Appendix 4

Gasoline Dispensing Facilities Hose Emissions Inventory For Vacuum Assist and Conventional Hoses

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Introduction

In 2011, California Air Resources Board (ARB) staff developed an emissions inventory for determining the permeation emissions from gasoline dispensing facility (GDF) hoses in California. Gasoline vapor emissions from hoses are the result of permeation of gasoline's constituent molecules through thermoplastic or rubber material of the hose. Specifically, staff considered emissions from only vacuum assist and conventional hoses. The combined vacuum assist and conventional statewide, year round and summertime average uncontrolled permeation emissions are estimated to be 1.00 and 1.26 tons per day (TPD) of reactive organic gas (ROG), respectively. The proposal is expected to reduce permeation emissions by 0.96 and 1.21 TPD for year round and summertime, respectively for these hoses. These reductions represent a 96 percent reduction from current levels.

GDF Hose Population and Hose Surface Area

In 2010, staff analyzed GDF population data gathered from air quality management districts (AQMDs or districts) within California to determine and characterize the population of fueling points at permitted GDFs (CARB, 2011). This report details that there are approximately 95,130 vapor recovery hoses in use at California GDFs, with approximately 65,420 being vacuum assist style vapor recovery hoses. Of these, staff estimates that approximately 64,950 are employed at GDFs using underground storage tanks (USTs) while the remaining 470 are in-use at GDFs employing aboveground storage tanks (ASTs).

There are approximately 1,010 conventional hoses in-use at facilities that predominantly refueled vehicles equipped with on-board refueling vapor recovery or ORVR. These facilities are generally exempt from Phase II vapor recovery requirements by district rules.

In order to determine permeation emissions of the hose population, it is necessary to determine the overall permeable surface area of the hose population. To do this, staff first calculated the surface area of an average hose, and then applied this average across the entire population.

Staff assumed that an average hoses length of approximately 10 feet (ft) for both vacuum assist and conventional GDF hoses. Staff further assumed an average nominal diameter of ¾ inch (in) for both types of hoses. From this, staff calculated the average permeable surface area for both a vacuum assist and conventional hose to be 1.823×10^{-1} square meters (m^2).

$$10 \times 12 \times 0.75 \times 3.14 \times (6.4516 \times 10^{-4})^{*} = 1.823 \times 10^{-1}$$

Applying the average hose permeable surface area to the vacuum assist hose population of 65,420, staff estimates a statewide vacuum assist hose permeable surface area of 11,930 m^2.

$$1.823 \times 10^{-1} \times 65{,}420 = 11{,}930^{**}$$

***After rounding for significant figures.*

Similarly, applying the average hose permeable surface area to the conventional hose population of 1,010 at ORVR fleet exempt facilities, staff estimates a statewide conventional hose permeable surface area at these facilities of 184 m^2.

$$1.823 \times 10^{-1} \times 1{,}010 = 184$$

Normalization of Permeation Emissions Results

Permeation of gasoline is reported in terms of grams per square meter per day or $g/m^2/day$ and is highly dependent upon temperature, concentration gradient across the hose wall, fuel type, hose material, and construction. Several technical papers published by the Society of Automotive Engineers (SAE) indicate a change in temperature of 10 °C typically results in a doubling of the permeation rate (SAE, 2003 and Lockhart, M., Nulman, M., Rossi, G., 2001). This rate of change is indicative of exponential growth. Staff used the above SAE model for adjusting permeation rates when normalizing for temperature differences.

Evaporative and permeation emissions are temperature driven, which varies widely throughout the year. It is important to understand that since average summertime and year-round temperatures are different, the average permeation emissions for summertime and year-round will also differ. It is also important to note here that the term summertime is used loosely within this report to refer to the portion of the year covered by the State Implementation Plan (SIP) for ozone, which is May through October. Since ROG is an ozone precursor, controlling ROG emissions during the summer is a very important measure to reduce ground level ozone. Year-round average emissions, while necessary for understanding annual emissions impacts are also important for calculating cost effectiveness of a proposed emission control technology.

ARB staff analyzed fuel temperature data collected by the California Energy Commission (CEC) to determine average summertime and annual fuel temperatures (CEC, 2009). The average monthly gasoline temperatures from the CEC data are summarized in Table 1.

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[*] Area Conversion – Square Inches to Square Meters

To determine the average summertime gasoline temperature staff averaged the monthly average CEC temperatures from the months of May through October, as these months correspond to the ozone SIP. Using these temperatures from Table 1, the average summertime gasoline temperature is 76.9 °F (25.0 °C).

