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

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Overpressure Study

Technical Support Document
Estimate of Pressure Driven Emissions Occurring at GDF Equipped with the Assist Phase II Enhanced Vapor Recovery System

December 6, 2017

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EXECUTIVE SUMMARY

The purpose of this study is to determining summer, winter, and year around pressure driven emissions from the Healy Phase II Enhanced Vapor Recovery System (assist system)[1]. As mentioned in other Technical Support Document such as VR-OP-G1, the California Air Resources Board (CARB) staff found that in-station diagnostics (ISD) overpressure alarms start occurring between November and March when gasoline was sold without limits on volatility measured as Reid vapor pressure. Beginning in 2009, CARB staff collected underground storage tank (tank) headspace pressure, ullage, and barometric pressures from four gasoline dispensing facilities (GDF) in the Sacramento area to calculate the pressure driven emissions (vent line and fugitive). Data were collected continuously beginning with the winter of 2009 and ending during the summer of 2013. Prior to any data collection, CARB staff conducted extensive performance testing at each GDF and made applicable repairs to establish optimal operating conditions. This eliminates any potential biases introduced by the faulty or inoperable equipment. To calculate the pressure driven emission factors from data collected, CARB staff developed an Excel macro called the Pressure Analysis and Calculation Emissions or PACE to determine the vent line and fugitive emissions using equations from CARB adopted test procedures.

In 2013, CARB staff expanded data collections to four additional Southern California GDFs that exhibited “pressure increasing while dispensing” or PWD[2]. As with the non-PWD sites in Sacramento, CARB staff conducted testing to ensure that repairs were made to correct any issues that may bias the collected data. Data collection began with the winter 2013 and ended with the winter of 2015. CARB staff manually calculated fugitive and vent line emissions, since PACE was not updated to calculate emissions from PWD GDFs.

The results indicated that the average summer pressure driven emission factors for the non-PWD and PWD GDFs were approximately the same. The average winter pressure driven emission factors for the PWD GDFs were approximately twelve times greater than the non-PWD GDFs. The statewide annual average emission factor and control efficiency were determined to be 0.345 pounds per 1,000 gallons dispensed (lbs/kgal) and 95.8 percent, respectively. This showed, even with PWD occurring at approximately 34 percent of California GDFs, that the assist system still meets CARB’s emission factor and efficiency performance standards of 0.38 lbs/kgal and 95 percent,

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[1] Pressure driven emissions from balance system is discussed in a Technical Support Document – Performance of Balance Type Phase II Vapor Recovery Systems Operating at Slightly Positive Underground Storage Tank Ullage Pressure.

[2] PWD is a severe case of overpressure where the pressure within the UST was high enough to cracked the pressure/vacuum vent valve to release emissions into the air.

respectively. However, if the percentage of GDF exhibiting PWD increases and/or the fugitive/vent line emissions increase, then the overall system efficiency will decrease. In order to reduce overpressure and associated fugitive and vent line emissions from assist system, CARB staff suggests following the recommendations listed in the Information Bulletin, Minimizing Winter Time In-Station Diagnostic System Overpressure Alarms[1].

I. INTRODUCTION and BACKGROUND

Over the past eight years, CARB staff has studied the increase of vapor recovery overpressure (OP) alarms at Healy Assist Phase II Enhanced Vapor Recovery (EVR) systems (assist system). These OP alarms are triggered by the in-station diagnostic (ISD) system during the November through March (winter fuel) period when there is no restriction on gasoline volatility as measured by Reid vapor pressure (RVP). The purpose of this OP study is to determine the summer, winter, and year-round hydrocarbon emissions from California gasoline dispensing facilities (GDF) with assist system. This study included four GDFs exhibiting PWD conditions during the winter fuel period and four GDFs that did not. PWD is a severe case of overpressure where the pressure within the headspace of the underground storage tank (UST) is high enough to crack or open the pressure vacuum relief valve for extended periods when fuel is being dispensed. This results in the releasing of gasoline vapors to the atmosphere. PWD occurs in the absence of vapor recovery equipment related defects or problems. The non-PWD sites remain at vacuum throughout the day and only exhibit positive pressure during overnight shut down or when throughput significantly slows down.

Emissions from California GDFs are controlled by vapor recovery systems. Phase II vapor recovery systems collect and store vapors displaced during the filling of vehicle fuel tanks. The assist system with ISD was first certified in 2005. According to a CARB staff survey of air pollution control districts conducted in 2013 (Appendix I), the assist system was installed at approximately 67% of the GDFs subject to vapor recovery in California.

ISD equipment is designed to monitor the collection and containment of gasoline vapors by vapor recovery equipment. The ISD software continuously monitors the vapor recovery equipment and issues warning and failure alarms when regulatory thresholds listed in Section 9 of CP-201[2] are exceeded. ISD will activate a warning alarm that notifies the GDF owner/operator of a potential vapor recovery system problem that may require maintenance. If the required corrective action is not taken within the specified time, ISD system will trigger a failure alarm and terminate all fuel dispensing or deactivate individual fueling points.

Among the parameters monitored by ISD is the pressure within the headspace or ullage of the UST. If the pressure within the UST exceeds a certain threshold within a certain period, an OP alarm is triggered. OP alarms are caused by gasoline evaporation rates which generate vapor volumes that cannot be contained within the UST vapor space and exceed the capacity of devices used to manage UST pressure. A GDF continuously exhibiting PWD will have multiple OP alarms per month.

