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Acurex Technical Report TR-84-153/EE

ENVIRONMENTAL ASSESSMENT OF A RECIPROCATING ENGINE RETROFITTED WITH NONSELECTIVE CATALYTIC REDUCTION

Project Summary

AP 42 sect 3.2

by

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June 1984

Acurex Project 7733
Contract No. 68-02-3188

Project Officer

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INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY
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U.S. ENVIRONMENTAL PROTECTION AGENCY
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PROJECT SUMMARY

This report describes emission results obtained from field testing of a rich-burn reciprocating internal combustion engine retrofitted with a nonselective catalytic reduction system (NSCR) for NO_x reduction. Two series of tests were performed: a comprehensive 1-day test program to characterize catalyst inlet and outlet organic and inorganic emissions at constant engine operation with catalyst NO_x reduction greater than 80 percent; and a 15-day exhaust emission monitoring program to measure the catalyst performance under typical engine operating conditions.

Emission measurements during the comprehensive test program included continuous monitoring of flue gas emissions; source assessment sampling system (SASS) sampling of the exhaust gas with subsequent laboratory analysis of samples to give solid particulate emissions, total organics in two boiling point ranges, compound category information within these ranges, specific quantitation of the semivolatile organic priority pollutants, and exhaust gas concentrations of 73 trace elements; Modified Method 6 sampling for NH_3 and total cyanides; and exhaust gas grab sampling for N_2O analysis by gas chromatography. Emission measurements during the 15-day monitoring program were limited to continuous monitoring of exhaust gas species.

Comprehensive test results indicated that over the 1-day test period the NO_x reduction performance of the catalyst ranged between 54 and 81 percent with an average of 70 percent. NO_x emissions at the catalyst inlet ranged

between 1,650 and 1,850 ppm as measured at 0.1 percent O_2 (1,700 ppm average). At the catalyst outlet NO_x ranged between 300 and 800 ppm, also at 0.1 percent O_2 (550 ppm average).

Catalyst inlet CO concentrations averaged 14,600 ppm as measured and total unburned hydrocarbons averaged 215 ppm. High catalyst inlet combustible concentrations are necessary to ensure sufficient reducing agent to allow the catalytic NO_x reduction reactions to occur. This required that the engine operate with an air/fuel ratio (A/F) near or slightly below the stoichiometric A/F of 16.35 (dry weight basis). TUHC concentrations were reduced to 125 ppm and CO levels reduced to an average of 13,200 ppm by the catalyst. Total organic (C_{6+}) emissions were also reduced by the catalyst from 15.5 to 2.1 mg/dscm (36 to 4.7 mg/Bhp-hr) in parallel with corresponding TUHC and CO reductions. Emissions of 14 polynuclear aromatic hydrocarbon (PAH) species were quantitated in both catalyst inlet and outlet exhaust. Again, inlet levels were generally higher than outlet levels, with the exception of naphthalene and phenol emissions, which increased.

Both NH_3 and cyanide (CN^-) levels in the exhaust increased across the catalyst. NH_3 levels increased from 31 to 485 ppm. Total cyanide levels increased from 0.02 to 8.2 ppm (0.051 to 22 mg/Bhp-hr).

During the 15-day performance test, the NO_x reduction performance was mostly in the 0 to 40 percent range. Only occasionally did NO_x reduction exceed 90 percent. During the periods of higher reduction performance, CO and TUHC emissions at the inlet were as high as 1 percent and 0.1 percent, respectively.

INTRODUCTION

In California, the South Coast Air Quality Management District (SCAQMD) continues to be in nonattainment of both federal and state NO_2 standards. Stationary reciprocating internal combustion engines are estimated to contribute about 14 percent of the NO_x (about 59 Mg/day (65 tons/day)) from all stationary sources and 5.1 percent of total NO_x emissions in the basin (References 1, 2). In 1979, the California Air Resources Board (CARB) proposed a control strategy for ICE's that called for retrofit of these sources with nonselective and selective gas treatment catalysts (NSCR and SCR, respectively) (Reference 3). The SCAQMD rule 1110 calls for demonstration of 90 percent NO_x reduction or an emissions limit of 0.28 µg/J (0.75 g/Bhp-hr) of heat output for rich burn engines, and 80 percent reduction or an emission limit of 0.56 µg/J (1.5 g/Bhp-hr) for lean burn engines. Following this rule, there has been a sustained R&D effort to demonstrate the capability of commercially available NSCR and SCR catalysts and identify any problems in their application.

This report describes the results of comprehensive emission tests and 15-day extended monitoring tests of a rich-burn reciprocating engine retrofitted with an NSCR system. Emissions were measured at both inlet (muffler outlet) and outlet of the catalyst to quantitate both NO_x reduction performance and the impact of the catalyst on other inorganic and organic pollutants.

The tests were performed on a Waukesha 610 kW (818-hp) L7042 GU four-stroke naturally aspirated electric generator engine owned and operated by Southern California Gas Company (SoCal). In November 1982, the engine was retrofitted with a DuPont PR-5 NSCR catalyst having about 4,000 operating

hours on another SoCal engine. This catalyst was previously tested and found capable of 90 percent NO_x reduction on the larger compressor engine. The PR-5 catalyst is based on a platinum-rhodium formulation and has an upper temperature limit of 1,450°F. Previous tests by SoCal had shown that 90 percent NO_x reduction was achieved over a narrow A/F range, with A/F sufficiently rich that catalyst inlet CO and TUHC concentrations exceeded 4,000 ppm and 1,000 ppm, respectively. This A/F is richer than the engine would normally be operated, resulting in a fuel penalty of 11 percent (Reference 4). The engine did not come equipped with a manufacturer-supplied automatic A/F control nor was one retrofitted for these tests.

SUMMARY AND CONCLUSIONS

Engine Operation

The test program called for the evaluation of NO_x reduction performance of the catalyst and its effect on organic and inorganic pollutants during 1 day of comprehensive tests with the engine A/F adjusted for optimum NO_x reduction at constant power output. In addition, the test program called for a continuous 15-day emission monitoring program to evaluate the NO_x control capability with the engine operating under typical conditions with varying load and A/F.

Table 1 summarizes engine operating characteristics during the comprehensive tests. Engine load was maintained relatively constant throughout this portion of the test program. Generator output varied from 415 to 455 kWe corresponding to approximately 450 to 490 kW (600- to 660-Bhp) engine shaft output. Brake specific fuel consumption was 12.3 MJ/kWh (8,660 Btu/Bhp-hr) based on fuel lower heating value. This represents a

TABLE 1. ENGINE OPERATION -- COMPREHENSIVE TESTS

Parameter	Range	Average
Ambient		
Dry bulb temperature, °C (°F)	26 to 29 (79 to 85)	29 (84)
Wet bulb temperature, °C (°F)	20 to 22 (68 to 71)	22 (71)
Relative humidity, percent	--	52
Barometric pressure, kPa (in. Hg)	--	96.4 (28.55)
Engine Operation		
Generator output, kW	415 to 455	425
Engine load, kW_t (Bhp)[a]	448 to 492 (601 to 660)	459 (616)
Fuel flow, m^3/h (scfh)	--	156 (5,569)
Heat input, MW (million Btu/hr)[b]	--	1.56 (5.33)
Specific fuel consumption, KJ/kWh (Btu/Bhp-hr)[b]	--	12,300 (8,660)
Air manifold pressure		
• L, kPa (in. Hg vac)	14 to 16 (4.1 to 4.6)	15 (4.4)
• R, kPa (in. Hg vac)	14 to 16 (4.1 to 4.8)	15 (4.5)
Speed, rpm	900 to 910	905
Catalyst inlet temperature, °C (°F)	533 to 536 (991 to 997)	535 (995)
Catalyst output temperature, °C (°F)	534 to 561 (994 to 1,042)	552 (1,025)
Gas Analysis, Percent Volume[c]		
O_2	--	0.073
N_2	--	1.119
CO_2	--	0.890
CH_4	--	90.119
C_2H_6	--	6.294
C_3H_8	--	1.247
iso-C_4H_{10}	--	0.094
n-C_4H_{10}	--	0.106
iso-C_5H_{12}	--	0.029
n-C_5H_{12}	--	0.029
C_{6+}	--	0.003
HHV, MJ/m^3 (Btu/ft^3)[d]		39.9 (1,072)
LHV, MJ/m^3 (Btu/ft^3)[d]		36.0 (968)

[a]Horsepower not a measured value -- calculated from generator output times 1.45
[b]Based on low heating value
[c]Based on data supplied by SoCal
[d]Calculated heating value

loss in fuel efficiency of about 15 percent based on the manufacturer's specification for full load operation.

Emission Measurements and Results -- Comprehensive Tests

The sampling and analysis procedures used in this test conformed to a modified EPA Level 1 protocol (Reference 5). The exhaust gas measurements included the following at both the catalyst inlet and outlet locations:

- Continuous monitoring for O_2, CO_2, CO, NO/NO_x and TUHC
- SASS sampling
- Modified Method 6 train sampling for NH_3 and total cyanide
- Gas grab sample for N_2O determination

The analysis protocol included:

- Analyzing SASS train samples for 73 trace elements using spark source mass spectrometry (SSMS), supplemented by atomic absorption spectrometry (AAS)
- Analyzing SASS train samples for total organic content in two boiling point ranges: 100° to 300°C by total chromatographable organics (TCO) analyses, and greater than 300°C by gravimetry (GRAV)
- Analyzing the SASS train sorbent module for 58 semivolatile organic species including many of the PAH compounds
- Performing infrared (IR) spectrometry analysis of organic sample extracts
- Performing liquid chromatography (LC) separation of selected sample extracts with subsequent TCO, GRAV, and IR analysis of LC fractions
- Performing mutagenicity and toxicity health effects bioassays of SASS samples

Table 2 summarizes emissions measured at the engine muffler outlet (catalyst inlet) and the catalyst outlet locations. Emissions are presented in milligrams per dry standard cubic meter (mg/dscm), nanograms per Joule heat input (ng/J) and in milligrams per horsepower-hour shaft output (mg/Bhp-hr). As a measure of the relative potential significance of the emissions for further analyses, an occupational exposure guideline concentration for each species is also noted in the table. The guideline noted is generally either the time-weighted-average Threshold Limit Value (TLV, Reference 6) or the 8-hr time-weighted-average exposure limit established by the Occupational Safety and Health Administration (OSHA, Reference 7). Only species emitted at levels exceeding 10 percent of their occupational exposure guidelines are noted in Table 2.

As shown in the table, NO_x emissions were reduced about 70 percent on the average from 770 ng/J (7.8 g/Bhp-hr) to 250 ng/J (2.5 g/Bhp-hr) on a heat input basis. Actually, NO_x reduction ranged from about 50 to 80 percent. This variation was probably caused by small perturbations in engine load accompanied by small changes in A/F. As noted above, this engine was not equipped with an automatic A/F controller. The degree of NO_x reduction attained is not sufficient to meet Rule 1110 requirements of 90 percent or 280 ng/J heat output (0.75 g/Bhp-hr).

Both ammonia and total cyanide increased significantly across the catalyst. Catalyst outlet ammonia levels exceeded inlet levels by one order of magnitude, 23 to 390 mg/dscm (31 to 490 ppm). Although much lower than ammonia, total cyanides showed a much greater percentage increase across the catalyst, from 0.022 to 10 mg/dscm. These results are in agreement with

TABLE 2. SUMMARY OF EXHAUST GAS EMISSIONS

Specie	Catalyst inlet[a]			Catalyst outlet[a]			Occupational exposure guideline[b] (mg/m^3)
	mg/dscm	ng/J	mg/Bhp-hr	mg/dscm	ng/J	mg/Bhp-hr	
Criteria and other gaseous pollutants and total organic emissions							
CO	5,350	1,210	1.22×10^4	4,840	1,030	10,400	55
NO_x (as NO_2)	3,410	770	7,790	1,180	250	2,530	6.0
NH_3	23	5.2	53	390	82	820	18
Total cyanide (as CN)	0.022	0.005	0.051	10	2.2	22	5.0
N_2O[c]	270	60	600	170	36	360	--[d]
Solid particulate	1.3	0.30	3.0	1.4	0.30	3.0	10[e]
Total chromatographable organics (C_7 to C_{16})	8.1	1.8	19	1.8	0.40	4.1	--
Total GRAV organics (C_{16+})	7.4	1.7	17	0.30	0.055	0.56	--
Trace elements							
Barium, Ba	0.049	0.011	0.11	0.064	0.014	0.14	0.50
Calcium, Ca	0.450	0.10	1.1	0.16	0.034	0.34	2.0
Chromium, Cr	0.0007	1.5×10^{-4}	0.0015	0.78	0.17	1.7	0.050
Copper, Cu	0.015	0.0035	0.035	1.2	0.25	2.5	0.10[f]
Iron, Fe	0.039	0.0090	0.091	0.41	0.088	0.88	1.0
Nickel, Ni	0.0008	1.8×10^{-4}	0.0018	0.69	0.15	1.5	0.10
Phosphorus, P	0.005	0.0012	0.012	0.03	0.0064	0.064	0.10
Potassium, K	0.17	0.040	0.41	0.36	0.076	0.76	2.09
Silicon, Si	0.12	0.028	0.28	1.4	0.31	3.1	10
Silver, Ag	0.0015	3.4×10^{-4}	0.0034	0.22	0.046	0.46	0.010
Sodium, Na	150	34	340	160	35	350	2.09
Zinc, Zn	0.024	0.0055	0.056	0.46	0.089	0.89	1.0

[a]Average exhaust gas O_2 and CO_2 were 0.1 and 10.2 percent at both inlet and outlet locations.
[b]Time-weighted average Threshold Limit Value (TLV) (Reference 4), unless noted.
[c]N_2O emissions were measured during low catalyst NO_x reduction efficiency following completion of the comprehensive tests. N_2O emissions are averages of two tests during which NO_x emissions were about 2,700 ppm.
[d]--denotes no occupational exposure guideline applicable.
[e]For nuisance particulate.
[f]8-hr time-weighted average OSHA exposure limit (Reference 5).
[g]Ceiling limit.

Solid particulate showed no noticeable change due to the catalyst. In line with a reduction in combustible emissions (TUHC (as CH_4) and CO), TCO and GRAV organics were also reduced by the catalyst by about 75 and 95 percent, respectively.

Table 3 summarizes the PAH and other organic compounds detected by GC/MS analysis of the catalyst inlet and outlet sample extracts. Consistent with the overall reduction in total combustible emissions, these compounds were present at significantly lower concentrations in the catalyst outlet exhaust than in the inlet exhaust. Interestingly, all three-ring fused aromatics were destroyed by passage through the reactor. Levels of phenol and naphthalene, one- and two-ring aromatics, instead were increased at the outlet, suggesting that these lower molecular weight aromatics were being formed from higher ring number compounds.

Bioassay tests were performed on the organic module extract (XAD-2 and organic module condensate) from both SASS trains (inlet and outlet). Only health effects tests were performed (Reference 8). These tests were the Ames mutagenicity assay and the CHO cytotoxicity assay. Table 4 summarizes the results of these assays. The data suggest that the XAD-2 extract from the inlet location was of high mutagenicity and moderate to high toxicity. The catalyst outlet XAD-2 extract was of moderate mutagenicity and toxicity. These are typical bioassay responses for combustion source XAD-2 extract.

Emission Measurements and Results -- 15-Day Monitoring

The sampling and analysis protocol for this portion of the test program consisted of continuous monitoring of inlet and outlet exhaust gas for O_2, CO_2, CO, NO/NO_x, and TUHC with certification of NO_x analyzer readings using EPA Method 7. Since both engine power output and A/F were not restricted to

TABLE 3. PAH AND OTHER ORGANIC SPECIES EMISSION SUMMARY (µg/dscm)

Semivolatile and nonvolatile organics	Inlet	Outlet[a]
Acenapthene	16.5	<0.4
Acenaphthylene	62.3	1.2
Benz(a)anthracene	5.1	<0.4
Benzofluoranthenes	1.9	<0.4
Bis(2-chloroethyl)ether	2.1	<0.4
Bis(2-ethylhexyl)phthalate	54.9	1.2
Butyl benzyl phthalate	0.7	<0.4
Chrysene	1.9	<0.4
Fluoranthene	0.5	<0.4
Fluorene	17.9	<0.4
Naphthalene	<0.4	28.5
Phenanthrene	40.3	1.4
Phenol	<0.4	1.8
Pyrene	2.2	<0.4

[a]Outlet results are based on the average of replicate analyses.

TABLE 4. BIOASSAY RESULTS

Sample	Assay	
	Ames[a]	CHO[b]
Catalyst Inlet, XAD-2 Extract	H	H/M
Catalyst Outlet, XAD-2 Extract	M	M

[a]Mutagenicity assay
[b]Toxicity assay
H = high; M = moderate; H/M = high to moderate.

specified ranges, the data obtained can be considered reflective of typical operating practice. Figures 1 through 5 summarize emission results. Each data point in these figures represents an hourly average. Therefore, frequent emission fluctuations are dampened by this hourly average reporting method.

Comprehensive tests were performed on June 7. This test period is indicated in Figure 1 by exhaust O_2 being near zero at both locations. Following these tests, the engine assumed a more typical operating condition which resulted in exhaust O_2 being in the range of 2 to 5 percent. (The difference between the inlet and outlet O_2 levels is considered suspect. Inlet concentrations of 2 percent are considered more accurate.) The result of the increase in A/F during the 15-day test period was an increase in inlet NO_x as well as a reduction in catalyst performance. In fact, NO_x reduction by the catayst generally ranged between 0 and 40 percent. Only once was NO_x reduced by more than 90 percent. This reduction which occurred during the early hours of June 18 was accompanied by a rapid increase in both CO and TUHC.

Summary

Emission tests of a rich-burn reciprocating internal combustion engine retrofitted with a NSCR NO_x control system suggest that significant NO_x reduction (>80 percent) cannot be maintained without tight control of A/F within a narrow range. This range spans A/F near or below stoichiometric. The data suggest that corresponding CO and TUHC engine emissions required for greater than 80 percent NO_x reduction by the catalyst are in excess of 3,000 ppm and 400 ppm at 15 percent O_2, respectively. The extended 15-day continuous monitoring testing indicates the inability of the engine tested to

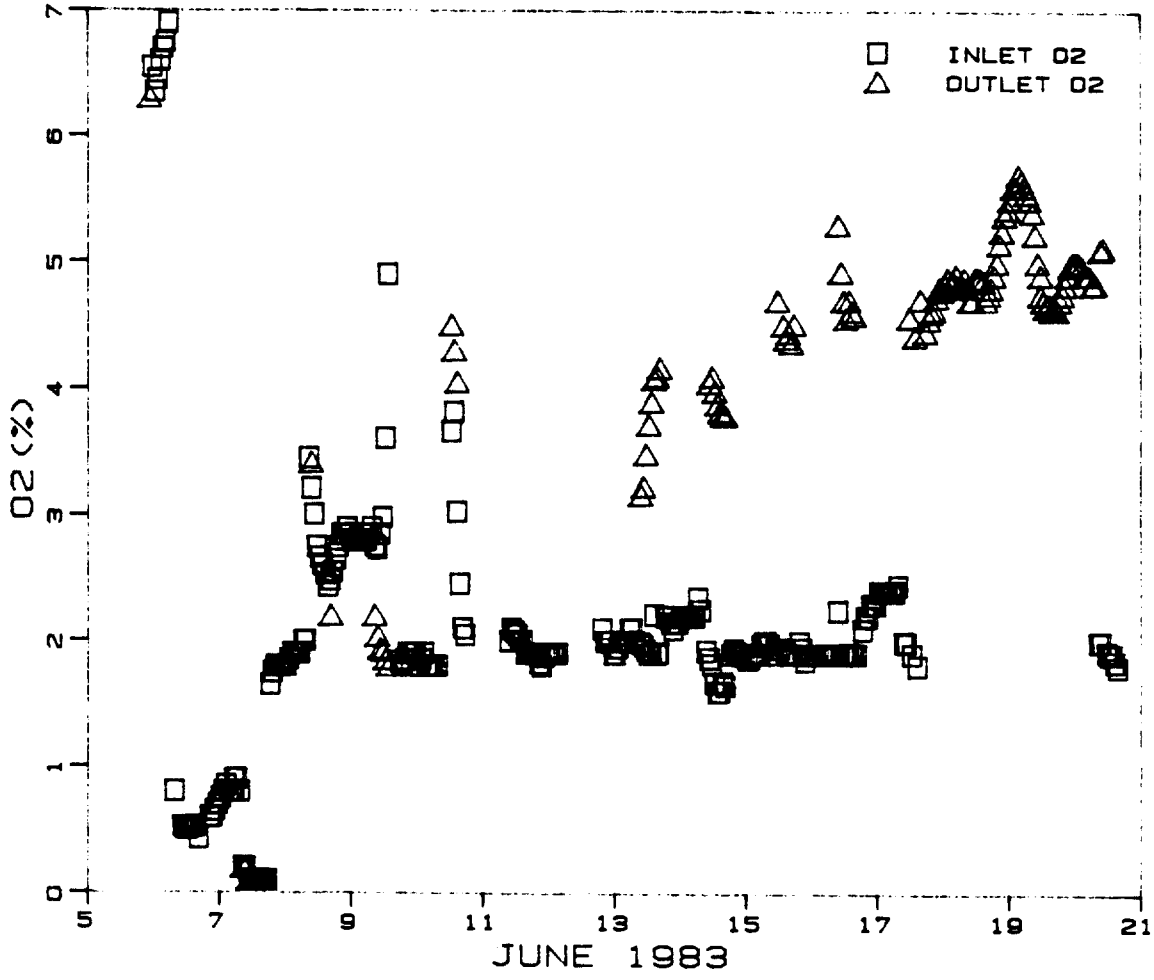

Figure 1. Exhaust O_2 during the 15-day continuous monitoring period.

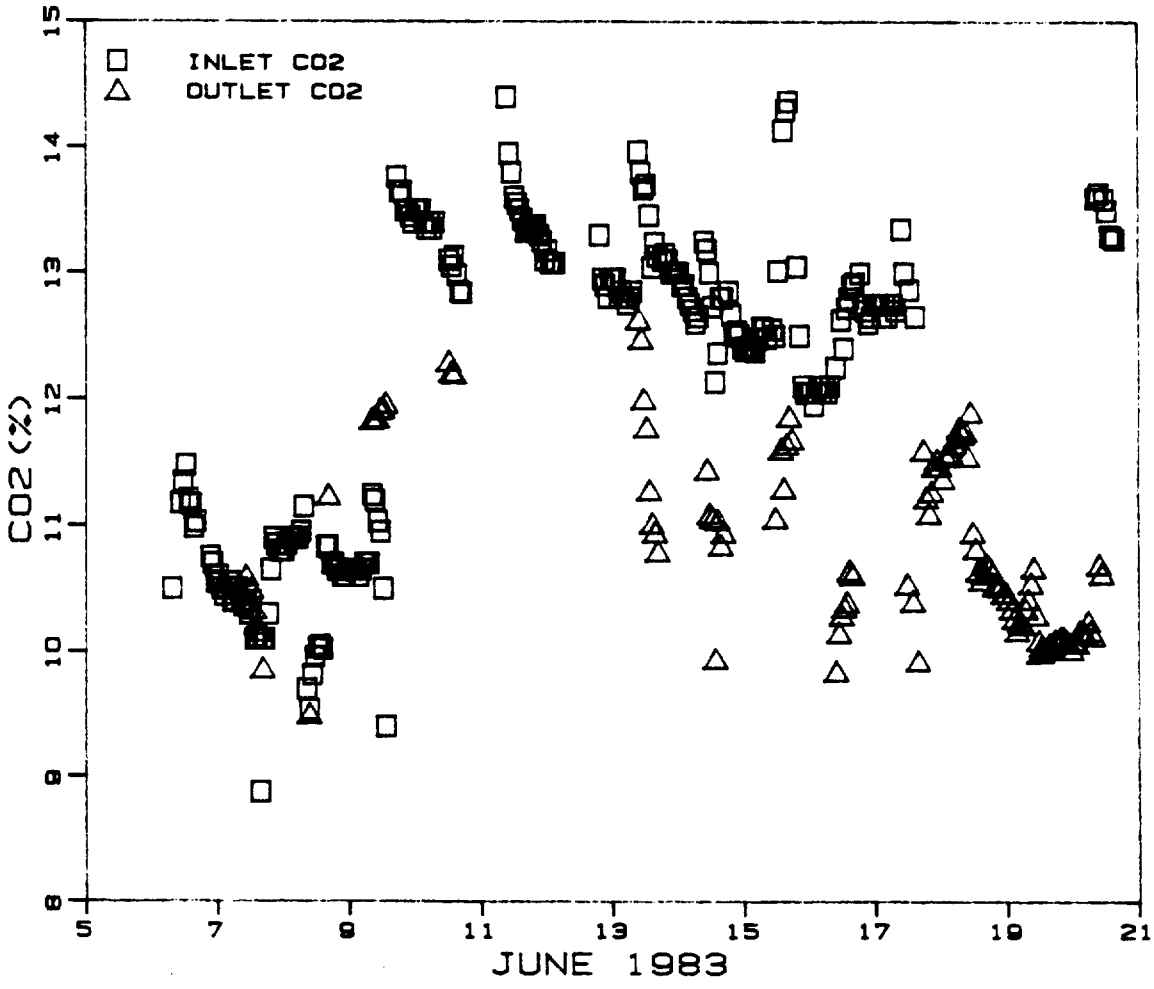

Figure 2. Exhaust CO_2 during the 15-day continuous monitoring period.

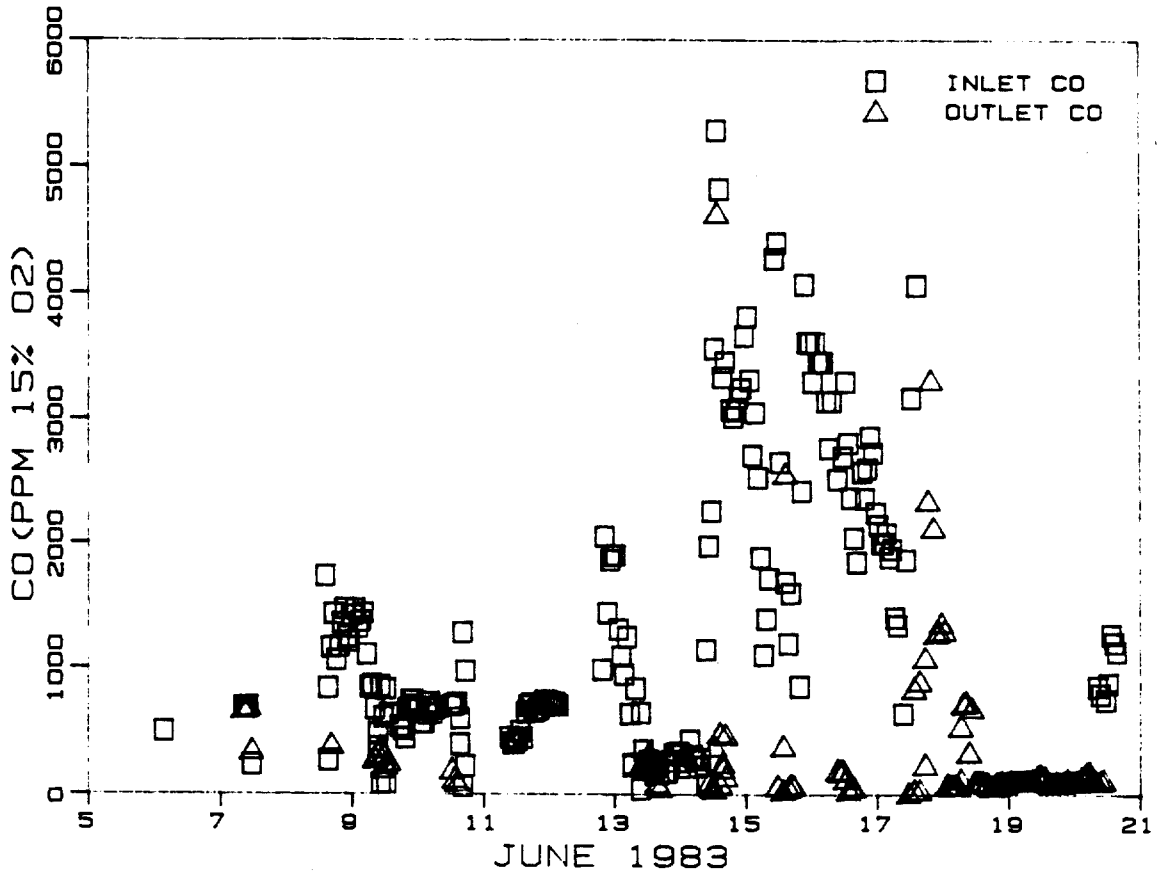

Figure 3. CO emissions during the 15-day continuous monitoring period.

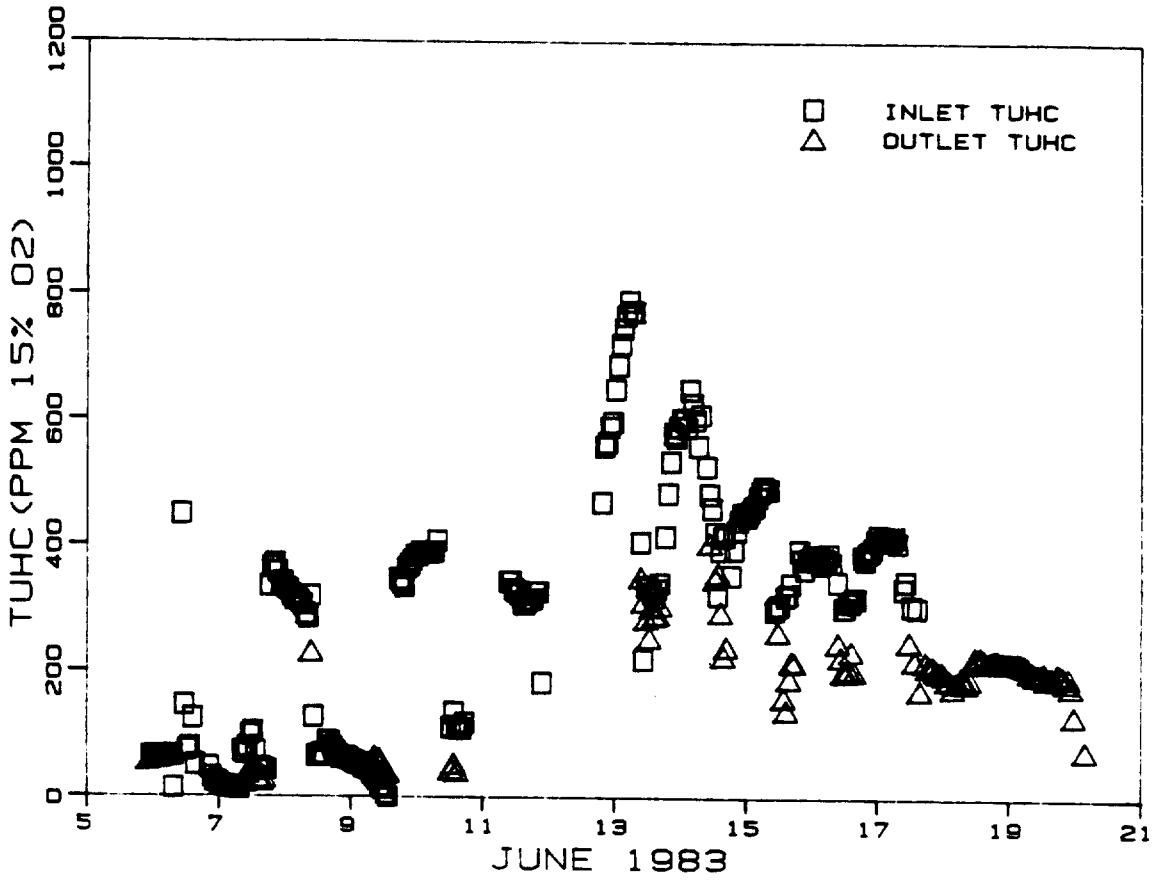

Figure 4. TUHC emissions during the 15-day continuous monitoring period.

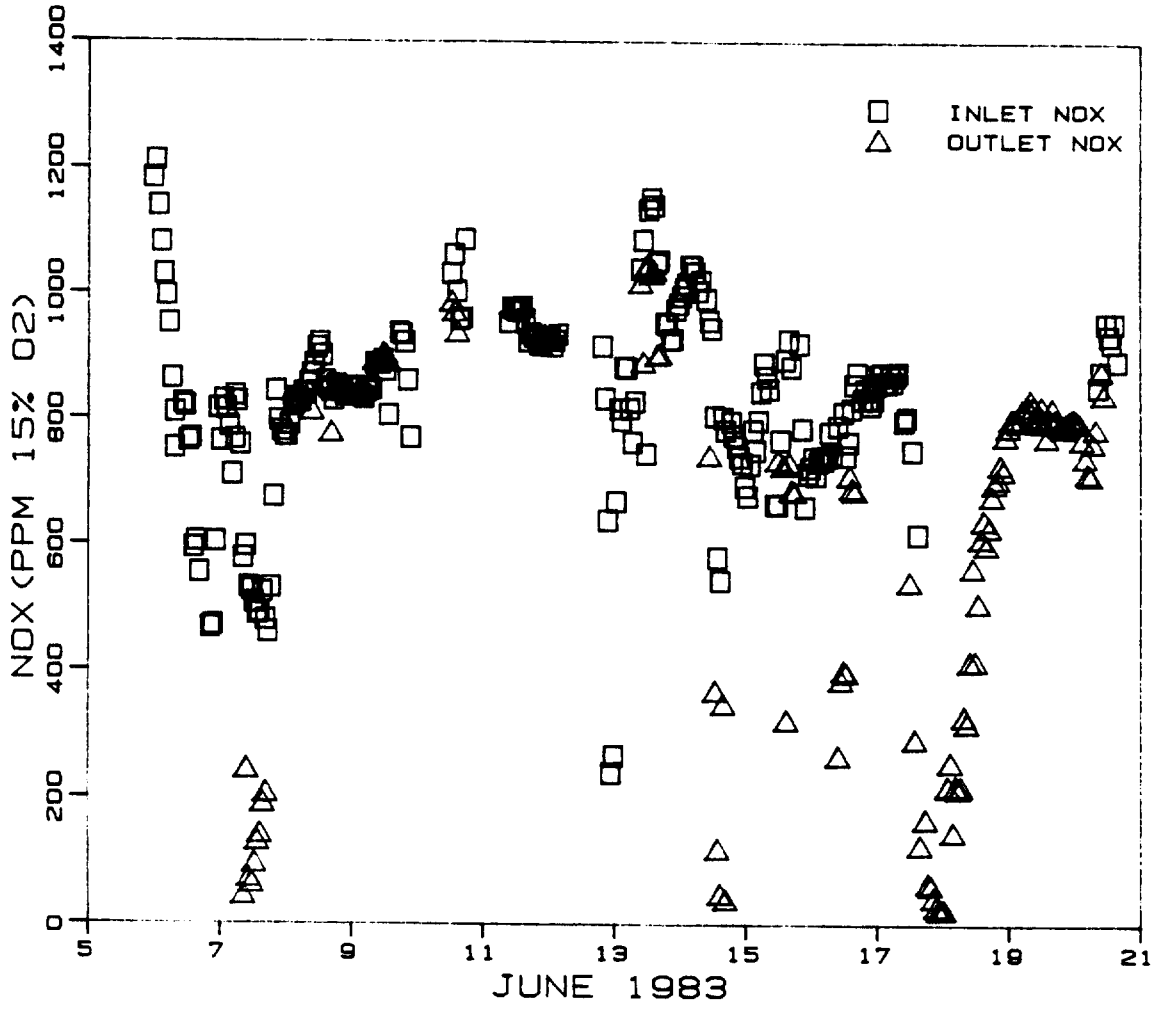

Figure 5. NO_x emissions during the 15-day continuous monitoring period.

be maintained at the necessary conditions of A/F, CO, and TUHC to achieve controlled NO_x emissions at or below the SCAQMD level. (The engine had no automatic A/F controller.) The catalyst was found to significantly reduce all combustible emissions including most PAH. This is in agreement with the oxidation reaction process of NSCR reactor. Significant increases in NH_3 and total cyanide emissions were recorded confirming anticipated and previously discovered trends. Exhaust levels of many inorganic trace elements also increased across the catalyst. Major elements of possible concern are chromium, copper, nickel, and sodium.

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SECTION 1

INTRODUCTION

This report describes and presents results for a set of environmental assessment tests performed for the Industrial Environmental Research Laboratory/Research Triangle Park (IERL/RTP) of EPA under the Combustion Modification Environmental Assessment (CMEA) program, EPA Contract No. 68-02-3188. The CMEA started in 1976 with a 3-year study the NO_x Control Technology Environmental Assessment (NO_x EA, EPA Contract No. 68-02-2160), having the following objectives:

- Identify potential multimedia environmental effects of stationary combustion sources and combustion modification technology
- Develop and document control application guidelines to minimize these effects
- Identify stationary source and combustion modification R&D priorities
- Disseminate program results to intended users

During the first year of the NO_x EA, data and methodologies for the environmental assessment were compiled. Furthermore, priorities for the schedule and level of effort for developing emission data for the various source/fuel/control combinations were identified. This effort revealed major data gaps, particularly for noncriteria pollutants (organic emissions and trace elements) for virtually all combinations of stationary combustion

sources and combustion modification techniques. Consequently, a series of seven environmental field test programs was undertaken to fill these data gaps. The results of these tests are documented in seven individual reports (References 1-1 through 1-7) and in the NO_x EA final report summarizing the entire 3-year effort (Reference 1-8).

The current CMEA program has, as major objectives, the continuation of multimedia environmental field tests initiated in the original NO_x EA program. These new tests, using standardized sampling and analytical procedures (Reference 1-9) are aimed at filling remaining data gaps and addressing the following priority needs:

- Advanced NO_x controls
- Alternate fuels
- Secondary sources
- EPA program data needs
  - -- Residential oil combustion
  - -- Wood firing in residential, commercial, and industrial sources
  - -- High interest emissions determination (e.g., listed and candidate hazardous air-pollutant species)
- Nonsteady-state operations

In California, the South Coast Air Quality Management District (SCAQMD) continues to be in nonattainment of both federal and state NO_2 standards. Reciprocating internal combustion engines (ICE's) in this district are estimated to contribute 14 percent of the NO_x (about 59 Mg/day (65 tons/day)) from all stationary sources and 5.1 percent of the total NO_x emissions in the basin (References 1-10 and 1-11). Furthermore, since acid precipitation in noncoal-burning regions such as the SCAQMD is being increasingly attributed

to NO_x emissions from sources with low stacks, reciprocating ICE's are being viewed as possibly contributing to the acid rain problem.

In 1979, the California Air Resources Board (CARB) proposed a control strategy for ICE's that called for retrofit of these sources with nonselective and selective gas treatment catalysts (NSCR and SCR, respectively). In keeping with this CARB strategy, the SCAQMD passed rule 1110 calling for demonstration tests of NSCR and SCR technologies for engine NO_x control. Southern California Gas Company (SoCal) has conducted several performance tests to evaluate NSCR and SCR catalysts for their applicability in reducing NO_x from SoCal operated ICE's. In addition to the problem of sustained NO_x reduction performance, several environmental concerns associated with this technology have been documented (Reference 1-12). In the case of NSCR, for example, the formation of ammonia and cyanide gases by the catalyst has been highlighted. For SCR, breakthrough ammonia and N_2O formation are also concerns.

In response to these concerns, a rich-burn reciprocating ICE operated by SoCal and retrofitted with a commercially available NSCR system was selected for testing under the CMEA program. The objective of the tests was to quantify multimedia emissions (including organics, inorganics, as well as, ammonia and cyanides) at the inlet and outlet of the NSCR catalytic reactor. In addition to these tests, NO_x reduction performance of the NSCR was monitored continuously over 15 days under typical operating conditions.

Table 1-1 lists all the tests performed in the CMEA program, outlining the source tested, fuel used, combustion modifications implemented and the level of sampling and analysis performed in each case. Results of these test programs are discussed in separate reports.

