CALIFORNIA AIR RESOURCES BOARD

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

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Overpressure Study

Technical Support Document: Evaluation of Healy Model 900 Assist Vapor Recovery Nozzle with Enhanced On-Board Refueling Vapor Recovery (ORVR) Vehicle Recognition Feature during the winter of 2015/2016

November 28, 2017

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Executive Summary

Throughout the winter of 2015/2016, California Air Resources Board (CARB) staff evaluated the performance of Healy Model 900 assist vapor recovery nozzles equipped with a prototype design feature called "Enhanced On-Board Refueling Vapor Recovery (ORVR) Vehicle Recognition" (EOR nozzle[1]). The EOR nozzle was developed by Franklin Fueling Systems[2] in response to a prior field study conducted by CARB staff (Assist Nozzle ORVR Recognition Study) which found that the conventional Healy Model 900 nozzle experiences excess air ingestion due to a poor seal at the vehicle fill pipe and nozzle interface with approximately 30% of vehicles equipped with ORVR. Excess air ingestion at the nozzle is of concern when combined with winter blend gasoline because it contributes to overpressure conditions within the headspace of the underground storage tanks which may lead to atmospheric venting of gasoline vapors. In some instances, excess air ingestion results in a severe form of overpressure known as "pressure increase while dispensing" (PWD).

To assess the effectiveness of EOR nozzles, arrangements were made to have EOR nozzles installed at four gasoline dispensing facilities (GDF), each with differing operating conditions. It should also be noted that the EOR feature of the nozzle can be retrofitted and replaced in the field[3] which adds an additional variable that was considered for this evaluation.

The EOR nozzle evaluation occurred over the course of five months (November 2015 to March of 2016) and involved the installation of 38 nozzles at four retail GDF located in various geographic regions in California. In addition to EOR nozzles, each GDF was equipped with an In-Station Diagnostic (ISD) system and a specialized CARB ISD data acquisition system, which allowed continuous capture of information pertaining to vapor recovery system performance before and after installation. The objective of the evaluation was to determine the effectiveness of the EOR nozzle with regard to improved ORVR vehicle recognition and mitigation of overpressure conditions, including PWD.

The first test site at which EOR nozzles were installed (at a retail GDF environment) was located in Granite Bay and was equipped with an **equal number** of conventional Healy Model 900 nozzles and EOR nozzles. At this facility, customer acceptance and potential unintended consequences of the new design (such as getting stuck in the vehicle fill pipe or premature shutoff) were evaluated. Although limited testing was

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[1] The EOR design feature of the Healy Model 900 nozzle was certified by CARB in August of 2017 per "Revision V" of Assist System Executive Orders VR-201 and VR-202. For ease of comparison, the non-EOR version of the Healy Model 900 nozzle is referred to as the "conventional nozzle" throughout this document. At the time this document was released, both nozzle versions are listed in the Assist System Executive Orders.

[2] Franklin Fueling Systems is the manufacturer of the Healy Model 900 Nozzle.

[3] The EOR design features are limited to the spout assembly section of the nozzle which can be replaced in the field on existing nozzles or factory assembled on new nozzles.

conducted, due to the test site's operating characteristics and the partial installation of EOR nozzles, the EOR nozzle improved ORVR vehicle recognition as determined by lower air ingestion and demonstrated favorable customer acceptance.

The second test site was located in San Diego and was equipped with 12 **field retrofitted** EOR spout assemblies. The EOR nozzle was effective at lowering air ingestion due to improved ORVR vehicle recognition. However, this evaluation was deemed inconclusive due to the transition from winter blend to summer blend gasoline and numerous vapor recovery component leaks which may have compromised leak integrity of underground storage tanks.

The third test site was located in Campbell and was equipped with eight **factory assembled** EOR nozzles. At this location, ORVR vehicle recognition was dramatically improved, UST pressure lowered, air ingestion reduced, and PWD was mitigated during the period when winter blend gasoline was sold.

The fourth test site was located in Gilroy and was equipped with twelve **factory assembled** EOR nozzles. At this location, ORVR vehicle recognition was dramatically improved, UST pressure lowered, air ingestion reduced, and PWD was mitigated during the period when winter blend gasoline was sold.

The results of this evaluation suggest that the EOR nozzle provides improved ORVR vehicle recognition and reduced air ingestion which should reduce the frequency of overpressure alarms and severity of PWD conditions at assist equipped GDF. Because this evaluation occurred at the tail end (February – March) of the 2015/2016 winter blend gasoline distribution time frame, CARB staff recommends that additional field studies be conducted in the future at a larger number of test sites to more completely assess the ability to mitigate overpressure conditions and reduce ISD alarm frequency.

I. Introduction

In the fall of 2013, CARB staff initiated an extensive field study which involved downloading ISD data from nearly 400 gasoline dispensing facilities (GDF) throughout California to help identify the key contributors and develop potential solutions to the overpressure phenomena. This study was conducted in close collaboration with local air districts, through California Air Pollution Control Officers Association's (CAPCOA) Vapor Recovery Subcommittee.

Due to the extensive amount of information collected in 2013, CARB staff in May 2014 formed an Overpressure Working Group with CAPCOA which was tasked with analyzing the data and identifying potential causes and solutions to the overpressure phenomena. One of the key findings from the 2013 study was that the majority of GDFs which exhibited overpressure were equipped with the Assist Phase II EVR system and those which exhibit PWD were found exclusively on approximately 33% of the assist site population. The assist sites which exhibited PWD were also found to have a higher site average vapor to liquid ratio when compared to assist sites which did not exhibit PWD.

In January 2015, CARB staff and CAPCOA staff conducted a statistically valid, in-use fueling survey to determine the ORVR vehicle recognition rate of the conventional Healy Model 900 assist vapor recovery nozzle. A key finding from this survey was that the mis-identification rate of the existing Healy nozzle with ORVR equipped vehicles is about 30%. This misidentification results in excess air ingestion[4]. Another key finding was that the Healy Model 900 nozzle can refuel without being fully engaged (latched) into the vehicle fill pipe.

In August 2015, these findings were shared with Franklin Fueling Systems (FFS), the company which manufactures the Healy Assist Phase II vapor recovery system. In response to these findings, FFS developed a new design feature called Enhanced ORVR-Vehicle Recognition or that is intended for use with the Healy Model 900 assist vapor recovery nozzle. The EOR design feature of the Healy Model 900 nozzle was certified by CARB in August of 2017 per "Revision V" of Assist System Executive Orders VR-201 and VR-202. For ease of comparison, the non-EOR version of the Healy Model 900 nozzle is referred to as the "conventional nozzle" throughout this document. At the time this document was released, both nozzle versions are listed in the Assist System Executive Orders.

The objective of this evaluation was to determine the effectiveness of the EOR nozzle with regard to improved ORVR vehicle recognition and mitigation of overpressure conditions within the underground storage tanks. This document provides the sequence

[4] Some air ingestion is related to vehicle fill pipe design. The EOR nozzle will not be a solution where the fill pipe is the source of air ingestion and thus, 100% ORVR recognition is not achievable with the EOR nozzle.

of events, summary of results, and discussion of key findings pertaining to EOR nozzle performance.

II. Methodology

For each test site at which EOR nozzles were evaluated, a multi-step methodology was followed. The EOR nozzle was the “manipulated variable” and all other vapor recovery system components were considered “controlled variables” and to the extent possible, were not to be altered. As depicted in Figure II-1, the methodology consists of several steps which include identification of a GDF that exhibits overpressure including PWD, installation of an ISD data acquisition system, validation of properly operating vapor recovery system, installation of EOR nozzles, capture of pertinent ISD data, and lastly, comparison of key benchmarks before and after installation.

Figure II-1: Multi Step Methodology for EOR Nozzle Evaluation

Step 1
- Identify GDF which routinely exhibits overpressure alarms (and PWD) during the winter fuel season and is equipped with Phase II EVR assist system including ISD.

Step 2
- Obtain permission from GDF operator to install monitoring equipment, and allow CARB to conduct testing.

Step 3
- Install monitoring equipment, and capture ISD data prior to EOR nozzle install to establish baseline operating conditions.

Step 4
- Conduct Phase I, Phase II, and ISD vapor recovery system testing to establish baseline operating conditions.

Step 5
- If necessary, make repairs and or adjustments to vapor recovery system to ensure compliance with applicable performance standards and eliminate biases.

Step 6
- Replace existing conventional nozzles with EOR nozzles at desired fueling positions. Conduct RVP sample collection to the extent possible.

Step 7
- Allow the site to operate as normal for several days, then capture pertinent ISD data and in limited cases, conduct an ORVR vehicle recognition survey.

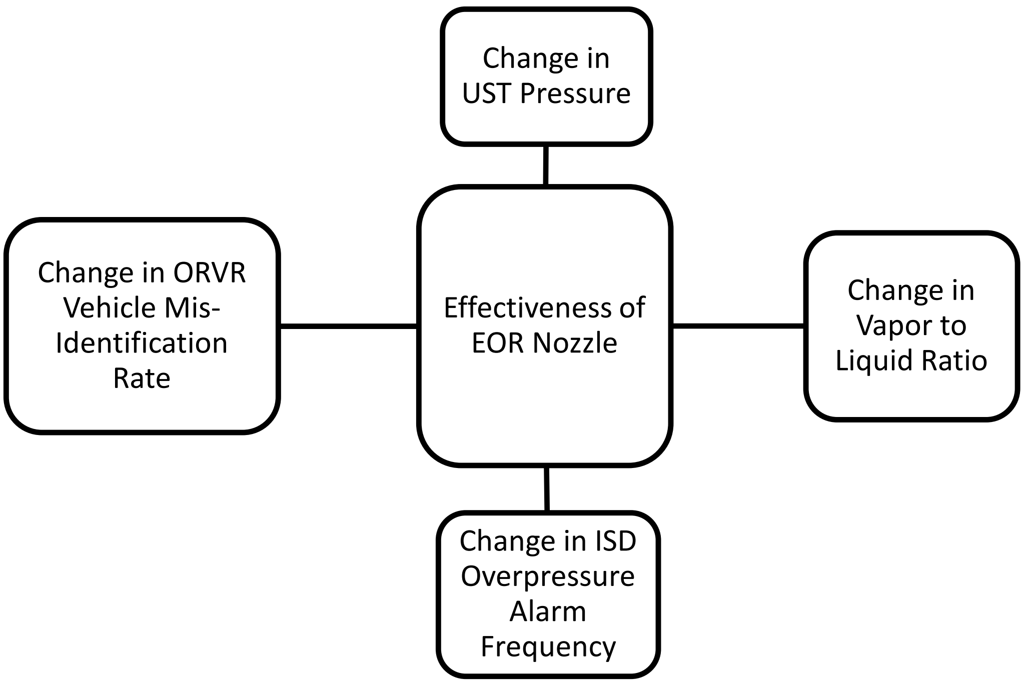
Step 8
- Perform analysis of vehicle survey data and/or ISD data, including change in pressure profile, change in V/L ratio, and change in ISD overpressure alarms before and after.

Step 9
- Document findings and draw conclusions on effectiveness of EOR nozzle with regard to overpressure and PWD conditions.

