CALIFORNIA AIR RESOURCES BOARD

Monitoring and Laboratory Division
Vapor Recovery and Fuel Transfer Branch
Vapor Recovery Regulatory Development Section

Project Number VR 11-11

Report No. VR-OP-B1

Overpressure Study

Technical Support Document
Performance of Balance Type Phase II Vapor Recovery Systems Operating at Slightly Positive Underground Storage Tank Ullage Pressure

December 6, 2017

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Executive Summary

The California Air Resources Board (CARB) investigated the effect of slight positive pressure within the ullage space of underground gasoline storage tanks on balance Phase II vapor recovery system (balance system) performance. Throughout 2013 and 2014, in-station diagnostics (ISD) ullage pressure data was collected from 121 gasoline dispensing facilities (GDF) equipped with balance systems. This data indicates that during the winter months, balance systems spend a significant amount of time at slightly positive ullage pressure. Therefore, it is reasonable to believe that there are numerous vehicle fueling events that occur while the ullage pressure is slightly positive. In July 2015, CARB staff conducted emission testing to determine vehicle refueling emission factors for balance systems when vehicle fueling is conducted while the underground storage tank (UST) ullage space pressure was controlled at a slight positive pressure.

Emission testing was conducted while refueling conventional vehicles (older vehicles that are not equipped with On-Board Refueling Vapor Recovery (ORVR) systems) and newer vehicles, which are equipped with ORVR. Testing was conducted under typical or baseline conditions when the UST ullage was at a slight vacuum between zero and negative 1.5 inches water column gauge ("WCG). Testing was also conducted under artificially simulated conditions in which the ullage pressure was controlled at a slight positive pressure between 0.1 to 0.3 "WCG. Both currently certified Phase II EVR balance system nozzles; VST and EMCO, were tested.

Test results demonstrate that refueling emission factors increase 13 to 22 times for ORVR vehicles and 10 to 16 times for Non-ORVR vehicles under operating conditions at which the UST ullage pressure is slightly positive when compared to typical operating conditions at which the UST ullage pressure is slightly negative. During the baseline test (conducted to demonstrate normal operating conditions) with a slight vacuum in the UST, emission test data indicates that both certified balance systems achieve a collection efficiency of approximately 98% for non-ORVR vehicles. In addition, test results indicate that is not possible for either certified balance system to meet the performance standard for emission factor ($\leq$ 0.38 lb/kgal) or vapor recovery efficiency ($\geq$ 95%) while dispensing gasoline to non-ORVR vehicles when the ullage is at slight positive pressure.

These data suggest that CARB should further investigate the performance of balance style Phase II vapor recovery systems in an effort to quantify the volume of fuel that is actually dispensed while there is positive ullage pressure in the UST and estimate emissions associated with such fueling events.

I. Introduction and Background

The first ORVR equipped vehicles became available with the 1998 model year. Beginning with the 2006 model year, all vehicles with a gross weight rating of 10,000 pounds or less were equipped with ORVR. Dispensing to ORVR equipped vehicles has increased the rate of gasoline evaporation occurring in underground storage tanks (UST) equipped with CARB certified Phase II vapor recovery systems. Increased evaporation occurs because air is returned to the UST as a result of ORVR vehicle refueling. Prior to the introduction of ORVR vehicles, each gallon of gasoline removed from the UST was replaced with a nearly equal volume of saturated hydrocarbon vapor from the vehicle fuel tank. These vapors effectively suppressed gasoline evaporation in the ullage space of the UST. Increased evaporation rates have led to positive pressure in the UST and increased pressure driven emissions from GDF equipped with Phase II vapor recovery.

