GM WORLDWIDE ENGINEERING STANDARDS	Test Procedure	GMW15423

Performance Testing of Fuel Hoses

1 Scope

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. This test procedure describes performance tests for fuel and fuel filler hoses.

1.2 Foreword. Not applicable.

1.3 Applicability. These tests shall be used to determine the performance of fuel and fuel filler hoses.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

ASTM D471	ASTM D4678	ISO 4794
ASTM D664	ISO 188	ISO 7500-1
ASTM D3703	ISO 1817	ISO 9513

2.2 GM Standards/Specifications.

9985670	GMW14914
GMW14292	GMW16709

2.3 Additional References.

GMPT-3-018

GMPT-6-019

3 Resources

3.1 Facilities.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label**.**

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this specification shall be determined correctly with respect to its physical definition.

3.2 Equipment.

3.2.1 Beaker 100 mL.

3.2.2 Test fuel to GMW14914, GME.

3.2.3 Test fuel to ISO 1817 (ASTM D471) Liquid C.

3.2.4 Methanol 99% minimum purity to 9985670.

3.2.5 Diesel Test Fuel to GMW14914, GMNA.

3.2.6 Sour Gasoline Test Fuel per 4.3.9.

3.2.7 Glass filter crucible No. 4 according to ISO 4794, porosity 10 to 16 m^{-6} and filtering device.

3.2.8 Glass fiber filter, Grade 934AH.

3.2.9 Balance with an accuracy of 0.1 mg.

3.2.10 Water jet pump.

3.2.11 Desiccator.

3.2.12 Heating oven to ISO 188.

3.2.13 Heating unit.

3.2.14 Metal control rods and end plugs in suitable size.

3.2.15 Test Machine with force-measuring device to ISO 7500-1 Class 1; and deflection measuring device to ISO 9513 Class 0.2. The test machine shall be such that the required test velocity can be maintained. Force gauge capable of measuring up to 100 N.

3.2.16 Stiffness Test apparatus, per Appendix A Figure A1.

3.3 Test Vehicle/Test Piece.

3.3.1 Tests are to be conducted on hoses as supplied.

3.3.2 For initial sample approval and arbitration purposes at least 3 tests; for routine quality control purpose one test shall be performed.

3.4 Test Time. Refer to the tests in 4.3, Instructions.

3.5 Test Required Information. Not applicable.

3.6 Personnel/Skills. Not applicable.

4 Procedure

4.1 Preparation. Not applicable.

4.2 Conditions.

4.2.1 Environmental Conditions. Not applicable.

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

For additional information, see respective tests in 4.3.

4.3 Instructions.

4.3.1 Test for Inner Cleanliness.

4.3.1.1 Test of Total Amount of Refuse. A complete hose shall be hung up vertically and washed 5 times with 20 mL Gasoline Tests Fuel to GMW14914, GME consecutively. The fluid shall be collected in a tared evaporating dish.

4.3.1.2 The test fuel shall be evaporated at +70 °C ± 10 °C for at least 24 h. Then the dish shall cool down for 1 h ± 0.1 h in a desiccator and the refuse in the dish shall be weighed. To determine that all fuel has evaporated, the dish is stored again at +70 °C ± 10 °C for at least 1 h, cooled down at 1 h ± 0.1 h in a desiccator and weighed again. If the weight determined does not differ more than 5% in total from the previous one, the evaporation is complete and the amount of residue is reported in mg/cm^2 inner surface. If weight difference is higher, evaporation and weighing must be continued until the 5% limit is met.

4.3.1.3 Test for Compact Part of Refuse. The total refuse shall be taken off in Gasoline Tests Fuel to GMW14914, GME and shall be filtered through a tared glass frit G4. The glass frit shall be dried for at least 4 h at +50 °C. After cooling down for 1 h ± 0.1 h in a desiccator the weight of the glass frit shall be determined with an accuracy of 0.1 mg and the amount of deposits shall be calculated. The deposits shall be reported as sediment (Compact Parts of Refuse) in milligram per square centimeter (mg/cm^2) inner surface. Handling of glass frit see GMW14292 5.2.2.1 and 5.2.2.2.

