EPA 340/1-77-012

# COMPLIANCE ANALYSIS OF SMALL BULK PLANTS

OCTOBER 1976

U.S. Environmental Protection Agency
Enforcement Division
Region VIII
Denver, Colorado

# COMPLIANCE ANALYSIS OF SMALL BULK PLANTS
(Testing)

Final Report

by

R. J. Bryan
R. L. Norton
P. S. Bakshi
J. Stevenson

Contract No.: 68-01-3156, Task Order No. 17

Project Officer: Gary Parish

Prepared for

U.S. Environmental Protection Agency
Enforcement Division
Region VIII
Denver, Colorado 80203

October 1976

ABSTRACT

Pacific Environmental Services (PES) has completed a testing program of vapor recovery systems at small bulk plants (less than 20,000 gallons/day) under EPA Contract No. 68-01-3156. Testing was conducted on a vapor balance system and on a secondary processor (straight refrigeration) system. The results of 41 tests are presented. Twenty-five of these tests were performed on the secondary system (7 transport deliveries, 18 bulk plant delivery vehicles) and sixteen were conducted on the vapor balance system (5 transport deliveries, 11 bulk plant delivery vehicles).

The test results indicate that both systems can function with vapor recovery efficiency greater than 90 percent, but only if account trucks are maintained leak-free.

TABLE OF CONTENTS


| Chapter | | Page |
|---|---|---|
| I. | INTRODUCTION | I- 1 |
| II. | SYSTEM DESCRIPTION | II- 1 |
| | A. VAPOR BALANCE SYSTEM | II- 1 |
| | B. REFRIGERATION SYSTEM | II- 3 |
| III. | TESTING AND EQUIPMENT | III- 1 |
| | A. VAPOR RETURN LINE | III- 1 |
| | B. STORAGE TANK VENTING LOSSES | III- 1 |
| | C. TEMPERATURE OF STORAGE TANKS | III- 4 |
| | D. HYDROCARBON CONCENTRATION | III- 4 |
| | E. REID VAPOR PRESSURE AND GAS CHROMATOGRAPHIC SAMPLES | III- 6 |
| | F. LEAK DETECTION | III- 6 |
| | G. CALIBRATIONS | III- 8 |
| | H. DESCRIPTION | III- 8 |
| | 1. REFRIGERATION SYSTEM | III- 8 |
| | 2. VAPOR BALANCE SYSTEM | III- 9 |
| IV. | SUMMARY OF RESULTS | IV- 1 |
| | A. TESTING OF REFRIGERATION SYSTEM | IV- 1 |
| | 1. PRESSURE RELATIONSHIP | IV- 7 |
| | 2. EXHAUST VENT LOSSES | IV- 7 |
| | B. TESTING OF VAPOR BALANCE SYSTEM | IV- 8 |
| | 1. PRESSURE RELATIONSHIP | IV-12 |
| | 2. EXHAUST VENT LOSSES | IV-12 |
| | C. GAS CHROMATOGRAPH ANALYSIS | IV-17 |
| | D. RVP ANALYSIS | IV-20 |
| V. | CONCLUSIONS | V- 1 |

TABLE OF CONTENTS (continued)


| Section | | Page |
|---|---|---|
| APPENDIX A | | |
| | TEST PROCEDURES AND SAMPLE CALCULATIONS | A-1 |
| APPENDIX B | | |
| | LIST OF EQUIPMENT | B-1 |
| APPENDIX C | | |
| | SAMPLE DATA SHEETS | C-1 |
| APPENDIX D | | |
| | LABORATORY ANALYSIS REPORTS | D-1 |
| APPENDIX E | | |
| | SAMPLE CALIBRATION CURVES | E-1 |


LIST OF FIGURES


| Figure | | Page |
|---|---|---|
| 1 | VAPOR BALANCE SYSTEM - BOULDER, COLORADO | II-2 |
| 2 | REFRIGERATION SYSTEM - ESCONDIDO, CALIFORNIA | II-5 |
| 2a | EXPANDED VIEW OF FLOW LINES AROUND REFRIGERATION UNIT | II-6 |
| 3 | VAPOR RETURN LINE TESTING FLOW DIAGRAM | III-2 & 3 |
| 4 | VENTING LOSS TESTING FLOW DIAGRAM | III-5 |
| 5 | TYPICAL CHART RECORDING OF HYDROCARBON CONCENTRATION | III-7 |
| Appendix Figures | | |
| A-1 | SAMPLING LOCATIONS | A-8 |
| A-2 | SAMPLING LOCATIONS (continued) | A-9 |
| E-1 | CALIBRATION OF DRY GAS METER | E-1 |
| E-2 | CALIBRATION OF ROTOMETERS | E-2 |
| E-3 | CALIBRATION OF BECKMAN 400 FID | E-3 |

TABLE OF CONTENTS (continued)

## LIST OF TABLES


| Table | | Page |
|---|---|---|
| 1 | SUMMARY OF RESULTS - ESCONDIDO | IV- 2 & 3 |
| 2 | EFFICIENCIES OF ACCOUNT TRUCKS AT ESCONDIDO | IV- 5 |
| 3 | FREQUENCY OF OPERATION VERSUS EFFICIENCY FOR ACCOUNT TRUCKS AT ESCONDIDO | IV- 6 |
| 4 | ESCONDIDO - EXHAUST VENT DATA | IV- 8 |
| 5 | SUMMARY OF RESULTS - BOULDER | IV-10 & 11 |
| 6 | BOULDER - EXHAUST VENT DATA | IV-14 |
| 7 | PRESSURE DATA DURING VENTING AT BOULDER | IV-15 |
| 8 | SUMMARY OF G. C. ANALYSIS | IV-18 |

# I. INTRODUCTION

Pacific Environmental Services (PES), under EPA Contract Number 68-01-3156, has conducted efficiency testing of vapor recovery systems installed at small bulk plant facilities. For the purposes of this study, a small bulk plant was defined as having a daily throughput of gasoline products of less than 76,000 liters (20,000 gallons). Two installations were studied, one a vapor-balance system without secondary vapor recovery, the other a vapor-balance system modified by refrigeration to maintain a reduced temperature in the storage tanks. The first, located in Boulder, Colorado, is operated by Continental Oil Company; the second, in Escondido, California, is operated by Standard Oil Company of California. These installations are described in Section II.

Efficiency testing was done by measuring amounts of liquid gasoline transferred and of gasoline vapor retrieved during transfers of gasoline into and out of the storage tanks. Efficiency is defined as the ratio of vapor retrieved to a theoretical estimate of the amount which would be lost during transfer if emissions were uncontrolled.

Testing was done under summer conditions. Data were obtained during 16 transfers in a four-day period in Boulder and during 25 transfers on five days of operation in Escondido. Data obtained included volume of liquid gasoline transferred; volume, temperature, pressure and hydrocarbon concentration of the displaced gas (vapor-laden air) and of any gas vented from the storage tanks; and temperature and pressure of the storage tank contents.

Equipment used for these measurements and the manner of installing and operating it are described in Section III; a detailed formal account of test procedures and of methods of calculating results is attached as Appendix A, and a list of necessary items of equipment constitutes Appendix B. Results of the testing are tabulated

and discussed in Section IV, with supporting information presented in Appendices C (Sample Data Sheets), D (Laboratory Analysis Reports) and E (Sample Calibration Curves). Finally, conclusions from this study are reviewed in Section V.

## II. SYSTEM DESCRIPTION

### A. VAPOR BALANCE SYSTEM

The vapor recovery system installed at the CONOCO bulk plant in Boulder, Colorado employs a vapor balance system which operates on the principle of a simple exchange of fluids between the truck tank and the storage tanks. In Phase I vapor recovery, liquid gasoline is pumped from the transport vehicle into the storage tanks and displaces an equivalent volume of vapor-laden air which is routed back to the vehicle through the vapor return line. In Phase II vapor recovery, the system is reversed, with the liquid gasoline pumped into the bulk plant delivery vehicle and the vapor-laden air displaced back to the storage tanks through the vapor return line. In principle, with tight connections, the system should operate with no hydrocarbon losses but due either to poor maintenance or improper installation, hydrocarbon losses were discovered through bulk plant delivery truck hatch covers and through safety vents on the fixed roof storage tanks.

The CONOCO vapor balance system incorporated a two inch vapor return line which was mainfolded to each of the five storage tanks handling gasoline. A spring actuated poppet valve was installed at the loading rack outlet of the vapor return line to eliminate hydrocarbon losses when the plant was idle. The CONOCO bulk plant was also designed to utilize one vapor return hook-up for both transport deliveries and dispensing product into bulk plant account trucks. This was accomplished through a series of valves enabling the loading rack pumps to be used for pumping in either direction. Figure 1 illustrates the vapor balance system tested at the CONOCO facility.

The system also incorporated a series of pressure relief vents installed in the storage tank system. A pressure vacuum (PV) vent was located in the vapor return line with a 2586 $N/m^2$* (6 oz) pressure setting and a 215 $N/m^2$ (1/2 oz) vacuum setting to allow the re-

* $N/m^2$ = Newton/meter$^2$

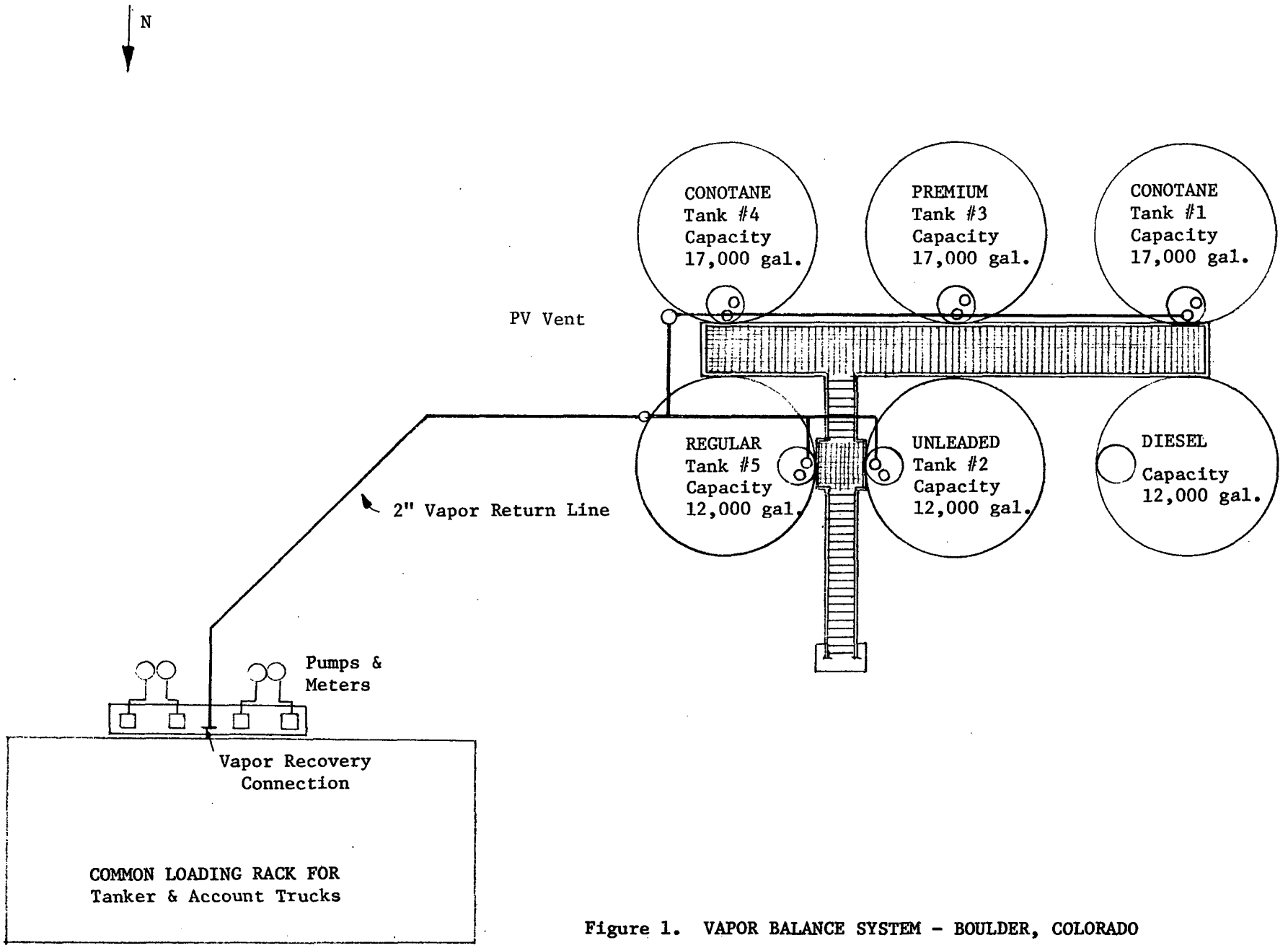



Figure 1. VAPOR BALANCE SYSTEM - BOULDER, COLORADO

lease of vapors or the entrance of air into the system during severe pressure changes in the loading or unloading operations. If the system pressure continued to increase and the PV vent could not allow the escape of vapors quickly enough, each storage tank had an emergency vent set to open at 4309 $N/m^2$ (10 oz) of pressure. If under extreme conditions these vents could not relieve the system pressure, a series of carbon shear pins and hatch covers would open between 13,790 $N/m^2$ and 20,680 $N/m^2$ (2 and 3 lbs) pressure. These final 2 steps in pressure relief are installed primarily as safety features if the PV vent cannot handle the pressure load.

## B. REFRIGERATION SYSTEM

The San Diego area was selected to obtain a suitable test location for a secondary processing unit since the vapor recovery regulations require such controls at small bulk plants. Initially, the majority of the bulk plants installed a catalytic incineration system for the control of vapors. Upon inspection of bulk plants in San Diego, it was found that all of these units were inoperative due mostly to mechanical failures. The only operating vapor recovery unit utilizes refrigeration to minimize pressure variations and, therefore, breathing losses caused by temperature changes within the storage space. This system differs from conventional secondary systems for vapor recovery in that there is no provision for venting stripped air directly from the refrigeration unit.

This vapor recovery system, installed at the Standard Oil Company bulk plant in Escondido, employs the refrigeration unit to reduce pressure in the storage tanks and thereby to minimize venting. In this system, vapors are drawn from the storage tanks by a blower, pass over cooling coils in the refrigeration unit and exhaust back to the storage tanks through an insulated return line. The system makes no effort to condense vapors but is designed strictly to maintain a constant temperature in the storage tanks (in this case 60°F) and thereby maintain a pressure below the venting level. The system is

actuated when the storage tank pressure reaches 748 $N/m^2$ (3 in $H_2O$) and continues to operate until the pressure falls below 374 $N/m^2$ (1.5 in $H_2O$) or until 20 minutes have elapsed. If after 20 minutes the pressure has not decreased to 374 $N/m^2$ the system is actuated again and runs for another 20 minutes. This cycle continues until the pressure falls below the set level of 374 $N/m^2$.

The Standard Oil bulk plant incorporated a 3-inch vapor return line manifolded to all tanks handling gasoline which included the insulated line that ran from the refrigeration unit back to the storage tanks. Separate vapor return connections were used for the delivery of gasoline to the bulk plant and the loading racks for dispensing gasoline. At each location the vapor return connection was sealed with a spring actuated valve.

The bulk plant also had four gasoline service-station-type pumps connected into the vapor recovery system. The same blower which was used for the storage tank refrigeration system was also used to supply vacuum assist at the nozzle of these pumps and was actuated when the dispensing pump was energized.

The PV vent utilized in the vapor recovery system had settings of 1,495 $N/m^2$ (6 in $H_2O$) for pressure relief and 249 $N/m^2$ - 498 $N/m^2$ (1 - 2 in $H_2O$) on vacuum. A series of safety vents similar to those used at the CONOCO facility were installed in the storage tank system. Figure 2 illustrates the refrigeration system studied.

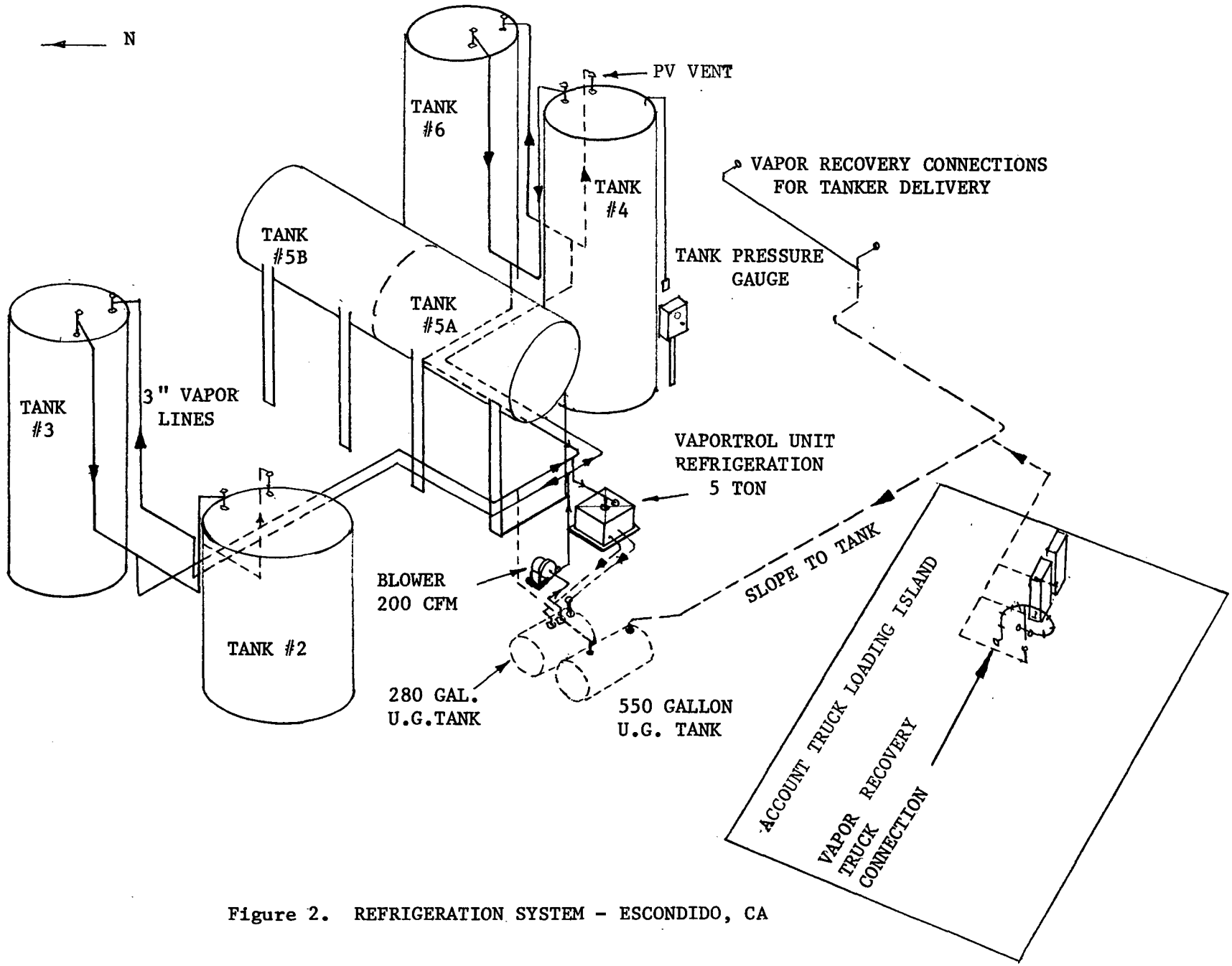
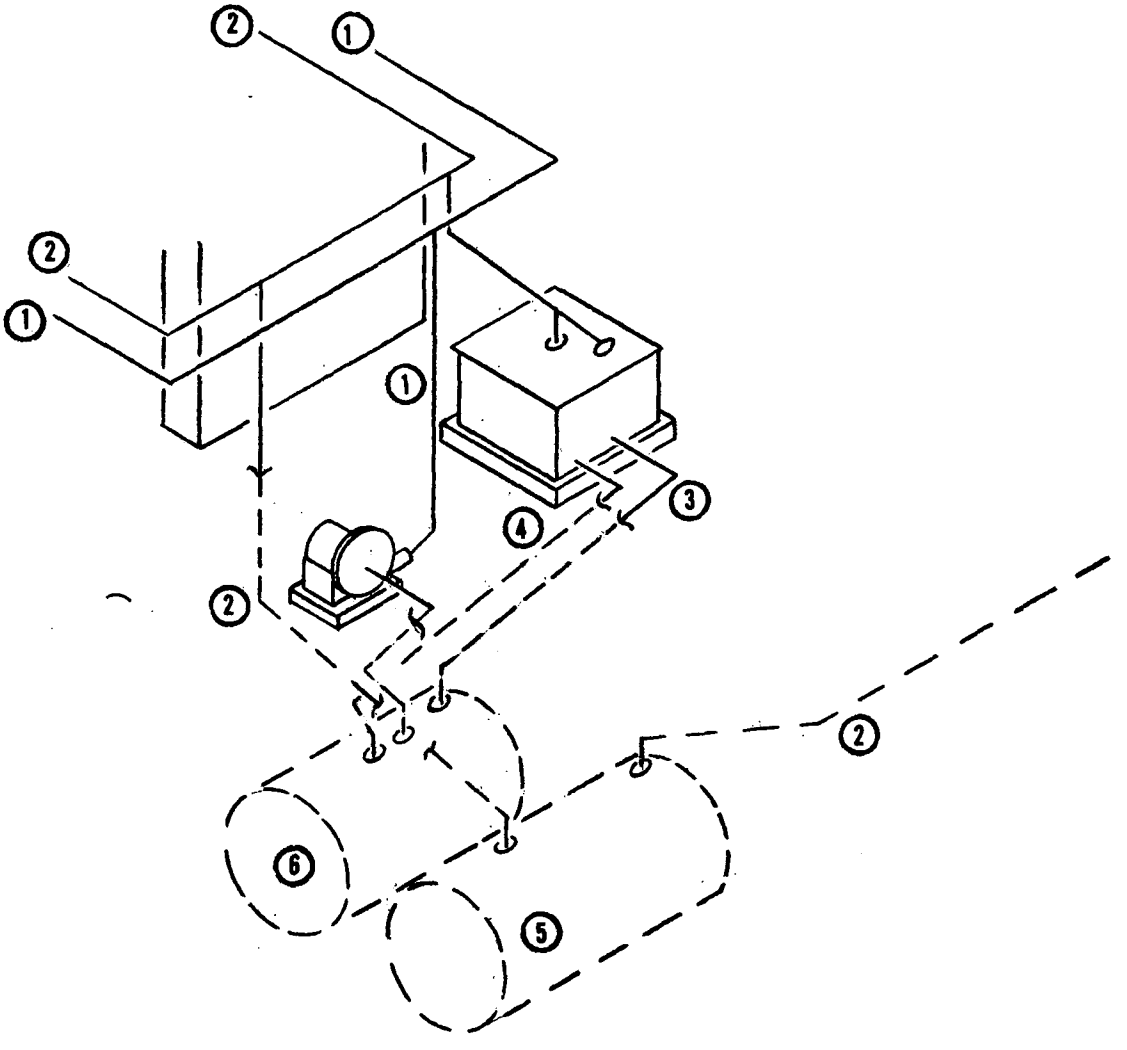



