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SAE Passenger Compartment Air Filter Test Code— Test Method for Gas Removing Filters

Foreword—The purpose of this Draft Technical Report is to give the technical community the opportunity to review, comment on, and use the Draft Technical Report prior to its final approval by SAE.

This Draft Technical Report represents the current thinking of the sponsoring Technical Committee. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringements arising therefrom, is the sole responsibility of the user.

Comments on this Draft are welcome and should be submitted in writing to Secretary, Technical Standards Board, SAE Headquarters, 400 Commonwealth Drive, Warrendale, PA 15096. This document shall have a life span of no more than 3 years from approval and may not be renewed.

The following test code has been established to evaluate filters used to reduce concentrations of nuisance gases and vapors in automotive interior ventilation systems.

The objectives are to describe, develop, and maintain a uniform test method for evaluating performance characteristics of filters used for the reduction of concentrations of these nuisance gases and vapors under specified laboratory conditions.

The performance characteristics of most concern are airflow restriction, gas removal efficiency, and capacity of the test filters.

1. Scope—This laboratory test method applies to air filters that improve air quality by reducing concentrations of gaseous, odorous, or hazardous components from ambient and/or re-circulated air in vehicle cabins. The test method provides information on pressure drop, as well as gas and/or vapor removal characteristics.

1.1 Purpose—The purpose of the test method is to describe and establish test criteria to enable comparisons of filters and filter components that remove or reduce the levels of containment gases or vapors from air streams under specified laboratory conditions.

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2. References

2.1 Applicable Publication—The following publication forms a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1669—Passenger Compartment Air Filter Test Code

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

2.2.1 ANSI/ASHRAE PUBLICATION—Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002.

ANSI/ASHRAE 62-1989—Ventilation for Acceptable Indoor Air Quality (includes supplement ANSI/ ASHRAE 62a-1989)

2.2.2 DIN PUBLICATION—Available from Deutsches Institut fur Normung, Burggrafeng Strasse 6, Postfach 1107, D-1000 Berlin 30 Germany.

DIN 71 460 Part 2

3. Definitions

3.1 Test Air Flow Rate—Average volume of air passing through the filter per unit time (m^3/h).

3.2 Pressure Drop—The difference in static pressure measured upstream and downstream of the filter at a specified flow rate (Pa).

3.3 Contaminant—An unwanted constituent dispersed in air.

3.4 Concentration—The quantity of one constituent dispersed in another; generally expressed as mass of contaminant/volume air (mg/m^3) or volume contaminant/volume air (parts per million by volume or ppm_v).

3.5 Influent Air—The cleaned air used to dilute contaminants to produce the challenge gas.

3.6 Challenge Gas—The homogeneous mixture of influent air and contaminant that is used to challenge the filter.

3.7 Challenge Gas Concentration—The ratio of the mass (or volume) of test contaminant per volume of influent air measured under specified conditions (mg/m^3 or ppm_v).

3.8 Test Gas Mass—The total mass of test contaminant (M_T) to which the filter is exposed (mg).

3.9 Influent Concentration—Homogeneous challenge gas concentration measured before (upstream of) the filter (mg/m^3 or ppm_v).

3.10 Effluent Concentration—Homogeneous challenge gas concentration measured after (downstream of) the filter (mg/m^3 or ppm_v).

3.11 Efficiency or Penetration—Relative comparison of the amount of contaminant removed or reduced by the filter compared to the amount exposed to it; described by Equations 1 and 2.

$$\% \text{ Efficiency} = 100\% * (C_1 - C_2)/(C_1) \quad \text{(Eq. 1)}$$

where:

C1 = Influent concentration
C2 = Effluent concentration

$$\% \text{ Penetration} = 100\% - \% \text{ Efficiency} \quad \text{(Eq. 2)}$$

3.12 Start of Test Time—Time of the first exposure of the filter to challenge gas (t_0).

3.13 End of Test Time—Time of the last exposure of the filter to challenge gas (t_f).

NOTE— End of test time may be determined by reaching a user specified efficiency (typically 5%) or a user specified time.

3.14 Total Test Time—Total time of exposure of the filter to the challenge gas ($t_f – t_0$).

3.15 Capacity—The mass (mg) of contaminant removed from the challenge gas stream by the filter during the total test time ($t_f – t_0$).

