APPENDIX I

Appropriateness of Test Procedure TP-201.1, "Volumetric Efficiency for Phase I Systems," on Gasoline Dispensing Facilities Equipped with Aboveground Storage Tanks

California Environmental Protection Agency

Monitoring and Laboratory Division Engineering and Certification Branch Engineering Evaluation Section

Appendix I:

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Date: April 2013

Introduction

ARB is responsible for the evaluation and certification of Phase I Enhanced Vapor Recovery (EVR) systems designed for use with underground (UST) and aboveground (AST) gasoline storage tanks installed at gasoline dispensing facilities. Over the last decade, ARB has certified a total of seven Phase I EVR systems for both UST and AST applications. Until recently, every system evaluated has successfully passed efficiency testing.

On three separate occasions, twice in the summer and once in the winter of 2011, the Morrison Brothers Phase I EVR AST system, designed for single-wall AST applications, failed to achieve the efficiency standard. Failure of this test resulted in direct emissions to the atmosphere. A fourth attempt in February of 2012, resulted in meeting the efficiency standard. The inconsistency of the results indicates a wider problem for future certifications and for in-use applications.

The objective of this document is to provide background information pertaining to ARB's Phase I systems, explain volumetric efficiency testing, to describe results of recent testing, and to recommend a course of action.

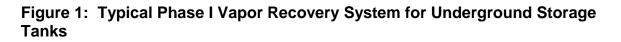
Background

Phase I Enhanced Vapor Recovery Systems:

Phase I vapor recovery is generally defined as the collection and containment of vapors during the transfer of gasoline from the cargo tank (or bulk delivery truck) to the storage tank (either AST or UST) located at the gasoline dispensing facility.

Phase I EVR systems, certified by ARB, consist of a series of components which are permanently installed (fixed) onto the tank openings and vent lines. Examples of such components include submerged drop tubes, dry break vapor adaptors, product adaptors, spill container drain valves, pressure vacuum vent valves, couplers, fittings, and automatic tank gauging ports.

During the transfer of gasoline from the cargo tank into the storage tank, the vapors contained in the headspace (empty space or ullage) of the storage tank are displaced. Rather than allowing these displaced vapors to escape directly to the atmosphere through an open vent line, Phase I components cap the vent line and establish a low resistance pathway which allows the displaced vapor to flow back into the empty compartments of the cargo tank. Phase I EVR systems currently certified by ARB are commonly referred to as a "two point" or "balance" systems. A dedicated adaptor and opening is provided for the fuel to enter the tank. A second dedicated adaptor and opening is provided for the vapors to exit the tank. To capture the vapors during fuel transfer, a flexible vapor return line is connected to the adaptors installed on the storage tank and cargo tank. Phase I components also establish leak tight seals at tank penetrations so that vapors are contained during the idle periods when no transfers take place. Typical Phase I vapor recovery components are illustrated in Figures 1 and 2.



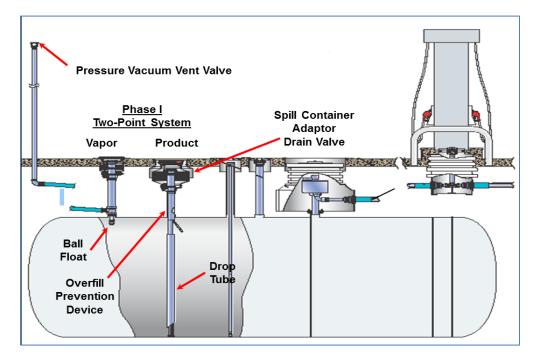
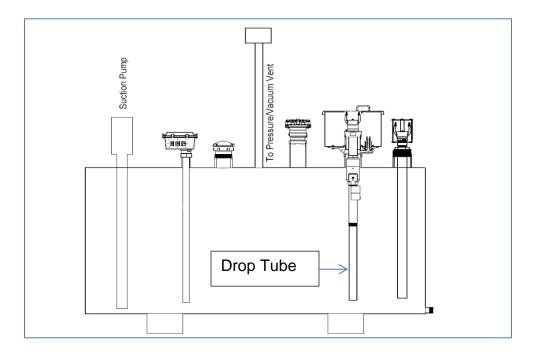


