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VAPOR CONDENSATION CONTROL OF JP-4 EMISSIONS FROM UNDERGROUND STORAGE TANKS AT MARCH AIR FORCE BASE, CALIFORNIA

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FINAL REPORT
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20 ABSTRACT (Continue on reverse side if necessary and identify by block number)

Three efficiency test runs were conducted on an Edwards Engineering Corporation Hydrocarbon Vapor Recovery Unit Model DE 1000 at the March Air Force Base Panero refueling area on 22 and 23 September and 1 October 1981. The recovery system was installed to control JP-4 vapors displaced from the filling of underground tanks. The purpose of the test was to assess the compliance with South Coast Air Quality Management District Rule 462 specifying minimum efficiencies for vapor condensation systems.

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An additional test was conducted at the Pritchard refueling area on 10 October 1981.

SUMMARY

Three efficiency test runs were conducted on an Edwards Engineering Corporation Hydrocarbon Vapor Recovery Unit Model DE 1000 at the March Air Force Base Panero refueling area on 22 and 23 September and 1 October 1981. The recovery system was installed to control JP-4 vapors displaced from the filling of underground tanks. The purpose of the test was to assess compliance with South Coast Air Quality Management District Rule 462 specifying minimum efficiencies for vapor condensation systems. Simultaneous inlet and outlet concentrations were measured with Flame Ionization Detectors (FIDs) and total outlet volume was measured with a Roots meter. Outlet bag samples were analyzed for hydrocarbon constituents with a gas chromatograph, and the inlet constituents needed for the calculations were taken from typical JP-4 vapor analysis. Test results showed efficiencies of 90.7%, 89.9%, and 88.1%, with an arithmetic average of 89.6%. Time weighting the efficiencies (Test Run 2 was longer than Test Runs 1 and 3 combined) shows an average efficiency of 89.7%. Gas chromatograph analysis of outlet vapors showed approximately one-half the constituents to be under C_4 and the other half to be C_{4s}.

One test run was conducted at the Pritchard refueling area on 10 October 1981, showing an efficiency of 85.7%. Because only one one-hour test was conducted, the results are statistically less valid than results for the Panero system.

The temperature of the fuel averaged 79.5 degrees F during this test program. This compares well with the maximum recorded fuel temperature during the period from 1978 to 1980, which was 80 degrees F. It is expected that the inlet loading would vary directly with the fuel temperature.

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PREFACE

This test program was conducted by Engineering-Science, Inc. (ES), 125 West Huntington Drive, Arcadia, California 91006, under Air Force Contract No. F33615-80-D-4001, Call Order 013, for the Air Force Occupational and Environmental Health Laboratory, Brooks Air Force Base, Texas.

Mr. Thomas Stauffer, AFESC/RDVC, Tyndall Air Force Base, Florida, was the Air Force technical contact.

This report summarizes testing conducted during the period from 22 September to 10 October 1981.

Lt. Joe Ragowicz of March Air Force Base assisted the test crew in access to the test sites and coordination within March Air Force Base.

This report has been reviewed by the Public Affairs Office and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nationals.

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TABLE OF CONTENTS

Section	Title	Page
I	INTRODUCTION	1
II	PROCESS DESCRIPTION AND CONTROL EQUIPMENT	3
	Process Description	3
	Control Equipment	5
III	SAMPLING AND ANALYTICAL PROCEDURES	8
	Hydrocarbon Concentration Measurement (Flame Ionization Detectors)	8
	Flow Measurement	12
	Hydrocarbon Constituent Measurement (Gas Chromatograph)	12
IV	SUMMARY OF RESULTS	14
	Recommendations	20
Appendix		
A	MARCH AIR FORCE BASE EXAMPLE CALCULATIONS	25
B	SAMPLE FIELD CALCULATIONS	27

LIST OF FIGURES

Figure	Title	Page
1	Schematic of the JP-4 Fuel Storage and Vapor Recovery System	4
2	Schematic of Edwards Engineering Corporation Hydrocarbon Vapor Recovery Unit Model DE 1000	6
3	Hydrocarbon Sampling System for Testing the Inlet Duct at the Edwards Vapor Recovery Unit at March AFB, CA	9
4	Hydrocarbon Sampling System for Testing the Outlet Duct at the Edwards Vapor Recovery Unit at March AFB, CA	10

LIST OF TABLES

Table	Title	Page
1	Summary of Inlet and Outlet Concentrations, Mass Rates, and Hydrocarbon Recovery Efficiency for Run 1, 22 September 1981, Panero Refueling Area	15
2	Summary of Inlet and Outlet Concentrations, Mass Rates, and Hydrocarbon Recovery Efficiency for Run 2, 23 September 1981, Panero Refueling Area	16
3	Summary of Inlet and Outlet Concentrations, Mass Rates, and Hydrocarbon Recovery Efficiency for Run 3, 1 October 1981, Panero Refueling Area	17
4	Summary of Inlet and Outlet Concentrations, Mass Rates, and Hydrocarbon Recovery Efficiency for Run 4, October 8, 1981 Panero Refueling Area	18
5	Sampling Data and Results From Testing HC Vapor Recovery Units at March AFB	19
6	Gas Chromatograph Analysis for Percent Composition of Outlet Vapors	21

SECTION I

INTRODUCTION

The U.S. Air Force installed low temperature condensation vapor recovery units on the underground jet fuel (JP-4) storage tank vents at March Air Force Base, California during 1981. The condensation units were installed to reduce the hydrocarbon vapor emissions that result from vapor displacemnt during filling of the tanks. The purpose of this task was to measure the collection efficiency and vapor emisson rates to satisfy the South Coast Air Quality Management District (SCAQMD) permitting requirements. SCAQMD Rule 462, as amended in 1968, specifies minimum efficiency levels for vapor condensation systems.

Engineering-Science, Inc. (ES), was retained under USAF Contract Number F33615-80-D-4001, Call Order 013, to conduct at least three independent efficiency test runs on one of the condensation units. Three efficiency test runs were conducted, one per day, on the Panero refueling unit at March AFB on 22-23 September, and 1 October 1980. On 8 October an additional test consisting of only one test run was conducted at the March AFB Pritchard refueling area. Because only one test run was performed on the Pritchard unit, the test results are statistically less valid than results for the Panero System.

Field testing was performed by Mr. Michael McDavitt and Mr. James Peterson, supervised by Mr. Donald Holtz and Mr. Lawrence Cottone, all of ES. Mr. Michael Sargeant, also of ES, conducted the gas chromatographic analysis.

