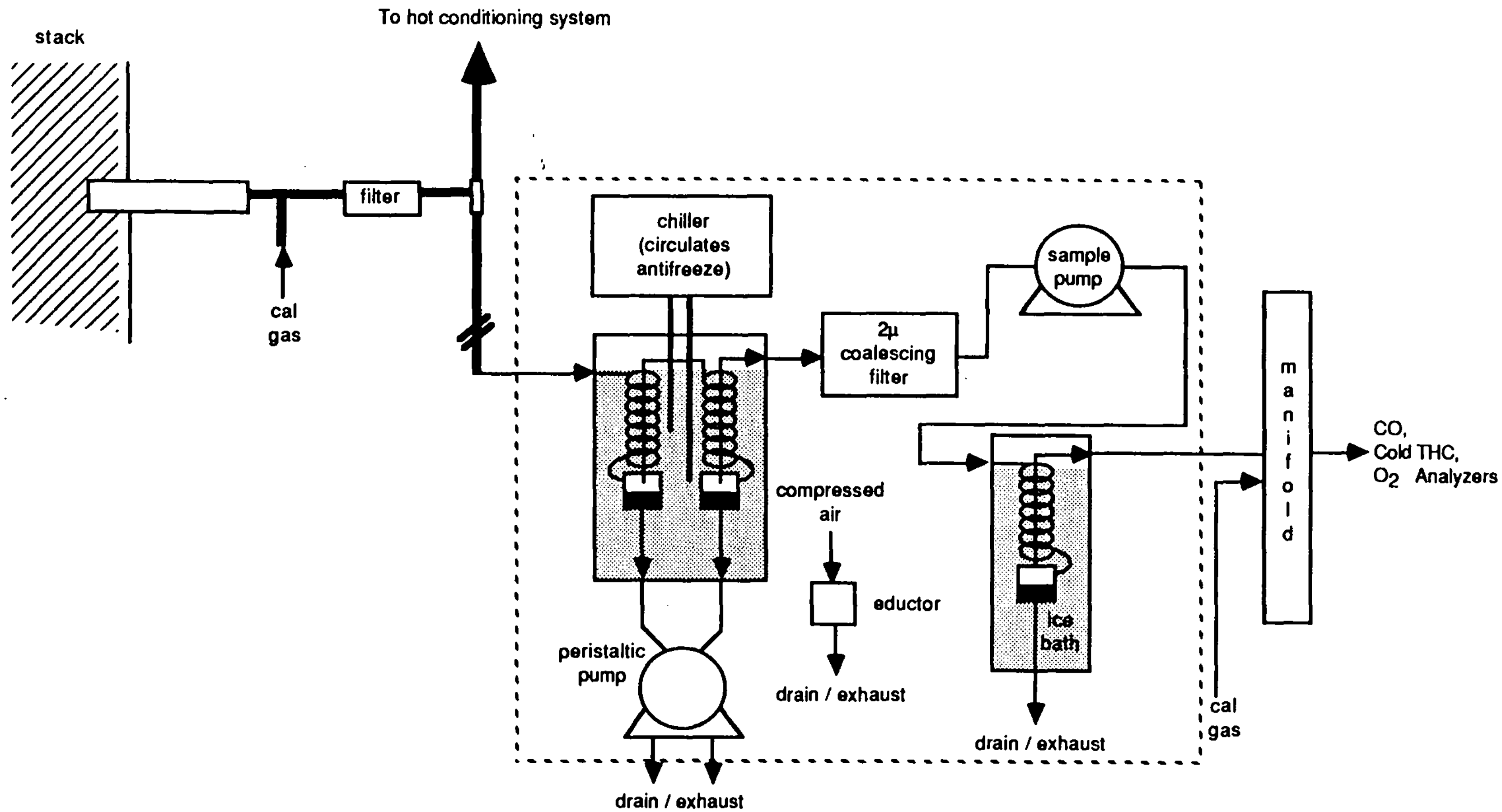


Figure 8. Detail of CO/cold THC sampling system.

in the flame. The electrostatic field causes the charged particles to migrate toward the electrodes. The resultant current flow between the electrodes is used as an input signal to an electrometer amplifier, and is displayed on the instrument meter as a percentage concentration. If the sample gas does not contain hydrocarbons, the ionization level is extremely small and produces a very low background current. When the sample gas contains hydrocarbons, ionization is increased and, with many compounds, is directly proportional to the number of carbon atoms in the sample.

Sample gas enters the instrument at flows ranging from 1 to 4 L/min. In the instrument, a small slipstream is pushed through capillary tubing to the FID. The remaining sample is exhausted. Precise regulation of the sample pressure is essential to obtain accurate FID measurements. The instrument characteristics are summarized below.

Instrument	Heated	Measurement Range
Beckman 400A	No	1250 ppm
Ratfisch 102	No	1000 ppm
Ratfisch 55	Yes	1000 ppm

Thermo Environmental Instruments (TECO) 48 Carbon Monoxide Analyzer

The TECO Model 48 employs the gas filter correlation (GFC) technique to measure CO by infrared (IR) absorption. GFC employs a correlation wheel consisting of two hemispherical cells, one filled with CO and the other filled with nitrogen (N_2). Radiation from the IR source is chopped and passed through the correlation wheel, alternating between the CO cell and the N_2 cell. Passing an infrared beam through the CO gas cell in the correlation filter provides a reference signal that cannot be attenuated further by the CO in the gas sample. The N_2 cell is transparent to the IR radiation and therefore produces a measurement beam which can be absorbed by CO in the sample cell. Radiation then passes through a narrow bandpass interference filter and enters a multiple optical pass sample cell, where absorption by the sample gas occurs. Other gases in the sample do not cause modulation of the detector signal, since they absorb the reference and measurement beams equally.

Infrared absorption is a non-linear measurement technique. To correct for this characteristic, instrument electronics convert the analyzer signal into a linear output. The exact calibration curve is stored in the instrument's microcomputer memory and is used to linearize the instrument output over all ranges. The microcomputer is also used to process signals from a pressure transducer and a temperature transducer to correct instrument output for changes in the temperature or pressure of the sample gas. The operating range of the instrument was 0-10,000 ppm CO.

Thermox O_2 Analyzer

The Thermox Model WDG III O_2 analyzer employs an electrochemical technique to measure the oxygen concentration in the effluent gas. The detector element consists of a closed-end zirconium oxide cell. Half of the cell is exposed to ambient air (reference) and the other half is exposed to the effluent gas sample. When the cell is heated red hot, it conducts an electrical current between porous platinum electrodes that consists of migrating oxygen ions. The ion migration produces a voltage output that is logarithmically proportional to the difference in oxygen concentration (partial pressures) between the reference side of the cell (ambient air) and the measurement side of the cell (sample gas). This voltage output is linearized and converted to a signal representing the oxygen concentration in the effluent gas. The measurement range was 0-25% O_2.

SAMPLING PROCEDURES

After the measurement system was assembled and satisfactorily completed a brief conditioning period, a cylinder gas audit (CGA) was conducted on the THC and CO analyzers to document the linearity and accuracy of each analyzers' measurement. The CGA was performed according to the procedures outlined in Appendix F, Procedure 1 of 40 CFR 60. Response time tests were also performed in conjunction with the CGA's.

