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

## Healy Model 900 Assist Vapor Recovery Nozzle ORVR Vehicle Recognition Study

November 29, 2017

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# I. Executive Summary

In January 2015, staff members from the California Air Resources Board (CARB) and the California Air Pollution Control Officers Association (CAPCOA) Vapor Recovery Subcommittee conducted a Healy Model 900 assist system vapor recovery nozzle Onboard Refueling Vapor Recovery (ORVR) vehicle recognition study (nozzle study) at six retail gasoline dispensing facilities (GDFs) located in San Diego, California. The objectives of the nozzle study were 1) to determine if the ORVR vapor-to-liquid (V/L) ratio and if the ORVR mis-identification rate of the Healy nozzle have changed since 2007 and 2) to determine if key correlations, similarities, and differences exist between GDFs which exhibit "pressure increasing while dispensing" (PWD) and those that do not (non-PWD). Three GDFs were selected because they exhibited PWD while the other three GDFs selected as a control group did not exhibit PWD conditions. Prior to conducting the nozzle study, extensive vapor recovery system (VRS) performance testing was conducted and applicable repairs were made to establish optimal operating conditions and to eliminate any potential biases introduced by faulty or inoperable equipment.

The nozzle study resulted in five key findings which are summarized as follows:

- The ORVR vehicle mis-identification rate of the Healy nozzle has increased from approximately 17% to approximately 30% when compared to a prior study conducted by CARB and CAPCOA staff in 2007.
- The average ORVR V/L ratio of the Healy nozzle has increased by approximately 38% when compared to the prior study conducted in 2007.
- In many cases, the ORVR mis-identification rate was found to be dependent on customer behavior as some vehicles were able to be fueled with a loose latch.
- Certain newer ORVR fill pipe designs (capless) utilize drain ports and injection molded components which when joined, may contain gaps which create an open path to the atmosphere. These openings which exist within the vehicle fill pipe cause the Healy Model 900 nozzle to ingest excess air during vehicle refueling.
- With regard to comparison of the Healy Model 900 nozzle performance at PWD and non-PWD sites, no clear correlation was revealed between the two data sets.

The results of this study suggest that efforts should be made to lower the ORVR vehicle V/L ratio and the mis-identification rate of the Healy Model 900 nozzle by eliminating the occurrence of loose latch fueling events. Efforts should also be made to eliminate newer ORVR vehicle fill pipe design features which compromise the ability of the nozzle to form a vapor tight seal during fueling events. A combination of these mitigation measures should reduce excess air ingestion, which should help mitigate the severity and frequency of overpressure conditions commonly found when winter blend gasoline is distributed at GDFs equipped with assist systems.

## II. Introduction and Background

During the week of January 12, 2015, CARB Vapor Recovery Program and CAPCOA Vapor Recovery Subcommittee staff conducted a field study at six retail GDFs located in the San Diego region. The purpose of the study was 1) to determine if the average ORVR vehicle V/L ratio and mis-identification rate of the Healy 900 nozzle have increased since 2007 and 2) to determine if correlations exist with regard to nozzle performance at GDFs equipped with the Healy Assist Phase II Enhanced Vapor Recovery (EVR) system which exhibit PWD and those that do not. PWD is a severe case of overpressure (OP) where the pressure within the underground storage tank (UST) is high enough to crack or open the pressure vacuum relief valve for extended periods of time when fuel is being dispensed. This results in the release of gasoline vapors to the atmosphere.

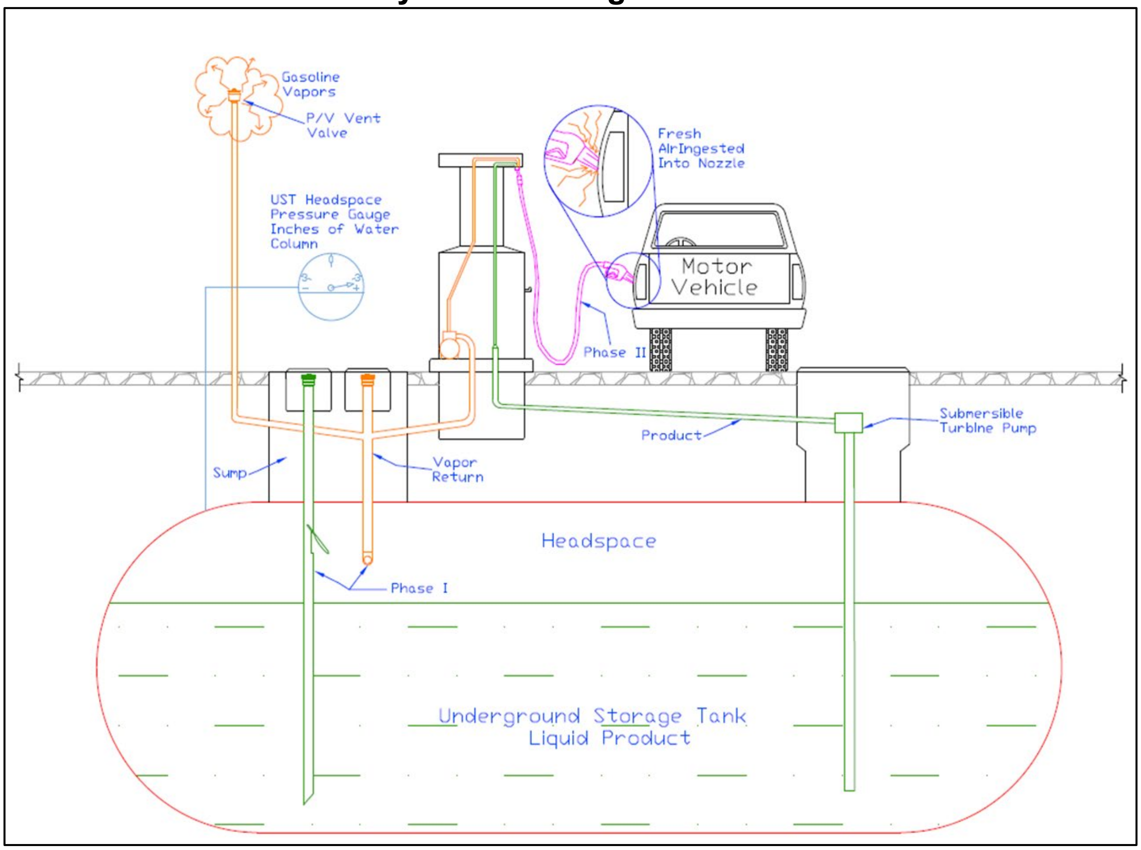
The Healy Assist Phase II Enhanced Vapor Recovery System (Assist System) with In-Station Diagnostics (ISD) was first certified in 2005. According to a CARB staff survey of air pollution control districts conducted in 2013 (Appendix I), the Assist System was installed at approximately 67% of the GDFs subject to vapor recovery requirements in California.