Figure 2: Typical Phase I Vapor Recovery System for Aboveground Storage Tanks



ARB Certification Phase I EVR System Performance Standards

According to ARB Certification Procedures <u>CP-201</u> (applies to vapor recovery systems designed for use with USTs) and <u>CP-206</u> (applies to vapor recovery systems designed for use with ASTs), Phase I EVR systems must achieve a volumetric transfer efficiency of at least 98%. In addition, Phase I EVR components must maintain leak integrity during idle periods and during periods of fuel transfer. In order to demonstrate compliance with these standards, equipment manufactures seeking ARB certification are required to install their systems at operating gasoline dispensing facilities (GDFs) in the Sacramento region. Once a system for at least 180 days. During this time frame, a number of tests are conducted to determine whether the components can maintain leak integrity and if the system can achieve a volumetric transfer efficiency of at least 98%. Typically, the efficiency testing is conducted once every sixty days (3 times) and leak integrity testing is conducted every thirty days (6 times).

Volumetric Efficiency Testing:

Volumetric efficiency testing for Phase I EVR systems quantifies the transfer efficiency when a bulk gasoline delivery occurs between a cargo tank and either a UST or an AST. Test Procedure 201.1 (<u>TP-201.1</u>) is used to determine compliance with the 98% transfer efficiency performance standard specified in the certification procedure.

The principle behind TP-201.1 is that during a gasoline delivery, the cargo tank and gasoline dispensing facility (GDF) are temporarily equipped with positive displacement meters (called roots meters) that measure the volume of vapor returned to the cargo tank and the volume of vapor discharged through the vent pipe, if any. Through various recordings of temperature and pressure, these volumes are corrected to standard conditions and a collection efficiency is calculated as follows:

$$\mathsf{E} = (100) \left[\frac{\mathsf{V}_{\text{returned}} - \mathsf{V}_{\text{vent}}}{\mathsf{V}_{\text{returned}}} \right]$$

Where:

Е	=	Phase I Volumetric Efficiency, percent
V _{returned}	=	Corrected Vapor Return Volume to Cargo Tank
V _{vent}	=	Corrected Vapor Return Volume Discharged Vent Pipe

According to the "Biases and Interferences" section of the test procedure, unusually large cargo tank headspace volumes may cause low efficiency. During the delivery, the headspace volume must range between 3% - 10% of the total tank capacity prior to delivery. Additionally, leaks in the system will bias the results, so all components must be leak tight.

Figure 3 provides a cross sectional view of a Phase I transfer and the equipment installed to measure the volume returned to the cargo tank, and volume lost through the vent line.

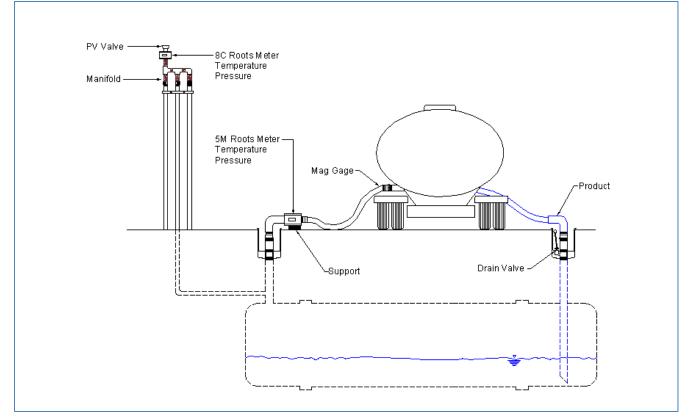


Figure 3: Phase I Efficiency Testing Configuration for a Typical UST

Medium to high volume retail GDF are normally equipped with two to three USTs, which range from 10,000 gallons to 15,000 gallons capacity each. Thus, retail GDF's may have anywhere between 30,000 to 45,000 gallons of tank capacity. During a Phase I fuel transfer into a retail GDF equipped with UST, between 8,000 – 9,000 gallons of fuel is delivered. As the liquid enters the tank, the vapors are displaced and routed back to the cargo tank. Once the cargo tank has completed the delivery, the vapors are driven back to the loading terminal and condensed back to liquid gasoline. For every gallon of product delivered, a gallon of vapor is displaced. Assuming a delivery of 8,000 gallons of liquid gasoline, then 8,000 gallons of vapor should be captured by the truck. If the system is working properly, very little to no vapor volume should be lost through the vent line.