Following the initial CGA, the measurement system was operated continuously for an approximate one-week operational test period. A calibration check was performed daily during this test period to quantify calibration drift for each analyzer. The drift assessment was conducted according to the test procedures of Performance Specification 2, 40 CFR 60, Appendix B.

SECTION 6

QUALITY ASSURANCE AND QUALITY CONTROL

This section discusses the quality assurance and quality control (QA/QC) activities performed for the sewage sludge incineration test program at Site 7. The objective of these activities, i.e., instrument drift and linearity checks, was to provide representative and comparable data of known quality.

Instrument drift checks, which compare pre- and post-test measurement of zero and span gases to the actual value, were performed for each run. These results are presented in Table 6. Zero and upscale drift were within 2 % for every measurement without any operator adjustments.

Five gases were used to determine linearity of the cold hydrocarbon system instruments and CO monitor during cylinder gas audits. Three- and two-point checks were performed on the Ratfisch 55 and Thermox O_2 analyzer, respectively. Table 7 presents the linearity check results.

During each stage of the test program, every effort was made to guarantee the integrity of the data collected. Additional quality control practices followed were:

- Conducted leak checks of all components, as well as the entire sampling system;

- Determined the calibration status of each analyzer both before and after each test period;

- Operational parameters of the analyzers were recorded throughout the test program. Logbooks were maintained which documented analyzer problems and corrective actions taken, as well as any other operational difficulties or observations; and

- All THC (propane) and CO calibration gases were prepared and certified by the vendor according to EPA Protocol I specifications. Additional hydrocarbon standard gases were $\pm 2\%$ N.B.S. traceable gas blends.

TABLE 6. SUMMARY OF CEM DRIFT CHECKS

Date and Run No.	Instrument Zero and Span Drift* (% of span)							
	CO		O_2		Beckman 400A		Ratfisch 102	
	Zero	Span	Zero	Span	Zero	Span	Zero	Span
10/28	0.01	-0.02	0.04	-0.80	0.0	-0.72	0.06	-0.40
10/29	0.03	-5.5	0.04	-0.68	0.16	0.15	0.03	-0.17
10/30	0.01	0.33	0.04	-0.80	.69	1.71	0.72	0.90
10/31 pre	0.02	0.27	0.40	-0.80	0.54	0.00	0.40	-0.28
post	0.0	-0.27	0.04	-0.80	0.68	-0.40	0.45	0.08
11/02 pre	0.0	0.13	0.04	-1.20	0.43	0.70	0.41	0.64
post	0.0	0.33	0.04	-1.04	0.64	1.14	0.89	0.35

$* \quad \frac{\text{response - gas value}}{\text{instrument span}} \times 100$

TABLE 7. LINEARITY CHECK RESULTS
HYDROCARBON INSTRUMENTS
OCTOBER 28, 1989

GAS VALUE (ppm)	BECKMAN RESPONSE		RATFISCH 102		RATFISCH 55*	
	ppm	% gas	ppm	% gas	ppm	% gas
0	0	0	0.6	--	-0.7	--
11.8	11.8	0	12.2	3.4	--	--
24.8	25.6	3.2	24.5	-1.2	--	--
45.0	46.5	3.3	45.6	1.3	--	--
85.0	85.1	0.1	80.5	-5.3	84.8	-.002
252	--	--	--	--	250.5	-.01
477	480	0.1	480.2	0.1	--	--

*3-point check conducted November 8, 1989.

CO
OCTOBER 28, 1989

Gas Value (ppm)	TECO 48 RESPONSE	
	ppm	% gas
0	0.7	--
50.1	54.4	8.6
100	102.5	2.5
683	648	-5.1
1972	1984	0.8
5007	4875	2.6

OXYGEN
OCTOBER 28, 1989

Gas Value (ppm)	THERMOX RESPONSE	
	%	% gas
0	0.1	--
10.0	9.8	-2.0
20.9	20.6	-1.4

APPENDIX A.

LINEAR REGRESSION ANALYSES

MOISTURE CALCULATIONS

SUMMARY OF 10/31/89 SAMPLING RUNS
Correlation using 1-minute averages

Run 1 - Uncorrected Data Regression Output:			Run 1 - Corrected Data Regression Output:		
Constant		-151.569043	Constant		-19.6164564
Std Err of Y Est		17.63483562	Std Err of Y Est		27.59881244
R Squared		0.860073231	R Squared		0.17037953
No. of Observations		84	No. of Observations		84
Degrees of Freedom		82	Degrees of Freedom		82
X Coefficient(s)	0.069128225		X Coefficient(s)	0.032764911	
Std Err of Coef.	0.003079152		Std Err of Coef.	0.007984231	
R Value	0.927		R Value	0.413	

Run 2 - Uncorrected Data Regression Output:			Run 2 - Corrected Data Regression Output:		
Constant		-7.25097949	Constant		27.86027225
Std Err of Y Est		5.874637969	Std Err of Y Est		6.320426695
R Squared		0.637731195	R Squared		0.321181046
No. of Observations		75	No. of Observations		75
Degrees of Freedom		73	Degrees of Freedom		73
X Coefficient(s)	0.027728114		X Coefficient(s)	0.020911434	
Std Err of Coef.	0.002445995		Std Err of Coef.	0.003558151	
R Value	0.799		R Value	0.567	

Run 3 - Uncorrected Data Regression Output:			Run 3 - Corrected Data Regression Output:		
Constant		-24.4170565	Constant		60.6368783
Std Err of Y Est		7.417970917	Std Err of Y Est		8.175286767
R Squared		0.769074156	R Squared		0.086250022
No. of Observations		72	No. of Observations		72
Degrees of Freedom		70	Degrees of Freedom		70
X Coefficient(s)	0.03820589		X Coefficient(s)	0.018656895	
Std Err of Coef.	0.002502266		Std Err of Coef.	0.007258125	
R Value	0.877		R Value	0.294	

SUMMARY OF 11/2/89 SAMPLING RUNS
Correlation using 1-minute data averages

Run 1 - Uncorrected Data Regression Output:			Run 1 - Corrected Data Regression Output:		
Constant		-343.007294	Constant		-466.80807
Std Err of Y Est		44.52362666	Std Err of Y Est		45.31121039
R Squared		0.792341024	R Squared		0.681393254
No. of Observations		56	No. of Observations		56
Degrees of Freedom		54	Degrees of Freedom		54
X Coefficient(s)	0.139419063		X Coefficient(s)	0.178473535	
Std Err of Coef.	0.009712803		Std Err of Coef.	0.016607548	
R Value	0.890		R Value	0.825	

Run 2 - Uncorrected Data Regression Output:			Run 2 - Corrected Data Regression Output:		
Constant		-60.8055185	Constant		69.6428649
Std Err of Y Est		9.852468085	Std Err of Y Est		10.49294926
R Squared		0.542955115	R Squared		0.012164216
No. of Observations		73	No. of Observations		73
Degrees of Freedom		71	Degrees of Freedom		71
X Coefficient(s)	0.052067574		X Coefficient(s)	0.007171676	
Std Err of Coef.	0.005669381		Std Err of Coef.	0.007669937	
R Value	0.737		R Value	0.110	