Figure 2. REFRIGERATION SYSTEM - ESCONDIDO, CA




1. Chilled vapor return to tank
2. Vapor return line (vapors can flow either into or from storage tanks)
3. Chilled vapor line
4. Liquid condensate line
5. Liquid drop-out in vapor return line
6. Condensate drop-out in chilled vapor system

Figure 2a. EXPANDED VIEW OF FLOW LINES AROUND REFRIGERATION UNIT

## III. TESTING AND EQUIPMENT

### A. VAPOR RETURN LINE

The hydrocarbon vapors returned to either the storage tanks or the transport vehicle were diverted from the existing vapor return line through a modified return system. This modified system used existing truck couplers to pass into a 3-inch flexible vapor recovery hose, through a volume meter and back into the vapor recovery system. The return volume was measured with a turbine flow meter rated at 9,000 CFH (Rockwell Model TP-9) which possesses an extremely low pressure drop of 50 $N/m^2$ (0.2 in $H_2O$). Pressure taps were installed in the modified return line at the inlet and the outlet of the turbine meter and pressure was determined using dual inclined manometers having ranges of 0 - 1,500 $N/m^2$ (0 - 6 in $H_2O$) and 0 - 6,800 $N/m^2$ (0 - 2 in Hg). An iron-constantan thermocouple was installed up stream of the meter for determinations of return vapor temperature. A vapor sample tap was located after the meter to insure the entire volume of return vapors passed through the meter. The sample extracted was extremely small (maximum 146 cc/min) and had no effect on the volume of vapors in the system. Figure 3 illustrates the vapor return test set-up for the filling of account trucks and transport delivery vehicles.

### B. STORAGE TANK VENTING LOSSES

A pressure switch and solenoid valve arrangement was installed in the vapor return line at the top of the storage tanks to simulate the pressure side of the PV vent allowing the measurement of venting losses. Since the measurement of in-breathing of air into the storage tanks was not required, the vacuum side of the PV vent was not simulated. The existing PV vent was not removed from the system and it could therefore allow in-breathing when necessary and would also act as a safety vent if there was a loss of electric power to the solenoid valve system.

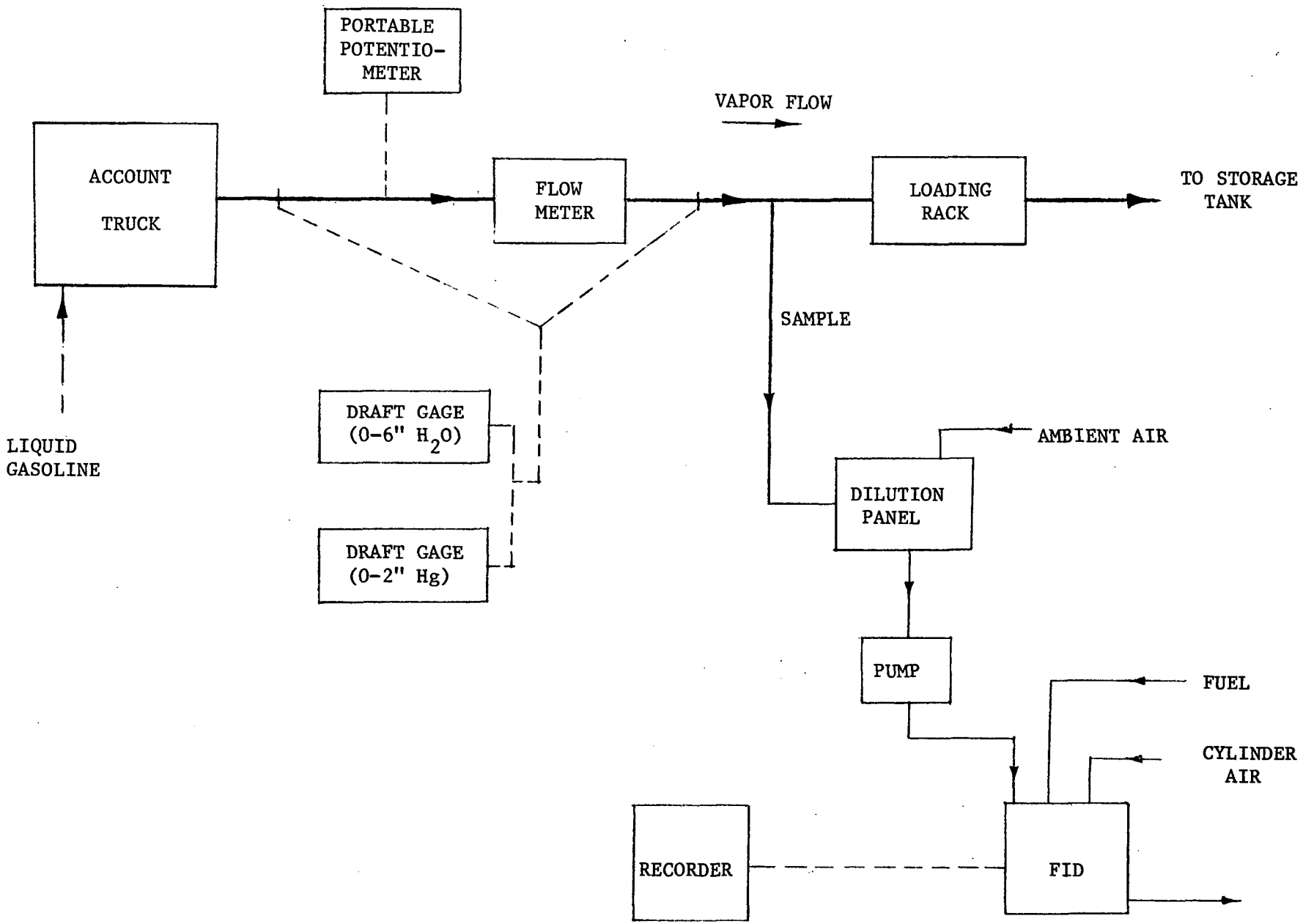



Figure 3a. VAPOR RETURN LINE TESTING FLOW DIAGRAM (FOR DISPENSING INTO ACCOUNT TRUCK)

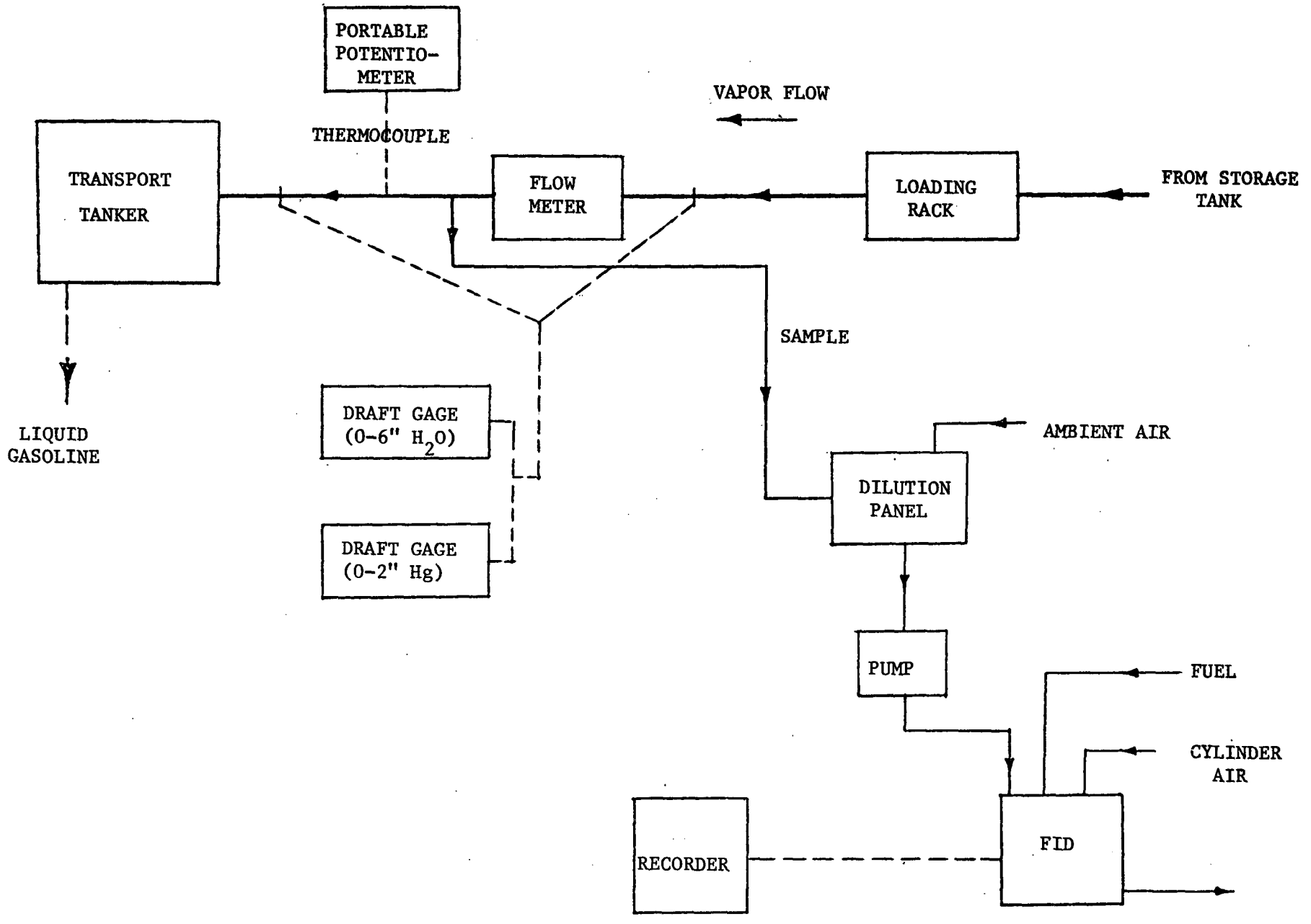



Figure 3b. VAPOR RETURN LINE TESTING FLOW DIAGRAM
(FOR TRANSPORT TANKER DISPENSING INTO BULK TANKS)

The pressure switch in the simulation system was set to energize just below the PV pressure setting so that the system would vent through the pressure and solenoid valve and not through the PV vent. At the exit of the solenoid valve a dry gas meter with a rated capacity of 1,000 CFH (American Meter AL-1,000) with a pressure drop less than 125 $N/m^2$ (0.5 in $H_2O$) was plumbed into the line to measure the volume of the vented vapors. Pressure, temperature and sample taps were placed in the exhaust line in a similar manner to the vapor return line. Figure 4 illustrates the test set-up for determining tank venting losses.

## C. TEMPERATURE OF STORAGE TANKS

Temperatures of storage tanks handling gasoline were monitored with surface mounted thermocouples placed on the shaded side of the tank. The assumption made when using surface mounted thermocouples is that the surface temperature of the metal storage tanks is equal to the liquid temperature within the tank. The thermocouples (Type J iron-constantan) led to a portable potentiometer (Thermo Electric "Minimite" Model No. 31101) for the determination of the temperatures. Using surface mounted thermocouples eliminated the problem of immersing a temperature indicating device through the top of the storage tank down to the liquid level.

## D. HYDROCARBON CONCENTRATION

The sample taps from the vent line and vapor return line each led to a Beckman 400 Flame Ionization Detector (FID) capable of measuring hydrocarbon concentrations of 0 - 10 percent (as methane) for determination of total hydrocarbon concentration. Each instrument had a corresponding dilution panel which diluted the sample approximately 30 to 1. The sample gas passed through a rotameter with a maximum capacity of 146 cc/min and was diluted with ambient air which passed through a rotameter with a maximum capacity of 2.5 liters/min. The rotameters were controlled with needle valves.

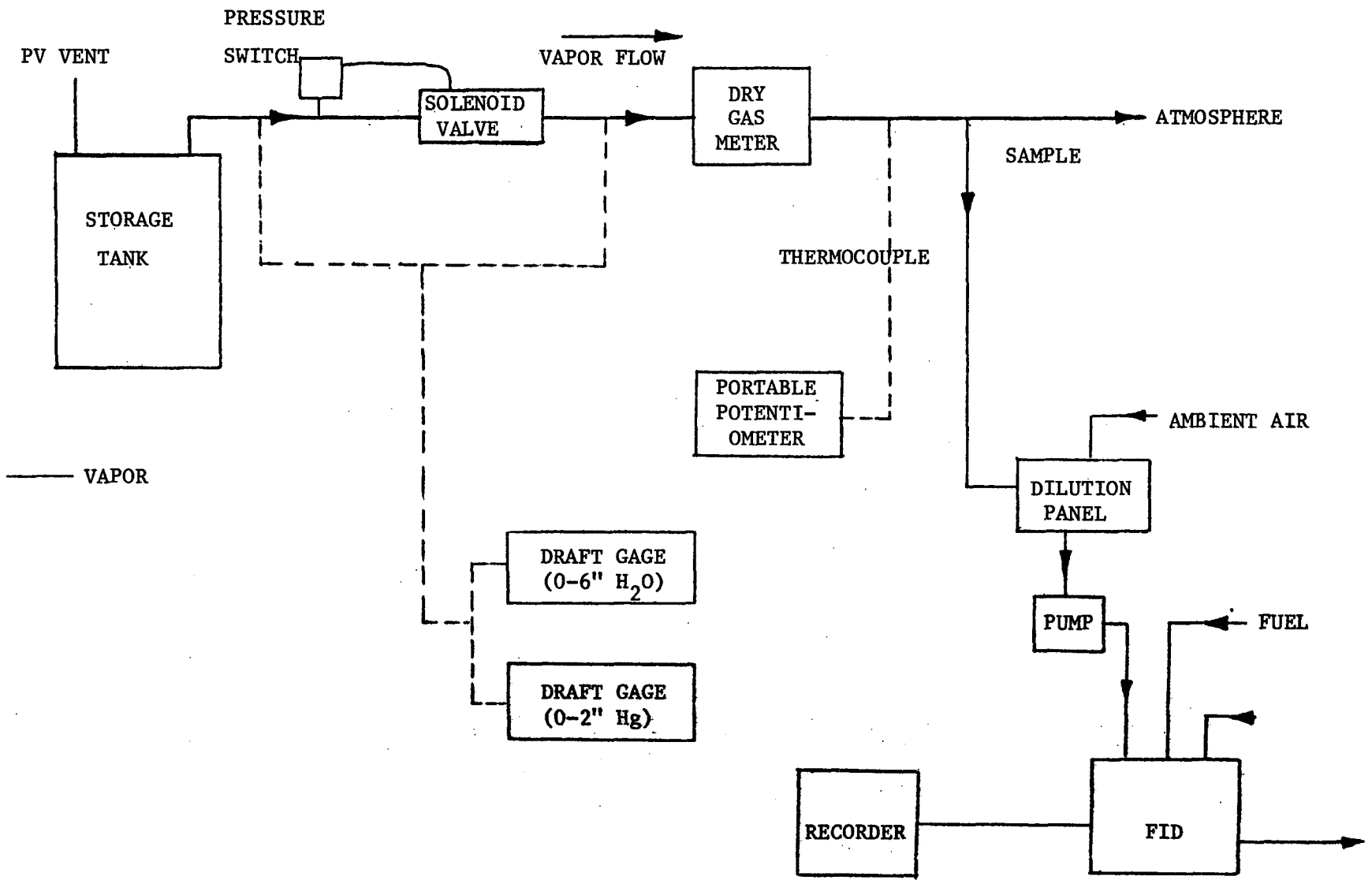



Figure 4. VENTING LOSS TESTING FLOW DIAGRAM

Interferences due to hydrocarbons in the ambient air or outgassing of hydrocarbons from the polyethylene sample line were ignored because they were very small compared to the extremely high concentration of the sample gas being analyzed. Continuous concentrations were recorded from both instruments simultaneously by a dual pen strip chart recorder. A typical chart recording is presented in Figure 5.