Figures 4(a-f) provide images of various efficiency testing conducted at gasoline dispensing facilities equipped with USTs. Figures 5(a-f) provide images of efficiency testing conducted at gasoline dispensing facilities equipped with ASTs.

Figure 4(a-f): Phase I Efficiency Testing Conducted on UST



Fuel Transfer From Cargo Tank to UST Volume Meter Installed on Vapor Return



Volume Meter Installed on Vent Line



Volumetic Meter Installed on Vent Line



Fuel Transfer From Cargo Tank to UST Volume Meter Installed on Vapor Return



Fuel Transfer From Cargo Tank to UST Volume Meter Installed on Vapor Return



Phase I Delivery Elbows (Product and Vapor)





Fuel Transfer from Cargo Tank to AST



Volume Meter Installed on Vent Line



Volume Meter Installed on Vent Line



Volume Meter Installed on Vent Line



Volume Meter Installed on Vapor Return and Vent Line



Fuel Transfer from Cargo Tank to AST

Currently Certified Systems

Currently, there are a total of seven Phase I EVR systems certified by ARB for use with ASTs and USTs. Five of these systems are designed for use with USTs and two are designed for use with ASTs. The following table provides a brief description of each, note that the first UST system was certified over ten years ago. This is because the compliance deadline for existing sites to install Phase I EVR UST was April 2005. The compliance deadline for existing sites to install Phase I AST EVR is July, 2014.

ARB Executive Order	System Description	Applicability	Date Initially Certified	Phase I Efficiency
VR-101	Phil Tite	UST	06/19/01	
VR-102	OPW	UST	10/10/02	
VR-103	EBW	UST	09/26/03	
VR-104	CNI	UST	09/26/03	
VR-105	Emco Wheaton Retail	UST	10/20/06	>98%
VR-401	OPW for Single Wall and Protected Tanks	AST	02/03/10	
VR-402	Morrison Brothers for Protected Tanks	AST	06/22/11	

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*the above table does not include pre-EVR systems

For further details, Phase I EVR System Executive Orders are available at the following webpage: <u>http://www.arb.ca.gov/vapor/eo-evrphasel.htm.</u>

Results of Phase I Efficiency Testing at the Morrison Brothers Single-Wall Site

As indicated in Table 1, on June 22, 2011, a Phase I EVR system manufactured by Morrison Brothers was certified for use with protected ASTs per ARB Executive Order (EO) VR-402-A. In order to gain ARB certification for single-wall AST applications, Morrison Brothers requested certification testing on a 550-gallon single-wall AST located in Ceres, California (See Figure 6). ASTs are commonly classified as either "single-wall" or "protected". Single-wall ASTs are constructed with a primary (single) wall typically made of steel. Protected ASTs are constructed with a primary (inner) tank encased by a secondary (outer) tank, with a layer of insulating material (at least three inches thick) between the primary and secondary walls. The insulating material is usually lightweight concrete or a similar material.

On August 8, 2011, ARB staff performed initial testing which consisted of a pressure/vacuum (p/v) vent valve test and a leak decay, both of which passed, and

determined that the AST and Phase I equipment was ready to initiate a 180-day test period and volumetric efficiency testing.



Figure 6: Morrison Brothers Phase I EVR System for Single Wall AST

Initial Failure of Efficiency Testing: 08/25/11

After traveling to the test site to perform another set of p/v vent valve and lead decay testing, ARB staff returned to the site on August 25, 2011 to perform the Phase I volumetric efficiency testing.