Benchmarks Identified to Measure Effectiveness of EOR Nozzle

As depicted in Figure II-2, four benchmarks were identified as a means to measure the effectiveness of the EOR nozzle with regard to overpressure mitigation and improved ORVR vehicle recognition. These benchmarks include: (1) change in UST pressure which relies on data captured by the ISD vapor pressure sensor; (2) change in nozzle vapor to liquid ratios observed on individual fueling transactions which relies on data captured by the ISD vapor flow meter; (3) change in ISD overpressure alarm frequency which relies on the ISD system monthly report, and (4) change in the ORVR vehicle mis-identification rate[5] of the nozzle which relies on a manual survey/observation of vehicle fueling events.

Figure II-2: Benchmarks Used to Determine Effectiveness of EOR Nozzle



Test Site Selection and Optimization of Phase II Vapor Recovery System

From late November 2015 to late March 2016, EOR nozzles were installed at four retail GDFs located in different regions of California. The first test site was located in Granite Bay which was close to CARB's Sacramento headquarters to allow for quick response from CARB staff. In terms of overpressure alarm frequency, the Granite Bay location had exhibited overpressure in prior years; however, it was not considered a PWD site, likely due to its relatively high throughput of approximately 280,000 gallons per month. The second test site was located in San Diego which from prior site visits had a well-documented history of exhibiting frequent ISD overpressure alarms and PWD. The third

[5] Due to time constraints and availability of staff resources, ORVR vehicle recognition surveys were only conducted at Granite Bay and San Diego test site locations.

and fourth test sites were located in Campbell and the Gilroy, both within the Bay Area region. These two sites also had an extensive history of exhibiting frequent ISD overpressure alarms and PWD.

Prior to installing the EOR nozzles at each test site, Phase I and Phase II vapor recovery system performance testing (including ISD operability) were conducted in order to establish baseline operating conditions and to ensure compliance with applicable performance standards or specifications. If vapor recovery equipment failures were found repairs were made because such issues could potentially bias the results. For example, leaks within the underground storage tanks, improperly calibrated ISD equipment, or improperly adjusted nozzle vapor to liquid ratio settings can mask true operating conditions. For the evaluation to be successful, the vapor recovery system at each test site must be in proper operating condition and in compliance with applicable performance standards.

The following paragraphs describe each test site and the steps taken to ensure that the vapor recovery system was operating in compliance with applicable standards and specifications listed in the Assist Phase II Vapor Recovery System Executive Order VR-202. It should also be noted that per suggestion from FFS, vapor to liquid ratios of the nozzles were adjusted between 0.95 and 1.00 which is toward the lower end of the allowable range of 0.95 to 1.15.

A. Granite Bay Test Site

Between November 30, 2015 and December 11, 2015, CARB staff worked with FFS field engineers at a retail GDF located in Granite Bay, California. Although this evaluation occurred with winter blend gasoline (high RVP), PWD was not observed prior to EOR nozzle installation. Table II-1 provides additional information pertaining to the test site's operating characteristics.

Table II-1: Granite Bay Test Site Operating Characteristics

Hours of Operation	24 Hours/7 Days
EVR System	VR-202 – Healy w/ CAS
ISD System	INCON 1.2.0
# of Fueling Points	12 (six EOR nozzles, six conventional Healy 900 nozzles)
Monthly Throughput	~280,000 gallons
PWD Status	Non-PWD

Table II-2 provides a description and results of the baseline vapor recovery system testing conducted by CARB staff prior to EOR nozzle installation. Phase I, Phase II, and ISD system were each found to be in full compliance with the performance standards and specifications listed in the applicable Executive Order. Because data collected by the ISD vapor pressure sensor and the ISD vapor flow meters are relied upon to evaluate the effectiveness of nozzle replacement, the full test results are provided in Appendix A. In addition, because nozzle dispensing rates and vapor to liquid ratios are critical contributors to overpressure (if improperly adjusted, can cause excess air ingestion) the full data set is also provided in Appendix A.

Table II-2: Vapor Recovery System Testing Conducted at Granite Bay Test Site

CARB Test Method	Description	Result
TP-201.3	Leak Decay	PASS
VR-202 IOM 18	Dispenser Integrity	PASS
VR-202 Exhibit 5	Vapor to Liquid Ratio of Nozzles	PASS
VR-202 Exhibit 5	Nozzle Dispensing Rate	PASS
VR-202 Exhibit 4	Clean Air Separator	PASS
VR-202 Exhibit 10	ISD Operability: Vapor Flow Meter	PASS
VR-202 Exhibit 10	ISD Operability: Vapor Pressure Sensor	PASS
TP-201.1E	Pressure / Vacuum Vent Valve	PASS

With 12 fueling points at the site, six were equipped with EOR nozzles and six were equipped with conventional Healy 900 nozzles. Vapor to liquid ratios were adjusted to be between 0.95 and 1.00 on all nozzles. Surveys were conducted to evaluate customer acceptance of the EOR nozzle and to compare ORVR vehicle recognition performance of both nozzle designs. A total of 400 fueling events were observed and the corresponding ISD transactions were captured. RVP was not sampled at this particular GDF due to the relatively short duration of data collection at this location.

B. San Diego Test Site

Between January 8, 2016 and February 14, 2016, CARB staff worked with FFS field engineers at a retail GDF located in San Diego, California. This was a PWD site with winter blend gasoline (high RVP). From past years of ISD data collection, this site exhibited PWD continuously throughout the winter in years 2013, 2014, and 2015. Table II-3 provides a listing of operating characteristics.

Table II-3: San Diego Test Site Operating Characteristics

Hours of Operation	24 Hours/7 Days
EVR System	VR-202 – Healy w/ CAS
ISD System	INCON 1.2.0
# of Fueling Points	12
Monthly Throughput	190,000 gallons
PWD Status	PWD in 2013, 2014, 2015

After obtaining permission from the GDF operator and San Diego County Air Pollution Control District, the existing Healy 900 nozzles were field retrofitted with the EOR spout assemblies on January 26, 2016. Retrofitting involves replacing the spout assembly of the existing nozzle with an EOR spout assembly. The vapor to liquid (V/L) ratio was adjusted to be between 0.95-1.00 for each nozzle. The vapor recovery system tests listed in Table II-4 were performed by an authorized service provider to ensure all items were in compliance with applicable regulatory performance standards. Leak decay and PV testing were not conducted at the request of the GDF operator to minimize disruption to normal site operation and sales.

Table II-4: Vapor Recovery Testing Conducted by Service Provider

Test	Procedure	Pass/Fail	Comments
Vapor to Liquid Ratio*	VR-202, Exhibit 5	Pass	Before and after spout replacement.
ISD Vapor Flow Meter Operability*	VR-202, Exhibit 10	Pass	N/A
Fuel Flow Rate	VR-202, Exhibit 5	Pass	Before and after spout replacement.
Dispenser Integrity	VR-202, IOM 18	Pass	N/A
Healy Interlock Test	VR-202, IOM 1	Pass	Before and after spout replacement.
Nozzle Auto Shut-Off	VR-202, IOM 2	Pass	After spout replacement.
ISD Vapor Pressure Sensor Operability	VR-202, Exhibit 10	Pass	N/A/

*Tri-Tester used for all V/L adjustments.

On February 1, 2016, additional work was conducted by CARB staff to remedy unanticipated problems encountered with the retrofit. This was prompted by a review of ISD data immediately following the EOR spout installation on January 26. The ISD data indicated that the new spout assemblies were causing increased air ingestion. The following week, seven of the twelve existing Healy 900 nozzle bodies were replaced with new bodies due to V/L adjustment problems (could not be adjusted to desired range). The V/Ls of all nozzles were adjusted between 0.95 and 0.97 as suggested by the manufacturer's representative, to minimize air ingestion. The additional tests that were performed and the corresponding results are shown in Table II-5. For reference, the full set of test results are provided in Appendix B. In addition, because nozzle dispensing rates and vapor to liquid ratios are critical contributors to overpressure (if improperly adjusted, can cause excess air ingestion) the full data set is also provided in Appendix B.

Table II-5: Vapor Recovery System Testing Conducted by CARB Staff

Test	Procedure	Pass/Fail	Comments
Vapor to Liquid Ratio*	VR-202, Exhibit 5	Pass	Adjusted to 0.95-0.97.
ISD Vapor Flow Meter Operability*	VR-202, Exhibit 10	Pass	N/A
Fuel Flow Rate	VR-202, Exhibit 5	Pass	N/A
Healy Interlock Test	VR-202, IOM 1	Pass	N/A
ISD Vapor Pressure Sensor Operability	VR-202, Exhibit 10	Pass	10 point verification conducted

*CARB roots meter and CARB test fixture used for all V/L adjustments rather than Tri Tester.

On February 2, 2016, further review of ISD data indicated a possible leak which prompted CARB staff to conduct additional troubleshooting. The tests that were performed and the corresponding results are shown in Table II-6.

Table II-6: Additional Vapor Recovery System Testing Conducted by CARB Staff

Test	Procedure	Pass/Fail	Comments
Healy Interlock Test	VR-202, IOM 1	Pass	N/A
Nozzle Bag Test	VR-202, Exhibit 7	Pass	N/A
ISD Vapor Pressure Sensor Operability	N/A	Pass	10 point verification conducted

RVP was sampled on Monday and Thursday from February 8 – February 29, 2016 to determine whether or not winter blend gasoline was still present at the GDF.

Please note that a series of unanticipated issues were encountered at the San Diego test site which compromised the validity of the data collected. Due to scheduling conflicts with the GDF's service provider, these issues where not resolved prior to the conclusion of the study and are further described in the "Discussion of Results" section of this document.

C. Campbell Test Site

From February 8, 2016, to March 30, 2016, CARB staff worked with FFS field engineers at a retail GDF located in Campbell, California. From ISD data collected by CARB staff during prior site visits, the Campbell test site was selected as an optimal location to evaluate the EOR nozzle due to an extensive number of overpressure alarms from February through March of 2013, 2014, and 2015. Table II-7 lists frequency of ISD overpressure alarms from years past.

Table II-7: ISD Overpressure Alarm History at Campbell Test Site

Location	Number of OP Alarms					
	Feb 2013	Mar 2013	Feb 2014	Mar 2014	Feb 2015	Mar 2015
Campbell	3	1	4	2	4	2

Table II-8 lists pertinent operating characteristics for the Campbell test site.

Table II-8: Campbell Test Site Operating Characteristics

Hours of Operation	6am-11pm
EVR System	VR-202 – Healy w/ CAS
ISD System	Veeder Root 1.02
# of Fueling Points	8
Monthly Throughput	115,000 gallons
PWD Status	PWD in 2013, 2015, 2016

After obtaining permission from the GDF operator and the Bay Area Air Quality Management District, FFS provided CARB staff with factory assembled EOR nozzles, and the following steps were taken:

1. Prior to nozzle installation, baseline testing was conducted on the vapor recovery system to ensure that the vapor recovery system complied with applicable regulatory and performance standards.
2. The EOR nozzles were installed during the week of February 22, 2016.
3. The nozzles were left in place for at least 30 days and a data logging system was installed to capture ISD information on a daily basis

Upon installation of the EOR nozzles, V/L ratios were adjusted to between 0.95 and 1.00. Information on the baseline tests performed at each GDF site is summarized in Table II-9 and further detailed information is located in Appendix C. Issues were encountered at the Campbell test site including a dispenser leak and low flow rates on the 91 grade. Each issue was rectified to a passing state before moving forward. Additional details on issues encountered are provided in the “Discussion of Results” section of this document.