TABLE 1-1. COMPLETED TESTS DURING THE CURRENT PROGRAM

Source	Description	Test points unit operation	Sampling protocol	Test collaborator
Spark-ignited natural-gas-fueled reciprocating internal combustion engine	Large-bore, 6-cylinder, opposed piston, 186 kW (250 Bhp)/cyl, 900 rpm, Model 38TDS8-1/8	-- Baseline (pre-NSPS) -- Increased air-fuel ratio aimed at meeting proposed NSPS of 700 ppm corrected to 15 percent O_2 and standard atmospheric conditions	Engine exhaust: -- SASS -- Method 5 -- Gas sample (C_1-C_6 HC) -- Continuous NO, NO_x, CO, CO_2, O_2, CH_4, TUHC Fuel Lube oil	Fairbanks Morse Division of Colt Industries
Compression-ignition diesel-fueled reciprocating internal combustion engine	Large-bore, 6-cylinder opposed piston, 261-kW (350 Bhp)/cyl, 900-rpm, Model 38TDD8-1/8	-- Baseline (pre-NSPS) -- Fuel injection retard aimed at meeting proposed NSPS of 600 ppm corrected to 15 percent O_2 and standard atmospheric conditions	Engine exhaust: -- SASS -- Method 8 -- Method 5 -- Gas sample (C_1-C_6 HC) -- Continuous NO, NO_x, CO, CO_2, O_2, CH_4, TUHC Fuel Lube oil	Fairbanks Morse Division of Colt Industries
Low-NO_x residential condensing heating system furnished by Karlsons Blueburner Systems Ltd. of Canada	Residential hot water heater equipped with M.A.N. low-NO_x burner, 0.55 ml/s (0.5 gal/hr) firing capacity, condensing flue gas	Low-NO_x burner design by M.A.N.	Furnace exhaust: -- SASS -- Method 8 -- Method 5 -- Gas sample (C_1-C_6 HC) -- Continuous NO, NO_x, CO, CO_2, O_2, CH_4, TUHC Fuel Waste water	New test
Rocketdyne/EPA low-NO_x residential forced warm air furnace	Residential warm air furnace with modified high pressure burner and firebox, 0.83 ml/s (0.75 gal/hr) firing capacity	Low-NO_x burner design and integrated furnace system	Furnace exhaust: -- SASS -- Method 8 -- Controlled condensation -- Method 5 -- Gas sample (C_1-C_6 HC) -- Continuous NO, NO_x, CO, CO_2, O_2, CH_4, TUHC Fuel	New test

TABLE 1-1. (continued)

Source	Description	Test points unit operation	Sampling protocol	Test collaborator
Pulverized coal-fired utility boiler, Conesville station	400-MW tangentially fired; new NSPS design aimed at meeting 301 ng/J NO_x limit	ESP inlet and outlet, one test	ESP inlet and outlet: -- SASS -- Method 5 -- Controlled condensation -- Gas sample (C_1-C_6 HC) -- Continuous NO, NO_x, CO, CO_2, O_2 Coal Bottom ash ESP ash	Exxon Research and Engineering (ER&E) conducting corrosion tests
Nova Scotia Technical College industrial boiler	1.14 kg/s steam (9,000 lb/hr) firetube fired with a mixture of coal-oil-water (COW)	-- Baseline (COW) -- Controlled SO_2 emissions with limestone injection	Boiler outlet: -- SASS -- Method 5 -- Method 8 -- Controlled condensation -- Gas sample (C_1-C_6 HC) -- Continuous O_2, CO_2, CO, NO_x Fuel	Envirocon performed particulate and sulfur emission tests
Adelphi University industrial boiler	1.89 kg/s steam (15,000 lb/hr) hot water firetube fired with a mixture of coal-oil-water (COW)	-- Baseline (COW) -- Controlled SO_2 emissions with Na_2CO_3 injection	Boiler outlet: -- SASS -- Method 5 -- Method 8 -- Controlled condensation -- Gas Sample (C_1-C_6 HC) -- Continuous O_2, CO_2, NO_x, CO Fuel	Adelphi University
Pittsburgh Energy Technology Center (PETC) industrial boiler	3.03 kg/s steam (24,000 lb/hr) watertube fired with a mixture of coal-oil (COM)	-- Baseline test only with COM	Boiler outlet: -- SASS -- Method 5 -- Controlled condensation -- Continuous O_2, CO_2, NO_x, TUHC, CO -- N_2O grab sample Fuel	PETC and General Electric (GE)

TABLE 1-1. (continued)

Source	Description	Test points unit operation	Sampling protocol	Test collaborator
TOSCO Refinery vertical crude oil heater	2.54 Ml/day (16,000 bbl/day) natural draft process heater burning oil/refinery gas	-- Baseline -- Staged combustion using air injection lances	Heater outlet: -- SASS -- Method 5 -- Controlled condensation -- Gas sample (C_1-C_6 HC) -- Continuous O_2, NO_x, CO, CO_2, HC -- N_2O, grab sample Fuel oil Refinery gas	KVB coordinated the staged combustion operation and continuous emission monitoring
Mohawk-Getty Oil industrial boiler	8.21 kg/s steam (65,000 lb/hr) watertube burning mixture of refinery gas and residual oil	-- Baseline -- Ammonia injection using the noncatalytic thermal deNO_x process	Economizer outlet: -- SASS -- Method 5, 17 -- Controlled condensation -- Gas Sample (C_1-C_6 HC) -- Ammonia emissions -- N_2O grab sample -- Continuous O_2, NO_x, CO, CO_2 Fuels (refinery gas and residual oil)	Mohawk-Getty Oil
Industrial boiler	2.52 kg/s steam (20,000 lb/hr) watertube burning woodwaste	-- Baseline (dry wood) -- Green wood	Boiler outlet: -- SASS -- Method 5 -- Controlled condensation -- Gas sample (C_1-C_6 HC) -- Continuous O_2, NO_x, CO Fuel Flyash	North Carolina Department of Natural Resources, EPA IERL-RTP
Industrial boiler	3.16 kg/s steam (29,000 lb/hr) firetube with refractory firebox burning woodwaste	-- Baseline (dry wood)	Outlet of cyclone particulate collector: -- SASS -- Method 5 -- Controlled condensation -- Gas sample (C_1-C_6 HC) -- Continuous O_2, NO_x, CO Fuel Bottom ash	North Carolina Department of Natural Resources, EPA IERL-RTP

TABLE 1-1. (continued)

Source	Description	Test points unit operation	Sampling protocol	Test collaborator
Enhanced oil recovery steam generator	15-MW (50 million Btu/hr) steam generator burning crude oil equipped with MHI low-NO_x burner	-- Performance mapping -- Low NO_x operation	Steamer outlet -- SASS -- Method 5 -- Method 8 -- Gas sample (C_1-C_6 HC) -- Continuous O_2, NO_x, CO, CO_2 -- N_2O grab sample Fuel	Getty Oil Company, CE-Natco
Pittsburgh Energy Technology Center (PETC) industrial boiler	3.03 kg/s steam (24,000 lb/hr) watertube fired with a mixture of coal-water slurry (CWS)	-- Baseline test only with CWS	Boiler outlet -- SASS -- Method 5 -- Method 8 -- Gas sample (C_1-C_6 HC) -- Continuous O_2, NO_x, CO, CO_2, TUHC -- N_2O grab sample Fuel Bottom ash Collector hopper ash	PETC
Internal combustion engine -- nonselective NO_x catalyst	(610 kW (818-hp) Waukesha engine equipped with DuPont NSCR catalyst	-- Low-NO_x with catalyst -- 15-day emissions monitoring	Catalyst inlet and outlet -- SASS -- NH_3 -- HCN -- Grab sample N_2O -- Continuous O_2, CO_2, NO_x TUHC Fuel	Southern California Gas Company
Industrial boiler	180 kg/hr steam (400 lb/hr) stoker-fired with a mixture of coal and plastic waste	-- Baseline (coal) -- Coal and plastic waste	Boiler outlet -- SASS -- VOST -- Method 5/8 -- HCl -- Continuous O_2, NO_x, CO, CO_2, TUHC -- N_2O grab sample Fuel Bottom ash Cyclone ash	Vermont Agency of Environmental Conservation

TABLE 1-1. (concluded)

Source	Description	Test points unit operation	Sampling protocol	Test collaborator
Industrial boiler	7.6 kg/s steam (60,000 lb/hr watertube retrofit for coal water slurry firing	-- Baseline (CWS)	Boiler outlet -- SASS -- VOST -- Method 5/8 -- Grab sample (C_1-C_6 HC) -- Grab sample (N_2O) -- Continuous NO_x, CO, CO_2, O_2, TUHC, SO_2 Fuel	EPRI, DuPont
Enhanced oil recovery steam generator	15-MW (50 million Btu/hr) steam generator burning crude oil, equipped with the EPA/EER low-NO_x burner	-- Low NO_x -- 30-day emissions monitoring	Steamer outlet -- SASS -- VOST -- Method 5/8 -- Controller condensation -- Anderson monitors -- Grab sample (C_1-C_6 HC) -- Grab sample (N_2O) -- Continuous NO_x, CO, CO_2, O_2, SO_2 Fuel	Chevron U.S.A., EERC

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1-10. Bartz, D., et al., "Control of Oxides of Nitrogen from Stationary Sources in the Sixth Coast Air Basin," KVB, Inc., Irvine, California, September 1974.

1-11. "Draft Air Quality Management Plan," South Coast Air Quality Management District, El Monte, California, October 1978.

1-12. Khakbiz, S., "Engineering Report -- DuPont Non-Selective System at Honor Rancho," Southern California Gas Company Engineering Job M-82-35, April 1983.

SECTION 2

SOURCE DESCRIPTION AND OPERATION

The tests were performed on a four-stroke, naturally aspirated Waukesha electric generator engine equipped with a PR-5 DuPont NSCR catalyst. This engine is located at the SoCal Honor Rancho underground storage field near Valencia, California. Table 2-1 summarizes the engine model specifications. The PR-5 DuPont catalyst, installed in November 1982 and having an initial operating life (per vendor information) of about 4,000 hr, is a platinum-rhodium-based formulation with an upper operating temperature limit of 788°C (1,450°F). The catalyst, located downstream of the engine silencer, was designed to reduce NO_x emissions by 90 percent or greater, and thereby meet SCAQMD rule 1110 of 0.28 µg/J (heat output), as NO_2 (0.75 g/Bhp-hr). Reducing gases, H_2, TUHC, and CO, in the exhaust gas react with NO_x in the presence of this noble metal catalyst to reduce both NO and NO_2. The NSCR chemical reaction process has been suggested to be as follows (Reference 2-1):

1. $CH_4 + 4NO_2 \rightarrow CO_2 + 4NO + 2H_2O$
2. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
3. $CH_4 + 4NO \rightarrow CO_2 + 2N_2 + 2H_2O$
4. $2CO + 2NO \rightarrow 2CO_2 + N_2$
5. $2H_2 + 2NO \rightarrow 2H_2O + N_2$

The NSCR process then requires fuel-rich engine operation or the addition of reducing agents in the flue gas upstream of the catalyst. To

TABLE 2-1. ENGINE MODEL SPECIFICATIONS[a]

Manufacturer	Waukesha
Model	L7042 GU
Strokes	4
Air charging	Naturally aspirated
Number of cylinders	V-12
Bore	0.238 m (9.375 in.)
Stroke	0.216 m (8.50 in.)
Displacement/cyl	9.62 l (587 $in.^3$)
Compression ratio	10:1
BMEP	703 kPa (102 psi)
Bhp/cyl @ rpm	50.7 kW (68 Bhp) @ 900 rpm
Generator output (electrical)	610 kW
BSFC	10,200 kJ/kWh (7,200 Btu/Bhp-hr)
Lubricating oil consumption	70 l/kWh (1.37 gal/Bhp-hr)

[a]Engine operating performance is based on continuous operation, ambient conditions of 99.2 kPa (29.38 in. Hg) and 29°C (85°F) and a natural gas fuel (lower heating value) of 33.5 MJ/m^3 (900 Btu/ft^3).

provide for an adequate concentration of reducing agents in the exhaust gas the engine often has to be operated with an air-to-fuel ratio (A/F) richer than that necessary for minimum fuel consumption. SoCal experience with the test engine has shown that A/F in the range of 17.2 to 17.4 is required to reduce NO_x emissions by 90 percent or more (Reference 2-2). Since the engine is not equipped with an automatic A/F controller, several manual adjustments are required to maintain this narrow range of A/F, especially during engine load changes. During normal operation, fluctuating demands are imposed on the engine generator and thus engine horsepower. This in turn causes changes in A/F and NO_x concentrations in the exhaust gas, often resulting in decreased catalyst performance.

During the CMEA tests, exhaust emissions (NO_x, O_2, CO, CO_2, and TUHC) were measured on a continuous basis for a period of 15 days during normal engine operating conditions (fluctuating loads and A/F). In addition, a comprehensive emission test program was performed over a 1-day period during which engine load and A/F were tightly controlled for catalyst NO_x reduction of greater than 80 percent. Table 2-2 summarizes the engine operation and ambient atmospheric conditions during this 1-day comprehensive testing period.

As noted, the comprehensive test program was performed at approximately 78 percent of rated load. Engine horsepower was most conveniently measured by the generator output, which corresponds to 1.45 times the generator kilowatts. Engine load oscillated about 60 hp (10 percent) over the test period with probable effects on A/F. Specific fuel consumption measured 12,300 kJ/kWh (8,660 Btu/Bhp-hr) based on the lower heating value of the fuel gas. This fuel consumption was well above the engine manufacturer

TABLE 2-2. ENGINE OPERATION

Parameter	Range	Average
Ambient		
Dry bulb temperature, °C (°F)	26 to 29 (79 to 85)	29 (84)
Wet bulb temperature, °C (°F)	20 to 22 (68 to 71)	22 (71)
Relative humidity, percent	--	52
Barometric pressure, kPa (in. Hg)	--	96.4 (28.55)
Engine Operation		
Generator output, kW	415 to 455	425
Engine load, kW_t (Bhp)[a]	448 to 492 (601 to 660)	459 (616)
Fuel flow, m^3/h (scfh)	--	156 (5,509)
Heat input, MW (million Btu/hr)[b]	--	1.56 (5.33)
Specific fuel consumption, KJ/kWh (Btu/Bhp-hr)[b]	--	12,300 (8,660)
Air manifold pressure		
• L, kPa (in. Hg vac)	14 to 16 (4.1 to 4.6)	15 (4.4)
• R, kPa (in. Hg vac)	14 to 16 (4.1 to 4.8)	15 (4.5)
Speed, rpm	900 to 910	905
Catalyst inlet temperature, °C (°F)	533 to 536 (991 to 997)	535 (995)
Catalyst output temperature, °C (°F)	534 to 561 (994 to 1,042)	552 (1,025)
Gas Analysis, Percent Volume[c]		
O_2	--	0.073
N_2	--	1.119
CO_2	--	0.890
CH_4	--	90.119
C_2H_6	--	6.294
C_3H_8	--	1.247
iso-C_4H_{10}	--	0.094
n-C_4H_{10}	--	0.106
iso-C_5H_{12}	--	0.029
n-C_5H_{12}	--	0.029
C_{6+}	--	0.003
HHV, MJ/m^3 (Btu/ft^3)[d]		39.9 (1,072)
LHV, MJ/m^3 (Btu/ft^3)[d]		36.0 (968)

[a]Horsepower not a measured value -- calculated from generator output times 1.45
[b]Based on lower heating value
[c]Based on data supplied by SoCal
[d]Calculated heating value

specifications. Exhaust gas temperature across the catalyst increased about 17°C (30°F) on the average reflecting the exothermic oxidation reaction promoted by the catalyst.

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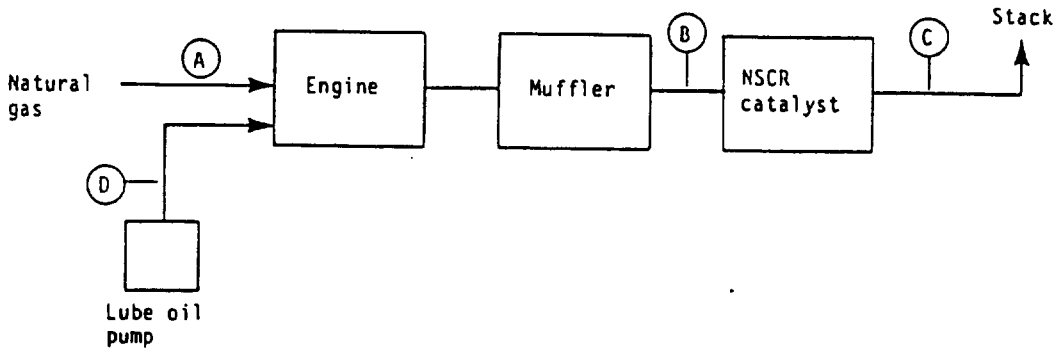
SECTION 3

EMISSION RESULTS

The objectives of this test program were: (1) to measure engine exhaust emissions during a 15-day test period to evaluate the continuous performance of the catalyst, utilizing continuous NO_x and other gas emission analyzers, and (2) to perform comprehensive tests over a 1-day period to measure the effect of the catalyst on inorganic and organic emissions including the possible formation of nitrogen compounds, such as NH_3 and HCN. Emission measurements were performed in cooperation with SoCal, owner and operator of the test facility, whose field crew and equipment included an emission monitoring laboratory with operating staff.

3.1 SAMPLING PROTOCOL

Figure 3-1 illustrates a schematic of the test site highlighting the sampling locations, sampling and analytical test matrix, and the test team performing the sampling and evaluation. As indicated, continuous monitoring of flue gas was performed both upstream and downstream of the catalytic reactor utilizing both heated and unheated sample lines. The sampling and gas conditioning system for this test program included continuous monitors for O_2, CO_2, CO, NO, NO_x, and TUHC. The continuous monitors were operated throughout a 15-day test period while engine load fluctuated according to generator demand. Certification of the NO_x analyzer readings was performed twice during this 15-day test period using standard EPA Method 7 protocol.



Sample Location	Type of Sample	Analyses[a]	Test Number
A -- Natural gas to engine	Grab sample -- Fuel	Gas chromatography for composition; heating value, specific gravity	SoCal
B -- Catalyst inlet	Extractive Sample -- Continuous Monitors	O_2, CO_2, CO, TUHC, NO, NO_x,	
	Sampling train -- SASS	Particulate by gravimetry, inorganics by SSMS and semi- and nonvolatile organics by EPA Method 625	Acurex
	Sampling train -- Modified Method 6	NH_3 by selective ion	Acurex
	Sampling train -- Modified Method 6	HCN by selective ion	Acurex
	Grab sample -- Gas bomb	N_2O by GC/ECD	Acurex
	Grab sample -- Method 7 flasks	NO_x	Acurex
C -- Catalyst outlet	Same as location B except no Method 7 taken		Acurex
D -- Lube oil pump	Grab sample -- Lube oil	Inorganics	Acurex

[a]Measurement and analysis techniques used are discussed in detail in Appendix A.

Figure 3-1. Sampling sites and analysis test matrix.

The source assessment sampling system (SASS), the NH_3, and the HCN, sampling trains were operated during 1 day of tests at both the inlet and outlet of the catalytic converter. Simultaneous inlet and outlet samples were performed to measure any change in the organic and inorganic composition of the exhaust gas across the catalyst. These measurements were performed while engine load was maintained constant and A/F was adjusted for effective NO_x reduction by the catalyst.

Figure 3-2 illustrates the actual test activity schedule. The following sections summarize the emission results. Sections 3.2 through 3.4 present emission results obtained during the comprehensive tests that took place on June 7, 1983. Section 3.5 summarizes results of continuous emission measurements and EPA Method 7 certification tests performed over the 15-day test period. Details of the sampling and analysis procedures used are discussed in Appendix A.

3.2 CRITERIA POLLUTANT AND OTHER VAPOR SPECIES EMISSIONS

Table 3-1 summarizes gaseous and particulate emissions measured during the 1-day comprehensive tests performed at the beginning of the 15-day continuous monitoring period. Exhaust O_2 was essentially undetected (reported as 0.1 percent dry). This indicates that the air-fuel mixture was near or below stoichiometric conditions, about 17.2 A/F weight basis.

Figures 3-3 and 3-4 show the variation in exhaust gas O_2 and CO_2 concentrations over the comprehensive test day (June 7, 1983). As indicated in the O_2 chart (Figure 3-3), prior to the start of the tests exhaust O_2 was reading approximately 0.8 percent. At about 9:00 a.m. the A/F was adjusted for richer burning conditions with exhaust O_2 dropping essentially to zero.

Test activity	June 1983															
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
• Continuous monitors (inlet/outlet)	Δ—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—Δ
• Comprehensive tests (inlet/outlet)																
-- SASS		Δ														
-- NH_3		Δ														
-- HCN		Δ														
-- N_2O			Δ													
• Method 7 certification tests (inlet)			Δ												Δ	

Figure 3-2. Test activity schedule

TABLE 3-1. CRITERIA AND OTHER GAS SPECIES EMISSIONS -- COMPREHENSIVE TESTS

Pollutant[a]	Catalyst Inlet			Catalyst Outlet		
As measured by continuous gas analyzers, range (average)						
O_2, percent dry	-- (0.1)			-- (0.1)		
CO_2, percent dry	9.8 to 10.5 (10.2)			9.8 to 10.6 (10.2)		
CO, ppm dry[b]	13,750 to 15,500 (14,600)			12,000 to 14,000 (13,200)		
NO_x, ppm dry	1,650 to 1,850 (1,700)			300 to 800 (550)		
TUHC, ppm dry as CH_4	140 to 370 (215)			80 to 200 (125)		
Corrected average gaseous emissions:	ppm[c]	ng/J[d]	g/Bhp-hr[e]	ppm[c]	ng/J[d]	g/Bhp-hr[e]
CO	4,270	1,210	12.2	3,860	1,030	10.4
NO_x[f]	486	770	7.79	157	250	2.53
TUHC[g]	61	34	0.33	36	20	0.20
NH_3	8.9	5.2	0.05	140	82	0.82
Total cyanide[h]	0.005	0.005	5.1×10^{-5}	2.3	2.2	0.022
Solid particulate mass emissions:						
-- SASS solid	--	0.309	0.003	--	0.303	0.003

[a]Appendix A discusses continuous monitor analyses used, sample gas conditioning system, particulate sampling equipment, and other sampling trains and procedures.
[b]CO emission data provided by SoCal.
[c]Corrected to 15 percent O_2, dry.
[d]On heat input basis, lower heating value.
[e]Shaft output basis.
[f]As NO_2
[g]As CH_4
[h]As HCN

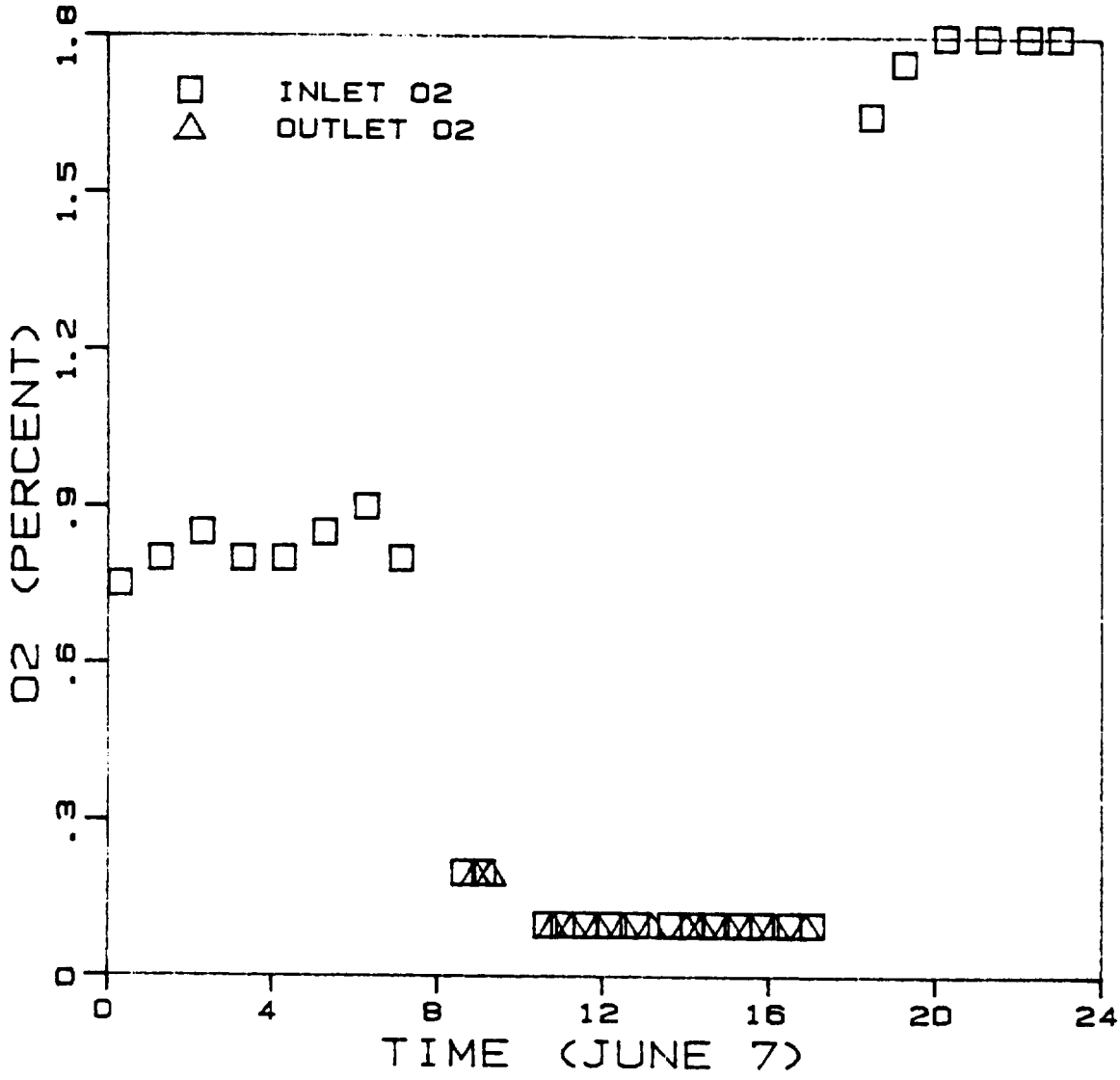


Figure 3-3. Exhaust gas O_2 during comprehensive tests.

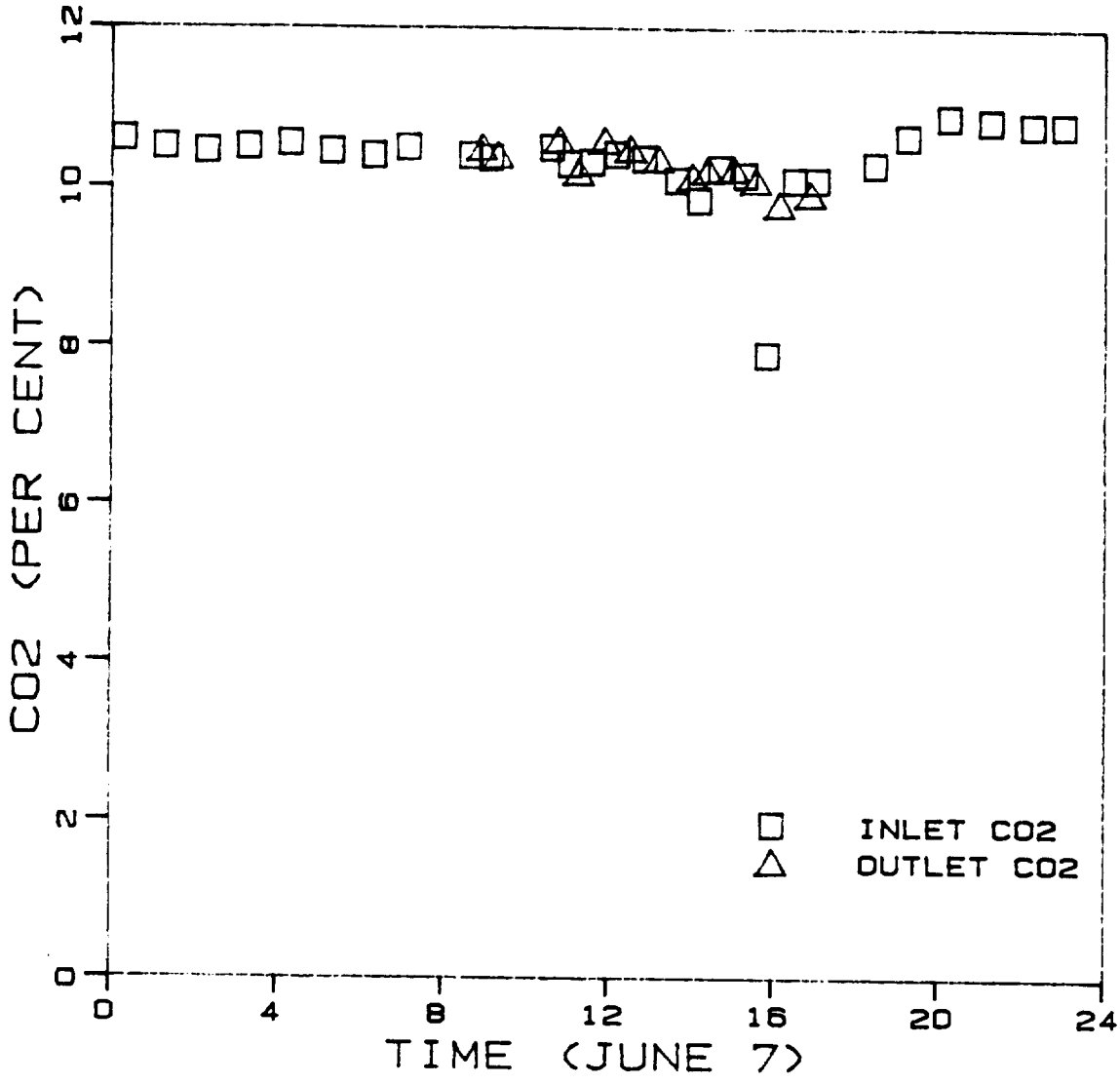


Figure 3-4. Exhaust gas CO_2 during comprehensive tests.

This condition was maintained until approximately 5:00 p.m. when all emission measurements were concluded.

CO emissions exceeded 3,000 ppm as measured by the low range CO analyzer in the Acurex van (the high range CO analyzer was inoperative on the comprehensive test day). This is above the quantitation limit of the analyzer. However, SoCal instrumentation provided data on CO during the test period. These emissions showed CO in excess of 1 percent at both inlet and outlet concentration. Only a 10 percent CO reduction by the catalyst was recorded by SoCal.

NO_x emissions at the catalyst inlet ranged from about 1,650 to 1,850 ppm as measured (at zero percent O_2) outlet emissions showed a greater variation, from 300 to 800 ppm. Figure 3-5 shows the variation in NO_x emissions over the test period. Inlet NO_x emissions corrected to 15 percent O_2 were about 800 ppm prior to the start of the comprehensive tests. Following engine adjustment for richer burning condition, inlet concentration decreased to about 530 ppm at the start of the tests with an apparent further decrease to 470 ppm at the end of the tests. At the conclusion of the tests, the engine load and A/F changed, resulting in an increase in NO_x back to about 800 ppm (15 percent O_2). Catalyst outlet NO_x emissions were monitored during the 8-hr comprehensive test period. These data show an initial concentration of about 90 ppm (at 15 percent O_2) followed by a gradual increase to 230 ppm at the end of the tests.

The resulting NO_x reduction efficiency of the catalyst during this time period is illustrated in Figure 3-6. Catalyst performance ranged from a maximum of 81 percent NO_x reduction at the start of the tests to 54 percent at the end of the tests. This reduced efficiency may have been caused by a

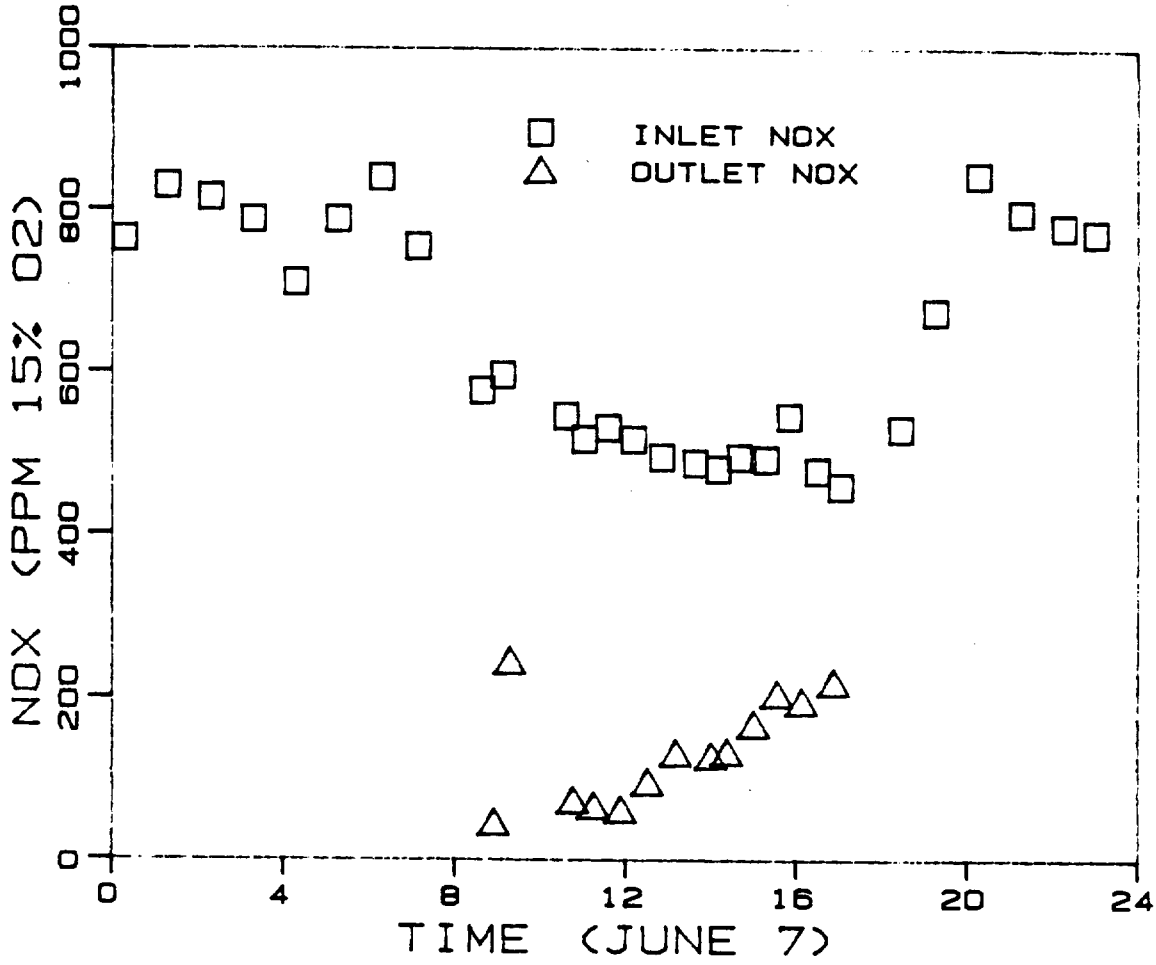


Figure 3-5. Exhaust gas NO_x emissions during comprehensive tests.

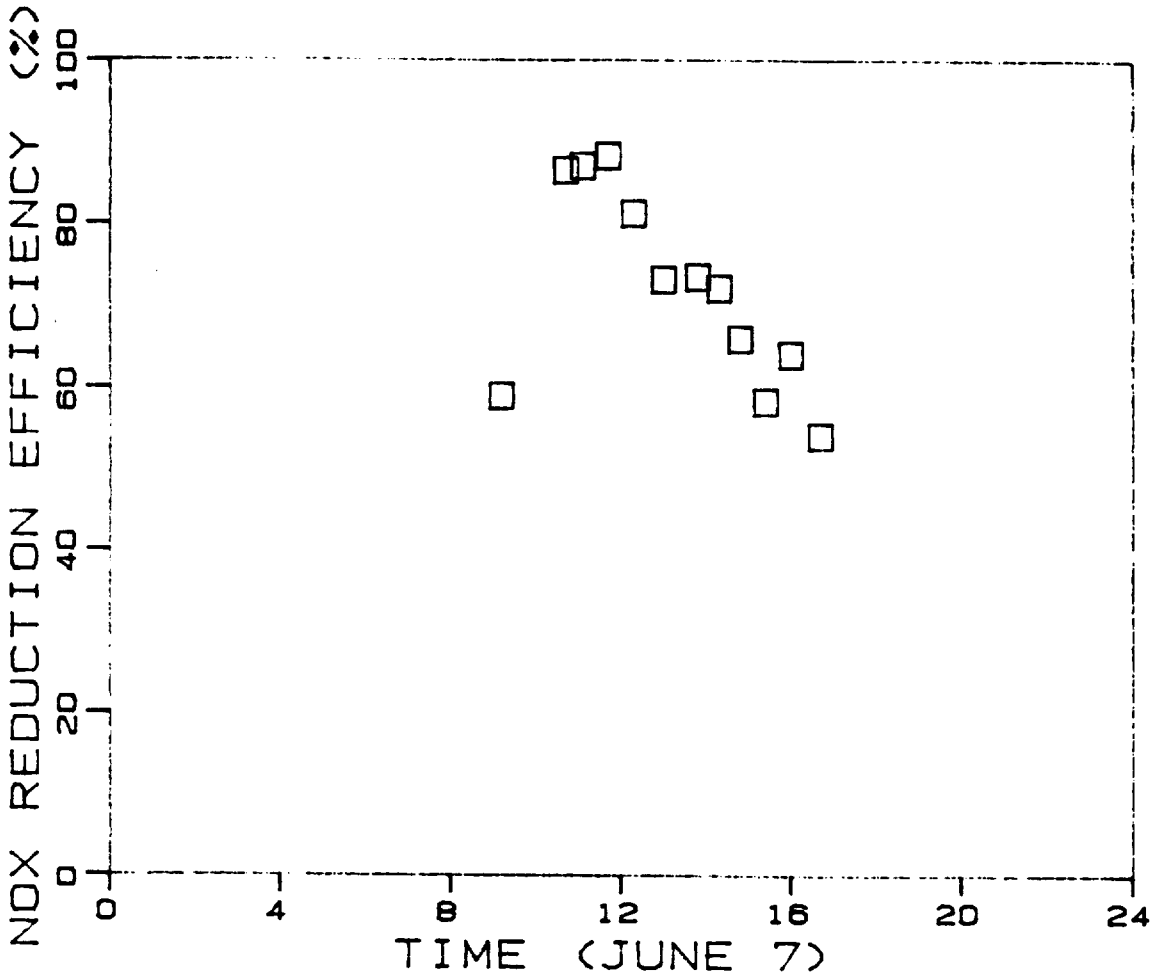


Figure 3-6. Catalyst NO_x reduction efficiency during comprehensive tests.

small perturbations in A/F. As indicated earlier, the exhaust O_2 of near zero percent indicates combustion at or below stoichiometric conditions. Small perturbations in A/F in this range would not be detected from monitoring O_2 levels which were already near zero. Neither the NO_x reduction efficiency nor the outlet NO_x concentrations measured during this test would meet the SCAQMD rule 1110 efficiency of 90 percent or an emission rate of 0.28 μg/J heat output.

Total unburned hydrocarbon ranged from 140 to 370 ppm as measured (215 ppm average) at the inlet. These emissions were reduced on passage through the catalyst to a range of 80 to 200 ppm (125 ppm average) at the outlet. This corresponds to an average hydrocarbon emission reduction of 42 percent. Figure 3-7 shows the variation in TUHC emissions over the test day. The increase in TUHC at about 8:00 a.m. corresponds to the adjustment in engine A/F toward rich burning condition.

Ammonia emissions were measured with an extractive sampling train, once at the inlet location and twice at the outlet location. The inlet concentration was 31 ppm at stack conditions (0.05g/Bhp-hr). Outlet NH_3 emissions ranged from 440 to 530 ppm (0.66 to 0.80g/Bhp-hr) with an average of 483 ppm (0.82g/Bhp-hr). This corresponds to a 15-fold increase in NH_3 emissions across the catalyst. Total cyanide emissions although lower than NH_3 emissions at both locations also showed a significant increase from about 0.02 ppm as measured at the inlet (0.051 mg/Bhp-hr) to 8.2 ppm (22 mg/Bhp-hr) at the outlet, a 400-fold increase.

Solid particulate emissions measured by the SASS train at both locations showed essentially no change from the inlet to outlet location.

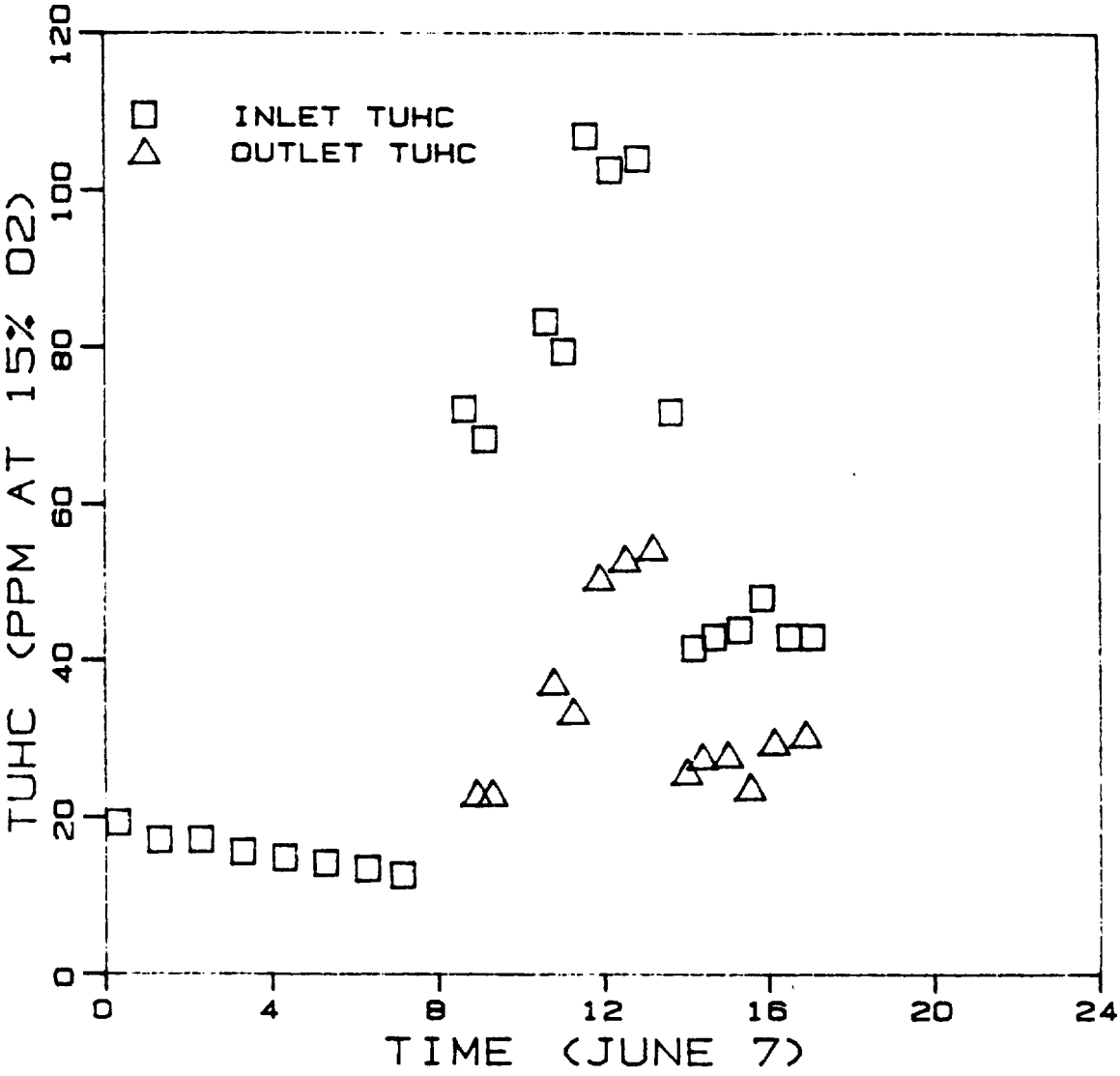


Figure 3-7. Exhaust gas hydrocarbon emissions during comprehensive tests.

N_2O emissions were measured by gas chromatography with electron capture detection of exhaust gas samples taken at the inlet and outlet of the catalyst. Table 3-2 summarizes these results. Information on O_2, NO, NO_x, and NO_2 (by difference) are also indicated. These emissions were recorded by continuous analyzers during the grab sampling of the gas for N_2O analyses. As indicated, no NO_x reduction was taking place during the time the N_2O samples were taken. The concentration of NO_2 varied from about 6 to 8 percent of the total NO_x. N_2O measured in duplicate tests at both inlet and outlet locations ranged from 64 to about 180 ppm at the inlet and 17 to 56 ppm at the outlet. All concentrations are corrected to 3 percent O_2. These N_2O concentrations represent about 2 to 7 percent of the total inlet NO_x and 0.6 to 2 percent of the total outlet NO_x. Previous N_2O data collected in the CMEA program has shown that N_2O from uncontrolled external combustion sources has ranged between 15 to 20 percent of the total NO_x (Reference 3-2). Although the concentration of N_2O varied for these two tests, the percent reduction by the catalyst remained fairly constant at 70 percent N_2O reduction by the catalyst. Conversely apparent NO_2 reduction by the catalyst was 15 to 20 percent.

3.3 TRACE ELEMENT EMISSIONS

Inorganic trace element concentrations were measured in the exhaust gas samples collected at the inlet and outlet of the catalytic reactor. Laboratory analyses included spark source mass spectroscopy (SSMS) for 70 elements and atomic absorption spectroscopy (AAS) for mercury, antimony, and arsenic. AAS was also used to confirm SSMS results on selected organics whose concentration exceeded the upper quantitation limit of the SSMS analyses. Once concentrations in the samples were determined by these analyses, trace element concentrations in both flue gas streams could be

TABLE 3-2. N_2O AND NO_x EMISSIONS[a]

Component	Upstream of catalyst	Downstream of catalyst
O_2, percent dry	2.8	2.0
NO_x, ppm dry	2,700	2,840
ppm dry at 3 percent O_2	2,670	2,690
NO, ppm dry	2,500	2,660
ppm dry at 3 percent O_2	2,470	2,520
NO_2[b], ppm dry	200	180
ppm dry at 3 percent O_2	198	171
N_2O, test 1, ppm dry	181	56
ppm dry at 3 percent O_2	179	53
N_2O -- test 2, ppm dry	65	18
ppm dry at 3 percent O_2	64	17

[a]Emissions are measured the day after the comprehensive tests are completed.
[b]By difference, NO_x to NO.

computed. These concentrations are summarized in Appendix B. Table 3-3 summarizes the emission rate of inorganic elements at the catalyst inlet and outlet locations. Only those elements detected at greater than blank levels in at least one sample are noted in the table. The emissions are reported in micrograms per second (µg/s). The mass balance is expressed by the ratio of emission rate to input rate from the lube oil. The consumption of lube oil was assumed to be 0.093 ml/s (1.37 gal/Bhp-hr) based on the engine manufacturer specifications.