To determine the average annual gasoline temperature staff averaged the monthly average CEC temperatures over the entire year. From the temperature values in Table 1, the average annual gasoline temperature is 71.0 °F (21.7 °C).

Table 1. CEC Observed Monthly Average Fuel Temperatures

Month	Average Temperature	
	°F	°C
January	60.4	15.8
February	62.9	17.2
March	65.7	18.7
April	67.3	19.6
May	71.0	21.7
June	75.3	24.1
July	79.6	26.4
August	81.5	27.5
September	79.8	26.6
October	74.4	23.6
November	70.6	21.4
December	63.5	17.5

Uncontrolled GDF Hose Permeation Rates

In 2009, staff conducted testing to determine gasoline permeation rates from vacuum assist and conventional GDF hoses (CARB, 2010). This report concluded that average vacuum assist and conventional GDF hoses, when subjected to an average temperature of 71.9 °F (22.2 °C), and filled with summer blend CaRFG 3 (California summer pump fuel) with 6% ethanol, permeate at a rate of approximately 77.4 $g/m^2/day$.

As previously discussed, staff assumes that the permeation rate changes with exponential growth such that the rate will double for every 10 °C increase in temperature. Based upon this information, the following equation is developed empirically to predict the uncontrolled permeation rate.

$$y = 16.628e^{0.0693x}$$

where y is the permeation rate ($g/m^2/day$) and x is the temperature (°C).

Normalizing the uncontrolled permeation rate to a summertime temperature of 76.9 °F (25.0 °C) and using the above equation, the average summertime permeation rate for vacuum assist and conventional hoses is estimated to be

94.0 g/m^2/day.

$$16.628e^{(0.0693 \cdot 25.0)} = 94.0$$

Similarly, normalizing the uncontrolled permeation rate to the year-around temperature of 71.0 °F (21.7 °C), the average year-round permeation rate for vacuum assist and conventional hoses is estimated to be 74.8 g/m^2/day.

Current Statewide Uncontrolled GDF Hose Emissions

In order to estimate statewide uncontrolled emissions for vacuum assist GDF hoses and conventional GDF hoses at ORVR fleet exempt facilities, staff applied the uncontrolled hose permeation rates across the hose populations.

The vacuum assist hose summertime statewide permeation emissions are estimated to be 1.24 TPD of ROG by applying the summertime permeation rate of 94.0 g/m^2/day and statewide vacuum assist hose surface area of 11,930 m^2 to the following equation.

$$94.0 \times 11{,}930 \times (1.1023 \times 10^{-6})^{(**)} = 1.24$$

Staff determined the vacuum assist hose average year-round statewide permeation emissions to be 0.984 TPD of ROG by applying the average year-round permeation rate of 74.8 g/m^2/day and statewide vacuum assist hose surface area of 11,930 m^2.

$$74.8 \times 11{,}930 \times (1.1023 \times 10^{-6})^{(**)} = 0.984$$

Similarly, for conventional hoses at ORVR exempt facilities, staff determined the average summertime uncontrolled statewide permeation emissions to be 1.91×10^{-2} TPD and the average year-round uncontrolled statewide permeation emissions to be 1.52×10^{-2} TPD.

When combining emissions from both types of hoses, average total summertime emissions are 1.26 TPD of ROG and average total year-round reductions are 1.00 TPD of ROG.

Proposed GDF Hose Emissions Limit

Staff is proposing a GDF hose permeation rate performance standard of 10.0 g/m^2/day using CE-10 test fuel (SAE, 2000) at a constant temperature of 100 °F (38.0 °C). Based upon the previously discussed exponential growth assumptions, the following empirical equation was developed to predict the permeation rate at 100 °F:

$$y = 0.7179e^{0.0693x}$$

where y is the permeation rate ($g/m^2/day$) and x is the temperature (°C).

Applying the average summertime temperature of 76.9 °F (25.0 °C) to the above equation, staff determined the average summertime permeation limit for vacuum assist and conventional hoses to be 4.06 $g/m^2/day$ as determined by the following calculation, assuming the other above conditions are constant.

$$0.7179e^{(0.0693 \cdot 25.0)} = 4.06$$

Similarly, the year-round permeation limit can be determined when applying a temperature of 71.0 °F (21.7 °C). The average year-round permeation limit for vacuum assist and conventional hoses is estimated to be 3.23 $g/m^2/day$, assuming the other above conditions are constant.