Run 3 - Uncorrected Data Regression Output:			Run 3 - Corrected Data Regression Output:		
Constant		-190.014311	Constant		-196.576597
Std Err of Y Est		16.20090568	Std Err of Y Est		16.27453726
R Squared		0.604525569	R Squared		0.365890571
No. of Observations		85	No. of Observations		85
Degrees of Freedom		83	Degrees of Freedom		83
X Coefficient(s)	0.079614062		X Coefficient(s)	0.0844304	
Std Err of Coef.	0.007068099		Std Err of Coef.	0.012200182	
R Value	0.778		R Value	0.605	

CO/THC Correlation Using Run Averages

Date	Run	CO Concentration	CO @ 7% O2	THC Concentration	THC @ 7% O2
10/31/89	1	3846.8	4291.8	113.6	123.1
	2	4833.7	5253.3	126.8	137.7
	3	4122.1	4467.0	133.0	144.0
11/02/89	1	4191.3	3837.9	241.3	218.1
	2	2854.3	2973.0	87.8	91.0
	3	4678.0	4320.0	182.4	168.2

SUMMARY OF ALL SIX RUNS

Uncorrected Data Regression Output:			Corrected Data Regression Output:		
Constant		-10.0162	Constant		98.73025
Std Err of Y Est		53.99703	Std Err of Y Est		47.25016
R Squared		0.241128	R Squared		0.04051
No. of Observations		6	No. of Observations		6
Degrees of Freedom		4	Degrees of Freedom		4
X Coefficient(s)	0.038530102206		X Coefficient(s)	0.011523	
Std Err of Coef.	0.03417673806		Std Err of Coef.	0.028039	
R value	0.491		R value	0.201	

SUMMARY OF 10/31 RUNS

Uncorrected Data Regression Output:			Corrected Data Regression Output:		
Constant		86.19392	Constant		97.09774
Std Err of Y Est		12.43487	Std Err of Y Est		13.98106
R Squared		0.212485	R Squared		0.149711
No. of Observations		3	No. of Observations		3
Degrees of Freedom		1	Degrees of Freedom		1
X Coefficient(s)	0.008968353453		X Coefficient(s)	0.008101	
Std Err of Coef.	0.01726545394		Std Err of Coef.	0.019305	
R value	0.461		R value	0.387	

SUMMARY OF 11/2 RUNS

Uncorrected Data Regression Output:			Corrected Data Regression Output:		
Constant		-84.4708	Constant		-92.9461
Std Err of Y Est		66.34354	Std Err of Y Est		62.46803
R Squared		0.633014	R Squared		0.524198
No. of Observations		3	No. of Observations		3
Degrees of Freedom		1	Degrees of Freedom		1
X Coefficient(s)	0.065245517173		X Coefficient(s)	0.067931	
Std Err of Coef.	0.049678569366		Std Err of Coef.	0.06472	
R value	0.796		R value	0.724	

MOISTURE CALCULATIONS FOR HOT/COLD THC COMPARISONS

$$\text{THC (dry)} = \frac{\text{THC (wet basis)}}{1 - \%H2O^{*}}$$

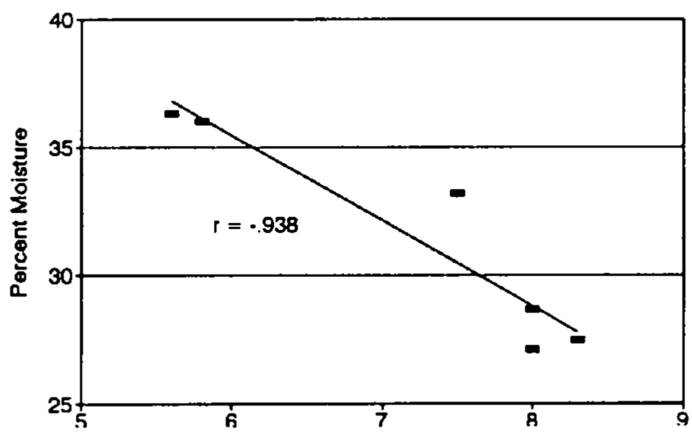
* Calculated below using measured O2 and the best-fit line of moisture vs. O2.

Date	Run	Measured H2O	Measured O2
10/31/89	1	27.5	8.3
	2	27.1	8.0
	3	28.7	8.0
11/02/89	1	36.3	5.6
	2	33.2	7.5
	3	36	5.8

Regression Output:		
Constant		55.42948
Std Err of Y Est		1.637735
R Squared		0.879956
No. of Observations		6
Degrees of Freedom		4
X Coefficient(s)	-3.32817	
Std Err of Coef.	0.614631	

Date	Time	Calc'd H2O	Measured O2
11/08/89	1230-1245	26.8	8.61
	1245-1300	24.3	9.34
	1300-1315	20.3	10.57
	1315-1330	20.3	10.56
	1330-1345	26.0	8.83
	1345-1400	33.9	6.48
	1400-1415	37.3	5.44
	1415-1430	34.3	6.36
	1430-1445	37.6	5.37
	1445-1500	40.4	4.51
	1500-1515	39.6	4.76

Best-fit Line for Moisture vs. O2



APPENDIX B.

MINUTE-BY-MINUTE
CEM DATA SUMMARIES

10-31-1989

TIME	Thermox % O2	TECO 48 ppm CO	Beckman ppm C3	Ratfisch ppm C3	TECO 48 ppm CO @7% O2	Beckman ppm THC @7% O2
13:50	7.5	4189.5			4336.1	
13:51	7.5	4214.7	139.9	139.8	4365.4	144.9
13:52	7.3	4268.6	145.8	161.6	4353.2	148.7
13:53	7.3	4395.2	148.6	151.6	4488.9	151.8
13:54	7.6	4235.7	144.5	134.3	4433.5	151.2
13:55	7.7	4244.9	145.2	135.1	4459.9	152.6
13:56	7.7	4235.1	145	134.2	4463.1	152.8
13:57	7.9	4150.2	140.4	129.5	4434.1	150.0
13:58	8.1	4070.4	138.4	132.4	4430.6	150.6
13:59	8.4	3898.5	135.3	122.8	4328.2	150.2
14:00	8.7	3817.7	131	117.6	4339.0	148.9
14:01	8.7	3788.5	129.9	115.5	4319.9	148.1
14:02	8.7	3757	131.9	118.7	4266.5	149.8
14:03	8.8	3808.1	129.3	115.8	4381.8	148.8
14:04	8.8	3683.1	130.1	106.8	4217.1	149.0
14:05	8.6	3727.5	131.7	108.4	4202.1	148.5
14:06	8.4	3828.9	133.6	115.1	4268.0	148.9
14:07	8.0	3999	136.7	120.5	4305.7	147.2
14:08	7.7	4096.4	141.6	113.2	4303.9	148.8
14:09	7.7	4197.2	141.3	114.3	4426.5	149.0
14:10	7.5	4241.5	145.8	118.9	4389.9	150.9
14:11	7.2	4305.6	148.4	109.5	4381.2	151.0
14:12	7.2	4418.1	150.7	109.2	4479.3	152.8
14:13	7.2	4534.6	149.1	108	4587.4	150.8
14:14	6.9	4549.5	155.5	112.8	4510.6	154.2
14:15	7.1	4540.2	153.7	111.2	4556.6	154.3
14:16	6.9	4729.4	153.3	111.2	4695.6	152.2
14:17	6.7	4724.9	159.4	116	4608.8	155.5
14:18	6.9	4716.7	154	111.1	4679.7	152.8
14:19	6.9	4751	151	108	4723.8	150.1
14:20	6.7	4621.1	154.4	110.4	4529.9	151.4
14:21	6.9	4712.8	152.1	108.7	4665.8	150.6
14:22	6.8	4865.7	154.5	110.3	4793.3	152.2
14:23	6.5	4834.5	163.8	118	4653.7	157.7
14:24	6.8	4820.5	158.9	121.9	4758.9	156.9
14:25	7.1	4752.4	157.6	128.9	4786.8	158.7
14:26	6.7	4742.2	170.8	122.8	4655.1	167.7
Run 3 Average	8.1	4122.1	133.0	120.7	4467.0	144.0