Sulfur emissions were the highest of all elements ranging from 89 to 280 mg/s (240 to 740 mg/dscm). These emissions translate to a sulfur concentration in the natural gas fuel of about 0.01 to 0.04 percent, corresponding to a typical H_2S concentration. The sulfur concentration in the lube oil accounted for an insignificant fraction of these emissions. Sodium emissions were second highest after sulfur. Again, the lube oil did not contribute to these emissions. It is possible that sodium salts may have been present in the gas fuel along with sulfur. It is also likely that suspended salts (NaCl and other sodium compounds) may have been present in the intake air.

Other trace elements whose emission rate exceeded 10 µg/s (26 µg/dscm) at either inlet or outlet location were barium, calcium, chromium, copper, fluorine, iron, magnesium, manganese, nickel, potassium, silicon, silver, tungsten, and zinc. In nearly all cases, the catalyst outlet emissions were higher than the inlet emissions, often by as much as one order of magnitude. This was especially the case for metals such as copper, iron, magnesium, manganese, nickel, and zinc. In general, the lube oil trace element input rates were insufficient to account for either catalyst inlet or outlet

TABLE 3-3. INORGANIC TRACE ELEMENT EMISSION RATES

Element	Emissions (µg/s)		Mass balance (exhaust gas/lube oil)	
	Inlet	Outlet	Catalyst inlet/lube	Catalyst Outlet/lube
Aluminum	6.5	2.4	15	5.6
Antimony	0.0025	0.11	NA[a]	NA
Arsenic	0.064	0.25	NA	NA
Barium	19	23	0.23	0.28
Beryllium	<0.0000064	<0.041	NA	NA
Bismuth	0.0010	0.043	0.061	0.25
Bromine	0.015	0.88	NA	NA
Cadmium	0.00047	--	NA	NA
Calcium	180	58	6.2	2.0
Cerium	3.1	0.20	NA	NA
Cesium	0.00015	1.6	NA	NA
Chlorine	>1.5	>1.4	>1.7	1.7
Chromium	0.26	290	15	>17,000
Cobalt	5.7	2.3	340	>140
Copper	5.9	>420	70	5,000
Fluorine	>0.83	>120	>1.9	>290
Gallium	0.20	1.9	NA	NA
Germanium	0.00060	0.00086	NA	NA
Hafnium	0.0030	0.0043	NA	NA
Iodine	0.32	0.024	19	1.4
Iron	15	150	36	350
Lanthanum	31	<0.20	NA	NA
Lead	0.056	0.15	3.3	9.1
Lithium	0.29	0.19	11	7.3
Magnesium	10	57	30	170
Manganese	0.4	12	4.7	140
Mercury	0.070	0.037	13	6.9
Molybdenum	3.1	0.99	37	12
Neodymium	0.00049	0.0047	NA	NA
Nickel	0.31	250	1.8	1,500

[a]NA -- Not applicable -- lube oil concentration was zero.

TABLE 3-3. (concluded)

Element	Emissions (µg/s)		Mass balance (exhaust gas/lube oil)	
	Inlet	Outlet	Catalyst inlet/lube	Catalyst Outlet/lube
Niobium	1.5	0.17	NA	NA
Palladium	0.0010	0.0057	NA	NA
Phosphorus	2.0	11	0.038	0.21
Potassium	68	130	40	77
Praseodymium	0.00013	0.000094	NA	NA
Rhodium	0.012	0.0043	NA	NA
Rubidium	--	0.41	NA	NA
Ruthenium	<0.00015	<0.00043	NA	NA
Scandium	--	0.21	0	>25
Selenium	0.0090	0.55	0.053	3.2
Silicon	220	500	88	200
Silver	0.59	79	NA	NA
Sodium	59,000	60,000	23,000	23,000
Strontium	1.0	2.0	12	24
Sulfur	89,000	280,000	250	780
Tantalum	--	4.1	NA	NA
Tellurium	0.00016	0.12	NA	NA
Thorium	0.0045	0.0072	NA	NA
Tin	0.031	0.013	NA	NA
Titanium	--	4.1	0	>240
Tungsten	51	2.6	NA	NA
Uranium	0.0032	0.0016	NA	NA
Vanadium	0.030	0.40	1.8	24
Yttrium	0.0016	0.044	NA	NA
Zinc	9.5	170	0.43	7.7
Zirconium	--	1.1	0	26

[a]NA -- Not applicable -- lube oil concentration was zero

emission rates. This suggests that metallic element emissions originated from internal parts of the engine, the muffler and/or the catalytic reactor. However, some contamination of the samples by means of sampling trains may also have been possible. This is probable in the case of silver results because silver nitrate is used in one of the SASS impingers as an absorbing solution.

Overall, it is quite evident that the exhaust gas trace element content increased across the catalyst. Platinum and rhodium, the two noble metals of the catalyst, generally were present at low levels. In fact, platinum was not detected in the exhaust gas at either location. This result was in part due to blank concentration exceeding sample concentration. Rhodium emissions were in the range of 4.3 to 12 ng/s. However, there was no detected increase across the catalyst.

3.4 ORGANIC SPECIES EMISSIONS

Organic analyses were performed on the exhaust gas samples collected at the catalyst inlet and outlet locations. SASS samples were analyzed for semivolatile and nonvolatile organics according to the EPA Level 1 protocol (Reference 3-1) as outlined in Appendix A. Semivolatile organic compounds with boiling points in the nominal C_7 to C_{16} range of 100° to 300°C (210° to 570°F) were determined in the laboratory by total chromatographable organic (TCO) analysis of the combined organic module sorbent (XAD-2) and condensate extracts. Nonvolatile organic species having boiling points in the nominal C_{16+} range of >300°C (570°F) were measured by gravimetric (GRAV) analysis of SASS sample extracts.

Infrared spectrometry (IR) was performed on the GRAV residue of SASS train extracts to identify organic functional groups possibly present. Gas

chromatography/mass spectrometry (GC/MS) analyses of the XAD-2 extracts were also performed to identify specific polynuclear aromatic hydrocarbons (PAH) and other organic components (the semivolatile organic priority pollutants). The components sought in the GC/MS analysis and their respective detection limits are listed in Table 3-4. In addition, liquid chromatography (LC) separation of selected sample extracts, with TCO and GRAV, and the analyses of the fractions eluted from the column, were performed.

3.4.1 TCO, GRAV, GC/MS and IR Analyses of Total Sample Extracts

Table 3-5 summarizes organic emission results based on TCO, GRAV and GC/MS analyses. The concentration of organics at the catalyst inlet location is significantly higher than that at the outlet location. This is evidenced by both TCO and GRAV results as well as by the concentration of the priority pollutants noted. The high levels of organics at the catalyst inlet reflect the near stoichiometric A/F setting prevalent during these tests. The reduction in organic emissions across the catalyst parallels the decrease in CO and hydrocarbon emissions noted in the preceding section.

Total organics in the range of $>C_6$ (boiling points greater than 100°C) were about 15 mg/dscm at the catalyst inlet location. The corresponding concentration at the catalyst outlet was about 2.0 mg/dscm.

Priority pollutants at the catalyst inlet whose concentration exceeded 10 µg/dscm were acenapthene, acenaphthylene, fluorene, and phenanthrene. All these compounds showed concentrations below or near the method detection limit (0.4 µg/dscm) at the outlet location indicating oxidation by the catalyst.

Interestingly, the PAH compounds most abundant in the catalyst inlet exhaust were those containing three or more fused rings. Naphthalene, the

TABLE 3-4. COMPOUNDS SOUGHT IN THE GC/MS AND THEIR DETECTION LIMITS (ng/μl INJECTED)

Acid Compounds			
2,4,6-trichlorophenol	5	2-nitrophenol	5
p-chloro-m-cresol	5	4-nitrophenol	20
2-chlorophenol	5	2,4-dinitrophenol	20
2,4-dichlorophenol	5	4,6-dinitro-o-cresol	20
2,4-dimethylphenol	5	pentachlorophenol	5
		phenol	1
Base Neutral Compounds			
1,2,4-trichlorobenzene	1	benzo(c)phenanthrene	40
1,2-dichlorobenzene	1	bis(2-chloroethoxy)methane	1
1,2-diphenylhydrazine (as azobenzene)	1	bis(2-chloroethyl)ether	1
		bis(2-chloroisopropyl)ether	1
1,3-dichlorobenzene	1	bis(2-ethylhexyl)phthalate	1
1,4-dichlorobenzene	1	butyl benzyl phthalate	1
2,4-dinitrotoluene	1	chrysene	1
2,6-dinitrotoluene	1	di-n-butyl phthalate	1
2-chloronaphthalene	1	di-n-octyl phthalate	1
3,3'-dichlorobenzidine	5	dibenzo(a,h)anthracene	5
3-methyl cholanthrene	40	dibenzo(c,g)carbazoleloteher	40
4-bromophenyl phenyl ether	1	diethyl phthalate	1
4-chlorophenyl phenyl ether	1	dimethyl phthalate	1
7,12-dimethyl benz(a)anthracene	40	fluoranthene	1
N-nitrosodi-n-propylamine	5	fluorene	1
N-nitrosodimethylamine	NA	hexachlorobenzene	1
N-nitrosodiphenylamine	1	hexachlorobutadiene	1
acenaphthene	1	hexachlorocyclopentadiene	1
acenaththylene	1	hexachloroethane	1
anthracene	1	indeno(1,2,3-cd)pyrene	5
benzo(ghi)perylene	5	isophorone	1
benzidine	20	naphthalene	1
benzo(b)fluoranthene	1	nitrobenzene	1
benzo(k)fluoranthene	1	perylene	40
benzo(a)anthracene	1	phenanthrene	1
benzo(a)pyrene	1	pyrene	1

TABLE 3-5. TOTAL ORGANIC AND SEMIVOLATILE ORGANIC PRIORITY POLLUTANT EMISSIONS, µg/dscm

	Catalyst inlet		Catalyst outlet	
• Organic Category:				
C_7 to C_{16} (TCO)	8,000[a]		1,800	
C_{16}^+ (GRAV)	7,400		300	
Total, $\geq C_7$	15,400		2,100	
• Semivolatile Priority Pollutants		Run 1	Run 2	Average
Acenapthene	16.5	<0.4	<0.4	<0.4
Acenaphthylene	62.3	1.2	1.2	1.2
Benz(a)anthracene	5.1	<0.4	<0.4	<0.4
Benzofluoranthenes	1.9	<0.4	<0.4	<0.4
Bis(2-chloroethyl)ether	2.1	<0.4	<0.4	<0.4
Bis(2-ethylhexyl)phthalate[b]	54.9	1.0	1.3	1.2
Butyl benzyl phthalate[b]	0.7	<0.4	<0.4	<0.4
Chrysene	1.9	<0.4	<0.4	<0.4
Fluoranthene	0.5	<0.4	<0.4	<0.4
Fluorene	17.9	<0.4	<0.4	<0.4
Naphthalene	<0.4	26.8	30.2	28.5
Phenanthrene	40.3	1.2	1.5	1.4
Phenol	<0.4	1.6	2.1	1.8
Pyrene	2.2	<0.4	<0.4	<0.4

[a]This number is based on the average of results of duplicate analyses which showed 270 mg and 170 mg TCO, respectively.
[b]Level corresponds to that commonly found in laboratory blanks.

two-fused-ring PAH very commonly found in combustion system exhaust gas, was absent in the catalyst inlet gas, as was phenol. At the catalyst outlet, however, levels of the higher order PAH's were much lower, but naphthalene and phenol levels were increased. Evidently, the higher order PAH's were being oxidized, though not completely, with naphthalene and phenol as incomplete oxidation products.

Table 3-6 summarizes results of the IR spectroscopy analyses of the XAD-2 plus organic module condensate extracts. As noted in the table, the catalyst outlet sorbent module extract and the sorbent blank extract had weak IR spectra (no peaks). The spectrum for the catalyst inlet sorbent extract (which had higher total organic content) suggests the presence of aliphatic hydrocarbons and oxygenates such as alcohols, carboxylic acids, aldehydes, and ketones.

3.4.2 Column Chromatography Separation and IR Spectra of LC Fractions

The XAD-2 and organic module sample extracts for the catalyst inlet sample were separated by polar character via LC fractionation on silica gel. GRAV and TCO content were then obtained for each LC fraction. Results of these analyses are summarized in Table 3-7. The data show a relatively even distribution of organics in each fraction, although the concentration in fraction 2 was the lowest at 0.16 mg/dscm. The highest was in LC6 with 1.9 mg/dscm. Fraction 6 normally contains oxygenated organics such as alcohols, phenols, esters, ketones, and amines. Fraction 3, the second highest in concentration generally contains aromatic hydrocarbons. Fractions 1 and 4, both at about 1 mg/dscm, generally contain aliphatic hydrocarbons and less polar oxygenated hydrocarbons such as ethers, respectively.

TABLE 3-6. IR SPECTRA SUMMARY

Sample	Number (cm^{-1})	Intensity[a]	Assignment
XAD-2 + OMC extract, catalyst inlet	3571-2944	M	O-H stretch
	2907	S	CH alkyl
	1673	S	C=O stretch
	1538	M	Unassigned
	1439	M	CH_2 alkyl
	1266	M	C-O stretch
XAD-2 + OMC extract, catalyst outlet	No peaks		
XAD-2 blank extract	No peaks		

[a]S = Strong
M = Moderate

TABLE 3-7. TCO AND GRAV RESULTS FOR THE LC FRACTIONS OF THE CATALYST INLET XAD-2 EXTRACT[a]

Fraction	TCO mg/dscm	GRAV mg/dscm	Total mg/dscm	Total ng/J heat input	Total mg/Bhp-hr
LC1	<0.033	0.99	0.99	0.23	2.3
LC2	0.033	0.13	0.16	0.037	0.37
LC3	0.51	1.2	1.7	0.39	3.9
LC4	0.073	0.92	0.99	0.23	2.3
LC5	<0.018	0.55	0.55	0.13	1.3
LC6	<0.018	1.9	1.9	0.44	4.3
LC7	<0.018	0.51	0.51	0.12	1.2
Total	0.62	6.2	6.8	1.6	15.7

[a]Results are based on the total organics recovered in each fraction corrected to total organics in the original sample.

IR spectra were obtained on the GRAV residue of each LC fraction. Table 3-8 summarizes these IR spectra results. Absorbances consistent with the presence only of aliphatic hydrocarbons were in the LC1 spectrum. The spectra of LC3 and 4 suggest the possible presence of aldehydes. Other oxygenated hydrocarbons such as carboxylic acids, alcohols, and ketones are suggested by the spectra of LC6 and 7. Comparing Table 3-5 to Table 3-7 shows that all absorbances in the spectrum of the total sample extract are accounted for in the fraction spectra. In fact the LC fraction spectra are more defined.

3.5 EXTENDED CONTINUOUS EMISSIONS MONITORING

Continuous monitoring for exhaust gas O_2, CO_2, CO, NO_x and TUHC was performed for a 15-day period from June 6 to June 21, 1983. With the exception of June 7, the engine was operated under normal conditions with no restrictions imposed on load or A/F; recall that the engine had no automatic A/F controller. Figures 3-8 through 3-12 illustrate emission data over this period. The emission data in these figures represent hourly averages of data taken on 5- to 15-minute intervals.

Although this method of presenting the test data represents a more manageable task, it also tends to "smooth out" some of the peaks in emissions that occurred during abrupt changes in engine operation. Nevertheless, the data do highlight some important characteristics of NSCR performance during unconstrained engine operation.

Exhaust O_2 data, summarized in Figure 3-8, show the near stoichiometric A/F of the comprehensive tests performed during June 7. Following these tests, the A/F was increased resulting in exhaust O_2 of about 2 percent at the catalyst inlet for most of the 15-day test period. Occasionally, the O_2

TABLE 3-8. SUMMARY OF IR SPECTRA FOR LC FRACTIONS OF THE CATALYST INLET XAD-2 EXTRACT[a]

Fraction	Frequency (cm^{-1})	Intensity[b]	Possible assignment	Possible compound categories present[c]
LC1	2945	S	C-H Alkyl	Aliphatic Hydrocarbons
LC2	No Peaks	--	--	--
LC3	2940	S	C-H Alkyl	Hydrocarbons, aldehydes
	1715	S	C=O	
LC4	2930	M	C-H Alkyl	Hydrocarbons, aldehydes
	1700	S	C=O	
	1555	M	Not assigned	
LC5	2930	S	C-H Alkyl	Hydrocarbons
LC6	3360	M	O-H Stretch	
	3065	W	C-H Alkyl	
	2935	S	C-H Alkyl	Hydrocarbons (Alkyl and alkenyl), carboxylic acids, alcohols, ketones
	1710	S	C=O Stretch	
	1605	W	C-C Alkenyl	
	1555	M	Not assigned	
	1540	W	CH_2	
	1380	W	CH_3	
	1278	W	C-O	
	740	W	C-H Alkyl	
LC7	3540	S	O-H Stretch	
	2940	W	C-H Alkyl	Hydrocarbons, carboxylic acids, alcohols
	1710	W	C=O Stretch	

[a]Spectra for the XAD-2 blank LC fractions had no peak.
[b]S = Strong, M = Moderate, W = Weak
[c]Possible compound categories present consistent with spectra and LC fraction.

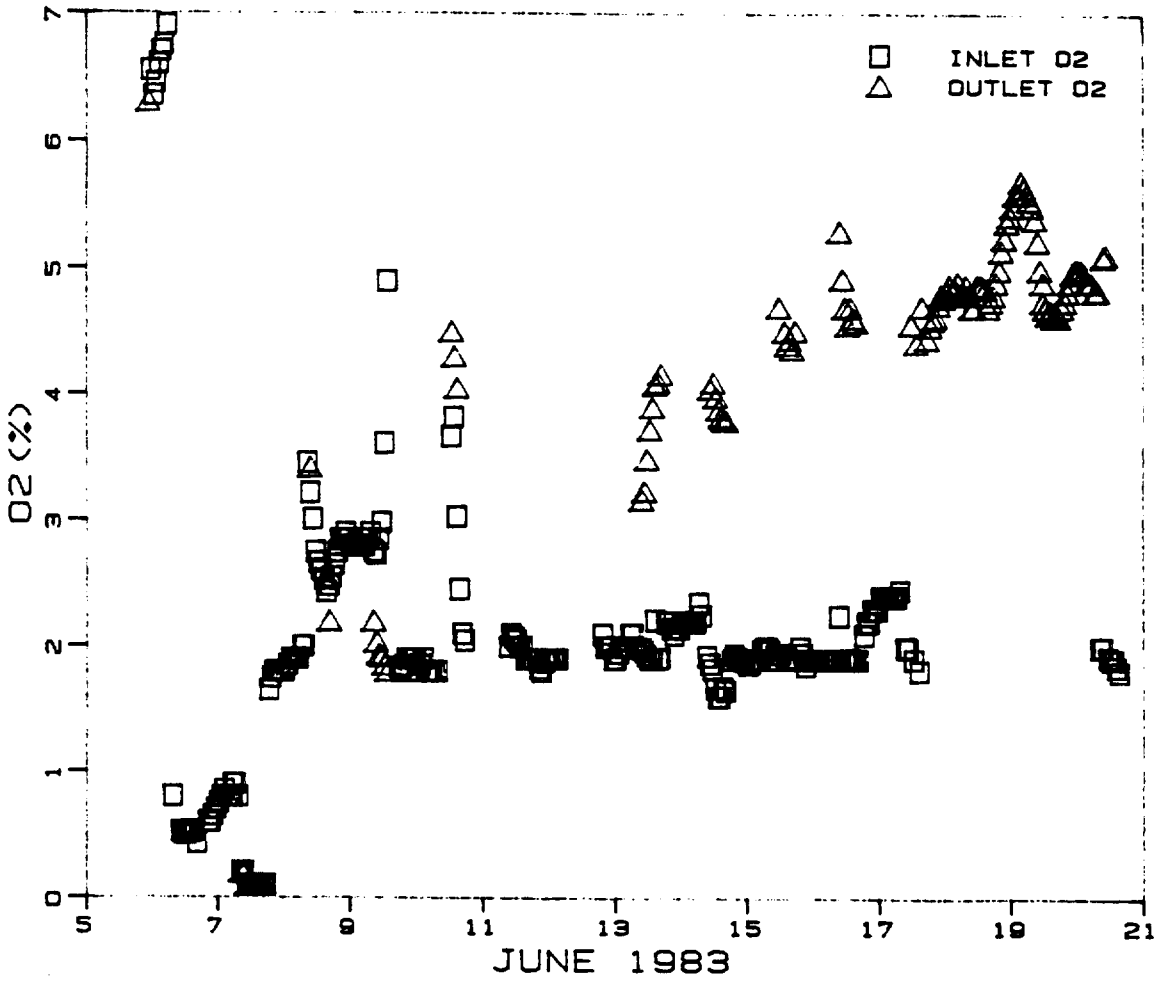


Figure 3-8. Exhaust O_2 for the 15-day continuous monitoring period.

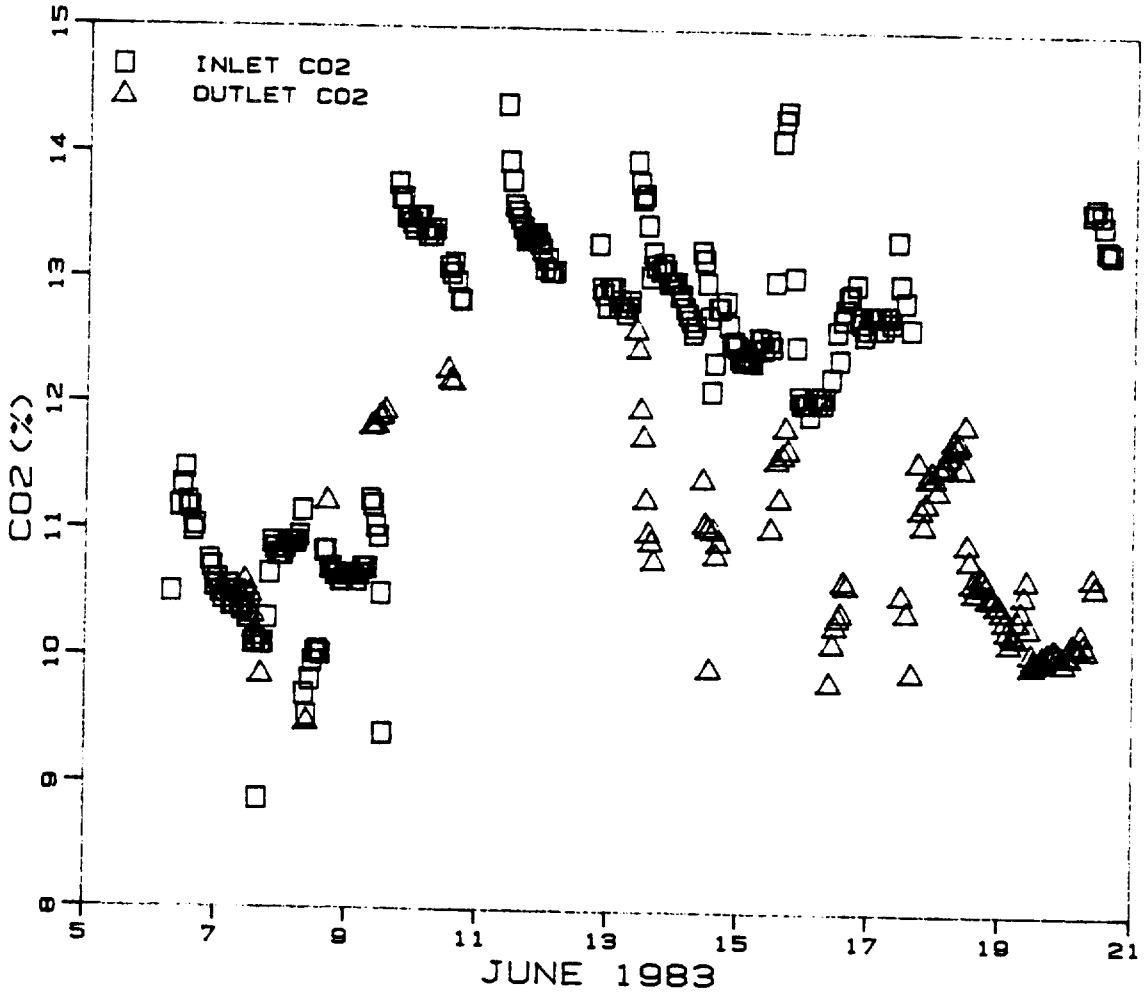


Figure 3-9. Exhaust CO_2 for the 15-day continuous monitoring period.

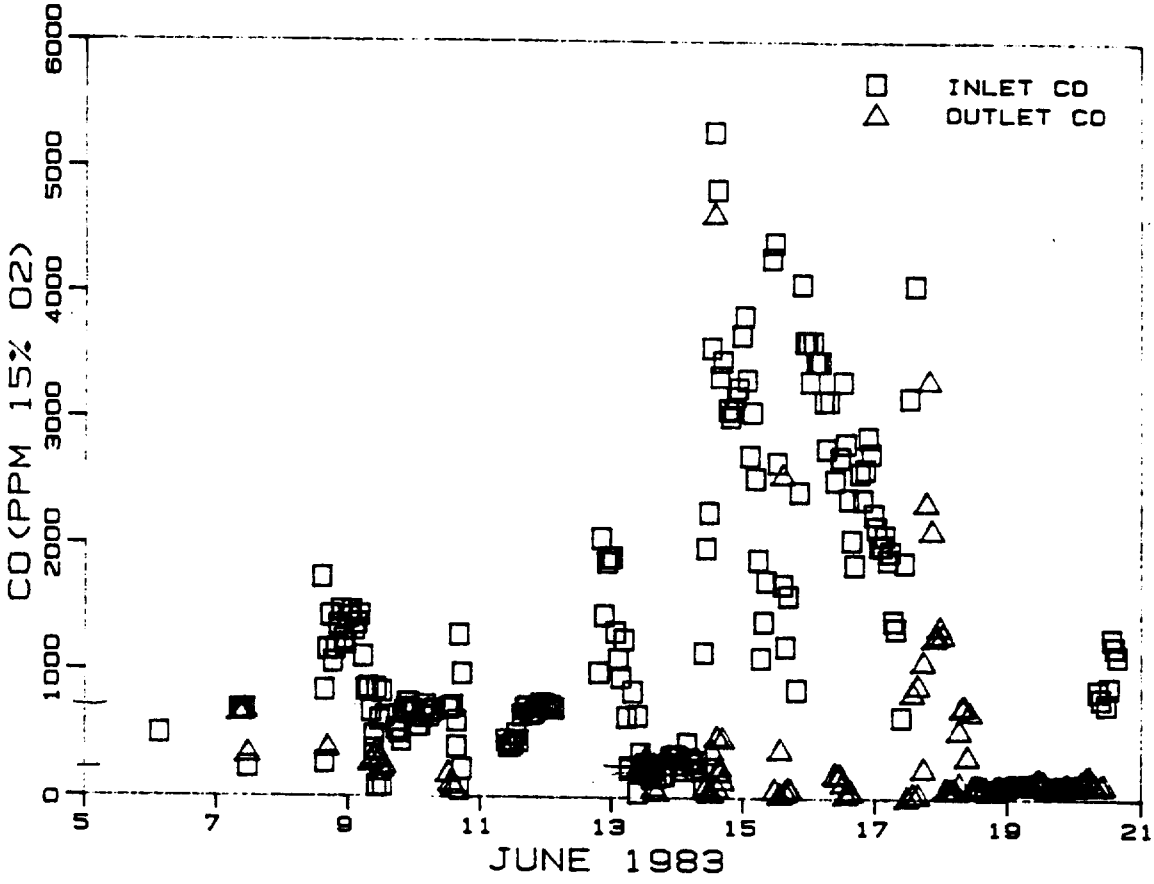


Figure 3-10. CO emissions for the 15-day continuous monitoring period.

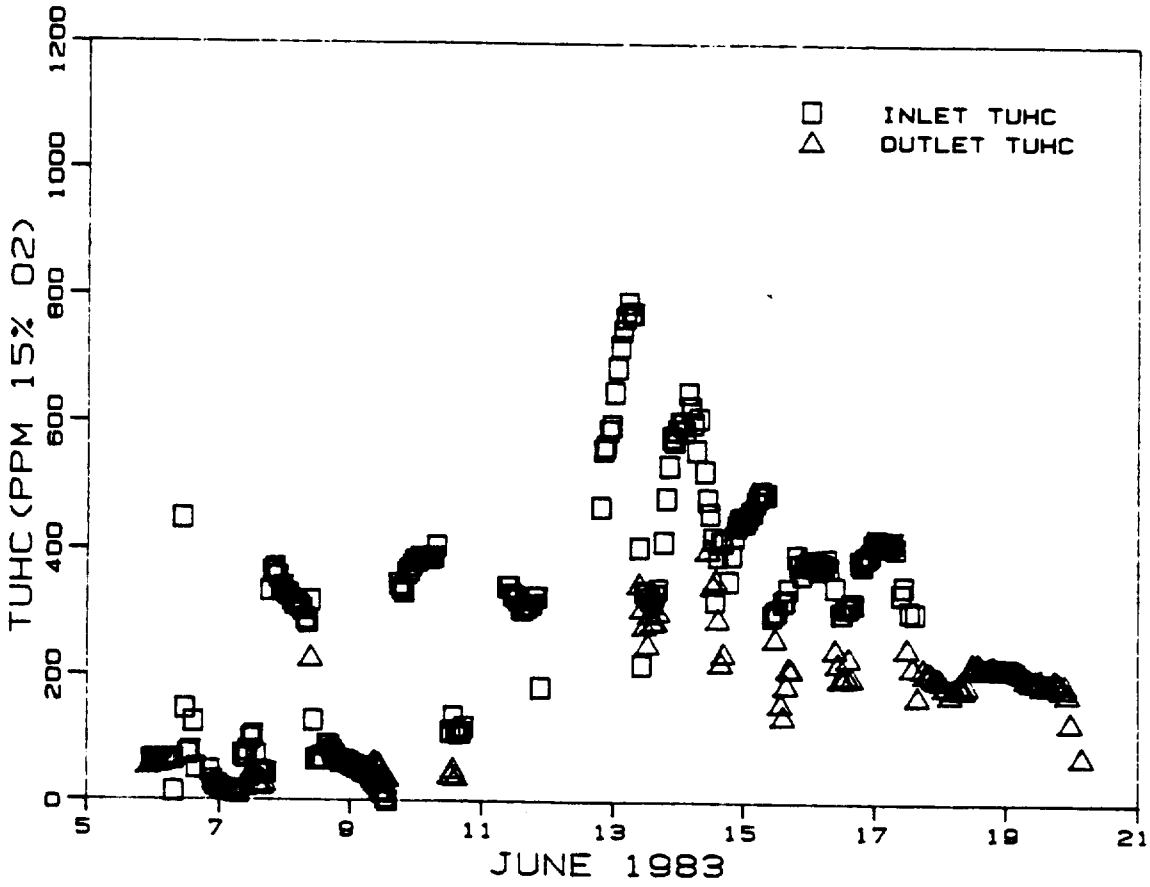


Figure 3-11. TUHC emissions for the 15-day continuous monitoring period.

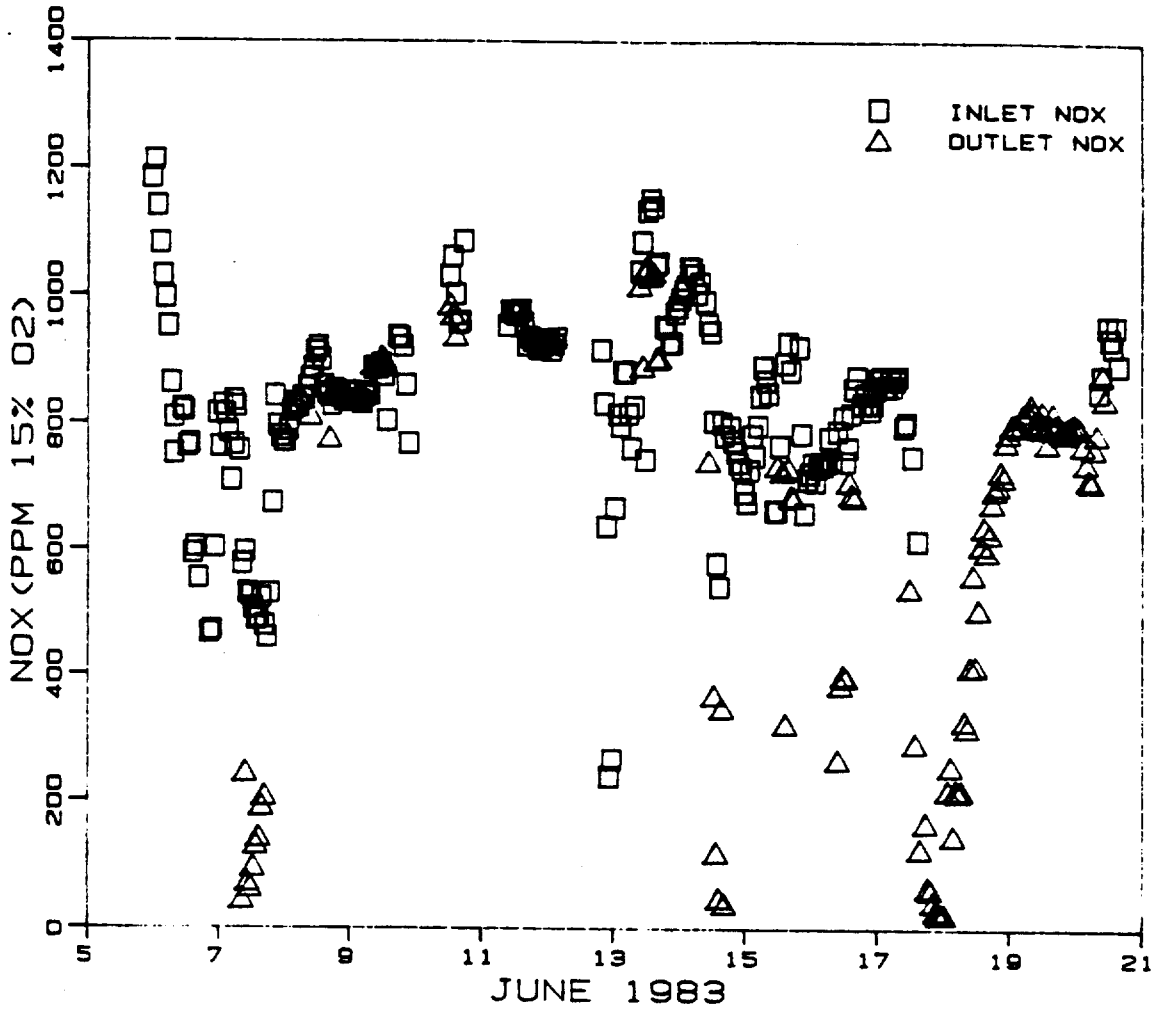


Figure 3-12. NO_X emissions for the 15-day continuous monitoring period.

the catalyst inlet for most of the 15-day test period. Occasionally, the O_2 climbed as high as 3 and 4 percent but remained at this level for less than a day. The difference between outlet O_2 and inlet O_2 shown in the data for the period following June 13 is considered suspect since it is unlikely that the O_2 would increase across the catalytic reactor.

Figure 3-9 illustrates the CO_2 emission trends. During the comprehensive tests and periods immediately preceding and following these tests exhaust CO_2 ranged from about 10 to 11 percent on a dry basis. Since stoichiometric CO_2 for the natural gas burned during these tests is 12 percent the CO emissions were probably in the range of 1 to 2 percent. The increase in inlet CO_2 to 13 and 14 percent after June 10 is considered suspect. In contrast, outlet CO_2 concentration was usually in the range of 10 to 12 percent. This may be more indicative of actual combustion conditions. This range of 10 to 12 percent CO_2 corresponds to 3.5 and zero percent O_2, respectively, with complete combustion.

Figure 3-10 illustrates the CO emission trends. Generally CO emissions were 700 ppm, corrected to 15 percent O_2, or lower for most of the test period. Although simultaneous inlet/outlet data were often not available. CO at the catalyst outlet was always lower than at the catalyst inlet.

Spikes of CO up to 5,000 ppm (corrected to 15 percent O_2) at either the inlet or outlet location can be seen. These are indicative of richer burning conditions. These spikes were often accompanied by improved NO_x reduction performance by the catalyst. A trend toward lower CO emissions in the latter part of the 15-day test period is also apparent. This is in agreement with the increased O_2 levels measured.

TUHC emissions, illustrated in Figure 3-11, show a substantial increase following the comprehensive tests on June 7. The highest emissions, up to 800 ppm at 15 percent O_2) were registered just prior to June 13. CO emissions were also highest during this period. Following this peak, TUHC emission decreased, in parallel with CO emissions as noted above. Outlet TUHC generally was 100 ppm lower than inlet TUHC.

Figure 3-12 illustrates catalytic inlet and outlet NO_x emissions over the monitoring period. The effective catalyst NO_x reduction during the comprehensive tests of June 7 is clearly evident. Also evident is the reduced catalyst performance throughout most of the remaining test period. One clear exception is the test data taken late in the day of June 17 and into the following morning. During this period outlet NO_x was reduced to below 50 ppm (15 percent O_2). This increased catalyst NO_x reduction performance occurred during richer engine operation, as suggested by the high measured CO emissions.

REFERENCES FOR SECTION 3

3-1. Lentzen, D. E., et al., "IERL-RTP Procedures Manual: Level 1 Environmental Assessment (Second Edition," EPA-600/7-78-201, NTIS PB293795, October 1978.

3-2. Waterland, L. R., et al., "Environmental Assessment of Industrial Boilers Firing Coal-Liquid Mixtures and Wood," in Proceedings of the 1982 Joint Symposium of Stationary Combustion NO_x Control, Volume 2. EPRI CS-3182, July 1983.

SECTION 4

ENVIRONMENTAL ASSESSMENT

This section discusses the potential environmental significance of the engine tested, including results of the bioassay testing of samples collected during the tests. As a means of ranking species discharged for possible further consideration, exhaust gas discharge stream species concentrations are compared to occupational exposure guidelines. Bioassay analyses were conducted as a more direct measure of the potential health and ecological effects of the emission stream. Both these analyses are aimed at identifying problem areas and providing the basis for ranking of pollutant species and discharge streams for further consideration.

4.1 EMISSIONS ASSESSMENT

To obtain a measure of the potential significance of the pollutant levels in the exhaust gas analyzed in this test program, exhaust concentrations were compared to an available set of health-effects-related indices. The indices used for comparison were occupational exposure guidelines. Two sources of such guidelines were used: the time-weighted-average Threshold Limit Values (TLV's) defined by the American Conference of Governmental Industrial Hygienists (ACGIH) (Reference 4-1) and 8-hr time-weighted-average exposure limits established by the Occupational Safety and Health Administration (OSHA) (Reference 4-2).

The comparisons of discharge stream species concentrations to these indices should be used only for ranking species emission levels for further testing and analyses. Table 4-1 lists those pollutant species emitted in the catalyst inlet and outlet exhaust gas streams at levels greater than 10 percent of their occupational exposure guideline.

4.2 BIOASSAY RESULTS

Health effects bioassay tests were performed on the organic sorbent (XAD-2) extract collected by the SASS train at the catalyst inlet and outlet locations. A detailed description of the biological analyses performed is presented in Volume II (Data Supplement) of this report. The bioassay tests performed (Reference 4-3) were:

- Ames assay, based on the property of Salmonella typhimurium mutants to revert due to exposure to various classes of mutagens
- Cytotoxicity assay (CHO) with mammalian cells in culture to measure cellular metabolic impairment and death resulting from exposure to soluble toxicants

The results of these assays are summarized in Table 4-2. The data suggest that the XAD-2 extracts from both locations were of high mutagenicity and high to moderate toxicity. These are typical bioassay responses for combustion source XAD-2 extract.

TABLE 4-1. EXHAUST GAS COMPONENTS EMITTED AT LEVELS EXCEEDING 10 PERCENT OF THEIR OCCUPATIONAL EXPOSURE GUIDELINE

Pollutant	Emission concentration, mg/dscm		Occupational exposure guideline (mg/m^3)
	Catalyst inlet	Catalyst outlet	
Carbon monoxide, CO	5,350	4,840	55
Nitrogen oxide, NO_x	3,410	1,180	6.0
Ammonia, NH_3	23	320	18
Nitrous oxides, N_2O[b]	270	170	--[c]
Cyanide, HCN	0.022	10	5.0
Sodium, Na	150	160	2.0[d]
Barium, Ba	0.049	0.064	0.5
Calcium, Ca	0.45	0.16	2.0
Chromium, Cr	0.0007	>0.78	0.05
Copper, Cu	0.015	>1.2	0.10[e]
Iron, Fe	0.039	0.41	1.0
Nickel, Ni	0.0008	0.69	0.10
Phosphorus, P	0.005	0.030	0.10
Potassium, K	0.17	0.36	2.0[d]
Silicon, Si	0.57	1.4	10
Silver, Ag	0.0015	0.22	0.010
Zinc, Zn	0.024	0.46	1.0

[a]TLV unless noted (Reference 4-1).
[b]N_2O emissions measured low catalyst NO_x reduction efficiency following completion of comprehensive tests.
[c]-- denotes no occupational exposure guideline applicable.
[d]Ceiling value.
[e]8-hr time-weighted-average OSHA exposure limit (Reference 4-2).

TABLE 4-2. BIOASSAY RESULTS

Sample	Assay	
	Ames[a]	CHO[b]
Catalyst inlet XAD-2 extract	H	H/M
Catalyst outlet XAD-2 extract	H	M

[a]Mutagenicity assay.
[b]Toxicity assay.
H = high; M = moderate; H/M = high to moderate.

REFERENCES FOR SECTION 4

4-1. "Threshold Limit Values for Chemical Substances and Physical Agents in the Work Environment with Intended Changes for 1983-84," American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio, 1983.

4-2. OSHA Safety and Health Standards, 29 CFR 1910, Subpart Z.

4-3. Brusick, D. J., and R. R. Young, "IERL-RTP Procedures Manual: Level 1 Environmental Assessment, Biological Tests," EPA 600/8-81-024, NTIS PB81-228766, October 1981.

SECTION 5

TEST QUALITY ASSURANCE AND QUALITY CONTROL

Quality assurance (QA) activities implemented for this test included:

- Certification of the NO_x continuous monitoring analyzer using standard EPA Method 7 protocol for accuracy determination of NO_x readings.
- Duplicate SSMS, TCO and GC/MS analyses of SASS samples for determination of analytical precision.

