VAPOR RECOVERY SYSTEMS AT GASOLINE DISPENSING FACILITIES ON-BOARD VAPOR RECOVERY EFFECTS

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EXECUTIVE SUMMARY

Emissions from gasoline service stations represent a significant inventory component. As automobile emission standards result in lower hydrocarbon exhaust emissions per mile, the relative importance of fueling station emissions increases. Gasoline dispensing facilities (GDF) have been subject to pollution control since the 1970s. These stationary sources are a potentially important source of hydrocarbon compounds (VOC) that interact with nitrogen oxides to form ambient oxidants. In nonattainment areas, initial control efforts addressed VOC releases through the installation of vapor recovery systems (VRS) for product delivery processes (Phase I) and product dispensing activities (Phase II). In 1985, emissions from GDFs were regulated statewide by mandating the installation of Phase II VRS on GDFs with annual throughput of at least 480,000 gallons. The purpose of this program is to reduce benzene exposure from fuel dispensing activities. More recently, season-specific formulations of gasoline have been rolled-out to fulfill the need for low volatility gasoline in the summer.

An alternative approach for controlling GDF transfer emissions is on-board refueling vapor recovery (ORVR). In contrast to Phase II VRS, ORVR systems route vapors displaced from the vehicle tank during refueling into an enlarged charcoal canister installed on the vehicle. The adsorbed vapors are subsequently drawn into the engine and burned. The specific process that ORVR systems operate on is that, during fueling, a seal created in the vehicle fillpipe prevents vapors from escaping the fillneck opening. Gasoline vapors are therefore routed to an onboard activated charcoal canister. The activated charcoal canister adsorbs the vapors which are desorbed during normal driving and mixed via a metering process with the engine intake air. Onboard diagnostics (OBD) monitor ORVR system integrity and alert the operator if any irregularities are detected.

ORVR has been debated since the 1970s as a potentially viable strategy for controlling refueling emissions. California environmental officials discussed the implementation of ORVR in the 1970s but opted in favor of Stage II VRS. In 1990, the Clean Air Act Amendments (CAAA) institutionalized ORVR by requiring the use of ORVR systems on new 1998 and later passenger cars. This provides the mechanism for the phasing out of Stage II VRS. The CAAA specifically states that manufacturers were to be given four years lead time following the adoption of ORVR regulations by EPA. ORVR requirements would be phased-in, with 40%, 80% and 100% compliance required four, five and six years, respectively, after ORVR rule adoption.

This research project was designed to evaluate the interaction between ORVR-equipped vehicles and vapor recovery systems (VRS) at gasoline dispensing facilities (GDF). In addition, the project was intended to determine whether ORVR-equipped vehicles increase or decrease GDF emissions as a function of VRS design. The results of this project indicate:

- When comparing simulated ORVR refueling with non-ORVR refueling events for Gilbarco vacuum assist systems, the field data collected in this research project do not indicate a consistent relationship between facility emissions and increased refueling frequency of ORVR equipped vehicles.

- Based on the 10% and 50% ORVR experimental conditions, empirical and modeled fugitive, vent line, and total facility emission factors suggest that ORVR effects may not be linear but reach an early maximum effect.

- The baseline conditions (i.e., no ORVR refueling), measured over a 30 hour period, yielded a fugitive hydrocarbon emission factor of 0.1210 pounds/1000 gallons with UST pressures predominantly in the 0.02-0.06 in. W.C. range. Vent line emissions considerably smaller by almost two orders of magnitude (0.0052 pounds/1000 gallon).

- Adding 10% ORVR vehicles into the daily refueling profile (representing early fleet penetration) generated fugitive and vent line releases emission factors of 0.9103 and 0.0098 pounds/1000 gallons respectively when measured over a 32 hour period. The resulting UST pressures increased to an average value of approximately 1.25 in. W.C. 0.0098. Fugitive releases were roughly two orders of magnitude larger can the vent line emission factor.

- The climax conditions of 50% ORVR equipped vehicles in the US on-road fleet did not demonstrate a commensurate increase in facility emissions. Measured over a 32 hour period, fugitive emissions were half of the 10% ORVR penetration value (0.4031 pounds/1000 gallons). Vent line emissions were 0.0011 pounds/1000 gallons, a value that is lower than both the baseline and 10% ORVR penetration value. The UST pressure profile for 50% ORVR penetration was centered around 0.5 in. W.C.

- Total facility emissions (the sum of fugitive and vent line emissions) demonstrated an early maximum effect with 10% ORVR penetration yielding larger emissions by approximately a factor of two compared to the late ORVR penetration scenario (50%). The control field conditions (0% ORVR) demonstrated total facility emissions seven times smaller that 10% ORVR penetration.

- Underground storage tank gauge pressure (UST) is the primary determinant of vent line, fugitive, and total facility emissions and vacuum asssist system leak rates. This strongly suggests the importance of maintaining neutral pressure as a strategy to control emissions at gasoline dispensing facilities. Pressure control systems of interest include nozzle and vapor pump designs that maximize the nozzle fill pipe interface seal to obtain the required collection efficiency at a V/L ratio at or below one. The other option is vapor processor methods (e.g., thermal oxidizers, carbon absorption units, selective permeation membranes). Many current certified nozzle and vapor

interface. Rather, they depend on high V/L ratios to achieve greater than 95% collection efficiency at the dispensing point.

TABLE OF CONTENTS

Page

FIGURES AND TABLES

Tables

Section 1

INTRODUCTION

1.1 STUDY OBJECTIVES

This research project was designed to evaluate the interaction between ORVR-equipped vehicles and vapor recovery systems (VRS) at gasoline dispensing facilities (GDF). In addition, the project was intended to determine whether ORVR-equipped vehicles increase or decrease GDF emissions as a function of VRS design. Specifically, there were two objectives for this project:

1. Develop, validate and demonstrate methods for simulating the refueling of ORVR-equipped vehicles at GDFs equipped with vacuum assist VRS.

2. Determine what impact the refueling of ORVR-equipped vehicles has on existing vent line and fugitive emission profiles for vacuum assist VRS.

1.2 BACKGROUND

Emissions from gasoline service stations represent a significant inventory component. As automobile emission standards result in lower hydrocarbon exhaust emissions per mile, the relative importance of fueling station emissions increases. Gasoline dispensing facilities (GDF) have been subject to pollution control since the 1970s. These stationary sources are a potentially important source of hydrocarbon compounds (VOC) that interact with nitrogen oxides to form ambient oxidants. In nonattainment areas, initial control efforts addressed VOC releases through the installation of vapor recovery systems (VRS) for product delivery processes (Phase I) and product dispensing activities (Phase II). In 1985, emissions from GDFs were regulated statewide by mandating the installation of Phase II VRS on GDFs with annual throughput of at least 480,000 gallons. The purpose of this program is to reduce benzene exposure from fuel dispensing activities. More recently, season-specific formulations of gasoline have been rolled-out to fulfill the need for low volatility gasoline in the summer.

1.2.1 Gasoline Dispensing Facilities Vapor Recovery Systems

At GDFs, vapor recovery is a general term describing methods for preventing the release of VOC emissions into the atmosphere during product unloading or customer refueling events. Figure 1-1 illustrates the general layout of a GDF vapor recovery system. Phase I vapor recovery controls emissions (i.e., transfer emissions) during product deliveries by capturing the vapors in the delivery truck and returning them to

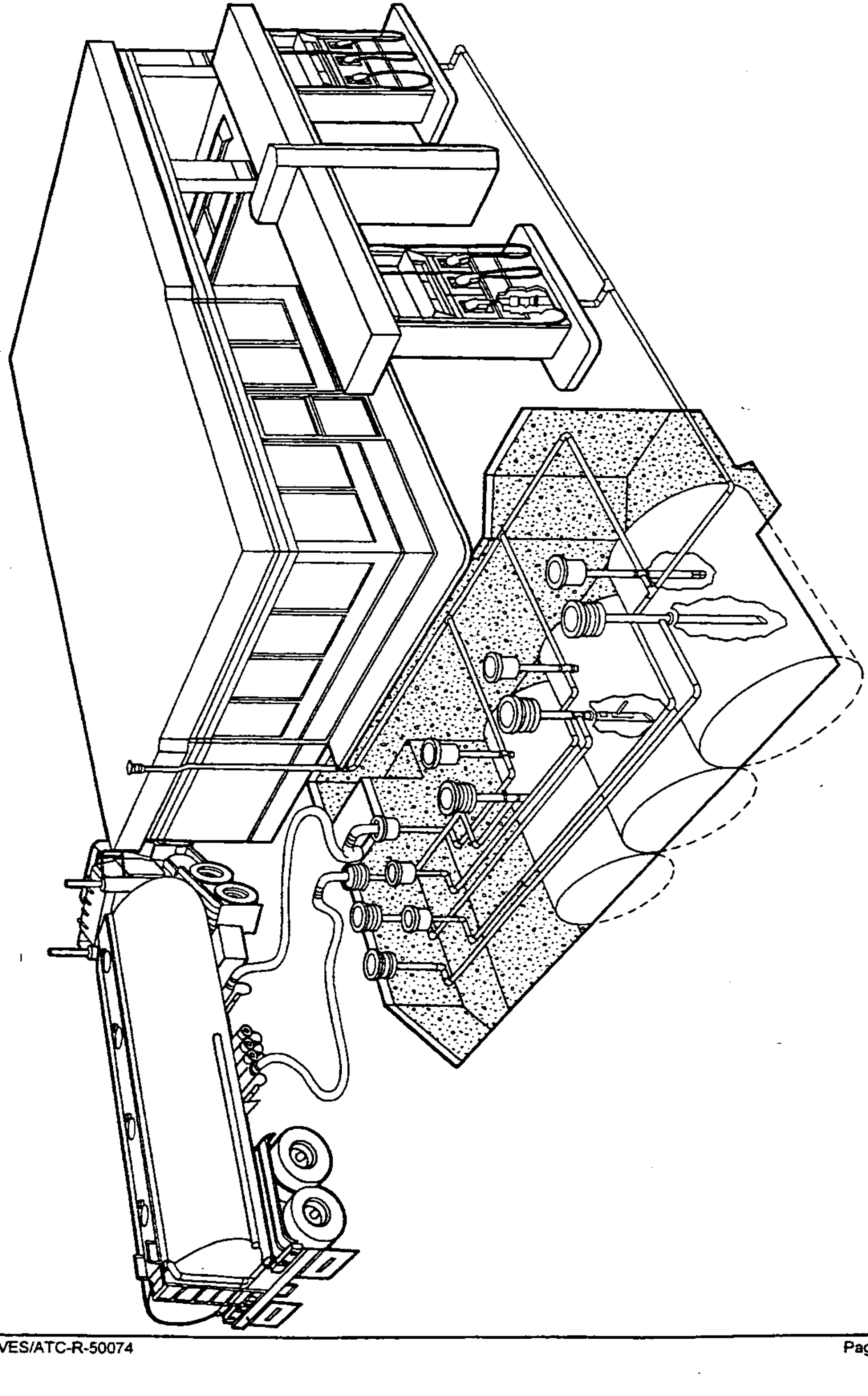


Figure 1-1 Typical Layout of Gasoline Dispensing Facility

the terminal for processing. Phase II vapor recovery, which controls emissions (i.e., transfer emissions) from vehicle fueling operations, captures vapors at the vehicle fill pipe and returns them to the facility underground storage tanks (UST). Two types of Phase II systems have been developed: (1) balance systems and (2) vacuum assist systems. Balance systems operate on the principle of positive displacement during refueling. Vacuum in the storage tank is created when fuel is removed, while at the same time, positive pressure is created in the vehicle fuel tank by incoming liquid gasoline. Saturated vapor is therefore forced out and pulled through the nozzle, vapor passage, and into the UST. The specific process under which balance systems function is a vapor path is established between the dispensing nozzle and the underground vapor return line connected to the dispenser via a coaxial hose. Fuel passes through the inner hose, while vapor is shunted through the outer hose. A bellows surrounding the nozzle spout completes the vapor return path from the vehicle fill pipe opening to the UST. During fueling, the bellows faceplate is pressed tight against the fill pipe opening so that vapors displaced from the fuel tank by the dispensed gasoline are forced back through the vapor return path and into the UST.

In a vacuum assist vapor recovery system, as soon as gasoline is dispensed a vacuum generating device (i.e., an in-line turbine or a vacuum pump) is used to create a suction which pulls vapors from the vehicle tank into the UST via a coaxial hose. In theory, a tight seal at the nozzle/fillpipe interface is not necessary for effective recovery. Vacuum assist systems vary in their design, their choice of vacuum creating devices, and collected vapor to air ratios, a fundamental metric measuring the vapor recovery efficiency of a vacuum assist system.

Some vacuum assist systems are equipped with a vacuum pump that is designed to collect a vapor volume larger than the space available for vapor storage above the liquid in the UST. Excess air along with the saturated vapor is drawn in due to loose fitting nozzles or the varying volumes of fuel dispensed while the vacuum remains constant. To offset this phenomena, an on-line processor, such as a high efficiency incinerator, is used to convert excess vapor into mainly carbon dioxide and water and possibly uncombusted gasoline vapors. The processor may be activated when the internal pressure of the storage tank reaches atmospheric or, in other processor systems, the processor is ignited when the vapor pressure in the return lines exceeds a designated amount (e.g., one inch water column).

Other vacuum assist system designs do not rely on processors. These systems use fluid driven pump units or rely exclusively on an electronically driven vacuum pump unit to generate (1) the prerequisite vacuum and (2) the control of air/liquid (A/L) ratio specifications based on the dispensing rate. In these systems, since the flow of fuel to the UST, directly or indirectly, regulates the vacuum produced at the vehicle fillpipe, the A/L ratio should be approximately one to one, eliminating the need for system processors.

As previously described, balance and vacuum assist systems are further differentiated by nozzle type. Balance nozzles integrate bellows or boots which surround the nozzle to form a seal at the nozzle/car interface. In contrast, assist nozzles may be bootless or may contain a bell or minibellows surrounding the nozzle design. While balance and vacuum assist systems attempt to control all VOC releases, spillage and fugitive emissions may occur at GDFs as part of both product delivery and dispensing activities.

Since 1990, pressure/vacuum valves have been added to the top of the UST vent line to reduce UST fugitive emissions. For example, since balance systems operate near atmospheric pressure, a P/V valve installed at the vent line riser can provide effective control of system emissions. Recent research activities suggest these devices are very effective in controlling vent line fugitive emissions (Shearer et. al., 1994).

1.2.2 On-Board Vapor Recovery

An alternative approach for controlling GDF transfer emissions is on-board refueling vapor recovery (ORVR). In contrast to Phase II VRS, ORVR systems route vapors displaced from the vehicle tank during refueling into an enlarged charcoal canister installed on the vehicle. The adsorbed vapors are subsequently drawn into the engine and burned. The specific process that ORVR systems operate on is during fueling, a seal created in the vehicle fillpipe prevents vapors from escaping the fillneck opening. One of two seal types is employed for this purpose: mechanical or dynamic. The mechanical seal consists of a viton (or similar material) o-ring which fits snugly around the nozzle spout when inserted into the fillpipe. The dynamic, or liquid, seal is created by reducing the cross sectional area of the fill pipe so that the dispensed gasoline forms a hydraulic pump creating positive pressure in the fuel tank headspace. At this stage, the gasoline vapors are routed to an onboard activated charcoal canister. The activated charcoal canister adsorbs the vapors which are desorbed during normal driving and mixed via a metering process with the engine intake air. Onboard diagnostics (OBD) monitor ORVR system integrity and alert the operator if any irregularities are detected.

ORVR has been debated since the 1970s as a potentially viable strategy for controlling refueling emissions. California environmental officials discussed the implementation of ORVR in the 1970s but opted in favor of Phase II VRS. In 1990, the Clean Air Act Amendments (CAAA) institutionalized ORVR by requiring the use of ORVR systems on new 1998 and later passenger cars. This provides the mechanism for the phasing out of Phase II VRS. The CAAA specifically states that manufacturers were to be given four years lead time following the adoption of ORVR regulations by EPA. ORVR requirements would be phased-in, with 40%, 80% and 100% compliance required four, five and six years, respectively, after ORVR rule adoption.

In April 1992, interpreting ORVR implementation as "infeasible or undesirable", EPA issued a Federal Register notice indicating that it would not promulgate ORVR systems of any type. In May 1993, the National Resources Defense Council successfully sued EPA contending the agency had a mandatory duty to promulgate ORVR regulations. In response to the court ruling, EPA promulgated ORVR regulations in 1994 which call for the phase in of ORVR systems according to the timetable specified in the CAAA.

Notwithstanding the political controversies surrounding ORVR systems, several fundamental questions remain relative to the value of ORVR. One issue targets the determination of which strategy, Phase II or ORVR, is the best pollution control design for controlling refueling emissions. A second concern addresses the question of whether incremental air quality benefits will result from the combination of Phase II or ORVR systems. Fundamental to these concerns is the assumption that the ORVR fillpipe/tank assembly does not allow vapors from the refueling event to be returned to the UST.

In May 1994, the California Air Resource Board (ARB) released a report investigating the interaction of Phase II and ORVR VRS (ARB, 1994). Addressing the compatibility of ORVR with Phase II systems, ARB evaluated eight different Phase II configurations to estimate the magnitude of hydrocarbon emissions using an array of empirical data, assumptions and calculations based on model cases. The results of this study suggest Phase II vacuum assist VRS synergistically interact with ORVR thereby increasing fugitive vent line emissions relative to GDFs configured with balance Phase II VRS. This phenomena is driven by air ingestion into the UST. Positive static gauge pressure is created and fugitive outbreathing of UST vapors subsequently occurs. ARB concludes that the demonstrated incompatibility between ORVR and some types of vacuum assist systems should be further studied to determine if smart interfaces or other strategies can be developed to overcome the problem.

Further investigating this phenomena, ARB executed an ORVR simulation project entitled "Interaction of Simulated Vehicular On-Board Vapor Recovery (ORVR) With Balance and Assist Phase II Vapor Recovery Systems" (ARB, 1996). The results of these tests echo the conclusions of the 1994 study. At an ORVR simulation rate of 32%, based on gasoline throughput, the balance system did not experience a significant pressure increase suggesting fugitive and vent emissions would not be adversely impacted by the introduction of ORVR cars. In contrast, with an ORVR penetration of 20%, vacuum assist systems may result in significant increase in vapor recovery operating pressure. This, in turn, triggers the probability of subsequent fugitive outbreathing of UST vapors.

1.3 STUDY ASSUMPTIONS AND HYPOTHESES

The primary assumption that this research project is dependent on is that the ORVR system seal at the fillneck-dispensing nozzle interface allows no leakage of hydrocarbon vapors. This assumption is based on two observations. The first is that the ORVR carbon canister will effectively capture all of the vehicle tank vapors during the refueling event. The second assumption is that the ORVR system seals will prohibit the escape of vehicle fuel tank vapors even if the on-board carbon canister does not capture 100% of the escaping vehicle fuel tank vapors during the refueling event. Both assumptions are dependent on the validity of the automobile industry engineering and its ability to generated effective pollution mitigation devices.

The net result of these assumptions is that this project did not validate the assumption that ORVR equipped vehicles do not allow vapors to be returned into the vapor return lines of vapor recovery system. As such, this research project evaluated the impact of ORVR equipped cars and their effects on UST pressure by measuring UST originating hydrocarbons at the vent line riser rather than the dispenser return line or at the nozzle vehicle interface. This decision was based on guidance from the project's Technical Advisory Panel. The membership of the panel included representatives from the United States Environmental Protection Agency's Office of Mobile Sources, the Bay Area Air Quality Management District, the Air Resources Board's Research Division, Monitoring and Laboratory Division, and Compliance Division, and the Western States Petroleum Assocation.

The hypothesis that this research project is intended to evaluate is that ORVR equipped vehicles increase the pressure in USTs due to an interaction with vacuum assist vapor recovery systems. The specific thesis that this project will validate or invalidate is that the interaction of vacuum assist systems with ORVR equipped vehicles may result in significant increases in UST pressure which in turn leads to increased vent line and/or fugitive emissions at the vent line riser and other fugitive sources.

1.4 STUDY REPORT CONTENT

The content of this report includes only field data collected at the Gilbarco vacuum assist site. However, the ORVR simulation methodologies for the Gilbarco, Wayne Dresser, Hasstech, Hirt and Healy vapor recovery systems are included in this report.

Section 2

MATERIALS AND METHODS

2.1 STUDY DESIGN

The study design of a research project specifies the test conditions that allow the specific objectives of the research project to be realized. For this project, the specifics of the test conditions articulate how the research project was executed.

2.1.1 Test Conditions

There were two basic test conditions for this project called test series: the ORVR simulation model test series and the ORVR impact test series. Each test series had unique study designs. However, the ORVR models (i.e., physical device) developed in the ORVR simulation test series was used to simulate ORVR equipped cars in the ORVR impact test series.

2.1.1.1 ORVR Simulation Model Test Series

The ORVR simulation model test series was designed to develop ORVR simulation models that could be used to model the impact of ORVR-equipped vehicles at GDFs without the actual presence of ORVR equipped vehicles during the test period. The specific objective of the ORVR simulation model test series was:

1. Develop physical models (i.e., devices) that will allow simulation of refueling events for ORVR-equipped cars at GDFs equipped with balance and vacuum assist VRS.

Based on this objective, there was a single phase for ORVR simulation test series:

1. Development of a device to simulate the refueling of ORVR equipped vehicles at balance and vacuum assist VRS-equipped GDFs.

Device Development to Simulate ORVR Equipped Vehicle Refueling at Balance and Vacuum Assist Vapor Recovery Systems

Physical models or "methods" were designed that allowed the simulation of refueling ORVR-equipped cars at GDFs equipped with balance and vacuum assist VRS. Section 2.3.1 describes in detail the nature of the balance, Gilbarco, Dresser Wayne, Hasstech, Hirt and Healy vacuum assist system ORVR model methodology.

2.1.1.2 ORVR Impacts Test Series

The primary goal of the ORVR impact test series was to directly quantify the effects ORVR-equipped cars have, in combination with vacuum assist VRS, on GDF vent and fugitive emissions. A single vacuum assist type of VRS was evaluated. Tables 2-1 and 2-2 tabulate the GDF and Gilbarco system characteristics used in this test series. The tested VRS system was equipped with an OPW P/V valve in conformity with GDF system requirements in select nonattainment areas in California. This is contrasted to the follow-up ARB ORVR/vacuum assist filed evaluation that used a Husky P/V valve. The implicit effect of having a P/V valve on the vent line was to limit emission releases on the ambient side of the P/V valve and to place an upper boundary on the pressure buildup in the vent line system plumbing. OPW P/V valves are designed to release at a pressure of 3 inches W.C. ± 0.5 inches. Conversely, the presence of a P/V valve allows pressure buildup compared to the lack of a P/V valve that would not allow the relative buildup of pressure in vent line plumbing. This could impact system fugitive emissions. VRS system type was the primary independent variable for this test series and vent and fugitive emissions were the dependent variables. The location of the test site was in the east San Francisco Bay area. The specifics of this site are discussed in Section 2.2.

Table 2-1
Vapor Recovery System Test Conditions

Test Mode	VRS Type	Vent P/V Valve	Assist Pump Location	Bell[1]	Incinerator
1	Vacuum Assist	Yes	Dispenser	Yes	No

1. A bell is a circular rubber or PVC fitting on the nozzle that fits against the car body during the refueling event.

Table 2-2
Criteria for ORVR Simulation Test Cases

Test Case	% of Gasoline Dispensing to ORVR Equipped Cars
1	0
2	10
3	50

Vent and Fugitive Emissions at Vacuum Assist VRS Equipped GDFs

Vent emissions and select parameters for the calculation of fugitive emissions were measured at the vacuum assist VRS equipped GDF identified as test mode 1 in Table 2-1. For each test case, the ORVR simulation methodologies were executed on the number of dispensers (see Section 2.3) required to meet the percent of gasoline dispensed for each of the two test cases (10% and 50%) as defined in Table 2-3. Vent and fugitive emission parameters were measured continuously for 36-48 hours for each test case and for 24 hours without the ORVR simulation devices for the purposes of comparing the ORVR emission profiles. Vent emissions were measured pursuant to the specifications of CARB TP-201.2. Select fugitive emission variables were quantified using a derivation of the draft CARB TP-201.2B. Hydrocarbons emissions upstream from the P/V valve were not assayed. Prior to, and immediately after the emissions testing, the BAAQMD assayed GDF static pressure, dynamic back pressure, air:liquid ratio and liquid removal performance using the methodology specified in CARB TP-201.3, TP-201.4, TP-201.5 and TP-201.6, respectively.

Development of Emission Factors for GDFs

Vent line emissions data and system leak rate data collected in the ORVR impact test series were used to derive vent line and fugitive emission factors for the Gilbarco vacuum assist VRS evaluated relative to ORVR/VRS interaction. The emission factors are reported in Section 3 of this report.

2.2 STUDY SITES

The criteria for selecting the GDF measurement sites included the following characteristics:

- Proximity to both Sacramento and the San Francisco Bay area.
- A product throughput of at least 100,000 gallons per month (> 16 nozzles).
- The presence of tank level monitors on the GDF underground storage tank or a computerized tracking system for product volume.
- The site contained the Gilbarco vacuum assist VRS required for the study.

Based on these criteria, Table 2-4 lists the site location used for the field study.

Table 2-3
Field Test Locations

Vapor Recovery System Type	WSPA Member Company	Address	Test Dates
Gilbarco Vacuum Assist	Shell	3621 San Pablo Dam Road El Sobrante, CA	2/4/98-2/17/98

Table 2-4 describes the vapor recovery equipment at the test site. The test location is configured with four two-sided dispensers with three nozzles per side (one for each grade of gasoline). During the ORVR simulation tests, one side of Dispenser Four was modified for the 10% ORVR simulation condition. For the 50% ORVR simulation condition, Dispenser Four, Six and Eight were modified.

Table 2-4
Vapor Recovery Specifications

VRS Type	Manufacturer Specifications	Nozzle Type
Gilbarco Vacuum Assist	Gilbarco VaporVac AL121OC (Executive Order G-70-150) OPW P/V Valve 523LPS-2250	OPW 11VA 27 19 Nozzles Emco Wheaton 4505 5 Nozzles

2.3 ORVR SIMULATION DEVICES

ORVR simulation devices and/or modification to existing vapor recovery systems were crafted for vacuum assist and balance vapor recovery systems. The following discussion provides specific descriptions of the methodology used to simulate ORVR simulation events at vacuum assist and balance vapor recovery systems.

2.3.1 Vacuum Assist System ORVR Model Devices

The ORVR simulation devices and/or methodologies for the tested vacuum assist VRS were designed so only air was returned to the UST during the refueling event. In addition, the ORVR simulation devices were required to adhere to the following requirements:

1. Allow fuel to enter the fillpipe during refueling.
2. Prevent the flow of vapor to the UST.
3. Control the flow of air into the vapor return line of the VRS.
4. Provide the same back-pressure:flow ratio as is found in an unmodified vacuum assist VRS.
5. Provide the same air:liquid ratio as is found in an unmodified vacuum assist VRS.
6. Provide the same liquid blockage removal performance as is found in an unmodified balance VRS.

In lieu of developing a universal device for each the five vacuum assist systems to be evaluated, an engineering solution was developed that was unique to each of the five vacuum assist vapor recovery systems based on their design and functional attributes. This was done in consultation with the chief engineer for each vapor recovery system manufacturers: Gilbarco, Dresser/Wayne, Hasstech, Hirt and Healy. Functions 1-3 were taken into account by optimizing the system engineering to realize these functions. Functions 4-6 were confirmed using CARB test procedures TP-201.4, TP-201.5 and TP-201.6.

2.3.1.1 Gilbarco Vacuum Assist Systems

One side of the Gilbarco Vapor Vac equipped dispenser was modified to allow the selected hose to flow fuel while an adjunct, inoperative nozzle vapor path was opened to allow the idle nozzle to ingest ambient air. This was executed by purposely misconnecting the electrical wires leading to the solenoid operated vapor valves (which are normally in the normally closed position) found in the upper housing of Gilbarco dispensers. When properly connected under normal operating conditions, the selected hose will flow fuel and the matching vapor valve is opened to provide a path for the returning fuel vapors in the coaxial hose delivering fuel. For the ORVR simulations, by misconnecting the vapor valves, fuel flowed in the selected nozzle but vapors were not ingested during the refueling event. This process allowed refueling of only the selected product grade (i.e., regular). Pumping of the other two products (89 and 92 octane) was not possible given the misconnection in the electronic vapor valve assembly.

2.3.1.2 Dresser Wayne Vacuum Assist Systems

For the purposes of modeling ORVR equipped cars, a solenoid valve open to atmosphere was attached to the return vapor in the base of the dispenser. The return vapor line, as normally configured, was disabled by the installation of the solenoid valve. This disallowed any refueling car vapors from being shunted into the UST during the refueling event. The solenoid valve was activated into an open position when the selected product lever was placed into the refueling position by the refueling customer. In the open position, the solenoid valve allowed fresh air to be fed into the UST during the refueling event. As a result of the ORVR simulation, only the desired product (i.e., regular grade) was operational for the modified dispenser. The other two products (89 and 92 octane) could not be pumped by the refueling customer.

2.3.1.3 Hasstech Vacuum Assist Systems

The ORVR simulation devices were constructed of liquid/vapor splitters. The ORVR simulator were made of two adapters/splitters which convert inverted coaxial flows in ¾'NPT for the liquid path, and ¼' NPT for the vapor path. A pair of adapters were attached back to back and installed in the place of the breakway. A restricter element/orifice was installed in ¼" NPT vapor fitting on the upper adapter. This orifice was sized to achieve the desired A/L ratio. CFC-1 liquid driven vapor valves were installed at the dispenser vapor manifold. This vapor valve allowed only air to be ingested when liquid was being dispensed.

2.3.1.4 Hirt Vacuum Assist Systems

To perform as an ORVR simulation device, a liquid (i.e., gasoline product) operated vapor valve was added between the "whip" hose and the dispenser. A rubber ring was added between the vapor valve and the "whip" hose to prevent vapors from being ingested by the bootless nozzle during the refueling event. A 1/8" NPT hole was added to the vapor valve to provide a means of installing a limiting orifice. The orifice allows fresh air to enter the system as would be the case during a refueling event with ORVR equipped cars. However, the vapor valve allows the ingestion of air only during the refueling event while shunting the refueling car gas tank vapors away from the return vapor line.

2.3.1.5 Healy Vacuum Assist Systems

The Healy Model 600 nozzle was adapted to serve as the ORVR simulation device. The vapor passage in the spout assembly was blocked inside the nozzle to prevent the recovery of vapors from the refueling vehicle's fill pipe area. A 0.200" hole to atmosphere was placed in the vapor passage on the lower part of the nozzle body. This hole was on the underside of the nozzle body, near the bushing for the white plunger. It is protected by the hand guard. This hole allows atmospheric air to be ingested by the nozzle any time the refueling lever is engaged.

2.3.2 Balance System ORVR Model Devices

The ORVR simulation device for balance VRS was designed so only air is returned to the UST during the refueling event. In addition, the ORVR simulation device had to adhere to the following requirements:

1. Allow fuel to enter the fillpipe.
2. Allow vapors to leave the fillpipe.
3. Allow air to enter the balance nozzle.
4. Seal the fillpipe-nozzle interface except for 1 and 3.
5. Provide the same back pressure:flow ratio found in an unmodified balance VRS.
6. Provide the same liquid blockage removal performance found in an unmodified balance VRS.

The balance ORVR simulation device consisted of a toroidal assembly that was constructed of two 0.75" thickness layers of ECH 4310 gasket material with an outside diameter of 3.625". The inside diameters of the upper and lower layers are 0.75" and 1.625", respectively. The torus has eight 0.25" openings along the perimeter in the lower section of the torus, each opening being 45 degrees apart from the adjacent opening. A 0.25" pathway in the upper section of the torus exposed the return line to ambient air during vehicle refueling. A 0.020 inch diameter orifice placed in this pathway allowed a flow rate of approximately 0.01 cfm at a gage pressure of 0.5 inches water column. This flow rate was based upon average leak rates observed during bench tests of an Emco Wheaton 4005 nozzle with three different fill pipe configurations.

During the ORVR simulation, the toroidal assembly was placed on one of the regular nozzles for 48 hours and on three of the nozzles for an additional 48 hours. Once on the nozzle, the upper layer, the toroidal upper layer was pressed against the bellows faceplate. The purpose of the torus was to allow the fuel tank vapors to be diverted into the atmosphere instead of being routed into the UST.

Functions 1-4 were confirmed by executing a "sleeve" test defined in CARB TP-201.2 on 10 vehicles. The vehicles were randomly selected based on the criteria defined in the "100 car matrix" found in CARB TP-201.2A. The ORVR simulation device assumed to meet functions 1-4 when the average performance values of the device agree with the performance values generated for unmodified balance nozzles, accounting for the experimental uncertainty and variation.

Function 5 was confirmed in a bench test using CARB back pressure specifications (e.g., 0.45 inches water at 60 cfm). Function 6 was confirmed using CARB test procedure TP-201.6. Three tests were performed on a balance nozzle with and without the ORVR simulation device to confirm these performance requirements. The ORVR simulation device was assumed to meet functions 5-6 when the average performance values of the device agree with the performance values generated for unmodified balance nozzles, accounting for the experimental uncertainty and variation.

2.4 FIELD PARAMETER MEASUREMENTS

The field measurement process targeted a suite of parameters including meteorological metrics, hydrocarbon concentrations (measured as propane), VRS vent pressure, VRS temperature, VRS vapor volume (measured as flow) and underground storage tank pressure. Figure 2-1 illustrates the field measurement program and it's various elements. The field measurement sample train consisted of a PVC manifold with sample ports that was placed over vent line riser. Discrete sample ports existed for temperature, pressure, and volume/hydrocarbon sampling functions. This method was developed, validated, and field tested at previous field test sites by the project researchers (AeroVironment, 1994).

The primary objective of the monitoring methodology was to develop a nonintrusive measurement system that did not affect vapor or airflow in and out of the vent line. Previous studies have been critiqued for using instrumentation, such as flowmeters, attached to the vent line outlet that increase or decrease vent line VOC emissions relative to baseline conditions. The range of parameters necessary to describe GDF system characteristics imposes demanding requirements for an ideal monitoring system. The monitoring system must be able to measure a wide range of flow rates (e.g., -50 to +50 liters per minute), vent line pressure values (e.g., -1 to +1 inch of water column [w.c.]) and VOC vent line concentrations (1-40,000 ppm). These measurements must not skew the calculated vent line VOC emission factors.

In order to measure VOC emissions from the vent line without affecting vent line flow, a nonperturbing and nonintrusive monitoring system was used for this study. Instead of putting a flowmeter on the vent line that could impose a restriction on flow, an open sampling manifold attached to an air pump was installed on the vent line. Air was drawn at 100 liters per minute (lpm) through a sample port in the manifold such that any air or vapors expelled from the vent would be captured in the manifold and drawn into the sampling system. The VOC concentration and flow rate in the sample line were

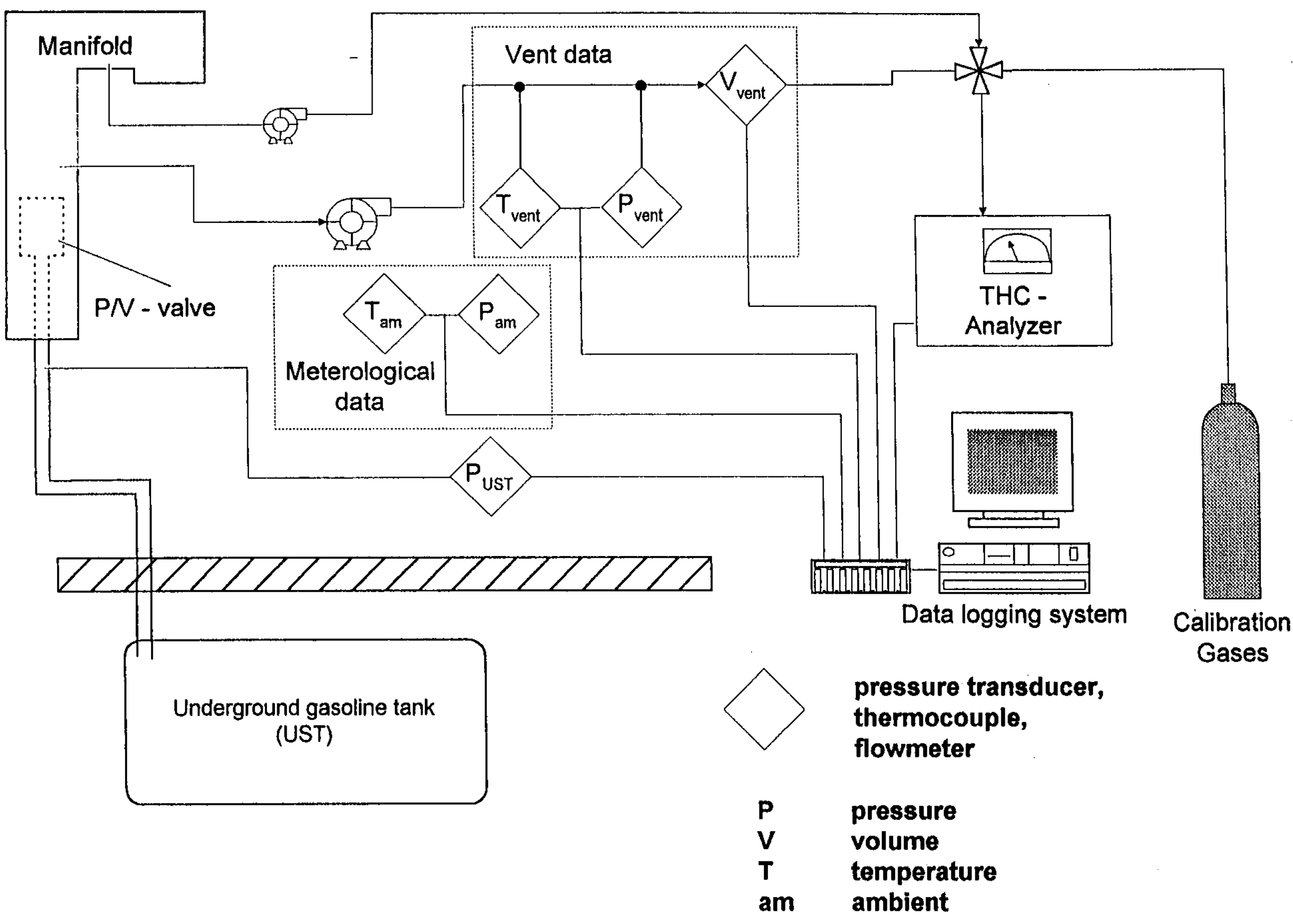


Figure 2-1 Field Measurement Set-up and Configuration

continuously monitored using a flame ionization detector hydrocarbon analyzer and a turbine flow sensor respectively. A data logger scanned the instantaneous VOC analyzer output and flowmeter sample rate data every second to calculate one-minute averages for flow rate, and VOC concentration calibrated to propane. These one-minute VOC and flow rate averages were used to calculate one-minute average VOC emission rates using the following expression:

$$\text{VOC concentration (mg/m}^3\text{) x flow rate (m}^3\text{/min) = VOC emission rate (mg/min)} \quad (2\text{-}1)$$

For the monitoring system to generate valid data, the following critical system performance requirements were established:

1. The sample train must not perturb normal UST in-breathing and out-breathing. The sample manifold was designed to minimize positive and negative pressures that could potentially impact VOC emissions from the vent line. Too high a sample rate could potentially influence UST emissions.

2. The sample line flow rate (100 lpm) must be higher than the greatest anticipated flow rate from the UST vent line. If the UST emission flow rate exceeded the sample line flow rate, the sampling system would not capture 100 percent of the vent line VOC emissions and underestimate vent line VOC emissions using Equation (2-1).

2.4.1 Meteorological Measurements

At each site, ambient meteorological measurements were data logged continuously during the C & TP measurement program. The location of the meteorological instrumentation was directly adjacent to the field test van to facilitate data logging ease. However, recognizing potential interference from the field test van, the meteorological tower was be far enough away (i.e., six feet above the top of the van) to minimize external interferences.

Ambient temperature values were assessed using an Omega K-type thermocouple probe assembly with a transjoint (TJ48-CASS-14G-12—BX-OST-M) integrated with an Action Instruments TC temperature signal conditioner (Model 4351-2000). A K-type thermocouple is a temperature measurement sensor that consists of two dissimilar metals joined together at one end (a junction) that produces a small thermoelectric voltage when the junction is heated. The voltage output is proportional to the difference in temperature between the hot junction and the lead wires. The change in thermoelectric voltage is interpreted by the TC temperature signal conditioner, a pulse accumulator device which conditions the temperature resistance signal. The conditioned signal is a voltage output with a 0-5 volt scale. . The signal conditioner output was calibrated to degrees Rankine prior to field deployment. The TC temperature signal conditioner output served as input into the field data acquisition system, with a temperature value recorded every second.

Ambient pressure was recorded using an Omega Model PX02 absolute pressure barometer. As with temperature, a pressure value was determined every second and subsequently data logged.

2.4.2 Hydrocarbon Measurements

The hydrocarbon measurements were performed according to modifications of procedures specified in ARB C & TPs. The modification consisted of sampling only at one sample point on the ambient side of the P/V valve on the vent line riser, instead of also sampling at the nozzle/vehicle interface and the dispenser return line. For this project, there are two relevant ARB certification and test procedures:

TP-201.2 - Determination of Efficiency of Phase II Vapor Recovery Systems of Dispensing Facilities: The purpose of this test procedure is to determine the percent vapor recovery efficiency for a vapor recovery system at a GDF. The percent vapor recovery efficiency is the percent of vapors displaced by dispensing which are recovered by a vapor recovery system rather that emitted to the atmosphere.

Proposed TP-201.2B - Determination of Flow Versus Pressure for Equipment in Phase II Vapor Recovery Systems of Dispensing Facilities: The TP-201.2B test procedure used for this project is a proposed procedure (Proposed Draft Date: 1/95) that has not been formally integrated into the ARB vapor recovery test procedures. The purpose of this proposed test procedure is to determine fugitive emission profiles for dominant fugitive emission sources (i.e., idle nozzles, UST overfill drains, P/V valves) and the vapor recovery efficiency at GDFs. This is in contrast to the current adopted TP-201.2B procedure that develops flow vs. pressure profiles for the entire GDF as opposed to specific GDF fugitive emission sources.

The mass flux of fugitive emissions from a dispensing facility is the product of the volumetric flow rate and the flow-weighted mass per volume concentrations. The volumetric flow rate is based on data for pressure vs. time from the facility and data for flow vs. pressure from a model of the facility. The model flow vs. pressure data provide a conversion for the facility pressure vs. time data to flow vs. time data. In contrast to the field based hydrocarbon test procedures, the flow/pressure simulation model for TP-201.2B was executed in the Acurex laboratory as a bench top experiment with site-specific pressure signatures provided by the BAAQMD performance tests. For the purposes of this project and as specified in TP-201.2, there was one test location at each of the field test sites where hydrocarbons, volume, temperature, and pressure were quantitatively measured (Figure 1, TP-201.2) at the UST vent line riser.

2.4.2.1 Analytical Procedures for TP-201.2

As specified in the C & TPs, the hydrocarbon measurements were performed according to EPA reference method 25A. EPA Method 25A describes the determination of total gaseous organic compound emissions using a flame ionization detector. The principle of operation for the flame ionization detector method (EPA 25A) is that a hydrocarbon gas sample is extracted from the source through a sample line and a glass fiber filter and subsequently fed to the flame ionization analyzer. Results are reported as volume concentration equivalents of the calibration gas or as carbon equivalents.

The specifications of the hydrocarbon analyzer used for this project are tabulated in Table 2-5. The hydrocarbon sample train for the sole sample point is described in TP-201.2.

Table 2-5
Hydrocarbon Analyzer Specifications

Instrument Model Number	Analytical Method	Test Points	Operating Range (ppm as C_3)	Use
Beckman Model 400A	FID	1	1,000	Concentrations at vent line outlet

The duration of the hydrocarbon assessment procedures for each ORVR penetration level was at least 36-48 hours for the ORVR impact test series. The hydrocarbon data was data logged into the data acquisition system with a data point collected every second.

2.4.2.2 Analytical Procedures for Proposed TP-201.2B

The objective of this TP-201.2B is to estimate site-specific fugitive emissions by determining the flow leaving the facility as a function of VRS pressure signatures. Fugitive emission sources include UST vent lines equipped with P/V valves, "closed" idle nozzle check valves and "closed" overfill drain valves.

Several parameters need to be quantitatively measured to produce a value for fugitive mass flux including:

- Facility VRS volumetric leak flow rate
- Facility VRS pressure profiles
- Hydrocarbon concentrations (hydrocarbon mass/volume of hydrocarbon emitted
- Facility VRS temperate profiles

To generate the pressure and flow values, the BAAQMD executed pre- and post-experiment two inch static pressure performance tests (C & TP TP-201.3) at each field test site. This procedure pressurizes the entire vapor recovery system to two inches water column. After five minutes, the VRS pressure is noted and compared to allowable levels. Using standard engineering principles, the volumetric leak flow rate can be calculated. For this project, the pre-test leak rate values were used to calculate flow values (Q). This value, coupled with the flow-weighted hydrocarbon mass per volume concentration, yields the mass flux of fugitive emissions leaving the GDF for the TP-201.3 pressure conditions.