10-31-1989 TIME	Thermox % O2	TECO 48 ppm CO	Beckman ppm C3	Ratfisch ppm C3	TECO 48 ppm CO @7% O2	Beckman ppm THC @7% O2
12:10	7.8	4889.3	132.9	134.7	5195.8	141.2
12:11	7.8	4888.3	131.9	133.6	5198.7	140.3
12:12	8.0	4960.3	129.3	130.9	5328.3	138.9
12:13	7.8	4825.7	133.2	134.7	5136.1	141.8
12:14	7.9	4832	129.7	131	5182.5	139.1
12:15	8.0	4751.9	127.6	128.9	5132.2	137.8
12:16	8.0	4703.3	128.7	130.1	5071.8	138.8
12:17	8.0	4701.4	134.1	135.2	5054.1	144.2
Run 2 Average	8.1	4833.7	126.8	127.4	5253.3	137.7
13:11	10.0	3529.4	105.9	106	4496.7	134.9
13:12	9.4	3649	111.2	111.9	4395.2	133.9
13:13	8.5	3952.8	117.4	119.3	4427.4	131.5
13:14	8.3	4016	119	120.8	4437.4	131.5
13:15	8.2	4062.8	119.9	122.1	4432.7	130.8
13:16	8.0	3970.3	121.9	124.2	4274.8	131.2
13:17	8.0	4023.5	121.9	124.2	4332.0	131.2
13:18	8.1	4048.7	121.8	123.9	4407.0	132.6
13:19	8.1	3988.5	122.1	124.2	4341.4	132.9
13:20	8.4	3965.4	119.9	121.9	4420.1	133.6
13:21	8.8	3841.6	119.2	120.5	4405.8	136.7
13:22	9.1	3690.5	115.9	116.5	4336.3	136.2
13:23	9.4	3605.4	113.3	113.6	4369.2	137.3
13:24	9.6	3563	113.4	113.4	4367.3	139.0
13:25	9.3	3636.1	113.5	113.7	4349.6	135.8
13:26	9.1	3793	115	115.6	4460.5	135.2
13:27	9.0	3918.1	118.2	118.9	4580.5	138.2
13:28	8.9	3896	118.1	119	4509.1	136.7
13:29	8.7	4030.9	118.9	120.3	4592.6	135.5
13:30	8.5	4111.7	122.5	123.5	4590.6	136.8
13:31	8.0	4212.8	124.4	126	4553.5	134.5
13:32	8.2	4228.2	122.9	124.3	4627.7	134.5
13:33	8.2	4235.9	126.2	127.7	4632.5	138.0
13:34	8.1	4182.4	126	127.6	4531.2	136.5
13:35	8.2	4138.1	124.7	126.3	4539.8	136.8
13:36	8.7	4030.8	124	124.9	4585.0	141.0
13:37	8.7	3915.9	122.8	123.7	4447.0	139.5
13:38	8.8	3896	122.7	123.4	4471.9	140.8
13:39	8.8	3858.3	123.5	124.3	4428.6	141.8
13:40	8.9	3829.1	121.1	121.5	4450.2	140.7
13:41	9.1	3803.8	119.2	119.6	4484.5	140.5
13:42	9.0	3804.5	120.7	121.1	4443.9	141.0
13:43	8.7	3893.8	121.4	122.1	4421.9	137.9
13:44	8.8	3907.7	121.1	121.9	4503.9	139.6
13:45	8.5	3922	123.4	124.7	4407.1	138.7
13:46	7.8	4172.2	127.6	130.1	4437.2	135.7
13:47	7.7	4247.5			4482.9	
13:48 Port Change (Particulate/Metals Train)						
13:49						

10-31-1989

TIME	Thermox % O2	TECO 48 ppm CO	Beckman ppm C3	Ratfisch ppm C3	TECO 48 ppm CO @7% O2	Beckman ppm THC @7% O2
08:51	10.2	2865.2	59.6	59.6	3718.6	77.4
08:52	10.4	2873.1	60.9	60.9	3796.2	80.5
08:53	10.5	2856.7	61	60.9	3825.4	81.7
08:54	10.9	2806.2	62.3	62.2	3912.4	86.9
08:55	11.0	2804.8	63.8	63.4	3938.1	89.6
08:56	11.2	2814.9	65.5	65	4033.7	93.9
08:57	11.5	2840.6	68.2	67.7	4204.9	101.0
08:58	11.3	2856.6	68.6	68	4123.2	99.0
08:59	11.6	2917	70.1	69.7	4336.5	104.2
09:00	11.8	2935.7	73	72.4	4504.0	112.0
09:01	12.3	3202.2	74.6	74.1	5175.6	120.6
09:02	12.4	3142.9	76.2	75.7	5157.8	125.1
09:03	12.2	3119.2	77	76.5	4977.8	122.9
09:04	12.0	3184.2	77.9	77.4	4973.1	121.7
09:05	11.9	3281.6	80.1	79.7	5073.9	123.8
09:06	11.8	3344.5	82.6	82.2	5091.8	125.8
09:07	11.5	3373.9	85	85	4989.1	125.7
09:08	10.4	3447.2	85	85.8	4554.8	112.3
09:09	9.3	3523.9	88.7	90.5	4233.6	106.6
09:10	9.0	3543.3	92.2	94.3	4152.8	108.1
09:11	8.7	3657.5	95.2	98.2	4150.1	108.0
09:12	8.6	3741.5	96.6	99.5	4235.1	109.3
09:13	9.0	3709.2	97.8	100.8	4343.5	114.5
09:14	8.2	3768.6	101.3	104.8	4108.5	110.4
09:15	8.0	3902.9	104.7	108.8	4205.5	112.8
09:16	7.6	3907.2	110.8	115.5	4095.8	116.1
09:17	7.3	3915.3	115.3	120.6	3995.8	117.7
09:18	7.7	3980.6	113.5	118.6	4175.9	119.1
09:19	8.1	3946.7	112	116.4	4289.2	121.7
09:20	7.7	4016.7	116.7	122.3	4229.7	122.9
09:21	7.3	4124.7	120	126.6	4212.6	122.6
09:22	6.9	4180.2	126.6	134.5	4141.5	125.4
09:23	6.4	4191.7	135.5	144.3	4023.8	130.1
09:24	6.0	4263.1	144	154.1	3985.0	134.6
09:25	5.4	4455.6	161	173.3	4006.0	144.8
09:26	4.3	4710.6	221.9	240.9	3937.3	185.5
09:27	3.5	5459.3	294.9	322.2	4361.2	235.6
09:28	3.1	6491.6	376.8	413.6	5057.9	293.6
09:29	Port Change (Particulate/Metals Train)					
09:30						
09:31	5.9	4893.2	163.7	176.2	4537.4	151.8
09:32	6.8	4459.7	144.8	154.5	4405.8	143.1
09:33	6.5	4435.7	138.7	148.7	4266.9	133.4
09:34	6.7	4253.8	136.9	146.2	4172.7	134.3
09:35	7.1	4120.2	128.8	137	4159.1	130.0
09:36	7.1	4101.9	128.3	136.1	4140.6	129.5
09:37	6.5	4122.5	137.9	147.3	3965.6	132.7
09:38	6.2	4178	142.9	153.4	3937.2	134.7
09:39	5.9	4233.3	143.1	153.9	3915.0	132.3
09:40	6.0	4249.8	147.7	158.5	3961.9	137.7
09:41	6.2	4389	144.2	154.6	4138.9	136.0