The following paragraphs discuss the results of these QA activities.

5.1 NO_x CERTIFICATION RESULTS

EPA Method 7 test protocols were used twice during the 15-day continuous monitoring period to certify the accuracy of the NO_x analyzers. Table 5-1 shows that, for the first certification test conducted on June 8, the NO_x monitor readings were consistently 550 to 650 ppm higher than corresponding Method 7 results. The associated relative accuracy of the instrument as determined by this test was 29 percent. This compares to an allowable relative accuracy of 20 percent in performance specification 2 (40 CFR, Part 60, Appendix B). However, the Method 7 results for this first test may be suspect. Insufficient O_2 may have been present in the engine exhaust tested to completely oxidize all the NO to NO_2 as required by the method. Method 7 procedures caution that if the gas being sampled contains insufficient O_2 for the conversion of NO to NO_2, then O_2 should be introduced

TABLE 5-1. METHOD 7 CERTIFICATION RESULTS: JUNE 8

Test No.	NO_x Reference Method Samples (ppm)				Average Analyzer Reading Catalyst Inlet (ppm)	Difference (ppm)
	Sample 1	Sample 2	Sample 3	Sample Average		
1	1,760	1,960	2,580	2,100	2,650	550
2	2,770	1,880	2,170	2,270	2,660	390
3	2,040	2,110	2,130	2,090	2,750	660
4	2,110	2,450	2,400	2,320	2,790	470
5	2,500	2,330	2,020	2,280	2,820	540
6	2,470	1,940	2,380	2,260	2,800	540
7	2,070	2,100	2,090	2,090	2,770	680
8	2,250	1,870	2,190	2,100	2,750	650
9	2,260	2,210	2,000	2,160	2,800	640
Mean reference method test value						2,190
Mean of differences						570

95 percent confidence interval = 70 ppm

$$\text{Relative accuracy} = \frac{\text{Mean of differences} + \text{95 percent confidence interval}}{\text{Mean reference method value}} \times 100$$

$$= 29 \text{ percent}^a$$

[a]Poor relative accuracy (≤20 percent allowed) due to insufficient O_2 in gas sample to efficiently oxidize NO to NO_2

into the sampling flasks. However, the method procedures offer no guide as to what constitutes insufficient O_2. For this first certification test, exhaust O_2 was about 2.7 percent; NO_x analyzer readings were 2,700 to 2,800 ppm. During the test it was decided that sufficient O_2 was available. However the discrepancy between the Method 7 results and the analyzer readings suggest this may not have been the case. For the second certification test performed on June 20, O_2 (air) was added to the Method 7 sampling flasks. Exhaust O_2 for this test was about 1.9 percent; NO_x analyzer readings were 2,900 to 3,000 ppm. Table 5-2 shows that, for this second certification test, Method 7 results and analyzer readings were in much closer agreement. The calculated relative accuracy of the analyzer during this test was 9.2 percent, well within the performance specification.

5.2 DUPLICATE ANALYSES

Blind duplicates were submitted for analysis of trace elements by SSMS. Precision of the analysis was then determined based on the relative standard deviation of the replicate samples. Table 5-3 summarizes the results of these SSMS duplicate analyses.

The average relative standard deviation for all the trace elements was 53 percent within the acceptable range of -50 to 100 percent or a factor of 2 in analytical precision.

Results of duplicate analyses for organic samples are summarized in Table 5-4. The average relative standard deviation for these duplicate analyses was 21 percent, well within the project precision goal for these measurements.

TABLE 5-2. METHOD 7 CERTIFICATION RESULTS: JUNE 20

Test No.	NO_x Reference Method Samples (ppm)				Average Analyzer Reading Catalyst Inlet (ppm)	Difference (ppm)
	Sample 1	Sample 2	Sample 3	Sample Average		
1	2,770	2,670	2,940	2,790	2,970	180
2	2,680	2,610	2,860	2,720	3,020	300
3	2,830	2,780	2,860	2,820	2,900	80
4	2,870	2,820	2,800	2,830	3,070	240
5	2,590	2,740	3,000	2,780	2,960	180
6	2,460	2,660	2,830	2,650	2,950	300
7	2,750	2,890	2,990	2,880	2,870	(10)
8	2,990	2,880	3,000	2,960	2,840	(120)
9	2,710	2,760	2,770	2,750	2,880	130
Mean reference method test value						2,800
Mean of differences						140

95 percent confidence interval = 110 ppm

$$\text{Relative accuracy} = \frac{\text{Mean of differences} + \text{95 percent confidence interval}}{\text{Mean reference method value}} \times 100$$

$$= 8.9 \text{ percent}^a$$

[a]Air was cycled to the flasks to ensure sufficient oxidant for NO to NO_2 conversion resulting in relative accuracy within Method 7 performance specification

TABLE 5-3. DUPLICATE SSMS ANALYSES OF CATALYST OUTLET SASS IMPINGER 1 SAMPLE, mg/l

Element	Sample 819379	Sample 819394	Relative standard deviation (percent)
Silver	1.75	2.12	13.5
Chlorine	<3	<3	0
Fluorine	4.18	4.44	1.6
Sodium	1,440	1,480	1.9
Sulfur	9,000	4,800	43
Selenium	<0.002	0.003	28
Mercury	0.0003	0.0004	20
Lead	0.02	0.02	0
Tungsten	0.01	0.007	25
Lanthanum	0.005	0.006	13
Barium	0.09	0.06	28
Tellerium	0.003	<0.001	71
Molybdenum	0.02	0.1	94
Niobium	0.002	0.007	79
Zirconium	0.003	0.009	71
Yttrium	0.002	0.001	47
Strontium	0.009	0.05	98
Bromine	0.04	0.05	16
Arsenic	0.001	0.001	0
Gallium	0.08	0.03	64
Zinc	10	5	47
Copper	>10	>10	0
Nickel	0.3	0.2	28
Cobalt	0.01	0.01	0
Iron	0.5	0.3	35
Manganese	0.1	0.07	25
Chromium	0.2	0.07	68
Vanadium	0.004	0.005	9
Titanium	0.4	0.2	47
Scandium	0.01	0.002	94
Calcium	2	2	0
Potassium	6	0.8	108
Phosphorus	0.3	0.2	28
Silicon	1	2	47
Aluminum	0.2	0.07	68
Magnesium	2	0.1	128
Boron	0.002	0.001	47
Beryllium	0.001	0.001	0
Lithium	0.007	0.002	79
Average standard deviation			53

TABLE 5-4. RESULTS OF DUPLICATE ORGANIC ANALYSES OF SASS SAMPLES

Analyses	Sample No. 369 Total mg	Sample No. 370 Total µg	Relative standard deviation (percent)
TCO	270,170		38
GC/MS:			
Phenol		42, 55	19
Naphthalene		710, 800	8.4
Acenaphthylene		31, 32	2.2
Phenanthrene		31, 41	20
Bis(2-ethyl hexyl)-phthalate		26, 35	21
Average standard deviation			21

APPENDIX A

SAMPLING AND ANALYSIS METHODS

Emissions test equipment was provided by Acurex Corporation. Onsite equipment included a continuous monitoring system for emissions measurements of gaseous criteria pollutants; the SASS train for particulate mass, selected inorganics, and semivolatile and nonvolatile organics; two separate sampling trains for NH_3 and HCN measurement; gas grab sampling equipment for determining N_2O emissions by laboratory gas chromatography, and for validation of NO_x measurements with EPA Method 7. The following sections summarize the sampling and analysis equipment and methods used in the field and laboratory.

A.1 CONTINUOUS MONITORING SYSTEM

Acurex provided a continuous monitoring system modified to allow online simultaneous NO_x sampling capability at inlet and outlet of the catalytic reactor. Figure A-1 illustrates a simplified schematic of the gas conditioning and monitoring system. The monitoring capability included O_2, CO_2, CO (high and low concentrations), NO, NO_x, $NO_x + NH_3$, and TUHC. A refrigeration gas conditioning system was used primarily at the inlet location and provided NO emissions. The heated sample line system was used primarily at the outlet location and provided data on NO and total NO_x. Table A-1 lists the instrumentation constituting the continuous monitoring and flue gas extractive sampling system. A datalogger was used in addition to strip charts to record data continuously.

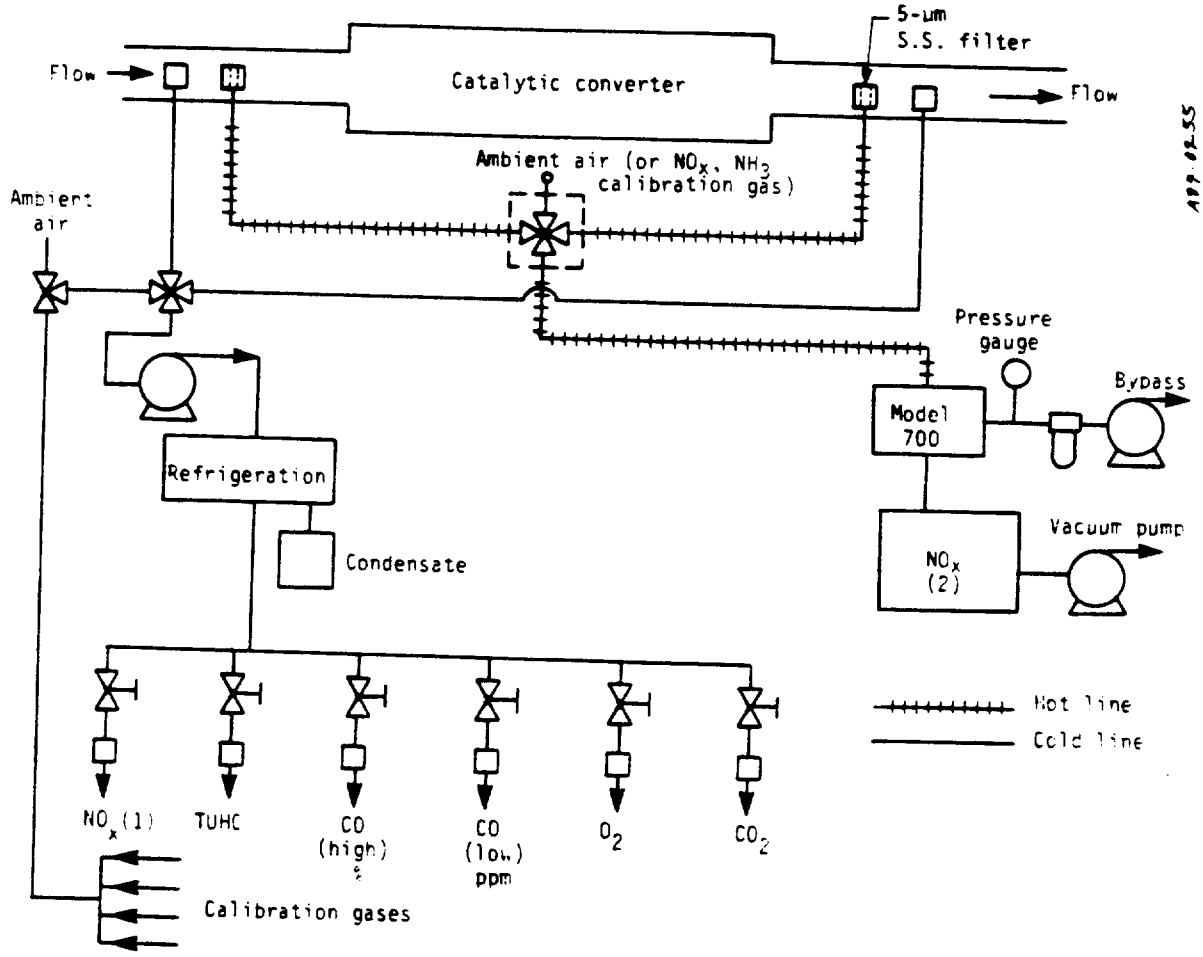


Figure A-1. Schematic of gas conditioning and continuous monitoring system.

Table A-1. CONTINUOUS MONITORING EQUIPMENT IN THE MOBILE LABORATORY

Instrument	Principle of operation	Manufacturer	Instrument model	Range
NO[a] NO_x	Chemiluminescence	Thermo Electron	10 AR	0-100 ppm 0-500 ppm 0-1,000 ppm 0-5,000 ppm
TUHC	Flame ionization detection	Beckman	400	0-10 ppm 0-100 ppm 0- 1,000 ppm
CO	Nondispersive infrared (NDIR)	ANARAD	500R	0-1,000 ppm
CO_2	Nondispersive infrared (NDIR)	ANARAD	AR500	0-20 percent
O_2	Fuel cell	Teledyne		0-5 precent 0-25 percent
Sample gas conditioner	Refrigerant dry-condenser	Hankinson	E-4G-SS	10 scfm
Data Logger	Electronic	Acurex	Audodata 9	99 channels
Strip chart recorder	Dual pen analog	Linear	400	1-10 mV 1-100 mV 0-1 V 0-10 V

[a]Two analyzers used for simultaneous inlet and outlet sampling

A.2 TRACE ELEMENTS AND ORGANIC EMISSIONS

Emissions of inorganic trace elements and organic compounds were sampled using the source assessment sampling system (SASS). Designed for Level 1 environmental assessment (Reference A-1), the SASS collects large quantities of gas and solid samples required for subsequent analyses of inorganic and organic emissions.

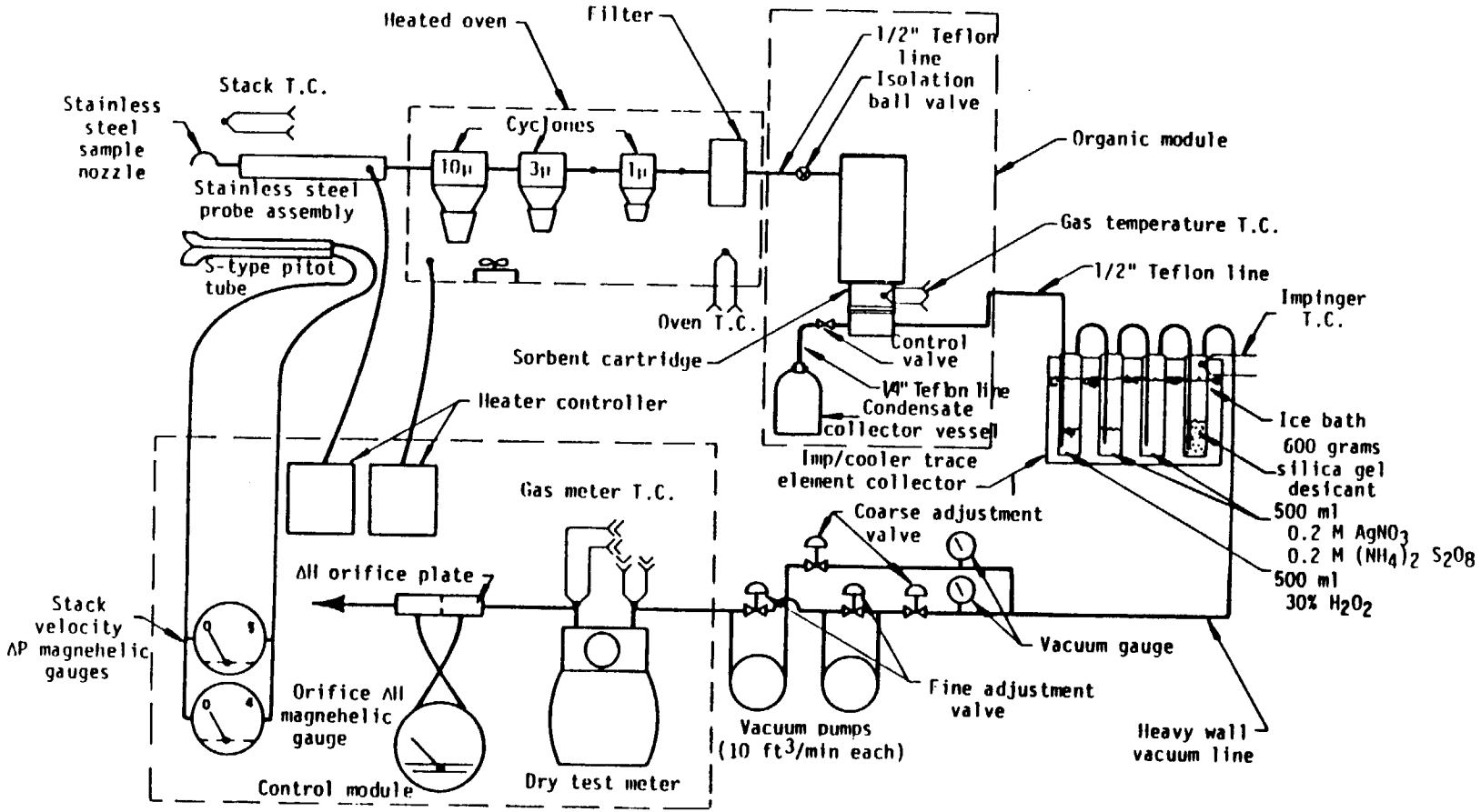
The SASS, illustrated in Figure A-2, is generally similar to the system utilized for total particulate mass emission tests (a high volume Method 5 train) with the exception of:

- The addition of a gas cooler and organic sampling module
- The addition of necessary vacuum pumps to allow a sampling rate of 2 l/s (4 cfm)

Particulate cyclones shown in Figure A-2 were not used for these tests because of low particulate loading in the flue gas.

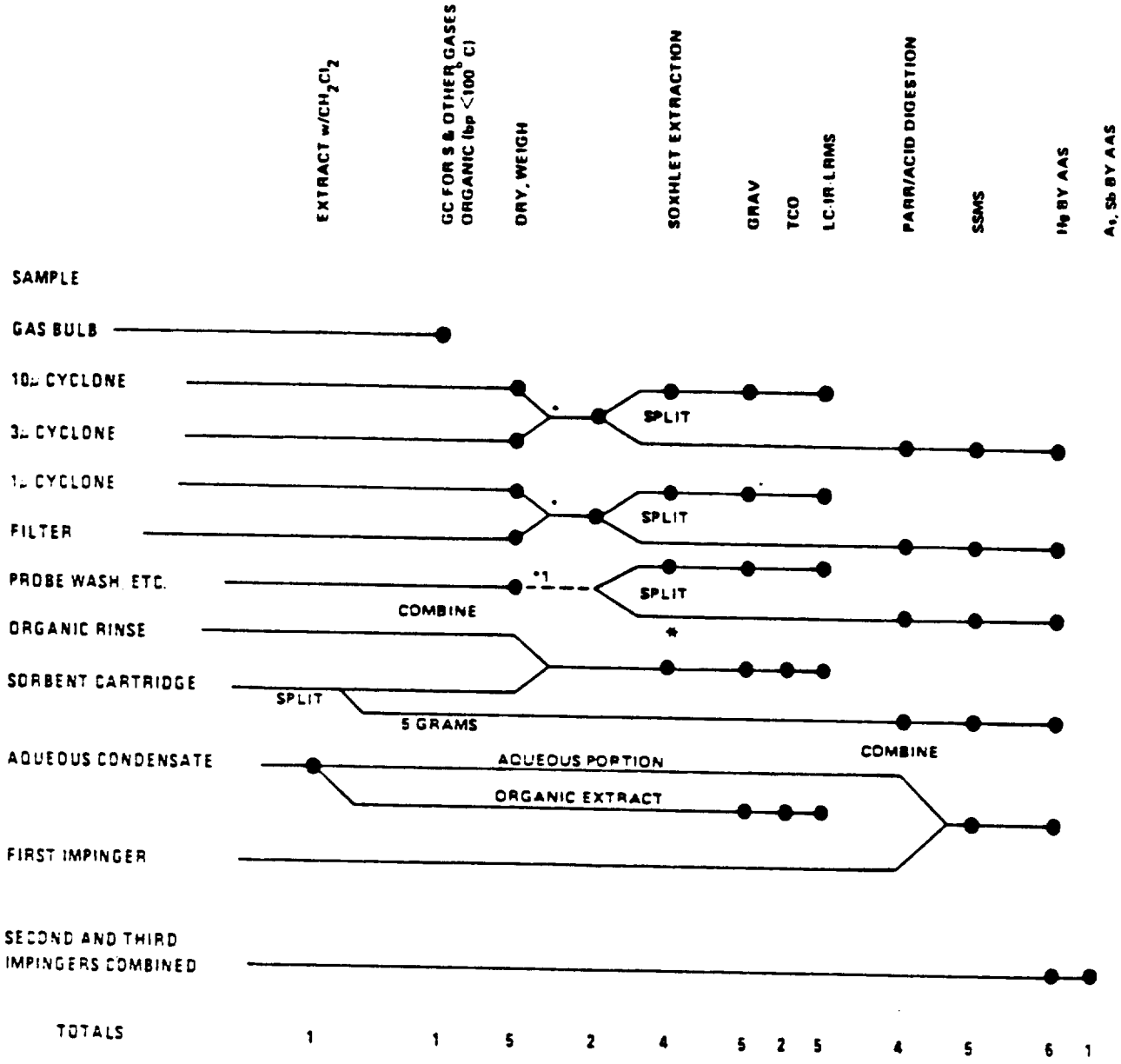
Schematics outlining the standard sampling and analytical procedures using the SASS equipment are presented in Figures A-3 and A-4. The following paragraphs briefly describe analytical procedures used in measuring trace elements and organic emissions.

Inorganic analyses of samples from the SASS train were performed by spark source mass spectroscopy (SSMS) for most of the trace elements. Atomic absorption spectrometry (AAS) was used for analyses of volatile mercury (Hg), antimony (Sb), and arsenic (As). Confirmatory analyses for selected metals were performed using flame atomic absorption spectrophotometry. Phosphorus was determined colorimetrically and sulfur was determined turbidimetrically in samples needing confirmatory analyses.



Note: T.C. = Thermocouple

Figure A-2. Source assessment sampling train schematic.



* If required sample should be set aside for biological analysis at this point.

[1] This step is required to define the total mass of particulate catch. If the sample exceeds 10% of the total cyclone and filter sample weight proceed to analysis. If the sample is less than 10% of the catch, hold in reserve.

Figure A-3. Flue gas analysis protocol for SASS samples.

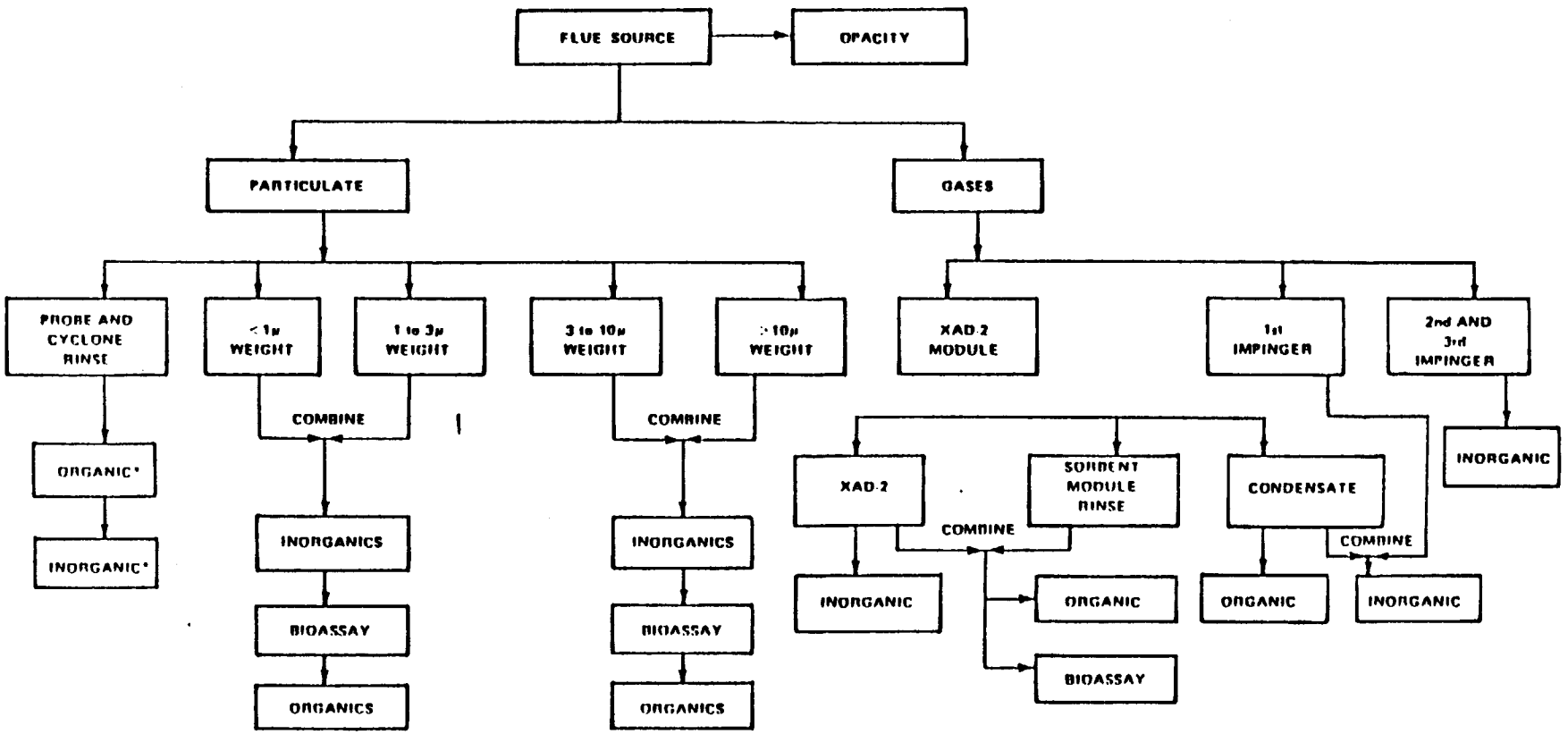


Figure A-4. Flue gas sample analysis protocol.

Quantitative information on total organic emissions was obtained by gas chromatography/flame ionization detector for total chromatographable organics (TCO) and by gravimetry (GRAV) of sample extracts. Infrared spectroscopy (IR) and gas chromatography/mass spectroscopy (GC/MS) were used for identification of organic functional groups and for determining polycyclic organic matter (POM) and other organic species concentrations (the semivolatile organic priority pollutants) in extract samples. Figure A-5 illustrates the organic analysis methodology used.

Passivation of the SASS train with 15 percent by volume HNO_3 solution was performed prior to equipment preparation and sampling to produce biologically inert surfaces. Detailed descriptions of equipment preparation, sampling procedures, and sample recovery are discussed in Reference A-1 and will not be repeated here.

A.3 NH_3 AND HCN SAMPLING AND ANALYSES

NH_3 and HCN were measured at the inlet and outlet locations of the catalytic converter utilizing two separate sampling trains. Both trains were similar to an EPA Method 6 train except that impinger solutions for NH_3 absorption were acid based (HCl) and for HCN were caustic based (NaOH). Concentrations of NH_3 and HCN in solutions were determined in the laboratory using approved wet chemical methods (Reference A-2).

A.4 N_2O SAMPLING AND ANALYSES

The stack gas grab samples were extracted into stainless steel cylinders for laboratory analysis for N_2O using a sampling train illustrated in Figure A-6. For analysis each sample cylinder was externally heated to 120°C (250°F), then a 1-ml sample was withdrawn with a gas-tight syringe for injection into the gas chromatograph (GC) equipped with an electron capture

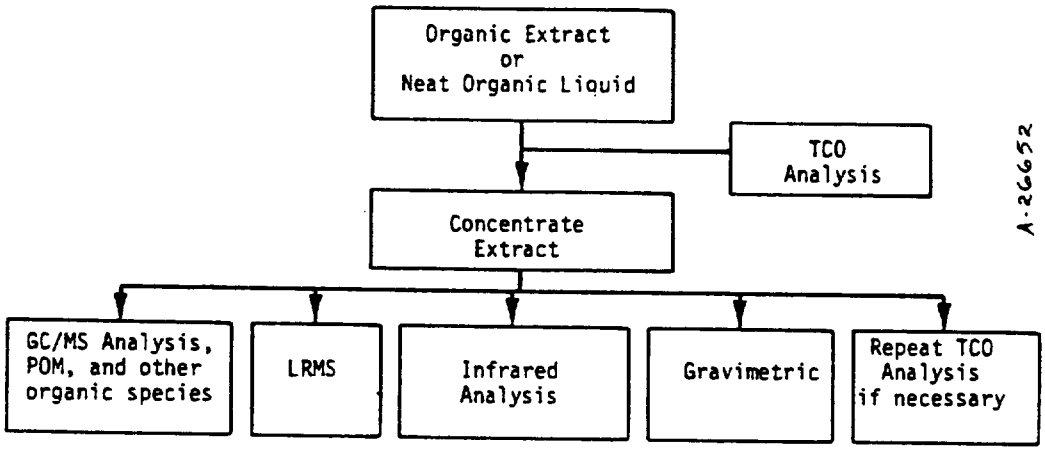


Figure A-5. Organic analysis methodology.

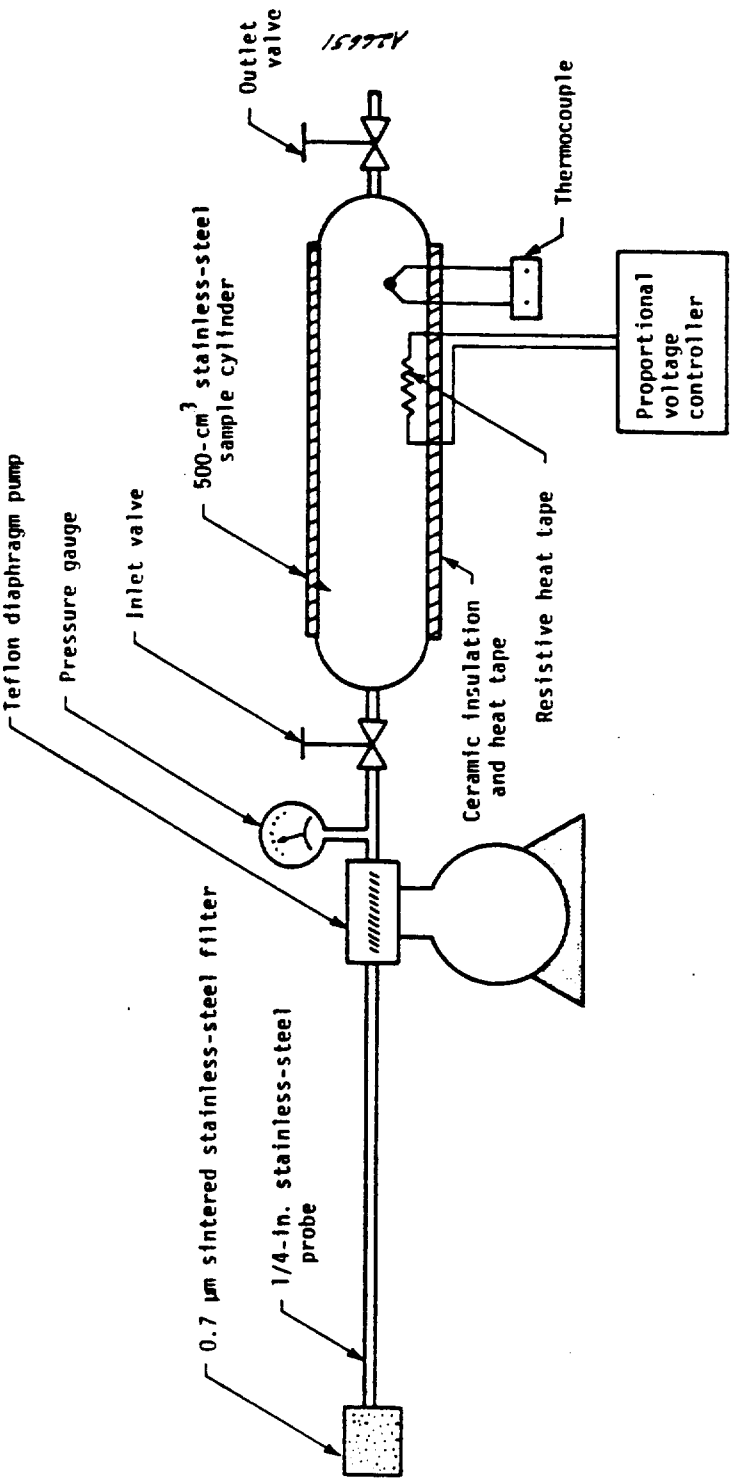


Figure A-6. N_2O sampling system.

detector (ECD). The GC column used was a 10 ft x 1/8 in. stainless steel column packed with 80/100 mesh chromosorb 101. The flow of nitrogen was 20 ml/min with the column kept at 45°C. Elution time for N_2O was approximately 5 min.

A.5 NO_x SAMPLING AND ANALYSES

Certification of the continuous NO_x monitor was performed using the standard EPA Method 7 equipment and protocols.

REFERENCES FOR APPENDIX A

A-1. Lentzen, D. E., et al., "IERL-RTP Procedures Manual: Level 1 Environmental Assessment (Second Edition)," EPA-600/7-78-201, NTIS PB293795, October 1978.

A-2. "Methods for Chemical Analysis of Water and Wastes," EPA-600/4-79-020, NTIS PB 297 686, March 1979.

APPENDIX B

TRACE ELEMENT CONCENTRATIONS

The following tables present sample trace element analysis results and trace element discharge stream concentrations. The tables labeled "ppm" represent element analysis results (µg/g or µg/ml) for each sample analyzed. The composition of lube oil and all catalyst inlet and outlet SASS train samples (filter, XAD-2, first impinger, and second and third impinger) are noted.

The tables labeled "concentration" give the calculated flue gas concentration (µg/dscm) of each element corresponding to each SASS train catalyst sample, and the SASS train sum (labeled "catalyst inlet" and "stack outlet," respectively).

Symbols appearing in the tables are:

- dscm Dry standard cubic meter at 1 atm and 20°C
- MCG Microgram
- ppm parts per million by weight
- < Less than
- > Greater than
- N Element not analyzed

Trace element concentrations less than the detectable limit or having a blank value greater than the sample value were given an arbitrary concentration of zero.

Detectability limits for the various SASS and liquid samples were the following:

- Filter -- <0.1 µg/g
- XAD-2 -- <0.1 µg/g
- Impinger and organic module concentrate -- <0.1 µg/ml
- Lube oil -- <0.1 µg/ml

The data inputs to a computer code for calculation of trace element flowrates were the following:

- Inlet Location
  - -- Gas volume sampled by SASS = 27.3 dscm
  - -- Calculated exhaust gas flowrate = 0.362 dscm/s
  - -- Weight of final filter = 1.0264g
  - -- Filter tare weight = 0.9897g
  - -- Weight of XAD-2 = 130g
  - -- SASS impinger 1 final volume = 1,725 ml
  - -- Organic condensate final volume = 1,900 ml
  - -- SASS impinger 2 and 3 final volume = 1,735 ml
- Outlet Location
  - -- Gas volume sampled by SASS = 26.5 dscm
  - -- Calculated exhaust gas flowrate = 0.366 dscm/s
  - -- Weight of final filter = 1.0326g
  - -- Filter tare weight i= 0.9950g
  - -- Weight of XAD-2 = 130g
  - -- SASS impinger 1 final volume = 1,425 ml
  - -- Organic condensate final volume = 1,515 ml
  - -- SASS impinger 2 and 3 final volume = 2,600 ml

- Engine Parameters
  - -- Total heat input rate = 1.73 MW
  - -- Lube oil consumption rate = 0.093 ml/s

PPM LUBE OIL

HONOR RANCHO ENGINE
NAT. GAS BASELINE
PPM

ELEMENT	LUBE OIL
ALUMINUM	.500E+01
ANTIMONY	.000E+00
ARSENIC	.000E+00
BARIUM	.970E+03
BERYLLIUM	.000E+00
BISMUTH	.200E+00
BORON	.100E+00
BROMINE	.000E+00
CADMIUM	.000E+00
CALCIUM	.334E+03
CERIUM	.000E+00
CESIUM	.000E+00
CHLORINE	.100E+02
CHROMIUM	<.200E+00
COBALT	<.200E+00
COPPER	.100E+01
FLUORINE	.500E+01
GALLIUM	.000E+00
GERMANIUM	.000E+00
HAFNIUM	.000E+00
IODINE	.200E+00
IRON	.500E+01
LANTHANUM	.000E+00
LEAD	.200E+00
LITHIUM	.300E+00
MAGNESIUM	.400E+01
MANGANESE	.100E+01
MERCURY	.620E-01
MOLYBDENUM	.100E+01
NEODYMIUM	.000E+00
NICKEL	.200E+01
NIOBIUM	.000E+00
PALLADIUM	.000E+00
PHOSPHORUS	.620E+03
POTASSIUM	.200E+02
PRASEODYMIUM	.000E+00
RHODIUM	.000E+00
RUBIDIUM	.000E+00
RUTHENIUM	.000E+00
SAMARIUM	.000E+00
SCANDIUM	<.100E+00
SELENIUM	.200E+01
SILICON	.300E+02
SILVER	.000E+00
SODIUM	.300E+02

PPM LUBE OIL

HONOR RANCHO ENGINE
NAT. GAS BASELINE
PPM

ELEMENT	LUBE OIL
STRONTIUM	.100E+02
SULFUR	.420E+04
TANTALUM	.000E+00
TELLURIUM	.000E+00
THORIUM	.000E+00
TIN	.000E+00
TITANIUM	<.200E+00
TUNGSTEN	.000E+00
URANIUM	.000E+00
VANADIUM	.200E+00
YTTRIUM	.000E+00
ZINC	.260E+03
ZIRCONIUM	.500E+00

HONOR RANCHO ENGINE
NAT. GAS BASELINE

PPM INLET

PPM

ELEMENT	FILTER	XAD	IMPINGER 1	IMPINGER 2+3
ALUMINUM	.438E+03	.000E+00	.000E+00	.000E+00
ANTIMONY	.171E+00	.000E+00	.000E+00	.000E+00
ARSENIC	.433E+01	.000E+00	.000E+00	.000E+00
BARIUM	.130E+04	.000E+00	.000E+00	.000E+00
BERYLLIUM	<.434E-03	.000E+00	.000E+00	.000E+00
BISMUTH	.700E-01	.000E+00	.000E+00	.000E+00
BORON	U.000E+00	.000E+00	.000E+00	.000E+00
BROMINE	.104E+01	.000E+00	.000E+00	.000E+00
CADMIUM	.317E-01	.000E+00	.000E+00	.000E+00
CALCIUM	.177E+04	.800E+02	.000E+00	.000E+00
CERIUM	.235E+00	.160E+01	.200E-02	.000E+00
CESIUM	.100E-01	.000E+00	.000E+00	.000E+00
CHLORINE	>.100E+03	.000E+00	.000E+00	.000E+00
CHROMIUM	.176E+02	.000E+00	.000E+00	.000E+00
COBALT	.213E+02	.290E+01	.000E+00	.000E+00
COPPER	.562E+01	.200E+01	.400E-01	.000E+00
FLUORINE	>.560E+02	.000E+00	.000E+00	.000E+00
GALLIUM	.617E+00	.100E+00	.000E+00	.000E+00
GERMANIUM	.404E-01	.000E+00	.000E+00	.000E+00
HAFNIUM	.200E+00	.000E+00	.000E+00	.000E+00
IODINE	.113E+00	.000E+00	.600E-02	.000E+00
IRON	.104E+04	.000E+00	.000E+00	.000E+00
LANTHANUM	.426E+00	.250E+01	.600E-02	.100E+01
LEAD	.381E+01	.000E+00	.000E+00	.000E+00
LITHIUM	.000E+00	.100E+00	.200E-02	.000E+00
MAGNESIUM	.264E+03	.000E+00	.120E+00	.000E+00
MANGANESE	.233E+01	.000E+00	.700E-02	.000E+00
MERCURY	.982E-01	.180E-01	.000E+00	.140E-02
MOLYBDENUM	.207E+02	.150E+01	.000E+00	.000E+00
NEODYMIUM	.330E-01	.000E+00	.000E+00	.000E+00
NICKEL	.210E+02	.000E+00	.000E+00	.000E+00
NIOBIUM	.330E+00	.000E+00	.300E-01	.000E+00
PALLADIUM	.700E-01	.000E+00	.000E+00	.000E+00
PHOSPHORUS	.134E+03	.000E+00	.000E+00	.000E+00
POTASSIUM	.000E+00	.310E+02	.200E+00	.000E+00
PRASEODYMIUM	.868E-02	.000E+00	.000E+00	.000E+00
RHODIUM	.800E+00	.000E+00	.000E+00	.000E+00
RUBIDIUM	.322E-01	.000E+00	.000E+00	.000E+00
RUTHENIUM	<.100E-01	.000E+00	.000E+00	.000E+00
SAMARIUM	.000E+00	.000E+00	.000E+00	.000E+00
SCANDIUM	.000E+00	.000E+00	.000E+00	.000E+00
SELENIUM	.613E+00	.000E+00	.000E+00	.000E+00
SILICON	.323E+04	.100E+02	.300E+01	.000E+00
SILVER	.394E+01	.000E+00	.100E-01	.000E+00
SODIUM	.281E+01	.100E+02	.113E+04	.000E+00

PPM INLET

HONOR RANCHO ENGINE
NAT. GAS BASELINE
PPM

ELEMENT	FILTER	XAD	IMPINGER 1	IMPINGER 2+3
STRONTIUM	.542E+02	.100E+00	.100E-02	.000E+00
SULFUR	.126E+03	.100E+02	.170E+04	.000E+00
TANTALUM	.000E+00	.000E+00	.000E+00	.000E+00
TELLURIUM	.109E-01	.000E+00	.000E+00	.000E+00
THORIUM	.304E+00	.000E+00	.000E+00	.000E+00
TIN	.304E+00	.000E+00	<.100E-02	.000E+00
TITANIUM	U.000E+00	.000E+00	.000E+00	.000E+00
TUNGSTEN	.900E+01	.000E+00	.980E+00	.000E+00
URANIUM	.214E+00	.000E+00	.000E+00	.000E+00
VANADIUM	.204E+01	.000E+00	.000E+00	.000E+00
YTTRIUM	.109E+00	.000E+00	.000E+00	.000E+00
ZINC	.290E+03	.000E+00	.100E+00	.000E+00
ZIRCONIUM	.000E+00	.000E+00	.000E+00	.000E+00