Preparation for the first test on 21 September 1981, was witnessed by USAF representative Mr. Tom Stauffer of Tyndall AFB, Florida, Mr. Ken Kitchingman of EPA Region IX in San Francisco, Mr. Philip Lammi of the Air Force Regional Civil Engineering office in San Francisco, and Ms. Christine Metz of the Defense Department in Washington.

South Coast Air Quality Management Rule 462 applies to organic liquid loading facilities that handle more than 20,000 gallons per day of organic liquids having a vapor pressure of 77.5 mm Hg (1.5 psia) or greater under

actual loading conditions. The rule states the following: "An absorber or condensation system which processes the displaced vapor [shall] recover at least 90% by weight of the organic vapors and gases charged to the system." The March AFB liquid loading facilities handle more than 20,000 gallons per day and during the hot summer months the JP-4 vapor pressure may exceed 77.5 mm Hg (1.5 psia).

The vapor recovery efficiency was determined by simultaneously employing flame ionization detection (FID) instruments at both the inlet and outlet sites of the unit. The instruments measured hydrocarbon concentrations and were calibrated with known concentrations of methane (CH_4). The outlet flow rates also were measured and, with the aid of gas chromatographic analysis of inlet and outlet concentrations, mass hydrocarbon flow rates and the efficiency at both inlet and outlet could be determined.

SECTION II

PROCESS DESCRIPTION AND CONTROL EQUIPMENT

PROCESS DESCRIPTION

Figure 1 illustrates the JP-4 storage system. The JP-4 is received via a pipeline and stored in floating-roof tanks from which it is either gravity fed or pumped to underground storage tanks in the airplane refueling areas. Two refueling areas, Panero and Pritchard, are regularly used at March AFB. The Panero refueling area is provided with 34 underground storage tanks with a capacity of 50,000 gallons per tank. The Pritchard refueling area has only six underground storage tanks (of the same capacity) and is farther from the bulk storage site than Panero.

The Panero refueling area was gravity fed from bulk storage for test runs 1, 2, and 3. Testing was facilitated on these dates at Panero by first pumping fuel to the Pritchard refueling area to create a deficit at the Panero site. Panero was then "topped off" from bulk storage by gravity feed.

When the underground tanks are filled, the displaced vapor volume passes through the vent pipe to the vapor condensor. Fuel flow rates vary from approximately 450 gpm during gravity flow to 670 gpm for pumped flow. Tank fillings and fuel transfers last up to four hours. The fuel flow rates give an approximation of the displaced vapor flow rates.

Because JP-4 constituent vapor pressures change at different rates with temperature changes, the relative composition of the displaced JP-4 vapor is dependent on the liquid fuel temperature. The fuel temperature was measured at noon daily from the Panero and Pritchard refueling areas by USAF personnel. The average fuel temperature for the four test dates was 79.5°F, and the composition of the JP-4 vapors was relatively constant throughout the four test days.

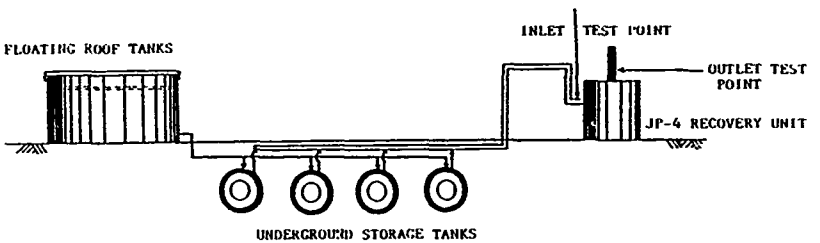


Figure 1. Schematic of the JP-4 Fuel Storage and Vapor Recovery System

Air Force exercises and other activities dictate fuel consumption, and hence the amount of fuel movement required to maintain near capacity-filled tanks. Fuel movement was generally low during the period of the testing. The amount of fuel received at refueling areas on the test dates ranged from 11,000 to 178,000 gallons.

Both refueling area systems are provided with breather values that relieve excess negative or positive vapor pressures. During Run 4, which was performed at the Pritchard site, it was observed that JP-4 vapors were venting out of the unit's breather valve. Since the breather valve was releasing vapors upstream of the vapor recovery unit, the measured emission rate from the system was lower than actual. This loss in vapors from the breather valve, however, would not have a direct influence on the efficiency of the vapor recovery unit.

CONTROL EQUIPMENT

Panero and Pritchard refueling areas are currently both equipped with Edwards Engineering Corporation Hydrocarbon Vapor Recovery Unit Model DE 1000. Figure 2 illustrates the general components and the air vapor flow path.

The vapor recovery unit is a once-through refrigerated condensor designed to maintain temperatures in the coil of -90°F. Displaced JP-4 vapors enter the unit through an 8-inch diameter iron pipe. The vapors first pass through a precooler coil which takes out most of the moisture and lowers the temperature to approximately 35°F.

The vapors then enter into the top of the low temperature condensing coil. The condensor, constructed of a series of finned coils, is designed to allow for some frost buildup at the entry area without impeding vapor flow. Condensate drops fall into a collector bin which drains to a hydrocarbon water separator.

Frost buildup on the condensor coils will clearly interfere with the vapor condensation potential of the system. For this reason, the unit is designed to defrost itself one hour per 24 hours during a period of inactivity.

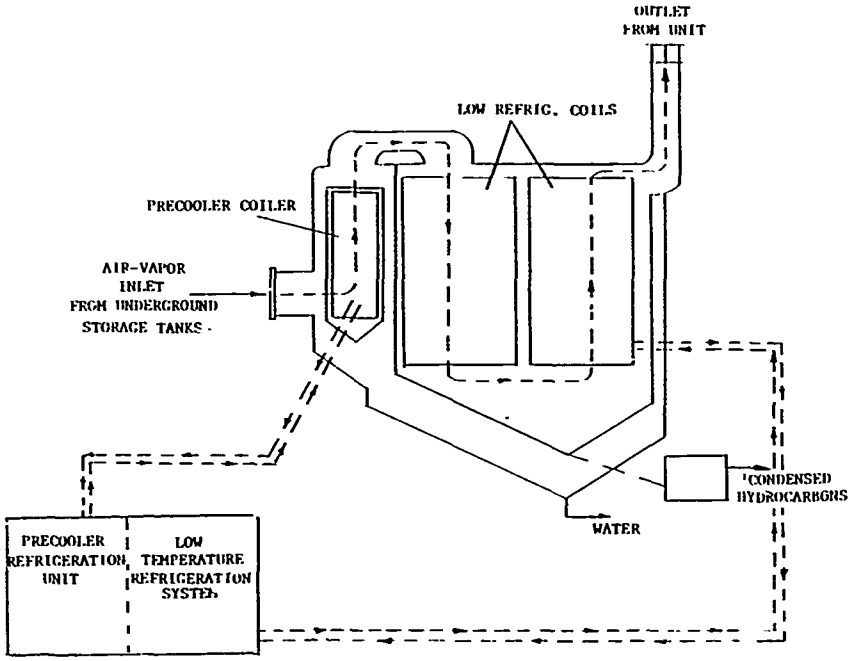


Figure 2. Schematic of Edwards Engineering Corporation Hydrocarbon Vapor Recovery Unit Model DE 1000