Gasoline sold in the winter without RVP limits is the primary driver for OP alarms. The more volatile the fuel the more gasoline will evaporate into a volume of unsaturated air before equilibrium is reached and evaporation subsides. The increase in RVP from summer to winter fuel leads to higher evaporation[3]. CARB regulations limit gasoline

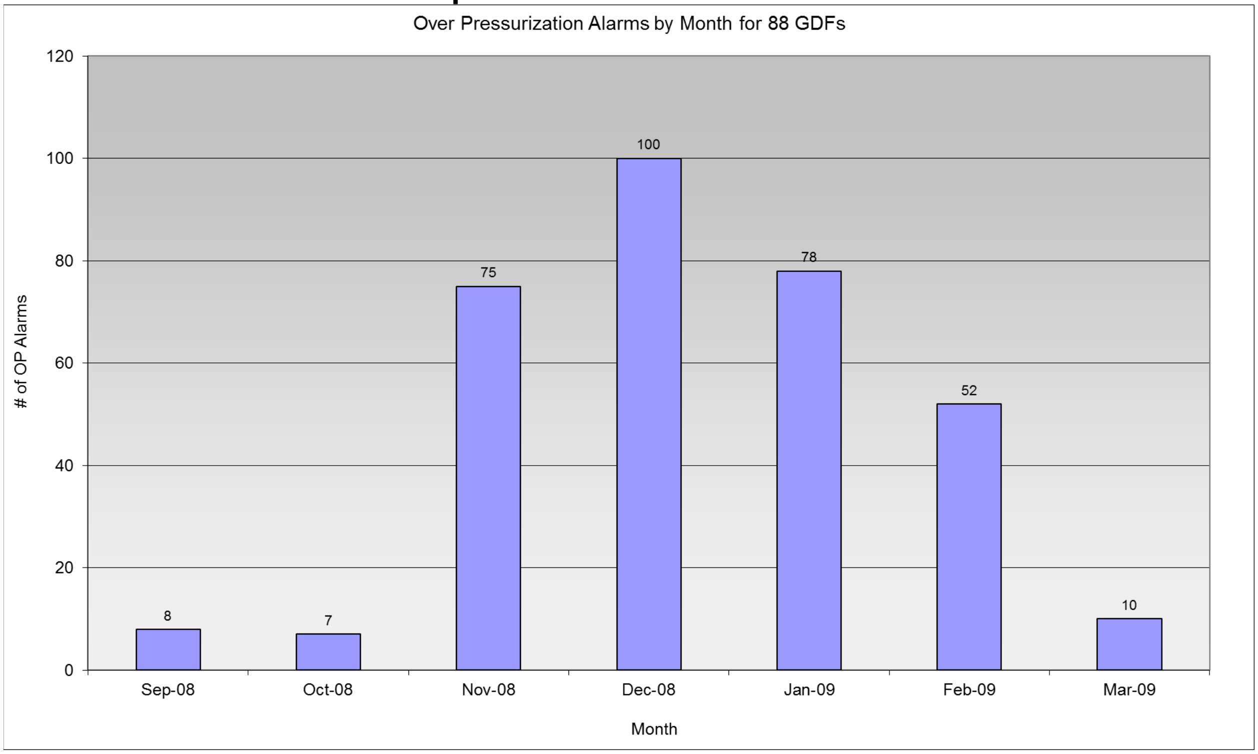
RVP to a nominal value of seven pounds per square inch gauge (psig) during the summer months. During winter months, gasoline RVP varies between 7 and 15 psig and is regulated by the applicable ASTM fuel specification[4]. In addition to RVP, the evaporation rate within USTs is influenced by the following factors:

a. type of vapor recovery system,
b. vapor to liquid ratio (V/L) ratio,
c. excess air ingestion due improper recognition of vehicles with on-board systems or imperfect seal at the fill pipe nozzle interface,
d. GDF operating hours, and
e. leaks within the vapor recovery system.

II. METHODOLOGY

In July 2009, CARB staff downloaded ISD data from 88 different GDFs equipped with the assist system primarily located in Sacramento and San Diego areas. The number of OP alarms over time was analyzed and is shown in Figure III-1.

Figure III-1
Overpressure Alarm Trend Chart



This trend chart showed that there was a significant increase in the number of OP alarms during the period between November and February, which corresponds to the period when gasoline without any volatility limits is sold. This trend initiated the OP study.

A. Non-PWD Test Sites

In November 2009, six sites were selected to participate in the OP study. Of these six sites, four had an assist system and the other two had a balance system. . This document will only discuss emissions attributed to the GDFs equipped with an Assist VRS. The emissions associated with GDFs equipped with a balance system are discussed in a separate Technical Support Document - Performance of Balance Type Phase II Vapor Recovery Systems Operating at Slightly Positive Underground Storage Tank Ullage Pressure[5](VR-OP-B1). The GDFs selected for this study were located within 50 miles of Sacramento to allow for frequent site visits for the purposes of equipment installation, data collection, performance testing, or the `observation of testing and maintenance conducted by service contractors.

CARB staff used data from the California Energy Commission (CEC) 2008 California Retail Fuel Outlet Annual Report[6] to determine the percentage of thevarious GDFs throughput categories. The throughput categories in the CEC data were combined to produce throughput categories which were used to determine the throughput categories of the four GDFs. The four throughput categories created were:

1. 50 to 150 kgal/month
2. 150 to 200 kgal/month
3. 200 to 400 kgal/month
4. Above 400 kgal/month

The throughput category below 50 kgal/month was not included because ISD is not required at sites below this monthly throughput.

The ISD non-PWD study sites equipped with an assist system, cover the four throughput category, are summarized in Table III-1.