4.3.2 Extractables Test.

4.3.2.1 A 300 mm length of hose shall be tested. Aluminum or steel end plugs are used to seal both ends of the hose sample. The minimum Outer Diameter (OD) of each plug must be equal to or larger than the maximum Inner Diameter (ID) of the size of hose tested to effectively seal the hose sample for test. The length of the plug shall be 12.5 mm. Each plug must allow for the support, placement, and positioning of a steel or aluminum rod within the ID of the hose such that a 4 to 6 mm gap is maintained between the OD of the rod and the ID of the hose for hoses with diameter >15 mm.

4.3.2.1.1 The purpose of the rod is to reduce the amount of solvent needed within the hose for the extraction process. Each plug must also have a port positioned such that solvent can be introduced into the assembly between the ID of the hose and the OD of the rod.

4.3.2.1.1.1 Total effective length of hose with end plugs inserted shall be 275 mm.

4.3.2.1.1.2 Where hose length of 300 mm cannot be reached, complete hose is to be tested.

4.3.2.2 Record hose sample ID, length, and inside surface area.

4.3.2.3 Assemble fixture rod and plugs to hose sample and fill the assembly with ISO 1817 Liquid C. Seal assembly and allow to rest horizontally at 22 °C to 25 °C for 24 h.

4.3.2.4. Drain fluid from hose into a beaker.

4.3.2.5 Add additional ISO 1817 Liquid C to assembly, in equal volume to original amount, to rinse the inside of the test assembly, and add this volume of solvent to the original solvent in the beaker.

4.3.2.6 Remove solvent by evaporation by heating at 80 °C to 95 °C until no fuel odor is detectable and then store sample at room temperature under a laboratory hood for a minimum of 16 h.

4.3.2.7 Take up the residue in the beaker with 20 mL of room temperature methanol.

4.3.2.8 Filter this solution on a tared crucible or fine fritted glass, rinsing beaker with 10 mL of room temperature methanol.

4.3.2.9 Place crucible or fine fritted glass in beaker and dry in a 65 °C to 90 °C oven for 1 h to ensure complete evaporation of methanol.

4.3.2.10 Cool to room temperature in a desiccator and weigh the crucible or fine fritted glass and determine mass of extractables expressed as gram per square meter (g/m^2) using inside surface area of hose in contact with the ISO 1817 Liquid C solvent. Handling of glass frit, see GMW14292, 5.2.2.1 and 5.2.2.2.

4.3.3 Compressibility. This test is to be conducted only on hoses with ID ≥ 30 mm.

4.3.3.1 Using a flat plate of minimum 100 mm length and width, apply a compressive force to a hose section of 100 mm length.

4.3.3.1.1 Apply a preload of 1 N and determine the original OD_1 of the hose parallel to the direction of the applied force.

4.3.3.1.2 Apply a load of total 50 N at a rate of 5 mm/minute and determine the OD_2 of the hose.

4.3.3.1.3 Subtract the measured OD_2 from the OD_1 of the hose at preload and calculate the percentage of compressibility.

4.3.4 Fuel Exposure and Cold Flexibility, Burst Strength.

4.3.4.1 Fill two 300 mm long samples of hose with ISO 1817 Liquid C and seal both ends.

4.3.4.2 Allow filled hoses to stand at room temperature for 48 h.

4.3.4.3 Drain ISO 1817 Liquid C from hoses.

4.3.4.4 Perform Cold Flexibility Test.

4.3.4.4.1 For fuel hoses of > 19.05 mm ID: Within 30 minutes after draining the fuel from the hoses, cut a 25 mm long sample out of the middle of one of the 300 mm long test samples.

4.3.4.4.1.1 Expose the sample for 70 h in a cold chamber at -40 °C ± 3 °C and while in the cold chamber flex the hose between flat plates within a period of 4 s through one-half its nominal ID.

4.3.4.4.2 For fuel hoses of ≤ 19.05 mm: Within 30 minutes after draining the fuel from the hoses start the Cold Flexibility Test to GMW16709, but at -40 °C ± 3 °C on one of the samples.

4.3.4.4.3 Use visual examination to evaluate the samples.

4.3.4.5 For fuel hoses of all ID sizes, perform the burst test of second hose with a pressure increase of 7 MPa/minute.

4.3.5 Fuel, Heat and Ozone Resistance; Adhesion Test. Two samples of hose shall be exposed to the following sequential tests.

