California Environmental Protection Agency

AIR RESOURCES BOARD

Monitoring and Laboratory Division

Attachment 1:

Revised Emission Factors for Phase II Vehicle Fueling at California Gasoline Dispensing Facilities

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I. INTRODUCTION

Vehicle fueling emissions occur when gasoline vapors are displaced by rising liquid in the vehicle fuel tank during gasoline dispensing. These vapors are adsorbed in a carbon canister installed on vehicles equipped with an on board refueling vapor recovery system (ORVR). When fueling non-ORVR vehicles, these vapors can be collected by a Phase II vapor recovery system and returned to the gasoline dispensing facility (GDF) storage tank. Without a Phase II vapor recovery system, the vapors displaced from fueling non-ORVR vehicles are uncontrolled and released to the atmosphere.

The current Air Resources Board (ARB) total organic gases (TOG) emission factors for GDFs, in use since May 1999, do not reflect improvements in Phase II vapor recovery system performance achieved by ARB's enhanced vapor recovery (EVR) program or the widespread penetration of ORVR in the vehicle fleet. Therefore, the current GDF emission factors for uncontrolled and controlled gasoline dispensing are representative of non-ORVR vehicles only. ARB staff has conducted field tests, literature research, and data analyses to account for these advances, resulting in the proposed revisions to the vehicle fueling emission factors presented in Table I-1 below.

Table I-1
Current and Revised Vehicle Fueling Emission Factors (lbs/kgal)

Category	Emission Factors	
	Current	Revised
Uncontrolled Emission Factor (No ORVR, No Phase II)	8.4	8.4
ORVR without Phase II	NA	0.42
ORVR with Phase II pre-EVR	NA	0.12
ORVR with Phase II EVR	NA	0.021
No ORVR with Phase II pre-EVR	0.74	2.4
No ORVR with Phase II EVR	NA	0.42

As shown in Table I-1, ARB's current vehicle fueling emissions inventory is based on two emission factors: 8.4 pounds of TOG per thousand gallons dispensed (lbs/kgal) for GDFs with uncontrolled vehicle fueling and 0.74 lbs/kgal for GDFs with Phase II pre-EVR vapor recovery. ARB's test results suggest that the uncontrolled emission factor (UEF) remains unchanged, but new or revised emission factors are needed to account for various levels of control efficiency resulting from different combinations of Phase II vapor recovery systems and ORVR technology, as well as improved Phase II vapor recovery system performance from implementation of ARB's EVR program.

ARB estimates that approximately 74 percent of the gasoline sold in California in 2013 will be dispensed to ORVR vehicles. With the current regulatory requirements for Phase II vapor recovery systems remaining in place, there will be a continuing decline in vehicle fueling emissions as the volume of fuel dispensed to ORVR vehicles increases. Table I-2 projects the gasoline fraction expected to be dispensed statewide to ORVR vehicles in calendar years 2013 through 2028 based on ARB's model for on-road mobile sources (EMFAC2011).

Table I-2
Percent Gasoline Dispensed to ORVR Vehicles in California

Calendar Year	Gasoline Dispensed to ORVR Vehicles (%)	Calendar Year	Gasoline Dispensed to ORVR Vehicles (%)
2013	74	2021	88
2014	76	2022	88
2015	78	2023	89
2016	80	2024	90
2017	82	2025	91
2018	83	2026	91
2019	85	2027	92
2020	87	2028	93

II. METHODOLOGY - REVISED VEHICLE FUELING EMISSION FACTORS

The method used to develop the revised vehicle fueling emission factors consists of determining an uncontrolled vehicle fueling emission factor (UEF) and then applying control efficiency (CE) factors that are representative of each possible combination of vapor recovery control technologies. For example, the combined CE when both ORVR and Phase II vapor recovery systems are in use is calculated as:

ORVR with Phase II = 1 - (1 - ORVR CE) * (1 - Phase II CE)

DETERMINATION OF UEF

Vehicle Fueling UEF

The vehicle fueling UEF was determined from field data collected by ARB staff during various Phase II vapor recovery system efficiency tests. The tests were performed using the equipment and procedures specified in the version of ARB Vapor Recovery Test Procedure TP-201.2, *Efficiency and Emission Factor for Phase II Systems* in effect at the time each test was performed.

