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Test Procedure to Measure Permeation of Elastomeric Hose or Tube by Weight Loss

RATIONALE

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TABLE OF CONTENTS

1.	SCOPE.....	2
2.	REFERENCES.....	2
2.1	Applicable Documents	2
2.1.1	SAE Publication	2
2.2	Related Publications	2
3.	USEFULNESS AND LIMITATIONS.....	3
4.	SAFETY	4
5.	APPARATUS	5
5.1	Reservoir Design for Method B.....	5
6.	TEST FUELS	6
7.	PROCEDURE	6
8.	CALCULATIONS.....	7
9.	DETERMINATION OF STEADY STATE AND CALCULATION OF PERMEATION RATE	7
10.	REPORTING	8
11.	NOTES.....	8
11.1	Marginal Indicia	8
	APPENDIX A - RECOMMENDED PERMEATION TESTING PLUG DESIGN	9
	APPENDIX B - PERMEATION TESTING -THWING ALBERT CUP DESIGN	13
	APPENDIX C - EXAMPLE OF GRAPHICAL TEST RESULT PRESENTATION	19

1. SCOPE

This test method is intended for measuring fuel permeation at elevated temperature through low permeating hose or tubing samples of elastomeric or composite construction. The expected accuracy of the method is about $\pm 10\%$ of the sample permeation rate.

Hose permeation testing can be done two ways: Method A – Plug and Fill or Method B – using a fuel reservoir.

Method A involves plugging one end of the hose, filling the sample to about 90% full with test fuel, plugging the other end, and then exposing the plugged sample to a desired test temperature, with the weight loss measured over time.

Method B involves plugging one end of a hose, and then connecting the other end to a fuel reservoir. The hose sample and reservoir are then exposed to a desired test temperature with the weight loss measured over time.

This procedure presents a recommended plug design that permits inserting the plugs prior to adding the test fluid. One of the plugs has a small fill hole with a gasketing system that insures low permeation. This design prevents assembly problems created by pressurizing a fuel filled configuration, when inserting plugs with high insertion forces.

Method A is intended for samples with low surface to volume ratios, so that the % fuel loss over the test period is low, and the resultant fuel compositional change does not significantly affect the permeation rate (typically less than 10% fuel loss for CE10 fuel). Method B should be used when fuel loss with Method A would be too large. This is typically done where hoses are small diameter (less than 18 mm) and have high permeation rates. The size of the reservoir chosen for Method B depends on the permeation rate of the sample and should be large enough to assure that fuel loss over the test period is less than about 10%. The amount of fuel loss that might be acceptable will depend on the fuel composition and the type of material tested. Uniform deviations from linearity of the weight loss versus time curves that are not a result of changes in environmental conditions such as temperature should be considered suspect regions and could be a result of compositional or configurational changes might be affecting the permeation rate.

Standard permeation test temperatures are 40 °C and 60 °C. Standard test fuels are Fuel C and Fuel CE10. Other fuels, such as Fuel CM15, and other volatile liquids may be tested according to this procedure as desired. The method is not applicable for measuring permeation of higher boiling materials that will not completely evaporate from the exterior sample surface at the test temperature.

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 issue of SAE publications shall apply.

2.1.1 SAE Publication

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

SAE J30	Fuel and Oil Hoses
SAE J1537	Validation Testing of Electric Fuel Pumps for Gasoline Fuel Injection Systems
SAE J1681	Gasoline, Alcohol, and Diesel Fuel Surrogates for Materials Testing
SAE J1737	Test Procedure to Determine the Hydrocarbon Losses from Fuel Tubes, Hoses, Fittings, and Fuel Line Assemblies by Recirculation
SAE J2665	Test Procedure to Measure the Fuel Permeability of Materials by the Cup Weight Loss Method

2.2 Related Publications

The following publications are provided for information purposes and are not a required part of this SAE Technical Report.

Tuckner, P., "Fuel Permeation Testing – Configurations, Methods, and Correlations," SAE Technical Paper 2001-01-1126, 2001

Tuckner, P. and Baker, J., "Fuel Permeation Testing Using Gravimetric Methods," SAE Technical Paper 2000-01-1096, 2000

Greenfield, M.L. and Rossi, G., "Vapor and Liquid Composition Differences Resulting from Fuel Evaporation," SAE Technical Paper 1999-01-0377, 1999

Brahmi, A. and Wolf, R., "A Comparison of Vapor and Liquid Fuel Permeation of Fuel Systems Polymers," SAE Technical Paper 1999-01-0380, 1999

Robinson, K.A., "Coolant Hose Clamp Fitting Design Guide," SAE Technical Paper 960269, 1996

3. USEFULNESS AND LIMITATIONS

The weight loss method, when used in accordance with the guidelines discussed in the procedure section, can be an easy, effective and relatively inexpensive technique for determining the permeation rates of hose or tubing samples.

- a. It is an appropriate method for testing hose or tubing with permeation rates above about 1 GMD. The maximum permeation rate that can be accurately determined with this method will depend on the sample surface to volume ratio and/or the canister size.
- b. The method is useful to establish a value for the permeation rate of a test fuel through a given sample to within about 10%.
- c. Method A is appropriate when the fuel is a pure fluid or for fuel mixtures when the change in fuel composition does not affect the measured permeation rate.
- d. Method B is preferred in testing smaller diameter hoses (low fuel volume capacity), that can have high permeation rates, with materials and fuels where fuel compositional changes affects permeation rates. CM15 is known to cause changes in permeation rates with many polymers over the compositional range where the methanol is lost sooner.