4.3.5.1 Totally fill and cap fuel hose samples with ISO 1817 Liquid C for 48 h at room temperature.

4.3.5.2 After exposure, drain hose sample and place in an air-circulating oven for 96 h at 100 °C ± 2 °C.

4.3.5.3 Repeat 4.5.1 and 4.5.2 above using fresh ISO 1817 Liquid C.

4.3.5.4 Expose a 25 mm wide x 150 mm long sample cut from the hose cover to ozone to 4.3.7.2 thru 4.3.7.4.

4.3.5.5 Perform Adhesion Test to respective Material Specification.

4.3.6 Dry Heat Resistance.

4.3.6.1 For fuel hoses of > 19.05 mm ID, perform the following test.

4.3.6.1.1 Expose a 300 mm length of hose for a period of 1 h at 125 °C ± 2 °C.

4.3.6.1.2 Remove the hose from the oven and plug each end with a short nylon or metal rod and resume heat aging at the temperature specified above for 720 h.

4.3.6.1.3 Remove the hose from the oven, remove plugs, and allow cooling to room temperature for a minimum of 2 h. Flex a 25 mm wide section of hose cut from the center of the test sample between flat plates within 4 s through one-half of its nominal ID.

4.3.6.2 For fuel hoses of ≤ 19.05 mm ID, perform the following test.

4.3.6.2.1 The hose shall be exposed 1008 (+0/-2 h) to +90 °C ± 3 °C for Temperature limit A, to +125 °C ± 3 °C for Temperature limit B and to +150 °C ± 3 °C for Temperature limit C mounted as shown in Figure A4.

4.3.6.2.2 Remove the hose from the oven and allow cooling to room temperature for a minimum of 2 h. Remove the hose from the fixture and slowly (taking 4 to 8 s) straighten it.

4.3.6.2.3 Use visual examination to evaluate the sample.

4.3.7 Heat Aging, Ozone Resistance.

4.3.7.1 Heat age a 25 mm wide x 150 mm long sample cut from the hose cover along the longitudinal axis of the hose for 70 h at 125 °C ± 2 °C.

4.3.7.2 Firmly fasten the rectangular sample to a test block in such a manner as to cause an extension of 20% as measured between gage marks 100 mm apart centered at the middle of the strip.

4.3.7.3 After mounting, the sample shall be permitted to rest in a relatively ozone-free atmosphere for 24 h at room temperature. The mounted sample shall be placed in a suitable ozone test chamber that is maintained at an ozone concentration of 100 ± 5 parts ozone per 100 million parts of air (volume basis) and a chamber ambient temperature of 38 °C ± 1 °C.

4.3.7.4 After 2 weeks of exposure, sample shall be removed from the chamber and permitted to cool to room temperature and then, while still on the fixture, shall be visually inspected for signs of cracking under 2x magnification. The area immediately adjacent to the sample attachment shall be ignored in making the visual inspection and rating.

4.3.8 Stiffness.

4.3.8.1 Test Sample Preparation. Mount a 125 mm straight fuel filler hose sample in the fixture as shown in Figure A1. The test plugs securing the ends of the hose must have an OD equal to the nominal ID of the hose being tested. The hose is clamped to the test plugs using constant-dimension clamps. The clamps to be used for the test are to be the production release clamps for the hose, or as specified by the GM Design Release Engineer for the program for which the hose is to be used. Torque the clamps to a minimum of 7.0 Nm.

4.3.8.2 Test Procedure. The test is conducted at ambient (23 °C ± 2 °C) temperature. While deflecting the fitting inserted in the upper portion of the fuel fill hose 45 degrees from vertical, record the peak force. Repeat the measurement at four 90 degree intervals around the circumference of the hose wall. Average the four measurements for the hose sample.

4.3.9 Sour Gasoline Recirculation Test. The hose is exposed to recirculating sour gasoline (Federal Emissions Test Fuel "Tier 2" - T-Butyl Hydroperoxide Mixture – defined in 4.3.9.2) for 1008 ± 4 h as shown in Figure A2 with a modified fuel reservoir as shown in Figure A3 according to the following procedures.

4.3.9.1 Connect the test sample as per the fuel recirculation test (Figure A2).

4.3.9.2 Sour gasoline can be purchased from a GM approved supplier or prepared directly in the laboratory.

4.3.9.2.1 Pre-blended sour gasoline can be purchased from several suppliers using the GM fuel specification GMPT-6-019.

4.3.9.2.2 Sour gasoline can be prepared as follows: Mix 3.8 mL of 70% T-Butyl Hydroperoxide per 1000 mL of Federal Emissions Test Fuel Tier II to GMPT-3-018 (see **Note:**). Stir vigorously. Allow the water to settle out of the mixture (no less than 3 h). Decant the fuel into a new container.