Hydrocarbon concentrations (mass/volume) were assayed at the vent line on the ambient side of the P/V valves rather on the VRS side. The lack of hydrocarbon data for vapors on the inside of the VRS has prompted an estimation of fugitive emissions based on anticipated ranges of system hydrocarbon concentration. Facility pressure and temperature profiles were collected during the execution of TP-201.2. These include maximum and minimum facility throughputs and product bulk drops.

To model the facility, a PVC pipe was pressurized to 2" WC and a hole was subsequently drilled in it of a size yielding the same average leak flow that occurred during a five minute pressure decay test on the VRS in which the pressure dropped from 2 "WC to 1.96 "WC. (as determined by TP-201.3). Having simulated the field leak rate, the PVC pipe was pressurized for a range of values to yield sufficient pressure/flow data points to estimate a pressure/flowrate function for the test site. With the facility model, volumetric leak flow rates were determined for the empirical time dependent pressure profile conditions found at the field test site. These data were then coupled with the measured ARB retest (ARB, 1999) hydrocarbon concentration data on the system side of the P/V valve to produce an estimate of field test site-specific hydrocarbon fugitive emissions. A discussion of the PVC testing apparatus is contained in Appendix G.

2.4.3 Pressure Measurements

Based the specifications of TP-201.2, pressure readings were taken at the vent line outlet concurrent with the hydrocarbon measurements. The specific locations for the pressure transducers on the sample manifold are upstream from the hydrocarbon vapor sampling line yet ambient from the P/V valve. The pressure transducers that were used are tabulated in Table 2-6. Concurrent with the vent line pressure values, underground storage tank (UST) gauge pressure conditions were assessed by suspending a pressure transducer down the vent line riser to a location approximately 2 feet below grade. This location served as a surrogate for measuring in situ UST pressure because of a lack of access to the actual UST.

Table 2-6
Pressure Transducers

Transducer Make	Model	Range
Omega	PX654-01BD5V	± 1.0 in. WC
Omega	PX240	±0 2.5 in. WC
Omega	PX654-50BD5V	±0 5.0 in. WC
Omega	PX654-10BD5V	±0 10.0 in. WC

2.4.3.1 Analytical Procedures for TP-201.2

As is apparent from Table 2-6, ranges of differential Omega pressure transducers were available for the field technicians. The specific transducer used depended on the vapor recovery system pressure profile at the time of the test. Initial pressure values were observed prior to initiation of actual field data acquisition for the ORVR control or simulation conditions. In addition, archival VRS pressure data were available from Gilbarco to aid in the selecting the appropriate pressure sensor. Vent pressure was measured using an Omega PX654-50BD5V (±0 5.0 in. WC) and UST pressure was quantified using an Omega PX240 (±0 2.5 in. WC). The pressure values were recorded every second and data logged using the test van data acquisition system.

2.4.4 Temperature Measurements

Based on the specifications of the study design document and the relevant C & TPs, temperature was continuously recorded at the vent line outlet.

2.4.4.1 Analytical Procedures for TP-201.2

Temperature was measured using an Omega K-type thermocouple probe assembly with a transjoint (TJ48-CASS-14G-12—BX-OST-M) integrated with an Action Instruments TC temperature signal conditioner (Model 4351-2000). The temperature signal conditioner was used to convert the thermocouple probe output into a voltage signal that can be input into the field test van data acquisition system. The range of the K-type thermocouple probe is 0-200 °F. The specific location of the thermocouple probe was upstream from the hydrocarbon measurement sample port. A temperature value was recorded every second and fed into the data acquisition system.

2.4.5 VOLUME MEASUREMENT

Pursuant to the C & TPs specifications, the volume of hydrocarbon vapor in the air sweep on the ambient side of the P/V valve was measured at the vent riser. As previously described, the primary objective of the monitoring methodology was to develop a nonintrusive measurement system that did not affect vapor or airflow in and out of the vent line. While TP-201.2 specifies the use of rotary positive displacement gas volume meters (e.g., ROOTS® meters), previous research has demonstrated that these devices may impede the flow of hydrocarbon vapors thus underreporting hydrocarbon vapor volume after correcting for temperature and pressure. An alternative method to quantify hydrocarbon vapor volume was developed and validated by AeroVironment Inc. (1994) using turbine flow sensors. This method was used to assay hydrocarbon vapor volume.

2.4.5.1 Analytical Procedures for TP-201.2

A MacMillian 100 Flo-Sen turbine flow sensor was used to measure hydrocarbon vapor volume at the outlet of the UST vent line on the ambient side of the P/V valve. The range of the flow sensor is 0-100 liters per minute. The principle of operation for the flow sensors is that a Pelton type turbine wheel is used to determine the flow rate of the hydrocarbon vapor. As the turbine wheel rotes in response to gas flow rate, electric pulses are generated. Processing circuitry provides a D.C. voltage output (0-5 V) that is proportional to flow rate. This voltage output signal was data logged each second and stored in the field test van data acquisition system. Vapor recovery system pressure and temperature was measured at the inlet of the flow sensor.

2.4.6 Data Acquisition System

All of the collected independent and dependent measure parameters were datalogged at one second intervals using a personal computer (PC) based data acquisition system. The PC is equipped with a 75 megahertz Pentium CPU processor and a standard I/O board (Model C10-DAS1-602/16 made by Computer Board) with 16 single ended channels. The data logging computer software is Laboratory Notebook. In addition to PC based data acquisition, strip chart records were also used to record the continuous independent and dependent variables.

2.5 PRE-TEST AND POST-TEST MEASUREMENTS FOR STATIC PRESSURE, DYNAMIC PRESSURE AND A/L TESTS

As specified in the ORVR impact series study design, prior to and following the execution of C &TPs, the Gilbarco vacuum assist vapor recovery system was evaluated for ARB specified performance. These tests determine if the VRS is functioning according to manufacturers design and ARB mandated performance specifications. The sequence of the pre-test events (Table 3-1) included an initial performance screen (and maintenance if necessary) by Service Station Maintenance Inc. to verify the VRS was operating properly. Second, three performance tests were executed by BAAQMD staff who are specially trained to execute these tests. The specific performance tests executed by the BAAQMD staff are tabulated in Table 2-7.

Table 2-7
ARB Performance Tests

Variable	Measurement Methodology	System Type
Static Pressure	ARB TP-201.3	All types
Dynamic Back Pressure	ARB TP-201.4	Balance
Air/Liquid Ratio	ARB TP-201.5	Vacuum Assist

If the particular VRS that was tested did not pass the performance tests before the hydrocarbon emission testing was initiated, the VRS was immediately serviced by Service Station Maintenance to bring the system back into compliance. Specifically, nozzles 3, 6 and 7 were serviced to bring into adequate A/L tolerances. Given that the BAAQMD staff were not mandated to return for pre-test follow-up performance testing after the system had been serviced, the post-test performance testing was used to validate that the vapor recovery service call successfully brought the system into compliance prior to beginning the ORVR test series. This was not the ideal method to validate system performance. However, it was the sole path available to the principal investigator to validate system performance criteria given that the BAAQMD was only contracted to execute a single pre- and post-test performance test at each field location.

The performance data for each of the performance tests were logged onto ARB sanctioned data sheets and is included in Appendix B. These data confirm that (as tabulated in the post-test BAAQMD data forms) the pre-test maintenance and procedures successfully brought all VRS elements into acceptable working order prior to executing the field testing.

2.6 QUALITY ASSURANCE/QUALITY CONTROL

Quality assurance was executed prior to the initiation of field activities and during the field data acquisition process (Appendix H). Before the deployment of the field measurement van, each pressure sensor, temperature thermocouple, turbine flow sensor, and hydrocarbon analyzer was evaluated for accuracy and precision based on manufacturer specifications. In addition, the test site P/V valve was evaluated for leak rate and cracking pressure. Pressure transducers were checked at 0, ±50% and ±100% of scale using known pressure conditions and subsequently calibrated to voltage output values (1-5 V) using a linear regression model. Thermocouples were calibrated using ice bath, mouth, and hot water conditions and a reference temperature value. The thermocouple output in degrees Fahrenheit was calibrated to voltage output (0-5 V) using a linear regression model. The turbine flow sensor was calibrated against a primary flow gas meter (Rodwell 445603) and subsequently used to establish a flow/voltage relationship using a linear regression model. The Beckman Model 400A Hydrocarbon FID analyzer was calibrated using reference gases (Praxair Distribution) at 0%, 50% and 90% of span range. The test site P/V valve was evaluated by exerting a known pressure onto the valve and recording flow rate in liters per minute. The cracking pressure was notated and compared to manufacturer specifications.

During the field measurement period which transpired over five days, the pressure, temperature and volume meters were not recalibrated. However, the Beckman Model 400 Hydrocarbon FID analyzer was calibrated as specified in Part 60, Appendix A, Method 25A. Immediately prior to the initiation of testing, a zero gas (less than 0.1 ppmv), mid-range span gas (45-55 percent of the applicable span value) and a high-level calibration gas (80-90 percent of the applicable span value) was used to evaluate the accuracy the hydrocarbon analyzer. This QA/QC check was also executed at the end of each testing day and during the actual testing approximately once every three hours.

2.7 EXISTING ORVR VEHICLES

In calendar year 1998, 40% of the new vehicles introduced into the United States passenger car fleet are required to be outfitted with ORVR systems. These vehicles were potentially part of the vehicle inventory that patronized the field test sites during the duration of the field test program. As such, they may have potentially interacted with the dynamics of the test site vapor recovery systems, thus impacting the research project dataset. To control for this possibility, the project research team was provided with a list of ORVR-equipped cars that are currently part of the US passenger car fleet by the US EPA Office of Mobile Sources. Appendix C includes these listing. An organized effort was made to catalog these vehicles if they patronized the field test sites during the actual field test period. This consisted of tracking which vehicle types were refueled during the ORVR simulation test periods. If a vehicle was identified as possibly having ORVR equipment, the vehicle driver was queried to determine whether the vehicle was included on EPA ORVR certification list. If it was, the vehicle was cataloged using vehicle make/model, and refueling time/date as record keeping identifiers.

Appendix F contains the ORVR equipped vehicles that were refueled during the study. While fill-up volume for ORVR equipped vehicles was not recorded, for the purposes of understanding the possible impact of these vehicles on the project data set, one could assume that the average fill-up was 10-12 gallons. Based on station daily product throughput data, the ORVR equipped vehicles could account for 5-7% of total daily throughput. This possible effect suggests that the combined impact of both simulated and actual ORVR penetration could have been 0-7% for the baseline scenario, 10-17% for the 10% ORVR penetration condition, and 50-57% for the 50% ORVR simulation events.

Section 3

RESULTS

As described in Section One of this report, only the Gilbarco vacuum assist system data are reported in this section. In addition, because of the possible impacts of ORVR equipped vehicles on the three levels of ORVR simulation (0%, 10%, 50%), the actual magnitude of the station ORVR penetration was a range (0-7%, 10-17%, 50-57%) rather than a specific value. Therefore, the baseline control condition did not represent an experimental condition where 0% ORVR vehicles were present at the field site during the duration of the study.

3.1 GILBARCO VAPOR RECOVERY SYSTEMS

3.1.1 Station Sampling Times, System Integrity Checks and Product Deliveries

Table 3-1 tabulates the sample times, product delivery events, and system integrity checks for Gilbarco test series. Sampling for baseline conditions occurred over four time periods and therefore was not continuous. These discrete non-continuous time periods are reflected in the 0% ORVR penetration figures (Figures 3-1 through 3-3). The sample periods were continuous for the 10% and 50% ORVR penetration sample conditions. The 10% ORVR simulation was executed by modifying dispenser number 3/4, and allowing regular grade refueling to occur only on the number 3 side of the 3/4 dispenser. Normal refueling occurred on the number 4 dispenser. The 50% ORVR simulation event occurred by modifying dispensers 5/6 and 7/8. Regular grade refueling was allowed only on dispensers 5 and dispenser 7 with dispensers 6 and 8 maintaining normal activity for all three grades. The purpose of having the Plus and Premium grades inactive on one side of the ORVR modified dispensers with respect to vehicle refueling was two-fold; (1) maintaining the appropriate level of ORVR simulation refueling at the site and (2) it was hypothesized, in consultation with vapor recovery manufacturer technical staff, that the ORVR simulation modifications to one side of a dispenser would effectively inactivate the other two grade of gasoline on the ORVR simulation side of the dispenser. The second observation was later questioned with respect to its validity.

A product delivery occurred during the 50% ORVR simulation time period. In addition, product drops took place six hours and two hours respectively prior to the inception of the 0% and 10% ORVR simulation conditions. The 10% ORVR simulation event received Regular and Plus grade product deliveries on 2/10/98 at 6:29 AM. Sampling began at 9:10 AM. Premium and Plus grade product was delivered during the 50% ORVR simulation test period at 11:40 AM the second day of the sample period (2/13/98).

System integrity checks were done prior to and immediately following the ORVR simulation testing. In pre-test evaluation, static pressure, dynamic pressure and A/L testing was executed by both Service Station Maintenance Inc. and the Bay Area Air Quality Management District (BAAQMD). Prior to the inception of site testing for ORVR simulation (several days before), Service Station Maintenance evaluated the site for system integrity. Once the site was designated "tight", the BAAQMD "officially" tested the site for pre-sampling certification. As is apparent from the test results (Appendix B), several of the site nozzles failed the A/L testing during the pre-test system integrity checks. As a frame of reference, the allowed A/L values for the Gilbarco VaporVac system is 1.00-1.20. The malfunctioning nozzles were repaired by Service Station Maintenance and checked for appropriate A/L values prior to the inception of ORVR simulation testing. Post ORVR simulation system integrity was executed by BAAQMD. All post-testing data were within acceptable ranges. This observation confirms that the nozzle A/L values were repaired prior to the inception of ORVR simulation testing.

3.1.2 Vent Line Emissions for Baseline Conditions

Tables 3-2, 3-5 and 3-8 summarize the observed hydrocarbon concentrations, hydrocarbon mass release rates and UST gauge pressure conditions for the control scenario, 0% ORVR penetration. These data are also presented in graphical form using 1-minute averages, 15 minute averages and one-hour averages. Figures 3-1 through 3-3 contain the hydrocarbon concentration and UST gauge pressure traces. Figures 3-10 through 3-12 display the hydrocarbon mass release rate and UST gauge pressure data. As is visible in each of these figures, hydrocarbon emission behavior mirrors the gauge pressure dynamic in the UST. However, when imposing a regression model on these data (hydrocarbon emissions as a function of UST gauge pressure), the anticipated correlation was not visible (Tables 3-12 and 3-13). This is in part due to the variance exhibited by each variable as a function of time. The observed variance in the one minute presentations is not an artifact of instrumentation noise (nor is the case with the 10% and 50% ORVR test conditions) but is a function of the changing gauge pressure conditions in the UST. The 15 minute and one hour averaging functions minimize the observed variance in both pressure and hydrocarbon concentration.

Table 3-11 summarizes the collected emissions and UST gauge pressure data for the Gilbarco vacuum assist vapor recovery system. This table also tabulates the volume of fuel dispensed during each experimental condition. For baseline conditions (i.e., no ORVR refueling), emission levels, reported as parts per million (ppm), were observed to be in the 0-2 ppm level for the majority of the measurement period. Bursts of vent line emissions were observed in the 100, 200 and 1170 ppm range. The corresponding UST gauge pressure values ranged from -.0.02 to 0.7 inches W.C. The peak positive gauge pressure values and corresponding hydrocarbon vent releases did not correlate with product deliveries. The predominant vent line emission release at the end of the 0% ORVR simulation sample period (12:00 – 16:03 on 2/7/98) was not related to a product delivery. A product delivery did occur on the final day of the 0% ORVR simulation testing at 10:56 PM, several hours after the baseline measurement program was complete. Translating the observed emission concentrations into a standardized emission factor metric (pounds HC/1000 gallons pumped), the vent line emission factor accumulated over the duration of the baseline sample period is 0.00518 pounds/1000 gallons. As will be discussed in Section 3.1.4, the baseline fugitive emission factor was nearly two orders of magnitude larger that the measured vent line emission factor value. This strongly suggests the dominant impacts that fugitive emissions have on the GDF hydrocarbon emission inventory.

To further evaluate the distributions of UST gauge pressures, they were charted using a histogram configuration (Figure 3-19). In terms of UST gauge pressure profiles, for the purposes of graphical presentation, the range of observable pressures were divided into ten discrete ranges. Each range represents approximately 1/10 of the observable gauge pressure ranges. Each histogram bar is labeled by both the highest value in the plotted range (the top value) and the actual range of gauge pressure values represented by the histogram bar (the bottom value in parenthesis). As is gleaned from Figure 3-19, approximately 70% of the observed UST gauge pressure values during the baseline testing were between 0.008 and 0.046 in. W.C.

3.1.3 Vent Line Emissions for 10% ORVR Penetration

The descriptive statistics for the hydrocarbon and gauge pressure data collected during the 10% ORVR penetration experimental condition are summarized in Tables 3-3, 3-6 and 3-9. These recorded field data are presented in graphical format in Figures 3-4 through 3-6 for gauge pressure and hydrocarbon concentration using one minute, 15 minute and one hour averaging functions. Figures 3-13 through 3-15 present similar data as the hydrocarbon data is presented as mass released per unit time. The relationship between vent line hydrocarbon emissions and UST gauge pressure is visible in these figures with hydrocarbon emissions increasing with UST gauge pressure. Compared to the 0% ORVR test conditions, the regression model for 10% ORVR penetration (Tables 3-14 and 3-15) suggests a stronger relationship as defined by an R square value of 0.35 and a correlation coefficient (R) of 0.59.

Table 3-11 summarizes the observed vent line emissions for the 10% ORVR penetration experimental conditions. As with the case for the baseline conditions, vent line emissions ranged from almost nondetectable levels to a concentration of 100 ppm. A product delivery did occur several hours prior to the inception of 10% ORVR hydrocarbon measurement at 6:29 AM. It is unclear whether the 11:30-11:49 AM hydrocarbon bursts in excess of 2000 ppm were related to this product drop event. There was an observed trailing effect over a four hour period where vent line emissions did eventually return to levels below 100 ppm. It is hypothesized that the observed hydrocarbon peaks are representative of station dynamics (e.g., system design, hydrocarbon molecule phase transfer at the liquid/air interface in the UST) rather than tanker truck refueling activities. However, it has been hypothesized by other researchers that a bulk delivery through a damaged fill connector can aspirate significant quantities of air into the UST. This causes gasoline evaporation and increased pressure in the UST with the full impact of this occurrence not being observed until hours after the delivery is complete.

Integrating the emission data into a standardized emission factor metric produced a vent line emissions factor of 0.00985 pounds/1000 gallons of gasoline pumped for the 10% ORVR penetration experimental condition. This value is larger than the baseline emission factor value by roughly a factor of two. When evaluating the rate hydrocarbon releases from the vent line, (Figures 3-13 through 3-15), the observed values were also larger than the baseline condition release rate. The range of hydrocarbon release rates was approximately between 10^{-6} and 10^{-4} pounds/minute. The higher rates at the beginning of the 10% ORVR simulation testing may have corresponded to the time period when product was being delivered to the UST from tanker trucks due to a several hour lag effect.

The UST gauge pressure conditions during the 10% ORVR penetration conditions were all positive values. They were between 0.097 and 2.604 inches W.C. The predominant gauge pressure peaks were at the beginning of the 10% ORVR simulation test period and lasted over a nine hour period (9:10 AM – 16:00, 2/10). It is unclear whether these gauge pressure values, and related emissions releases, are related to the product drop that occurred two hours prior to the beginning of emissions testing. When evaluating the distribution of gauge pressure frequencies, (Figure 3-20), 70% of the observed gauge pressure recordings were between 0.348 and 1.351 in. W.C.

3.1.4 Vent Line Emissions for 50% ORVR Penetration

Tables 3-4, 3-7 and 3-10 summarize the descriptive statistics for vent hydrocarbon emissions (ppm and lbs/min) and UST gauge pressure for 50% ORVR penetration. Figures 3-7 through 3-9 display one minute block averages and 15 minute/one hour running averages for hydrocarbon concentrations and UST gauge pressure. When converting hydrocarbon concentration to mass released per unit time, these data are illustrated in Figures 3-18 through 3-20. During this time period, a product delivery occurred at 11:40. This event does not appear to be related to significant hydrocarbon and gauge pressure peak excursions observed at the end of the 50% ORVR simulation sampling period. However, immediately following the product delivery, there was brief peak in gauge pressure at 12:00 PM. A small simultaneous release in emissions was also observed at this time. As is visible in the one hour running average figures, hydrocarbon mass releases increase (less so with the hydrocarbon concentration values) with UST gauge pressure. The strength of this relationship was not echoed in the regression analysis (Table 3-17). This was also the case with the regression model evaluating hydrocarbon concentration figures and UST gauge pressure.

In contrast to both the baseline and 10% ORVR penetration conditions, vent line hydrocarbon emissions for 50% ORVR penetration were considerably lower, ranging from near non-detect levels to 40 ppm (Table 3-11). Emission release rates were similar to both baseline and 10% ORVR penetration release profiles, ranging from 10^{-6} to 10^{-4} pounds hydrocarbon released per minute. Vent line hydrocarbon emissions directly correspond to UST gauge pressure with larger UST gauge pressure values triggering larger quantities of vent line hydrocarbon emissions. The calculated emission factor in pounds of hydrocarbon released per 1000 gallons pumped was 0.0011. This value is smaller than both the baseline and 10% ORVR penetration emission factors. As was apparent in the 0% ORVR simulation test period, fugitive emissions during the 50% ORVR penetration test period were greater than two orders of magnitude larger that the observed vent line emissions factor.

UST gauge pressure ranged from –2.01 to 1.390 in. W.C. This range is deceptive in that the majority (98%) of the gauge pressure readings during the duration of the 50% ORVR penetration were greater than 0.031 in. W.C. (Figure 3-21). The observed gauge pressure conditions were relatively constant maintaining values in a band between 0.3–0.8 inches W.C. for the majority of the 50% ORVR simulation test conditions.

3.1.5 Fugitive Emissions

As specified in draft TP-201.2B, site-specific fugitive emissions are quantified by establishing a flow (Q) vs. pressure (P) relationship for the total facility by reproducing the (Q) vs. (P) function in a laboratory setting using a physical model. The methodology is described in Section 2.4.2.2. The model output (Q) vs. (P) function and the data used to generate the (Q) vs. (P) curve is contained in appendix D. The initial data points for this exercise were taken from the pre-test static pressure test conducted by the BAAQMD. This function was applied to the system pressure values for each of the three ORVR penetration test conditions. As a frame of reference, the pre-test static pressure test yielded an average pressure of 1.965 inches W.C. and an average Q of 0.0771 cfm. Post-test data generated an average pressure of 1.970 inches W.C. and an average Q of 0.0654 cfm.

Tables 3-18 through 3-20 summarize the flow characteristics (Q) defined as system average leak rate (cfm). These data are also charted on Figures 3-22 through 3-30 with UST gauge pressure values. The control condition (0% ORVR) exhibited the lowest Q with a mean value of 0.0113 and a minimum and maximum of 0.0002 and 0.019 respectively. The ORVR simulation conditions produced higher flow values. The mean 10% ORVR penetration flow was 0.0869. The min/max range was 0.02-0.144. The 50% ORVR penetration condition exhibited a smaller mean value (0.0605) though the observed maximum was roughly in the same range. The fact that the 10% and 50% leak rates are very close is a noteworthy observation given that the vent line emissions values for the 10% and 50% ORVR simulation conditions were significantly variant.

The observed Q values are in the same order of magnitude as those observed by ARB field staff during the 1999 ORVR retest field study at the same test location. This suggests that the site-specific leak rate is reproducible under a variety of temporal conditions. As is visible from Figures 3-22 through 3-30, leak rates correlate with system pressure, an observation that is intuitive and supported by both physics tenants and vapor recovery system design. The buildup of pressure in relatively closed systems will move towards a state of disorder, thus releasing pressure, as predicted by the second law of thermodynamics, using all available pressure release locations (i.e., fugitive emission sources like nozzles, Stage I and II fittings, P/V valves).

As described in Section 2.4.2.2, hydrocarbon concentrations were not measured on the system side of the P/V valve. Using project empirical data, it is therefore not possible to specify the hydrocarbon mass/volume variable $[HC_{m/v}]$ that is required to quantify study-specific fugitive emissions using the expression:

$$(HC) = (Q) \times [HC_{m/v}] \times time \qquad (3\text{-}1)$$

However, it is possible to generate fugitive emissions for this facility using the ARB ORVR retest data (ARB, 1999). These data were applied to the Q function derived during this study to produce facility-specific fugitive emissions data. Table 3-21 tabulates the ARB measured VRS side hydrocarbon concentrations, the observed leak rate values for this project for two of the ORVR simulation test periods, and the calculated fugitive emission factors in pounds per 1000 gallons.

A fugitive emission factor for the 10% ORVR simulation test condition was not calculated because the ARB ORVR simulation test project did not simulate an early ORVR penetration test condition. However, if we assume a linear relationship between fugitive emission concentration and ORVR throughput, an average fugitive emission factor for the 10% ORVR penetration can be calculated using the ARB 0% and 45% penetration data (Table 3-22).

The control ORVR simulation condition (0%) yielded a fugitive emission factor of 0.1210 lb/1000 gallons. This value completely masks the observed 0% ORVR simulation vent line emission factor of 0.00518 lb/1000 gallons suggesting that other fugitive emission sources (other than the vent line emission point) are the dominant emission releases at gasoline dispensing facilities, at least for the testing executed during this study. The calculated fugitive emission factor for the 50% ORVR simulation sample period was 0.4031 lb/1000 gallons, a value which is greater by approximately a factor of four when compared to the 0% simulation fugitive emission factor. The magnitude of the 50% ORVR simulation fugitive emission factor was greater than three orders of magnitude larger than the measured 50% vent line emission factor for this test condition.

The predicted 10% ORVR simulation fugitive emission factor is 0.9103 lb/1000 gallons, a value significantly larger than either the 0% or 50% ORVR simulation fugitive emission factor by a factor of nine and two respectively. In addition, the predicted 10% ORVR simulation fugitive emission factor is approximately three orders of magnitude larger than the calculated empirical 10% ORVR vent line emission factor. As was the case with vent line emissions, product deliveries do not appear to trigger burst of fugitive emission releases.

3.1.6 Total Emissions

Using the empirical vent line and fugitive emission factors developed in this field program, average total emission factors for the 0% and 50% ORVR simulation conditions can be calculated (Table 3-23). In addition, total emissions for the 10% ORVR penetration can be estimated integrating the modeled fugitive emission value generated by the linear model calculation using the ARB 0% and 45% ORVR generation data.

The control experimental condition (0% ORVR) yielded an average total emission factor of 0.1262 pounds/1000 gallons which represents an average vapor recovery system efficiency loss of 1.43%. The hypothesized increase in efficiency loss of ORVR penetration was demonstrated with the magnitude of the 50% ORVR simulation total emission factor. Using the ARB ORVR simulation refueling data (ARB, 1999), the calculated 50% ORVR penetration average total emission factor was 0.4042 representing a VRS efficiency loss of 4.81%.

The early ORVR penetration (10%) total emission factor was over two times larger than the 50 % ORVR simulation condition. Total emissions for 10% ORVR simulation were 0.9202 pounds/1000 gallons. This represents a loss of VRS efficiency of 10.95%. The reduction of total GDF emissions when considering early vs. late ORVR penetration conditions suggests a possible early maximum effect which is later offset by other GDF system parameter dynamics.

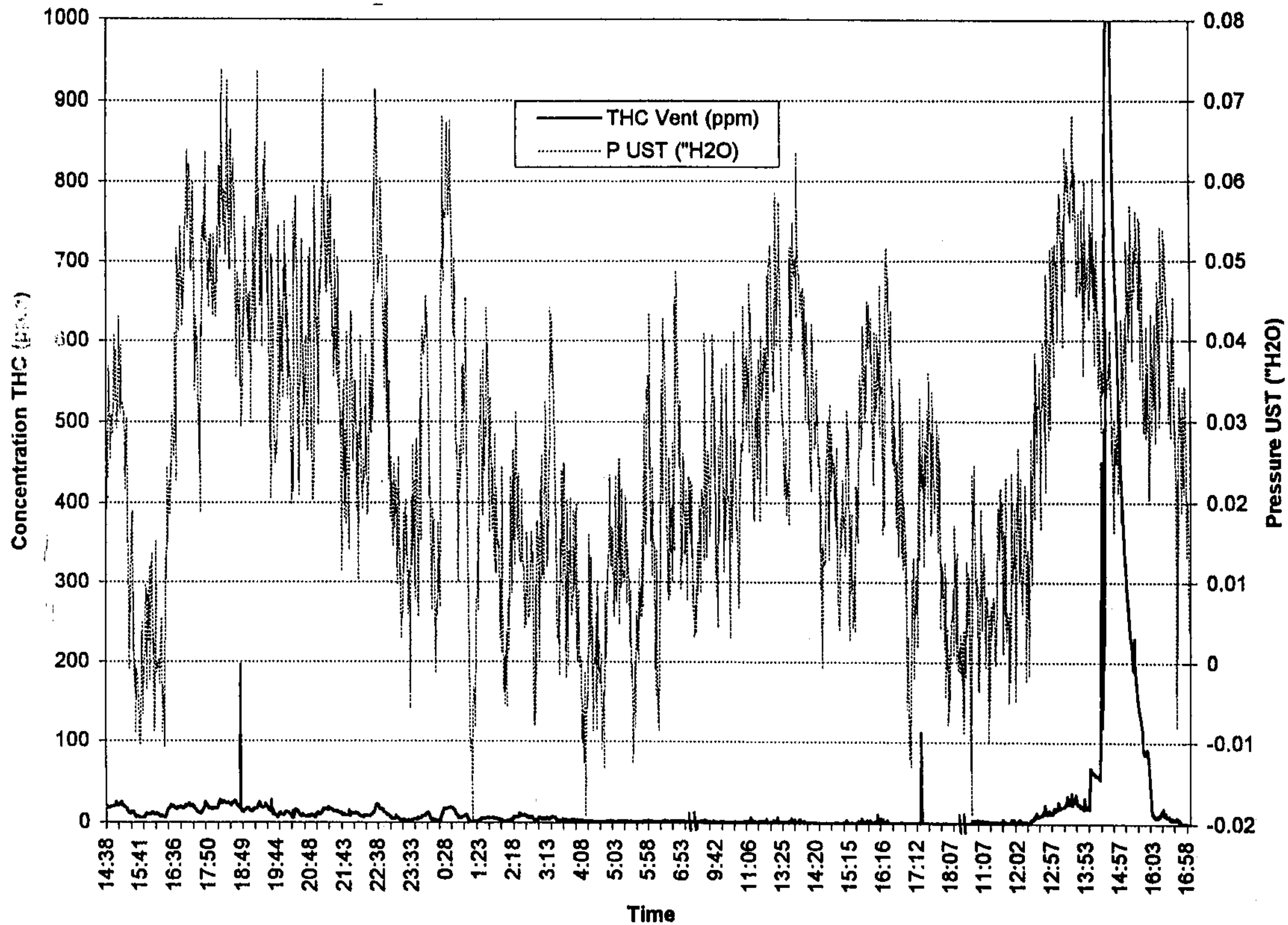


Figure 3-1 Gilbarco Vacuum Assist System Emissions (ppm) and UST Pressure for 0% ORVR Penetration*

*Sampling periods are not continuous

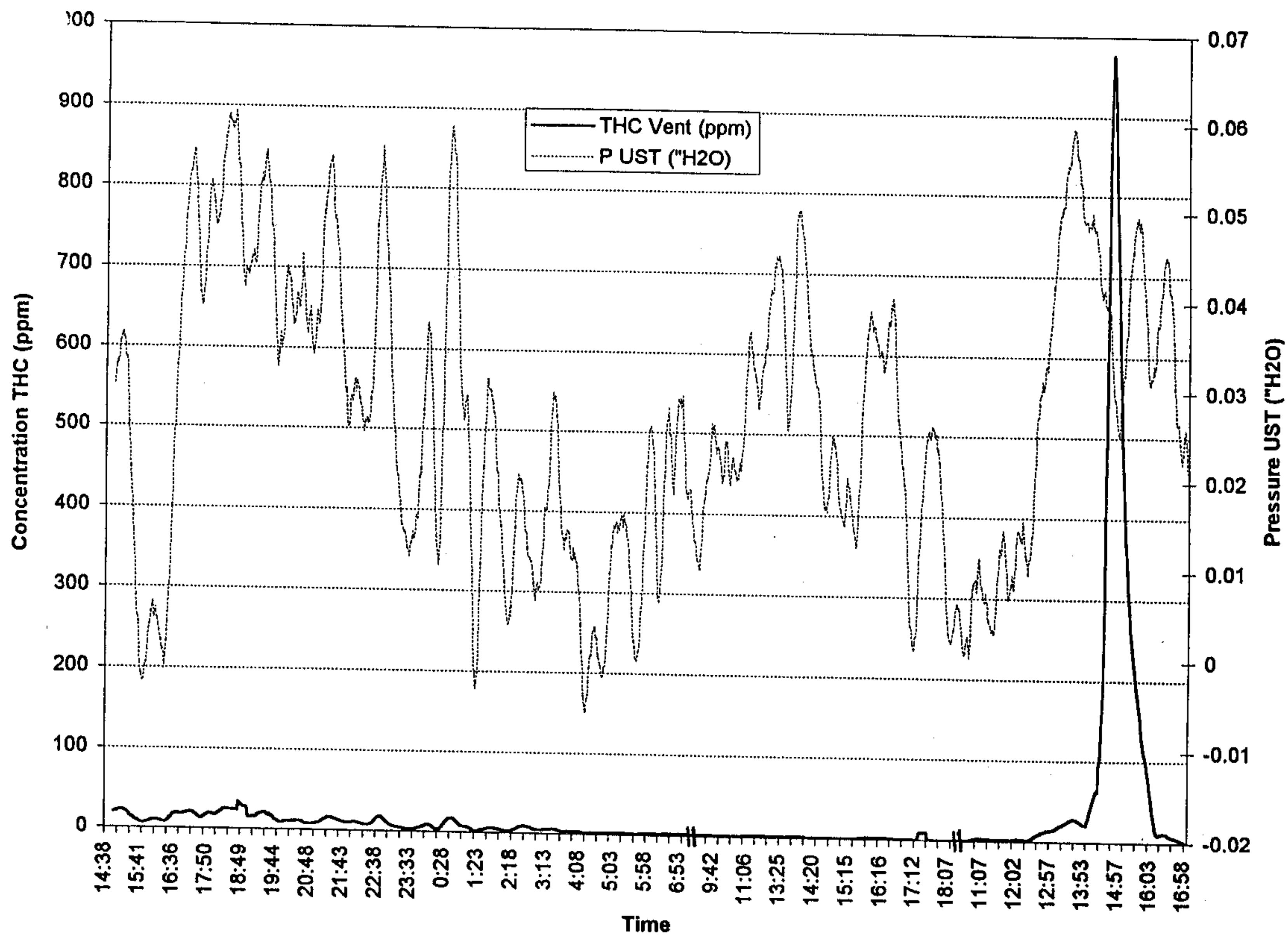


Figure 3-2 Gilbarco Vacuum Assist System 15 Minute Average Emissions (ppm) and UST Pressure for 0% ORVR Penetration*
*Sampling periods are not continuous

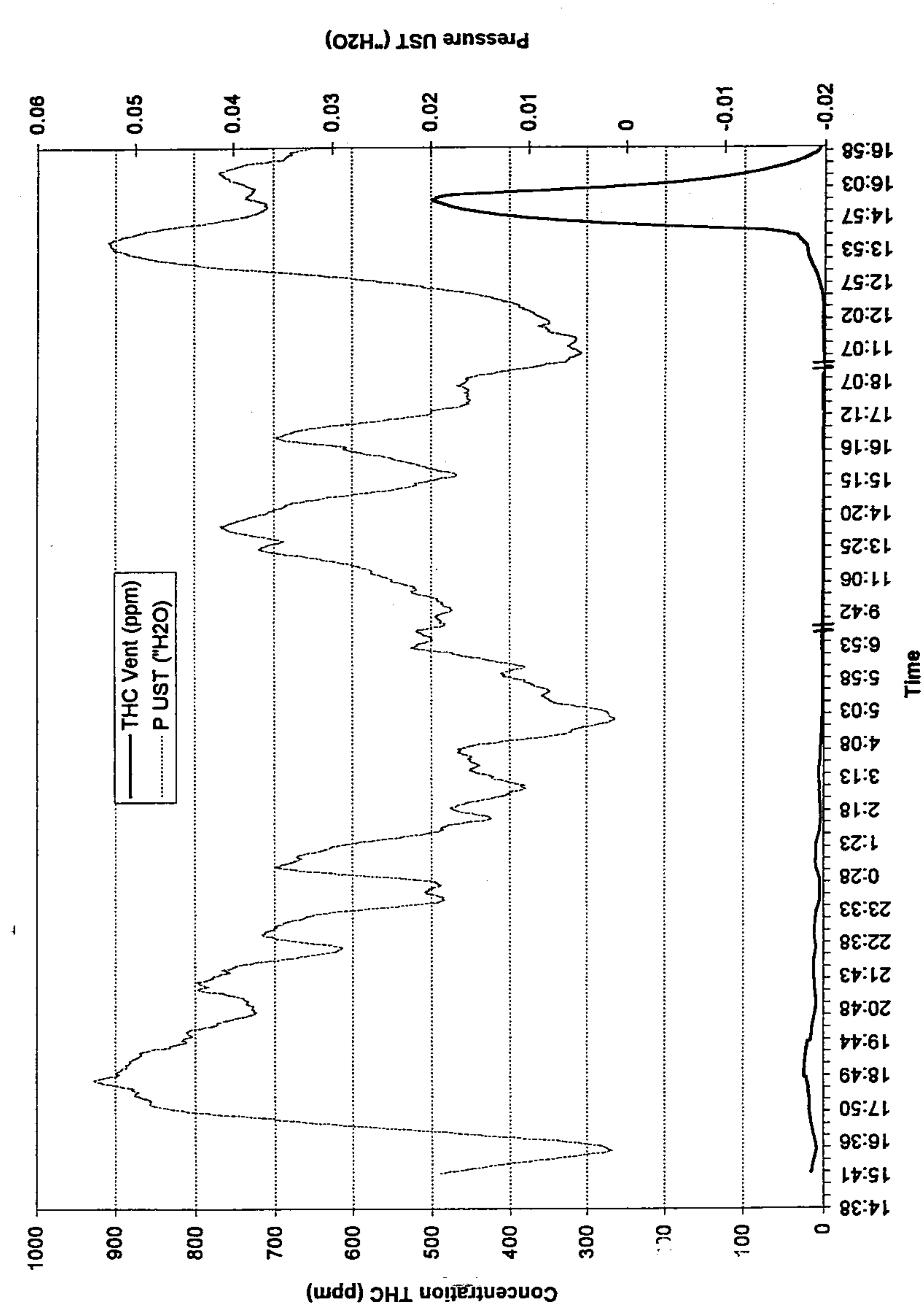


Figure 3-3 Gilbarco Vacuum Assist System 60 Minute Average Emissions (ppm) and UST Pressure for 0% ORVR Penetration*

* Sampling periods are not continuous

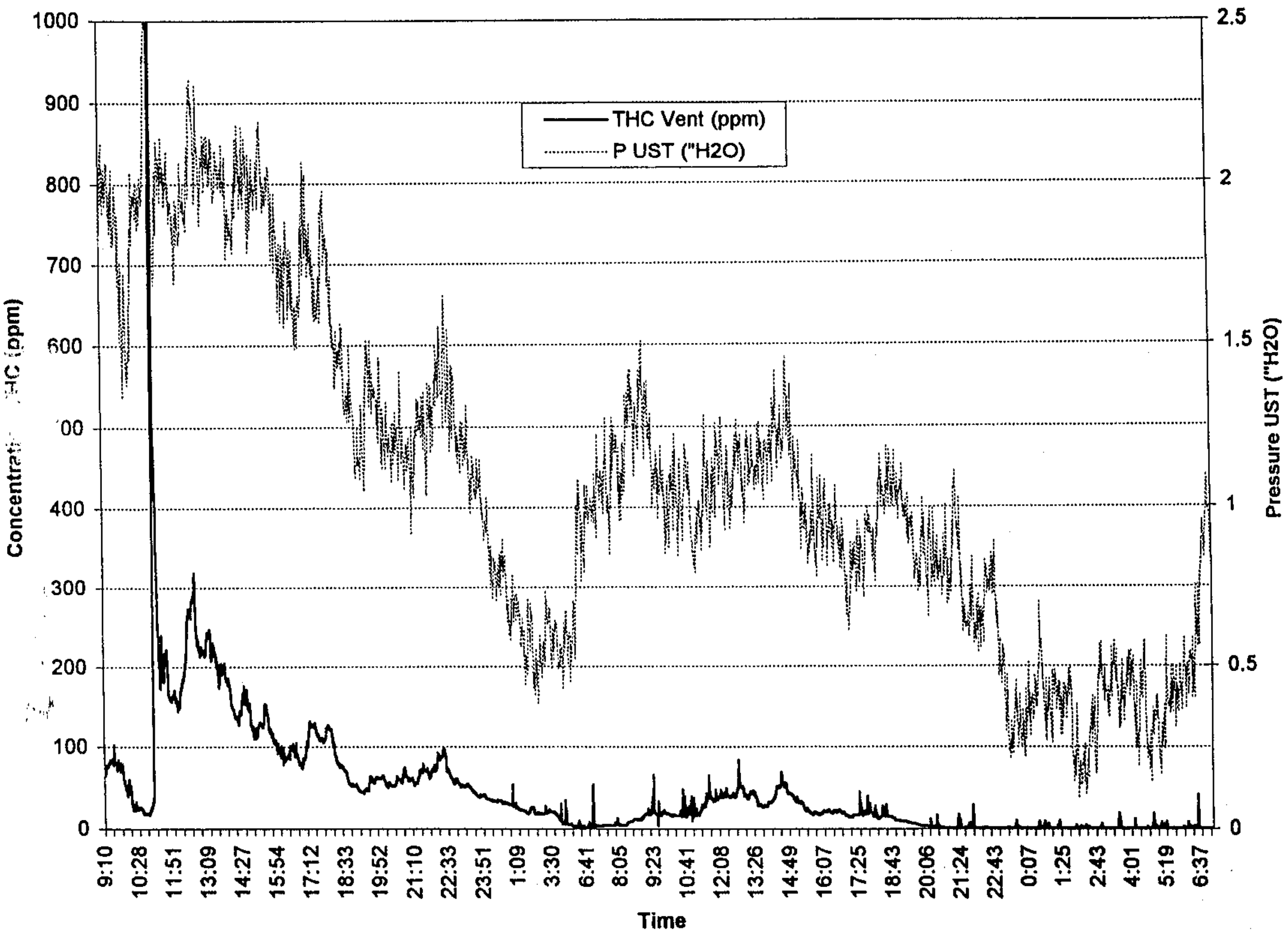


Figure 3-4 Gilbarco Vacuum Assist System Vent Emissions (ppm) and UST Pressure for 10% ORVR Penetration

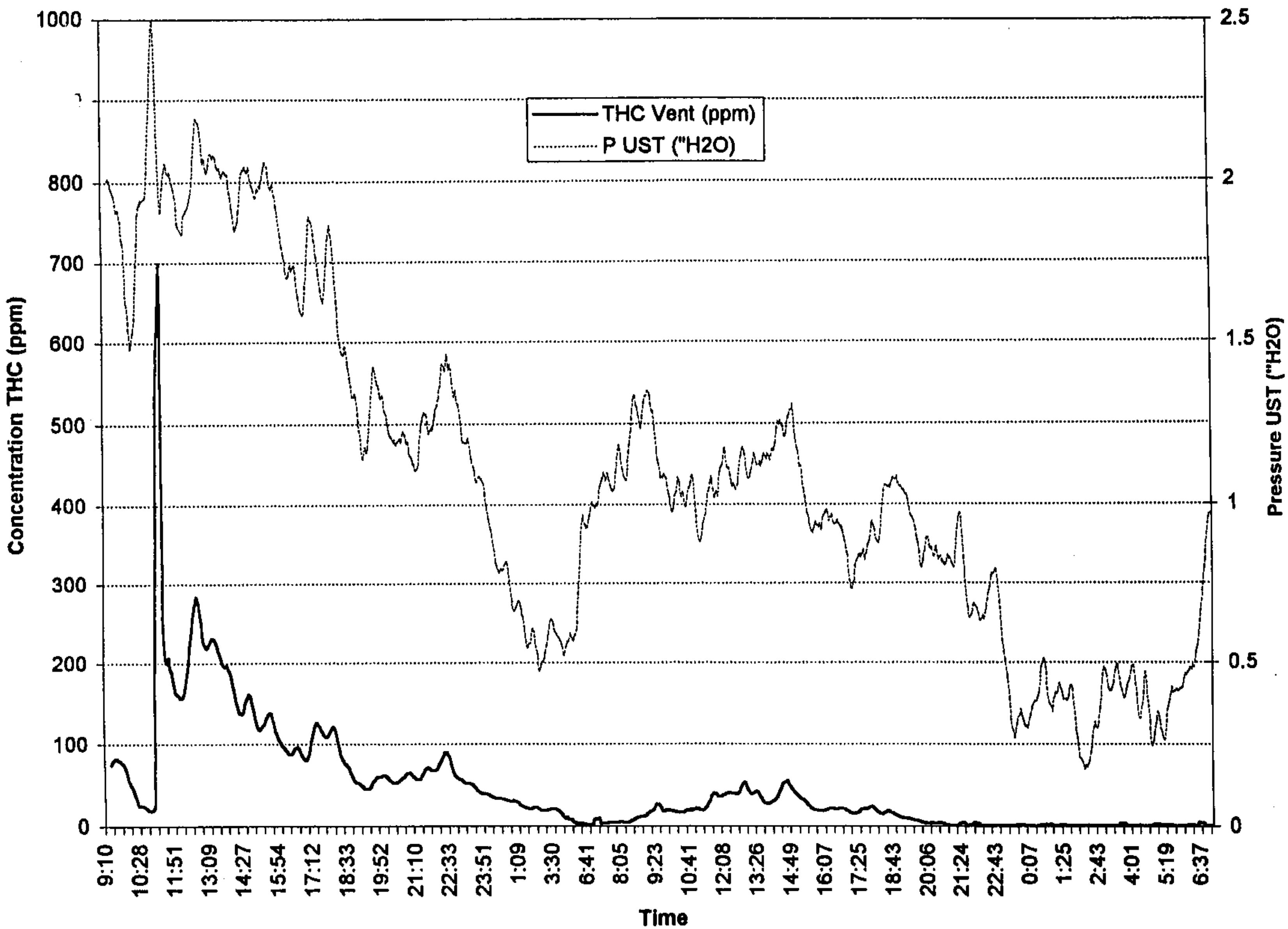


Figure 3-5 Gilbarco Vacuum Assist System 15 Minute Average Vent Emissions (ppm) and UST Pressure for 10% ORVR Penetration