Remaining JP-4 vapors that are not completely or unavoidably removed are vented out an aluminum stack at the top of the unit. Insufficient residence time and/or inadequate contact with the coil surface probably accounts for the incomplete condensation of those constituents with boiling points above the systems operating temperature. Other hydrocarbon constituents with boiling points at or below the operating temperature, such as methane, ethane and ethene, pass freely through the system.

SECTION III

SAMPLING AND ANALYTICAL PROCEDURES

HYDROCARBON CONCENTRATION MEASUREMENT (FLAME IONIZATION DETECTORS)

Two Flame Ionization Detector (FID) instruments were used simultaneously to determine hydrocarbon concentrations at the inlet and outlet of the vapor recovery units. Scott Total Hydrocarbon Analyzers (THCAs) Models 215 and 116 were used at the inlet and outlet sites, respectively. Figures 3 and 4 illustrate the various features of the sampling system.

To bring the inlet hydrocarbon concentration measurement into the span range of the Model 215 THCA it was necessary to dilute the inlet gas with hydrocarbon-free air. The mixed gas was then delivered in excess to the THCA on both inlet and outlet systems. An in-line rotameter, prior to the analyzer sample inlet point, helped regulate consistent flow to the detector. Constant detector conditions were maintained by the internal pump pressure regulator and bypass flow valve. The manufacturer's recommended pressure setting of 1.0 lb per square inch and a bypass flow rate of 6 standard cubic feet per hour were used for calibration and sample collection.

A stainless steel lined pump was used to withdraw the hydrocarbon vapors from the inlet pipe, and a tetrafluorocarbon lined pump was used on the outlet side. The temperature of the gas exiting the pumps was monitored during operation. Attempts were made to duplicate sampling temperature conditions when calibrating the dilution system.

The sample collection system was leak-checked before and after each field use. A vacuum gauge and toggle switch upstream of the pump allowed for leak checks of about 20 inches of mercury. If the system failed to hold a vacuum for one minute after isolating the pump, the system was considered to have a significant leak. All leak checks performed after the conclusion of a test run passed.

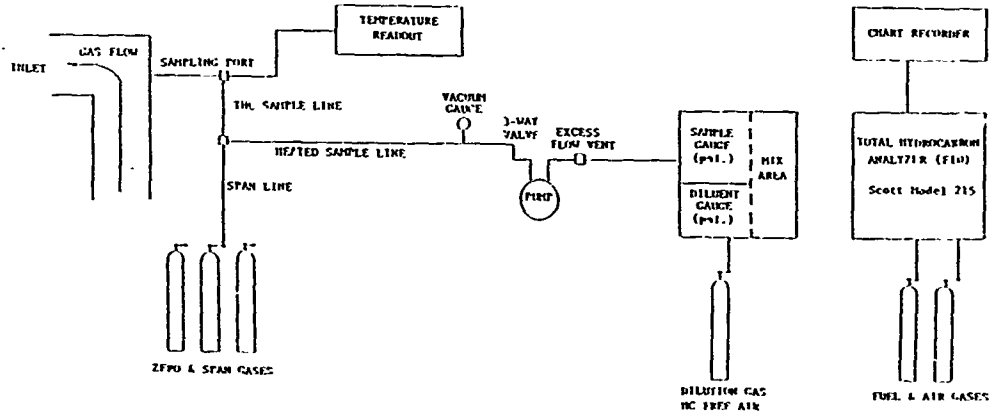
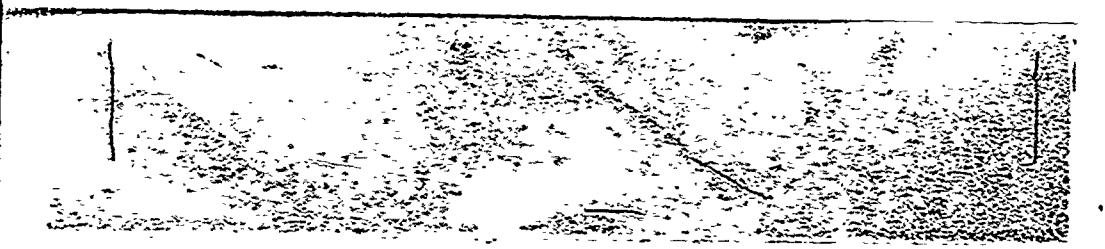


Figure 3. Hydrocarbon Sampling System for Testing the Inlet Duct at the Edwards Vapor Recovery Unit at March AFB, CA



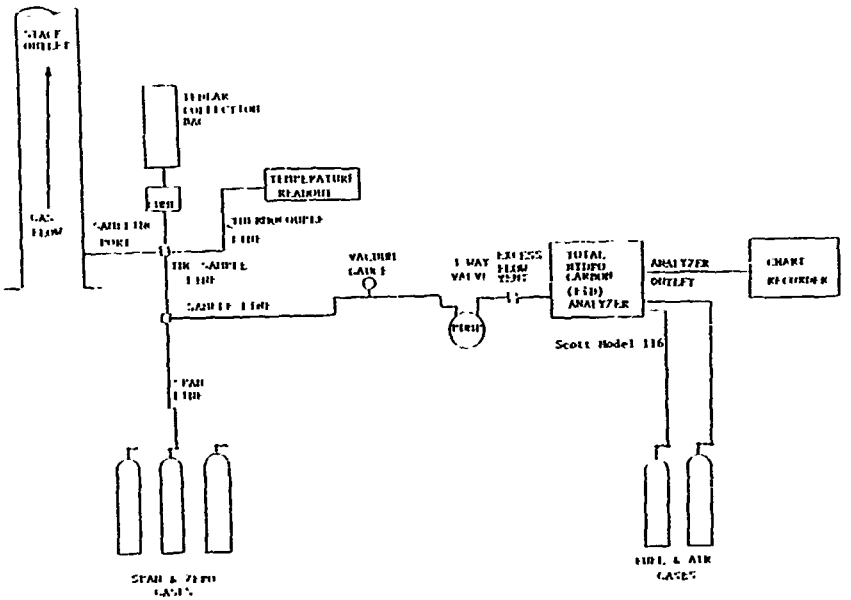


Figure 4. Hydrocarbon Sampling System for Testing the Outlet Duct at the Edwards Vapor Recovery Unit at March AFB, CA

Inlet hydrocarbon vapor concentrations were anticipated to exceed the full span range (>100,000 ppm) of the Scott Model 215 THCA. Thus, the use of a dilution system was imperative. Prior to the field tests, two sample dilution units were partially replumbed to perform the required dilutions.