Table II-9: Vapor Recovery Performance Testing Conducted at Campbell Test Site

CARB Test Method	Description	Result
TP-201.3	Leak Decay	PASS
VR-202 IOM 18	Dispenser Integrity	PASS
VR-202 Exhibit 5	Vapor to Liquid Ratio of Nozzles	PASS
VR-202 Exhibit 5	Nozzle Dispensing Rate	PASS
VR-202 Exhibit 4	Clean Air Separator	PASS
VR-202 Exhibit 9	ISD Operability: Vapor Flow Meter	PASS
VR-202 Exhibit 9	ISD Operability: Vapor Pressure Sensor	PASS
TP-201.1E	Pressure Vacuum Vent Valve	PASS

D. Gilroy Test Site

From February 8, 2016, to March 30, 2016, CARB staff worked with FFS field engineers at a retail GDF located in Gilroy, California. From ISD data collected by CARB staff over the past several years, the Gilroy test site had extensive number of overpressure alarms from February through March in 2013, 2014 and 2015. Table II-10 lists frequency of ISD overpressure alarms from years past.

Table II-10: ISD Overpressure Alarm History at Gilroy Test Site

City	Number of OP Alarms					
	Feb 2013	Mar 2013	Feb 2014	Mar 2014	Feb 2015	Mar 2015
Gilroy	4	3	3	3	4	4

Table II-11 lists pertinent operating characteristics of the Gilroy test site.

Table II-11: Gilroy Test Site Operating Characteristics

Hours of Operation	24 Hours/7 Days
EVR System	VR-202 – Healy w/ CAS
ISD System	Veeder Root 1.02
# of Fueling Points	12
Monthly Throughput	108,000 gallons
PWD Status	PWD in 2013, 2015, 2016

After obtaining permission from the GDF operator and the Bay Area Air Quality Management District, FFS provided factory assembled EOR nozzles, and the following steps were taken:

1. Prior to nozzle installation, baseline testing was conducted on the vapor recovery system to ensure that the vapor recovery system complied with applicable regulatory and performance standards.
2. The EOR nozzles were installed during the week of February 22, 2016.
3. The nozzles were left in place for at least 30 days and a data logging system was installed to capture ISD information on a daily basis.

Upon installation of the EOR nozzles, V/L ratios were adjusted to between 0.95 and 1.00. Information on the baseline tests performed are summarized in Table II-12 and further detailed in Appendix D. Issues were encountered at Gilroy including containment leaks identified by conducting a 10 inch pressure decay test[6]. Leaking components were repaired, and the leak decay test was repeated resulting in a passing

[6] The 10 inch pressure decay test method referenced above was developed by and is commonly utilized within the San Diego County Air Pollution Control District as a screening procedure to determine leak integrity of GDF equipped with Phase I and Phase II vapor recovery systems.

state before moving forward. Additional details on issues encountered are provided in the "Discussion of Results" section of this document.

Table II-12: Vapor Recovery Performance Testing Conducted at Gilroy Test Site

CARB Test Method	Description	Result
TP-201.3	Leak Decay	PASS
VR-202 IOM 18	Dispenser Integrity	PASS
VR-202 Exhibit 5	Vapor to Liquid Ratio of Nozzles	PASS
VR-202 Exhibit 5	Nozzle Dispensing Rate	PASS
VR-202 Exhibit 4	Clean Air Separator	PASS
VR-202 Exhibit 9	ISD Operability: Vapor Flow Meter	PASS
VR-202 Exhibit 9	ISD Operability: Vapor Pressure Sensor	PASS
TP-201.1E	Pressure Vacuum Vent Valve	PASS

RVP was sampled at Gilroy and Campbell throughout the duration of the evaluation to ensure that winter blend gasoline was present at each GDF. Table II-10 lists the dates that RVP sample was taken.

Table II-13: RVP Sample Dates for Campbell and Gilroy Test Sites

2/28/2016	3/03/2016	3/09/2016
3/16/2016	3/23/2016	3/30/2016

III. Results

The results of data analysis pertaining to the EOR nozzle evaluation are presented in this section of the document. For ease of reference, this section is organized by test site and information is listed in chronological order. Data tables and charts are utilized in order to present the information in a clear and concise manner.

A. Granite Bay Test Site

The first test site at which EOR nozzles were installed was located in Granite Bay and was equipped with an **equal number** of conventional Healy nozzles and EOR nozzles. This hybrid configuration was deemed necessary to evaluate customer acceptance of the EOR nozzle and to determine if any unintended consequences (such as getting stuck in the vehicle fill pipe or premature shutoff) occurred. Although limited testing was conducted at Granite Bay when compared to the remaining three test sites, the EOR nozzle improved ORVR vehicle recognition, demonstrated favorable customer acceptance, and lowered air ingestion. For reference, a copy of the Assist Nozzle ORVR Vehicle Recognition Protocol is provided in Appendix E and the raw data collected during the ORVR vehicle recognition survey is provided in Appendix F.

Change in ORVR Vehicle Mis-Identification Rate

Over the course of five days, CARB staff observed customer fueling events using the conventional Healy 900 nozzles and the newly developed EOR nozzles. Customer acceptance of the EOR was favorable and no difficulties were observed in terms of fueling such as premature shut off, excess spillage, or initiating fueling event. An ORVR recognition study was conducted by observing a total of 410 vehicle fueling events, with 289 events on EOR nozzles and 121 events on conventional nozzles. The purpose of the recognition study was to determine the ORVR vehicle misidentification rate of the EOR nozzle versus the conventional Healy nozzle. The term “ORVR vehicle mis-identification” means that a vapor to liquid ratio of greater than 0.5 was observed (from ISD data) upon refueling an ORVR equipped vehicle. The ORVR vehicle misidentification rate for these vehicles was 24.7% on the EOR nozzle and 43.9% on the conventional Healy nozzle. The mis-identification rate was significantly lower on the EOR nozzle. Table III-1 provides an overview of the details.

Table III-1: Results of ORVR Vehicle Recognition Survey at Granite Bay Test Site

Nozzle Type	# of Vehicles	# of ORVR Vehicles	# of ORVR Vehicles w/ V/L>0.5	Misidentification Rate
Overall	410	329	100	30.4%
Prototype(EOR)	289	231	57	24.7%
Certified	121	98	43	43.9%

In addition to determining the ORVR vehicle mis-identification rate of the EOR nozzle compared to the conventional Healy nozzle, CARB staff was able to use ISD data collected during the vehicle survey to compare average vapor to liquid ratios of both configurations. As indicted in Table III-2 below, the vapor to liquid ratio of the conventional Healy nozzle was 0.65 and the EOR nozzle was 0.56.

Table III-2: Vapor to Liquid Ratios (V/L) Observed at Granite Bay Test Site

Nozzle Type	Overall V/L	ORVR V/L	Non-ORVR V/L
Overall	0.59	0.52	0.89
EOR Nozzle	0.56	0.49	0.87
Conventional Healy Nozzle	0.65	0.58	0.95

B. San Diego Test Site

Over a five-week period, between late January and early March 2016, ISD data was collected before and after EOR nozzle installation at the San Diego test site. The results of data analysis are provided in the paragraphs below. For reference, the raw ISD data collected from the San Diego test site are provided in Appendix G. A copy of the Assist Nozzle ORVR Vehicle Recognition Protocol is provided in Appendix E. The raw data pertaining to the ORVR Vehicle Recognition Vehicle survey is provided in Appendix H.

Change in UST Pressure

Table III-3 provides a comparison of UST pressure data with the conventional Healy nozzle and UST pressure data with the EOR nozzle. Please note, the timeframes and duration are not identical as the historical data was collected from prior site visits and the EOR nozzle data was collected after the installation of a CARB data acquisition system along with EOR nozzles. The average pressure with the conventional Healy nozzle is positive 2.3 inches of water column and the average pressure with the EOR nozzle is negative 4.2 inches of water column. The EOR nozzle shows a lower average.

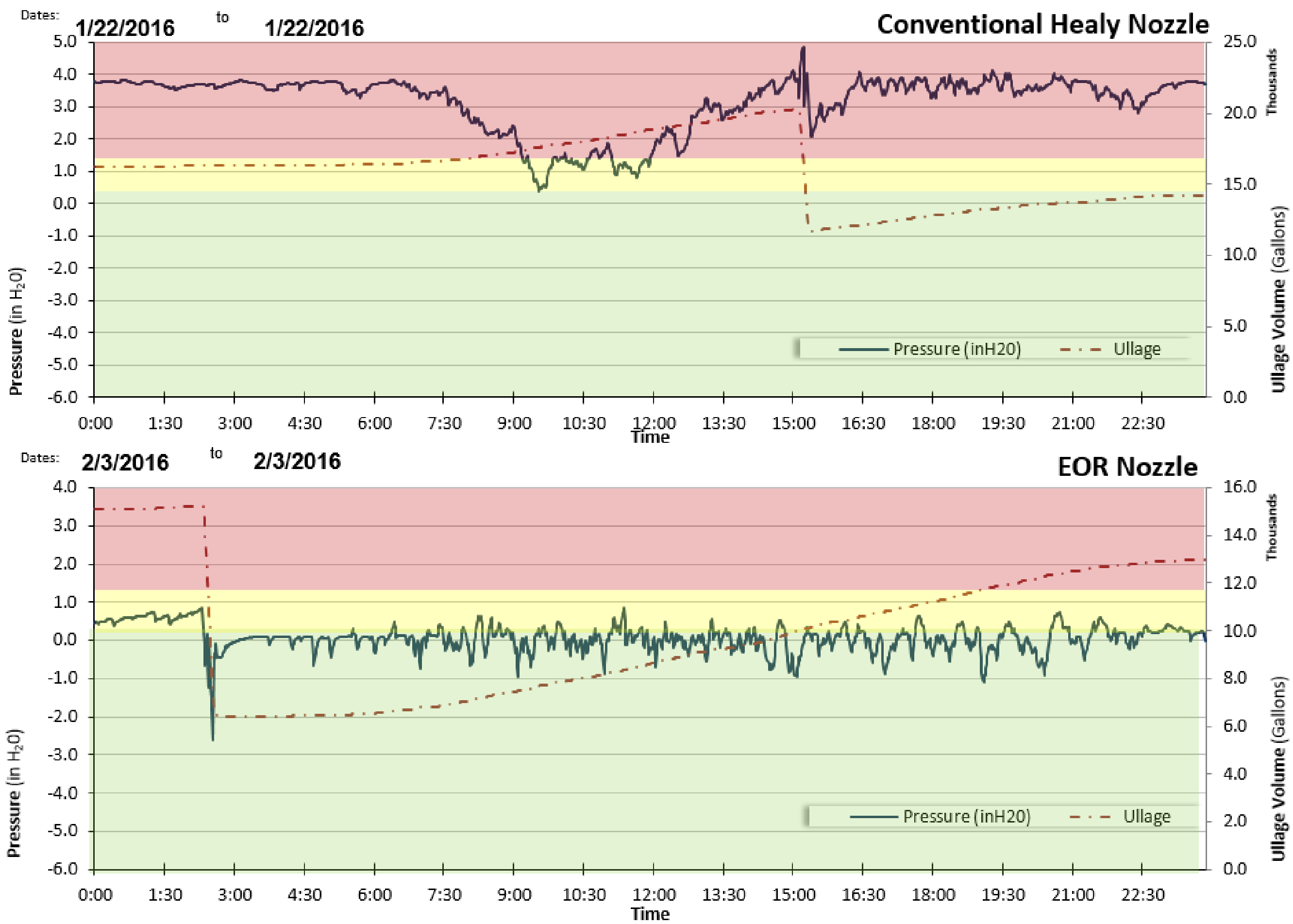
Table III-3: San Diego – UST Pressure Data

		UST Pressure (in$H_2$0)		
	Date of Data Set	Average	Daily Max	Daily Min
Conventional Healy Nozzle	12/03/2013	2.1	4.0	-0.5
	2/11/2014	2.7	4.0	0.4
	12/08/2015	2.7	4.1	-2.6
	1/19/2016-1/22/2016	1.9	4.8	-0.9
	Average:	**2.3**	**4.2**	**-0.9**
EOR Nozzle	2/03/2016-2/09/2016	0.7	3.6	-2.6
	2/10/2016-2/16/2016	-0.4	1.7	-7.3
	2/17/2016-2/23/2016	-8.5*	1.1	-9.3
	2/24/2016-3/01/2016	-8.7*	1.2	-9.3
	Average:	**-4.2**	**1.9**	**-7.1**

* Change in UST pressure likely due to change in RVP of winter blend gasoline, see Table II-7, results of RVP sampling and analysis from San Diego GDF.

