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Technical Support Document

Multi Year Field Study to Determine Extent of the ISD Overpressure Alarm Issue Occurring at California Gasoline Dispensing Facilities (Mega Blitz of 2013, 2015, and 2018)

Date: December 2019

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Executive Summary

In December of 2013, 2015 and 2018, CARB staff collected In-Station Diagnostic (ISD) system alarm history data, ISD generated underground storage tank ullage pressure and ullage volume data, ISD generated individual fueling transaction data, and general operating parameter information from approximately 300 gasoline dispensing facilities (GDF) or service stations located throughout nine geographic regions in California.

The objective of this multi-year study was to determine: 1) the frequency and seasonal distribution of ISD overpressure alarms, 2) frequency and seasonal distribution of ISD leak alarms, 3) prevalence of GDF exhibiting pressure increase while dispensing (PWD), and 4) to examine the relationship between site average vapor to liquid ratios (indicative of excess air ingestion at the nozzle) and severity of overpressure conditions. Given the extensive amount of information collected each year, alarm frequency results were examined on a monthly, seasonal, and annual average basis over a seven year time frame.

Additional analysis including the relationship between GDF operating parameters and overpressure alarm frequency are discussed where applicable. Data analysis was conducted in a longitudinal manner, meaning that only information collected at the same GDF locations with the same vapor recovery system configuration for all three surveys, were included in the analysis. This means any configuration change (Assist to Balance) were not analyzed.

In terms of ISD overpressure alarm frequency, throughout the seven-year study duration, a total of 10,676 overpressure alarms occurred at 283 sites. In terms of seasonal distribution, a total of 9,204 or 86% of alarms occurred during the winter time (defined as November through February) and the remaining 1,472 or 14% of alarms occurred in the summer time (defined as April through October). March is not included because it is a transitional month and can bias the results in either direction. In terms of vapor recovery system type, 9,547 or 89% of the alarms occurred at Phase II EVR assist equipped sites and the remaining 1,129 or 11% occurred at Phase II EVR balance equipped sites. On an annual basis, assist equipped sites average 8.9 overpressure alarms per year. Balance equipped sites average 1.5 overpressure alarms per year. The data collected in 2013, 2015, and 2018 indicate that balance equipped sites consistently exhibit a lower proportion of overpressure alarms when compared to assist equipped sites.

In terms of ISD leak alarm frequency, throughout the seven-year study duration, a total of 6,711 leak alarms occurred at 283 sites. In terms of seasonal distribution, a total of 1,988 or 30% of alarms occurred during the winter time (defined as November through February) and the remaining 4,723 or 70% of alarms occurred in the summer time (defined as March through October). In terms of vapor recovery system type, 3,494 or 52% of the alarms occurred at Phase II EVR assist equipped sites and the remaining 3,217 or 48% occurred at Phase II EVR balance equipped sites. On an annual basis, assist equipped sites average 3.2 leak alarms per year. Balance equipped sites average 4.4 leak alarms per year. The data collected in 2013, 2015, and 2018 indicate that balance equipped sites consistently exhibit a higher proportion of leak alarms than assist equipped sites.

This multi-year study also confirmed the continued existence of pressure-increase-while-dispensing (PWD) at a significant percentage of GDF. Understanding the prevalence of PWD provides CARB staff with a key parameter for estimating the magnitude of statewide annualized pressure driven emissions. In 2013, 59 sites or 21% of the GDF population surveyed exhibited PWD. In 2015, 72 sites or 25% of the GDF population surveyed exhibited PWD. In 2018, 57 sites or 20% of the GDF population surveyed exhibited PWD. This suggests that prevalence of PWD has peaked in 2015 and slightly declined in 2018 to lowest level recorded. In terms of Phase II vapor recovery system type, PWD occurs exclusively at assist equipped GDF. PWD does not occur at balance equipped GDF. Lastly, the survey confirmed that PWD only occurs during the winter months, November through February at sites where the monthly gasoline throughput was less than 350,000 gallons.

In terms of vapor to liquid ratio findings, GDF that exhibit PWD continued to exhibit higher site averages when compared to non-PWD sites. In 2013 the site average vapor to liquid ratio at PWD sites was 7% higher when compared to non PWD sites. In 2015 the site average vapor to liquid ratio at PWD sites was 6% higher when compared to non PWD sites. In 2018 the same trend continued, but to a slightly less extent as the PWD site average was 4% higher when compared to non PWD sites. This finding suggests that PWD sites are more likely to experience excess air ingestion during vehicle refueling events.

All three surveys confirmed that the frequency of overpressure alarms and magnitude of pressure driven emissions vary due to site specific operating parameters and are the result of several contributing factors rather than a single variable. While winter blend gasoline with uncontrolled RVP is the underlying driver for overpressure alarms, there are a number of factors that contribute such as type of Phase II EVR system (assist versus balance);excess air ingestion at the nozzle, monthly gasoline throughput, and GDF operating hours.

In order to fully address the ISD overpressure alarm issue, CARB staff should carefully consider statewide air quality impact associated with changes to the existing ISD overpressure alarm thresholds contained in applicable certification procedures and explore the feasibility and cost effectiveness of higher capacity vapor processors. Because the frequency of alarms and severity of overpressure conditions vary based on site-specific operating parameters, a one size fits all solution will not be suitable rather, site specific factors and flexibility in implementation should be explored.

Lastly, in response to numerous findings resulting from these surveys, additional field studies (focused on a single parameter rather than multiple) were developed and conducted. A complete listing of these additional studies is available on CARB’s vapor recovery program webpage at: https://ww2.arb.ca.gov/our-work/programs/vapor-recovery-overpressure .

I. Introduction

Shortly after statewide implementation of Phase II Enhanced Vapor Recovery requirements in 2009-2010, California Air Resources Board (CARB) staff became aware of a high frequency of wintertime In-Station Diagnostic system (ISD) overpressure alarms that were not attributed to repairable vapor recovery equipment failures. This prompted the formation of a working group with the California Air Pollution Control Officers Association (CAPCOA) Vapor Recovery Subcommittee. The working group proceed with four key actions as follows:

a. Issued an ISD alarm response enforcement policy called “Advisory 405” allowing gas station operators to self-clear winter time overpressure alarms until a regulatory solution is enacted;
b. Identified and conducted a series of investigative field studies to determine ISD alarm frequency and magnitude of pressure driven emissions;
c. Reviewed and analyzed the results of field studies to determine primary causes so that effective solutions can be identified; and
d. Amended existing vapor recovery nozzle and vehicle fill pipe regulations to address the compatibility/excess air ingestion issue

One of the most comprehensive and in depth field studies, known as the “Mega Blitz of 2013/2014” involved the collection of ISD data (including monthly alarm history, underground storage tank ullage volume and ullage pressure data, and vehicle fueling transaction data) and operating parameters (monthly gasoline throughput, operating hours, and type of vapor recovery equipment installed) from 400 gasoline dispensing facilities (GDF) located throughout nine, populated weighted regions in California. For the Mega 2013/2014 mega blitz, each of the 400 GDF were visited on four separate occasions; immediately prior to, twice during, and immediately after the seasonal introduction of uncontrolled Reid Vapor Pressure (RVP) winter blend gasoline in November of 2013.

Among several important findings, the study revealed that about 50% of ISD equipped GDF experienced one or more ISD overpressure alarms in the winter, compared to only 6% in the summer. Additionally, an approximate 10 fold increase in ISD overpressure alarm frequency occurred in November of 2013 (the first month of winter blend gasoline) when compared to October of 2013 (the last month of summer blend gasoline). This study also confirmed the existence of pressure-increase-while-dispensing (PWD) at 35% of GDF equipped with the Phase II EVR assist system. PWD is of concern because it indicates that gasoline vapors are being emitted from the storage tank vent lines directly to atmosphere. Lastly, the study showed that GDF with PWD, also exhibit elevated vapor to liquid ratios during individual vehicle fueling transactions, suggesting excess air ingestion at the nozzle is a key contributor.

Given the significance of these findings and recognizing that further work was needed to address the excess air ingestion issue (involving design changes to vehicle fill pipes and vapor recovery nozzle dimensions) and the establishment of long term study sites with year round continuous monitoring equipment to more accurately quantify pressure driven emissions, CARB and CAPCOA staff decided to repeat the collection of ISD data and GDF operating parameters in December of 2015, and again in December of 2018. The decision was made to revisit the original sites of 2013/2014 to determine if the findings of the prior study were repeatable and to enable long term trend analysis.

This document provides the results of all three surveys via a series of data tables and charts comparing information collected in December of 2015 and December of 2018 with information initially collected in December of 2013 (considered the original baseline data set). The primary focus of this report is on four parameters: frequency and distribution of ISD overpressure alarms, frequency and distribution of ISD leak alarms, percentage of GDF exhibiting PWD, and the relationship between vapor-to-liquid (V/L) ratio site average and overpressure severity.

Additional information including relationship between GDF operating parameters and overpressure alarm frequency and "one-off" investigations explored in December of 2015 (such as the assist nozzle interlock failure rate) and December of 2018 (percentage of balance nozzle market share and percentage of assist sites equipped with an updated version of the assist nozzle EOR) are also explored and discussed where applicable.

II. Background

ISD systems are designed to provide continuous real time monitoring of critical gasoline vapor recovery system parameters and components, and to alert the operator when a failure mode, as defined in CARB regulations (title 17, California Code of Regulations, section 94011), is detected so that corrective action can be taken expeditiously. ISD systems record two types of gasoline vapor recovery system failure alarms. The first failure alarm will notify the GDF owner/operator of a potential vapor recovery system problem that requires maintenance. If the required corrective action is not taken within the specified time, the ISD system will trigger a second failure alarm and will terminate at individual fueling points or the entire station.

In use evaluations of Phase II EVR systems indicate that ISD systems are effective year round in reducing gasoline vapor emissions through early identification of vapor recovery performance degradation. Thus, ISD provides information that is important to protect air quality and public health. However, in 2009, CARB staff became aware of overpressure alarms indicating that the headspace of the GDF underground storage tank (UST) was held at positive pressure for an excessive amount of time, yet no repairable equipment failures were found. Most overpressure alarms occur during a winter timeframe, when there is no limit on gasoline volatility measured as Reid Vapor Pressure (RVP)[1]. These overpressure alarms were particularly troublesome for the GDF operator due to their frequency in winter and expense associated with troubleshooting that doesnot result in equipment repair.

[1] CARB regulations limit the RVP of Gasoline to 7 psi for all months except between November 1 and March 31.

CARB staff initiated an early field study in 2009 to better understand the cause of the overpressure alarms and what could be done to mitigate the impact on GDF operators. Staff found that over 90% of total overpressure alarms occurring between November and March were not attributed to an equipment failure and took steps to offer short-term relief to GDF operators. CARB staff worked with the California Air Pollution Control Officers Association (CAPCOA) to draft Advisory 405, which was initially released in 2009. The advisory and subsequent amended versions, allowed station operators to self-clear ISD overpressure alarms between November 1 and March 31. At the time CARB staff released the advisory, it was understood to be a short-term solution and staff committed to a long-term study and public workshops that would lead to a permanent solution and possible regulatory action in 2013.

Shortly after conducting public workshops in October and November of 2012, CARB staff was presented with pressure and ullage data from 12 Phase II EVR assist system equipped GDF located in the South Coast Air Quality Management District (SCAQMD). The data was collected during the 2012-2013 winter fuel season and showed that all 12 sites exhibited rising pressure in the underground storage tanks during gasoline dispensing. Under normal operating conditions, the Phase II EVR assist system operates at negative pressure as the gasoline liquid volume in the storage tank decreases. Negative pressure is desirable because pressure driven fugitive and vent line emissions are nonexistent.

Additionally, each UST system exhibited overpressure for prolonged periods of time. A review of the alarm history was conducted for 8 of the 12 sites (ISD performance standards only require archiving one year of alarm history data and an extended alarm history was not available for 4 sites). The alarm history revealed a significant increase in the number of overpressure alarms for the 2012-2013 winter compared to the previous two winters. As pressure profiles remained unchanged after testing and minor repairs, CARB staff determined that the overpressure occurrences were unlikely to be caused by equipment defects and suspected that the volatility of gasoline being delivered to these sites during the winter months was likely the root cause of the overpressure. Just days after Southern California refineries began distributing low RVP gasoline, the overpressure occurrences ceased to exist at all 12 sites.

Before undertaking any “Mega Blitz” investigations/field surveys, CARB staff collected ISD data from 46 randomly selected sites in the Sacramento and San Diego regions from January 2013 through March 2013. Staff estimated that 11 percent of the Sacramento sites and 40 percent of San Diego sites exhibited overpressure during dispensing. These numbers led staff to question the percentage of GDFs statewide that could be experiencing overpressure and pressure increase while dispensing, or PWD, as well as how the statewide emission estimate would be affected by GDFs that operate at higher than expected pressures. Staff then proposed a larger state-wide study, known as the Mega Blitz, which involved the collection of ISD alarm history, fueling transaction data, and pressure/ullage data stored on the ISD console.

The Mega Blitz of 2013/2014 was a large scale manual collection of ISD data and GDF operating characteristics from approximately 400 GDFs located in nine defined geographic regions containing approximately 95% of the GDFs in California.[2] Of the approximately 400 GDFs surveyed, 69% were equipped with the Assist Phase II EVR (Assist) system and 31% were equipped with the Balance Phase II EVR (Balance) system.[3] For the entire sample population, 55% experienced one or more wintertime overpressure alarm. For those GDF equipped with the Assist system, 70% experienced one or more winter time ISD overpressure alarm and 34% exhibited PWD. For those GDF equipped with the Balance system, only 20% experienced one or more wintertime overpressure alarm and none exhibited PWD.

The Mega Blitz of 2013/2014 revealed that the causes of overpressure are complex and the result of a number of factors. While winter blend gasoline (high RVP) is the primary contributor, nozzle type, GDF operating hours, monthly throughput, and excess air ingestion at the nozzle (V/L ratio of the Assist nozzle) are key contributors to the problem. The study led to a number of other studies and recommendations,[4] and staff determined it was necessary to revisit Mega Blitz sites to collect more data at a future date.

[2] A target of 400 ISD downloads was selected as representing approximately a 5% sample size of the total number of GDFs with ISD throughout California.

[3] As of December of 2018, statewide, approximately 60% of GDFs are equipped with an Assist EVR Phase II system installed under Executive Order (EO) VR-202 and the remaining 40% are equipped with a Balance Phase II EVR system under EO VR-204. Similarly, the ISD system type is split between two different manufacturers, Veeder-Root and INCON. Approximately 90% of ISD systems are Veeder-Root, while 10% are INCON.

III. Methodology

This section of the report describes the methodology used by CARB staff to collect and special tools developed to analyze the data. This section consists of two segments. The first segment describes the data collection methodology. The second segment describes the data analysis methodology developed for this unique project.

A. Data Collection

For December 2015 and December 2018, staff attempted to collect the exact same information from the exact same GDFs initially included in the 2013/2014 study. Due to a number of factors, including sites closing, problems establishing a communication connection to download the data, and conversion of existing sites from the assist Phase II EVR system to the balance Phase II EVR system, the number of sites utilized in this analysis dropped from 395 in 2013, to 329 in 2015, and then to 283 in 2018. Unlike the initial study in 2013, staff visited each facility only once, in December of 2015 and once in December of 2018. The December collection date was intentionally selected to ensure that CARB and CAPCOA staff would capture pressure data directly after the wintertime switch to high RVP fuel occurred. As with the 2013 study, the data collection was conducted over a two week time frame, within the first 14 days in December of 2015 and again in December of 2018.