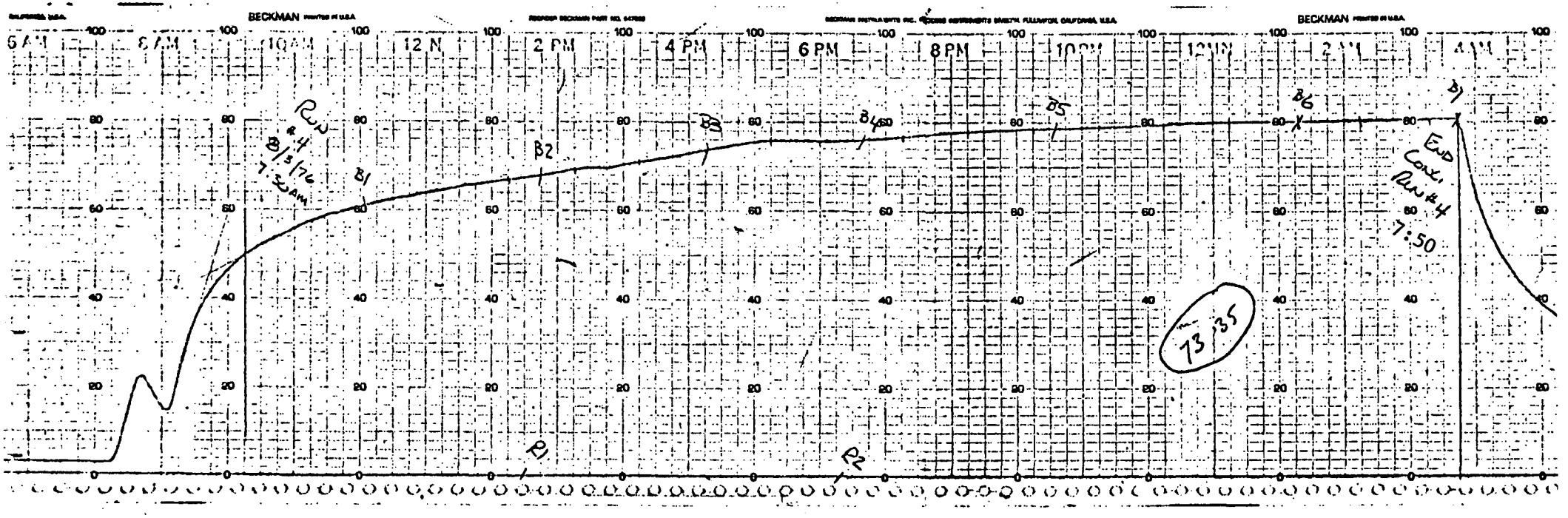
## E. REID VAPOR PRESSURE AND GAS CHROMATOGRAPHIC SAMPLES

Reid vapor pressure (RVP) samples were taken during selected test runs for analysis of product volatility. Samples were taken as described in ASTM Method D270-65 and analysis performed as described in ASTM Method D323-58. Grab samples of the returned hydrocarbon vapors were obtained for gas chromatographic (GC) analysis using an evacuated gas sampling bulb drawn to approximately 10 inches of mercury absolute. A lower absolute pressure could not be obtained because of problems with the vacuum pump in the field. This was corrected for in the GC results by calculating, using partial pressures, the amount of air not removed from the sample bulb and adjusting the hydrocarbon concentrations. One sample of the liquid condensate taken from the vapor return line was also subjected to GC analysis. The GC samples were transported to the laboratory and analyzed for concentrations of $C_1$ - $C_{12}$ hydrocarbons.

## F. LEAK DETECTION

Hydrocarbon vapor leaks in the vapor recovery system were identified using a portable combustible gas analyzer (Bacharach Instruments Combustible Gas Analyzer Model SSP).* During the test runs the vapor return line, storage tank vents, hose connections and vehicle hatch covers were all checked for hydrocarbon leakage.

*This unit measured hydrocarbon concentrations in the ranges of 0 - 1,000 ppm and 0 - 1 LEL (lower explosive limit). This instrument measures only relative concentration and not volume.




$B_1$, $B_2$, etc. Curve for concentration of vapors in vapor return line

$R_1$, $R_2$, etc. Curve for concentration of vapor through P.V. vent on bulk tank

Figure 5. TYPICAL CHART RECORDING OF HYDROCARBON CONCENTRATION

## G. CALIBRATIONS

Two rotameters used to measure sample gas flow rate (0 - 146 cc/min) were calibrated using a moving bubble meter and rotameters used for measuring dilution air (0 - 2.5 liters/min) were calibrated against a wet test meter. Procedures presented in the EPA Air Pollution Training Institute Course Manual 435 were used. Since the rotameters were calibrated with air at room conditions, they were corrected for standard conditions and density when measuring gasoline vapor flow rates. The dry gas meters were calibrated against a standardized orifice meter. All temperatures were measured by thermocouples attached to a portable potentiometer and calibrated against a mercury-in-glass thermometer.

Two model 400 FID's were used for measurement of hydrocarbon concentrations. Both analyzers were subjected each day to a multipoint calibration using 1.48 percent propane gas. These calibrations were performed for a sample pressure of 6,900 $N/m^2$ ( 1 psi). The Dwyer 1823-20 pressure switch, having a range of 750 $N/m^2$ - 5,500 $N/m^2$ (3 - 22 in $H_2O$), was adjusted with a U-tube manometer.

Typical calibration curves are attached in Appendix E.

## H. DESCRIPTION

### 1. Refrigeration System

Testing was performed on the refrigeration system in Escondido from July 19, 1976 through July 26, 1976. In all, 7 transport deliveries and 19 bulk plant account trucks were monitored. Arrangements were made with the plant manager to have the transports deliver gasoline during normal operating hours (deliveries were usually made at night) because of problems with access to the plant. Since the refrigeration unit did not vent to the atmosphere but instead back to the storage tanks, the testing was the same as would be performed when testing a vapor balance system.

On the first day of testing at the Escondido facility, a sizeable leak was discovered through a maintenance hatch on one of the storage tanks. Standard Oil personnel, present on site to observe the testing, assisted in sealing the hatch and the testing resumed.

Initially when sampling return vapors to the transport delivery vehicle, an OPW 1711D female dry break connector was installed so that when the return line was disconnected from the vehicle, vapors would not escape from the system. This coupler would also connect directly to the test vehicle. The male vapor return coupler on the vehicle did not have a compatible dry break thereby not actuating the mechanism to allow the flow of vapors. For this reason, the OPW coupler was removed from the set-up and the existing bulk plant spring loaded fitting was used which required the use of an adapter to attach to the vehicle. Because no flow of vapors was present in run 6, this test was discarded. Insufficient data was recorded in run number 1, therefore, it has not been included in the calculations.

2. Vapor Balance System

Testing was conducted on the vapor balance system in Boulder from August 2, 1976 through August 5, 1976. In all, 5 transport deliveries and 11 bulk plant account trucks were monitored. On 2 occasions, arrangements were made with bulk plant personnel to have 3 product pumps running simultaneously to obtain data on a worst case flow through the system (approximately 300 gal/min).

Numerous hydrocarbon vapor leaks were found in the system eminating from the storage tank safety relief vents and from the compartment hatch covers on the account trucks. Attempts were made to force these vents and hatches closed and thereby eliminate the leaks but this could not be done so steps were taken to quantify the emissions. This was accomplished by sealing a plastic bag over the leak area, timing the fill of the bag and determining the volume of the vapors in the bag. Approximate leakage rates derived from this method ranged from 0.014 $m^3$/min (0.5 CFM) through 1 safety relief vent to 0.085 $m^3$/min

(3 CFM) through the account truck compartment hatch covers. These leak rates were only approximate and not used in efficiency calculations, but only to show the relative loss of vapors through these "sealed" vents.

## IV. SUMMARY OF RESULTS

The results of 41 tests are presented. Twenty five of these were performed at Escondido and sixteen at Boulder. Copies of the original data sheets can be obtained by contacting the EPA Project Office.

### A. Testing of Refrigeration System

The Standard Oil Company facility at Escondido has been treated as a vapor displacement system. The refrigeration system at this facility does not condense vapors but is designed strictly to maintain a constant temperature in the storage tanks (60 $^{o}$F) and thereby maintain a pressure below the venting level, thus decreasing both breathing and working losses. This made a direct evaluation of the refrigeration system impossible since it was difficult to relate its operation as being independent of the vapor balance system.

Seven transport deliveries were tested at Escondido and an average volumetric efficiency of 97.0 was obtained. The above average is based on five deliveries (see Table 1) because on run #6, the poppet of the dry break coupling jammed causing no return vapor volume to be measured and in run #9, insufficient data was recorded and, hence, they have been excluded from the calculations. The average loss in volume (theoretical minus standard) was estimated at 36.5 cu. ft.

For the account truck tests, the average efficiency would be a rather misleading number since various factors have to be considered, such as the type of account truck, system pressure and ambient temperature. Each account truck has its own characteristics, (i.e. hatch leakage, capacity, etc.) and these all vary from one truck to another.

Truck #2 was the smallest account truck at the facility, and was not in daily use as were the other trucks. More pressure build-up occurred during the loading of this truck than when any of the

Table 1. SUMMARY OF RESULTS - ESCONDIDO

| Date | Run | Plant | Dispensed Liquid | | Returned Vapor Volume | | | | | | Average Bulk Tank Temperature | | Average Vapor Temperature | | Pressure In Vapor Return Line | | Vapor Line Concentration In % Propane By Volume | | Vapor Line Conc. In % HC by Volume Based on Avg. Carbon Number | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Actual | | Standard | | Theo.** | | | | | | | | | | | |
| | | | Gal. | Liters | $Ft^3$ | $M^3$ | $Ft^3$ | $M^3$ | $Ft^3$ | $M^3$ | °F | °C | °F | °C | Inches of Water | $N/M^2$ | Trans-port | Truck | Trans-port | Truck |
| 7/20/76 | 2+ | Escondido | 8170 | 30920 | 1081.0 | 30.6 | 1032.0 | 29.2 | 1066.0 | 30.2 | 76.9 | 24.9 | 88.7 | 31.5 | -1.20 | - 299 | 12.12 | - | 8.13 | - |
| 7/20/76 | 3 | Escondido | 980 | 3708 | 139.0 | 3.9 | 128.0 | 3.6 | 127.0 | 3.6 | 80.7 | 27.1 | 107.0 | 41.7 | 1.71 | 426 | - | 13.08 | - | 8.78 |
| 7/20/76 | 4 | Escondido | 1220 | 4617 | 110.5 | 3.1 | 103.0 | 2.9 | 153.0 | 4.3 | 81.3 | 27.4 | 99.5 | 37.5 | 4.43 | 1103 | - | 38.70 | - | 25.97 |
| 7/21/76 | 5 | Escondido | 8200 | 31037 | 1090.0 | 30.8 | 1054.0 | 29.8 | 1079.0 | 30.5 | 71.2 | 21.8 | 81.0 | 27.2 | -1.04 | - 258 | 14.94 | - | 10.03 | - |
| 7/21/76 | 6 | Escondido | 8710 | 32967 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 7/22/76 | 7 | Escondido | 2110 | 7986 | 220.0 | 6.2 | 219.0 | 6.2 | 277.3 | 7.9 | 71.0 | 21.7 | 65.0 | 18.3 | -0.04 | - 10 | - | 10.16 | - | 6.82 |
| 7/22/76 | 8 | Escondido | 1540 | 5829 | 184.0 | 5.2 | 182.6 | 5.2 | 202.6 | 5.7 | 71.1 | 21.7 | 67.0 | 19.4 | 1.40 | 349 | - | 11.78 | - | 7.91 |
| 7/22/76 | 9 | Escondido | 8200 | 31037 | - | - | - | - | 1063.1 | 30.1 | 81.8 | 27.7 | 77.1 | 25.1 | -0.16 | - 40 | 14.06 | - | 9.44 | - |
| 7/22/76 | 10 | Escondido | 2610 | 9879 | 242.0 | 6.9 | 237.2 | 6.7 | 344.1 | 9.7 | 70.5 | 21.4 | 73.7 | 23.2 | 4.20 | 1046 | - | 14.10 | - | 9.46 |
| 7/22/76 | 11 | Escondido | 2650 | 10030 | 200.0 | 5.7 | 188.0 | 5.3 | 345.0 | 9.8 | 77.3 | 25.2 | 96.8 | 36.0 | 1.91 | 476 | - | 9.70 | - | 6.51 |
| 7/22/76 | 12 | Escondido | 800 | 3028 | 116.0 | 3.3 | 109.2 | 3.1 | 103.7 | 2.9 | 79.8 | 26.6 | 96.0 | 35.6 | 5.59 | 1392 | - | 13.83 | - | 9.28 |
| 7/22/76 | 13 | Escondido | 1930 | 7305 | 242.0 | 6.9 | 230.0 | 6.5 | 249.1 | 7.1 | 82.0 | 27.8 | 90.7 | 32.6 | 0.69 | 172 | - | 13.40 | - | 8.99 |
| 7/22/76 | 14 | Escondido | 8200 | 31037 | 1041.0 | 29.5 | 992.2 | 28.1 | 1062.0 | 30.1 | 80.5 | 26.9 | 89.3 | 31.8 | 1.00 | 249 | 49.22 | - | 33.03 | - |
| 7/23/76 | 15 | Escondido | 1660 | 6283 | 125.5 | 3.6 | 124.3 | 3.5 | 218.5 | 6.2 | 73.3 | 22.9 | 70.0 | 21.1 | -0.16 | - 10 | - | 27.38 | - | 18.37 |
| 7/23/76 | 16 | Escondido | 1660 | 6283 | 170.5 | 4.8 | 168.0 | 4.8 | 217.9 | 6.2 | 74.5 | 23.6 | 73.0 | 22.8 | 1.95 | 486 | - | 29.23 | - | 19.62 |
| 7/23/76 | 17 | Escondido | 1930 | 7305 | 353.5 | 10.0 | 248.8* | 7.0 | 254.6 | 7.2 | 75.0 | 23.9 | 72.0 | 22.2 | 3.80 | 947 | - | 42.26 | - | 28.36 |
| 7/23/76 | 18 | Escondido | 8200 | 31037 | 1100.0 | 31.2 | 1051.3 | 29.8 | 1070.2 | 30.3 | 78.0 | 25.6 | 89.6 | 32.0 | 2.60 | 648 | 45.50 | - | 30.54 | - |
| 7/23/76 | 19 | Escondido | 1930 | 7305 | 218.0 | 6.2 | 207.3 | 5.9 | 251.2 | 7.1 | 79.0 | 26.1 | 92.0 | 33.3 | -0.11 | - 28 | - | 39.85 | - | 26.74 |
| 7/23/76 | 20 | Escondido | 650 | 2460 | 70.0 | 2.0 | 65.6 | 1.9 | 84.0 | 2.4 | 83.0 | 28.3 | 100.0 | 37.8 | 3.30 | 822 | - | 41.56 | - | 27.89 |
| 7/23/76 | 21 | Escondido | 2650 | 10030 | 200.0 | 5.7 | 187.9 | 5.3 | 338.9 | 9.6 | 88.8 | 31.6 | 98.8 | 37.1 | -0.98 | - 244 | - | 28.25 | - | 18.96 |
| 7/23/76 | 22 | Escondido | 2600 | 9841 | 344.5 | 9.8 | 320.2 | 9.1 | 332.5 | 9.4 | 88.5 | 31.4 | 104.7 | 40.4 | 0.90 | 224 | - | 42.89 | - | 28.78 |
| 7/23/76 | 23 | Escondido | 520 | 1968 | 80.0 | 2.3 | 74.5 | 2.1 | 65.9 | 1.9 | 93.0 | 33.9 | 103.5 | 39.7 | 1.96 | 488 | - | 26.74 | - | 17.95 |
| 7/26/76 | 24 | Escondido | 2110 | 7986 | 120.5 | 3.4 | 118.7 | 3.4 | 275.5 | 7.8 | 74.1 | 23.4 | 69.5 | 20.8 | -1.27 | - 316 | - | 27.41 | - | 18.40 |
| 7/26/76 | 25 | Escondido | 2640 | 9992 | 390.5 | 11.1 | 376.6 | 10.7 | 345.1 | 9.8 | 73.9 | 23.3 | 81.4 | 27.4 | 3.86 | 962 | - | 28.45 | - | 19.10 |
| 7/26/76 | 26 | Escondido | 8815 | 33365 | 1172.5 | 33.2 | 1121.5 | 31.8 | 1142.4 | 32.4 | 79.0 | 26.1 | 83.4 | 28.6 | 0.66 | 164 | 45.64 | - | 30.63 | - |

* An observation error-corrected from 348.8 to 248.8

** Theo. - Theoretical volume of vapors displaced based upon the volume of gasoline transferred, (V/L = 1.0)

\+ Run number 1 not included because of insufficient data recorded.

++ Sample calculations in Appendix A.

## Table 1. SUMMARY OF RESULTS - ESCONDIDO (Cont'd)

| Run | Volume of Vapor Lost Due to Leaks | | Mass of Vapors Lost | | Mass of Returned Vapors | | Pressure In Bulk Tanks | | | | Emission Rate | | Efficiencies Ew=Ev | | Type of Loading |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Based on % Vol. as Propane | Based on % Vol. as H.C. | Based on % Vol as Propane | Based on % Vol. as H.C. | Before | | After | | Based on % Vol as Propane | Based on % Vol. as H.C. | % | % | |
| | $Ft^3$ | $M^3$ | Gms | Gms | Gms | Gms | $"H_2O$ | $N/M^2$ | $"H_2O$ | $N/M^2$ | Gms/Gal. | Gms/Gal. | Transport | Truck | |
| 2 | 34.0 | .96 | - | - | - | - | 1.0 | 249 | 5.1 | 1270 | - | - | 96.8 | - | Transport Tanker |
| 3 | - | - | - | - | - | - | 0.5 | 125 | | - | - | - | - | 100.0 | Account Truck |
| 4 | 50.0 | 1.42 | 1004.0 | 986.7 | 2068.2 | 2032.6 | 0.5 | 125 | 3.0 | 747 | 0.823 | 0.809 | - | 67.3 | Account Truck |
| 5 | 25.0 | .71 | - | - | - | - | 1.3 | 324 | 0.5 | 125 | - | - | 97.7 | - | Transport Tanker |
| 6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 7 | 58.3 | 1.65 | 307.4 | 302.1 | 1154.4 | 1134.9 | -0.6 | -149 | -0.5 | - 125 | 0.146 | 0.143 | - | 79.0 | Account Truck |
| 8 | 19.6 | 0.56 | 119.8 | 117.8 | 1116.1 | 1097.6 | 0.5 | 125 | 0.4 | 100 | 0.078 | 0.076 | - | 90.3 | Account Truck |
| 9 | - | - | - | - | - | - | 0.5 | 125 | 1.9 | 473 | - | - | - | - | Transport Tanker |
| 10 | 106.9 | 3.03 | 781.8 | 768.5 | 1734.8 | 1705.1 | 1.3 | 324 | 3.5 | 872 | 0.299 | 0.294 | - | 69.0 | Account Truck |
| 11 | 157.0 | 4.45 | 790.3 | 776.7 | 945.7 | 930.0 | 1.3 | 324 | 2.5 | 623 | 0.293 | 0.293 | - | 54.0 | Account Truck |
| 12 | - | - | - | - | - | - | 4.0 | 996 | 5.6 | 1395 | - | - | - | 100.0 | Account Truck |
| 13 | 19.1 | 0.54 | 132.8 | 130.5 | 1598.9 | 1571.2 | 0.1 | 25 | 0.8 | 199 | 0.069 | 0.068 | - | 92.0 | Account Truck |
| 14 | 69.8 | 1.98 | - | - | - | - | 0.3 | 75 | 0.6 | 149 | - | - | 93.4 | - | Transport Tanker |
| 15 | 94.2 | 2.67 | 1338.6 | 1314.9 | 1766.3 | 1735.1 | -0.8 | -187 | -0.5 | - 125 | 0.806 | 0.792 | - | 57.0 | Account Truck |
| 16 | 49.9 | 1.41 | 756.5 | 744.0 | 2547.4 | 2504.7 | 0.9 | -218 | 4.5 | 1121 | 0.456 | 0.448 | - | 77.0 | Account Truck |
| 17 | 5.8 | 0.16 | 127.2 | 125.0 | 5455.0 | 5361.7 | 3.5 | 872 | 3.0 | 747 | 0.066 | 0.065 | - | 98.0 | Account Truck |
| 18 | 18.9 | 0.54 | - | - | - | - | 2.3 | 573 | 3.7 | 922 | - | - | 98.2 | - | Transport Tanker |
| 19 | 43.9 | 1.24 | 908.0 | 892.0 | 4285.8 | 4212.2 | 2.0 | 498 | 2.9 | 722 | 0.467 | 0.462 | - | 83.0 | Account Truck |
| 20 | 14.4 | 0.41 | 310.5 | 305.2 | 1414.4 | 1390.3 | 0.6 | 149 | 0.3 | 75 | 0.477 | 0.469 | - | 78.0 | Account Truck |
| 21 | 151.0 | 4.28 | 2213.3 | 2175.5 | 2754.4 | 2707.2 | 0.5 | 125 | -1.6 | - 399 | 0.836 | 0.821 | - | 55.0 | Account Truck |
| 22 | 12.3 | 0.35 | 273.7 | 269.0 | 7125.5 | 7002.7 | -0.2 | - 50 | 0.0 | 0 | 0.105 | 0.103 | - | 96.0 | Account Truck |
| 23 | - | - | - | - | - | - | 0.0 | 0 | 1.3 | 324 | - | - | - | 100.0 | Account Truck |
| 24 | 156.8 | 4.44 | 2229.6 | 2192.4 | 1687.6 | 1659.7 | -1.5 | -374 | -0.4 | - 100 | 1.056 | 1.039 | - | 43.0 | Account Truck |
| 25 | - | - | - | - | - | - | 3.3 | 822 | 3.3 | 822 | - | - | - | 100.0 | Account Truck |
| 26 | 20.9 | 0.59 | - | - | - | - | 2.9 | 722 | 3.2 | 797 | - | - | 98.7 | - | Transport Tanker |

others were loaded. This trend had been noticed by the bulk plant manager even before the testing started. Possibly, the small compartments in the account truck caused a rapid displacement of vapors from the compartments, which further caused a transient pressure build-up.