As mentioned previously staff determined statewide emissions limits for vacuum assist GDF hoses and conventional GDF hoses by applying the hose permeation limits across the hose populations.

Vacuum assist hose summertime statewide permeation emissions were determined to be 5.34×10^{-2} TPD of ROG by applying the summertime permeation limit of 4.06 $g/m^2/day$ and statewide vacuum assist hose surface area of 11,930 m^2.

$$4.06 \times 11{,}930 \times (1.1023 \times 10^{-6})^{*} = 5.34 \times 10^{-2}$$

Staff determined the vacuum assist hose average year-round statewide permeation emissions limit to be 4.25×10^{-2} TPD of ROG by applying the average year-round permeation limit of 3.23 $g/m^2/day$ and statewide vacuum assist hose surface area of 11,930 m^2.

$$3.23 \times 11{,}930 \times (1.1023 \times 10^{-6})^{*} = 4.25 \times 10^{-2}$$

Similarly, for conventional hoses at ORVR exempt facilities, staff determined the average summertime statewide permeation emissions to be 8.23×10^{-4} TPD and the average year-round statewide permeation emissions to be 6.55×10^{-4} TPD.

Statewide GDF Hose Emissions Reductions

In order to determine how many emissions would be reduced by the proposed low permeation vacuum assist hoses and conventional hoses at ORVR fleet exempt facilities, staff subtracted the statewide emissions limits from the statewide uncontrolled emissions.

For example, staff determined the average summertime statewide emissions

* Short Tons per Gram at Standard Surface Conditions

reductions from vacuum assist hose permeation to be 1.19 TPD of ROG by subtracting the statewide summertime permeation limit of 5.34×10^{-2} TPD from the statewide vacuum assist uncontrolled emissions of 1.24 TPD.

$$1.24 - 5.34 \times 10^{-2} = 1.19$$

Staff determined the average year-round statewide emissions reductions from vacuum assist hose permeation to be 0.942 TPD of ROG by subtracting the statewide summertime permeation limit of 4.25×10^{-2} TPD from the statewide vacuum assist uncontrolled emissions of 0.984 TPD.

$$0.984 - 4.25 \times 10^{-2} = 0.942$$

Similarly, for conventional hoses at ORVR exempt facilities, staff determined the average summertime statewide permeation reductions to be 1.83×10^{-2} TPD and the average year-round statewide permeation reductions to be 1.45×10^{-2} TPD.

When combining reductions from both types of hoses, average total summertime reductions are 1.21 TPD (96%) of ROG and average total year-round reductions are 0.96 TPD (96%) of ROG.

References

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Low Permeation Hose Emissions Summary Table

	Vacuum Assist	Conventional	Total	
HOSE POPULATION				
Population affected	68.05%	1.05%	69.10%	
Population	65,420	1,010	66,430	hoses
HOSE PERMEATION SURFACE AREA				
Statewide,	11930	184.0	12110	m^2
PROPOSED HOSE EMISSION LIMIT				
With CE-10 Test Fuel @ 38.0°C	10.0	10.0	-	$g/m^2/day$
Test Standard Normalized to 25.0°C	4.06	4.06	-	$g/m^2/day$
Test Standard Normalized to 21.7°C	3.23	3.23	-	$g/m^2/day$
SUMMER EMISSIONS BASELINE				
Per Hose of ROG	94.0	94.0	-	$g/m^2/day$
Statewide Emissions of ROG	1.24	1.91E-02	1.26	TPD
	2,480	38.2	2,520	lb/day
ANNUAL EMISSIONS BASELINE				
Per Hose of ROG	74.8	74.8	-	$g/m^2/day$
Statewide Emissions of ROG	0.984	1.52E-02	1.00	TPD
	1,970	30.4	2,000	lb/day
SUMMER EMISSIONS ALLOWED				
Statewide Emissions of ROG	5.34E-02	8.23E-04	5.42E-02	TPD
	107	1.65	109	lb/day
ANNUAL EMISSIONS ALLOWED				
Statewide Emissions of ROG	4.25E-02	6.55E-04	4.32E-02	TPD
	85.0	1.31	86.3	lb/day
SUMMER EMISSION REDUCTIONS				
Statewide Percent Reductions	-	-	96%	
Statewide Emissions of ROG	1.19	1.83E-02	1.21	TPD
	2,380	36.6	2,420	lb/day
ANNUAL EMISSION REDUCTIONS				
Statewide Percent Reductions	-	-	96%	
Statewide Emissions of ROG	0.942	1.45E-02	0.957	TPD
	1,880	29.0	1,910	lb/day