



SURFACE VEHICLE STANDARD

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Test Procedure for Determining Refrigerant Emissions from Mobile Air Conditioning Systems

RATIONALE

This SAE Standard covers a method for measuring refrigerant system emission and has been updated for the addition of evaluating multiple refrigerants, the addition of zero-span gas calibration for more accurate measurements, and the refinement of the equations in deriving the mass emission amounts. The intent of this SAE Standard is to ensure proper measurement of refrigerant emission in an air conditioning (A/C) system.

INTRODUCTION

Vehicle makers and A/C system and component suppliers are continually improving the containment of system refrigerant. For development purposes, a common means of measuring refrigerant emissions was deemed desirable; this standard test method is intended to serve that purpose. For commonality with existing vehicle testing, the testing takes place in a chamber (mini-shed) under a static temperature profile and under the California Air Resources Board's Title 13 ambient profile (CARB Profile).

1. SCOPE

This SAE Standard covers the mini-shed testing methodology to measure the rate of refrigerant loss from an automotive air conditioning (A/C) system. This SAE procedure encompasses both front and rear air conditioning systems utilizing refrigerants operating under sub-critical conditions. The SAE procedure will cover multiple refrigerants to emission testing and is utilized for evaluating air conditioning systems. Heat pump systems can also be evaluated; however, they will have different usage and mission profiles.

1.1 Purpose

The purpose of the SAE mini-shed test refrigerant emission procedure is to provide a means of measuring refrigerant emissions from properly assembled vehicle air conditioning systems under specific A/C usage conditions (i.e., typical use conditions) and to convert the results to an estimated annual refrigerant emission rate grams per year (g/year). Such conversion from laboratory test results to estimated vehicle emission applies to properly assembled systems and does not account for normal production assembly variations.

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2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest version of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J2727 Mobile Air Conditioning System Refrigerant Emission Charts for R-134a, R-1234yf, and R-152a

2.1.2 Other Publications

Armines, D.C. (n.d.). Research Study on the Definition of the Implementation of a Method of Measurement of Annual Leak Flow Rates (LFRs) of MAC Systems. *École Nationale Supérieure des Mines de Paris*.

CARB. (n.d.). Title 13: Ambient profile. *California Air Resources Board*.

EU. (2007). Commission regulation (EC) no. 706/2007. *European Union*.

3. TEST PROCEDURE

3.1 System Assembly

3.1.1 Starting with components that have never been exposed to refrigerant, assemble the A/C system on the test fixture per system schematic. Do not charge the system with refrigerant.

3.1.2 Tighten each fitting to its specified minimum torque.

3.1.3 Make all electrical connections and pressure connections.

3.1.4 Place test fixture in the emission test chamber (Volume of ~1 m³).

3.1.5 The emission test chamber (mini-shed) should be equipped with an expansion bag or equivalent feature to assure isobaric conditions throughout the test. Changes in temperature cause corresponding changes in pressure (which can cause leakage from the chamber), or in volume (which slightly affect concentration (ppm)/vol readings). Variations in volume are preferred over mass losses and additions from the chamber and its surroundings during testing as the temperature cycles up and down. Under isobaric conditions, the volume expansion and subsequent contraction will be approximately 10% of the total chamber volume between the prescribed maximum and minimum temperatures in the cycles. Readings taken at calibration temperature should not be affected.

3.1.6 Larger chambers may be required for large A/C systems and will require proportionately larger volumetric injections of refrigerant during the calibration procedure (below).

3.1.7 The target accuracy of the measuring equipment for the total MAC system is established at ±2 g/year.

3.1.8 The zero and span of the gas analyzer must be calibrated before any test according to manufacturer instructions.

3.1.8.1 A zero gas is normally a pure gas that does not contain the component to be measured, and it should be as similar to the matrix of the measured sample as possible

3.1.8.2 Span gases are reference gases, or gas mixtures, that are of a precisely defined nature or composition of the refrigerant you are measuring at the max concentration (i.e., 100 ppm of the refrigerant intended for the system).

- 3.1.8.3 The repeatability of the analyzer expressed as one standard deviation must be better than 1% of full-scale deflection at zero and at $80\% \pm 20\%$ of full scale on all ranges used. This is typically provided by the manufacture of the gas analyzer equipment.

3.2 Chamber Calibration

- 3.2.1 Refrigerant vapor injected in this procedure is to be accomplished at known and recorded atmospheric pressure and temperature for subsequent conversion to mass injected. An alternative method to determining the empty chamber volume is to inject a known mass of refrigerant. One would utilize the same methodology described below, but a conversion of the refrigerant volume injected into the chamber would be calculated multiplying the mass of refrigerant by the density, defined by the ambient atmospheric pressure and temperature.