To conduct each site visit, CARB and CAPCOA staff utilized a field data collection form to record GDF operating parameters, a laptop computer equipped with ISD system communication software, communication cables, detailed ISD download instructions, and a list of ISD download commands. At a typical site, assuming no issues were encountered with access to the ISD console, the data download and manual recording of GDF operating parameters took about 60 minutes (per GDF). The collection of desired information was accomplished with minimal disruption to the GDF operations.

1) GDF Operating Parameters

The field data collection form (see Appendix I) was utilized by CARB and CAPCOA staff to manually record various operating parameters for each GDF site visit conducted, even those where it was not possible to establish connection with the ISD console. Information collected included: physical address, air district designation, brand of gasoline sold, operating hours, type of Phase II EVR system installed, type of ISD system installed including software version, number of underground storage tanks including capacity of each, number of fueling positions, number of nozzles, nozzle make and model, monthly gasoline throughput, type of vapor processor (pressure management system), and make and model of pressure vacuum vent valve installed.

2) ISD Data Download

As further described in the data analysis section of this document, in order to efficiently and accurately examine the large amount of ISD data stored at each GDF, the decision was made to electronically download the data (via direct connection with laptop computer) rather than printing hard copies of various reports directly from the ISD console. Thus, the only information manually recorded at each site was related to GDF operating parameters describe above.

The ISD download instructions (see Appendix II) provided step by step instructions on how to connect to the ISD console (Veeder-Root or INCON) via laptop computer, how to input the desired ISD report retrieval commands, and how to copy and save the data file to the laptop and then transfer to a thumb drive for redundant data capture. For each field survey (2013, 2015, and 2018) at least six ISD reports/parameters were retrieved via electronic data download. A description of each report/parameter is provided in Table 1 below:

Table 1: Typical ISD Data Available via Download

Parameter	Unit of Measure	Duration
UST ullage pressure	Inches of water column (gauge)	Most recent 30 hours, recorded in 20 second intervals
UST ullage volume	Gallons	Most recent 30 hours, recorded in 20 second intervals
Vehicle fueling transaction including: • Liquid volume • Vapor volume	Gallons	Most recent 1,000 fueling transactions per dispenser
Monthly report including Gross and Degradation alarms for: • Overpressure warning • Overpressure failure • Leak warning • Leak failure • Collection warning • Collection failure	Alarm count, typically one alarm per week maximum	12 month minimum, typically over 24 months is available
Daily Detail Report • collection • leak rate • containment • operational time • status	Daily values Percentiles	365 days minimum
Volume of gasoline delivered to each UST Includes total capacity of each UST installed	Gallons	10 Most recent bulk deliveries

For GDF's equipped with the Veeder Root ISD system (90% of sites in California) the following commands were utilized to retrieve the desired information:

- I&1400 – ISD Vapor Pressure Events (see Figure 1 below);
- IV0200 – ISD Monthly Status Report (see Figure 2 below);
- IV0400 – ISD Daily Report Details (see Figure 3 below); and
- I&1800 – ISD Vapor Flow Meter Events (see Figure 4 below)

Figure 1: ISD Underground Storage Tank Pressure Ullage Data Available Via "I&1400" Command

```
VAPOR PRESSURE EVENTS
INDEX   DATE-TIME                    PRESSURE ULLAGE    FLAGS
0001    16-02-25 02:03:16               0.044  16916.0   0000
0002    16-02-25 02:03:36               0.043  16916.0   0000
0003    16-02-25 02:03:57               0.043  16916.1   0000
0004    16-02-25 02:04:17               0.042  16916.1   0000
0005    16-02-25 02:04:36               0.041  16916.1   0000
0006    16-02-25 02:04:57               0.041  16916.1   0000
0007    16-02-25 02:05:18               0.039  16916.0   0000
0008    16-02-25 02:05:37               0.038  16916.0   0000
0009    16-02-25 02:05:59               0.037  16916.1   0000
0010    16-02-25 02:06:17               0.036  16915.9   0000
```

Figure 2: ISD Monthly Status Report Data Available Via "IV0200" Command

```
ISD MONTHLY STATUS REPORT

EVR TYPE: BALANCE
ISD TYPE: 01.05
VAPOR PROCESSOR TYPE: VEEDER-ROOT POLISHER

OVERALL STATUS              :PASS        EVR VAPOR COLLECTION :PASS
EVR VAPOR CONTAINMENT       :PASS
ISD MONITOR UP-TIME         :100%
EVR/ISD PASS TIME           :100%        VAPOR PROCESSOR      :PASS


ISD MONITORING TEST PASS/FAIL THRESHOLDS
                                                    PERIOD    BELOW  ABOVE

VAPOR COLLECTION BALANCE SYS FLOW PERFORMANCE        1DAYS    0.60   ----
VAPOR CONTAINMENT GROSS FAIL, 95th PERCENTILE        7DAYS    ----   1.30"wcg
VAPOR CONTAINMENT DEGRADATION, 75th PERCENTILE      30DAYS    ----   0.30"wcg
VAPOR CONTAINMENT LEAK DETECTION FAIL @2"WCG         7DAYS    ----   12.50cfh
STAGE I VAPOR TRANSFER FAIL, 50th PERCENTILE        20MINS    ----   2.50"wcg
VAPOR PROCESSOR SELF TEST FAIL                       1DAYS    ----   ----
VAPOR PROCESSOR MASS EMISSION FAIL (LB/KGAL)         1DAYS    ----   0.32

WARNING ALARMS
DATE      TIME      DESCRIPTION                    READING          VALUE

FAILURE ALARMS
DATE      TIME      DESCRIPTION                    READING          VALUE

SHUTDOWN & MISCELLANEOUS EVENTS
DATE      TIME      DESCRIPTION                    ACTION/NAME
15-12-02 11:29:03 PROCESSOR MODE                  AUTOMATIC
15-12-02 09:17:04 PROCESSOR MODE                  MANUAL
```

Figure 3: ISD Daily Details Report Data Available Via "IV0400" Command

```
ISD DAILY REPORT DETAILS

EVR TYPE: BALANCE
ISD TYPE: 01.02
VAPOR PROCESSOR TYPE: VEEDER-ROOT POLISHER

OVERALL STATUS            :WARN          EVR VAPOR COLLECTION :PASS
EVR VAPOR CONTAINMENT     :WARN
ISD MONITOR UP-TIME       :100%          STAGE I TRANSFERS:  1 of  1 PASS
EVR/ISD PASS TIME         : 90%          VAPOR PROCESSOR      :WARN

Status Codes: (W)Warn (F)Fail (D)Degradation Fail (G)Gross Fail
(ISD-W)ISD Self-Test Warning (ISD-F)ISD Self-Test Fail (N)No Test

       ISD    ISD  ---CONTAINMENT TESTS---     STAGE        ---COLLECTION TESTS
       EVR    %UP  GROSS  DGRD  MAX  MIN  LEAK   I   VAPOR  FP1   FP2   FP3
DATE  STATUS TIME   95%    75%  "WC  "WC  CFH   XFR  PRCSR  BLEND BLEND BLEND
03/01   PASS 100%  0.5  -0.0   0.0 -1.1   0          PASS   0.94  0.81  0.95
03/02   PASS 100%  0.4   0.0   0.2 -1.0   0          PASS   0.86  1.02  0.94
03/03   PASS 100%  0.5   0.0   0.8 -2.0   6          PASS   0.90  1.11  0.95
03/04   PASS 100%  0.4   0.0   2.0 -1.1   7          PASS   0.96  0.97  0.93
03/05   PASS 100%  0.4   0.0   0.0 -1.0   7          PASS   0.82  0.80  0.79
```

Figure 4: ISD Vapor Flow Meter Events Available Via "I&1800" Command

```
AFM BUSY EVENTS: FLOWMETER 1
INDEX START DATE-TIME    DUR    A/L    VAPOR   FUEL  #EV FLAGS  FPS    HOSES
 0001 16-02-11 09:12:31   61    0.31     1.6    5.1   1  003E  00     00
 0002 16-02-11 09:22:14  126    0.23     3.0   13.1   1  003E  01     01
 0003 16-02-11 09:29:47  122    0.77    10.6   13.8   1  002E  00     00
 0004 16-02-11 09:43:50  355    1.12    25.8   23.0   2  0032  00&01  00&01
 0005 16-02-11 10:02:55   98    0.19     2.1   11.0   1  003E  00     00
 0006 16-02-11 10:10:51  205    0.37    13.3   35.7   2  0032  00&01  00&01
 0007 16-02-11 10:19:41  106    0.18     1.9   11.1   1  003E  00     00
 0008 16-02-11 10:25:06  232    0.67     9.0   13.5   1  002E  00     00
 0009 16-02-11 10:33:35  142    0.22     3.9   17.6   1  003E  01     01
 0010 16-02-11 10:47:47   81    1.06     3.7    3.5   1  002E  00     00
```

3) Vapor Recovery Nozzle Surveys

In addition to the ISD data gathering methodology which mirrored that of the 2013/2014 Mega Blitz, CARB staff took the opportunity during their site visits (in December of 2015, December of 2018, and a follow-up survey conducted in February/March of 2019) to gather specific information related to vapor recovery nozzle in-use performance and distribution. The following paragraphs describe the reason for each of these surveys in further detail.

i. Healy Model 900 Assist Nozzle Interlock Testing (Dec 2015)

During a November 10, 2015 public workshop, a stakeholder suggested that the Healy Model 900 assist system nozzle had an interlock failure rate of approximately 25%. Interlock failure is of concern because vehicle fueling can occur without a proper nozzle boot seal at the fill pipe interface, resulting in excess air ingestion and contributing to overpressure. While not envisioned as part of the original study design for the 2013/2014 mega blitz, CARB staff determined that it would be worth including as an additional task within the December 2015 site visits. As such, CARB staff conducted a limited number of nozzle interlock tests at select assist equipped GDF.

To determine interlock failure rate, CARB staff utilized the Healy nozzle interlock inspection criteria from the Installation, Operation and Maintenance (IOM) Manual, Sections 1 and 2, from Executive Order VR-202 (see Appendix VII). While at a randomly selected number of assist system sites (due to time constraints and limited resources, it was not feasible to survey all nozzles at all assist sites), staff removed nozzles from within the dispenser cradle, authorized the dispenser, held the nozzle and inserted spout into approved containers, and actuated the nozzle lever without compressing the boot. A ‘pass’ occurs when no fuel is dispensed while a ‘fail’ occurs if fuel dispenses. Staff tested a total of 414 assist system nozzles at 57 GDFs located in 5 districts. Results were tabulated in an excel spreadsheet for analysis (see Appendix VIII).

ii. Balance Nozzle Distribution (Dec 2018)

In December of 2018, CARB staff took the extra step of conducting a balance system nozzle survey at each site visit. This survey was focused strictly on the115 balance equipped sites and involved recording the make, model and serial number of each balance nozzle installed. The objective of this survey was to validate CARB estimations pertaining to market share of VST balance nozzles versus EMCO balance nozzles. Serial numbers were recorded to determine average age of nozzle to determine typical useful life of nozzles.

iii. Healy Model 900 EOR Population (Feb-Mar 2019)

In January 2015, CARB staff conducted a vehicle refueling survey at six retail GDFs in San Diego County and found that excess air ingestion of the Healy Model 900 nozzle (assist nozzle) occurs for approximately 30% of motor vehicles produced after the 2003 model year. The survey also found that air is ingested when the assist nozzle is not fully engaged (latched) into the vehicle fill pipe but is still able to refuel the vehicle.

In response to these findings, Franklin Fueling Systems (FFS), manufacturer of the Phase II EVR assist system, made design enhancements to the spout assembly of the Healy Model 900 assist nozzle. The improvements enable a better seal between the nozzle’s vapor collection boot and the vehicle fill pipe, thereby reducing excess air ingestion. The new spout assembly, referred to as Enhanced ORVR-Vehicle Recognition (EOR) and can be field retrofitted onto existing nozzle bodies. During the winter of 2016/2017, CARB staff evaluated the performance of the EOR spout assembly (considered prototypes at the time) at eight GDFs, each with differing operating conditions.

On August 23, 2017, the new spout assembly was certified by CARB per “Revision V” of Executive Orders VR-201 and VR-202. Although CARB certified the EOR spout assemblies for use as a field retrofit on existing nozzles or as factory installed new nozzles, CARB staff determined that the new nozzles outperformed the field retrofitted version and therefore, suggested installation of new nozzles.

Shortly after the December 2018 download, it was decided to return to all the assist sites in late February and March of 2019 and conduct an EOR nozzle survey. The objective was to determine the market penetration of the recently certified EOR version of the assist nozzle. Out of 168 assist sites in the December 2018, CARB staff returned to 147. There were a few regions of the state excluded, such as San Luis Obispo and the Mountain Counties because of poor road conditions due to winter weather and distance of travel.

As a final note, CARB Staff requested the convening a workgroup consisting of vehicle and nozzle manufacturers to develop fill pipe and nozzle standards and specification to ensure compatibility. This workgroup call the SAE Fuel System Working Group was form in 2015. The vehicle fill pipe and nozzle standards and specifications developed by this work group was adopted by CARB in 2019. This will result in fill pipe and nozzle compatibility in the future.

B. Data Analysis

Once the site visits were conducted, the ISD data was downloaded, and GDF operating parameters recorded, all information was electronically uploaded to computer file servers located at CARB offices in Sacramento. Due to the number of sites in the original data set converting from assist to balance (15% conversion rate in 2015, followed by a 16% conversion rate in 2018) and communication issues with the ISD console, the total population included in the survey steadily declined over the years. As a result, all data analysis presented within in this report is conducted in a longitudinal manner, meaning that analysis was only completed on GDF with the same Phase II vapor recovery system for all three surveys. For example, data collected at sites that converted from assist to balance are not presented in this report. Additionally, sites where staff was not able to capture the ISD download due to communication errors were also excluded.

During the preliminary planning stages of the 2013/2014 Mega Blitz, staff identified 20 parameters that could contribute to the overpressure conditions (see Appendix IX). As described within the list, overpressure conditions can vary based on site specific operating parameters, geographic region, and time (hourly, daily, seasonally, or yearly). In attempting to determine the causes of overpressure and PWD, staff used these parameters as a basis or guideline to establish data analysis tasks. Unlike the Mega Blitz of 2013/2014, the Mega Blitz of December 2015 and December 2018 focused on a smaller set of variables to identify continuing trends and causes of the overpressure issue.

CARB staff carefully reviewed the monthly alarm report segment for each ISD download (each download contains over 12 months of alarm history) and tabulated monthly alarm counts for the gross overpressure alarm and the weekly leak alarm. Tabulated monthly alarm counts where then manually entered into an existing excel spreadsheet (used in the previous 2013/2014 survey) containing operating parameters for each GDF. This process was carefully conducted for all available data collected in December of 2015 and then repeated with all available data collected in December of 2018.

Due to the amount of information available in the monthly report segment of each ISD download and in order to avoid potential confusion with trend analysis, a dedicated spreadsheet was created for monthly ISD overpressure alarm counts (based on the gross overpressure alarm) and a second dedicated spreadsheet was created for monthly ISD leak alarm counts (based on the weekly leak alarm). The monthly alarm count spreadsheets were then used to evaluate seasonal trends (summer vs winter) and if relationships exist between alarm frequency and GDF operating parameters. Also, because the information is tabulated on a monthly basis for several years of available data for each download (2011-2018) long term trend analysis can be performed.

In addition to alarm counts, staff also utilized the available data to determine percentage of sites exhibiting PWD and to determine the site average vapor to liquid ratio as an indicator of excess air ingestion at the nozzle.