3.16 Desorption—The release of previously trapped contaminants from a test filter.

3.17 Breakthrough Concentration—A user defined, specified level of effluent concentration which the user deems unacceptable.

4. Measurement Accuracy

4.1 Flow Rate Monitors—The measurement devices are to be calibrated relative to the respective challenge or contaminant gases; their accuracy shall be within ±2% of the specified value.

4.2 Pressure Monitors—The differential pressure shall be within ±2% of the measured value.

4.3 Temperature—Temperature shall be monitored within ±0.5 °C accuracy.

4.4 Relative Humidity—Relative humidity shall be monitored within ±1% (absolute).

4.5 Concentration—Influent concentration measurements shall be accurate to within ±1% (±1% of C_1).

5. General Conditions and Test Contaminants

5.1 General Conditions

5.1.1 CONDITIONING OF AIR—The temperature of the challenge gas mixture shall be 23 °C ± 1 °C and the relative humidity shall be 50% ± 3%.

5.1.2 CLEANLINESS OF INFLUENT AIR—The content of organic contaminants in the influent air must not exceed an equivalent of 2 ppm_v total hydrocarbon. HEPA filtration is recommended for the removal of particulate contaminants.

5.2 Test Contaminants—Test contaminants are chosen either because their presence at high levels signifies a deterioration in air quality, or because they provide useful indications of performance for certain types of purification systems. Recommended contaminants, purities, and concentrations are shown in Table 1.

TABLE 1—RECOMMENDED CONTAMINANTS, PURITIES, AND CONCENTRATIONS

Test Contaminant	Minimum Purity	Concentration mL/m^3 (ppm_v)	Concentration Conversion Factor(1) x
n-butane(2)	99.5	80 ± 8	2.4
toluene	99.5	80 ± 8	3.8

1. Allows conversion to mg/m^3. Example: for n-butane, 1 mL/m^3 = 2.4 mg/m^3 at pressure of 1013 mbar and temperature of 23 °C.
2. n-butane is included because it provides a useful and facile test for activated carbon-based adsorption systems. Butane may be of limited value for systems which do not rely on activated carbon adsportion. In these cases, another test contaminant may be substituted.

Additional test contaminants (e.g., SO_2, NO_2, NH_3, H_2S, CH_2O, CO, NO,...) may be included as agreed between supplier and user.

6. Test Equipment

6.1 General Layout—The test stand shall meet the performance requirements outlined in 6.2 to 6.7. An example of a test stand configuration is shown in Figure A1. All parts of the system which contact the challenge gas shall be chosen and designed such that they are chemically resistant and that errors due to adsorptive effects on part surfaces are minimized. The test stand shall include equipment or apparatus for conditioning the air supply, flow measurement, pressure drop measurement, contaminant injection, sampling, and sample analyzing.

The test stand/equipment should preferably be operated in a sub-barometric pressure mode, i.e., the fan/ blower placed down stream of the sample. This configuration prevents penetration of challenge gas into the ambient atmosphere in the case of equipment leaks. Furthermore, systematic errors due to the challenge gas contracting the fan unit are excluded. Although operating in a sub-barometric pressure gas mode is preferred for the previously described reasons, a system operating in a positive pressure mode that meets the requirements of 6.2 to 6.7 is acceptable.

6.2 Test Stand Performance—The test stand shall be validated as part of the overall test system (stand and associated equipment) as detailed in Section 9. Validation shall be performed whenever test conditions (e.g., flow rate) or test stand configuration (e.g., mixing or fixturing) are altered significantly. Test instruments must be calibrated per manufacturer's recommended practice and frequency.

6.3 Air Supply—The influent air shall be conditioned and cleaned in accordance with 5.1.1 and 5.1.2. The system shall demonstrate the ability to maintain these conditions over the period of time required to complete a filter evaluation. The system must be capable of delivering and maintaining a user specified flow and shall contain a flow controller according to 6.7.1.

6.4 Test Duct—In general, the test duct shall be designed so that adsorption of test contaminants on test stand surfaces is minimized. The test duct is to be designed so that the challenge gas is fed evenly to the complete filter surface. Punched sheets, static mixers or deflectors may be useful for this purpose. Mixing of the injected test contaminant with the test duct's air will require rigorous attention and validation.