Figure III-1 provides a pair pressure and ullage profiles collected from San Diego for 24 hours with the conventional Healy nozzle versus 24 hours with the EOR nozzle. The conventional nozzle has a pressure greater than 3.0 inches water column for the majority of the day, whereas the EOR nozzle has a pressure less than 1.0 inch water column.

Figure III-1: San Diego – UST Pressure and Ullage Profile



Change in Vapor to Liquid Ratio

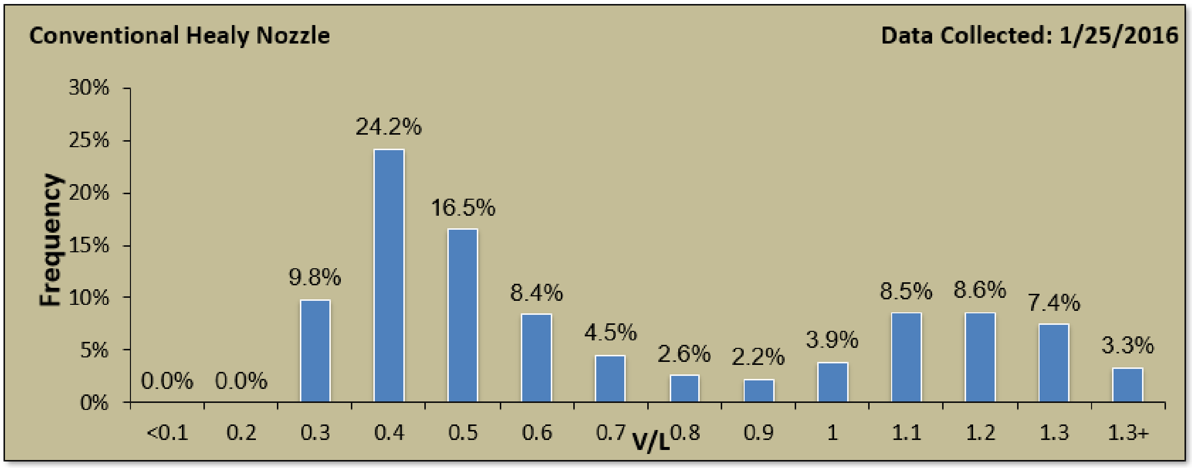
In comparing the vapor to liquid ratios for San Diego between the conventional Healy nozzle and the EOR nozzle, the site average was 0.67 for the conventional and 0.60 for the EOR nozzle. The EOR generated a lower site V/L average. For fueling events with a V/L less than or equal to 0.5, the percentage increased from 40.4% to 58.0% from the conventional nozzle to the EOR nozzle, as provided in Table III-4.

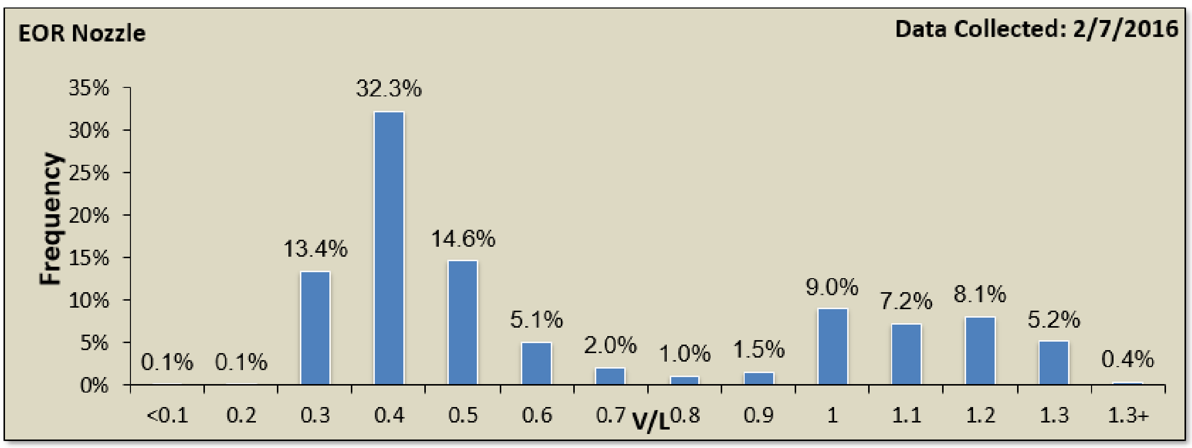
Table III-4: San Diego – Vapor to Liquid Ratio (V/L)

	Date of Data Set	Average Site V/L	Fueling Events V/L ≤ 0.5
Conventional Healy Nozzle	12/03/2013	0.72	23.3%
	2/11/2014	0.67	38.8%
	12/08/2015	0.66	49.1%
	1/21/2016 - 1/24/2016	0.64	50.6%
	Average:	**0.67**	**40.4%**
EOR Nozzle	2/03/2016-2/09/2016	0.59	60.2%
	2/10/2016-2/16/2016	0.62	57.7%
	2/17/2016-2/23/2016	0.59	58.2%
	2/24/2016-3/01/2016	0.60	55.9%
	Average:	**0.60**	**58.0%**

Histograms of vapor to liquid ratios were generated to illustrate the comparison between the conventional Healy nozzle and the EOR nozzle. Figure III-2 details the histogram of each. The EOR nozzle generates a lower percentage at 0.8 V/L and a higher percentage at 0.4 V/L and 1.0 V/L.

Figure III-2: San Diego – V/L Histograms for Conventional and EOR Nozzle





Change in ISD Overpressure Alarm Frequency

At the San Diego test site, frequency of ISD overpressure alarms before and after the installation of EOR nozzles was observed. In the month prior to installation, overpressure alarms were observed on a weekly basis. After installation and the first weekly clearing cycles, overpressure alarms seemed to be mitigated. Table III-5 provides more details. Upon further analysis, change in overpressure alarm frequency on and after February 15, 2016, was likely attributed to the introduction of summer blend gasoline, see Table III-7, San Diego-Reid Vapor Pressure (RVP).

Table III-5: Frequency of ISD Overpressure Alarms Before and After EOR Nozzle Installation

Date	Alarm Description	Reading
1/01/16	Ullage Pressure Warning	Monthly
1/05/16	Ullage Pressure Failure	Weekly
1/12/16	Ullage Pressure Warning	Weekly
1/19/16	Ullage Pressure Warning	Weekly
1/26/16	Ullage Pressure Warning	Weekly
2/01/16	**EOR Nozzle Installed at Site**	
2/01/16	Ullage Pressure Warning	Monthly
2/09/16	Ullage Pressure Warning	Weekly
2/15/16	No Pressure Alarms	
2/22/16	No Pressure Alarms	
2/29/16	No Pressure Alarms	

Change in ORVR Vehicle Mis-Identification Rate

The San Diego test site was also utilized for an ORVR vehicle recognition survey which was previously conducted (as part of a different field study) in January 2015 with conventional Healy nozzles. The same survey was then repeated in March 2016 with EOR nozzles. For comparison, Table III-6 shows the data from both surveys. Over 300 ORVR vehicles were observed in both instances. The raw field data associated with the ORVR vehicle recognition survey is available in Appendix H.

Table III-6: Results of ORVR Vehicle Recognition Survey at San Diego Test Site

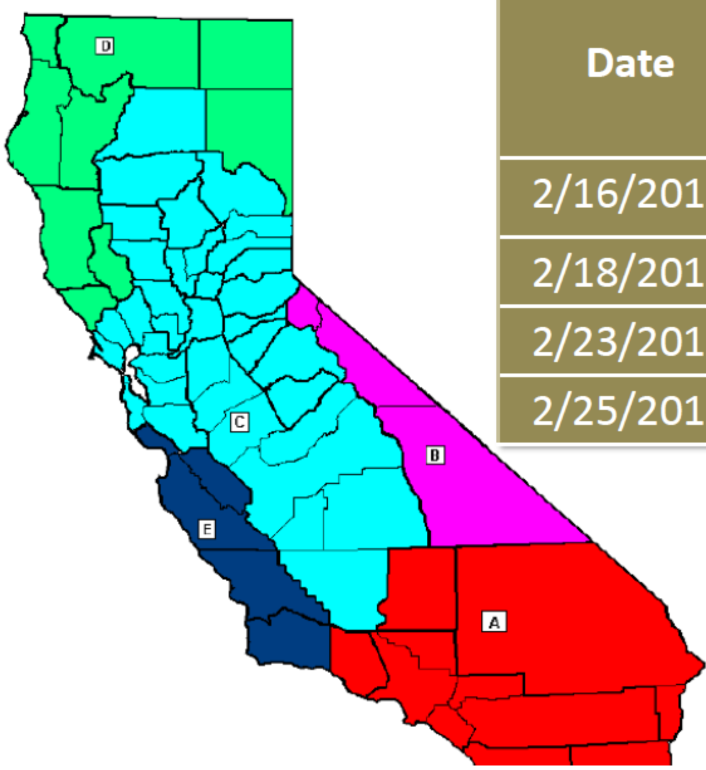
	Date of Survey	January 2015 Conventional Healy Nozzle	March 2016 EOR Nozzle
# of ORVR Vehicles Surveyed		369	321
# of ORVR Vehicles with V/L>0.5		169	121
% Mis - ID		38.7%	37.7%
V/L	Overall	0.64	0.62
	ORVR	0.60	0.57
	Non-ORVR	0.99	1.00

Reid Vapor Pressure of Gasoline

To determine whether winter blend gasoline was present during the EOR nozzle evaluation, CARB's Enforcement Division staff collected gasoline samples and submitted them to CARB's Haagen-Smit Laboratory for RVP analysis. The results are listed in Table III-7. The RVP for regular gasoline is shown to be 9.07 on 2/16/2016 and 7.34 on 2/25/2016. These RVP results indicate transitioning down toward summer blend gasoline in mid-February.