Note: If Test Fuel Tier II cannot be found, use ISO 1817 Liquid C. Deviation must be stated in test report.

4.3.9.2.3 Possible supplier for the fluids for sour gas recirculation test: Gage Products Company (US), Haltermann (US and Europe) and Total (France).

4.3.9.3 Remove 5 mL of fuel and analyze for the peroxide concentration per the Test Method ASTM D3703. The peroxide concentration should equal 540 ± 32 mg/kg initially. Pour the fuel into the reservoir.

4.3.9.4 Set flow rate at 700 mL/minute ± 70 mL/minute.

4.3.9.5 Maintain the temperature at 40 °C ± 2 °C.

4.3.9.6 Measure the peroxide concentration twice each week.

4.3.9.7 Run the test for 6 weeks. Change the sour gasoline after the first 24 h and thereafter:

4.3.9.7.1 When the peroxide concentration is less than 432 mg/kg or greater than 594 mg/kg, **or**;

4.3.9.7.2 Once a week if the peroxide concentration remains between 432 mg/kg and 594 mg/kg.

4.3.9.8 Correct for evaporative losses when necessary by adding sour gasoline of peroxide concentration = 540 mg/kg ± 32 mg/kg.

4.3.9.9. Any pump (Figure A2) may be used provided the specified flow rate can be maintained and pump components do not contaminate the sour gasoline. Brass or copper materials shall not be used for any pump component that will be exposed to recirculating sour gasoline.

4.3.9.10 After six (6) weeks of exposure, the fuel hose samples shall be tested to the requirements listed in the respective Material Specification.

4.3.10 Biodiesel Fuel Exposure.

4.3.10.1 The total duration of the test is 22 weeks of fuel exposure. Twenty-seven hose samples shall be tested. Three control samples not exposed to the fuel shall also be tested. Samples shall be filled with biodiesel test fluid GMW14914, GMNA. The ends of the hoses shall be plugged securely and the hose samples shall be heat-aged at 60 °C or deviating temperature to respective material specification. During heat aging, the hose samples shall be rotated 180 degrees around the long axis of the hose every 24 h (except on weekend). Fuel shall be changed in the samples every two weeks. The peroxide concentration to ASTM D3703 and the Total Acid Number (TAN) to ASTM D664 shall be measured every week for the first four weeks and at six-week intervals after this and reported.

4.3.10.2 Expose the hoses to the test fuel per 4.3.10.1. At intervals of 72 h, 168 h, and 3 week intervals after this, three hose samples are to be removed from test. Two of these samples are to be tested for burst. The third sample is to be evaluated for cracking or other damage to the liner of the hose; dumbbells for tensile tests of lining are taken from this hose as well.

4.3.11 Vacuum Collapse Test.

4.3.11.1 Take 300 mm length of hose, plug one end, fill with ASTM D4678, IRM 903 oil and plug other end.

4.3.11.2 Expose hose to 125 °C ± 2 °C for 72 (+0/-2 h).

4.3.11.3 Return to room temperature for 30 minutes and drain fluid from hose.

4.3.11.4 Insert a steel ball having diameter equal to one-half the hose nominal ID.

4.3.11.5 Assemble suitable end fittings on hose so that one end may be completely sealed against air leakage and the other may be connected to a vacuum supply.

4.3.11.6 Subject hose for 15 to 30 s to a vacuum of 88 kPa below atmospheric pressure for hose having inside diameter less than 12.5 mm or 34 kPa below atmospheric pressure for hose of 12.5 mm through 19.05 mm diameter.

4.3.11.7 With vacuum applied and hose held in a straight position, attempt to roll the ball from one end of hose to the other.

4.3.12 Kink Test.

4.3.12.1 Use a board or plate approximately 20 mm thick with hole diameter, center distance, and sample length as shown in Table A2, Appendix A for the specified hose ID.

4.3.12.2 Condition sample length of hose for 2 h at 20 °C to 27 °C.

4.3.12.3 Insert one end of hose into board with end flush with the opposite side of the board.

4.3.12.4 Carefully bend hose along its natural curvature and insert the other end carefully into the second hole until it projects 65 mm out of the other side.