ISD equipment is designed to monitor the collection and containment of gasoline vapors by vapor recovery equipment installed at GDFs. The ISD software continuously monitors the vapor recovery equipment and issues warning and failure alarms when regulatory thresholds listed in Section 9 of certification procedure CP-201[1] are exceeded. ISD will activate a warning alarm that notifies the GDF owner/operator of a potential vapor recovery system problem that may require maintenance. If the required corrective action is not taken within the specified time, the ISD system will trigger a failure alarm and terminate all fuel dispensing or deactivate individual fueling points.

Among the parameters monitored by ISD is the pressure within the headspace or ullage of the UST. If the pressure within the UST exceeds a certain threshold, an OP alarm is triggered. A GDF continuously exhibiting PWD will have multiple OP alarms per month.

The Assist System is designed to reduce the volume of vapor collected relative to the volume of liquid dispensed when fueling ORVR equipped vehicles. For the Assist System to work properly, the Healy Model 900 nozzle must limit the amount of air ingestion during the fueling of ORVR equipped vehicles. This is referred to as ORVR recognition and relies upon a tight seal being formed at the nozzle and vehicle fill pipe interface. With a tight seal, the vapor volume available for collection by the nozzle is limited and thus a vacuum rapidly develops in the nozzle bellows. This vacuum activates a diaphragm which restricts the vapor return path in the nozzle which drops the vapor to liquid ratio (V/L) below 0.5 when fueling ORVR vehicles. In some instances, an ORVR fueling will result in an elevated ORVR V/L (>0.5) due to excess air ingestion by the nozzle during the fueling process. This excess air will be returned to the UST, resulting in higher evaporation rates and vapor growth in the UST contributing to OP containment alarms and excess pressure-driven emissions. Figure II-1 provides an illustration of air ingestion by a nozzle at a GDF equipped with an Assist System.

**Figure II-1**
**Assist System – Air Ingestion at Nozzle**




As previously stated, the primary objective of the nozzle study was to determine if the ORVR V/L ratio and ORVR mis-identification rate have changed since 2007 when CARB and CAPCOA staff conducted a similar survey as part of the In-Station Diagnostic Evaluation Field Study[2]. Due to the increased prevalence of PWD, this latest study was deemed necessary to determine if the V/L ratio and mis-identification rate have changed due to design variations of the vehicle fill pipe, problems with the nozzle, or nozzle/fill-pipe compatibility. Mis-identification is a term used to describe the fueling of an ORVR equipped vehicle which yields a V/L greater than 0.5. Under optimal fueling conditions, the fueling of an ORVR equipped vehicle will result in a V/L less than 0.5.

Upon analysis of ISD data collected from approximately 400 retail GDFs by CARB staff in 2013[3], it was determined that the percentage of GDFs equipped with the Assist System that exhibited PWD was approximately 34%. Although wintertime RVP is the underlying driver for overpressure and PWD, the nozzle study described here enabled CARB staff to determine whether air introduced during ORVR fueling events at GDFs is a significant contributor to PWD. The second objective of this study was to analyze the data and look for correlations, similarities, and differences between PWD and non-PWD GDFs.

## III. Methodology

Prior to deployment of staff resources and commencement of field data collection at the six GDFs in San Diego, CARB and CAPCOA staff agreed upon a basic methodology and developed a test protocol to ensure uniform collection of data. The GDFs were carefully selected based on site characteristics such as ISD alarm history, facility maintenance practices, monthly throughput, and the owner's/operator's willingness to participate in the nozzle study. During the planning stages of the study, a statistical sampling plan, using Neyman's[4] optimal allocation in a stratified sample, was designed to determine the number of sites, the number of nozzles, and the number of ORVR and non-ORVR fueling observations needed to ensure the results of the nozzle study had a minimum confidence level of 90%. The nozzle study statistical sampling plan is described in Appendix II.

The statistical sampling plan indicated that a total of six GDFs (three PWD and three non-PWD) equipped with the Assist System were required along with the collection of approximately 1,000 vehicle fueling events on ORVR equipped vehicles. The following paragraphs describe key components which comprise the methodology of the study.

### A. Test Sites

CARB and CAPCOA staff obtained permission from six owners/operators to participate in the study. Information pertaining to the six GDFs that were chosen to participate is listed in Table III-1.

**Table III-1**
**Nozzle Study Test Site Information**

| Site Name | Location | Monthly Throughput | PWD Observed | ISD System |
|---|---|---|---|---|
| Site A | San Diego, CA | 175,000 | Yes | Veeder-Root |
| Site B | San Diego, CA | 210,000 | Yes | Incon |
| Site C | San Diego, CA | 240,000 | Yes | Incon |
| Site D | Santee, CA | 155,000 | No | Veeder-Root |
| Site E | Cardiff, CA | 200,000 | No | Veeder-Root |
| Site F | San Diego, CA | 130,000 | No | Veeder-Root |

Note: All six sites were equipped with the Phase II EVR Assist System

### B. Vapor Recovery System (VRS) Performance Testing

During the week of December 15, 2014, CARB staff conducted Phase I and Phase II vapor recovery system (VRS) performance testing at each GDF in order to establish baseline operating conditions and to ensure that each GDF complied with applicable regulatory performance standards and specifications. This testing was deemed necessary to determine if the GDF was suitable for the nozzle study. If vapor recovery equipment was found to be out of compliance, the results of the study could be biased. The results of the baseline VRS performance testing are listed in Table III-2.