Of the four account trucks used at the Escondido plant, account trucks number 1 and 2 had few leaks but trucks 3 and 7 both had substantial leaks through the hatches. The wear and tear undergone by trucks number 1 and 2 was comparatively much less since they were used every other day. Table #3 lists the number of loads of gasoline carried by each truck. Truck # 1 was the newest and least used truck. This could be responsible for the high efficiency (Table 2) obtained whenever truck #1 was used. In certain runs, efficiencies greater than 100% were obtained which are unlikely and are basically attributed to measurement errors.

An average concentration of 30.24% by volume as propane (20.30% by volume as hydrocarbons) was obtained in the vapor return line during delivery of gasoline by the transport tanker. The concentration in the vapor return line during loading of the account truck was found to be 25.44% by volume as propane (17.07% by volume as hydrocarbons). The G-C analyses are attached in Appendix D.

Table 2. EFFICIENCIES OF ACCOUNT TRUCKS AT ESCONDIDO

| Date | Run Number | Truck Number | Capacity of Truck | | EW% |
|---|---|---|---|---|---|
| | | | Gal. | Liters | |
| * | | | | | |
| 7/22/76 | 7 | 7 | 2650 | 10030 | 79.0 |
| 7/22/76 | 8 | 2 | 1540 | 5829 | 90.3 |
| 7/22/76 | 10 | 3 | 2650 | 10030 | 69.0 |
| 7/22/76 | 11 | 7 | 2650 | 10030 | 54.0 |
| 7/22/76 | 12 | 2 | 1540 | 5829 | 100.0 |
| 7/22/76 | 13 | 3 | 2650 | 10030 | 92.0 |
| 7/23/76 | 15 | 7 | 2650 | 10030 | 57.0 |
| 7/23/76 | 16 | 3 | 2650 | 10030 | 77.0 |
| 7/23/76 | 17 | 1 | 2910 | 11014 | 98.0 |
| 7/23/76 | 19 | 1 | 2910 | 11014 | 83.0 |
| 7/23/76 | 20 | 2 | 1540 | 5829 | 78.0 |
| 7/23/76 | 21 | 7 | 2650 | 10030 | 55.0 |
| 7/23/76 | 22 | 1 | 2910 | 11014 | 96.0 |
| 7/23/76 | 23 | 2 | 1540 | 5829 | 100.0 |
| 7/26/76 | 24 | 7 | 2650 | 10030 | 43.0 |
| 7/26/76 | 25 | 1 | 2910 | 11014 | 100.0 |

* Runs from 7/20/76 to 7/21/76 were not included because of insufficient data collected [data collected did not include truck number]

Table 3. FREQUENCY OF OPERATION
VERSUS EFFICIENCY FOR BULK TRUCKS AT ESCONDIDO

| Truck Number | Capacity in Gallons | Number of Loads Per Week | Average Observed Efficiency |
|---|---|---|---|
| 1 | 2910/load | 6 | 94.3% |
| 2 | 1540/load | 8 | 92.1% |
| 3 | 2650/load | 10 | 79.3% |
| 7 | 2650/load | 10 | 57.6% |

1. Pressure Relationship

An increase in pressure occurred after every transport delivery. Usually, a similar pressure increase was noticed during the loading of account trucks, but there were certain runs such as # 17, where there was a decrease in pressure. A decrease in pressure signifies a possible leak either in the account truck (hatches) or in the vapor return line or a possible vacuum being present in the account truck before loading. A pressure drop always occurred when account truck #1 was loaded. Since this truck had no leaks, a possible explanation could be that the initial equalization of pressure between tank and truck caused the drop in pressure.

2. Exhaust Vent Losses

Venting of vapors through the exhaust vent on the bulk tanks only took place on the 22nd of July in the afternoon, at an ambient temperature of 80 $^{o}$F. The pressure exceeded the 1308 $N/m^2$ (5.25 inches) of $H_2O$ limit set on the PES pressure switch, thus opening the solenoid valve and venting vapors to the atmosphere. The volume vented was extremely small (less than 1 cu. ft.), since no reading was recorded on the dry gas meter, but a maximum concentration of 9.3% by volume as propane (6.2% by volume as hydrocarbons) was recorded on the F.I.D. The results are shown in Table #4. Some other concentrations were obtained during run numbers 10 and 12 but these were due to malfunction of equipment on the bulk tanks and hence, have been disregarded in calculations.

Table 4. ESCONDIDO - EXHAUST VENT DATA

| Date | Run | Plant | Time | Ambient Temperature °F | Ambient Temperature °C | Ambient Pressure Hg | Ambient Pressure N/M²x10³ | Gas Meter Initial Ft³ | Gas Meter Final Ft³ | Vapor Temperature °F | Vapor Temperature °C | Exhaust Concentration % Prop. | Exhaust Concentration % H.C. | Pressure in Bulk Tanks Pre Inches $H_2O$ | Pre N/M² | Post Inches $H_2O$ | Post N/M² | Liquid Dispensed Gals. | Liquid Dispensed Ltrs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/20/76 | 2 | Escondido | 10:50 | 68 | 20.0 | 29.68 | 100.5 | 0 | 0 | - | - | 0.0 | 0.0 | 1.0 | 249.0 | 5.1 | 1270 | 8170 | 30923 |
| 7/20/76 | 3 | Escondido | 14:10 | 83 | 28.3 | 29.65 | 100.4 | 0 | 0 | - | - | 0.0 | 0.0 | 0.5 | 124.5 | | - | 980 | 3709 |
| 7/20/76 | 4 | Escondido | 14:30 | 83 | 28.3 | 29.65 | 100.4 | 0 | 0 | - | - | 0.0 | 0.0 | 0.5 | 124.5 | 3.0 | 747 | 1220 | 4618 |
| 7/21/76 | 5 | Escondido | 8:36 | 68 | 20.0 | 29.60 | 100.2 | 0 | 0 | - | - | 0.0 | 0.0 | 1.3 | 323.7 | 0.5 | 125 | 8200 | 31037 |
| 7/21/76 | 6 | Escondido | 11:15 | 78 | 25.5 | 29.62 | 100.3 | 0 | 0 | - | - | 0.0 | 0.0 | - | - | - | - | 8710 | 32967 |
| 7/22/76 | 7 | Escondido | 7:25 | 65 | 18.3 | 29.61 | 100.3 | 0 | 0 | - | - | 0.0 | 0.0 | -0.6 | -129.0 | -0.5 | - 125 | 2110 | 7986 |
| 7/22/76 | 8 | Escondido | 7:55 | 65 | 18.3 | 29.61 | 100.3 | 0 | 0 | - | - | 0.0 | 0.0 | 0.5 | 125.0 | 0.4 | 100 | 1540 | 5829 |
| 7/22/76 | 9 | Escondido | 8:30 | 65 | 18.3 | 29.63 | 100.4 | 0 | 0 | - | - | 0.0 | 0.0 | 0.5 | 125.0 | 1.9 | 473 | 8200 | 31037 |
| 7/22/76 | 10 | Escondido | 9:05 | 67 | 19.4 | 29.63 | 100.4 | 0 | 0 | - | - | 3.4 | 2.3 | 1.3 | 324.0 | 3.5 | 872 | 2610 | 9879 |
| 7/22/76 | 11 | Escondido | 10:59 | 72 | 22.2 | 29.64 | 100.4 | 0 | 0 | 94.8 | 34.9 | 5.6 | 3.8 | 1.3 | 324.0 | 2.5 | 623 | 2650 | 10030 |
| 7/22/76 | 12 | Escondido | 11:17 | 80 | 26.7 | 29.64 | 100.4 | 0 | Nil | - | - | 9.3 | 6.2 | 4.0 | 996.0 | 5.6 | 1395 | 800 | 3028 |
| 7/22/76 | 13 | Escondido | 14:21 | 81 | 27.2 | 29.65 | 100.4 | 0 | 0 | - | - | 0.0 | 0.0 | 0.1 | 25.0 | 0.8 | 199 | 1930 | 7305 |
| 7/22/76 | 14 | Escondido | 16:56 | - | - | 29.65 | 100.4 | 0 | 0 | - | - | 0.0 | 0.0 | 0.3 | 75.0 | 0.6 | 149 | 8200 | 31037 |
| 7/23/76 | 15 | Escondido | 7:42 | 65 | 18.3 | 29.72 | 100.7 | 0 | 0 | - | - | 0.0 | 0.0 | -0.8 | -187.0 | -0.5 | - 125 | 1660 | 6283 |
| 7/23/76 | 16 | Escondido | 7:55 | 68 | 20.0 | 29.73 | 100.7 | 0 | 0 | - | - | 0.0 | 0.0 | -0.9 | 217.0 | 4.5 | 1121 | 1660 | 6283 |
| 7/23/76 | 17 | Escondido | 8:06 | 70 | 21.1 | 29.73 | 100.7 | 0 | 0 | - | - | 0.0 | 0.0 | 3.5 | 872.0 | 3.0 | 747 | 1930 | 7305 |
| 7/23/76 | 18 | Escondido | 9:01 | 73 | 22.8 | 29.74 | 100.8 | 0 | 0 | - | - | 0.0 | 0.0 | 2.3 | 573.0 | 3.7 | 922 | 8200 | 31037 |
| 7/23/76 | 19 | Escondido | 9:51 | 76 | 24.4 | 29.74 | 100.8 | 0 | 0 | - | - | 0.0 | 0.0 | 2.0 | 498.0 | 2.9 | 722 | 1930 | 7305 |
| 7/23/76 | 20 | Escondido | 10:20 | 77 | 25.0 | 29.74 | 100.8 | 0 | 0 | - | - | 0.0 | 0.0 | 0.6 | 149.0 | 0.3 | 75 | 650 | 2460 |
| 7/23/76 | 21 | Escondido | 11:55 | 86 | 30.0 | 29.74 | 100.8 | 0 | 0 | - | - | 0.0 | 0.0 | 0.5 | 125.0 | -1.6 | -399 | 2650 | 10030 |
| 7/23/76 | 22 | Escondido | 14:08 | 86 | 30.0 | 29.72 | 100.7 | 0 | 0 | - | - | 0.0 | 0.0 | -0.2 | - 50.0 | 0.0 | 0 | 2600 | 9841 |
| 7/23/76 | 23 | Escondido | 14:45 | 86 | 30.0 | 29.72 | 100.7 | 0 | 0 | - | - | 0.0 | 0.0 | 0.0 | 0.0 | 1.3 | 324 | 520 | 1968 |
| 7/26/76 | 24 | Escondido | 7:25 | 70 | 21.1 | 29.57 | 100.2 | 0 | 0 | - | - | 0.0 | 0.0 | -1.5 | -374.0 | -0.4 | - 100 | 2110 | 7986 |
| 7/26/76 | 25 | Escondido | 8:52 | 70 | 21.1 | 29.59 | 100.2 | 0 | 0 | - | - | 0.0 | 0.0 | 3.3 | 822.0 | 3.3 | 822 | 2640 | 9992 |
| 7/26/76 | 26 | Escondido | 9:18 | 73 | 22.8 | 29.59 | 100.2 | 0 | 0 | - | - | 0.0 | 0.0 | 2.9 | 722.0 | 3.2 | 797 | 8815 | 33365 |

B. Testing of Vapor Balance System

The testing at Boulder, Colorado was much less complex, mainly because the CONOCO bulk plant had a much smaller throughput. Only one truck had vapor recovery apparatus and this was used for nearly all deliveries. Another smaller bulk truck with no vapor recovery apparatus was used on two of the four days of testing.

Five transport deliveries and eleven account truck loadings were tested. The average volumetric efficiencies for the transport deliveries were found to be 95.39%. Consistent values were obtained indicating that leaks were minimal. An average concentration of 43.88% by volume as propane (29.45% by volume as hydrocarbons) was found in the vapor return line.

The efficiency for the account trucks ranged from 79.45% to 97.02%. This wide range of efficiencies was due to the leaks present in the account truck and bulk tanks. In general, when high pressure is present in the system, low efficiencies are expected, as in run #2, 11, and 16 because greater leak rates occur for higher pressure values in the bulk tanks. An average concentration of 38.34% by volume as propane (25.73% by volume as hydrocarbon) found in the vapor return line. Table #5 gives all the various efficiencies and emission rates for tests performed at Boulder, Colorado.

The highest emission rate was 0.553 grams/gallon (based on calculation of mass of vapors lost by % volume as hydrocarbons and average molecular weight) in run #11. The average emission rate of 0.277 grams/gallon was obtained for the eleven account trucks tested.

## Table 5. SUMMARY OF RESULTS - BOULDER

| Date | Run | Plant | Dispensed Liquid | | Returned Vapor Volume | | | | | | Average Bulk Tank Temperature | | Average Vapor Temperature | | Pressure In Vapor Return Line | | Vapor Line Concentration In % Propane By Volume | | Vapor Line Conc. In % HC by Volume Based on Avg. Carbon Number | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Actual | | Standard | | Theo.** | | | | | | | | | | | |
| | | | Gals. | Liters | $Ft^3$ | $M^3$ | $Ft^3$ | $M^3$ | $Ft^3$ | $M^3$ | °F | °C | °F | °C | Inches of Water | $N/M^2$ | Trans-port | Truck | Trans-port | Truck |
| 8/2/76 | 1 | Boulder | 9500 | 35958 | 1182 | 33.5 | 1023.5 | 29.0 | 1093.7 | 31.0 | 74.4 | 23.6 | 59.8 | 15.4 | 4.54 | 1131 | 39.58 | - | 26.56 | - |
| 8/2/76 | 2 | Boulder | 3000 | 11355 | 324 | 9.2 | 279.3 | 7.9 | 344.2 | 9.7 | 64.1 | 17.8 | 64.0 | 17.8 | 3.03 | 755 | - | 37.36 | - | 25.07 |
| 8/2/76 | 3 | Boulder | 3000 | 11355 | 390 | 11.0 | 334.0 | 9.5 | 344.3 | 9.7 | 66.2 | 19.0 | 67.5 | 19.7 | 1.15 | 286 | - | 39.19 | - | 26.30 |
| 8/3/76 | 4 | Boulder | 3000 | 11355 | 340 | 9.6 | 295.7 | 8.4 | 345.0 | 9.8 | 62.66 | 17.0 | 57.0 | 13.9 | 1.17 | 291 | - | 36.05 | - | 24.19 |
| 8/3/76 | 5 | Boulder | 3000 | 11355 | 356 | 10.1 | 303.3 | 8.6 | 344.3 | 9.8 | 63.45 | 17.5 | 70.2 | 21.2 | 1.69 | 422 | - | 40.55 | - | 27.21 |
| 8/3/76 | 6 | Boulder | 3000 | 11355 | 360 | 10.2 | 300.0 | 8.5 | 344.1 | 9.7 | 64.33 | 18.0 | 79.8 | 26.6 | 3.03 | 754 | - | 47.30 | - | 31.74 |
| 8/3/76 | 7 | Boulder | 9500 | 35958 | 1252 | 35.5 | 1053.8 | 29.8 | 1055.1 | 29.8 | 80.00 | 26.7 | 86.8 | 30.5 | 5.18 | 1290 | 47.50 | - | 31.88 | - |
| 8/3/76 | 8 | Boulder | 3000 | 11355 | 380 | 10.8 | 317.4 | 9.0 | 336.3 | 9.5 | 74.8 | 23.8 | 77.0 | 25.0 | -0.13 | - 31 | - | 46.90 | - | 31.48 |
| 8/3/76 | 9 | Boulder | 9500 | 35958 | 1070 | 30.3 | 933.5 | 26.4 | 1063.8 | 30.1 | 84.5 | 29.2 | 62.8 | 17.1 | 4.68 | 1166 | 43.60 | - | 29.26 | - |
| 8/4/76 | 10 | Boulder | 3000 | 11355 | 360 | 10.2 | 308.1 | 8.7 | 340.2 | 9.6 | 71.3 | 21.9 | 66.7 | 19.3 | 2.10 | 522 | - | 38.30 | - | 25.70 |
| 8/4/76 | 11 | Boulder | 3000 | 11355 | 326 | 9.2 | 274.2 | 7.8 | 345.1 | 9.8 | 69.9 | 21.1 | 82.2 | 27.9 | 3.32 | 826 | - | 45.90 | - | 30.80 |
| 8/4/76 | 12 | Boulder | 9500 | 35958 | 1184 | 33.5 | 988.9 | 28.0 | 1040.7 | 29.5 | 91.7 | 33.2 | 81.4 | 27.4 | 1.18 | 293 | 47.00 | - | 31.54 | - |
| 8/5/76 | 13 | Boulder | 9500 | 35958 | 1230 | 34.8 | 1061.8 | 30.1 | 1077.5 | 30.5 | 83.5 | 28.6 | 74.2 | 23.4 | 1.27 | 305 | 41.70 | - | 27.99 | - |
| 8/5/76 | 14 | Boulder | 3000 | 11355 | 380 | 10.8 | 319.9 | 9.1 | 340.3 | 9.6 | 72.0 | 22.2 | 76.3 | 24.6 | 3.36 | 837 | - | 14.90 | - | 10.00 |
| 8/5/76 | 15 | Boulder | 3000 | 11355 | 355 | 10.1 | 295.4 | 8.4 | 341.5 | 9.7 | 72.1 | 22.3 | 84.5 | 29.2 | 4.62 | 1150 | - | 36.60 | - | 24.56 |
| 8/5/76 | 16 | Boulder | 3000 | 11355 | 342 | 9.7 | 278.0 | 7.9 | 335.3 | 9.5 | 76.2 | 24.6 | 91.5 | 33.1 | 4.83 | 1202 | - | 38.70 | - | 25.97 |

** Theo. - Theoretical volume of vapors displaced based upon the volume of gasoline transferred, (V/L = 1.0)

+ Sample calculations in Appendix A.