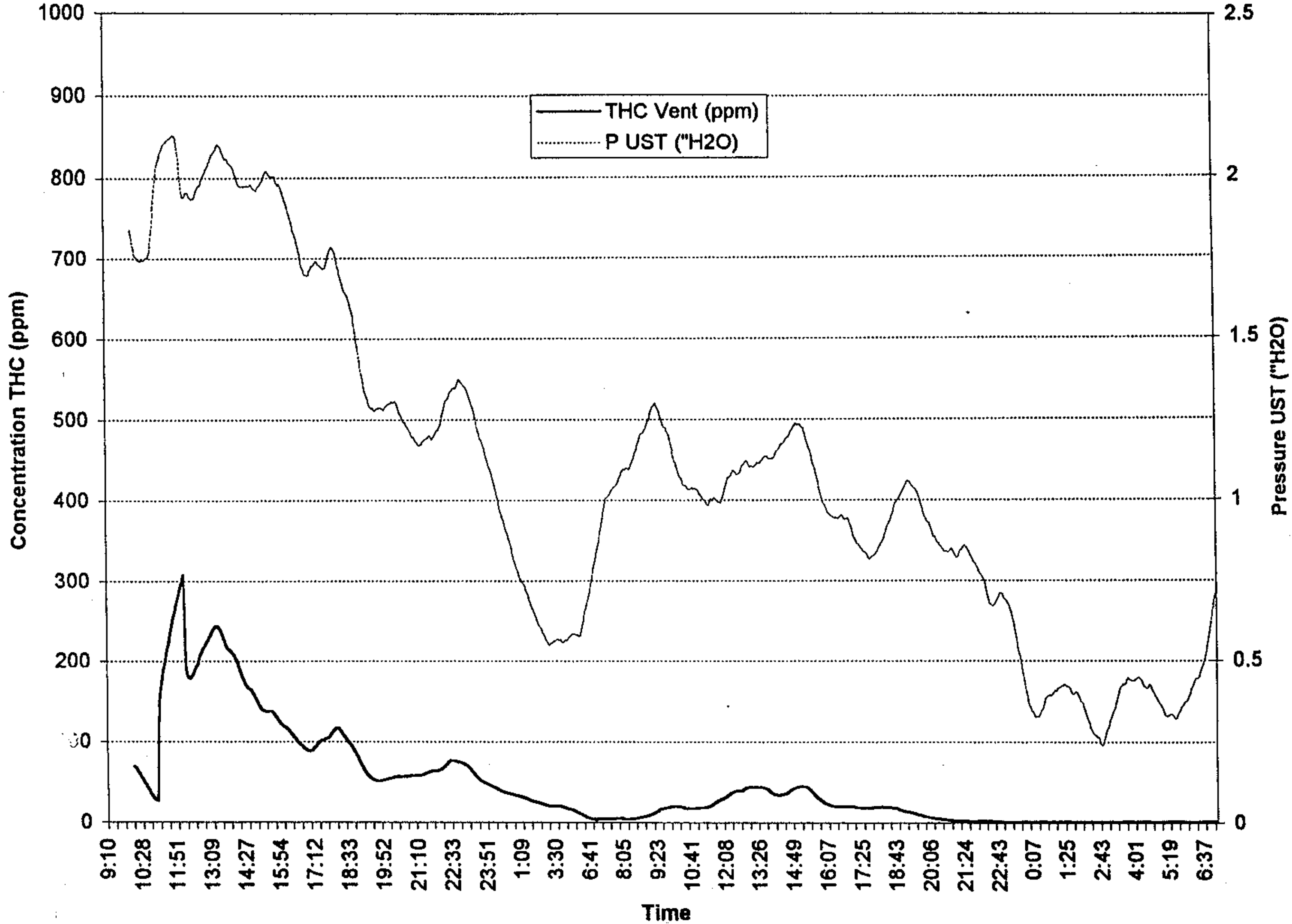


Figure 3-6 Gilbarco Vacuum Assist System 60 Minute Average Vent Emissions (ppm) and UST Pressure for 10% ORVR Penetration

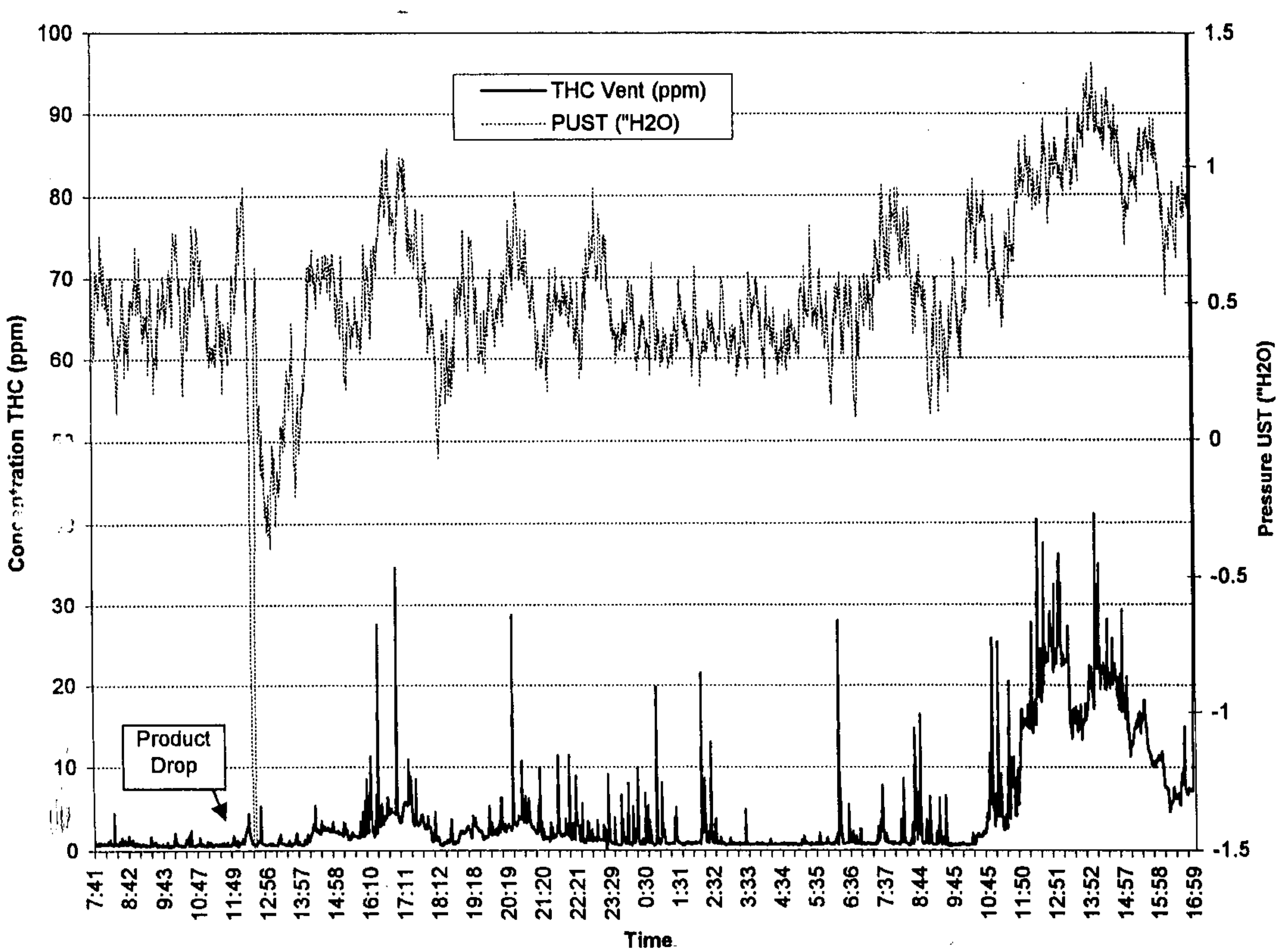


Figure 3-7 Gilbarco Vacuum Assist System Vent Emissions (ppm) and UST Pressure for 50% ORVR Penetration

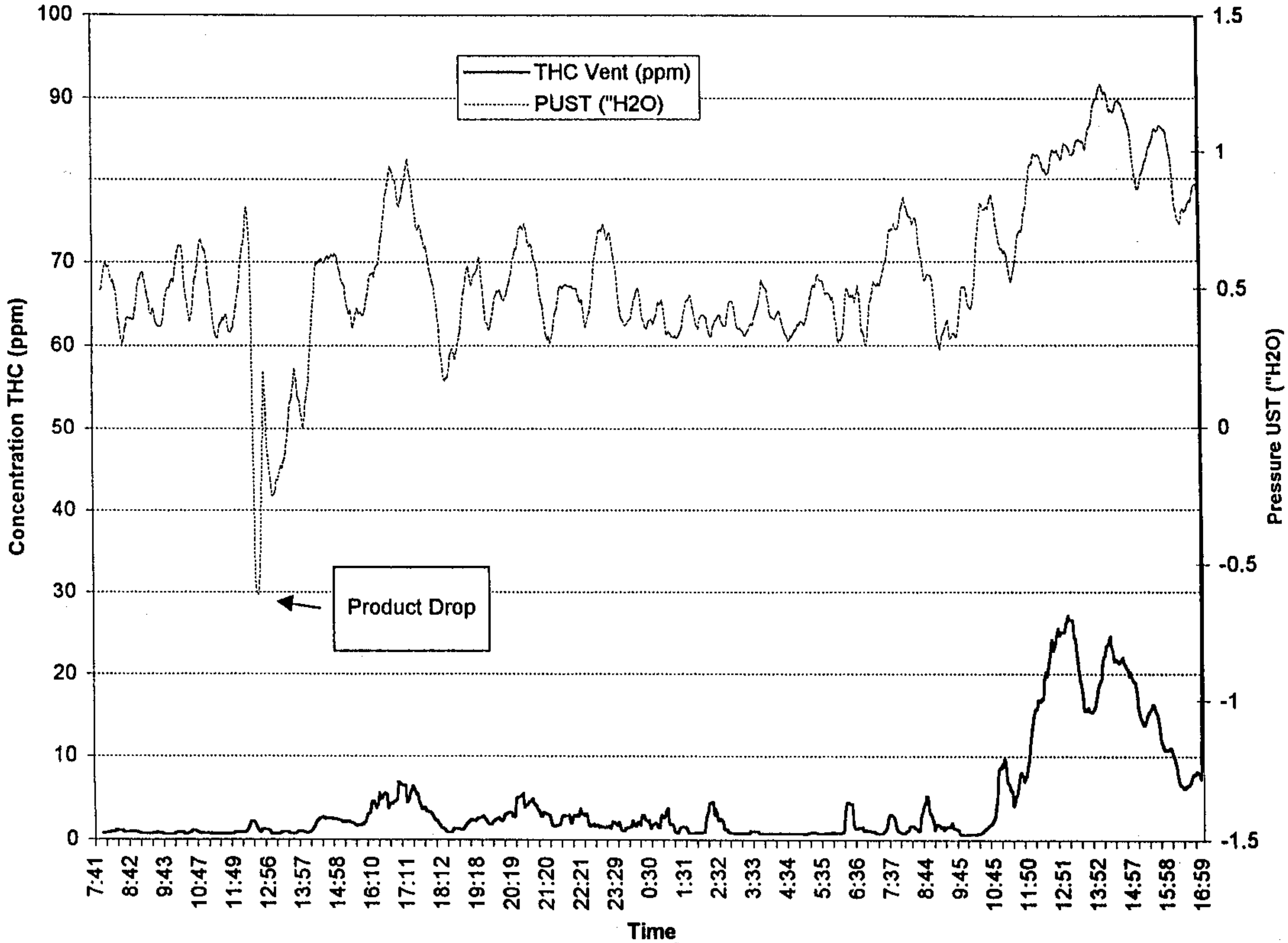
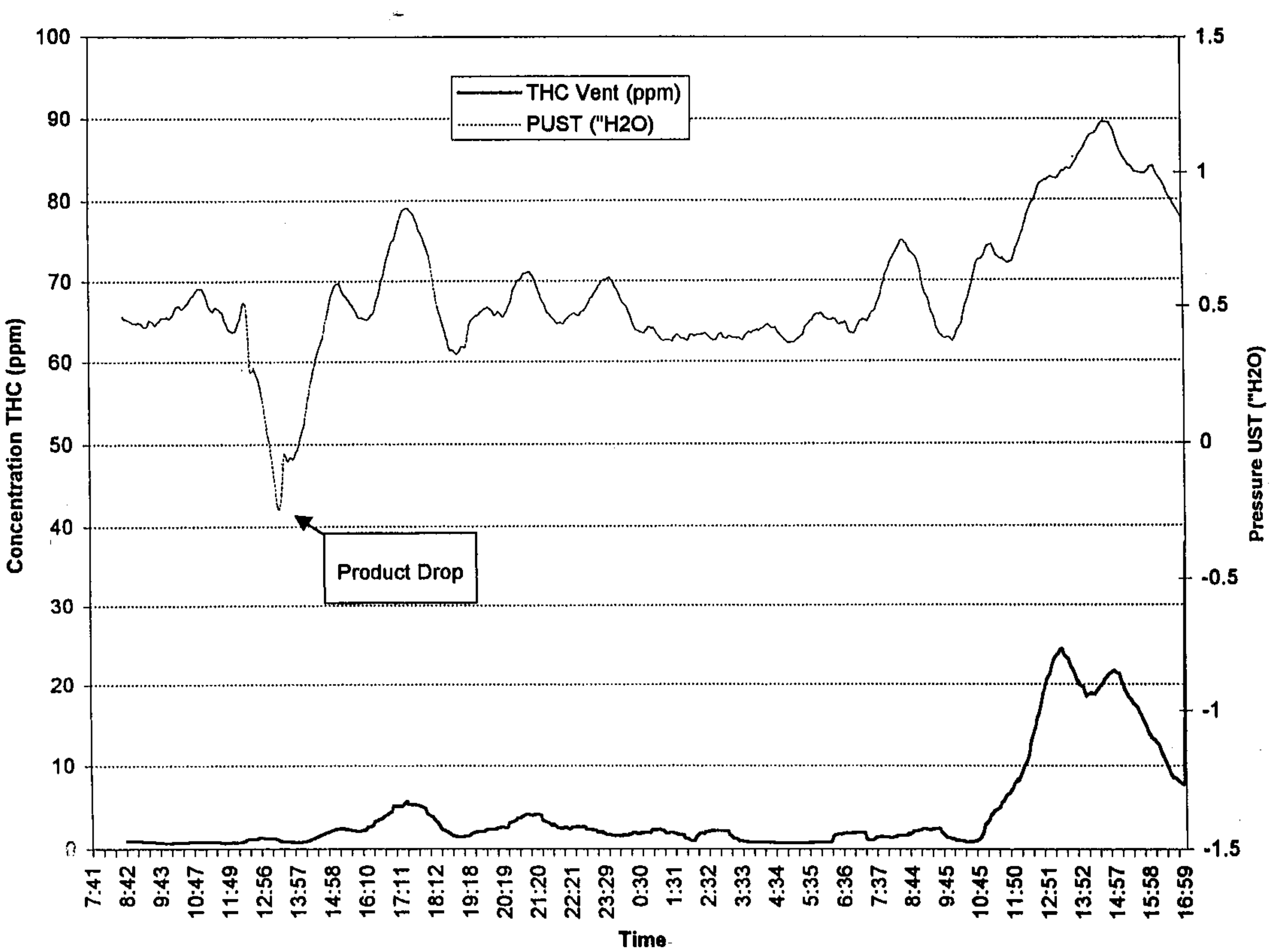


Figure 3-8 Gilbarco Vacuum Assist System 15 Minute Average Vent Emissions (ppm) and UST Pressure for 50% ORVR Penetration



ure 3-9 Gilbarco Vacuum Assist System 60 Minute Average t Emissions (ppm) and UST Pressure for 50% ORVR Penetr n

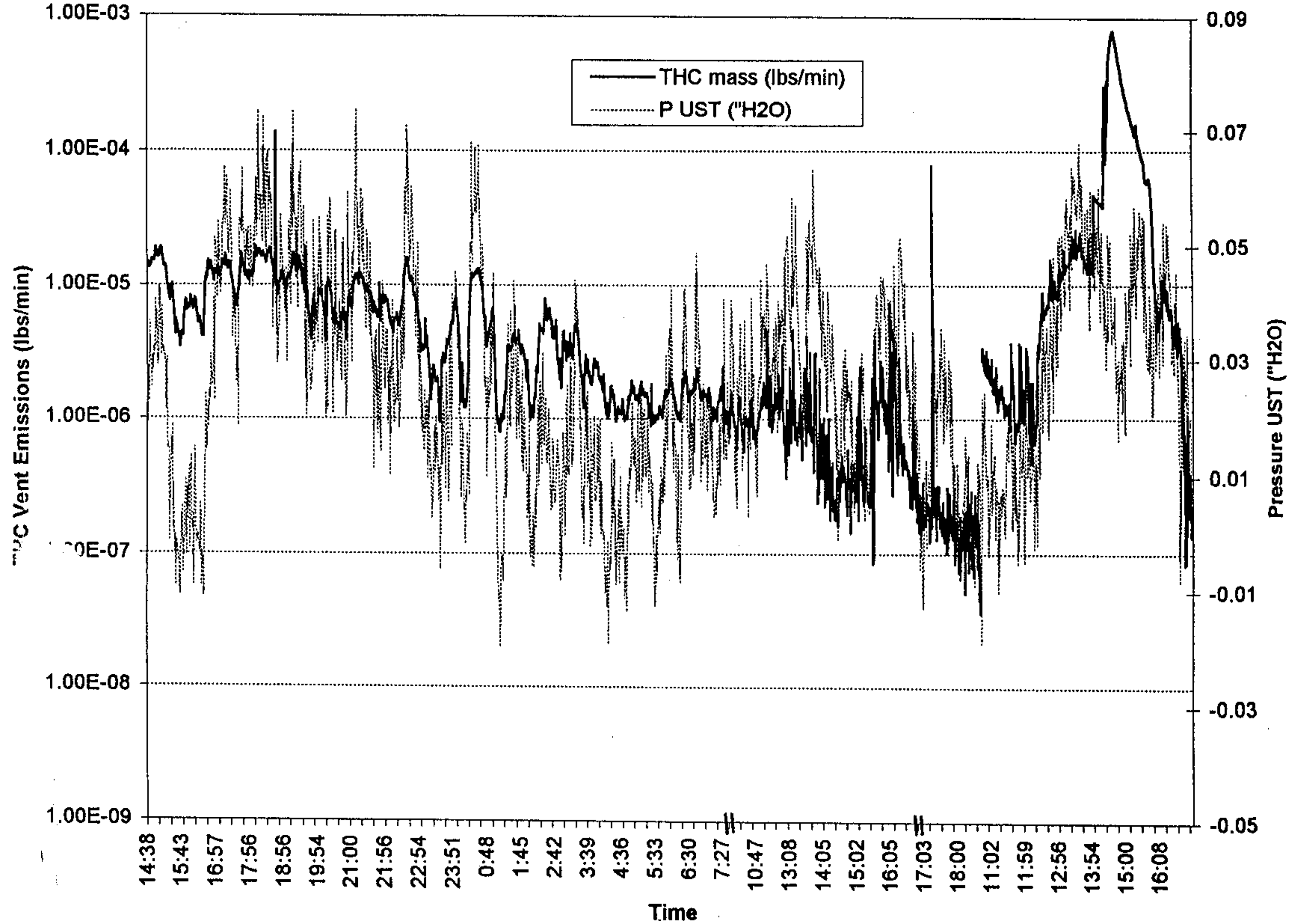


Figure 3-10 Gilbarco Vacuum Assist System Emissions (lbs/min) and UST Pressure for 0% ORVR Penetration*
***Sampling periods are not continuous**

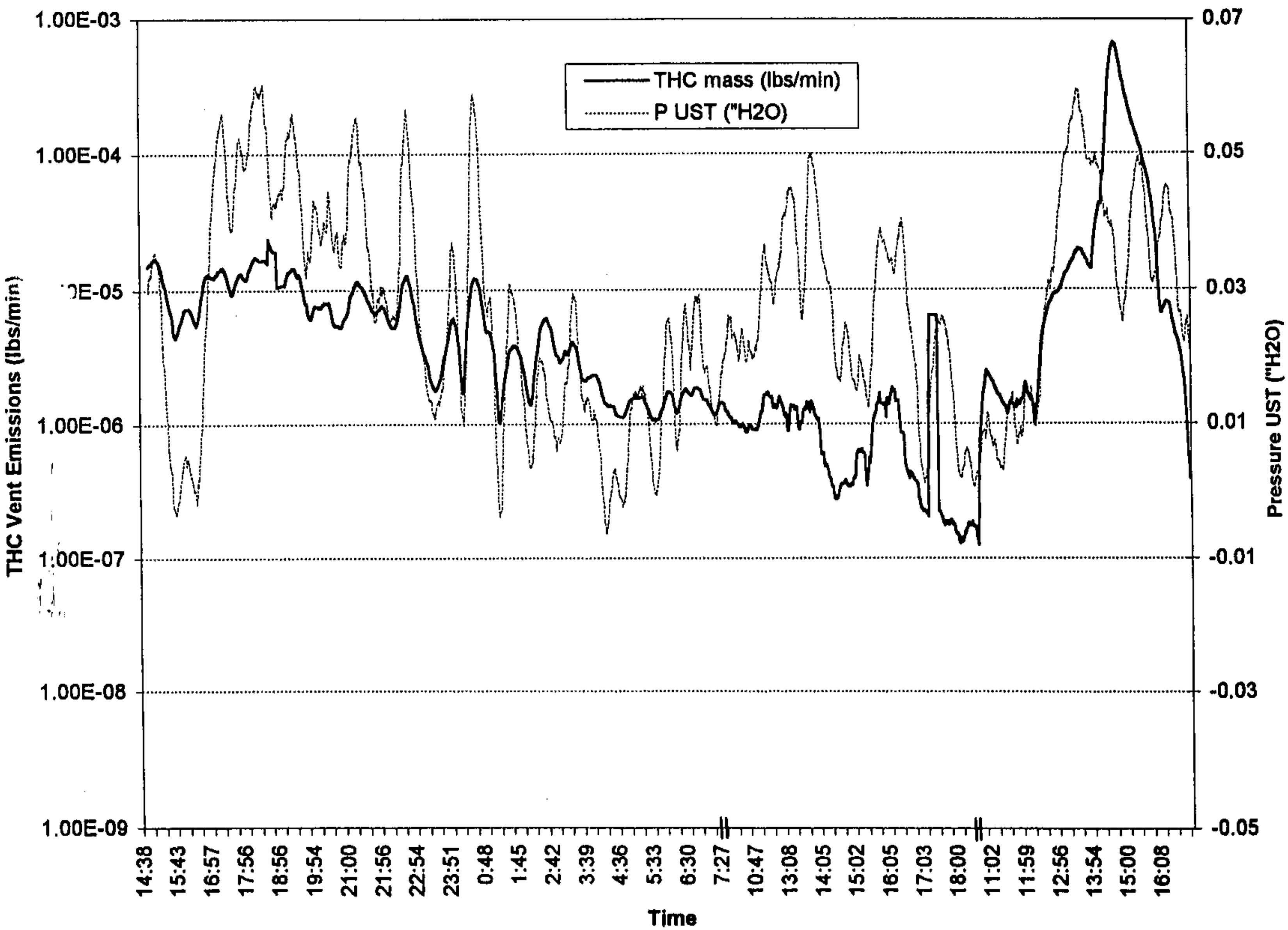


Figure 3-11 Gilbarco Vacuum Assist System 15 Minute Average Emissions (lbs/min) and UST Pressure for 0% ORVR Penetration*
*Sampling periods are not continuous

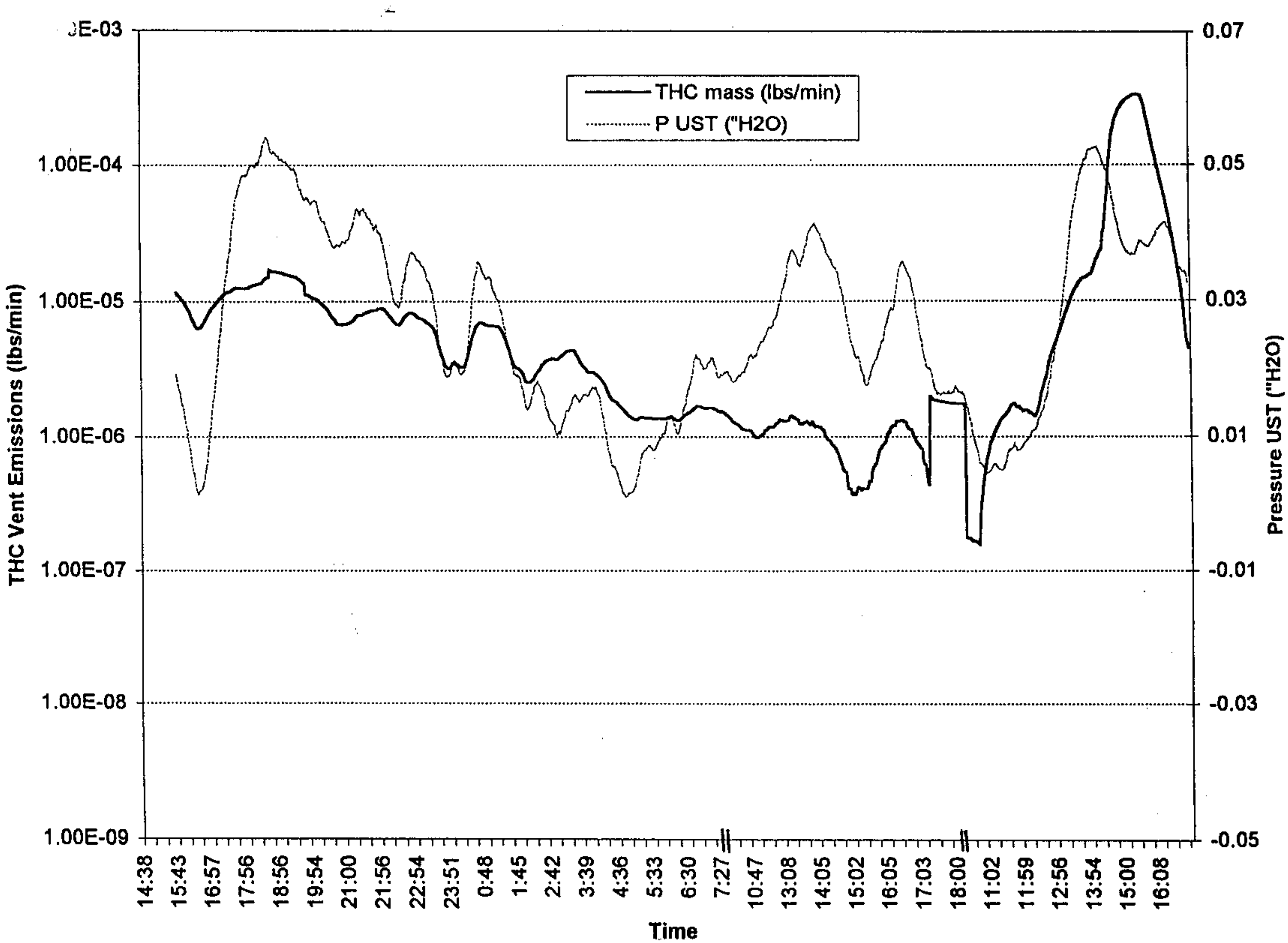


Figure 3-12 Gilbarco Vacuum Assist System 60 Minute Average Emissions (lbs/min) and UST Pressure for 0% ORVR Penetration*

***Sampling periods are not continuous**

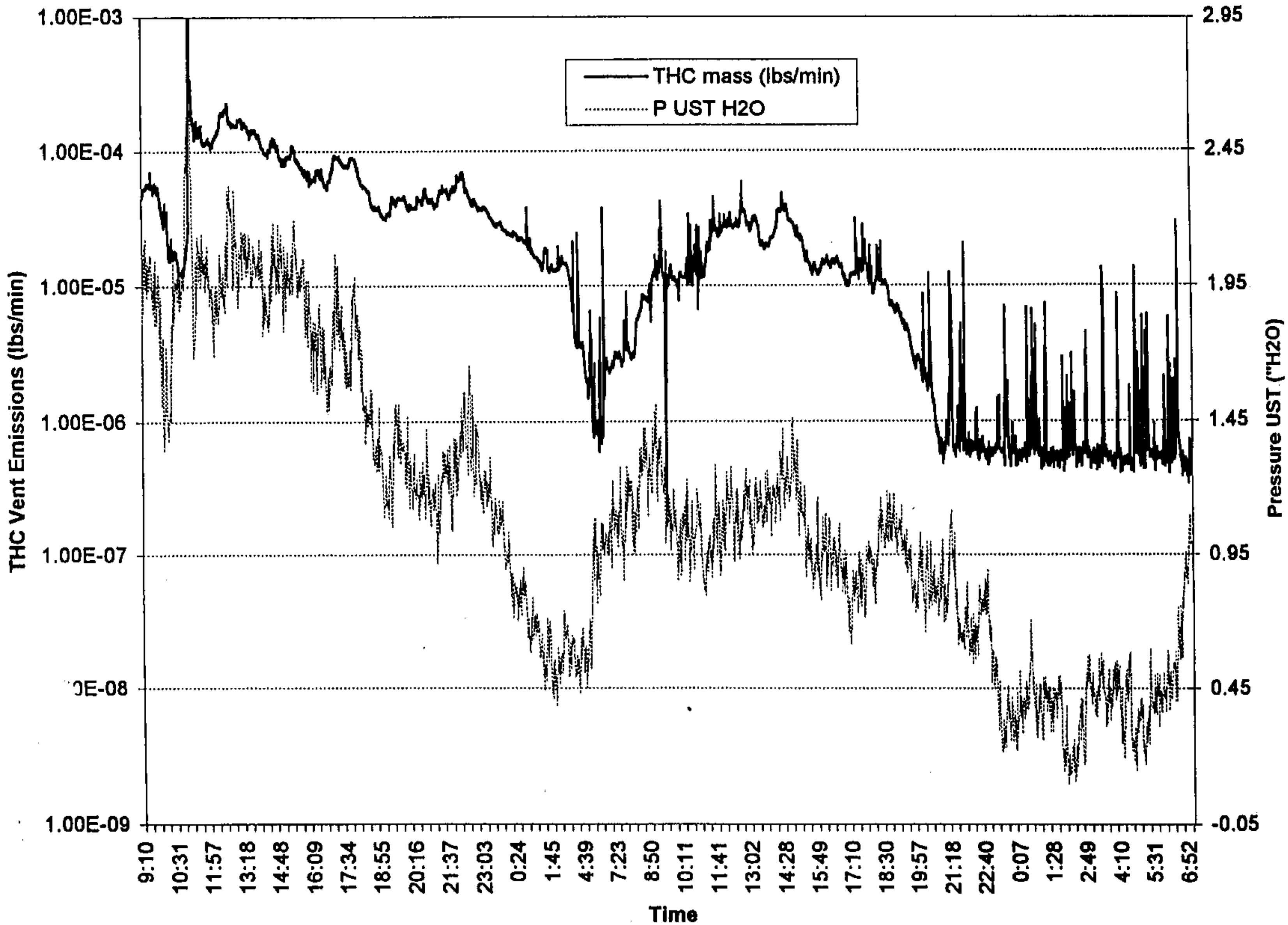


Figure 3-13 Gilbarco Vacuum Assist System Emissions (lbs/min) and UST Pressure for 10% ORVR Penetration

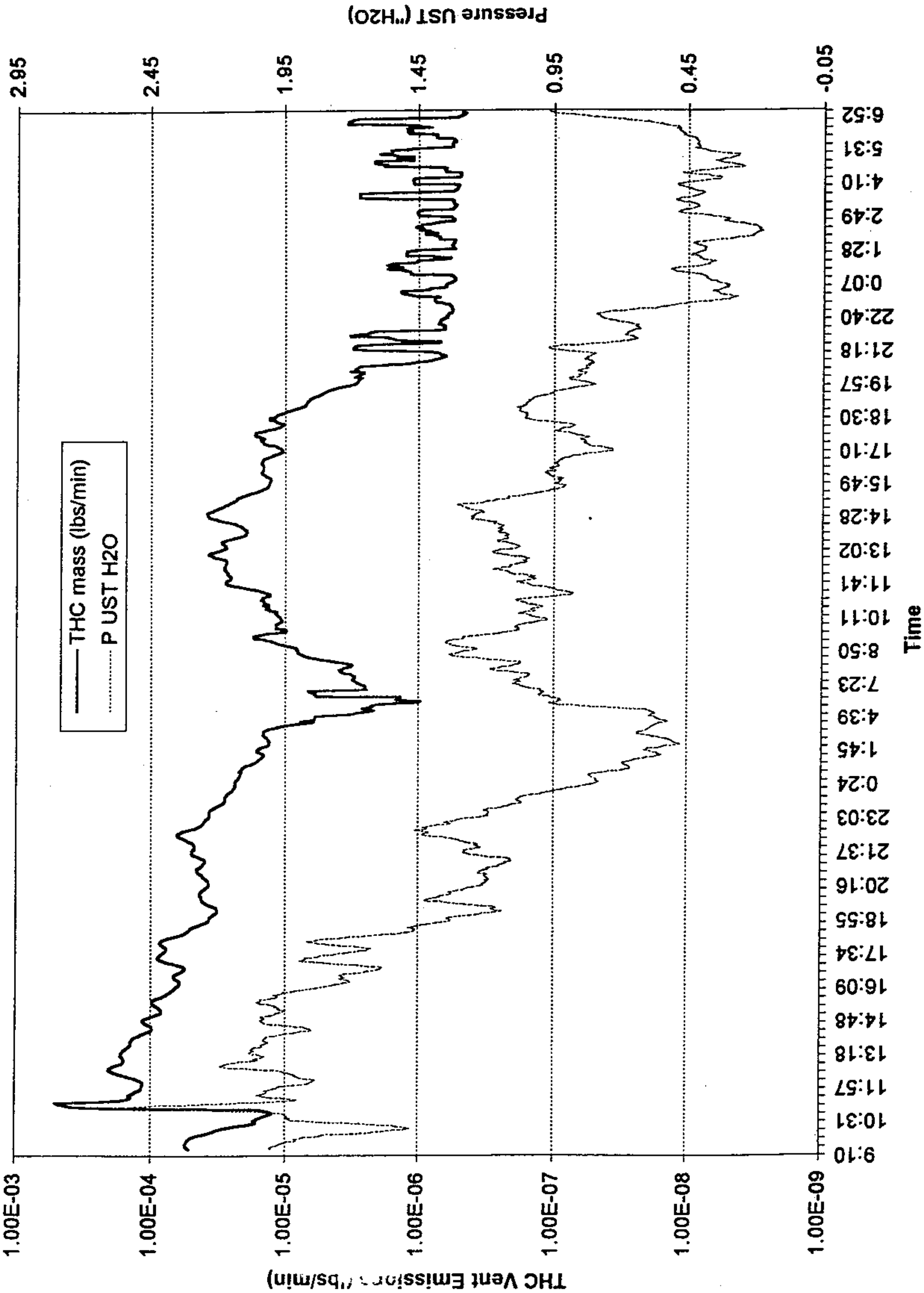


Figure 3-14 Gilbarco Vacuum Assist System 15 Minute Average Emissions (lbs/min) and UST Pressure for 10% ORVR Penetration

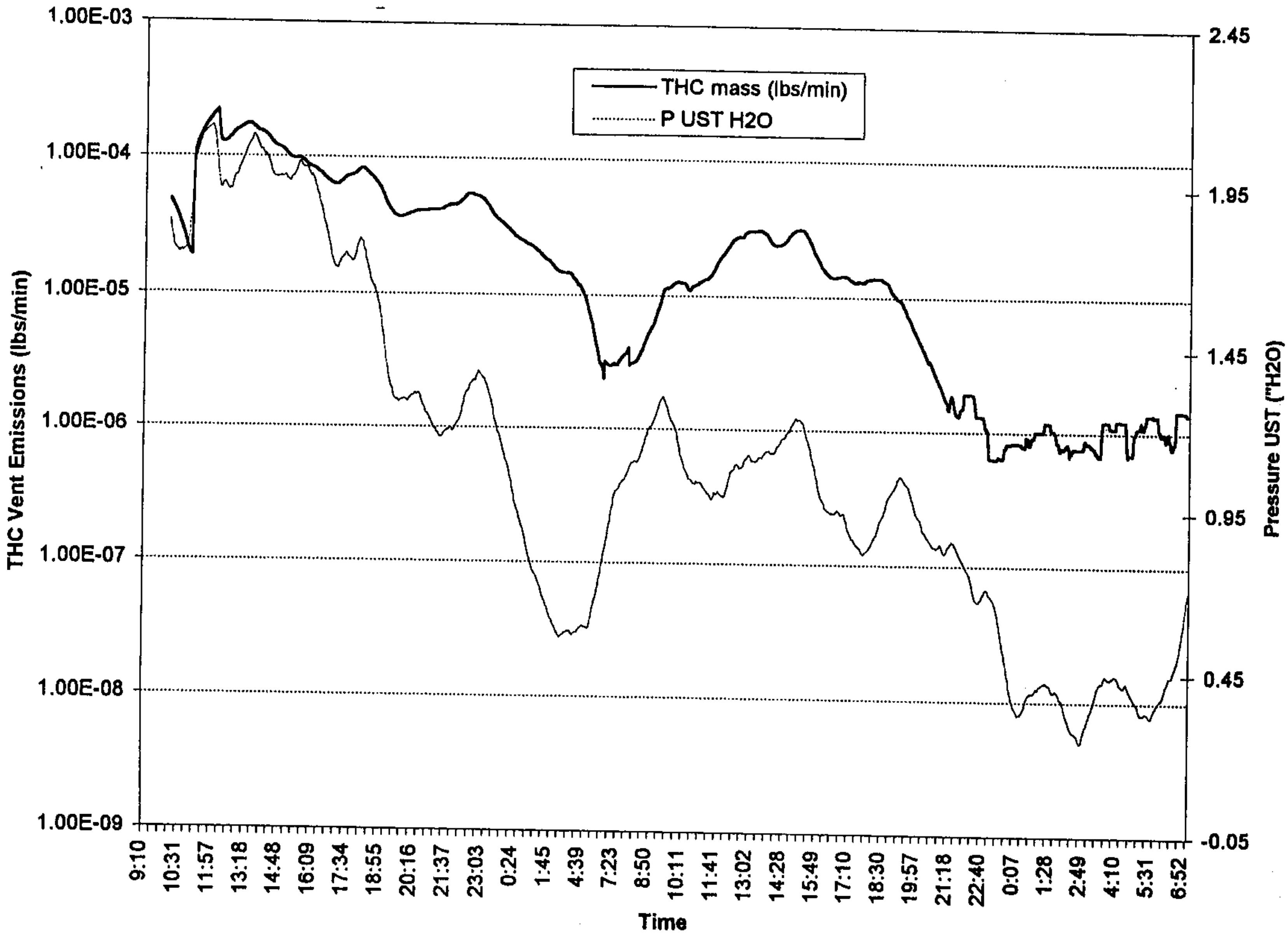


Figure 3-15 Gilbarco Vacuum Assist System 60 Minute Average Emissions (lbs/min) and UST Pressure for 10% ORVR Penetration

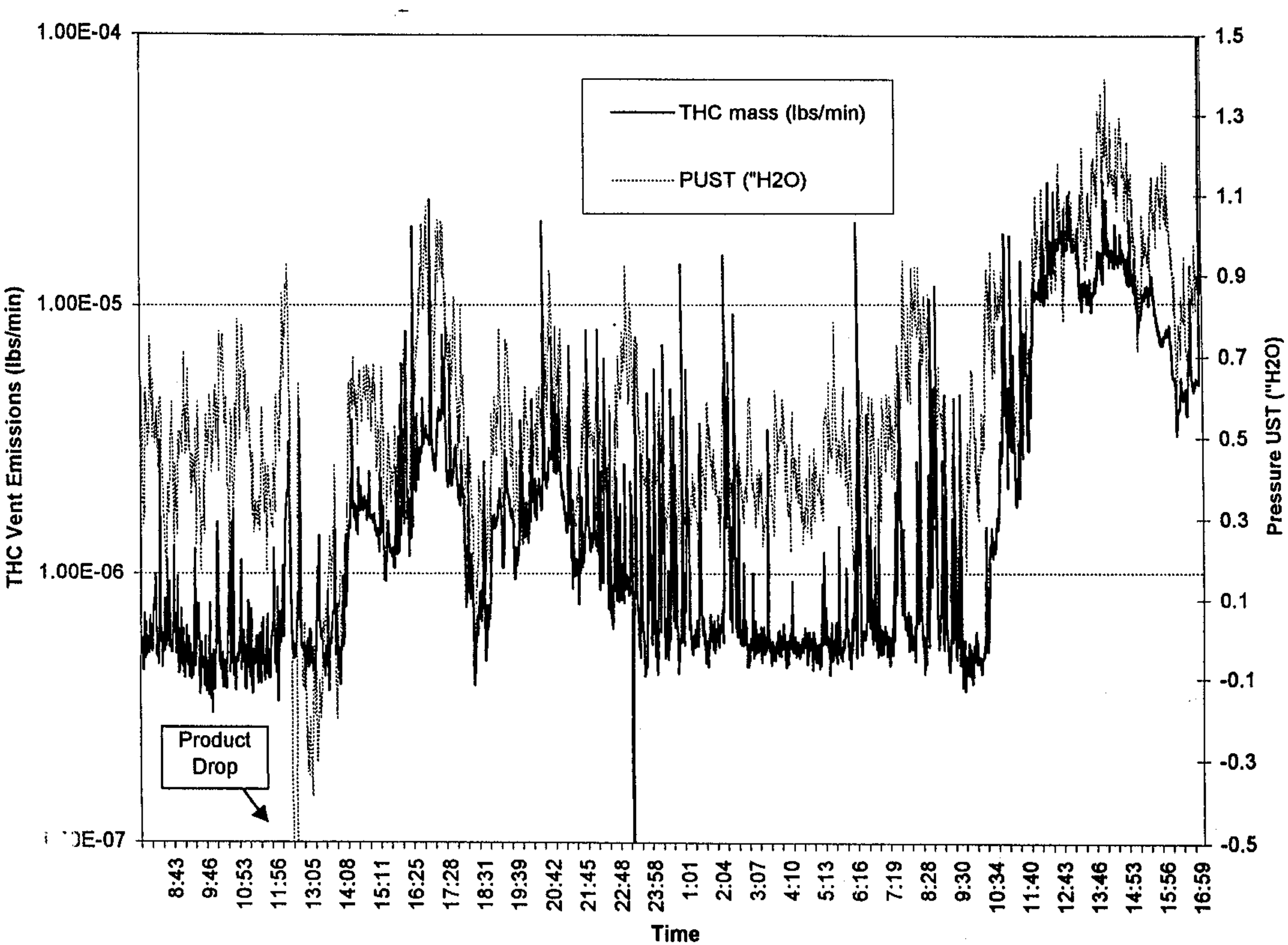


Figure 3-16 Gilbarco Vacuum Assist System Vent Emissions (lbs/min) and UST Pressure for 50% ORVR Penetration