At approximately 10:00 AM, ARB staff arrived on-site and installed test equipment (roots meters) on the vapor return from the AST to the cargo tank and on the vent line of the AST. The system was initially set up for a fuel drop of 280 gallons. As the vapor return line was opened and the first 58 gallons was transferred, tank pressure rose dramatically and scaled-out the manometer. The P/V valve cracking pressure was reached and vapor was lost through the vent line.



Figure 7: Cargo Tank Used to Fill AST at Morrison Brothers Test Site

At this point, ARB staff ceased the fuel drop, released the pressure on the tank via the vapor return line at the roots meter, and cleared the instruments. An exact measurement was not recorded, but over 5 cubic feet of vapor (over 37 gallons) of vapor had been lost through the P/V vent valve. The test procedure does not allow for clearing of the instruments, therefore, at this point, the system had failed the Phase I efficiency testing. This initial loss of vapor caused by a surge of pressure from the cargo tank resulted in a volumetric efficiency of 86%.

For data gathering purposes, ARB staff decided to restart the fuel drop and the Phase I efficiency testing. 222 gallons of fuel was then dropped into the AST. The roots meter at the vapor return to the cargo tank recorded 30 cubic feet, which equates to 224.4 gallons of vapor. The roots meter on the vent line recorded 0.3 cubic feet, which equates to 2.0 gallons.

Per the TP-201.1, the test is not concluded until 15 minutes after the fuel drop. If at the end of the 15 minutes, the tank pressure is greater than 1.0 inches WC, then staff must record vapor loss through the vent line for an additional 45 minutes. Immediately after the fuel drop, the AST's pressure was already greater than 2.0 inches WC. Therefore staff had to wait for a full hour.

Using the equations found in the TP-201.1 and not including the initial surge of vapor lost when the cargo tanker connected to the AST, if the numbers were run directly at the end of the fuel drop, the Phase I equipment would have passed efficiency at 99.1%.

Over the next 60 minutes, pressure on the tank grew to 3.5 inches WC and the roots meter totals grew to a total of 1.0 cubic feet, which equates to 7.7 gallons. See Table 2 for results.

At the end of the 60 minutes, the Phase I efficiency had dropped to 96.6%. It was calculated that 98% efficiency would have been reached when the roots meter on the vent line hit 0.60 cubic feet. That occurred 35 minutes into the hour waiting period.

After the failed test, ARB staff discussed the causes behind the failures. It was originally hypothesized that the cargo tank was either over-pressured as it had been filled the day before, and/or the fuel compartments on the cargo truck shared a vapor space that may have led to greater vapors being pushed through the AST.

Second Failure of Efficiency Testing: 09/08/11

Another trip was made to the test site on September 8, 2011 to run a second Phase I efficiency test. ARB staff arrived at approximately 10:00 AM and set up roots meters on vapor return and vent stack. Staff then joined the empty cargo truck at the bulk plant (see Figure 8) and observed 450 gallons of gasoline being bottom loaded into a 500 gallon compartment (See Figure 9). Staff learned that except for a shared rail space at the top of the cargo tank, vapor is only returned to the compartment utilized during fueling.



Figure 8: Bulk Plant Tanks located at the Morrison Brothers Test Site



Figure 9: Bottom Loading of Cargo Tank Prior to Efficiency Testing At the Morrison Brothers Test Site

The cargo truck was then driven back to the AST site (approximately 200 feet away) and prepared for a fuel drop of 300 gallons. As soon as the vapor return was opened between the truck and the AST, the manometer was scaled-out and the P/V vent cracked. Approximately 15 cubic feet (112 gallons) of vapor was vented through the P/V valve resulting in an efficiency of 62%. The decision was made to clear the instruments and allow the tanker truck and AST to stabilize before starting the Phase I Efficiency test. Once again, this instantly failed the Phase I efficiency testing, as the test procedure does not allow for equipment to be cleared. (See Figure 10)

The fuel drop was initiated and temperature and pressure readings were taken from both roots meters every 15 seconds. It took approximately 5 minutes and 15 seconds to drop 300 gallons of fuel. The roots meter on the vapor return line to the cargo tank recorded 42 cubic feet, which equates to 314.2 gallons of vapor. The roots meter on the vent line had a zero reading, providing for an efficiency of 100% directly at the end of the fuel drop.