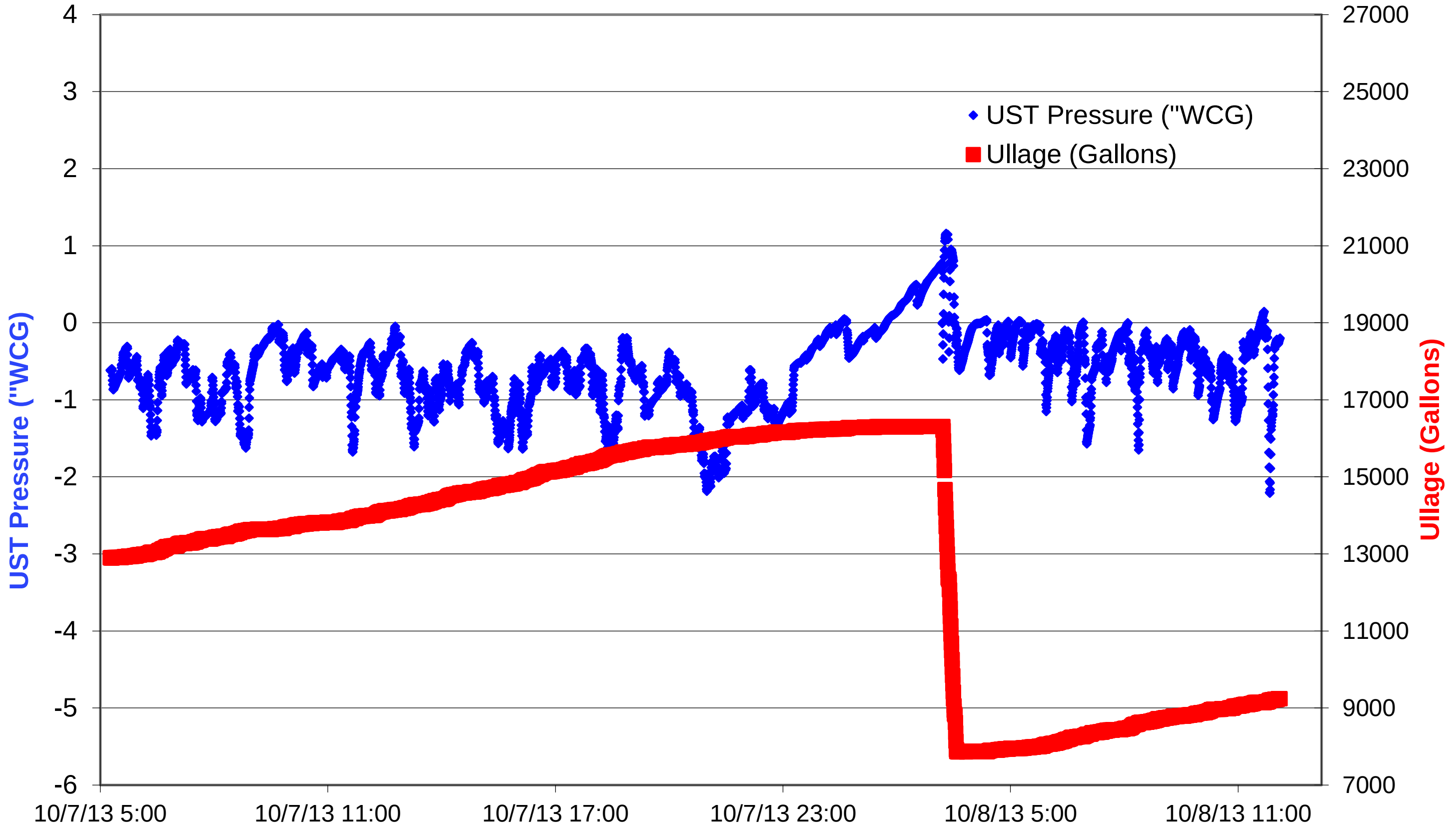
UST ullage pressure and ullage volume data was collected in 2013 and 2014 from the ISD systems of almost 400 gasoline dispensing facilities (GDF) statewide. Of this population, 121 GDF were equipped with balance systems and 274 were equipped with assist systems. The data indicates that balance systems did not exhibit pressurization during dispensing operations (referred to as PWD) compared to assist systems. The pressure profile for assist systems exhibiting PWD shows that vapors generated by gasoline evaporation are pressurizing the ullage space of the UST to a level near the cracking pressure of the pressure vacuum vent valve (2.5 to 6 “WCG) while gasoline is being withdrawn from the UST during vehicle refueling events. This level of pressure in the ullage space causes significant emissions from the UST vent line and from fugitive leaks throughout the vapor recovery system. The ISD data analyzed by CARB staff indicates that 30-40 % of assist systems exhibit PWD in the winter months.

In contrast, GDFs with balance systems do not exhibit PWD. With the exception of shut down and periods when dispensing rate is slow, there are no vent line emissions from the balance system and the UST pressure seldom exceeds 0.5 “WCG. The ISD ullage pressure and ullage volume data collected from the 121 balance systems shows that many facilities spend a significant portion of the operating day at slight positive ullage pressure. Figure 1 contains a pair of graphs which compare 30 hours of ullage pressure and ullage volume from a typical balance system GDF during October (summer fuel) and December (winter fuel). It is apparent that the time spent at slight positive pressure is greater when the higher volatility winter fuel is present in the UST. Table 1 contains data on the percentage of time that positive ullage pressure was present in the UST for 27 Southern California balance equipped GDF’s. These data are based on the past 30 hours of ullage pressure and ullage volume data that are available at any time on the ISD system. Data is presented for October (summer fuel) and

December (winter fuel). The average percentage of time spent at positive pressure for these sites was 13% in October 2013 and 25% in December 2013.

The rate of gasoline evaporation in the UST is primarily determined by gasoline properties (volatility and temperature) and the amount of vapor returned from non-ORVR vehicles. Both balance and assist vapor recovery systems fuel the same fleet of vehicles and dispense the same gasoline. Therefore, it is reasonable to conclude that the evaporation rate is similar for both systems since both systems collect a similar quantity of the vapor that will suppress evaporation. Based on the hypothesis that both systems experience similar gasoline evaporation rates it is reasonable to conclude that because balance systems exhibit lower UST pressure, vapors must be exiting the system by means other than fugitive and vent line emissions. The balance nozzle, which allows flow in either direction through an open vapor check valve, is the most likely emission point when UST ullage pressures are only slightly positive. Therefore, emission measurement was focused on the interface of the balance nozzle with the vehicle fill pipe. Figure 2 depicts the basic configuration of a balance system and the spot light shows the nozzle vehicle interface where emissions were measured.