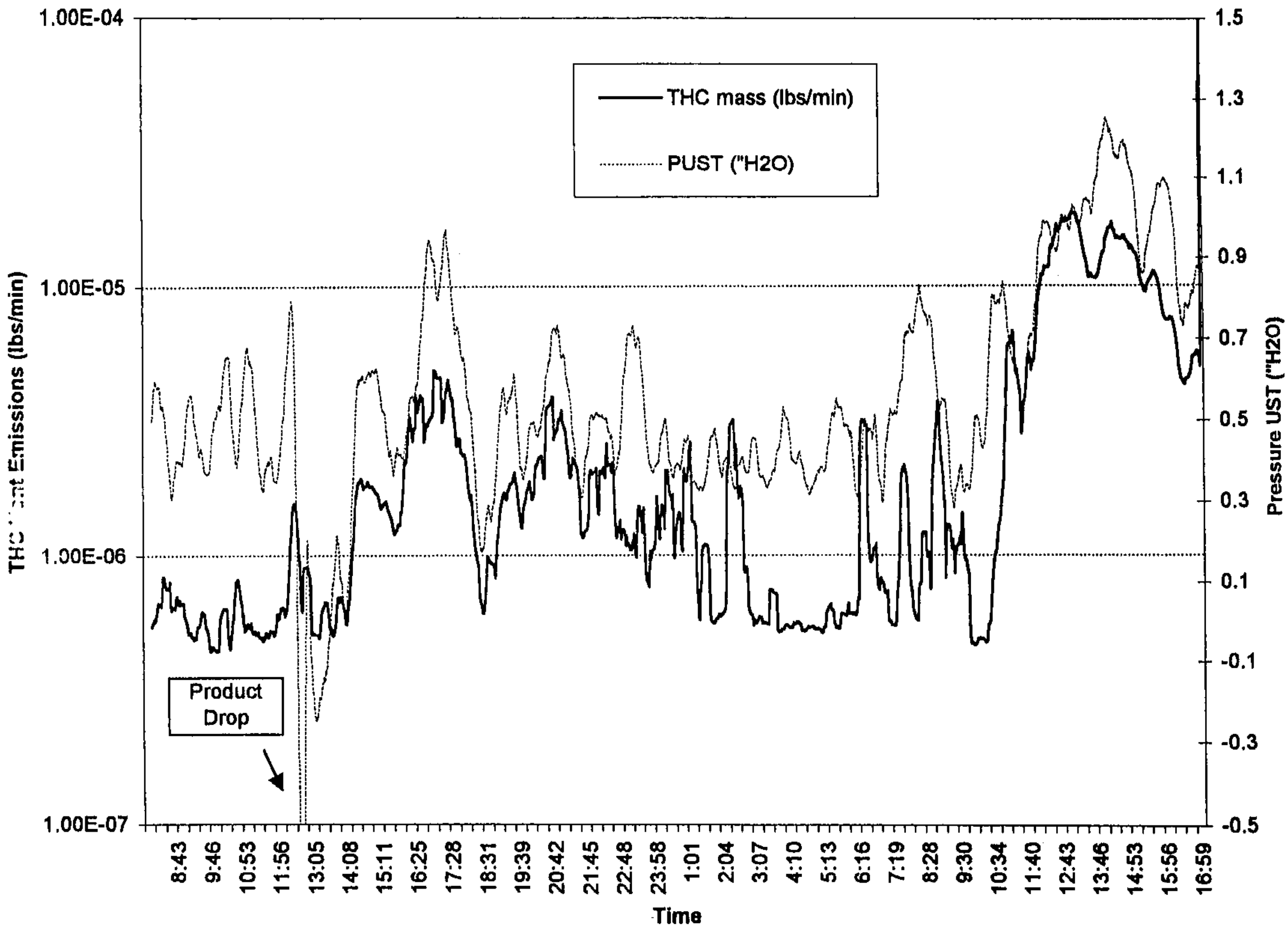


Figure 3-17 Gilbarco Vacuum Assist System 15 Minute Average Vent Emissions (lbs/min) and UST Pressure for 50% ORVR Penetration

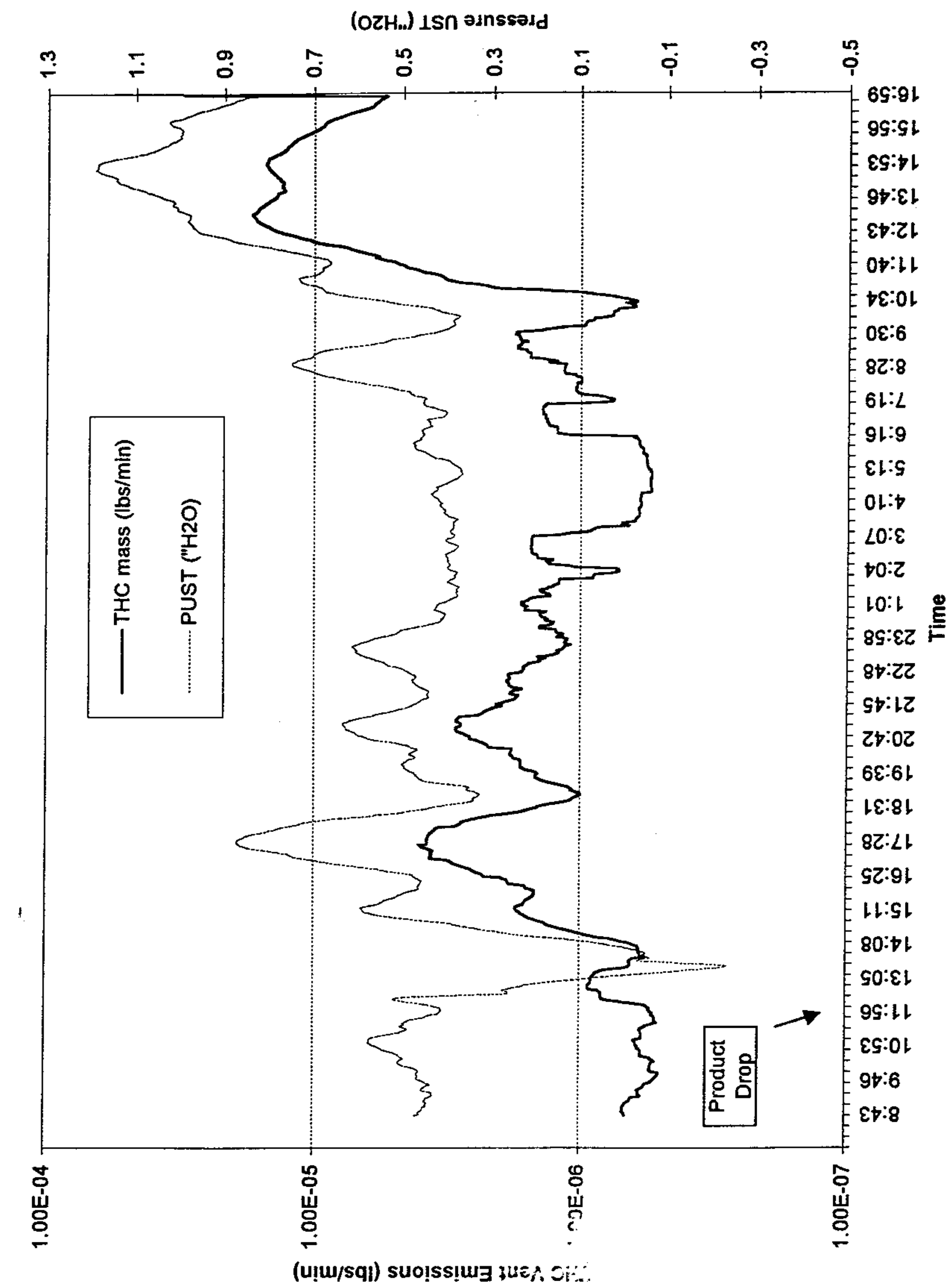


Figure 3-18 Gilbarco Vacuum Assist System 60 Minute Average Vent Emissions (lbs/min) and UST Pressure for 50% ORVR Penetration

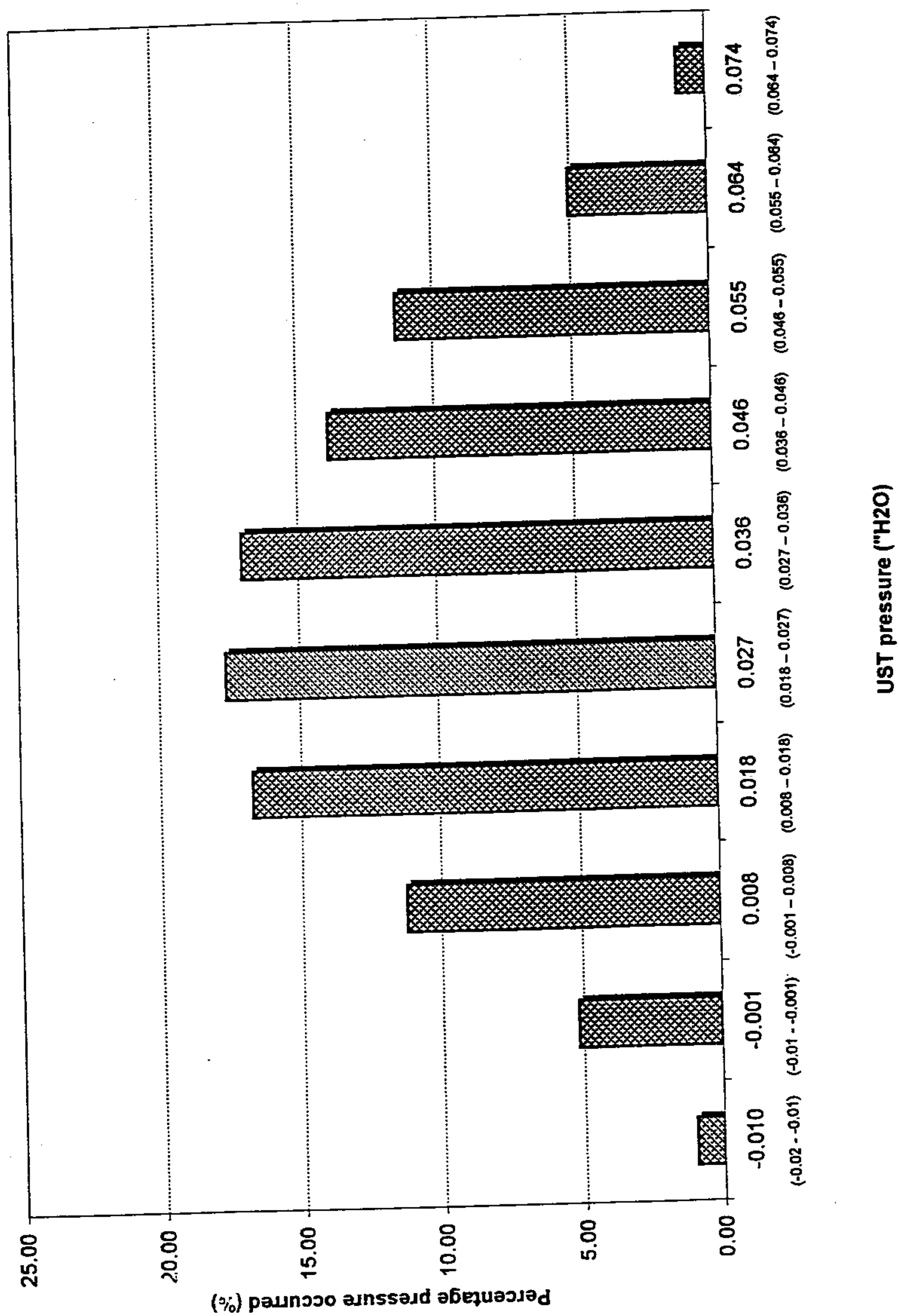


Figure 3-19 Gilbarco Vacuum Assist System UST Pressure Distributions 0% ORVR Penetration

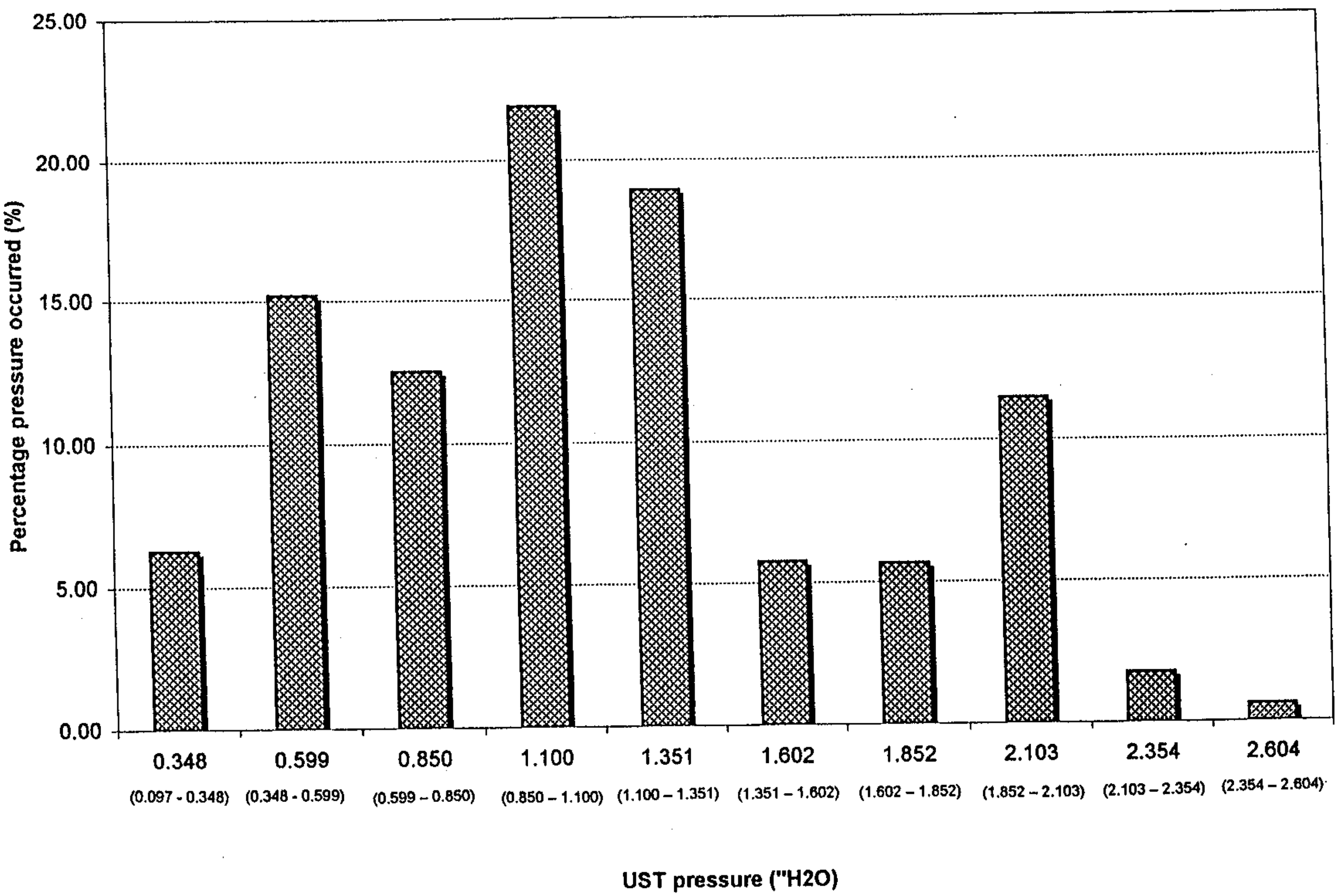


Figure 3-20 Gilbarco Vacuum Assist System UST Pressure Distributions 10% ORVR Penetration

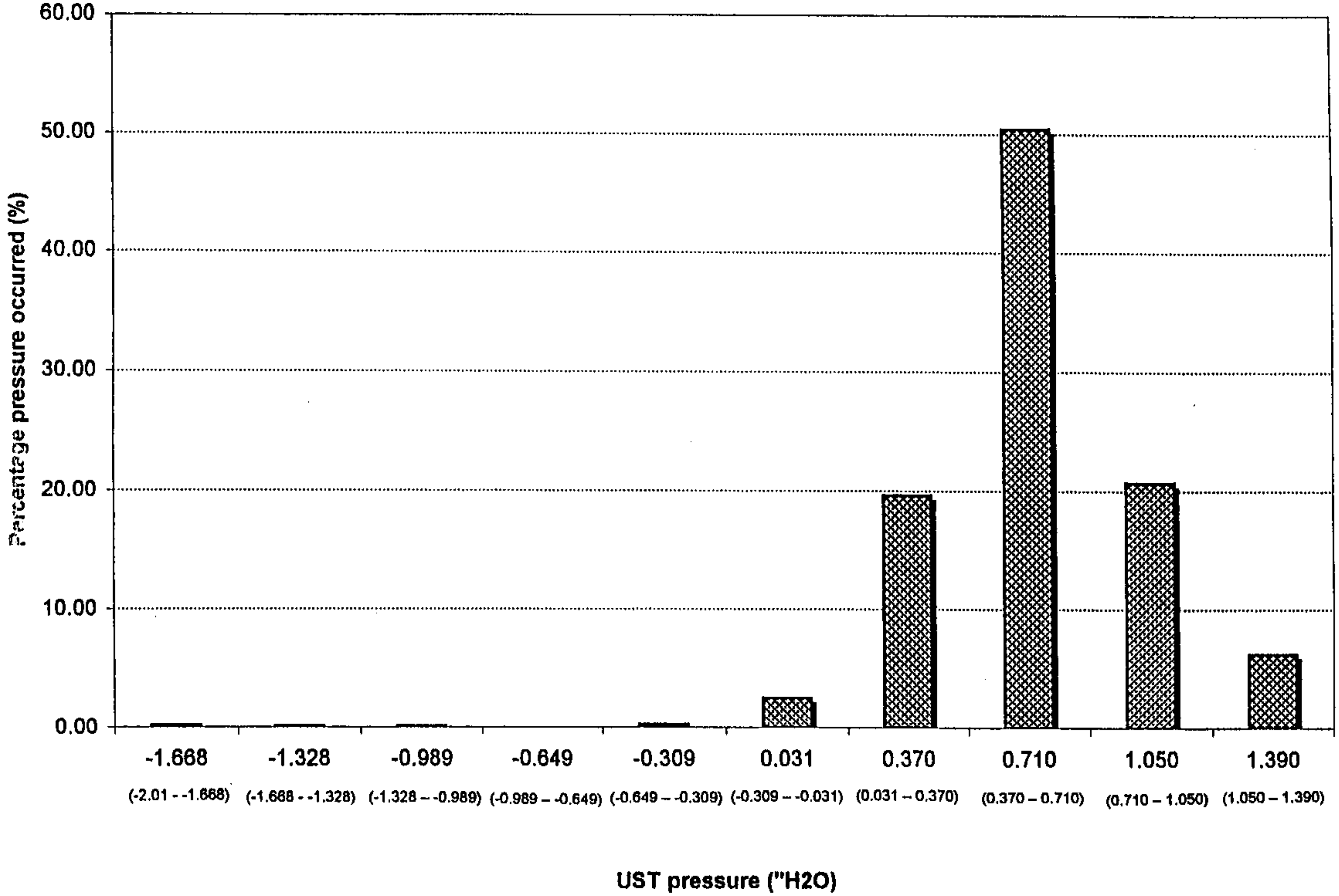


Figure 3-21 Gilbarco Vacuum Assist System UST Pressure Distributions 50% ORVR Penetration

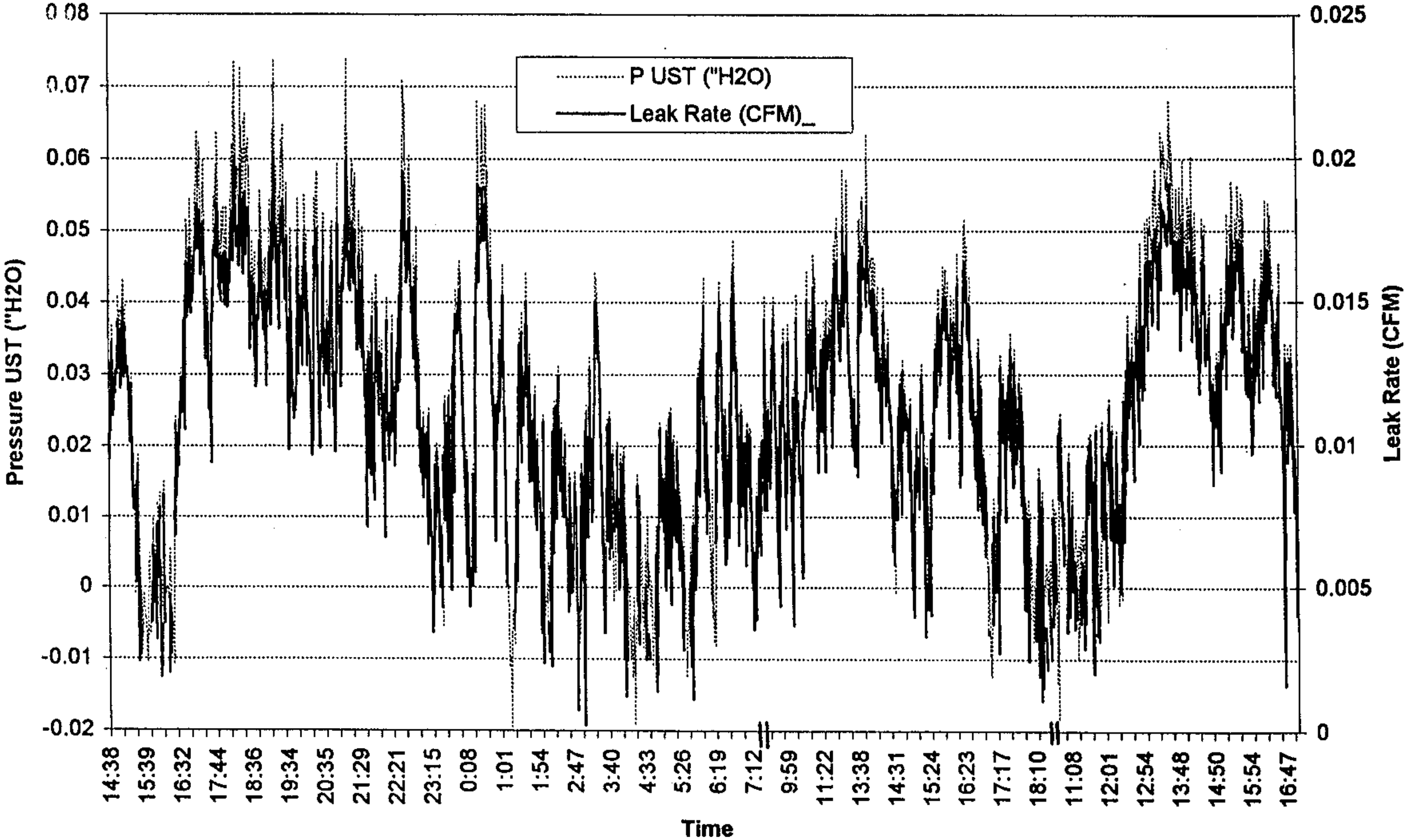


Figure 3-22 Gilbarco Vacuum Assist Leak Rate and UST Pressure for 0% ORVR Penetration*
***Sampling periods are not continuous**

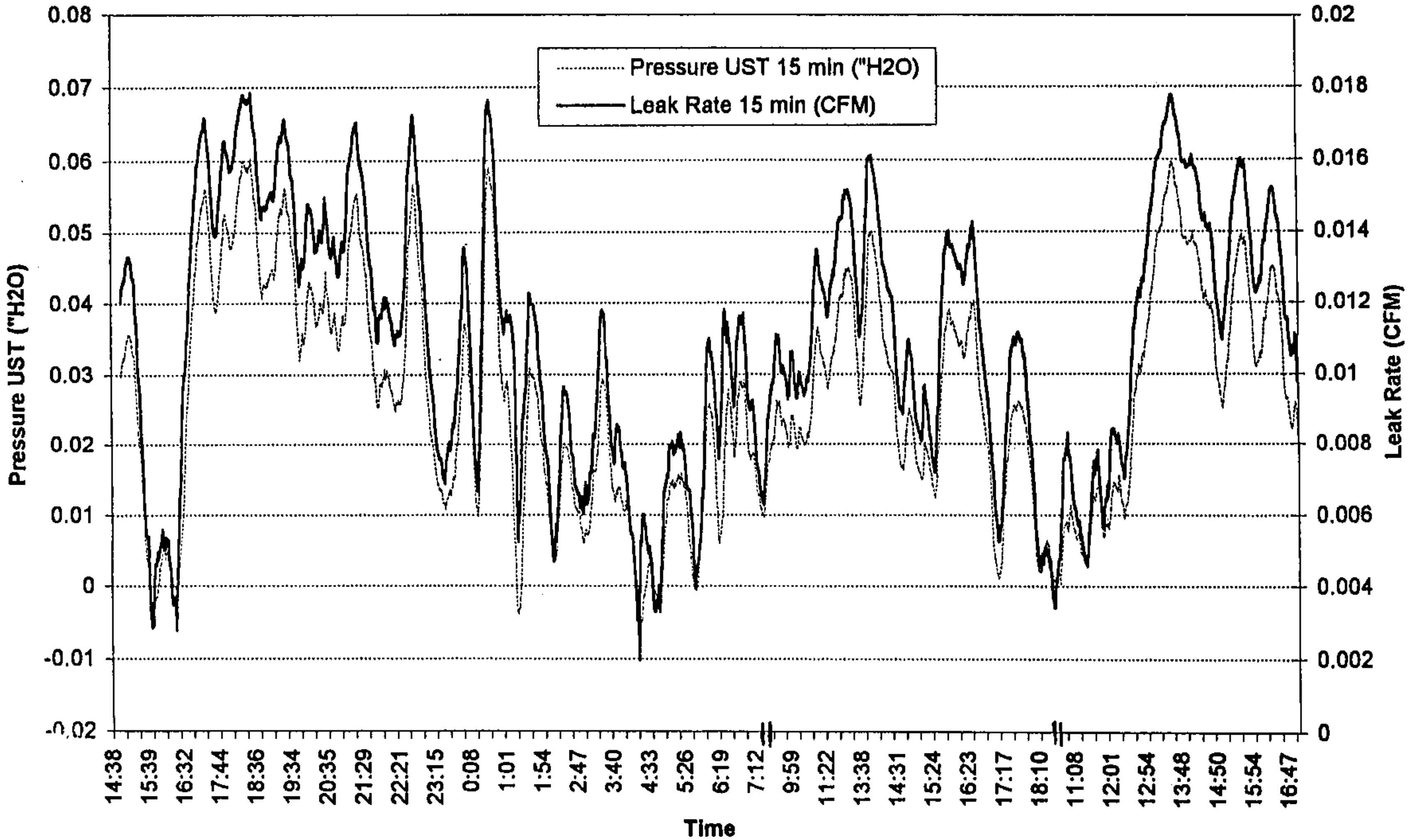


Figure 3-23 Gilbarco Vacuum Assist 15 Minute Average Leak Rate and UST Pressure for 0% ORVR Penetration*
***Sampling periods are not continuous**

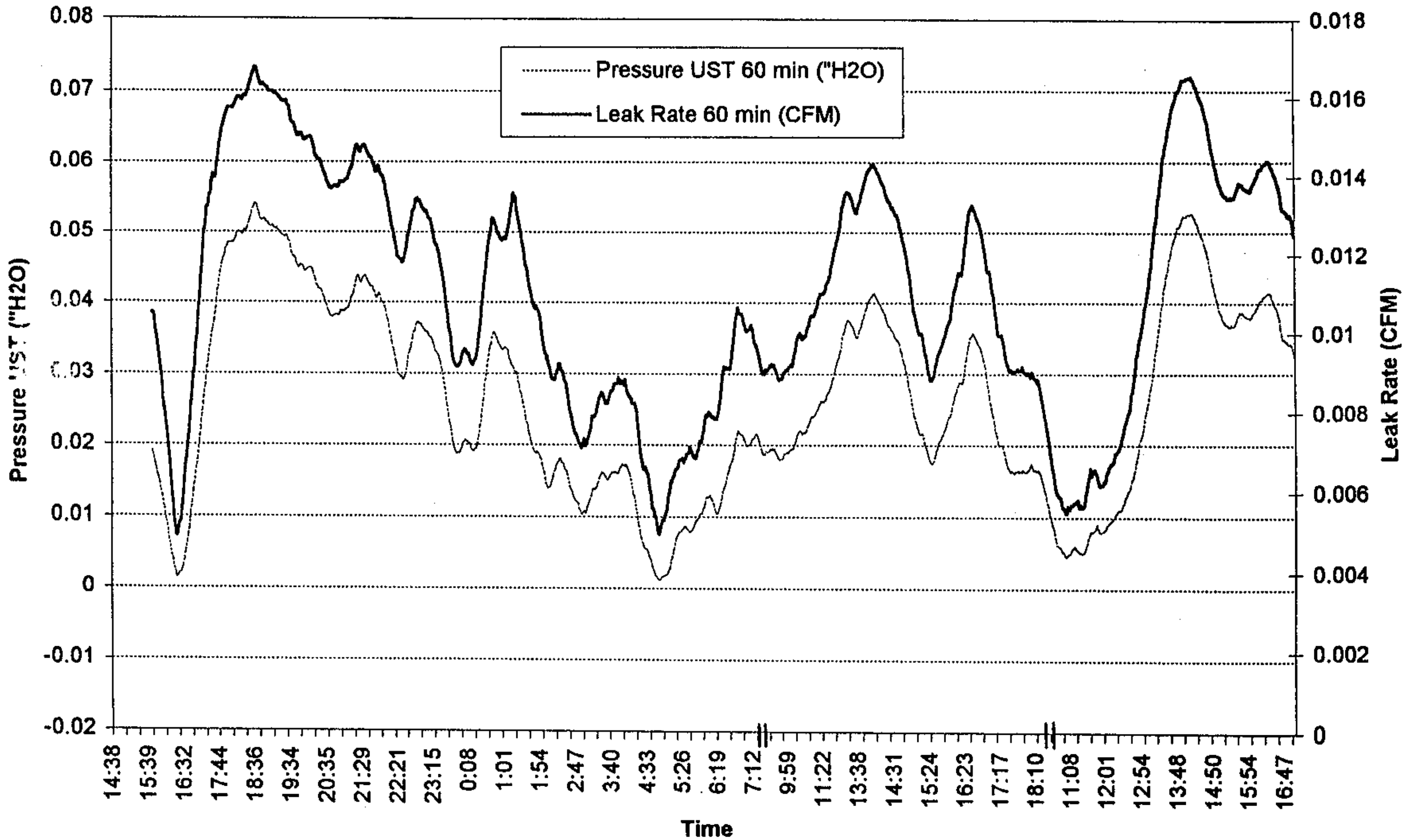


Figure 3-24 Gilbarco Vacuum Assist 60 Minute Average Leak Rate and UST Pressure for 0% ORVR Penetration*
***Sampling periods are not continuous**

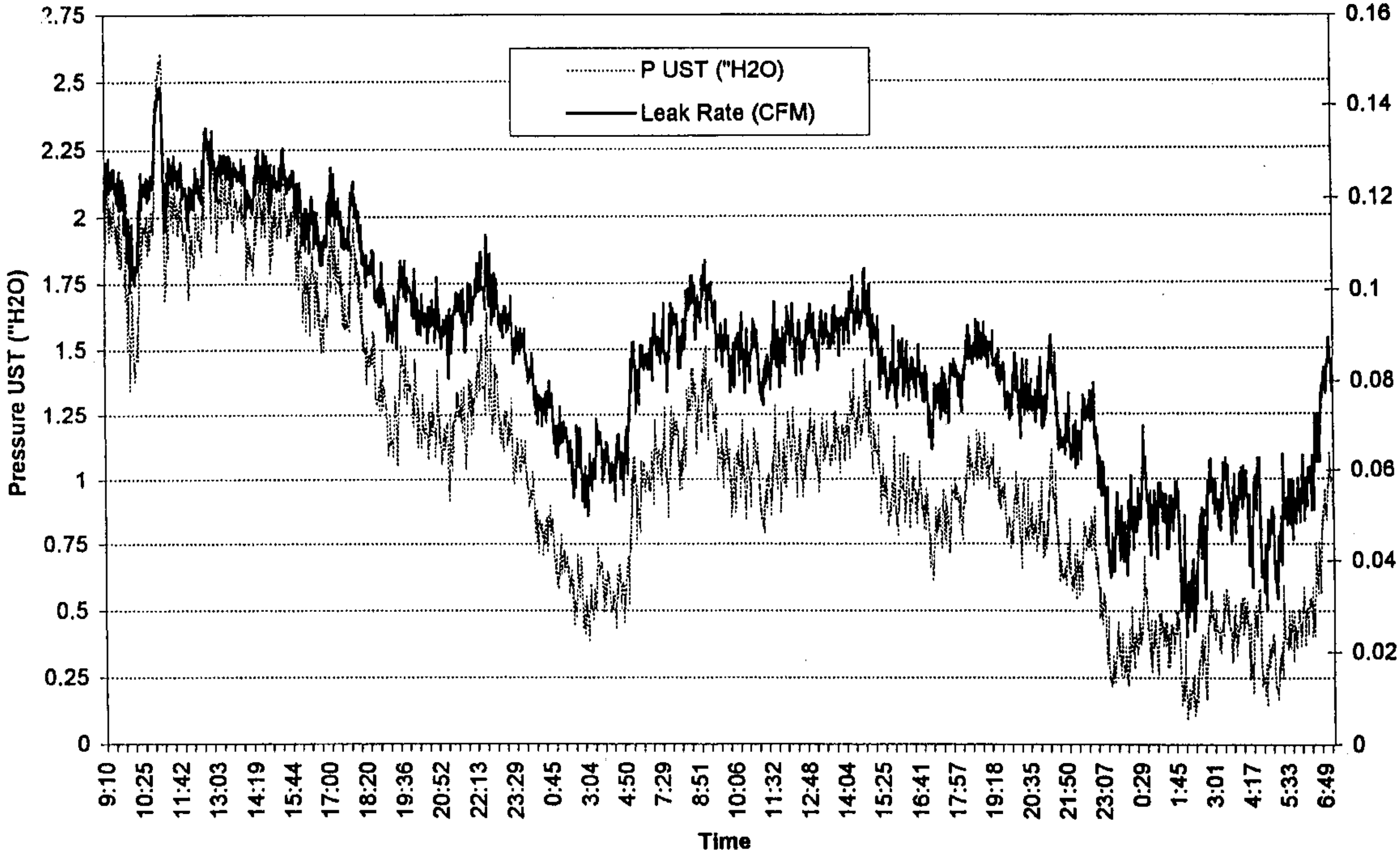


Figure 3-25 Gilbarco Vacuum Assist Leak Rate and UST Pressure for 10% ORVR Penetration

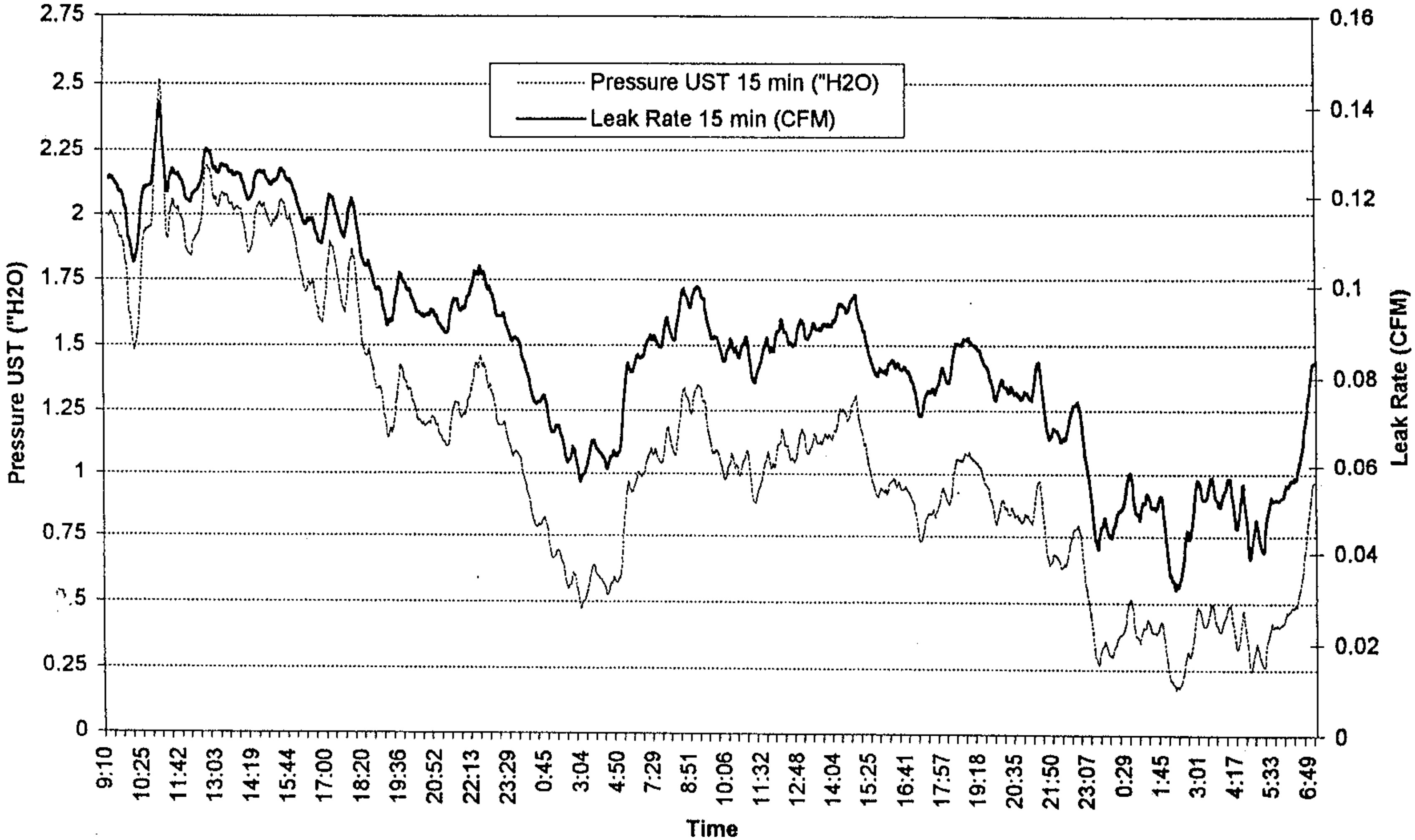


Figure 3-26 Gilbarco Vacuum Assist 15 Minute Average Leak Rate and UST Pressure for 10% ORVR Penetration

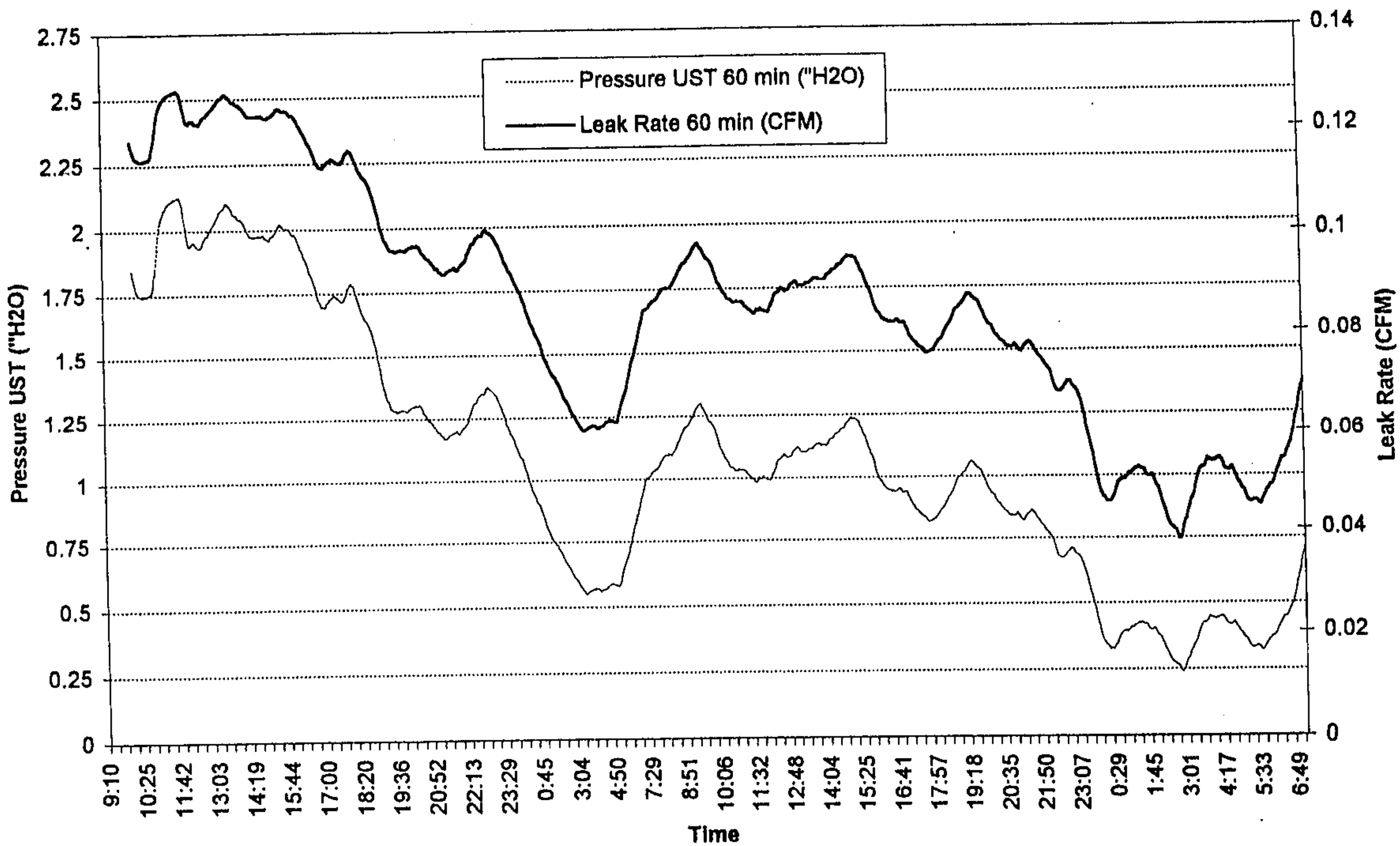


Figure 3-27 Gilbarco Vacuum Assist 60 Minute Averag[illegible]ak Rate and UST Pressure for 10% ORVR Penetration

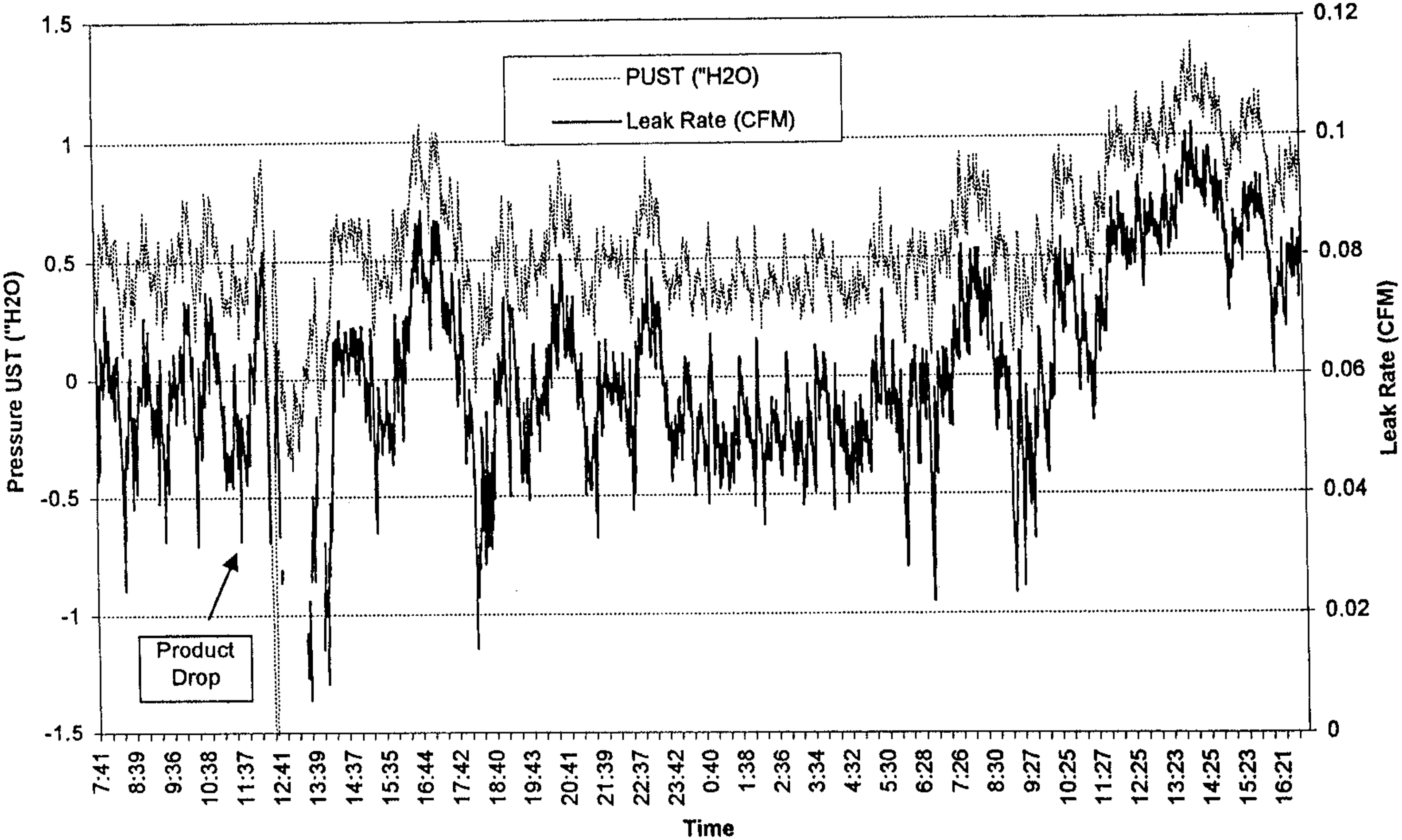


Figure 3-28 Gilbarco Vacuum Assist Leak Rate and UST Pressure for 50% ORVR Penetration*
***Negative pressures do not generate outflow values**