HONOR RANCHO ENGINE
NAT. GAS BASELINE

PPM OUTLET

PPM

ELEMENT	FILTER	XAD	IMPINGER 1	IMPINGER 2+3
ALUMINUM	.508E+02	.000E+00	.400E-01	.000E+00
ANTIMONY	.371E+00	.000E+00	<.500E-02	.000E+00
ARSENIC	.173E+02	.000E+00	.000E+00	.000E+00
BARIUM	.159E+04	.000E+00	.200E-01	.000E+00
BERYLLIUM	<.331E-03	.000E+00	<.100E-02	.000E+00
BISMUTH	.300E+00	.000E+00	.000E+00	.000E+00
BORON	U.000E+00	.000E+00	.000E+00	.000E+00
BROMINE	.403E+01	.000E+00	.200E-01	.000E+00
CADMIUM	.000E+00	.000E+00	.000E+00	.000E+00
CALCIUM	.116E+04	.000E+00	.100E+01	.000E+00
CERIUM	.123E+01	.100E+00	.000E+00	.000E+00
CESIUM	<.100E-01	.000E+00	.400E-01	.000E+00
CHLORINE	>.100E+03	.000E+00	<.270E+01	.000E+00
CHROMIUM	.301E+02	.157E+03	.100E+00	.000E+00
COBALT	.290E+02	.900E+00	.700E-02	.000E+00
COPPER	.396E+02	.800E+01	>.998E+01	.000E+00
FLUORINE	>.555E+02	.150E+02	.231E+01	.000E+00
GALLIUM	.613E+00	.000E+00	.460E-01	.000E+00
GERMANIUM	.603E-01	.000E+00	.000E+00	.000E+00
HAFNIUM	.300E+00	.000E+00	.000E+00	.000E+00
IODINE	.171E+01	.000E+00	.000E+00	.000E+00
IRON	.221E+03	.750E+02	.300E+00	.000E+00
LANTHANUM	.000E+00	.000E+00	<.500E-02	.000E+00
LEAD	.108E+02	.000E+00	.000E+00	.000E+00
LITHIUM	.426E+00	.100E+00	.000E+00	.000E+00
MAGNESIUM	.116E+03	.100E+02	.920E+00	.000E+00
MANGANESE	.632E+01	.480E+01	.770E-01	.000E+00
MERCURY	.113E+00	.160E-01	.150E-03	.000E+00
MOLYBDENUM	.671E+01	.500E+00	.000E+00	.000E+00
NEODYMIUM	.332E+00	.000E+00	.000E+00	.000E+00
NICKEL	.240E+02	.135E+03	.193E+00	.000E+00
NIOBIUM	.323E+00	.000E+00	.400E-02	.000E+00
PALLADIUM	.400E+00	.000E+00	.000E+00	.000E+00
PHOSPHORUS	.143E+03	.500E+01	.000E+00	.000E+00
POTASSIUM	.000E+00	.110E+02	.270E+01	.000E+00
PRASEODYMIUM	.662E-02	.000E+00	.000E+00	.000E+00
RHODIUM	.300E+00	.000E+00	.000E+00	.000E+00
RUBIDIUM	.517E-01	.000E+00	.100E-01	.000E+00
RUTHENIUM	<.300E-01	.000E+00	.000E+00	.000E+00
SAMARIUM	.000E+00	.000E+00	.000E+00	.000E+00
SCANDIUM	.510E+00	.000E+00	.500E-02	.000E+00
SELENIUM	.710E+00	.300E+00	.000E+00	.000E+00
SILICON	.126E+04	.270E+03	.000E+00	.000E+00
SILVER	.194E+01	.000E+00	.194E+01	.000E+00
SODIUM	.000E+00	.100E+02	.146E+04	.000E+00

PPM OUTLET

HONOR RANCHO ENGINE
NAT. GAS BASELINE
PPM

ELEMENT	FILTER	XAD	IMPINGER 1	IMPINGER 2+3
STRONTIUM	.482E+02	.100E+00	.280E-01	.000E+00
SULFUR	.214E+03	.000E+00	.680E+04	.000E+00
TANTALUM	.100E+00	.000E+00	.100E+00	.000E+00
TELLURIUM	.662E-03	.000E+00	.300E-02	.000E+00
THORIUM	.503E+00	.000E+00	.000E+00	.000E+00
TIN	.903E+00	.000E+00	.000E+00	.000E+00
TITANIUM	U.000E+00	.000E+00	.100E+00	.000E+00
TUNGSTEN	.700E+01	.000E+00	.600E-01	.000E+00
URANIUM	.113E+00	.000E+00	.000E+00	.000E+00
VANADIUM	.303E+01	.200E+00	.000E+00	.000E+00
YTTRIUM	.207E+00	.000E+00	.100E-02	.000E+00
ZINC	.327E+03	.300E+01	.390E+01	.000E+00
ZIRCONIUM	.298E+00	.600E+00	.000E+00	.000E+00

HONOR RANCHO ENGINE
NAT. GAS BASELINE

CONCENTRATION MCG/DSCM

ELEMENT	CATALYST INLET	FILTER	XAD	IMPINGER 1	IMPINGER 2+3
ALUMINUM	.165E+02	.165E+02	.000E+00	.000E+00	.000E+00
ANTIMONY	.644E-02	.644E-02	.000E+00	.000E+00	.000E+00
ARSENIC	.163E+00	.163E+00	.000E+00	.000E+00	.000E+00
BARIUM	.490E+02	.490E+02	.000E+00	.000E+00	.000E+00
BERYLLIUM	< .163E-04	< .163E-04	.000E+00	.000E+00	.000E+00
BISMUTH	.263E-02	.263E-02	.000E+00	.000E+00	.000E+00
BORON	.000E+00	U .000E+00	.000E+00	.000E+00	.000E+00
BROMINE	.392E-01	.392E-01	.000E+00	.000E+00	.000E+00
CADMIUM	.119E-02	.119E-02	.000E+00	.000E+00	.000E+00
CALCIUM	.448E+03	.666E+02	.381E+03	.000E+00	.000E+00
CERIUM	.789E+01	.882E-02	.762E+01	.266E+00	.000E+00
CESIUM	.376E-03	.376E-03	.000E+00	.000E+00	.000E+00
CHLORINE	> .000E+00	> .376E+01	.000E+00	.000E+00	.000E+00
CHROMIUM	.661E+00	.661E+00	.000E+00	.000E+00	.000E+00
COBALT	.146E+02	.801E+00	.138E+02	.000E+00	.000E+00
COPPER	.151E+02	.211E+00	.952E+01	.532E+01	.000E+00
FLUORINE	> .000E+00	> .211E+01	.000E+00	.000E+00	.000E+00
GALLIUM	.499E+00	.232E-01	.476E+00	.000E+00	.000E+00
GERMANIUM	.152E-02	.152E-02	.000E+00	.000E+00	.000E+00
HAFNIUM	.752E-02	.752E-02	.000E+00	.000E+00	.000E+00
IODINE	.803E+00	.425E-02	.000E+00	.798E+00	.000E+00
IRON	.392E+02	.392E+02	.000E+00	.000E+00	.000E+00
LANTHANUM	.763E+02	.160E-01	.119E+02	.798E+00	.636E+02
LEAD	.143E+00	.143E+00	.000E+00	.000E+00	.000E+00
LITHIUM	.742E+00	.000E+00	.476E+00	.266E+00	.000E+00
MAGNESIUM	.259E+02	.994E+01	.000E+00	.160E+02	.000E+00
MANGANESE	.102E+01	.876E-01	.000E+00	.932E+00	.000E+00
MERCURY	.178E+00	.369E-02	.857E-01	.000E+00	.890E-01
MOLYBDENUM	.792E+01	.779E+00	.714E+01	.000E+00	.000E+00
NEODYMIUM	.124E-02	.124E-02	.000E+00	.000E+00	.000E+00
NICKEL	.788E+00	.788E+00	.000E+00	.000E+00	.000E+00
NIOBIUM	.400E+01	.124E-01	.000E+00	.399E+01	.000E+00
PALLADIUM	.263E-02	.263E-02	.000E+00	.000E+00	.000E+00
PHOSPHORUS	.504E+01	.504E+01	.000E+00	.000E+00	.000E+00
POTASSIUM	.174E+03	.000E+00	.148E+03	.266E+02	.000E+00
PRASEODYMIUM	.326E-03	.326E-03	.000E+00	.000E+00	.000E+00
RHODIUM	.301E-01	.301E-01	.000E+00	.000E+00	.000E+00
RUBIDIUM	.121E-02	.121E-02	.000E+00	.000E+00	.000E+00
RUTHENIUM	< .376E-03	< .376E-03	.000E+00	.000E+00	.000E+00
SAMARIUM	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
SCANDIUM	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
SELENIUM	.230E-01	.230E-01	.000E+00	.000E+00	.000E+00
SILICON	.568E+03	.122E+03	.476E+02	.399E+03	.000E+00
SILVER	.148E+01	.148E+00	.000E+00	.133E+01	.000E+00
SODIUM	.150E+06	.106E+00	.476E+02	.150E+06	.000E+00

CONCENTRATION

HONOR RANCHO ENGINE
NAT. GAS BASELINE
MCG/DSCM

ELEMENT	CATALYST INLET		FILTER	XAD	IMPINGER 1	IMPINGER 2+3
STRONTIUM	.265E+01		.204E+01	.476E+00	.133E+00	.000E+00
SULFUR	.226E+06		.473E+01	.476E+02	.226E+06	.000E+00
TANTALUM	.000E+00		.000E+00	.000E+00	.000E+00	.000E+00
TELLURIUM	.409E-03		.409E-03	.000E+00	.000E+00	.000E+00
THORIUM	.114E-01		.114E-01	.000E+00	.000E+00	.000E+00
TIN	<X<.145E+00		.114E-01	.000E+00	< .133E+00	.000E+00
TITANIUM	.000E+00	U	.000E+00	.000E+00	.000E+00	.000E+00
TUNGSTEN	.131E+03		.338E+00	.000E+00	.130E+03	.000E+00
URANIUM	.804E-02		.804E-02	.000E+00	.000E+00	.000E+00
VANADIUM	.768E-01		.768E-01	.000E+00	.000E+00	.000E+00
YTTRIUM	.409E-02		.409E-02	.000E+00	.000E+00	.000E+00
ZINC	.242E+02		.109E+02	.000E+00	.133E+02	.000E+00
ZIRCONIUM	.000E+00		.000E+00	.000E+00	.000E+00	.000E+00

HONOR RANCHO ENGINE
NAT. GAS BASELINE

CONCENTRATION MCG/DSCM ELEMENT	CATALYST OUTLET	FILTER	XAD	IMPINGER 1	IMPINGER 2+3
ALUMINUM	.645E+01	.198E+01	.000E+00	.447E+01	.000E+00
ANTIMONY	<X<.573E+00	.145E-01	.000E+00	< .558E+00	.000E+00
ARSENIC	.675E+00	.675E+00	.000E+00	.000E+00	.000E+00
BARIUM	.640E+02	.618E+02	.000E+00	.223E+01	.000E+00
BERYLLIUM	< .112E+00	< .129E-04	.000E+00	< .112E+00	.000E+00
BISMUTH	.117E-01	.117E-01	.000E+00	.000E+00	.000E+00
BORON	.000E+00	U .000E+00	.000E+00	.000E+00	.000E+00
BROMINE	.239E+01	.157E+00	.000E+00	.223E+01	.000E+00
CADMIUM	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
CALCIUM	.157E+03	.453E+02	.000E+00	.112E+03	.000E+00
CERIUM	.538E+00	.478E-01	.491E+00	.000E+00	.000E+00
CESIUM	.447E+01	< .390E-03	.000E+00	.447E+01	.000E+00
CHLORINE	> .000E+00	> .390E+01	.000E+00	< .302E+03	.000E+00
CHROMIUM	.783E+03	.117E+01	.770E+03	.112E+02	.000E+00
COBALT	.633E+01	.113E+01	.442E+01	.782E+00	.000E+00
COPPER	> .000E+00	.154E+01	.392E+02	> .111E+04	.000E+00
FLUORINE	> .000E+00	> .216E+01	.736E+02	.258E+03	.000E+00
GALLIUM	.516E+01	.239E-01	.000E+00	.514E+01	.000E+00
GERMANIUM	.235E-02	.235E-02	.000E+00	.000E+00	.000E+00
HAFNIUM	.117E-01	.117E-01	.000E+00	.000E+00	.000E+00
IODINE	.666E-01	.666E-01	.000E+00	.000E+00	.000E+00
IRON	.410E+03	.861E+01	.368E+03	.335E+02	.000E+00
LANTHANUM	< .558E+00	.000E+00	.000E+00	< .558E+00	.000E+00
LEAD	.421E+00	.421E+00	.000E+00	.000E+00	.000E+00
LITHIUM	.507E+00	.166E-01	.491E+00	.000E+00	.000E+00
MAGNESIUM	.156E+03	.453E+01	.491E+02	.103E+03	.000E+00
MANGANESE	.324E+02	.246E+00	.235E+02	.860E+01	.000E+00
MERCURY	.996E-01	.440E-02	.785E-01	.168E-01	.000E+00
MOLYBDENUM	.271E+01	.261E+00	.245E+01	.000E+00	.000E+00
NEODYMIUM	.129E-01	.129E-01	.000E+00	.000E+00	.000E+00
NICKEL	.685E+03	.933E+00	.662E+03	.216E+02	.000E+00
NIOBIUM	.459E+00	.126E-01	.000E+00	.447E+00	.000E+00
PALLADIUM	.156E-01	.156E-01	.000E+00	.000E+00	.000E+00
PHOSPHORUS	.301E+02	.556E+01	.245E+02	.000E+00	.000E+00
POTASSIUM	.356E+03	.000E+00	.540E+02	.302E+03	.000E+00
PRASEODYMIUM	.258E-03	.258E-03	.000E+00	.000E+00	.000E+00
RHODIUM	.117E-01	.117E-01	.000E+00	.000E+00	.000E+00
RUBIDIUM	.112E+01	.201E-02	.000E+00	.112E+01	.000E+00
RUTHENIUM	< .117E-02	< .117E-02	.000E+00	.000E+00	.000E+00
SAMARIUM	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
SCANDIUM	.578E+00	.199E-01	.000E+00	.558E+00	.000E+00
SELENIUM	.150E+01	.277E-01	.147E+01	.000E+00	.000E+00
SILICON	.137E+04	.491E+02	.132E+04	.000E+00	.000E+00
SILVER	.217E+03	.757E-01	.000E+00	.217E+03	.000E+00
SODIUM	.163E+06	.000E+00	.491E+02	.163E+06	.000E+00

HONOR RANCHO ENGINE
NAT. GAS BASELINE

CONCENTRATION ELEMENT	MCG/DSCM CATALYST OUTLET		FILTER	XAD	IMPINGER 1	IMPINGER 2+3
STRONTIUM	.549E+01		.188E+01	.491E+00	.313E+01	.000E+00
SULFUR	.760E+06		.832E+01	.000E+00	.760E+06	.000E+00
TANTALUM	.112E+02		.390E-02	.000E+00	.112E+02	.000E+00
TELLURIUM	.335E+00		.258E-04	.000E+00	.335E+00	.000E+00
THORIUM	.196E-01		.196E-01	.000E+00	.000E+00	.000E+00
TIN	.352E-01		.352E-01	.000E+00	.000E+00	.000E+00
TITANIUM	.112E+02	U	.000E+00	.000E+00	.112E+02	.000E+00
TUNGSTEN	.697E+01		.273E+00	.000E+00	.670E+01	.000E+00
URANIUM	.440E-02		.440E-02	.000E+00	.000E+00	.000E+00
VANADIUM	.110E+01		.118E+00	.981E+00	.000E+00	.000E+00
YTTRIUM	.120E+00		.805E-02	.000E+00	.112E+00	.000E+00
ZINC	.463E+03		.127E+02	.147E+02	.436E+03	.000E+00
ZIRCONIUM	.295E+01		.116E-01	.294E+01	.000E+00	.000E+00

MASS/HEAT INPUT

HONOR RANCHO ENGINE
NAT. GAS BASELINE
NG/J

ELEMENT	CATALYST INLET	FILTER	XAD	IMPINGER 1	IMPINGER 2+3
ALUMINUM	.377E-02	.377E-02	.000E+00	.000E+00	.000E+00
ANTIMONY	.147E-05	.147E-05	.000E+00	.000E+00	.000E+00
ARSENIC	.373E-04	.373E-04	.000E+00	.000E+00	.000E+00
BARIUM	.112E-01	.112E-01	.000E+00	.000E+00	.000E+00
BERYLLIUM	< .374E-08	< .374E-08	.000E+00	.000E+00	.000E+00
BISMUTH	.603E-06	.603E-06	.000E+00	.000E+00	.000E+00
BORON	.000E+00	U .000E+00	.000E+00	.000E+00	.000E+00
BROMINE	.898E-05	.898E-05	.000E+00	.000E+00	.000E+00
CADMIUM	.273E-06	.273E-06	.000E+00	.000E+00	.000E+00
CALCIUM	.102E+00	.152E-01	.872E-01	.000E+00	.000E+00
CERIUM	.181E-02	.202E-05	.174E-02	.609E-04	.000E+00
CESIUM	.861E-07	.861E-07	.000E+00	.000E+00	.000E+00
CHLORINE	> .000E+00	> .861E-03	.000E+00	.000E+00	.000E+00
CHROMIUM	.151E-03	.151E-03	.000E+00	.000E+00	.000E+00
COBALT	.334E-02	.183E-03	.316E-02	.000E+00	.000E+00
COPPER	.345E-02	.484E-04	.218E-02	.122E-02	.000E+00
FLUORINE	> .000E+00	> .482E-03	.000E+00	.000E+00	.000E+00
GALLIUM	.114E-03	.531E-05	.109E-03	.000E+00	.000E+00
GERMANIUM	.348E-06	.348E-06	.000E+00	.000E+00	.000E+00
HAFNIUM	.172E-05	.172E-05	.000E+00	.000E+00	.000E+00
IODINE	.184E-03	.973E-06	.000E+00	.183E-03	.000E+00
IRON	.896E-02	.896E-02	.000E+00	.000E+00	.000E+00
LANTHANUM	.175E-01	.367E-05	.273E-02	.183E-03	.145E-01
LEAD	.328E-04	.328E-04	.000E+00	.000E+00	.000E+00
LITHIUM	.170E-03	.000E+00	.109E-03	.609E-04	.000E+00
MAGNESIUM	.593E-02	.228E-02	.000E+00	.366E-02	.000E+00
MANGANESE	.233E-03	.201E-04	.000E+00	.213E-03	.000E+00
MERCURY	.408E-04	.845E-06	.196E-04	.000E+00	.204E-04
MOLYBDENUM	.181E-02	.178E-03	.164E-02	.000E+00	.000E+00
NEODYMIUM	.284E-06	.284E-06	.000E+00	.000E+00	.000E+00
NICKEL	.180E-03	.180E-03	.000E+00	.000E+00	.000E+00
NIOBIUM	.917E-03	.284E-05	.000E+00	.914E-03	.000E+00
PALLADIUM	.603E-06	.603E-06	.000E+00	.000E+00	.000E+00
PHOSPHORUS	.115E-02	.115E-02	.000E+00	.000E+00	.000E+00
POTASSIUM	.399E-01	.000E+00	.338E-01	.609E-02	.000E+00
PRASEODYMIUM	.747E-07	.747E-07	.000E+00	.000E+00	.000E+00
RHODIUM	.689E-05	.689E-05	.000E+00	.000E+00	.000E+00
RUBIDIUM	.277E-06	.277E-06	.000E+00	.000E+00	.000E+00
RUTHENIUM	< .861E-07	< .861E-07	.000E+00	.000E+00	.000E+00
SAMARIUM	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
SCANDIUM	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
SELENIUM	.528E-05	.528E-05	.000E+00	.000E+00	.000E+00
SILICON	.130E+00	.278E-01	.109E-01	.914E-01	.000E+00
SILVER	.339E-03	.339E-04	.000E+00	.305E-03	.000E+00
SODIUM	.344E+02	.242E-04	.109E-01	.344E+02	.000E+00

MASS/HEAT INPUT

HONOR RANCHO ENGINE
NAT. GAS BASELINE
NG/J

ELEMENT	CATALYST INLET		FILTER	XAD	IMPINGER 1	IMPINGER 2+3
STRONTIUM	.606E-03		.467E-03	.109E-03	.305E-04	.000E+00
SULFUR	.518E+02		.108E-02	.109E-01	.518E+02	.000E+00
TANTALUM	.000E+00		.000E+00	.000E+00	.000E+00	.000E+00
TELLURIUM	.935E-07		.935E-07	.000E+00	.000E+00	.000E+00
THORIUM	.262E-05		.262E-05	.000E+00	.000E+00	.000E+00
TIN	<X<.331E-04		.262E-05	.000E+00	< .305E-04	.000E+00
TITANIUM	.000E+00	U	.000E+00	.000E+00	.000E+00	.000E+00
TUNGSTEN	.299E-01		.775E-04	.000E+00	.299E-01	.000E+00
URANIUM	.184E-05		.184E-05	.000E+00	.000E+00	.000E+00
VANADIUM	.176E-04		.176E-04	.000E+00	.000E+00	.000E+00
YTTRIUM	.935E-06		.935E-06	.000E+00	.000E+00	.000E+00
ZINC	.554E-02		.250E-02	.000E+00	.305E-02	.000E+00
ZIRCONIUM	.000E+00		.000E+00	.000E+00	.000E+00	.000E+00

MASS/HEAT INPUT

HONOR RANCHO ENGINE
NAT. GAS BASELINE
NG/J

ELEMENT	CATALYST OUTLET	FILTER	XAD	IMPINGER 1	IMPINGER 2+3
ALUMINUM	.138E-02	.423E-03	.000E+00	.955E-03	.000E+00
ANTIMONY	<X<.122E-03	.309E-05	.000E+00	< .119E-03	.000E+00
ARSENIC	.144E-03	.144E-03	.000E+00	.000E+00	.000E+00
BARIUM	.137E-01	.132E-01	.000E+00	.478E-03	.000E+00
BERYLLIUM	< .239E-04	< .276E-08	.000E+00	< .239E-04	.000E+00
BISMUTH	.250E-05	.250E-05	.000E+00	.000E+00	.000E+00
BORON	.000E+00	U .000E+00	.000E+00	.000E+00	.000E+00
BROMINE	.511E-03	.336E-04	.000E+00	.478E-03	.000E+00
CADMIUM	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
CALCIUM	.336E-01	.969E-02	.000E+00	.239E-01	.000E+00
CERIUM	.115E-03	.102E-04	.105E-03	.000E+00	.000E+00
CESIUM	.955E-03	< .833E-07	.000E+00	.955E-03	.000E+00
CHLORINE	> .000E+00	> .833E-03	.000E+00	< .645E-01	.000E+00
CHROMIUM	.167E+00	.250E-03	.165E+00	.239E-02	.000E+00
COBALT	.135E-02	.242E-03	.944E-03	.167E-03	.000E+00
COPPER	> .000E+00	.330E-03	.839E-02	> .238E+00	.000E+00
FLUORINE	> .000E+00	> .462E-03	.157E-01	.552E-01	.000E+00
GALLIUM	.110E-02	.511E-05	.000E+00	.110E-02	.000E+00
GERMANIUM	.502E-06	.502E-06	.000E+00	.000E+00	.000E+00
HAFNIUM	.250E-05	.250E-05	.000E+00	.000E+00	.000E+00
IODINE	.142E-04	.142E-04	.000E+00	.000E+00	.000E+00
IRON	.876E-01	.184E-02	.786E-01	.716E-02	.000E+00
LANTHANUM	< .119E-03	.000E+00	.000E+00	< .119E-03	.000E+00
LEAD	.900E-04	.900E-04	.000E+00	.000E+00	.000E+00
LITHIUM	.108E-03	.355E-05	.105E-03	.000E+00	.000E+00
MAGNESIUM	.334E-01	.969E-03	.105E-01	.220E-01	.000E+00
MANGANESE	.692E-02	.527E-04	.503E-02	.184E-02	.000E+00
MERCURY	.213E-04	.941E-06	.168E-04	.358E-05	.000E+00
MOLYBDENUM	.580E-03	.559E-04	.524E-03	.000E+00	.000E+00
NEODYMIUM	.277E-05	.277E-05	.000E+00	.000E+00	.000E+00
NICKEL	.146E+00	.199E-03	.142E+00	.461E-02	.000E+00
NIOBIUM	.982E-04	.269E-05	.000E+00	.955E-04	.000E+00
PALLADIUM	.333E-05	.333E-05	.000E+00	.000E+00	.000E+00
PHOSPHORUS	.643E-02	.119E-02	.524E-02	.000E+00	.000E+00
POTASSIUM	.760E-01	.000E+00	.115E-01	.645E-01	.000E+00
PRASEODYMIUM	.551E-07	.551E-07	.000E+00	.000E+00	.000E+00
RHODIUM	.250E-05	.250E-05	.000E+00	.000E+00	.000E+00
RUBIDIUM	.239E-03	.430E-06	.000E+00	.239E-03	.000E+00
RUTHENIUM	< .250E-06	< .250E-06	.000E+00	.000E+00	.000E+00
SAMARIUM	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
SCANDIUM	.124E-03	.425E-05	.000E+00	.119E-03	.000E+00
SELENIUM	.320E-03	.591E-05	.315E-03	.000E+00	.000E+00
SILICON	.294E+00	.105E-01	.283E+00	.000E+00	.000E+00
SILVER	.463E-01	.162E-04	.000E+00	.463E-01	.000E+00
SODIUM	.348E+02	.000E+00	.105E-01	.348E+02	.000E+00

MASS/HEAT INPUT

HONOR RANCHO ENGINE
NAT. GAS BASELINE
NG/J

ELEMENT	CATALYST OUTLET		FILTER	XAD	IMPINGER 1	IMPINGER 2+3
STRONTIUM	.117E-02		.401E-03	.105E-03	.669E-03	.000E+00
SULFUR	.162E+03		.178E-02	.000E+00	.162E+03	.000E+00
TANTALUM	.239E-02		.833E-06	.000E+00	.239E-02	.000E+00
TELLURIUM	.716E-04		.551E-08	.000E+00	.716E-04	.000E+00
THORIUM	.419E-05		.419E-05	.000E+00	.000E+00	.000E+00
TIN	.752E-05		.752E-05	.000E+00	.000E+00	.000E+00
TITANIUM	.239E-02	U	.000E+00	.000E+00	.239E-02	.000E+00
TUNGSTEN	.149E-02		.583E-04	.000E+00	.143E-02	.000E+00
URANIUM	.941E-06		.941E-06	.000E+00	.000E+00	.000E+00
VANADIUM	.235E-03		.253E-04	.210E-03	.000E+00	.000E+00
YTTRIUM	.256E-04		.172E-05	.000E+00	.239E-04	.000E+00
ZINC	.990E-01		.272E-02	.315E-02	.931E-01	.000E+00
ZIRCONIUM	.632E-03		.248E-05	.629E-03	.000E+00	.000E+00

HONOR RANCHO ENGINE
NAT. GAS BASELINE
MCG/SEC

MASS FLOW ELEMENT	LUBE OIL	CATALYST INLET	CATALYST OUTLET
ALUMINUM	.424E+00	.645E+01	.236E+01
ANTIMONY	.000E+00	.252E-02	.529E-02<X<.210E+00
ARSENIC	.000E+00	.638E-01	.247E+00
BARIUM	.824E+02	.192E+02	.234E+02
BERYLLIUM	.000E+00	< .640E-05	< .409E-01
BISMUTH	.170E-01	.103E-02	.428E-02
BORON	.849E-02	.000E+00	.000E+00
BROMINE	.000E+00	.154E-01	.875E+00
CADMIUM	.000E+00	.468E-03	.000E+00
CALCIUM	.284E+02	.175E+03	.575E+02
CERIUM	.000E+00	.309E+01	.197E+00
CESIUM	.000E+00	.147E-03	.164E+01
CHLORINE	.849E+00	> .147E+01	> .143E+01
CHROMIUM	< .170E-01	.259E+00	.286E+03
COBALT	< .170E-01	.573E+01	.232E+01
COPPER	.849E-01	.590E+01	> .423E+03
FLUORINE	.424E+00	> .825E+00	> .122E+03
GALLIUM	.000E+00	.196E+00	.189E+01
GERMANIUM	.000E+00	.596E-03	.860E-03
HAFNIUM	.000E+00	.295E-02	.428E-02
IODINE	.170E-01	.315E+00	.244E-01
IRON	.424E+00	.153E+02	.150E+03
LANTHANUM	.000E+00	.299E+02	< .204E+00
LEAD	.170E-01	.561E-01	.154E+00
LITHIUM	.255E-01	.291E+00	.186E+00
MAGNESIUM	.340E+00	.102E+02	.572E+02
MANGANESE	.849E-01	.400E+00	.119E+02
MERCURY	.526E-02	.699E-01	.365E-01
MOLYBDENUM	.849E-01	.311E+01	.993E+00
NEODYMIUM	.000E+00	.487E-03	.474E-02
NICKEL	.170E+00	.309E+00	.251E+03
NIOBIUM	.000E+00	.157E+01	.168E+00
PALLADIUM	.000E+00	.103E-02	.570E-02
PHOSPHORUS	.526E+02	.197E+01	.110E+02
POTASSIUM	.170E+01	.683E+02	.130E+03
PRASEODYMIUM	.000E+00	.128E-03	.944E-04
RHODIUM	.000E+00	.118E-01	.428E-02
RUBIDIUM	.000E+00	.474E-03	.410E+00
RUTHENIUM	.000E+00	< .147E-03	< .428E-03
SAMARIUM	.000E+00	.000E+00	.000E+00
SCANDIUM	< .849E-02	.000E+00	.212E+00
SELENIUM	.170E+00	.903E-02	.549E+00
SILICON	.255E+01	.223E+03	.503E+03
SILVER	.000E+00	.580E+00	.793E+02
SODIUM	.255E+01	.589E+05	.597E+05

HONOR RANCHO ENGINE
NAT. GAS BASELINE
MCG/SEC

MASS FLOW ELEMENT	LUBE OIL	CATALYST INLET	CATALYST OUTLET
STRONTIUM	.849E+00	.104E+01	.201E+01
SULFUR	.357E+03	.887E+05	.278E+06
TANTALUM	.000E+00	.000E+00	.409E+01
TELLURIUM	.000E+00	.160E-03	.123E+00
THORIUM	.000E+00	.449E-02	.718E-02
TIN	.000E+00	.449E-02<X<.567E-01	.129E-01
TITANIUM	< .170E-01	.000E+00	.409E+01
TUNGSTEN	.000E+00	.513E+02	.255E+01
URANIUM	.000E+00	.315E-02	.161E-02
VANADIUM	.170E-01	.301E-01	.402E+00
YTTRIUM	.000E+00	.160E-02	.438E-01
ZINC	.221E+02	.949E+01	.169E+03
ZIRCONIUM	.424E-01	.000E+00	.108E+01

HONOR RANCHO ENGINE
NAT. GAS BASELINE
MCG/SEC

MASS FLOW ELEMENT	CATALYST INLET	XAD	XAD	IMPINGER 1	IMPINGER 2+3
ALUMINUM	.645E+01	.000E+00	.000E+00	.000E+00	.000E+00
ANTIMONY	.252E-02	.000E+00	.000E+00	.000E+00	.000E+00
ARSENIC	.638E-01	.000E+00	.000E+00	.000E+00	.000E+00
BARIUM	.192E+02	.000E+00	.000E+00	.000E+00	.000E+00
BERYLLIUM	< .640E-05	.000E+00	.000E+00	.000E+00	.000E+00
BISMUTH	.103E-02	.000E+00	.000E+00	.000E+00	.000E+00
BORON	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
BROMINE	.154E-01	.000E+00	.000E+00	.000E+00	.000E+00
CADMIUM	.468E-03	.000E+00	.000E+00	.000E+00	.000E+00
CALCIUM	.175E+03	.149E+03	.149E+03	.000E+00	.000E+00
CERIUM	.309E+01	.299E+01	.299E+01	.104E+00	.000E+00
CESIUM	.147E-03	.000E+00	.000E+00	.000E+00	.000E+00
CHLORINE	> .000E+00	.000E+00	.000E+00	.000E+00	.000E+00
CHROMIUM	.259E+00	.000E+00	.000E+00	.000E+00	.000E+00
COBALT	.573E+01	.541E+01	.541E+01	.000E+00	.000E+00
COPPER	.590E+01	.373E+01	.373E+01	.209E+01	.000E+00
FLUORINE	> .000E+00	.000E+00	.000E+00	.000E+00	.000E+00
GALLIUM	.196E+00	.187E+00	.187E+00	.000E+00	.000E+00
GERMANIUM	.596E-03	.000E+00	.000E+00	.000E+00	.000E+00
HAFNIUM	.295E-02	.000E+00	.000E+00	.000E+00	.000E+00
IODINE	.315E+00	.000E+00	.000E+00	.313E+00	.000E+00
IRON	.153E+02	.000E+00	.000E+00	.000E+00	.000E+00
LANTHANUM	.299E+02	.467E+01	.467E+01	.313E+00	.249E+02
LEAD	.561E-01	.000E+00	.000E+00	.000E+00	.000E+00
LITHIUM	.291E+00	.187E+00	.187E+00	.104E+00	.000E+00
MAGNESIUM	.102E+02	.000E+00	.000E+00	.626E+01	.000E+00
MANGANESE	.400E+00	.000E+00	.000E+00	.365E+00	.000E+00
MERCURY	.699E-01	.336E-01	.336E-01	.000E+00	.349E-01
MOLYBDENUM	.311E+01	.280E+01	.280E+01	.000E+00	.000E+00
NEODYMIUM	.487E-03	.000E+00	.000E+00	.000E+00	.000E+00
NICKEL	.309E+00	.000E+00	.000E+00	.000E+00	.000E+00
NIOBIUM	.157E+01	.000E+00	.000E+00	.156E+01	.000E+00
PALLADIUM	.103E-02	.000E+00	.000E+00	.000E+00	.000E+00
PHOSPHORUS	.197E+01	.000E+00	.000E+00	.000E+00	.000E+00
POTASSIUM	.683E+02	.579E+02	.579E+02	.104E+02	.000E+00
PRASEODYMIUM	.128E-03	.000E+00	.000E+00	.000E+00	.000E+00
RHODIUM	.118E-01	.000E+00	.000E+00	.000E+00	.000E+00
RUBIDIUM	.474E-03	.000E+00	.000E+00	.000E+00	.000E+00
RUTHENIUM	< .147E-03	.000E+00	.000E+00	.000E+00	.000E+00
SAMARIUM	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
SCANDIUM	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
SELENIUM	.903E-02	.000E+00	.000E+00	.000E+00	.000E+00
SILICON	.223E+03	.187E+02	.187E+02	.156E+03	.000E+00
SILVER	.580E+00	.000E+00	.000E+00	.522E+00	.000E+00
SODIUM	.589E+05	.187E+02	.187E+02	.589E+05	.000E+00

HONOR RANCHO ENGINE
NAT. GAS BASELINE
MCG/SEC

MASS FLOW ELEMENT	CATALYST INLET	XAD	XAD	IMPINGER 1	IMPINGER 2+3
STRONTIUM	.104E+01	.187E+00	.187E+00	.522E-01	.000E+00
SULFUR	.887E+05	.187E+02	.187E+02	.887E+05	.000E+00
TANTALUM	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
TELLURIUM	.160E-03	.000E+00	.000E+00	.000E+00	.000E+00
THORIUM	.449E-02	.000E+00	.000E+00	.000E+00	.000E+00
TIN	<X<.567E-01	.000E+00	.000E+00	< .522E-01	.000E+00
TITANIUM	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
TUNGSTEN	.513E+02	.000E+00	.000E+00	.511E+02	.000E+00
URANIUM	.315E-02	.000E+00	.000E+00	.000E+00	.000E+00
VANADIUM	.301E-01	.000E+00	.000E+00	.000E+00	.000E+00
YTTRIUM	.160E-02	.000E+00	.000E+00	.000E+00	.000E+00
ZINC	.949E+01	.000E+00	.000E+00	.522E+01	.000E+00
ZIRCONIUM	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00

HONOR RANCHO ENGINE
NAT. GAS BASELINE
MCG/SEC

MASS FLOW ELEMENT	CATALYST OUTLET	FILTER	XAD	IMPINGER 1	IMPINGER 2+3
ALUMINUM	.236E+01	.725E+00	.000E+00	.164E+01	.000E+00
ANTIMONY	<X<.210E+00	.529E-02	.000E+00	< .204E+00	.000E+00
ARSENIC	.247E+00	.247E+00	.000E+00	.000E+00	.000E+00
BARIUM	.234E+02	.226E+02	.000E+00	.818E+00	.000E+00
BERYLLIUM	< .409E-01	< .472E-05	.000E+00	< .409E-01	.000E+00
BISMUTH	.428E-02	.428E-02	.000E+00	.000E+00	.000E+00
BORON	.000E+00	U .000E+00	.000E+00	.000E+00	.000E+00
BROMINE	.875E+00	.575E-01	.000E+00	.818E+00	.000E+00
CADMIUM	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
CALCIUM	.575E+02	.166E+02	.000E+00	.409E+02	.000E+00
CERIUM	.197E+00	.175E-01	.180E+00	.000E+00	.000E+00
CESIUM	.164E+01	< .143E-03	.000E+00	.164E+01	.000E+00
CHLORINE	> .000E+00	> .143E+01	.000E+00	< .110E+03	.000E+00
CHROMIUM	.286E+03	.429E+00	.282E+03	.409E+01	.000E+00
COBALT	.232E+01	.414E+00	.162E+01	.286E+00	.000E+00
COPPER	> .000E+00	.565E+00	.144E+02	> .408E+03	.000E+00
FLUORINE	> .000E+00	> .792E+00	.269E+02	.944E+02	.000E+00
GALLIUM	.189E+01	.875E-02	.000E+00	.188E+01	.000E+00
GERMANIUM	.860E-03	.860E-03	.000E+00	.000E+00	.000E+00
HAFNIUM	.428E-02	.428E-02	.000E+00	.000E+00	.000E+00
IODINE	.244E-01	.244E-01	.000E+00	.000E+00	.000E+00
IRON	.150E+03	.315E+01	.135E+03	.123E+02	.000E+00
LANTHANUM	< .204E+00	.000E+00	.000E+00	< .204E+00	.000E+00
LEAD	.154E+00	.154E+00	.000E+00	.000E+00	.000E+00
LITHIUM	.186E+00	.608E-02	.180E+00	.000E+00	.000E+00
MAGNESIUM	.572E+02	.166E+01	.180E+02	.376E+02	.000E+00
MANGANESE	.119E+02	.902E-01	.862E+01	.315E+01	.000E+00
MERCURY	.365E-01	.161E-02	.287E-01	.613E-02	.000E+00
MOLYBDENUM	.993E+00	.957E-01	.898E+00	.000E+00	.000E+00
NEODYMIUM	.474E-02	.474E-02	.000E+00	.000E+00	.000E+00
NICKEL	.251E+03	.342E+00	.242E+03	.789E+01	.000E+00
NIOBIUM	.168E+00	.461E-02	.000E+00	.164E+00	.000E+00
PALLADIUM	.570E-02	.570E-02	.000E+00	.000E+00	.000E+00
PHOSPHORUS	.110E+02	.204E+01	.898E+01	.000E+00	.000E+00
POTASSIUM	.130E+03	.000E+00	.198E+02	.110E+03	.000E+00
PRASEODYMIUM	.944E-04	.944E-04	.000E+00	.000E+00	.000E+00
RHODIUM	.428E-02	.428E-02	.000E+00	.000E+00	.000E+00
RUBIDIUM	.410E+00	.737E-03	.000E+00	.409E+00	.000E+00
RUTHENIUM	< .428E-03	< .428E-03	.000E+00	.000E+00	.000E+00
SAMARIUM	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
SCANDIUM	.212E+00	.727E-02	.000E+00	.204E+00	.000E+00
SELENIUM	.549E+00	.101E-01	.539E+00	.000E+00	.000E+00
SILICON	.503E+03	.180E+02	.485E+03	.000E+00	.000E+00
SILVER	.793E+02	.277E-01	.000E+00	.793E+02	.000E+00
SODIUM	.597E+05	.000E+00	.180E+02	.596E+05	.000E+00

HONOR RANCHO ENGINE
NAT. GAS BASELINE
MCG/SEC

MASS FLOW ELEMENT	CATALYST OUTLET		FILTER	XAD	IMPINGER 1	IMPINGER 2+3
STRONTIUM	.201E+01		.687E+00	.180E+00	.114E+01	.000E+00
SULFUR	.278E+06		.305E+01	.000E+00	.278E+06	.000E+00
TANTALUM	.409E+01		.143E-02	.000E+00	.409E+01	.000E+00
TELLURIUM	.123E+00		.944E-05	.000E+00	.123E+00	.000E+00
THORIUM	.718E-02		.718E-02	.000E+00	.000E+00	.000E+00
TIN	.129E-01		.129E-01	.000E+00	.000E+00	.000E+00
TITANIUM	.409E+01	U	.000E+00	.000E+00	.409E+01	.000E+00
TUNGSTEN	.255E+01		.998E-01	.000E+00	.245E+01	.000E+00
URANIUM	.161E-02		.161E-02	.000E+00	.000E+00	.000E+00
VANADIUM	.402E+00		.433E-01	.359E+00	.000E+00	.000E+00
YTTRIUM	.438E-01		.295E-02	.000E+00	.409E-01	.000E+00
ZINC	.169E+03		.466E+01	.539E+01	.159E+03	.000E+00
ZIRCONIUM	.108E+01		.425E-02	.108E+01	.000E+00	.000E+00

HONOR RANCHO ENGINE
NAT. GAS BASELINE

ENGINE MASS BALANCE
INPUT = LUBE OIL (MAIN FUEL = NATURAL GAS, NOT ANALYZED FOR TRACE ELEMENTS) OUTPUT=CATALYST INLET

ELEMENT	TOTAL IN	TOTAL OUT	MASS BALANCE (OUT/IN)
ALUMINUM	.424E+00	.645E+01	.152E+02
ANTIMONY		.252E-02	*
ARSENIC		.638E-01	*
BARIUM	.824E+02	.192E+02	.233E+00
BERYLLIUM		X<.640E-05	*
BISMUTH	.170E-01	.103E-02	.608E-01
BORON	.849E-02		.000E+00
BROMINE		.154E-01	*
CADMIUM		.468E-03	*
CALCIUM	.284E+02	.175E+03	.619E+01
CERIUM		.309E+01	*
CESIUM		.147E-03	*
CHLORINE	.849E+00	.147E+01 <X	.174E+01 <X
CHROMIUM	X<.170E-01	.259E+00	.153E+02 <X
COBALT	X<.170E-01	.573E+01	.337E+03 <X
COPPER	.849E-01	.590E+01	.695E+02
FLUORINE	.424E+00	.825E+00 <X	.194E+01 <X
GALLIUM		.196E+00	*
GERMANIUM		.596E-03	*
HAFNIUM		.295E-02	*
IODINE	.170E-01	.315E+00	.185E+02
IRON	.424E+00	.153E+02	.362E+02
LANTHANUM		.299E+02	*
LEAD	.170E-01	.561E-01	.331E+01
LITHIUM	.255E-01	.291E+00	.114E+02
MAGNESIUM	.340E+00	.102E+02	.299E+02
MANGANESE	.849E-01	.400E+00	.471E+01
MERCURY	.526E-02	.699E-01	.133E+02
MOLYBDENUM	.849E-01	.311E+01	.366E+02
NEODYMIUM		.487E-03	*
NICKEL	.170E+00	.309E+00	.182E+01
NIOBIUM		.157E+01	*
PALLADIUM		.103E-02	*
PHOSPHORUS	.526E+02	.197E+01	.375E-01
POTASSIUM	.170E+01	.683E+02	.402E+02
PRASEODYMIUM		.128E-03	*
RHODIUM		.118E-01	*
RUBIDIUM		.474E-03	*
SAMARIUM		X<.147E-03	*
SCANDIUM	X<.849E-02		.000E+00
SELENIUM	.170E+00	.903E-02	.532E-01
SILICON	.255E+01	.223E+03	.875E+02
SILVER		.580E+00	*
SODIUM	.255E+01	.589E+05	.231E+05