Table 5. SUMMARY OF RESULTS - BOULDER (Cont'd)

| Run | Volume of Vapor Lost Due to Leaks | | Mass of Vapors Lost | | Mass of Returned Vapors | | Pressure In Bulk Tanks | | | | Emission Rate | | Efficiencies Ew=Ev | | Type of Loading |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Based on % Vol. as Propane | Based on % Vol. as H.C. | Based on % Vol as Propane | Based on % Vol. as H.C. | Before | | After | | Based on % Vol as Propane | Based on % Vol as H.C. | % | % | |
| | $Ft^3$ | $M^3$ | Gms | Gms | Gms | Gms | $"H_2O$ | $N/M^2$ | $"H_2O$ | $N/M^2$ | Gms/Gal. | Gms/Gal. | Transport | Truck | |
| 1 | 70.20 | 2.0 | - | - | - | - | 4.5 | 1121 | 6.0 | 1495 | - | - | 93.58 | - | Transport Tanker |
| 2 | 64.90 | 1.8 | 1258.1 | 1236.4 | 5414.6 | 5320.8 | 2.7 | 673 | 0.8 | 199 | 0.420 | 0.412 | - | 81.14 | Account Truck |
| 3 | 10.27 | 0.3 | 208.8 | 205.2 | 6791.9 | 6675.0 | 1.0 | 249 | -0.1 | - 25 | 0.069 | 0.068 | - | 97.02 | Account Truck |
| 4 | 49.30 | 1.4 | 922.1 | 906.2 | 5530.6 | 5435.8 | -0.1 | - 25 | 0.0 | 0 | 0.307 | 0.302 | - | 85.71 | Account Truck |
| 5 | 41.03 | 1.2 | 863.2 | 848.4 | 6381.5 | 6271.2 | 3.0 | 747 | 0.7 | 174 | 0.288 | 0.283 | - | 88.08 | Account Truck |
| 6 | 44.10 | 1.2 | 1081.4 | 1063.6 | 7356.3 | 7235.7 | 3.2 | 797 | 2.3 | 573 | 0.361 | 0.355 | - | 87.18 | Account Truck |
| 7 | 1.30 | 0.1 | - | - | - | - | 3.8 | 947 | 8.5 | 2117 | - | - | 99.87 | - | Transport Tanker |
| 8 | 18.90 | 0.5 | 459.8 | 452.1 | 7722.1 | 7592.6 | -0.8 | - 199 | -0.7 | - 174 | 0.152 | 0.151 | - | 94.38 | Account Truck |
| 9 | 130.23 | 3.7 | - | - | - | - | -0.6 | - 149 | 1.7 | 423 | - | - | 89.94 | - | Transport Tanker |
| 10 | 32.17 | 0.9 | 638.2 | 628.2 | 6122.2 | 6016.9 | 1.1 | 274 | 0.8 | 199 | 0.213 | 0.209 | - | 90.55 | Account Truck |
| 11 | 70.93 | 2.0 | 1689.2 | 1660.1 | 6529.3 | 6417.5 | 3.6 | 897 | 1.4 | 349 | 0.565 | 0.553 | - | 79.45 | Account Truck |
| 12 | 51.79 | 1.5 | - | - | - | - | -0.5 | - 125 | 3.0 | 747 | - | - | 95.02 | - | Transport Tanker |
| 13 | 15.70 | 0.4 | - | - | - | - | 0.5 | 125 | 2.3 | 573 | - | - | 98.54 | - | Transport Tanker |
| 14 | 20.44 | 0.6 | 158.0 | 155.3 | 2472.8 | 2430.9 | 2.5 | 623 | 1.8 | 448 | 0.052 | 0.052 | - | 93.99 | Account Truck |
| 15 | 46.03 | 1.3 | 874.1 | 859.05 | 5610.3 | 5513.0 | 4.7 | 1171 | 2.2 | 548 | 0.293 | 0.286 | - | 86.52 | Account Truck |
| 16 | 57.25 | 1.6 | 1149.56 | 1129.8 | 5582.2 | 5486.1 | 5.2 | 1295 | 3.0 | 747 | 0.379 | 0.377 | - | 82.92 | Account Truck |

1. Pressure Relationship

During a transport delivery, a consistent pressure increase in the bulk tanks was found. An average pressure increase of 683 $N/m^2$ (2.74 inches of water) was obtained for the five deliveries. This is in line with what was found in Escondido. The change in pressure could be attributed to various factors. This is explained in the next section.

A consistent loss of pressure in the bulk tanks was found during the loading of the account trucks. Considering the large leaks through truck hatch covers, it seems evident that the loss of vapors through here, as well as the transfer of liquid gasoline from the bulk tanks, were responsible for the decrease in the pressure reading. The amount of pressure loss was different in each loading but an average loss of about 314 $N/m^2$ (1.26 inches of water) was obtained for the eleven tests performed with the account trucks.

2. Exhaust Vent Losses

On the second day of testing at Boulder, Colorado, it was cloudy in the morning and the ambient temperature was as low as 16.7 $^{o}C$ (62 $^{o}F$). It did get warmer in the afternoon and the ambient temperature went up to 32.2 $^{o}C$ (90 $^{o}F$). Either this sudden rise in temperature or vapor growth from the recent gasoline transfer (9,500 gallons) caused venting of vapors through the exhaust vent on the bulk tank.

Vapor growth occurs after air is drawn in through tank vacuum vents or through potential leaks to compensate for the decrease in volume of liquid drained from tank. This fresh air dilutes the vapor concentration causing volatile hydrocarbons to evaporate from the liquid to restore the equilibrium.

The pressure exceeded the PES pressure switch setting of 2553 $N/m^2$ (10.25 inches). A volume of 0.14 $m^3$ (5 cubic feet) was recorded on the Dry Gas Meter at a vapor temperature of 33.1 $^oC$ (91.6 $^oF$). Tabulated data is shown in Table 6. The pressure kept rising constantly and reached a maximum value of 3014 $N/m^2$ (12.1 inches) twenty-four minutes after venting started. This sudden rise in pressure caused all the safety vents on the bulk tanks to leak, necessitating flow measurements with plastic bags. The pressure decreased below 2553 $N/m^3$ (10.25 inches) about sixty minutes after venting started. Table #7 shows the rise and fall of pressure with time.

Although the pressure went below 2553 $N/m^2$ (10.25 inches of water), substantial leaks were present through all the PV vents on the bulk tanks. Efforts to prevent leakage by sealing the vents were fruitless, though the leaks were reduced.

A total of 7.08 $m^3$ (250 cu. ft.) of vapor was estimated to have been vented out through various leaks. (Leakage of vapor from various hatches and vents was estimated using the bag technique described on Page III-9). This, with the 0.14 $m^3$ (5 cu. ft.) reading of the dry gas meter gave a total of 7.22 $m^3$ (255 cu. ft.) of vapor vented during the period when pressure was above 2553 $N/m^2$ (10.25 inches of water). The concentration of vapors vented was recorded as 40.8% by volume as propane (27.4% by volume as hydrocarbons).

This venting of vapors could be attributed to two possible factors. Run #9 was a transport delivery of 35958 liters (9500 gallons) to the bulk plant, and the entrance of this gasoline into the system could have caused vapor growth. Coupled with the increase of ambient temperature, considerable pressure increase could take place. Since the pressure in the vapor space in the bulk tank increased with temperature, probably some of the air-vapor mixture in the bulk tank had to be discharged or "breathed-out" to prevent the safe operating pressure of the tank from being

Table 6. BOULDER - EXHAUST VENT DATA

| Date | Run | Plant | Time | Ambient Temperature °F | Ambient Temperature °C | Ambient Pressure Hg | Ambient Pressure $N/M^2 x10^3$ | Gas Meter Initial $Ft^3$ | Gas Meter Final $Ft^3$ | Vapor Temperature °F | Vapor Temperature °C | Exhaust Concentration % Prop. | Exhaust Concentration % H.C. | Pressure in Bulk Tanks Pre Inches $H_2O$ | Pre $N/M^2$ | Post Inches $H_2O$ | Post $N/M^2$ | Liquid Dispensed Gals. | Liquid Dispensed Ltrs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8/2/76 | 1 | Boulder | 1127 | 58 | 14.4 | - | - | 0 | 0 | - | - | 0.0 | 0.0 | 4.5 | 1121 | 6.0 | 1495 | 9500 | 35958 |
| 8/2/76 | 2 | Boulder | 1315 | 58 | 14.4 | - | - | 0 | 0 | - | - | 0.0 | 0.0 | 2.7 | 673 | 0.8 | 199 | 3000 | 11355 |
| 8/2/76 | 3 | Boulder | 1430 | 58 | 14.4 | - | - | 0 | 0 | - | - | 0.0 | 0.0 | 1.0 | 249 | - 0.1 | - 25 | 3000 | 11355 |
| 8/3/76 | 4 | Boulder | 0724 | 62 | 16.7 | 30.13 | 102.1 | 0 | 0 | - | - | 0.0 | 0.0 | 0.1 | - 25 | 0.0 | 0 | 3000 | 11355 |
| 8/3/76 | 5 | Boulder | 0840 | 66 | 18.9 | 30.13 | 102.1 | 0 | 0 | - | - | 0.0 | 0.0 | 3.0 | 747 | 0.7 | 423 | 3000 | 11355 |
| 8/3/76 | 6 | Boulder | 0955 | 69 | 20.6 | 30.13 | 102.1 | 0 | 0 | - | - | 0.0 | 0.0 | 3.2 | 797 | 2.3 | 573 | 3000 | 11355 |
| 8/3/76 | 7 | Boulder | 1040 | 72 | 22.2 | 30.13 | 102.1 | 0 | 0 | - | - | 0.0 | 0.0 | 3.8 | 947 | 8.5 | 2117 | 9500 | 35958 |
| 8/3/76 | 8 | Boulder | 1350 | 79 | 26.1 | 30.13 | 102.1 | 0 | 0 | - | - | 0.0 | 0.0 | - 0.8 | - 199 | -00.7 | - 174 | 3000 | 11355 |
| 8/3/76 | 9 | Boulder | 1425 | 68 | 20.0 | 30.10 | 102.0 | 0 | 0 | - | - | 0.0 | 0.0 | - 0.6 | - 149 | 1.7 | 423 | 9500 | 35958 |
| 8/3/76 | Special | Boulder | 1530 | 90 | 32.2 | 30.10 | 102.0 | 0 | 5+250* | 91.6 | 33.1 | 40.8 | 27.4 | 10.2 | 2553 | 10.2 | 2553 | | |
| 8/4/76 | 10 | Boulder | 0745 | 71 | 21.7 | 30.00 | 101.6 | 0 | 0 | - | - | 0.0 | 0.0 | 1.1 | 274 | 0.8 | 199 | 3000 | 11355 |
| 8/4/76 | 11 | Boulder | 0850 | 72 | 22.2 | 30.00 | 101.6 | 0 | 0 | - | - | 0.0 | 0.0 | 3.6 | 898 | 1.4 | 349 | 3000 | 11355 |
| 8/4/76 | 12 | Boulder | 1350 | 78 | 25.6 | 30.00 | 101.6 | 0 | 0 | - | - | 0.0 | 0.0 | - 0.5 | - 125 | 3.0 | 747 | 9500 | 35958 |
| 8/5/76 | 13 | Boulder | 0725 | 68 | 20.0 | 30.05 | 101.8 | 0 | 0 | - | - | 0.0 | 0.0 | 0.5 | 125 | 2.3 | 573 | 9500 | 35958 |
| 8/5/76 | 14 | Boulder | 0825 | 75 | 23.9 | 30.05 | 101.8 | 0 | 0 | - | - | 0.0 | 0.0 | 2.5 | 623 | 1.8 | 448 | 3000 | 11355 |
| 8/5/76 | 15 | Boulder | 0935 | 74 | 23.3 | 30.05 | 101.8 | 0 | 0 | - | - | 0.0 | 0.0 | 4.7 | 1171 | 2.2 | 548 | 3000 | 11355 |
| 8/5/76 | 16 | Boulder | 1115 | 79 | 26.1 | 30.05 | 101.8 | 0 | 0 | - | - | 0.0 | 0.0 | 5.2 | 1295 | 3.0 | 747 | 3000 | 11355 |

*Leak Total = 250 cu. ft.

Table 7. PRESSURE DATA DURING VENTING AT BOULDER

| Time on 8/3/76 | Pressure in Bulk Tanks | | Average Temperature in Bulk Tanks | | Remarks |
|---|---|---|---|---|---|
| | Inches $H_2O$ | $N/m^2$ | $^oF$ | $^oC$ | |
| 1531 | 10.0 | 2491 | | | |
| 1532 | 10.3 | 2553 | | | Start of venting |
| 1537 | 10.7 | 2653 | | | |
| 1539 | 11.0 | 2740 | 79.0 | 26.1 | |
| 1542 | 11.3 | 2815 | | | |
| 1545 | 11.5 | 2865 | | | |
| 1548 | 11.7 | 2914 | | | |
| 1556 | 12.0 | 2989 | | | |
| 1557 | 12.1 | 3014 | 79.6 | 26.4 | |
| 1601 | 12.1 | 3014 | | | |
| 1605 | 12.0 | 2989 | | | |
| 1613 | 11.8 | 2939 | 81.2 | 27.3 | |
| 1617 | 11.3 | 2815 | | | |
| 1622 | 10.7 | 2665 | | | |
| 1630 | 10.2 | 2541 | | | Venting stopped |
| 1634 | 9.9 | 2479 | | | |
| 1636 | 9.8 | 2441 | 83.2 | 28.4 | |
| 1641 | 9.7 | 2416 | | | |
| 1646 | 9.6 | 2391 | | | |
| 1652 | 9.4 | 2342 | | | |
| 1655 | 8.7 | 2167 | | | |

exceeded. Other than the venting on this particular day, no other venting through the exhaust vent took place for the remainder of the tests.

## C. Gas Chromatograph Analysis

A gas chromatograph analysis was done on grab samples taken during testing both at Boulder and Escondido. Altogether, nine samples were analyzed. Analyses were performed at West Coast Technical Service in Cerritos, California and Rinehart Labs, Inc. in Denver, Colorado.

Analysis for composition by gas chromatography indicated that the main constituents were butanes ($C_4$) and pentanes ($C_5$). The lab reports are attached in Appendix D.

Glass bulbs were used for sampling. The bulbs were first evacuated and then grab sampling was done through a quick disconnect in the vapor return line. Five samples were taken at Escondido and seven samples at Boulder. During transportation from Escondido to West Coast Technical Service, evidence of leakage was found in several sample bulbs and the samples were discarded. Only two bulbs could be salvaged, but because of the high percentage of air (Appendix D) these had leakage problems also. No such problems were encountered at Boulder.

In Table 8, total hydrocarbon concentration is presented both in % volume as hydrocarbons and % volume as propane. Since the chromatograph analysis gives the total concentration in % volume as hydrocarbons, the flame ionization detector concentration in % volume as propane has been converted to % volume as hydrocarbon based on the ratio of average carbon number obtained from G.C. analysis and the carbon number of propane (3) which the F.I.D. is calibrated to detect.

The average molecular weight of the hydrocarbon vapors obtained from G.C. analysis is 64.44. This average is based on the seven G.C. samples obtained in Boulder. The two G.C. samples ob-

Table 8. SUMMARY OF G. C. ANALYSIS

| Run No. | Location | Date | * Average Molecular Weight | * Average Carbon Number | Total H.C. from G.C. Analysis in % Volume Hydrocarbons | | Total H.C. from F.I.D. | | Total H.C. From G.C. Analysis. % Volume Propane Corrected for Air Content |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | As analysed | ** Corrected for Air | % Volume H.C. Based on Carbon Number | % Volume Propane | |
| 11 | Escondido | 7/22/76 | 67.93 | 4.74 | 1.24 | 1.84 | 8.90 | 14.06 | 2.90 |
| 15 | Escondido | 7/23/76 | 69.71 | 4.87 | 4.58 | 6.78 | 16.87 | 27.38 | 11.00 |
| 9 | Boulder | 8/ 3/76 | 65.49 | 4.55 | 10.23 | 17.05 | 28.75 | 43.60 | 25.85 |
| 11 | Boulder | 8/ 4/76 | 65.64 | 4.56 | 19.67 | 33.17 | 30.20 | 45.90 | 50.43 |
| 12 | Boulder | 8/ 4/76 | 63.52 | 4.41 | 17.46 | 29.22 | 31.97 | 41.70 | 42.97 |
| 13 | Boulder | 8/ 5/76 | 63.99 | 4.44 | 23.93 | 40.92 | 28.17 | 41.70 | 60.62 |
| 14 | Boulder | 8/ 5/76 | 65.44 | 4.54 | 8.34 | 14.32 | 9.85 | 14.90 | 21.70 |
| 15 | Boulder | 8/ 5/76 | 64.73 | 4.49 | 16.47 | 28.27 | 24.45 | 36.60 | 42.37 |
| 16 | Boulder | 8/ 5/76 | 62.28 | 4.32 | 20.49 | 35.11 | 26.88 | 38.70 | 50.56 |

Average Carbon number excluding Run numbers 11 and 15 = 4.47

Average Molecular Weight excluding Run numbers 11 and 15 = 64.44

* Sample calculation in Appendix A.

**Corrected for amount of air not evacuated from sample bulb.

tained in Escondido were excluded in the calculation because of the high percentage of air present in them.

The concentration derived from the F.I.D. curve is the average concentration of hydrocarbons during the test period. A grab sample of vapors was also taken during the test period for G. C. analysis. Since the G. C. sample is a relatively instantaneous concentration. This value is not necessary equivalent to the average concentration obtained for the test period.

## D. RVP ANALYSIS

Reid Vapor Pressure (RVP) samples were drawn from the account trucks and the transport tankers. These samples were taken according to method specified by ASTM D270-65. All RVP samples were analyzed by E. W. Saybolt & Company, Wilmington, California. Copies of their lab reports are included in Appendix D.

The range of RVP samples collected at Escondido is from 8.7 to 9.3. Samples collected at Boulder had a range of 7.6 to 8.8.

Existing reference tables,which relate volume percent hydrocarbons in a saturated gasoline vapor/air mixture to the variables RVP and temperature, generally predict higher values of percent HC than observed among the sample analyses performed for this program. For instance, a gasoline of 8 lb RVP at 100$^{o}$F normally contains 57.8%* hydrocarbons by volume (at saturation) and approximately 65.3% for a gasoline of 9 lb RVP representing the range of expected values of percent HC during the testing.

Comparing this with the average values for percent HC observed during the testing at Escondido, the analyses indicate that a typical vapor/air emission during product transfer was not saturated. On the other hand a few analyses taken during the testing at Boulder did indicate percent HC values very close to the predicted saturated values.

The deviation from equilibrium of saturation is usually caused by "in breathing" by tanks. When the air temperature cools, as at night, the vapor space within the tank cools and the vapors contract. Fresh air is drawn in through tank vacuum vents to compensate for the decrease in vapor volume. As this fresh air dilutes the vapor concentration, more volatile hydrocarbons evaporate from the liquid to restore the equilibrium.

*API Bulletin 2518, June 1962.

Another possible cause of unsaturated vapors at Escondido could be the use of gasoline station pumps which have a vacuum assist system of operation. (The suction of vapors at the nozzle interface causes air to be drawn in.)

Escondido, California

| | | |
|---|---|---|
| Average R.V.P. | Transport Tankers | 9.25 |
| Average R.V.P. | Account Trucks | 8.84 |

Boulder, Colorado

| | | |
|---|---|---|
| Average R.V.P. | Transport Tankers | 8.48 |
| Average R.V.P. | Account Trucks | 8.42 |

The tanker and bulk tank R.V.P.'s were nearly equal and suggest that the volatility of the gasoline was not appreciably different.

# V. CONCLUSIONS

As a result of tests performed on vapor recovery installations at two gasoline bulk plants, the following conclusions have been reached.

1. Vapor-balance systems, with or without associated refrigeration for cooling storage tanks, can control vapor emissions, during delivery of gasoline by transport tankers, with efficiency greater than 90 percent. In all of ten such transfers observed in this study, the efficiency observed ranged from 90 to 100 percent.
2. Vapor-balance systems, with or without associated refrigeration, can control vapor emissions during loading of account trucks with efficiency greater than 90 percent. In twelve of thirty such transfers observed in this study, the efficiency observed ranged from 90 to 100 percent.
3. The tests performed yielded no evidence that the secondary system employed at one bulk plant provided better emission control than the unassisted system employed at the other plant. Minimum observed efficiencies in loading of account trucks were 43 percent with the refrigeration system, as compared with 79 percent for the unassisted vapor balance system.
4. The efficiency attainable in loading account trucks appears to depend markedly on the condition of hatches and seals, and on the degree of care exercised in making connections. At the Escondido bulk plant, four account trucks were used; during loading, the two newer trucks had consistently lower emissions than the oldest truck, but none of the four consistently showed control efficiency as high as 90 percent.
5. Venting of a storage tank occurred once during the period of testing at each of the plants. The venting of the tank at Escondido, with the refrigeration system, released only a negligible amount of gas, unmeasurable with the study equipment. The venting from the tank at Boulder, however, continued for about an hour and released

an estimated 7 cubic meters (250 cubic feet) of gas containing about 25 percent hydrocarbons. (This would be roughly equivalent to about 7 liters of liquid gasoline, or about two gallons). Losses of this order of magnitude may be preventable by a secondary control system of the type used in the Escondido plant.

6. The average molecular weight of hydrocarbon vapors recovered, as indicated by gas chromatographic analysis, was about 64 (intermediate between butane and pentane).

7. Reid Vapor Pressure measurements of the liquid gasoline transferred indicated that gases emitted during liquid transfer at the Escondido facility were typically not saturated with gasoline vapor, whereas those emitted during transfer at Boulder were near saturation. This difference is possibly attributable to the effect of the refrigeration unit at Escondido.

Control of gasoline vapors associated with product transfer at the bulk plant is a relatively new field. This testing has resulted in the understanding of many factors as well as the evolution of new uncertainties. As an aid to minimizing hydrocarbon losses to the atmosphere, thorough inspections could be conducted periodically of bulk tanks, vapor return connections and bulk trucks for leakage of vapor. To eliminate hydrocarbon losses from the pressurized storage tanks due to the opening of liquid level measuring hatches, tank level indicators could be installed.