Table III-7: San Diego – Reid Vapor Pressure

Date	San Diego Chevron	
	Regular Grade	Premium Grade
2/16/2016	9.07	9.65
2/18/2016	8.75	8.77
2/23/2016	7.52	7.47
2/25/2016	7.34	7.30



Summer Control Period	
A	April 1 – Oct 31

C. Campbell Test Site

Data was collected for approximately seven weeks at the Campbell test site, and the results are provided below. For reference, the raw ISD data captured at Campbell is provided in Appendix I.

Change in UST Pressure

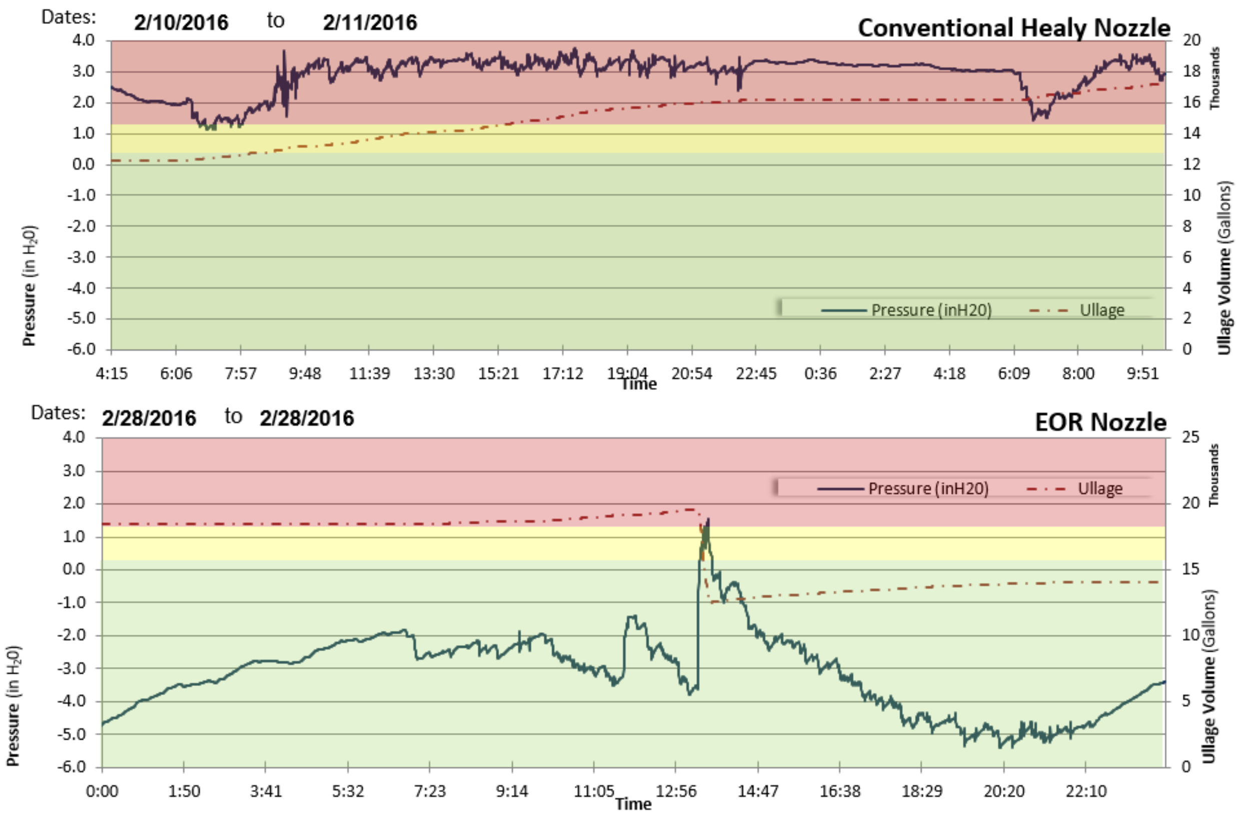
Table III-8 provides a comparison of UST pressure data for the Campbell GDF with the conventional Healy nozzle and the EOR nozzle. Please note, the timeframes and duration of the data collected was not equal. Historical data was collected from previous site visits and EOR nozzle data was collected after installation of CARB data acquisition system. The average pressure with the conventional Healy nozzle was 2.6 inches water column, while the average pressure with the EOR nozzle was -4.8 inches water column.

Table III-8: Campbell – UST Pressure Data

		Pressure (inH_20)		
	Date of Data Set	Average	Max	Min
Conventional Healy Nozzle	12/3/2013	3.1	4.5	1.0
	2/24/2014	1.3	4.1	-0.5
	12/8/2015	3.2	4.2	2.3
	2/11/2016	2.9	3.7	1.1
	Average:	**2.6**	**4.1**	**1.0**
EOR Nozzle	2/28/16 - 03/05/16	-3.7	1.6	-6.0
	03/06/16 – 03/12/16	-5.3	-1.1	-6.0
	03/13/16 – 03/19/16	-4.8	6.4	-6.0
	03/20/16 – 03/26/16	-5.6	1.8	-6.0
	03/27/16 – 03/30/16	-4.7	6.5	-6.0
	Average:	**-4.8**	**3.0**	**-6.0**

Figure III-3 provides a pair of pressure and ullage profiles collected from Campbell for 24 hours with the conventional Healy nozzle versus 24 hours with the EOR nozzle. The conventional Healy nozzle has a pressure greater than 3.0 inches water column, whereas the EOR nozzle has a pressure less than negative (-) 1.5 inches water column.

Figure III-3: Campbell – UST Pressure and Ullage Profile



Change in Nozzle Vapor to Liquid Ratio

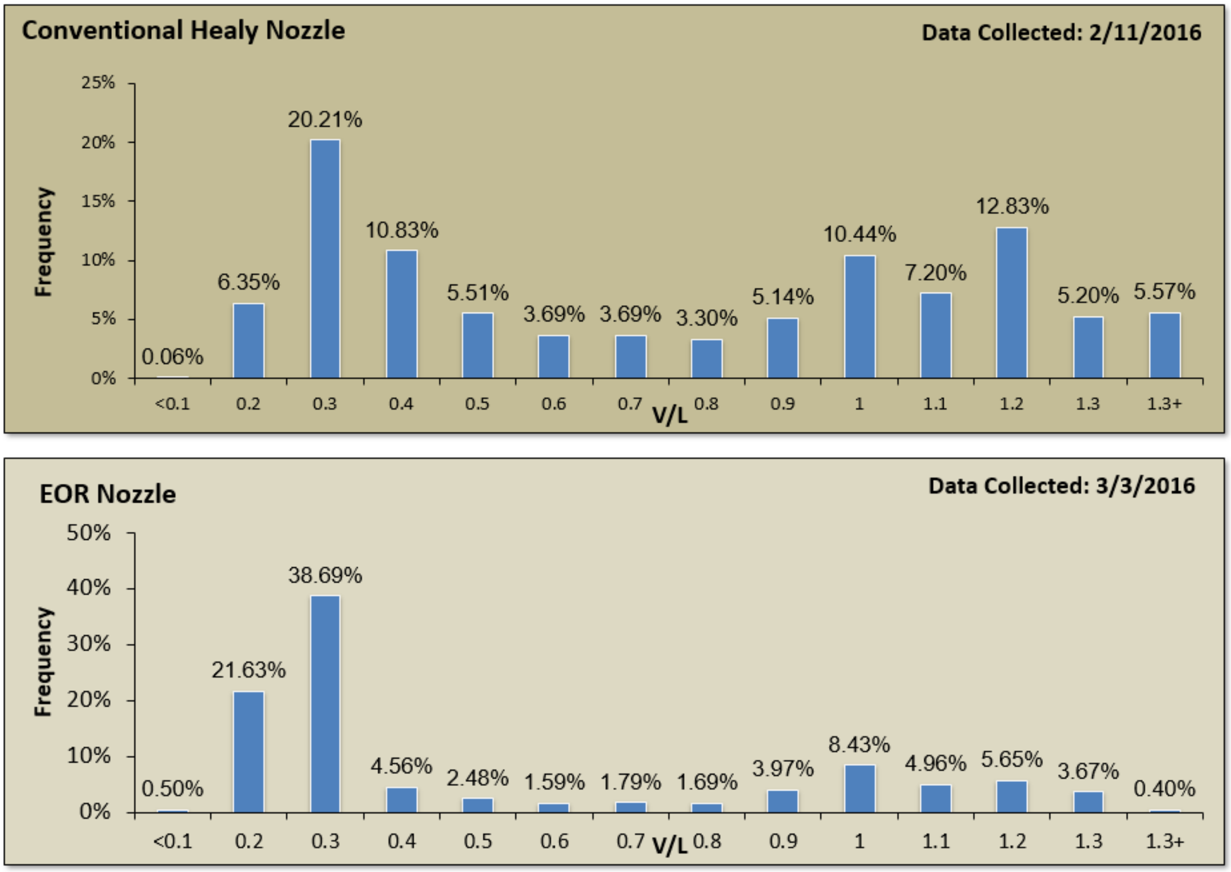
In comparing the nozzle vapor to liquid ratios at the Campbell site, the site average was 0.70 for the conventional nozzle and 0.50 for the EOR nozzle. The EOR had a lower site V/L average. For fueling events with a V/L less than or equal to 0.5, the percentage increased from 45.4% to 67.0% for the conventional nozzle compared to the EOR nozzle. Table III-9 provides more details.

Table III-9: Campbell – Vapor to Liquid Ratio (V/L)

	Date of Data Set	Vapor to Liquid Ratio Overall Site Average	Fueling Events ≤ 0.5 V/L
Conventional Healy Nozzle	12/3/2013	0.68	47.6%
	2/24/2014	0.69	46.3%
	12/8/2015	0.71	44.8%
	2/11/2016	0.72	43.0%
	Average:	**0.70**	**45.4%**
EOR Nozzle	2/28/16 - 03/05/16	0.48	66.4%
	03/06/16 – 03/12/16	0.51	65.9%
	03/13/16 – 03/19/16	0.49	67.2%
	03/20/16 – 03/26/16	0.50	66.7%
	03/27/16 – 03/30/16	0.51	68.9%
	Average:	**0.50**	**67.0%**

Histograms were also generated for the conventional nozzle and the EOR nozzle. Figure III-4 provides a depiction of each. The EOR nozzle generates a lower percentage at 0.6, 0.7, and 0.8 V/L and a higher percentage at 0.3 V/L.

Figure III-4: Campbell – V/L Histograms for Conventional and EOR Nozzle



Change in ISD Overpressure Alarm Frequency

At the Campbell test site, frequency of ISD overpressure alarms before and after installation of the EOR nozzle was observed. For the month prior to installation, overpressure alarms were active every week. After installation and the first weekly cycle (March 1), overpressure alarms activated only one time on March 18. Table III-10 provides more information.