Table III-1
ISD Overpressure Study Non-PWD Test Sites

Site Name	Location	Monthly Thrpt	PWD Observed	ISD System	DAQ Installed
Site A	Sacramento, CA	750,000	No	Veeder-Root	Yes
Site B	Marysville, CA	330,000	No	Incon	No
Site C	Sacramento, CA	170,000	No	Veeder-Root	Yes
Site D	Sacramento, CA	145,000	No	Incon	No

B. PWD Test Sites

In November 2012, CARB staff became aware of GDFs exhibiting pressure increasing during dispensing operations or PWD. This phenomenon were not observed by CARB staff in the past. In November 2013, four PWD sites located in Southern California were added to the OP study. These four PWD sites were located in Southern California because PWD occurred predominantly in Southern California, and the sites were shown to have exceptional maintenance history. The PWD test sites are shown in Table III-2.

Table III-2
ISD Overpressure Study PWD Test Sites

Site Name	Location	Monthly Thrpt	PWD Observed	ISD System	DAQ Installed
Site E	Pomona, CA	90,000	Yes	Veeder-Root	Yes
Site F	Carson, CA	110,000	Yes	Veeder-Root	Yes*
Site G	San Diego, CA	110,000	Yes	Veeder-Root	Yes**
Site H	San Diego, CA	160,000	Yes	Veeder-Root	Yes**

*Barometric Pressure Data used from Site E.
**Barometric Pressure Data used from data logger installed at GDF in Santee, CA.

C. Equipment Installation

All eight PWD and non-PWD sites were equipped with an ISD system that captured pressure and ullage data. CARB staff installed data logger equipment at a majority of the test sites to record the UST and barometric pressure. CARB staff also installed Franklin Fueling Systems pressure vacuum (PV-Zero) valves at all eight test sites, data acquisition equipment (DAQ) at GDFs equipped with a Veeder-Root ISD system, and an USB flash drive at GDFs equipped with an Incon ISD system. The DAQ or USB flash drive was installed at all eight test sites to continuously record the date, time, UST pressure, and UST ullage. The barometric pressure was recorded using a CARB data logger at sites A, B, C, D, and E shown in Tables III-1 and III-2. The barometric pressure for sites F, G, and H was obtained from study sites in close proximity.

The PV-Zero valve operates using a similar concept to a common P-Trap used in plumbing drain applications to create a liquid air seal. The liquid seals the UST ullage vapors from the atmosphere while still maintaining the proper differential pressure set points. After the differential pressure has been exceeded, air or vapor bubbles through the liquid media until the pressure returns to the operational pressure settings. Because the PV-Zero does not use seals or gaskets to seal off the UST ullage from atmosphere, the unit will not allow vapor or air to pass through at pressure less than the cracking set point. The PV-Zero valve has a fixed cracking pressure (approximately four inches water column (“WC)), allowing the volume of vent emissions to be calculated from UST ullage volume and changes in UST static pressure. If maintained properly, the PV-Zero valve has a zero leak rate.

D. Vapor Recovery System Performance Testing

Prior to the commencement of data collection, all eight assist sites were subjected to performance testing to demonstrate compliance with applicable performance standards. CARB staff identified vapor recovery system performance standards that were thought to affect the UST pressure profile. CARB staff conducted Phase I and Phase II testing at each GDF in order to establish baseline operating conditions and to ensure that each GDF complies with applicable regulatory performance standards and specifications. Table III-3 provides a complete listing of performance tests conducted by CARB staff at each of the eight GDFs.

Table III-3
VRS Performance Tests

Test Procedure	Description
VR-202 Exhibit 4	Determination of Static Pressure Performance of the Healy Clean Air Separator
VR-202 Exhibit 5	Vapor to Liquid Ratio
VR-202 Exhibit 7	Nozzle Bag Test
VR-202 Exhibit 9 or VR-202 Exhibit 10	Veeder-Root ISD Operability Test Procedure or INCON VRM Operability Test Procedure
VR-202 IOM 2	Nozzle Inspection (boot alignment, tears, cupping of face seal)
VR-202 IOM 8	Dispenser Integrity
TP-201.3	Leak Decay Test

The eight GDFs were also subject to periodical scheduled compliance testing as required by the Air District: SMAQMD, SDAPCD – Annual; SCAQMD – Semi Annual. GDFs with non-compliant results were repaired and retested until compliance with applicable performance standards is achieved.

CARB staff initially performed vapor recovery performance testing at sites A, B, C, and D listed in Table III-1. CARB staff initially witnessed annual compliance testing by certified maintenance contractors at sites E, F, G, and H listed in Table III-2. After the first year, CARB staff used the annual compliance testing results, as required by each Air District's permit to operate, to ensure compliance.