A Hastings bubblemeter was used to calibrate the gas flow rates through the units' capillary network. Gas flow potentials were determined for different combinations of capillaries and at a range of gauge settings. Gauge settings were controlled by a regulator provided on the units.

One unit was used to deliver diluent gas (zero air with <0.1 ppm THC) while the other was used to deliver calibration gases (methane in air) or sample gases. After exiting their respective dilution units, the two gas streams were combined and provided in excess to the THCA.

These preliminary gas flow rate determinations were used as estimates for use in the field. Prior to each sample collection period, the following steps were taken: (1) the sample collection pump was warmed up to simulate the conditions taking place during a test period (a thermocouple was situated at the outlet of the pump to monitor the temperature), (2) the previously determined gauge settings for the desired dilution were checked with the bubblemeter and noted, (3) the actual, achieved dilution was calculated from the proportional gas flow rates, and (4) the accuracy of the system was verified by diluting a known concentration of span gas (methane) with hydrocarbon-free air at the previously calculated dilution.

The dilution system was then operated at these appropriate settings for the test period. Periodic span and zero checks were made at various intervals depending on the test length.

Following the test, a calculation of the sample delivery rate was made. Similar steps were taken as in the pretest check, but emphasis was put on simulating the pump's outlet temperature that was produced during the test period. The ultimately determined dilution factor was used in the calculation of the concentration of the inlet vapors.

No dilution was necessary for the outlet concentrations. Span gases of 25,200 ppm and 10,100 ppm were used to span the Scott Model 116 THCA.

FLOW MEASUREMENT

Total flow was measured by placing a Dresser Industries Roots Meter Model 11 M125 over the vent stack and sealing with silica sealer. The 11,000 cfh maximum capacity of the meter was more than adequate to measure the total flows. Readings were taken each minute during the test runs, except in Run 1 when readings were recorded only at the beginning and end of the run.

HYDROCARBON CONSTITUENT MEASUREMENT (GAS CHROMATOGRAPH)

The laboratory analysis for speciating the vapor recovery system inlet and outlet hydrocarbon samplers were conducted using standard gas chromatographic techniques. A Tracor Model 550 Gas Chromatograph equipped with a FID was used. The instrument was interfaced with a Spectraphysics Model SP 2000 Integrating System which provided electronic integration for each chromatogram.

The chromatographic column which was used for all the analyses was commercially prepared by Supelco and was a Durapak, N-Octane/Porasil C, 120/150 mesh, 2.3 mm x 1.5 M, stainless steel. Column temperature was maintained at 25°C, detector temperature was 250°C, carrier gas was nitrogen at a flow rate of 25 cc/min. The gas chromatograph was equipped with a gas sampling valve with 1 cc ambient temperature sample loop.

Instrument calibration was accomplished by using a specialty gas vendor certified calibration gas. The calibration gas was a mixture of C_1 to C_5 hydrocarbons certified accurate to $\pm$ 2%. Prior to each set of analyses, the gas chromatograph was calibrated to determine the instrument response (millivolts/ppm) for each component. Since only one column was used, retention time data used for component identification permits only tentative identification.

Each sample was then injected and the results recorded by the SP 2000 Integration System and printed by an SP 4100 Integrator. Those components which fell within a 3% analytical window programmed into the integrator were automatically calculated and converted to ppm. Those which fell outside the window were manually calculated by dividing the area under the curve for each component (millivolts) by the response factor established in the calibration.

SECTION IV

SUMMARY OF RESULTS

Tables 1 through 4 summarize the hydrocarbon concentrations measured as methane and as corrected for hydrocarbon constituents at both the inlet and outlet sampling locations. The tables also present the mass inlet loading and the mass emission rates from which the efficiencies also are calculated and presented. Test Runs 1, 2, and 3 were conducted at the Panero refueling area, and test Run 4 was conducted at the Pritchard refueling area. On Run 1, shown in Table 1, more credence should be given the overall average mass emission rates and efficiencies than the individual time periods, as Roots meter readings were recorded only at the beginning and end of the test period. Calculations for individual time periods shown in the table for Run 1 were based on an average actual flow rate through the Roots meter. Table 5 lists, in addition to the summary results in Tables 1-4, most of the data taken during the testing and the results of intermediate and final calculations for each of the specific time periods. The symbols in the headings relate to the sample calculations in Appendix A.

The Panero refueling area control system was sampled for a total of 287 minutes during the three runs. Average efficiencies for each of the three runs were 90.7%, 89.9%, and 88.1% for an arithmetic average of 89.6%. Time weighting the average results in an 89.7% overall efficiency. Fuel movement periods dictated the length of the test runs. Run No's. 1 and 3 were therefore only one hour, while Run No. 2 was almost four hours. Time weighting the results was employed because of the difference in the sample times.

Flow rates at Panero corrected to standard conditions of 60°F and one atmosphere ranged from 21 cfm to 58 cfm, averaging 43 cfm. There appears to be an inverse correlation between flow rates and hydrocarbon removal efficiencies at least in the flow rates encountered in this test series. The same relationship seems to exist between inlet loading and efficiency. During the first half of Run 2 however, the lower efficiencies could be the result of the relatively lower flow rates.