Table III-10: Frequency of ISD Overpressure Alarms Before & After EOR Nozzle Installation

Date	Alarm Description	Reading
2/02/16	CONTAINMENT GROSS OVER PRESSURE	Weekly
2/09/16	CONTAINMENT GROSS OVER PRESSURE	Weekly
2/16/16	CONTAINMENT GROSS OVER PRESSURE	Weekly
2/23/16	CONTAINMENT GROSS OVER PRESSURE	Weekly
2/25/16	**EOR Nozzle Installed at Site**	
3/01/16	CONTAINMENT GROSS OVER PRESSURE	Weekly
3/08/16	No Alarms	
3/15/16	No Alarms	
3/18/16	CONTAINMENT GROSS OVER PRESSURE	Weekly
3/22/16	No Alarms	
3/29/16	No Alarms	

D. Gilroy Test Site

Data was collected for approximately seven weeks at the Gilroy test site, and the results are provided below. For reference, the raw ISD data is provided in Appendix J.

Change in UST Pressure

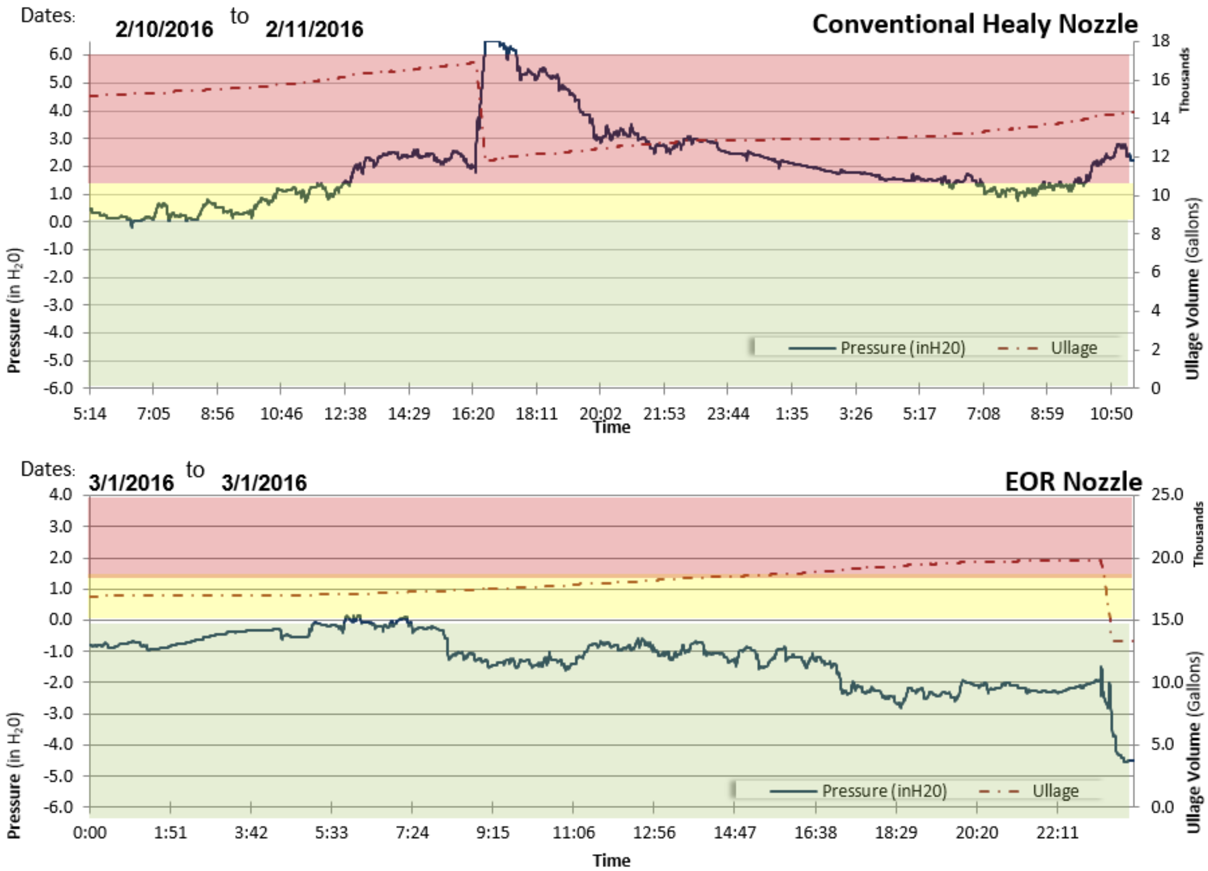
Table III-11 provides a comparison of UST pressure data for the Gilroy test site with the conventional Healy nozzle and the EOR nozzle. Please note, the timeframes and duration of the data collected are not equal. The historical certified nozzle data was collected from past evaluations and the EOR nozzle data was collected after installation of a CARB data acquisition system. The average UST pressure of the conventional Healy nozzle was 2.5 inches water column, and the average pressure with the EOR nozzle was -3.0 inches water column. The EOR nozzle exhibits a lower average.

Table III-11: Gilroy – UST Pressure Data & Profile

		Pressure (inH$_2$0)		
	Date of Data Set	Average	Max	Min
Conventional Healy Nozzle	12/3/2013	3.5	4.3	3.1
	2/24/2014	3.3	4.1	2.3
	12/9/2015	1.2	3.2	-6.0
	2/11/2016	2.0	6.5	-0.2
	Average:	**2.5**	**4.5**	**-0.2**
EOR Nozzle	2/28/16 - 03/05/16	-2.1	1.9	-5.7
	03/06/16 – 03/12/16	-2.8	2.9	-6.0
	03/13/16 – 03/19/16	-2.6	6.5	-6.0
	03/20/16 – 03/26/16	-2.6	3.9	-6.0
	03/27/16 – 03/30/16	-4.8	-1.8	-6.0
	Average:	**-3.0**	**2.7**	**-5.9**

Figure III-5 provides a pair of pressure and ullage profiles collected in Gilroy for 24 hours with the conventional nozzle versus 24 hours with the EOR nozzle. The conventional nozzle has a pressure mostly greater than 1.0 inch water column, whereas the EOR nozzle has a pressure mostly less than negative 1.0 inch water column.

Figure III-5: Gilroy - UST Pressure and Ullage Profile



Change in Nozzle Vapor to Liquid Ratio

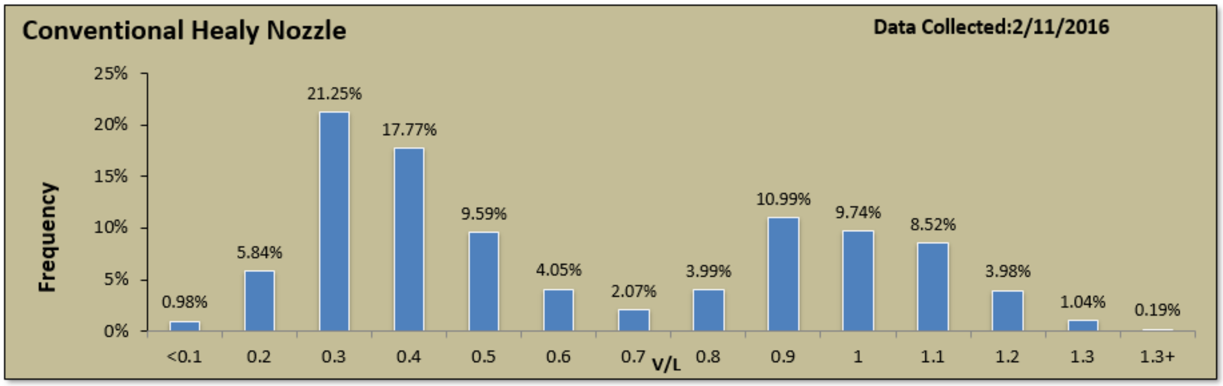
In comparing the site average vapor to liquid rato for the Gilroy test site, the site average was 0.63 for the conventional Healy nozzle and 0.52 for the EOR nozzle. The EOR nozzle generated a lower site V/L average. For fueling events of V/L less than or equal to 0.5, the percentage increased from 50.1% to 64.6% upon comparison of the two nozzle designs. Table III-12 provides further details.

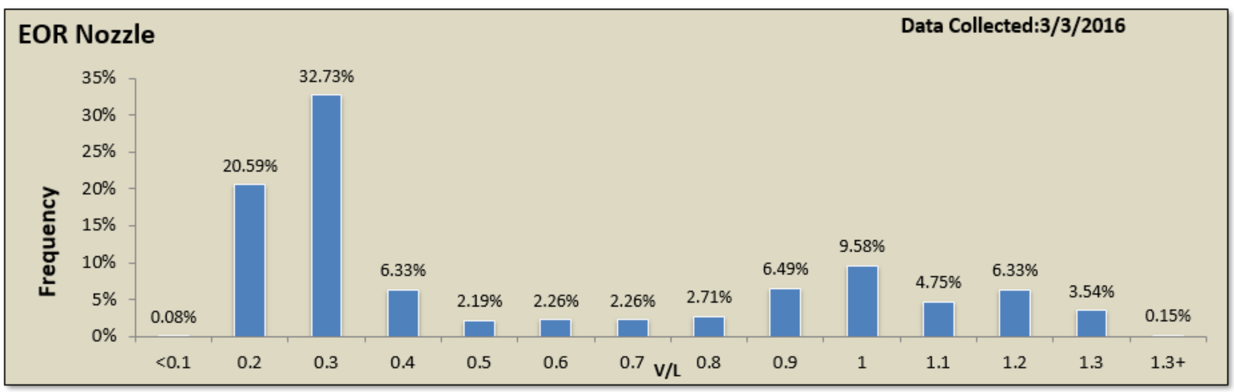
Table III-12: Gilroy - Vapor to Liquid Ratio (V/L)

	Date of Data Set	Vapor to Liquid Ratio Overall Site Average	Fueling Events ≤ 0.5 V/L
Conventional Healy Nozzle	12/3/2013	0.69	40.5%
	2/24/2014	0.67	48.5%
	12/9/2015	0.57	56.1%
	2/11/2016	0.58	55.4%
	Average:	**0.63**	**50.1%**
EOR Nozzle	2/28/16 - 03/05/16	0.51	64.4%
	03/06/16 – 03/12/16	0.51	65.3%
	03/13/16 – 03/19/16	0.52	63.5%
	03/20/16 – 03/26/16	0.53	65.1%
	03/27/16 – 03/30/16	0.54	64.8%
	Average:	**0.52**	**64.6%**

Figure III-6 provides the histograms comparing the Gilroy test site V/Ls for the conventional Healy nozzle and the EOR nozzle. The EOR nozzle generates a lower percentage at 0.6 and 0.8 V/L, and a higher percentage at 0.3 V/L. As with the histogram generated for Campbell, the frequency of V/L in the range 0.4 to 0.8 was also reduced.

Figure III-6: Gilroy - V/L Histograms for Conventional and EOR Nozzle





Change in ISD Overpressure Alarm Frequency

At the Gilroy test site, frequency of ISD overpressure alarms before and after installation of the EOR nozzle was observed. For the month before installation, overpressure alarms were active for three out of four weeks. For the EOR nozzle installation, extra work was done on the site to ensure it would pass all baseline tests. This caused no alarms to be seen before the EOR nozzle installation. After installation and the first weekly clearing cycles, the frequency of overpressure alarms appears to be mitigated. Table III-13 provides further information.