For each of the desired data analysis tasks (overpressure alarm count, leak alarm count, percentage of PWD, and site average vapor to liquid ratios) the following paragraphs provide further details on the methods utilized.

1) Overpressure Alarm Frequency

An excel spreadsheet, initially created for the Mega Blitz of 2013/2014, was updated with relevant data gathered not only from the ISD downloads, but from the field data collection form containing GDF operating parameters. For example, for each of the 283 sites included in the longitudinal analysis, information on location, hours of operation, type of vapor recovery and ISD system installed, recent fuel deliveries, gasoline throughput, gasoline capacity, average UST and delivered fuel temperature, and changes to the sites between visits was recorded. Upon entry of information collected in December of 2015, the total number of fields increased to accommodate additional monthly alarm count entries, information pertaining to EVR system type, the presence of PWD, and changes in operating hours and monthly throughput specific to 2015. In 2018, the spreadsheet was further expanded for a grand total of 153 fields, mostly to accommodate the additional monthly alarm count data.

Once specific site details were checked against previous data, staff then populated all fields with overpressure warning alarm count information. For the Overpressure alarm specific spreadsheet (see Appendix III), staff analyzed monthly reports going as far back to October 2011. From the ISD monthly reports, staff tabulated the overpressure warning alarm occurrences in each month, up until the last Mega Blitz download site visit in December 2018.

2) Leak Alarm Frequency

A second excel spreadsheet (see Appendix IV) consisting of the same site specific fields as the overpressure alarm spreadsheet was created to store and tabulate ISD leak alarm frequency for the entire sample population. Similar to the ISD overpressure alarm frequency spreadsheet, a total of 151 fields were eventually created to document frequency of leak alarms captured in 2013, 2015, and 2018.

3) Percentage of GDF Exhibiting PWD

To determine the prevalence of PWD, CARB staff carefully examined a segment of each ISD download containing available UST pressure and ullage volume data. A typical ISD download file contains the most recent 30 hours of UST pressure and ullage volume data. In order to automate the desired data analysis tasks, a customized excel macro program was created. This excel macro is called “VR 1400 P/U Plot”.

For Veeder-Root ISD system, the I&1400 command provides the most recent 30 hours of UST pressure and ullage volume data and consists of 5,400 records. To identify PWD, the macro is designed to set a number of specific flags for each file. To be designated as PWD several flags are triggered: 1) at least 20% of the daily ullage data must exceed 1.3 inches water column; 2) at least 75% of the daily ullage pressure data must not be between negative 0.2 and positive 0.2 inches water column (otherwise the data would be deemed invalid indicative of a leak); and 3) at least three consecutive hours of positive pressure slope and positive ullage volume based on daily ullage pressure data. Once the raw ISD data file was fed into the macro and the queried flags identified, staff were able to identify specific GDF sites exhibiting instances of PWD in for each data download file. See Appendix V for an example of the VR 1400 PU Plot macro.

Additionally, with the VR 1400 PU Plot macro, staff generated UST pressure and UST ullage volume charts for each GDF as depicted in Figure 5 below, demonstrating a typical site where PWD is not exhibited. As ullage volume increases (more gasoline dispensed), UST ullage pressure stays in vacuum, increasing overnight when dispensing activity is low, but not reaching positive pressure. Using the VR 1400 PU Plot macro, staff generated Figure 6 below, which provides an example of a site that is exhibiting PWD. While gasoline is dispensed and ullage increases over an approximate day and a half, the UST ullage remains at positive pressure.

Figure 5: Example of UST Pressure and Ullage Volume Chart: Non PWD

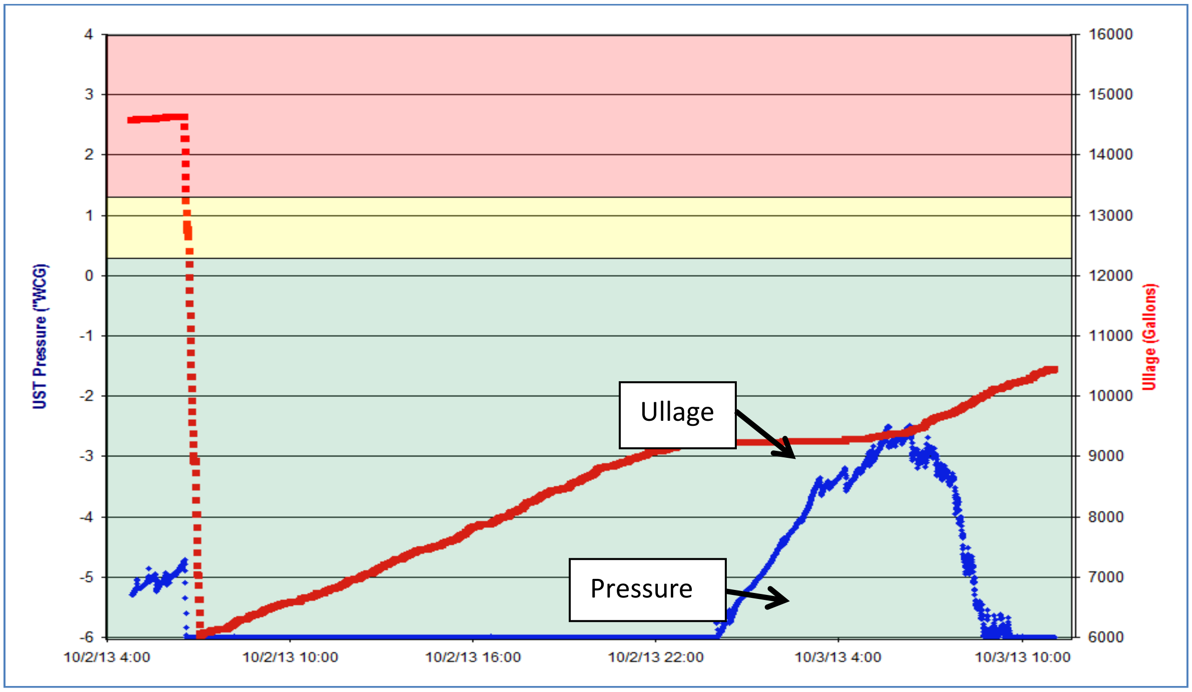
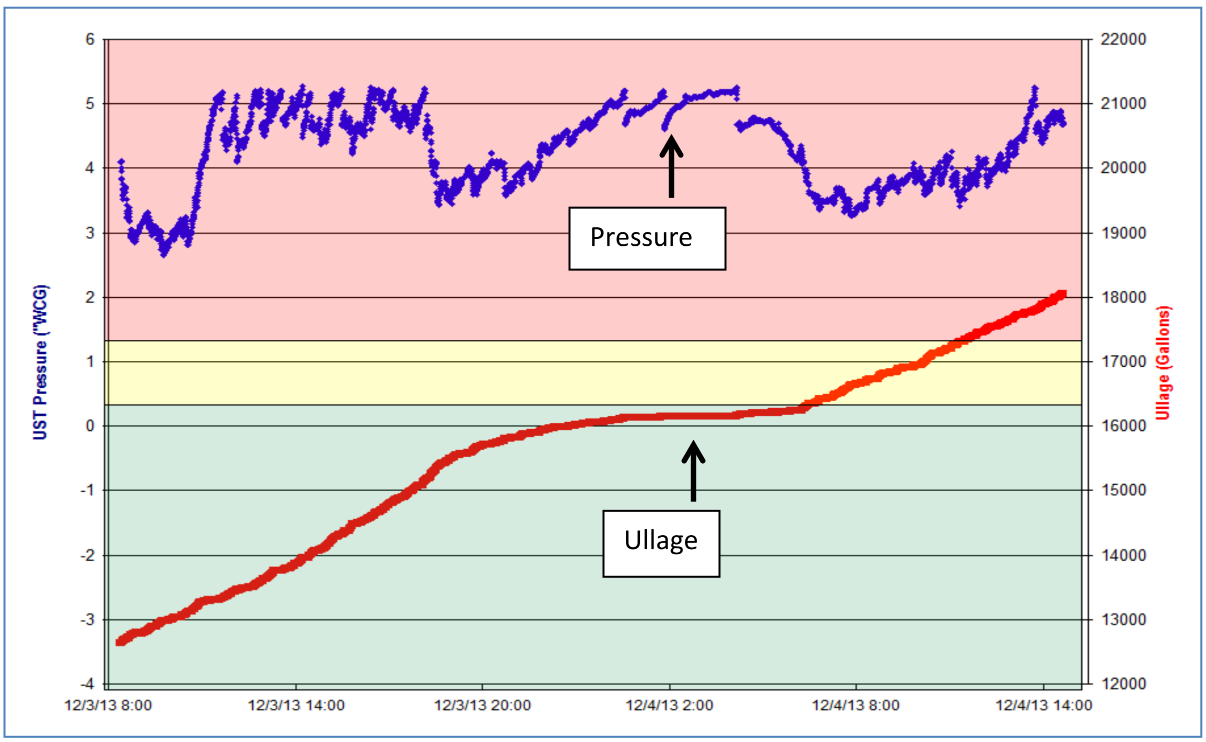


Figure 6: Example of Pressure and Ullage Volume Chart: Exhibiting PWD

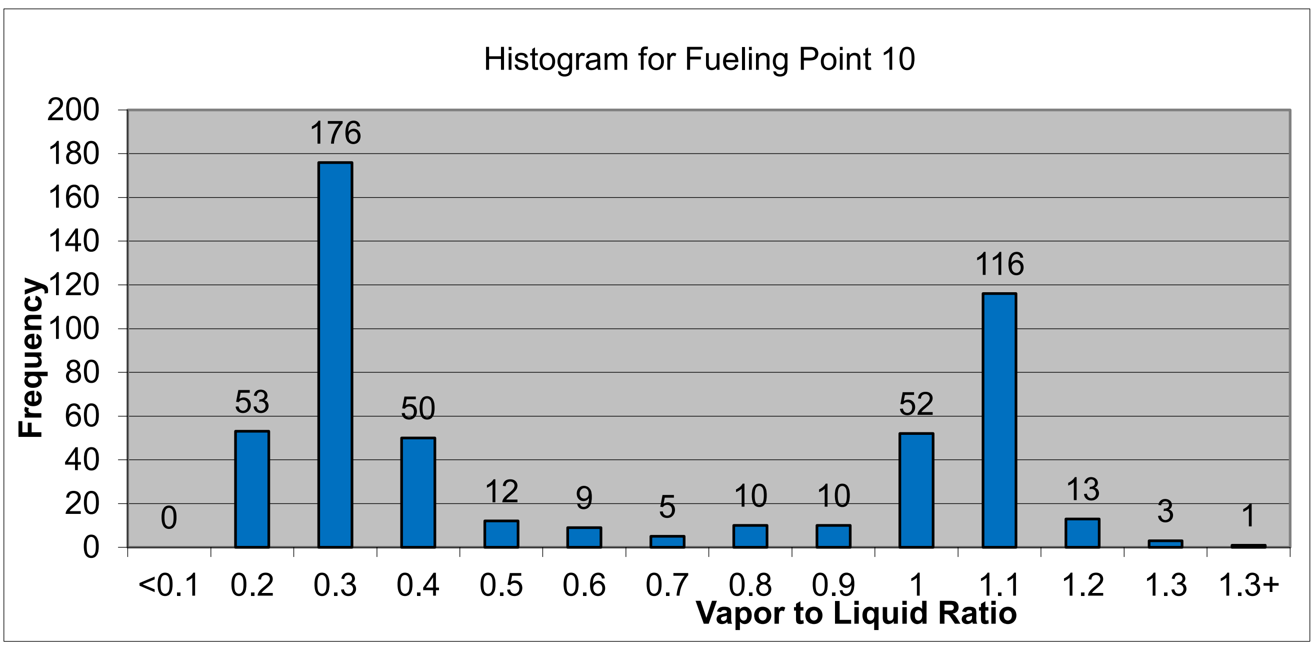


4) Site Average Vapor to Liquid Ratio

To determine site average vapor to liquid ratio (the volume of vapor collected divided by the volume of liquid gasoline dispensed), indicative of excess air ingestion at the vapor recovery nozzle, CARB staff carefully examined a segment of each ISD download containing the most recent 1,000 fueling transactions available for each dispenser installed at each site. In order to automate the desired data analysis tasks, a dedicated excel macro was created to combine all dispenser data and calculated a site average vapor to liquid ratio. This excel macro is called the “Histogram Assistance Tool” (HAT).

The HAT macro queries individual GDF site ISD data for the vapor-to-liquid ratios (V/L) of specific fueling points and hoses at each location, providing the distribution of V/L for the most recent 1,000 individual fueling transaction for each vapor flow meter, and the V/L average for the entire site. The HAT tool allows staff to determine whether the distribution of V/L falls within a normal pattern for each GDF location. An example of a normal distribution is depicted in Figure 7 and an example of an abnormal distribution is depicted in Figure 8 below.[5] As indicated in Table 2, for each site selected, the HAT macro allowed staff to determine the site average vapor-to-liquid ratio by dividing the total vapor volume collected by the total liquid volume dispensed during fueling transactions. Additional parameters are available such as total number of fueling events and various bins for vapor to liquid ratio results. For example, percentage of fueling events with V/L less than or equal to 0.5, percentage of fueling events with V/L greater than 1.0 and so on.

Figure 7: Example of Normal Distribution of Vapor to Liquid Ratios



[5] The large number of fueling transactions with a V/L of 0.3 is indicative of assist nozzle performance with ORVR vehicles and the large number of fueling transactions with a V/L of 1.1 is indicative assist nozzle performance with non-ORVR vehicles.