TABLE 1. SUMMARY OF INLET AND OUTLET CONCENTRATIONS, MASS RATES, AND HYDROCARBON RECOVERY EFFICIENCY FOR RUN 1, SEPTEMBER 22, 1981 PANERO REFUELING AREA

	INLET			OUTLET			
Time Interval	Measured Fraction by Volume (as Methane)	Corrected Fraction HC by Volume	Mass HC Emission Rate lbs/hr	Measured Fraction HC by Volume (as Methane)	Corrected Fraction HC by Volume	Mass HC Emission Rate	Percent Recovery Efficiency
1035-1045	0.4361	0.0895	49.34	0.0410	0.0123	4.35	91.2
1045-1055	0.4345	0.0892	48.06	0.0410	0.0126	4.40	90.8
1055-1105	0.4464	0.0910	50.72	0.0470	0.0142	5.05	90.0
1105-1115	0.4819	0.0989	52.52	0.050	0.0151	5.13	90.2
1115-1125	0.5016	0.1025	57.38	0.0475	0.0143	5.07	91.2
Average			51.60			4.80	90.7

TABLE 2. SUMMARY OF INLET AND OUTLET CONCENTRATIONS, MASS RATES, AND HYDROCARBON RECOVERY EFFICIENCY FOR RUN 2, 23 SEPTEMBER 1981 PANERO REFUELING AREA.

	INLET			OUTLET			
Time Interval	Measured Fraction by Volume (as Methane)	Corrected Fraction HC by Volume	Mass HC Emission Rate lbs/hr	Measured Fraction HC by Volume (as Methane)	Corrected Fraction HC by Volume	Mass HC Emission Rate	Percent Recovery Efficiency
1009-1019	0.2223	0.0450	29.83	0.014	0.0041	1.85	93.8
1019-1029	0.3255	0.0660	44.96	0.004	0.0116	5.41	88.0
1029-1039	0.3414	0.0700	45.75	0.0445	0.0129	5.68	87.6
1039-1049	0.2978	0.0610	39.04	0.0430	0.0125	5.44	86.1
1049-1059	0.3295	0.0670	43.30	0.0420	0.0122	5.33	87.7
1059-1109	0.2938	0.0600	40.54	0.0425	0.0123	5.66	86.0
1139-1149	0.3573	0.0730	49.65	0.0465	0.0135	6.16	87.6
1149-1159	0.3811	0.0780	53.21	0.0470	0.0136	6.24	88.3
1159-1209	0.3970	0.0810	53.90	0.0480	0.0139	6.20	88.5
1209-1219	0.4049	0.0830	55.39	0.0465	0.0135	5.98	89.2
1240-1250	0.3772	0.0770	27.74	0.0355	0.0103	2.48	91.1
1250-1300	0.3811	0.0790	26.03	0.0340	0.0099	2.15	91.7
1300-1310	0.3811	0.0780	25.88	0.0315	0.0091	2.02	92.2
1310-1320	0.3811	0.0780	28.91	0.0302	0.0087	2.15	92.6
1320-1330	0.3891	0.0790	21.72	0.0305	0.0088	1.61	92.6
1330-1340	0.3946	0.0810	47.39	0.0325	0.0094	3.66	92.3
1340-1350	0.4105	0.0840	45.80	0.0385	0.0112	4.04	90.2
1350-1400	0.4327	0.0880	25.54	0.0375	0.0109	2.09	91.8
Average			39.14			4.12	89.9

TABLE 3. SUMMARY OF INLET AND OUTLET CONCENTRATIONS, MASS RATES, AND HYDROCARBON RECOVERY EFFICIENCY FOR RUN 3, 1 OCTOBER 1981 PANERO REFUELING AREA.

	INLET			OUTLET			
Time Interval	Measured Fraction by Volume (as Methane)	Corrected Fraction HC by Volume	Mass HC Emission Rate lbs/hr	Measured Fraction HC by Volume (as Methane)	Corrected Fraction HC by Volume	Mass HC Emission Rate	Percent Recovery Efficiency
0924-0934	0.3622	0.0739	24.50	0.038	0.0109	2.44	90.0
0934-0944	0.3821	0.0780	41.08	0.052	0.0149	5.34	87.0
0944-0954	0.4099	0.0836	37.05	0.061	0.0175	5.24	85.9
0954-1004	0.4020	0.0820	36.52	0.052	0.0149	4.50	87.7
1004-1014	0.3900	0.0796	36.87	0.0465	0.0134	4.16	88.7
1014-1021	0.3940	0.0804	19.87	0.0433	0.0124	2.07	89.6
Average*			32.65			4.06	88.1

*Time weighted

TABLE 4. SUMMARY OF INLET AND OUTLET CONCENTRATIONS, MASS RATES, AND HYDROCARBON RECOVERY EFFICIENCY FOR RUN 4, 8 OCTOBER 1981 PRITCHARD REFUELING AREA.

	INLET			OUTLET			
Time Interval	Measured Fraction by Volume (as Methane)	Corrected Fraction HC by Volume	Mass HC Emission Rate l'bs/hr	Measured Fraction HC by Volume (as Methane)	Corrected Fraction HC by Volume	Mass HC Emission Rate	Percent Recovery Efficiency
1004-1014	0.4053	0.08227	64.37	0.0615	0.0180	9.27	85.6
1014-1024	0.4068	0.0830	62.84	0.0620	0.0182	9.10	85.5
1024-1034	0.3976	0.0811	54.10	0.0627	0.0184	8.14	85.0
1034-1044	0.3899	0.0794	54.39	0.0583	0.0171	7.74	85.8
1044-1054	0.3937	0.0803	48.31	0.0610	0.0179	7.15	85.2
1054-1104	0.3860	0.0788	29.17	0.0545	0.0159	3.90	86.5
1104-1106	0.3899	0.0796	26.25	0.0491	0.014[illegible]	3.15	88.0
Average*			51.36			7.41	85.7