The testing required for compliance will vary depending upon the regulation promulgated. A regulation based upon emission rate (gm/gallon) would require testing as described in Appendix A for both balance systems and secondary vapor recovery systems. A regulation based upon volume percent could require simplified testing for vapor balance systems and secondary systems whose processor does not vent to the atmosphere (as the system in Escondido). In these cases, volume measurements of the return vapor and venting losses (barring any leaks) would only be required.

Assuming that the concentrations in the return line and at the vent are the same, efficiencies would be calculated on theoretical versus actual volume of vapors returned to the system.

# APPENDIX A

# TEST PROCEDURES AND SAMPLE CALCULATIONS

## GASOLINE VAPOR EMISSION TEST PROCEDURE FOR SMALL BULK PLANTS

### 1. Principle

Hydrocarbon mass emissions are determined directly and indirectly using flow meters and hydrocarbon analyzers. The volume of liquid gasoline dispensed (or transferred to storage tanks) is determined. Results are expressed in terms of grams emitted per gallon dispensed (or volumetric control efficiency, for filling storage tanks equipped with vapor balance systems not utilizing secondary processing units).

### 2. Application

This method is applicable to determining emission rates from the delivery of gasoline to bulk plant storage tanks utilizing secondary processing systems, and to the dispensing of gasoline from bulk plants to delivery trucks equipped with vapor return lines whether or not secondary processing units are utilized at the bulk plant. Volumetric efficiency only is determined for delivery of gasoline to bulk plant tanks where vapor balance systems not utilizing secondary processing units are installed.

### 3. Definitions

3.1 Small bulk plant. An intermediate gasoline distributing facility where delivery to and from the bulk plant storage tanks is by truck, and where total volume of gasoline delivered from the plant does not exceed 20,000 gallons per day.

3.2 Vapor balance or displacement vapor recovery system. A gasoline vapor control system which uses direct displacement to force vapors into the storage tanks (or bulk delivery truck tank) to prevent the emission of displaced vapors to the atmosphere during delivery of gasoline to the bulk plant storage tanks or during the filling of bulk delivery truck tanks from the bulk plant.

3.3 Secondary processing unit. A gasoline vapor control system which utilizes a means of destroying or recovering gasoline vapors which otherwise might be vented during the transfer of gasoline to or from bulk plants. Some secondary processing units incorporate vacuum-inducing devices to aspirate vapors into the processing unit.

### 4. Summary of the Methods

This procedure describes test conditions and test procedures to be followed in determining hydrocarbon emission rates and or recovery efficiencies from vapor balance and secondary processing vapor recovery systems installed to control emissions from the filling of bulk plant

storage tanks or bulk delivery truck loading operation at small bulk plants.

4.1 Transport delivery to bulk plant having vapor balance system only. Direct measurements of volumetric vent losses are made for determination of emission losses and system efficiency of vapor balance collection systems during bulk deliveries to small bulk plants. The volume of vapors exhausted to atmosphere during a bulk delivery is measured. Control efficiency is determined from the ratio of volume emitted (corrected to the temperature of the bulk tank) divided by the volume of gasoline delivered.

4.2 Transport delivery to bulk plant having vapor return plus secondary processing unit. Direct measurements of hydrocarbon concentration and volume of secondary processor emissions are made in order to determine efficiency of the secondary system in controlling vapors displaced during bulk delivery of gasoline to bulk plant storage tanks. All possible points of emission are checked for vapor leaks and estimates made of their magnitude.

4.3 Loading of bulk delivery trucks at bulk plants having vapor balance system only. Direct measurements of hydrocarbon concentrations and volume at tank vent and in vapor return line are made in order to determine mass rate of emissions and efficiency in controlling vapors displaced during loading of bulk delivery trucks at bulk plants. All possible points of emission are checked for vapor leaks and estimates made of their magnitude.

4.4 Loading of bulk delivery trucks at bulk plants having vapor return plus secondary processing unit. Direct measurements of hydrocarbon concentrations and flow are made on secondary processor emissions and on vapor returned from the bulk delivery truck in order to determine mass rate of emissions and efficiency in controlling vapors displaced during loading of bulk delivery trucks at bulk plants. All possible points of emission are checked for vapor leaks and estimates made of their magnitude.

5. Test Scope and Conditions

5.1 Test Period. The elapsed time during which the test is conducted shall not be less than three days.

5.2 Number of loadings to be tested:

5.2.1 Transport delivery to bulk plant. A minimum of five transport deliveries shall be tested.

5.2.2 Loading bulk delivery trucks. A minimum of ten bulk delivery truck loadings shall be tested.

5.3 Bulk plant status during test period. The test procedure is designed to measure emissions and control efficiency under normal conditions of operation. The following guidelines are provided to assist in determining normal operation.

5.3.1 Simultaneous use of more than one dispenser during loading of bulk delivery trucks shall occur to the extent that such use would normally occur.

5.3.2 Dispensing rates shall be at the maximum rate possible consistent with normal and safe operating practices.

5.4 Secondary processing unit status during test period. Control set points, cycling rates, temperatures of cooling devices, pressures, and other operating parameters shall be as specified for the processing unit by the manufacturer. Any deviations from these conditions shall be allowed only to the extent that normal operating practice has resulted in a permanent change in these conditions. Allowance shall be made for effects of ambient temperatures.

6. Basic Measurements and Equipment Required

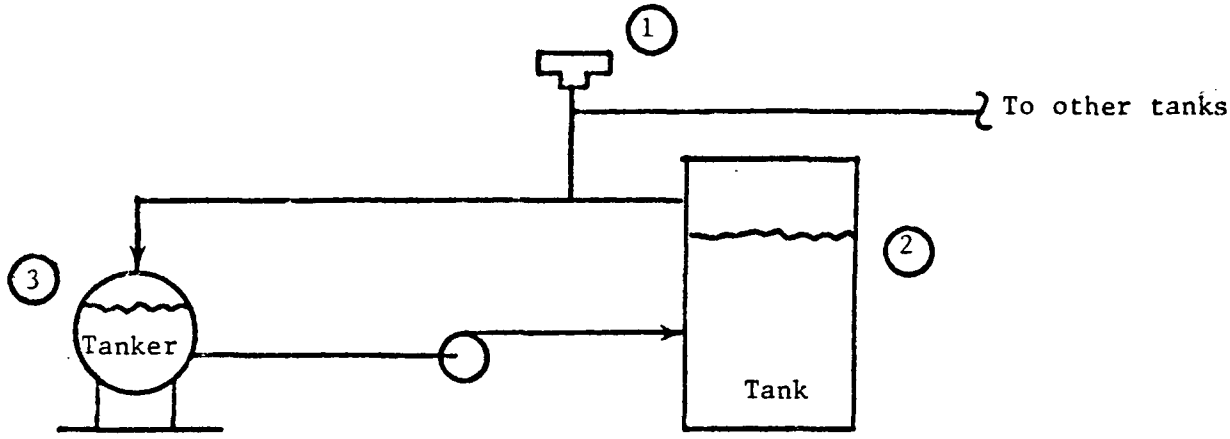
6.1 Basic measurements required for the determination of emissions from gasoline bulk plants are described below. Some measurements are noted as optional. These are not necessary in determination of emission rates or of efficiencies of control, but can be of value in the description of the operation of the vapor recovery system. The various sampling points are numbered in Figure 1.

6.1.1 Transport delivery to bulk plant - vapor balance.

| Sample Point | Measurement Necessary |
|---|---|
| 1 (Vent outlet for bulk plant tank) | Volume of vapors exhausted |
| 2 (Bulk plant tank) | Temperature of liquid, pressure in tank |
| 3 (transport tanker) | Temperature of liquid, pressure in tanker truck, volume and rate of gasoline delivered, Reid vapor - pressure of fuel delivered. Check for leaks at all connections |

6.1.2 Transport delivery to bulk plant - secondary processor

a. Transport delivery to bulk plant- vapor balance




b. Transport delivery to bulk plant - secondary processor

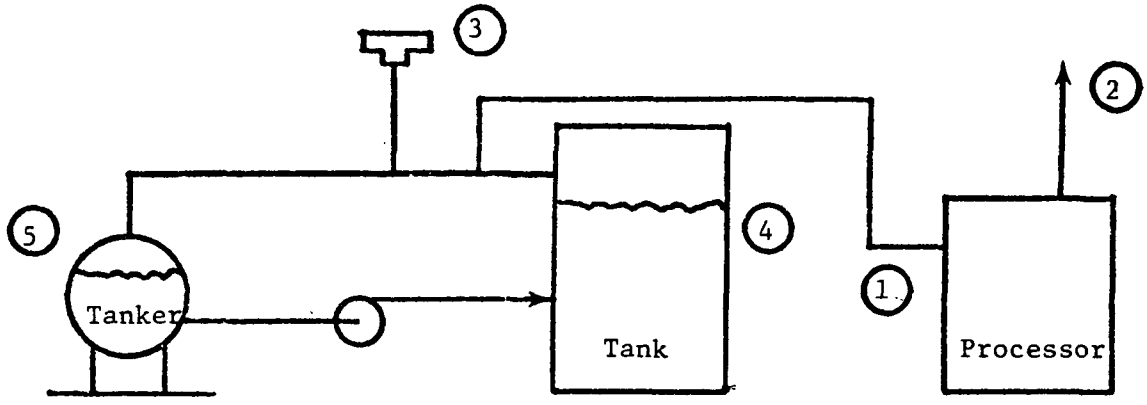



Figure 1. SAMPLING LOCATIONS

| Sample Point | Measurement |
|---|---|
| 1 (inlet of processor) | Hydrocarbon concentration |
| 2 (exhaust vent of processor) | Hydrocarbon concentration<br>Volume of exhaust gases<br>Temperature<br>Pressure |
| 3 (tank vent) | Check for hydrocarbon leaks |
| 4 (bulk plant tank) | Temperature of liquid<br>Pressure in tank |
| 5 (transport tanker) | Temperature of liquid<br>Pressure in tank<br>Volume and rate of gasoline delivered<br>Reid vapor pressure of gasoline<br>Check for leaks at all connections |

6.1.3 Loading bulk truck at bulk plant - vapor balance

| Sample Point | Measurement |
|---|---|
| 1 (tank vent) | Hydrocarbon concentration<br>Volume of vapors exhausted |
| 2 (tank) | Temperature of liquid<br>Pressure in tank |
| 3 (vapor return line) | Hydrocarbon concentration<br>Volume of returned vapors<br>Pressure<br>Gas chromatograph analysis of HC vapors |
| 4 (bulk truck) | Temperature of liquid<br>Pressure in truck before and after filling |
| 5 (gasoline dispenser) | Volume and rate of delivered gasoline<br>Reid vapor pressure of dispensed gasoline |

leak check at all connections, vents, and hatches

6.1.4 Loading bulk plant truck - secondary processor

| Sample Point | Measurement |
|---|---|
| 1 (inlet to processor) | Pressure |
| 2 (exhaust vent of processor) | Hydrocarbon concentration<br>Volume of exhaust gases<br>Temperature<br>Pressure |
| 3 (tank vent) | Check for leaks |
| 4 (tank) | Temperature of liquid<br>Pressure in tank |
| 5 (return vapor line) | Hydrocarbon concentration<br>Volume of returned vapors<br>Pressure<br>Gas chromatograph analysis of HC vapors |
| 6 (bulk truck) | Temperature of liquid<br>Pressure in truck before and after loading |
| 7 (gasoline dispenser) | Volume and rate of dispensed gasoline)<br><br>Reid vapor pressure of dispensed gasoline |

leak check at all connections, vents, and hatches

## 7.0 TEST PROCEDURES

7.1 Install into the vapor return line the (TP-9) Rockwell Turbine meter. This meter is equipped with flexible hosing and appropriate couplings (OPW female #1711D and # 1711GC). At the coupling on the meter inlet side install one tap for 1/4" O.D. tubing and a tap for a thermocouple. At the coupling on the outlet side install two taps for 1/4" O.D. tubing connected to the Beckman F.I.D. Hydrocarbon Analyzer and to a 0-6" inclined manometer. The sample line to the H.C. Analyzer pump should draw about 500 cc/min of sample, and the sample line should be disconnected when no loading is in progress.

7.2 Install negative and positive pressure switches (Dwyer) on the vacuum and positive pressure sides at the exhaust vent. The diaphragm motion of the pressure switches will actuate the electric switch of the appropriate solenoid valve. Thus, regulating breathing in and out of the bulk storage tank. (These pressure switches and solenoids valves (ASCO) perform the same function as the P-V vent at the exhaust). On the positive pressure side a 1000 cfh dry gas meter is installed. Attach a 1/4" tap at the volume meter outlet. Attach a sample line for the F.I.D. Hydrocarbon Analyzer to this tap.

## 8.0 MEASUREMENTS AND DATA REQUIRED FOR EVALUATING SYSTEM EFFICIENCY INCLUDE:

8.1 Record the temperature and volume of gasoline in each bulk storage tank at the beginning and end of each test period (or daily at least).

8.2 At the end of each test period, record the meter readings of the gasoline dispensed.

8.3 Record the initial reading from the dry gas meter at the exhaust gas vent of the bulk storage tank.

8.4 Record ambient temperature and barometric pressure every two hours during the test period.

8.5 Record the identification number, compartment number and volume of each truck tested.

8.6 Prior to loading, record the liquid temperature and pressure in bulk storage tanks.

8.7 Record the initial reading on the meter in the vapor return line prior to loading.

8.8 Time the loading operation so as to obtain the total dispensing time and dispensing rate of liquid.

8.9 After loading begins, record the pressure in the vapor return line.

8.95 Extract a sample for RVP analysis during loading from the delivered gasoline.

8.10 During loading check all fittings with the explosimeter. Record any incidents of leakage of hydrocarbon vapors.

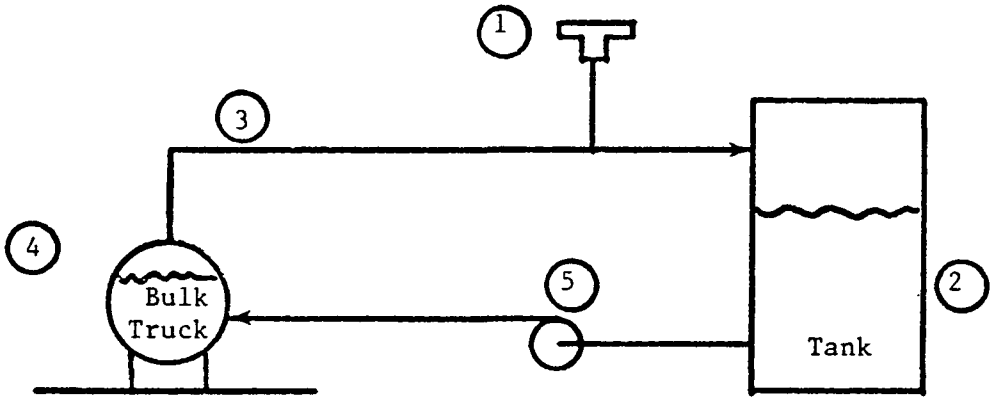
8.11 During loading monitor the temperature and hydrocarbon concentration of the returned vapors and/or vented vapors.

8.12 During refueling, extract a sample of the returned vapors for chromatograph hydrocarbon analysis.

8.13 After refueling, record the final gas meter reading, average temperature and average concentration of returned vapors and/or vented vapors.

8.14 Record the meter readings associated with any changes in H.C. concentration. (It would be helpful to extract samples of the exhaust vapors for chromatograph analysis during periods of increased H.C. concentration.)

c. Loading bulk truck at bulk plant - vapor balance




d. Loading bulk truck at bulk plant - secondary processor

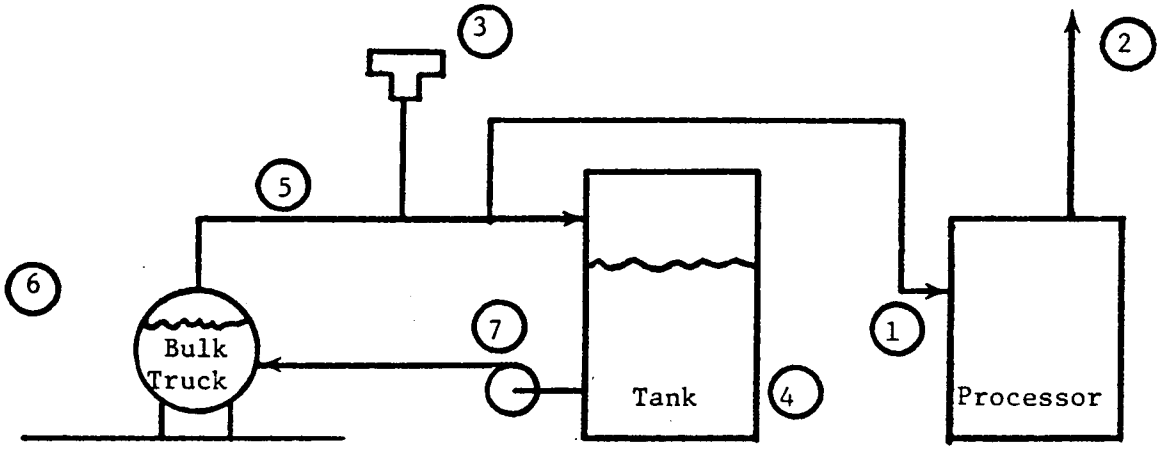



Figure 1. SAMPLING LOCATIONS (continued)

| BULK PLANT GASOLINE VAPOR CONTROL SUMMARY OF MEASUREMENTS | TRANSPORT DELIVERY TO BULK PLANT | | LOADING OF BULK DELIVERY TRUCKS | |
|---|---|---|---|---|
| | Vapor Balance System Only | Vapor Return Plus Secondary Processing Unit | Vapor Balance System Only | Vapor Return Plus Secondary Processing Unit |
| AMBIENT DATA | | | | |
| Temperature, °R | $T_a$ | $T_a$ | $T_a$ | $T_a$ |
| Barometric Pressure, in.Hg. | $P_a$ | $P_a$ | $P_a$ | $P_a$ |
| BULK PLANT TANKS | 2** | 4 | 2 | 4 |
| Temperature of vapor, °R | $T_b$ | $T_b$ | $T_b$ | $T_b$ |
| Gage pressure of vapor, in.$H_2O$ | $(\Delta H_b)$* | $(\Delta H_b)$ | $(\Delta H_b)$ | $(\Delta H_b)$ |
| Gasoline volume change, gal. | $(G_b)$ | $(G_b)$ | $(G_b)$ | $(G_b)$ |
| TRANSPORT TANKER | 3 | 5 | | |
| Identification Data | + | + | | |
| Vapor temperature, °R | $(T_v)$ | $(T_v)$ | | |
| Gage pressure in tanker, in.$H_2O$ | $(\Delta H_v)$ | $(\Delta H_v)$ | | |
| RVP of gasoline | + | + | | |
| Gasoline delivered, gal. | $G_v$ | $G_v$ | | |
| Delivery time, minutes | (t) | (t) | | |
| Leak checks | + | + | | |
| BULK PLANT TANK VENT | 1 | 3 | 1 | 3 |
| Volume of vapor vented, $ft^3$ | $v_g$ | | $v_g$ | |
| Temperature of metered vapors, °R | $T_g$ | | $T_g$ | |
| Gage pressure at meter, in.$H_2O$ | $\Delta H_g$ | | $\Delta H_g$ | |
| Hydrocarbon concentration, vol. frac. | | | $C_g$ | |
| Leak check (only) | | + | | + |
| VAPOR RETURN LINE FROM TRUCK | | | 3 | 5 |
| Volume of return vapor, $ft^3$ | | | $v_r$ | $v_r$ |
| Temperature of metered vapors, °R | | | $T_r$ | $T_r$ |
| Gage pressure at meter, in.$H_2O$ | | | $\Delta H_r$ | $\Delta H_r$ |
| Hydrocarbon concentration, vol. frac. (GC Analysis) | | | $C_r$ (+) | $C_r$ (+) |

*Items in parantheses are measured, but not used directly in emission calculations.