10-31-1989 TIME	Thermox % O2	TECO 48 ppm CO	Beckman ppm C3	Ratfisch ppm C3	TECO 48 ppm CO @7% O2	Beckman ppm THC @7% O2
09:42	6.1	4276.6	138.2	148	4024.7	130.1
09:43	6.7	4260.8	133.6	142.1	4176.7	131.0
09:44	8.0	4123.9	126.2	129.9	4443.6	136.0
09:45	8.1	4040.9	121.9	126	4388.2	132.4
09:46	8.8	4116.9	109.9	113.3	4709.9	125.7
09:47	9.3	4095.5	105.7	108.5	4894.9	126.3
09:48	9.4	3996.1	103.1	105.6	4842.7	124.9
09:49	9.5	3910.7	101.9	104.3	4776.7	124.5
09:50	9.6	3871.7	101.5	103.7	4766.8	125.0
09:51	9.7	3882.7	100.1	102.2	4805.8	123.9
09:52	9.5	3882.1	100.8	103.3	4716.9	122.5
09:53	9.1	3892.5	100.7	103.5	4577.5	118.4
09:54	8.5	3939.5	100.8	104.2	4412.5	112.9
09:55	8.3	3868.8	101.5	105.1	4264.6	111.9
09:56	7.9	3891.4	103.9	108.2	4157.6	111.0
09:57	7.5	3951	109.1	113.9	4110.7	113.5
09:58	7.6	3966.2	108.1	113.2	4151.4	113.1
09:59	7.6	3936	109.3	114.3	4101.2	113.9
10:00	7.4	3919.9	110.2	115	4030.1	113.3
10:01	7.7	3929.8	108	113	4128.8	113.5
10:02	7.9	3872.3	108.5	112.5	4124.5	115.6
10:03	7.8	3784	109.3	113.4	4024.3	116.2
10:04	7.8	3936.4	109.8	114.1	4180.0	116.6
10:05	7.9	3880.5	110.1	114.4	4136.4	117.4
10:06	7.6	3826	110.6	115.5	3983.6	115.2
10:07	7.3	3859.7	111.6	116.8	3953.6	114.3
10:08	7.4	3833.9	113.3	118.4	3947.5	116.7
10:09	7.5	3826	111.7	116.8	3954.0	115.4
10:10	7.5	3885.2	111	116.2	4024.2	115.0
Run 1 Average	8.4	3846.8	113.6	118.8	4291.5	123.1
11:01	8.5	4569.1	109	108.8	5121.8	122.2
11:02	8.5	4504.5	111.7	111.3	5037.2	124.9
11:03	8.3	4336	121	120.7	4772.0	133.2
11:04	8.6	4597.4	108.4	108	5212.4	122.9
11:05	8.5	4511.3	112.5	112.3	5048.9	125.9
11:06	8.6	4311.3	120	119.8	4872.1	135.6
11:07	8.2	4871.2	119.6	119.4	5310.6	130.4
11:08	8.1	4996.1	128.2	128.7	5404.3	138.7
11:09	8.0	4709.7	133.5	133.4	5074.8	143.8
11:10	8.0	5014.1	123.3	123.1	5415.4	133.2
11:11	7.7	5122.6	143.2	143.9	5406.5	151.1
11:12	7.8	4954.8	143.1	143.4	5269.5	152.2
11:13	7.9	5259.4	134.2	134.2	5610.6	143.2
11:14	7.8	5227.7	143	143.8	5546.9	151.7
11:15	7.9	5143.8	146	146.4	5504.1	156.2
11:16	8.2	5127.1	127.9	127.5	5611.6	140.0
11:17	8.3	5155.6	135.4	135.9	5683.0	149.3
11:18	8.4	4865.7	128.1	128.2	5393.4	142.0

TIME	Thermox % O2	TECO 48 ppm CO	Beckman ppm C3	Ratfisch ppm C3	TECO 48 ppm CO @7% O2	Beckman ppm THC @7% O2
10-31-1989						
11:19	8.7	4700.2	117.3	116.7	5368.3	134.0
11:20	8.7	4779.6	119.8	119.4	5436.7	136.3
11:21	8.8	4457.4	121.5	120.7	5107.8	139.2
11:22	8.7	4647.4	114.6	113.9	5308.0	130.9
11:23	8.6	4522.5	116.5	116.5	5119.1	131.9
11:24	8.3	4650.7	123.9	123.8	5126.5	136.6
11:25	8.5	4583.8	113.9	113.8	5117.7	127.2
11:26	8.3	4601.2	115.5	115.7	5075.9	127.4
11:27	8.2	4636.7	117.3	117.5	5066.8	128.2
11:28	8.4	4586.7	115.4	115.4	5096.3	128.2
11:29	8.4	4690.9	113.6	113.7	5220.5	126.4
11:30	8.4	4533.4	114.6	114.7	5045.2	127.5
11:31	8.6	4484.4	114.5	114.6	5051.3	129.0
11:32	8.6	4616.9	111.6	111.8	5204.8	125.8
11:33	8.4	4470.7	116.5	116.7	4959.5	129.2
11:34	8.4	4644.5	118.1	118.2	5160.6	131.2
11:35	8.4	4691.6	117.5	118.2	5196.3	130.1
11:36	8.4	4649.9	118.7	119.1	5154.2	131.6
11:37	8.5	4571.3	120.6	120.3	5107.8	134.8
11:38	8.1	4806.4	124.6	124.2	5223.5	135.4
11:39	Port Change (Particulate/Metals Train)					
11:40						
11:41	7.7	5275.2	135.4	136.4	5538.2	142.1
11:42	7.6	5383.1	139.4	140.9	5609.1	145.3
11:43	7.6	5333	140.9	142.2	5582.0	147.5
11:44	7.6	5300.5	134.2	135.9	5552.1	140.6
11:45	7.4	5451.2	148.3	150.1	5625.2	153.0
11:46	7.4	5364.5	147.9	148.1	5507.1	151.8
11:47	7.6	5466.1	134.7	135.3	5699.8	140.5
11:48	7.7	5284.8	143.8	144.1	5556.6	151.2
11:49	7.8	5126.3	139.3	139.9	5422.8	147.4
11:50	7.8	5162	133.5	134.5	5477.2	141.7
11:51	7.8	5219.8	132.9	134	5551.3	141.3
11:52	7.8	4943.3	131.9	133.1	5257.2	140.3
11:53	7.9	4942.9	126.4	127.4	5289.2	135.3
11:54	8.0	4834.6	126.5	127.7	5189.3	135.8
11:55	7.9	4800.1	133.6	135.1	5132.4	142.8
11:56	7.9	5022.3	131	132.7	5357.6	139.7
11:57	8.1	5025.1	126	127.3	5444.2	136.5
11:58	8.0	4715.3	128.8	130.1	5092.7	139.1
11:59	8.2	4659	122.5	123.8	5095.2	134.0
12:00	8.2	4709.1	124.1	125.1	5137.9	135.4
12:01	7.8	4757.3	132.9	134.3	5055.5	141.2
12:02	8.0	4823.3	126.2	127.4	5209.3	136.3
12:03	8.2	4779.3	124.8	125.6	5247.4	137.0
12:04	8.0	4603.4	129.3	130.6	4971.8	139.6
12:05	8.3	4661.8	124.5	125.6	5142.8	137.3
12:06	8.4	4622	124.3	125.3	5143.8	138.3
12:07	8.2	4671.2	127.7	128.8	5100.5	139.4
12:08	8.2	4632.5	126.1	127.4	5066.2	137.9
12:09	8.1	4799.8	129.9	131.5	5204.2	140.8