- 3.2.1.1 Record the atmospheric pressure.

- 3.2.1.2 Record the ambient temperature

- 3.2.2 Refrigerant concentration measurements (ppm by volume readings) should be taken every 2 minutes. If the equipment has a longer response time, measurements should be taken at the shortest measurement interval possible.

- 3.2.3 To verify the chamber's integrity, inject 100 cc of refrigerant per cubic meter chamber volume and record the concentration (ppm) measurement for 24 hours. Readings shall vary no more than 5% after initial stabilization.

- 3.2.4 The following procedure is intended to enable construction of a calibration curve covering the full range of expected refrigerant emission to be measured.

- 3.2.5 Purge the chamber with fans. Flush the gas analyzer lines with dry nitrogen or dry air to remove any residual water vapor and refrigerant from the line sets.

- 3.2.6 Close the chamber and record the refrigerant concentration (ppm). If above 5 ppm of refrigerant, open the chamber and start fans to purge the chamber. Close the chamber and re-measure concentration (ppm). Repeat as necessary until the level drops below 5 ppm.

- 3.2.7 Stabilize the system at $20\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ chamber temperature for 1 hour, recording emissions. Record the initial chamber concentration (ppm) for 10 minutes. Concentration (ppm) readings should vary less than 10%. If greater, check for refrigerant intrusion from outside the chamber or equipment malfunction.

- 3.2.8 Record the initial chamber concentration (ppm); then, with a gas-tight syringe, inject 5.0 cc of pure refrigerant vapor into the chamber and record the refrigerant concentration for at least 10 minutes. Last two readings must be within 10% of each other. If greater, check for refrigerant intrusion from outside the chamber or equipment malfunction. Open the chamber, and start fans to purge the chamber. Close the chamber and re-measure concentration (ppm). Repeat as necessary until the level drops below 5 ppm.

- 3.2.9 Repeat 3.2.8, injecting 10.0 cc of pure refrigerant vapor.

- 3.2.10 Repeat 3.2.8, injecting 20.0 cc of pure refrigerant vapor.

- 3.2.11 Repeat 3.2.8, injecting 30.0 cc of pure refrigerant vapor.

- 3.2.12 Repeat 3.2.8, injecting 40.0 cc of pure refrigerant vapor.

- 3.2.13 Continue additions as necessary to construct calibration curves covering the expected range of the test chamber concentrations.

3.3 Calibration Curves

3.3.1 This purpose of developing the calibration curves is to understand the net volume in the chamber. The net volume is defined as the volume of the empty chamber minus the mobile air conditioning system being tested. The net volume, chamber concentration, chamber pressure, and chamber temperature are all required to calculate the refrigerant mass emitted by the system and this calculation is shown in 3.8.7 and 3.15.1.

3.3.2 Calculate the net change in refrigerant emission concentration (c) for each injection.

$$c = \text{final concentration} - \text{initial concentration}$$

(Eq. 1)

3.3.3 From the volumes of refrigerant added in 3.2.8 to 3.2.13 and their corresponding net changes in measured concentration (c), construct a calibration curve of injected refrigerant (V_{ref}) versus concentration (c), as shown in Figure 1. The slope of this line is the empty volume inside the chamber ($V_{\text{shed}} - V_{\text{mac}}$) and will be used in further calculations. Record the atmospheric pressure to which this calibration curve corresponds for subsequent atmospheric pressure corrections of test data.