Figure 8: Example of Abnormal Distribution of Vapor to Liquid Ratios

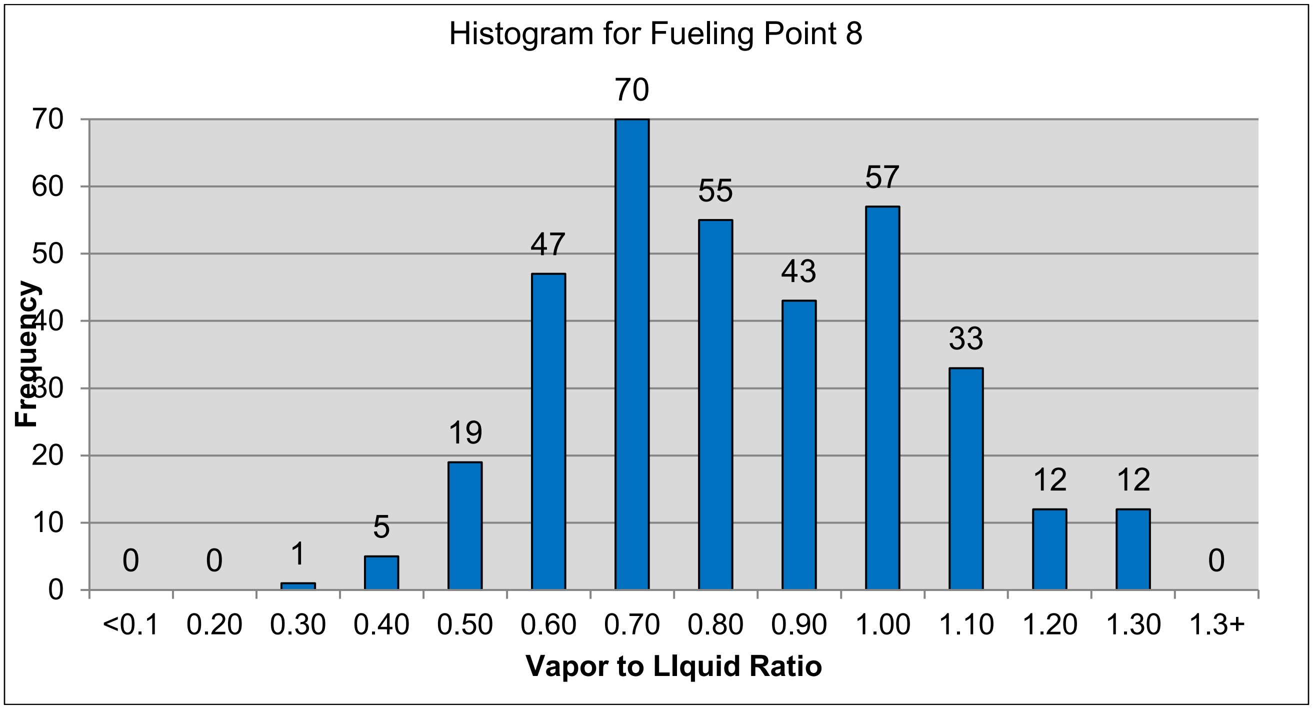


Table 2: Summary Information Available Via HAT Macro

Parameter	# of Events	Percentage
Fueling Events V/L <= 0.5	2,692	63%
Fueling Events V/L > 0.5 and <= 0.8	378	9%
Fueling Events V/L > 0.8 and <= 1.0	521	12%
Fueling Events V/L > 1.0	682	16%
Total Fueling Events	4,273	100%
Total Vapor Volume (V)	32,418 gallons	
Total Fuel Volume (L)	101,211 gallons	
Site Average Vapor to Liquid Ratio (V/L)	0.32	

C. Data Entry QA/QC

To properly evaluate the data gathered and analyzed during the site surveys of 2013, 2015, and 2018, it was necessary to perform quality assurance/quality control (QA/QC) on alarm count summary tables created by staff. Once data was manually inputted into the excel spreadsheets, staff performed data entry checks on one another's entries to ensure accuracy. If discrepancies were discovered, staff made the corrections in the main databases while keeping track of errors and corrections made in separate excel tables. While staff checked the accuracy of specific GDF site information, the main focus of the QA/QC was on the overpressure and leak alarm counts. As data was undergoing QA/QC, other staff members simultaneously created an excel macro that could identify and tally overpressure and leak alarms once the ISD files were inputted. Once the tally alarm count macro was created, and compared with the manual entry and data check performed by staff, discrepancies between the two were solely based on human error. The introduction of the tally alarm count macro enabled staff to automate much of the data obtained in the December 2018 download and QA/QC checks quicker and with more confidence.

IV. Results

This section of the report provides the results of various data analysis tasks previously described within the methodology section. To clearly convey results, this section of the report relies on data summary tables and charts comparing data collected over various time frames. The primary focus of this report section is on four parameters: frequency of ISD overpressure alarms, frequency of ISD leak alarms, percentage of sites exhibiting PWD, and the site average vapor-to-liquid (V/L) ratios associated with PWD sites.

Additional information including relationship between GDF operating parameters and overpressure alarm frequency and the results of various nozzle surveys previously described in the methodology section are also provided.

Much of the content contained in this section has been presented at public workshop and meetings with districts.

A. General Information

As a first step in generating useful results, staff began with analysis of general information primarily contained within the field data collection form. During the Mega Blitz of 2013/2014, a total of 400 GDF site visits were conducted. Within that population, a total of 395 ISD download files were captured. Due to a number of issues, including conversion of existing Phase II EVR systems from Assist to Balance, connection issues, corrupted ISD data, and site closure, 66 sites were dropped from the analysis in December of 2015, resulting in a total of 329 ISD downloads. With the December 2018 survey, 46 additional sites were dropped from the analysis leaving a total of 283. Table 1 below provides general information for each of the field surveys. Table 2 below shows the geographic distribution of sites throughout the state and the actual number of ISD downloads captured in each region for each survey.

Table 3: General Information Multi Year Field Survey

Parameter	Dec 2013	Dec 2015	Dec 2018
Total Number of Site Visits	400	353	295
Number of ISD Downloads Achieved	395	329	283
ISD Data Capture Rate	99%	93%	97%
Number of Assist vs Balance Sites	272 -123	210 -119	168 -115
Conversion Rate from Assist to Balance	N.A.	15%	16%
Number of Sites That Converted from Assist to Balance From Last Survey	N.A.	42	34
Sample Size (Assuming ~7,400 GDF statewide equipped with ISD)	5.3%	4.4%	3.9%
Geographic Regions Represented	9	9	9

Table 4: Geographic Distribution of GDF Selected for ISD Data Collection

District(s)	South Coast	Bay Area	San Joaquin Valley	San Luis Obispo, North Coast, Mojave, El Dorado, Placer	San Diego*	Sacramento, Yolo-Solano, Feather River*	Other Districts Not Sampled
% Statewide Population	40.3%	17.1%	11.3%	11.1%	8.3%	6.9%	4.9%
Downloads in 2013	136	58	38	37	85	46	0
Downloads in 2015	106	53	34	31	66	39	0
Downloads in 2018	90	46	28	26	58	35	0

*San Diego County and Sacramento Metro Air Pollution Control Districts were sampled at a greater number (oversampled) when compared to weighted percentage of GDF population.

Of the 283 GDF included in the 2018 data set, 168 were equipped with the Assist Phase II EVR system and 115 were equipped with the Balance Phase II EVR (Table 4). Of the 283 sites, 224 were open 24 hours a day while 59 shut down at night. Of the 168 Assist system sites, 138 were open 24 hours a day and 25 shut down at night. As previously indicated, if sites had converted from Assist to Balance systems, they were excluded from the study as their alarm history data would no longer allow for longitudinal analysis.

Table 5: Number of ISD Downloads Achieved in 2013, 2015 and 2018 Including Breakdown of Phase II EVR System (Balance vs Assist)

ISD Data Collection	Dec 2013 Number/Percent		Dec 2015 Number/Percent		Dec 2018 Number/Percent	
Total Number of ISD Downloads	395	100%	329	100%	283	100%
Assist Equipped GDF	272	68.9%	210	63.8%	168	59.4%
Balance Equipped GDF	123	31.1%	119	36.2%	115	40.6%

B. Overpressure Alarm Frequency

For the overpressure alarm data, alarm frequency was queried based on differing time frames: monthly alarm count, (with a focus on October vs November), seasonal alarm count (winter blend vs summer blend gasoline), and annual average. The following paragraphs describe the results of each query.

1) Monthly Basis

Initially, analysis was focused on the months of October and November, as that is when summer blend gasoline transitions into winter blend, uncontrolled RVP gasoline, yet ambient temperatures remain relatively high in November compared to other winter months. Table 6 compares the prevalence of overpressure alarms in October of 2013, 2015, and 2018 with November of 2013, 2015, and 2018. This analysis was performed for all GDF sites combined and then the split between assist and balance system sites. For example, there was an average of 0.05 overpressure alarms per site in October 2018 with summertime fuel, which increased to an average of 1.19 overpressure alarms per site in November 2018 and wintertime fuel. From October to November the percentage of sites with at least one alarm increased from 2.8% to 48.4%. Alarms per site during that time increased for Assist and Balance system sites. In November 2018, 67.3% of Assist system sites had at least one overpressure alarm while 20.9% of Balance system sites experienced at least one alarm. Similar results are provided within table 6 for October and November of 2013 and 2015. The key point is that a significant increase in alarm frequency occurs when winter blend gasoline is introduced in early November of each year.

Table 6: Prevalence of ISD Overpressure Alarms: 2013 vs 2015 vs 2018

Data Set	Overpressure Alarms	Oct 2013	Oct 2015	Oct 2018	Nov 2013	Nov 2015	Nov 2018
All Sites (283)	Average Number of Alarms Per Site	0.10	0.16	0.05	1.20	1.43	1.19
	% of Sites With at Least One Alarm	6.0%	9.2%	2.8%	48.8%	54.4%	48.4%
Assist Sites (168)	Average Number of Alarms Per Site	0.15	0.24	0.09	1.77	2.19	1.69
	% of Sites With at Least One Alarm	8.9%	13.7%	4.8%	68.5%	80.4%	67.3%
Balance Sites (115)	Average Number of Alarms Per Site	0.03	0.04	0.00	0.37	0.33	0.45
	% of Sites With at Least One Alarm	1.7%	2.6%	0.0%	20.0%	16.5%	20.9%

Recognizing that the months of October and November represent only a fraction of the available data (October and November provide a relatively narrow focus given the total number of months within the data set), CARB staff further evaluated every month of available data for the full duration or the entire data set consisting of 85 months. This allowed for the creation of various bar charts depicting the total number of alarms per month on the vertical axis and month/year on the horizontal axis. Figure 9 clearly demonstrates the relationship between overpressure alarm frequency and month of year. For the winter months of November, December, January and February, an approximate tenfold increase in alarm frequency is observed when compared to a typical summer months such as August, September, or October.

Figure 10 depicts the frequency of overpressure alarms at 168 assist equipped sites for the entire study duration. Figure 11 depicts the frequency of overpressure alarms at the 115 balance equipped site for the entire study duration. When comparing Figure 10 and Figure 11, it is evident that the vast majority of overpressure alarms occur at assist equipped sites, in particular during the winter months of November, December, January and February.

Figure 9: Monthly Count of ISD Overpressure Alarms at 283 GDF in CA: October 2011 to December 2018 All Sites

