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DRAFT

Overpressure Study
Technical Support Document

Use of ISD Data to Calculate Parameters for Balance System Pressure Driven Emission Estimates

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Executive Summary

California Air Resources Board (CARB) staff has completed multiple field studies to assess how positive pressure in the headspace (ullage) of underground storage tanks (USTs) at gasoline dispensing facilities (GDF) affects the performance of balance Phase II vapor recovery systems (balance VRS) and associated pressure driven emissions (PDE). This report describes how CARB staff evaluated in-station diagnostic (ISD) system monitoring data downloaded from study sites to determine appropriate values for two key parameters needed to develop reasonably conservative estimates of statewide average PDE from GDFs with balance VRS:

- Percentage of GDF gasoline throughput that is dispensed while the system is at positive pressure, typically referred to as "percent volume dispensed at positive pressure (VDAPP)" or VDAPP; and
- Volume of gasoline vapor that is vented from idle (no fuel dispensing) nozzles when the nozzle is left out of the dispenser with the vapor check valve held open, typically referred to as "reverse idle flow emissions" or RIFE. This situation normally occurs when an idle nozzles is latched into a vehicle fill pipe before or after a fueling event.

CARB staff will use the results of these studies to assess the potential impact of overpressure emissions on air quality and public health, and to determine the cost effectiveness of proposed regulations. The results will also be used to update statewide and regional estimates of emissions from GDFs.

Between 2013 and 2018, CARB staff conducted two types of monitoring that produced extensive VDAPP compilations: five short-term "Mega Blitz" (Blitz) statewide monitoring events at more than a 100 GDFs with balance VRS, and long-term monitoring at 26 GDFs with balance VRS. Information needed to calculate RIFE could not be collected during the Blitz events due to limitations of ISD, but was collected at the long-term study sites.

Qualitative and statistical analyses of the VDAPP and RIFE values generated from the different studies indicate the following values based on the 2017-18 long-term study sites' monitoring results are representative of average statewide conditions and will enable reasonably conservative estimates of PDE from GDFs with balance VRS:

	VDAPP	RIFE
Winter:	8.89%	0.059 lb/kgal[1]
Summer:	2.35%	0.041 lb/kgal

[1] lb/kgal = pounds per thousand gallons of gasoline dispensed

I. Introduction and Background

CARB staff's Overpressure Study Technical Support Document Report Number VR-OP-B1 (CARB, 2017(a)) presented an assessment of pressure driven emissions from balance vapor recovery systems. Positive pressure in the UST was shown to reduce the vapor collection efficiency at the nozzle and increase vehicle-refueling emissions. CARB staff conducted emission testing under typical baseline conditions when the UST ullage was at a slight vacuum between zero and negative 1.5 inches water column gauge ("WCG). CARB staff also conducted testing 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. Data characterizing the vapor return line pressure ("WCG) during fueling events for phase of testing are as follows:

System Tested	Minimum	Average	Maximum
EMCO Baseline	- 0.82	- 0.37	+ 0.01
VST Baseline	- 1.45	- 0.67	- 0.01
EMCO Pressure	+ 0.07	+ 0.18	+ 0.29
VST Pressure	+ 0.07	+ 0.16	+ 0.28

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 with the UST ullage pressure slightly positive when compared to typical operating conditions with the UST ullage pressure slightly negative. During the baseline test (conducted to demonstrate typical operating conditions with a slight vacuum in the UST) the test results indicate 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 certification performance standard for emission factor ($\leq$ 0.38 lb/kgal) or Phase II vapor recovery system efficiency ($\geq$ 95%) while dispensing gasoline to non-ORVR vehicles while the ullage is at slight positive pressure. The results of our analysis show these conditions exist during fueling events that account for only a small fraction of the total volume dispensed.

CARB staff estimated balance system emissions to assess the potential impact of overpressure emissions on air quality and public health. Emission estimates are also necessary to determine the cost effectiveness of any proposed regulations intended to control overpressure emissions. To calculate pressure driven emissions for GDFs with balance Phase II vapor recovery systems (balance VRS), CARB developed calculation methods based on ISD data collected from operating retail GDFs. This report presents the data and methods used to estimate two key parameters used in emission calculations for GDFs with balance VRS:

1. Volume Dispensed at Positive Pressure (VDAPP): The VDAPP parameter provides the fraction of the total volume gasoline dispensed while the system is at slight positive pressure. This parameter is needed to determine vehicle-refueling emissions. One emission factor is applied to the volume that is dispensed while the UST at slight positive pressure and a second (lower) emission factor that is applied to the volume dispensed while the UST is at vacuum.

2. Reverse Idle Flow Emissions (RIFE): The design of the balance VRS allows flow into or out of the nozzle vapor path when the nozzle bellows is compressed and the vapor check valve is open. After the completion of a fueling event, vapors can escape from an idle nozzle that is latched into a vehicle unless the nozzle and fill pipe are perfectly sealed from the atmosphere. An imperfect seal is common and can occur when the nozzle is not properly latched into the fill pipe or with ORVR fill pipe designs that include open paths to the atmosphere. RIFE quantifies emissions from open nozzle check valves that can occur during idle periods when the nozzle is out of the dispenser hanger and the vapor check valve is open, but there is no flow of gasoline through the nozzle.