11-02-1989

TIME	Thermox % O2	TECO 48 ppm CO	Beckman ppm C3	Ratfisch ppm C3	TECO 48 ppm CO @7% O2	Beckman ppm THC @7% O2
08:32	8.0	3093.4	83.8	89.3	3325.5	90.1
08:33	7.7	3122.0	86.3	92.1	3297.6	91.2
08:34	7.4	3233.9	92.8	99.5	3322.3	95.3
08:35	7.1	3121.1	97.9	105.1	3136.9	98.4
08:36	7.0	3285.1	101.7	109.3	3275.7	101.4
08:37	6.9	3546.1	107.7	116.1	3520.8	106.9
08:38	6.8	3539.9	125.5	134.5	3479.8	123.4
08:39	6.8	3514.6	123.4	131.7	3472.1	121.9
08:40	6.8	3612.8	113.7	123.2	3554.0	111.8
08:41	6.9	3656.0	128.4	138.0	3635.1	127.7
08:42	7.0	3424.0	133.9	143.4	3411.7	133.4
08:43	7.0	3595.6	121.8	130.3	3585.3	121.5
08:44	7.0	3805.8	133.1	143.0	3803.1	133.0
	Invalid Data -- Sampling system problem					
09:02	6.4	3691.9	160.8	172.4	3529.4	153.7
09:03	6.4	3479.6	149.0	162.3	3324.2	142.3
09:04	6.3	3462.1	142.8	154.4	3300.6	136.1
09:05	6.4	3836.7	136.3	149.6	3670.3	130.4
09:06	5.9	3777.3	207.2	224.5	3495.6	191.7
09:07	5.5	3981.3	219.1	237.5	3593.5	197.8
09:08	5.6	4268.3	174.4	190.9	3875.2	158.3
09:09	Invalid Data -- Port Change particulate/metals train					
09:10						
09:11	5.3	4169.9	238.1	257.1	3713.1	212.0
09:12	5.2	4756.5	217.0	238.3	4216.5	192.4
09:13	5.2	4409.1	261.0	285.5	3891.2	230.3
09:14	5.2	4143.8	267.2	290.0	3666.4	236.4
09:15	5.2	4406.7	207.3	226.3	3904.0	183.7
09:16	5.1	4558.6	232.2	254.3	4020.6	204.8
09:17	4.8	4179.1	262.0	285.2	3617.0	226.8
09:18	4.6	4275.7	274.6	297.2	3641.7	233.9
09:19	4.2	5071.3	291.7	319.3	4226.1	243.1
09:20	4.4	4926.5	294.3	322.4	4142.7	247.5
09:21	4.3	4540.4	312.4	339.2	3792.8	261.0
09:22	4.1	4762.3	319.5	345.9	3930.9	263.7
09:23	4.2	5172.7	365.1	396.8	4308.0	304.1
09:24	4.5	5174.4	370.5	399.0	4380.3	313.6
09:25	4.3	5091.0	359.5	388.2	4255.3	300.5
09:26	4.3	5216.6	395.2	425.0	4368.1	330.9
09:27	4.7	5265.3	392.3	422.6	4503.9	335.6
09:28	4.9	4813.9	364.0	389.4	4169.0	315.2
09:29	4.6	5051.6	340.6	365.8	4313.1	290.8
09:30	4.7	5064.5	379.8	408.3	4342.8	325.7
09:31	5.4	4512.5	319.9	340.7	4036.3	286.1
09:32	5.6	4373.5	245.2	261.3	3981.1	223.2
09:33	5.8	4113.9	226.4	242.5	3794.5	208.8
09:34	5.7	4009.5	284.8	302.0	3676.3	261.1
09:35	6.0	3986.5	261.5	276.7	3714.0	243.6
09:36	5.7	4285.5	266.0	281.0	3906.1	242.5
09:37	5.5	4484.4	302.9	323.1	4050.2	273.6
09:38	5.8	4244.6	370.3	388.2	3902.1	340.4
09:39	6.0	4562.7	339.4	357.1	4259.3	316.8