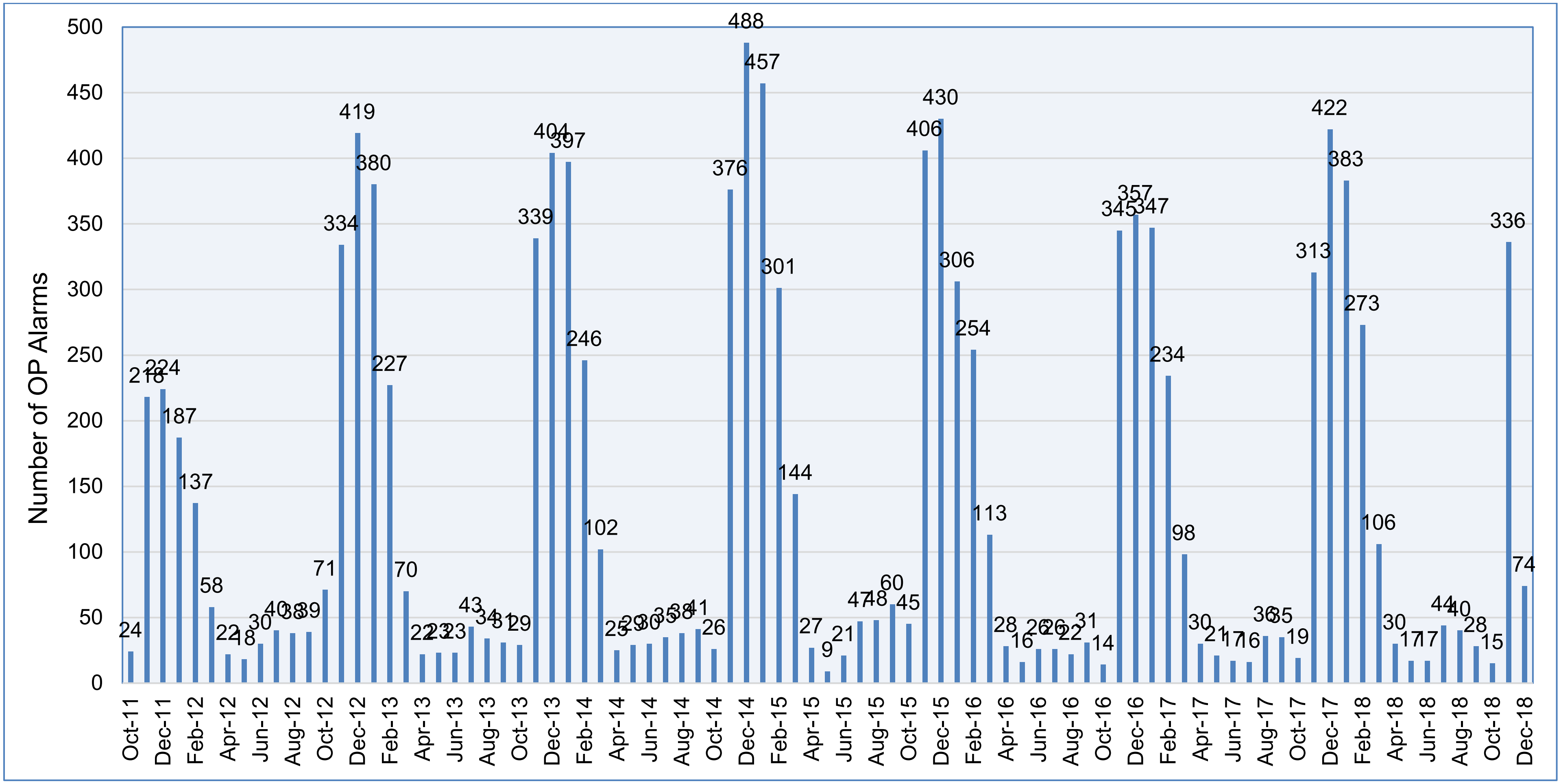


Figure 10: Monthly Count of ISD Overpressure Alarms at 168 Assist Equipped GDF

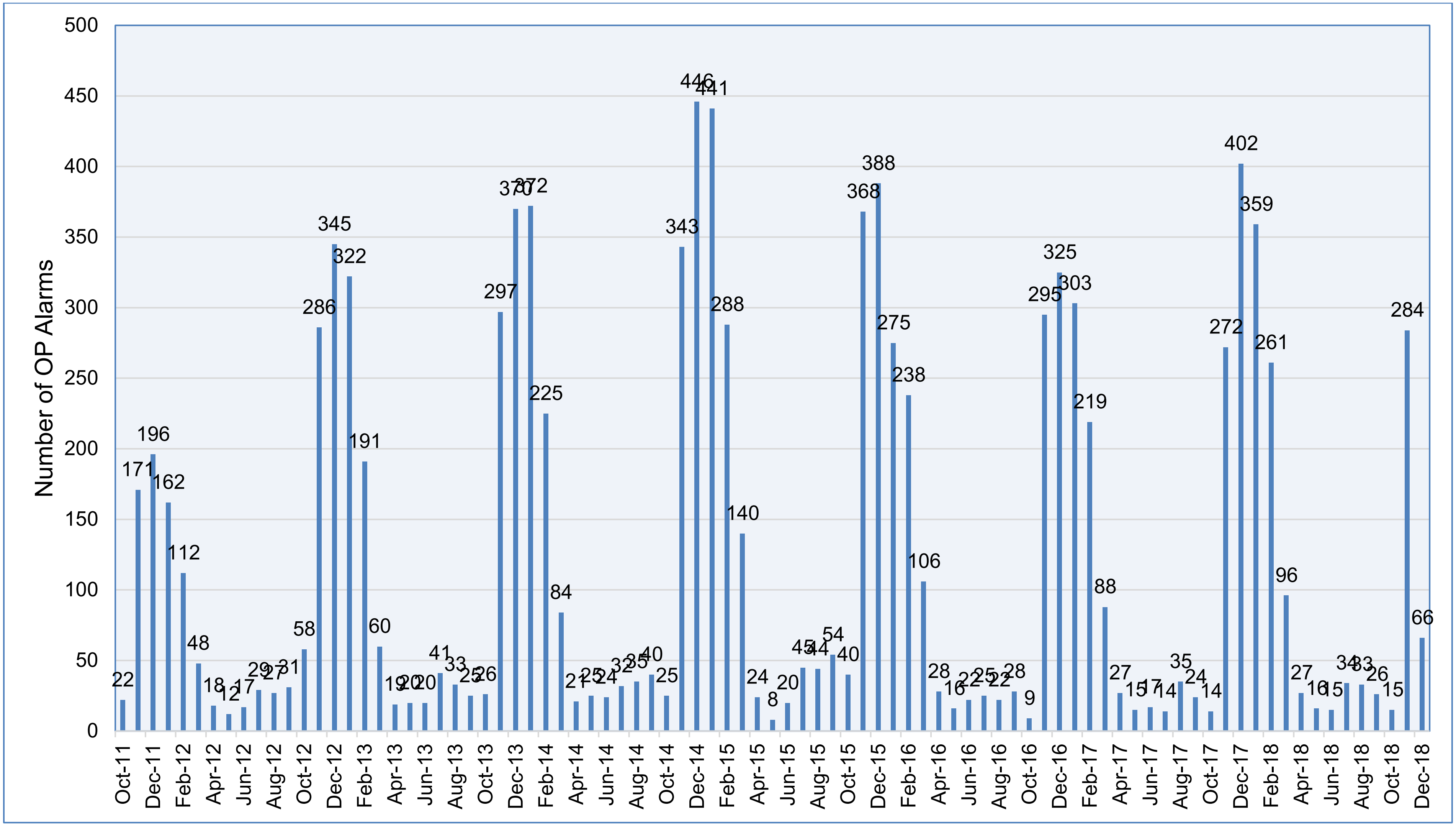
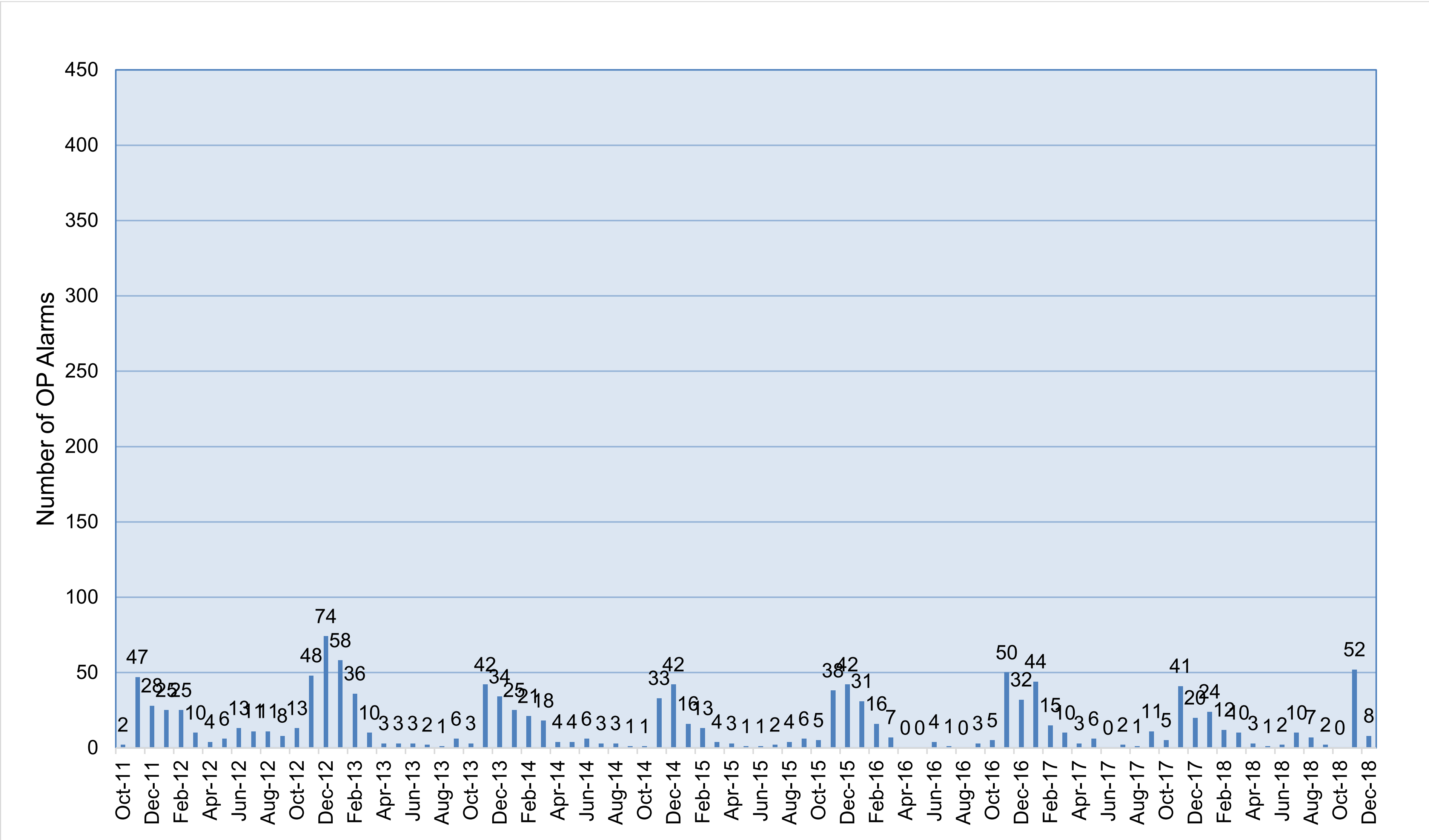


Figure 11: Monthly Count of ISD Overpressure Alarms at 115 Balance Equipped GDF



2) Seasonal Basis: Winter Blend vs Summer Blend

In addition to monthly analysis, CARB staff performed seasonal analysis of the available data set and populated a series of data tables and charts. For seasonal analysis, winter consists of four months: November, December, January, and February. Summer consists of seven months: April, May, June, July, August, September, and October. The month of March was deliberately not included in seasonal analysis because for Northern California and Central California, March remains a transition month for winter blend gasoline. Including the month of March in this analysis can bias the results high if it is considered a summer month or bias the results low if it is considered winter month.

Table 7 and Table 8 provide the total number of alarms, the average number of alarms per month, the number of months, and the number of alarm per site per month, for each available season within the data set. Although some information is available, data from the Summer of 2011 and the winter of 2018 are not included in this analysis because each season contained only partial information. For example, the summer of 2011 was excluded because it only consisted of alarm count data for the month of October 2011. The winter of 2018/2019 was also excluded because it only contained alarm frequency data for the month of November 2018 and part of December 2018.

Table 7: Seasonal Distribution of ISD Overpressure Alarms Winter of 2011/2012 through Winter of 2014/2015

Parameter	Winter 2011-2012	Summer 2012	Winter 2012-2013	Summer 2013	Winter 2013-2014	Summer 2014	Winter 2014-2015
# of Alarms	766	258	1360	205	1386	224	1622
Average # of Alarms per Month	192	37	340	29	347	32	406
# of Months	4	7	4	7	4	7	4
# of Alarms per Site per Month	0.68	0.13	1.20	0.10	1.22	0.11	1.43

Table 8: Seasonal Distribution of ISD Overpressure Alarms: Summer of 2015 through Summer of 2018

Parameter	Summer 2015	Winter 2015-2016	Summer 2016	Winter 2016-2017	Summer 2017	Winter 2017-2018	Summer 2018
# of Alarms	257	1396	163	1283	174	1391	191
Average # of Alarms per Month	37	349	23	321	25	348	27
# of Months	7	4	7	4	7	4	7
# of Alarms per Site, per Month	0.13	1.23	0.08	1.13	0.09	1.23	0.10

Winter of 2018-2019 not included in this summary table due to partial data set, data was downloaded in December of 2018, only 6 weeks into the 16 week winter time frame

Using the values contained in Tables 7 and 8, CARB staff created a series of bar charts to convey the results in graphical fashion. Figure 12a and 12b depict the number of overpressure alarms across the 283 study sites on a seasonal basis, summer vs winter. Figure 12a includes all sites combined. Figure 12b breaks apart balance sites and assist sites. Figure 12a and 12b provides clear evidence that a strong correlation exists between increase in overpressure alarm frequency and winter blend gasoline. Figure 12b also provides evidence that the vast majority of overpressure alarms occur at assist equipped GDF when compared to balance equipped GDF.

Figure 12a: Seasonal (Winter vs Summer) Count of ISD Overpressure Alarms

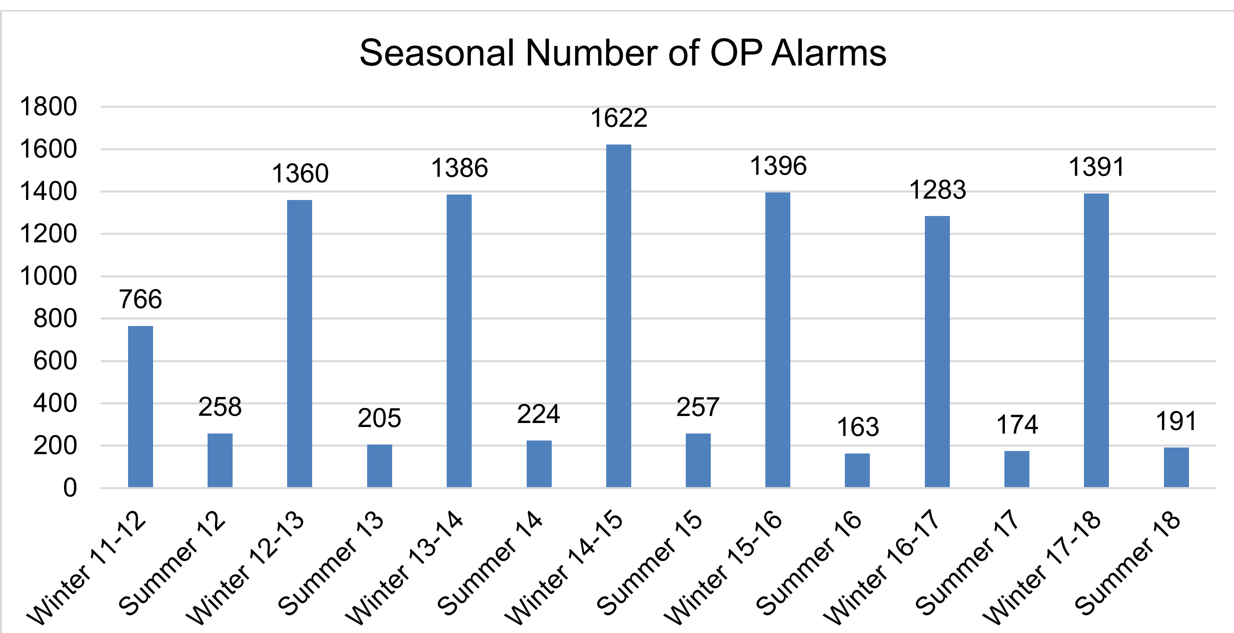
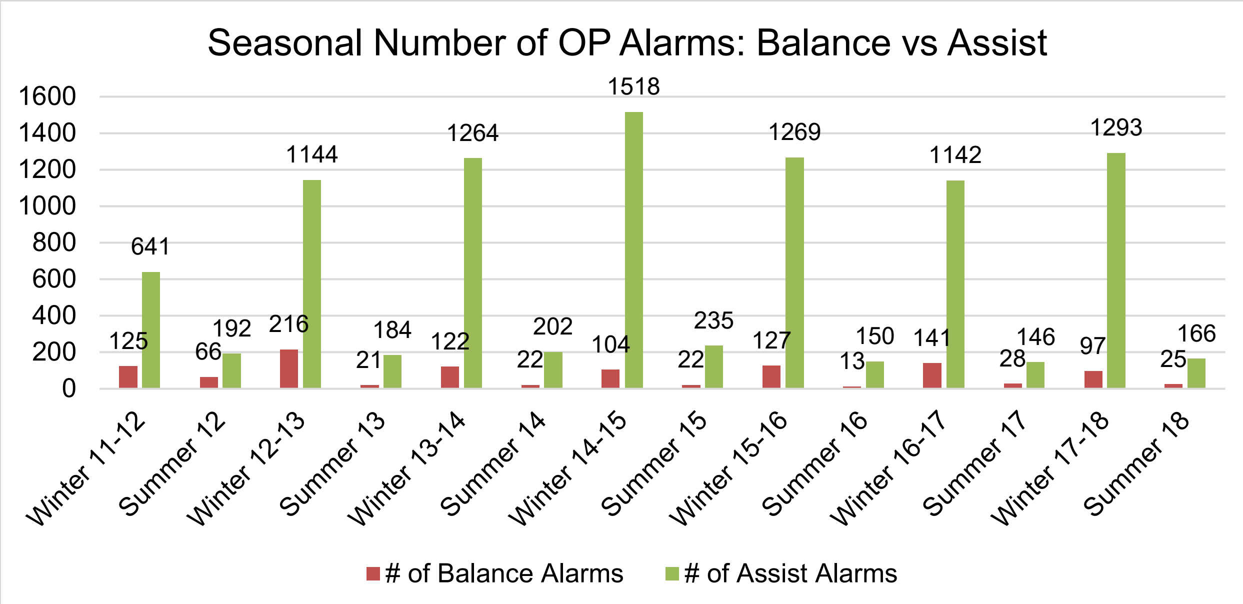


Figure 12b: Seasonal (Balance vs Assist) Count of ISD Overpressure Alarms



3) Annual Average Basis

As indicated in Table 9 below, staff determined the average number of overpressure alarms per year per site by tabulating the total number of alarms (within the entire data set) and dividing by the total number of sites (within the entire data set), then dividing that value by the number of years of the study duration. Given the large amount of monthly alarm frequency information within the data set, determining the annual average number of overpressure alarms per site is very helpful when attempting to summarize the results. This same method was conducted for all sites, assist sites, and balance sites. As indicated in the table below, on average a typical site will experience 5.9 alarms per year. On average, assist equipped sites will experience 8.9 alarms per year. On average, balance equipped sites will experience 1.5 alarms per year.

As with the seasonal analysis, for the annual average analysis, the month of March was deliberately not included because for Northern California and Central California, March remains a transition month for winter blend gasoline. Including the month of March for annual analysis can bias the results high if it is considered a summer month or bias the results low if it is considered winter month. In addition, although some information is available, data from the Summer of 2011 and the winter of 2018 are not included in this analysis because each year contained only partial information.

Table 9 provides the values needed to perform the calculation. These include the total number sites, total number of alarms for the entire study duration, the study duration in months, the average number of alarms per site, the study duration in year, and the average number of alarms per site per year. Upon evaluation of all sites, an average of 5.9 overpressure alarms occur per year. Upon analysis of the assist equipped GDF, an average of 8.9 overpressure alarms occur per year. Upon analysis of the balance equipped GDF, an average of 1.5 overpressure alarms occur per year.