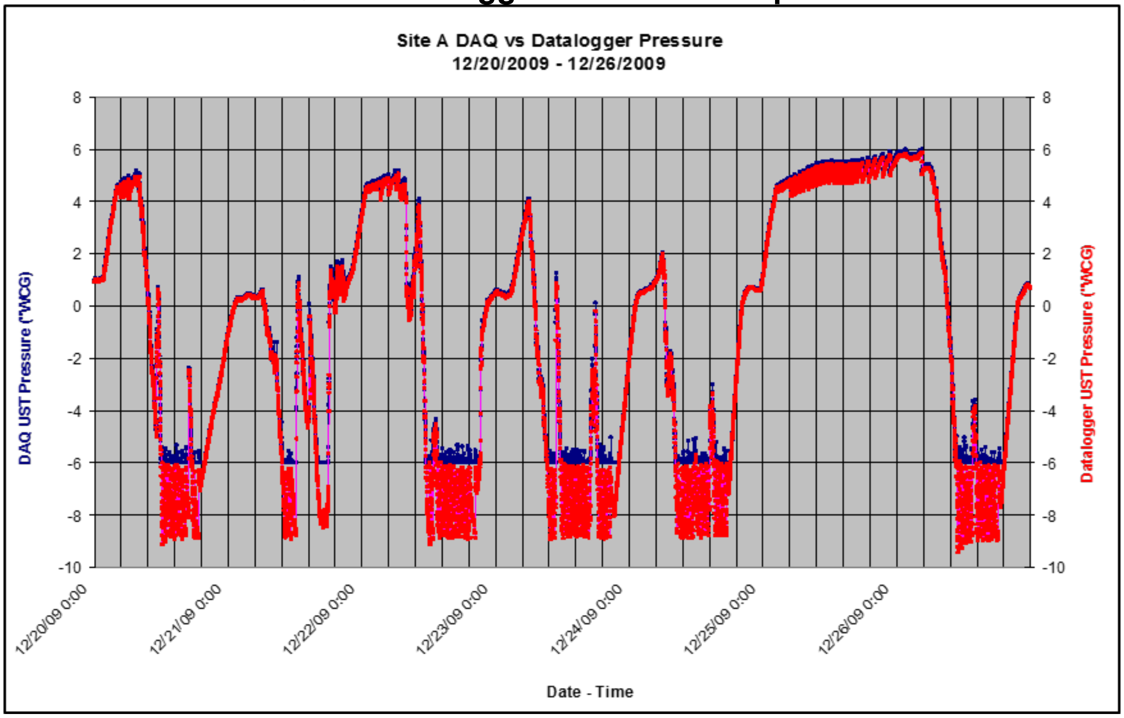
E. Data Collection

At each GDF CARB staff installed a DAQ equipped with a Veeder-Root ISD console to primarily monitor the UST pressure and ullage. The DAQ is a stand-alone personal computer with the Windows Operating System and Veeder-Root Inform software. The DAQ is connected to the Veeder-Root ISD console via an RS232 cable and periodically throughout the day, the Inform software pulls ISD data from the Veeder-Root console and stores it on the computer. The DAQ must be powered on and the RS232 cable must be connected in order for data transfer to occur.

It was not possible to install a DAQ at the GDFs equipped with an Incon ISD system due to the configuration of the Incon console. CARB staff installed an approved USB flash drive into the USB port of the Incon console. The data logging feature of the Incon ISD system was turned on and ISD data was automatically saved to the USB drive on a weekly basis. CARB staff would travel to the GDFs on a weekly or bi-monthly basis to download the ISD data from the USB flash drive.

In addition to the DAQ and USB flash drive, CARB data loggers with Campbell Scientific data logging software were installed at a majority of the eight GDFs. The CARB data logger was used to monitor the UST pressure and the barometric pressure at the GDF. If a CARB data logger was installed at a GDF within close proximity (~50 miles) of another GDF then a CARB data logger was not installed due to the lack of equipment. The barometric pressure data from the GDF in close proximity was used. The purpose of monitoring the UST pressure with the CARB data logger was two-fold: 1) The UST pressure could be used for instances where the UST pressure monitored by the DAQ or USB flash drive was not recorded and 2) The ISD pressure recorded by the DAQ/USB flash drive and data logger could be overlayed as a check on the accuracy of the pressure transducer – see Figure III-2.

Figure III-2
DAQ vs Data Logger Pressure Comparison



In Figure III-2, the reason the DAQ and data logger pressure do not overlay each other below negative six “WC is because the Veeder-Root pressure transducer’s vacuum range is limited to negative six “WC whereas the data logger has a range of negative ten “WC.

The UST pressure, UST ullage, and barometric pressure were used to estimate the volume of vent line and fugitive emissions that occur as a result of overpressure/PWD conditions.

Gasoline RVP samples from Sites A, B, C, and D in Table III-1 were collected on a weekly basis during the months of November through April and on a monthly basis during the months of May through October. Gasoline RVP samples from Sites E, F, G, and H in Table III-2 were collected on a weekly basis during the months of November through April and only once in May and once in October for the remainder of the year[3].

F. Fugitive and Vent Line Emission Calculations

The UST pressure, UST ullage, and barometric pressure were used to estimate the volume of fugitive and vent line emissions that occur during overpressure/PWD conditions. The assist system utilizes a Clean Air Separator (CAS) to manage pressure. The CAS is a passive system that controls pressure by utilizing an inner bladder within an outer tank that is connected to the UST ullage. Since the CAS is a passive system, there are no processor emissions from the assist system equipped with a CAS.

The pressure-related fugitive flowrates were calculated using equations in Table 9.1 of TP-201.3F[7] that correspond to the system type, number of nozzles, and pressure measurements present at the test site. The maximum pressure range listed in Table 9.1 is 2.00 – 3.50 “WC. However, in this study, the maximum pressure at a PWD site exceeded the top end of this range. It was assumed that the fugitive equations for the maximum pressure range of 2.00-3.50 “WC in Table 9.1 also applied to pressures greater than 3.50 ”WC. Table III-4 shows the all the equations used to calculate the fugitive flowrates at the allowable leak rate in the OP study.

Table III-4
Fugitive Equations for Assist Vapor Recovery Systems

System Type	Nozzles	Pressure Range (in WC)	Equation for Q (Flow Rate in CFM)
Assist	7-12	0.00 – 1.00	$Q = -0.0188 P^2 + 0.0644 P - 0.0028$
		1.00 – 2.00	$Q = -0.0049 P^2 + 0.0408 P + 0.007$
		> 2.00	$Q = -0.0018 P^2 + 0.0291 P + 0.0181$
	13-18	0.00 – 1.00	$Q = -0.0205 P^2 + 0.0694 P - 0.0031$
		1.00 – 2.00	$Q = -0.0054 P^2 + 0.0434 P + 0.0081$
		> 2.00	$Q = -0.0022 P^2 + 0.0327 P + 0.017$
	19-24	0.00 – 1.00	$Q = -0.0228 P^2 + 0.0744 P - 0.0034$
		1.00 – 2.00	$Q = -0.0055 P^2 + 0.0454 P + 0.0087$
		> 2.00	$Q = -0.002 P^2 + 0.0318 P + 0.0217$

Table III-4 and equations 9.2,1, 9.2.2, and 9.3.1 in TP-201.2F were then used to calculate the total fugitive volume and fugitive mass using an average summer RVP vapor concentration of 44.2% and an average winter RVP vapor concentration of 49.4%[8].