During the dispensing operations, UST ullage pressures at GDFs with balance VRS are negative most of the time. This is the natural tendency, if the volume of gasoline dispensed is greater than the volume of vapor and air returned to the UST. However, the fueling of ORVR vehicles returns unsaturated air to the UST, which causes gasoline evaporation in the storage tank. If the dispensing rate does not create adequate space to accommodate the volume of gasoline vapor created by evaporation the system will tend toward positive pressure.

ISD pressure data show that a slight positive pressure can exist in the balance system for significant periods of time. The average positive pressure is typically less than 0.5 "WCG. Data collected from balance study sites shows that during the winter fuel season the average percentage of time at positive pressure was 28% based on 193 weeks of data collected at 15 GDFs. During the summer fuel season, these same 15 study sites showed and average percentage of time at positive pressure was 16% based on 208 weeks of data. The data supporting these findings is too extensive to include in this report; a Microsoft Excel file with the data is available upon request.

II. Data Collection

To determine the VDAPP and RIFE parameters, CARB staff collected data during field studies conducted at operational retail GDFs between October 2013 and September 2018. The GDFs monitored for this analysis were equipped with a balance Phase II vapor recovery system and were located in multiple Air Districts across California.

A. Data Collection Sites and Methodology

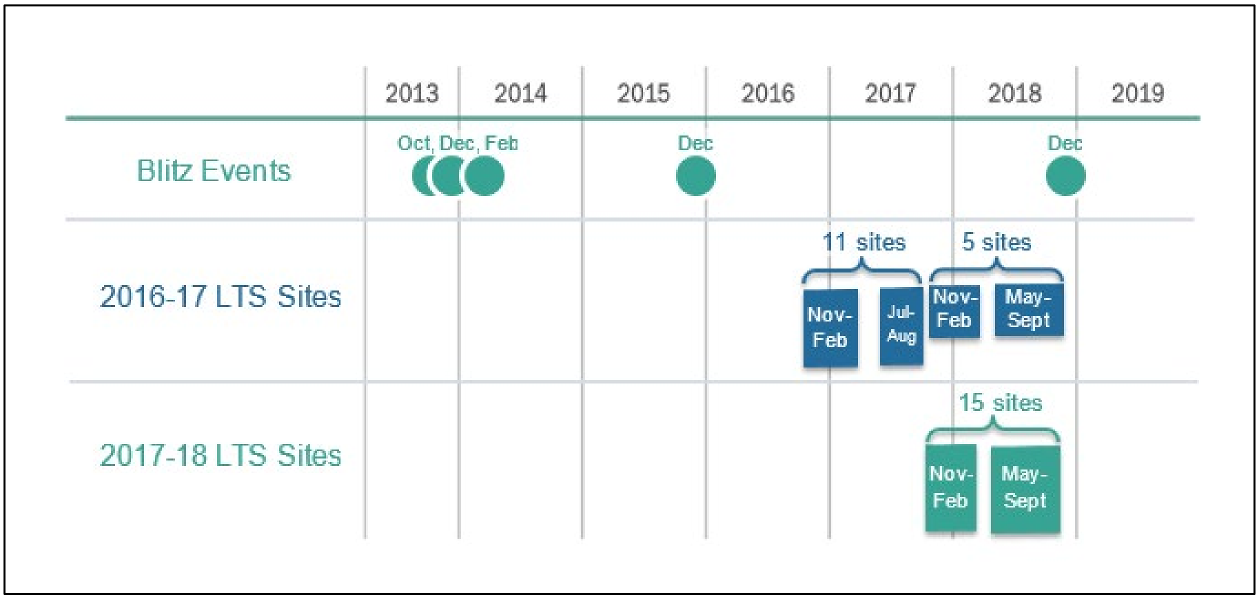
The field studies included two different types of data collection. First, there were short-term data collection efforts lasting approximately two weeks. These data collection projects have been referred to as “Mega Blitz” monitoring events in past CARB reports, presentations and workshops and are described in detail in another CARB Technical Support Document (CARB, 2017(b)). The Blitz monitoring events occurred in October 2013, December 2013, February 2014, December 2015 and December 2018. The data from the Blitz events was used to calculate the VDAPP parameter for between 77 and 108 individual sites in each Blitz. To collect the data CARB and Air District staff visited the sites over a period of approximately two weeks. Staff was onsite at each location for approximately one hour to connect a laptop computer to the ISD console and download the available data.

The pressure data stored on the ISD console is limited to a 30-hour window preceding the download. Consequently, the data collected during a Blitz monitoring event can only provide a short-term (one day) snap shot of the site VDAPP parameter. Analysis using short-term data is further limited by a six-hour window for the vapor flow meter totalizer data stored on the ISD console. This data is required for the RIFE calculation and six hours is not sufficient to produce a representative result. At least a 24-hour window is necessary to capture the full variation in dispensing activity and system pressures that normally occur throughout the operating day. Due to this limitation, CARB staff did not collect the vapor meter data contained in the six-hour report during the Blitz monitoring events.

CARB staff designed and implemented a second method of data collection to overcome the issues associated with the limited data stored on the ISD console. CARB staff applied this method to a limited number of long-term study sites. At each study site, a data acquisition system, using a computer with a windows operating system, was connected to the RS-232 output card of the ISD System and left in place for the course of the study. Software on the computer was programmed to send commands to the ISD system to initiate downloads of various ISD data reports at scheduled intervals. In this manner, it was possible to capture all data generated by the ISD system and extend the analysis to include seven-day periods covering multiple weeks of the winter and summer fuel seasons.