Table 9: Annual Average Overpressure Alarms

Phase II System Type	Site Count	Total Number of Alarms Duration of Study	Study Duration Months	Average Number of Alarms Per Site Over Entire Study Duration	Study Duration Years	Average Number of Alarms Per Site Per Year
All Sites	283	10,675	77	37.7	6.4	5.9
Balance Sites	115	1,129	77	9.8	6.4	1.5
Assist sites	168	9,547	77	56.8	6.4	8.9

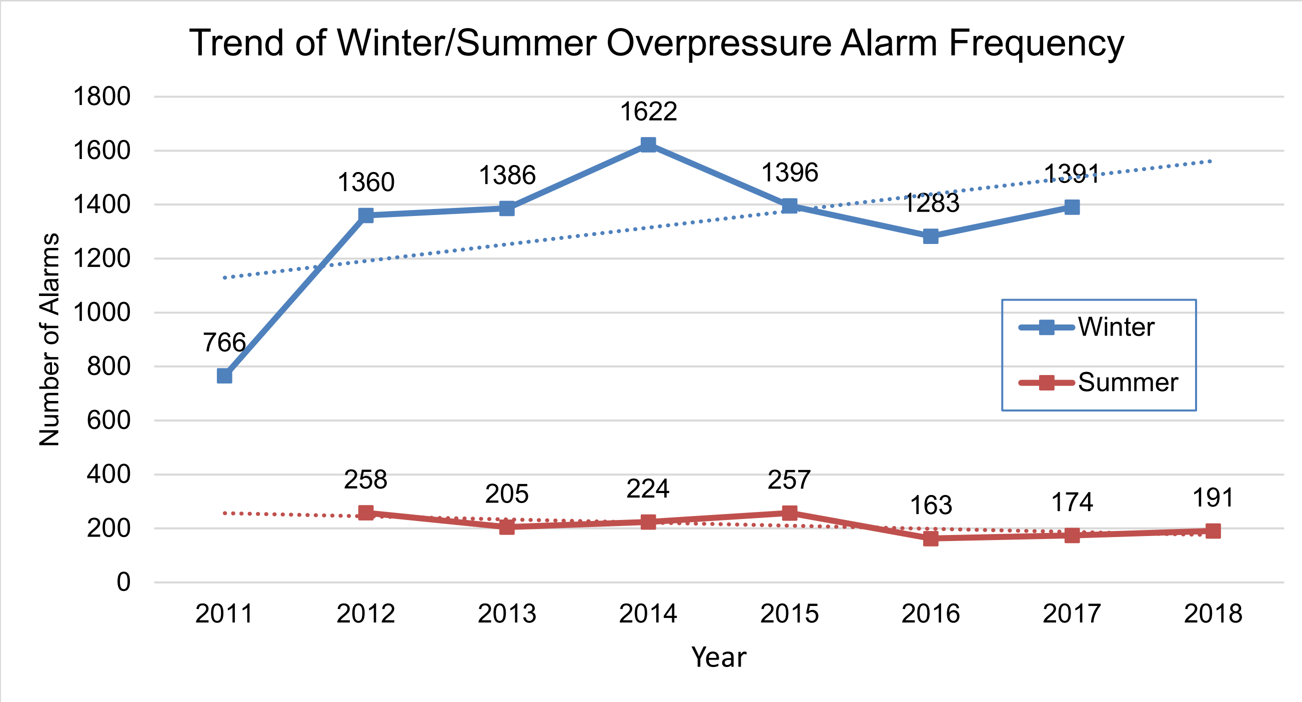
4) Trend in ISD Overpressure Alarm Frequency

In terms of ISD overpressure alarm frequency, throughout the seven year study duration, a total of 10,676 overpressure alarms occurred at 283 sites. In terms of seasonal distribution, a total of 9,204 or 86% of alarms occurred during the winter time (defined as November through February) and the remaining 1,472 or 14% of alarms occurred in the summer time (defined as April through October). In terms of vapor recovery system type, 9,547 or 89% of the alarms occurred at Phase II EVR assist equipped sites and the remaining 1,129 or 11% occurred at Phase II EVR balance equipped sites. On an annual basis, assist equipped sites average 8.9 overpressure alarms per year. Balance equipped sites average 1.5 overpressure alarms per year. The data collected in 2013, 2015, and 2018 indicate that balance equipped sites consistently exhibit a lower proportion of overpressure alarms when compared to assist equipped sites.

In terms of winter time overpressure alarm trend analysis, an upward trend is observed over the seven year data set as depicted in Figure 13. The highest number of alarms occurred in the winter of 14/15 at 1,622. On average, 1,315 alarms occur in the winter season. For this calculation, the winter of 2018/2019 was not included because only partial data set was captured.

In terms of summer time overpressure alarm trend analysis, a downward trend is observed over the seven-year duration as depicted in Figure 13. The highest number of alarms occurred in the summer of 2012 at 258. On average, 210 alarms occur in the summer season. For this calculation, the summer of 2011 was not included because only partial data set was captured.

Figure 13: Trend of Winter/Summer Time Overpressure Alarm Frequency



C. Leak Alarm Frequency

For the leak alarm data, alarm frequency was queried based on differing time frames: monthly alarm count, (with a focus on October vs November), seasonal alarm count (winter blend vs summer blend gasoline), and annual average. The following paragraphs describe the results of each query.

1) Monthly Basis

Initially, analysis was focused on the months of October and November, as that is when summer blend gasoline transitions into winter blend, uncontrolled RVP gasoline, yet ambient temperatures remain relatively high in November compared to other winter months. Table 10 compares the prevalence of leak alarms in October of 2013, 2015, and 2018 with November of 2013, 2015, and 2018. This analysis was performed for all GDF sites combined and then the split between assist and balance system sites.

For example, there was an average of 0.28 leak alarms per site in October 2018 with summertime fuel, which slightly decreased to an average of 0.23 leak alarms per site in November 2018 and wintertime fuel. From October to November, the percentage of sites with at least one alarm fell slightly from 15.9% to 15.6%. Alarms per site during that time decreased for both Assist system sites. In November 2018, 13.1% of Assist system sites had at least one leak alarm while 19.1% of Balance system sites experienced at least one alarm.

Similar results are provided within table 10 for October and November of 2013 and 2015. The key point is that a decrease in alarm frequency occurs when winter blend gasoline is introduced in early November of each year as the conversion to high RVP fuel takes place.

Table 10: Prevalence of ISD of Leak Alarms: October vs November

Data Set	Leak Alarms	Oct 2013	Oct 2015	Oct 2018	Nov 2013	Nov 2015	Nov 2018
All Sites (283)	Average Number of Alarms Per Site	0.36	0.31	0.28	0.32	0.30	0.23
	% of Sites With at Least One Alarm	16.6%	16.6%	15.9%	17.7%	15.9%	15.6%
Assist Sites (168)	Average Number of Alarms Per Site	0.36	0.40	0.22	0.31	0.33	0.17
	% of Sites With at Least One Alarm	15.5%	20.2%	13.7%	17.3%	17.9%	13.1%
Balance Sites (115)	Average Number of Alarms Per Site	0.36	0.17	0.37	0.34	0.25	0.33
	% of Sites With at Least One Alarm	18.3%	11.3%	19.1%	18.3%	13.0%	19.1%

2) Seasonal Basis: Winter Blend vs Summer Blend

In addition to monthly analysis, CARB staff performed seasonal analysis of the available data set and populated a series of data tables and charts. For seasonal analysis, winter consists of four months: November, December, January, and February. Summer consists of seven months: April, May, June, July, August, September, and October. The month of March was deliberately not included in seasonal analysis because for Northern California and Central California, March remains a transition month for winter blend gasoline. Including the month of March in this analysis can bias the results high if it is considered a summer month or bias the results low if it is considered winter month.

Table 11 and Table 12 provide the total number of alarms, the average number of alarms per month, the number of months, and the number of alarm per site per month, for each available season within the data set. Although the information is available, data from the Summer of

2011 and the winter of 2018 are not included in this analysis because each season contained only partial information. For example, the summer of 2011 was excluded because it only consisted of alarm count data for the month of October 2011. The winter of 2018/2019 was also excluded because it only contained alarm frequency data for the month of November 2018 and part of December 2018.

Table 11: Seasonal Distribution of ISD Leak Alarms Winter of 2011/2012 through Winter of 2014/2015

Parameter	Winter 2011-2012	Summer 2012	Winter 2012-2013	Summer 2013	Winter 2013-2014	Summer 2014	Winter 2014-2015
# of Alarms	285	804	413	759	296	732	305
Average # of Alarms per Month	71	115	103	108	74	105	76
# of Months	4	7	4	7	4	7	4
# of Alarms per Site per Month	0.25	0.41	0.36	0.38	0.26	0.37	0.27

Table 12: Seasonal Distribution of ISD Leak Alarms: Summer of 2015 through Summer of 2018

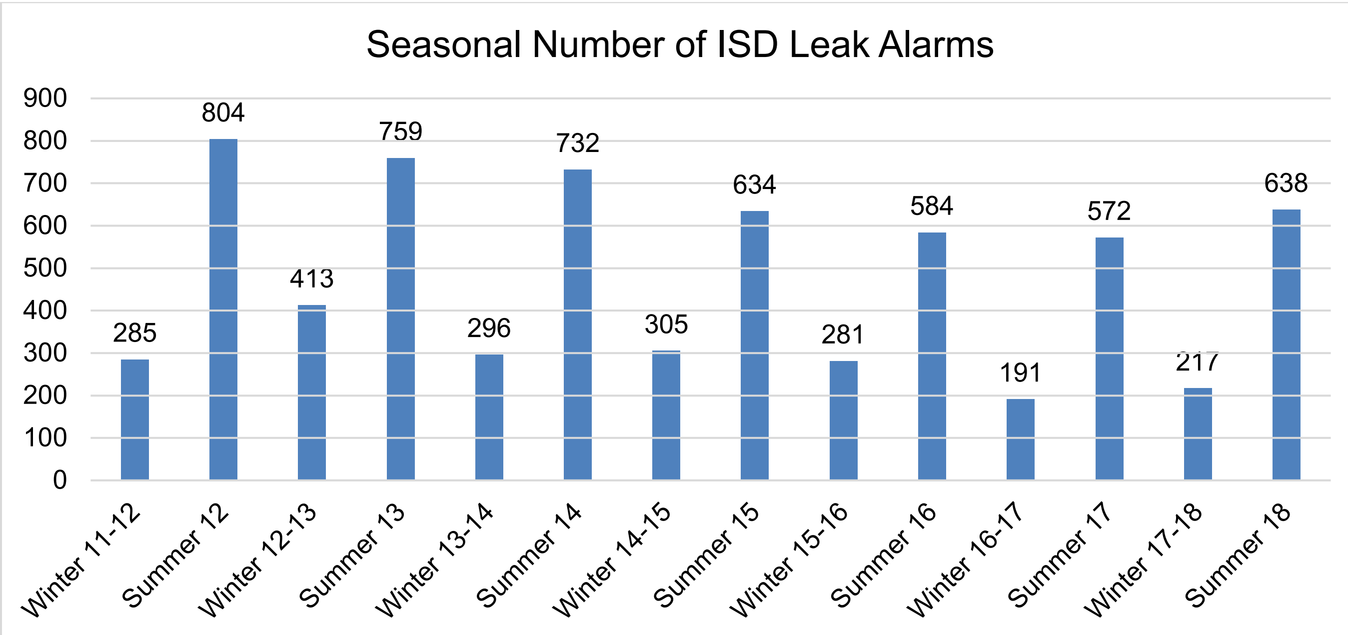
Parameter	Summer 2015	Winter 2015-2016	Summer 2016	Winter 2016-2017	Summer 2017	Winter 2017-2018	Summer 2018
# of Alarms	634	281	584	191	572	217	638
Average # of Alarms per Month	91	70	83	48	82	54	91
# of Months	7	4	7	4	7	4	7
# of Alarms per Site, per Month	0.32	0.25	0.29	0.17	0.29	0.19	0.32

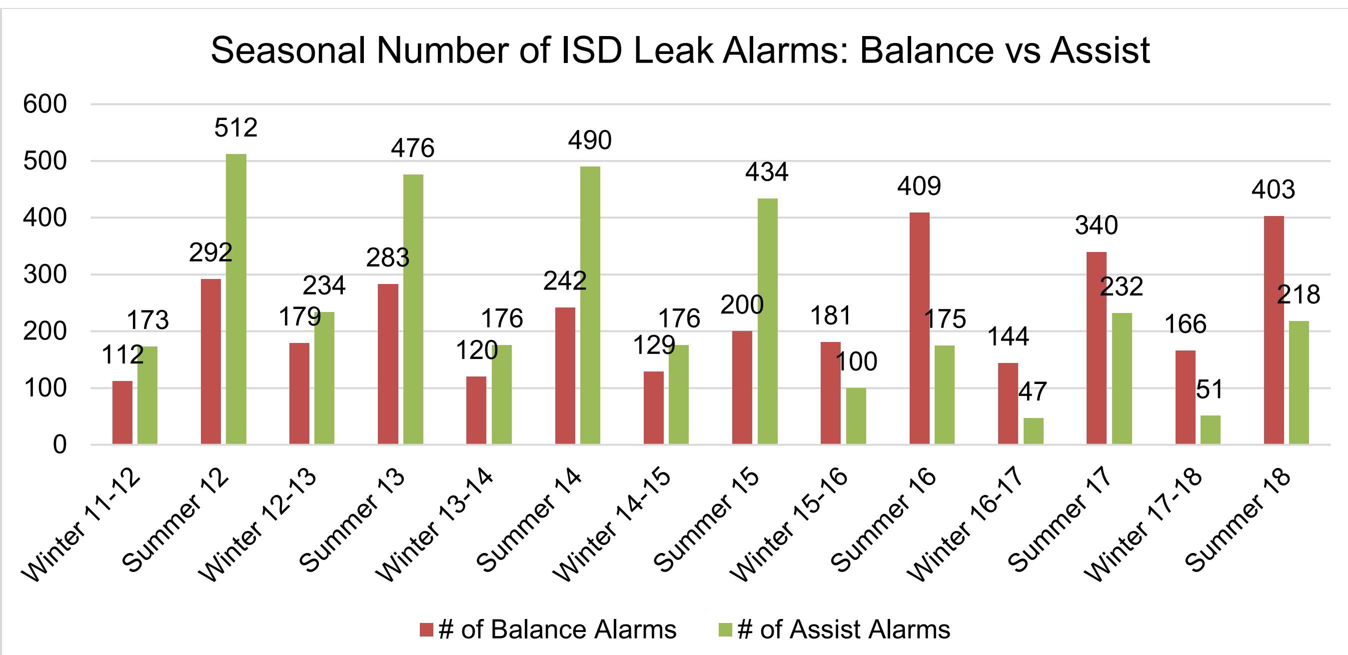
Winter of 2018-2019 not included in this summary table due to partial data set, data was downloaded in December of 2018, only 6 weeks into the 16 week winter time frame

Using the values contained in Tables 11 and 12, CARB staff created a series of bar charts to convey the results in graphical fashion. Figure 14 depicts the number of leak alarms across the 283 study sites on a seasonal basis, summer vs winter. The upper chart within Figure 14 includes all sites combined. The lower chart within Figure 14 breaks apart the balance and assist sites. Figure 14 provides clear evidence that a strong correlation exists between a decrease in leak alarm frequency and winter blend gasoline. Figure 14 also provides evidence that the vast majority of leak alarms occur during the summer season. This is likely due to the fact that in the summer, due to low RVP gasoline, evaporation rates within the

UST are suppressed. In the winter, due to high RVP gasoline, evaporation rates within the UST can average around 100 gallons per hour. As such, higher evaporation rates in the winter can mask containment leaks within the UST system.

Figure 14: Seasonal Number of Leak Alarms





3) Annual Average Basis

As indicated in the Table 13, staff determined the average number of leak alarms per year per site by tabulating the total number of alarms (within the entire data set) and dividing by the total number of sites (within the data set), then dividing that value by the number of years of the study duration. Given the large amount of monthly alarm frequency information within the data set, determining the annual average number of leak alarms per site is very helpful when attempting to summarize the results. This same method was conducted for all sites, assist sites, and balance sites. On average, a typical site will experience 3.7 leak alarms per year. On average, assist equipped sites will experience 3.2 leak alarms per year. On average, balance equipped sites will experience 4.3 alarms per year. Balance equipped sites are more prone to exhibit leak alarms.