**Table III-2**
**Results of Baseline VRS Performance Testing**
**Week of December 15, 2014**

| Test Site | TP-201.3 Leak Decay | Exhibit 4 VR 201/202 Clean Air Separator (CAS) | VP-1000 Dispenser Integrity Vacuum Test | VP-1000 Dispensing Vacuum Test | Exhibit 5 VR 201/202 V/L Testing | Exhibit 9 VR-202 ISD Operability Vapor Pressure Sensor | Exhibit 9 VR-202 ISD Operability Vapor Flow Meter |
|---|---|---|---|---|---|---|---|
| **Site A San Diego, CA** | Pass | Pass | Pass | Pass | 8 Nozzles 8 Fail | Pass | Pass |
| **Site B San Diego, CA** | Pass | Pass | 6 Dispensers 2 Fail | Pass | 12 Nozzles 11 Fail | Pass | Pass |
| **Site C San Diego, CA** | Pass | Pass | 6 Dispensers 1 Fail | Pass | 12 Nozzles 11 Fail | Pass | 6 Flow Meters 1 Fail Dispenser (1-2) |
| **Site D Santee, CA** | Pass | Pass | 5 Dispensers 2 Fail | Pass | 10 Nozzles 9 Fail | Pass | Pass |
| **Site E Cardiff, CA** | Pass | Pass | Pass | Pass | 8 Nozzles 5 Fail | Pass | Pass |
| **Site F San Diego, CA** | Pass | Pass | 6 Dispensers 3 Fail | Pass | 12 Nozzles 11 Fail | Pass | Pass |

As indicated in the Table III-2, vapor recovery equipment issues were encountered during baseline VRS performance testing. Low V/Ls were observed at all six sites and dispenser leak integrity failures were observed at four of the six sites. The GDF operators were allowed two weeks to have certified maintenance contractors repair all equipment that failed performance testing.

Although not indicated in Table III-2, VRS testing was conducted at a seventh site in case one of the primary sites was unable to complete the necessary repairs. Due to cooperation and agreement to make timely repairs from the six primary site GDF operators, it was not necessary to use the seventh site in the vehicle observation segment of the study.

During the week of January 5, 2015, CARB staff returned to verify that all repairs had been successfully completed. In addition to repair verification, CARB staff adjusted nozzle V/L that were outside of the V/L regulatory range. The results of the VRS performance testing after repairs were completed are listed in Table III-3.

**Table III-3**
**Results of VRS Performance Testing after Repairs – Week of January 5, 2015**

| Site Description | VP-1000 Dispenser Integrity Vacuum Test | Exhibit 5 VR 201/202 V/L Testing | Exhibt 5 V/L Site Average | Exhibit 9 VR-202 ISD Operability Vapor Flow Meter |
|---|---|---|---|---|
| **Site A San Diego, CA** | Pass | Pass | 1.03 | N/A |
| **Site B San Diego, CA** | Pass | Pass | 1.02 | N/A |
| **Site C San Diego, CA** | Pass | Pass | 1.03 | Pass |
| **Site D Santee, CA** | Pass | Pass | 1.02 | N/A |
| **Site E Cardiff, CA** | Pass | Pass | 0.99 | N/A |
| **Site F San Diego, CA** | Pass | Pass | 1.03 | N/A |

After completing repairs, the six GDFs were checked to determine whether PWD/non-PWD conditions were still present. All six GDFs continued to exhibit the same PWD and non-PWD conditions as they had prior to CARB testing. The complete set of VRS performance test results is listed in Appendix III.

## C. Data Collection

After all performance testing was completed to verify the vapor recovery systems were operating properly, vehicle refueling data was collected at the six GDFs. At each GDF, refueling observations were performed at six pre-selected fueling points by three staff members; two from CARB and one from the San Diego County Air Pollution Control District. Each staff member was responsible for monitoring fueling events at two fueling positions. At each fueling position, based on the statistical sampling plan detailed in Appendix II, a minimum of 26 ORVR and 3 non-ORVR valid fueling events were observed.

In order for a fueling event to be deemed valid, staff prevented simultaneous fuelings from occurring by coning off the opposite side of the dispenser so that only one side of the dispenser was being used. Fueling events during which both sides of the dispenser were active did not qualify as valid because ISD does not record the individual V/L for simultaneous transactions. Fueling events of less than three gallons also did not qualify as valid due to the ISD requiring a minimum amount of fuel dispensed per valid transaction. Additionally, fueling events for vehicle manufactured during the phase in of ORVR requirements were excluded because it was not certain if such vehicles were actually equipped with ORVR. A description of the ORVR vehicle phase-in schedule is provided in Figure III-1.

**Figure III-1**
**ORVR Vehicle Phase-In Schedule: Transition Years Shown In Yellow**

<table>
<tr><th>Model Year</th><th>Passenger Cars</th><th>Light Duty Trucks</th><th>Medium Duty and Light Heavy Duty Trucks</th></tr>
<tr><td>1997 or Older</td><td>Non-ORVR</td><td rowspan="4">Non-ORVR</td><td rowspan="7">Non-ORVR</td></tr>
<tr><td>1998</td><td rowspan="2">Transition Years</td></tr>
<tr><td>1999</td></tr>
<tr><td>2000</td><td rowspan="7">ORVR</td></tr>
<tr><td>2001</td><td rowspan="2">Transition Years</td></tr>
<tr><td>2002</td></tr>
<tr><td>2003</td><td rowspan="4">ORVR</td></tr>
<tr><td>2004</td><td rowspan="2">Transition Years</td></tr>
<tr><td>2005</td></tr>
<tr><td>2006 or Newer</td><td>ORVR</td></tr>
</table>

In addition to the ORVR vehicle phase-in schedule, CARB and CAPCOA staff also utilized a matrix that defined the difference between light duty trucks and medium duty and light heavy duty trucks by gross vehicle weight rating (GVWR). GVWR is the maximum operating weight/mass of a vehicle as specified by the manufacturer including the vehicle's chassis, body, engine, engine fluids, fuel, accessories, driver, passengers and cargo but excluding that of any trailers. It was necessary to use this matrix to properly classify vans, trucks, and sport utility vehicles as ORVR or non-ORVR. The ORVR determination for light duty trucks and medium duty and light heavy duty trucks by GVWR is detailed in Appendix IV.

CARB and CAPCOA staff recorded the necessary vehicle information onto the data collection form shown in the Healy 900 Assist Nozzle ORVR Recognition Study Protocol (Appendix V – Table 2).

Dedicated data collection forms were prepared for each fueling point at which vehicle fueling information was collected. The only field of information that was obtained from the customer was the vehicle model year. If the customer did not know the vehicle model year then staff checked the inside of the vehicle door for the manufacturing date. Vehicle model years that were questionable were omitted from the data collection form and the fueling event was not included in the study.