In addition to fugitive emissions, the vent line emissions were also calculated. Appendix II shows the derivation of the equations from a material balance in the UST ullage space that were used to calculate the vent line volume. The following two equations were used to calculate the vent line volume at each minute:

During dispensing:

$$V_I = ((P_i V_i - P_{I+1} V_{I+1}) / P_{Bar} \qquad \text{Equation III-1}$$

During non-dispensing (ullage is constant):

$$V_i = V_{i+1}(P_i - P_{i+1}) / P_{Bar} \qquad \text{Equation III-2}$$

where:
V_i = Volume leaving UST in the i_{th} minute as vent line emissions
P_i = UST Pressure at time t_1
P_{i+1} = UST Pressure one minute later at time $t_{i+1;}$ $t_{i+1} = t_i + 1$ minute
Vi = UST Ullage Volume at time i = t_i
V_{i+1} = UST Ullage Volume one minute later at time = t_{i+1}
P_{Bar} = Barometric Pressure (assumed constant over 1 minute interval)

The total vent line volume was then calculated using the following equation:

$$V_{tot} = \sum_{i=1}^{n} V_i \qquad \text{Equation III-3}$$

where:

V_{tot}	=	Total volume of vent line emissions for the entire period monitored
V_i	=	Volume (>0) leaving UST in ith minute as vent line emissions
n	=	Number of pressure intervals

The vented volume mass was then calculated using the following equation:

$$V_M = \left[\frac{(V_{tot})(C)(MW)}{(MV)}\right] \qquad \text{Equation III-4}$$

where:

V_M	=	Vented Volume Mass
C	=	Hydrocarbon vapor concentration (%HC), 44.2% C_3 summer[8], 49.4% C_3 winter[8]
MW	=	Molecular weight, lb/lb-mole based on propane, measurement or 44.0 for C_3
MV	=	Molar volume, 385.0 ft^3/lb-mole at 68 °F

Finally, the emission factor was calculated by using the following equation:

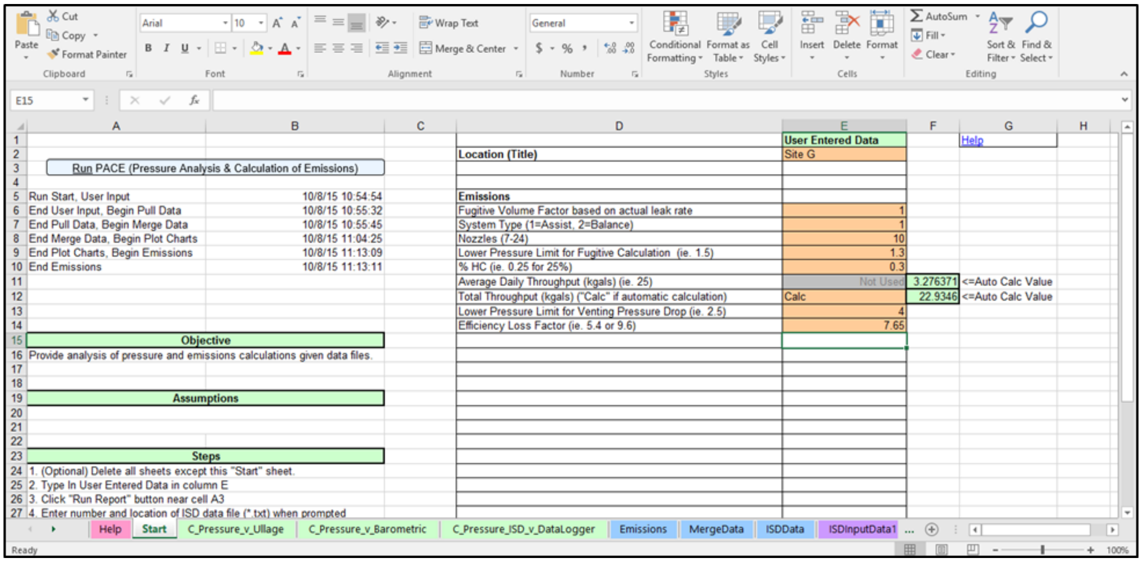
$$EF_T = \left[\frac{(V_M + V_F)}{(G)}\right] \qquad \text{Equation III-5}$$

where:

EF_T	=	Emission Factor, lbs/kgal
V_M	=	Vented Volume Mass
V_F	=	Fugitive Volume Mass
G	=	Average gasoline throughput, kgal

In order to make the calculations more efficient, CARB staff created a Microsoft Excel macro called PACE. Currently, PACE can only be run in 2003 Version of Microsoft Excel as the macro was not rewritten for newer versions of Microsoft Excel. PACE was created to increase efficiency while minimizing user errors when running emission calculations. The front end of the user interface of PACE is shown in Figure III-3.