In general, a duct similar to that described in SAE J1669 (particulate) may be used to meet these specifications. However, the design details of the SAE J1669 layout that are specific to particle handling and measurement and do not influence the handling and measurement of gases are not obligatory for the test equipment.

6.5 Contaminant Generation and Supply—Test contaminants which are already gaseous under test conditions may be supplied to the duct directly.

Test contaminants which are liquid under test conditions, e.g., toluene, shall be volatilized prior to injection into the duct. This can be accomplished by heating or providing energy by ultrasonic or other means. Temperature requirements outlined in 5.1.1 apply also in this particular case. Furthermore, condensation of test contaminants shall be avoided by appropriate means, (e.g., heating, duct design) especially in the vicinity of the contaminant injection area.

Test contaminants generated via chemical reaction, e.g., NO_2, shall be generated in a separate chamber and subsequently injected into the duct in order to ensure the required contaminant chemical purity.

6.6 Sampling and Analysis of Challenge Gas—The challenge gas is sampled upstream and downstream of the test filter. Placement of the sampling ports must give representative samples. This must be validated per Section 9. A defined partial flow shall be extracted from the test duct, preferably by means of an independently controlled flow to the gas analyzer.

6.7 Test Equipment Constituents

6.7.1 FLOW RATE MONITORS—The measurement devices are to be calibrated relative to the respective test gases; their accuracy as specified in 4.1.

6.7.2 PRESSURE MONITORS—The differential pressure shall be measured by means of a high-precision pressure sensor or a gauged electronic pressure sensor. Its accuracy shall be as specified in 4.2.

6.7.3 TEMPERATURE—Temperature shall be monitored with an accuracy as specified in 4.3.

6.7.4 RELATIVE HUMIDITY—Relative humidity shall be monitored and have an accuracy as specified in 4.4.

6.7.5 DATA RECORDING—Data of temperature, barometric and differential pressure, and relative humidity shall be recorded periodically.

6.7.6 GAS ANALYZERS—Gas analyzers shall completely cover the range of concentration values specific to the respective challenge gas. A detection limit of 5% of the upstream concentration shall be assured. A calibration function shall be determined over the complete range of concentration values for each contaminant gas. The concentration shall be measured with the accuracy stated in 4.5. The analyzers' signal-to-noise ratio (S/N) shall exceed 3.

Gas analyzers' sampling frequency shall be at least 1 min^{-1}. The concentration of the challenge gas downstream of the filter (C2(t)) is to be sampled at this frequency. For configurations that show low change in downstream concentration, the sampling frequency may be reduced to 0.2 min^{-1} provided that the change in downstream concentration meets the required accuracy during the respective period. This applies especially to the period when the downstream concentration period is below the analyzer's detection limit. The sampling frequency shall be increased early enough to a value of 1 min^{-1} in order to completely record the increase in downstream concentration at this higher sampling frequency. The period with reduced sampling frequency shall be determined in a preceding, separate test run.

7. Preparation of Filter/Filter Element for Testing—Clean, unused filters shall be statically preconditioned for at least 24 h at test environmental conditions.

8. Tests

8.1 Purpose—The purpose of these tests are to determine removal efficiency, capacity, desorption characteristics (optional) and flow resistance of filters that remove gases and vapors using the equipment described in Section 6. The system must be validated per Section 9 prior to testing filters.

8.2 Air Flow Restriction Test (Pressure Drop)—The purpose of this test is to determine the flow characteristics of a clean filter in clean air. The flow rate-pressure drop curve is determined by measuring the pressure drop at 10%, 25%, 50%, 75%, 100%, and 110% of the nominal flow of the filter.

8.2.1 The air flow restriction test is performed using the SAE J1669 procedure (Section 7.2).

8.3 Preparation of Challenge Gases—The preparation of challenge gases shall be made by introducing the contaminant gas or vapor into an influent stream of clean air with such measuring and controlling devices that the concentration and total flow of the challenge gas is at the desired uniform concentration, purity, and nominal flow of the filter.