Figure 1: South Coast Balance Site Ullage Pressure Comparison October and December



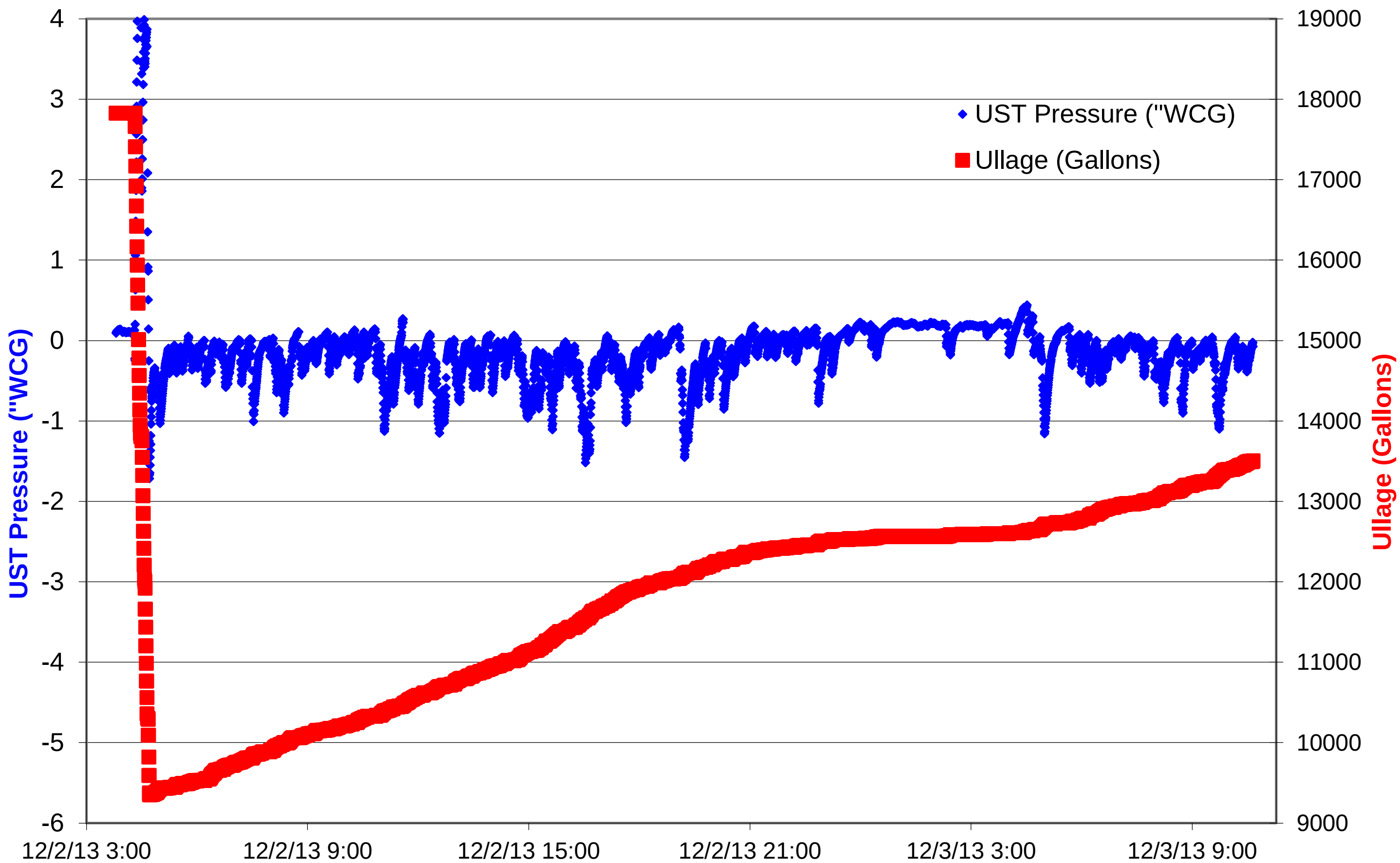
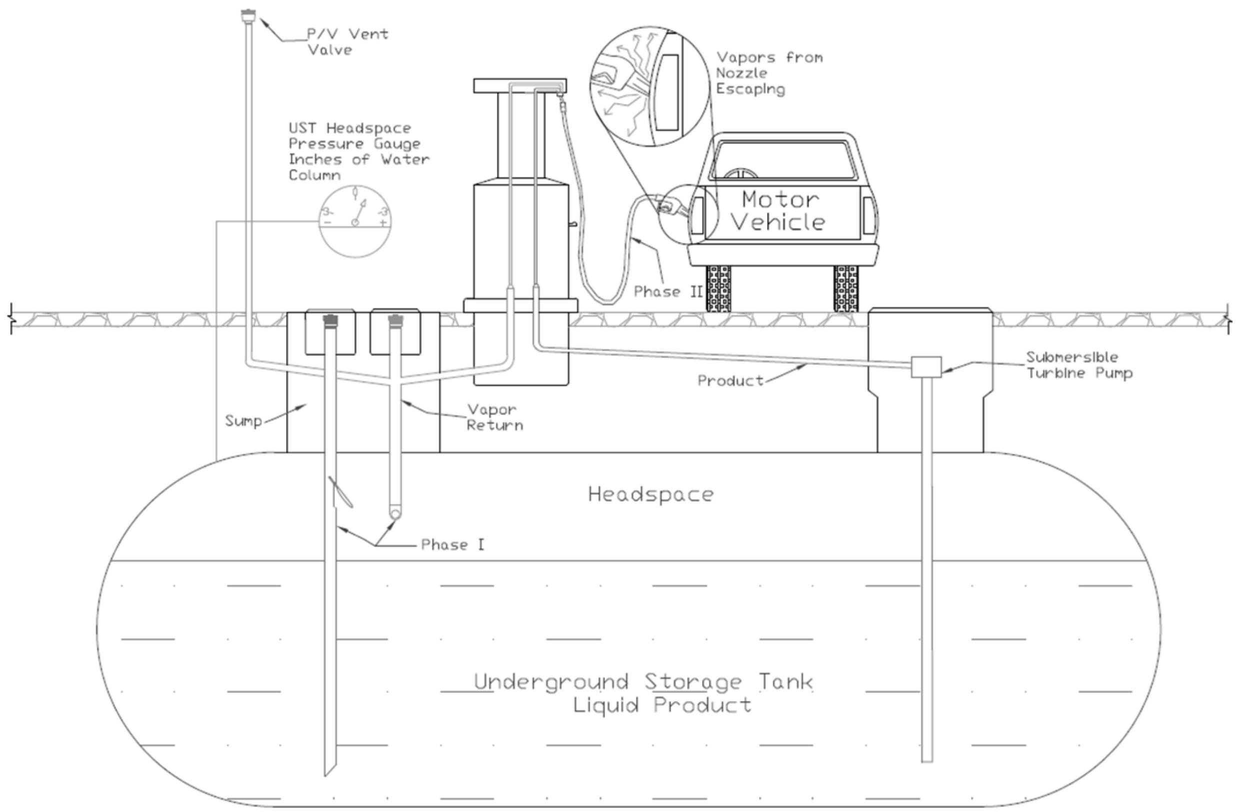