*Time weighted

TABLE 5. SAMPLING DATA AND RESULTS FROM TESTING HC VAPOR RECOVERY UNITS AT MARCH AIR FORCE BASE

Date/ Run #	Time	Duct Temp. °F	Baro. Press. - Hg	Actual Outlet Flow Rate (Q_{ao}) ft³/min	Standard Outlet Flow Rate (Q_{so}) ft³/min	Outlet HC Conc. as CH_4 (C_o) (ppm)	Actual Outlet HC Conc. C_{ao} (ppm)	Fraction HC in Outlet Gas (B_{HCo})	Air Flow Rate -Std. (Q_{af}) ft³/min	Inlet HC Conc. as CH_4 (C_i) (ppm)	Actual Inlet HC Conc. (C_{ia}) (ppm)	Fraction HC in Inlet Gas (B_{HCi})	Inlet Gas Flow -Std. (Q_{gi}) ft³/min	Average Molecular Wt. Outlet HC	Average Carbon No. Outlet	Mass HC Loading Inlet	Mass HC Loading Outlet	% Efficiency
PAMPO REFUELING AREA																		
09/22/81																		
Run 1	1035-1045	-32	28.36	40	46	41,000	12,349	0.0123	45.49	436,080	88,996	0.089	49.53	48.48	3.32	49.34	4.35	91.2
	1045-1055	-26	28.36	40	45	42,000	12,651	0.0126	44.86	434,500	83,673	0.089	49.19	48.48	3.32	48.06	4.40	90.8
	1055-1105	-34	28.36	40	46	47,000	14,156	0.0142	45.62	446,350	91,092	0.091	50.20	48.48	3.32	50.72	5.05	90.0
	1105-1115	-14	28.36	40	44	50,000	15,060	0.0151	43.33	481,900	98,347	0.098	48.26	48.48	3.32	52.52	5.13	90.2
	1115-1125	-33	28.36	40	46	47,500	14,307	0.0143	45.50	501,650	102,378	0.102	50.66	48.48	3.32	57.38	5.07	91.2
Average	1035-1125	-27.8	28.36	40	46	45,500	13,705	0.0137	44.98	460,096	93,897	0.0939	49.64	48.48	3.32	51.75	4.80	90.7
09/23/81																		
Run 2	1009-1019	16	28.39	55	57	14,000	4,106	0.0041	57.01	222,320	45,371	0.045	59.70	49.75	3.41	29.83	1.85	93.8
	1019-1029	-26	28.39	51	58	40,000	11,730	0.0117	57.30	325,540	66,437	0.066	61.35	49.75	3.41	44.96	5.41	88.0
	1029-1039	-33	28.39	48	55	44,500	13,050	0.0130	56.74	341,420	69,678	0.070	58.86	49.75	3.41	45.75	5.68	87.6
	1039-1049	-37	28.39	47	55	43,000	12,610	0.0126	56.13	297,750	60,765	0.061	57.64	49.75	3.41	39.06	5.44	86.1
	1049-1059	-38	28.39	47	55	42,000	12,317	0.0123	54.27	329,510	67,247	0.067	58.20	49.75	3.41	43.30	5.33	87.7
	1059-1109	-34	28.39	50	58	42,500	12,463	0.0124	57.20	293,780	59,955	0.060	60.85	49.75	3.41	40.54	5.66	86.0
	1139-1149	-40	28.39	49	58	46,500	13,636	0.0136	56.78	357,300	72,918	0.073	61.25	49.75	3.41	49.65	6.16	87.6
	1149-1159	-39	28.39	49	57	47,000	13,783	0.0138	56.65	381,120	77,780	0.078	61.44	49.75	3.41	53.21	6.24	88.3
	1159-1209	-36	28.39	48	56	48,000	13,076	0.0141	55.07	397,000	81,020	0.081	59.93	49.75	3.41	53.90	6.20	88.5
	1209-1219	-36	28.39	48	56	46,500	13,636	0.0136	55.11	404,940	82,641	0.083	60.10	49.75	3.41	55.39	5.98	89.2
	1240-1250	-36	28.39	36	30	35,500	10,411	0.0104	29.95	377,350	76,969	0.077	32.45	49.75	3.41	27.74	2.48	91.1
	1250-1300	-31	28.39	24	28	34,000	9,970	0.0099	27.23	389,750	79,490	0.079	29.67	49.75	3.41	26.03	2.15	91.7
	1300-1310	-34	28.39	24	28	31,500	9,237	0.0092	27.55	381,120	77,780	0.078	29.88	49.75	3.41	25.88	2.02	92.2
	1310-1320	-31	28.39	27	31	30,200	8,856	0.0088	30.78	381,320	77,780	0.078	33.38	49.75	3.41	28.91	2.15	92.6
	1320-1330	-31	28.39	20	23	30,500	8,944	0.0089	22.80	389,060	79,400	0.079	24.76	49.75	3.41	21.72	1.61	92.6
	1330-1340	-36	28.39	42	49	32,500	9,531	0.0095	48.42	394,618	80,534	0.081	52.69	49.75	3.41	47.39	3.66	92.3
	134 -1350	-37	28.39	39	45	38,500	11,290	0.0113	44.98	416,498	83,275	0.084	49.10	49.75	3.41	45.60	4.04	91.2
	135- 900	-39	28.39	21	24	37,500	10,977	0.0110	23.83	432,730	88,312	0.088	26.14	49.75	3.41	25.54	2.09	91.8
10/01/81																		
Run 3	092-0 34	- 5	28.28	26	28	38,000	11,079	0.0110	27.65	342,209	73,916	0.0739	29.86	50.05	3.43	26.50	2.44	90.8
	0934-0944	- 6	28.28	41	44	52,000	15,160	0.0152	43.71	382,100	77,980	0.0780	47.43	50.05	3.43	42.08	5.34	87.0
	0944-0954	-11	28.28	34	37	61,000	17,784	0.0178	36.56	409,900	83,653	0.0836	39.91	50.05	3.43	37.05	5.24	85.9
	0954-1004	-13	28.28	34	37	52,000	15,169	0.0152	36.81	402,000	82,041	0.0820	40.11	50.05	3.43	36.52	4.50	87.7
	1004-1014	-18	28.28	35	39	46,500	13,556	0.0135	38 39	390,000	79,592	0.0796	41.72	50.05	3.43	36.87	4.16	88.7
	1014-1021	-19	28.28	18.6	21	43,300	12,624	0.0126	20.47	394,000	80,408	0.0804	22.26	50.05	3.43	19.87	2.07	89.6
PRITCHARD REFUELING AREA																		
10/08/81																		
Run 4	1004-1014	-18	28.22	59	65	41,500	18,035	0.0180	64.29	405,300	82,714	0.0827	70.20	49.67	3.41	64.37	9.27	85.6
	1014-1024	-21	28.22	57	64	62,000	18,182	0.0182	62.52	406,800	83,020	0.0830	68.18	49.67	3.41	62.84	9.10	85.5
	1024-1034	-24	28.22	56	56	62,700	18,257	0.0184	55.21	397,600	81,143	0.0811	60.06	49.67	3.41	54.10	8.16	85.0
	1034-1044	-26	28.22	51	58	58,900	17,497	0.0171	56.44	389,900	79,571	0.0796	61.54	49.67	3.41	54.39	7.74	85.8
	1044-1054	-25	28.22	45	51	61,000	17,889	0.0179	49.83	393, 00	80,347	0 0803	54.18	49.67	3.41	48.31	7.15	85.2
	1054-1104	-20	28.22	28	31	54,500	15,982	0.0159	30.71	386,000	78,776	0.0788	33.34	49.67	3.41	29.17	3.90	86.6
	1104-1106	-16	28.22	25	28	49,100	14,399	0.0144	27.34	389,900	79,571	0.0796	29.70	49.67	3.41	26.25	3.15	88.0

Duct temperatures, which reflect condensor temperatures, were normal during the period of that run. In Run 3 the warmer duct temperatures could be the cause of the slightly lower efficiencies measured during that test run.