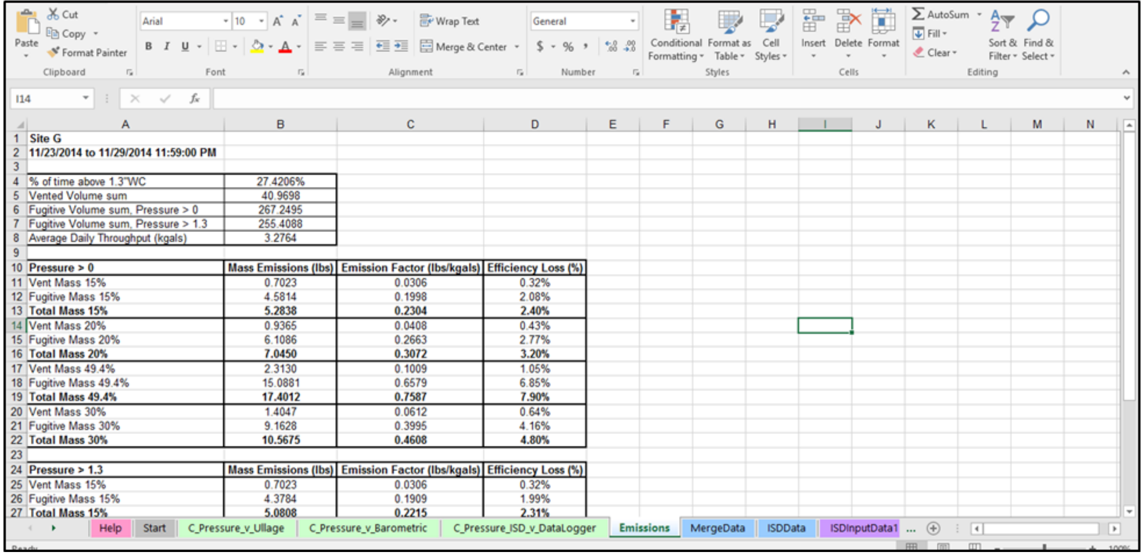
Figure III-3
PACE User Interface



	A	B	C	D	E	F	G
1					User Entered Data		Help
2				Location (Title)	Site G		
3	Run PACE (Pressure Analysis & Calculation of Emissions)						
4							
5	Run Start, User Input	10/8/15 10:54:54		Emissions			
6	End User Input, Begin Pull Data	10/8/15 10:55:32		Fugitive Volume Factor based on actual leak rate	1		
7	End Pull Data, Begin Merge Data	10/8/15 10:55:45		System Type (1=Assist, 2=Balance)	1		
8	End Merge Data, Begin Plot Charts	10/8/15 11:04:25		Nozzles (7-24)	10		
9	End Plot Charts, Begin Emissions	10/8/15 11:13:09		Lower Pressure Limit for Fugitive Calculation (ie. 1.5)	1.3		
10	End Emissions	10/8/15 11:13:11		% HC (ie. 0.25 for 25%)	0.3		
11				Average Daily Throughput (kgals) (ie. 25)	Not Used	3.276371	<=Auto Calc Value
12				Total Throughput (kgals) ("Calc" if automatic calculation)	Calc	22.9346	<=Auto Calc Value
13				Lower Pressure Limit for Venting Pressure Drop (ie. 2.5)	4		
14				Efficiency Loss Factor (ie. 5.4 or 9.6)	7.65		
15	Objective						
16	Provide analysis of pressure and emissions calculations given data files.						
17							
18							
19	Assumptions						
20							
21							
22							
23	Steps						
24	1. (Optional) Delete all sheets except this "Start" sheet.						
25	2. Type In User Entered Data in column E						
26	3. Click "Run Report" button near cell A3						
27	4. Enter number and location of ISD data file (*.txt) when prompted						

PACE allows CARB staff to input data (system type, number of nozzles, %HC, etc.) in the orange colored cells shown in Figure III-3 so that PACE can be customized. After defined values were entered, CARB staff selected specific ISD DAQ/Incon pressure files and corresponding data logger data files containing barometric pressure to run PACE. After the pressure and data logger files were selected, PACE will automatically run. At the end of run, PACE will generate a data table showing fugitive and vent line emissions and emission factors (see Figure III-4).

Figure III-4
Sample PACE Emission Calculation Results



	A	B	C	D
1	**Site G**			
2	**11/23/2014 to 11/29/2014 11:59:00 PM**			
3				
4	% of time above 1.3"WC	27.4206%		
5	Vented Volume sum	40.9698		
6	Fugitive Volume sum, Pressure > 0	267.2495		
7	Fugitive Volume sum, Pressure > 1.3	255.4088		
8	Average Daily Throughput (kgals)	3.2764		
9				
10	**Pressure > 0**	**Mass Emissions (lbs)**	**Emission Factor (lbs/kgals)**	**Efficiency Loss (%)**
11	Vent Mass 15%	0.7023	0.0306	0.32%
12	Fugitive Mass 15%	4.5814	0.1998	2.08%
13	**Total Mass 15%**	**5.2838**	**0.2304**	**2.40%**
14	Vent Mass 20%	0.9365	0.0408	0.43%
15	Fugitive Mass 20%	6.1086	0.2663	2.77%
16	**Total Mass 20%**	**7.0450**	**0.3072**	**3.20%**
17	Vent Mass 49.4%	2.3130	0.1009	1.05%
18	Fugitive Mass 49.4%	15.0881	0.6579	6.85%
19	**Total Mass 49.4%**	**17.4012**	**0.7587**	**7.90%**
20	Vent Mass 30%	1.4047	0.0612	0.64%
21	Fugitive Mass 30%	9.1628	0.3995	4.16%
22	**Total Mass 30%**	**10.5675**	**0.4608**	**4.80%**
23				
24	**Pressure > 1.3**	**Mass Emissions (lbs)**	**Emission Factor (lbs/kgals)**	**Efficiency Loss (%)**
25	Vent Mass 15%	0.7023	0.0306	0.32%
26	Fugitive Mass 15%	4.3784	0.1909	1.99%
27	**Total Mass 15%**	**5.0808**	**0.2215**	**2.31%**

Prior to running PACE with collected field data, CARB staff checked for accuracy by manually calculating the vent line and fugitive emissions and comparing them to the PACE results shown in Figure III-4. If discrepancies were found, CARB staff made the necessary corrections to the macro. The PACE macro was not released until the manual calculations identically matched the PACE results.