Prior to initiating ISD data collection at each long-term study site, Phase II vapor recovery system performance testing (including ISD operability) was conducted to verify compliance with applicable performance standards or specifications. Because the calculation of VDAPP and RIFE rely on data generated by the ISD systems pressure transducer and vapor return meters, the precision of these monitors was established. If performance testing revealed vapor recovery equipment failures, these issues were addressed prior to the start of data collection to ensure the accuracy and representativeness of the data. Test results for performance testing conducted at the beginning and ending for the data collection periods are too extensive to include in this report; Microsoft Excel files with the spreadsheets are available upon request.
A chronology of the data monitoring periods for Blitz events and long-term study sites is shown **in Figure II-1**.

Figure II-1: Chronology of Blitz and Long-term Study (LTS) Monitoring Data



B. ISD Reports Collected for VDAPP & RIFE Analysis

Three ISD reports are necessary to determine the RIFE and VDAPP parameters. The first report contains data on fueling transactions and provides the following parameters: the fueling transaction start time and date, the volume of fuel dispensed, the duration of the fueling transaction, and the volume of vapor flowing through the meter during the transaction. A positive vapor flow is recorded when the net flow is from the nozzle into the VRS and a negative vapor flow is recorded when the net flow is from the VRS and out of the nozzle. Data from the 1,000 most recent fueling transactions are available in a report for each dispenser at the GDF. An example of a portion of this report appears in **Figure II-2**.

The second report contains 30 hours of date and time stamped pressure data with three data points recorded each minute at approximately twenty-second intervals. It also includes data showing the combined ullage of the storage tanks, which is not used in the VDAPP or RIFE analysis. An example of a portion of this report appears in **Figure II-2**.

The third report contains six hours of date and time stamped readings from the vapor return meter volume totalizers. These reports also contain three data points recorded each minute at approximately twenty-second intervals. By comparing consecutive totalizer readings, the volume and direction of flow can be determined for each sampling interval. An example of a portion of this report appears in **Figure II-3**.

By selecting an appropriate download schedule for each report it is possible to collect all data generated by the ISD system before it is overwritten by new data. CARB staff visited the study sites at two- to three-week intervals to collect the data and ensure the data acquisition system was functioning properly. The study did not obtain 100% data capture due to uncontrollable events including power failures, disconnection of RS-232 cable by GDF personnel or service contractors, and failure of computer components.

Figure II-2: ISD Data Reports Utilized in VDAPP Calculations

- I&1800 Report – Veeder-Root report that records the last 1000 transactions for each VFM

INDEX	START DA	TE-TIME	DUR	A/L	VAPOR	FUEL	#EV	FLAGS	FPS	HOSES
757	7/29/2016	6:03:58	258	0.31	4	12.8	1	003E	2	1
758	7/29/2016	6:20:46	105	0.68	2.1	3	1	002E	2	1
759	7/29/2016	6:30:36	90	1.48	12.7	8.6	1	002E	2	1
760	7/29/2016	6:41:00	133	-0.13	-1.8	13.8	1	003E	2	1
761	7/29/2016	6:48:21	63	0.07	0.4	6.1	1	003E	2	1

- I&1400 Report – Veeder-Root report that records the last 30 hours of pressure-ullage data every 20 seconds

INDEX	DATE-TIME	PRESSURE	ULLAGE	FLAGS
889	16-07-29 00:01:00	-0.356	9622.5	0
890	16-07-29 00:01:20	-0.343	9622.9	0
891	16-07-29 00:01:40	-0.333	9622.9	0
892	16-07-29 00:02:00	-0.32	9622.8	0
893	16-07-29 00:02:20	-0.313	9622.7	0

Figure II-3: ISD Data Reports Utilized in RIFE Calculations

- I&1800 Report – Veeder-Root report that records the last 1000 transactions for each VFM

INDEX	START DA	TE-TIME	DUR	A/L	VAPOR	FUEL	#EV	FLAGS	FPS	HOSES
757	7/29/2016	6:03:58	258	0.31	4	12.8	1	003E	2	1
758	7/29/2016	6:20:46	105	0.68	2.1	3	1	002E	2	1
759	7/29/2016	6:30:36	90	1.48	12.7	8.6	1	002E	2	1
760	7/29/2016	6:41:00	133	-0.13	-1.8	13.8	1	003E	2	1
761	7/29/2016	6:48:21	63	0.07	0.4	6.1	1	003E	2	1

- I&1200 Report – Veeder-Root report that records the last 6 hours of VFM readings every 20 seconds

Index	Date	Time	Volume
672	7/29/2016	6:04:00	880554.768
673	7/29/2016	6:04:20	880554.520
674	7/29/2016	6:04:40	880554.414
675	7/29/2016	6:05:00	880554.804
676	7/29/2016	6:05:20	880555.441

III. Data Analysis

The data is downloaded from the ISD systems in the form of text files. CARB staff developed Microsoft Excel macros to import this data into spreadsheets and perform the necessary calculations. The time stamps on the data in each report make it possible to align the data from the different reports to yield the desired results.