All fueling events used for the determination of the UEF were conducted on non-ORVR vehicles. To minimize any bias introduced by the fueling of ORVR vehicles, only data from non-ORVR vehicles for which the preceding test vehicle was also a non-ORVR vehicle were used. (This was necessary because fueling an ORVR vehicle reduces the vapor concentration at the vapor return line sampling location, which causes a low bias in the vapor return mass for a subsequent fueling, even of a non-ORVR vehicle.)

Data used to calculate the vehicle fueling UEF are presented in Table II-1 and Table II-2. Table II-1 summarizes data from eight tests used to calculate the vehicle fueling UEF for summer RVP fuel. Seven tests consisted of Phase II vapor recovery system efficiency tests in which 6,350 gallons of gasoline were dispensed to non-ORVR vehicles. The remaining test was an uncontrolled vehicle fueling emissions test in which 62 gallons of gasoline were dispensed to six non-ORVR vehicles at a GDF without Phase II vapor recovery. The average vehicle fueling UEF for summer RVP fuel determined from the eight tests is 7.65 lbs/kgal.

Table II-2 summarizes data from the three tests used to calculate the vehicle fueling UEF for winter RVP fuel. In the first test, 1065 gallons of gasoline were dispensed to 101 non-ORVR vehicles at a GDF equipped with a Phase II vapor recovery system. The second test was an uncontrolled vehicle fueling emissions test performed by dispensing 460 gallons of gasoline to 41 non-ORVR vehicles at a GDF with a disabled Phase II vapor recovery system. The third test was an uncontrolled vehicle fueling emissions test performed by dispensing 116 gallons of gasoline to 10 non-ORVR vehicles at a GDF without Phase II vapor recovery. The average vehicle fueling UEF for winter RVP fuel determined from the three tests is 9.50 lbs/kgal.

The annual vehicle fueling UEF is calculated by weighting the average summer and winter RVP fuel UEFs for statewide gasoline throughput during the respective summer and winter periods. The California State Board of Equalization (BOE) reported approximately 14.51 billion gallons of gasoline were dispensed statewide to motor vehicles in 2012.[1] Of the total, approximately 8.59 billion gallons, or 59.2 percent, of gasoline was dispensed during the April through October summer RVP fuel period. The remaining 5.92 billion gallons, or 40.8 percent, was dispensed during the January through March and November through December winter RVP fuel periods. Based on the BOE throughput data, the vehicle fueling UEF, weighted for seasonal variation in statewide gasoline throughput, is calculated using the following equation:

$$\begin{aligned}\text{Vehicle Fueling UEF} &= \text{Summer Fuel UEF}*(59.2\%) + \text{Winter Fuel UEF}*(40.8\%)\\ &= 7.65\ \text{lbs/kgal}*(0.592) + 9.50\ \text{lbs/kgal}*(0.408)\\ &= 8.4\ \text{lbs/kgal}\end{aligned}$$

Based on ARB test results, the average annual vehicle fueling UEF is 8.4 lbs/kgal, which equals the UEF estimated in the previous methodology.

Table II-1

Vapor Recovery Emission Test Results for Summer RVP Fuel Vehicle Fueling UEF

Vapor Recovery System	Purpose of Test	Location	Date	File Number	Number of Fuelings	Gallons Dispensed	Vapor Mass (lbsx1000)	UEF (lbs/kgal)
Hirt	Certification	Sacramento	Apr 1996	2000 ISOR	100	679	4535	6.68
Catlow	Certification	Sacramento	Sep 1996	2000 ISOR	100	842	6732	8.00
Healy	Certification	Sacramento	Sep 1996	2000 ISOR	100	939	6914	7.36
Hasstech	Certification	Sacramento	Aug 1997	2000 ISOR	100	1012	9509	9.40
Healy	Certification	Sacramento	Jun 1998	2000 ISOR	100	886	5712	6.45
Saber	Certification	Sacramento	Apr 1999	2000 ISOR	100	981	6465	6.59
OPW	Certification	Sacramento	Jul 1999	2000 ISOR	100	1012	8836	8.73
No Phase II	Research	San Jose	July 2007	ST-08-12	6	61.6	354.4	5.75
			Overall Summer RVP Fuel Results:			**6412.6**	**49057**	**7.65**

Note:
2000 ISOR – *Initial Statement of Reasons for Proposed Amendments to the Vapor Recovery Certification and Test Procedures for Gasoline Loading and Motor Vehicle Refueling at Service Stations* Table V-II, page 93.