As with the seasonal analysis, for the annual average analysis, the month of March was deliberately not included because for Northern California and Central California, March remains a transition month for winter blend gasoline. Including the month of March for annual analysis can bias the results high if it is considered a summer month or low if it is considered winter month. In addition, although the information is available, data from the Summer of 2011 and the winter of 2018 are not included in this analysis because each year contained only partial information.

Table 13 provides the values needed to perform the calculation. These include the total number sites, total number of leak alarms for the entire study duration, the study duration in months, the average number of alarms per site, the study duration in year, and the average number of alarms per site per year.

Table 13: Annual Average Number of Leak Alarms

Phase II System Type	Site Count	Total Number of Alarms Duration of Study	Study Duration Months	Average Number of Alarms Per Site Over Entire Study Duration	Study Duration Years	Average Number of Alarms Per Site Per Year
All Sites	283	6,711	77	23.7	6.4	3.7
Balance Sites	115	3,217	77	27.8	6.4	4.3
Assist sites	168	3,494	77	20.8	6.4	3.2

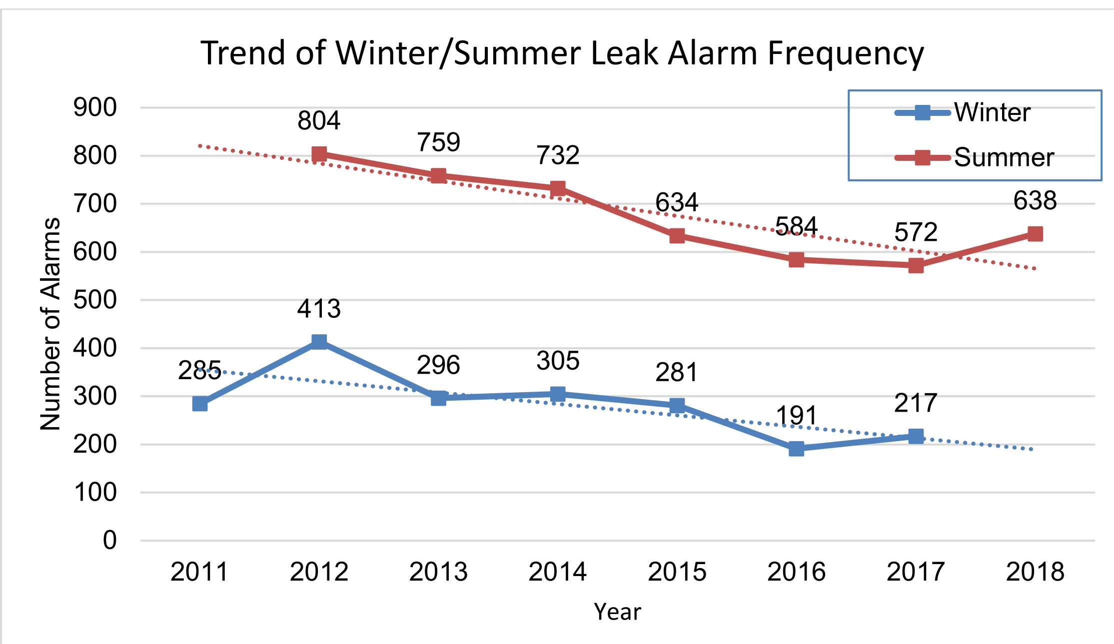
4) Trend in ISD Leak Alarm Frequency

In terms of ISD leak alarm frequency, throughout the seven year study duration, a total of 6,711 leak alarms occurred at 283 sites. In terms of seasonal distribution, a total of 1,988 or 30% of alarms occurred during the winter time (defined as November through February) and the remaining 4,723 or 70% of alarms occurred in the summer time (defined as March through October). In terms of vapor recovery system type, 3,494 or 52% of the alarms occurred at Phase II EVR assist equipped sites and the remaining 3,217 or 48% occurred at Phase II EVR balance equipped sites. On an annual basis, assist equipped sites average 3.2 leak alarms per year. Balance equipped sites average 4.4 leak alarms per year. The data collected in 2013, 2015, and 2018 indicate that balance equipped sites consistently exhibit a higher proportion of leak alarms than assist equipped sites.

In terms of winter time leak alarm trend analysis, a general downward trend is observed over the seven year data set as depicted in Figure 15. The highest number of alarms occurred in the winter of 12/13 at 413. On average, 284 leak alarms occur per winter season. For this calculation, the winter of 2018/2019 was not included because only partial data set was captured.

In terms of summer time leak alarm trend analysis, a downward trend is observed over the seven year duration as depicted in Figure 15. The highest number of alarms occurred in the summer of 2012 at 804. On average, 675 leak alarms occur per summer season. For this calculation, the summer of 2011 was not included because only partial data set was captured

Figure 15: Trend of Winter/Summer Time Leak Alarm Frequency



D. Percentage of GDF Exhibiting PWD

One of main objectives of this multi-year field study was to identify the number of GDF sites that exhibit UST ullage pressure increase while gasoline is being dispensed (PWD). Once the prevalence of PWD is determined, it can be used in connection with other field studies, to estimate the magnitude of pressure driven emissions on a statewide basis.

As described in the methodology section of this document, within a segment of the ISD data collected in 2013, 2015 and 2018, staff examined UST ullage pressure and UST ullage volume data to identify the number and percentage of sites experiencing PWD. Table 14 identifies the number of sites experiencing PWD in December 2013, 2015, and 2018. Table 15 identifies the percentage of sites exhibiting PWD in December of each year.In December of 2018, out of 283 GDF sites, 57 sites experienced PWD, which equates to 20.1%. In December of 2015, out of 283 sites, 72 experienced PWD, which equates to 25.4%. In December of 2013, out of 283 sites, 59 experienced PWD, which equates to 20.8%. For reference, the full data set is provided within this report as Appendix XIII

Further analysis shows that in December of 2013, 2015, and 2018, that all of the sites experiencing PWD, are equipped with the Phase II EVR assist system. Conversely, balance equipped sites do not exhibit PWD in any of the years surveyed.

Table 14: Number of GDF Exhibiting PWD in December of 2013, 2015, and 2018

Phase II System Type	Number of Sites	December 2013	December 2015	December 2018
All Sites	283	59	72	57
Balance Sites	115	0	0	0
Assist Sites	168	59	72	57

Table 15: Percentage of GDF Exhibiting PWD in December of 2013, 2015, and 2018

Phase II System Type	Number of Sites	% PWD December 2013	% PWD December 2015	% PWD December 2018
All Sites	283	20.8%	25.4%	20.1%
Balance Sites	115	0.0%	0.0%	0.0%
Assist Sites	168	35.1%	42.9%	33.9%

In terms of regional/geographical analys, data collected in December of 2015 indicated that 50% of assist equipped sites located in Southern California exhibited PWD, while about 31% of assist sites located in Northern California exhibited PWD. Staff performed the same analysis on 2018 data set and found the opposite trend. In other words, assist sites located in Northern California exhibited a relatively higher percentage of PWD than sites located in Southern California. Results are provided in Table 17 below. In December of 2018, a total of 65 assist equipped sites were located in Northern California. Of this population, 26 experienced PWD. In December of 2018, a total of 103 assist equipped sites were located in Southern California. Of this population, 31 experienced PWD. The percentage of Northern California sites with PWD in December 2018 was 40.0% while the percentage of Southern California sites with PWD was 30.1%. This lack of repeatability between 2015 and 2018 may be due to the longitudinal assessment performed on this data. As previously mentioned, the site population changed over time due to converting from assist to balance, approximately 15% of assist converted in between 2013 and 2015 and another 16% converted from 2015 to 2018.

Table 16: Prevalence of PWD: Northern vs Southern California in December 2018

Region	Number of Assist Sites	Number with PWD in December 2018	Percentage with PWD in December 2018
Northern California	65	26	40.0%
Southern California	103	31	30.1%

Table 17: PWD in Southern California vs Northern California 2013, 2015, and 2018

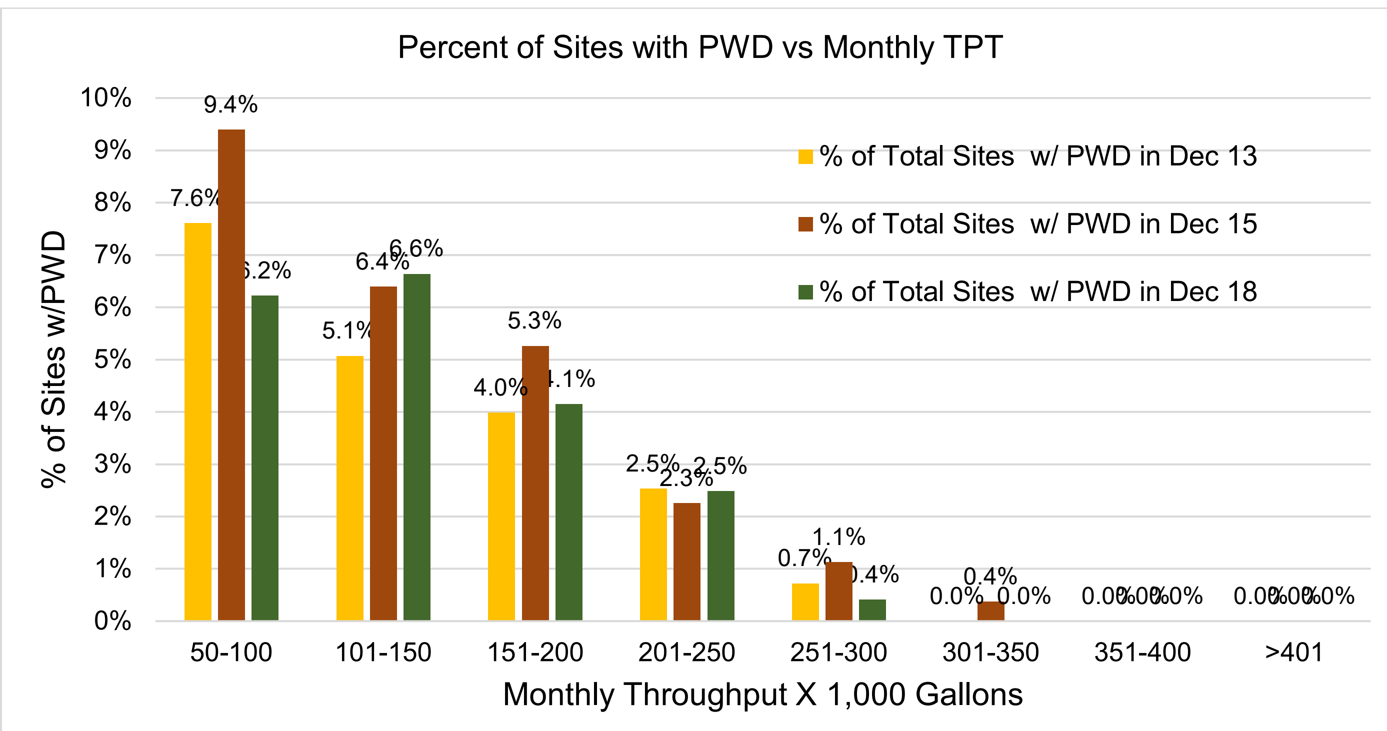
Area	**# of Assist Sites**	**# with PWD in December 2018**	**% with PWD in December 2018**	**% with PWD in December 2015**	**% with PWD in December 2013**
Northern California	65	26	40.0%	30.8%	40.0%
Southern California	103	31	30.1%	50.5%	32.0%

CARB staff further queried the data to determine if a relationship existed between PWD and monthly gasoline throughput. As indicated in Table 18, the average monthly throughput for PWD GDF ranges between 120,000 and 130,000 gallons per month. The average monthly throughput for non-PWD sites ranges between 200,000 and 240,000 gallons per month. On average, non PWD sites have a monthly throughput of 100,000 gallons greater than PWD sites. This supports the CARB staff assumption that the larger volume dispensed per month, the larger amount of space created is in the UST allowing for higher evaporation rate and thus, larger throughput sites are less likely to exhibit PWD. This also supports that fact that operating parameters play a key role with the magnitude of emissions.

Table 18: Relationship between PWD and Monthly Gasoline Throughput:

% of Assist Sites with PWD	35.12%	42.86%	33.93%
% of Assist Sites without PWD	64.88%	57.14%	66.07%
# of Assist Sites with PWD	59	72	57
# of Assist Sites without PWD	109	96	111
Average Monthly TPT at sites with PWD	127,847	130,417	122,696
Average Monthly TPT at sites without PWD	236,772	238,927	204,212

Figure 16: Relationship between PWD and Monthly Gasoline Throughput



In terms of trend analysis, this multi-year study confirmed the continued existence of pressure-increase-while-dispensing (PWD) at a significant percentage of GDF surveyed. Documenting the prevalence of PWD provides CARB staff with a key parameter for determining the magnitude of statewide annualized pressure driven emissions. In 2013, 59 sites or 21% of the GDF population surveyed exhibited PWD. In 2015, 72 sites or 25% of the GDF population surveyed exhibited PWD. In 2018, 57 sites or 20% of the GDF population surveyed exhibited PWD. This suggests that prevalence of PWD has peaked in 2015 and declined in 2018 to lowest level recorded. In terms of Phase II vapor recovery system type, PWD occurs exclusively at assist equipped GDF. PWD does not occur at balance equipped GDF. Lastly, the survey confirmed that PWD only occurs during the winter months, November through February at sites with a monthly throughput of less than 350,000 gallons.

Table 19: Prevalence of PWD December of 2013 and 2015 and 2018

Site Type	# of Sites	% with PWD in December 2013	% with PWD in December 2015	% with PWD in December 2018
All Sites	283	20.8%	25.4%	20.1%
Balance Sites	115	0.0%	0.0%	0.0%
Assist Sites	168	35.1%	42.9%	33.9%

Examining the PWD information on a regional basis shows a high variation of results and lack of repeatability or clearly identifiable pattern. Table 20 below provides the percentage of PWD for each of the surveys broke up into nine geographic regions with the sample set. This provides further evidence that PWD and severity of overpressure conditions is difficult to predict in advance.

Table 20: Regional Prevalence of PWD in California

Area	% PWD - Dec 2013	% PWD - Dec 2015	% PWD - Dec 2018
Bay Area - Overall	29.3%	20.8%	23.9%
Mojave Desert - Overall	57.1%	33.3%	0.0%
Mountain - Overall	25.0%	12.5%	33.3%
North Coast - Overall	0.0%	0.0%	0.0%
Sacramento - Overall	8.0%	7.7%	11.4%
San Diego - Overall	19.2%	34.8%	15.5%
San Joaquin - Overall	43.6%	26.5%	32.1%
San Luis Obispo - Overall	25.0%	33.3%	30.8%
South Coast - Overall	21.8%	36.8%	20.0%

E. Site Average Vapor-to-Liquid Ratio

To assess the relationship between excess air ingestion at the nozzle and the occurrence of PWD, staff compared the site average vapor to liquid (V/L) ratios of PWD to non-PWD system sites. Utilizing PWD information from the 2013/2014 Mega Blitz study as a starting point, staff compared V/L average the of sites located in South Coast and San Diego that did and did not experiencing PWD in all three surveys: December 2013, 2015 and 2018. The 13 non PWD South Coast sites had an average V/L of 0.59 and the 19 non PWD San Diego sites had and average V/L of 0.54. Sites with PWD in 2013, 2015 and 2018 were also compared. Eight South Coast PWD sites had an average V/L of 0.64 and one San Diego PWD site had an average V/L of 0.60.