**Circled numbers refer to test locations on diagrams

| BULK PLANT GASOLINE VAPOR CONTROL SUMMARY OF MEASUREMENTS (continued) | TRANSPORT DELIVERY TO BULK PLANT | | LOADING OF BULK DELIVERY TRUCKS | |
|---|---|---|---|---|
| | Vapor Balance System Only | Vapor Return Plus Secondary Processing Unit | Vapor Balance System Only | Vapor Return Plus Secondary Processing Unit |
| PROCESSOR INLET | | 1 | | 1 |
| Hydrocarbon concentration, vol. frac. | | $C_i$ | | |
| Gage pressure, inches $H_2O$ | | $\Delta H_i$ | | $\Delta H_i$ |
| PROCESSOR EXHAUST VENT | | 2 | | 2 |
| Volume of vapor vented, $ft^3$ | | $v_s$ | | $v_s$ |
| Temperature of metered vapor, °R | | $T_s$ | | $T_s$ |
| Gage pressure at meter, in.$H_2O$ | | $\Delta H_s$ | | $\Delta H_s$ |
| Hydrocarbon concentration, vol. frac. | | $C_s$ | | $C_s$ |
| GASOLINE DISPENSER | | | 5 | 7 |
| Gasoline dispenced, gal. (total) | | | $G_v$ | $G_v$ |
| Gasoline dispensed, gal. (during operation of processor) | | | | $G_p$ |
| Delivery time, minutes | | | (t) | (t) |
| RVP of gasoline | | | + | + |
| BULK TRUCK | | | 4 | 6 |
| Identification Data | | | + | + |
| Vapor Temperature, °R | | | $(T_v)$ | $(T_v)$ |
| Gage pressure in truck, in.$H_2O$ | | | $(\Delta H_v)$ | $(\Delta H_v)$ |
| Leak checks | | | + | + |

## CALCULATIONS

Notes: a) SCF = $ft^3$ @ 68°F (528°R) and 29.92 in.Hg

b) Starred (*) values subject to increase if leaks occur.

1. Transport delivery to bulk plant having vapor balance system only

$$E_v, \text{ Volumetric efficiency, \%} = \left(\frac{\text{(Vapor Displaced - Vapor Vented)}}{\text{Vapor Displaced}}\right) 100$$

$$\text{Vapor displaced, SCF} = \frac{G_v}{7.481} \left(\frac{528}{T_b}\right) \left(\frac{P_a + \Delta H_v/13.6}{29.92}\right)$$

$$\text{Vapor vented, SCF} = v_g \left(\frac{528}{Tg}\right) \left(\frac{P_a + \Delta H_g/13.6}{29.92}\right)$$

Assume $\Delta H_r = \Delta H_g$

$$\text{Then } E_v \text{ \%} = \frac{(G_v/7.481\ T_b - v_g/T_g)\ 100}{G_v/7.481\ T_b}$$

$$= 100 - \frac{748.1\ v_g^*\ T_b}{G_v\ T_g}$$

2. Transport delivery to bulk plant having vapor return plus secondary processing unit

i) $E_v$, vol. effic., % = $100 - \dfrac{748.1\ v_s^*\ T_b}{G_v\ T_s}$

ii) $V_s$ = volume of vapor vented from processor, SCF

$$= \frac{v_s \times 528 \times (P_a + \Delta H_s/13.6)}{T_s \times 29.92}$$

iii) $W_s$ = wt of hydrocarbon vented from processor, gm

$$= V_s \times C_s \times M_p \times \frac{454}{385}$$

where $M_p$ = Molecular wt. of calibration gas (propane), lb/lb-mole

iv) Emission Rate, gm/gallon = $W_s^*/G_v$

v) Weight efficiency (optional)

v) continued

$$E_w, \text{ weight efficiency, } \% = 100 \left( \frac{\text{Wt HC Displ. - Wt. HC vented}}{\text{Wt. HC Displ.}} \right)$$

$$V_v = \text{Vol. of vapor displaced, SCF} = \frac{G_v \times 528 \times (P_a + \Delta H_i/13.6)}{7.481 \times T_b \times 29.92}$$

$$W_v = \text{Wt. of hydrocarbons displaced, gm} = V_v \times C_i \times M_p \times 454/385$$

$$E_w, \% = 100\ (W_v - W_s)/W^*_v$$

3. <u>Loading of bulk delivery trucks at bulk plants having vapor balance system only</u>

i) $V_g$ = volume of vapor vented from bulk tank, SCF

$$= \frac{v_g \times 528 \times (P_a + \Delta H_g/13.6)}{T_g \times 29.92}$$

ii) $W_g$ = weight of hydrocarbon vented, gm

$$= V_g \times C_g \times M_p \times 454/385$$

iii) $V_r$ = Volume of vapor returned from bulk truck during filling, SCF

$$= \frac{v_r \times 528 \times (P_a + \Delta H_r/13.6)}{T_r \times 29.92}$$

iv) $W_r$ = weight of hydrocarbons returned, gm

$$= V_r \times C_r \times M_p \times 454/385$$

v) Emission Rate, gm/gallon = $W^*_g/G_v$

vi) Weight efficiency, %

$$E_W\ \% = 100\ \frac{(W_g + W_r) - W_g}{W_g + W_r} = 100\ \frac{W_r}{W_r + W_g}$$

4. <u>Loading of bulk delivery trucks at bulk plants having vapor return plus secondary processing unit</u>

i) $V_s$ = vol. of vapor vented from processor, SCF

$$= \frac{v_s \times 528 \times (P_a + \Delta H_s/13.6)}{T_s \times 29.92}$$

ii) $W_s$ = wt. of hydrocarbon vented, gm.

$$= V_s \times C_s \times M_p \times 454/385$$

iii) $V'_r$ = total vol. of vapor returned from bulk truck during filling, SCF

$$= \frac{v_r \times 528 \times (P_a + \Delta H_r/13.6)}{T_r \times 29.92}$$

iv) $V_r$ = vol. of vapor vented to processor when latter is operating, SCF

$$= V_r' \times G_p/G_v$$

v) $W_r$ = weight of hydrocarbon vented to processor, gm.

$$= V_r \times C_r \times M_p \times 454/385$$

vi) Emission Rate, gm/gallon = $W^*_s/G_v$

vii) Weight efficiency, %

$$E_W, \% = 100 \frac{(W_s + W_r) - W_s}{W_r + W_s} = 100 \frac{W_r}{W_r + W_s}$$

## SAMPLE CALCULATIONS

1) Transport delivery to bulk plant

Volumetric efficiency ($E_v$) = 100 $\left(\frac{\text{Vapor displaced - Vapor vented and lost}}{\text{Vapor displaced}}\right)$

Run #7 - Boulder, Colorado

$$\text{Vapor displaced, S.C.F.} = \frac{G_v}{7.481}\left(\frac{528}{T_b}\right)\left(\frac{P_a + \Delta H_r/13.6}{29.92}\right)$$

$$= \frac{9500}{7.481} \times \frac{(528)}{(546.83)} \quad \frac{(25.7 + .622/13.6)}{29.92}$$

$$= 1055.1 \text{ ft}^3$$

Vapor vented ($V_g$) = 0

Volume of vapor lost due to leaks = 1.3 $ft^3$

$$\therefore \quad \text{Volumetric efficiency} = \left(\frac{1053.8}{1055.1}\right) 100$$

$$= 99.87\%$$

2) Loading of account trucks at bulk plants

Run #8 - Escondido, California

i) Volume of vapor vented from bulk tank S.C.F. = 0

but leaks = 19.6 $ft^3$

ii) $W_g$ = weight of hydrocarbon vented, gm

$$= V_g \times C_g \times M_p \times 454/385$$

$$= 19.6 \times \frac{11.78}{100} \times 44 \times 454/385$$

$$= 119.8 \text{ grams}$$

SAMPLE CALCULATIONS (Cont'd)

iii) $V_r$ = Volume of vapors returned from account truck during filling SCF

$$= \frac{V_r \times 528 \times (P_a + \Delta H_r/13.6)}{Tr \times 29.92}$$

$$= \frac{184 \times 528}{(460 + 67)} \times \frac{(29.6 + 0.2/13.6)}{29.92}$$

$$= 182.6 \text{ ft}^3$$

iv) $W_r$ = Weight of hydrocarbons returned, grams

$$= V_r \times C_r \times M_p \times 454/385$$

$$= 182.6 \times \frac{11.78}{100} \times 44 \times \frac{454}{385}$$

$$= 1116.1 \text{ grams}$$

vi) Weight efficiency %

$$E_w\% = 100\ (W_r/W_r + W_g)$$

$$= 100\ (1116.1/1116.1 + 119.8)$$

$$= 90.3\%$$

Note:

Since it is assumed that concentration of leaks is the same as that of the vapors in the vapor return line, the volumetric efficiency is equal to weight efficiency and a direct calculation for efficiency can be made from the standard and ideal volumes.

$$E_v = E_w = \left(\frac{202.6 - 19.6}{202.6}\right) 100$$

$$= 90.3\%$$

SAMPLE CALCULATIONS (Cont'd)

G.C. #16

Total % Hydrocarbons = 20.491 [reference Page D-4]

$$\text{Average carbon number} = \frac{\text{Total number of carbon atoms present}}{\text{Total Hydrocarbons}}$$

= [1.13 x 1 + 0.001 x 2 + 0.15 x 2 + 0.03 x 3 + 0.82 x 3 + 3.03 x 4 + 1.12 x 4 + 3.53 x 4 + 0.84 x 4 + 6.18 x 5 + 2.89 x 5 + 0.44 x 6 + 0.16 x 7 + 0.17 x 8]/ 20.491

= 88.532/20.491

= 4.32

Similary

Average molecular weight = [1.13 x 16 + 0.01 x 26 + 0.15 x 28 + 0.03 x 42 + 0.82 x 44 + 3.03 x 58 + 1.12 x 56 + 3.53 x 58 + 0.84 x 56 + 6.18 x 72 + 2.89 x 72 + 0.44 x 86 + 0.16 x 100 + 0.17 x 114]/ 20.491

$$= \frac{1276.146}{20.491}$$

= 62.28

$$\text{\% volume as hydrocarbon} = \text{\% volume as propane} \times \frac{\text{carbon number of propane}}{\text{Av. Carbon Number}}$$

$$= 38.70 \times \frac{3}{4.32}$$

% volume as hydrocarbon = 26.88

# APPENDIX B

# LIST OF EQUIPMENT

## EQUIPMENT FOR BULK PLANT TESTING

| | |
|---|---|
| 2 | Beckman Model 400 FID continuous hydrocarbon analyzers with automatic fuel shut-off |
| 1 | Dual Pen - Dual speed compatible recorder |
| 1 | American Meter Model AL-1000 |
| 2 | Inclined manometers Dwyer Model 246 (0-6") |
| 2 | Inclined Manometers Dwyer Model 202.5 (0-2") |
| 1 | Rockwell turbine meter Model TP-9 |
| 1 | Combustible gas analyzer - Bacharach Instruments Model SSP |
| 2 | Solenoid valves with accompanying pressure switches |
| 1 | Male-Female pair modified OPW vapor return truck connectors |
| 40 | RVP Sample Recovery Containers |
| 15 | G.C. Gas Sample Bulbs |
| 7 | Thermocouples Thermo Electric J-18-G-304-0-120-4A |
| 1 | Portable Potentiometer Thermo Electric Minimite Model 31101 |
| 1 | Thermocouple Panel and Selector switch Thermo Electric Models 41806-Jx and 33104 |
| 1 | Instrument Rack Assembly (Standard 19") |
| 1 | Equipment Support Cart |
| 2 | 150 $ft^3$ Hydrogen fuel mixture cylinders (He 60%, $H_2$ 40%) Scott-Marrin |
| 4 | 150 $ft^3$ zero air cylinders - Scott-Marrin |
| 1 | 150 $ft^3$ span gas cylinder (1.48% propane in air) - Scott-Marrin |
| 3 | 2-Stage regulators - Scott-Marrin 2SB75-350 & 2SB75-590 |
| 2 | Brooks Rotameters (0-140 cc/min.) |
| 2 | Brooks Rotameters (0-2.5 l/min.) |
| 4 | Needle valves |
| | Polyethylene tubing |

# APPENDIX C

## SAMPLE DATA SHEETS

P.E.S. - SANTA MONICA, CA. 90404

BULK PLANT TEST PROGRAM

VAPOR RETURN DATA

TEST NO. _____ DATE _____

TEST LOCATION _____

NO. OF BULK TANKS _____

☐ TRANSPORT DELIVERY ☐ BULK TRUCK DISPENSING

| TIME | GAS METER READING | | | REMARKS |
|---|---|---|---|---|
| | READING CF | PRESSURE, "$H_2O$ | | |
| | | INLET | OUTLET | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

TYPE AND VOLUME OF GASOLINE BEING PUMPED = _____

RVP SAMPLE # = _____

G.C. SAMPLE # = _____

LEAK CHECKS:

DATA TAKEN BY _____

P.E.S. - SANTA MONICA, CA. 90404

BULK PLANT TEST PROGRAM

BULK TANK AND AMBIENT DATA

TEST NO. _____ DATE _____

TEST LOCATION _____

NO. OF BULK TANKS _____ CONTROL SYSTEM _____

| | | | | | |
|---|---|---|---|---|---|
| BULK TANK NO. | | | | | |
| CAPACITY GAL. | | | | | |
| LIQ. VOL. INITIAL | | | | | |
| LIQ. VOL. FINAL | | | | | |
| GASOLINE VOL. CHANGE, GAL. | | | | | |
| TIME | | | | | |
| GAUGE PRESSURE OF VAPOR, "$H_2O$ | | | | | |
| GASMETER READING, C.F. | | | | | |

BAROMETRIC PRESSURE, "Hg = AMBIENT TEMP =

LEAK CHECKS

REMARKS:

DATA TAKEN BY _____

P.E.S. - SANTA MONICA, CA. 90404

BULK PLANT TEST PROGRAM

H.C. VAPOR DATA

TEST NO. _____ DATE _____

TEST LOCATION _____

NO. OF BULK TANKS _____

| | POSITIVE | VACUUM |
|---|---|---|
| P.V. SETTINGS | | |
| P.E.S. | | |

| TIME | TEMPERATURE OF | | | | | | | ROTOMETERS | | | | HYDROCARBON CONCENTRATION NOTED FROM POINTS # | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | BLUE | | RED | | | |
| | #1 | #2 | #3 | #4 | #5 | #6 | #7 | VAPOR | AIR | VAPOR | AIR | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

REMARKS:

DATA TAKEN BY _____

# APPENDIX D

# LABORATORY ANALYSES REPORTS

RECEIVED AUG 1 2 1976

CABLE ADDRESS "SAYBOLTOIL"
ALL CODES USED - SPECIFY

SPECIALISTS IN TANK CALIBRATING

INSPECTION OF BULK CARGOES, PETROLEUM AND OTHER LIQUIDS. LICENSED WEIGHERS AND SAMPLERS OF VEGETABLE OILS, WAXES AND FATS.

LOS ANGELES AREA - SPRUCE 5-1153
HARBOR AREA - TERMINAL 5-8383

E. W. SAYBOLT & CO., INC.

JOS. H. McCABE JOS. H. McCABE, JR.
APPROVED AND LICENSED BY
THE NEW YORK PRODUCE EXCHANGE

INSPECTORS OF PETROLEUM

LOS ANGELES AREA
P. O. BOX 1146 - 115 AVALON BLVD.
WILMINGTON, CALIF. 90744

LABORATORIES
KENILWORTH, N.J.
PHILADELPHIA, PA.
HAMMOND, IND.
NEW ORLEANS, LA.
CORPUS CHRISTI, TEX.
PASADENA (HOUSTON), TEX.
WILMINGTON, CALIF.
TAMPICO, MEX.
SEATTLE, WASH.
PORTLAND, ORE.
CHICAGO, ILL.
BOSTON, MASS.
WEST HAVEN, CONN.

SERVING THE PETROLEUM INDUSTRY FOR OVER 60 YEARS
DEPENDABLE INSPECTION SERVICE AT ALL PORTS ON THE ATLANTIC, GULF AND PACIFIC COASTS

# LABORATORY ANALYSIS REPORT

SAMPLE DESIGNATED BY CLIENT AS GASOLINE AUGUST 11,1976

FROM Submitted by Pacific Enironmental Services, Inc.

FOR Analysis

THIS LABORATORY REPORT MAY NOT BE PUBLISHED OR USED EXCEPT IN FULL. SHALL NOT BE USED FOR ADVERTISING OR IN CONNECTION WITH ADVERTISING OF ANY KIND UNLESS PERMISSION FOR THE PUBLISHING OR ADVERTISING OF AN APPROVED ABSTRACT HAS BEEN OBTAINED, IN WRITING FROM E. W. SAYBOLT & CO., INC.

| | REID VAPOR PRESSURE @ 100°F |
|---|---|
| Premium, 8-3-76, # 8B | 8.8 |
| Premium, 8-4-76, #11A | 8.8 |
| Premium, 8-5-76, #16 | 8.7 |
| Supreme, 8-3-76, # 7A | 8.7 |
| Supreme, 8-3-76, Run B-4 | 8.4 |
| Supreme, Run B-3, Truck #9 | 8.5 |
| Unleaded, 8-3-76, Run #6 | 8.7 |
| Unleaded, 8-4-76, # 11B | 8.5 |
| Unleaded, 8-4-76, # 12A | 8.8 |
| Regular, 8-4-76, # 11C | 7.6 |
| Conotane, 8-3-76, Run # B-4 | 8.5 |
| Conotane, 8-3-76, # 7B | 8.5 |
| Conotane, 8-3-76, # 8A | 8.0 |
| Conotane, 8-3-76, # 9 | 8.5 |
| Conotane, 8-4-76, #10 | 8.4 |
| Conotane, 8-4-76, # 12-B | 8.4 |
| Conotane, 8-5-76, #13 | 8.0 |
| Conotane, 8-5-76, #14 | 8.3 |
| Conotane, Run # B-3, Truck #9 | 8.3 |

E. W. SAYBOLT & CO., INC.
DEPUTY INSPECTOR OF PETROLEUM
APPROVED BY NEW YORK PRODUCE EXCHANGE

D-1



MEMBERS OF A. S. T. M. A. P. I.—S. A. E.

SAMPLES, IF ANY, SHALL BE RETAINED FOR A PERIOD OF 45 DAYS UNLESS A LONGER PERIOD IS REQUESTED IN WRITING

CABLE ADDRESS "SAYBOLTOIL"
ALL CODES USED - SPECIFY

SPECIALISTS IN TANK CALIBRATING

INSPECTION OF BULK CARGOES, PETROLEUM AND OTHER LIQUIDS. LICENSED WEIGHERS AND SAMPLERS OF VEGETABLE OILS, WAXES AND FATS.

LOS ANGELES AREA - SPRUCE 5-1153
HARBOR AREA - TERMINAL 5-8383

E. W. SAYBOLT & CO., INC.

JOS. H. McCABE JOS. H. McCABE, JR.
APPROVED AND LICENSED BY
THE NEW YORK PRODUCE EXCHANGE

INSPECTORS OF PETROLEUM

LOS ANGELES AREA
P. O. BOX 1146 - 115 AVALON BLVD.
WILMINGTON, CALIF. 90744

LABORATORIES
KENILWORTH, N.J.
PHILADELPHIA, PA.
HAMMOND, IND.
NEW ORLEANS, LA.
CORPUS CHRISTI, TEX.
PASADENA (HOUSTON), TEX.
WILMINGTON, CALIF.
TAMPICO, MEX.
SEATTLE, WASH.
PORTLAND, ORE.
CHICAGO, ILL.
BOSTON, MASS.
WEST HAVEN, CONN.

SERVING THE PETROLEUM INDUSTRY FOR OVER 60 YEARS
DEPENDABLE INSPECTION SERVICE AT ALL PORTS ON THE ATLANTIC, GULF AND PACIFIC COASTS

# LABORATORY ANALYSIS REPORT

SAMPLE DESIGNATED BY CLIENT AS GASOLINE JULY 29,1976

FROM Submitted by Pacific Environmental Services, Inc.