Table 1: ISD Data from GDF Equipped With Balance Systems Positive Ullage Pressure

City	Hours of Operation	Throughput kgal/mo.	% of Data Points Greater than Zero in Oct.	% of Data Points Greater than Zero in Dec.	Avg. of Data Points Greater than Zero in Oct.	Avg. of Data Points Greater than Zero in Dec.
Diamond Bar	24 Hr.	100	19.5%	34.4%	0.27	0.16
Ontario	24 Hr.	110	15.9%	17.6%	0.27	0.20
Chino	24 Hr.	110	7.4%	31.8%	0.35	0.24
Stanton	24 Hr.	115	21.6%	36.5%	0.17	0.17
Yorba Linda	Closed Nightly	116	24.7%	28.2%	0.10	0.25
Brea	24 Hr.	119	16.2%	32.2%	0.08	0.22
Chino	24 Hr.	125	17.7%	19.4%	0.27	0.14
La Habra	24 Hr.	128	23.8%	27.2%	0.34	0.21
Bellflower	24 Hr.	132	10.6%	18.5%	0.20	0.07
Sun City	Closed Nightly	133	12.4%	23.4%	0.05	0.18
Costa Mesa	24 Hr.	143	15.9%	32.0%	0.14	0.82
Ontario	24 Hr.	150	8.2%	25.7%	0.08	0.23
Long Beach	24 Hr.	151	14.5%	29.3%	0.20	0.11
Stanton	Closed Nightly	154	13.8%	25.9%	0.41	0.07
Stanton	24 Hr.	155	1.4%	15.9%	0.17	0.36
Murrieta	24 Hr.	160	2.9%	19.1%	0.12	0.13
City of Industry	24 Hr.	160	19.8%	28.2%	0.02	0.27
Los Angeles	24 Hr.	161	4.3%	30.8%	0.03	0.14
Hollywood	24 Hr.	165	14.9%	32.2%	0.26	0.23
Burbank	24 Hr.	170	22.6%	20.2%	0.21	0.45
Bellflower	24 Hr.	170	15.5%	27.3%	0.27	0.22
Garden Grove	24 Hr.	180	8.0%	25.7%	0.22	0.16
Santa Monica	24 Hr.	200	5.2%	13.0%	0.05	0.17
Yorba Linda	24 Hr.	203	17.5%	28.2%	0.34	1.08
Santa Ana	24 Hr.	205	12.0%	19.1%	0.13	0.23
Diamond Bar	24 Hr.	250	4.0%	17.0%	0.08	0.24
Ontario	24 Hr.	280	9.8%	21.0%	0.12	0.13
	Average		**13.35%**	**25.19%**	**0.18**	**0.26**
	Std. Dev.		6.62%	6.34%	0.11	0.22
	Minimum		1.4%	13.0%	0.02	0.07
	Maximum		24.7%	36.5%	0.41	1.08

Figure 2 – Balance System Schematic Showing Nozzle Emission Point



II. Methodology

A multistep process was used in the evaluation and is describe below:

1. Conduct vapor recovery system performance testing and repairs to ensure the vapor recovery systems and components are in compliance with all applicable performance standards.
2. Conduct ISD operability testing to document accuracy of ISD vapor return meter and UST ullage pressure transducer.
3. Monitor the interface of the balance nozzle and vehicle during ORVR and non-ORVR fueling events to determine baseline emission factors for ORVR and non-ORVR vehicles while the UST ullage is at typical vacuum levels, also referred to as “baseline operating conditions.”
4. Sparge air through the liquid gasoline near the bottom of one of the UST’s to hold the system at a slight pressure of 0.1 to 0.3 “WCG and isolate vapor processor from Phase II system to facilitate system pressurization.