However, at the end of the fuel drop, the tank pressure was 2.8 inches of WC. Therefore, per the TP, the AST had to be monitored for a full 60 minutes before efficiency could be determined. Over the next 60 minutes, pressure on the tank grew to 3.6 inches of WC and the roots meter totals grew to a total of 1.1 cubic feet, which equates to 8.5 gallons. The equation done at the end provided an efficiency of 97.3%. See Table 2 for results.

It was calculated that a passing 98% efficiency would have been reached when the roots meter on the vent line hit 0.84 cubic feet. That occurred 43 minutes into the hour waiting period.

Figure 10: Measurement of Headspace Pressure, Temperature, and Vent Volume after Fuel Delivery at Morison Brothers Test Site



Third Failure of Efficiency Testing: 12/15/11

On December 15, 2011, ARB staff arrived at approximately 7:00 AM to perform the third Phase I Efficiency Test. Discussion between ARB and Morrison Brothers staff resulted in the hypothesis that direct sunlight as well as ambient and fuel temperature may play a role in the pressurization of the AST during and after the Phase I transfer of fuel to the AST (See Figure 11). The cargo tank was again loaded immediately before the start of the Phase I Efficiency testing, and all certification testing equipment and delivery equipment was connected appropriately. The internal pressure of the AST was allowed to stabilize before the delivery was initiated.

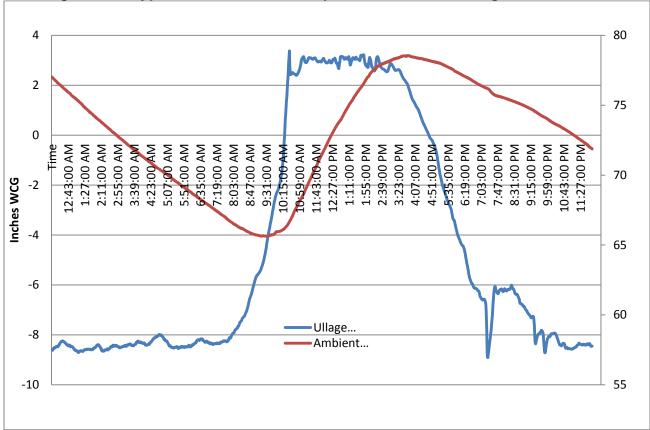


Figure 11: Typical Pressure vs. Temperature Profile of Single Wall AST

During the delivery, 300 gallons of fuel was delivered into a tank that contained approximately 100 gallons of fuel. At the end of the delivery 38 CF (284.3 gallons) of vapor was returned to the cargo tank and. 0.4 CF (3.1 gallons) of vapor was lost through the vent line on the AST. If the test had ended at the conclusion of the fueling, then efficiency would have been 98.9%, however AST pressure was at 3.8 inches of WC and the test had to continue for an hour. After the one hour wait, 0.95 CF (7.1 gallons) of vapor was lost through the vent line on the AST, resulting in a total efficiency of 97.5%. See Table 2 for results.

It was calculated that the minimum passing of 98% efficiency would have been reached when the roots meter on the vent line hit 0.8 cubic feet. That occurred approximately 30 minutes into the hour waiting period.

Fourth Efficiency Test: 02/01/12

On February 1, 2012, ARB staff performed a fourth Phase I Efficiency Test. Building upon the data gather from the previous three failures, ARB staff determined that the optimum circumstances would be to run the Phase I Efficiency test while ambient and fuel temperatures were low, and while there was the greatest available ullage in the AST and delivering the highest volume of fuel. It was hypothesized that a nearly empty

AST prior to delivery would decrease the agitation of warmer, existing fuel, while filling to AST to near capacity would decrease the headspace in which fuel could volatize.