The one test run at Pritchard showed an average efficiency of 85.7%, somewhat lower than at Panero. Inlet loadings were as high, if not higher, than Panero. The explanation for the lower efficiency could be the combination of warmer duct temperatures, higher gas flows and higher inlet concentrations than than those found in two of the three Panero test runs.

Gas chromatographic analyses of the outlet vapors are summarized in Table 6. Hydrocarbons C_1 through C_4 were identified in each sample. C_4 compounds comprised over 50% of every sample total. Constituent analysis of the inlet vapors was not a part of this study. For calculation purposes, a typical JP-4 vapor constituent breakdown at 70°F fuel temperature was used. This analysis, supplied by the Air Force and conducted by Monsanto Research, showed C_4 through C_6 hydrocarbons to predominate.

RECOMMENDATIONS

If there is sufficient concern regarding the possible relationship between flow rate (and mass loading) and control efficiency, additional testing is recommended. The current test series was conducted with minimal control over the pumping rates. The apparent relationships could be verified under more controlled conditions.

TABLE 6. GAS CHROMATOGRAPH ANALYSIS FOR PERCENT COMPOSITION OF OUTLET VAPORS MARCH AIR FORCE BASE, CA, PANERO REFUELING UNIT

Run No.:	1		2					3		4	
Date:	9/22/81		9/22/81					10/01/81		10/8/81	
Sample:	1		2	3	4	Average for Samples 2-4		5		6	
Component	Mole %	Mole Wt.	Mole %	Mole %	Mole %	Mole %	Mole Wt.	Mole %	Mole Wt.	Mole %	Mole Wt.
CH_4	4.70	0.75	4.68	4.30	5.41	4.80	0.77	4.37	0.70	3.50	0.560
C_2H_4	0.03	0.01	0.03	0.02	0.02	0.02	0.01	0.02	0.01	0.03	0.008
C_2H_6	11.86	3.56	11.78	8.36	8.37	9.50	2.85	9.12	2.74	9.93	2.979
C_3H_6	---	---	---	---	0.33	---	0.05	---	---	---	---
C_3H_8	30.52	13.43	30.34	23.94	21.88	25.39	11.17	25.34	11.15	29.06	12.786
C_4H_8/ C_4H_{10}	52.91	30.29	53.16	63.37	63.99	60.17	34.90	61.16	35.46	57.48	33.34
Run Avg.	100.02	48.44				99.99	49.75	99.99	50.05	100.00	49.67

Run No.:	1		2					3		4	
Date:	9/22/81		9/23/81					8/01/81		8/08/81	
Sample:	1		2	3	4	Average for Samples 2-4		5		6	
Carbon Number	Mole %	Carbon Number	Mole %	Mole %	Mole %	Mole %	Carbon Number	Mole %	Carbon Number	Mole %	Carbon Number
1	4.70	0.047	4.68	4.30	5.41	4.80	0.048	4.37	0.044	3.50	0.035
2	11.89	0.238	11.81	8.38	8.39	9.52	0.190	9.14	0.183	9.96	0.199
3	30.52	0.916	30.34	23.94	22.21	25.50	0.765	25.34	0.760	29.06	0.872
4	52.91	2.116	53.16	63.37	63.99	60.17	2.407	61.14	2.445	57.48	2.300
Avg.	100.02	3.32				99.99	3.41	99.99	3.43	100.00	3.41

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APPENDIX A

MARCH AIR FORCE BASE EXAMPLE CALCULATIONS

Measured Parameters

C_I = Inlet HC concentration, ppm measured as CH_4 (Total Hydrocarbon [HC] Analyzer)
C_o = Outlet HC concentration, ppm measured as CH_4 (Total Hydrocarbon [HC] Analyzer)
Q_{AO} = Outlet gas flow, actual cubic feet per minute (Roots Meter)
T_{STD} = Temperature at standard condition
T_{SO} = Outlet gas temperature (type and thermocouple)
P_{STD} = Barometric pressure at standard condition
P_B = Barometric pressure
MW_I = Inlet average molecular weight
MW_o = Outlet average molecular weight
R_I = Inlet average carbon number
R_O = Outlet average carbon number

Given:

Run #1 Time 1035-1125

C_I = 460,096 ppm
C_O = 45,500 ppm
T_{STD} = 60°F
T_{SO} = -27.8°F
P_{STD} = 29.92"Hg
P_B = 28.36"Hg
Q_{AO} = 40 ft^3/min
MW_I = 70.14*
MW_o = 48.48
R_I = 4.9
R_O = 3.32

(1) Q_{SO} = Outlet flowrate @ standard condition

$$Q_{SO} = Q_{AO} \times \frac{T_{STD}}{T_{SO}} \times \frac{P_B}{P_{STD}}$$

$$= 40\ ft^3/min \times \frac{520°F}{432.2} \times \frac{28.36}{29.92}$$

$$= 45.62\ ft^3/min$$

* Calculated from typical JP-4 vapor constituent analysis @ 70°F. The analysis was prepared by MMonsanto and supplied to ES by Tom Stauffer, Tyndall AFB.

(2) Determination of average molecular wt and carbon no. of the outlet gas as per GC analysis

	Mole %	Contribution to Mole Wt	Carbon No.	%	Carbon Contribution to Gas Composition
CH_4	4.7	0.752	1	4.7	0.047
C_2H_4	0.03	0.01	2	11.84	0.236
C_2H_6	11.81	3.54	3	30.19	0.906
C_3H_8	30.19	13.28	4	53.27	2.131
				100.00	3.32 avg. C No.