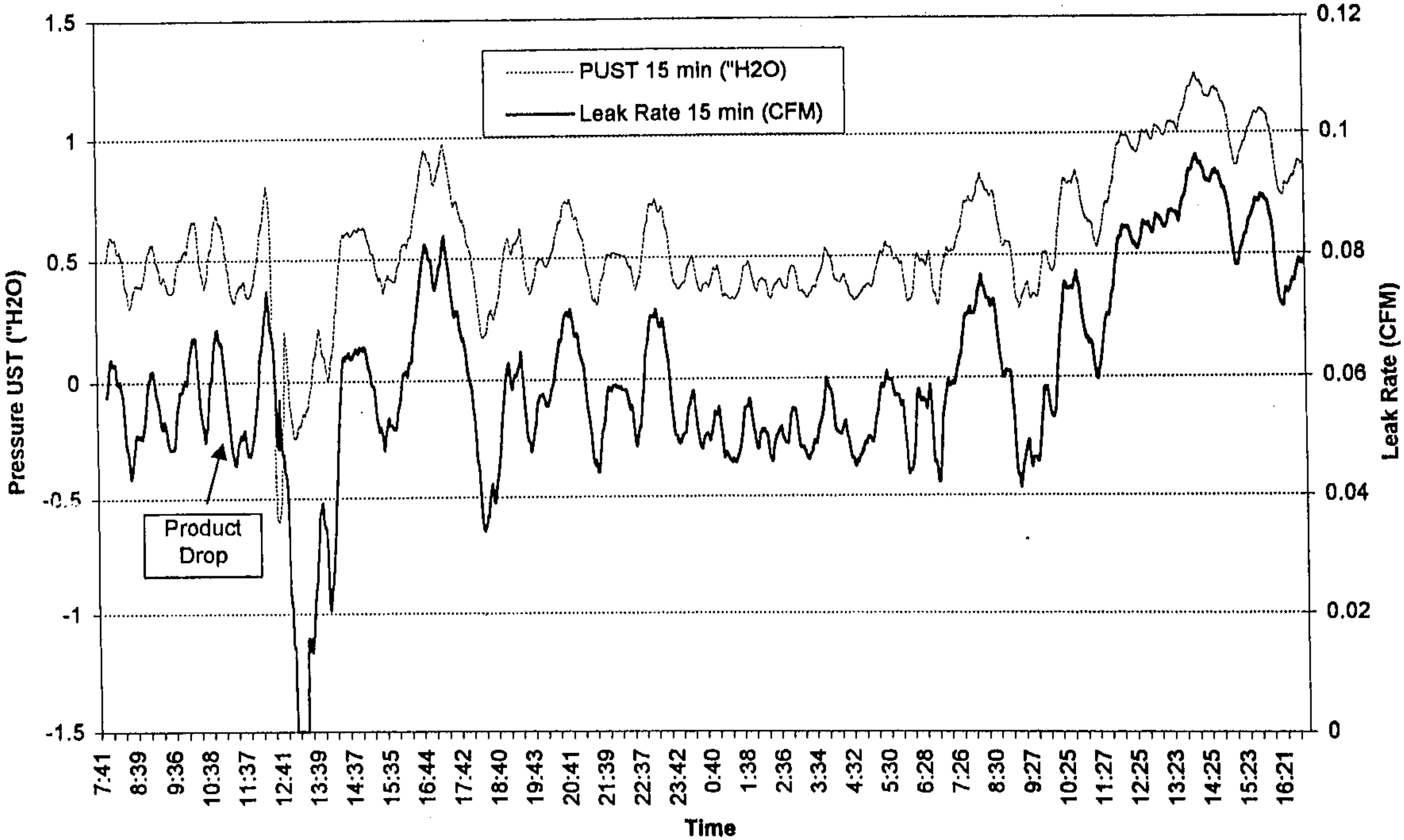


Figure 3-29 Gilbarco Vacuum Assist 15 Minute Average Leak Rate and UST Pressure for 50% ORVR Penetration*
***Negative pressures do [illegible] generate outflow values**

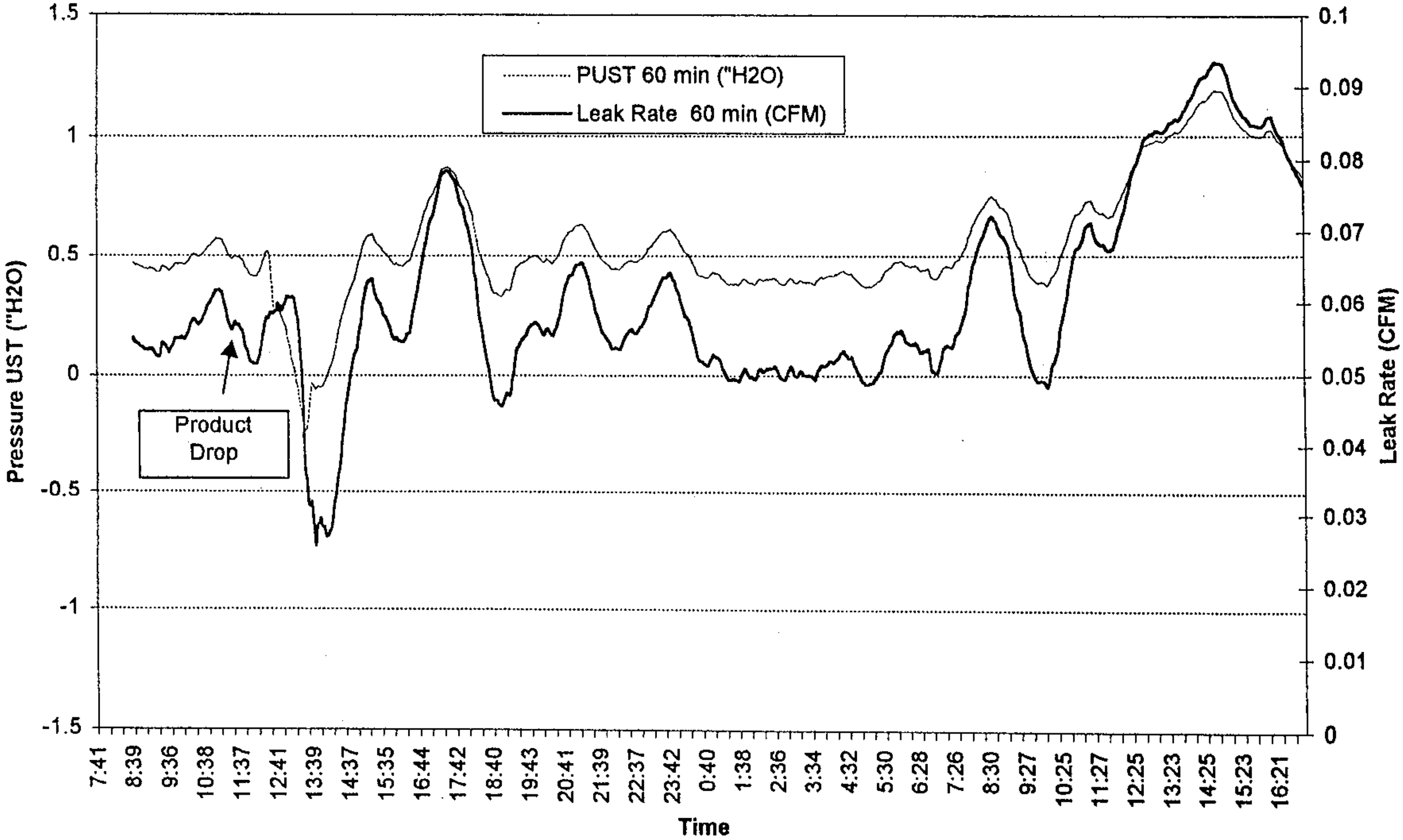


Figure 3-30 Gilbarco Vacuum Assist 60 Minute Average Leak Rate and UST Pressure for 50% ORVR Penetration

Table 3-1

Sampling, Product Delivery and System Integrity Check Schedule

ORVR Penetration	Date	Field Testing Time	ORVR Modified Dispenser Test Location	System Maintenance, Pressure Integrity & A/L Testing: Service Station Maintenance	System Maintenance, Pressure Integrity & A/L Testing: BAAQMD	Product Delivery Time 2/7/98	Product Delivery Time 2/10/98	Product Delivery Time 2/13/98
-	2/3	-	-	Testing Occurred	-	-	-	-
-	2/4	10:00 – 10:50 12:30 – 15:00	-	-	Testing Occurred	-	-	-
-	2/4	15:00-17:00		Maintenance Occurred	-	-	-	-
0%	2/5	14:38 – 24:00	-	-	-	-	-	-
0%	2/6	0:00 – 7:31	-	-	-	-	-	-
0%	2/6	9:26 – 18:55	-	-	-	-	-	-
0% Total 0% Testing Hours: 50	2/7	10:47 – 17:02	-	-	-	22:56	-	-
10%	2/10	9:10 – 24:00	Dispenser 2	-	-	-	6:29	-
10%	2/11	0:00 – 24:00	Dispenser 2	-	-	-	-	-
10% Total 10% Testing Hours: 46	2/12	0:00 – 7:05	Dispenser 2	-	-	-	-	-
50%	2/12	7:41 – 24:00	Dispenser 5 & 7	-	-	-	-	-
50% Total 50% Testing Hours: 33	2/13	0:00 – 17:01	Dispenser 5 & 7	-	-	-	-	11:40
-	2/17	11:20 – 12:15 12:30-3:00	All Locations	-	Testing Occurred	-	-	-

Table 3-2

Hydrocarbon Vent Emissions (ppm) for 0% ORVR
Descriptive Statistics

Statistics	Value
Mean	25.59
Standard Error	2.55
Median	
Mode	2.17
Standard Deviation	107.14
Sample Variance	11479.08
Kurtosis	61.25
Skewness	7.46
Range	1169.03
Minimum	0
Maximum	1169.03
Sum	45182.01
Count	1765

Table 3-3

Hydrocarbon Vent Emissions (ppm) for 10% ORVR
Descriptive Statistics

Statistics	Value
Mean	47.46
Standard Error	1.81
Median	21.31
Mode	0.88
Standard Deviation	90.77
Sample Variance	8240.39
Kurtosis	222.17
Skewness	11.79
Range	1999.52
Minimum	0.47
Maximum	2000
Sum	119841
Count	2525

Table 3-4

Hydrocarbon Vent Emissions (ppm) for 50% ORVR Descriptive Statistics

Statistics	Value
Mean	4.34
Standard Error	NR
Median	1.44
Mode	0.74
Standard Deviation	6.47
Sample Variance	41.92
Kurtosis	4.99
Skewness	2.30
Range	41.01
Minimum	0.024
Maximum	41.03
Sum	8438.50
Count	1944

Table 3-4

Hydrocarbon Vent Emissions (ppm) for 50% ORVR
Descriptive Statistics

Statistics	Value
Mean	4.34
Standard Error	NR
Median	1.44
Mode	0.74
Standard Deviation	6.47
Sample Variance	41.92
Kurtosis	4.99
Skewness	2.30
Range	41.01
Minimum	0.024
Maximum	41.03
Sum	8438.50
Count	1944

Table 3-5

Hydrocarbon Vent Emissions (mass) for 0% ORVR
Descriptive Statistics

Statistics	Value
Mean	1.772E-05
Standard Error	1.758E-06
Median	3.029E-06
Mode	NA
Standard Deviation	7.384E-05
Sample Variance	5.452E-09
Kurtosis	61.255
Skewness	7.466
Range	0.00081
Minimum	0
Maximum	0.00081
Sum	0.031
Count	1763

Table 3-6

Hydrocarbon Vent Emissions (mass) for 10% ORVR
Descriptive Statistics

Statistics	Value
Mean	3.37 E-5
Standard Error	1.3 E-6
Median	1.49 E-5
Mode	NA
Standard Deviation	6.51 E-6
Sample Variance	4.24 E-9
Kurtosis	225.57
Skewness	11.91
Range	0.0014
Minimum	2.13 E-7
Maximum	0.00144
Sum	0.085
Count	2524

Table 3-7

Hydrocarbon Vent Emissions (mass) for 50% ORVR
Descriptive Statistics

Statistics	Value
Mean	3.04 E-6
Standard Error	1.03 E-6
Median	1.49 E-5
Mode	NA
Standard Deviation	4.5 E-6
Sample Variance	2.03 E-11
Kurtosis	4.98
Skewness	2.30
Range	2.85 E-5
Minimum	1.7 E-8
Maximum	2.85 E-5
Sum	0.0059
Count	1944

Table 3-8

UST Pressure (" H_2O) for 0% ORVR
Descriptive Statistics

Statistics	Value
Mean	0.0266
Standard Error	0.0266
Median	0.262
Mode	0.0329
Standard Deviation	0.0181
Sample Variance	0.00033
Kurtosis	-0.723
Skewness	0.0648
Range	0.0932
Minimum	-0.0195
Maximum	0.0737
Sum	45182.013
Count	1765

Table 3-9

UST Pressure ("H_2O) for 10% ORVR
Descriptive Statistics

Statistics	Value
Mean	1.086
Standard Error	0.0105
Median	1.0433
Mode	NA
Standard Deviation	0.531
Sample Variance	0.283
Kurtosis	-0.557
Skewness	0.432
Range	2.507
Minimum	0.0975
Maximum	2.604
Sum	2743.917
Count	2525

Table 3-10

UST Pressure ("H_2O) for 50% ORVR
Descriptive Statistics

Statistics	Value
Mean	0.556
Standard Error	NR
Median	0.525
Mode	NA
Standard Deviation	0.307
Sample Variance	0.0946
Kurtosis	8.0259
Skewness	-1.006
Range	3.397
Minimum	-2.007
Maximum	1.389
Sum	1082.489
Count	1944

Table 3-11
Gilbarco Vacuum Assist System Vent Line Emissions Data

% ORVR	Total Hydrocarbons (pounds)	Sampling Time (Minutes)	Gasoline Throughput[1] (Gallons)	Emission Factor (lbs/1000 gal)
0%	0.0313	1764	6030	0.00518
10%	0.0844	2545	8573	0.00985
50%	0.00752	1955	6787	0.00111

1. Gallons dispensed are only for times that actual emissions testing occurred.

Table 3-12

Evaluation of Hydrocarbon Concentration as a Function of UST Pressure (0% ORVR)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.122761813
R Square	0.015070463
Adjusted R Square	0.014511796
Standard Error	106.3602601
Observations	1765

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	305163.4533	305163.5	26.97576	2.29894E-07
Residual	1763	19943946.21	11312.5		
Total	1764	20249109.66			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	6.327939324	4.491782979	1.408781	0.159076	-2.481847105	15.13772575	-2.4818471	15.13772575
X Variable 1	723.8385996	139.365369	5.19382	2.3E-07	450.4996733	997.177526	450.499673	997.177526

Table 3-13

Evaluation of Hydrocarbon Mass Release as a Function of UST Pressure (0% ORVR)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.124303399
R Square	0.015451335
Adjusted R Square	0.014892567
Standard Error	2.41243E-06
Observations	1764

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.60933E-10	1.61E-10	27.65252	1.62884E-07
Residual	1762	1.02545E-08	5.82E-12		
Total	1763	1.04154E-08			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.34823E-07	1.01937E-07	1.322609	0.186137	-6.51073E-08	3.34752E-07	-6.51073E-08	3.34752E-07
X Variable 1	1.66272E-05	3.16193E-06	5.258566	1.63E-07	1.04257E-05	2.28288E-05	1.04257E-05	2.28288E-05

Table 3-14

Evaluation of Hydrocarbon Concentration as a Function of UST Pressure (10% ORVR)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.594413549
R Square	0.353327468
Adjusted R Square	0.353071157
Standard Error	73.01336896
Observations	2525

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	7348776.056	7348776	1378.511	4.0265E-241
Residual	2523	13449992.01	5330.952		
Total	2524	20798768.07			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	-62.76668814	3.305352713	-18.9894	2.9E-75	-69.24817727	-56.285199	-69.248177	-56.285199
X Variable 1	101.4341664	2.731990256	37.1283	4E-241	96.07698773	106.791345	96.0769877	106.791345

Table 3-15

Evaluation of Hydrocarbon Mass Release as a Function of UST Pressure (10% ORVR)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.592301433
R Square	0.350820988
Adjusted R Square	0.350563581
Standard Error	5.24762E-05
Observations	2524

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3.7531E-06	3.75E-06	1362.907	6.6033E-239
Residual	2522	6.94495E-06	2.75E-09		
Total	2523	1.06981E-05			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	-4.50904E-05	2.37588E-06	-18.9784	3.5E-75	-4.97492E-05	-4.04E-05	-4.975E-05	-4.0431E-05
X Variable 1	7.24906E-05	1.96358E-06	36.91757	6.6E-239	6.86402E-05	7.634E-05	6.864E-05	7.6341E-05

Table 3-16

Evaluation of Hydrocarbon Concentration as a Function of UST Pressure (50% ORVR)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.199485938
R Square	0.03979464
Adjusted R Square	0.039302983
Standard Error	25.30544487
Observations	1955

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	51831.12624	51831.13	80.93991	5.37015E-19
Residual	1953	1250633.899	640.3655		
Total	1954	1302465.026			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-4.05868943	1.186312492	-3.421265	0.000636	-6.38526153	-1.732117328	-6.385261532	-1.732117328
X Variable 1	16.73319607	1.859934086	8.996661	5.37E-19	13.0855309	20.38086123	13.0855309	20.38086123

Table 3-17

Evaluation of Hydrocarbon Mass Release as a Function of UST Pressure (50% ORVR)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.198877262
R Square	0.039552166
Adjusted R Square	0.039060385
Standard Error	1.86938E-05
Observations	1955

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	2.81055E-08	2.81E-08	80.42642	6.89223E-19
Residual	1953	6.82488E-07	3.49E-10		
Total	1954	7.10594E-07			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-3.03937E-06	8.76358E-07	-3.46818	0.000535	-4.75807E-06	-1.321E-06	-4.75807E-06	-1.32067E-06
X Variable 1	1.23219E-05	1.37398E-06	8.968078	6.89E-19	9.62733E-06	1.5017E-05	9.62733E-06	1.50166E-05

Table 3-18

System Average Leak Rate (cfm) for 0% ORVR Descriptive Statistics

Statistics	Value
Mean	0.0113
Standard Error	0.0001
Median	0.0117
Mode	0.0128
Standard Deviation	0.00405
Sample Variance	1.64 E-5
Kurtosis	-0.617
Skewness	-0.316
Range	0.0198
Minimum	0.000186
Maximum	0.0199
Sum	18.612
Count	1639

Table 3-19

System Average Leak Rate (cfm) for 10% ORVR Descriptive Statistics

Statistics	Value
Mean	0.0860
Standard Error	0.000493
Median	0.0869
Mode	NA
Standard Deviation	0.0248
Sample Variance	0.000613
Kurtosis	-0.6375
Skewness	-0.0308
Range	0.121
Minimum	0.0233
Maximum	0.1444
Sum	217.327
Count	2525

Table 3-20

System Average Leak Rate (cfm) for 50% ORVR Descriptive Statistics

Statistics	Value
Mean	0.0605
Standard Error	NR
Median	0.0591
Mode	NA
Standard Deviation	0.01520
Sample Variance	0.000231
Kurtosis	0.178
Skewness	0.125
Range	0.0964
Minimum	0.00549
Maximum	0.10189
Sum	109.312
Count	1806

Table 3-21

Empirical Fugitive Emissions

Percent ORVR Simulation	Average Leak Rate (cfm)	Average Vent Hydrocarbon Concentration[1,2] (%C3-H8)	Average Fugitive Emission Factor (lb/1000 gallon)
0	0.0113	34.3	0.1210
10	0.0860	ND	ND
50	0.0605	20.5	0.4031

1. Measured hydrocarbon concentrations provided by the California Air Resources Board (ARB, 1999)
2. The CARB study simulated 45% ORVR compared to 50% ORVR simulated during the current AVES study.

Table 3-22

Calculated and Predicted Fugitive Emissions

% ORVR Simulation	ARB Measured HC Concentration (vol % as C_3)	Predicted HC Concentration: CARB Data[1] & Linearity Assumption[2] (vol % as C_3)	Average Fugitive Emission Factor: AV Flow Data[3] & Predicted HC Concentration[4] (lb/1000 gallon)	Average VRS Efficiency Loss[5] (%)
0 (AVES & CARB)	34.3 %	34.3%[1]	0.1210[3]	1.4
10 (AVES)	ND	31.2%[2]	0.9103[4]	10.8
45 (CARB)	20.5%	20.5%[1]	NA	NA
50 (AVES)	ND	17.4%[1]	0.3421[3]	4.1

5. Assumes an uncontrolled emission factor of 8.4 lb/1000

Table 3-23

Summary of Calculated Empirical and Modeled Emissions

Percent ORVR Simulation	Average Fugitive Emission Factor (lb/1000 gallon)	Average Vent Line Emission Factor (lb/1000 gallon)	Average Total Emission Factor (lb/1000 gallon)	Average VRS Efficiency Loss[1] (%)
0	0.1210[2]	0.00518[2]	0.1262[2]	1.43
10	0.9103[3]	0.00985[2]	0.9202[4]	10.95
50	0.4031[2]	0.00111[2]	0.4042[2]	4.81

1. Assumes an uncontrolled emission factor of 8.4 lb/1000 gallons
2. Calculated using empirical data
3. Calculated using modeled data
4. Calculated using empirical and modeled data

Section 4

DISCUSSION

4.1 SYSTEM EMISSIONS

For the tested Gilbarco vacuum assist vapor recovery system, pressure related fugitive emissions dominated the emission releases at the tested field location. Observed calculated fugitive emissions appear to be associated with the degree of ORVR simulation. The fugitive emission rate was larger by almost a factor of four for the 50% ORVR simulation conditions compared to the 0% ORVR simulation values (i.e., 0.4031 vs. 0.1210 lb/1000 gallons respectively). These values are in the same range as those reported by ARB (ARB, 1999) even though the ARB testing was conducted in the summer as opposed to the current study's winter testing schedule. One would expect different emission factors due to fuel RVP and ambient temperature differences between summer and winter conditions. The introduction of the predicted 10% ORVR simulation fugitive emission factor (0.9103 lb/1000 gallons) suggests that ORVR penetration effects are not linear but may reach an early maximum effect. The basis of this hypothesis is that the early penetration (10%) ORVR fugitive emission factor is over two times larger that the 50% ORVR emission factor.

It is important to recognize that pressure releases and therefore fugitive emissions are allowed for vapor recovery systems as specified in the ARB static pressure test methodology. A given amount of fugitive emissions are therefore predicted based on the outflow curves generated by the static pressure decay characteristics data. The most important fugitive sources relative to their emissions release potential will be determined by the pressure release characteristics at each fugitive emissions source.

Fugitive emission release rates can be influenced by the heterogeneity of vapor saturation in system air parcels. For example, specific fugitive emission sources (e.g., UST fittings) can have greater emission releases due to greater fuel air saturation of vapors proximal to the fugitive emission source compared to other fugitive emission release sources (e.g., P/V valves). Clearly, with increased fuel air vapor saturation, hydrocarbon release rates will be larger. Vapor saturation is influenced by many factors including proximity to product, aging, and the influence of fresh air inflow/outflow breathing. The complexity of modeling these phenomena imposed restrictions on resolving the precise influence of vapor saturation on fugitive emission releases.

The hypothesized relationship that vent line emissions will increase with higher refueling frequencies of ORVR equipped vehicles was not consistently observed in this project. Compared to baseline vent line emission levels, the 10% ORVR penetration experimental condition did see an increase in vent line emissions. However, vent line emissions for the 50% ORVR penetration field conditions did not increase relative to both baseline and 10% ORVR penetration. The lack of an observed correlation between vent line emissions and ORVR penetration (i.e., UST pressure) could have been caused by the changing proportion of vent line emissions to total fugitive emission from the 30-40 potential leak sources (e.g., nozzles, Stage I and II fittings, P/V valves) at different system pressures. Vent line emissions can also be expected to vary when (1) there is less vapor volume emitted from the vent line riser or (2) the released vapor volumes do not change but are leaner with respect to hydrocarbon concentration.

The dominance of the fugitive emission factors compared to the vent line emission factors (Table 3-23) could account for the low vent line emissions. For this study, P/V valves (i.e., vent line emissions) are considered a fugitive emission source as is the case in previous ARB research studies targeting gasoline dispensing facility emissions. However, they are reported as a separate emission point for this report. Based on the measured vent lines emissions and the total calculated fugitive emission factor, the sum of all other fugitive emission sources (apart from P/V valves) are more important in accounting for total fugitive emission releases than is the contribution of vent line/P/V valves to fugitive releases. This can be attributed to the pressure release potential of other dominant fugitive sources and the fact that P/V valves are not designed to release significant quantities of emissions until their cracking pressure design valve is reached (3 inches W.C. ± 0.5 inches). The system pressure conditions for the 10% ORVR simulation event were the only pressure values that approached the P/V valve cracking pressure thresholds during this research program. The larger vent line emission factor for 10% ORVR penetration can be attributed to these higher system pressure values. For the other field conditions (0% and 50% ORVR), vent line emissions were limited due to a lack of P/V valve hydrocarbon releases.

The 1999 ARB ORVR simulation refueling study provides the closest data set for comparison with the current study vent line emission factors. The average control emission factor (0% ORVR simulation) generated by the ARB study was 0.000241 pounds/1000 gallons. This value is smaller than the current study average control vent line emission factor of 0.0052 pounds/1000 gallons. For the 50% ORVR simulation condition (ARB used 45% ORVR simulation), the ARB average vent line emission value was 0.114 pounds/1000 gallons, though a range of 0.000245-0.245 pounds was reported. The smaller value was recorded at the onset of the 50% ORVR simulation testing. The vent line emission factor increased over a five day test period to 0.222. These values are contrasted to the 0.0011 pounds/1000 gallons average vent line emission factor for the 50% ORVR simulation condition generated in the research program described in this report. The range of ARB 50% ORVR values underscores the importance of a field test program with a duration of at least five days to adequately describe ORVR impacts on gasoline dispensing facility emissions.

The magnitude of total system empirical and predicted emission factors (0.1262, 0.9202 and 0.4042 lb/1000 gallons for the 0%, 10%, and 50% ORVR simulation conditions, respectively) are smaller than previously reported field and theoretical work. The ARB theoretical study (1994) predicted a vacuum assist total emission factor of 2.90 pounds/1000 gallons during the refueling of ORVR equipped vehicles. While the

2.9 lb/1000 gallons is a worst case theoretical value based on the assumption that all air introduced into the UST will reach a saturation concentration in equilibrium with the stored liquid, this value is larger by one order of magnitude compared to the ORVR simulation emission factors calculated with the current study data set. The 1999 ARB ORVR simulation study reported total average GDF emissions of 0.2583 and 0.7929 pounds/1000 gallons for the 0% and 45% ORVR simulations conditions respectively. These values are roughly two times the emitted total GDF hydrocarbon emissions observed during this study.

The impact of product deliveries on vent line and fugitive emissions is not consistently apparent from the project data set. Product drops are correlated with increases in system pressure that in turn generate larger releases of vent line and fugitive emissions when compared to non-product delivery conditions. However, the magnitude of these increases is not the same for each product delivery event. The hypothesis that product drop emissions are related to product delivery volume was not supported by the project. Each product delivery event consisted of approximately 9,000 gallons.

Whether product deliveries will increase system emissions is partially a function of whether Stage I emission reduction methodologies are adhered to. Incorrectly connecting Stage I vapor recovery system hoses (i.e., improper order of hose connections or loose connections) can yield increases in system pressure which in turn impacts vapor recovery systems emission releases. It is unknown how consistent the Stage I emission reduction methodologies are applied by tank truck operators. Given the range of sequences that Stage I vapor hoses can be connected to both the tank trucks and the Stage I UST fittings, the degree of system pressure buildup attributed to the correct or incorrect application of Stage I methodologies can be highly variable. However, even if Stage I emission technology is properly used, pressure buildup does appear to occur during product drops which may have a concomitant impact on system emission releases. Pressure buildup due to product drops is not a universal phenomenon. The ARB 1996 ORVR study demonstrated pressure reductions during product deliveries.

The lack of a predictable relationship between ORVR simulation and vent line or fugitive emissions can be attributed to a variety of factors which underscores the complexity of trying to generate realistic or predictable emission factors for gasoline dispensing facilities. The driving forces that govern the magnitude of hydrocarbon emission releases at gasoline dispensing facilities include:

<u>Product Throughput</u>

Tank throughput
Product turnover rate
Fuel delivery and dispensing profile
Initial fuel vapor space ullage volume
Initial fuel volume

Vent line volume

Temperature

Diurnal temperature variation
Temperature of fuel delivered to tank
Temperature of fuel in UST

System Parameters

Elevation of vent line outlet above UST
Slope of UST
Tank diameter
Tank volume
UST gauge pressure

Fuel Characteristics

Fuel air saturation
Fuel Reid Vapor Pressure (RVP)
Saturated vapor concentration

Meteorological Characteristics

Local wind velocity profile
Local barometric pressure changes

Control Technology

Phase I vapor recovery system efficiency
Phase II vapor recovery system efficiency
Vapor/Liquid ratio for Phase II refueling
Pressure/Vacuum (P/V) valve efficiency

To adequately understand emission releases from GDF vent lines or other fugitive sources would require controlling for the dominant variables that influence hydrocarbon emissions. However, the focus of this research project was not a comprehensive evaluation assessment of hydrocarbon releases but rather an attempt to explore what impact ORVR equipped cars have on vent line or fugitive emissions. Given the range of factors that can influence GDF system emissions, one possibility in trying to understand the results of this project is that, for the 50% ORVR simulation condition (relative to 10% ORVR), there may have been system leaks which would reduce the amount of emission releases at the vent line (i.e., other fugitive emission sources diffused the impact of the vent line releases).

The post-measurement static pressure test executed by the BAAQMD did pass the appropriate criteria relative to system tightness. However, reviewing the pressure release data for the pre- and post-test static pressure tests, there was a modest increase in pressure release rate for the post-ORVR simulation static pressure test compared to the pre-ORVR simulation static pressure test. The magnitude of the fugitive emission factor and leak rates (Q) for the 50% ORVR simulation time frame compared to the 0% ORVR and 10% simulation test periods also suggest that (1) fugitive emissions (e.g., leaks) are greater for the 50% ORVR simulation condition than for the 0% baseline condition and (2) the leak rate for the 50% ORVR simulation is smaller than the 10% ORVR simulation leak rate. This could result in smaller vent line emissions for the 50% ORVR simulation condition. Whether these factors could account for the large differences in 50% ORVR simulation vent line emission factor compared to the 0% and 10% ORVR simulation testing cannot be definitely determined.

A second possibility is that the sample period for each experimental condition (i.e., baseline, 10% ORVR, 50% ORVR) may have been too short to adequately investigate the variance implicit in complex systems such as vapor recovery systems. The control sampling time (0% ORVR) was 27 hours while the 10% ORVR and 50% ORVR penetration condition sampling duration was approximately 46 hours and 34 hours respectively. Based on the observations from the current study, the follow-up ORVR field measurement program executed by ARB did consider this factor when designing the field measurement protocol. Five days of baseline measurement followed by 6 days of 50% ORVR penetration measurement were used to evaluate the impact of ORVR equipped vehicles on refueling vent line emissions. Using this methodology, a relationship in the hypothesized direction was observed between vent line emissions and ORVR equipped vehicles. In addition, the 50% ORVR vent line emission factor increased by at least two orders of magnitude over the six day sampling period. During the first two days of the sampling period, however, the observed vent line emission factors were in the same range as those reported in this study.

A third possibility is that ORVR impacts on GDF emissions reach a maximum rather than emulating as a linear function. The project data suggest that refueling ORVR equipped vehicles will trigger greater releases of fugitive emissions. Based on (1) the similarity of the leak rate values for both the 10% and 50% ORVR simulation conditions and (2) the predicted 10% ORVR simulation and calculated 50% ORVR simulation emissions factors, the impact of increased ORVR penetration at vacuum assist VRS equipped sites may not necessarily trigger a concomitant increase in fugitive emissions. Rather an emissions maximum may be reached during the early penetration of ORVR vehicles above which fugitive emissions will not rise proportional to the introduction of ORVR vehicles into the on-road vehicle fleet. A possible hypothesis to account for this behavior is that at higher levels of ORVR penetration, return air to the UST occurs at rates faster than gasoline evaporation can saturate this air with gasoline vapor. At higher throughput, static pressure does not have time to saturate. This yields a scenario where vapor concentrations are lower for high levels of

ORVR penetration compared to the early introduction of ORVR vehicles into the on-road vehicle fleet.

It is unclear what the impact of refueling new ORVR equipped cars (as opposed to simulated ORVR refueling) had on the observed vent line and fugitive emission factors. There was roughly the same amount of ORVR equipped cars refueled during the 10% and 50% ORVR simulation test conditions (42 and 38 vehicles respectively). If one assumes an average fill up of ten gallons (total fuel throughput for the 10% and 50% was 8573 and 6787 gallons), total vehicles fueled during 10% ORVR simulation was 857 and 687 for the 50% simulation condition. Therefore, approximately 6-7% of the vehicles refueled during the 10% and 50% conditions were ORVR equipped vehicles (e.g., 42/857=6%). Accounting for the fact that these vehicles in part refueled at the ORVR simulation dispensers (thus offsetting the ORVR simulation impacts), the 10% and 50% ORVR simulation values may have been marginally larger with respect to ORVR penetration.

One interesting observation relative to the numbers of ORVR equipped cars refueled during this project is the data generated by current efforts to track the refueling behavior of ORVR equipped vehicles in the existing auto fleet. These data suggest that current ORVR vehicle penetration is 6-8% based on site surveys at vapor recovery system manufacturer's test sites. This value has not been independently validated nor has it been investigated with respect to factors that could skew the numbers of refueling ORVR vehicles at specific refueling sites (i.e., proximity to airports or new rental car fleet locations). Notwithstanding the lack of data validation, the 6-8% ORVR penetration value is considerably higher than what was predicted several years ago for 1999-2000 time frame (2-3% ORVR penetration).

4.2 PRESSURE DATA

While a linear relationship was not definitively established between ORVR equipped vehicles and GDF emissions based on the applied regression models, the impact of UST gauge pressure on vent line and fugitive emissions was consistently observed in this project. When plotting UST gauge pressure profiles and vent line or fugitive emissions on the same graph, the trend for each of these two parameters suggested a proportional relationship for all of the recorded experimental conditions. In other words, when UST gauge pressure increased, vent line and fugitive mass emissions increased. This relationship did appear to be indirectly influenced by the level of ORVR penetration, especially for fugitive emissions.

The empirical dataset did not consistently suggest that with higher ORVR penetration levels, UST gauge pressure values increase. While 10% ORVR penetration exhibited marked increases in UST gauge pressures relative to the 0% ORVR control condition, the 50% ORVR condition did not display proportionally greater increases relative to the 10% ORVR simulation condition. However, when contrasting the two ORVR simulation conditions to the control ORVR level (0% ORVR), there was a marked increase in UST gauge pressures. These data can be contrasted to the pressure data reported by ARB (1996) when evaluating the interaction of UST gauge pressure with ORVR simulation conditions. The vacuum assist ORVR simulation ARB pressure data and the current study ORVR 10% and 50% ORVR simulation data are roughly equivalent in pressure distributions. ARB (1996) reports 94.7% of the UST gauge pressure data > 0 inches W.C. for 20% ORVR simulation levels. The current study observed 100% of the UST gauge pressure data > 0 inches W.C. for both the 10% and 50% ORVR simulation conditions.

Notwithstanding the uncertain impacts of ORVR simulation based on the current study data set, with larger UST gauge pressures, greater hydrocarbon volume releases are observed at both the vent line and the constellation of fugitive sources at the gasoline dispensing facility. The consistency of this relationship suggests that emission control strategies that target the maintenance of neutral UST system gauge pressure would be effective at minimizing hydrocarbon emissions at gasoline dispensing facilities.

The proportional relationship between UST gauge pressure and GDF emissions was observed during both product deliveries and during the normal automobile refueling activities. Product delivery did produce an increase in UST gauge pressure though the magnitude of this effect was not predictable. However, the gauge pressure increases did not always produce a simultaneous increase in vent line emissions. As was visible in the 10% ORVR simulation test condition, the impact of product delivery appeared to have a noticeable lag effect as UST gauge pressure remained elevated (relative to pre-product drop conditions) for several hours after the drop delivery event terminated.

4.3 SYSTEM FLOW DATA

The calculated system flow value (Q), interpreted as the system leak rate, was in the range of values quantified by the ARB field ORVR retest project at the same location (ARB, 1999). In addition, Q increased with the presence of ORVR simulated refueling events relative to non-ORVR control conditions. Given the observation from the ARB ORVR retest data that fugitive emissions (originating from systemic leaks) dominate the GDF emission inventory when compared to vent emissions, the calculated Q value from this project confirms the ARB dataset information. Application of system hydrocarbon concentration values from the ARB ORVR simulation tests to the current study Q values generates fugitive emission factors for the 0% and 50% ORVR simulation conditions roughly equivalent to the calculated ARB fugitive emission factors. Note that ARB did not test for early (10%) ORVR penetration.

As previously described, the leak rates for 10% and 50% ORVR are similar but the vent line and fugitive emissions were variant. As earlier suggested, a possible hypothesis explaining this observation is that high levels of ORVR penetration are returning air to the UST at a rate faster than evaporation of gasoline can saturate this air within gasoline vapor. The result is that VRS vapor concentrations at high ORVR levels are lower than at lower ORVR levels. Therefore, for the same pressure and leak rate, the emission rate will also be lower for 50% ORVR versus 10% ORVR. Thus, fugitive mass emission rate as a function of increasing ORVR throughput may increase to some maximum and then begin to fall off as the evaporation rate becomes limited by mass transfer effects rather than the amount of air available in the UST.

The magnitude of the fugitive emission factors compared to the vent line emission values suggests the importance of leak rate (Q) and pressure as determinant factors in governing the magnitude of gasoline dispensing facility emissions. This observation would lend evidence to the proposal that an underground storage tank static pressure management system that maintains neutral UST static pressures could be a valuable emissions control strategy at gasoline dispensing facilities. Pressure control systems of interest include nozzle and vapor pump designs that maximize the nozzle fill pipe interface seal to obtain the required collection efficiency at a V/L ratio at or below one. The other option is vapor processor methods (e.g., thermal oxidizers, carbon absorption units, selective permeation membranes). Many current certified nozzle and vapor pump designs do not include an effective seal at the nozzle fill neck interface. Rather, they depend on high V/L ratios to achieve greater than 95% collection efficiency at the dispensing point.

Section 5

SUMMARY AND CONCLUSIONS

5.1 SUMMARY

When comparing ORVR refueling with non-ORVR refueling events for Gilbarco vacuum assist systems, the field data collected in this research project do not indicate a linear relationship between vent line or fugitive emissions and increased refueling frequency of ORVR equipped vehicles. Using the observed flow values (Q) from this study and the ARB ORVR simulation study hydrocarbon concentrations, fugitive emission values were calculated for the 0% and 50% ORVR simulation conditions. A 10% ORVR simulation fugitive emission factor was also predicted using the ARB hydrocarbon data at 0% and 45% ORVR along with the assumption of a linear relationship between concentration and ORVR throughput. The magnitude of the resultant fugitive emissions suggests that fugitive emissions dominate the emission profiles at gasoline dispensing facilities. Total fugitive emission rates are at least two-three orders of magnitude larger that the vent line emission rates, one of the multitude of fugitive sources at GDFs. Relative to the impacts of ORVR refueling, the project data suggests an increase in fugitive emissions with the introduction of ORVR vehicles into the on-road vehicle fleet. The observed values were in the same range as those recorded in the 1999 ARB ORVR retest study (ARB, 1999). The proportional relation of flow and UST gauge pressure underscores the importance of maintaining neutral UST gauge pressure as a means of controlling gasoline dispensing facility emission releases.

The baseline conditions (i.e., no ORVR refueling), measured over a 30 hour period, yielded a vent line emission factor of 0.00518 pounds/1000 gallon with UST gauge pressures predominantly in the 0.02-0.06 in. W.C. range. Adding 10% ORVR vehicles into the daily refueling profile (representing early fleet penetration) yielded a predicted increase in the vent line emission factor to 0.00985 pounds/1000 gallons when measured over a 32 hour period. This is an increase by approximately a factor of two over the baseline measurement condition. The resulting UST gauge pressures during the 10% ORVR simulation event increased to an average value of approximately 1.25 in. W.C.

The climax conditions of 50% ORVR equipped vehicles in the US on-road fleet did not demonstrate a linear relationship in vent line emissions. Measured over a 32 hour period, vent line emissions were 0.00111 pounds/1000 gallons. This value is lower than both the baseline and 10% ORVR penetration value. Though the UST gauge pressure profile for 50% ORVR penetration was centered around 0.5 in. W.C., the gauge pressures were on average greater than the 0% ORVR control values.

The lack of vent line emissions or pressure increases during the 50% simulation period compared to 10% ORVR simulation sample condition cannot be attributed to a specific set of causal factors. However, (1) the potential for systems leaks as evident in the 50% ORVR simulation leak rate (Q), (2) the small differences in pre- and post-test static pressure characteristics, and (3) the magnitude of the fugitive emission factors could account for the differences in the observed vent line emission values between the 0%, 10% and 50% ORVR simulation conditions. Additional factors that may have influenced the ORVR penetration/gasoline dispensing facility emission data are the complexity of vapor saturation dynamics, the duration of sampling times for each ORVR simulation condition, and the occurrence of product deliveries during the field test program.

While the experiment conditions were different from the current study, the vent line emission data for this project are lower than previously reported vent line emission factors by AeroVironment (1994) and ARB (1994). However, data from the recently released ARB ORVR simulation study (1999) is consistent with the calculated vent line and fugitive emission factors from this study. With the exception of ambient temperature conditions and summer fuel RVP, the 1999 ARB study is similar in experimental design and field conditions to the current study. This lends itself to a meaningful comparison to these project data. The increase of GDF fugitive emissions as a function of ORVR equipped vehicle penetration is also similar between the 1999 ARB study and the research project in this report. However, the relationship was not linear in that greater levels of ORVR refueling did not trigger a concomitant increase in facility fugitive emissions. This suggests that ORVR impacts may reach a maximum rather than being proportional to the magnitude of ORVR penetration into the on-road vehicle fleet.

The implication of this hypothesis is that a plateau exists relative to the impacts of ORVR equipped vehicles at vacuum assist vapor recovery system quipped gasoline dispensing facilities. Once a given penetration of ORVR equipped vehicles occurs in the on-road vehicle fleet, the impact of these vehicles on emission releases at gasoline dispensing facilities will level off. One possible explanation for this behavior may be that, above a given level of ORVR penetration, the complexity of vapor recovery system dynamics (e.g., vapor saturation heterogeneity) offsets ORVR impacts.

5.2 CONCLUSION

Based on five days of field testing, for the evaluated Gilbarco vacuum assist vapor recovery system, the modeled impact of ORVR refueling on vent line and fugitive emissions did not demonstrate a prominent linear relationship. It was hypothesized at the onset of this project that an increase in ORVR equipped vehicle refueling would trigger increases in UST gauge pressure and subsequent higher vent line and fugitive emissions for vacuum assist systems. A linear relationship was not observed by the collected empirical data. The introduction of 10% ORVR equipped vehicles into the refueling fleet did produce increased UST positive gauge pressures with concomitant increases in vent line and fugitive emissions. However, this trend was not manifest when elevating the level of ORVR equipped vehicle penetration to 50%.

Using UST gauge pressure, system leak rate and the resultant fugitive emissions (of which vent line emissions are part of) as a metric for evaluating the impacts of ORVR refueling does suggest a relationship. Leak rates do increase with the simulated refueling of ORVR equipped vehicles. In addition, calculated fugitive emissions for the 50% ORVR simulation condition are significantly larger than the baseline 0% ORVR simulation condition. However, based on the leak rate data and calculated/predicted fugitive emission factors, an increase of ORVR refueling (i.e., from 10% to 50% simulated ORVR penetration) does not trigger a proportional increase in fugitive emissions.

The cause of the inconsistent relationship between vent line emissions and ORVR equipped vehicles could be attributed to the complexity in factors that influence hydrocarbon emission releases at gasoline dispensing facilities. In addition, the experimental design for this project could also have influenced the empirical outcomes. For example, the data collection time period may have been too limited to adequately evaluate the intrinsic variabilities implicit in the dynamics of Stage II vapor recovery systems. The size of the vent line emission releases compared to the total fugitive emission factors underscores the importance of other fugitive emission sources (e.g., nozzles, Stage I fittings) in determining the magnitude of gasoline dispensing facility emission releases. It also suggests that the role of UST pressure is critical for controlling fugitive emissions.

Section 6

RECOMMENDATIONS

6.1 RECOMMENDATIONS

Based on an evaluation of the empirical dataset collected for this project, future studies investigating the impacts of ORVR equipped vehicles on vent line emissions should address the following issues:

- While the study design and study methodology for this research project was reviewed by both ARB staff and the project Technical Advisory Committee, these documents did not include the necessary ad hoc flexibilities (i.e., at a given moment in the field) to respond to the realities of the field conditions encountered in this project. Of concern are the difficulties in maintaining system static pressure over time. This is not meant to be a criticism of the project's Technical Advisory Committee or ARB staff. Rather, the need to execute ad hoc decisions in a field setting based on the information available at the time is a critical component in project's where the field setting is dynamic with respect to changing protocol or methodologies. Future ORVR impact studies need to integrate the lessons from this project in project study design and QAPP documents.

- The data collection time should be significantly longer than the time periods allocated for this project. A minimum of 7 days for each experimental condition (i.e., baseline and different levels of ORVR penetration in the vehicle fleet) should be considered, assuming resources are available to support the field measurement program.