HONOR RANCHO ENGINE
NAT. GAS BASELINE

ENGINE MASS BALANCE
INPUT = LUBE OIL (MAIN FUEL = NATURAL GAS, NOT ANALYZED FOR TRACE ELEMENTS) OUTPUT=CATALYST INLET

ELEMENT	TOTAL IN	TOTAL OUT	MASS BALANCE (OUT/IN)
STRONTIUM	.849E+00	.104E+01	.122E+01
SULFUR	.357E+03	.887E+05	.249E+03
TANTALUM			*
TELLURIUM		.160E-03	*
THORIUM		.449E-02	*
TIN			
TITANIUM	X<.170E-01	.449E-02<X<.567E-01	*
TUNGSTEN			.000E+00
URANIUM		.513E+02	*
VANADIUM	.170E-01	.315E-02	*
		.301E-01	.177E+01
YTTRIUM		.160E-02	*
ZINC	.221E+02	.949E+01	.430E+00
ZIRCONIUM	.424E-01		.000E+00

HONOR RANCHO ENGINE
NAT. GAS BASELINE

ENGINE + CATALYST

INPUT = LUBE OIL (MAIN FUEL = NATURAL GAS, NOT ANALYZED FOR TRACE ELEMENTS) OUTPUT=CATALYST OUTLET

ELEMENT	TOTAL IN	TOTAL OUT	MASS BALANCE (OUT/IN)
ALUMINUM	.424E+00	.236E+01	.556E+01
ANTIMONY		.529E-02<X<.210E+00	*
ARSENIC		.247E+00	*
BARIUM	.824E+02	.234E+02	.284E+00
BERYLLIUM		X<.409E-01	*
BISMUTH	.170E-01	.428E-02	.252E+00
BORON	.849E-02		.000E+00
BROMINE		.875E+00	*
CADMIUM			*
CALCIUM	.284E+02	.575E+02	.203E+01
CERIUM		.197E+00	*
CESIUM		.164E+01	*
CHLORINE	.849E+00	.143E+01 <X	.168E+01 <X
CHROMIUM	X<.170E-01	.286E+03	.169E+05 <X
COBALT	X<.170E-01	.232E+01	.136E+03 <X
COPPER	.849E-01	.423E+03 <X	.498E+04 <X
FLUORINE	.424E+00	.122E+03 <X	.288E+03 <X
GALLIUM		.189E+01	*
GERMANIUM		.860E-03	*
HAFNIUM		.428E-02	*
IODINE	.170E-01	.244E-01	.144E+01
IRON	.424E+00	.150E+03	.354E+03
LANTHANUM		X<.204E+00	*
LEAD	.170E-01	.154E+00	.908E+01
LITHIUM	.255E-01	.186E+00	.729E+01
MAGNESIUM	.340E+00	.572E+02	.169E+03
MANGANESE	.849E-01	.119E+02	.140E+03
MERCURY	.526E-02	.365E-01	.693E+01
MOLYBDENUM	.849E-01	.993E+00	.117E+02
NEODYMIUM		.474E-02	*
NICKEL	.170E+00	.251E+03	.148E+04
NIOBIUM		.168E+00	*
PALLADIUM		.570E-02	*
PHOSPHORUS	.526E+02	.110E+02	.209E+00
POTASSIUM	.170E+01	.130E+03	.766E+02
PRASEODYMIUM		.944E-04	*
RHODIUM		.428E-02	*
RUBIDIUM		.410E+00	*
RUTHENIUM		X<.428E-03	*
SAMARIUM			*
SCANDIUM	X<.849E-02	.212E+00	.249E+02 <X
SELENIUM	.170E+00	.549E+00	.323E+01
SILICON	.255E+01	.503E+03	.197E+03
SILVER		.793E+02	*
SODIUM	.255E+01	.597E+05	.234E+05

HONOR RANCHO ENGINE
NAT. GAS BASELINE

ENGINE + CATALYST
INPUT = LUBE OIL (MAIN FUEL = NATURAL GAS, NOT ANALYZED FOR TRACE ELEMENTS) OUTPUT=CATALYST OUTLET

ELEMENT	TOTAL IN	TOTAL OUT	MASS BALANCE (OUT/IN)
STRONTIUM	.849E+00	.201E+01	.237E+01
SULFUR	.357E+03	.278E+06	.780E+03
TANTALUM		.409E+01	*
TELLURIUM		.123E+00	*
THORIUM		.718E-02	*
TIN		.129E-01	*
TITANIUM	X<.170E-01	.409E+01	.241E+03 <X
TUNGSTEN		.255E+01	*
URANIUM		.161E-02	*
VANADIUM	.170E-01	.402E+00	.237E+02
YTTRIUM		.438E-01	*
ZINC	.221E+02	.169E+03	.768E+01
ZIRCONIUM	.424E-01	.108E+01	.255E+02

HONOR RANCHO ENGINE
NAT. GAS BASELINE

CATALYST

ELEMENT	INPUT = CATALYST INLET TOTAL IN	OUTPUT = CATALYST OUTLET TOTAL OUT	MASS BALANCE (OUT/IN)
ALUMINUM	.645E+01	.236E+01	.366E+00
ANTIMONY	.252E-02	.529E-02<X<.210E+00	.210E+01<X<.831E+02
ARSENIC	.638E-01	.247E+00	.387E+01
BARIUM	.192E+02	.234E+02	.122E+01
BERYLLIUM	X<.640E-05	X<.409E-01	*
BISMUTH	.103E-02	.428E-02	.415E+01
BORON			*
BROMINE	.154E-01	.875E+00	.569E+02
CADMIUM	.468E-03		.000E+00
CALCIUM	.175E+03	.575E+02	.328E+00
CERIUM	.309E+01	.197E+00	.637E-01
CESIUM	.147E-03	.164E+01	.111E+05
CHLORINE	.147E+01 <X	.143E+01 <X	*
CHROMIUM	.259E+00	.286E+03	.110E+04
COBALT	.573E+01	.232E+01	.404E+00
COPPER	.590E+01	.423E+03 <X	.716E+02 <X
FLUORINE	.825E+00 <X	.122E+03 <X	*
GALLIUM	.196E+00	.189E+01	.965E+01
GERMANIUM	.596E-03	.860E-03	.144E+01
HAFNIUM	.295E-02	.428E-02	.145E+01
IODINE	.315E+00	.244E-01	.775E-01
IRON	.153E+02	.150E+03	.978E+01
LANTHANUM	.299E+02	X<.204E+00	.000E+00<X<.684E-02
LEAD	.561E-01	.154E+00	.275E+01
LITHIUM	.291E+00	.186E+00	.638E+00
MAGNESIUM	.102E+02	.572E+02	.563E+01
MANGANESE	.400E+00	.119E+02	.297E+02
MERCURY	.699E-01	.365E-01	.522E+00
MOLYBDENUM	.311E+01	.993E+00	.320E+00
NEODYMIUM	.487E-03	.474E-02	.973E+01
NICKEL	.309E+00	.251E+03	.812E+03
NIOBIUM	.157E+01	.168E+00	.107E+00
PALLADIUM	.103E-02	.570E-02	.553E+01
PHOSPHORUS	.197E+01	.110E+02	.558E+01
POTASSIUM	.683E+02	.130E+03	.191E+01
PRASEODYMIUM	.128E-03	.944E-04	.738E+00
RHODIUM	.118E-01	.428E-02	.363E+00
RUBIDIUM	.474E-03	.410E+00	.864E+03
RUTHENIUM	X<.147E-03	X<.428E-03	*
SAMARIUM			*
SCANDIUM		.212E+00	*
SELENIUM	.903E-02	.549E+00	.607E+02
SILICON	.223E+03	.503E+03	.226E+01
SILVER	.580E+00	.793E+02	.137E+03
SODIUM	.589E+05	.597E+05	.101E+01

HONOR RANCHO ENGINE
NAT. GAS BASELINE

CATALYST
INPUT = CATALYST INLET OUTPUT = CATALYST OUTLET

ELEMENT	TOTAL IN	TOTAL OUT	MASS BALANCE (OUT/IN)
STRONTIUM	.104E+01	.201E+01	.194E+01
SULFUR	.887E+05	.278E+06	.313E+01
TANTALUM		.409E+01	*
TELLURIUM	.160E-03	.123E+00	.766E+03
THORIUM	.449E-02	.718E-02	.160E+01
TIN	.449E-02<X<.567E-01	.129E-01	.227E+00<X<.287E+01
TITANIUM		.409E+01	*
TUNGSTEN	.513E+02	.255E+01	.498E-01
URANIUM	.315E-02	.161E-02	.511E+00
VANADIUM	.301E-01	.402E+00	.134E+02
YTTRIUM	.160E-02	.438E-01	.274E+02
ZINC	.949E+01	.169E+03	.179E+02
ZIRCONIUM		.108E+01	*

EPA-600/7-84-073B Waterland Hueg

Acurex Technical Report TR-84-153/EE

ENVIRONMENTAL ASSESSMENT OF A RECIPROCATING ENGINE RETROFITTED WITH NONSELECTIVE CATALYTIC REDUCTION

Volume II: Data Supplement

April 1984

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Acurex Project 7733

Contract 68-02-3188

For

Project Officer
R. E. Hall

Combustion Research Branch
Energy Assessment and Control Division
Industrial Environmental Research Laboratory
Research Triangle Park, North Carolina 27711

By

C. Castaldini and L. R. Waterland

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SECTION 1

INTRODUCTION

The purpose of this data supplement is to document data in greater detail than was possible in Volume I (Technical Results) of this report. It is intended to provide sufficient detail for researchers to perform their own analysis of the data obtained. Readers are referred to the technical volume for objectives, description of source emission results, interpretations, and conclusions.

The remaining sections of this data supplement contain the following information:

- Section 2, Engine Operating Data
  - -- Engine load, generator output, fuel flow, pressures, and temperatures
- Section 3, Sampling Data Sheets
  - -- Complete listing of continuous monitor data for entire 15-day test period (computer listing from field data sheets); operating data tables for SASS (for solid particulate, trace elements and organics sampling), and impinger sampling systems for NH_3 and HCN sampling
- Section 4, Analytical Laboratory Results
  - -- Ammonia, cyanide, and N_2O analysis results, SASS particulate weights, trace element emissions by spark mass spectrometry

(SSMS) analysis and atomic absorption spectroscopy (AAS) analysis; total chromatographable organic (TCO) and gravimetric (GRAV) results and infrared (IR) spectra of total sample extracts; determination of organic compounds by gas chromatography/mass spectrometry (GC/MS); liquid chromatography (LC) fractionation of inlet organic extract with TCO, GRAV, and IR analysis of LC fractions; natural gas fuel analysis.

SECTION 2

ENGINE OPERATING DATA

ENGINE/GENERATOR OPERATING PARAMETERS

Plant SCG Honor Rancho
Location Valencia
Source Waukesha IC Engine

Date June 7 -- Comprehensive Tests
Operator

Time (24-hr)	Generator output (kW)	Engine output (hp)[a]	Engine speed (rpm)	Air intake manifold vacuum (in. Hg)		Fuel regulator pressure (in. H_2O)		Gas meter (10^3 ft^3)	Fuel gas temp (°F)	Stack temp (°F)	Fuel press (psi)	Water temp (°F)	Oil temp (°F)	Vacuum (in. Hg)	Stack press (in. H_2O)	Catalyst temp (°F)		Ambient temp (°F)	
				Left	Right	Left	Right									In	Out	Dry Bulb	Wet Bulb
0845	398	597	905	4.8	5.2	3.7	3.6	107.8	69	1,069	11	169	152	9.2	4.3	1,051	997	--	--
0925	410	615	905	5.1	5.1	3.6	3.5	129.2	70	1,069	11	171	156	9.8	6.1	1,056	1,008	--	--
1045	400	600	905	4.8	4.7	3.7	3.5	170.3	77	1,074	11	171	163	7.8	6.4	1,017	1,005	--	--
1130	400	600	905	4.4	4.5	3.8	3.5	195.9	79	1,068	11	171	166	8.2	6.3	954	1,002	82	--
1210	412	618	900	4.6	4.8	3.8	3.5	215.3	82	1,076	11	172	166	8.2	--	1,013	--	--	--
1340	415	623	905	4.8	4.2	3.7	3.7	264.8	86	1,071	11	173	170	7.2	6.8	--	--	--	--
1435	455	683	905	4.3	4.5	3.8	3.5	299.8	86	1,070	11	174	171	8.0	6.8	997	994	84	71
1512	420	630	910	4.3	4.7	3.6	3.7	315.2	86	1,071	11	172	170	8.2	6.7	997	1,006	84	71
1552	430	645	905	4.3	4.3	3.7	3.5	335.4	84	1,060	11	172	169	7.5	6.3	991	1,022	85	71
1627	425	638	905	4.4	4.1	3.6	3.8	335.9	84	1,070	11	172	171	6.9	7.0	993	1,039	85	71
1655	427	640	905	4.1	4.3	3.6	3.8	372.2	84	1,073	11	172	171	7.5	7.2	1,002	1,042	86	71
1732	430	645	902	4.5	4.6	3.8	3.7	393.2	82	1,070	11	172	170	7.5	6.8	992	1,042	83	70
1802	425	638	905	4.5	4.6	3.8	3.7	409.0	80	1,074	11	172	168	8.0	6.2	--	1,032	79	68
1830[b]	415	623	--[c]	--	--	--	--	421.2	80	1,075	11	--	--	--	--	--	--	--	--

[a]Horsepower was not measured. Estimated to be about 1.5 times the electrical generator output.
[b]Engine operating hours = 5343.7.
[c]Not measured.

ADDITIONAL ENGINE OPERATING DATA -- 15-DAY CONTINUOUS MONITORING PERIOD

Day (June 1983)	Operating hours	Time	Generator output (kW)	Engine output (hp)[a]	Engine speed (rpm)	Stack temp (°F)	Fuel meter (10^3 ft^3)
6	5359.8	1030	225	383			8773.5
		1200	200	300	905		8802.7
	5365.3	1600	260	390	910		8881.5
9	5381.9	0824	160	240	910	900	9213.5
		0900	160	240	910	880	9223.2
		0942	190	285	910	900	9236.5
		1102	215	320	910	926	9262.0
		1143	200	300	910	905	9275.0
	5386.4	1259	210	315	910	893	9299.2
13	5479.9	0957	225	338	900	905	11282.3
		1034	190	285	900	892	11294.4
		1241	220	330	905	890	11333.2
	5484.0	1400	240	360	910	883	11359.0
14	5554.9	1047	275	413	910	1,008	11752.5
		1136	320	480	910	1,045	11773.5
		1317	435	650	905	1,082	11823.0
		1404	450	680	900	1,081	11849.2
		1511	320	480	905	1,078	11884.3
		1553	330	495	910	1,082	11903.5
	5510.9	1643	350	575	910	1,085	11928.5
15	5528.7	1022	415	623	905	1,091	12408.0
		1104	250	375	900	1,022	12430.0
		1152	210	315	900	937	12456.5
		1217	500	750	910	1,031	12465.2
		1253	210	315	905	1,024	12472.2
		1420	250	375	900	989	12504.0
		1454	250	375	905	960	12525.1
	5534.2	1552	230	345	905	966	12535.7
16	5552.4	0959	340	510	905	1,077	12993.5
		1022	380	495	905	1,040	13004.0
		1101	290	435	910	1,041	13021.0
		1124	300	450	910	1,042	13031.0
		1152	310	465	910	1,066	13043.3
		1233	325	490	905	1,060	13062.7
		1241	320	480	910	1,013	13067.0
		1347	290	435	905	1,041	13091.5
		1441	220	330	905	974	13112.5

ADDITIONAL ENGINE OPERATING DATA -- 15-DAY CONTINUOUS MONITOR (continued)

Day (June 1983)	Operating hours	Time	Generator output (kW)	Engine output (hp)[a]	Engine speed (rpm)	Stack temp (°F)	Fuel meter (10^3 ft^3)
		1505	260	390	905	976	13121.9
	5558.5	1600	220	330	910	975	13142.0
17	5576.3	0940	140	210	910	867	13511.8
		1026	225	338	905	977	13526.6
		1048	240	360	905	952	13534.1
		1127	315	470	905	1,013	13549.0
		1203	300	450	905	1,065	13564.0
		1242	330	495	905	1,075	13581.0
		1300	350	525	905	1,070	13599.0
		1316	230	345	905	1,001	13656.0
		1329	350	525	905	1,061	13601.0
		1430	320	480	905	1,066	13628.5
		1531	330	495	905	1,065	13655.8
	5582.5	1552	325	490	905	1,082	13666.1
20	5649.6	1041	250	375	900	934	15164.5
		1306	280	420	905	955	15211.7
		1352	260	390	905	964	15229.0
		1524	270	405	910	958	15264.3
	5655.5	1635	270	407	905	955	15290.0

[a]Horsepower not a measured value. Assumed to correspond to about 1.5 times the generator output.

SECTION 3

SAMPLING DATA SHEETS

3.1 SUMMARY TABLES FOR SASS, NH_3, AND HCN SAMPLING SYSTEMS

3.2 OPERATING DATA TABLES FOR SASS

3.3 OPERATING DATA TABLES FOR NH_3 SAMPLING TRAIN

3.4 OPERATING DATA TABLES FOR HCN SAMPLING TRAIN

3.1 SUMMARY TABLES FOR SASS, NH_3, AND HCN SAMPLING SYSTEMS

ISOKINETIC CALCULATIONS - USEPA: M/5 BASIS

SOUTHERN CAL GAS - NO. 2

RUN NUMBER	2-NH3-O	1-HCN-I	1-HCN-O
DATE OF TEST	6-7-83	6-7-83	6-7-83
OPERATOR	RCB	BCD	BCD
METER VOLUME, CF	18.27	17.316	18.269
METER COEF	0.9908	0.9995	0.9908
BAROMETRIC PRES, HG	28.62	28.62	28.62
DELTA H, IN H2O	1.1	1	1.1
METER TEMP, DEG F	86.6	70.5	87.4
STACK TEMP, DEG F	1026	996	1032
CONDENSATE, ML	91.2	82.4	90.2
PERCENT CO2	10.2	10.2	10.2
PERCENT O2	0.1	0.1	0.1
PERCENT CO	0	0	0
PERCENT N2	89.7	89.7	89.7
STATIC PRES, IN H2O	0.15	0.15	0.15
PITOT COEF	0	0	0
SQRT DELTA P, IN H2O	0	0	0
STACK AREA, SQ FT	0	0	0
NOZZLE DIAM, IN	0	0	0
TEST TIME, MIN	30	30	0
MASS PARTICULATE, G	0	0	0
F-FACTOR, DSCF/MBTU			
VOLUME, DSCF	17.089	16.539	17.063
WATER VAPOR, SCF	4.293	3.879	4.246
PERCENT MOISTURE	0.201	0.190	0.199
MOLECULAR WT DRY, LB/LB	29.636	29.636	29.636
MOLECULAR WT WET, LB/LB	27.30	27.43	27.32
STACK PRES, IN HG	28.63	28.63	28.63
STACK VELOCITY, FT/SEC	0.00	0.00	0.00
MASS FLOW, DSCFM	0	0	0
MASS FLOW, ACFM	0	0	0
PERCENT EXCESS AIR			
PERCENT ISOKINETIC	#DIV/0!	#DIV/0!	#DIV/0!
GRAIN LOADING, GR/DSCF	0.00000	0.00000	0.00000
GRAIN LOADING, GR/ACF	0.00000	0.00000	0.00000
EMISSION RATE, LB/HR-STD	0.00000	0.00000	0.00000
EMISSION RATE, LB/MBTU			

ISOKINETIC CALCULATIONS - USEPA: M/5 BASIS

SOUTHERN CAL GAS - NO. 1

RUN NUMBER	1-SASS-I	1-SASS-O	1-NH3-I	I-NH3-O
DATE OF TEST	6/7/83	6/7/83	6/7/83	6/7/83
OPERATOR	PWK	PWK	BCD	BCD
METER VOLUME, CF	1026.375	1039.64	16.828	18.03
METER COEF	0.974	1.016	0.9995	0.9908
BAROMETRIC PRES, HG	28.55	28.55	28.62	28.62
DELTA H, IN H2O	1.08	1.41	1	1.1
METER TEMP, DEG F	92.2	93.2	64.7	79.6
STACK TEMP, DEG F	997	1029	997.3	1025.5
CONDENSATE, ML	3952	4586	78.6	66.9
PERCENT CO2	10.2	10.2	10.2	10.2
PERCENT O2	0.1	0.1	0.1	0.1
PERCENT CO	0	0	0	0
PERCENT N2	89.7	89.7	89.7	89.7
STATIC PRES, IN H2O	0.15	0.15	0.15	0.15
PITOT COEF	0.79	0.79	0	0
SQRT DELTA P, IN H2O	0.664	0.644	0	0
STACK AREA, SQ FT	0.785	0.785	0	0
NOZZLE DIAM, IN	0.612	0.612	0	0
TEST TIME, MIN	360	320	30	30
MASS PARTICULATE, G	0.0367	0.0376	0	0
F-FACTOR, DSCF/MBTU	0			
VOLUME, DSCF	964.290	935.475	16.251	17.084
WATER VAPOR, SCF	186.021	215.863	3.700	3.149
PERCENT MOISTURE	0.162	0.187	0.185	0.156
MOLECULAR WT DRY, LB/LB	29.636	29.636	29.636	29.636
MOLECULAR WT WET, LB/LB	27.75	27.45	27.48	27.82
STACK PRES, IN HG	28.56	28.56	28.63	28.63
STACK VELOCITY, FT/SEC	60.80	59.94	0.00	0.00
MASS FLOW, DSCFM	830	776	0	0
MASS FLOW, ACFM	2,864	2,823	0	0
PERCENT EXCESS AIR				
PERCENT ISOKINETIC	124.053	144.806	#DIV/0!	#DIV/0!
GRAIN LOADING, GR/DSCF	0.00059	0.00062	0.00000	0.00000
GRAIN LOADING, GR/ACF	0.00564	0.00577	0.00000	0.00000
EMISSION RATE, LB/HR-STD	0.00418	0.00413	0.00000	0.00000
EMISSION RATE, LB/MBTU				

3.2 OPERATING DATA TABLES FOR SASS

ACUREX CORPORATION

Run 1-SASS (INLET)

Acurex Project No. 307735.51
Field Dates 6-6/8-82
Plant HONOR RANCH STORAGE STA.
Sampling Location ENG. 3
Sampling Date 6-7-82

FIELD CREW

Crew Chief: BRUCE C. DAROS
Testing Engineer: 1 PETE W. KAUFMANN
2 REGAN C. BEST
C.M. ~~Engr.~~ Technician: 1 SHERMAN A. SMITH
2
3
Lab Technician: 1 GREG NICOLL
2
Process Engineer: 1 HOWARD B. MASON
2

FIELD SAMPLE REFERENCE NUMBERS:

819363
819366
819381
819380
819362
819383
819369
819372
819377
819375
819378
819393

ISOKINECTIC SAMPLING WORKSHEET

Plant Honor Rancho - Storage Stk. Peformed by Kaufmann

Date 6/7/83

Sample Location Inlet

Test No./Type SASS

$$K = \frac{782.687\ (Cp)^2\ (1-B_{wo})^2\ P_s\ M_d}{K_o^2\ M_s\ P_m}$$

where: K = Contant of fixed and assumed parameters (dimensionless)

Pitot coefficient (dimensionless)	C_p	assume .85
Water vapor in the gas stream (proportion by volume)	B_{wo}	assume .12
Absolute stack gas pressure (in. Hg)	P_s	assume + .5
Molecular weight, stack gas dry (lb/lb-mole)	M_d	CO_2 - 10 O_2 - 0.2 N_2 - 898
Orifice coefficient (dimensionless)	K_o	3.561 .9794
Molecular weight, stack gas wet (lb/lb-mole) $M_d(1-B_{wo}) + 18(B_{wo})$	M_s	
Abolute meter pressure (in. Hg)	P_m	27.55
$\frac{782.687\ (\_\_\_)^2\ (1-\_\_\_)^2\ (\_\_\_)\ (\_\_\_)}{(\_\_\_)^2\ (\_\_\_)\ (\_\_\_)}$	K	35.841

ISOKINECTIC NOZZLE CALCULATION
AND
SAMPLING RATE CALCULATION

Plant Honor Rancho Storage Sta. Performed by Kaufmann

Date 6/7/83

Sample Location Inlet

Test No./Type SASS

$$N_d = \left(\frac{\Delta H \; T_s}{K \; T_m \; \Delta P} \right)^{.25}$$

where: N_d = Nozzel diameter (inches)

Average pressure differential across the orifice meter (in. H_2O)	ΔH	2.1
Temperature stack gas, average (^oF)	T_s	1000
Temperature of gas meter, average (^oF)	T_m	100
Stack gas velocity pressure (in H_2O)	ΔP	[illegible]
$\left(\frac{(\_\_\_)\ (\_\_\_ + 460)}{(\_\_\_)\ (\_\_\_ + 460)(\_\_\_)} \right)^{.25}$	N_d	

$$\Delta H = K \; (N_d)^4 \; \frac{T_m}{T_s} \; (\Delta P)$$

where: ΔH = Pressure differential across the orifice meter (in H_2O)

Nozzel diameter, actual (inches)	N_d	
Temperature of gas meter (^oF)	T_m	
Temperature of stack gas (^oF)	T_s	
Stack gas velocity pressure (in H_2O)	ΔP	
$\left((\_\_\_)\ (\_\_\_)^4 \frac{(\_\_\_ + 460)}{(\_\_\_ + 460)} (\_\_\_) \right)$	ΔH	
Magic number _____ $(\quad)^4$	$K(N_d)^4$	

Plant HOOPER RANCHO
Date 6-7-83
Sample Location INLET
Sample Type SASS
Run Number 1
Operator P.W. KAUFMANN
Ambient Temperature
Barometric Pressure
Static Pressure, (H_2O)
Filter Number(s)

Leak Check: Initial at ____ " Hg, ____ CFM
Final at 21 " Hg, .015 CFM
Pitot Leak Check:

Impinger Volumes

Initial	Final	Net Gain
500		
500		
500		

Silica Gel

SASS Condensate
Total Volume 3952*

Probe Length and Type 5' SS
Nozzel Size & I.D.
Pitot Coefficient & I.D. .79
Assumed Moisture 15%
Molecular Weight, Dry, (M_d)
Meter Box Number 105
Meter Coefficient 3.581
α Factor 6.974
K = 37.223
$K(Nd)^4$ = ___ x (___)^4 = ___

$\Delta H = K(N_d)^4 \left(\frac{Tm}{Ts}\right)$ (P)

Traverse Point Number	Clock Time (24-hr) Clock / Sampling Time, min	Gas Meter Reading (V_m), ft 3	Velocity Head (ΔP_s), in. H_2O	Orifice Pressure Differential (ΔH), in. H_2O Desired	Orifice Pressure Differential (ΔH), in. H_2O Actual	Temperature °F Stack	Probe	Impinger	Organic Module	Oven	Gas Meter In	Gas Meter Out	Pump Vacuum in. Hg	Avg. $\sqrt{\Delta P}$
	1211 / 0	Init. 879.127												
	10	—			0.9	998	826		300	306	83	83	22	
	20	—			0.9	996	828		63	342	—	—	22	
	30	959.70			0.9	997	825		63	350	89	86	22	
	40	987.2			0.9	997	827		65	356	92	88	22	
	50	015.5			0.9	997	831		65	367	94	89	21	
	60	042.7			0.9	997	826		65	373	94	90	21	
	70	070.1			0.9	999	824		62	379	94	90	21	
	80	097.5			0.9	996	823		62	382	95	95	21	
	90	122.92			0.9	995	822		62	382	95	91	21	

* SEE SASS ANALYTICAL DATA SHEET

Comments:

Traverse Point Number	Clock Time (24-hr) Clock / Sampling Time, min	Gas Meter Reading (V_m), ft 3	Velocity Head (ΔP_s), in. H_2O	Orifice Pressure Differential (ΔH), in. H_2O		Temperature °F					Gas Meter		Pump Vacuum in. Hg	Avg. $\sqrt{\Delta P}$
				Desired	Actual	Stack	Probe	Impinger	Organic Module	Oven	In	Out		
	100				0.9	997	820		63	380	96	91	21	
	110	178.4			0.9	996	821		64	377	97	92	21	
	120	206.5			0.9	997	820		64	379	97	92	21	
	130	~~236.6~~			0.9	995	818		63	379	97	92	21	
	140	260.6			0.9	996	817		62	377	96	92	21	
	stop 150	284.647								—	—			
1451	160	323.1			1.9	996	740		60	330	93	91	20	
	170	356.1			1.6	996	814		62	335	98	92	20	
	180	392.5			1.6	997	817		64	348	101	93	20	
	190	426.5			1.6	995	817		65	366	102	94	20	
	200	460.7			1.6	999	818		65	371	103	94	20	
	210	494.7			1.6	1000	821		66	374	102	95	20	
	stop 220	528.422			1.6	982	852		67	374	101	94	20	
	1610 220	528.422			—	—	—		—	—	—	—	—	
	230	—			1.5	997	826		69	346	93	93	21	
	240	583.8			1.0	999	825		67	357	95	92	21	
	250	618.2			1.0	1000	824		65	358	96	92	21	

Run No. 1-SASS (INLET) Date 6-7-87 Sampling Location HOWARD RANCHO

Comments: 150 change SiO2, drain condensate.

220 Drain condensate.

Traverse Point Number	Clock Time (24-hr) Clock / Sampling Time, min	Gas Meter Reading (V_m), ft 3	Velocity Head (ΔP_s), in. H_2O	Orifice Pressure Differential (ΔH), in. H_2O		Temperature °F					Gas Meter		Pump Vacuum in. Hg	Avg. $\sqrt{\Delta P}$
				Desired	Actual	Stack	Probe	Impinger	Organic Module	Oven	In	Out		
	255	Init. 613.2												
Stop	260	638.785			1.0	1001	826		63	370	91	92	21	
1702	~~270~~ 280	638.785			—	—	—		—	—	—	—	—	
	~~1702~~ / 270	665.8			1.0	1001	763		61	330	89	89	21	
	280	—			1.0	1001	825		62	378	92	89	21	
	290	720.1			1.0	998	823		63	351	94	89	21	
	300	746.9			1.0	1000	824		63	362	94	89	21	
	310	773.6			1.0	998	824		64	370	94	89	21	
	320	~~799~~ 800.0			1.0	998	825		64	371	92	88	21	
	330	828.1			1.0	999	829		65	373	92	86	21	
	340	—			0.9	995	822		64	373	91	86	21	
	350	879.8			0.9	994	764		64	375	89	82	21	
Stop	~~0~~ 360	1905.502			0.9	993	762		64	373	90	86	21	
	300 —	1,026.375			1.08	997					94.3	90.2	20.5	

Run No. 1-SASS (INLET)

Date 6-7-83

$\frac{37.8}{35}$ 3492÷35 (92.2)

Sampling Location Hooker Rancho

Comments: 260 change SiO2 draw coordinate

$\frac{3207}{34}$ $\frac{3065}{34}$

SASS ANALYTICAL DATA

Plant So Cal / Honor Rancho Sample No. Inlet

Sampling Location Valencia, CA Run No. 1

Recovered By G. Nicoll Recovery Date 6-7-83 Run Date 6-7-83

Comments

Analyst Responsible

Calculations and Report Reviewed By Report Date

FILTERS USED

No.	tare = 0.99191 g	Used (yes/no)	Pretared Container (No.)
MV-142-330			
	10μ	No	
	3μ	No	
	1μ	No	

IMPINGER VOLUMES

	Initial	Final	+ Rinse to
First (H_2O_2)	500 ml	1685 ml	1725 mL
Second (APS + $AgNO_3$)	500 ml	1620 ml	1735 mL
Third (APS + $AgNO_3$)	500 ml	\ ml	
TOTALS	1500 ml	3305 ml	Gain 1805 ml

SILICA GEL WEIGHTS

Initial	Final
750 g	863 g
750 g	866 g
750 g	843 g
TOTALS 2250 g	2572 g

Gain 322 g

CONDENSATE

TOTAL VOLUME COLLECTED			+ Rinse to 1408 mL (0 mL Rinse added) 1825 ml
Volume Neat	1825 ml		
Volume Extracted	ml		
Volume CH_2Cl_2 Extract (3 x ml)	ml		
Extracted Condensate: pH Neat			
Amount 96% HNO_3 added			
pH Final			

TOTAL GAIN 3952 ml

ISOKINETIC PERFORMANCE WORKSHEET & PARTICULATE CALCULATIONS

Plant Honor Rancho

Performed by Kaufmann

Date 6/7/83

Sample Location Inlet

Test No./Type 1/SASS

Barometric Pressure (in. Hg)	P_b	28.55
Meter volume (std), $17.647\left(\frac{V_m}{\alpha}\right)\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_m + 460}\right)$ 1,026.375 $17.64\left(\frac{(\_\_\_)}{(.974)}\right)\left(\frac{(28.55) + \frac{(1.08)}{13.6}}{(92.2) + 460}\right)$	$V_{m\ std}$	963.744
Volume of liquid collected (grams)	Vl_c	3952
Volume of liquid at standard condition (scf) $Vl_c \times 0.04707$	$V_{w\ std}$	186.021
Stack gas proportion of water vapor $\frac{V_{w\ std}}{V_{w\ std} + V_{m\ std}}$, $\frac{(186.021)}{(\_\_\_) + (\_\_\_)}$ 186.021 963.744	B_{wo}	.162
Molecular weight, stack gas dry (lb/lb-mole) AVG FROM MPR $(\%\ CO_2 \times 0.44) + (\%\ O_2 \times 0.32) + (\%\ N_2 + \%\ CO \times 0.28)$ $(10.2 \times 0.44) + (0.1 \times 0.32) + (89.7 + \_\_\_ \times 0.28)$	M_d	29.64
Molecular weight, stack gas wet (lb/lb-mole) $Md(1-B_{wo}) + 18(B_{wo})$, $(29.64)(1-.162) + 18(.162)$	M_s	27.76
Absolute stack pressure (in. Hg) $P_b + \frac{P_{stack}\ (in.\ H_2O)}{13.6}$, $(28.55 + \frac{(\_\_\_)}{13.6}$ +.15 (assumed)	P_s	28.56

7602/5/81/Rev 1

Temperature stack gas, average (°F)	T_s	997
Stack velocity (fps) $85.49\ (C_p)\ (\sqrt{\Delta P_{s\ avg}})\ \sqrt{\dfrac{T_s avg + 460}{P_s \quad M_s}}$ $85.49\ (\underline{.79})(\sqrt{.664})^2\ \sqrt{\dfrac{(\_\_\_) + 460}{(\_\_\_)(\_\_\_)}}$	$V_{s(avg)}$	60.8
Total sample time (minutes)	θ	360
Nozzle diameter, actual (inches)	N_d	.612 ASSUMED FOR PURPOSE OF CALC.
Percent isokinetic (%) $\dfrac{17.33\ (T_s + 460)(V_w\ std + V_m\ std)}{\theta \quad V_s \quad P_s \quad N_d^2}$ $\dfrac{17.33\ (\_\_\_ + 460)((\_\_\_) + (\_\_\_))}{(\_\_\_)(\_\_\_)(\_\_\_)(\underline{2})}$	%I	124.05
Area of stack (ft^2) $\pi = 3.1416$ 12" DIAM $\pi r^2 \div 144$, $\pi(\underline{6''})^2 \div 144$	A_s	.785
Stack gas volume at standard conditions (dscfm) $60\ (1 - B_{wo})Vs_{avg}\ A_s \left(\dfrac{528}{T_s\ avg + 460}\right)\left(\dfrac{Ps}{29.92}\right)$ $60\ (1 - \_\_\_)(\_\_\_)(\_\_\_)\left(\dfrac{528}{\_\_\_ + 460}\right)\left(\dfrac{(\_\_\_)}{(29.92)}\right)$	ACFM = Q_s	2862 [1] 830
Particulate matter concentration, dry (gr/dscf) $15.432\ \dfrac{M_p(grams)}{Vm_{std}}$, $15.432\ \dfrac{(\_\_\_)}{(\_\_\_)}$	$C_{s(std)}$	FRONT HALF RINSE FILTER
Emission rate of particulate matter (lb/hr) $0.00857\ (Q_s)\ C_{s(std)}$, $0.00857\ (\_\_\_)(\_\_\_)$	E_p	

0.0022 g
0.0345 g
0.0367 g

[1] CALC. BY L. WATERLAND

7602/5/81/Rev 1

ACUREX CORPORATION

Run 1-SASS (OUTLET)

Acurex Project No. 3077S5.51
Field Dates 6-6/8-83
Plant HONOR RANCHO STORAGE STA.
Sampling Location ENG 3
Sampling Date 6-7-83

FIELD CREW

Crew Chief: BRUCE C. DeROS
Testing Engineer: 1 PETE W. KAUFMAN-SASS
2 REGAN C BEST
~~Engr~~. Technician: 1 SHERMAN A. SMITH -CM
2
3
Lab Technician: 1 GREG NICOLL
2
Process Engineer: 1 HOWARD B. MASON
2

FIELD SAMPLE REFERENCE NUMBERS:

819368	819371
819365	819376
819364	819379
819367	819385
819382	819394
819370	819360
819373	

ISOKINECTIC SAMPLING WORKSHEET

Plant Hoover Ranch Storage Spa. Peformed by Kaufmann

Date 6/7/83

Sample Location Outlet

Test No./Type SASS

$$K = \frac{782.687\ (Cp)^2\ (1-B_{wo})^2\ P_s\ M_d}{K_o^2\ M_s\ P_m}$$

where: K = Contant of fixed and assumed parameters (dimensionless)

Pitot coefficient (dimensionless)	C_p	assume .85
Water vapor in the gas stream (proportion by volume)	B_{wo}	assume .2
Absolute stack gas pressure (in. Hg)	P_s	assume .5
Molecular weight, stack gas dry (lb/lb-mole)	M_d	CO_2 - 10 O_2 0.7 N 89.8
Orifice coefficient (dimensionless)	K_o	3.537 α - 1.016
Molecular weight, stack gas wet (lb/lb-mole) $M_d(1-B_{wo}) + 18(B_{wo})$	M_s	
Abolute meter pressure (in. Hg)	P_m	29.55
$\frac{782.687\ (\quad)^2\ (1-\quad)^2\ (\quad)\ (\quad)}{(\quad)^2\ (\quad)\ (\quad)}$	K	36.778

ISOKINECTIC NOZZLE CALCULATION
AND
SAMPLING RATE CALCULATION

Plant Honor Rancho Storage Sta. Performed by Kaufmann

Date 6/7/83

Sample Location Outlet

Test No./Type SASS

$$N_d = \left(\frac{\Delta H \; T_s}{K \; T_m \; \Delta P} \right)^{.25}$$

where: N_d = Nozzel diameter (inches)

Average pressure differential across the orifice meter (in. H_2O)	ΔH	2.1
Temperature stack gas, average (^oF)	T_s	1050
Temperature of gas meter, average (^oF)	T_m	100
Stack gas velocity pressure (in H_2O)	ΔP	1.1
$\left(\frac{(\_\_\_)\ (\_\_\_ + 460)}{(\_\_\_)\ (\_\_\_ + 460)(\_\_\_)} \right)^{.25}$	N_d	.612

$$\Delta H = K \, (N_d)^4 \, \frac{T_m}{T_s} \, (\Delta P)$$

where: ΔH = Pressure differential across the orifice meter (in H_2O)

Nozzel diameter, actual (inches)	N_d	
Temperature of gas meter (^oF)	T_m	
Temperature of stack gas (^oF)	T_s	
Stack gas velocity pressure (in H_2O)	ΔP	
$\left((\_\_\_)\ (\_\_\_)^4 \frac{(\_\_\_ + 460)}{(\_\_\_ + 460)} (\_\_\_) \right)$	ΔH	
Magic number _____ $(\quad)^4$	$K(N_d)^4$	

Plant HOWARD RANCHO
Date 6-7-83
Sample Location OUTLET
Sample Type SASS
Run Number 1
Operator P.W. KAUFMANN
Ambient Temperature
Barometric Pressure 28.55
Static Pressure, (H_2O)
Filter Number(s)

Leak Check: Initial at ____ " Hg, ____ CFM
Final at 22 " Hg, 0.11 CFM
Pitot Leak Check:

Impinger Volumes

Initial	Final	Net Gain
500		
500		
500		

Silica Gel

SASS Condensate
Total Volume 4586 +

Probe Length and Type 3' SS
Nozzel Size & I.D.
Pitot Coefficient & I.D.
Assumed Moisture
Molecular Weight, Dry, (M_d)
Meter Box Number
Meter Coefficient 3.537
α Factor 1.016
K =
$K(Nd)^4$ = ___ x (___)^4 = ___
$\Delta H = K(N_d)^4 \left(\frac{Tm}{Ts}\right)$ (P)

Traverse Point Number	Sampling Time, min / Clock Time (24-hr) Clock	Gas Meter Reading (V_m), ft 3	Velocity Head (ΔP_s), in. H_2O	Orifice Pressure Differential (ΔH), in. H_2O		Temperature °F							Pump Vacuum in. Hg	Avg. $\sqrt{\Delta P}$
				Desired	Actual	Stack	Probe	Impinger	Organic Module	Oven	Gas Meter In	Gas Meter Out		
	0 ~~1209~~	Init. ~~161.447~~												
	0 1240	167.318					415							
	10	203.4			1.6	1025			62	265	79	79	20	
	20	235.90			1.5	1035	654		62	262	85	83	20	
	30	268.0			1.4	1026	664		62	331	88	86	20	
	40	302.1			1.4	1036	669		65	354	90	88	20	
	50	332.4			1.4	1038	666		68	321	91	89	20	
	60	365.35			1.4	1027	686		73	340	93	91	20	
	70				1.4	1027	654		61	324	95	92	20	

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Comments:

Traverse Point Number	Clock Time (24-hr) Clock / Sampling Time, min / ΔD	Gas Meter Reading (V_m), ft 3	Velocity Head (ΔP_s), in. H_2O	Orifice Pressure Differential (ΔH), in. H_2O		Temperature °F					Gas Meter		Pump Vacuum in. Hg	Avg. $\sqrt{\Delta P}$
		Init.		Desired	Actual	Stack	Probe	Impinger	Organic Module	Oven	In	Out		
	80	459.9			1.4	1059	664		62	336	95	93	20	
	90	462.7			1.4	1029	664		64	478	96	94	20	
	100				1.4	1026	668		62	402	94	93	26	
	110	528.5			1.4	1027	660		64	366	94	93	20	
	stop 120	559.99				—	—							
1459	130	593.4			1.5	1036	305		71	313	93	92	20	
	140	628.4			1.4	1031	646		65	404	95	93	20	
	150	557.5			1.4	1032	663		62	386	97	95	20	
	160	690.1			1.4	1032	664		61	350	99	96	20	
	170	722.9			1.4	1032	665		65	379	100	97	20	
	180	755.7			1.4	1014	650		66	347	100	98	20	
	190	789.7			1.4	1024	658		64	354	100	98	20	
	200	—			1.4	1030	661		71	327	100	98	20	
	210	854.2			1.4	1031	661		65	353	99	96	20	
	220	886			1.4	1031	661		62	325	99	98	20	
	230	—			1.4	1032	664		63	323	99	97	20	
	stop ↗													

Run No. 1-SASS (OUTLET) Date 6-7-83 Sampling Location HONOR RANCHO

Comments: 120 change SiO2 (condensate drained while train operates)