5. Monitor the interface of the balance nozzle and vehicle fill pipe during ORVR and Non-ORVR fueling events to determine if gasoline vapor can be emitted to atmosphere from an UST held at slight positive pressure.
6. If vapor volume is exiting the UST through the balance nozzle vapor path, then determine the mass of hydrocarbon that is lost to the atmosphere at the nozzle and vehicle fill pipe interface during the monitored fueling events.
7. Conduct the same sequence of testing using a similar population of vehicles on each currently certified balance system (VST and EMCO).

II.A Test Site Selection and Preparation

In order to identify an operating GDF for use as a test site, CARB staff worked in cooperation with staff from the South Coast Air Quality Management District (District). District staff found an operator who was willing to work with CARB staff on the project. The operator offered five potential test sites. Three were eliminated because high throughput (180 to 330 kgal / month) would make it difficult to maintain positive pressure in the system. The two other sites were evaluated for site layout and suitability as a test site and the site with the more favorable layout was chosen. Operating parameters for the selected test site are shown in Table 2.

Table 2 - Balance System Test Site Operating Parameters

Site Location	Fullerton, CA
Approximate Monthly Throughput	100,000 gallons
Hours of Operation	0600 -2300
UST Capacities (kgal) (Based on ISD inventory report)	15, 15, 12
No. of Dispensers	6
No. of Fueling Points	12
Dynamic Back Pressure at Test Fueling Point No. 11 (“WC at @ 60 cfh)	0.273 (0.344 w/ test meter installed)
Dynamic Back Pressure at Test Fueling Point No. 11 (“WC at @ 80 cfh)	0.425 (0.438 w/ test meter installed)

Prior to the commencement of emission testing the balance Phase II vapor recovery system was subjected to performance testing to demonstrate compliance with applicable performance standards. These standards are listed in Table 3.

Passing results were obtained for all performance standards prior to commencing the emission testing. In some cases more than one round of testing followed by VRS maintenance, repair and retesting was required to achieve compliance with a particular performance standard. Details of the vapor recovery system performance testing are provided in Appendix 1.

II.B Pressurization of UST Ullage Space

The UST ullage space was pressurized with saturated vapors by bubbling air through the liquid gasoline. A metal bellows pump was used to pass air through a Teflon line that extended below the liquid surface near the bottom of the 87 grade UST. This line entered the UST through a modified cap on the Phase I Liquid adaptor and extended to the bottom of the UST. Pump flow rate was controlled at approximately 100 cubic feet per hour (cfh) using a rotameter. Assuming that the air was saturated with gasoline vapor as it bubbled to the liquid surface, the flow rate of vapors introduced to the UST can be estimated based on the required RVP for summer fuel and temperature of the gasoline indicated by the tank inventory system. The true vapor pressure for RVP 7 gasoline at 80 degrees F has been estimated to be approximately 5.15 psi[1]. The fuel saturated vapor concentration in the ullage would be approximately 35% by volume gasoline vapor. Assuming the air becomes saturated the total flow of air and vapor added to the ullage space would be approximately 154 cfh or 19 gallons per minute.

A pressure switch was used to enable and disable the metal bellows pump to maintain the UST ullage pressure between set points of approximately 0.1 and 0.3 "WCG during testing of vehicle refueling events. During testing of vehicle refueling events the vapor return line pressure was recorded on strip charts and a digital data logger. In addition, ISD ullage pressure data covering the duration of the testing was downloaded from the system console. This data was used to document UST ullage pressure during monitored fueling events. Graphs of the ISD data showing examples of the pressure and ullage traces during the emission testing are provided in Appendix 2

II.C Measurement of Emissions at Nozzle-Vehicle Fill Pipe Interface

The equipment and procedures specified for "Test Point 1" in CARB Test Procedure TP-201.2 [2]. were utilized to quantify emissions at the nozzle and vehicle fill pipe interface. This equipment includes: the nozzle sleeve, a sample sweep pump, a positive displacement volume meter, pressure and temperature monitors and both 0 – 0.5% range and 0 – 7.5% range NDIR instruments for non-methane hydrocarbon as propane. During emission monitoring of fueling events simultaneous fueling on the opposite side of the dispenser was not permitted.

Vehicle data was recorded for each monitored fueling event. This data includes the make model and production year for the vehicle and the volume of gasoline transferred during the event. ISD data for the test fueling point was collected as secondary documentation for the vapor and liquid volumes associated with each fueling event.