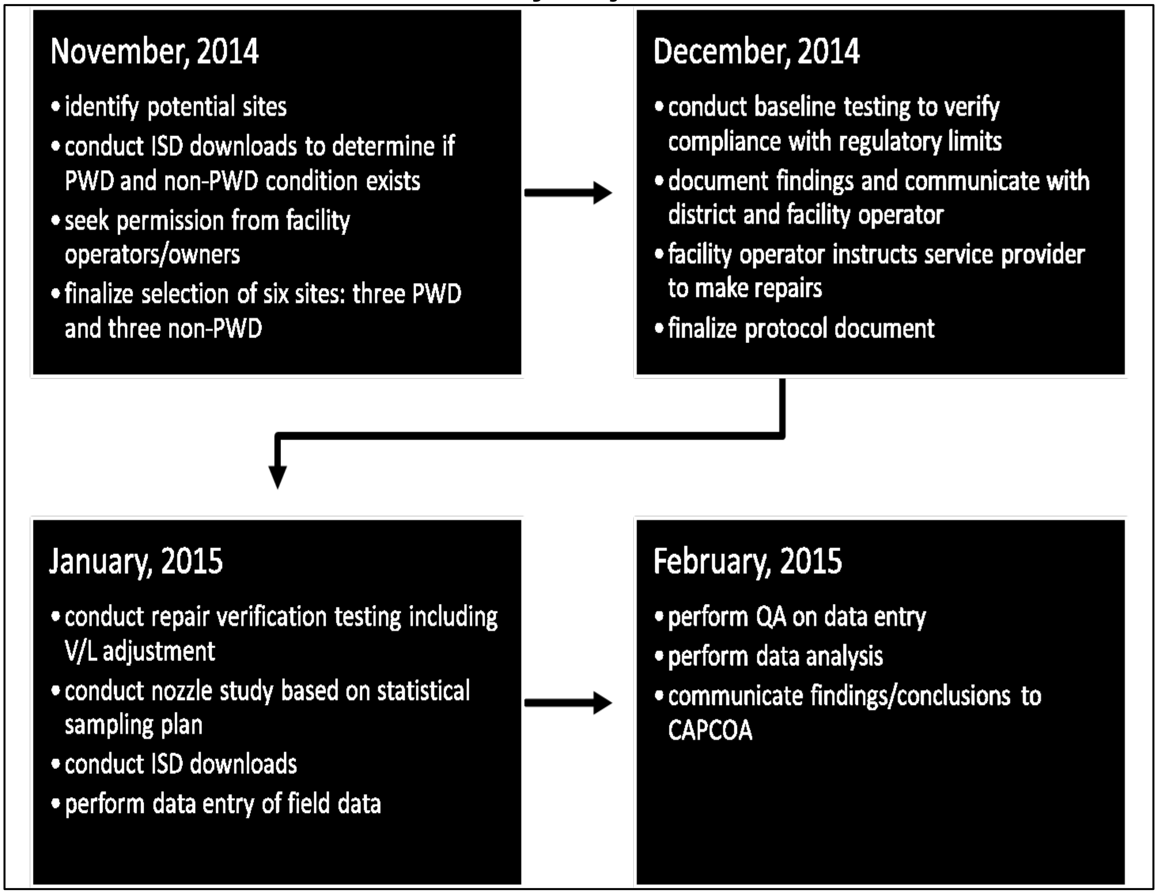
The remaining content of the data collection form was completed by CARB and CAPCOA staff without customer intervention. CARB and CAPCOA staff did not assist customers during the fueling of their vehicles. The dispensing rate was also measured and recorded at the six pre-selected fueling points once per day to ensure the fueling point dispensing rate was between six and ten gallons per minute as required per Assist System Executive Order VR-202.

At the end of each day, CARB staff connected a laptop computer to the ISD console to collect pressure-ullage and individual fueling event V/L transaction data. The time, dispensed liquid, returned vapor volume, and V/L for each observed fueling event, which was downloaded from the ISD system, was correlated to the recorded events based on the start time for the dispensing event and the volume of liquid dispensed. This was done to ensure that all data was collected by the ISD system and that the minimum number of events required by the statistical sampling plan would be observed. The testing protocol is fully detailed in the Healy 900 Assist Nozzle ORVR Recognition Study Protocol in Appendix V.

At the conclusion of the nozzle study, all data collection forms were collected and data entered into a Microsoft (MS) Excel spreadsheet to create a MS Excel database. The corresponding ISD data that was downloaded from the ISD console was also entered into the same MS Excel spreadsheet and matched to each fueling event.

The MS Excel database consisted of 26 different fields for each fueling event and a total of 1,597 total fueling events. The database was then checked for accuracy by CARB staff that did not do the original data entry. It was necessary to perform quality assurance (QA) on the database to ensure that all data was input correctly. If discrepancies were found, staff made the corrections in the main database while keeping track of errors and corrections (Appendix VI). The final MS Excel database, after the QA check, was used to conduct data analysis and identify correlations and trends within the data set. The final MS Excel database and corresponding data analysis is detailed in Appendix VII. The entire project timeline for the nozzle study is illustrated in Figure III-2.

**Figure III-2**
**Nozzle Study Project Timeline**



## IV. Results

Upon completion of the nozzle study, a total of 1,597 valid fueling events (1,355 ORVR and 242 non-ORVR) were observed. With each fueling event, CARB and CAPCOA staff observed and recorded vehicle information followed by the retrieval of V/L ratio data from ISD. Table IV-1 and IV-2 show the V/L ratio and the mis-identification rate from the nozzle study for both PWD and non-PWD GDFs.

**Table IV-1**
**V/L Ratio for PWD and Non-PWD GDFs in Nozzle Study**

| Data Set | Overall V/L | ORVR V/L | Non-ORVR V/L |
|---|---|---|---|
| All 6 Sites | 0.61 | 0.54 | 0.98 |
| 3 PWD Sites | 0.61 | 0.54 | 0.98 |
| 3 Non-PWD Sites | 0.60 | 0.53 | 0.98 |

**Table IV-2**
**Mis-Identification Rate for PWD and Non-PWD GDFs in Nozzle Study**

| Data Set | Total # of Fueling Events | # of ORVR Fueling Events | # of ORVR Fueling Events w/ V/L >0.5 | Mis-Identification Rate |
|---|---|---|---|---|
| All 6 Sites | 1597 | 1355 | 411 | 30.3% |
| 3 PWD Sites | 853 | 716 | 216 | 30.2% |
| 3 Non-PWD Sites | 744 | 639 | 195 | 30.5% |

The V/L ratio for ORVR vehicles was obtained for all ORVR fueling events in the nozzle study. Analysis of the ORVR V/L ratio results showed that newer model year vehicles had a higher mis-identification rate than older ORVR model year vehicles which is illustrated in Table IV-3.