240 change SiO2

Traverse Point Number	Clock Time (24-hr) Clock / Sampling Time, min	Gas Meter Reading (V_m), ft 3	Velocity Head (ΔP_s), in. H_2O	Orifice Pressure Differential (ΔH), in. H_2O		Temperature °F					Gas Meter		Pump Vacuum in. Hg	Avg. $\sqrt{\Delta P}$
				Desired	Actual	Stack	Probe	Impinger	Organic Module	Oven	In	Out		
	1702 / 230	Init. 918.875												
	240	930.4			1.4	1035	439		61	323	92	93	20	
	250	—			1.4	1031	643		60	451	92	92	20	
	260	1015.1			1.4	1031	659		60	357	94	93	20	
	270	1046.5			1.4	1030	660		62	327	94	93	20	
	280	1078.8			1.4	1032	661		65	359	94	93	20	
	290	1111.1			1.4	1029	657		69	340	94	93	20	
	300	1145.5			1.4	1032	659		60	311	92	92	20	
	310	—			1.3	1031	659		59	334	90	90	20	
Stop	320	1206.956			1.3	1033	660		64	324	89	89	20	
	320 / —	1039.640			1.41	1029					93.9	92.5		

Run No. 1-SASS (OUTLET) Date 6-7-83 $\frac{31908}{31}$ Sampling Location Hanson Rancho (93.2)

Comments: $\frac{2912}{31}$ 2867

3-20

SASS ANALYTICAL DATA

Plant So Cal / Honor Rancho Sample No. Outlet

Sampling Location Valencia, CA Run No. 1

Recovered By G. Nicoll Recovery Date 6-7-83 Run Date 6-7-83

Comments

Analyst Responsible

Calculations and Report Reviewed By Report Date

FILTERS USED		CYCLONES	
No. MV-142-331 0.99840g tare		Used (yes/no)	Pretared Container (No.)
	10μ	No	
	3μ	No	
	1μ	No	

IMPINGER VOLUMES

	Initial	Final	
First (H_2O_2)	500 mℓ	1360 mℓ	+ Rinse to 1425 mL
Second (APS + $AgNO_3$)	500 mℓ	2465 mℓ	2600 mL
Third (APS + $AgNO_3$)	500 mℓ	mℓ	
TOTALS	1500 mℓ	3825 mℓ	Gain 2325 mℓ

SILICA GEL WEIGHTS

	Initial	Final	
	750 g	859 g	
	750 g	870 g	
	750 g	1282 g	overloaded
TOTALS	2250 g	3011 g	Gain 761+ g

CONDENSATE

TOTAL VOLUME COLLECTED		1500 mℓ
Volume Neat	1500 mℓ	+Rinse to 1515 mL
Volume Extracted	mℓ	
Volume CH_2Cl_2 Extract (3 x ___ mℓ)	mℓ	
Extracted Condensate: pH Neat		
Amount 96% HNO_3 added		
pH Final		

TOTAL GAIN 4586+ mℓ

ISOKINETIC PERFORMANCE WORKSHEET & PARTICULATE CALCULATIONS

Plant Honor Rancho Performed by B.S. DaRos

Date 6-7-83

Sample Location OUTLET

Test No./Type 1/SASS

Barometric Pressure (in. Hg)	P_b	28.55
Meter volume (std), $17.64\left(\frac{V_m}{\alpha}\right)\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_m + 460}\right)$ $17.64\left(\frac{(\_\_\_)}{(1.016)}\right)\left(\frac{(28.55) + \frac{(1.41)}{13.6}}{(93.2) + 460}\right)$ 1039.640	$V_{m\ std}$	935.475
Volume of liquid collected (grams)	Vl_c	4586
Volume of liquid at standard condition (scf) $Vl_c \times 0.04707$	$V_{w\ std}$	215.863
Stack gas proportion of water vapor $\frac{V_{w\ std}}{V_{w\ std} + V_{m\ std}}$, $\frac{(\_\_\_)}{(\_\_\_) + (\_\_\_)}$	B_{wo}	0.187
Molecular weight, stack gas dry (lb/lb-mole) (% CO_2 x 0.44) + (% O_2 x 0.32) + (% N_2 + % CO x 0.28) (10.2 x 0.44) + (0.1 x 0.32) + (89.7 + ___ x 0.28)	M_d	29.636
Molecular weight, stack gas wet (lb/lb-mole) $Md(1-B_{wo}) + 18(B_{wo})$, (29.636(1-.187) + 18(.187)	M_s	27.45
Absolute stack pressure (in. Hg) $P_b + \frac{P_{stack}\ (\text{in. } H_2O)}{13.6}$, $(28.55) + \frac{(.15)}{13.6}$	P_s	28.56

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Temperature stack gas, average (^{o}F)	T_s	1029
Stack velocity (fps) $85.49\ (C_p)\ (\sqrt{\Delta P_{s\ avg}})\ \sqrt{\frac{T_s avg + 460}{P_s \quad M_s}}$ $85.49\ (.79)(\sqrt{.644})^2 \sqrt{\frac{(1029) + 460}{(28.56)(27.45)}}$	$V_{s(avg)}$	57.94
Total sample time (minutes)	θ	320
Nozzle diameter, actual (inches)	N_d	.612
Percent isokinetic (%) $\frac{17.33\ (T_s + 460)(V_w\ std + V_m\ std)}{\theta \quad V_s \quad P_s \quad N_d^2}$ $\frac{17.33\ (\_\_\_ + 460)((\_\_\_) + (\_\_\_))}{(\_\_\_)(\_\_\_)(\_\_\_)(\_\_\_^2)}$	%I	44.806
Area of stack (ft^2) $\pi = 3.1416$ $\pi r^2 \div 144$, $\pi(6")^2 \div 144$	A_s	.785
Stack gas volume at standard conditions (dscfm) $60\ (1 - B_{wo})Vs_{avg}\ A_s \left(\frac{528}{T_s\ avg + 460}\right) \left(\frac{Ps}{29.92}\right)$ $60\ (1 - \_\_\_)(\_\_\_)(\_\_\_)\left(\frac{528}{\_\_\_ + 460}\right) \left(\frac{(\_\_\_)}{(29.92)}\right)$	ACFM Q_s	2,823 776
Particulate matter concentration, dry (gr/dscf) $15.432\ \frac{M_p(grams)}{Vm_{std}}$, $15.432\ \frac{(\_\_\_\_\_)}{(\_\_\_\_\_)}$	$C_{s(std)}$	FRONT HALF + FILTER 0.0034 g 0.0342 0.0376
Emission rate of particulate matter (lb/hr) $0.00857\ (Q_s)\ C_{s(std)}$, $0.00857\ (\_\_\_\_\_)(\_\_\_\_\_)$	E_p	

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3.3 OPERATING DATA TABLES FOR NH_3 SAMPLING TRAIN

ACUREX CORPORATION

Run 1-NH_3 (INLET)

Acurex Project No. 307735.51

Field Dates 6-6/8-83

Plant Honor Rancho Storage Sta.

Sampling Location Eng 3

Sampling Date 6-7-83

FIELD CREW

Crew Chief:		Bruce C. DaRos
Testing Engineer:	1	" "
	2	Regan C. Best
C.M. ~~Engr.~~ Technician:	1	Sherman A. Smith
	2	
	3	
Lab Technician:	1	Greg Nicoll
	2	
Process Engineer:	1	Howard B. Mason
	2	

FIELD SAMPLE REFERENCE NUMBERS:

~~819386~~ void

819359

819387

FIELD DATA

Plant Hooker Rancho
Date 6-7-83
Sample Location Inlet
Sample Type NH_3
Run Number 1
Operator R.C. DeRes
Ambient Temperature
Barometric Pressure 28.62 @ 1315
Static Pressure, (H_2O)
Filter Number(s) N/A

Leak Check: Initial at 12 " Hg, .004 CFM
Final at 5 " Hg, .002 CFM
Pitot Leak Check:

+64.0 Rinse

Impinger Volumes

Initial	Final	Net Gain
100		
100	273	73.0
MT		

Silica Gel

591.4	597.0	5.6

SASS Condensate
Total Volume 78.6

Probe Length and Type SS
Nozzel Size & I.D. N/A
Pitot Coefficient & I.D. N/A
Assumed Moisture
Molecular Weight, Dry, (M_d)
Meter Box Number D556 NAPP
Meter Coefficient
α Factor .9995
K =
$K(Nd)^4$ = ___ x (___)^4 = ___
$\Delta H = K(N_d)^4 \left(\frac{Tm}{Ts}\right)$ (P)

Traverse Point Number	Clock Time (24-hr) Clock / Sampling Time, min	Gas Meter Reading (V_m), ft 3	Velocity Head (ΔP_s), in. H_2O	Orifice Pressure Differential (ΔH), in. H_2O Desired	Orifice Pressure Differential (ΔH), in. H_2O Actual	Temperature °F Stack	Probe	Impinger	Organic Module	Oven	Gas Meter In	Gas Meter Out	Pump Vacuum in. Hg	Avg. $\sqrt{\Delta P}$
	1250 / 0	Init. 278,622												
	1300 / 10	284.42			1.0	998					62	68	2.0	
	1310 / 20	289.72			1.0	997					65	63	2.0	
	1320 / 30	295,450			1.0	998					68	62	2.0	
	— / 30	16.827				997.3					64.7		2.0	

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Comments:

ISOKINETIC PERFORMANCE WORKSHEET & PARTICULATE CALCULATIONS

Plant Honor Rancho Performed by Da Ros

Date 6-7-83

Sample Location INLET

Test No./Type 1-NH3

Barometric Pressure (in. Hg)	P_b	28.62
Meter volume (std), $17.64 \left(\frac{V_m}{\alpha}\right)\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_m + 460}\right)$ $17.64 \left(\frac{(16.828)}{(.9995)}\right)\left(\frac{(28.62) + \frac{(\quad)}{13.6}}{(64.7) + 460}\right)$	$V_{m\ std}$	16.251
Volume of liquid collected (grams)	Vl_c	78.6
Volume of liquid at standard condition (scf) $Vl_c \times 0.04707$	$V_{w\ std}$	3.700
Stack gas proportion of water vapor $\frac{V_{w\ std}}{V_{w\ std} + V_{m\ std}}$, $\frac{(3.7)}{(3.7) + (16.251)}$	B_{wo}	0.185
Molecular weight, stack gas dry (lb/lb-mole) (% CO_2 x 0.44) + (% O_2 x 0.32) + (% N_2 + % CO x 0.28) (10.2 x 0.44) + (2.1 x 0.32) + (89.7 + ____ x 0.28)	M_d	29.636
Molecular weight, stack gas wet (lb/lb-mole) $Md(1-B_{wo}) + 18(B_{wo})$, (29.636)(1-.185) + 18(.185)	M_s	28.63
Absolute stack pressure (in. Hg) $P_b + \frac{P_{stack}\ (in.\ H_2O)}{13.6}$, $(28.62) + \frac{(.15)}{13.6}$	P_s	28.63

Temperature stack gas, average (^{o}F)	T_s	997.3
Stack velocity (fps) $85.49\ (C_p)\ (\sqrt{\Delta P_{s\ avg}})\ \sqrt{\frac{T_s avg + 460}{P_s \quad M_s}}$ $85.49\ (\_\_\_\_)(\sqrt{\quad})\ \sqrt{\frac{(\_\_\_\_) + 460}{(\_\_\_\_)(\_\_\_\_)}}$	$V_{s(avg)}$	
Total sample time (minutes)	θ	30
Nozzle diameter, actual (inches)	N_d	N/A
Percent isokinetic (%) $\frac{17.33\ (T_s + 460)(V_w\ std + V_m\ std)}{\theta \quad V_s \quad P_s \quad N_d^2}$ $\frac{17.33\ (\_\_\_\_ + 460)((\_\_\_\_) + (\_\_\_\_))}{(\_\_\_\_\_)(\_\_\_\_\_)(\_\_\_\_\_)(\_\_\_\_\_^2)}$	%I	N/A
Area of stack (ft^2) $\pi = 3.1416$ $\pi r^2 \div 144$, $\pi(\_\_\_\_)^2 \div 144$	A_s	
Stack gas volume at standard conditions (dscfm) $60\ (1 - B_{wo})Vs_{avg}\ A_s \left(\frac{528}{T_s\ avg + 460}\right) \left(\frac{Ps}{29.92}\right)$ $60\ (1 - \_\_\_)(\_\_\_)(\_\_\_)\left(\frac{528}{\_\_\_\_\_ + 460}\right) \left(\frac{(\_\_\_)}{(29.92)}\right)$	Q_s	
Particulate matter concentration, dry (gr/dscf) $15.432\ \frac{M_p(grams)}{Vm_{std}}$, $15.432\ \frac{(\_\_\_\_\_)}{(\_\_\_\_\_)}$	$C_{s(std)}$	
Emission rate of particulate matter (lb/hr) $0.00857\ (Q_s)\ C_{s(std)}$, $0.00857\ (\_\_\_\_\_)(\_\_\_\_\_)$	E_p	

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ACUREX CORPORATION

Run 1-NH3 (OUTLET)

Acurex Project No. 307735.51

Field Dates 6-6/8-83

Plant HANFORD RANCHO STORAGE STA.

Sampling Location ENG 3

Sampling Date 6-7-83

FIELD CREW

Crew Chief: BRUCE C. DaROS

Testing Engineer: 1 " "

2 REGAN C. BEST

C.M. ~~Engr.~~ Technician: 1 SHERMAN A. SMITH

2

3

Lab Technician: 1 GREG NICEL

2

Process Engineer: 1 HOWARD B. MASON

2

FIELD SAMPLE REFERENCE NUMBERS:

819388

FIELD DATA

Plant Howard Ranch
Date 6-7-83
Sample Location OUTLET
Sample Type NH_3
Run Number 1
Operator B.C. DeRos
Ambient Temperature 85°F
Barometric Pressure 28.62
Static Pressure, (H_2O)
Filter Number(s) N/A

Leak Check: Initial at 17" Hg, .006 CFM
Final at 6" Hg, .200 CFM
Pitot Leak Check: N/A

+33 Ainse

Impinger Volumes

	Initial	Final	Net Gain
	100		
	100	263	63
	MT		
Silica Gel			
	594.6	598.5	3.9
SASS Condensate			
Total Volume			66.9

Probe Length and Type SS
Nozzel Size & I.D. N/A
Pitot Coefficient & I.D. N/A
Assumed Moisture
Molecular Weight, Dry, (M_d)
Meter Box Number D585 (NAPP)
Meter Coefficient
α Factor .9908
K =
$K(Nd)^4$ = ___ x (___)^4 = ___
$\Delta H = K(N_d)^4 \left(\frac{Tm}{Ts}\right)$ (P)

Traverse Point Number	Clock Time (24-hr) Clock / Sampling Time, min	Gas Meter Reading (V_m), ft^3	Velocity Head (ΔP_s), in. H_2O	Orifice Pressure Differential (ΔH), in. H_2O		Temperature °F							Pump Vacuum in. Hg	Avg. $\sqrt{\Delta P}$
				Desired	Actual	Stack	Probe	Impinger	Organic Module	Oven	Gas Meter In	Gas Meter Out		
	1250 / 00	Init 929.707												
	5.0	932.79			1.1	1025					76	77	4	
	10.0	935.83			1.1	—					75	76	4	
	15.0	938.81			1.1	—					81	80	4	
	20.0	941.80			1.1	1026					83	83	4	
	25.0	944.75			1.1	1026					81	81	4	
	30.0 End	947.737												
	30 —	18.03			1.1	1025.5					79.6		4	

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Comments:

ISOKINETIC PERFORMANCE WORKSHEET & PARTICULATE CALCULATIONS

Plant HONOR RANCHO Performed by DaBos

Date 6-7-83

Sample Location OUTLET

Test No./Type 1-NH3

Barometric Pressure (in. Hg)	P_b	28.62
Meter volume (std), $17.64\left(\frac{V_m}{\alpha}\right)\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_m + 460}\right)$ $17.64\left(\frac{(18.03)}{(.9908)}\right)\left(\frac{(28.62) + \frac{(1.1)}{13.6}}{(79.6) + 460}\right)$	$V_{m\ std}$	17.084
Volume of liquid collected (grams)	Vl_c	66.9
Volume of liquid at standard condition (scf) $Vl_c \times 0.04707$	$V_{w\ std}$	3.149
Stack gas proportion of water vapor $\frac{V_{w\ std}}{V_{w\ std} + V_{m\ std}}$, $\frac{(3.149)}{(3.149) + (17.084)}$	B_{wo}	0.156
Molecular weight, stack gas dry (lb/lb-mole) $(\%\ CO_2 \times 0.44) + (\%\ O_2 \times 0.32) + (\%\ N_2 + \%\ CO \times 0.28)$ $(10.2 \times 0.44) + (.1 \times 0.32) + (89.7 + \_\_\_ \times 0.28)$	M_d	29.636
Molecular weight, stack gas wet (lb/lb-mole) $Md(1-B_{wo}) + 18(B_{wo})$, $(29.636)(1-.156) + 18(.156)$	M_s	27.82
Absolute stack pressure (in. Hg) $P_b + \frac{P_{stack}\ (in.\ H_2O)}{13.6}$, $(28.62) + \frac{(.15)}{13.6}$	P_s	28.63

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Temperature stack gas, average (^{o}F)	T_s	1025.5
Stack velocity (fps) $85.49\ (C_p)\ (\sqrt{\Delta P_{s\ avg}})\ \sqrt{\frac{T_s avg + 460}{P_s \quad M_s}}$ $85.49\ (\_\_\_\_)(\sqrt{\quad})\ \sqrt{\frac{(\_\_\_\_) + 460}{(\_\_\_\_)(\_\_\_\_)}}$	$V_{s(avg)}$	
Total sample time (minutes)	θ	30
Nozzle diameter, actual (inches)	N_d	N/A
Percent isokinetic (%) $\frac{17.33\ (T_s + 460)(V_w\ std + V_m\ std)}{\theta \quad V_s \quad P_s \quad N_d^2}$ $\frac{17.33\ (\_\_\_\_ + 460)((\_\_\_\_) + (\_\_\_\_))}{(\_\_\_\_)(\_\_\_\_)(\_\_\_\_)(\_\_\_\_^2)}$	%I	N/A
Area of stack (ft^2) $\pi = 3.1416$ $\pi r^2 \div 144$, $\pi(\_\_\_\_)^2 \div 144$	A_s	
Stack gas volume at standard conditions (dscfm) $60\ (1 - B_{wo})Vs_{avg}\ A_s \left(\frac{528}{T_s\ avg + 460}\right) \left(\frac{Ps}{29.92}\right)$ $60\ (1 - \_\_\_)(\_\_\_)(\_\_\_)\left(\frac{528}{\_\_\_\_ + 460}\right) \left(\frac{(\_\_\_)}{(29.92)}\right)$	Q_s	
Particulate matter concentration, dry (gr/dscf) $15.432\ \frac{M_p(grams)}{Vm_{std}}$, $15.432\ \frac{(\_\_\_\_\_)}{(\_\_\_\_\_)}$	$C_{s(std)}$	
Emission rate of particulate matter (lb/hr) $0.00857\ (Q_s)\ C_{s(std)}$, $0.00857\ (\_\_\_\_\_)(\_\_\_\_\_)$	E_p	

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ACUREX CORPORATION

Run 2-NH_3 (OUTLET)

Acurex Project No. 30735.51
Field Dates 6-6/8-83
Plant HOOKER RENSCHO STORAGE STM.
Sampling Location ENG 3
Sampling Date 6-7-83

FIELD CREW

Crew Chief: BRUCE C. DeROS
Testing Engineer: 1 "
2 REGAN C. BEST
~~Engr.~~ CA Technician: 1 SHERMAN A. SMITH
2
3
Lab Technician: 1 GREG NICOLL
2
Process Engineer: 1 HOWARD B. MASON
2

FIELD SAMPLE REFERENCE NUMBERS:

819384

FIELD DATA

Plant Honor Rancho
Date 6-7-83
Sample Location Engine 3 Outlet
Sample Type NH3
Run Number 2
Operator Bob
Ambient Temperature
Barometric Pressure 28.62
Static Pressure, (H_2O)
Filter Number(s) N/A

Leak Check: Initial at 6 " Hg, .002 CFM
Final at 27 " Hg, .002 CFM
Pitot Leak Check:

+30 mL Rinse

Impinger Volumes

Initial	Final	Net Gain
100		
100	287	87
0		

Silica Gel

598.5	602.7	4.2

SASS Condensate
Total Volume 91.2

Probe Length and Type
Nozzel Size & I.D.
Pitot Coefficient & I.D.
Assumed Moisture
Molecular Weight, Dry, (M_d)
Meter Box Number DSS5 (NAPP)
Meter Coefficient
α Factor .9908
K =
$K(Md)^4$ = ___ x (___)^4 = ___
$\Delta H = K(M_d)^4 \left(\frac{Tm}{Ts}\right)$ (P)

Traverse Point Number	Clock Time (24-hr) Clock / Sampling Time, min	Gas Meter Reading (V_m), ft 3	Velocity Head (ΔP_s), in. H_2O	Orifice Pressure Differential (ΔH), in. H_2O		Temperature °F							Pump Vacuum in. Hg	Avg. $\sqrt{\Delta P}$
				Desired	Actual	Stack	Probe	Impinger	Organic Module	Oven	Gas Meter In	Gas Meter Out		
	1650	Init. 967.259												
	0.0	967.259			1.1	1020					85	85	4	
	5.0	970.38			1.1	1020					87	86	4	
	10.0	973.46			1.1	1027					87	86	4	
	15.0	976.48			1.1	1029					87	86	4	
	20.0	979.49			1.1	1030					88	87	4	
	25.0	982.51			1.1	1030					88	87	4	
	30.0	985.529												
	30	18.27			1.1	1026					86.6		4	

7602/5/81/Rev 1

Comments:

ISOKINETIC PERFORMANCE WORKSHEET & PARTICULATE CALCULATIONS

Plant Honor Rancho Performed by DiaRos

Date 6-7-83

Sample Location OUTLET

Test No./Type 2-NH_3

Barometric Pressure (in. Hg)	P_b	28.62
Meter volume (std), $17.64\left(\frac{V_m}{\alpha}\right)\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_m + 460}\right)$ $17.64\left(\frac{(18.27)}{(.9908)}\right)\left(\frac{(28.62) + \frac{(1.1)}{13.6}}{(86.6) + 460}\right)$	$V_{m\ std}$	17.089
Volume of liquid collected (grams)	Vl_c	91.2
Volume of liquid at standard condition (scf) $Vl_c \times 0.04707$	$V_{w\ std}$	4.293
Stack gas proportion of water vapor $\frac{V_{w\ std}}{V_{w\ std} + V_{m\ std}}$, $\frac{(4.293)}{(4.293) + (17.089)}$	B_{wo}	0.201
Molecular weight, stack gas dry (lb/lb-mole) $(\%\ CO_2 \times 0.44) + (\%\ O_2 \times 0.32) + (\%\ N_2 + \%\ CO \times 0.28)$ $(10.2 \times 0.44) + (.1 \times 0.32) + (89.7 + \_\_\_ \times 0.28)$	M_d	29.636
Molecular weight, stack gas wet (lb/lb-mole) $Md(1-B_{wo}) + 18(B_{wo})$, $(29.636)(1-.201) + 18(.201)$	M_s	27.30
Absolute stack pressure (in. Hg) $P_b + \frac{P_{stack}\ (\text{in. } H_2O)}{13.6}$, $28.62) + \frac{(.15)}{13.6}$	P_s	28.63

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Temperature stack gas, average (^{o}F)	T_s	1026
Stack velocity (fps) $85.49\ (C_p)\ (\sqrt{\Delta P_{s\ avg}})\ \sqrt{\frac{T_s avg + 460}{P_s \quad M_s}}$ $85.49\ (\_\_\_\_)(\quad)\ \sqrt{\frac{(\_\_\_\_) + 460}{(\_\_\_\_)(\_\_\_\_)}}$	$V_{s(avg)}$	
Total sample time (minutes)	θ	30
Nozzle diameter, actual (inches)	N_d	N/A
Percent isokinetic (%) $\frac{17.33\ (T_s + 460)(V_w\ std + V_m\ std)}{\theta \quad V_s \quad P_s \quad N_d^2}$ $\frac{17.33\ (\_\_\_\_ + 460)((\_\_\_\_) + (\_\_\_\_))}{(\_\_\_\_)(\_\_\_\_)(\_\_\_\_)(\_\_\_\_)^2}$	%I	N/A
Area of stack (ft^2) $\pi = 3.1416$ $\pi r^2 \div 144$, $\pi(\_\_\_\_)^2 \div 144$	A_s	
Stack gas volume at standard conditions (dscfm) $60\ (1 - B_{wo})Vs_{avg}\ A_s \left(\frac{528}{T_s\ avg + 460}\right) \left(\frac{Ps}{29.92}\right)$ $60\ (1 - \_\_\_)(\_\_\_)(\_\_\_)\left(\frac{528}{\_\_\_\_ + 460}\right) \left(\frac{(\_\_\_)}{(29.92)}\right)$	Q_s	
Particulate matter concentration, dry (gr/dscf) $15.432\ \frac{M_p(grams)}{Vm_{std}}$, $15.432\ \frac{(\_\_\_\_)}{(\_\_\_\_)}$	$C_{s(std)}$	
Emission rate of particulate matter (lb/hr) $0.00857\ (Q_s)\ C_{s(std)}$, $0.00857\ (\_\_\_\_)(\_\_\_\_)$	E_p	

3.4 OPERATING DATA TABLES FOR HCN SAMPLING TRAIN

ACUREX CORPORATION

Run 1 - HCN (INLET)

Acurex Project No. 3077351
Field Dates 6-6/8-83
Plant HOOKER RANCHO STORAGE STA.
Sampling Location ENGR 3
Sampling Date 6-7-83

FIELD CREW

Crew Chief: BRUCE C. DuRos
Testing Engineer: 1 " "
2 REGINA C. BEST
~~Engr~~ CM. Technician: 1 SHERMAN A. SMITH
2
3
Lab Technician: 1 GREG NICOLL
2
Process Engineer: 1 HOWARD B. MASON
2

FIELD SAMPLE REFERENCE NUMBERS:

~~819389~~ VOID

819356

819390

FIELD DATA

Plant Hanna Rancho
Date 6-7-83
Sample Location Inlet
Sample Type HCN
Run Number 1
Operator B.C. DaRos
Ambient Temperature ~76°F
Barometric Pressure 28.62
Static Pressure, (H_2O)
Filter Number(s) N/A

Leak Check: Initial at 6 Hg, .002 CFM
Final at 6 Hg, .002 CFM
Pitot Leak Check: N/A

+ 64.0 Rinse

Impinger Volumes

Initial	Final	Net Gain
100		
100	276	76

Silica Gel

585.0	591.4	6.4

SASS Condensate
Total Volume 82.4

Probe Length and Type SS
Nozzle Size & I.D. N/A
Pitot Coefficient & I.D. N/A
Assumed Moisture
Molecular Weight, Dry, (M_d)
Meter Box Number DS56
Meter Coefficient
α Factor .9995
K =
$K(Nd)^4$ = ___ x (___)^4 = ___
$\Delta H = K(N_d)^4 \left(\frac{Tm}{Ts}\right)$ (P)

Traverse Point Number	Clock Time (24-hr) Clock / Sampling Time, min	Gas Meter Reading (V_m), ft 3	Velocity Head (ΔP_s), in. H_2O	Orifice Pressure Differential (ΔH), in. H_2O Desired	Orifice Pressure Differential (ΔH), in. H_2O Actual	Temperature °F Stack	Probe	Impinger	Organic Module	Oven	Gas Meter In	Gas Meter Out	Pump Vacuum in. Hg	Avg. $\sqrt{\Delta P}$
	1450 / 0	Init. 295.854												
	10	301.61			1.0	996					69	71	2.5	
	20	307.22			1.0	997					71	70	2.5	
	30	313.170			1.0	996					71	71	2.5	
	30 —	17.316			1.0	996.3					70.5		2.5	

7602/5/81/Rev 1

Comments:

ISOKINETIC PERFORMANCE WORKSHEET & PARTICULATE CALCULATIONS

Plant Honor Rancho — Performed by D.A.Ros

Date 6-7-83

Sample Location INLET

Test No./Type 1 - HCN

Barometric Pressure (in. Hg)	P_b	28.62
Meter volume (std), $17.64 \left(\frac{V_m}{\alpha}\right)\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_m + 460}\right)$ $17.64 \left(\frac{(17.316)}{(.9995)}\right)\left(\frac{(28.62) + \frac{(1.0)}{13.6}}{(70.5) + 460}\right)$	$V_{m\ std}$	16.539
Volume of liquid collected (grams)	Vl_c	82.4
Volume of liquid at standard condition (scf) $Vl_c \times 0.04707$	$V_{w\ std}$	3.879
Stack gas proportion of water vapor $\frac{V_{w\ std}}{V_{w\ std} + V_{m\ std}}$, $\frac{(.190)}{(.190) + (16.539)}$	B_{wo}	0.190
Molecular weight, stack gas dry (lb/lb-mole) (% CO_2 x 0.44) + (% O_2 x 0.32) + (% N_2 + % CO x 0.28) (10.2 x 0.44) + (0.1 x 0.32) + (89.7 + ____ x 0.28)	M_d	29.636
Molecular weight, stack gas wet (lb/lb-mole) $Md(1-B_{wo}) + 18(B_{wo})$, (29.636)(1- .190) + 18(.190)	M_s	27.43
Absolute stack pressure (in. Hg) $P_b + \frac{P_{stack}\ (in.\ H_2O)}{13.6}$, $(28.62) + \frac{(.15)}{13.6}$	P_s	28.63

Temperature stack gas, average (^{o}F)	T_s	996
Stack velocity (fps) $85.49\ (C_p)\ (\sqrt{\Delta P_{s\ avg}})\ \sqrt{\frac{T_s avg + 460}{P_s\ M_s}}$ $85.49\ (\_\_\_\_)(\sqrt{\_\_\_\_})\ \sqrt{\frac{(\_\_\_\_) + 460}{(\_\_\_\_)(\_\_\_\_)}}$	$V_{s(avg)}$	
Total sample time (minutes)	θ	30
Nozzle diameter, actual (inches)	N_d	N/A
Percent isokinetic (%) $\frac{17.33\ (T_s + 460)(V_w\ std + V_m\ std)}{\theta\ \ V_s\ \ P_s\ \ N_d^2}$ $\frac{17.33\ (\_\_\_\_ + 460)((\_\_\_\_) + (\_\_\_\_))}{(\_\_\_\_)(\_\_\_\_)(\_\_\_\_)(\_\_\_\_^2)}$	%I	N/A
Area of stack (ft^2) $\pi = 3.1416$ $\pi r^2 \div 144$, $\pi(\_\_\_\_)^2 \div 144$	A_s	
Stack gas volume at standard conditions (dscfm) $60\ (1 - B_{wo})Vs_{avg}\ A_s \left(\frac{528}{T_s\ avg + 460}\right) \left(\frac{Ps}{29.92}\right)$ $60\ (1 - \_\_\_)(\_\_\_)(\_\_\_)\left(\frac{528}{\_\_\_\_ + 460}\right) \left(\frac{(\_\_\_)}{(29.92)}\right)$	Q_s	
Particulate matter concentration, dry (gr/dscf) $15.432\ \frac{M_p(grams)}{Vm_{std}}$, $15.432\ \frac{(\_\_\_\_)}{(\_\_\_\_)}$	$C_{s(std)}$	
Emission rate of particulate matter (lb/hr) $0.00857\ (Q_s)\ C_{s(std)}$, $0.00857\ (\_\_\_\_)(\_\_\_\_)$	E_p	

7602/5/81/Rev 1

ACUREX CORPORATION

Run 1- HCN (OUTLET)

Acurex Project No. 307735.51
Field Dates 6-6/8-83
Plant HONOR RANCHO STORAGE SM.
Sampling Location ENGR 3
Sampling Date 6-7-83

FIELD CREW

Crew Chief: BRUCE C. DaROS
Testing Engineer: 1 " "
C.M. 2 REGAN C. BEST
~~Engr~~. Technician: 1 SHERMAN A. SMITH
2
3
Lab Technician: 1 GREG NICOLL
2
Process Engineer: 1 HOWARD B. MASON
2

FIELD SAMPLE REFERENCE NUMBERS:

819391

FIELD DATA

Plant Hooker Rancho
Date 6-7-83
Sample Location OUTLET
Sample Type HCN
Run Number 1
Operator R.C. DaRos
Ambient Temperature 78°F
Barometric Pressure 28.62
Static Pressure, (H_2O)
Filter Number(s) N/A

Leak Check: Initial at 6 " Hg, .002 CFM
Final at 4 " Hg, .005 CFM
Pitot Leak Check: N/A

† 74.0 Rinse

Impinger Volumes

Initial	Final	Net Gain
100		
100	262	82
0		

Silica Gel

570.0	578.2	8.2

SASS Condensate
Total Volume 90.2

Probe Length and Type SS
Nozzel Size & I.D. N/A
Pitot Coefficient & I.D. N/A
Assumed Moisture
Molecular Weight, Dry, (M_d)
Meter Box Number DGS5
Meter Coefficient
α Factor .9908
K =
$K(Nd)^4$ = ___ x (___)^4 = ___

$\Delta H = K(N_d)^4 \left(\frac{Tm}{Ts}\right)^2 (P)$

Traverse Point Number	Clock Time (24-hr) Clock / Sampling Time, min	Gas Meter Reading (V_m), ft 3	Velocity Head (ΔP_s), in. H_2O	Orifice Pressure Differential (ΔH), in. H_2O Desired	Orifice Pressure Differential (ΔH), in. H_2O Actual	Temperature °F Stack	Probe	Impinger	Organic Module	Oven	Gas Meter In	Gas Meter Out	Pump Vacuum in. Hg	Avg. $\sqrt{\Delta P}$
	1450 / 0.0	Init. 948.926												
	0.0	948.926			1.1	103					84	88	3	
	5.0	952.06			1.1						86	87	3	
	10.0	955.90			1.1						87	86	3	
	15.0	958.17			1.1						88	87	3	
	20.0	961.22			1.1	1032					89	88	3	
	25.0	964.18			1.1	1037					90	89	3	
	30.0 End	967.195												
	30 —	16.269			1.1	1032					97.4		3	

7602/5/81/Rev 1

Comments:

ISOKINETIC PERFORMANCE WORKSHEET & PARTICULATE CALCULATIONS

Plant Hanford Rancho — Performed by Dan Ros

Date 6-7-83

Sample Location OUTLET

Test No./Type 1-HCN

Barometric Pressure (in. Hg)	P_b	28.62
Meter volume (std), $17.64 \left(\frac{V_m}{\alpha}\right)\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_m + 460}\right)$ $17.64 \left(\frac{(18.269)}{(.9908)}\right)\left(\frac{(28.62) + \frac{(1.1)}{13.6}}{(87.4) + 460}\right)$	$V_{m\ std}$	17.063
Volume of liquid collected (grams)	Vl_c	90.2
Volume of liquid at standard condition (scf) Vl_c x 0.04707	$V_{w\ std}$	4.246
Stack gas proportion of water vapor $\frac{V_{w\ std}}{V_{w\ std} + V_{m\ std}}$, $\frac{(4.206)}{(4.206) + (17.063)}$	B_{wo}	0.199
Molecular weight, stack gas dry (lb/lb-mole) (% CO_2 x 0.44) + (% O_2 x 0.32) + (% N_2 + % CO x 0.28) (10.2 x 0.44) + (.1 x 0.32) + (89.7 + ____ x 0.28)	M_d	29.636
Molecular weight, stack gas wet (lb/lb-mole) $Md(1-B_{wo}) + 18(B_{wo})$, (29.636)(1-.199) + 18(.199)	M_s	27.32
Absolute stack pressure (in. Hg) $P_b + \frac{P_{stack}\ (in.\ H_2O)}{13.6}$, $(28.62) + \frac{(.15)}{13.6}$	P_s	28.63

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Temperature stack gas, average (^{o}F)	T_s	1032
Stack velocity (fps) $85.49\ (C_p)\ (\sqrt{\Delta P_{s\ avg}})\ \sqrt{\frac{T_s avg + 460}{P_s \quad M_s}}$ $85.49\ (\_\_\_\_)(\sqrt{\quad})\ \sqrt{\frac{(\_\_\_\_) + 460}{(\_\_\_\_)(\_\_\_\_)}}$	$V_{s(avg)}$	
Total sample time (minutes)	θ	30
Nozzle diameter, actual (inches)	N_d	N/A
Percent isokinetic (%) $\frac{17.33\ (T_s + 460)(V_w\ std + V_m\ std)}{\theta \quad V_s \quad P_s \quad N_d^2}$ $\frac{17.33\ (\_\_\_\_ + 460)((\_\_\_\_) + (\_\_\_\_))}{(\_\_\_\_)(\_\_\_\_)(\_\_\_\_)(\_\_\_\_^2)}$	%I	N/A
Area of stack (ft^2) $\pi = 3.1416$ $\pi r^2 \div 144$, $\pi(\_\_\_\_)^2 \div 144$	A_s	
Stack gas volume at standard conditions (dscfm) $60\ (1 - B_{wo})Vs_{avg}\ A_s \left(\frac{528}{T_s\ avg + 460}\right) \left(\frac{Ps}{29.92}\right)$ $60\ (1 - \_\_\_)(\_\_\_)(\_\_\_)\left(\frac{528}{\_\_\_\_ + 460}\right) \left(\frac{(\_\_\_)}{(29.92)}\right)$	Q_s	
Particulate matter concentration, dry (gr/dscf) $15.432\ \frac{M_p(grams)}{Vm_{std}}$, $15.432\ \frac{(\_\_\_\_)}{(\_\_\_\_)}$	$C_{s(std)}$	
Emission rate of particulate matter (lb/hr) $0.00857\ (Q_s)\ C_{s(std)}$, $0.00857\ (\_\_\_\_)(\_\_\_\_)$	E_p	

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SECTION 4

ANALYTICAL RESULTS

4.1 AMMONIA, CYANIDE, AND N_2O ANALYSES AND PARTICULATE WEIGHTS

4.2 TRACE ELEMENT ANALYSIS RESULTS

4.3 TOTAL CHROMATOGRAPHABLE ORGANICS (TCO), GRAVIMETRIC ORGANICS (GRAV), INFRARED (IR) SPECTRA, AND GAS CHROMATOGRAPHY/MASS SPECTROMETRY (GC/MS) OF TOTAL SAMPLE EXTRACTS

4.4 LIQUID CHROMATOGRAPHY (LC) SEPARATION OF THE INLET XAD-2 EXTRACT WITH TCO, GRAV, AND IR ANALYSIS OF LC FRACTIONS

4.5 BIOASSAY RESULTS

4.6 NATURAL GAS FUEL ANALYSIS

4.1 AMMONIA, CYANIDE, AND N_2O ANALYSES AND PARTICULATE WEIGHTS

ACUREX Corporation

Energy & Environmental Division

Acurex

August 30, 1983
Acurex ID#: 8308-039
Client PO#: 307736.52

Attention: Larry Waterland

Subject: Honor Rancho Ammonia and Cyanide Determinations; received 8/24/83.

The above samples were analyzed for ammonia by EPA Method 350.2 (colorimetric) or for total cyanide by EPA Method 335.2 (spectrophotometric). Results are presented below.

Sample #	Description	Volume, mL ± 5 mL	Ammonia, mg as NH_3	Total Cyanide, mg
819359	NH_3 Blank	305	0.02	--
819387	NH_3 Inlet	340	10	--
819388	NH_3 Outlet	300	150	--
819384	NH_3 Outlet, Run #2	310	180	--
819356	HCN Blank	380	--	<0.002
819390	HCN Inlet	340	--	0.006
819391	HCN Outlet	360	--	2.8

Prepared by: Stephen Guinnane
Stephen Guinnane
Analyst

Approved by: Greg Nicoll
Greg Nicoll
Manager, Inorganic Chemistry

SG/GN/ats

555 Clyde Avenue, P.O. Box 7555, Mountain View, CA 94039 (415) 964-3200 Telex: 34-6391 TWX: 910-7796593

ACUREX Corporation

Energy & Environmental Division

Acurex/ES

July 26, 1983
Acurex ID#: 8306-068
Client PO#: 307736.52

Attention: Larry Waterland

Subject: Analysis of Four Gas Bombs for N_2O by GC/ECD.

The above referenced samples were analyzed by GC/ECD using the CMEA procedure in Section 9 except for the following: the column used was a 10' x 1/8" stainless steel column packed with 80/100 mesh Chromosorb 101; the flow was 20 ml/min, and the temperature was 45°C isothermal.

Results are listed in the table below.

Sample ID #	Test #	ppm N_2O
819350	1	46
819351	2	15
819352	3	150
819353	4	54

If you have any questions, please call.

Prepared by: William G. Hellier
William G. Hellier
Staff Chemist

Approved by: Viorica Lopez-Avila
Viorica Lopez-Avila, Ph.D.
Technical Director

WGH/VLA/ats

555 Clyde Avenue, P.O. Box 7555, Mountain View, CA 94039 (415) 964-3200 Telex: 34-6391 TWX: 910-7796593

ACUREX Corporation
ANALYSIS LABORATORIES

DATA REPORTING FORM

CUSTOMER CMEA
DATE November 14, 1983
CUSTOMER CONTRACT NO. 307736.52
ACUREX CONTRACT NO. 8306-050
RESULTS REPORT TO L. Waterland
TELEPHONE
ADDRESS
Honor Rancho

SAMPLE ID (CUSTOMER)	365	366	367	363	364	378	379	381	382	
SAMPLE ID (LAB)	Filter Blank	Filter In	Filter Out	Probe In	Probe Out	Imp 1 In	Imp 1 Out	Imp 2 & 3 In	Imp 2 & 3 Out	
PARAMETER										UNITS
Filter and ash weight	0.9970	1.0264	1.0326	--	--	--	--	--	--	gram
Probe, Nozzle, hose weight	--	--	--	0.0022	0.0045	--	--	--	--	gram
Impinger and Rinse Volume	--	--	--	--	--	2775	2960	1750	2575	ml

ANALYST S. Guinnane
REVIEWER Greg Driscoll

Form EED-057 4/80

4.2 TRACE ELEMENT ANALYSIS RESULTS

COMMERCIAL TESTING & ENGINEERING CO.

Reply to
Instrument Analysis Division
490 Orchard Street
Golden, CO 80401

Phone: 303-278-9521

September 30, 1983

Mr. Christopher Mann
Acurex Corporation
P.O. Box 7555
Mountian View, CA 94039

RE: IAD #97-M661-116-14
Acurex Project 7601
Subcontract SW59159A
Release No. 9

Analytical Report

Fourteen samples were received for analysis on September 13, 1983. These samples were assigned our IAD identification #97-M661-116-14.

Trace element determinations using Spark Source Mass Spectrometry per EPA level 1 protocol will be reported in separate reports upon completion of analysis.

Arsenic and Antimony were determined on three of the samples using hydride generation atomic absorption spectrophotometry. Mercury was determined on all fourteen samples using flameless cold vapor atomic absorption spectrophotometry.

The results of these determinations are presented in Table No. I and No. II and are reported in parts per million (ppm) by weight on an "as received" basis.