Emission testing was performed for approximately 50 ORVR and 50 non-ORVR fueling events for each certified balance nozzle while the UST ullage pressure was slightly positive. A modified vehicle matrix was used to ensure a representative sample of Make and Model years was tested.

Emission test was also performed for 15 ORVR and 15 non-ORVR fueling events for each certified balance nozzle under normal operating conditions at which the UST ullage gauge pressure was at vacuum. This testing established the performance of the system in the absence of positive UST pressure. This is “baseline” mode of operation is representative of conditions that existed during the certification testing for the balance VRS.

II.D Vehicle Matrices

CARB Vapor Recovery Test Procedure TP 201.2A, Determination of Vehicle Matrix for Phase II Systems [3] outlines the procedure for creating a test matrix of non-ORVR vehicles. However, because both ORVR and non-ORVR vehicles were tested for this project, modifications to this procedure were necessary.

Table 4 shows a 30-car baseline vehicle matrix that was used to demonstrate that the vapor recovery system met the emission factor and efficiency performance standards when the ullage pressure in the UST is at vacuum. This matrix was designed to provide 15 ORVR vehicles and 15 non-ORVR vehicles. To ensure that this matrix was met, vehicles manufactured in transition years were not used to fill the baseline test matrix, since these years include both ORVR and non-ORVR vehicles. The CARB ORVR implementation schedule is included in the California Code of Regulations section 1978 (a)(3). This schedule is shown in Table 5. Transition years are those in which the required ORVR percentage is 40% or 80%.

Table 6 shows a 50-vehicle non-ORVR matrix, and Table 7 shows a 50-vehicle ORVR matrix. These matrices are based on the vehicle population in the State of California for 2014 and were developed to measure performance of each currently certified balance type nozzle (VST and EMCO) when the UST ullage space was held at slightly positive pressure. The matrices shown in Tables 6 and 7 specify allowable vehicle classes and model years so that transition year vehicles are not included in either the ORVR or non-ORVR matrix.

Table 3 – Vapor Recovery System Performance Tests

Component	Performance Standard	Test Procedure	Test Result
PV Vent Valve	Pressure Settings 2.5 to 6.0 inches H_2O Positive Pressure 6.0 to 10.0 inches H_2O Negative Pressure Leak rate at +2.0 inches $H_2O \leq 0.17$ CFH Leak rate at -4.0 inches $H_2O \leq 0.63$ CFH	TP-201.1E Leak Rate and Cracking Pressure of Pressure/Vacuum Vent Valves	Pass
Phase I Adaptors	$\leq$ 108 pound-inch (9 pound-foot) Static Torque	TP-201.1B Static Torque of Rotatable Phase I Adaptors	Pass
Drop Tubes Phase I	$\leq$ 0.17 CFH at 2.0 inches H_2O	TP-201.1D Leak Rate of Drop Tube Overfill Protection Devices and Spill Container Drain Valves	Pass
Liquid Removal device	Capable of Removing 5 ml/ gal. (average)	TP-201.6C Compliance Determination of Liquid Removal Rate	Pass
Hanging Hardware and vapor return piping	Pressure Drop from Nozzle to UST ΔP at 60 CFH of $N_2 \leq 0.35$ inches H_2O ΔP at 80 CFH of $N_2 \leq 0.62$ inches H_2O	TP-201.4 Dynamic Back Pressure	Pass
Nozzle Insertion Interlock	Verification of No Liquid Flow Prior to Bellows Compression	Installation Operation and Maintenance Manual For Executive Order VR-204-R, Section 2	Pass
Nozzle	Dispensing Flow Rate	CARB E.O. VR-204 Exhibit 2, System Specifications	Pass
ISD Vapor Return Meter	$\pm$ 15% of reference gas meter volume	CARB E.O.VR-204, Exhibit 17, Veeder-Root; ISD Vapor Flow Meter Operability Test Procedure	Pass
ISD Vapor Pressure Sensor	$\pm$ 0.2 "WC from reference digital manometer	CARB E.O.VR-204, Exhibit 10, Veeder-Root; Vapor Pressure Sensor Verification Test Procedure	Pass
Complete Vapor Recovery System	See CARB CP-201, Section 4.2, static Pressure Performance	TP-201.3 Determination of 2 Inch WC Static Pressure Performance of Vapor Recovery Systems of Dispensing Facilities	Pass

Table 4 – 30-Car Baseline Matrix
(Do not include Transition Years Vehicles Shown in Table 2.)

Model Years	Chrysler Dodge	Ford Lincoln Mercury	G.M.	Toyota Lexus Scion	Honda Acura	Totals
2008-2015	2	2	2	2	2	**10**
2001-2007	1	1	1	1	1	**5**
1994-2000	2	2	2	2	2	**10**
1966-1993	1	1	1	1	1	**5**
Totals	**6**	**6**	**6**	**6**	**6**	**30**

Table 5 - CARB ORVR Vehicle Phase-In Schedule by Model Year
(Transition Years are 40% or 80%.)