4.3.12.5 After hose has been in this position for 5 minutes, insert a steel ball having diameter equal to one-half the hose nominal ID and attempt to roll ball from one end of hose to the other.

4.3.13 Ovality Test.

4.3.13.1 Condition a sample length (300 mm preferred) of hose for 2 h at 20 °C to 27 °C.

4.3.13.2 With the hose in a straight position and in its free unstressed state, insert a steel test ball having a diameter equal to that shown in Table A3 for the nominal hose ID. Attempt to roll ball from one end of hose to the other.

4.3.14 High Temperature Impulse Test.

4.3.14.1 Hose shall be impulse tested for 250 000 cycles between 0.5 bar and 7.5 bar at a frequency of 1 Hz and temperature of test fuel and test chamber +90 °C. The maximum and minimum pressure value must each be held for at least 10% of the total wave duration, the wave form is trapezoid. After every 45 minutes of impulse testing, the pressure shall be reduced to 0 bar with no media flow and the temperature of the hose shall be increased to +150 °C, held at this temperature, and then reduced to +90 °C over a period of 45 minutes minimum. Minimum hold time at +150 °C during this period shall be 10 minutes. A hydraulic pressure system, utilizing Diesel Fuel (or alternative fuel to be specified) as test fluid is to be used.

4.3.14.2 Any leakage or loss of pressure shall be reported during the period of testing.

4.3.15 Electrical Conductivity.

4.3.15.1 Hoses must be checked for contamination and be cleaned eventually. Cleaning agent is distilled water, use of organic solvents is forbidden.

4.3.15.2 Tests are performed on sections of 150 mm length. The outer diameter of the plug (material brass) is identical to the inner diameter of the hose to be tested. The plugs are inserted 25 mm into the hose.

(In arbitrary cases the measurement must be repeated with following conditions: Before inserting the plugs the lining of the hose must be coated with copper paste (carefully by means of a cotton bud) to enable better contact of the surfaces.)

4.3.15.3 Attach the ohmmeter electrodes to the plugs (or fittings) at each end.

4.3.15.4 Measure the resistance between the plugs or fittings over the entire length of the part, with the part laid on a nonconductive surface. Voltage applied for the measurement shall be (550 ± 50) V, DC.

4.3.15.5 Resistance is to be recorded in mega ohms (MΩ). Ohmmeter used must be capable of measuring from 10^{-1} to 10^{9} ohms at 550 V DC.

Calculate the electrical conductivity to the following equation:

$$R_0 = R\left(\frac{\pi d}{l}\right)$$

Where:

R_0 = Specific surface resistance (Ω).
R = Surface resistance (Ω) (measured value).
π = Constant value (3.1416).
d = Inner diameter of hose.
l = Distance of electrodes.

4.3.15.6 The resistivity measured for the hose test sample must meet the requirements listed in the respective Material Specification.

5 Data

5.1 Calculations. Calculate the results as defined in the respective tests.

5.2 Interpretation of Results. Note the results of each test and compare with the requirements in the respective material specification.

5.3 Test Documentation. Distribute the results in a test report.

6 Safety

This standard may involve hazardous materials, operations, and equipment. This standard does not propose to address all the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

7 Notes

7.1 Glossary. Not applicable.

7.2 Acronyms, Abbreviations, and Symbols.

ID Inner Diameter

OD Outer Diameter

OD_1 Initial Outer Diameter for Compressibility Test

OD_2 Final Outer Diameter for Compressibility Test

TAN Total Acid Number

8 Coding System

This standard shall be referenced in other documents, drawings, etc., as follows:

Test to GMW15423 Section 4.3.x.

9 Release and Revisions

This standard was originated in August 2006. It was first approved by the Global Elastomers Team in February 2009. It was first published in February 2009.