In preparation, Morrison Brothers nearly emptied (less than 10% of total fuel volume remained) the 550-gallon AST to ensure the greatest ullage volume. Then 478.5 gallons of fuel was delivered to the AST. The measured vapor return to the delivery truck was 65.8 CF, or 492.2 gallons. At the end of the delivery, 0.3 CF (2.1 gallons) had been lost through the P/V vent valve. After waiting for the required hour, 0.6 CF (4.7 gallons) had been lost, resulting in a passing Efficiency of 99.0%. See Table 2 for results.

Date	Pass/Fail*	Efficiency	Vent Volume (at	Vent Volume (at	Efficiency %			
		%	end of 60 minute	End of Fuel	(at end of fuel			
			wait)	Drop)	drop)			
8/25/11	Fail	96.6%	1.0 CF (7.7	0.3 CF (2.02	99.1%			
			gallons)	gallons)				
9/8/11	Fail	97.3%	1.1 CF (8.5	0 CF (0 gallons)	100%			
			gallons)					
12/15/11	Fail	97.5%	0.9 CF (7.1	0.4 CF (3.1	98.8%			
			gallons)	gallons)				
2/1/12	Pass	99.0%	0.6 CF (4.7	0.3 CF (2.1	99.2%			
			gallons)	gallons)				
*A passing Efficiency is 98%								

Table 2: Results of Phase I Efficiency Testing on Single Wall 550-gallon AST

Reasoning

While ARB and Morrison Brothers staff eventually had a passing Phase I Efficiency test, the fact that the Phase I system failed three times was troubling. Through engineering evaluations and internal and external discussion, it was determined that the fault of the failures lay not in the design of the Phase I system, which had successfully passed Phase I Efficiency testing on a protected AST, but in the single-wall AST and it's applied standing loss control system. An existing single-wall AST with certified standing loss control will emit hydrocarbons through the P/V vent valve due to pressurization during heating and cooling cycles (pressure-driven vent line emissions).

Other factors, such as a small fuel delivery, a greater volume of existing fuel in the AST prior to delivery, and a greater ullage volume left in the AST after delivery, all working in concert with the design of the single-wall AST and standing loss control application to create greater pressurization of the AST during delivery and during the TP-201.1 required one-hour waiting period to result in hydrocarbon emission that bias the Phase I Efficiency test results towards failure.

Unlike USTs, which are larger and insulated by backfill material, ASTs typically found at gasoline dispensing facilities are significantly smaller and subject to greater diurnal temperature variations. When the volatile liquid gasoline vaporizes, the smaller AST is

far more likely to be subject to rapid increases in ullage pressure, which results in greater pressure-driven vent line emissions, as illustrated in Figure 11. These diurnal AST emissions are subject to and captured by the separate standards of standing loss control. Therefore, the longer an AST sits idle, the greater the chance of hydrocarbon pressurization and possible vent line emissions. Including the standing loss control vent emissions that occur in the idle period after a delivery biases the Phase I Efficiency test results towards failure.

Recommendation

Vent line emissions that bias the results of TP-201.1 towards failure can be attributed to the standing losses that readily occur on single wall AST. The small tank size and rapid temperature fluctuations found in ASTs was not considered when TP-201.1 was originally written and applied to both USTs and ASTs. Therefore, to prevent the double-counting of these emissions while performing the Phase I Efficiency test on ASTs, ARB staff recommends modifying portions of TP-201.1 to address those conditions that are specific to ASTs.

Specifically, ARB staff has two recommendations. First, due to fact that small ASTs operate at higher internal pressures and that the vapor space of fuel delivery truck is generally under pressure when it arrives at the gasoline dispensing facility and connects to the waiting AST, greater pressurization of the AST can occur before the delivery even begins. To prevent emissions that occur because of this pressurization from biasing the testing during delivery, ARB staff recommends that the cargo truck and AST be allowed to stabilize and any emissions registered on the totalizer prior to commencement of delivery be reset to zero.

Secondly, due to standing loss emissions being counted twice while performing TP-201.1, ARB staff recommends the removal of the waiting period after a delivery has been made for ASTs only. The venting which occurs after the delivery from the cargo tank is completed is unrelated to the performance of the Phase I EVR system, and including that venting in the Phase I efficiency calculations, as required by the current procedure, biases the test towards failure.