Class of Vehicle	40% of Fleet	80% of Fleet	100% of Fleet
Passenger Cars	1998	1999	2000
Light-Duty Trucks 0-6,000 lbs. GVWR	2001	2002	2003
Light-Duty Trucks / Medium-Duty Vehicles 6,001-8,500 lbs. GVWR	2004	2005	2006

Table 6 - Balance Study 50-Car Matrix of Non-ORVR Vehicles

Model Years & Vehicle Classes	Chrysler Dodge	Ford Lincoln Mercury	G.M.	Toyota Lexus Scion	Honda Acura	Nissan Infinity Datsun	VW/ Volvo	All Others	Totals
2000 Lt Duty Trk & 2000-2003 Med Duty Trucks	1	1	2	2	1	1	1	1	**10**
1998-1999 Lt & Med Duty Trucks	1	1	1	1	1	0	0	0	**5**
1991-1997 All Vehicle Class	1	4	4	3	3	1	2	2	**20**
1968-1990 All Vehicle Class	1	3	5	2	1	1	1	1	**15**
Totals	**4**	**9**	**12**	**8**	**6**	**3**	**4**	**4**	**50**

Table 7 - Balance Study 50-Car Matrix of ORVR Vehicles

Model Years & Vehicle Classes	Chrysler Dodge	Ford Lincoln Mercury	G.M.	Toyota Lexus Scion	Honda Acura	Nissan Infinity Datsun	VW/ Volvo	All Others	Totals
2011-2015 All Vehicle Class	1	2	2	3	2	1	2	2	**15**
2006-2010 All Vehicle Class	1	2	3	4	2	1	2	2	**17**
2000-2005 Passenger Cars	2	3	4	4	2	1	1	1	**18**
Totals	**4**	**7**	**9**	**11**	**6**	**3**	**5**	**5**	**50**

II.E Vapor Concentration Monitoring of UST Ullage

During vehicle emission testing the hydrocarbon concentration was continuously monitored at the phase II vapor return line in the dispenser where TP-201.2 nozzle fill-pipe monitoring was performed. Monitoring with sampling and sample return was conducted following the procedures outlined for “Test Point 2” in TP-201.2. This data was collected to verify that vapor concentrations were within normal operating parameters during testing.

III. Results

For each currently certified balance system (VST and EMCO), the emission factor for TP-201.2, “Test Point 1” (the nozzle vehicle fill pipe interface) was determined during baseline fueling events performed while the UST was at vacuum and during fueling events while the 87 grade UST was sparged with air to maintain a slight pressure of 0.1 to 0.3 “WCG in the ullage space.

Emission testing was conducted July 15 -18, 2015 on the VST nozzle and July 29-August 1, 2015 on the EMCO nozzle. Ten VST vehicle refueling tests were also conducted on August 1 to fill gaps in the matrix from the previous round of testing. During baseline testing, valid results for vehicles required in the matrix were obtained for 15 ORVR equipped vehicles and 15 non-ORVR vehicles for both the VST and EMCO nozzles. During pressurized testing, valid results for vehicles required in the matrix were obtained for 49 ORVR equipped vehicles and 49 non-ORVR vehicles for the VST nozzle and for 50 ORVR equipped vehicles and 47 non-ORVR vehicles with the EMCO nozzle. Fifty four additional vehicles were also tested but were omitted from analysis because the vehicle itself failed one or more criteria outlined in TP-201.2 or because the vehicle represented an extra within a matrix cell that had already been filled. Appendix 3 identifies the number of vehicles omitted and the reasons these test runs were not included in the analysis and results. Appendix 4 provides a complete listing of test vehicles included in the analysis along with pertinent emission data and ISD data.

Table 8 summarizes the results for both the baseline testing and the testing conducted with the UST ullage space under slight pressure. The refueling emission factor is reported for vehicles equipped with ORVR and for Non-ORVR vehicles. The reported emission factor is calculated based on the total mass collected at the nozzle vehicle interface for all valid vehicle tests and the total volume of gasoline dispensed for all valid vehicle tests. The results for individual vehicles are included in the tables provided in Appendix 4.

Table 8 - Balance Emission Test Results Summary

	Baseline Testing				Testing at Slightly Positive Ullage Pressure			
	VST Nozzle		EMCO Nozzle		VST Nozzle		EMCO Nozzle	
	ORVR	Non-ORVR	ORVR	Non-ORVR	ORVR	Non-ORVR	ORVR	Non-ORVR
Vehicle Refueling Emission Factor lb/kgal	0.03	0.13	0.06	0.16	0.27	1.33	1.34	2.55
% Efficiency Loss Based on Standard UEF (uncontrolled emission factor) of 7.65 lb/kgal	0.4%	1.6%	0.7%	2.1%	3.5%	17.4%	17.6%	33.3%
UEF Determined From Non-ORVR Vehicle Test Data	NA	5.99	NA	7.55	NA	6.34	NA	7.04
% Efficiency Loss Based on the UEF Determined from Non-ORVR Vehicle Test Data	0.5%	2%	1%	2%	4%	21%	19%	36%
Number of Valid Vehicle Refueling Tests	15	15	15	15	49	49	50	47
No. of Vehicles Exceeding the 0.38 lb/kgal Performance Standard for Non-ORVR Vehicle Refueling	0	3	0	2	10	37 (76%)	30	31 (66%)
Ave Vapor Return Line Pressure ("WCG)	-0.80	-0.58	-0.45	-0.30	0.15	0.18	0.16	0.19
Maximum Single Vehicle Refueling Emission Factor (lb/kgal)	0.12	0.78	0.11	0.96	1.29	7.04	5.74	10.82
Maximum Single Vehicle % Efficiency Loss based on the UEF determined from Non-ORVR Vehicle Test Data	2%	13%	1%	13%	20%	111%	82%	154%