- The challenges of maintaining vapor recovery system integrity (e.g., system tightness) need to be aggressively addressed in any future study. There are several areas that include difficult to control for phenomena (i.e., the impact of customers on gasoline dispensing equipment, the influences of delivery truck personnel on Phase I integrity) that have dramatic impacts on system tightness. A systematic effort needs to be exerted to either control for these factors or to estimate, within an acceptable range of error, the systematic error term that is introduced into the emission factor calculations due to compromises in system integrity.

- The impact of system leak rate (Q) and pressure in determining the magnitude of fugitive emission releases suggests the importance of an emission control strategy that targets the maintenance of neutral system pressure.

- The potential impact of product deliveries on vent line and fugitive emission releases suggests the need to vigilantly monitor the correct application of Stage I vapor recovery methodologies. Deviance from standard practices can result in significant increases in system pressure and concomitant emission releases.

- The possibility that ORVR impacts on vacuum assist vapor recovery systems are not linear should be investigated. Maximums may exist with respect to the impact of ORVR equipped vehicles on gasoline dispensing facility emissions. Once a given level of ORVR penetration in the on-road vehicle fleet exists, their impacts on gasoline dispensing facility emissions may be offset by the complexity of vapor recovery system dynamics.

Section 7

REFERENCES

California Air Resources Board, 1994: Estimated Hydrocarbon Emissions of Phase II and Onboard Vapor Recovery Systems. Engineering Evaluation Branch, Monitoring and Laboratory Division.

California Air Resources Board, 1996: Interaction of Simulated Vehicular On-Board Vapor Recovery (ORVR) With Balance and Assist Phase II Vapor Recovery Systems. Project No. C-95-073.

California Air Resources Board, 1999: Total Hydrocarbon Emissions from Two Phase II Vacuum Assist Vapor Recovery Systems During Baseline Operation and Simulated Refueling of Onboard Refueling Vapor Recovery (ORVR) Equipped Vehicles, Preliminary Draft Report, Project ST-98-XX.

Shearer. D. F. and D. F. Gilson (1994). Underground Storage Tank Vent Line Emissions from Retail Gasoline Outlets. AeroVironment Final Report prepared for Western States Petroleum Association, AV-FR-92-01-204R2.

Appendix A

GILBARCO VACUUM ASSIST DATA

The enclosed electronic file contains the collected data for the Gilbarco vacuum assist system. While data was collected for each variable every second, the data are presented as one minute block averages. The column headings are defined as:

Time: the average minute value

THC Vent: the measured concentration of hydrocarbon vapor measured as PPM propone

Tambient: the measured ambient temperature in Rankine units

T Vent: the measured vent line temperature in Rankine units.

P Vent: the measured vent line pressure in inches of mercury.

V Vent: the measured vapor volume in cubic feet per second

P UST: the pressure in the UST measured below grade in the vent line riser in inches of mercury.

PUST: the pressure in the UST in inches of water generated by the converting the inches mercury value.

P ambient: ambient pressure in inches of mercury

Vvent: the measured vent volume standardized to temperature and pressure conditions in scf/min units

THC mass: Hydrocarbon mass released from the vent line in units of pounds per minute using the Vvent and hydrocarbon data (ppm) as input parameters.

The methods used to derive these value are described in Section 2 of this report.

Appendix B

BAY AREA AIR QUALITY MANAGEMENT DISTRICT PERFORMANCE DATA

Distribution:
- Firm
- Permit Services
- Requester

BAY AREA AIR QUALITY MANAGEMENT DISTRICT

939 Ellis Street
San Francisco, California 94109
(415) 771-6000

SUMMARY OF SOURCE TEST RESULTS

Report No. 98179
Test Date: 2/4/98

Test Times:
Run A: 10:00 – 10:50
Run B:
Run C:

Source Information		BAAQMD Representatives
Firm Name and Address: El Sobrante Shell and Food 3621 San Pablo Dam Rd. El Sobrante, CA 94803	Firm Representative and Title: Oyster Petroleum Owner/Operator Phone No. (510) 223-1445	Source Test Team: E. Stevenson C. McClure G. Bradbury K. Kunaniec
Permit Condition N/A	Source: Phase II Vapor Recovery GDF No. 1355 Permit No. Operates 24 hr/day & 365 days/year	Phase II System Type: Balance - Vapor Assist – Gilbarco Type: Other -

Operating Parameters:
Number of Nozzles Served by Tank #1 8
Nmber of Nozzles Served by Tank #2 8
Number of Nozzles Served by Tank #3 8
Total Number of Gas Nozzles at Facitilty 24

Applicable Regulations: CARB Contract #95-344
VN Recommended: NO

Source Test Results and Comments: Source Test Method ST-30

TANK #:	1	2	3	TOTAL
1. Product Grade	87	89	92	
2. Actual Tank Capacity, gallons	9,730	9,730	9,730	29,190
3. Gasoline Volume, Gallons	3,296	4,992	4,136	12,424
4. Ullage, gallons (#2 -#3)				16,766
5. Phase I System Type				Two Point
6. Initial Test Pressure, Inches H_2O **(2.0)**				2.00
7. Pressure After 1 Minute, Inches H_2O				2.00
8. Pressure After 2 Minutes, Inches H_2O				1.99
9. Pressure After 3 Minutes, Inches H_2O				1.97
10. Pressure After 4 Minutes, Inches H_2O				1.95
11. Final Pressure After 5 Minutes, Inches H_2O				1.93
12. Allowable Final Pressure from Table 30-I				1.93
13. Test Status [**Pass** or **Fail**]				PASS

NO COMMERCIAL USE OF THESE RESULTS IS AUTHORIZED

Air Quality Engineer	Date	Supervising Air Quality Engineer	Date	Approved by Air Quality Engineering Manager	Date
tevenson		C. McClure		K. Kunaniec	

Distribution:	BAY AREA AIR QUALITY MANAGEMENT DISTRICT	Report No. 98180
Firm Permit Services Requester	939 Ellis Street San Francisco, California 94109 (415) 771-6000	Test Date: 2/4/98
	SUMMARY OF SOURCE TEST RESULTS	Test Times: Run A: 11:00 – 11:30 Run B: Run C:

Source Information		BAAQMD Representatives
Firm Name and Address: El Sobrante Shell and Food 3621 San Pablo Dam Rd. El Sobrante, CA 94803	Firm Representative and Title: Oyster Petroleum Owner/Operator Phone No. (510) 223-1445	Source Test Team: E. Stevenson C. McClure G. Bradbury K. Kunaniec
Permit Condition N/A	Source: Phase II Vapor Recovery GDF No. 1355 Permit No. Operates 24 hr/day & 365 days/year	Phase II System Type: Balance - Vapor Assist – Gilbarco Type: Other -

Operating Parameters: Dispensers: Gilbarco AL121OC
Hoses: Goodyear Flexsteel Vapor Assist II with Husky Breakaways
Nozzles: OPW 11VA 27 and Emco Wheaton 4505

Applicable Regulations:	CARB Contract #95-344	VN Recommended: NO

Source Test Results and Comments: Source Test Method ST-27

DISP. #	GAS GRADE	DYNAMIC BACK PRESSURE, INCHES H_2O 60 CFH
1 & 2	ALL	0.02
3 & 4	ALL	0.02
5 & 6	ALL	0.02
7 & 8	ALL	0.02

Note: Allowable Dynamic Back Pressures are 0.15, 0.45, and 0.95 at Nitrogen flowrates of 20, 60, and 100 CFH, respectively.

NO COMMERCIAL USE OF THESE RESULTS IS AUTHORIZED

Air Quality Engineer	Date	Supervising Air Quality Engineer	Date	Approved by Air Quality Engineering Manager	Date
E. Stevenson		C. McClure		K. Kunaniec	

Distribution: Firm, Permit Services, Requester	**BAY AREA AIR QUALITY MANAGEMENT DISTRICT** 939 Ellis Street San Francisco, California 94109 (415) 771-6000 **SUMMARY OF SOURCE TEST RESULTS**	Report No. 98181 Test Date: 2/4/98 Test Times: Run A: 12:30 – 3:00

Source Information		BAAQMD Representatives
Firm Name and Address: El Sobrante Shell and Food 3621 San Pablo Dam Rd. El Sobrante, CA 94803	Firm Representative and Title: Oyster Petroleum Owner/Operator Phone No. (510) 223-1445	Source Test Team: Eric Stevenson George Bradbury
	Source: GDF Vapor Recovery System	Permit Services / Enforcement
Permit Condition N/A	GDF # 1355 Application #	Test Requested by: K. Kunaniec

Operating Parameters: Dispensers: Gilbarco AL121OC
Hoses: Goodyear Flexsteel Vapor Assist II with Husky Breakaways
Nozzles: OPW 11VA 27 except where noted in serial number by –ew, then the nozzle is an Emco Wheaton 4505

Applicable Regulations:	CARB Contract #95-344	VN Recommended: NO

Source Test Results and Comments: Source Test Method ST-39

Pump #	Gas Grade	Nozzle Serial #	Total Pumped gallons	Disp. Rate, gpm	Total Flow, cu ft	A-V/L	Avg. A-V/L	Pass-Fail	Roundness Pass-Fail	Comments
8	87	246564jan5	4.534	8.2	0.71	1.17		Pass	Pass	
6	87	445014aug5	4.561	7.8	0.73	1.20		Pass	Fail	
7	87	445326aug5	7.490	7.6	1.20	1.20		Pass	Pass	
[illegible]	87	445328aug6	7.498	7.8	1.18	1.18		Pass	Pass	
[illegible]	87	246057jan5	7.483	7.7	1.19	1.19		Pass	Fail	
3	87	260477feb5	7.493	8.0	0.89	0.89				
			7.511	7.9	0.91	0.91				
			7.509	7.9	0.96	0.96	0.92	Fail	Fail	
4	87	245401jan5	7.522	7.9	1.11	1.10		Pass	Fail	
2	87	24203-ew	7.492	6.6	1.07	1.07		Pass	Pass	
2	89	24202-ew	7.493	9.4	1.00	1.00		Pass	Pass	
1	89	24447-ew	7.515	9.0	1.08	1.08		Pass	Pass	
3	89	252500feb5	7.500	8.8	0.85	0.85				
			7.565	9.3	0.81	0.80				
			7.474	9.0	0.78	0.78	0.81	Fail	Fail	
4	89	260524feb5	7.507	9.2	1.09	1.09		Pass	Fail	
5	89	445329aug6	7.521	9.2	1.02	1.01		Pass	Pass	
7	89	260531feb5	7.441	8.9	1.05	1.06		Pass	Fail	
6	89	445323aug6	7.497	9.4	1.00	1.00		Pass	Pass	
8	89	252574feb5	7.514	9.4	1.21	1.20		Pass	Fail	
3	92	259743feb5	7.462	9.1	1.09	1.09		Pass	Fail	
4	92	445020aug6	7.465	8.6	1.22	1.22				
			7.577	8.9	1.20	1.18				
			7.483	8.8	1.20	1.20	1.20	Pass	Pass	
5	92	445018aug6	7.502	9.2	1.11	1.11		Pass	Pass	
7	92	292923apr5	7.531	9.2	0.71	0.71				
			7.527	8.9	0.75	0.75				
			7.464	9.1	0.75	0.75	0.73	Fail	Pass	
6	92	445827aug6	7.468	9.1	0.44	0.44		Fail		

Pump #	Gas Grade	Nozzle Serial #	Total Pumped gallons	Disp. Rate, gpm	Total Flow, cu ft	A-V/L	Avg. A-V/L	Pass-Fail	Roundness Pass-Fail	Comments
			7.062	9.4	0.43	0.46				
			7.020	9.4	0.48	0.51	0.47	Fail	Pass	
8	92	259729feb5	7.508	9.0	1.09	1.09		Pass	Fail	
2	92	24201-ew	7.468	9.1	1.04	1.04		Pass	Pass	
1	92	24448-ew	7.453	9.1	1.12	1.12		Pass	Pass	

A-V/L limits for this configuration are 1.10 to 1.20

NO COMMERCIAL USE OF THESE RESULTS IS AUTHORIZED

Results are not Official Unless Signatures Appear Below

Air Quality Engineer Date	Supervising Air Quality Engineer Date	Approved by Air Quality Engineering Manager Date
E. Stevenson	C. McClure	K. Kunaniec

Distribution:
- Firm
- Permit Services
- Requester

BAY AREA AIR QUALITY MANAGEMENT DISTRICT

939 Ellis Street
San Francisco, California 94109
(415) 771-6000

SUMMARY OF SOURCE TEST RESULTS

Report No. 98182
Test Date: 2/17/98

Test Times:
Run A: 11:20 – 12:15
Run B:
Run C:

Source Information		BAAQMD Representatives
Firm Name and Address: El Sobrante Shell and Food 3621 San Pablo Dam Rd. El Sobrante, CA 94803	Firm Representative and Title: Oyster Petroleum Owner/Operator Phone No. (510) 223-1445	Source Test Team: E. Stevenson C. McClure G. Bradbury K. Kunaniec
Permit Condition N/A	Source: Phase II Vapor Recovery GDF No. 1355 Permit No. Operates 24 hr/day & 365 days/year	Phase II System Type: Balance - Vapor Assist – Gilbarco Type: Other -

Operating Parameters:
Number of Nozzles Served by Tank #1 8
Nmber of Nozzles Served by Tank #2 8
Number of Nozzles Served by Tank #3 8
Total Number of Gas Nozzles at Facitilty 24

Applicable Regulations: CARB Contract #95-344 | VN Recommended: NO

Source Test Results and Comments: Source Test Method ST-30

TANK #:	1	2	3	TOTAL
1. Product Grade	87	89	92	
2. Actual Tank Capacity, gallons	9,730	9,730	9,730	29,190
3. Gasoline Volume, Gallons	6,168	3,880	2,551	12,599
4. Ullage, gallons (#2 -#3)				16,592
5. Phase I System Type				Two Point
6. Initial Test Pressure, Inches H_2O **(2.0)**				2.00
7. Pressure After 1 Minute, Inches H_2O				1.99
8. Pressure After 2 Minutes, Inches H_2O				1.97
9. Pressure After 3 Minutes, Inches H_2O				1.95
10. Pressure After 4 Minutes, Inches H_2O				1.95
11. Final Pressure After 5 Minutes, Inches H_2O				1.94
12. Allowable Final Pressure from Table 30-I				1.93
13. Test Status [**Pass** or **Fail**]				PASS

Air Quality Engineer	Date	Supervising Air Quality Engineer	Date	Approved by Air Quality Engineering Manager	Date
evens		C. McClure		K. Kunaniec	

Distribution:	BAY AREA AIR QUALITY MANAGEMENT DISTRICT	Report No. 98184
Firm Permit Services Requester	939 Ellis Street San Francisco, California 94109 (415) 771-6000	Test Date: 2/17/98 Test Times: Run A: 12:30 – 3:00

SUMMARY OF SOURCE TEST RESULTS

Source Information		BAAQMD Representatives
Firm Name and Address: El Sobrante Shell and Food 3621 San Pablo Dam Rd. El Sobrante, CA 94803	Firm Representative and Title: Oyster Petroleum Owner/Operator Phone No. (510) 223-1445	Source Test Team: Eric Stevenson George Bradbury
Permit Condition N/A	Source: GDF Vapor Recovery System GDF # 1355 Application #	Permit Services / Enforcement Test Requested by: K. Kunaniec

Operating Parameters: Dispensers: Gilbarco AL121OC
Hoses: Goodyear Flexsteel Vapor Assist II with Husky Breakaways
Nozzles: OPW 11VA 27 except where noted in serial number by --ew, then the nozzle is an Emco Wheaton 4505

Applicable Regulations: CARB Contract #95-344 | VN Recommended: NO

Source Test Results and Comments: Source Test Method ST-39

Pump #	Gas Grade	Nozzle Serial #	Total Pumped gallons	Disp. Rate, gpm	Total Flow, cu ft	A-V/L	Avg. A-V/L	Pass-Fail	Roundness Pass-Fail	Comments
1	87	246057jan5	7.510	8.0	1.17	1.17		Pass	Pass	
5	87	445328aug6	7.495	7.9	1.18	1.18		Pass	Pass	
7	87	445326aug6	7.456	8.3	1.14	1.14		Pass	Pass	
4	87	245401jan5	7.500	8.3	1.18	1.18		Pass	Fail	
3	87	280477feb5	7.688	8.1	1.08	1.05		Pass	Pass	
8	87	246564jan5	7.487	8.3	1.08	1.08		Pass	Pass	
6	87	445014aug6	7.459	8.3	1.08	1.08		Pass	Fail	OPW 66CAS Breakaway
2	87	24203-ew	8.071	8.1	1.08	1.00		Pass	Pass	
3	89	252500feb5	7.590	8.8	1.02	1.01		Pass	Pass	
4	89	260524feb5	6.831	9.1	1.06	1.16		Pass	Fail	
5	89	445329aug6	7.498	9.0	1.13	1.13		Pass	Pass	
6	89	445323aug6	7.501	9.2	1.09	1.09		Pass	Pass	
7	89	260531feb5	7.522	9.0	1.09	1.08		Pass	Fail	
8	92	252547feb5	0.000	####	0.00	####		####	Pass	Shut-Off, Could Not Test
1	89	24447-ew	7.533	8.4	1.12	1.11		Pass	Pass	
2	89	24202-ew	7.509	9.2	1.04	1.04		Pass	Pass	
1	92	24449-ew	7.494	9.0	1.10	1.10		Pass	Pass	
2	92	24201-ew	7.509	9.2	1.08	1.08		Pass	Pass	
4	92	445020aug6	7.519	8.7	1.17	1.16		Pass	Fail	
3	92	259743feb5	7.496	9.2	1.03	1.03		Pass	Fail	
8	92	252574feb	0.000	####	0.00	####		####	Fail	Shut-Off, Could Not Test

Pump #	Gas Grade	Nozzle Serial #	Total Pumped gallons	Disp. Rate, gpm	Total Flow, cu ft	A-V/L	Avg. A-V/L	Pass-Fail	Roundness Pass-Fail	Comments
6	92	445827aug6	7.505	8.2	1.06	1.06		Pass	Pass	
5	92	445018aug5	7.462	9.3	1.11	1.11		Pass	Pass	
7	92	282923apr5	7.504	9.2	1.08	1.08		Pass	Pass	

A-V/L limits for this configuration are 1.00 to 1.20

NO COMMERCIAL USE OF THESE RESULTS IS AUTHORIZED

Air Quality Engineer Date	Supervising Air Quality Engineer Date	Approved by Air Quality Engineering Manager Date
E[illegible]tevenson	C. McClure	K. Kunaniec

Appendix C

ORVR EQUIPPED VEHICLES

EPA CERTIFIED

The column headings for the EPA Certification data are:

Column 1: Auto Manufacturer and CARB Executive Order if known

Column 2: Engine Family, Evap. Family and Certificate Number

Column 3: Emission Control System Number

Column 4; Effective Certificate Date (if issued)

Column 5: Auto Model Name

EPA
1998 MODEL YEAR CERTIFICATES
Light-Duty Vehicles
with
Onboard Refueling Vapor Recovery
October 3, 1997

	REVISED	1	09-24-97	
	WCRXV0195V20/WCRXR0101G1G 20LDV21	1	09-15-97 TLEV	CHRYSLER: CONCORDE; DODGE: INTREPID
ARB A-9-382	WCRXV0165V20/WCRXR0101G1G 20LDV22	1	09-15-97 TLEV	CHRYSLER: CONCORDE; DODGE: INTREPID
	WCRXV02.7VB0/WCRXR0101GBG 20LDV23	1	09-24-97	CHRYSLER: CONCORDE; DODGE: INTREPID
EWOO	WDWXV01.6D01/WDWXR0095A0L 178LDV01	1	08-27-97 TLEV	DAEWOO: LANOS
	WDWXV01.5S01/WDWXR0095A0L 178LDV05	1	08-22-97 TLEV	DAEWOO: LANOS
	WDWXV02.0D01/WDWXR0095A0L 178LDV06	1	09-23-97 TLEV	DAEWOO: NUBIRA
RD				
	WFMXV02.0BFA/WFMXR0080BAE 30LDV17	1	07-30-97	FORD: ESCORT WAGON
	REVISED		07-30-97	ADDED:FORD:ESCORT LINCOLN-MERCURY: TRACER WAGON, TRACER
RB A-10-736	WFMXV02.0ATA/WFMXR0080B0E 30LDV21	1	07-30-97	FORD: ESCORT, ESCORT WAGON
	REVISED		07-31-97	ADDED: LINCOLN-MERCURY: TRACER, TRACER WAGON

EPA
1998 MODEL YEAR CERTIFICATES
Light-Duty Vehicles
with
Onboard Refueling Vapor Recovery
October 3, 1997

CARB A-10-737	WFMXV02.0ALA/WFMXR0080B0E 30LDV25	1	07-31-97	FORD: ESCORT, ESCORT WAGON; LINCOLN-MERCURY: TRACER, TRACER WAGON
	WFMXV04.6ABA/WFMXR0115BAE 30LDV27	1	09-25-97	FORD: CROWN VICTORIA, CROWN VICTORIA POLICE LINCOLN-MERCURY: GRAND MARQUIS, TOWN CAR
	WFMXV04.6AAA/WFMXR0115BAE 30LDV29	1	10-02-97	FORD: CROWN VICTORIA, CROWN VICTORIA POLICE LINCOLN-MERCURY: GRAND MARQUIS, TOWN CAR
FUJI				
	WFJXV02.2AAA/WFJXR01251BB FUJI-LDV-98-04	1	05-08-97	SUBARU:LEGACY AWD, LEGACY WAGON AWD, IMPREZA AWD, IMPREZA WAGON AWD
	WFJXV02.2AAA/WFJXR01251BB FUJI-LDV-98-05	1	05-08-97	SUBARU:LEGACY AWD, LEGACY WAGON AWD, IMPREZA AWD, IMPREZA WAGON AWD
ARB A-2-104	WFJXV02.2BCB/WFJXR01251BB FUJI-LDV-98-6	1	05-08-97 TLEV	SUBARU:LEGACY AWD, LEGACY WAGON AWD, IMPREZA AWD, IMPREZA WAGON AWD
	WFJXV02.2BCB/WFJXR01251BB FUJI-LDV-98-07	1	05-08-97 TLEV	SUBARU:LEGACY AWD, LEGACY WAGON AWD, IMPREZA AWD, IMPREZA WAGON AWD
	WFJXV02.5CAC/WFJXR01251BB 660LDV08	1	09-02-97	SUBARU: FORESTER AWD
ARB A-2-105-1-A	WFJXV02.5DCD/WFJXR01251BB 660LDV09	1	09-02-97 TLEV	SUBARU: FORESTER AWD

EPA
1998 MODEL YEAR CERTIFICATES
Light-Duty Vehicles
with
Onboard Refueling Vapor Recovery
October 3, 1997

GENERAL MOTORS

	WGMXV01.9001/WGMXR0080902 GM-LDV-98-11	1	05-27-97	SATURN: SC, SL, SW
	WGMXV01.9003/WGMXR0080902 GM-LDV-98-12	1	05-27-97	SATURN: SC, SL, SW
ARB A-6-784	WGMXV01.9002/WGMXR0080902 GM-LDV-98-13	1	05-27-97 TLEV	SATURN: SC, SL, SW
ARB A-6-785	WGMXV01.9004/WGMXR0080902 GM-LDV-98-14	1	06-05-97 TLEV	SATURN: SC, SL, SW
	WGMXV03.1041/WGMXR0124912 GM-LDV-98-17	1	06-16-97	CHEVROLET: MALIBU; PONTIAC: GRAND PRIX; BUICK: CENTURY; OLDSMOBILE: CUTLASS
	WGMXV03.8050/WGMXR0133910 GM-LDV-98-19	1	06-13-97	BUICK: RIVIERA, PARK AVENUE
	WGMXV03.8050/WGMXR0133918 GM-LDV-98-20	1	06-13-97	PONTIAC: GRAND PRIX; BUICK: REGAL
	WGMXV04.6065/WGMXR0133910 GM-LDV-98-23	1	06-19-97	CADILLAC: SEVILLE, OLDSMOBILE: AURORA
ARB A-6-797-A	WGMXV04.6066/WGMXR0133910 GM-LDV-26	1	07-01-97	CADILLAC: SEVILLE; OLDSMOBILE: AURORA
ARB A-6-796-A	WGMXV03.8051/WGMXR0133918	1	07-10-97	PONTIAC:GRAND PRIX, BUICK:REGAL

EPA
1998 MODEL YEAR CERTIFICATES
Light-Duty Vehicles
with
Onboard Refueling Vapor Recovery
October 3, 1997

	GM-LDV-98-28			
CARB A-6-796-A	WGMXV03.8051/WGMXR0133910 GM-LDV-98-29	1	07-10-97	BUICK: RIVIERA, PARK AVENUE
CARB A-6-792-A	WGMXV03.1043/WGMXR0124912 GM-LDV-98-31	1	07-10-97	CHEVROLET: MALIBU; OLDSMOBILE: CUTLASS; PONTIAC: GRAND PRIX; BUICK CENTURY
	WGMXV03.8047/WGMXR0133910 GM-LDV-98-35	1	07-17-97	BUICK: PARK AVENUE
	WGMXV03.8047/WGMXR0133918 GM-LDV-98-36	1	07-17-97	PONTIAC: GRAND PRIX; OLDSMOBILE: INTRIGUE; BUICK: REGAL
CARB A-6-794	WGMXV03.8048/WGMXR0133910 GM-LDV-98-37	1	07-17-97 TLEV	BUICK: PARK AVENUE
CARB A-6-794	WGMXV03.8048/WGMXR0133918 GM-LDV-98-38	1	07-17-98 TLEV	PONTIAC: GRAND PRIX; OLDSMOBILE: INTRIGUE; BUICK: REGAL
	WGMXV02.4024/WGMXR0124912 GM-LDV-98-39	1	07-17-97	CHEVROLET: MALIBU; OLDSMOBILE: CUTLASS
CARB A-6-789	WGMXV02.4026/WGMXR0124912 GM-LDV-98-40	1	07-17-97 TLEV	CHEVROLET: MALIBU; OLDSMOBILE: CUTLASS
CARB A-6-828-A	WGMXV03.1044/WGMXR0124912 40LDV42	1	09-09-97 TLEV	CHEVROLET: MALIBU; OLDSMOBILE: CUTLASS

EPA
1998 MODEL YEAR CERTIFICATES
Light-Duty Vehicles
with
Onboard Refueling Vapor Recovery
October 3, 1997

RB A-6-828-A	WGMXV03.1044/WGMXR0133918 40LDV43	1	09-09-97 TLEV	BUICK: CENTURY; PONTIAC: GRAND PRIX
	WGMXV03.1041/WGMXR0133918 GM-LDV-98-45	1	09-23-97	PONTIAC GRAND PRIX; BUICK CENTURY
RB A-6-792-A	WGMXV03.1043/WGMXR0133918 GM-LDV-98-46	1	09-23-97	PONTIAC GRAND PRIX; BUICK CENTURY
NDA MOTORS				
RB A-23-229	WHNXV03.0FL2/WHNXR0130AAA 260LDV08	1	09-08-97 TLEV	HONDA: ACCORD
	WHNXV03.0FF1/WHNXR0130AAA 260LDV09	1	09-08-97	HONDA: ACCORD
	WHNXV02.3PA3/WHNXR0130AAA 260LDV10	1	09-11-97 LEV	HONDA: ACCORD
B A-23-228	WHNXV02.3PL4/WHNXR0130AAA 260LDV11	1	09-04-97 CAL.ULEV - FED T1	HONDA: ACCORD
	WHNXV02.3PF1/WHNXR0130AAA 260LDV12	1	09-08-97	HONDA: ACCORD
B A-23-226	WHNXV02.3PL2/WHNXR0130AAA 260LDV13	1	09-08-97 TLEV	HONDA: ACCORD

EPA
1998 MODEL YEAR CERTIFICATES
Light-Duty Vehicles
with
Onboard Refueling Vapor Recovery
October 3, 1997

HYUNDAI				
CARB A-254-54	WHYXV01.82GM/WHYXR013421E 265LDV07	1	08-21-97 TLEV	HYUNDAI: ELANTRA
CARB A-254-55	WHYXV02.02GM/WHYXR013421E 265LDV08	1	08-21-97 TLEV	HYUNDIA: TIBURON
	WHYXV01.81EL/WHYXR01341KE 265LDV09	1	08-27-97	HYUNDAI: ELANTRA
	WHYXV02.01TB/WHYXR01341KE 265LDV10	1	08-27-97	HYUNDAI: TIBURON
KIA MOTORS	WKMXV01.8A01/WKMXR0100A01 338LDV01	1	09-11-97	KIA: SEPHIA
MAZDA MOTOR				
	WTKXV02.0VBA/WTKXR0125BFA 560LDV06	1	08-11-97	MAZDA: 626
CARB A-16-224	WTKXV02.0VDM/WTKXR0125BFA 560LDV07	1	08-15-97	MAZDA: 626
	WTKXV02.5VB2/WTKXR0125BFA 560LDV08	1	08-11-97	MAZDA: 626

EPA
1998 MODEL YEAR CERTIFICATES
Light-Duty Vehicles
with
Onboard Refueling Vapor Recovery
October 3, 1997

MERCEDES BENZ				
	WMBXV03.2GKB/WMBXR0155MYN 200LDV09	1	09-25-97 LEV	MERCEDES-BENZ: E320
	WMBXV02.3GSU/WMBXR0115MYY 200LDV10	1	09-25-97	MERCEDES-BENZ: SLK230
	WMBXV05.0GNB/WMBXR0155MYY 200LDV11	1	09-29-97 TLEV	MERCEDES-BENZ: SL500
	WMBXV06.0GNU/WMBXR0155MYY 200LDV12	1	09-29-97	MERCEDES-BENZ: SL600
MITSUBISHI (196 & 490)				
	WDSXV02.4G2G/WDSXR016511A 196LDV04	1	06-24-97 LEV	DIAMOND STAR MOTORS/MITSUBISHI: ECLIPSE CONVERT.
	WDSXV02.4GPG/WDSXR016511A 196LDV06	1	06-24-97	DIAMOND STAR MOTORS:MITSUBISHI ECLIPSE CONVERT.
	WDSXV02.5GPG/WDSXR016511A 196LDV08	1	07-02-97	DIAMOND STAR MOTORS/CHRYSLER: SEBRING, DODGE AVENGER
CARB A-292-40	WDSXV02.5G1G/WDSXR016511A 196LDV09 REVISED DATE 07-03-97	1	07-02-97 TLEV 08-12-97	CHRYSLER: SEBRING; DODGE:DODGE AVENGER

EPA
1998 MODEL YEAR CERTIFICATES
Light-Duty Vehicles with Onboard Refueling Vapor Recovery
October 3, 1997

SAAB	WSAXV02.3ND1/WSAXV0080YD1 470LDV02	1	09-11-97	SAAB: SAAB 900, SAAB 900 CONVERTIBLE
	WSAXV02.0TD1/WSAXV0080YD1 470LDV03	1	09-11-97	SAAB: SAAB 900, SAAB 900 CONVERTIBLE
SUZUKI				
	WSKXV1.30CNA/WSKXR0085RMA SUZUK-LDV-98-04	1	06-12-97	SUZUKI: SWIFT; CHEVROLET:METRO
CARB-A-259-61	WSKXV1.30LNA/WSKXR0085RMA SUZUK-LDV-98-06	1	07-03-97 LEV	SUZUKI: SWIFT; CHEVROLET: METRO
TOYOTA	WTYXV02.2XBA/WTYXR0135AK1 570LDV01	1	07-15-97	TOYOTA: CAMRY
CARB A-14-319	WTYXV02.2GXB/WTYXR0135AK1 570LDV02	1	07-31-97	TOYOTA: CAMRY
	WTYXV01.8XBA/WTYXR0115AK1 570LDV05	1	07-25-97	TOYOTA: COROLLA
CARB A-14-318	WTYXV01.8DXB/WTYXR0115AK1 570LDV06	1	08-12-97 TLEV	TOYOTA: COROLLA

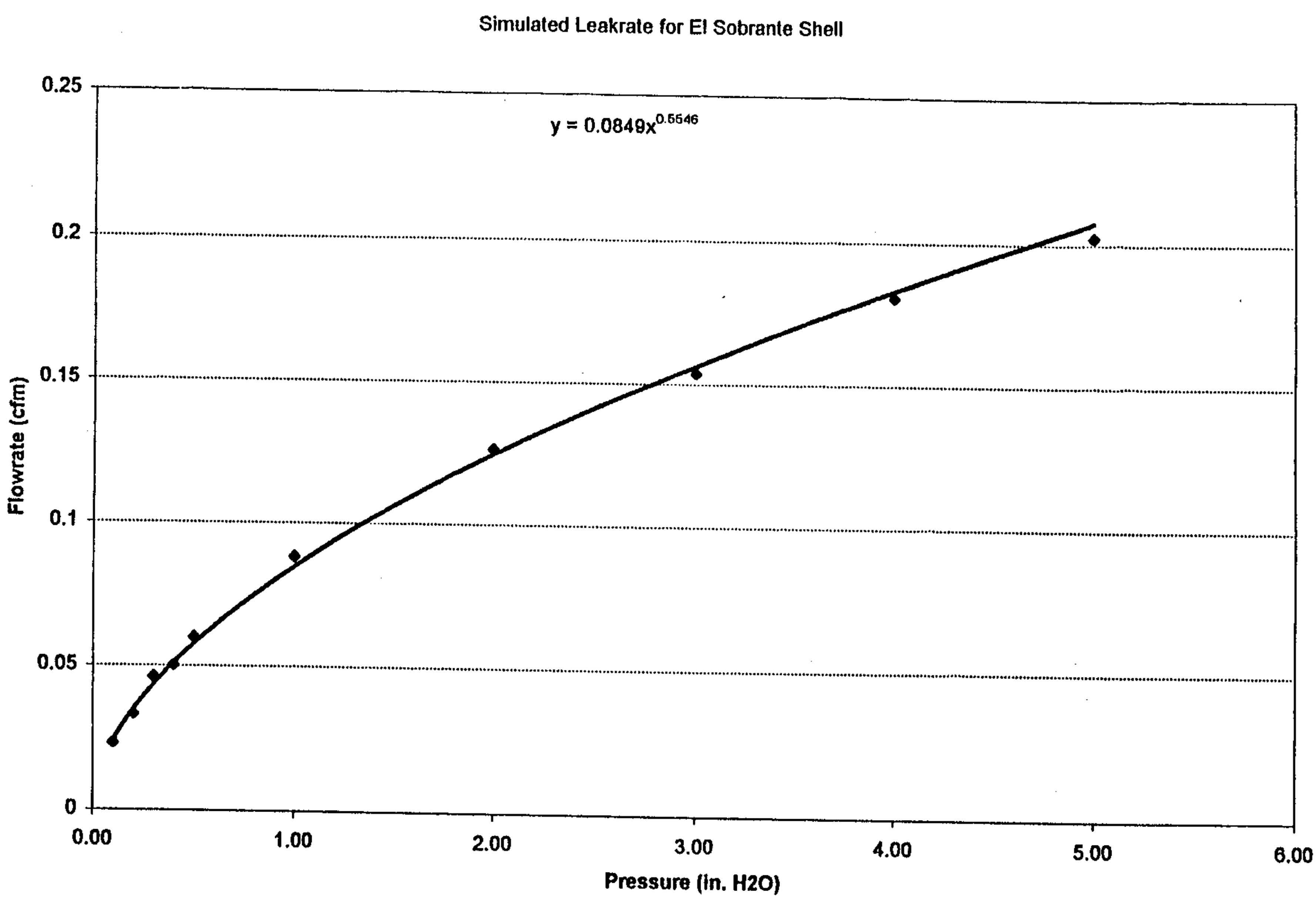
EPA
1998 MODEL YEAR CERTIFICATES
Light-Duty Vehicles
with
Onboard Refueling Vapor Recovery
October 3, 1997

LVO

WVVXV2.43PA1/WVVXR0133PA1 VOLVO-LDV-98-06 TIER 1-FED	1 &	06-05-97 TLEV-CALIF	VOLVO: S70, V70, C70
WVVXV2.43TPF/WVVXR0133PA1 VOLVO-LDV-98-07	1	07-22-97	VOLVO: S70, V70
WVVXV2.43BUF/WVVXR0133PA1 VOLVO-LDV-98-08	1	07-22-97	VOLVO: S70, V70

Appendix D

LEAK RATE SIMULATION DATA



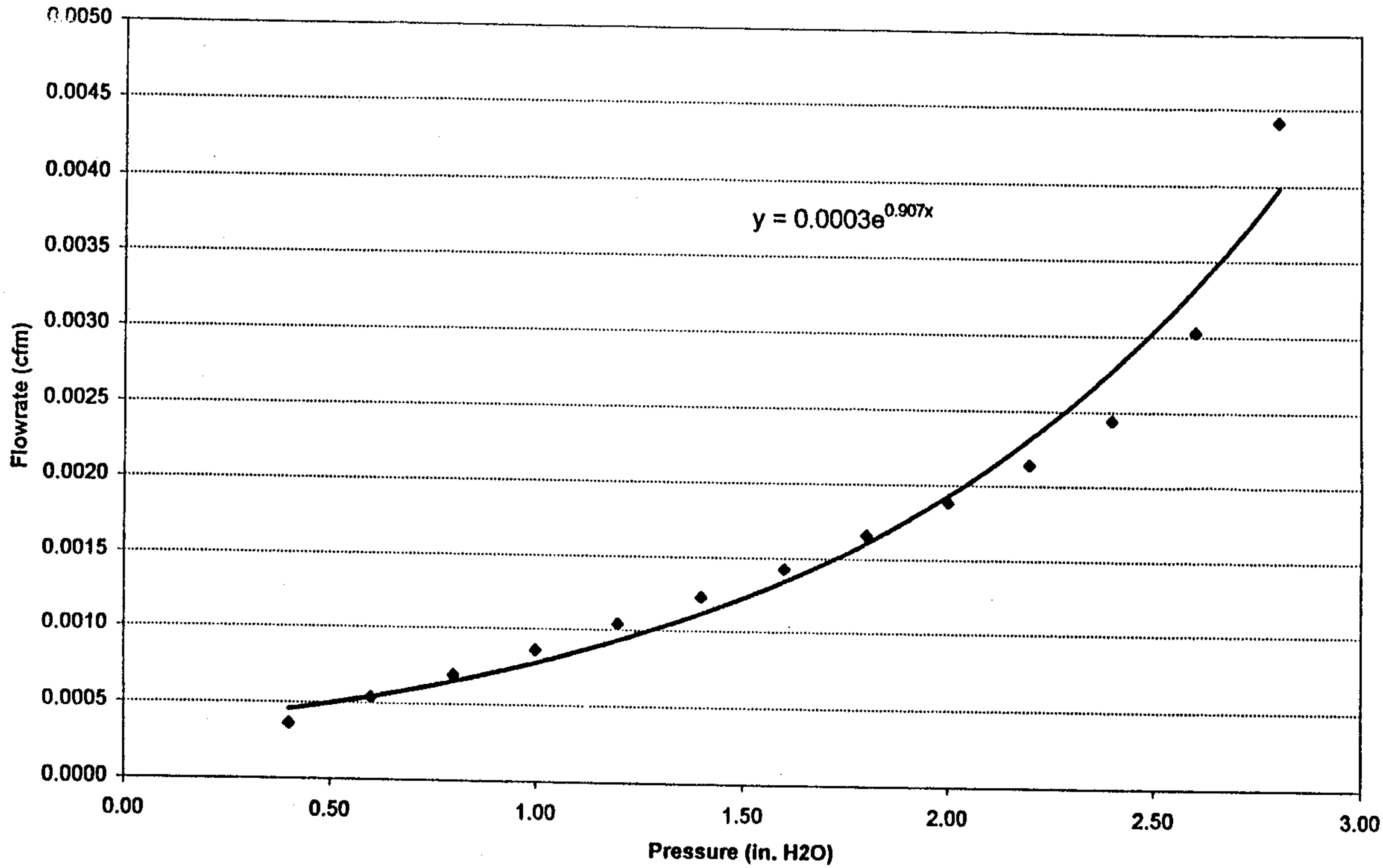
Simulated Leakrate for El Sobrante Shell
y = 0.0849x^0.5546
0.25
0.2
0.15
0.1
0.05
0
Flowrate (cfm)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
Pressure (in. H2O)

April 2, 1998 (1700)
B.P. 30.13 in. Hg
Temp. 68 deg. F

2 - 0.055" Diameter Holes used to simulate leak rate from El Sobrante Shell
BAAQMD Flowrate Data: 0.134 cfm @ 2.00 WC

Delta P in H2O	Flowrate L/min	Flowrate cfm
0.10	0.65	0.0230
0.20	0.94	0.0332
0.30	1.31	0.0463
0.40	1.42	0.0501
0.50	1.70	0.0600
1.00	2.50	0.0883
2.00	3.58	0.1264
3.00	4.35	0.1536
4.00	5.12	0.1808
5.00	5.73	0.2023

Pressure/Vacuum Valve

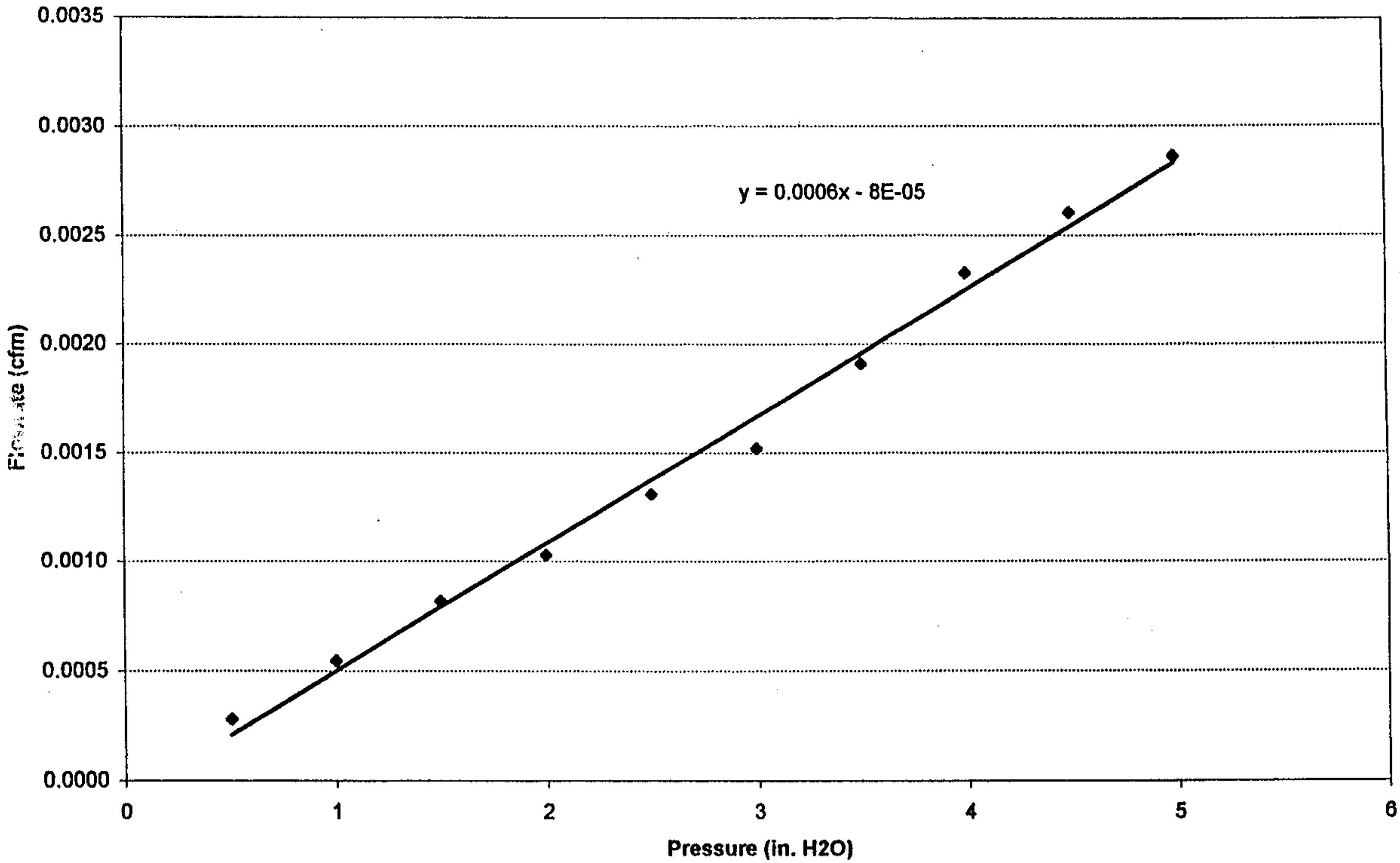


March 31, 1998 (1100)
B.P. 29.77 in. Hg
Temp. 66 deg. F

Pressure/Vacuum Vent Valve

Delta P in H2O	Flowrate L/min	Flowrate cfm
0.40	0.0101	0.0004
0.60	0.0152	0.0005
0.80	0.0195	0.0007
1.00	0.0244	0.0009
1.20	0.0295	0.0010
1.40	0.0348	0.0012
1.60	0.0403	0.0014
1.80	0.0469	0.0017
2.00	0.0533	0.0019
2.20	0.0606	0.0021
2.40	0.0691	0.0024
2.60	0.0857	0.0030
2.80	0.1250	0.0044

Nozzle Checkvalve



March 31, 1998 (1700)
B.P. 29.77 in. Hg
Temp. 66 deg. F

Nozzle with Idle Check Valve

Delta P in H2O	Flowrate L/min	Flowrate cfm
0.5	0.0078	0.0003
1.00	0.0154	0.0005
1.50	0.0231	0.0008
2.00	0.0291	0.0010
2.50	0.0370	0.0013
3.00	0.0430	0.0015
3.50	0.0541	0.0019
4.00	0.0658	0.0023
4.50	0.0737	0.0026
5.00	0.0810	0.0029

Appendix E

PROJECT QAPP

50074-B000

VAPOR RECOVERY SYSTEMS AT GASOLINE DISPENSING FACILITIES ON-BOARD VAPOR RECOVERY EFFECTS

QUALITY ASSURANCE PROJECT PLAN

Prepared for:

California Air Resources Board
2020 L Street
Sacramento, CA 95814

By

AeroVironment Environmental Services Inc.
2697 Union Street
San Francisco, California 94123

November 1997

TABLE OF CONTENTS

SECTION 1

INTRODUCTION

The California Air Resources Board (ARB) is sponsoring a technical evaluation study in Northern California. The specific test locations are located between Sacramento and the San Francisco Bay area and are scheduled to take place from fall 1997-fall 1998. The field study will include the following components:

- Field management and coordination.
- The selection and use of gasoline dispensing facilities (GDF) as field test sites.
- A field test van that will execute ARB's certification and test procedures (C & TP) for measuring hydrocarbon emissions, pressure, volume and temperature profiles from vapor recovery systems (VRS) at GDFs.
- A field test van that will execute ARB's certification and test procedures (C & TP) for measuring static and dynamic pressure and air/liquid ratios for GDF vapor recovery systems.
- Quality assurance.
- Data Management.