C_4H_{10} $\frac{53.27}{100.00}$ $\frac{30.90}{43.48}$ avg. mol. wt/mole

MW_o = (mol. wt of CH_4 x % CH_4) + (mol. wt C_2H_4 x % C_2H_4) + (mol. wt C_3H_8 x % C_3H_8) + (mol. wt C_4H_{10} x % C_4H_{10})

= (16 x 0.047) + (28 x 0.0003) + (30 x 0.1181) + (44 x 0.3019) + (58 x 0.5327)

MW_o = 48.48

R_o = (No. of C for CH_4 x %) + (No. of C for C_2H_4 x % total sum for C_2 compound) + (No. of C for C_3H_8 x % total of C_3 compound) + (No. of C for D_4H_8 x % total sum for C_4 compound)

= (1.0 x 0.047) + (2 x 0.1184) + (3 x 0.3019) + (4 x 0.5327)

= (0.047) + (0.236) + (0.906) + (2.131)

R_o = 3.32

(3) Determination of Q_{AP} (air flow rate through the control device @ standard condition)

C_{OA} = Actual outlet HC concentration, ppm

$$C_{OA} = \frac{C_o}{R_o} = \frac{45,500}{3.32}$$

C_{OA} = 13,705 ppm

$$B_{HCO} = \frac{C_{OA}}{1{,}000{,}000} = \text{Fraction of HC in outlet gas}$$

$$= \frac{13{,}750}{1{,}000{,}000}$$

$$B_{HCO} = 0.0137$$

$$Q_{AF} = Q_{SO} \times (1-B_{HCO})$$

$$= 45.62 \text{ ft}^3/\text{min} \times (1-.0137)$$

$$= 44.98 \text{ ft}^3/\text{min}$$

(4) Determination of Q_{SI} (Inlet gas flow rate at standard condition)

$$C_{IA} = \frac{C_I}{R_I} = \text{Actual inlet HC concentration}$$

$$= \frac{460{,}096 \text{ ppm}}{4.9}$$

$$C_{IA} = 93{,}897 \text{ ppm}$$

$$B_{HCI} = \frac{C_{IA}}{1{,}000{,}000} = \text{Fraction of HC inlet gas}$$

$$= \frac{93{,}897 \text{ ppm}}{1{,}000{,}000}$$

$$B_{HCI} = 0.0939$$

$$Q_{SI} = \frac{Q_{AF}}{(1-B_{HCI})}$$

$$= \frac{44.98 \text{ ft}^3/\text{min}}{(1-0.0939)}$$

$$Q_{SI} = 49.64 \text{ ft}^3/\text{min}$$

(5) Mass Hydrocarbon Loadings Determination

M_I = Inlet mass hydrocarbon loading

$$M_I = \frac{Q_{SI} \times B_{HCI}}{379\ SCF} \times M_{WI} \times \frac{60\ min}{hr}$$

$$= \frac{49.64\ ft^3/min \times 0.0939}{379\ SCF} \times 70.14 \times \frac{60\ min}{hr}$$

M_I = 51.75 lbs HC/hr

M_O = Outlet mass hydrocarbon loading

$$M_O = \frac{Q_{SO} \times B_{FCO}}{379\ SCF} \times M_O \times \frac{60\ min}{hr}$$

$$= \frac{45.62\ ft^3/min \times 0.0137}{379\ SCF} \times 48.48 \times \frac{60\ min}{hr}$$

M_O = 4.80 lbs HC/hr

HC Removal Efficiency = ΣE

$$\Sigma E = \frac{M_I - M_O}{M_I} \times 100$$

$$= \frac{51.75 - 4.76}{51.75} \times 100$$

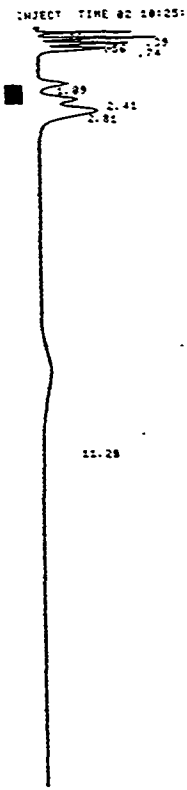
$$= \frac{46.99}{51.75} \times 100$$

ΣE = 90.7%

APPENDIX B

SAMPLE FIELD CALCULATIONS

EXAMPLE GC CALIBRATION



GC CALIBRATION REPORT

[redacted]0.0BER0

MARCH AFB HC 82 10:25:46

FILE 1 METHOD 5. PLN 3 INDEX 1 CAL'B

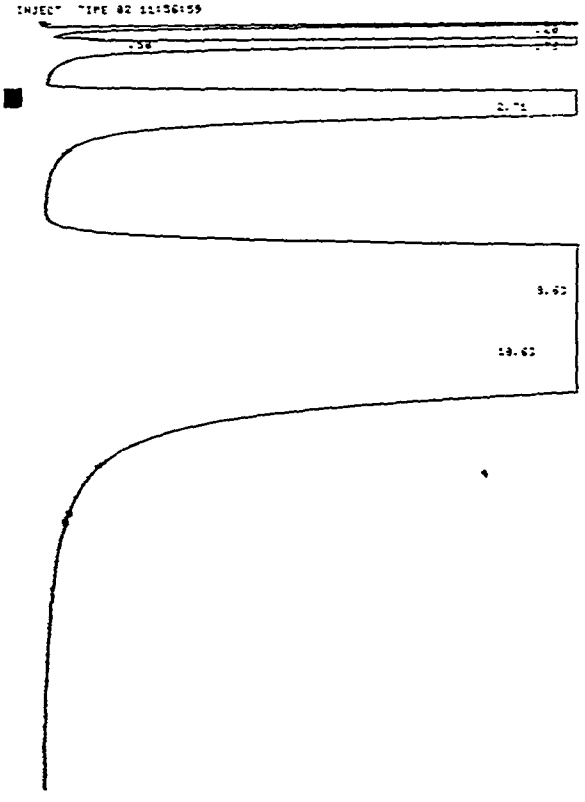
ANALYST: W.C. SARGEANT

NAME	CONC	RT	AREA	BC	PF
CH4	15.2	0.0	481	01	26.512
C2H2	15.	0.39	775	02	51.667
C2H4	15.1	0.56	684	02	52.549
C2H6	14.2	0.74	984	03	62.217
C3H4	12.6	1.89	497	01	26.544
C3H6	11.8	2.41	928	02	77.966
C3H8	11.2	2.81	2188	03	67.892
C4H10	15.7	11.28	1885	01	114.968
TOTALS	132.2		9288		

NEW FILE:

NAME	PF	RT
CH4	26.512	0.19
C2H2	51.667	0.28
C2H4	52.549	0.35
C2H6	62.217	0.72
C3H4	26.544	1.65
C3H6	77.966	2.12
C3H8	67.892	2.75
C4H10	114.968	11.17

EXAMPLE GC TEST RUN

Sample #5

10-1-81