Table No. I
(ppm by Weight)

Sample ID	Arsenic (As)	Antimony (Sb)
819381 HR Imp 2 & 3, Inlet	≤0.04	≤0.04
819382 HR Imp 2 & 3, Outlet	≤0.04	≤0.04
810380 HR Imp 2 & 3, Blank	≤0.04	≤0.04

GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, IL 60148 AREA CODE 312 953-5300
OVER 40 BRANCH LABORATORIES STRATEGICALLY LOCATED IN PRINCIPAL COAL MINING AREAS, TIDEWATER AND GREAT LAKES PORTS, AND RIVER LOADING FACILITIES

Charter Member

Table No. II
(ppm by Weight)

Sample ID	Mercury (Hg)
819366 HR Filter, Inlet	0.125
819367 HR Filter, Outlet	0.140
819365 HR Filter, Blank	0.028
819369 HR XAD-2, Inlet	0.042
819370 HR XAD-2, Outlet	0.040
819368 HR XAD-2, Blank	0.024
819378 HR Imp 1, Inlet	≤0.0002
819379 HR Imp 1, Outlet	0.0003
819394 DE Imp 1	0.0004
819377 HR Imp 1 Blank	≤0.0002
819360 HR Lube Oil	0.062
819381 HR Imp 2 & 3, Inlet	0.0016
819382 HR Imp 2 & 3, Outlet	≤0.0002
819380 HR Imp 2 & 3, Blank	≤0.0002

If you have any questions concerning these results, please call.

Harold A. Connell
Assistant Laboratory Manager

Robert L. Taylor, Ph.D., Mngr. 30 Sep 83.
Instrumental Analysis Division

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For Your Protection

COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, ILLINOIS 60148 AREA CODE 312 953-9300
Reply to
INSTRUMENTAL ANALYSIS DIVISION, 490 ORCHARD STREET, GOLDEN, COLORADO 80401, PHONE: 303 278-9521

To: Mr. Christopher Mann
Acurex Corporation
P.O. Box 7555
Mountain View, CA 94039

Date: October 24, 1983

AMENDED ANALYTICAL REPORT

Analyst: J. Oldham

P. O. No.: Subcontract SW59159A Release 9

Sample No.: 819360 Lube Oil

IAD No.: 97-M661-116-14

SPARK SOURCE MASS SPECTROGRAPHIC ANALYSIS
CONCENTRATION IN PPM WEIGHT

ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.
Uranium		Terbium		Ruthenium		Vanadium	0.2
Thorium		Gadolinium		Molybdenum	1	Titanium	≤0.2
Bismuth	0.2	Europium		Niobium		Scandium	≤0.1
Lead	2	Samarium		Zirconium	0.5	Calcium	MC
Thallium		Neodymium		Yttrium		Potassium	20
Mercury	*0.062	Praseodymium		Strontium	10	Chlorine	10
Gold		Cerium		Rubidium		Sulfur	>560
Platinum	**0.4	Lanthanum		Bromine		~~Phosphorus~~	620
Iridium		Barium	970	Selenium	2	Silicon	30
Osmium		Cesium		Arsenic		~~Aluminum~~	5
Rhenium		Iodine	0.2	Germanium		Magnesium	4
Tungsten		Tellurium		Gallium		Sodium	30
Tantalum		Antimony		Zinc	260	Fluorine	≈5
Hafnium		Tin		Copper	1	Oxygen	NR
Lutetium		Indium	STD	Nickel	2	Nitrogen	NR
Ytterbium		Cadmium		Cobalt	≤0.2	Carbon	NR
Thulium		Silver		Iron	5	Boron	0.1
Erbium		Palladium		Manganese	1	Beryllium	
Holmium		Rhodium		Chromium	≤0.2	Lithium	0.3
Dysprosium						Hydrogen	NR

*Flameless Atomic Absorption
**Possible Contamination

STD — Internal Standard
NR — Not Reported
All elements not detected < 0.1 ppm
MC — Major Component > 1000 ppm
INT — Interference

4-9

Approved: Charles R. Wilson

COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, ILLINOIS 60148 AREA CODE 312 953-9300

Reply to INSTRUMENTAL ANALYSIS DIVISION, 490 ORCHARD STREET, GOLDEN, COLORADO 80401, PHONE: 303 278-9521

To: Mr. Christopher Mann
Acurex Corporation
P.O. Box 7555
Mountain View, CA 94039

Date: Oct. 24, 1983

Subcontract #SW59159A
Release 9
P. O. No.:

Analyst: Jim Oldham

AMENDED ANALYTICAL REPORT

Sample No.: 819369
XAD-2 Inlet

SPARK SOURCE MASS SPECTROGRAPHIC ANALYSIS

IAD No.: 97-M661-116-14

CONCENTRATION IN PPM WEIGHT

ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.
Uranium		Terbium		Ruthenium		Vanadium	0.2
Thorium		Gadolinium		Molybdenum	2	Titanium	0.2
Bismuth		Europium		Niobium		Scandium	
Lead	0.5	Samarium		Zirconium	0.4	Calcium	160
Thallium		Neodymium		Yttrium		Potassium	35
Mercury	*0.042	Praseodymium		Strontium	0.5	Chlorine	5
Gold		Cerium	2	Rubidium		Sulfur	20
Platinum	**4	Lanthanum	3	Bromine	0.5	Phosphorus	5
Iridium		Barium	5	Selenium		Silicon	20
Osmium		Cesium	≤0.1	Arsenic	<0.1	Aluminum	5
Rhenium		Iodine	0.5	Germanium		Magnesium	5
Tungsten		Tellurium		Gallium	0.4	Sodium	15
Tantalum		Antimony		Zinc	1	Fluorine	≈5
Hafnium		Tin		Copper	4	Oxygen	NR
Lutetium		Indium	STD	Nickel	2	Nitrogen	NR
Ytterbium		Cadmium		Cobalt	3	Carbon	NR
Thulium		Silver		Iron	10	Boron	<0.1
Erbium		Palladium		Manganese	0.2	Beryllium	
Holmium		Rhodium		Chromium	2	Lithium	0.2
Dysprosium						Hydrogen	NR

*Flameless Atomic Absorption
**Probable Contamination

STD — Internal Standard
NR — Not Reported
All elements not detected < 0.1 ppm
MC — Major Component >1000 ppm
INT — Interference

4-10

Approved: Charles R. Wilson

COMMERCIAL TESTING & ENGINEERING CO.

Reply to GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, ILLINOIS 60148 AREA CODE 312 953-9300
INSTRUMENTAL ANALYSIS DIVISION, 490 ORCHARD STREET, GOLDEN, COLORADO 80401, PHONE: 303 278-9521

To: Mr. Christopher Mann
Acurex Corporation
P.O. Box 7555
Mountain View, CA 94039

Date: October 24, 1983

P. O. No.: Subcontract SW59159A Release 9

AMENDED ANALYTICAL REPORT

Analyst: J. Oldham

Sample No.: 819370 XAD-2 Outlet

SPARK SOURCE MASS SPECTROGRAPHIC ANALYSIS

IAD No.: 97-M661-116-14

CONCENTRATION IN PPM WEIGHT

ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.
Uranium		Terbium		Ruthenium		Vanadium	0.5
Thorium		Gadolinium		Molybdenum	1	Titanium	2
Bismuth		Europium		Niobium		Scandium	
Lead	1	Samarium		Zirconium	1	Calcium	80
Thallium		Neodymium		Yttrium		Potassium	15
Mercury	*0.040	Praseodymium		Strontium	0.5	Chlorine	5
Gold		Cerium	0.5	Rubidium		Sulfur	10
Platinum	**0.5	Lanthanum	0.4	Bromine	0.5	Phosphorus	10
Iridium		Barium	4	Selenium	0.5	Silicon	280
Osmium		Cesium	≤0.1	Arsenic	<0.1	Aluminum	5
Rhenium		Iodine	0.5	Germanium		Magnesium	15
Tungsten		Tellurium		Gallium	0.1	Sodium	15
Tantalum		Antimony		Zinc	4	Fluorine	***≤20
Hafnium		Tin		Copper	10	Oxygen	NR
Lutetium		Indium	STD	Nickel	MC	Nitrogen	NR
Ytterbium		Cadmium		Cobalt	1	Carbon	NR
Thulium		Silver		Iron	85	Boron	<0.1
Erbium		Palladium		Manganese	5	Beryllium	
Holmium		Rhodium		Chromium	160	Lithium	0.2
Dysprosium						Hydrogen	NR

*Flameless Atomic Absorption
**Probable Contamination
***Heterogeneous

STD — Internal Standard
NR — Not Reported
All elements not detected < 0.1 ppm
MC — Major Component > 1000 ppm
INT — Interference

4-11 Approved: Charles R. Wilson

L. Waterland 2-2260

COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, ILLINOIS 60148 AREA CODE 312 953-9300
Reply to INSTRUMENTAL ANALYSIS DIVISION, 490 ORCHARD STREET, GOLDEN, COLORADO 80401, PHONE: 303 278-9521

To: Mr. Christopher Mann
Acurex Corporation
P.O. Box 7555
Mountain View, CA

Date: Oct. 24, 1983

Analyst: Jim Oldham

P. O. No.: Subcontract SW59159A
Release 9

Sample No.: 819368
XAD-2 Blank

IAD No.: 97-M661-116-14

AMENDED ANALYTICAL REPORT
SPARK SOURCE MASS SPECTROGRAPHIC ANALYSIS
CONCENTRATION IN PPM WEIGHT

ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.
Uranium		Terbium		Ruthenium		Vanadium	0.3
Thorium		Gadolinium		Molybdenum	0.5	Titanium	5
Bismuth		Europium		Niobium		Scandium	
Lead	1	Samarium		Zirconium	0.4	Calcium	80
Thallium		Neodymium		Yttrium		Potassium	4
Mercury	*0.024	Praseodymium		Strontium	0.4	Chlorine	10
Gold		Cerium	0.4	Rubidium		Sulfur	10
→ Platinum	**4	Lanthanum	0.5	Bromine	1	Phosphorus	5
Iridium		Barium	5	Selenium	≤0.2	Silicon	10
Osmium		Cesium	≤0.1	Arsenic	<0.1	Aluminum	5
Rhenium		Iodine	0.5	Germanium		Magnesium	5
Tungsten		Tellurium		Gallium	0.3	Sodium	5
Tantalum		Antimony		Zinc	1	Fluorine	≈5
Hafnium		Tin		Copper	2	Oxygen	NR
Lutetium		Indium	STD	Nickel	5	Nitrogen	NR
Ytterbium		Cadmium		Cobalt	≤0.1	Carbon	NR
Thulium		Silver		Iron	10	Boron	<0.1
Erbium		Palladium		Manganese	0.2	Beryllium	
Holmium		Rhodium		Chromium	3	Lithium	0.1
Dysprosium						Hydrogen	NR

* Flameless Atomic Absorption
** Probable Contamination

STD — Internal Standard
NR — Not Reported
All elements not detected < 0.1 ppm
MC — Major Component >1000 ppm
INT — Interference

4-12 Approved: Charles R. Wilson

COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, ILLINOIS 60148 AREA CODE 312 953-9300

Reply to INSTRUMENTAL ANALYSIS DIVISION, 490 ORCHARD STREET, GOLDEN, COLORADO 80401, PHONE: 303 278-9521

To: Mr. Christopher Mann
Acurex Corporation
555 Clyde Avenue
P.O. Box 7555
Mountain View, CA 94039

Date: October 18, 1983

Analyst: J. Oldham

P. O. No.: Subcontract SW59159A Project #7601

Sample No.: 819366
HR Filter, Inlet

SPARK SOURCE MASS SPECTROGRAPHIC ANALYSIS
CONCENTRATION IN PPM WEIGHT of filter

IAD No.: 97-M661-116-14

ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.
Uranium	0.3	Terbium		Ruthenium	≤0.01	Vanadium	3
Thorium	0.4	Gadolinium		Molybdenum	21	Titanium	>100
Bismuth	0.07	Europium		Niobium	1	Scandium	0.2
Lead	4	Samarium		Zirconium	6	Calcium	>100
Thallium		Neodymium	0.1	Yttrium	0.3	Potassium	>100
Mercury	*0.125	Praseodymium	0.2	Strontium	59	Chlorine	>100
Gold	INT	Cerium	1	Rubidium	0.08	Sulfur	>57
Platinum		Lanthanum	1	Bromine	2	Phosphorus	>100
Iridium		Barium	>100	Selenium	0.9	Silicon	>100
Osmium		Cesium	0.01	Arsenic	5	Aluminum	>9
Rhenium		Iodine	0.4	Germanium	0.05	Magnesium	>100
Tungsten	9	Tellurium	0.03	Gallium	1	Sodium	>23
Tantalum		Antimony	0.2	Zinc	>100	Fluorine	>100
Hafnium	0.2	Tin	0.4	Copper	6	Oxygen	NR
Lutetium		Indium	STD	Nickel	21	Nitrogen	NR
Ytterbium		Cadmium	0.07	Cobalt	>100	Carbon	NR
Thulium		Silver	4	Iron	>100	Boron	>100
Erbium		Palladium	0.07	Manganese	3	Beryllium	<0.01
Holmium		Rhodium	**0.8	Chromium	>100	Lithium	0.3
Dysprosium						Hydrogen	NR

*Flameless Atomic Absorption
**Heterogeneous

STD — Internal Standard
NR — Not Reported
All elements not detected < 0.01 µg/g of filter
MC — Major Component > 100 µg/g of filter
INT — Interference

Approved: Charles R. Wilson
4-13

COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, ILLINOIS 60148 AREA CODE 312 953-9300
Reply to
INSTRUMENTAL ANALYSIS DIVISION, 490 ORCHARD STREET, GOLDEN, COLORADO 80401, PHONE: 303 278-9521

To: Mr. Christopher Mann
Acurex Corporation
555 Clyde Avenue
P.O. Box 7555
Mountain View, CA 94039

Date: October 18, 1983

Analyst: J. Oldham

P. O. No.: Subcontract SW59159A Project #7601

Sample No.: 819367
HR Filter, Outlet

SPARK SOURCE MASS SPECTROGRAPHIC ANALYSIS

IAD No.: 97-M661-116-14

CONCENTRATION IN PPM WEIGHT of filter

ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.
Uranium	0.2	Terbium		Ruthenium	≤0.03	Vanadium	4
Thorium	0.6	Gadolinium		Molybdenum	7	Titanium	>100
Bismuth	0.3	Europium		Niobium	1	Scandium	0.8
Lead	11	Samarium	≤0.07	Zirconium	9	Calcium	>100
Thallium		Neodymium	0.4	Yttrium	0.4	Potassium	>100
Mercury	*0.140	Praseodymium	0.2	Strontium	53	Chlorine	>100
Gold	INT	Cerium	2	Rubidium	0.1	Sulfur	>82
Platinum		Lanthanum	1	Bromine	5	Phosphorus	>100
Iridium		Barium	>100	Selenium	1	Silicon	>100
Osmium		Cesium	<0.01	Arsenic	18	Aluminum	>13
Rhenium		Iodine	2	Germanium	0.07	Magnesium	>100
Tungsten	7	Tellurium	0.02	Gallium	1	Sodium	>34
Tantalum	0.1	Antimony	0.4	Zinc	>100	Fluorine	>100
Hafnium	0.3	Tin	1	Copper	40	Oxygen	NR
Lutetium		Indium	STD	Nickel	24	Nitrogen	NR
Ytterbium		Cadmium	2	Cobalt	>100	Carbon	NR
Thulium		Silver	2	Iron	>100	Boron	>100
Erbium		Palladium	0.4	Manganese	7	Beryllium	<0.01
Holmium		Rhodium	0.3	Chromium	>100	Lithium	0.8
Dysprosium						Hydrogen	NR

*Flameless Atomic Absorption

STD — Internal Standard
NR — Not Reported
All elements not detected < 0.01 µg/g of filter
MC — Major Component > 100 µg/g of filter
INT — Interference

Approved: Charles R. Wilson
4-14

COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, ILLINOIS 60148 AREA CODE 312 953-9300
Reply to
INSTRUMENTAL ANALYSIS DIVISION, 490 ORCHARD STREET, GOLDEN, COLORADO 80401, PHONE: 303 278-9521

To: Mr. Christopher Mann
Acurex Corporation
555 Clyde Avenue
P.O. Box 7555
Mountain View, CA 94039

Date: October 18,1983

Analyst: J. Oldham

P. O. No.: Subcontract SW59159A Project #7601

Sample No.: 819365
HR Filter Blank

SPARK SOURCE MASS SPECTROGRAPHIC ANALYSIS

IAD No.: 97-M661-116-14

CONCENTRATION IN PPM WEIGHT of filter

ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.
Uranium	0.09	Terbium		Ruthenium		Vanadium	1
Thorium	0.1	Gadolinium		Molybdenum	0.3	Titanium	>100
Bismuth		Europium		Niobium	0.7	Scandium	0.3
Lead	0.2	Samarium	≤0.1	Zirconium	9	Calcium	>100
Thallium		Neodymium	≤0.07	Yttrium	0.2	Potassium	81
Mercury	*0.028	Praseodymium	0.2	Strontium	5	Chlorine	>100
Gold		Cerium	0.8	Rubidium	0.05	Sulfur	>82
Platinum		Lanthanum	0.6	Bromine	1	Phosphorus	23
Iridium		Barium	63	Selenium	0.3	Silicon	>100
Osmium		Cesium		Arsenic	0.7	Aluminum	>13
Rhenium		Iodine	0.3	Germanium	0.01	Magnesium	>100
Tungsten		Tellurium	0.02	Gallium	0.4	Sodium	>34
Tantalum		Antimony	≤0.03	Zinc	2	Fluorine	≈46
Hafnium		Tin	0.1	Copper	0.4	Oxygen	NR
Lutetium		Indium	STD	Nickel	0.05	Nitrogen	NR
Ytterbium		Cadmium	≤0.04	Cobalt	0.1	Carbon	NR
Thulium		Silver	0.06	Iron	32	Boron	>100
Erbium		Palladium		Manganese	0.7	Beryllium	<0.01
Holmium		Rhodium		Chromium	2	Lithium	0.4
Dysprosium		*Flameless Atomic Absorption				Hydrogen	NR

STD — Internal Standard
NR — Not Reported
All elements not detected <0.01 µg/g of filter
MC — Major Component >100 µg/g of filter
INT — Interference

Approved: Charles R. Wilson

4-15

COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, ILLINOIS 60148 AREA CODE 312 953-9300

Reply to INSTRUMENTAL ANALYSIS DIVISION, 490 ORCHARD STREET, GOLDEN, COLORADO 80401, PHONE: 303 278-9521

To: Mr. Christopher Mann
Acurex Corporation
555 Clyde Avenue
P.O. Box 7555
Mountain View, CA 94039

Date: October 18, 1983

Analyst: J. Oldham

P. O. No.: Subcontract SW59159A Project #7601

Sample No.: 813378
HR Imp 1, Inlet

SPARK SOURCE MASS SPECTROGRAPHIC ANALYSIS
CONCENTRATION IN µg/mL

IAD No.: 97-M661-116-14

ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.
Uranium		Terbium		Ruthenium		Vanadium	<0.001
Thorium		Gadolinium		Molybdenum	0.04	Titanium	0.07
Bismuth		Europium		Niobium	0.03	Scandium	
Lead	0.01	Samarium		Zirconium	0.004	Calcium	0.8
Thallium		Neodymium		Yttrium		Potassium	0.9
Mercury	* ≤0.0002	Praseodymium		Strontium	0.003	Chlorine	0.03
Gold		Cerium	0.002	Rubidium		Sulfur	>4
Platinum		Lanthanum	0.006	Bromine	0.005	Phosphorus	0.1
Iridium		Barium	0.03	Selenium	0.05	Silicon	0.5
Osmium		Cesium		Arsenic	<0.001	Aluminum	0.07
Rhenium		Iodine	0.006	Germanium		Magnesium	0.2
Tungsten	1	Tellurium		Gallium	0.002	Sodium	>1
Tantalum		Antimony		Zinc	0.2	Fluorine	≅0.5
Hafnium		Tin	≤0.001	Copper	0.06	Oxygen	NR
Lutetium		Indium	STD	Nickel	0.002	Nitrogen	NR
Ytterbium		Cadmium		Cobalt	<0.001	Carbon	NR
Thulium		Silver	0.01	Iron	0.08	Boron	0.001
Erbium		Palladium		Manganese	0.01	Beryllium	
Holmium		Rhodium		Chromium	0.02	Lithium	0.004
Dysprosium						Hydrogen	NR

* Flameless Atomic Absorption

STD — Internal Standard
NR — Not Reported
All elements not detected < 0.001 µg/ml
MC — Major Component >10 µg/ml
INT — Interference

Approved: Charles R. Wilson

4-16

COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, ILLINOIS 60148 AREA CODE 312 953-9300
Reply to
INSTRUMENTAL ANALYSIS DIVISION, 490 ORCHARD STREET, GOLDEN, COLORADO 80401, PHONE: 303 278-9521

To: Mr. Christopher Mann
Acurex Corporation
555 Clyde Avenue
P.O. Box 7555
Mountain View, CA 94039

Date: October 18, 1983

Analyst: J. Oldham

P. O. No.: Subcontract SW59159A Project #7601

Sample No.: 819379
HR Imp 1, Outlet

SPARK SOURCE MASS SPECTROGRAPHIC ANALYSIS

IAD No.: 97-M661-116-14

CONCENTRATION IN µg/mL

ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.
Uranium		Terbium		Ruthenium		Vanadium	0.004
Thorium		Gadolinium		Molybdenum	≤0.02	Titanium	0.4
Bismuth		Europium		Niobium	0.002	Scandium	0.01
Lead	0.02	Samarium		Zirconium	≤0.003	Calcium	2
Thallium		Neodymium		Yttrium	0.002	Potassium	6
Mercury	*0.0003	Praseodymium		Strontium	0.009	Chlorine	MC
Gold		Cerium		Rubidium	**0.03	Sulfur	MC
Platinum		Lanthanum	≤0.005	Bromine	0.04	Phosphorus	0.3
Iridium		Barium	0.09	Selenium	INT	Silicon	1
Osmium		Cesium		Arsenic	<0.001	Aluminum	0.2
Rhenium		Iodine		Germanium		Magnesium	2
Tungsten	0.01	Tellurium	0.003	Gallium	0.08	Sodium	>5
Tantalum	**0.2	Antimony	≤0.005	Zinc	**MC	Fluorine	≈3
Hafnium		Tin		Copper	MC	Oxygen	NR
Lutetium		Indium	STD	Nickel	0.3	Nitrogen	NR
Ytterbium		Cadmium		Cobalt	0.01	Carbon	NR
Thulium		Silver	MC	Iron	0.5	Boron	0.002
Erbium		Palladium		Manganese	0.1	Beryllium	
Holmium		Rhodium		Chromium	0.2	Lithium	0.007
Dysprosium						Hydrogen	NR

*Flameless Atomic Absorption
**Heterogeneous

STD — Internal Standard
NR — Not Reported
All elements not detected <0.002 µg/mL
MC — Major Component >10 µg/mL
INT — Interference

4-17 Approved: Charles R. Wilson

COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, ILLINOIS 60148 AREA CODE 312 953-9300

Reply to INSTRUMENTAL ANALYSIS DIVISION, 490 ORCHARD STREET, GOLDEN, COLORADO 80401, PHONE: 303 278-9521

To: Mr. Christopher Mann
Acurex Corporation
555 Clyde Avenue
P.O. Box 7555
Mountain View, CA 94039

Date: October 18, 1983

Analyst: J. Oldham

P. O. No.: Subcontract SW59159A Project #7601

Sample No.: 819377
HR Imp 1 Blank

SPARK SOURCE MASS SPECTROGRAPHIC ANALYSIS

CONCENTRATION IN µg/mL

IAD No.: 97-M661-116-14

ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.
Uranium		Terbium		Ruthenium		Vanadium	0.008
Thorium		Gadolinium		Molybdenum	**0.2	Titanium	0.2
Bismuth		Europium		Niobium		Scandium	≤0.005
Lead	0.02	Samarium		Zirconium	0.007	Calcium	1
Thallium		Neodymium		Yttrium		Potassium	0.7
Mercury	*≤0.0002	Praseodymium		Strontium	0.002	Chlorine	0.3
Gold		Cerium		Rubidium		Sulfur	MC
Platinum		Lanthanum		Bromine	0.02	Phosphorus	0.8
Iridium		Barium	0.05	Selenium	0.07	Silicon	**2
Osmium		Cesium		Arsenic	0.002	Aluminum	0.09
Rhenium		Iodine		Germanium		Magnesium	0.08
Tungsten	0.02	Tellurium		Gallium	0.004	Sodium	1
Tantalum		Antimony		Zinc	**0.1	Fluorine	≈2
Hafnium		Tin		Copper	**0.02	Oxygen	NR
Lutetium		Indium	STD	Nickel	0.007	Nitrogen	NR
Ytterbium		Cadmium		Cobalt	≤0.003	Carbon	NR
Thulium		Silver		Iron	0.1	Boron	0.004
Erbium		Palladium		Manganese	0.003	Beryllium	
Holmium		Rhodium		Chromium	0.03	Lithium	0.002
Dysprosium		*Flameless Atomic Absorption **Heterogeneous				Hydrogen	NR

STD — Internal Standard
NR — Not Reported
All elements not detected ≤ 0.003 µg/mL
MC — Major Component > 10 µg/mL
INT — Interference

Approved: Charles R. Wilson

4-18

COMMERCIAL TESTING & ENGINEERING CO.

Reply to GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, ILLINOIS 60148 AREA CODE 312 953-9300
INSTRUMENTAL ANALYSIS DIVISION, 490 ORCHARD STREET, GOLDEN, COLORADO 80401, PHONE: 303 278-9521

To: Mr. Christopher Mann
Acurex Corporation
555 Clyde Avenue
P.O. Box 7555
Mountain View, CA 94039

Date: October 18, 1983

Analyst: J. Oldham

P. O. No.: Subcontract SW59159A Project #7601

Sample No.: 819394
DE Imp 1

SPARK SOURCE MASS SPECTROGRAPHIC ANALYSIS

IAD No.: 97-M661-116-14

Blnd. Duplicate of Impl Outlet

CONCENTRATION IN µg/mL

ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.
Uranium		Terbium		Ruthenium		Vanadium	0.005
Thorium		Gadolinium		Molybdenum	0.1	Titanium	0.2
Bismuth		Europium		Niobium	0.007	Scandium	≤0.002
Lead	0.02	Samarium		Zirconium	0.009	Calcium	2
Thallium		Neodymium		Yttrium	0.001	Potassium	0.8
Mercury	*0.0004	Praseodymium		Strontium	0.05	Chlorine	MC
Gold		Cerium		Rubidium	0.001	Sulfur	>8
Platinum		Lanthanum	≤0.006	Bromine	0.05	Phosphorus	0.2
Iridium		Barium	0.06	Selenium	INT	Silicon	2
Osmium		Cesium	**0.04	Arsenic	0.001	Aluminum	0.07
Rhenium		Iodine		Germanium		Magnesium	0.1
Tungsten	≤0.007	Tellurium		Gallium	0.03	Sodium	>3
Tantalum	≤0.005	Antimony		Zinc	4	Fluorine	**MC
Hafnium		Tin		Copper	MC	Oxygen	NR
Lutetium		Indium	STD	Nickel	0.2	Nitrogen	NR
Ytterbium		Cadmium		Cobalt	0.01	Carbon	NR
Thulium		Silver	MC	Iron	0.3	Boron	0.001
Erbium		Palladium		Manganese	0.07	Beryllium	<0.001
Holmium		Rhodium		Chromium	0.07	Lithium	0.002
Dysprosium						Hydrogen	NR

*Flameless Atomic Absorption
**Heterogeneous

STD — Internal Standard
NR — Not Reported
All elements not detected < 0.001 µg/mL
MC — Major Component > 10 µg/mL
INT — Interference

Approved: Charles R. Wilson

4-19

COMMERCIAL TESTING & ENGINEERING CO.

Reply to
Instrumental Analysis Division
490 Orchard Street
Golden, CO 80401

December 19, 1983

Phone: 303-278-9521

Mr. Christopher Mann
Acurex Corporation
555 Clyde Avenue
Mountain View, CA 94039

Re: IAD #97-N137-116-09
Subcontract #SW59159A
Release #10

Analytical Report

Nine samples, previously analyzed for trace elements by spark source mass spectrometry under our IAD identification #97-M661-116-14, were logged under our IAD identification #97-N137-116-09 on November 18, 1983.

Samples #1, 2, and 3 were prepared in accordance with the procedure of ASTM, Part 05.05, Method D3683. Aluminum, barium, calcium, cobalt, chromium, iron, potassium, magnesium, sodium, silicon, titanium, and zinc were determined using flame atomic absorption spectrophotometry. Phosphorus was determined colorimetrically and sulfur was determined turbidimetrically. Boron, chlorine, and fluorine were not determined due to lack of enough sample for analysis. The results of these determinations are presented in Table No. I and are reported in total micrograms on the filter on an "as received" basis.

Appropriate dilutions, using deionized water, were made on samples #5, 6, 7, and 8. Chlorine and fluorine were determined using specific ion electrode methodology. Silver and sodium were determined using flame atomic absorption spectrophotometry. Sulfur was determined turbidimetrically. Selenium was determined using hydride generation atomic absorption spectrophotometry. The results of these determinations are presented in Table No. II and are reported in milligrams per litre (mg/L) on an "as received" basis.

Sample #4 was prepared in accordance with the procedure of the EPA SASS Train Level I Protocol. Nickel was determined using flame atomic absorption spectrophotometry. The result of this determination is presented in Table No. III and is reported in micrograms per gram (µg/g) on an "as received" basis.

GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, IL 60148 AREA CODE 312 953-9300
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DENVER, CO • GOLDEN, CO • HELPER, UT • HENDERSON, KY • HOUSTON, TX • JASPER, AL • MIDDLESBORO, KY • MOBILE, AL • NEW BETHLEHEM, PA

A representative portion of sample #9 was diluted with MIBK. Calcium was then determined using flame atomic absorption spectrophotometry versus organometallic standards. Sulfur was determined using X-ray fluorescence spectrometry. The results of these determinations are also presented in Table No. III and are reported in micrograms per gram (µg/g) on an "as received" basis.

Table No. I
(Total micrograms on Filter)

Parameter	#1-819366 HR Filter, Inlet	#2-819367 HR Filter, Outlet	#3-819365 HR Filter, Blank
Aluminum (Al)	830	440	≤ 400
Barium (Ba)	1,400	1,700	---
Calcium (Ca)	2,800	2,200	≤1,000
Cobalt (Co)	22	30	---
Chromium (Cr)	20	33	---
Iron (Fe)	1,100	260	---
Potassium (K)	12	10	---
Magnesium (Mg)	370	220	≤ 100
Sodium (Na)	180	150	180
Phosphorus (P)	160	170	---
Sulfur (S)	620	720	≤ 500
Silicon (Si)	4,300	2,300	≤1,000
Titanium (Ti)	82	≤60	≤ 300
Zinc (Zn)	300	340	---

Table No. II
(mg/L - As Received)

Parameter	#5-819378 HR Imp 1, Inlet	#6-819379 HR Imp 1, Outlet	#7-819394 DE Imp 1	#8-819377 HR Imp 1, Blank
Silver (Ag)	---	1.75	2.12	---
Chlorine (Cl)	---	≤ 3	≤3	---
Fluorine (F)	---	4.18	4.44	---
Sodium (Na)	1,130	1,440	1,480	---
Sulfur (S)	1,800	9,000	4,800	≤ 100
Selenium (Se)	---	≤ 0.002	0.003	---

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-466

Table No. III
(µg/g - As Received)

Parameter	#4-819370 HR XAD-2 Outlet	#9-819360 HR Lube Oil
Calcium (Ca)	---	334
Nickel (Ni)	140	---
Sulfur (S)	---	4,200

ppm

If you have any questions concerning these results, please call.

Harold A. Connell
Assistant Lab Manager

Robert L. Taylor, Ph.D., Mngr.
Instrumental Analysis Division

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4.3 TOTAL CHROMATOGRAPHABLE ORGANICS (TCO), GRAVIMETRIC ORGANICS (GRAV), INFRARED (IR) SPECTRA, AND GAS CHROMATOGRAPHY/MASS SPECTROMETRY (GC/MS) OF TOTAL SAMPLE EXTRACTS

ACUREX Corporation

Energy & Environmental Division

Acurex/ES (CMEA)
M/S 2-2260

November 14, 1983
Acurex ID#: 8306-050
Client PO#: 307736.62

Attention: Larry Waterland

Sample: Honor Rancho Trains; Received 6/21/83

The above-referenced samples were analyzed by Level 1 protocol. The XAD and OMC extracts were combined per your instruction. Organic extracts were also analyzed for the semivolatile priority pollutants by gas chromatography/mass spectrometry employing a J&W SE-54 30 meter capillary column. The column was held at 30°C for 2 minutes, then ramped at 10°C per minute to 270°C. In addition to the priority pollutants, other organics including benzo(c)phenanthrene, dibenzo(c,g)carbazole, 7,12-dimethylbenzo(a) anthracene, 3-methylcholanthrene, and perylene were sought employing the computerized library search and manual interpretation. The assignment and quantitation of these organics is tentative since analytical standards of these compounds were not available for analysis. Benzo(c)phenanthrene, dibenzo(c,g)carbazole, 7,12-dimethylbenzo(a)anthracene, 3-methylcholanthrene and perylene were not detected in any of the samples at levels above 400 µg/train.

Half of the XAD-2 resin extract for the Inlet test was taken to near dryness during extraction of the resin. This may result in a lower TCO value.

Submitted by: Greg Nicoll 12/9/83
Greg Nicoll
Operations Manager

Viorica Lopez-Avila
Viorica Lopez-Avila, Ph.D.
Technical Director

GN/VLA/ats

Enclosures

555 Clyde Avenue, P.O. Box 7555, Mountain View, CA 94039 (415) 964-3200 Telex: 34-6391 TWX: 910-7796593

ACUREX Corporation
ANALYSIS LABORATORIES

DATA REPORTING FORM

CUSTOMER CMEA DATE November 14, 1983

CUSTOMER CONTRACT NO. 307736.52 ACUREX CONTRACT NO. 8306-050

RESULTS REPORT TO L. Waterland TELEPHONE

ADDRESS

Honor Rancho

SAMPLE ID (CUSTOMER)	--	368	369	370	370					
SAMPLE ID (LAB)	Shake-out Blank	XAD Blank	XAD In+	XAD Out+	XAD out a+					
PARAMETER										UNITS
GRAV	<2	<2	203	7	--					mg/train
TCO	<0.2	<0.2	270; 170[a]	49	--					mg/train
Fluoranthene	<10	<10	15	<10	<10					µg/train
Pyrene	<10	<10	60	<10	<10					
Butyl benqyl phthalate	<10	<10	19	<10	<10					
Benz(a)anthracene	<10	<10	140	<10	<10					
Chrysente	<10	<10	53	<10	<10					
Benzofluoranthenes	<10	<10	52	<10	<10					
Phenol	<10	<10	<10	42	55					
Naphthalene	<10	<10	<10	710	800					
Acenaphthylene	<10	<10	1700	31	32					
Phenanthrene	<10	<10	1100	31	41					
Bis(2-ethylhexyl)-phthalate	<10	<10	1500	26[b]	35[b]					

4-25

+ Plus OMC
a - Duplicate injection
b - Level normally found in laboratory blanks

ANALYST S. Kraska, S. Guinnane, C. Beeman

REVIEWER Greg Nicoll

Form EED-057 4/80

ACUREX Corporation
ANALYSIS LABORATORIES

DATA REPORTING FORM

CUSTOMER CMEA DATE November 14, 1983

CUSTOMER CONTRACT NO. 307736.52 ACUREX CONTRACT NO. 8306-050

RESULTS REPORT TO L. Waterland TELEPHONE

ADDRESS

Honor Rancho

SAMPLE ID (CUSTOMER)	--	368	369	370	370					
SAMPLE ID (LAB)	Shake-out Blank	XAD Blank	XAD In+	XAD Out+	XAD Out a+					
PARAMETER										UNITS
Bis(2-chloroethyl)-ether	<10	<10	57	<10	<10					µg/train
Acenaphthene	<10	<10	450	<10	<10					↓
Fluorene	<10	<10	490	<10	<10					↓

+ Plus OMC

a - Duplicate Injection

Form EED-057 4/80

ANALYST S. Kraska

REVIEWER Greg Nicoll

IR REPORT

SAMPLE: XAD Inlet 819369

Wave Number (cm^{-1})	Intensity	Assignment	Comments
3571-2941	m	OH	Broad
2907	S	CH Alkane	
1673	S	C = o	
1538	m	Unassigned	
1439	m	CH_2 Methylene	
1266	m	C-O Stretch	
		Aliphatic hydrocarbon	
		Acid (-COOH)	

IR REPORT

SAMPLE: XAD Outlet 819370

Wave Number (cm^{-1})	Intensity	Assignment	Comments
		No detectable peaks	

IR REPORT

SAMPLE: XAD Blank 819368

Wave Number (cm^{-1})	Intensity	Assignment	Comments
		No detectable peaks	

IR REPORT

SAMPLE: Shake out blank

Wave Number (cm^{-1})	Intensity	Assignment	Comments
		No detectable peaks	

4.4 LIQUID CHROMATOGRAPHY (LC) SEPARATION OF THE INLET XAD-2 EXTRACT, WITH TCO, GRAV, AND IR ANALYSES OF LC FRACTIONS

ACUREX Corporation

Energy & Environmental Division

Acurex/ES (CMEA)
MS 2-2260

March 13, 1984
Acurex ID#: 8401-029
Client PO#: 307736.62

Attention: Larry Waterland

Sample: Honor Rancho Inlet XAD, Rock of Ages XADs;
Received 1/20/84

The above samples were subjected to liquid chromatography followed by TCO, gravimetric measurement, and infrared spectrophotometry according to Level 1 protocol.

Results are enclosed.

Prepared by: John S. Labash
Chemist

Approved by: Greg Nicoll
Manager, Inorganic Chemistry

JSL/GN/ats

555 Clyde Avenue, P.O. Box 7555, Mountain View, CA 94039 (415) 964-3200 Telex: 34-6391 TWX: 910-7796593

SAMPLE: 819369 Honor Rancho XAD-2 Inlet

	TCB mg	BRAV mg	TCB + BRAV Total mg	Concentration mg/dscm
Total Sample[1]	220	203	420	
Taken for LC[2]	48	45	93	
Recovered[3]	3.7	37.6	41	

Fraction	TCB in mg				BRAV in mg				TCB + BRAV Total mg	Concentration mg/dscm
	Found in Fraction	Blank	Corrected	Total[4]	Found in Fraction	Blank	Corrected	Total[4]		
1	<0.2	<0.2	<0.2	<0.9	6.0	<0.5	6.0	27	27	
2	0.2	<0.1	0.2	0.9	0.8	<0.4	0.8	3.6	4.5	
3	3.0*	<0.1	3.0	14	7.4	<0.4	7.4	34	48	
4	0.7	0.2	0.5	2	5.6	<0.4	5.6	25	27	
5	<0.1	<0.1	<0.1	<0.5	3.2	<0.4	3.2	15	15	
6	<0.1	<0.1	<0.1	<0.5	11.6	<0.4	11.6	53	53	
7	<0.1	<0.1	<0.1	<0.5	3.6	0.6	3.0	14	14	
Sum	3.9	<0.9	3.7	17	38.2	0.6	37.6	172	188	

1. Quantity in entire sample, determined before LC
2. Portion of whole sample used for LC, actual mg
3. Quantity recovered from LC columns, actual mg
4. Total mg computed back to total sample

*Duplicate injection gave 2.8

IR REPORT

SAMPLE: 1-29-1 LCF 1

Wave Number (cm^{-1})	Intensity	Assignment	Comments
2945	S	CH Alkane	Weak Spectrum

IR REPORT

SAMPLE: 1-29-1 LCF 2

Wave Number (cm^{-1})	Intensity	Assignment	Comments
		No Peaks	

IR REPORT

SAMPLE: 1-29-1 LCF 3

Wave Number (cm^{-1})	Intensity	Assignment	Comments
2940	S	CH Alkane	Weak
1715	S	C=O *	Spectrum
		* Tentative assignment	

IR REPORT

SAMPLE: 1-29-1 LCF 4

Wave Number (cm^{-1})	Intensity	Assignment	Comments
2930	M	CH Alkane	
1700	S	C=O *	Broad
1555	M	Not assigned	
			Weak Spectrum
		* Tentative assignment	

IR REPORT

SAMPLE: 1-29-1 LCF 5

Wave Number (cm^{-1})	Intensity	Assignment	Comments
2930	S	CH Alkane	
1555	S	Not Assigned	

IR REPORT

SAMPLE: 1-29-1 LCF 6

Wave Number (cm^{-1})	Intensity	Assignment	Comments
3360	M	OH	Broad
3065	W	=C-H Alkene	
2935	S	CH Alkane	
1710	S	C=O Stretch	
1605	W	C=C Alkene	
1555	M	Unassigned	
1450	W	CH_2	
1380	W	CH_3	
1278	W	C-O	
740	W	=C-H Alkene	

IR REPORT

SAMPLE: 1-29-1 LCF 7

Wave Number (cm^{-1})	Intensity	Assignment	Comments
3540	S	OH*	Broad Peak
2940	W	CH Alkane	
1710	W	C=O	
			* Tentative assignment

IR REPORT

SAMPLE: 1-29-BLK LCF-1

Wave Number (cm^{-1})	Intensity	Assignment	Comments
		No Peaks	

IR REPORT

SAMPLE: 1-29-BLK LCF 2

Wave Number (cm^{-1})	Intensity	Assignment	Comments
		No Peaks	

IR REPORT

SAMPLE: 1-29-BLK LCF 3

Wave Number (cm^{-1})	Intensity	Assignment	Comments
		No Peaks	

IR REPORT

SAMPLE: 1-29-BLK LCF 4

Wave Number (cm^{-1})	Intensity	Assignment	Comments
		No Peaks	

SAMPLE: 1-29-BLK LCF 5

Wave Number (cm^{-1})	Intensity	Assignment	Comments
2935	S	CH Alkane	
			Weak spectrum

IR REPORT

SAMPLE: 1-29-BLK LCF 6

Wave Number (cm^{-1})	Intensity	Assignment	Comments
		No Peaks	

IR REPORT

SAMPLE: 1-29-BLK LCF 7

Wave Number (cm^{-1})	Intensity	Assignment Comments
		No Peaks

4.5 BIOASSAY RESULTS

4.6 NATURAL GAS FUEL ANALYSIS

ACUREX Corporation

COMMUNICATION MEMO

☐ TELEPHONE ☐ CONFERENCE	DATE	TIME	SERIAL/FILE NO.	PAGE
PERSON CONTACTED: Bud Cooper			TELEPHONE: (213) 866-4350	
COMPANY: So. Calif. Gas Co.			PREPARED BY: Mason	
LOCATION: LAX			☐ INFO. ONLY ☐ ACTION REQUIRED	
SUBJECT: Honor Rancho Gas Analysis			RESPONSIBLE PERSON	

NOTES AND DISCUSSION

Cooper has completed the gas analysis for the CMEA Honor Rancho test:

O_2	0.073 %
N_2	1.119
CO_2	0.890
CH_4	90.119
C_2H_6	6.294
C_3H_8	1.247
Iso-butane	0.094
n-butane	0.106
Iso-pentane	0.029
n-pentane	0.029
C_6 and Higher	0.003
	100.003 %

Bud would like to get a copy of test results when available

CC: Waterland, DeRos, Carlo, DeRosier

☐ CONTINUED ON BACK