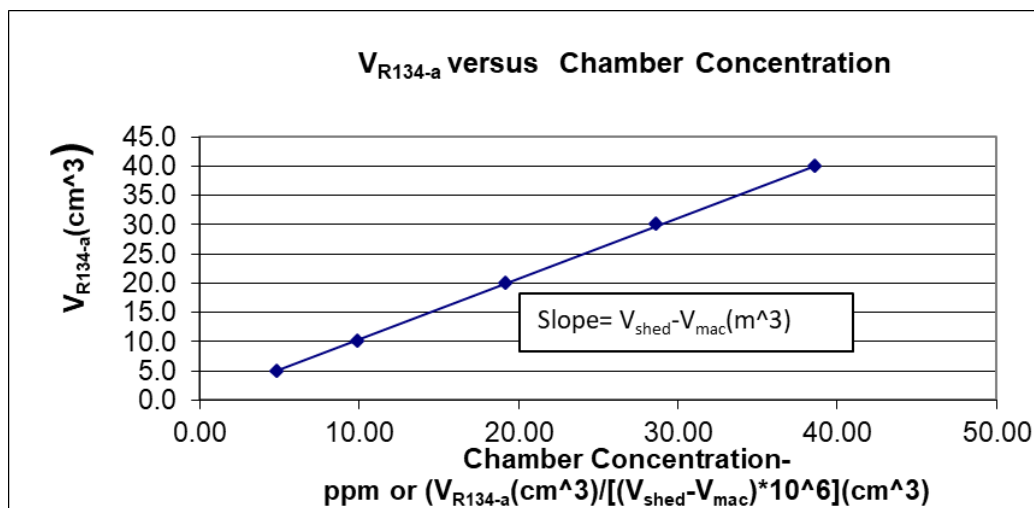


Figure 1 - R-134a example

3.4 System Charge and Leak Test

3.4.1 Charge the system with the specified production intent oil and refrigerant charges.

3.4.2 Optional step: Leak check all components and connections with a leak detector capable of measuring leaks at least as small as 4 g/year to identify gross leaks requiring repair prior to further testing.

3.5 System Installation

3.5.1 Place test fixture into the emission test chamber.

3.5.2 Purge the chamber with fans. Flush the gas analyzer lines with dry nitrogen or dry air to remove any residual water vapor and refrigerant from the line sets.

3.5.3 Close the door and record the concentration (ppm). If above 5 ppm of refrigerant, open the chamber and start fans to purge the chamber. Repeat as necessary until the level drops below 5 ppm.

3.5.4 Stabilize the system at 20 °C chamber temperature for 1 hour, recording emissions.

3.6 Preconditioning Dynamic

3.6.1 Run per conditions in Table 1 (break-in), recording emissions to verify proper assembly.

3.7 System Seasoning (Conforming to EU F-Gas Emission Regulations)

3.7.1 Transfer the A/C system on the test fixture to an environmental chamber, which can be the same as the emissions chamber. Set the temperature to $40\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ and maintain for 20 days or set temperature to $50\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ maintained for 10 days, then ramp to $40\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ and maintain for 1 day. The duration of seasoning can be reduced if component emission stability is achieved prior to testing.

3.8 Long-Term Static Emission (Conforming to EU F-Gas Test Requirements)

3.8.1 Remove the A/C system on the test fixture from the environmental chamber. Install into the refrigerant emission chamber pre-stabilized at $40\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$. However, it can be noted that utilizing of the refrigerant emission chamber as the environmental chamber can be one in the same.

3.8.2 Optional step: Leak check all components and connections with a leak detector capable of measuring leaks at least as small as 4 g/year to identify gross leaks requiring repair prior to further testing.

3.8.3 Flush the gas analyzer lines with dry nitrogen or dry air to remove any residual water vapor and refrigerant from the line sets.

3.8.4 Close the chamber and record the concentration (ppm). If above 5 ppm of refrigerant, open the chamber and start fans to purge the chamber. Close the chamber and re-measure concentration (ppm). Repeat as necessary until the level drops below 5 ppm.

3.8.5 Leave system in the chamber for 4 hours to achieve temperature stability.

3.8.6 With the A/C system in the chamber stabilized at $40\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$, record the concentration (ppm) for 24 hours. Subtract the final concentration (ppm) from the initial concentration (ppm) to yield net emissions. The duration of testing can be reduced if system emission stability is achieved. The measurements should continue if no steady state of emission rate has been established.

3.8.7 Convert concentration (ppm) to mass emission using calibration curve, applying atmospheric pressure correction. The calculation would be based as follows:

3.8.8 The total leakage-mass of refrigerant is calculated by the following formula:

$$m_{\text{Refrg}} = (V_{\text{Shed}} - V_{\text{MAC}}) * M_{\text{Refrg}} * [C_{\text{R134ae}} * (P_e / T_e) - C_{\text{R134ai}} * (P_i / T_i)] / R \text{ [mg]} \quad (\text{Eq. 2})$$

where:

V_{Shed} = SHED-chamber net volume [m^3]

V_{MAC} = Gross volume of the MAC system or component [m^3]

C_{R134ai} = refrigerant initial concentration [ppm]

C_{R134ae} = refrigerant final concentration [ppm]

T_i = SHED initial temperature [K]

T_e = SHED final temperature [K]

P_i = SHED initial pressure [kPa]

P_e = SHED final pressure [kPa]

M_{Refrg} = molar mass refrigerant (R134a = 102 kg/kmol) [kg/kmol]

R = gas constant [$\text{kJ}/(\text{kmol} * \text{K})$]