8.4 Determination of Efficiency/Penetration—The purpose of this test is to determine the gas removal capabilities of the test filter. The test is conducted with constant air flow and concentration of the test contaminant as described in 5.2.

8.4.1 Efficiency determinations shall be made on new, preconditioned filters as described in Section 7. Filters are challenged with test contaminants at the test concentration under specified flow, temperature, and humidity conditions. The test shall continue until the concentration of the measured effluent gas stream is equal to 95% of the concentration of the measured influent gas stream or until a predetermined specified time period has elapsed.

8.4.2 TEST PROCEDURE

a. Condition a new filter.
b. Install the filter in the test stand, establish specified flow rate and measure temperature and relative humidity.
c. Continuously inject the amount of contaminant necessary to establish and maintain the required challenge gas concentration and expose the challenge gas to the filter to start the test. Note the start test time.
d. Measure the concentration of the influent challenge gas initially and periodically as thereafter.
e. Measure the concentration of the effluent gas at the required intervals as per 6.7.6.
f. Continue concentration measurements until the concentration of the effluent gas is equal to a predetermined percent of the influent gas (typically 95%) or a predetermined time period has elapsed. Note the end test time.
g. At the conclusion of the test, stop contaminant injection and the air flow through the test filter.
h. Calculate efficiency (or penetration) from concentration data as per 3.11.

8.5 Determination of Capacity—Filter capacity is calculated by integrating the efficiency curve over the testing time.

8.6 Data and Analysis—Data are recorded numerically and are to be presented in both graphical and tabular form. Raw numbers should be presented such that a normalization procedure can be utilized to correct for differences from standard conditions if necessary.

8.7 Desorption Tests (Optional)

8.7.1 DETERMINATION OF DESORPTION—FLOWING CONDITION

a. After completion of penetration test in 8.4, stop injection of challenge gas. Confirm upstream challenge gas concentration is under 5% of challenge rate.
b. Monitor exit gas concentration as a function of time, until concentration falls below 5% of maximum.

8.8 By-Products Determination—TBD

9. System Validation

9.1 Air Flow Uniformity—As per SAE J1669, Section 8.1.

9.2 Verification Challenge Gas Stability—No Test Filter—This test is for the purpose of ensuring stable gas concentrations will be maintained across the filter face and verifying minimal gas adsorption occurs in the vicinity of filter holder. This test should be conducted at both the maximum and minimum flow rates for which the test stand will be used. In addition, it should be conducted at both the specified test concentration and at 10% of the specified challenge gas concentration.

a. Establish test air flow, temperature, and relative humidity through the test stand without a test filter installed.
b. Start injection of challenge gas at the desired concentration.
c. Measure 3 upstream and downstream challenge gas concentrations not only at the standard sampling locations, but also at locations equidistant on either side of the test duct's filter mounting and one diameter upstream and downstream of the standard sampling locations.
d. Compare up and downstream concentrations. These up and downstream concentrations should all be within 5%.

9.3 Flow Calibration—As per SAE J1669, Section 8.5.

9.4 Repeatability—As per SAE J1669, Section 8.6.

9.5 Documentation—As per SAE J1669, Section 8.7 (relevant parts).

***10. Documentation*—**The test report will at least contain the following information:

10.1 General Data

a. Date of test
b. Test lab and technician performing test
c. Test method, and detailed description if any deviation from standard
d. Unambiguous identification of test sample
e. Sample face area in cm^2 and depth of media in cm
f. Test air condition in °C and %RH
g. Flow rate in m^3/h
h. Type of gas and concentration in ppm_v
i. Pre-conditioning of the sample
j. Barometric and system pressure upstream of the filter and at the flow meter

10.2 Test Results

a. Pressure drop in Pa at test flow rate
b. Graphic adsorption curve using efficiency $[(C_1–C_2)/C_1]$*100(%) versus time (min)
c. Efficiency in %, 1 min and 5 min after initial gas exposure
d. Adsorption capacity (integrated area under curve to specified % efficiency or predetermined test time) in mg
e. Desorption data, TBD

NOTE—If 95% breakthrough is not reached, estimate and so state, or calculate capacity to a lesser breakthrough and so state.

PREPARED BY THE SAE AIR CLEANER TEST CODE STANDARDS COMMITTEE