A. Calculation of Volume Dispensed at Positive Pressure (VDAPP)

The liquid volumes are imported into the spreadsheet for each fueling event that occur during the time period for which pressure data are available Fueling event data is matched with pressure data using the date and time stamps available in the reports. The spreadsheet sums the liquid volumes for all transactions in the analysis period to determine the total volume dispensed. The spreadsheet also calculates the sum of the liquid volumes for all transactions for which a positive UST pressure is logged concurrently with the fueling event start time. These results are used to calculate the percentage of the gasoline volume that is dispensed while the system is at positive pressure. The spreadsheet also calculates two other results that assist in characterizing GDF operations: the percentage of time that the system was at positive pressure during the analysis period and an estimate of the GDF monthly throughput extrapolated from the total volume dispensed during the analysis period. For long-term study sites, individual results were determined for each week, beginning Sunday at 0000 hours and ending Saturday at 2359 hours. In weeks with missing data, the VDAPP result was still calculated and included in the analysis as long as at least 3.5 days of data were available. For Blitz sites, the analysis period is only 30 hours.

The following assumptions are inherent in the VDAPP calculation:

- The ISD vapor pressure sensor is operating with accuracy and precision, well beyond tolerances allowed per annual operability test of plus or minus 0.20 inches water column.
- When evaluating Blitz data, the most recent 30 hours of available ISD data is representative of site operating conditions.
- An observed variation in UST pressure of at least 0.5 inches water column indicates that the system has sufficient pressure integrity to distinguish between positive and negative gauge pressure. Systems found to be operating with a “flat line” pressure profile are not used in the analysis.
- The ISD vapor flow meter is reading accurately, well beyond the specification of plus or minus 15%, which is required by the ISD operability test procedure.

B. Calculation of Reverse Idle Flow emission Factor (RIFE)

The data from the fueling transaction report is used to identify all transactions where the vapor flow meter (VFM) produced a negative vapor volume for the transaction (vapor from the UST flowed out of nozzle) The total negative volume for all transactions in the week being analyzed is calculated. The fuel volumes reported for each transaction are also summed to produce the total gasoline volume dispensed in the week being analyzed.

The data from the VFM readings report is used to calculate change in volume between each successive VFM readings. All negative volume changes calculated are summed to produce the total negative volume for the week to be analyzed.

The Reverse Idle Flow Volume is calculated as the absolute value of the difference between total negative flow volume for the week analyzed and the negative volume that occurred during fueling transactions during the week analyzed. This difference is the negative flow that occurred during idle nozzle periods. This volume is multiplied by an assumed value for saturated vapors to produce the mass emissions associated with reverse idle flow. The mass of reverse idle flow emissions is divided by the total throughput for the analysis period to calculate an emission factor in units of lb/kgal. Individual results for the long-term study sites were determined for each week, beginning Sunday at 0000 hours and ending Saturday at 2359 hours. In weeks with missing data, the RIFE result was still calculated and included in the analysis as long as at least 3.5 days of data were available. RIFE was not calculated for Blitz study sites because meter totalizer data is not available.

The following assumptions are inherent in the RIFE calculation:

- Any emissions associated with reverse flow during fueling events are included in vehicle refueling emission factors determined from emission test results using CARB Test Procedure TP-201.2.
- If any vapor can slip by the VFM during idle periods without registering a change in the totalizer reading, the volume is not large enough to produce an unacceptable low bias in the RIFE result.
- The vapor concentration associated with reverse idle flow emissions is the same as the uncontrolled emission factors for vehicle refueling: 9.5 lb/kgal with winter fuel and 7.65 lb/kgal with summer fuel (CARB, 2013).
- The entire volume of vapors that pass through the meter in the reverse direction during idle periods enters the atmosphere.

IV. Results from Short-Term Data Collected at Blitz Sites

The VDAPP parameter was calculated for each Blitz site for which the required pressure and fueling transaction data was available. VDAPP was calculated for Blitz site data collected in October 2013, December 2013, February 2014, December 2015 and December 2018. Table IV-1 provides a summary of the VDAPP results from each of the five Blitz monitoring events. Table IV-1 provides the dates of data collection, the number of Blitz sites for which a VDAPP value was determined, the range in monthly gasoline throughputs determined by the VDAPP analysis and the average value of VDAPP determined for each data set. The table also includes the average VDAPP for the 66 sites common to all December Blitz events (2013, 2015, and 2018). Spreadsheets of the individual Blitz site VDAPP results are too large to include in this report; a Microsoft Excel file with the spreadsheets is available upon request.

Table IV-1: Summary of Blitz Short-Term Study Site Average VDAPP Results

Time Period	Date Range	Number of VDAPP Results	Range in GDF Dispensing Rate (kgal/month)^	Average VDAPP All Sites	Average VDAPP for 66 Sites present in all December Blitz Events
October 2013	09/30/13 – 10/24/13	91	34 -390	2.26%	N/A
December 2013	12/03/13 – 12/17/13	108	34 - 426	6.87%	7.81%
February 2014	01/30/14 – 03/11/14	82	29 - 367	6.04%	N/A
December 2015	12/07/15 – 12/17/15	91	29 - 509	9.37%	9.45%
December 2018	12/04/18 – 12/20/18	77	42 -566	8.56%	8.48%

^ The dispensing rates (throughputs) are extrapolated from 30 hours of data and represent the average fuel-dispensing rate for 30-hours of data downloaded from each GDF ISD system.

V. Results from Long-Term Study Sites

CARB staff established and monitored two sets of long-term study sites between November 2016 and September 2018. The first set of study sites included 11 GDFs that were monitored between November 2016 and August 2017. Between November 2017 and September 2018, a second set of 15 new sites was added to the monitoring project. Monitoring also continued on five of the study sites from the previous year. The second set of study sites was established because a comparison of the VDAPP results from the 2013 and 2015 Blitz sites with the results from the first set of long-term study sites indicated that the study site data was not representative of statewide averages and would underestimate emissions. These comparisons are discussed in the next section of the report.