Table II-2

Vapor Recovery Emission Test Results for Winter RVP Fuel Vehicle Fueling UEF

Vapor Recovery System	Purpose of Test	Location	Date	File Number	Number of Fuelings	Gallons Dispensed	Vapor Mass (lbsx1000)	UEF (lbs/kgal)
Healy	Certification	Folsom	Nov 1997	VOC Testing	101	1065.3	10091.5	9.47
Disabled	Research	Sacramento	Dec 1999	ST-99-50	41	459.7	4438.4	9.65
No Phase II	Research	San Jose	Dec 2007	ST-08-13	10	115.8	1065.6	9.20
			Overall Winter RVP Fuel Results:			**1640.8**	**15595.5**	**9.50**

Note:
VOC Testing – Phase II vapor recovery efficiency test performed by VOC Testing, an ARB certified independent tester.

DETERMINIATION OF CE

ORVR CE

The revised vehicle fueling emission factors assume 95 percent in-use CE for ORVR systems, based on the ORVR certification performance standard of 95 percent. U.S. Environmental Protection Agency (U.S. EPA) test data suggests greater than 95 percent in-use CE for ORVR systems.[2, 3] However, U.S. EPA tests were performed on ORVR vehicles less than three model years old. Because data on longer-term efficiency of ORVR systems were not presented, ARB staff determined that the 95 percent certification performance standard represents the most conservative in-use CE for ORVR vehicles.

Phase II Pre-EVR CE

The revised vehicle refueling emission factors assume 71 percent in-use CE for Phase II pre-EVR systems, based primarily on results from a study conducted in 2000 by the San Diego County Air Pollution Control District (SDCAPCD) and data provided by the South Coast Air Quality Management District (SCAQMD).

Phase II pre-EVR systems are required to achieve at least 95 percent efficiency during certification testing. However, the SDCAPCD study found that in-use Phase II pre-EVR balance systems were prone to malfunctions (e.g., hose blockages, nozzle faceplate gaps, and dispenser leaks) that resulted in a lower in-use control efficiency of approximately 70 percent, with 11 percent of the nozzles experiencing full system failure.[4]

Data provided by the South Coast Air Quality Management District (SCAQMD) shows that, as of 2006 (prior to the upgrade to Phase II EVR) about 92 percent of Phase II pre-EVR systems were balance systems and 8 percent were assist systems.[5] To calculate the in-use CE of assist systems, ARB staff assumed that assist nozzles experience complete failure at the same rate (11 percent) reported for balance systems in the SDCAPCD report referenced above. However, assist systems, based on the way they operate are not expected to experience partial failures as reported for balance systems. Therefore, 11 percent of Phase II pre-EVR assist systems were assumed to have 0 percent efficiency due to an equipment failure such as a failed vapor pump, or a complete blockage in the vapor return line. The efficiency of the remaining 89 percent of assist systems was assumed to be 95 percent. Based on the SDCAPCD and SCAQMD data, and the stated assumptions for Phase II pre-EVR assist systems, the Phase II pre-EVR CE is calculated using the following equation:

$$\text{Phase II Pre-EVR CE} = 0.92 * (\text{Balance CE}) + 0.08\ (0.89 * \text{Assist CE})$$
$$= 0.92 * 70\% + 0.08 * 0.89 * 95\% = 71\%$$

Phase II EVR CE

The revised vehicle fueling emission factors assume 95 percent in-use CE for Phase II EVR systems, based on both the certification performance standard of 95 percent and the results from thirteen separate in-use efficiency tests of Phase II EVR assist systems. Approximately 70 percent of Phase II EVR systems installed at California GDFs are

assist systems. Phase II EVR in-use efficiency data was collected using the equipment and procedures referenced in the version of ARB Vapor Recovery Test Procedure TP-201.2, *Efficiency and Emission Factor for Phase II Systems*, in effect at the time each test was performed. The thirteen efficiency tests represent 221 non-ORVR vehicle fueling events.