Issue	Publication Date	Description (Organization)
1	FEB 2009	Initial publication.
2	OCT 2011	Additional tests added regarding small diameter fuel hoses. (Global Elastomers Team)

Appendix A

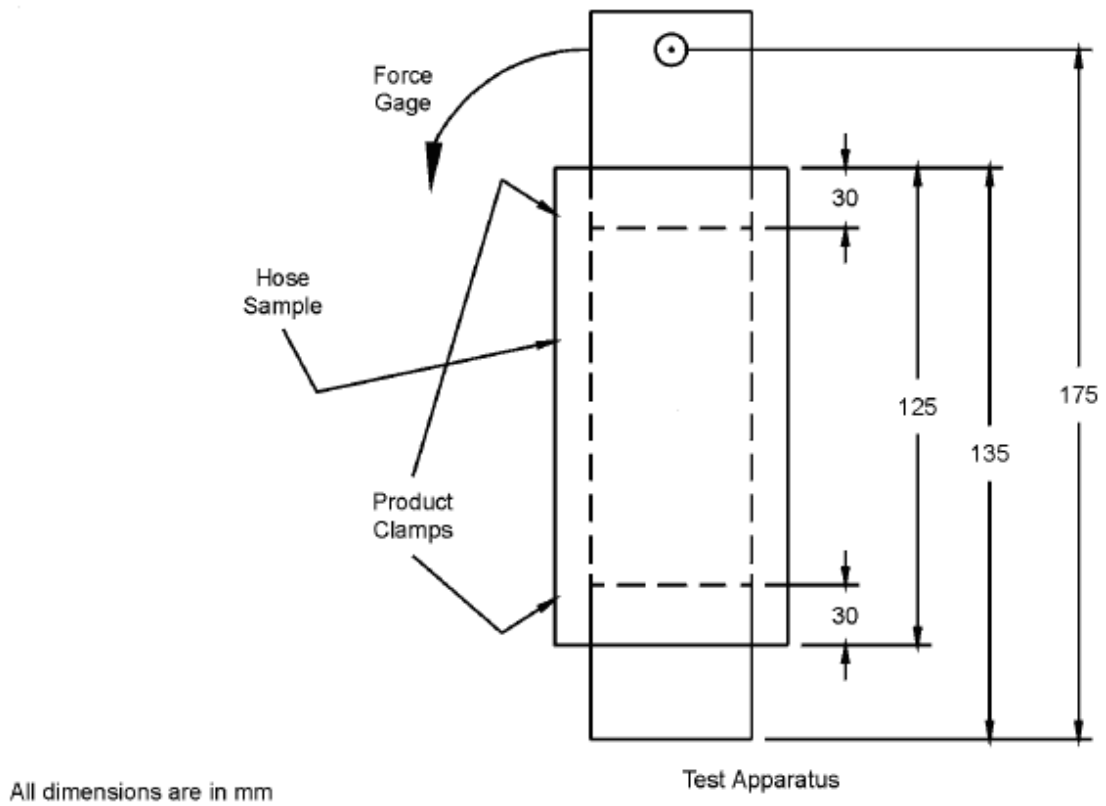
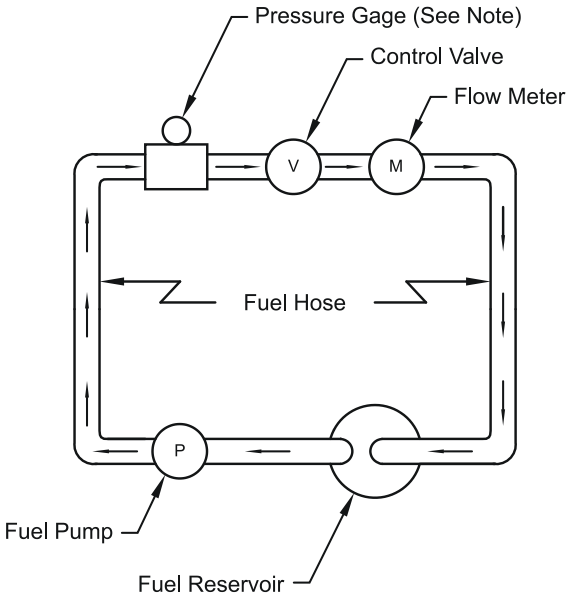


