Development of Proposed Puff Equation:

Evaporative Emissions Minimum Canister Size

For Vehicles with a NIRCOS* Fuel System

By: California Air Resources Board (CARB)

May 2021

Proposed Equation as of May 2021. Subject to change before official rulemaking occurs.

Any questions or comments, email Jason Gordon: Jason.gordon@arb.ca.gov

*NIRCOS: non-integrated refueling only canister system

Contents:

I. The equation:

$$\text{Min Canister nominal WC} = 1.6 \times (5.3 \times 14.7/P_{tvs} \times [(P_{tvs} \times V_{tvs})/14.7 - V_{tvs}) + 5 \times V_{tvs}]$$

- Gives the working capacity in grams
- Would apply to vehicles with a non-integrated refueling only canister system (NIRCOS)
  - V_{tvs} is tank vapor space (Gallons)
    - This is 90% of the fuel tank capacity
  - P_{tvs} is fuel tank's maximum pressure in-use (absolute pressure in psi)
    - *See section III. for guidance on what value to use for P_{tvs} for your particular vehicle*

II. How equation was developed:

- Minimum Canister nominal WC = 1.6 x (Mass HC Puff + Mass HC Refuel)
  - Nominal WC = working capacity, grams, defined per California Evaporative Emission Test Procedure [1], III.D.3.4
    - Uses a load rate of 15 g/hour butane
  - 1.6 accounts for needing larger WC to accommodate refueling vapor loading rate

Loading:	Adsorption performance [a]:
15 g/hour butane (nominal)	7.8
Refueling (ORVR)	4.8

[a] g/100c 15 BWC carbon, per Evap Manual [2] pg. 108.

- Adjustment factor: 7.8/4.8 = 1.6
    - This ratio appears to be about the same for 17 BWC carbon, since the figures in the numerator and denominator appear to increase proportionately.

- **Nominal WC = 1.6 x ORVR WC**

- Mass HC Puff = $5.3 \times 14.7/P_{tvs} \times ((P_{tvs} \times V_{tvs})/14.7 - V_{tvs})$

  This was patterned using Evap Manual[2] Practice Problem 6-4 pg. 178.
    - V_{tvs} is tank vapor space (Gallons)
        - This is 90% of the fuel tank capacity
    - P_{tvs} is fuel tank's maximum pressure in-use (absolute pressure in psi)
        - *See section below for guidance on what value to use for P_{tvs} for your particular vehicle*

    - Development
    - $(P_{tvs} \times V_{tvs})/ T_{tvs} = (P_{atm} \times V_{atm})/ T_{atm}$ (from ideal gas law)
    - Assume $T_{tvs} = T_{atm}$

    - $V_{atm} = (P_{tvs} \times V_{tvs})/ P_{atm}$ (eqn. 1)

    - $V_{esc} = V_{atm} – V_{tvs}$ (eqn. 2)
        - V_{esc} is the volume of the HC vapors which escape from the tank vapor space

- Dens. HC vapor in tank = 5.3 (grams / gallon @ P_{tvs})
  - Per Evap manual[2], refueling nomograph, RVP 7 fuel, 105 F, Page 82 (represents ~worst case California summer refueling)

- Dens. HC vapor = 5.3 (grams / gallon @ P_{tvs}) x [V_{tvs} (gallon @ P_{tvs}) / V_{atm} (gallon @ P_{atm})] (eqn. 3)

  - This gives Dens. HC vapor once it is released from the tank: (grams / gallon @ P_{atm})

- Mass HC Puff = Dens. HC vapor x V_{esc}

- Mass HC Puff = 5.3 x (V_{tvs} / V_{atm}) x (V_{atm} - V_{tvs}) (subbed in eqn. 2,3)

- Mass HC Puff = 5.3 x (V_{tvs} / (P_{tvs} x V_{tvs})/ P_{atm}) x ((P_{tvs} x V_{tvs})/ P_{atm} - V_{tvs}) (subbed in eqn. 1)

- **Mass HC Puff = 5.3 x (14.7 / P_{tvs}) x [(P_{tvs} x V_{tvs})/ 14.7 - V_{tvs}]**

- **Mass HC Refuel = 5 x V_{tvs}**
  - Assumes 5 grams/gallon vapor generation
  - Per Evap manual[2] Page 88, 80 F Tank, 67 F Dispense (this vapor generation represents the ~mid-range of refueling situations with RVP 9 gasoline which can yield

different results, such as top fill, bottom fill, air entrainment, for a liquid seal). Assumed that RVP 9 fuel characteristics shown in this figure would have similar characteristics to RVP 7 fuel dispensed at a higher temperature.

- V_{tvs} is tank vapor space (Gallons)
    - This is 90% of the fuel tank capacity

III. Pressures to use for P_{tvs}

a. Case 1: If vehicle purges fuel tank pressure during engine operation, but does not purge tank pressure during electric driving
    i. Use either 18.6 psia, or the maximum tank pressure during engine operation[b] for P_{tvs} whichever is greater
        1. Source: 18.6 psia is the estimated pressure inside a sealed fuel tank at 105 degrees F, assuming the tank was initially filled & sealed at 75 degrees F. This value was obtained from Evap Manual[2] Practice Problem 6-3 pg. 178

b. Case 2: If vehicle purges tank pressure during both engine operation, and during electric driving
    i. Use either maximum tank pressure during electric driving[b], or the maximum tank pressure during engine operation[b] for P_{tvs}, whichever is greater

c. Case 3: If vehicle does not purge fuel tank pressure during engine operation, and does not fuel purge tank pressure during electric driving
    i. CARB's understanding is that NIRCOS fuel tanks are typically purged during engine operation to keep fuel tank pressure manageable. But in the odd case where a vehicle does not purge the tank during engine operation, the manufacturer would input the maximum tank pressure during engine operation[c] for P_{tvs}

[b] maximum pressure (absolute) in tank reached before it is purged by the engine, under any driving condition

[c] maximum pressure (absolute) which would occur in the fuel tank when driving a running loss test with the engine running (charge sustaining operation the entire time), for the particular vehicle for P_{tvs}

IV. Examples of calculations

d. Vehicle A: Vehicle attributes: Fuel tank volume: 12 Gallons, Purges fuel tank during engine operation and maximum in-tank pressure during engine operation is 15.7 psia.
Calculation: Will use 18.6 psia for P_{tvs}, per section III. Above
And V_{tvs} is 0.9 * 12 = 10.8 gallons per section I. above
Putting these values into the equation:

Min Canister nominal WC = $1.6 \times (5.3 \times 14.7/P_{tvs} \times [(P_{tvs} \times V_{tvs})/14.7 - V_{tvs}) + 5 \times V_{tvs}]$

Min Canister nominal WC = $1.6 \times (5.3 \times 14.7/18.6 \times [(18.6 \times 10.8)/14.7 – 10.8) + 5 \times 10.8]$

Minimum Canister Nominal Working Capacity (for the vehicle in this example) = 106 grams

V. References:

1. *"California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles", Amended September 2, 2015*
2. *"Evaporative and Refueling Emission Control Training/Workshop Manual", Reddy, Sam R, version 3.0, January 20, 2010.*