In selecting the second set of study sites, an effort was made to select sites that were likely to exhibit moderate to high values for VDAPP. The goal was to collect data that would either supplement or replace the data collected in the first year to produce an estimate of the statewide average VDAPP that would be more representative and not underestimate emissions. Blitz data was reviewed to identify GDFs that had exhibited a VDAPP value greater than 10% in at least one of the December 2013 or December 2015 Blitz monitoring events and these sites were targeted for inclusion in the second set of study sites.

Table V-1 provides characteristics of all 26 long-term study sites. There is information about site location, monthly throughput, nozzle and vapor processor equipment and the period each site was monitored. **Table V-2** provides seasonal VDAPP and RIFE results for the first set of study sites monitored in 2016-2017. **Table V-3** shows seasonal VDAPP and RIFE results for the second set of study sites monitored in 2017-2018. In each table the site is identified and the number of weekly data points generated for VDAPP and RIFE are shown along with the average value of the parameters at each site.

Five long-term study sites were monitored in both 2016-2017 and 2017-2018. Monitoring of these sites was continued for a second year to provide information about the variability of long-term study site results for RIFE and VDAPP. **Table V-4** provides the seasonal VDAPP and RIFE results for each site for both years. The table also provides the number of individual weekly results included in the seasonal average for each site. For site 22, a direct comparison of results is not possible because the brand of the nozzle was changed after the first year of monitoring.

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Table V-1: Characteristics of Long-Term Study Sites

Site Code	City	Air District	TP (kgal/mo) 2016-2017	TP (kgal/mo) 2017-2018	Nozzle	Vapor Processor	Includes 2016-2017	Includes 2017-2018
1	Richmond	BAAQMD		190	VST	Canister		X
2	Berkeley	BAAQMD		105	VST	Canister		X
3	Emeryville	BAAQMD		152	VST	Canister		X
4	San Jose	BAAQMD	441		VST	CAS	X	
5	El Sobrante	BAAQMD		139	VST	Canister		X
6	Anaheim	SCAQMD		52	VST	Canister		X
7	Stanton	SCAQMD		103	VST	CAS		X
8	Chino	SCAQMD		136	VST	Canister		X
9	Yorba Linda	SCAQMD		157	VST	Canister		X
10	Ontario	SCAQMD		187	VST	Canister		X
11	Yorba Linda	SCAQMD		99	VST	Canister		X
12	Pomona	SCAQMD	94	106	VST	CAS	X	X
13	Torrance	SCAQMD	101	104	VST	CAS	X	X
14	Bonsall	SDCAPCD	381		EMCO	CAS	X	
15	San Diego	SDCAPCD		60	EMCO	Canister		X
16	San Diego	SDCAPCD		88	VST	CAS		X
17	San Diego	SDCAPCD		100	Mixed	Canister		X
18	San Diego	SDCAPCD	99	99	VST	CAS	X	X
19	San Diego	SDCAPCD	135		VST	CAS	X	
20	Ocean Beach	SDCAPCD	170	171	VST	CAS	X	X
21	Stockton	SJVUAPCD	188		Mixed	HIRT	X	
22	Stockton	SJVUAPCD	158	163	Varied	CAS	X	X
23	Sacramento	SMAQMD		153	EMCO	Canister		X
24	Folsom	SMAQMD	327		VST	Canister	X	
25	Sacramento	SMAQMD	135		VST	CAS	X	
26	Elk Grove	SMAQMD		49	VST	Canister		X

Table V-2: Summary of VDAPP and RIFE Results for 2016-2017 Long-Term Study Sites

Site Code^	Air District	# Weeks Analyzed VDAPP / RIFE		Mean %VDAPP		Mean RIFE Emission Factor (lb/kgal)	
		Winter^^	Summer^^	Winter	Summer	Winter	Summer
4	BAAQMD	12 / 10	4 / 4	4.36%	1.28%	0.039	0.020
12	SCAQMD	15 / 15	4 / 4	2.10%	0.72%	0.041	0.046
13	SCAQMD	14 / 14	4 / 4	1.84%	0.54%	0.042	0.031
14	SDCAPCD	15 / 11	4 / 4	4.97%	2.05%	0.090	0.067
18	SDCAPCD	10 / 10	4 / 4	2.63%	0.44%	0.030	0.025
19	SDCAPCD	15 / 15	4 / 4	2.43%	0.55%	0.041	0.034
20	SDCAPCD	14 / 14	4 / 4	2.12%	0.20%	0.051	0.032
21	SJVUAPCD	7 / 7	3 / 4	0.44%	0.21%	0.082	0.069
22	SJVUAPCD	11 / 11	4 / 4	1.95%	0.58%	0.043	0.044
24	SMAQMD	10 / 10	4 / 4	4.64%	2.46%	0.032	0.357
25	SMAQMD	14 / 14	4 / 4	2.04%	2.13%	0.032	0.030

^ Sites 12, 13, 18, 20 and 22 also were monitored in 2017-2018 (see Table V-4).

^^ Winter includes November through February and summer includes March through October.

