SAE INTERNATIONAL

SURFACE VEHICLE STANDARD

J2405™ SEP2021

Issued 1997-08
Reaffirmed 2007-07
Revised 2021-09

Superseding J2405 JUL2007

Low-Permeation Fuel Fill and Vent Tube

RATIONALE

This document is being revised to perform corrections to the “end out of squareness” degrees in Table 1, which were unrealistic for manufacturing.

1. SCOPE

This SAE Standard covers the minimum requirements for a low-permeation tubing (100 g/m^2/day or less) for use as a low pressure (14.5 kPa) liquid- or vapor-carrying component for use in gasoline or diesel fuel filler, vent, and vapor systems. The construction shall be designed to be functional over a temperature range of -40 to 100 °C for the T1 designation, or -40 to 125 °C for the T2 designation.

2. REFERENCES

2.1 Applicable Documents

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

2.1.1 SAE Publications

Available from SAE, 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 J1737 Test Procedure to Determine the Hydrocarbon Losses from Fuel Tubes, Hoses, Fittings, and Fuel Line Assemblies by Recirculation

2.1.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM D380 Methods of Testing Rubber Hose

ASTM D413 Test Methods for Rubber Property: Adhesion to Flexible Substrate

ASTM D471 Test for Rubber Property: Effect of Liquids

ASTM D1149 Test Method for Rubber Deterioration:Surface Ozone Cracking in a Chamber (Flat Specimens)

TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada)
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: http://www.sae.org

For more information on this standard, visit
https://www.sae.org/standards/content/J2405_202109/

2.2 Related Publications

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

2.2.1 SAE Publications

Available from SAE, 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 J30 Fuel and Oil Hoses

SAE J1645 Fuel Systems and Components - Electrostatic Charge Mitigation

SAE J1681 Gasoline, Alcohol, and Diesel Fuel Surrogates for Materials Testing

SAE J2260 Nonmetallic Fuel System Tubing with One or More Layers

2.2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM D257 DC Resistance or Conductance of Insulating Materials

ASTM D412 Test for Rubber Properties in Tension

ASTM D573 Test for Rubber: Deterioration in an Air Oven

2.2.3 ARPM Publications

Available from the Association for Rubber Products Manufacturers, Inc. 7321 Shadeland Station Way, Suite 285 Indianapolis, IN 46256 www.arpminc.org

ARPM IP-2 Hose Handbook, Chapter 6, Hose Test Methods: Electrical Resistance Tests for Hose and Hose Assemblies

3. CONSTRUCTION

The construction typically consists of a smooth bore or laminated tube of one or more synthetic rubber compound(s) and/or thermoplastic material(s) resistant to chemical attack, swelling, and permeation by gasoline, alcohol extended gasoline, or diesel fuel. It may also be covered with a suitable oil, ozone, and heat-resistant synthetic rubber compound or thermoplastic. The specific construction details are to be agreed between the supplier and the original purchaser.

4. DIMENSIONS

4.1 The ends of the tube shall be square within 3.0 mm for sizes up to, but excluding, 25.4 mm ID, 6.4 mm for sizes 25.4 mm through 50.8 mm ID, and 9.5 mm for sizes over 50.8 mm ID. See Table 1.

4.2 When tubing is supplied in specific cut or long lengths, the length tolerances shall be as in Table 2.

4.3 End squareness shall be measured as the angle between a plane intersecting the long and short extremes of the tube end and a plane perpendicular to the tube axis. The allowable maximum out-of-squareness is specified in Table 1.

5. WHEN A TUBE IS SUPPLIED AS A PREFORMED ITEM, THE TOLERANCE SHALL BE AS FOLLOWS

5.1 Squareness of Ends

The tolerance on squareness of ends of preformed parts shall be a minimum 15% of the nominal tube OD on all sizes through 25.4 mm ID, 6.3 mm for sizes over 25.4 mm ID through 50.8 mm ID, and 9.5 mm for sizes over 50.8 mm ID. End squareness shall be measured as described in 4.1.

5.2 Arms Lengths

Measured from end to intersection of nearest centerline. Each end shall be as described in Section 4. These tolerances apply also to the length of an expanded end.

5.3 General Layout

Dimensions locating bend intersections are to establish the theoretical centerline of the tube. Actual outside contour of the tube must be held within 4.8 mm in all planes with respect to the theoretical outside contour. To check contour, tube ends should first be placed in nominal position (it may have to be flexed to correct any distortion caused by handling after vulcanization in the producing plant or in shipment) in a checking fixture made in accordance with user requirements from which contour deviation can be measured. Allowance shall be provided in the end-mounting area of the fixture for the arm length tolerances which are applicable.

When the ID of an end of the tube is enlarged, the wall gauge of the enlarged end normally changes. Allowable change should be +0.8/-0.5 mm. The wall gauge within bends of a preformed tube may differ from the gauge in straight portions. The difference shall not exceed 33%.