**Table IV-3**
**ORVR V/L Ratio by Vehicle Model Year**

| Vehicle Model Year Duration | ORVR V/L | Mis-Identification Rate |
|---|---|---|
| 2000-2011 | 0.50 | 26% |
| 2012-2015 | 0.62 | 38% |

Further analysis revealed that certain vehicle makes (vehicle manufacturers) exhibited mis-identification rates significantly higher than the study wide average of 30%. As indicated in Table IV-4, the top two manufacturers (in terms of highest mis-identification rates) were Mercedes and BMW. Both manufacturers commonly use the “bayonet style” fill pipe design with a primary and secondary ring at which the vapor recovery nozzle boot comes into contact with. Additional discussion on the bayonet design is provided in section V of this document, under discussion of results.

**Table IV-4**
**ORVR Equipped Vehicle Manufacturers with a High Mis-Identification Rate**

| Vehicle Manufacturer | Mis-Identification Rate |
|---|---|
| Mercedes | 85.7% |
| BMW | 69.0% |
| Ford | 54.1% |
| Lincoln | 36.4% |
| Cadillac | 35.7% |
| Chrysler | 32.4% |

Although some vehicle manufacturers had a high mis-identification rate, conversely, there were several manufacturers that had a low mis-identification rate when compared to the study wide average of 30%. As indicated in the Table IV-5, GMC and Buick vehicles yielded mis-identification rates of less than 10%. Such information is noteworthy because these particular design characteristics should be further studied and potentially standardized because they indicate compatibility with the assist vapor recovery system.

**Table IV-5**
**ORVR Equipped Vehicle Manufacturers with a Low Mis-Identification Rate**

| Vehicle Manufacturer | Mis-Identification Rate |
|---|---|
| GMC | 8.3% |
| Buick | 9.1% |
| Mazda | 9.3% |
| Volkswagen | 10.5% |
| Kia | 16.2% |
| Volvo | 16.7% |

Approximately four percent of the total vehicles surveyed were ORVR equipped vehicles with a capless fill pipe design. Of the total population sampled, vehicles manufactured by Ford, and to a lesser extent Chrysler, were routinely observed with capless fill pipes. As shown in Table IV-6, Chrysler and Ford vehicles with capless fill pipes also exhibited a high mis-identification rates and high V/L ratios. Additional discussion on the capless fill pipe design is provided in section V of this document, discussion of results.

**Table IV-6**
**Mis-Identification Rate and V/L Ratio of ORVR Vehicles with a Capless Fuel Pipe System**

| Vehicle Make | # of Capless Vehicles Observed | # of Capless Fueling Events with V/L >0.5 | Mis-Identification Rate | Percentage of Fueling Events w/ V/L >1.0 | Average V/L |
|---|---|---|---|---|---|
| Chrysler | 3 | 3 | 100% | 100% | 1.25 |
| Ford | 56 | 46 | 82.1% | 78.6% | 1.09 |

## V. Discussion of Results

Upon review and analysis of the extensive data set captured throughout the nozzle study, a number of important findings became apparent.  Two of these findings (loose latch and capless, both discussed below) greatly improved CARB's understanding of the dynamics which occur during the fueling of ORVR equipped vehicles at GDF equipped with the Assist System.  Due to the number of findings, this section of the document is divided into a series of subsections, each with its own heading for ease of reference.

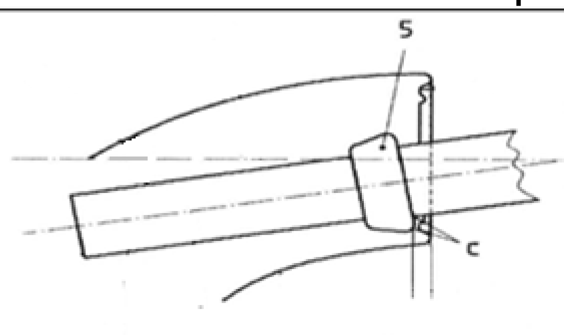
### A. PWD/Non-PWD Analysis

As indicated in Section IV of this document, the ORVR V/L ratio and mis-identification rate for PWD and non-PWD GDFs were essentially the same.  The data reveals that the ORVR V/L ratio and mis-identification rate did not have a significant effect on the presence or absence of PWD.  These results suggest that in addition to wintertime RVP and excess air ingestion, other GDF characteristics such as monthly gasoline throughput, UST ullage volume, GDF operating hours, etc. can determine whether or not a GDF exhibits PWD.  Further study and analysis is needed to determine why a GDF may or may not exhibit PWD.

### B. Secure Latch vs Loose Latch

Analysis of the individual fueling events showed that the Healy nozzle ORVR vehicle mis-identification rate can vary within the same vehicle make, vehicle model, and model year.  This suggests that customer behavior may play a significant role with regard to ORVR V/L and the mis-identification rate.  This hypothesis led to the finding that air ingestion can vary depending on whether the nozzle was securely or loosely latched within the ORVR vehicle fill pipe[5].  Figure V-1 shows a cross-sectional view of a nozzle spout inside the vehicle fill pipe.

**Figure V-1**
**Cross Sectional View of Nozzle Spout and Vehicle Fill Pipe**




| Item | Description |
|---|---|
| 5 | Nozzle Latch Ring |
| C | Fill Pipe Locking Lip |

The nozzle spout has a latch ring which needs to securely engage upon the locking lip of the vehicle fill pipe during fueling in order to ensure a secure latch.  During the nozzle study and in a subsequent CARB study[5], field data showed that many different vehicle makes and models were able to be fueled with a loose latch. The term loose latch means that the nozzle is not fully engaged or securely connected to the fill pipe locking lip of the vehicle fill pipe. Figure V-2 illustrates an example of a secure and loose latch fueling into an ORVR vehicle fill pipe.