At the outset, PACE was originally designed for non-PWD sites and constant ullage since it was assumed that there were no emissions occurring during dispensing operations (Equation III-2). However, when CARB staff became aware of PWD in November 2012, PWD emissions needed to be calculated. Due to the lack of resources and CARB changing Excel to later versions, the PACE macro was not updated to include PWD emissions but these emissions were calculated manually in Microsoft Excel using Equations III-1, III-2, III-3, III-4, and III-5 after each PACE run was completed.

III. RESULTS

CARB staff designed PACE to handle the most data without crashing. Through testing, CARB staff determined that using an entire week of data would provide the most optimal results without comprising the Microsoft Excel macro. CARB staff used the values listed in Figure III-3 to run PACE for the summer fuel period and changed the %HC to 49.4 and the Efficiency Loss Factor (Uncontrolled Emission Factor) to 9.5 to run PACE for the winter fuel period. CARB staff ran PACE using seven days of data starting on Sunday morning at 12:00 am and ending Saturday night at 11:59 pm. PACE was run for each non-PWD and PWD GDF shown in Table III-1 and III-2 for all data that was available. If the DAQ/Incon data files and/or data logger data files were missing, then PACE was not run for those days/weeks. If there was less than four days of data for an entire week then PACE was also not run for that week. Table IV-1 shows (in green) the dates for which PACE was run for each GDF in the OP study.

Table IV-1
Dates for PACE Runs

Site Name	Winter 2009/2010	Summer 2010	Winter 2010/2011	Summer 2011	Winter 2011/2012	Summer 2012	Winter 2012/2013	Summer 2013	Winter 2013/2014	Summer 2014	Winter 2014/2015	Summer 2015	Winter 2015/2016	Summer 2016
Site A	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩						
Site B	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩						
Site C	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩			🟩	🟩		
Site D	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩						
Site E									🟩	🟩	🟩			
Site F									🟩			🟩	🟩	
Site G											🟩	🟩	🟩	
Site H											🟩	🟩	🟩	

In analyzing all the weekly/monthly mass emissions and emission factor data, CARB staff concluded that the winter period was November through February and the summer period was March through October. The mass and emission factors during March were in much closer agreement to the summer fuel period (April – October) than the winter fuel period (November – February) and thus March data was included within the summer fuel period.

After all the PACE runs were completed, the total mass emissions (fugitive mass + vent line mass) were used to calculate the overall emission factor for the winter and summer period for each GDF. Table IV-2 shows the emission factor for each non-PWD and PWD GDF for the winter and summer period.

Table IV-2
Non-PWD and PWD Emission Factors

Site Name	Location	PWD Observed	Winter Pressure Driven Emission Factor (lbs/kgal)	Summer Pressure Driven Emission Factor (lbs/kgal)
Site A	Sacramento, CA	No	0.0874	0.0271
Site B	Marysville, CA	No	0.0114	0.0019
Site C	Sacramento, CA	No	0.2414	0.0173
Site D	Sacramento, CA	No	0.1047	0.0034
Site E	Pomona, CA	Yes	1.4405	0.0179
Site F	Carson, CA	Yes	2.2481	0.0069
Site G	San Diego, CA	Yes	1.3786	0.0159
Site H	San Diego, CA	Yes	0.3869	0.0077

According to the 2014 California Retail Fuel Outlet Annual Report[9] survey, 17.7% of the gasoline throughput went through sites with an annual throughput of 400 kgal/month or greater (Site A listed in Table III-1). GDFs dispensing below 50 kgal/month were not included as these GDFs are not required to install ISD. 34.2% of the GDFs with the assist system surveyed during the 2013/2014 Mega Blitz[10] were found to exhibit PWD during December 2013 (NOTE: 34.2% PWD% at 272 sites in 2013, 38.2% PWD% at 89 sites in 2014, 44.3% PWD% at 210 sites in 2015). Using these two parameters, along with the winter (Appendix III) and summer emission factors (Appendix IV) for non-PWD and PWD GDFs in the OP study, the annual average pressure driven emission factor for assist systems was calculated to be 0.189 lbs/kgal.

Table IV-3 summarizes the statewide annual average emission factor and percent efficiency for assist systems. The statewide annual average emission factor for Assist systems is defined as the sum of the pressure driven emission factor and the non-ORVR (Onboard Refueling Vapor Recovery) dispensing nozzle emission factor of 0.18 lbs/kgal that was calculated during the 2004 Healy Assist system certification[11] (Appendix V).

Table IV-3
Statewide Annual Average Emission Factor and % Efficiency For Assist Systems

Annual Avg Emission Factor (lbs/kgal)	**0.345**
% Efficiency	**95.8%**

IV. DISCUSSION OF RESULTS

Table IV-1 shows all the dates for which PACE was run. For the non-PWD sites, data collection primarily ended prior to the 2013-2014 winter fuel period. Data collection for the PWD sites commenced the following winter after the discovery of PWD. Due to time constraints and data loss, only two winter fuel periods and one summer fuel period were included in the PWD PACE runs.

Table IV-2 shows the winter and summer emission factors for each non-PWD and PWD GDF in the study. Since PWD is a severe case of overpressure that only occurs during the winter fuel period, the pressure driven emission factors at PWD GDFs were found to be approximately twelve times greater than the pressure driven emission factors at non PWD GDFs. 74% of all weeks at PWD GDFs in the study had an efficiency loss greater than 5% for the week while 6.7% of all weeks at the non-PWD GDFs in the study had an efficiency loss greater than 5% for the week. The average summer pressure driven emissions factors at PWD GDFs (0.0121 lbs/kgal) were essentially the same as at non-PWD GDFs (0.0124 lbs/kgal) since PWD is only a winter time phenomenon.