As indicated in the methodology section of this report, the ISD downloads contain the most recent 1000 fueling transactions for each dispenser. This is typically representative of the most recent two weeks of data. Unlike the ISD alarm history for overpressure or leaks, it was not possible to generate results on a seasonal or monthly basis.

Table 21: Site Average V/L Ratios Generated at PWD and Non-PWD GDF

PWD in December 2013	PWD in December 2015	PWD in December 2018	2018 Site V/L Average SCAQMD	2018 Site V/L Average SDCAPCD
No	No	No	0.59 (13 sites)	0.54 (19 sites)
Yes	Yes	Yes	0.64 (8 sites)	0.60 (1 sites)

This prompted staff to further investigate the available data because there was only one site exhibiting PWD in 2013, 2015, and 2018 within the data set for San Diego. Due to the limited amount of information in San Diego, staff assumed that reliance on only one site is not statistically valid.

As an alternative analysis, the site average vapor to liquid data was further queried to focus solely on PWD and non PWD sites located in the South Coast AQMD for all three years. This was done for several reasons including:

- 40% of the California's GDF population resides within the South Coast AQMD,
- South Coast AQMD has a rigorous vapor recovery enforcement program with dedicated section solely responsible for GDF
- South Coast AQMD prohibitory Rule 461 requires GDF to test vapor recovery systems twice per year if throughput is over 100,000 gallons per month
- Due to data analysis resource constraints, it was not possible to conduct this analysis on all assist sites captured in the study for all three surveys

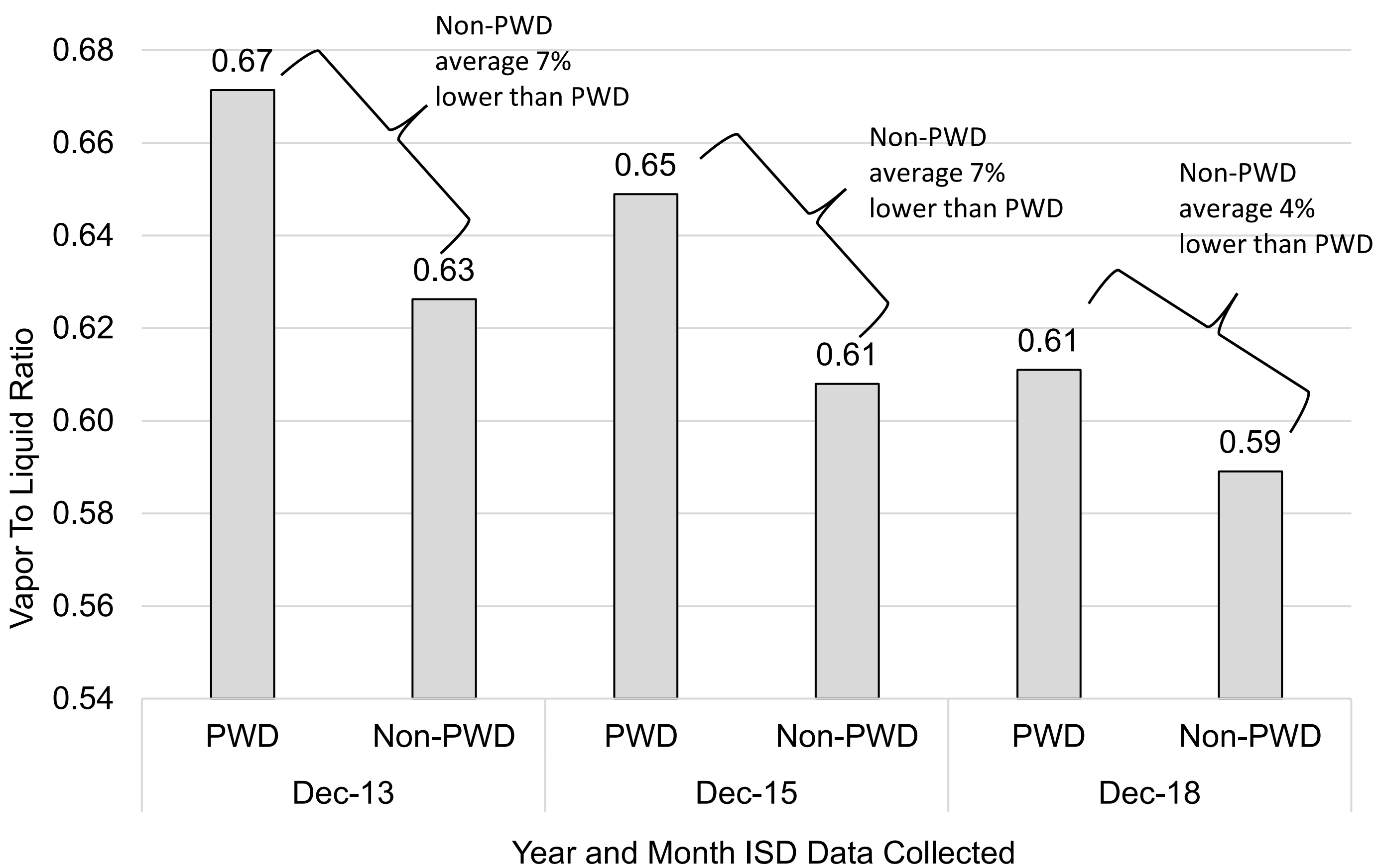
The results of this alternative analysis are presented in Table 22. For each year, site average vapor to liquid ratios were generated for approximately 40 sites in South Coast AQMD. Half of the sites were selected because they exhibited PWD, the other half were selected because they did not exhibit PWD. One the site averages were determined, they were combined for each category, for each year. As indicated in the table, percent difference was calculated when comparing the results of the PWD and non PWD site averages.

Table 22: Site Average V/L Ratios Generated at PWD vs Non PWD

Date	Status	Site Average V/L	Count	Percent Difference Non PWD vs PWD	Percent Difference PWD vs Non PWD
Dec-13	PWD	0.67	21	7.2% lower	6.7% higher
	Non-PWD	0.63	21		
Dec-15	PWD	0.65	19	6.7% lower	6.3 % higher
	Non-PWD	0.61	20		
Dec-18	PWD	0.61	18	3.7% lower	3.6% higher
	Non-PWD	0.59	28		

As depicted in Figure 18, GDF that exhibit PWD continued to exhibit higher site average vapor to liquid ratios when compared to non-PWD. This finding suggests that PWD sites are more likely to experience excess air ingestion during fueling events. In terms of trend analysis, the average vapor to liquid ratio at non PWD sites was 7% lower when compared to PWD sites in both 2013 and 2015. In 2018 the same trend continued, but to a slightly less pronounced as the non PWD site average vapor to liquid ratio was 4% lower when compared to PWD sites.

Figure 18: Comparison of Site Average Vapor to Liquid Ratios at Non PWD and PWD GDF Located in South Coast AQMD



F. Vapor Recovery Nozzle Survey

This section of the report provides the results of three different nozzle surveys conducted at various times throughput the seven year study period. The first survey was to determine in use performance of the Healy assist nozzle's interlock feature. The second was to determine balance nozzle make and model distribution of the two certified nozzles: VST and EMCO. The third was to help determine implementation rate of the new Healy assist nozzle design, known as EOR, that was certified in August of 2017. Results of each study are provided in the paragraphs below.

1) Healy Model 900 Assist Nozzle Interlock Testing (Dec 2015)

In examining the interlock of the Healy Model 900 Assist system nozzle, staff tested 414 nozzles at 57 GDFs located in 5 districts. Using the nozzle interlock inspection criteria described in Section III of this document, 25 nozzles failed, for a 6% failure rate. 94% of nozzles tested dispensed no fuel while the boot was not compressed. The full data set, see appendix VII.

Table 23: Healy Model 900 Assist Nozzle In-Use Interlock Testing Results

Total Number of Nozzles	Number of Nozzles that Pass	Number of Nozzles that Fail	Percentage of Nozzles that Pass	Percentage of Nozzles that Fail
414	389	25	94%	6%

CARB staff found that the failure rate was only 6% as opposed to the reported 25% from the stakeholder at the 2015 workshop. The failure of nozzle interlock does indicate that there are a number of Assist nozzles statewide that can dispense fuel without the boot being compressed, thus allowing the ingestion of air and contributing to PWD and overpressure. However, a failure rate of 6% does not indicate a widespread or significant occurrence. As such, CARB staff assumes that interlock failure certainly does not help, but never the less, was not considered as a significant contributor to the statewide PWD and overpressure phenomenon.

2) Balance Nozzle Distribution (Dec 2018)

In December of 2018, the decision was made to record the make and model of nozzles installed at Phase II EVR balance equipped facilities. Staff went to 116 sites located throughout nine air districts. A total of 1,151 balance nozzles were documented, of which, 990 were VST and 161 were EMCO nozzles. The full data set for this analysis is provided within Appendix XI. The table below provides the results of this analysis in summary fashion.

Table 24: Comparison of VST and EMCO Nozzles at Balance sites December of 2018

Total number of Nozzles	Number of VST Nozzles	Number of EMCO Nozzles	Percentage of VST Nozzles	Percentage of EMCO Nozzles
1,151	990	161	86.0%	14.0%

3) Healy Model 900 Assist Nozzle EOR Population (Feb-Mar 2019)

In late February and early March of 2019, CARB staff returned to the majority of assist equipped sites to conduct an EOR nozzle survey. Out of 168 assist sites in the December 2018 population, CARB staff returned to 147 sites. The total number of assist nozzles per site were recorded, then further categorized as EOR and non EOR. The full data set for this analysis is provided within appendix XII. Table 25 below provides the results of this analysis in summary fashion. As of March of 2019, EOR nozzles occupy 45% of the assist site population.

Table 25: EOR Nozzle Penetration with Assist Site Population of the Mega Blitz

Total number of Assist sites survey	146
Total number of PWD sites	50
PWD % of analyzed sites	34.2%
Total Number of Nozzles surveyed	1,523
Total Number of Non-EOR nozzles	838
Total Number of EOR nozzles	685
% EOR	45.0%

V. Conclusions

Many factors contribute to overpressure conditions at GDFs. The primary cause is uncontrolled Reid Vapor Pressure (RVP) of gasoline available in the winter months from November to March. Wintertime fuel RVP is higher than that of summertime fuel and leads to greater volatility, higher UST system pressure, and greater emissions. Other important factors include type of Phase II EVR system (Assist versus Balance), excess air ingestion at the nozzle, monthly throughput, and GDF operating hours. Even when these parameters are clearly defined, predicting the frequency of alarms and the severity of overpressure conditions is problematic.

Upon reflection of the results presented within this document, conclusions can be drawn pertaining to overpressure alarm frequency, leak alarm frequency, prevalence of PWD, and relationship between site average vapor to liquid ratio and severity of overpressure conditions. It is worth reiterating that the following conclusions are based upon a longitudinal analysis of the data set, meaning that to the extent possible, in order to be included in this analysis, GDF operating parameters and ISD downloads were identical for each site for all three surveys conducted in 2013, 2015, and 2018.

<u>Overpressure Alarms</u>

A. 86% of overpressure alarms are concentrated over the course of four winter months: November through February. The seasonal distribution in overpressure alarm frequency is attributed to uncontrolled RVP fuel.
B. 14% of overpressure alarms are distributed over the course of seven summer months, further reducing the frequency on a monthly basis
C. 89% of overpressure alarms occurred at 168 assist equipped sites
D. 11% of overpressure alarms occurred at 115 balance equipped sites

<u>Leak Alarms</u>

E. 30% of leak alarms occur over the course of four winter months: November through February.
F. 70% of leak alarms are distributed over the course of seven summer months, further reducing the frequency on a monthly basis
G. 52% of leak alarms occurred at 168 assist equipped sites
H. 48% of leak alarms occurred at 115 balance equipped sites

<u>Pressure Increase While Dispensing</u>

I. During the winter fuel season, PWD remains at a significant percentage of GDF, approximately 20% of the sites surveyed
J. Balance system equipped sites do not exhibit PWD, suggesting that further investigation may be warranted to determine if balance systems somehow mask pressure driven emissions due to reverse flow at the nozzle vapor path

<u>Site Average Vapor to Liquid Ratio</u>

K. During winter fuel season, PWD assist system sites exhibit a higher V/L ratio (ranging from 4-7% higher) when compared to non-PWD assist sites, suggesting that excess air ingestion at the nozzle into the UST system is a key contributor.

VI. Recommendations

A comprehensive solution to the overpressure issue will likely require a menu of options, tied to GDF operational characteristics such as monthly throughput, operating hours, percentage of ORVR vehicles, type of dispensing nozzle, and type of vapor processor installed. As a statewide regulatory agency, CARB staff recognizes that monthly gasoline throughput, ORVR population, and hours of operation can vary from site to site. As a result, predicting the frequency of alarms and the severity of overpressure conditions is very challenging. Despite this variation, CARB can make improvements to the compatibility of Phase II EVR nozzles and vehicle fill pipe designs. We can also amend the ISD overpressure alarm thresholds to provide more meaningful information for the GDF operator.

In terms of recommendations, CARB staff suggests that the following additional field studies be completed and the results be shared with all interested parties:

- Make available the results of this multiyear field survey with various stakeholders so that additional query of the data set can be performed;
- Conduct further study of the EOR version of the assist system nozzle to determine whether a better seal between the nozzle and the vehicle reduces excess air ingestion into the UST system;
- Quantify vent line and fugitive emissions from assist sites exhibiting PWD to better understand the magnitude of emissions;
- Although balance equipped sites experience relatively few overpressure alarms and do not exhibit PWD, it is possible that reverse flow through the nozzle vapor path (occurs when the nozzle vapor valve is open and positive pressure exists within the storage tank headspace) may help relieve positive pressure conditions, thus leading to far fewer alarms. To further understand the contribution of reverse flow and balance system operation, two additional field studies are recommended:
    - Develop nozzle specific (VST and EMCO) collection emission factors for both ORVR vehicles and non-ORVR vehicles when the UST headspace is held at slightly positive pressure;
    - Establish a representative number of long term balance system study sites to quantify the volume of gasoline dispensed at positive pressure and to quantify revers idle flow emissions
- Consider amending the ISD overpressure alarm criteria from “time at pressure” to site specific “emission based;”
- Continue work with other branches within CARB to determine appropriate fill pipe specifications for gasoline powered vehicles;
- Conduct an Assist Nozzle On-board Refueling Vapor Recovery (ORVR) Vehicle recognition study to determine trend in performance
- Consider amendment of CARB GDF emission factors pertaining to pressure driven or breathing losses to reflect our latest understanding

VII: Appendices

Appendix I: Field Data Collection Form

Appendix II: ISD Download Instructions

Appendix III: ISD Overpressure Alarm Frequency Spreadsheet

Appendix IV: ISD Leak Alarm Frequency Spreadsheet

Appendix V: Example VR 1400 PU Plot

Appendix VI: Example Histogram Assistant Tool (HAT)

Appendix VII: Executive Order VR-202, IOM Sections 1 and 2

Appendix VIII: Healy Model 900 Assist Nozzle In-Use Interlock Test Results

Appendix IX: Parameters Effecting UST Pressure Profiles

Appendix X: Site Average Vapor to Liquid Ratio Analysis

Appendix XI: Balance Nozzle Survey 2018

Appendix XII: Healy Nozzle Survey 2019

Appendix XIII: PWD Analysis 2013, 2015, & 2018