Table II-3 summarizes results from the thirteen in-use efficiency tests of Phase II EVR assist Systems. The tests determined an average in-use efficiency of 95.1 percent for 221 non-ORVR fueling events. In addition, GDFs with Phase II EVR and throughputs above 600,000 gallons per year are required to install ARB certified in-station diagnostic (ISD) systems designed to alert GDF operators when critical parameters that affect efficiency do not comply with ISD performance criteria. If the operator ignores ISD warning alarms, ISD will suspend fueling. This requirement helps ensure a high level of emissions control for Phase II EVR systems and supports the assumption of a 95 percent overall CE.

Table II-3
Phase II EVR In-Use Efficiency Test Results

Test Site	Date	Non-ORVR Vehicle Fueling Events	Phase II EVR Efficiency
Arco Fruitridge	12/15/2008	13	93.2%
Arco Fruitridge	12/16/2008	15	91.2%
Arco Fruitridge	12/17/2008	16	91.0%
Arco Fruitridge	12/17/2008	11	97.2%
Arco Northgate	1/5/2009	15	91.7%
Arco Northgate	1/6/2009	15	95.8%
Arco Northgate	1/6/2009	15	97.8%
Arco Northgate	1/8/2009	15	98.5%
Arco Northgate	1/8/2009	16	95.2%
Arco North	1/26/2010	25	94.2%
Arco Harbour	3/9/2010	22	98.2%
Arco North	7/12/2010	21	95.8%
Arco Harbour	9/27/2010	22	96.8%
		Total Test Events: 221	**Average Efficiency: 95.1%**

DETERMINATION OF EMISSION FACTORS

ORVR without Phase II Vapor Recovery Emission Factor

The revised emission factor for fueling ORVR vehicles at GDFs without Phase II vapor recovery systems is calculated from the UEF and ORVR CE using the following equation:

ORVR w/o Phase II = UEF * (1 - ORVR CE)
= 8.4 lbs/kgal * (1 - 0.95) = 0.42 lbs/kgal

ORVR with Phase II pre-EVR Emission Factor

The revised emission factor for fueling ORVR vehicles at GDFs with Phase II pre-EVR systems is calculated from the UEF, ORVR CE, and Phase II pre-EVR CE using the following equation:

ORVR w/ Phase II EVR = UEF * (1 - ORVR CE) * (1 - Phase II pre-EVR CE)
= 8.4 lbs/kgal * (1 - 0.95) * (1 - 0.71) = 0.12 lbs/kgal

ORVR with Phase II EVR Emission Factor

The revised emission factor for fueling ORVR vehicles at GDFs with Phase II EVR systems is calculated from the UEF, ORVR CE, and Phase II EVR CE using the following equation:

ORVR w/ Phase II EVR = UEF * (1 - ORVR CE) * (1 - Phase II EVR CE)
= 8.4 lbs/kgal * (1 - 0.95) * (1 - 0.95) = 0.021 lbs/kgal

Non-ORVR with Phase II pre-EVR Emission Factor

The revised emission factor for fueling non-ORVR vehicles at GDFs with Phase II pre-EVR systems is calculated from the UEF and Phase II pre-EVR CE using the following equation:

Non-ORVR w/ Phase II pre-EVR = UEF * (1 - Phase II pre-EVR CE)
= 8.4 lbs/kgal * (1 - 0.71) = 2.4 lbs/kgal

Non-ORVR with Phase II EVR Emission Factor

The revised emission factor for fueling non-ORVR vehicles at GDFs with Phase II EVR systems is calculated from the UEF and Phase II EVR CE using the following equation:

Non-ORVR w/ Phase II EVR = UEF * (1 - Phase EVR II CE)
= 8.4 lbs/kgal * (1 - 0.95) = 0.42 lbs/kgal

III. REFERENCES

1. California State Board of Equalization Fuel Taxes and Statistics Report-2012. http://www.boe.ca.gov/sptaxprog/spftrpts12.htm

2. SHED test data for 337 2004-2005 model vehicles is available from David Good, U.S. EPA Office of Air and Radiation, Office of Transportation and Air Quality, Compliance Information Systems.

3. NESCAUM Report – Onboard Refueling Vapor Recovery Systems Analysis of Widespread Use, pages 9-10, Skelton and Rector, 8/20/2007.

4. Barnard R. McEntire, Performance of Balance Vapor Recovery Systems at Gasoline Dispensing Facilities, San Diego Air Pollution Control District, May 18, 2000.

5. Data on 2006 Balance/Assist Split for Pre-EVR systems provided to Frances Cameron by South Coast Air Quality Management District Staff