Table V-3: Summary of VDAPP and RIFE Results for 2017-2018 Long-Term Study Sites

Site Code	Air District	# Weeks Analyzed VDAPP / RIFE		Mean %VDAPP		Mean RIFE Emission Factor (lb/kgal)	
		Winter	Summer	Winter	Summer	Winter	Summer
1	BAAQMD	13 / 13	15 / 15	2.79%	0.47%	0.061	0.038
2	BAAQMD	15 / 15	16 / 16	7.06%	1.32%	0.037	0.021
3	BAAQMD	13 / 13	17 / 17	11.76%	3.59%	0.046	0.032
5	BAAQMD	12 / 12	17 / 17	6.95%	2.31%	0.059	0.040
6	SCAQMD	15 / 15	14 / 14	10.43%	3.31%	0.053	0.031
7	SCAQMD	11 / 11	6 / 6	13.67%	3.82%	0.043	0.033
8	SCAQMD	12 / 12	16 / 15	9.51%	2.62%	0.040	0.051
9	SCAQMD	13 / 13	8 / 8	12.45%	3.90%	0.073	0.026
10	SCAQMD	15 / 15	11 / 11	10.12%	1.94%	0.062	0.041
11	SCAQMD	15 / 15	13 / 13	9.56%	1.99%	0.053	0.037
15	SDCAPCD	12 / 10	12 / 12	7.90%	0.93%	0.062	0.050
16	SDCAPCD	13 / 12	13 / 13	5.66%	2.35%	0.043	0.033
17	SDCAPCD	13 / 13	13 / 13	7.51%	2.33%	0.059	0.052
23	SMAQMD	10 / 10	18 / 18	6.86%	3.30%	0.154	0.108
26	SMAQMD	11 / 11	19 / 19	18.30%	2.70%	0.067	0.046

Table V-4: Two-Year Comparison of VDAPP and RIFE Results for Long-Term Study Sites Monitored in 2016-2017 and 2017-2018

Site Code	Mean %VDAPP (# of weeks analyzed)				Mean RIFE Emission Factor (lb/kgal) (# of weeks analyzed)			
	Winter		Summer		Winter		Summer	
	2016	2017	2017	2018	2016	2017	2017	2018
12	2.10% (15)	2.53% (15)	0.72% (4)	0.96% (16)	0.041 (15)	0.053 (15)	0.046 (4)	0.060 (16)
13	1.84% (14)	1.86% (13)	0.54% (4)	0.35% (9)	0.042 (14)	0.031 (13)	0.031 (4)	0.034 (9)
18	2.63% (10)	2.11% (15)	0.44% (4)	0.77% (13)	0.030 (10)	0.028 (14)	0.025 (4)	0.028 (13)
20	2.12% (14)	1.35% (16)	0.20% (4)	0.26% (13)	0.051 (14)	0.044 (16)	0.032 (4)	0.029 (13)
22^	1.95% (11)	2.23% (14)	0.58% (4)	0.43% (9)	0.043 (11)	0.109 (14)	0.044 (4)	0.078 (9)

^ Site 22 was equipped with VST nozzles in 2016-2017 and EMCO nozzles in 2017-2018.

VI. Comparisons of VDAPP Results from Long-Term Study Sites and Short-Term Blitz Sites

CARB staff performed qualitative and statistical comparisons of the various data sets to evaluate seasonal and inter-annual variability and to determine VDAPP and RIFE values appropriate for use in developing reasonably conservative regional and statewide estimates of pressure driven emissions from GDFs with balance Phase II vapor recovery systems. Only VDAPP results are available from both short-term and long-term study sites. (RIFE results are available only for long-term study sites.) CARB staff first completed a qualitative comparison of December daily VDAPPs because both Blitz and long-term study data sets include daily data collected in the first half of December and together provide data for the years 2013, 2015, 2016, 2017 and 2018.

Table VI-1 describes the December data sets and reports the average December VDAPP for each short-term and long-term study data set. Histograms were prepared for each December data set showing the percentage of data points that fell into different ranges of VDAPP for each data set. These histograms are shown in **Figure VI-1**. The results illustrated in **Table VI-1** and **Figure VI-1** indicate the 2016-2017 long-term study sites have a December VDAPP distribution that is much lower than the December VDAPP distributions of the 2017-2018 long-term study sites and short-term Blitz sites.

Because of the results of this qualitative comparison, CARB staff conducted a statistical evaluation of VDAPP and RIFE using the short- and long-term data sets that are available (**Appendix 1**). The statistical evaluation found that the 2016-17 long-term study sites have statistically significantly lower October, December, and February daily VDAPPs than the October (2013), December (2013, 2015, 2018), and February (2014) Blitz sites, respectively. Therefore, the 2016-2017 long-term study sites are not representative of regional and statewide conditions. Furthermore, use of 2016-17 long-term study site VDAPP data would lead to regional and statewide pressure driven emission estimates that are substantially under-estimated.

In contrast, the 2017-2018 long-term study sites have October, December, and February daily VDAPPs that are not statistically different from the October (2013), December (2015), and February (2014) Blitzes' VDAPPs, respectively. These comparisons indicate the distribution and average of 2017-18 long-term study sites' VDAPPs are comparable to Blitz VDAPPs and therefore are representative of statewide conditions. In addition, December VDAPPs from the 2017-2018 long-term study sites are significantly higher than those from December 2013 Blitz and December 2018 Blitz. Therefore, use of 2017 18 long-term study sites' VDAPPs may slightly over-estimate current statewide emissions from GDFs in December (early winter season). However, CARB staff considers the potential over-estimate to be reasonably conservative because the 2017-18 long-term study sites' mean VDAPP is not statistically different from the mean VDAPP for the December 2015 Blitz.