**Figure V-2**
**Secure Latch vs Loose Latch Fueling**

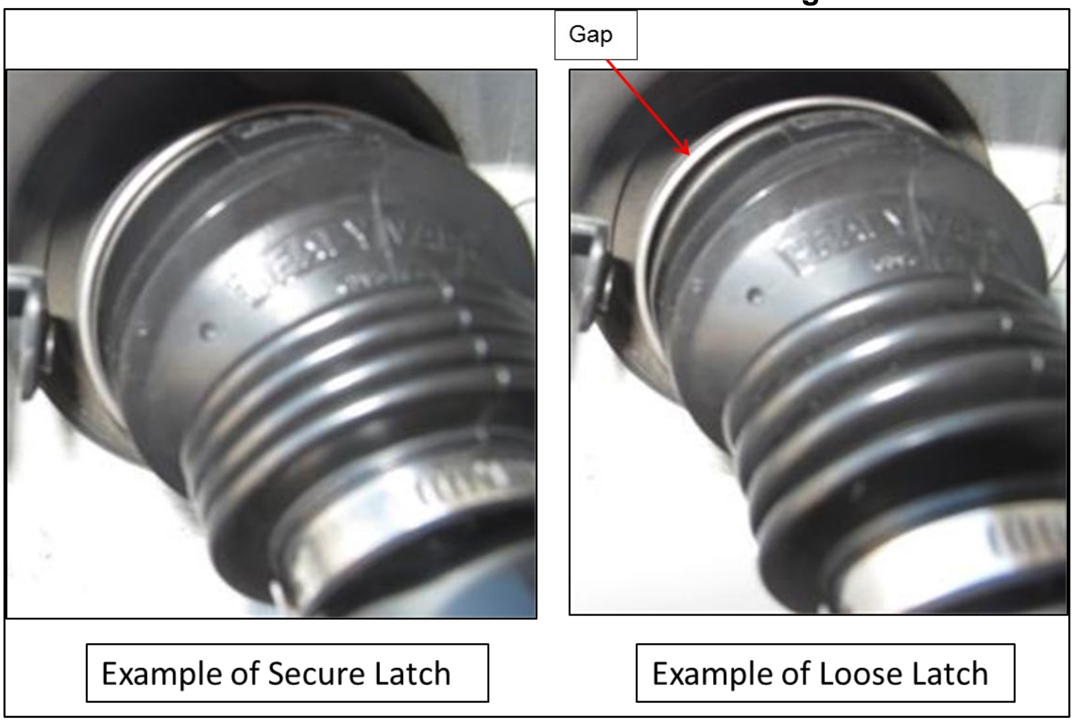



Figure V-2 shows an example of an obvious loose latch during the fueling of an ORVR equipped vehicle. In most cases, the loose latch cannot be visually seen but can be determined by the V/L measurement. This finding prompted CARB staff to conduct a new field study focused on the fueling of ORVR equipped vehicles with the nozzle securely and loosely latched into the vehicle fill pipe[5]. This field study was conducted by CARB staff at a retail GDF in Sacramento. Fueling of ORVR equipped vehicles with a loose latch exhibited a higher V/L ratio measurement due to excess air ingestion at the fill pipe/nozzle interface. The additional air ingested via the fill pipe/nozzle interface increases the evaporation rate and vapor growth within the UST which leads to excess pressure-driven emissions. ORVR equipped vehicles that are fueled with a loose latch will have high V/Ls and thus result in a high mis-identification rate.

### C. Vehicle Fill Pipe Design

CARB's motor vehicle regulations require vehicle manufacturers to design vehicle fill pipes according to standards and specifications which ensure a good seal is established between the nozzle and vehicle fill pipe interface. In 2008, new vehicle fill pipe designs entered the market. Many manufacturers moved from a traditional capped fill pipe system to a capless fill pipe system. Figure V-3 shows an example of a capless fill pipe system.

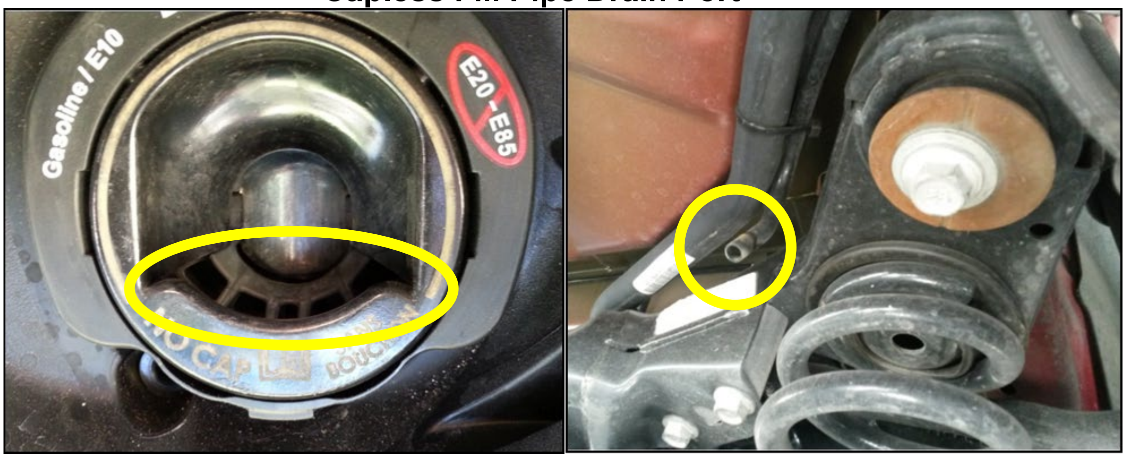
**Figure V-3**
**Capless Fill Pipe System**


According to vehicle manufacturers, the development and implementation of the capless fill pipe design was prompted by several reasons including the following:

- Reduced warranty claims – The evaporative system within a vehicle monitors the fuel vapors to ensure that no vapors are escaping the sealed system. When the gas cap is left off or improperly secured, the system senses a leak and creates a trouble code that causes a false illumination of the check engine light within the vehicle.
- Improper fueling – Capless fill pipe designs include an integrated Mis-Fuel Inhibitor (MFI) which only allows the vehicle to be fueled with the correct fuel nozzle.
- Fuel theft - The MFI also prevents fuel theft as the fuel nozzle detector that guides the nozzle to the fill neck of the system inhibits forced entry and syphoning.
- Customer experience – The capless system eliminates the need to remove and replace a separate fuel cap. This is extremely helpful to arthritic customers and customers in geographic areas where gas caps are prone to freezing.

Some capless fill pipe systems were designed with a drain port that prevents water, dirt, and dust from entering the fuel pipe. The drain port extends from the fill pipe to the bottom of the vehicle. Figure V-4 shows an example of the drain port in the capless fill pipe and at the underside of the vehicle.