FOR Analysis P.O. NO 641

THIS LABORATORY REPORT MAY NOT BE PUBLISHED OR USED EXCEPT IN FULL. SHALL NOT BE USED FOR ADVERTISING OR IN CONNECTION WITH ADVERTISING OF ANY KIND UNLESS PERMISSION FOR THE PUBLISHING OR ADVERTISING OF AN APPROVED ABSTRACT HAS BEEN OBTAINED, IN WRITING FROM E. W. SAYBOLT & CO., INC.

| | REID VAPOR PRESSURE @ 100°F |
|---|---|
| Unleaded, Run #7, 7-22-76 | 8.7 |
| Unleaded, Run #18, 7-23-76 | 9.2 |
| Unleaded, Run #20, 7-23-76 | 8.7 |
| Unleaded, Run #23, 7-26-76 | 9.0 |
| Lowlead, Run #4 7-22-76 | 8.9 |
| Lowlead, Run #7 7-22-76 | 8.7 |
| Lowlead, Run #16 7-23-76 | 8.7 |
| Lowlead, Run #19 7-23-76 | 8.9 |
| Lowlead, Run #23 7-26-76 | 9.0 |
| Supreme, Run #5 7-21-76 | 9.3 |
| Supreme, Run #8 7-22-76 | 8.9 |
| Supreme, Run #21 7-23-76 | 8.8 |
| Supreme, Run #23 7-26-76 | 9.0 |
| Supreme, Run #25 7-26-76 | 8.8 |

E. W. SAYBOLT & CO., INC.

J B Campbell
DEPUTY INSPECTOR OF PETROLEUM
APPROVED BY NEW YORK PRODUCE EXCHANGE

D-2

RECEIVED AUG 1 1 1976

**RINEHART LABORATORIES, INC.**

5810 LAMAR STREET • ARVADA, COLO. 80001 • P.O. BOX 564 • PHONE 422-4020

R. W. RINEHART, Sr., Ph.D., Pres.
A. W. STONE, Sec.-Treas.

Reference No. 760330
P.O. #639
August 9, 1976

To: Mr. Robert L. Norton
Pacific Environmental Services, Inc.
1930 14th Street
Santa Monica, California 90404

Subject: GC Analysis of Seven Gasoline Vapor Samples and One Condensate Sample, identified as follows;

#1 - Run #9 8/3/76 Transport
2 - GC Sample #11 8/4/76 Delivery Vehicle
3 - GC #12 8/4/76 Transport
4 - GC #13 8/5/76 Transport
5 - GC #14 8/5/76 Delivery
6 - GC #15 8/5/76 Delivery
7 - GC #16 8/5/76 Delivery
8 - Condensate 8/4/76 Boulder

Results:

Interpretation and quantitation of our gas chromatograph runs of the samples are shown on the following page.

A. W. Stone

Reference No. 760330
P.O. #639

DATA

VOL. %

| | GC #9 | GC #11 | GC #12 | GC #13 | GC #14 | GC #15 | GC #16 |
|---|---|---|---|---|---|---|---|
| Methane | 0.02 | 0.04 | 0.04 | 0.08 | 0.02 | 0.03 | 1.13 |
| Ethylene | 0.0007 | 0.001 | 0.003 | 0.002 | 0.001 | 0.001 | 0.001 |
| Ethane | 0.08 | 0.15 | 0.19 | 0.25 | 0.05 | 0.11 | 0.15 |
| Propylene | 0.03 | 0.04 | 0.17 | 0.02 | 0.02 | 0.02 | 0.03 |
| Propane | 0.42 | 0.81 | 0.91 | 1.13 | 0.32 | 0.66 | 0.82 |
| Isobutane | 1.52 | 2.99 | 2.87 | 3.83 | 1.21 | 2.59 | 3.03 |
| Isobutylene | 0.46 | 1.03 | 0.96 | 1.42 | 0.39 | 0.86 | 1.12 |
| n-butane | 1.98 | 3.58 | 3.33 | 4.54 | 1.60 | 3.08 | 3.53 |
| cis-2-butane | 0.37 | 0.73 | 0.73 | 0.93 | 0.33 | 0.63 | 0.84 |
| Isopentane | 3.21 | 5.93 | 5.32 | 7.29 | 2.77 | 5.37 | 6.18 |
| n-pentane | 1.48 | 2.97 | 2.60 | 3.90 | 1.29 | 2.72 | 2.89 |
| Hexanes | 0.44 | 0.92 | 0.22 | 0.36 | 0.14 | 0.23 | 0.44 |
| Heptanes | 0.17 | 0.37 | 0.07 | 0.11 | 0.09 | 0.09 | 0.16 |
| Octanes | 0.05 | 0.11 | 0.05 | 0.07 | 0.11 | 0.08 | 0.17 |

CONDENSATE ---- 2.0 % Water

0.9 % Oil (Lubricating Type)

Balance - Gasoline

Rinehart Laboratories, Inc.
Arvada, Colorado

RECEIVED AUG 1 1 1976

# Report

WEST COAST TECHNICAL SERVICE INC.

17605 Fabrica Way, Suite D
Cerritos, California 90701
213/921-9831
714/523-9200

Prepared For
Mr. Robert Norton
Pacific Environmental Services, Inc.
1930 - 14th Street
Santa Monica, CA 90404

Date: August 10, 1976
Job No.: 10967
P.O. No.: 628

The two gas samples received from you on July 26, 1976 have been analyzed for composition by gas chromatography. The results are as follows:

| | Volume Percent | |
|---|---|---|
| | Sample #1 Run 11 | Run #15 Standard Oil Escondido |
| Air | 98.74 | 95.37 |
| Methane | ----- | 0.01 |
| Carbon Dioxide | 0.01 | 0.05 |
| Ethane | ----- | 0.01 |
| Propane | 0.04 | 0.13 |
| Isobutane | 0.08 | 0.25 |
| n-Butane | 0.41 | 1.35 |
| Butenes | 0.02 | 0.07 |
| Isopentane | 0.35 | 1.26 |
| n-Pentane | 0.08 | 0.25 |
| Pentenes | 0.06 | 0.27 |
| Hexanes | 0.12 | 0.55 |
| Hexenes | 0.01 | 0.01 |
| Heptanes | 0.03 | 0.15 |
| Benzene | 0.02 | 0.11 |
| Octanes | 0.01 | 0.09 |
| Toluene | 0.01 | 0.06 |
| Nonanes | ----- | 0.01 |

If we can be of any further service, please do not hesitate to contact us.

Respectfully submitted,

WEST COAST TECHNICAL SERVICE INC.

H. Dwight Pisher, Ph.D.
Vice President-Technical Director

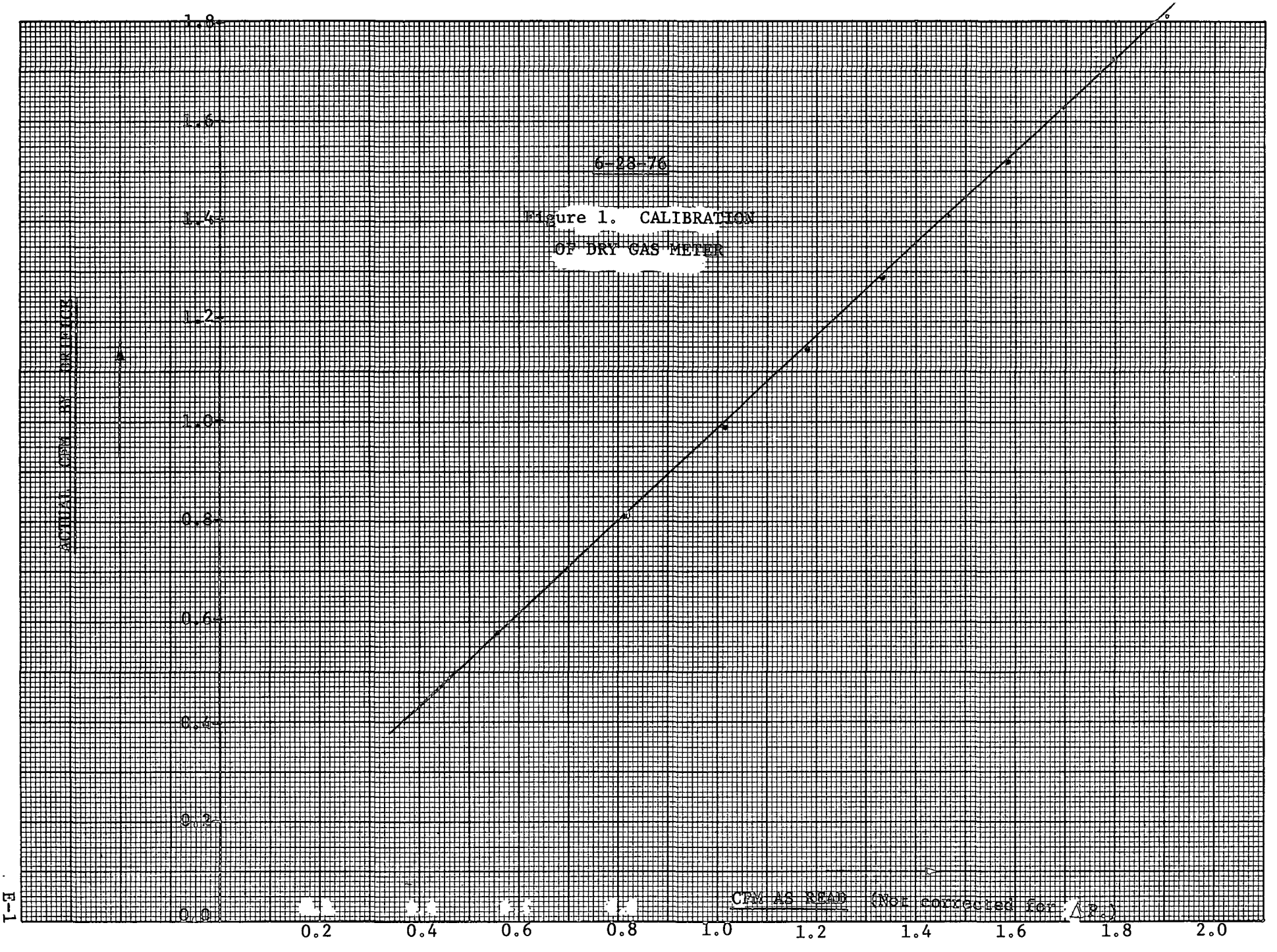
HDF/kd



This report pertains only to the samples investigated and does not necessarily apply to other apparently identical or similar materials. This report is submitted for the exclusive use of the client to whom it is addressed. Any reproduction of this report or use of this Laboratory's name for advertising or publicity purposes without written authorization is prohibited.

# APPENDIX E

# SAMPLE CALIBRATION CURVES


6-28-76
Figure 1. CALIBRATION
OF DRY GAS METER
ACTUAL CFM BY TICS
CFM AS READ (Not corrected for Δp)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0

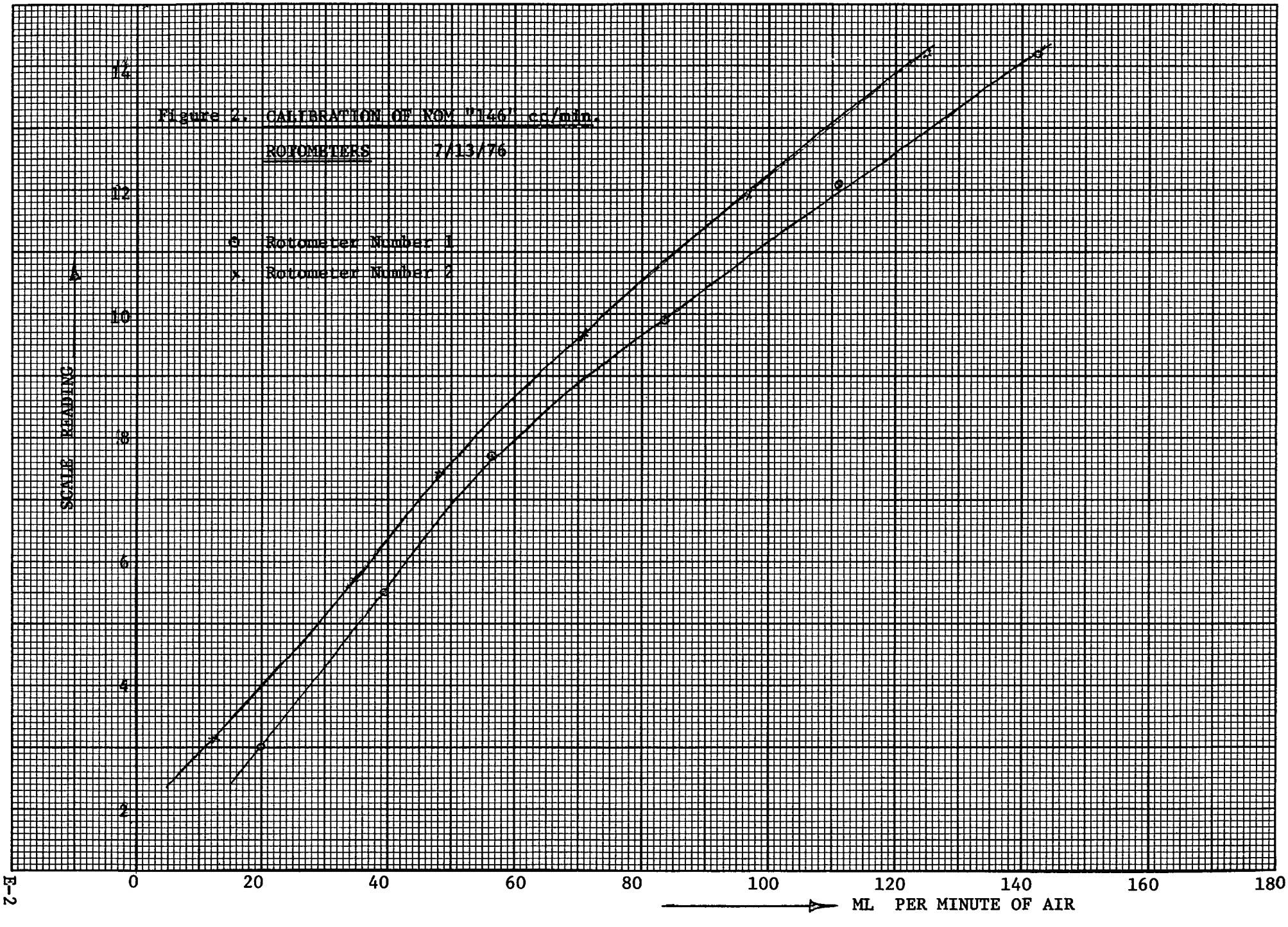
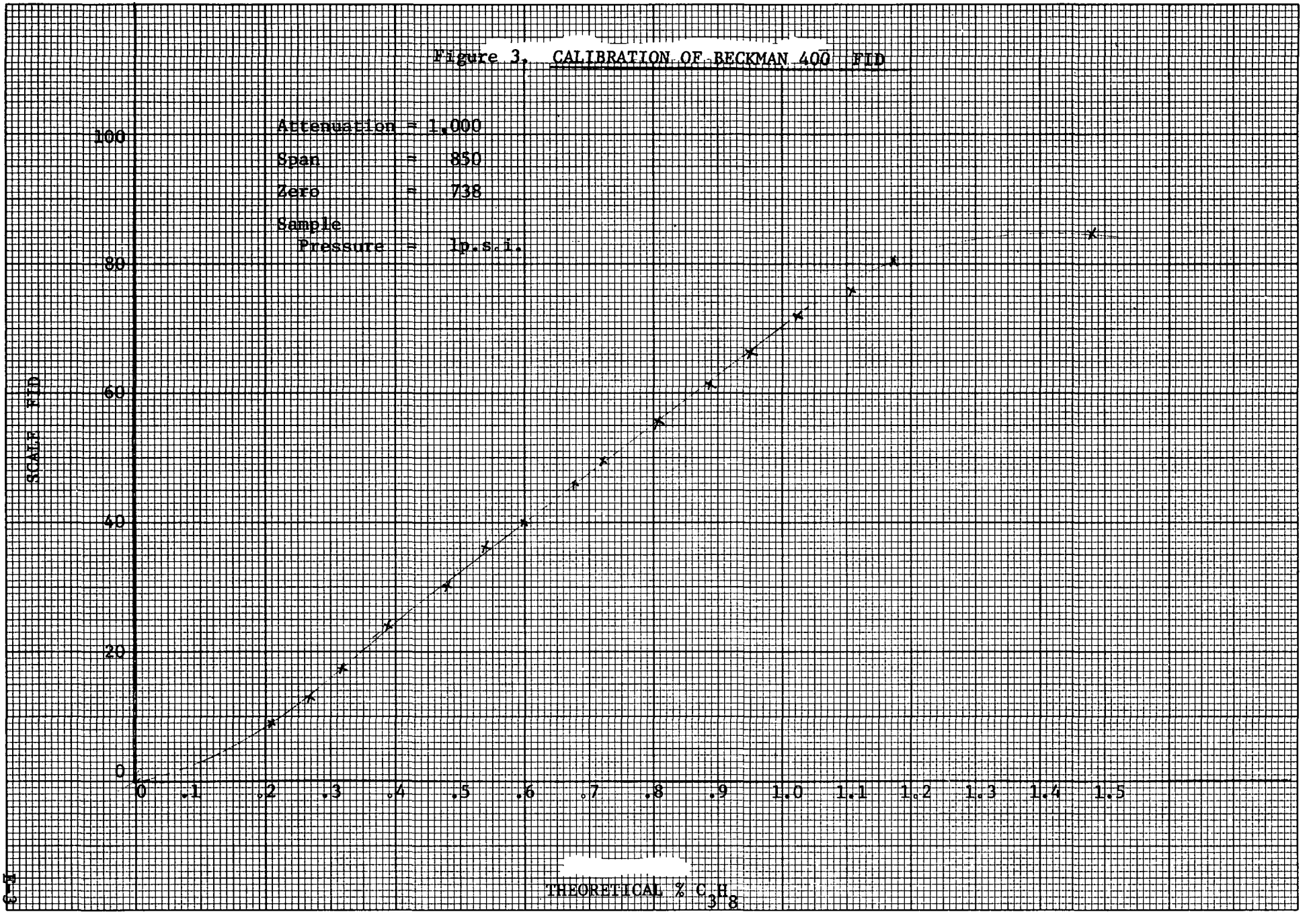


Figure 2. CALIBRATION OF KOM "146" cc/min.
ROTOMETERS 7/13/76
Rotometer Number 1
Rotometer Number 2
SCALE READING
2
4
6
8
10
12
14
0
20
40
60
80
100
120
140
160
180
ML PER MINUTE OF AIR

Figure 3. CALIBRATION OF BECKMAN 400 FID



## TECHNICAL REPORT DATA
*(Please read Instructions on the reverse before completing)*

| | | |
|---|---|---|
| 1. REPORT NO. EPA 340/1-77-012 | 2. | 3. RECIPIENT'S ACCESSION NO. |
| 4. TITLE AND SUBTITLE Compliance Analysis of Small Bulk Plants | | 5. REPORT DATE October 1976 |
| | | 6. PERFORMING ORGANIZATION CODE |
| 7. AUTHOR(S) | | 8. PERFORMING ORGANIZATION REPORT NO. |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS Pacific Environmental Services, Inc. 1930 14th Street Santa Monica, CA 90404 | | 10. PROGRAM ELEMENT NO. |
| | | 11. CONTRACT/GRANT NO. 68-01-3156, Task 17 |
| 12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency Enforcement Division, Region VIII Denver, Colorado 80203 | | 13. TYPE OF REPORT AND PERIOD COVERED Final Report |
| | | 14. SPONSORING AGENCY CODE |

15. SUPPLEMENTARY NOTES
Project Officer: Mr. Gary Parish
(303) 327-2361

16. ABSTRACT

Pacific Environmental Services (PES) has completed a testing program of vapor recovery systems at small bulk plants (less than 20,000 gallons/day) under EPA Contract No. 68-01-3156. Testing was conducted on a vapor balance system and on a secondary processor (straight refrigeration) system. The results of 41 tests are presented. Twenty-five of these tests were performed on the secondary system (7 transport deliveries, 18 bulk plant delivery vehicles) and sixteen were conducted on the vapor balance system (5 transport deliveries, 11 bulk plant delivery vehicles).

The test results indicate that both systems can function with vapor recovery efficiency greater than 90 percent, but only if account trucks are maintained leak-free.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| Air Pollution | Air Pollution Control | |
| Gasoline Bulk Terminals | Stationary Sources | |
| Vapor Balancing | Organic Vapors | |
| Vapor Recovery | Organic Vapors | |

| | | |
|---|---|---|
| 18. DISTRIBUTION STATEMENT Release: Unlimited Available free from DSSE/EPA while the supplies last | 19. SECURITY CLASS *(This Report)* Unclassified | 21. NO. OF PAGES |
| | 20. SECURITY CLASS *(This page)* Unclassified | 22. PRICE |

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

☆U.S. GOVERNMENT PRINTING OFFICE: 1977-720-117/2021