As a result, CARB staff recommends using mean values based only on the VDAPP and RIFE data collected at the fifteen 2017-18 long-term study sites to develop reasonably conservative estimates of regional and statewide pressure driven emissions. In summary, CARB staff recommends using:

- Natural log transformed VDAPPs and RIFEs because VDAPP and RIFE are not normally distributed, and use of transformed VDAPP and RIFE results in means that are less influenced by outliers and allows for statistical comparisons between data sets; and
- Means of site-specific VDAPP and RIFE means because the evaluation described in Appendix 1 found that 2017-18 long-term study sites with more data might generate means with a low bias.

The above methodology results in the following mean VDAPP and RIFE values:

	VDAPP	RIFE	Data Period
Winter:	8.89%	0.059 lb/kgal	November 2017-February 2018
Summer:	2.35%	0.041 lb/kgal	April-September 2018

The statistical evaluation described in Appendix 1 also has the following findings about statewide seasonal and inter-annual variability:

- Winter VDAPPs are significantly higher than summer VDAPPs. Therefore, seasonal, not annual, values should be used to estimate statewide emissions.
- Winter season VDAPPs peak in December.
- The mean and distribution of VDAPPs for all sites monitored during the December 2015 Blitz event are significantly higher than those of the December 2013 and 2018 Blitz events; however, they are comparable to those of the 2017-18 long-term study sites. In addition, the VDAPP means and distributions for the 66 sites common to the three December Blitz events (2013, 2015, and 2018) are not significantly different from each other. These longitudinal findings indicate statewide average annual VDAPPs have not significantly changed between 2013 and 2018.
- The mean and distribution of VDAPPs for all sites monitored in the December 2015 Blitz are significantly higher than those in the December 2013 and 2018 Blitz studies; however, they are comparable to those of the 2017-18 long-term study sites. In addition, the VDAPP means and distributions for the 66 sites common to the three December Blitz studies (2013, 2015, and 2018) are not significantly different from each other. These longitudinal findings indicate that statewide average annual VDAPPs have not significantly changed between 2013 and 2018.

Table VI-1: Comparison of December VDAPP Results for Short-Term and Long-Term Study Sites

	77 Blitz Sites Dec 4-20, 2018	**91 Blitz Sites Dec 7-17, 2015**	**108 Blitz Sites Dec 3-17, 2013**	**15 Long-term Study Sites Dec 10-16, 2017**	**10 Long-term Study Sites Dec. 11-17, 2016^**
Number of Days	77	91	108	104	68
Average VDAPP	8.56%	9.37%	6.87%	11.66%	2.85%
Percent of Data w/ VDAPP < 5%	33.8%	30.8%	46.3%	12.5%	92.6%
Percent of Data w/ VDAPP > 10%	33.8%	40.7%	24.1%	45.2%	0.0%
Minimum Throughput (kgal/ month)	> 34	> 29	> 34	> 34	> 91
Maximum Throughput (kgal/ month)	< 425.0	< 510.0	< 425	< 240	< 525

^ Site 21 was not included in this comparison because monitoring data was not available for this site in December 2016. Site 21 is equipped with the Hirt processor, which is operating at only several hundred of the approximately 10,000 GDFs operating in California.

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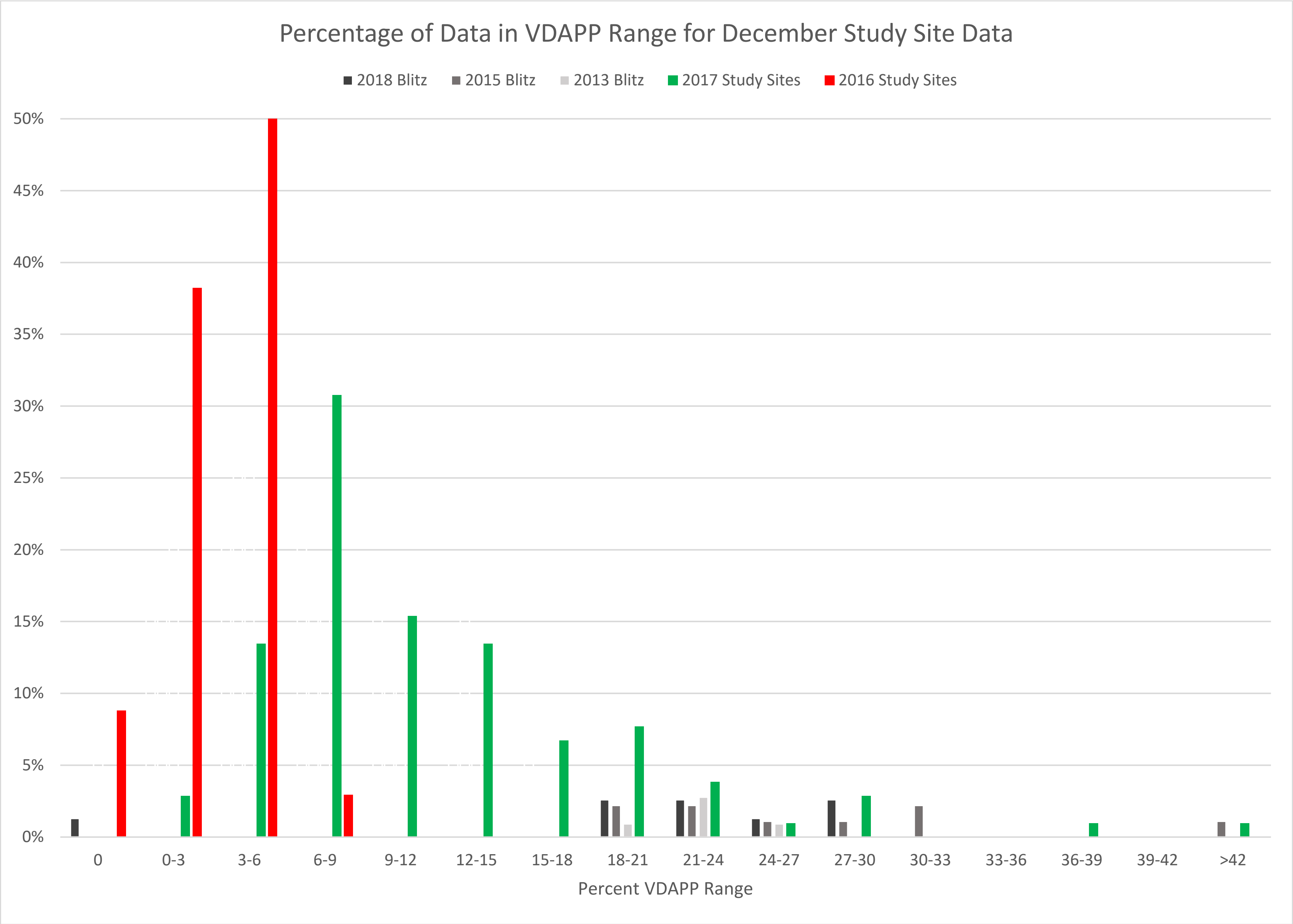
Figure VI-1: Distribution of VDAPP Results for Short-Term and Long-Term Study Sites