**Figure V-4**
**Capless Fill Pipe Drain Port**



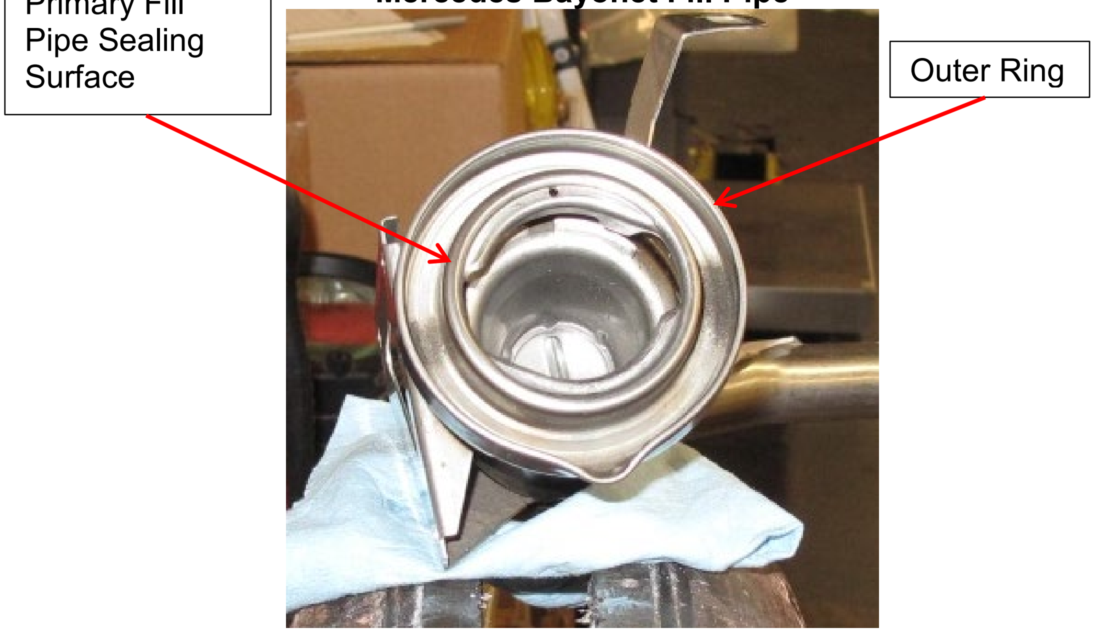

When fueling an ORVR equipped vehicle with a capless fill pipe with a Healy nozzle, fresh air is allowed to enter the nozzle bellows from the drain port underneath the vehicle. During this fueling, no vacuum is created in the nozzle bellows and there is no restriction of the vapor path in the nozzle. As a result, a V/L ratio of greater than one may occur. The fresh air that is allowed to enter through the drain port is returned to the UST which increases the pressure in the UST due to gasoline evaporation.

In addition to the drain port feature, some capless designs have other openings/gaps within the fuel pipe assembly. These openings are either engineered vents intentionally designed into the fuel pipe or are created when different components (typically made of injection molded plastics) which comprise the capless fill pipe assembly are press fitted together during the manufacturing process. Similar to the drain port, these openings/gaps create a path to the atmosphere and allow excess air ingestion during the fueling of ORVR equipped vehicles which results in V/Ls which are similar to non-ORVR equipped vehicles.

ORVR equipped vehicles with capless fill pipe designs comprised approximately four percent of the data set in the nozzle study. The mis-identification rate for ORVR vehicles with a capless design was over 80% with 78% of the vehicles surveyed having a V/L greater than 1.0. This is illustrated in Table IV-6. Unless corrective action is taken quickly, this will become an increasingly larger problem as a larger number of vehicle manufacturers are moving toward the capless designs.

Table IV-4 shows vehicle makes that yielded a high mis-identification rate. Not all the vehicle makes shown in Table IV-4 had a capless fill pipe design yet they still yielded a high mis-identification rate. CARB staff studied the cause of the high mis-identification rate of Mercedes vehicles. The results of the nozzle study showed that approximately 91% of the Mercedes vehicles surveyed were equipped with a bayonet fill pipe design. The Mercedes vehicles with a bayonet fill pipe also had a mis-identification rate of approximately 91%. A picture of the bayonet fill pipe is shown in Figure V-5.

**Figure V-5**
**Mercedes Bayonet Fill Pipe**




The fill pipe was tested in a lab by using a bayonet fill pipe which was removed from a Mercedes vehicle. The nozzle was then securely latched into the fill pipe. A smoke leak detector was connected to the open end of the fill pipe to determine whether the nozzle/fill pipe interface was a secure or loose latch. The smoke testing revealed that if the nozzle sits on the outer ring of the fill pipe, which is a common occurrence during vehicle fueling, the bayonet fill pipe can inhibit the Healy 900 vapor recovery nozzle from making a good seal at the bottom of the fill pipe sealing surface. The loose latch created during the fueling of a Mercedes vehicle with a bayonet fill pipe is the main cause of the high mis-identification rate for vehicles equipped with this design. Figure V-6 shows the set up used to test the Mercedes bayonet fill pipe for leaks.

**Figure V-6**
**Smoke Testing Apparatus Used for Leak Testing**

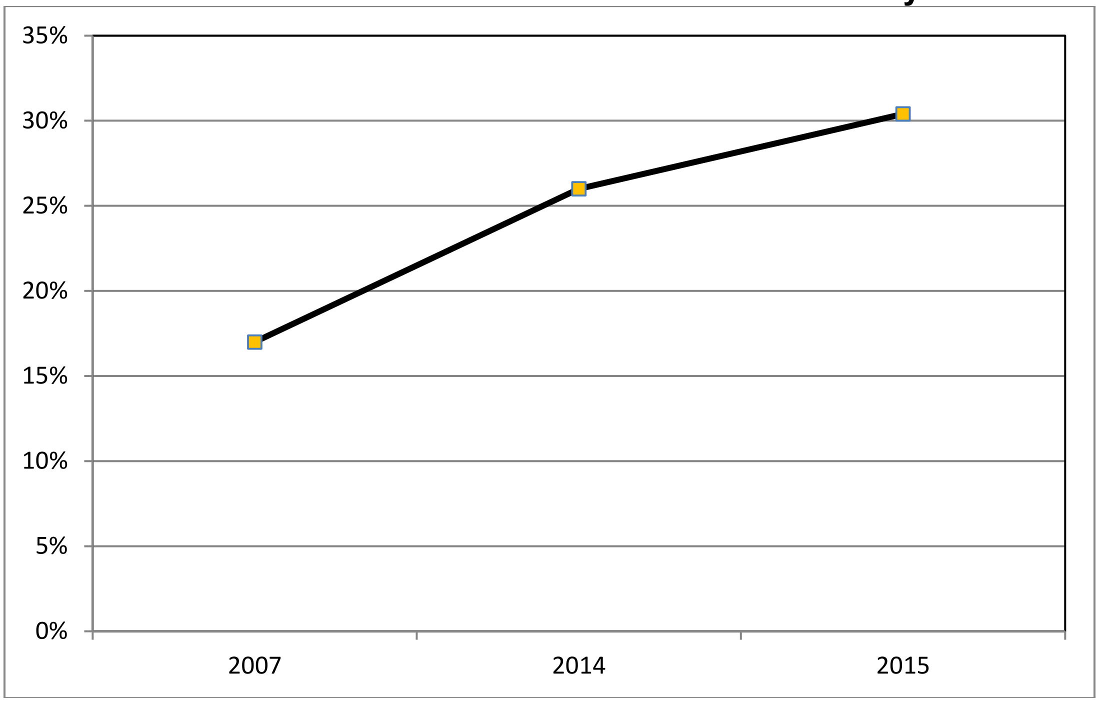
The high mis-identification rate for Ford and Lincoln vehicles is mainly caused by the capless fill pipe design but the cause of the high mis-identification rate for BMW, Cadillac, and Chrysler still needs to be studied.