11-02-1989 TIME	Thermox % O2	TECO 48 ppm CO	Beckman ppm C3	Ratfisch ppm C3	TECO 48 ppm CO @7% O2	Beckman ppm THC @7% O2
09:40	5.6	4921.0	360.0	381.1	4462.0	326.4
09:41	5.6	4626.5	398.0	420.7	4214.2	362.5
09:42	6.0	4347.8	340.1	357.9	4053.3	317.1
09:43	6.3	4555.3	314.9	330.3	4336.9	299.8
09:44	7.3	4312.7	226.7	240.5	4394.9	231.0
09:45	6.6	3529.0	240.1	251.0	3432.7	233.5
09:46	6.8	3750.5	235.0	246.1	3694.7	231.5
Run 1 Average	5.8	4191.3	241.3	259.0	3837.9	218.1
10:21	8.5	2426.7	73.1	76.1	2713.7	81.7
10:22	8.3	2362.8	71.5	74.8	2608.7	78.9
10:23	8.2	2423.0	71.7	75.4	2660.3	78.7
10:24	8.4	2416.5	71.9	75.1	2682.9	79.8
10:25	8.0	2406.8	74.4	77.3	2595.4	80.2
10:26	8.2	2547.8	74.1	77.1	2782.0	80.9
10:27	8.1	2597.7	77.8	81.5	2812.2	84.2
10:28	7.7	2590.2	79.0	83.4	2733.8	83.4
10:29	7.5	2535.7	79.6	84.7	2620.5	82.3
10:30	7.5	2689.3	78.4	83.8	2795.9	81.5
10:31	7.2	2715.1	90.0	95.5	2750.7	91.2
10:32	6.7	2795.4	96.4	102.5	2726.7	94.0
10:33	6.6	3000.4	98.3	104.8	2916.5	95.6
10:34	6.5	3273.1	116.6	124.8	3166.0	112.8
10:35	6.5	3023.9	116.1	123.9	2908.8	111.7
10:36	6.3	3106.9	112.0	120.0	2966.1	106.9
10:37	6.3	3385.1	124.1	133.2	3214.0	117.8
10:38	6.5	3196.1	112.2	120.7	3085.1	108.3
10:39	6.5	2948.8	108.8	116.8	2848.4	105.1
10:40	6.9	3092.3	97.7	105.2	3072.4	97.1
10:41	6.8	3004.5	101.5	109.1	2968.2	100.3
10:42	6.7	2959.8	117.4	124.3	2897.3	114.9
10:43	6.6	3115.3	106.6	113.6	3017.6	103.3
10:44	6.6	3308.5	111.7	119.8	3213.7	108.5
10:45	6.7	3065.7	113.3	120.7	2994.6	110.7
10:46	6.6	2967.4	114.4	121.2	2882.4	111.1
10:47	6.9	3143.1	95.1	102.2	3122.9	94.5
10:48	7.2	2879.7	92.7	99.8	2911.1	93.7
10:49	7.1	2843.8	97.7	104.5	2864.4	98.4
10:50	7.4	2777.5	89.5	95.2	2857.7	92.1
10:51	7.5	2913.9	88.0	93.3	3029.4	91.5
10:52	7.4	2891.9	98.3	104.0	2982.0	101.4
10:53	7.2	2879.5	96.1	101.7	2917.3	97.4
10:54	7.4	3033.6	90.7	96.5	3114.3	93.1
10:55	7.0	3029.0	97.3	103.6	3033.4	97.4
10:56	7.1	2941.1	97.4	103.2	2953.9	97.8
10:57	6.8	2928.9	103.2	109.3	2883.3	101.6
10:58	Invalid Data -- Port Change particulate/metals train					
10:59						
11:00	7.1	2925.4	96.6	103.0	2940.2	97.1
11:01	7.4	2975.4	88.3	94.1	3061.3	90.8

11-02-1989 TIME	Thermox % O2	TECO 48 ppm CO	Beckman ppm C3	Ratfisch ppm C3	TECO 48 ppm CO @7% O2	Beckman ppm THC @7% O2
11:02	7.4	3061.8	96.2	102.3	3159.5	99.3
11:03	7.6	2888.8	88.9	95.1	3025.9	93.1
11:04	7.5	2801.2	90.6	96.7	2914.4	94.3
11:05	7.6	3076.5	85.8	91.4	3215.3	89.7
11:06	7.7	2925.2	87.7	93.0	3071.0	92.1
11:07	7.8	2727.6	82.9	87.4	2900.8	88.2
11:08	7.9	2746.1	79.9	84.8	2934.0	85.4
11:09	7.8	2781.4	81.0	86.3	2940.0	85.6
11:10	7.6	2813.1	85.7	91.1	2948.9	89.8
11:11	7.5	2753.5	83.2	88.9	2858.4	86.4
11:12	7.6	2856.6	81.2	86.9	2992.2	85.1
11:13	7.5	2944.3	88.2	94.3	3056.4	91.6
11:14	7.3	2852.1	88.3	94.0	2908.6	90.0
11:15	7.6	2926.5	85.5	91.1	3047.1	89.0
11:16	7.6	2978.2	81.5	87.2	3121.9	85.4
11:17	7.6	2815.5	83.5	88.7	2949.2	87.5
11:18	7.7	2748.3	80.8	85.7	2894.0	85.1
11:19	7.9	2812.1	75.1	80.3	3004.5	80.2
11:20	8.0	2792.5	79.1	84.7	3011.3	85.3
11:21	8.0	2709.9	76.6	82.0	2924.5	82.7
11:22	8.3	2750.3	74.1	78.8	3022.1	81.4
11:23	8.3	2809.4	73.4	77.9	3094.3	80.8
11:24	8.3	2746.5	74.9	79.3	3029.9	82.6
11:25	8.4	2697.9	73.8	78.2	3002.5	82.1
11:26	8.6	2788.0	69.7	74.2	3137.9	78.4
11:27	8.5	2728.3	71.3	75.3	3051.0	79.7
11:28	8.4	2721.9	75.6	79.7	3031.6	84.2
11:29	8.2	2888.6	74.3	78.9	3169.0	81.5
11:30	8.3	2944.8	71.6	76.1	3259.0	79.2
11:31	8.3	2888.0	74.7	78.6	3175.9	82.1
11:32	8.5	2834.0	71.2	75.0	3171.7	79.7
11:33	8.7	2884.5	68.1	71.8	3286.4	77.6
11:34	8.8	2803.7	68.1	71.6	3218.1	78.2
11:35	8.9	2749.2	68.2	71.2	3195.1	79.3
Run 2 Average	7.6	2854.3	87.8	93.3	2973.0	91.0
13:01	5.6	5094.9	243.5	263.2	4622.7	220.9
13:02	6.2	4793.2	226.1	241.8	4532.3	213.8
13:03	6.1	4718.1	219.0	234.1	4425.2	205.4
13:04	6.4	4429.1	174.7	187.3	4234.1	167.0
13:05	6.4	4401.4	188.6	201.3	4213.5	180.5
13:06	6.6	4195.3	165.9	177.1	4083.7	161.5
13:07	6.5	4352.9	167.3	177.9	4195.9	161.3
13:08	6.6	4301.2	157.9	167.8	4192.6	153.9
13:09	6.9	4076.7	140.5	149.6	4038.9	139.2
13:10	6.6	4167.4	148.6	158.4	4056.5	144.6
13:11	6.8	4208.8	159.4	168.8	4155.0	157.4
13:12	6.6	4277.3	149.0	158.2	4146.1	144.4
13:13	6.2	4322.8	157.8	167.9	4084.8	149.1
13:14	6.3	4370.4	160.0	169.4	4146.7	151.8