The VRS hydrocarbon and performance test measurements are planned for the fall 1997 and early winter of 1998. Each site-specific test period will take approximately 7 days.

AeroVironment Environmental Services Inc., AVES, has been contracted by ARB to perform the study design, field measurement program, data processing and reporting for this program. This quality assurance project plan (QAPP) describes the measurement program to be performed by AVES.

1.1 PROJECT OBJECTIVES

This research project is designed to evaluate the interaction between ORVR-equipped vehicles and vapor recovery systems (VRS) at gasoline dispensing facilities (GDF). In addition, this project will determine whether ORVR-equipped vehicles increase or decrease GDF emissions as a function of VRS design. Specifically, there are three general objectives for this project:

1. Characterize the performance of ORVR system seals in preventing hydrocarbon emissions at the fillpipe-nozzle interface using both non-vapor recovery system nozzles and nozzles used with balance and vacuum assist Stage II VRS as test cases.

2. Develop, validate and demonstrate methods for simulating the refueling of ORVR-equipped vehicles at GDFs equipped with balance and vacuum assist VRS.

3. Determine what impact the refueling of ORVR-equipped vehicles have on existing emission profiles for balance and vacuum assist VRS.

1.2 SCOPE OF WORK

There will be two basic test conditions for this project which will be called test series: the ORVR simulation model test series and the ORVR impact test series. Each test series will have unique study designs. However, the ORVR model (i.e., physical device) developed in the

ORVR simulation test series will be used to simulate ORVR equipped cars in the ORVR impact test series.

ORVR SIMULATION MODEL TEST SERIES

The ORVR simulation model test series is designed to develop physical models that can be used to simulate ORVR refueling events at GDFs. Implicit in this process are two assumptions addressing the expected efficiency of ORVR as a hydrocarbon control strategy: (1) ORVR system seals will not allow any hydrocarbons to escape to the atmosphere at the fillpipe-dispensing nozzle interface; (2) only air will be returned to the underground storage tank (UST) when ORVR equipped cars are refueled at GDFs. The objectives of the ORVR simulation model test series are:

1. Quantify uncontrolled GDF transfer emissions for the current fleet using Phase II gasoline and derive an uncontrolled GDF emission factor to supersede the 8.4 pounds per 1000 gallon value currently used by ARB.

2. Develop physical models (i.e., devices) that will allow simulation of refueling events for ORVR-equipped cars at GDFs equipped with balance and vacuum assist VRS.

Based on these objectives, there will be three discrete phases to ORVR simulation test series:

1. Development of a device to simulate the refueling of ORVR equipped vehicles at balance VRS-equipped GDFs.
2. Development of a device to simulate the refueling of ORVR equipped vehicles at vacuum assist VRS-equipped GDFs.
3. Quantification of transfer emissions at GDFs without VRS.

Device Development to Simulate ORVR Equipped Vehicle Refilling at Balance Vapor Recovery Systems

A physical model or "device" will be developed that will allow the simulation of refueling ORVR-equipped cars at GDFs equipped with balance-type VRS. The device developed will serve as a prototype to fabricate a number of devices which will later be used in the ORVR Impact test series. The ORVR simulation device for balance VRS will be designed so only air is returned to the UST during the refueling event. In addition, the ORVR simulation device must adhere to the following requirements:

1. Allow fuel to enter the fillpipe.
2. Allow vapors to leave the fillpipe.
3. Allow air to enter the balance nozzle.
4. Seal the fillpipe-nozzle interface except for 1 and 3.
5. Provide the same back pressure:flow ratio found in an unmodified balance VRS.
6. Provide the same liquid blockage removal performance found in an unmodified balance VRS.

Functions 1-4 will be confirmed by executing a "sleeve" test defined in ARB TP-201.2 on a minimum of 10-15 vehicles. The vehicles will be selected based on the criteria defined in the "100 car matrix" found in ARB TP-201.2A. The ORVR simulation device will be assumed to meet functions 1-4 when the average performance values of the device agree with the performance values generated for unmodified balance nozzles, accounting for the experimental uncertainty and variation.

Functions 5-6 will be confirmed using ARB test procedures TP-201.4 and TP-201.6. At least three tests will be performed on a balance nozzle with and without the ORVR simulation device. The BAAQMD will execute these tests. The ORVR simulation device will be assumed to meet functions 5-6 when the average performance values of the device agree with the performance values generated for unmodified balance nozzles, accounting for the experimental uncertainty and variation.

Confirmation of functions 1-6 will occur at the balance-equipped GDF test conditions tabulated in Table 1-1. The fuel characteristics and GDF conditions (e.g., fuel temperature) will be representative of ambient conditions and GDF status the day of the testing. The location of the testing will be at the balance-equipped GDFs tabulated in Table 1-2. The primary location refers to the first choice location.

Table 1-1
Vapor Recovery System Test Conditions

Test Mode	VRS Type	Vent Valve	Assist Pump Location	Bell	Incinerator
2	Balance	No	N/A	No	No
3	Balance	Yes	N/A	No	No

Table 1-2
Balance VRS Field Test Locations

Vapor Recovery System Type	WSPA Member Company Site Number	Location	Primary/Secondary Location
Balance	ARCO #2180	3000 Travis Boulevard Fairfield, CA	Primary
Balance	Chevron #5595	1700 Mt. Diablo Martinez, CA	Secondary
Balance	Chevron #94640	2895 N. Main Street Walnut Creek, CA	Secondary
Balance	Chevron #0336	4295 Clayton Road Concord, CA	Secondary

Device Development to Simulate ORVR Equipped Vehicle Refueling at Vacuum Assist Vapor Recovery Systems

A physical model or "device" will be designed and fabricated that will allow the simulation of refueling ORVR-equipped cars at GDFs equipped with vacuum assist-type VRS. The device developed will serve as a prototype to fabricate a number of devices which will be used in the ORVR Impact test series. the ORVR simulation device for vacuum assist VRS will be designed so only air is returned to the UST during the refueling event. In addition, the ORVR simulation device must adhere to the following requirements:

1. Allow fuel to enter the fillpipe during refueling.
2. Prevent the flow of vapor to the UST.
3. Control the flow of air into the vapor return line of the VRS.
4. Provide the same back-pressure:flow ratio as is found in an unmodified vacuum assist VRS.

5. Provide the same air:liquid ratio as is found in an unmodified vacuum assist VRS.
6. Provide the same liquid blockage removal performance as is found in an unmodified balance VRS.

Functions 1-3 will be confirmed by executing a "sleeve" test defined in ARB TP-201.2 on a minimum of 10-15 vehicles. The vehicles will be selected based on the criteria defined in the "100 car matrix" found in ARB TP-201.2A. The ORVR simulation device will be assumed to meet functions 1-3 when the average performance values of the device agree with the performance values generated for unmodified vacuum assist nozzles, accounting for the experimental uncertainty and variation.

Functions 4-6 will be confirmed using ARB test procedures TP-201.4, TP-201.5 and TP-201.6. At least three tests will be performed on a vacuum assist nozzle with and without the ORVR simulation device. The BAAQMD will execute these tests. The ORVR simulation device will be assumed to meet functions 4-6 when the average performance values of the device agree with the performance values generated for unmodified vacuum assist nozzles, accounting for the experimental uncertainty and variation. Confirmation of functions 1-6 will occur at the same vacuum assist-equipped GDFs used for the "vapor return" experiments described earlier in this section.

The location of the testing will be vacuum assist GDFs in the east San Francisco Bay area configured with the conditions tabulated in Table 1-3. The locations of the specific test sites are listed in Table 1-4. The primary location refers to the first choice location. The fuel characteristics and GDF condition (e.g., fuel temperature) will be representative of ambient conditions and GDF status the day of the testing.

Table 1-3
Vacuum Assist Vapor Recovery System Test Conditions

Test Mode	VRS Type	Vent Valve	Assist Pump Location	Bell	Incinerator
4 Gilbarco	Vacuum Assist	Yes	Dispenser	No	No
5 Dresser Wayne	Vacuum Assist	Yes	Dispenser	Yes	No
6 Hirt	Vacuum Assist	Yes	Roof	?	Perhaps
7 Hasstech	Vacuum Assist	Yes	Midstream	?	Perhaps

Table 1-4
Vacuum Assist Field Test Locations

Vapor Recovery System Type	WSPA Member Company Site Number	Location	Primary/Secondary Location
Gilbarco Vacuum Assist	Shell	3621 San Pablo Dam El Sobrante, CA	Primary
	Unocal 6013	119 Red Top Road Fairfield, CA	Secondary
	Shell Oil	3035 Geary Blvd. San Francisco, CA	Secondary
Dresser Wayne Vacuum Assist	Chevron 4014	2695 Pinole Valley Road Pinole, CA	Primary
	Shell	2690 Pinole Valley Road Pinole, CA	Secondary
	Chevron 3072	2329 N. Main Street Walnut Creek, CA	Secondary
	Shell	708 Admiral Callghgn Lane Walnut Creek, CA	Primary
Hirt Vacuum Assist	Rotten Robbie 36	1515 Danville Blvd. Alamo, CA 94507	Primary
	Beacon Oil 558	32245 Fremont Blvd. Fremont, CA	Secondary
	Olympic	2000 19th Avenue San Francisco, CA	Secondary
Hasstech Vacuum Assist	Unocal	10151 E. 14 Street Oakland, CA	Primary
	Beacon 594	40500 Fremont Blvd. Fremont, CA 94536	Secondary
	Olympic	3300 Army Street San Francisco, CA	Secondary

Quantification of transfer emissions at GDFs without VRS

Uncontrolled transfer emissions will be quantified at an exempt facility (a GDF without Stage II VRS). Transfer emissions will be quantified used the "sleeve" test in ARB TP-201.2 . Emissions will be reported as pounds of hydrocarbon emitted per 1,000 gallons of gasoline dispensed and as grams of hydrocarbon emitted per gallon of fuel dispensed. Transfer emissions will be measured over the course of a 100 vehicle test as mandated by TP-201.2.

The results of these measurements will be contrasted with the 8.4 pounds of hydrocarbon emitted 1,000 gallons emission factor, the transfer emission factor calculated in the ORVR system seal performance test, and published uncontrolled transfer emission factors internal to mathematical models which are used to evaluate uncontrolled emission factors (e.g., EPA and SAE models). A list of the exempt stations for use in this test series is tabulated in Table 1-5.

Table 1-5
Exempt VRS Field Test Locations

Vapor Recovery System Type	WSPA Member Company Site Number	Location	Primary/Secondary Location
Exempt	TBD	TBD	TBD
	TBD	TBD	TBD

ORVR IMPACTS TEST SERIES

The primary goal of the ORVR impact test series is to directly quantify the effects that ORVR-equipped cars will have, in combination with various types of VRS, on GDF vent and fugitive hydrocarbon emissions. Eight different types of VRS will be evaluated. Tables 1-6 and 1-7 tabulate the various VRS types to be used in this test series. VRS system type will be the primary independent variable for this test series and vent/fugitive emissions will be the dependent variable. The location of the test sites are in the east San Francisco Bay area. A list of test site locations is tabulated in Table 4-1. These facilities have at least 16 nozzles in operation. All emissions testing will be executed in the fall and early winter. Ambient temperature and pressure conditions and winter fuel will be the secondary independent variables influencing vent and fugitive emissions variance.

Table 1-6
Vapor Recovery System Test Conditions

Test Mode	VRS Type	Vent Valve	Assist Pump Location	Bell	Incinerator
1	None	No	N/A	No	No
2	Balance 1	No	N/A	No	No
3	Balance 2	Yes	N/A	No	No
4	Vacuum Assist 1	Yes	Dispenser	No	No
5	Vacuum Assist 2	Yes	Dispenser	Yes	No
6	Vacuum Assist 3	Yes	Roof	?	Perhaps
7	Vacuum Assist 4	Yes	Midstream	?	Perhaps
8	Vacuum Assist 5	Yes	-	?	Perhaps

Table 1-7
Vapor Recovery Specifications

VRS Type	Manufacturer	Nozzle
Balance 1	(Executive Order 52)	Balance nozzles OPW III V or Husky V34* Emco Wheaton A4005 * - preferred
Balance 2	(Executive Order 52)	Balance nozzles OPW III V or Husky V34* Emco Wheaton A4005 * - preferred
Vacuum Assist	Gilbarco VaporVac (Executive Order 150)	OPW II VAI
Vacuum Assist	Dresser Wayne (Executive Order 153)	OPW II VAI
Vacuum Assist	Hirt (Executive Order G-70-33) old system the new system is not certified	Balance nozzles OPW III V or Husky V34* Emco Wheaton A4005 * - preferred
Vacuum Assist	Hasstech (Executive Order 7) (Executive Order 70-164) the new bootless system	Husky V34 or OPWIII VAI
Vacuum Assist	Healy (Executive Order 70) (Executive Order G-70-165) new system	Healy 200/400 (old) Healy 600 (new system)

Vent and Fugitive Emissions at Uncontrolled GDFs

Vent emissions will be measured continuously at an uncontrolled GDF (i.e., no stage II VRS) for at least 48 hours using the relevant methods in ARB TP-201.2. Prior to, and immediately after the emissions testing, the BAAQMD will assay GDF static pressure using the methodology specified in ARB TP-201.3. Fugitive emissions will be quantified later in the Acurex laboratory using ARB TP-201.2B.

Vent and Fugitive Emissions at Balance VRS Equipped GDFs

Vent and fugitive emissions will measured at the balance VRS equipped GDF identified as test modes 2 and 3 in Table 1-6. The balance VRS field test sites listed in Table 1-2 will be used for the field test sites. The difference between mode 2 and 3 is the presence of a P/V valve on the vent line. Prior to the initiation of the field emissions test, a one-week record of nozzle product throughput will be collected. These data will used to identify nozzles which have sufficient product throughput to achieve the two test case criteria identified in Table 1-8. For each test case, the ORVR simulation device(s) will be placed on the number of nozzles required to meet the per cent of gasoline dispensed for each of the two test cases. Concurrently with the hydrocarbon measurement procedures, refueling 1998 calendar year automobiles equipped with ORVR will be cataloged using the list contained in Appendix D as a frame of reference.

Table 1-8
Criteria for ORVR Simulation Test Cases

Test Case	% of Gasoline Dispensing to ORVR Equipped Cars
1	5-15
2	20-60

Vent emissions will be measured continuously for at least 48 hours. Vent emissions will be measured pursuant to the specifications of ARB TP-201.2. Fugitive emissions will be quantified later in the Acurex laboratory using ARB TP-201.2B. Prior to, and immediately after the emissions testing, the BAAQMD will assay GDF static pressure, dynamic back pressure and liquid removal performance using the methodology specified in ARB TP-201.3, TP-201.4 and TP-201.6, respectively. All of the GDF performance and emissions testing will occur in the fall-winter months. The emission results will be expressed as pounds of hydrocarbon emitted per 1,000 gallons of gasoline dispensed.

Vent and Fugitive Emissions at Vacuum Assist VRS Equipped GDFs

Vent emissions will measured at the vacuum assist VRS equipped GDFs identified as test modes 4-8 in Table 1-6. The field test locations are tabulated in Table 4-1. Prior to the initiation of the field emissions test, a one-week record of nozzle product throughput will be collected. These data will used to identify nozzles which have sufficient product throughput to achieve the two test case criteria identified in Table 1-8. Similar to the balance test sites, for each test case, the ORVR simulation device(s) will be placed on the number of nozzles required to meet the per cent of gasoline dispensed for each of the two test cases. Concurrently with the hydrocarbon measurement procedures, refueling 1998 calendar year automobiles equipped with ORVR will be cataloged using the list contained in Appendix D as a frame of reference.

Vent emissions will be measured continuously for at least 48 hours. Vent emissions will be measured pursuant to the specifications of ARB TP-201.2. Fugitive emissions will be quantified later in the Acurex laboratory using ARB TP-201.2B. Prior to, and immediately after the emissions testing, the BAAQMD will assay GDF static pressure, dynamic back pressure, air:liquid ratio and liquid removal performance using the methodology specified in ARB TP-201.3, TP-201.4, TP-201.5 and TP-201.6, respectively. All of the GDF performance and emissions testing will occur in the fall and early winter months. The emission results will be expressed as pounds of hydrocarbon emitted per 1,000 gallons of gasoline dispensed.

Development of Emission Factor Models for GDFs

The emissions data collected in both the ORVR simulation test series and the ORVR impact test series will be used to derive eight emission factor models representing the eight types of VRS evaluated relative to ORVR/VRS interaction. The independent variable is the percent of gasoline dispensed to ORVR equipped vehicles and the dependent variable is GDF vent and fugitive emissions. Each model will predict hydrocarbon emissions from each facility in pounds per hydrocarbon emitted per 1,000 gallons dispensed as a function of the percent gasoline dispensed into ORVR-equipped vehicles. Each will address the following emission sources:

- Transfer emissions from non-ORVR equipped vehicles, adjusting for whether the GDF is uncontrolled or controlled (i.e., equipped with VRS) for hydrocarbon emissions. VRS equipped GDFs will be assumed to be 95% efficient in controlling transfer emissions.
- Transfer emissions from ORVR-equipped vehicles originating from ORVR system seal leaks as a function of VRS type.
- Vent emissions as a function of VRS type.
- Fugitive emissions as a function of VRS type.
- ORVR canister hydrocarbon losses which will be assumed to be 5% of uncontrolled transfer emissions as specified in the project RFP.

The independent dependent variable relationship will be evaluated in terms of whether it is linear or nonlinear.

SECTION 2

ORGANIZATION AND RESPONSIBILITY

The organization chart for this project is presented in Figure 2-1.

Dr. Robert Grant is the ARB contract officer for this project.

Dr. David Shearer will serve as AVES's project manager. He is responsible for the overall operation of AVES program. In addition, he is charged with crafting the study design and QAPP documents, overseeing the field study and drafting the project final reports.

A technical advisory panel (TAP) will provide technical review of project milestones. The TAP membership consists of the following individuals:

- Robert Grant, ARB
- James Loop, ARB
- Cynthia Castronova, ARB
- Laura McKinney, ARB
- Ken Kunaniec, CAPCOA
- Dave Good, USEPA
- Glen Passavant, USEPA
- Don Gilson, Western States Petroleum Association (WSPA)
- Harold Haskew, American Automobile Manufacturing Association (AAMA)

Mr. Stefan Unnasch from Acurex Environmental will be the manager of Acurex's work scope. He will be responsible for the set-up and operation of the monitoring sites. This includes the assembling of a field test van and executing the hydrocarbon, pressure, temperature, and flow measurement and data acquisition procedures as defined in the ARB C & TPs or the project proposal.

Mr. Chadd Garretson from Acurex Environmental, a senior measurement engineer, is the field site manager. He is charged with overall site operations responsibility relative to GDF interface, equipment set-up and tear down, and execution of the C & TPs.

Mr. Volker Druenert from Acurex Environmental, a senior instrument technician, is responsible for the calibration, maintenance and daily operation of the VRS and meteorological monitoring equipment.

Mr. Bernard Leong from Basic Research will assist the Acurex field staff in executing the field tests.

Mr. Ken Kunaniec from the Bay Area Air Quality Management District is responsible for the pre- and post-test VRS performance tests.

The performance and system audit responsibilities will be performed by Mr. David Bush, AeroVironment's manager for quality assurance.

Ms. Lydia Chu, head of the data management group, is responsible for the data reduction.

Project Organization

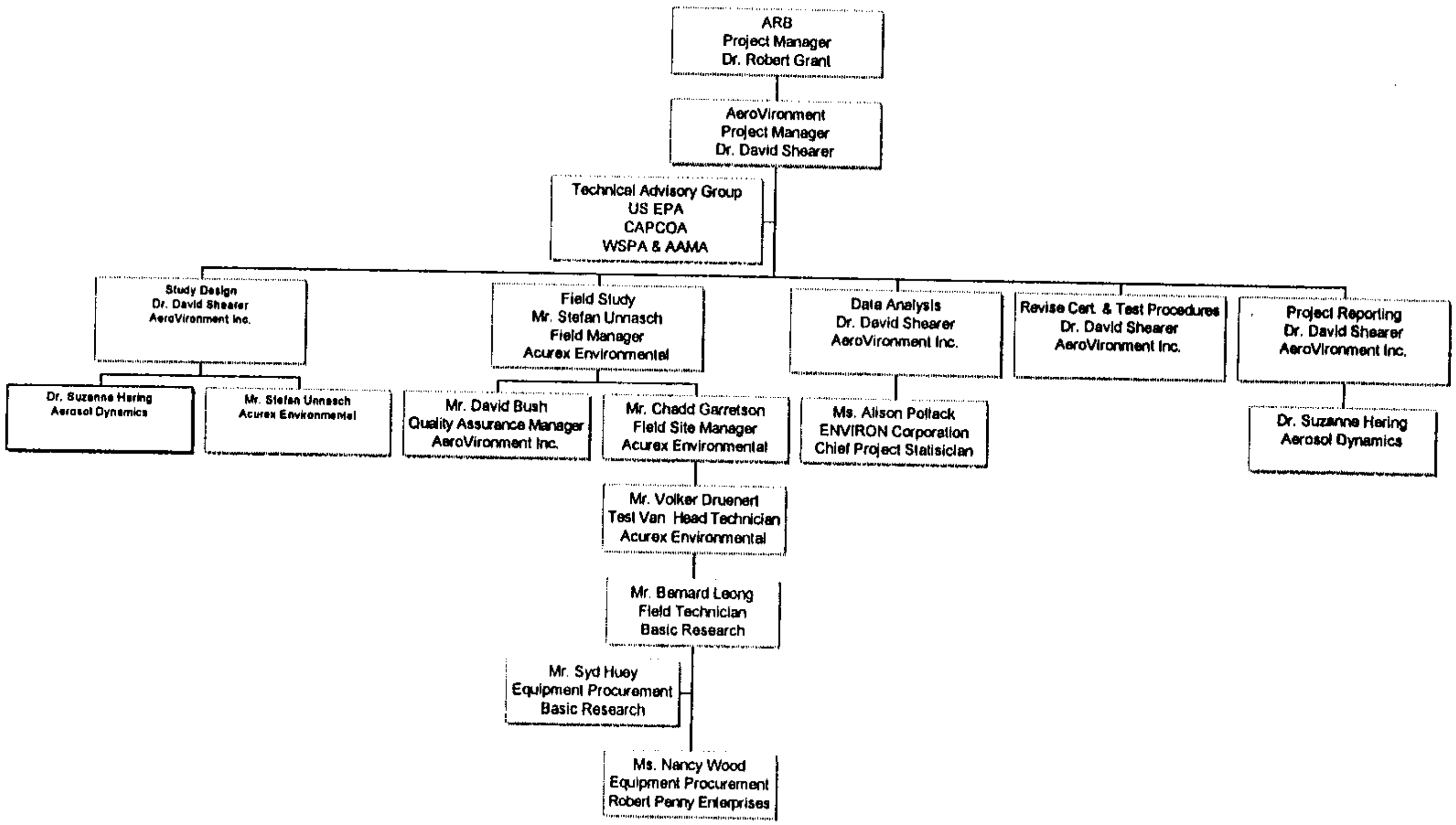


FIGURE 2-1.

Ms. Alison Pollack from ENVIRON is responsible for designing and executing the statistical analysis.

Dr. Suzanne Hering from Aerosol Dynamics is responsible for assisting in crafting the study design document.

Mr. Sidney Huey from Basic Research is responsible for purchasing the required field test equipment and data acquisition systems.

Mr. Robert Penny of Robert Penny Enterprise will assist in purchasing the required field test equipment and data acquisition systems.

SECTION 3

QUALITY ASSURANCE OBJECTIVES FOR MEASUREMENT DATA

3.1 INTRODUCTION

The Quality Assurance Project Plan defines the data quality goals for the project and the quality control activities necessary to obtain them. These goals are stated in terms of precision, accuracy and completeness. Quality Assurance (QA) is defined as independent assessments of the effectiveness of the measurement program and the quality assurance procedures employed. This includes both performance and system audits. Quality Control (QC) is defined as the operational procedures used to evaluate whether a measurement process is generating valid data. This includes periodic calibrations, duplicate checks, zero-span checks and review of the data for reasonableness and consistency. QC procedures are used to document claims of accuracy.

3.2 QUALITY ASSURANCE OBJECTIVES FOR MEASUREMENT DATA

Table 3-1 delineates the QA objectives for all field activities that generate data. These objectives are presented in terms of accuracy, precision and completeness. The Environmental Protection Agency (EPA) defines these terms as follows:

- Accuracy is the degree of agreement between the measurement or the average of measurements for a parameter and the accepted reference or true value. It is the combination of the bias and precision in a measurement system.
- Precision is the measure of mutual agreement among individual measurements of the same property.
- Completeness is the measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained.

Table 3-1
Quality Assurance Objectives
Field Measurement Program

Equipment	Accuracy	Precision	Data Completeness
Temperature			
Ambient Temperature K-type thermocouple	0.2 °F	0.2%.	85%
VRS Temperature K-type thermocouple	0.2 °F	0.2%.	85%
Pressure			
VRS Pressure Transducers* (Omega)	±0.50%	0.10%	85%
Ambient Pressure* Transducers (Sensyn)	±0.50%	0.10%	85%
Vapor Volume			
McMillian 100 Flo-Sen*	±3.0%	10%	85%
Roots Meters*	±3.0%	10%	85%
Hydrocarbon Measurement			
California Analytical NDIR*	10%	10%	85%
Beckman GC FID*	10%	10%	85%
Horiba GC-FID*	10%	10%	85%
Foxboro OVA*			85%
Ratfisch*	10%	10%	85%

* - Relative to full scale

SECTION 4

MONITORING PROCEDURES

AVES, in collaboration with Acurex Environmental Corporation, will execute the GDF measurement program. The measurement program is designed to conform to the requirements of the study design document and the ARB C&TPs. The C & TPs specify that hydrocarbon, pressure, temperature, and flow measurements will be executed at three locations on the site-specific Phase II vapor recovery systems:

- The nozzle/vehicle interface.
- The product dispenser return vapor line.
- The outlet for the underground storage tank vent line.

In addition, for this project the C & TPs define protocols for assessing one other potential sources of GDF emissions:

- The estimated amount of fugitive emissions leaving site-specific vapor recovery systems as a function of facility pressure profiles.

These measurements will be executed for both the ORVR simulation model and ORVR impact test series at the following test points:

- The nozzle/vehicle interface - ORVR simulation model and ORVR impact test series.
- The product dispenser return vapor line - ORVR impact test series.
- The outlet for the underground storage tank vent line - ORVR impact test series.

The following discussion describes how the test sites were chosen and the how the parameter-specific measurements will be executed.

4.1 GASOLINE DISPENSING FACILITY SITE SELECTION PROTOCOL

The criteria for selecting the GDF measurement sites included the following characteristics:

- Proximity to both Sacramento and the San Francisco Bay area. The agreed upon locations are in the east San Francisco Bay Area within 75 miles of Sacramento.
- A product throughput of at least 100,000 gallons per month (> 16 nozzles).
- The presence of tank level monitors on the GDF underground storage tank or a computerized tracking system for product volume.
- The site has one of the seven system types required for the study.
- The sites are distributed evenly across the membership of the Western States Petroleum Association member companies.

Based on these criteria, Table 4-1 lists the sites that will be used for the field study. Within each site category, the primary site versus secondary sites is specified. This denotation clarifies which of the sites are backup locations (secondary) and which sites are the first choices within each vapor recovery category. At least two backup sites for each vapor recovery system type are identified.

Table 4-1
Field Test Locations

Vapor Recovery System Type	WSPA Member Company Site Number	Location	Primary/Secondary Location
Exempt	TBD	TBD	TBD
	TBD	TBD	TBD
Balance	ARCO #2180	3000 Travis Boulevard Fairfield, CA	Primary
	Chevron #5595	1700 Mt. Diablo Martinez, CA	Secondary
	Chevron #94640	2895 N. Main Street Walnut Creek, CA	Secondary
	Chevron #0336	4295 Clayton Road Concord, CA	Secondary
Gilbarco Vacuum Assist	Shell	3621 San Pablo Dam El Sobrante, CA	Primary
	Unocal 6013	119 Red Top Road Fairfield, CA	Secondary
	Shell Oil	3035 Geary Blvd. San Francisco, CA	Secondary
Dresser Wayne Vacuum Assist	Chevron 4014	2695 Pinole Valley Road Pinole, CA	Primary
	Shell	2690 Pinole Valley Road Pinole, CA	Secondary
	Chevron 3072	2329 N. Main Street Walnut Creek, CA	Secondary
	Shell	708 Admiral Callghgn Lane Walnut Creek, CA	Primary
Hirt Vacuum Assist	Rotten Robbie 36	1515 Danville Blvd. Alamo, CA 94507	Primary
	Beacon Oil 558	32245 Fremont Blvd. Fremont, CA	Secondary
	Olympic	2000 19th Avenue San Francisco, CA	Secondary
Hasstech Vacuum Assist	Unocal	10151 E. 14 Street Oakland, CA	Primary
	Beacon 594	40500 Fremont Blvd. Fremont, CA 94536	Secondary
	Olympic	3300 Army Street San Francisco, CA	Secondary
Healy Vacuum Assist	Chevron	4400 Piedmont Ave. Oakland, CA	Primary

4.2 METEOROLOGICAL MEASUREMENTS

At each site, ambient meteorological measurements will be data logged continuously during the C & TP measurement program. The location of the meteorological instrumentation will be in close proximity to the field test van to facilitate data logging ease. However, recognizing potential interferences from the field test van, the meteorological tower will be far enough away to minimize external interferences.

Ambient temperature values will be assessed using an Omega K-type thermocouple probe integrated with an Action Instruments TC temperature signal conditioner (Model 4351-2000). A K-type thermocouple functions by measuring the resistance across a thermocouple probe with a 0-5 volt scale. The temperature signal conditioner is a pulse accumulator which conditions the temperature resistance signal. A temperature value will be recorded every second and fed into the data acquisition system.

Ambient pressure will be recorded using a Sensyn Model LM1801 absolute pressure transducer. As with temperature, a pressure value will be determined every second and will subsequently be data logged..

4.3 HYDROCARBON MEASUREMENTS

The hydrocarbon measurements will be performed according to the procedures specified in ARB C & TPs. For this project, there are three relevant certification and test procedures:

TP-201.2 - Determination of Efficiency of Phase II Vapor Recovery Systems of Dispensing Facilities: The purpose of this test procedure is to determine the percent vapor recovery efficiency for a vapor recovery system at a GDF. The percent vapor recovery efficiency is the percent of vapors displaced by dispensing which are recovered by a vapor recovery system rather that emitted to the atmosphere.

TP-201.2A - Determination of Vehicle Matrix for Phase II Vapor Recovery Systems of Dispensing Facilities: The sample of vehicles to be used in Method TP-201.2 for testing vapor control systems shall be made up of vehicles representative of the on road vehicle population in terms of vehicle miles traveled. This calculation procedure produces such a representative vehicle matrix.

TP-201.2B - Determination of Flow Versus Pressure for Equipment in Phase II Vapor Recovery Systems of Dispensing Facilities: The purpose of this test procedure is to determine The fugitive emissions and the vapor recovery efficiency at GDFs. The mass flux of fugitive emissions from a dispensing facility is the product of the volumetric flow rate and the flow-weighted mass per volume concentrations. The volumetric flow rate is based on data for pressure vs. time from the facility and data for flow vs. pressure from a model of the facility. The model flow vs. pressure data are to provide a conversion for the facility pressure vs. time data to flow vs. time data.

The specifics of these test procedures are contained in Appendices A-C. Unless specified in this document, the hydrocarbon test procedures will be executed as specified in the C & TP. TP-201.2 and TP-201.2A will be are executed in the field. TP-201.2B will be executed in the Acurex laboratory as a benchtop experiment with site-specific pressure signatures provided by the BAAQMD performance tests.

For the purposes of this project and as specified in TP-201.2, there will be three test locations at each of the field test sites for the ORVR impact test series (Only Test Point 1 for the ORVR simulation model test series) where hydrocarbons (temperature, pressure and vapor volume will also be measured at these test points) will be quantitatively measured (Figure 4-1 [Appendix A, Figure 1, TP-201.2}):

- Test Point 1 - The nozzle fill neck interface.
- Test Point 2 - The dispenser vapor return line.
- Test Point 3 -The UST vent line outlet.

In addition, an ancillary hydrocarbon detection procedure (measured as percent LEL) will be executed at only test point one for the purposes of assessing leakage at the vehicle/nozzle interface.

4.3.1 Analytical Procedures for TP-201.2

As specified in the C & TPs, the hydrocarbon measurements will be performed according to EPA reference method 25A and 25B. EPA Method 25A describes the determination of total gaseous organic compound emissions using a flame ionization detector and EPA Method 25B specifies the determination of total gaseous organic compound emissions using a nondispersive infrared analyzer.

The principle of operation for the flame ionization detector method (EPA 25A) is that a hydrocarbon gas sample is extracted from the source through a sample line and a glass fiber filter to a flame ionization analyzer. Results are reported as volume concentration equivalents of the calibration gas or as carbon equivalents. The principle of operation for the nondispersive infrared method (EPA 25B) is similar. A hydrocarbon gas sample is extracted from the source through a sample line and a glass fiber filter to a nondispersive infrared analyzer (NDIR). analyzer. Results are also reported as volume concentration equivalents of the calibration gas or as carbon equivalents.

The specifications of the hydrocarbon analyzers to be used for this project are tabulated in Table 4-2. Based the specifications defined in TP-201.2, the primary distinction between the sample trains for the FID and NDIR analyzers is that the hydrocarbon sample stream from the NDIR is returned unaltered from the NDIR outlet to the sample manifold. The hydrocarbon sample train for each sample points is described in Appendix A for sample points 1-3. The exception to this reference is for sample point 3. A method developed by AeroVironment for a UST vent line study (AeroVironment, 1994) will be used. Figure 4-1 illustrates the sample train to be used for this method.

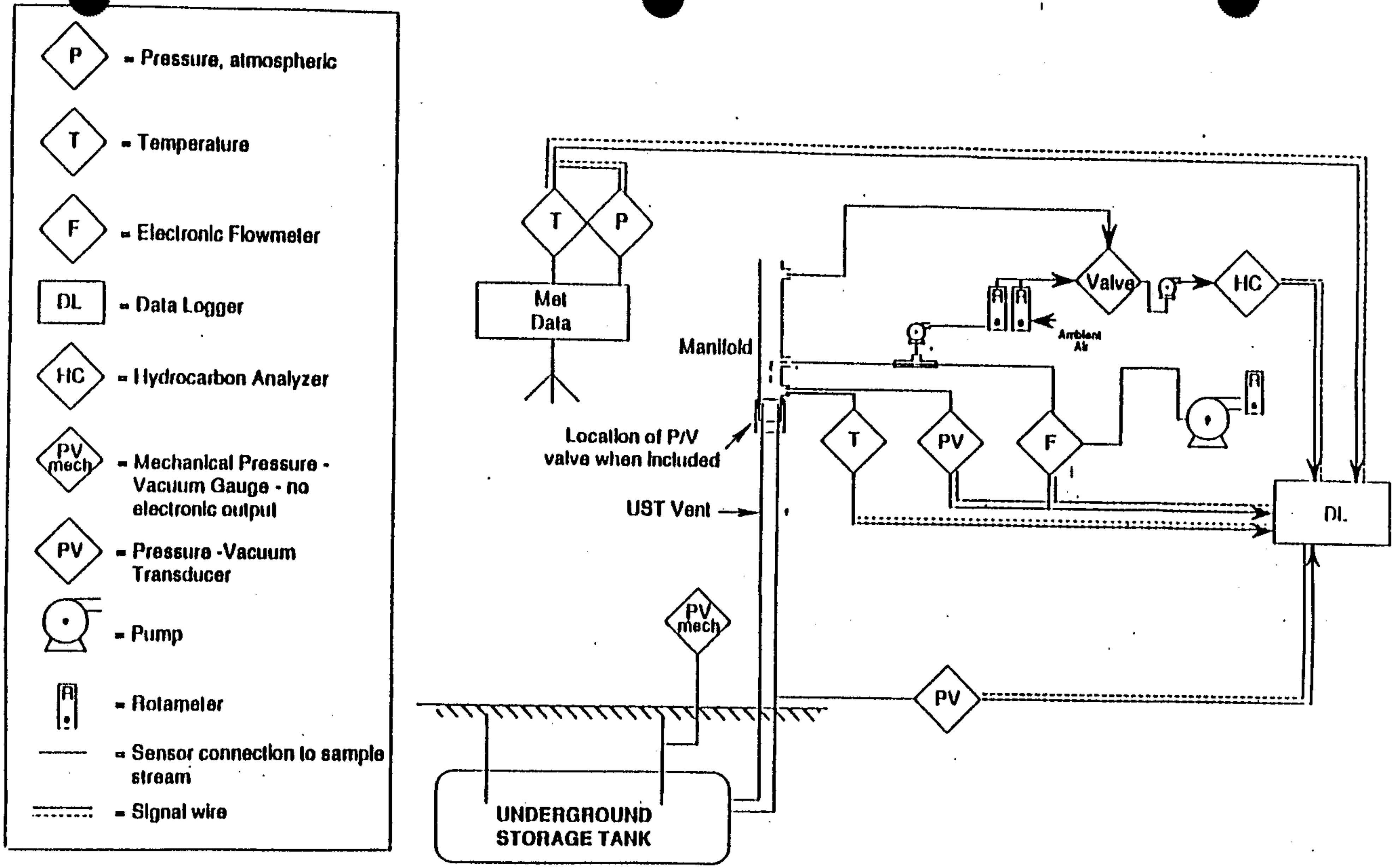


FIGURE 4-1 Underground Storage Tank Vent Line Monitoring Scheme.

Table 4-2
Hydrocarbon Analyzer Specifications

Instrument Model Number	Analytical Method	Test Points	Operating Range (ppm as C_3)	Use
Horiba Model OPE-435	FID	3	0-1000	Low sleeve Test Point Used to Assess End of Event
Ratfisch Model RS 55CA	FID	3	0-1000	Vent Line High Flow (100-150 lpm)
Beckman Model 400A	FID	1	100,000 (0-10%)	High Concentration at Nozzle/fillneck Interface
Century OVA Model 128GC	FID	3	0-100	Vent Low Flow Qualitative Measure to Assess Breakthrough at P/V Valve
California Analytical Model 100	NDIR	2	1,000,000 (0-100%)	Return Line

An additional hydrocarbon detection procedure will be executed only at test point one. The purpose of this procedure is to check for hydrocarbon leaks at the nozzle vehicle fillneck interface. Leaks in excess of 0.1% of LEL will be deemed as not conforming to the maximum leakage requirements for a vehicle to qualify for additional hydrocarbon testing. The methodology to execute this procedure is specified in TP-201.2, Sections 5.1 8.1.1.4.2 (Appendix A). The hydrocarbon leak detection will be executed with a combustible gas detector (Century OVA Model 108), as specified in EPA Method 21.

The duration of the hydrocarbon assessment procedures for each vapor recovery system type will be at each 48 hours for the ORVR impact test series. For the ORVR simulation test series, at least 10-15 cars will be evaluated at test point 1. The specific vehicles to be tested are notated in the 100 car matrix published by ARB. The 100 car matrix is intended to represent the current fleet mix found on California's roadways based on vehicle miles traveled. The refueling events must be for at least X gallons.

The hydrocarbon data will be data logged into the data acquisition system with a data point collected every second from each of the hydrocarbon analyzers.

4.3.2 Analytical Procedures for TP-201.2B

The procedures for TP-201.2B are contained in Appendix C. The objective this C & TP is to estimate site-specific fugitive emissions by determining the flow leaving the facility as a function of VRS pressure signatures. Fugitive emission sources include UST vent lines equipped with P/V valves, "closed" idle nozzle check valves and "closed" overfill drain valves.

Several parameters need to be quantitatively measured to produce a value for fugitive mass flux including:

- Facility VRS volumetric leak flow rate
- Facility VRS pressure profiles

- Hydrocarbon concentrations (hydrocarbon mass/volume of hydrocarbon emitted
- Facility VRS temperate profiles

To generate the pressure and flow values, the Bay Air Quality Management District will execute two inch static pressure performance tests (C & TP TP-201.3) at each field test sites. This procedure pressurizes the entire vapor recovery system to two inches water column. After five minutes, the VRS pressure is noted and compared to allowable levels. Using standard engineering principles, the volumetric leak flow rate can be calculated. This value, coupled with the flow-weighted hydrocarbon mass per volume concentration yields the mass flux of fugitive emissions leaving the GDF for the TP-201.3 pressure conditions.

Hydrocarbon concentrations (mass/volume) will be assayed at the field test sites at test point 3 with P/V valves in place. Facility pressure and temperature profiles will be collected during the execution of TP-201.2 at test points 1-3 for representative facility operating conditions. These include maximum and minimum facility throughputs and product bulk drops.

To model the facility, a piece of capped PVC pipe will be pressurized using bottle nitrogen. A small hole will subsequently be added to the PVC pipe such that the flow out that hole equals the site-specific leak flow rate as a function of pressure (as determined by TP-201.3). Having established the facility model, volumetric leak flow rates will be determined for the time dependent pressure profile conditions found at each field test sites. These data will then be coupled with the hydrocarbon mass/volume data to produce an estimate of field test site-specific hydrocarbon fugitive emissions.

4.4 PRESSURE MEASUREMENT

Based the specifications of TP-201.2, pressure readings will be taken at test points 1-3 concurrent with the hydrocarbon measurements. Pressure will be assessed at all of field test sites for both the uncontrolled and controlled test sites. The specific locations of the pressure transducers on the sample manifold relative to the flow measurement devices (roots meter or flow meter) are noted in TP-201.2 (Appendix A). In general, they are upstream from the hydrocarbon vapor flow devices. The pressure transducers that will be used are tabulated in Table 4-3.

Table 4-3
Pressure Transducers

Transducer Make	Model	Range
Omega	PX-653-0.025BD5V	± 0.25 in. WC
Omega	PX654-01BD5V	± 1.0 in. WC
Omega	PX240	±0 2.5 in. WC
Omega	PX654-50BD5V	±0 5.0 in. WC
Omega	PX654-10BD5V	±0 10.0 in. WC

4.4.1 Analytical Procedures for TP-201.2

As is apparent from Table 4-3, a range of differential Omega pressure transducers will be available for the field technicians. The specific transducer that will be used will depend on the vapor recovery system pressure profile at the time of the test. For each of the three test point locations, the pressure values will be recorded every second and data logged using the test van data acquisition system.

In addition to the three test point pressure transducers, at the vent and nozzle locations, a magnehelic gauge (0-25 in WC) will also be used to assess vapor recovery system pressure. This is feasible because the test system is steady state. The pressure at each of these locations will be recorded on field data sheets for each refueling episode.

4.5 TEMPERATURE MEASUREMENT

Based on the specifications of the study design document and the relevant C & TPs, at each of the test site locations in the uncontrolled test series hydrocarbon vapor temperature will be continuously recorded at test points 1-3 and in the UST for the product dispenser being evaluated. Hydrocarbon vapor temperature values will also be assayed for test points 1-3 in the controlled test series depending on the outcome of the uncontrolled test series data analyses.

4.5.1 Analytical Procedures for TP-201.2

Temperature will be measured using Omega K-type probe integrated with an Action Instruments TC temperature signal conditioner (Model 4351-2000). A K-type thermocouple probe functions by measuring the resistance across a thermocouple with a 0-5 volt scale. The temperature signal conditioner is used to convert the thermocouple probe analog output into a digital signal that can be input into the field test van data acquisition system. The range of the K-type thermocouple probe is 0-200 °F. The specific locations of the thermocouples probe on the sample manifold relative to the flow measurement devices (ROOTS® meter or flow sensors) are noted in TP-201.2 (Appendix A). In general, they are upstream from the hydrocarbon vapor flow devices. A temperature value will be recorded every second and fed into the data acquisition system.