Vehicle makes that did not have an open port within the vehicle fill pipe and were capable of obtaining a secure latch during the fueling of an ORVR equipped vehicle yielded a low mis-identification rate and are shown in Table IV-5.

### D. ORVR Mis-Identification Rate

Over the last eight years, three studies pertaining to Healy nozzle ORVR recognition have been conducted; two collaboratively between CARB and CAPCOA staff and one by San Diego County Air Pollution Control District staff. In each of these three studies, only the fueling of vehicles was observed and customers were not assisted during the fueling process. Figure V-7 shows the increasing trend in the mis-identification rate for the three studies conducted since 2007.

**Figure V-7**
**Trends in ORVR Vehicle Mis-Identification Rate of Healy Nozzle**




In 2007, CARB and CAPCOA staff conducted an 18 month In-Use ISD Evaluation Field Study on the first ISD system certified by CARB in which the fueling of 547 ORVR equipped vehicles was observed. The results of this study showed that the mis-identification rate for ORVR equipped vehicles at that time was approximately 17%. In June 2014, a small ORVR Recognition Study was conducted by San Diego County Air Pollution Control District staff in which the fueling of 96 ORVR vehicles was observed. The mis-identification rate for this study was determined to be approximately 26%. The small ORVR Recognition Study led to the larger nozzle study conducted in San Diego in January 2015 by CARB and CAPCOA staff. From this latest nozzle study, the mis-identification rate was determined to be approximately 30% (Table IV-2).

Between 2007 and 2015, the percentage of gasoline dispensed to ORVR vehicles has increased from approximately 50%[6] to approximately 78%[7]. As the gasoline dispensed to ORVR equipped vehicles has increased, the mis-identification rate has also increased from approximately 17% to approximately 30%. The ORVR V/L also increased from 0.39, as determined in the 18 month In-Use ISD Evaluation Field Study, to 0.54, as determined in the nozzle study (Table IV-1). The increase in the mis-identification rate and ORVR V/L from 2007 to 2015 at GDFs can be attributed to the increase in the percentage of gasoline dispensed to ORVR equipped vehicles, fueling ORVR equipped vehicles with a loose latch, and fueling into capless vehicle fill pipes that have open ports to the atmosphere. Table IV-3 shows that the overall V/L and mis-identification rate have increased for vehicles manufactured after 2012. This is problematic because this suggests that newer model ORVR equipped vehicles are ingesting more air during vehicle fueling. Table IV-4 shows the vehicle manufacturers that had a high mis-identification rate during the nozzle study. As the ORVR V/L, mis-identification rate, and the percentage of gasoline dispensed to ORVR equipped vehicles increases, the likelihood of a GDF equipped with an assist system exhibiting PWD also increases.

## VI. Conclusions and Recommendations

During the nozzle study, CARB and CAPCOA staff collected information pertaining to the performance of the Healy nozzle based on over 1,500 vehicle fueling events at six GDFs in San Diego. The nozzle study resulted in five key findings which are summarized as follows:

1. The ORVR equipped vehicle mis-identification rate of the Healy Model 900 nozzle has increased from approximately 17% to approximately 30% when compared to a prior study conducted by CARB and CAPCOA staff in 2007.
2. The average ORVR vehicle V/L ratio of the Healy nozzle has increased by approximately 38% when compared to the prior study conducted in 2007.
3. In many cases, the ORVR equipped vehicle mis-identification rate was found to be dependent on customer behavior as some vehicles were able to be fueled with a loose latch.
4. Certain newer ORVR vehicle fill pipe designs (capless) utilize drain ports and injection molded components which when joined, may contain gaps which create an open path to the atmosphere. These openings which exist within the vehicle fill pipe cause the Healy Model 900 nozzle to ingest excess air during vehicle refueling. Capless fill pipe designs need to be addressed immediately.
5. With regard to comparison of Healy nozzle performance at PWD and non-PWD sites, no clear correlation was revealed between the two data sets.

The results of this study suggest that efforts should be made to lower the ORVR equipped vehicle V/L ratio and the mis-identification rate of the Healy nozzle by eliminating the occurrence of loose latch fueling events. Efforts should also be made to eliminate newer ORVR equipped vehicle fill pipe design features which compromise the ability of the Healy nozzle to form a vapor tight seal during fueling events. A combination of these mitigation measures should reduce excess air ingestion, which should help mitigate the severity and frequency of overpressure conditions.

Although the reduction of the ORVR V/L and mis-identification rate may not eliminate all occurrences of ISD overpressure alarms and PWD, the reduction will lower the evaporation rate and significantly reduce pressure-driven emissions at GDFs. Upon conclusion of the study, the following actions were taken by CARB staff:

1. Share the results of the nozzle study with Franklin Fueling Systems, the original equipment manufacturer of the Healy nozzle to determine if design modifications can be made such that the nozzle cannot dispense fuel into an ORVR vehicle unless a good seal is made between the nozzle and the vehicle fill pipe. This would ensure that the nozzle cannot dispense fuel with a loose latch and the V/L is independent of customer behavior.
2. Share the results of the nozzle study with CARB's Emissions Compliance, Automotive Regulation and Science (ECARS) Division to determine if the ORVR equipped vehicles with capless fill pipes and open vent ports comply with CARB's On-Road Light-Duty Emissions Certification Requirements[8].

3. Work with CARB ECARS staff to determine if existing vehicle fill pipe performance standards should be amended to ensure new model ORVR equipped vehicles and EVR nozzles are compatible. This would eliminate vehicle fill pipes with open ports to atmosphere that allow air ingestion during fueling operations.
4. Determine if existing Phase II vapor recovery nozzle certification standards should be amended to help eliminate the fueling of ORVR equipped vehicles with a loose latch.
5. Work with vapor recovery nozzle manufacturers, automotive industry, fill pipe suppliers, and applicable CARB staff to come up with recommendations on developing specifications to ensure nozzle and vehicle fill pipe compatibility.

## VII. References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## VIII. Appendices

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| Appendix II | Nozzle Study Statistical Sampling Plan |
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| Appendix IV | ORVR Determination by GVWR |
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| Appendix VII | Nozzle Study Database |