The CARB certification standard of 95% vapor recovery efficiency is calculated by including emissions at the test nozzle and pressure driven emissions from the UST vent lines, fugitive leaks, and vapor processor exhaust, if present. As stated earlier, there are no processor emissions with the Healy system since the CAS is a passive processor. The emission factors and efficiency losses shown in Table IV-3 suggest that the overall year-round performance of the Healy Assist system is not significantly degraded by the presence of PWD and overpressure conditions occurring at some GDFs in California. As found in the 2013/2014 Mega Blitz, if PWD occurs at approximately 34% of the GDFs, the Healy Assist VRS will meet CARB’s performance standards requiring a vehicle refueling emission factor of less than or equal to 0.38 lb/kgal and a vapor recovery efficiency of at least 95% when refueling non-ORVR vehicles. Assuming that the winter and summer pressure driven emission factors listed in Table IV-2 remained the same for non-PWD and PWD GDFs, then the Healy Assist system would fail to achieve a 94.5% collection efficiency if more than 60% of the GDFs exhibited PWD.

V. CONCLUSIONS AND RECOMMENDATIONS

Upon completion of the OP study and data analysis, CARB staff is able to reach the following conclusions:

1. The average summer pressure driven emission factors between non-PWD and PWD GDFs were essentially the same.
2. Since PWD is a winter fuel phenomenon, the average winter pressure driven emission factor for PWD GDFs was significantly greater than that of non-PWD GDFs.
3. Even though PWD occurs at approximately 34% of the GDFs in California, the assist system still meets CARB's performance standards requiring a vehicle refueling emission factor of less than or equal to 0.38 lb/kgal and a vapor recovery efficiency of at least 95% when refueling non-ORVR vehicles.
4. In order to reduce overpressure and associated fugitive and vent line emissions, CARB staff suggests following the recommendations listed in the Information Bulletin: Minimizing Winter Time In-Station Diagnostic System Overpressure Alarms[1].

Following the conclusion of the OP study, CARB staff has the following recommendations for additional study:

1. Staff recommends further study on the impact of the volume of vapor/air returned to the UST from the Phase II VRS due to dispensing and its overall impact on the calculation of vent line emissions (Appendix II).
2. Staff recommends that these new Healy Assist system pressure driven emission factors and the newly revised balance pressure driven emission factors[5] be used to update the document: Revised Emission Factors for Gasoline Marketing Operations at California Gasoline Dispensing Facilities[8].

VI. REFERENCES

1. California Air Resources Board, Informational Bulletin - New Recommendation to Minimize Winter time In-Station Diagnostic System Overpressure Alarms for Assist Phase II Systems, December 4, 2017. Available at https://www.arb.ca.gov/vapor/op/advisory/infobulletin_EORnozzle_120417.pdf
2. California Air Resources Board, Certification Procedure for Vapor Recovery Systems at Gasoline Dispensing Facilities, CP-201, April 23, 2015. Available at https://www.arb.ca.gov/testmeth/vol2/CP201_april2016.pdf
3. California Air Resources Board, Technical Support Document, Gasoline Sampling and Analysis to Investigate the Effect of Reid Vapor Pressure on Vapor Recovery Systems Overpressure (Report No. VR-OP-G1), December 1, 2017. Available at https://www.arb.ca.gov/vapor/op/studies/gdf/vropg1.pdf
4. ASTM International, D4814 - 16b Standard Specification for Automotive Spark-Ignition Engine Fuel, 2016. Available at *https://www.astm.org/Standards/D4814.htm*
5. California Air Resources Board, Technical Support Document, Performance of Balance Type Phase II Vapor Recovery Systems Operating at Slightly Positive Underground Storage Tank Ullage Pressure (VR-OP-B1), December 6, 2017.
6. California Energy Commission, 2008 California Retail Fuel Outlet Annual Report, 2008.
7. California Air Resources Board, Pressure Related Fugitive Emissions, TP-201.2F, October 8, 2003. Available at https://www.arb.ca.gov/testmeth/vol2/tp201.2f_Oct2003.pdf
8. California Air Resources Board, Revised Emission Factors for Gasoline Marketing Operations at California Gasoline Dispensing Facilities, December 23, 2013. Available at https://www.arb.ca.gov/vapor/gdf-emisfactor/attachment_1%20-%2020%20nov%202013.pdf
9. California Energy Commission,2014 California Retail Fuel Outlet Annual Report, 2014.
10. California Air Resources Board, Technical Support Document, DRAFT 2013/2014 Field Study to Determine the Extent of the Overpressure Issue Occurring at California Gasoline Dispensing Facilities (Report No. VR-OP-G2), December 6, 2017.
11. California Air Resources Board, Vapor Recovery Efficiency and Emission Factor for the Healy 900/VP1000 (EVR) Phase II Vapor Recovery System Equipped with Vacuum Assist Nozzle and Vapor Bladder Tank, December 15, 2004.

VII. APPENDICES

APPENDIX I	**Phase II EVR System District Survey**
APPENDIX II	**Calculation of the Vent Line Emission Volume from Material Balance In the UST Ullage Space**
APPENDIX III	**Calculation of the Winter Pressure Driven Emission Factor for Assist Systems**
APPENDIX IV	**Calculation of the Summer Pressure Driven Emission Factor for Assist Systems**
APPENDIX V	**Calculation of the Statewide Annual Average Emission Factor for Assist Systems**

Appendices will be available upon request