4.6 VOLUME MEASUREMENT

Pursuant to the C & TPs specifications, the volume of hydrocarbon vapor will be measured at test points 1-3 for both the uncontrolled and controlled test series. While TP-201.2 (Appendix A) specifies the use of rotary positive displacement gas volume meters (e.g., ROOTS® meters) for this task, previous research has demonstrated that these devices may impede the flow of hydrocarbon vapors thus underreporting hydrocarbon vapor volume after correcting for temperature and pressure. An alternative method to quantify hydrocarbon vapor volume was developed and validated by AeroVironment Inc. (1994) using turbine flow sensors. Based on the proposed and accepted methodology for this project, this method will be used at test points 1 and 3 to assay hydrocarbon vapor.

4.6.1 Analytical Procedures for TP-201.2

MacMillian 100 Flo-Sen turbine flow sensors will be used to measure hydrocarbon vapor volume at the nozzle/fillneck interface and at the outlet of the UST vent line (test points 1 and 3). The range of the flow sensors is 0-100 liters per minute. The principle of operation for the flow sensors is that a Pelton type turbine wheel is used to determine the flow rate of the hydrocarbon vapor. As the turbine wheel rotes in response to gas flow rate, electric pulses are generated. Processing circuitry provides a D.C. voltage output (0-5 V) that is proportional to flow rate. This voltage output signal will be data logged each second and stored in the field test van data acquisition system. For these test points, vapor recovery system pressure and temperature will be measured at the inlet of the flow sensor. The hydrocarbon sample will be collected at the outlet of the flow sensors.

At test point 2, a ROOTS® rotary positive displacement gas meter will be used to quantify hydrocarbon vapor volume. The ROOTS® meter that will be used is a Dressor Model 3M175. The ROOTS® meters volume measurements will be electronically logged using a solid state pulser that transmits 100 pulses per revolution (where one revolution equals 1 cubic feet). Pulses will be totaled using an Action Instruments pulse accumulator which provides an operating range of 0-4180 pulses full scale. These values will be data logged using the field test van data acquisition system. During data processing, the hydrocarbon vapor volumes will be corrected for temperature and pressure based on the ambient temperature and pressure data collected concurrent with the C &TP test series.

4.7 ORVR SIMULATIONS

The ORVR refueling simulations will be executed with physical models that will be designed, field tested and fabricated based on the performance specifications described in ORVR simulation test series scope of work. It is anticipated that the balance VRS ORVR simulation model will be very similar to the neoprene donut toruses that ARB's Monitoring and Laboratory Division (MLD) staff has already developed. These devices have been demonstrated to meet the necessary conditions relative to VRS performance. To revalidate this assumption, a dynamic back pressure test assembly will be used to demonstrate that the maximum allowable pressure drops through the refueling system (i.e., a nozzle, vapor hose, swivels and underground piping) will not be exceeded. The design for the vacuum assist VRS ORVR simulation model will be developed during the early stages of this project based on the criteria specified in Section 1.2 of this document.

Once the ORVR simulation test models are developed, validated and fabricated, they will be used to simulate two levels of ORVR penetration at the field test sites: 5-15% and 20-60% penetration. In other words, 5-15% and 20-60% of the gasoline product used for refueling events will be delivered using the ORVR simulation models. The precise levels of penetration will be determined in consultation with the project Technical Advisory Panel. To further control for the interaction of ORVR vehicles on VRS performance, the numbers of 1998 ORVR equipped cars that are refueling at the field test sites will be cataloged based on the data contained in Appendix D. This information was provided by EPA's Office of Mobile Sources.

4.8 DATA ACQUISITION SYSTEMS

All of the collected independent and dependent measure parameters will be data logged at one second intervals using a personal computer (PC) based data acquisition system. The PC is equipped with a 75 megahertz Pentium CPU processor and a standard I/O board (Model C10-DAS1-602/16 made by Computer Board) with 16 single ended channels The data logging computer software is Laboratory Notebook. In addition to PC base data acquisition, strip chart records will also be used to record the continuous independent and dependent variables.

4.9 PRE-TEST AND POST-TEST MEASUREMENTS (STATIC AND DYNAMIC PRESSURE AND A/L TESTS)

As specified in the both the uncontrolled and controlled test series study design, prior to and following the execution of C &TPs, the site-specific vapor recovery systems will be evaluated for ARB specified performance. These tests will determine if the VRS are functioning according to manufacturers design and ARB mandated performance specifications. Three performance tests will be executed by Bay Area Air Quality Management District (BAAQMD) staff who are specially trained to execute these tests. The tests and their respective ARB designations are listed in Table 4-5.

Table 4-5
ARB Performance Tests

Variable	Measurement Methodology
Static Pressure	ARB TP-201.3
Dynamic Back Pressure	ARB TP-201.4
Air/liquid Ratio	ARB TP-201.5

If the particular VRS that is being tested does not pass the performance tests before the hydrocarbon emission testing is initiated, the VRS will be serviced and retested to assure that its passes the minimum specifications for vapor recovery system performance.

The performance data for each of the performance tests will be logged onto ARB sanctioned data sheets and will later be included in the project final report. In addition, the site-specific pressure profiles will be used as input data to execute TP-201.2B, the fugitive emissions C &TP.

4.9.1 Analytical Procedures

The analytical procedures for each of the performance tests are found in the ARB C & TPs.

4.10 SITE OPERATING PROCEDURES, QUALITY CONTROL CHECKS AND CALIBRATION

Field test site checks will be performed daily by the field test staff to ensure that the test equipment is properly installed and functioning correctly and that the field test van functioning according to design. Acurex field staff will be trained for these procedures. Hydrocarbon analyzer zero-span checks will be performed daily. Calibration of the hydrocarbon analyzers will be performed at the beginning and end of each site-specific field program. Additional calibrations will be performed quarterly or when analyzers are repaired and reinstalled.

The meteorological sensors will be calibrated at the beginning of the field measurement program.

4.10.1 Van Check Procedures

Field test van checks will be performed during each site visit by the site technician following a format prescribed by the field test station check forms. A model form for a ozone analyzer is illustrated in Figure 4-2. A form will be designed that is specific to the field test van.

The purpose of the field test van check is to ensure that the monitoring van is operating properly. This procedure gives warning of developing equipment problems and identifies instrument problems.

KCRA Tower Check List Log

Instrument	Item Checked	Reference	Range	Before	After
Station	Date	mm-dd-yy	NA		
	Time	hh:mm	NA		
	Checked by	Name	NA		
Chart Recorder	Trace	clear	NA		
	Supply	> 4 feet	NA		
	Date/Time	Mark chart	NA		
Data Logger	Proper time	PDT	+/- 2 min		
Ozone Daisbi 1008RS Analyzer	Sample flow	1.9 lpm	1.5 to 2.0		
	Sample frequency	40 K	30 to 48		
	Control frequency	50 K	50		
	Cell temperature	39 deg C	35 to 45		
	Sample pressure	atm	>0.8		
	30 ft				
	400 ft				
	800 ft				
	1200 ft				
	1600 ft				
	Auto span	Record setting			
	Last A factor	NA	NA		
	Last B factor	NA	NA		
Zero check	Lamp setting	off	NA		
	Trn-std display	0.010 ppm	.005 to .015		
	DAS	0.000	-.005 to .005		
Precision check	Lamp setting				
	Trn-std display	0.100 ppm	.090 to .110		
	Trn-std true	0.090 ppm	.081 to .099		
	DAS	0.090 ppm	.081 to .099		
	% difference	0%	+/- 10%		
Span check	Lamp setting				
	Trn-std display	0.410 ppm	.369 to .451		
	Trn-std true	0.400 ppm	.360 to .440		
	DAS	0.400 ppm	.360 to .440		
	% difference	0%	+/- 10%		
Dasibi 1003 Transfer Standard	Sample flow	1.9 lpm	1.5 to 2.0		
	Sample frequency	40 K	30 to 48		
	Control frequency	50 K	24 to 30		
	Cell temperature	39 deg C	35 to 45		
	Auto span	Record setting			
	Last A factor	NA	NA		
	Last B factor	NA	NA		
	Site pressure	29.9 in. Hg	NA		

Transfer standard true =
(("trn-std" - "trn-std zero")*(29.9/"site press")*(273+"cell temp"/313)*"last A")-"last B"

During each field test van check, the site technician visually inspects the meteorological sensors, the temperature, pressure, and flow probes, hydrocarbon inlet system (i.e., the sample manifold) and the hydrocarbon analytical equipment.

The field test van has a bound logbook for notating Acurex's comments concerning the test van operation as well as maintaining a record of van maintenance activity. AVES's and Acurex's procedures require that a logbook entry be made whenever a test van is serviced, checked or altered. It serves as a legal record of all activities within the field test van and is used to substantiate the integrity of the collected data.

Once a month, the field site technicians will send copies of all recorded data and logbook pages to AVES San Francisco for processing.

4.10.2 <u>Quality Control Checks and Frequency</u>

The quality control checks include periodic operational checks of the field instruments by the site operator coupled with computerized data screening by AVES Monrovia data processing operations for outliers.

4.10.2.1 Zero, Span and Precision Checks - Hydrocarbons

Each of the hydrocarbon analyzers will be subjected to a zero and span check on a daily basis (drift check every 2-3 hours). The zero and span check data will be reviewed daily by an Acurex data technician.

As specified in EPA Methods 25A and 25B, the FID and NDIR analyzers will be calibrated using primary gas standards of appropriate concentrations. Standards in excess of 9,000 ppm will be blended on-site using an Environs mass flow gas dilution system (Series 4000) plus research grade propane (C_3). Other sources of liquid propane may be used if they can be shown to be equivalent to research grade with reference to instrument response equivalency (i.e., within 2% of range for mid-level gas). The span gas concentrations are about 90 percent of the analyzer's nominal operating range. The measurement system performance specifications will be ± 3 percent of the span value for zero drift, and calibration drift and ± 5 percent for calibration error.. The frequency of calibration will be daily: prior to testing, two hours after the initial calibration was executed and at any time a calibration drift is evident. The OVA will be calibrated with a high range and 0 gas.

To perform zero and span checks, a zero concentration and one span concentration is introduced into each analyzer. The span gas concentrations are about 90 percent of the analyzer's nominal operating range. The analyzer operates in its normal sampling mode. The test gas passes through all filters, scrubbers, conditioners and other components used during normal sampling.

The zero and span data are used to determine whether the analyzer is in need of adjustment and to evaluate the validity of the data obtained. The following criteria are used in evaluating the data:

<u>Zero checks</u>-As part of the quality control checks, the daily zero checks should be within ±3% of full scale from the zero value established during the calibration. If on two consecutive zero checks (at least one day apart) the zero is greater than this tolerance the instrument will be removed from service, the problem corrected, the instrument calibrated and put back on line. If

the zero check exceeds 4% of full scale the instrument will be taken off line immediately, a "before" calibration performed, the problem with the instrument corrected and a new "after" calibration performed. If the zero check exceeds 5% of full scale, serious instrument problems are present with the monitor and/or calibration system. This is a threshold to invalidate data. The same action as the 4% criteria should be taken.

Span checks-As part of the quality control checks, the daily, or other interval, span checks (1.5 -2.5 times of the expected concentration) should be within ± 10% of span value established during the calibration. If on two consecutive span checks (at least one day apart) the span is greater than this tolerance the instrument will be removed from service, the problem corrected, the instrument calibrated and put back on line. If the span check exceeds 15% the instrument will be taken off line immediately, a "before" calibration performed, the problem with the instrument corrected and a new "after" calibration performed. If the span check exceeds 25%, serious instrument problems are present with the monitor and/or calibration system. This is a threshold to invalidate data. The same action as the 15% criteria should be taken.

Precision checks will performed each month using a span gas 20% of the hydrocarbon analyzer range. At least four different measurements will be taken. The mean and standard deviation of these values will be used to calculate the precision value.

4.10.2.2 Temperature

Temperature quality assurance checks will be executed on a monthly basis using a one point intercomparison between a field standard (an Campbell 107 naturally aspirated thermometer) and the K-type thermocouple probe.

4.10.2.3 Pressure

Ambient pressure quality assurance checks will be executed on a monthly basis using a one point intercomparison between a field standard (a portable altimeter) and the pressure transducer.

For each of the vapor recovery system pressure transducers that will be used in this study, a calibration check will be executed prior to and immediately following the test period in accordance to manufacturers specification.

4.10.2.4 Volume

The flow sensors will be calibrated with the ROOTS® meter in the field test van and checked for proper running order at the onset, during the middle and at the conclusion of the testing for each field test location., The ROOTS® meters used for this project will be calibrated on an annual basis.

4.10.3 Calibration Procedures and Frequency

Calibrations establish data accuracy and data comparability by ensuring traceability of the transfer standards to higher quality standards such as the EPA reference calibration methods and NIST standards. They also verify instrument operation and response. The requirements for calibration of air quality instruments and meteorological equipment have been specified by the EPA (Quality Assurance Handbook for Air Pollution Measurement Systems, Vols. II and IV.

EPA-600/4-77-027a, 1987, 1989). For some instruments, calibration standards have not been established and these are calibrated in accordance with AVES's experience.

The standard used to obtain test concentrations for hydrocarbons is specified in the Traceability Protocol for Establishing True Concentration of Gases Used for Calibration and Audits of Continuous Source Emission Monitors (Protocol No. 1) (June, 1978) published by the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park. Working standards documentation is maintained in a central file at Acurex.

4.10.3.1 Hydrocarbon Calibration Equipment and Procedure

Once a week, the hydrocarbon instrumentation will be calibrated before the daily zero and span checks with three gas concentrations: low-level (25-35% of applicable span value), mid-level (45-55% of applicable span value) : high-level (80-90% of applicable span value). The field technician will also recalibrate an analyzer whenever the zero, or span checks indicate that recalibration is necessary or whenever an instrument has been repaired or serviced. For meteorological instrumentation this interval is once every six months.

4.11 PREVENTATIVE MAINTENANCE

All aspects of maintenance are prescribed and performed according to manufacturer's specifications, which provides for regular, thorough maintenance of each instrument owned or operated by AVES or Acurex. Full-scale maintenance of each instrument is performed at regularly scheduled intervals at AVES's or Acurex's instrument shop in Monrovia. In addition, the site technician follows established procedures for regular maintenance, while the instrument is in the field.

All instruments were serviced prior to field deployment. Except for sample inlet filter changing, no routine instrument maintenance is required during the monitoring project.

4.11.1 Spare Parts Policy

AeroVironment and Acurex maintains a complete inventory of spare parts and equipment for this program at its Monrovia and Mountain View facilities. AVES's and Acurex's parts inventory is based on both manufacturers' recommendations and its own experience with equipment problems from both normal operation and vandalism-induced failure.

4.11.2 Training

The site technicians will be trained by Acurex in the following areas:

- Site and field test van check procedure and operation
- Equipment maintenance
- Record keeping

This training takes place partially through updates and changes to the standard operating procedures. Constant communication among the site technician and the Field Operations Manager is also invaluable to the training process.

SECTION 5

DATA REDUCTION, VALIDATION AND REPORTING

The objective of the data processing and validation effort is a quality assured data base containing the project monitoring data in a consistent format. The procedures that AVES has implemented for data processing and validation ensure that reported data are valid and comparable to those collected by federal, state and local air pollution agencies. These procedures meet the requirements and guidelines of the Environmental Protection Agency, e.g., Appendices A and B of 40 CFR 58; Quality Assurance Handbook for Air Pollution Measurement Systems, Volumes I and II (1984, 1987b). Data processing procedures for this program are discussed below.

5.1 DATA BASE and PROCESSING

At the beginning of the project, before data are forwarded from the field, AVES's database coordinator, with the aid of the section manager, will create a project database directory. This directory will contain information specific to the project. A directory entry will be made for each of the parameter months of data on the database. The following information will be entered into the project-specific directory:

- project name
- site number(s)
- site name(s)
- component number (e.g., O_3=44201)
- reporting period
- status code
- units (ppm)
- reporting precision (specifies number of decimal places)
- outlier flags
- date of last access and update

In the field, data will be collected using data loggers with a capacity to store about two weeks of data. AVES San Francisco will retrieve the data every two weeks from the Acurex field staff. The polled data will be automatically screened for anomalies. Any anomalies will cause AVES's computer to alert data processing personnel to investigate.

Most data processing activities, including data screening and filtering, universal data editing and handling, data file indexing and protection will be conducted with the aid of AVESEDMS. The AVESEDMS database system has been tested and documented completely. AVES's data-processing staff includes a database coordinator dedicated to testing, maintaining, documenting, and controlling AVESEDMS. The following list summarizes some of the data processing and validation procedures that are handled automatically by application software and command language procedures.

- Outlier screening of data summaries
- Database loading of data
- Updating of on-line status files
- Database entry and editing
- Database access and process flow control

- Data flagging
- Data calibration (if required). Data are adjusted by applying the slope and intercept obtained from the linear regression of the appropriate calibration to the monitored data.
- Daily data backups
- Database creation and expansion
- Database archival and retrieval
- Creation of routine data summaries

The automation of these processes ensures that these steps will be performed in a consistent manner that minimizes the potential for processing errors.

Before they are loaded into the database, the data will go through an automatic screening program that will flag any anomalies. The screening routines will check all data for outliers, instrument problems, and data system problems. The screening program will test for data that exceed set minimums, maximums, and rate-of-change values. The data transfer will be reviewed routinely by data management personnel. Data that are lost can be recovered either from the data logger printouts or from the floppy diskette backups.

5.2 DOCUMENTATION AND DATA CUSTODY

All documentation and data pertinent to data processing will be shipped to AVES from the field monthly. The monthly shipment will include site logs, checklist logs, zero/span checks, and multipoint calibration results. Data processing's procedures include checking the shipment for completeness and actions required.

Within one working day of receipt, each form of data and documentation will be logged separately in the incoming data log book for the project. These forms enable prompt identification of missing documentation and allow data clerks to track missing data.

If documents are missing (for example, if a checklist log has not been received from a specific site) or if any problems with the receipt of data arise, the project manager will be informed and he will take appropriate steps to recover the missing information (such as contacting the station operator). A correspondence file will be maintained in AVES's data library to ensure total program documentation; all documentation, including calibration records, data analyses, summaries and reports will be filed there. The data will be filed in appropriately labeled drawers and bins. Once the data and documentation have been received, logged in and filed, they will be available to the data technician to begin processing and validation procedures.

5.3 DATA VALIDATION

All data produced by this project are reviewed before use. AVES data validation procedures start with observations and reports made by the site operator and continue with review and analysis of all logs, checklists and data.

All flagged or anomalous data are investigated. Unless there is substantial evidence that suspect data are erroneous, these data will be retained. AVES's data processing procedures allow only the project's principal investigator (the project manager for this program) to invalidate data.

Zero and span check data for the hydrocarbon analyzers are reviewed routinely as part of the data validation effort. Data collected during periods when the span response deviates by more than 25 percent or the zero response deviates by more than 0.025 ppm from true values are invalidated. Data collected during periods when the span response deviates between 15 percent and 25 percent or the zero response deviates between 0.015 and 0.025 ppm are adjusted using correction factors obtained from the calibration and zero/span checks. The zero/span checks will be used to determine the affected period and the correction factors used to adjust the values.

All changes resulting from review of the documentation will be made directly on the raw data report and comments added as necessary to explain the changes. The raw data reports will be reviewed to ensure that all outliers have been corrected, replaced by the proper missing data code, or checked off as valid. Once the raw data have been completely checked, corrected and signed off by the quality control coordinator, changes will be made to the database and any necessary correction factors applied.

5.4 FIELD AND LABORATORY PROCEDURES USED TO ASSESS DATA ACCURACY, PRECISION, AND COMPLETENESS

Data collected during the program will be identified, validated, and reported. When data are reduced, the method of reduction will be described in the text of the report. Restraints on statistical inferences will be stated.

Pacific standard time will be referenced during data collection. All field measurement, meteorological, and laboratory data will be reported consistently, in accepted standard units.

The data will be assessed for accuracy, precision and completeness using the procedures described in the following subsections.

5.4.1 Accuracy

Accuracy is the difference between the analyzer response and the reference value obtained during the multipoint instrument audit.

$$\text{Accuracy} = \frac{Y - X}{X} \times 100$$

where: Y = analyzer value
X = the true concentration as determined by the audit.

5.4.2 Precision

Method precision will be determined from the weekly precision checks. The calculation to be used is provided in EPA (1987).

5.4.3 Completeness

For the field sampling and laboratory analyses, completeness is calculated as the ratio of acceptable measurements obtained to the total number of planned measurements. This ration does not include downtime due to routine zero span and precision checks, calibrations or audits. Loss of data due to these operations will be minimized to the extent possible through management of the time of when they take place.

SECTION 6

PERFORMANCE AND SYSTEM AUDITS

The objectives of an auditing program are to ensure the integrity of the data and to assess the accuracy of the data. Two types of audits are included in an auditing program: systems audits and performance audits.

A systems audit is an independent qualitative evaluation of the ability of an operation to generate quality data. Systems audits are conducted to evaluate all field, data processing, internal reporting, and analysis activities. A systems audit will be performed by a member of AVES's QA Department. The auditor will check that standard procedures are being followed. Additionally, he will inspect copies of data, calibration factors, and problem reports to verify that correct protocols have been observed.

A performance audit is an independent quantitative evaluation of the quality of data produced by the total measurement system, including sample collection, sample analysis and data processing. It is an assessment of the measurement process under normal operations. A performance audit will be performed by a AVES QA engineer two weeks after the start of field sampling. The performance audit will include multipoint audits of all analyzers and measurement instrumentation. Audit results will be compared against the measurement goals for accuracy presented in the previous sections.

The audit procedures will conform to guidelines described in the EPA Quality Assurance Handbook for Air Pollution Measurement Systems, Volumes I (1984) and II (1987b). Procedures are discussed below. Other relevant guidelines are outlined in the EPA Ambient Air Quality Surveillance Regulations 40 CFR 58, Appendices A through E. All instruments and materials used to perform the audits will be traceable to the National Institute of Standards and Technology (NIST). A trained quality assurance engineer will perform each audit. Each member of the AVES quality assurance staff is experienced in on-site audits and in-the-field quality assurance procedures for air monitoring programs.

6.1 AUDIT EQUIPMENT

- **Dilution Systems**

The AVES QA Department designated audit calibration units are a Dasibi Model 5009 MC and a Dasibi Model 1009 MC dilution system. Mass flow rates are certified quarterly using a Meriam laminar flow element, which is a transfer standard for mass flow. AV's primary flow device is a NIST-certified Bubble-O-Meter. Both the Meriam and Bubble-O-Meter are housed in the AV QA standards laboratory in Monrovia, California. The audit calibration units are certified once per quarter.

- **Audit Span Gases**

Audit gases are analyzed in accordance with the Traceability Protocol for Establishing True Concentrations of Gases Used for Calibrations and Audits of Air Pollution Analyzers (Protocol No. 2), May 1987, in the EPA Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, Section 2.0.7. All cylinders are recertified every six months. Cylinder gases used by AVES are supplied by Scott-Marrin, Inc., Riverside, California.

- **Ultrapure Air Cylinders**

Ultrapure air is used in the performance of the audits of the continuous THC and CO analyzers. Ultrapure air cylinders are obtained from Scott-Marrin, Inc. when the pressure in the cylinder currently in use drops to 300 lb/in^2. Each ultrapure air cylinder, with the exception of that used to audit the CO_2 analyzer, contains a concentration of 350 ppm CO_2 to simulate ambient air conditions.

- **Ozone Transfer Standard**

The EPA technical assistance document, Transfer Standards for Calibration of Air Monitoring Analyzers for Ozone (September, 1979), EPA-600/4-79-056 has been adopted by the AV QA department as the guideline for certification and recertification of ozone primary and transfer standards.

The AV QA primary ozone standard is a Dasibi 1003 RS. Comparison of AV QA's primary standard with an EPA standard photometer is performed once per year. The QA Department's designated ozone transfer standards are a Dasibi 5009 MC Serial Number 281 and a Dasibi 1003 PC Serial Number 5311. These ozone analyzers were converted to a transfer standard configuration in accordance with EPA guidelines (September, 1979). Ozone analyzers that are converted to a transfer standard configuration must be compared to the AV primary ozone standard by means of a 6 x 6 comparison as the final step in the conversion process. Ozone transfer standards that are in regular use must be compared by means of a 1 x 8 (zero and seven upscale concentration points) comparison with the AV primary ozone standard twice per quarter.

- **Temperature Sensors**

Mercury-in-glass thermometers are compared to the AV QA department's NIST-traceable thermometer by an eight-point calibration before their first use in the field. All thermometers are referenced to this thermometer which is an NIST-traceable Brooklyn thermometer, Serial number 6D619. All field thermometers are recertified each year.

- **Laminar Flow Elements**

Laminar flow elements are maintained by AVES's Quality Assurance Department as a secondary standard. All laminar flow elements are certified annually by an external laboratory.

- **Meteorological Instrument Audit Equipment**

The device AV uses to audit horizontal and vertical wind speed sensing systems is an RM Young Model 18810 Selectable Speed Anemometer drive. Its rotational velocities are certified quarterly using a Cole-Parmer Model 8211 Phototach.

The wind direction boom alignment is checked with a Brunton Compass. There is no certification procedure for compasses. The compass is checked for damage before each use.

The relative humidity and dew point audit device is a Psychro-Dyne psychrometer. The wet and dry bulb thermometers of the psychrometer are certified by comparing there readings with an NIST-traceable Brooklyn thermometer, Serial number 6D619. The psychrometer is recertified each year.

6.2 PERFORMANCE AUDIT PROCEDURES

As stated previously, AVES conducts performance audits in accordance with procedures described in the EPA Quality Assurance Handbook for Air Pollution Measurement Systems, Volumes I (1984) and II (1987b).

- **CO, CO_2 and NMHC Analyzers**

A multipoint audit will be performed to obtain the analyzer's response to a known input. The audit will be performed by diluting gas concentrations obtained from standard gas cylinders of CO, CO_2 and methane using the Dasibi calibrator. This audit will provide the analyzer response at three evenly spaced span points covering the entire analyzer range and the zero point. The procedures follow the EPA-recommended methods (EPA, 1987b) and are described briefly below.

The audits of the air quality samplers begin with the station technician identifying the appropriate data channel and taking it off line so that ambient data are no longer being collected. The sample line or inlet filter is then connected to the Dasibi calibrator via a vented "T" arrangement that introduces the audit span gas through as much of the normal sampling train (i.e., filters, scrubbers, etc.) as possible. The analyzers are challenged with specific concentrations of span gas as follows:

Audit Point	Concentration Range (Percent of scale)
1	.0
2	6% to 16%
3	30% to 40%
4	70% to 90%

- **Temperature**

The temperature-sensing systems are audited by immersing the system thermister together with an NIST-traceable mercury-in-glass thermometer in the same water bath and comparing the readings of the thermometer with the DAS at three temperatures across the normal operating range of the system.

- **Flow Meters**

The performance of ROOTS® meters and other any other flow devices will be audited using an appropriate laminar flow element (LFE). The LFE will be placed in-line with the Roots meter. Measured audit flow rates will be compared the flow rates supplied by the site technician. Site comparison flow rates should correspond to the flow rates used to calculate sample concentrations. The ambient temperature and atmospheric pressure will be recorded for each flow rate audited, allowing audit flow rates to be reported in either volumetric or standard units, using the following equations:

$$Q_{std} = Q_{vol} \times (P_a / 29.92) \times (298 / T_a)$$

$$Q_{vol} = Q_{std} \times (29.92 / P_a) \times (T_a / 298)$$

where Q_{std} is the flow rate at standard conditions (P = 29.92" Hg, T = 298°C)
Q_{vol} is the volumetric flow rate
P_a is the ambient pressure in inches of Hg
T_a is the ambient temperature in °C

- **Relative Humidity**

Relative humidity is audited by calculating the equivalent station dew point temperature from the station relative humidity and temperature readings and comparing this value with the audit dew point temperature. The audit dew point temperature is calculated from measurements of the wet bulb and dry bulb temperatures of the NIST-traceable thermometers installed in a Psychro-Dyne motorized psychrometer and the barometric pressure provided by a Peet Brothers, Ultimeter Model 3 electronic barometer.

- **Pressure Transducers**

Output from the pressure transducers will be audited by teeing in an incline manometer and comparing the transducer reading with the manometer reading

- **Barometric Pressure**

Barometric pressure sensors are audited by a one-point ambient comparison with an audit barometer. The audit barometer is a Peet Brothers Ultimeter Model 3 electronic altimeter/barometer.

- **Data Acquisition System**

Audit of the strip chart recorders and data loggers will be performed as part of the instrumentation audit. Since all instrument audit responses are synonymous with data system response, data system responses are audited as the various instruments interfaced with the data system are audited. The strip chart recorders and data loggers will be checked for proper data scanning frequency and clock time.

6.3 SYSTEMS AUDIT

AVES's quality assurance department will perform a systems audit in conjunction with the performance audit. The EPA has established guidelines for installing and operating air monitoring programs to assure the collection of accurate, complete, and precise data (EPA, 1987). In addition, vapor recovery test procedures are specified in TP-201 (ARB, 1996). A systems audit verifies that these guidelines and procedures are being adhered to and that data of acceptable quality can be collected. It is a qualitative appraisal of the quality assurance/quality control systems used for each monitoring sensor.

During the systems audit, the overall organization and operation of the monitoring program is examined. This includes evaluating sample flow requirements, sampling probe location, calibration and instrument check procedures, data-processing procedures, instrument operating range, and quality control procedures and methods. In addition, system components will be checked for conformity with TP-201 procedures. The audit will be performed using a checklist to document audit findings and provide a standardized method for performing the systems audit.

Upon completion of the systems audit, the auditor will prepare a report detailing deficiencies found during the audit. In the report, he will, if necessary, recommend actions required to improve the project and to meet regulatory agency guidelines. Included in the report will be copies of the systems audit checklist.

Quality assurance will be performed by AVES's Quality Assurance (QA) department. The QA department is an independent section of AV and reports findings directly to the project manager. QA will include both a system audit and a performance audit.

SECTION 7

REPORTING

7.1 DATA REPORTING

After each major ORVR impact test series (e.g., balance systems), preliminary data reports will be prepared by AVES and sent to AVES project manager. The data report will include a description of the measurements and data precision, completeness and blank filter analysis results.

At the end of the ORVR impact test series field program, the preliminary data will undergo further validation in preparation for data analysis. Upon completion of this validation task, data analysis will be executed. The results of this effort will be summarized in a project progress report and sent to the technical advisor panel.

At the conclusion of all data analysis activities, a draft final report will be completed and submitted to the TAP for review in a format specified by ARB. Upon receiving their comments, the project final report will be completed.

Monthly progress reports will be send to the ARB project manager describing progress to date, expected action items for the following month, and problems or concerns.

SECTION 8

CORRECTIVE ACTION

Corrective action will be initiated whenever a problem is identified. The goal of corrective action is to remedy any problem before the project or equipment and/or parameters drop below the desired accuracy, precision, or completeness.

The data polling scientist or instrument technician are the primary individuals on this project for identifying problems and initiating corrective action. The local site operator is secondary on this project for identifying most problems except for those problems that can only be identified by visual site inspection. Once a problem has been identified, the person who found it will either fix it himself or request the project manager for assistance.

Whenever a problem is identified, the project manager will be notified. A computerized copy of the action report will be filled out using AVES's computerized problem reporting system. The problem reporting system assures completeness of documentation and automatically notifies (computer mail) all project personnel about the problem. The project manager is responsible for appropriate action to maintaining the monitoring objective. For instance, in order to maintain the 80 percent hydrocarbon sampling completeness goal, if the data poller or site operator find the analyzer inoperative, the project manager will take action to prevent more than six days of lost data in a month.

SECTION 9

SCHEDULE

9.1 STUDY SCHEDULE

The proposed schedule for the uncontrolled and controlled test series are illustrated in Table 9-1.

Table 9-1
Timeline
Vapor Recovery Systems at Gasoline Dispensing Facilities
Season Effects

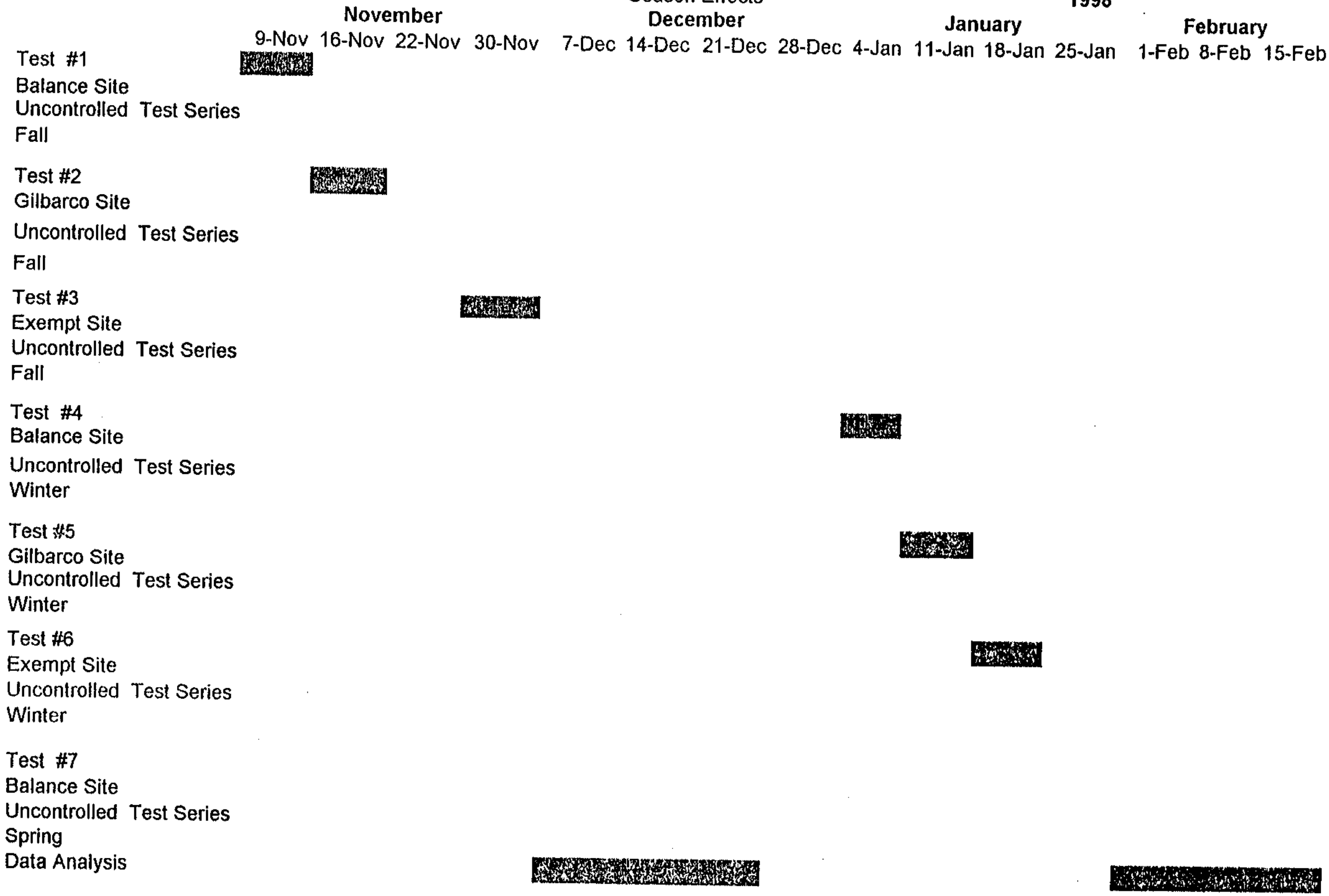


Table 9-1
Timeline
Vapor Recovery Systems at Gasoline Dispensing Facilities
Season Effects

	February			March				April					May		
	22-Feb	1-Mar	8-Mar	15-Mar	22-Mar	29-Mar	5-Apr	12-Apr	19-Apr	26-Apr	3-May	10-May	17-May	24-May	31-May
Test #1 Balance Site Uncontrolled Test Series Fall															
Test #2 Gilbarco Site Uncontrolled Test Series Fall															
Test #3 Exempt Site Uncontrolled Test Series Fall															
Test #4 Balance Site Uncontrolled Test Series Winter															
Test #5 Gilbarco Site Uncontrolled Test Series Winter															
Test #6 Exempt Site Uncontrolled Test Series Winter															
Test #7 Balance Site Uncontrolled Test Series Spring															

Table 9-1
Timeline
Vapor Recovery Systems at Gasoline Dispensing Facilities
Season Effects

	February		March				April				May				
	22-Feb	1-Mar	8-Mar	15-Mar	22-Mar	29-Mar	5-Apr	12-Apr	19-Apr	26-Apr	3-May	10-May	17-May	24-May	31-May
Test #8 Gilbarco Site Uncontrolled Test Series Spring						■									
Test #9 Exempt Site Uncontrolled Test Series Spring							■								
Test #10 Balance Site Uncontrolled Test Series Summer															
Test #11 Gilbarco Site Uncontrolled Test Series Summer															
Test #12 Exempt Site Uncontrolled Test Series Summer															
Data Analysis								■	■	■	■				
Test #13 Exempt Site Controlled Test Series															
Test #14 Balance Site No P/V Valve Controlled Test Series															

Table 9-1
Timeline
Vapor Recovery Systems at Gasoline Dispensing Facilities
Season Effects

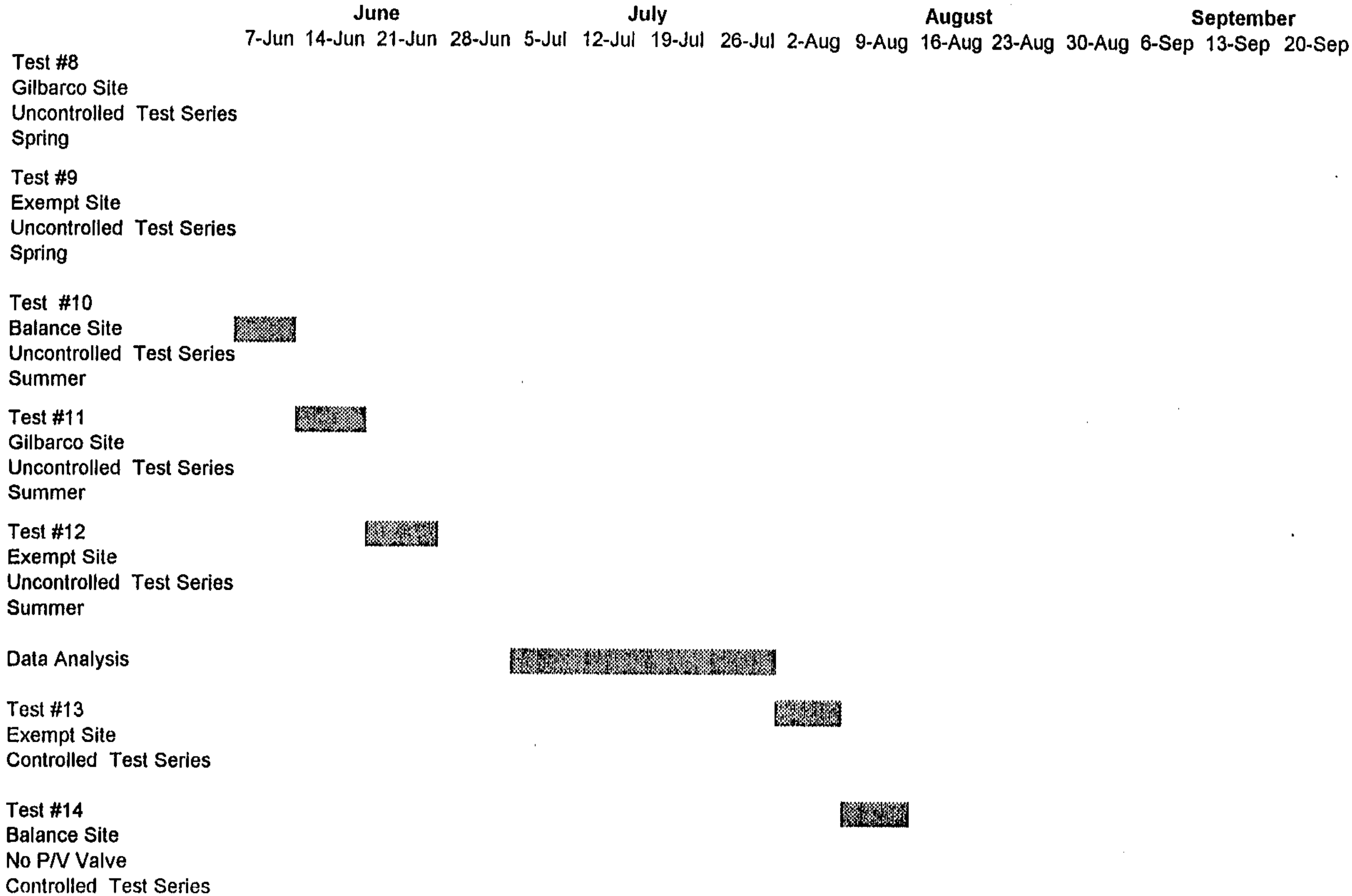


Table 9-1

Timeline

Vapor Recovery Systems at Gasoline Dispensing Facilities

Season Effects

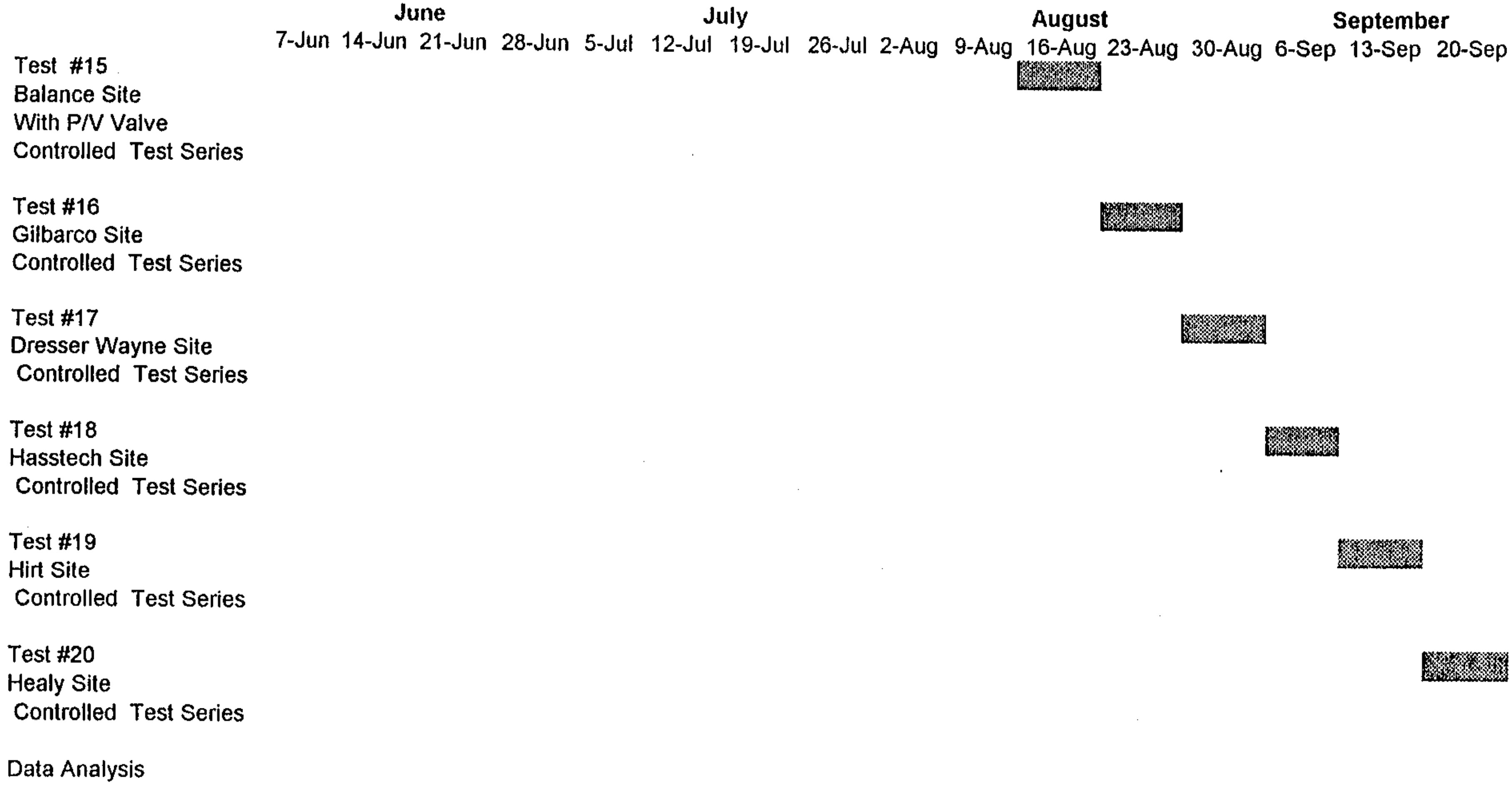


Table 9-1
Timeline
Vapor Recovery Systems at Gasoline Dispensing Facilities
Season Effects

	October					November					December			
	27-Sep	4-Oct	11-Oct	18-Oct	25-Oct	1-Nov	8-Nov	15-Nov	22-Nov	29-Nov	6-Dec	13-Dec	20-Dec	27-Dec
Test #15 Balance Site With P/V Valve Controlled Test Series														
Test #16 Gilbarco Site Controlled Test Series														
Test #17 Dresser Wayne Site Controlled Test Series														
Test #18 Hasstech Site Controlled Test Series														
Test #19 Hirt Site Controlled Test Series														
Test #20 Healy Site Controlled Test Series														
Data Analysis														

SECTION 10

REFERENCES

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