Table III-13: Frequency of ISD Overpressure Alarms Before & After EOR Nozzle Installation

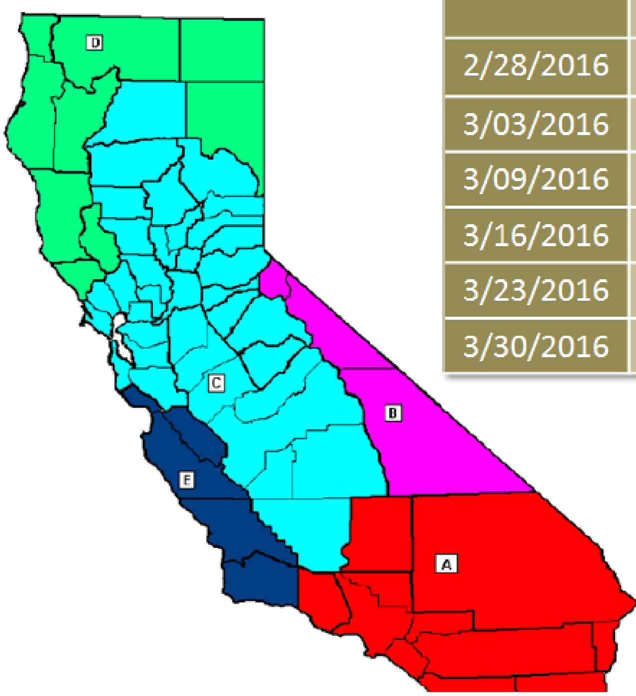
Date	Alarm Description	Reading
2/04/16	CONTAINMENT GROSS OVER PRESSURE	Weekly
2/05/16	CONTAINMENT GROSS OVER PRESSURE	Weekly
2/12/16	CONTAINMENT GROSS OVER PRESSURE	Weekly
2/19/16	No Alarms	
2/26/16	**EOR Nozzle Installed at Site**	
2/28/16	CONTAINMENT GROSS OVER PRESSURE	Weekly
3/06/16	No Alarms	
3/13/16	No Alarms	
3/20/16	No Alarms	
3/27/16	No Alarms	

E. Reid Vapor Pressure of Gasoline

To determine whether winter blend gasoline was present, samples were collected by CARB's Enforcement Division staff and analyzed by CARB's Haagen-Smit Laboratory to determine RVP. The results are listed in Table III-14 below. The RVP for regular gasoline is shown to be 13.08 (Campbell) and 12.98 (Gilroy) on February 28, 2016. On March 30, 2016, RVP for regular gasoline is shown to be 10.60 (Campbell) and 12.89 (Gilroy). All results showed both GDFs were dispensing winter blend gasoline in March.

Table III-14: Campbell and Gilroy – Reid Vapor Pressure

Date	Campbell Shell		Gilroy Chevron	
	Regular Grade	Premium Grade	Regular Grade	Premium Grade
2/28/2016	13.08	12.73	12.98	13.14
3/03/2016	13.04	12.63	13.14	13.14
3/09/2016	12.79	12.57	13.20	13.13
3/16/2016	13.00	13.10	9.49	9.50
3/23/2016	8.06	8.60	12.95	12.60
3/30/2016	10.60	11.39	12.89	7.44



Summer Control Period	
C	May 1 – Oct 31

IV. Discussion of Results

Over the course of five months during the winter of 2015/2016, the EOR nozzle was evaluated at four retail GDFs. At each facility, pertinent data was collected from the ISD system before and after installation. Prior to EOR nozzle installation, baseline vapor recovery system testing was conducted and if necessary, repairs were made to bring each facility into compliance with applicable performance standards and specifications. To further minimize excess air ingestion, the vapor to liquid ratio of each EOR nozzle was adjusted to between 0.95 and 1.00 which is the low end of the allowable range. This section of the document summarizes CARB staff findings pertaining to EOR nozzle performance.

Issues Encountered at Each Test Site

The Granite Bay test site was intentionally partially equipped with EOR nozzles to determine customer acceptance of the new design. Six of the twelve fueling positions were equipped with EOR nozzles while the remaining six fueling positions were equipped with conventional Healy nozzles. Upon installation of the EOR nozzles and attempts to adjust the vapor to liquid ratio between 0.95 and 1.00, it became evident that the conventional Healy nozzle spout adaptor (required to conduct V/L testing) was not compatible with the EOR nozzle due to leakage. Luckily, CARB staff had access to the Triangle Gold[7] universal nozzle adaptor which was successful in achieving a leak tight seal with the EOR nozzle. For Granite Bay and the remainder of the test sites, the Triangle Gold adaptor was used for vapor to liquid ratio testing of the EOR nozzle.

The San Diego test site was fully equipped with twelve field retrofitted versions of the EOR nozzles by an authorized service provider. After installation of EOR spout assemblies during the week of January 25, the PWD condition actually worsened due to increased air ingestion at the nozzle. Because EOR performance at Granite Bay was favorable, CARB staff suspected that improper installation may have occurred and was interested in quickly correcting the problem before the introduction of summer blend gasoline[8]. Based on troubleshooting by CARB staff during the week of February 1, it was discovered that seven out of twelve existing nozzles had to be replaced due to lack of response to vapor to liquid ratio adjustment. Additionally, CARB staff found metal shavings on some spouts assemblies which may have contributed to an inability to adjust the vapor to liquid ratio. After troubleshooting and repair, PWD was mitigated from February 1 and 3, but returned briefly from February 4 and 6, then disappeared again. Later testing requested by FFS revealed a leaking P/V valve and drop tube. Both components were replaced and one EOR nozzle had elevated V/L. Unfortunately, the RVP of gasoline at the San Diego test began to drop below 10 psi in mid-February and by the end of February, the RVP was slightly above 7. The lower RVP gasoline

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[7] FFS later provided a new nozzle spout adaptor for the EOR nozzle. In a certification summary for EOR nozzle certification, CARB staff conducted testing demonstrating that the Triangle Gold Spout adapter is equivalent to the new FFS spout adapter.

[7] Southern California refineries generally start producing summer blend gasoline sometime in February to comply with the refining schedule to produce summer blend gasoline by March 1.

might explain the reason that PWD disappeared after February 9. With these issues, it is not possible to draw a valid conclusion whether or not EOR spout replacement mitigated PWD or overpressure at this particular GDF. The vapor to liquid ratio data collected by the ISD system was deemed valid and coud be used for comparison.

The Campbell test site was fully equipped with eight factory assembled EOR Nozzles. Prior to EOR nozzle installation, low flow rates (less than 6 gallons per minute) for the 91 grade were observed at all fueling positions. Dispenser integrity leaks were observed at fueling points 3 and 4.

The Gilroy test site was also fully equipped with twelve factory assembled EOR nozzles. Days after initial assessment, leaks developed in the containment system, which were identified by the ISD system. A 10 inch pressure decay test was conducted and multiple leaks were found at the vent riser, the Phase I riser, and the vapor return piping.

Fortunately, all issues found at Campbell and Gilroy sites were corrected prior to the installation of EOR nozzles and the RVP of the gasoline remained high throughout the month of March.

Observations Pertaining to EOR Nozzle Performance

Although the amount of information collected varied by test site (limited information from Granite Bay due to mixture of nozzles) and numerous issues were encountered (San Diego in particular), the following observations can be made pertaining to the performance of the EOR nozzle when compared to the conventional Healy nozzle.

A. UST Pressure Lowered at Two of Four Test Sites

Due to the issues encountered at San Diego test site and the partial installation of EOR nozzles at Granite Bay, UST pressure data collected from only two of the four test sites (Campbell and Gilroy) was deemed valid and acceptable for analysis. As indicated in the table below and the results section of this document, the UST pressure was successfully lowered upon installation of the EOR nozzle at both Campbell and Gilroy test sites. Prior to EOR install, both sites exhibited relatively high UST pressures including PWD. With EOR nozzles installed, the UST pressure averages dropped to vacuum levels.

Table IV-1: Change in UST Pressure Observed During EOR Nozzle Evaluation

Test Site	UST Pressure Average (Inches Water Column Gauge)	
	Conventional Healy Nozzle	EOR Nozzle
Granite Bay[9]	N.A.	N.A.
San Diego[10]	2.3	Inconclusive
Campbell	2.6	-4.8
Gilroy	2.5	-3.0

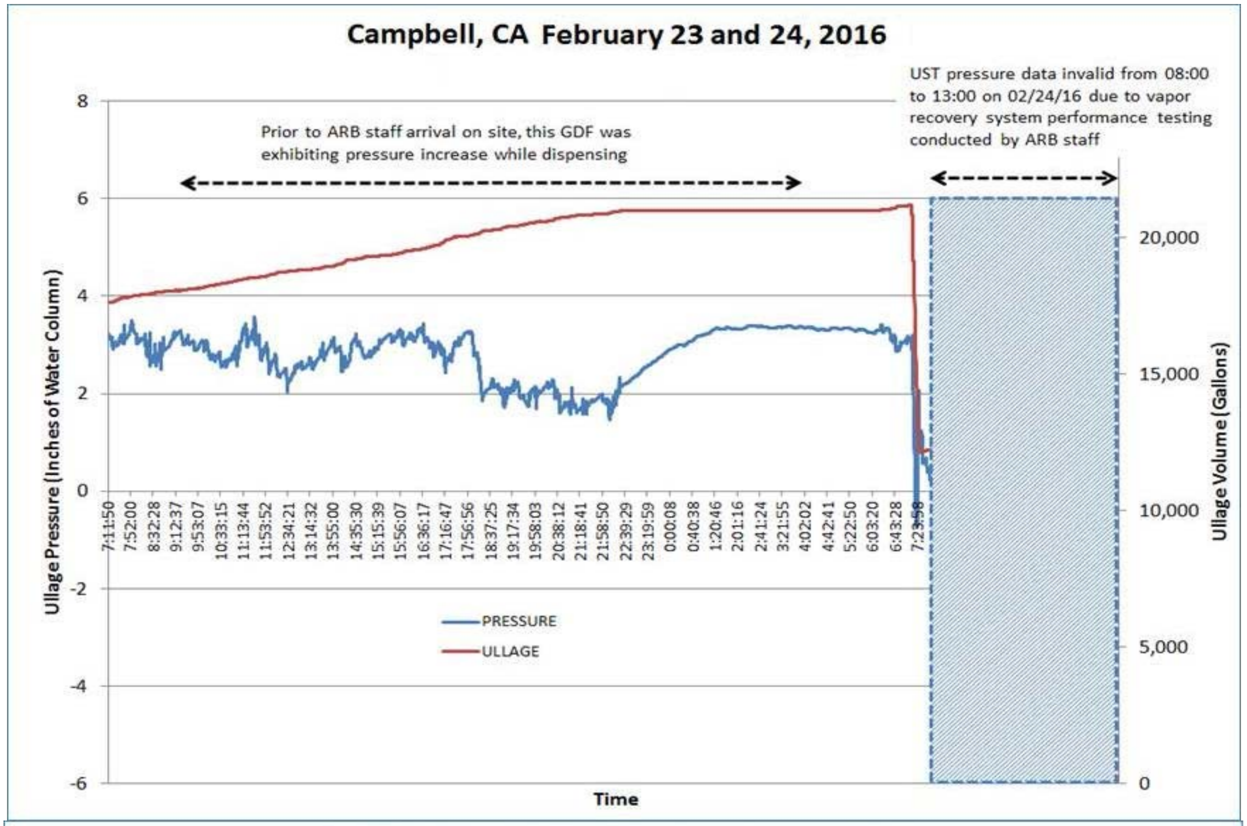
B. PWD Mitigated at Two of Four Test Sites