11-02-1989

TIME	Thermox % O2	TECO 48 ppm CO	Beckman ppm C3	Ratfisch ppm C3	TECO 48 ppm CO @7% O2	Beckman ppm THC @7% O2
13:15	6.4	4396.1	149.7	159.3	4214.2	143.5
13:16	6.2	4486.0	164.7	174.1	4244.8	155.8
13:17	6.0	4558.4	188.0	198.6	4246.8	175.1
13:18	6.1	4615.9	171.0	181.2	4320.6	160.1
13:19	6.0	4656.2	183.4	193.9	4335.0	170.7
13:20	5.6	4890.8	232.4	244.6	4431.7	210.6
13:21	5.4	5011.8	229.6	241.9	4497.4	206.0
13:22	5.5	4979.4	203.0	216.1	4503.2	183.6
13:23	5.3	5144.5	250.4	264.1	4592.7	223.5
13:24	5.3	5075.4	223.3	237.2	4533.9	199.5
13:25	5.7	4891.9	178.8	190.1	4467.6	163.3
13:26	5.8	4801.5	187.1	197.7	4419.9	172.2
13:27	5.7	4788.6	200.9	212.0	4381.9	183.8
13:28	5.7	4714.6	184.3	194.9	4311.4	168.5
13:29	6.0	4760.8	167.8	178.2	4426.4	156.0
13:30	5.9	4748.5	177.2	187.1	4397.3	164.1
13:31	6.0	4455.9	165.5	175.2	4162.4	154.6
13:32	6.3	4379.4	143.2	152.0	4160.9	136.1
13:33	6.3	4360.7	148.1	157.2	4140.3	140.6
13:34	6.2	4410.0	150.1	160.0	4164.3	141.7
13:35	6.0	4335.7	174.8	184.1	4036.6	162.7
13:36	6.0	4680.0	153.9	164.6	4374.7	143.9
13:37	5.9	4658.2	180.7	191.7	4322.4	167.7
13:38	6.0	4424.8	168.8	178.9	4133.4	157.7
13:39	6.1	4494.1	147.8	156.9	4232.2	139.2
13:40	6.0	4665.4	173.0	183.5	4358.1	161.6
13:41	6.0	4478.3	176.6	186.2	4163.8	164.2
13:42	6.1	4497.8	161.2	169.5	4230.0	151.6
13:43	6.2	4603.4	149.5	159.9	4361.8	141.7
13:44	5.9	4517.1	172.3	182.8	4191.4	159.9
13:45	6.1	4354.1	163.4	172.8	4092.1	153.6
13:46	6.3	4543.4	140.3	149.3	4310.8	133.1
13:47	6.0	4619.3	173.1	183.5	4309.3	161.5
13:48	5.8	4554.1	177.2	188.1	4189.4	163.0
13:49	5.9	4720.5	174.1	183.7	4374.3	161.3
13:50	5.6	4841.8	170.6	182.4	4407.4	155.3
13:51	Invalid Data -- Port Change particulate/metals train					
13:52						
13:53	5.6	4727.7	174.0	185.3	4300.7	158.3
13:54	5.4	4846.7	217.2	230.0	4349.2	194.9
13:55	5.1	4982.9	225.4	239.7	4394.8	198.8
13:56	5.2	5005.9	236.7	251.2	4423.5	209.2
13:57	5.3	5164.8	214.4	229.2	4599.0	190.9
13:58	5.1	5124.5	235.0	249.5	4511.1	206.9
13:59	5.6	4804.6	202.7	215.0	4350.7	183.6
14:00	5.8	4950.7	178.3	189.9	4557.3	164.1
14:01	5.9	4882.9	182.5	195.1	4518.8	168.9
14:02	5.7	4524.3	184.8	196.5	4148.3	169.4
14:03	5.7	4714.3	189.1	200.6	4308.3	172.8
14:04	5.7	4844.0	189.8	202.4	4415.2	173.0
14:05	5.3	5062.4	219.3	232.8	4519.4	195.8
14:06	5.5	5015.7	209.2	223.1	4536.0	189.2

11-02-1989 TIME	Thermox % O2	TECO 48 ppm CO	Beckman ppm C3	Ratfisch ppm C3	TECO 48 ppm CO @7% O2	Beckman ppm THC @7% O2
14:07	5.8	5058.6	183.9	196.0	4644.3	168.8
14:08	5.6	4961.6	193.1	205.7	4516.5	175.8
14:09	5.9	4743.4	176.5	188.1	4386.8	163.2
14:10	6.2	4664.4	157.3	167.4	4407.6	148.6
14:11	6.2	4518.4	160.6	170.9	4260.9	151.4
14:12	6.0	4686.8	169.4	179.2	4357.6	157.5
14:13	5.8	4734.3	174.8	185.6	4352.3	160.7
14:14	5.9	4697.5	172.4	182.5	4358.8	160.0
14:15	5.8	4673.8	169.1	179.2	4305.2	155.8
14:16	5.7	4678.1	166.5	177.3	4280.8	152.4
14:17	5.7	4717.4	186.3	196.8	4313.9	170.4
14:18	5.9	4787.8	169.0	179.2	4422.0	156.1
14:19	5.7	4775.2	170.9	180.8	4369.7	156.4
14:20	5.6	4690.2	188.6	199.8	4249.9	170.9
14:21	5.4	4842.9	196.4	207.6	4343.0	176.1
14:22	5.4	4865.3	197.4	209.2	4360.3	176.9
14:23	5.1	4844.5	190.5	202.6	4267.3	167.8
14:24	5.2	4835.7	208.8	220.3	4270.4	184.4
14:25	5.2	4806.4	205.7	218.2	4252.6	182.0
14:26	5.2	4899.2	192.3	204.6	4323.7	169.7
14:27	5.1	4670.4	203.5	217.4	4101.0	178.7
Run 3 Average	5.9	4678.0	182.4	193.7	4320.5	168.2

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before complet

1. REPORT NO.	2.	3.
EPA/600/R-92/003e		PB92-151596

4. TITLE AND SUBTITLE

EMISSIONS OF METALS, CHROMIUM AND NICKEL SPECIES, AND ORGANICS FROM MUNICIPAL WASTEWATER SLUDGE INCINERATORS VOLUME V: Site 7 Test Report - CEMS Evaluation

5. REPORT DATE

March 1992

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)

Cone, A. Laurie, and Scott A. Shanklin

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

Entropy Environmentalists, Inc.
Research Triangle Park
North Carolina, 27709

10. PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO.

Contract No. 68-CO-0027
Work Assignment No. 0-5

12. SPONSORING AGENCY NAME AND ADDRESS

Risk Reduction Engineering Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, OH 45268

13. TYPE OF REPORT AND PERIOD COVERED

Draft Report 1989 - 91

14. SPONSORING AGENCY CODE

EPA/600/14

15. SUPPLEMENTARY NOTES

EPA Technical Contact: Dr. Harry E. Bostian, (513) 569-7619, FTS: 684-7619

16. ABSTRACT

The U. S. Environmental Protection Agency (EPA) Office of Water Regulations and Standards (OWRS) has recently revised the risk-based sludge regulations under Section 405d of the Clean Water Act. The revised regulations include a provision for monitoring total hydrocarbon (THC) and/or carbon monoxide (CO) emissions as a surrogate for organic emissions measurements.

With the assistance of EPA's Risk Reduction Engineering Laboratory (RREL), OWRS has implemented a research program to investigate the relationship of CO and hydrocarbon emissions and the viability of the monitoring systems used to continuously measure these emissions. This test report presents the results obtained at the Site 7 municipal wastewater treatment facility.

The CO and THC emission levels showed good agreement during the test program, i.e., increases in CO are accompanied by increases in THC. The actual correlation coefficients ranged from .73-.93 using one-minute averaged data from six test runs. Comparisons of CO and THC values corrected to 7% oxygen levels do not provide the same measure of correlation (r-values from .11 to .83). Possible explanation of the apparent change in agreement is being investigated further. This report presents uncorrected and corrected emission data in both tabular and graphic formats.

This report was submitted in fulfillment of Contract No. 68-CO-0027, Work Assignment No. 0-5 by Entropy Environmentalists, Inc. under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from October 28 to November 8, 1989, and work was completed as of August 26, 1991.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Water pollution, sludge disposal, incinerator(s), organic compounds, combustion products	Emissions, multiple hearth, total hydrocarbons, continuous monitoring	

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
RELEASE TO PUBLIC	UNCLASSIFIED	49
	20. SECURITY CLASS *(This page)*	22. PRICE
	UNCLASSIFIED	

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE