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Subject: EVALUATION OF NOZZLE SPILLAGE CERTIFICATION DATA

Liquid gasoline spillage associated with motor vehicle refueling at gasoline dispensing facilities (GDF) has been controlled since the inception of the vapor recovery program.[1] Spillage occurs when liquid gasoline releases happen before, during, and after refueling events between a dispensing nozzle and vehicle fuel tank. As the liquid gasoline evaporates, vapor emissions are created. The implementation of Enhanced Vapor Recovery (EVR) and Enhanced Conventional (ECO) nozzle standards and the installation of Phase II EVR equipment brought greater controls for nozzle spillage.

This technical memorandum provides a summary of certification and test procedures for nozzle spillage and a compilation of mass emission factors for spillage based on CARB certification test data for five nozzles certified since the Board adopted EVR and ECO regulations. The last section of this memorandum provides conclusions, implications, and staff recommendations based on the spillage mass emission factors.

CERTIFICATION PROCEDURES AND PERFORMANCE STANDARDS

According to State law, vapor recovery equipment that is required by local Air District rules for the control of hydrocarbon and toxic emissions generated at GDFs must be certified by CARB. In 1975, CARB adopted the first certification and test procedures for vapor recovery systems installed at GDFs. The certification procedures contain the performance standards and specifications that must be met by equipment manufacturers to obtain CARB certification in the form of an Executive Order. Over the past few decades, CARB has periodically updated the certification procedures to reflect improvements in vapor recovery technologies, to modify requirements for existing

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[1] State law (Health and Safety Code section 41954(b)) requires CARB to adopt performance standards to control gasoline vapors for motor vehicle refueling that do not cause excessive liquid gasoline spillage.

installations to achieve additional emission reductions, and to improve cost-effectiveness.

CARB approved EVR regulations for GDFs equipped with underground storage tanks (UST) in March 2000 and aboveground storage tanks (AST) in June 2007. The EVR regulations were enacted to achieve additional emission reductions and to increase equipment reliability and durability. EVR regulations resulted in a major change to the certification procedures by increasing testing requirements and adopting nearly 80 new performance standards or specifications. Among the numerous EVR requirements were more stringent controls for Phase II systems such as standards designed to control the release of liquid gasoline at the nozzle, including liquid retention, post fueling drips, and spillage.

When adopting the first EVR nozzle spillage standard for certification procedure CP-201 for vapor recovery systems at GDFs with USTs [CARB, 2000 and 2019a], CARB sought additional emission reductions from spillage by reducing the limit for maximum spillage (‘spillage performance standard’) from 0.42 pounds/1,000 gallons (lbs/kgal) to 0.24 lbs/kgal [CARB, 2000]. In 2007, CARB adopted the same spillage performance standard of 0.24 lbs/kgal for nozzles in certification procedure CP-206 for vapor recovery systems at GDFs with ASTs [CARB, 2007 and 2019c].

In April 2015, CARB approved new performance standards and specifications for Enhanced Conventional (ECO) nozzles [CARB, 2015]. ECO nozzles are designed for use at non-retail GDFs that have been exempted by Air Districts from requirements to control emissions from refueling vehicles. Such non-retail GDFs are exempt because they fuel a captive fleet of newer vehicles that capture gasoline vapors during vehicle refueling using on board refueling vapor recovery (ORVR) systems. Examples of exempt GDFs include rental car facilities and new car dealerships. CARB adopted a lower spillage performance standard of 0.12 lbs/kgal for ECO nozzles in CP-207 [CARB, 2015 and 2019b]

In their 2015 evaluation, CARB staff found that the lower spillage performance standard for ECO nozzles was easily achievable by the three CARB-certified EVR nozzles. CARB staff committed to reevaluating the spillage performance standard in CP-201 and CP-206, and reported to the Board that they would likely return with a recommendation to lower the standard in CP-201 and CP-206 to improve accuracy in reporting emissions and provide consistency between the certification procedures [CARB, 2015].

All three certification procedures—CP-201, CP-206, and CP-207—specify the minimum number of dispensing episodes that must be observed during certification testing of any system for spillage:

	Minimum Number of Self-Service Refueling Operations	
	Fill-Ups [terminated by full tank shut-off[2], not including top offs[3]]	**Total** [not including top offs]
EVR nozzles used at GDFs with USTs (CP-201):	400	1,000
EVR nozzles used at GDFs with ASTs (CP-206):	20	50
ECO nozzles (CP-207):	160	400

In addition, all three certification procedures require the emission factors for nozzle spillage to not exceed their respective performance standards for each of the following three test categories:

- All refueling events;
- Refueling operations terminated before activation of the primary shutoff; and
- Refueling events terminated by activation of the primary shutoff.

TEST PROCEDURE FOR NOZZLE SPILLAGE

The CARB Executive Officer or delegate approves or denies certification of vapor recovery systems and components based on the results of certification testing procedures adopted by the Board through the formal public rulemaking process. CP201, CP-206, and CP-207 require that CARB evaluate spillage from nozzles undergoing certification review using field testing and calculation methods specified by Vapor Recovery Test Procedure TP-201.2C Spillage from Phase II Systems [TP-201.2C; CARB, 2001]. TP-201.2C was first adopted by the Board in 1996 and amended most recently in 2001 [CARB, 2000 and 2001] as part of the rulemaking for EVR regulations [CARB, 2000].

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2 Nozzles have an aspirator port (aka sensor port or automatic shutoff port) located at the tip of the nozzle spout that leads to a sensor that activates the nozzle's primary shutoff mechanism at some minimum flowrate (specific to each nozzle design) and the port is blocked. Once a vehicle tank is full, gasoline blocks the aspirator port and activates the nozzle's primary shutoff mechanism. To ensure sufficient flowrate for proper shutoff function in California, any nozzle that is tested as flowing lower than 5 gallons per minute is subject to an immediate tag out of service consistent with the requirements of the Title 17 defect list.

3 Top off: The attempt to dispense gasoline to a motor vehicle or utility equipment fuel tank after the dispensing nozzle primary shutoff mechanism has engaged. The filling of a class of vehicle tanks which, because of the configuration of the fill pipe, cause premature activation of the primary shutoff, shall not be considered topping off [per Vapor Recovery Definitions D-200; CARB, 2019d].

The purpose of TP-201.2C is to quantify the frequencies and quantities of liquid gasoline spilled during vehicle refueling events. It is applicable for determining compliance with the allowable mass emission factor for spillage (spillage performance standard).

During certification testing, CARB staff measures and records the dimensions of all observed spills that occur during each episode of dispensing liquid into a vehicle by counting the number of drops of gasoline and, for spills on pavement that cannot be quantified by counting drops, by measuring the spill area. A dispensing episode includes:

- Pre-Fueling Spillage. This includes removal of the nozzle from the pump through insertion of the nozzle spout into the vehicle fill pipe.
- Fueling Spillage. This includes any spillage that occurs during dispensing of gasoline liquid into the vehicle, prior to activation of the nozzle's primary shutoff mechanism.
- Spitback. This is the forcible ejection of liquid gasoline upon activation of the nozzle's primary shutoff mechanism.
- Post-Fueling Spillage. This includes removal of the nozzle from the vehicle through proper mounting of the nozzle on the dispenser.

CARB staff also records the number of gallons dispensed and:

- Whether a fill-up occurred;
- Whether a top-off occurred;
- The number of shut-off clicks; and
- The time, in seconds, for the refueling event.

Using methods and equations specified by TP-201.2C, CARB staff completes the following general steps for each nozzle spillage certification test:

- For each dispensing episode, convert the spill areas to spill volumes, in milliliters, using a calibration graph or equation derived from calibration data. For those spills that were quantified as drops, use a conversion of 20 drops of gasoline per milliliter.
- Convert the volume of all gasoline spillage throughout the certification test to pounds by dividing the spill volume (milliliters) by 3785.4 (conversion from milliliters to gallons) and multiplying by 6.28 pounds/gallon (specific weight of liquid gasoline).

- Calculate the total gallons of gasoline dispensed under each of the following four scenarios:
    1. All refueling events that did not include any top offs.
    2. All refueling events ended by the activation of the nozzle's primary shutoff mechanism.
    3. All refueling events not ended by the activation of the nozzle's primary shutoff mechanism.
    4. All refueling events, including events terminated by top offs.
- Calculate the mass emission factor of gasoline spillage (pounds per 1,000 gallons, or lbs/kgal) for each of the four scenarios by dividing the pounds of gasoline spilled by the sum of all gallons dispensed multiplied by 1,000.

MASS EMISSION FACTORS BASED ON CERTIFICATION TEST DATA

There are two types of Phase II vapor recovery systems in California: balance systems and vacuum assist systems (assist systems). Assist systems use a nozzle with a dedicated vapor return pathway and a dispenser-mounted vacuum pump to collect vapor from the vehicle fuel tank as gasoline is dispensed from the facility storage tank. Balance systems use nozzles with a dedicated low resistance vapor return pathway and rely on direct displacement to pull vapor from the vehicle fuel tank to the GDF storage tank. Currently there are three vapor recovery nozzles certified by CARB and commercially available for use in California, two are balance nozzles, and one is an assist nozzle. In addition, CARB has certified two ECO nozzles.

Manufacturer	Type	Model
Emco Wheaton Retail	EVR balance	A4005-EVR
Franklin Fueling Systems	EVR assist	Healy Model 900
OPW Retail Fueling	ECO	OPW 14E
Vapor Systems Technologies, Inc.	EVR balance ECO	EVR-NB (G2) Enviro-Loc

CARB staff compiled more than 4,000 spillage results from certification testing conducted per Test Procedure TP201.2C for the five certified nozzles into one Microsoft Excel spreadsheet. This spreadsheet is available as a companion file [CARB, 2020c] to this memorandum. For the three EVR nozzles, CARB staff calculated spillage mass emission factors for each of the three test evaluation categories ('scenarios') specified by the certification procedures, and for three additional scenarios, to assess the effects of customer behavior on spillage at retail GDFs. For the ECO nozzles, CARB staff assessed just one scenario: Refueling events terminated by activation of the primary shutoff with no top offs. As noted earlier, ECO nozzles are certified for use only at non-retail GDFs, such as rental car facilities and new car dealerships, that fuel captive fleets of newer vehicles equipped with ORVR systems. Consequently, every certification test fueling event for the ECO nozzles was witnessed by CARB staff at a government fleet facility, rental car facilities, or Booster Mobile On-Demand Fueling Vehicle. All ECO nozzle test events were fill-ups terminated by activation of the primary shutoff and fueling technicians never topped off. Table 1 provides the mass emission factors for all EVR and ECO nozzles.

Table 1: Nozzle spillage emission factors (lbs/kgal) based on certification data

Mass Emission Factor Scenarios	EVR Nozzles			ECO Nozzles	
	Nozzle A	Nozzle B	Nozzle C	Nozzle D	Nozzle E
1. All refueling events, including events terminated by top offs	0.016	0.016	0.015	0.017	0.027
2. Refueling events terminated before activation of the primary shutoff	0.026	0.022	0.020	na [a]	na
3. Refueling events terminated by activation of the primary shutoff [includes top offs]	0.013	0.014	0.013	na	na
4. Refueling events terminated by activation of the primary shutoff [does not include top offs]	0.012	0.011	0.010	0.017	0.027
5. All refueling events that did not include any top offs	0.016	0.015	0.013	na	na
6. Only top off refueling events	0.019	0.020	0.030	na	na

[a] na = not available. All fueling events for the ECO nozzles (Nozzles D and E) were fill ups and none were top offs.

The spillage mass emission factors range from 0.010 to 0.030 lbs/kgal for all scenarios, and from 0.013 to 0.027 lbs/kgal for the three CP-required evaluation scenarios. Not only do the five nozzles comply with the respective spillage performance standards, all have mass emission factors that are substantially lower than the performance standards. The highest mass emission factor calculated for the CP-required evaluation scenarios for EVR nozzles is 0.026 lbs/kgal, which is only approximately a tenth of the performance standard for EVR nozzles, 0.24 lbs/kgal. The highest mass emission factor calculated for the ECO nozzles is 0.027 lbs/kgal, which is only a quarter of the lower performance standard for ECO nozzles, 0.12 lbs/kgal.

EVR nozzle scenario #6, ‘Only top off refueling events’, had the highest of all mass emission factors, 0.030 lbs/kgal. The certification procedures do not require comparison of this scenario to the performance standards. Even so, this scenario, along with scenario #2, helps characterize the upper range of effects that customer behavior can have on nozzle spillage.

CONCLUSIONS AND IMPLICATIONS

The mass emission factors based on certification data for all five nozzles are substantially lower than CARB performance standards. This demonstrates nozzles are performing much better than predicted for EVR implementation at the time CARB adopted the EVR regulations. For the CP-required evaluation scenarios, the highest mass emission factor observed for any of the three EVR nozzles (0.026 lbs/kgal) is only approximately a tenth of the EVR performance standard (0.24 lbs/kgal). The highest mass emission factor observed for the two ECO nozzles (0.027 lbs/kgal) is only a quarter of the ECO performance standard (0.12 lbs/kgal).

These findings have several implications for our understanding of current and future nozzle spillage emissions:

1. <u>Actual GDF emissions might increase if nozzle spillage performance standards are not amended</u>. Currently certified nozzles are performing much better than CARB certification standards and result in lower emissions than predicted for EVR implementation at the time CARB adopted the EVR regulations. However, if the performance standards are not amended to memorialize this superior performance, future manufacturers would be allowed to introduce new nozzles that perform less efficiently and result in higher emissions while still complying with current performance standards. To prevent the potential for increased emissions, the performance standards need to be lowered to reflect the performance of currently certified nozzles.

2. <u>Revising the standards to reflect the performance of currently certified nozzles would lead to improved GDF emission estimates for Statewide Implementation Plan emission inventories and Air District permits</u>. CARB and Air Districts use estimates of GDF emissions combined with estimates for other emission sources to assess potential local and regional impacts on air quality and public health. CARB and most Air Districts use emission factors published by CARB in 2013 to estimate the emissions from GDFs based on the annual gasoline throughput of the GDFs [CARB, 2013]. CARB’s 2013 publication includes a nozzle spillage emission factor of 0.24 lbs/kgal. This emission factor is nearly ten times higher than the highest mass emission factor observed for any of the five certified nozzles. As a result, GDF

emission estimates for Statewide Implementation Plan (SIP) emission inventories and Air District permits could be over-estimated.

As illustrated in Table 2 (next page), the CARB 2013 emission factors indicate spillage comprises about half of total GDF emissions. For comparison, Table 2 includes three updated versions of the spillage emission factor: 0.027 lbs/kgal (the maximum observed by the certification tests), and 0.050 and 0.075 lbs/kgal (approximately two and three times the maximum observed, respectively). The higher versions are used in this comparison to account for potential variability in customer behavior at retail GDFs and in-use performance degradation that might occur. Though CARB does not have field data that proves a degradation in performance during the useful life of a nozzle, and there is no in-use performance standard for spillage, the assumption was made to ensure our evaluation would err on the side of protecting air quality.

The comparisons in Table 2 indicate that if CARB were to update the 2013 spillage emission factor, estimates of total GDF emissions used in SIP emission inventories and Air District permits might be reduced by about a third or more. For example, if the 2013 spillage emission factor were updated to 0.05 lbs/kgal (twice the maximum observed spillage emission factor), the estimate of total statewide, annualized GDF emissions would decrease by approximately 4.0 tons per day (TPD), from 10.3 to 6.3 TPD (Table 2). However, the superior nozzle spillage performance is not reflected in the current nozzle spillage certification standards and CARB staff does not claim emission reductions that are not required by law or regulation. We cannot assume that the superior nozzle spillage performance will continue into the future if that performance is not memorialized in the regulations. Therefore, CARB cannot update the spillage emission factor for use in emission inventories and permits until the Board formally amends the certification standards through the rulemaking process.

3. A stricter (lower) nozzle spillage performance is feasible and would support overall vapor recovery program effectiveness. Even the evaluation scenarios that characterize the upper range of effects that customer behavior can have on nozzle spillage produce emission factors (0.019 to 0.030 lbs/kgal, Table 1) that are substantially lower than EVR and ECO spillage performance standards (0.24 and 0.12 lbs/kgal, respectively). Table 2 compares the three updated versions of the spillage emission factor to the CARB 2013 emission factors for other uncontrolled and controlled GDF emissions. The updated spillage emission factors increase the estimated emissions controlled by EVR systems, which causes the percentage of emissions that are controlled to increase by approximately 1 percent, from approximately 97 to 98 percent.

Table 2. Comparison of CARB's 2013 emission factors to updated versions of the nozzle spillage mass emission factor and spillage emission rates

Annualized Emission Factors (lbs/kgal)	Uncontrolled Emission Factors If There Were No Vapor Recovery Controls [a, b]	2013 EVR Emission Factors [b]	2013 EVR Emission Factors with Updated Spillage version 1 [c, e]	2013 EVR Emission Factors with Updated Spillage version 2	2013 EVR Emission Factors with Updated Spillage version 3
Phase I Bulk Transfer Losses	7.7	0.154	0.154	0.154	0.154
Phase II Fueling	8.4	0.066	0.066	0.066	0.066
Phase II Fueling - Spillage	**0.61**	**0.24**	**0.027**	**0.050**	**0.075**
Pressure Driven Emissions	0.76	0.024	0.024 [d ,e]	0.024	0.024
Hose Permeation	0.031	0.004	0.004	0.004	0.004
Total Uncontrolled Emissions	17.501	0.488	0.275	0.298	0.323
Spillage as a percent of GDF total uncontrolled emissions	*not applicable*	*49%*	*10%*	*17%*	*23%*
Percent reduction in total GDF emissions compared to 2013 EVR Emission Factors, as reduce spillage	*not applicable*	*not applicable*	*44%*	*39%*	*34%*
GDF Emissions Controlled by CARB Regulations	*not applicable*	17.013	17.226	17.203	17.178
Total Controlled + Uncontrolled Emissions	*not applicable*	17.501	17.501	17.501	17.501
Percentage of GDF Emissions Controlled by Vapor Recovery Program	*not applicable*	*97.2%*	*98.4%*	*98.3%*	*98.2%*
Statewide Spillage Emission Rate (tons per day) [f]:		**5.1**	**0.6**	**1.1**	**1.6**
Statewide Total GDF Emission Rate (tons per day):		**10.3**	**5.8**	**6.3**	**6.8**

[a] "Uncontrolled emission factors" are used to calculate what emissions would occur for the theoretical scenario in which none of the emission control requirements indicated in the first column (Phases I and II, ORVR, pressure management, spillage and hose permeation) are in effect.

[b] Citations: CARB, 2013 and 2020a.

[c] The three versions of an updated spillage emission factor are the maximum observed by the certification tests (0.027 lbs/kgal), and approximately two and three times the maximum observed (0.050 and 0.075 lbs/kgal, respectively).

[d] The emission factor for pressure driven emissions (PDE) will likely change during the next update of the CARB 2013 emission factors. CARB staff completed a suite of field studies and evaluations that concluded PDE are about seven times higher than previously estimated, 0.179 lbs/kgal compared to 0.024 lbs/kgal [CARB, 2020a and 2020b].

[e] The differences between the prior and updated GDF emission estimates for spillage and PDE do not represent a change in actual emissions, and instead reflect emissions that have been occurring but were not accurately reflected in GDF emission estimates.

[f] Emission rate estimates based on an annual gasoline throughput of 15,471,229,347 gallons estimated for 2018 [CEC, 2019].

4. There is no need to have a spillage performance standard for EVR nozzles that is different from the standard for ECO nozzles. Currently, there is a disparity between the spillage performance standards amongst the certification procedures. CP-201 and CP-206 require a performance standard of 0.24 lbs/kgal, while CP-207 has a more stringent standard of 0.12 lbs/kgal. The certification test results indicate both types of nozzles have superior performance and have nearly identical emission factors for each of the evaluation scenarios. Having the same standard for all nozzle types would reduce confusion for those nozzle manufacturers that have brought forward both EVR and ECO nozzles to be certified by CARB. Further, more gasoline will be dispensed through ECO nozzles in the future as more non-retail captive fleets are replaced with ORVR-equipped vehicles and their GDFs are no longer required to install Phase II EVR systems. Having the same standard for all nozzle types would prevent the potential for emission increases as such GDFs replace their EVR nozzles with ECO nozzles.

STAFF RECOMMENDATIONS

Based on these evaluation findings and implications, CARB staff recommends the Board consider lowering the nozzle spillage performance standards in CP-201, CP-206, and CP-207. Increasing the stringency of the standard would memorialize emission reductions that are already occurring and prevent emissions from increasing.

CARB staff proposes a revised spillage performance standard of 0.05 lbs/kgal for both EVR and ECO nozzles. This more stringent standard of 0.05 lbs/kgal is both feasible and necessary to ensure that the superior performance of current nozzles will be present in any new nozzle designs certified in the future. This will help safeguard public health benefits by preventing future manufacturers from bringing in less efficient nozzles that would lead to emission increases. Further, the proposed standard provides consistency between the certification procedures.

The proposed spillage performance standard is about a quarter of the current standard for EVR nozzles, and about half of the current standard for ECO nozzles. Although it is substantially more stringent, the proposed standard of 0.050 lbs/kgal is about double the highest emission factor calculated for the different evaluation scenarios. Staff proposes the higher value of 0.05 lbs/kgal as the standard, rather than the maximum observed value, to provide a margin for potential variability in customer behavior at retail GDFs and to allow flexibility and innovation among nozzle manufacturers.

Because the currently certified nozzles already meet this proposed standard, implementation of the proposed standard would not require manufacturers to change the design of the currently certified nozzles and would not require GDF operators to change out or retrofit their nozzles. Further, an abbreviated administrative procedure (with no additional testing required) can be used to re-certify the nozzles as compliant with the proposed standard once it is adopted because CARB certification test data already demonstrate compliance. As a result, potential implementation costs to the regulated community would be negligible.

CARB staff is currently conducting certification testing for two manufacturers seeking addition to CARB Executive Order NVR-1[4] for each one of their ECO nozzle designs. Data submitted by the manufacturers for both prototype nozzles indicate the nozzles achieve the proposed spillage performance standard. Even so, ECO nozzles currently under evaluation and testing will be certified per the current spillage performance standard of 0.12 lbs/kgal, assuming the certification evaluation process is completed before any proposed changes to spillage performance standards are adopted in the future. However, once the Board and Office of Administrative Law approve the proposed nozzle spillage standard, if the ECO nozzles do not achieve the new standard, they would need to be modified to achieve the new standard to be recertified (four years after their initial certification).

If you have questions regarding this evaluation or need further information, please contact Donielle Jackson via email at donielle.jackson@arb.ca.gov or (916) 445-9308, or Michelle Wood via email at michelle.wood@arb.ca.gov or (916) 445-3641.

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