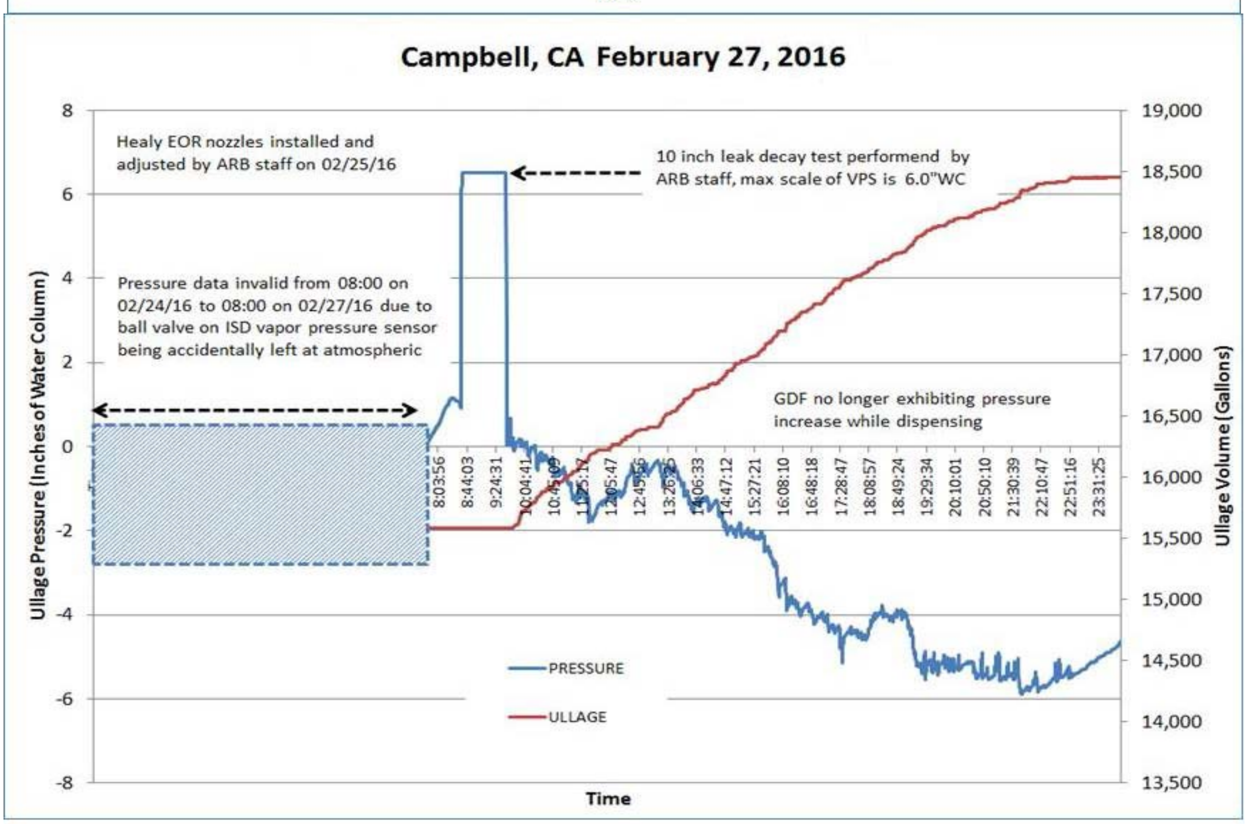
PWD condition was mitigated at two of the four test sites (Campbell and Gilroy) due to the installation of the EOR nozzles. An example of PWD mitigation is depicted in Figures IV-1 (provided below) for the Campbell test site. Figures IV-1 illustrates the UST pressure and ullage profile hours before and after the EOR nozzle installation. As indicated in Figure IV-1, upon installation of the EOR nozzle, the UST pressure values change from positive to negative within hours.

[9] UST pressure data was not collected or analyzed from the Granite Bay test site because the facility was not fully equipped with EOR nozzles, six out of twelve fueling positions were EOR the remaining six were conventional Healy nozzles

[10] UST pressure data collected from the San Diego test site was deemed inconclusive because containment leaks were later found and due to the fact that low RVP winter blend gasoline was introduced at the site in mid-February which was earlier that anticipated by CARB staff

Figure IV-1: Campbell Pressure Trace Before & After Installation of EOR Nozzle





C. Vapor to Liquid Ratios Lowered at All Four Test Sites

At all four test sites, the nozzle vapor to liquid ratio site averages were lowered by at least 10% due to the installation of the EOR nozzles. This means that less fresh air is being ingested at the nozzle; therefore less evaporation is expected to occur within the headspace of the USTs. As indicated in the table below, the EOR nozzle lowered the vapor to liquid ratio by an average of 18% based on all four test sites.

Table IV-2: Change in Vapor to Liquid Ratios Observed During EOR Nozzle Evaluation

Test Site	Vapor To Liquid Ratio		Percent Change
	Conventional Healy Nozzle	EOR Nozzle	
Granite Bay	0.65	0.56	-13.8
San Diego	0.67	0.60	-10.4
Campbell	0.72	0.50	-30.5
Gilroy	0.63	0.52	-17.5
		Four Site Average	-18.1

D. Percentage of Fueling Events w/ Vapor to Liquid Ratio < 0.5 Lowered at All Four Test Sites

The percentage of fueling events with a V/L less than or equal to 0.5 increased at all four test sites due to the installation of the EOR nozzle. This indicated that the EOR nozzle was doing a better job of recognizing vehicles equipped with ORVR and less air ingestion was occurring. As indicated in the table below, the EOR nozzle increased the percentage of fueling events with a V/L less than 0.5 by an average of 19 percentage points.

Table IV-3: Change in Distribution of Fueling Events Observed During EOR Nozzle Evaluation

Test Site	Percentage of Fueling Events with Vapor To Liquid Ratio Less Than or Equal to 0.5		Percentage Point Difference
	Conventional Healy Nozzle	EOR Nozzle	
Granite Bay	56%	75%	19
San Diego	40%	58%	18
Campbell	45%	67%	22
Gilroy	50%	65%	15
		Four Site Average	19

E. Frequency of ISD Alarms Decreased at Two of Four Test Sites

The number of ISD overpressure alarms after installation of the EOR nozzles was reduced at two of the four test sites. Data collected from the remaining two sites (Granite Bay and San Diego) was deemed inconclusive due to the reasons explained above pertaining to UST pressure. Ideally, 100% of the ISD alarms would be mitigated for all sites upon EOR nozzle installation. This was not observed, but at the Campbell and Gilroy test sites, ISD overpressure alarm frequency was reduced by 58%.

Table IV-4: Change in ISD Overpressure Alarm Frequency during EOR Nozzle Evaluation

Test Site	**Number of ISD Overpressure Alarms**		**Percent Reduction**
	February 2016 Conventional Healy Nozzle	**March 2016 EOR Nozzle**	
Granite Bay[11]	N.A.	N.A.	N.A.
San Diego[12]	5	Inconclusive	N.A.
Campbell	4	2	50%
Gilroy	3	1	66%
Two Site Average Reduction in ISD Overpressure Alarms			58%

[11] ISD alarm history data was not collected or analyzed from the Granite Bay test site because the facility was not fully equipped with EOR nozzles, six out of twelve fueling positions were EOR the remaining six were conventional Healy nozzles

[12] ISD alarm history data collected from the San Diego test site was deemed inconclusive because containment leaks were later found and due to the fact that low RVP winter blend gasoline was introduced at the site in mid-February which was earlier than anticipated by CARB staff

V. Conclusions and Recommendations

The objective of this evaluation was to determine the effectiveness of the EOR nozzle feature with regard to improved ORVR vehicle recognition and mitigation of overpressure conditions that commonly occur at GDF's equipped with the Assist Phase II Enhanced Vapor Recovery System during the time of year when winter blend gasoline is sold in California.

In terms of performance relative to the conventional Healy Model 900 nozzle, based on data collected at four test sites, CARB staff has concluded that the EOR nozzle was effective in lowering UST pressure, lowering site average V/L ratio, and lowering the frequency of ISD overpressure alarms. The EOR nozzle also showed improvement with regard to ORVR vehicle mis-identification based on an ORVR vehicle recognition survey was also conducted at two of the four test sites. The following table summarizes the findings specific to EOR nozzles.

Table V-1: Summary of Findings Pertaining to EOR Nozzle Evaluation

	Test Site			
Parameter	Granite Bay[13]	San Diego[14]	Campbell[15]	Gilroy[16]
Change in UST Pressure?	Not Applicable	Inconclusive	Lowered	Lowered
Change in Site Average V/L[17]?	Lowered	Lowered	Lowered	Lowered
Change in Percentage of V/L <0.5?	Lowered	Increased	Increased	Increase
Change in ORVR Vehicle Recognition Survey?	Improved	Improved	Not Evaluated	Not Evaluated
Change in Frequency of ISD OP Alarm?	Not Applicable	Inconclusive	Lowered	Lowered

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[13] Change in UST pressure and frequency of ISD overpressure alarms not evaluated because this test site was partially equipped with EOR nozzles.
[14] Change in UST pressure likely due to change in RVP of winter blend gasoline, see Table II-7, results of RVP sampling and analysis from San Diego test site
[15] Due to time constraints and availability of CARB staff resources, ORVR vehicle recognition survey was not conducted at this test site
[16] Due to time constraints and availability of CARB staff resources, ORVR vehicle recognition survey was not conducted at this test site
[17] Vapor to Liquid Ratio of all EOR nozzles at each site was intentionally adjusted to 0.95 – 1.00 which is the low end of the allowable range

Because this evaluation occurred at the tail end (February – March) of the 2015/2016 winter blend gasoline distribution time frame, CARB staff recommends that additional field studies be conducted in the future at a larger number of test sites to more completely assess the ability to mitigate overpressure conditions and reduce ISD alarm frequency. These additional studies should cover the entire winter fuel blend time frame which begins in November and ends in March.

Appendices

The following appendices are provided as a supplement to the technical support document:

Appendix A. Results of Vapor Recovery System Testing Conducted at Granite Bay Test Site

Appendix B. Results of Vapor Recovery System Testing Conducted at San Diego Test Site

Appendix C. Results of Vapor Recovery System Testing Conducted at Campbell Test Site

Appendix D. Results of Vapor Recovery System Testing Conducted at Gilroy Test Site

Appendix E. Healy Nozzle ORVR Recognition Protocol

Appendix F. Results of ORVR Equipped Vehicle Recognition Survey Conducted at Granite Bay Test Site

Appendix G. ISD Data Collected at San Diego Test Site

Appendix H. Results of ORVR Equipped Vehicle Recognition Survey Conducted at San Diego Test Site

Appendix I. ISD Data Collected at Campbell Test Site

Appendix J. ISD Data Collected at Gilroy Test Site