The method does have some limitations:

- a. The permeation rate of the individual components of a fuel mixture cannot be determined.
- b. The method should be used with caution when the components of a fuel mixture have widely different permeation rates: the more highly permeating component(s) can be depleted from the mixture before the test is completed. As a guide, it is recommended that the total fuel loss during the test be limited to a maximum of 10%. This limit may be higher or lower depending on the fuel composition being tested. The objective is to be able to show that the permeation rate does not change noticeably over the range of weight loss being observed.
- c. For low permeation rates, below about 1 GMD, the weight change may be small enough that accuracy can be a problem. To address this issue, smaller configurations that can be run on balances with greater sensitivity or extending the time between weight loss measurements can help achieve more accurate values. It is desirable to have the weight loss of the sample between measurements equal to at least 10 times the sensitivity of the balance used.
- d. When using Method A for hoses with high permeation rates and/or small diameters, the rapid loss of fluid may prevent attainment of steady state at a time when the composition change has begun to affect changes in the permeation rate, or where all of the fuel is lost before steady state has occurred. In this case, it is more appropriate to use Method B (the canister method) to increase the volume of fuel in the test system.
- e. The following is a list of potential sources of error that should be minimized as much as possible:
 1. Weighing accuracy and small weight changes.

2. Buoyancy effects, weight loss due to loss of plasticizers or additives.
3. Leakage around fittings or plugs used to seal the ends of the hose or tube.
4. Leakage at welds or seams in the canister. Canisters should be carefully designed and leak checked, for example with Helium, prior to being used.
5. Fuel depletion and change in test fluid composition. This is generally not an issue with Method B when using a properly sized canister, provided the sample is well mixed. Failure to mix the fuel in the sample with the fuel in the reservoir at regular intervals during the soak period may lead to errors.
6. Temperature control and temperature variation within the oven or chamber.
7. Weight changes due to water vapor permeation into and out of the sample or absorption of fuel by the outer hose layers from other samples. This can be an issue when testing low permeating hoses in an environment where humidity or venting is not controlled. It is advisable to place samples in a contained environment that is vented with dry air or nitrogen at the test temperature. This can be most important for testing at room temperature in climates with significantly varying humidity.

These sources of error should be reviewed and good experimental techniques employed to minimize the sources of error. Examples of these techniques are described in the method.

4. SAFETY

This method is intended for measuring permeation of potentially toxic and/or flammable liquids at elevated temperatures. Each laboratory is responsible for assuring that this method is performed in a safe manner according to its internal safety regulations and practices.

5. APPARATUS

- a. Impermeable plugs or blind fittings designed to seal the end of the test sample. For elastomeric hose samples, profiled plugs described in Appendix A are recommended. One of the plugs may be designed with a fill hole and seal to allow for easier assembly of the test configuration. The design intent of these sealing plugs is to provide sufficient expansion of the hose over the plugs to insure good contact throughout the plug insertion length. 7% expansion was chosen as the initial design criteria. The plug design also includes a double tapered insertion section, that is intended to provide a larger expansion portion of the plug to prevent the plug from being pushed out the end of the hose at possible higher temperatures and pressures during the test. The double taper is intended to begin at the inner diameter of the hose and then expand to 12% and then back to the 7% primary expansion of the plug. The double taper transition is intended to be gradual enough to insure good uniform contact over this profile. The intent is to have enough expansion to insure good contact and sealing pressure, but not so much where insertion becomes very difficult. This design was developed to provide the greatest chance for uniform sealing and appears to work very well, but was not optimized for insertion force, which may be higher than is desired. The plugs are made with a rear collar at a defined distance from the end of the plug, so when inserted completely into the hose, the permeation area can be calculated from the hose diameter and its length minus the plug insertion distance. General design guidelines for the plugs are shown in Appendix A.
- b. Scale or Analytical balance capable of measuring the sample as accurately as the sample weight and size will allow. A balance accurate to at least 0.001 g is recommended. Those that have the capacity to measure 400 to 0.0001 g can provide more sensitivity for very low permeation hoses.
- c. Explosion proof oven or vented chamber capable of holding the filled samples and maintaining their temperature within ± 1 °C of the desired test temperature.
- d. Plug gages to measure the hose sample I.D.
- e. Fuel Reservoir for Method B (see Reservoir Design below).

5.1 Reservoir Design for Method B

Reservoir design is key to achieving good reproducible results with this method. Care must be taken in the design and fabrication of the reservoirs to assure that they are completely fuel tight and do not contribute to fuel weight loss.

Reservoirs can be of two design types:

- a. One Piece Construction, where the reservoir consists of a one piece welded reservoir with an integral tube connection that serves as the both the fill port for the fuel and the interface for the sample being tested. The limitation of this design is the need to check all welded interfaces to insure no leaks, and the larger cost of making new complete canisters for each different size hose.
- b. Multi-component Gasketed Design, consists of a standard canister with interchangeable hose adapters connected by a simple low permeation gasketed joint. Gasketed surfaces are designed to minimize permeation loss and can be evaluated as a control sample define a know permeation through the gasket and to assure that it is insignificant compared to that of the hose being tested. The advantage of this type of modular design is low cost because that a standard canister reservoir can be reused with different small fittings made for evaluating different size hoses. These fitting can be made using the same design profiles suggested for use Method A. The limitations with this design are that:
 1. certain materials are required for the gaskets
 2. consistent procedures are required for assembly, and
 3. control samples need to be run to evaluate the permeation through the gaskets.

General design guidelines for this configuration are shown in Appendix B.