Figure A1: Test Apparatus for Stiffness Test



Note: Optional for Monitoring Flow

Figure A2: Fuel Recirculation Test, Test Setup

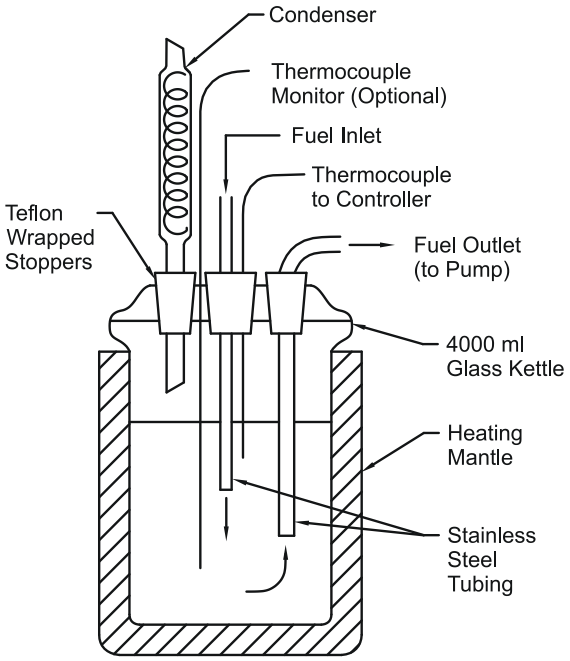


Figure A3: Sour Gasoline Recirculation Test, Heating Vessel

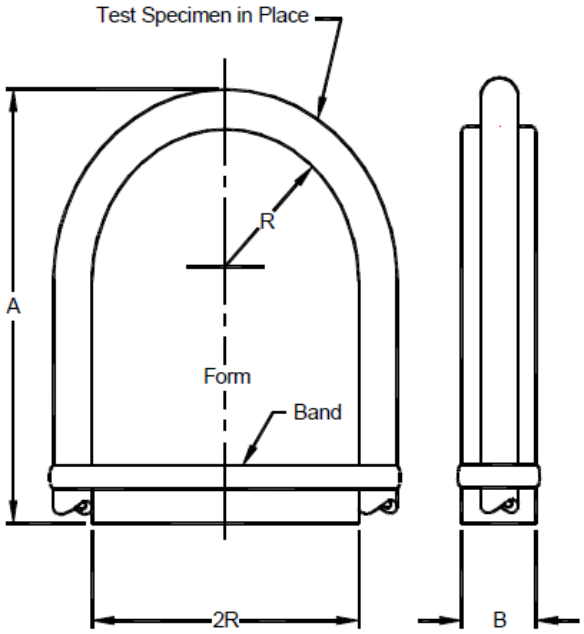


Figure A4: Test Sample on for Heat Aging Test (See Table A1)

Table A1: Dimensions for Heat Aging Test (See Figure A4)

Hose ID		Dimensions of Heat Aging Test Form		
mm	in	A	R	B min.
3.97	5/32	115	40	15
4.76	3/16	115	40	15
5.56	7/32	115	40	15
6.35	1/4	115	40	15
7.14	9/32	120	45	20
7.94	5/16	120	45	20
8.73	11/32	120	45	20
9.53	3/8	130	50	20
11.11	7/16	130	50	20
12.70	1/2	130	50	20
15.88	5/8	140	55	25
19.05	3/4	150	65	25

min. = minimum; **mm** = millimeters; **in** = inches

Table A2: Kink Test

Hose Size (Nominal ID)		Hose Sample Length (mm)	Test Fixture		
			Hole Center Distance (mm)	Hole Diameter (mm)	
mm	in			min.	max.
3.97	5/32	250	13	10.5	11.0
4.76	3/16	250	13	11.5	12.0
5.56	7/32	275	16	12.5	13.0
6.35	1/4	275	19	14.0	14.5
7.14	9/32	275	35	14.5	15.0
7.94	5/16	275	45	15.5	16.0
8.73	11/32	275	50	16.0	16.5
9.53	3/8	300	75	17.0	17.5
11.11	7/16	300	88	19.5	20.0
12.70	1/2	300	100	21.0	21.5
15.88	5/8	450	150	25.0	25.5
19.05	3/4	450	200	30.0	30.5

max. = maximum; **min.** = minimum

Table A3: Ovality Test

Hose Size (Nominal ID)		Steel Test Ball Diameter	
mm	**in**	**mm**	**in**
3.97	5/32	2.78	7/64
4.76	3/16	3.57	9/64
5.56	7/32	3.97	10/64
6.35	1/4	4.76	12/64
7.14	9/32	5.16	13/64
7.94	5/16	5.95	15/64
8.73	11/32	6.75	17/64
9.53	3/8	7.14	18/64
11.11	7/16	8.33	21/64
12.70	1/2	9.52	24/64
15.88	5/8	11.91	30/64
19.05	3/4	14.29	36/64