VII. Conclusions and Recommendations

Key findings from the qualitative and statistical analyses of VDAPP and RIFE from short- and long-term monitoring events include the following:

- The distribution and average of 2016-2017 long-term study sites' daily VDAPPs are significantly lower than those of the Blitz sites. Therefore, the 2016-2017 long-term study sites are not representative of statewide conditions.
- The distribution and average of 2017-18 long-term study sites' VDAPPs are comparable to Blitz VDAPPs and therefore are representative of statewide conditions. December VDAPPs from the 2017-2018 long-term study sites are slightly but significantly higher than those from December 2013 Blitz and December 2018 Blitz. Therefore, use of 2017-18 long-term study sites' VDAPPs may slightly over-estimate current statewide emissions from GDFs in December (early winter season). However, CARB staff considers the potential over-estimate to be reasonably conservative because the 2017-18 long-term study sites' mean VDAPP is not statistically different from the mean VDAPP for the December 2015 Blitz.
- Winter VDAPPs and RIFEs are significantly higher than summer VDAPPs and RIFEs. Therefore, seasonal values should be used to estimate statewide emissions. The means of weekly VDAPP and RIFE of the 2017-18 long-term study sites have a downward trend as winter progresses.
- Two years of data from four long-term study sites shows minor variation in VDAPP and RIFE from year to year.
- Even though the mean and distribution of VDAPPs for all sites monitored by the December 2015 Blitz event are significantly higher than those of the December 2013 and 2018 Blitz events, they are comparable to those of the 2017-18 long-term study sites. In addition, the VDAPP means and distributions for the 66 sites common to the three December Blitz events (2013, 2015, and 2018) are not significantly different from each other. These findings indicate statewide average annual VDAPPs have not significantly changed between 2013 and 2018.

Based on an assessment of all available data and the results of statistical evaluations, CARB staff recommends using the following VDAPP and RIFE values to calculate reasonably conservative seasonal and annual estimates of current regional and statewide pressure driven emissions from GDFs with balance VRS:

	%VDAPP	RIFE
Winter:	8.89%	0.059 lb/kgal
Summer:	2.35%	0.041 lb/kgal

These values are the means of long-term study 2017-18 site-specific mean weekly VDAPPs and RIFE during the winter (2017-18) and summer (2018), respectively.

VIII. References

CARB. 2013. Revised Emission Factors for Gasoline Marketing Operations at California Gasoline Dispensing Facilities. Report prepared by staff of the Monitoring and Laboratory Division, California Air Resources Board (CARB). December 23, 2013. Available at: https://ww2.arb.ca.gov/gasoline-dispensing-facility-emission-factors

CARB. 2017(a). Performance of Balance Type Phase II Vapor Recovery Systems Operating at Slightly Positive Underground Storage Tank Ullage Pressure, Report Number VR-OP-B1. Overpressure Study Technical Support Document prepared by staff of the Monitoring and Laboratory Division, California Air Resources Board (CARB). December 6, 2017. Available at: https://ww2.arb.ca.gov/resources/documents/overpressure-studies-and-technical-support-documents

CARB. 2017(b). 2013/2014 Field Study to Determine the Extent of the Overpressure Issue Occurring at California Gasoline Dispensing Facilities, Report Number VR OP-G2. Overpressure Study Technical Support Document prepared by staff of the Vapor Recovery and Fuel Transfer Branch, Monitoring and Laboratory Division, California Air Resources Board (CARB). December 7, 2017. Available at: https://www.arb.ca.gov/vapor/op/studies/gdf/vropg2.pdf

Appendix 1

Appendix 1, *Statistical Evaluation of VDAPP and RIFE at Gasoline Dispensing Facilities with Balance Phase II Enhanced Vapor Recovery Systems*, is available in a separate Adobe Acrobat file at this CARB website:

https://ww2.arb.ca.gov/resources/documents/overpressure-studies-and-technical-support-documents