IV. Discussion of Results

The emission factors and efficiency losses shown in Table 8 suggest that the performance of balance systems is degraded by the presence of slight pressures within the ullage space of the UST. If enough fuel is dispensed under these conditions, the vapor recovery system would fail to meet CARB's performance emission factor and efficiency standards of 0.38 lb/kgal and 95 percent, respectively, when refueling Non-ORVR (conventional) vehicles.

The efficiencies determined for dispensing to Non-ORVR vehicles at baseline and pressurized conditions allow an estimate of the percentage of dispensing that could occur at positive pressure and still meet a collection efficiency of at least 94.5 %. The VST balance system would fail to achieve a 94.5 % collection efficiency if more than 19% of GDF throughput were dispensed with slight ullage pressure in the UST. The EMCO balance system would fail to achieve a 94.5% collection efficiency if more than 11% of GDF throughput were dispensed at slight ullage pressure.

The CARB certification standard of 95% vapor recovery efficiency is calculated by including other emissions in addition to those that occur at the test nozzle during Non-ORVR vehicle refueling. These emission points include pressure driven emissions from the UST vent lines, fugitive leaks, and vapor processor exhaust, if present. Furthermore the emission testing of ORVR vehicles conducted for this study reveals that ORVR vehicle fueling with slight ullage pressure in the UST creates another emission point that is not currently addressed in the CARB vapor recovery certification standards and test procedures. When estimates for these additional emissions are considered, analysis shows that dispensing as little as 13.4% of fuel volume, for VST balance systems, or 5.7% of fuel volume, for EMCO balance systems, from a UST at slightly positive ullage pressure would drop the overall vapor recovery efficiency below 94.5%.

V. Conclusions and Recommendations

Balance systems can experience efficiency losses of greater than 5% if a relatively small fraction of the total GDF throughput is dispensed while the UST ullage space is at slightly positive pressure. This level of pressure is lower than the set points that can trigger ISD overpressure alarms. As a result, these conditions can occur without any indication of an ongoing emission problem or any disruption of operations associated with ISD overpressure alarms. It is likely that the lower ullage pressure observed in balance systems when compared to assist systems may be due, in part, to the loss of vapor from the UST through open nozzle check valves. Check valves can remain open to atmosphere while nozzles are engaged with the vehicle if the fill-pipe is not adequately sealed and isolated from the atmosphere. Ullage pressure can also be relieved from the system through the nozzle check valve during less common fueling events involving portable fuel containers, motorcycles, boats, and fuel tanks on equipment other than motor vehicles.

Some balance system manufacturers have theorized that the vapors exiting the nozzle during ORVR refueling events are entrained in the liquid stream entering the vehicle fill pipe and routed to the vehicle ORVR system. The emission factors determined for refueling ORVR vehicles while the UST ullage is at slight positive pressure demonstrate that there are vapors that are lost to the atmosphere. Test results indicate that these emissions represent a system efficiency loss of 4 to 18 % depending upon on the make and model of the nozzle.

Staff recommends that the emissions associated with balance systems operating under slightly positive UST ullage pressure be further evaluated to estimate emissions associated with dispensing gasoline from balance systems operating at slight positive pressure. Further research and analysis will be necessary to develop an estimate for the percentage of fuel that is dispensed with slight ullage pressure in the UST. This percentage coupled with the emission factors presented in this report will allow an estimate of pressure driven emissions from balance systems.

VI. References

1. U.S. Environmental Protection Agency, AP 42, Fifth Edition Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, Chapter 7, Organic Liquid Storage Tanks, Table 7.1-2. Properties of Selected Petroleum Liquids, USEPA, November 2006. Available at https://www3.epa.gov/ttn/chief/ap42/ch07/index.html

2. California Air Resources Board, Efficiency and Emission Factor for Phase II Systems, TP-201.2, July 26, 2012. Available at http://www.arb.ca.gov/testmeth/vol2/tp201.2_april2013.pdf

3. California Air Resources Board, Determination of Vehicle Matrix for Phase II Systems, TP-201.2A, July 26, 2012. Availabe at http://www.arb.ca.gov/testmeth/vol2/tp201.2a_april2013.pdf

VII. Appendices

Appendix 1 - VRS Testing and Repairs Conducted Prior to Emission Testing

Appendix 2 - ISD UST Pressure and Ullage Charts Generated During Testing

Appendix 3 - Identification of Test Vehicles Not Included in Analysis

Appendix 4 - Vehicle Data, Emission Data, and ISD Data Included in Analysis

Appendices available upon request