Table 1 - Dimensions and tolerances

Nominal Size mm	Inside Diameter mm	Outside Diameter[1] mm	Maximum Out-of-Squareness End Angle[2]
4.0	4.0 ± 0.4	9.1 ± 0.6	15.0 degrees
4.8	4.8 ± 0.4	10.3 ± 0.6	14.0 degrees
5.6	5.6 ± 0.4	11.1 ± 0.6	14.0 degrees
6.4	6.4 ± 0.4	12.7 ± 0.6	14.0 degrees
7.0	7.0 ± 0.4	13.5 ± 0.6	14.0 degrees
7.9	7.9 ± 0.4	14.3 ± 0.6	14.0 degrees
8.7	8.7 ± 0.4	15.1 ± 0.6	14.0 degrees
9.5	9.5 ± 0.4	15.9 ± 0.6	14.0 degrees
11.1	11.1 ± 0.6	18.3 ± 0.8	14.0 degrees
12.7	12.7 ± 0.6	19.8 ± 0.8	14.0 degrees
15.9	15.9 ± 0.8	23.8 ± 0.8	13.0 degrees
19.1	19.1 ± 0.8	28.6 ± 0.8	13.0 degrees
25.4	25.4 ± 0.8	34.9 ± 1.6	12.0 degrees
31.8	31.8 ± 1.0	Not specified[3]	11.0 degrees
38.1	38.1 ± 1.0	Not specified[3]	10.0 degrees
44.5	44.5 ± 1.0	Not specified[3]	10.0 degrees
50.8	50.8 ± 1.0	Not specified[3]	9.0 degrees
57.2	57.2 ± 1.0	Not specified[3]	8.0 degrees
63.5	63.5 ± 1.0	Not specified[3]	7.0 degrees

[1] Concentricity based on total indicator reading between the inside bore and the outer surface of the tube shall not exceed the values given as follows:
Sizes 6.4 mm and under: 0.762 mm
Sizes over 6.4 mm up to 12.7 mm: 1.016 mm
Sizes over 12.7 mm: 1.270 mm

[2] These values were determined by the equation:

$$A = 15 \text{ degrees} - K \times D$$

where:
A = maximum out-of-squareness angle, rounded to the nearest 1.0 degree
K = 0.12 degree per mm of diameter (a slope factor derived from linear best-fit previous squareness requirement)
D = nominal inside diameter in millimeters

[3] The wall gauge for sizes 31.8 to 50.8 mm shall be between 4.3 to 5.9 mm, and for sizes 57.2 to 63.5 mm, between 4.3 to 6.4 mm.

Table 2 - Cut or long length tolerances

Length m	Precision mm	Commercial mm
0-0.3	±3.0	+9.5/ -3.0
Over 0.3-0.6	±4.8	+9.5/ -4.8
Over 0.6-0.9	±6.3	+12.7/ -6.3
Over 0.9-1.2	±9.5	+12.7/ -9.5
Over 1.2-1.8	±12.7	+19.0/-12.7
Over 1.8	±1%	+2%/ 0%

6. TESTS

Procedures described by ASTM D380 are to be followed. All temperature tolerances are ±2 °C, unless otherwise specified.

6.1 Qualification Testing

In order to qualify under this specification, tube or the assembly must meet all the applicable test requirements of Section 7. Tube for testing will be 12.7 mm ID or agreed upon between supplier and user. The construction must be representative of constructions of all other sizes. The impermeable layer thickness cannot be reduced with other sizes.

6.2 Frequency of Testing for Qualification

Qualification testing to be performed once each year except for permeation testing which only needs to be tested initially.

6.3 Inspection Testing

On tube or the assembly, the following inspection tests shall apply: (7.1) burst, (7.2) vacuum collapse, (7.11.1) original adhesion, (7.12) kink resistance, and (7.6) electrical conductivity (if required).

6.4 Frequency of Testing for Inspection and Quality Acceptance Standards

Quality acceptance standards to be agreed upon between supplier and the original purchaser.

7. TEST REQUIREMENTS

7.1 Burst Test (Inspection Test on All Sizes)

The minimum burst shall be 350 kPa per ASTM D380.

7.2 Vacuum Collapse Test (Inspection Test on All Sizes)

For straight tube, a 1 m length of tube or the assembly shall be held in a straight line. On preformed parts, the vacuum collapse test shall be performed on the finished part. No diameter shall decrease by more than 20% during application of vacuum for a minimum of 15 seconds and not more than 60 seconds. Tube sizes as listed in Table 3 shall be subjected to the corresponding vacuum pressure:

Table 3 - Vacuum collapse minimum pressures

Tube ID Size mm	Vacuum Pressure kPa
<12.7	81
12.7 to 25.4	34
>25.4 to 44.5	14.3
>44.5	Limit to be agreed upon between supplier and manufacturer

7.3 Low-Temperature Flexibility (Qualification Test)

Fill tube with Reference Fuel C and seal both ends. Allow it to condition at 23 °C for 168 hours. Drain the fuel. Immediately expose the tube around a mandrel that is ten times the nominal OD to a temperature of -40 °C for 24 hours. Bend the tube or sample around the mandrel within 4 seconds while keeping both at -40 °C . It shall not fracture and shall not show cracks, checks, or breaks in any of the layers of construction.

7.4 Original Material Properties (Qualification Test)

The test procedure and apparatus shall be in accordance with ASTM D412, where applicable.

a. Original tensile strength of cover: 7 MPa min

b. Original tensile strength of tube or laminated tube: 7 MPa min

c. Original elongation of cover: 150% min

d. Original elongation of tube or laminated tube: 150% min

7.5 Heat Resistance (Qualification Test)

Expose a 300 mm length tube for 1000 hours at the prescribed test temperature. The test temperature for a T1 construction is 100 °C, and 125 °C for the T2 construction. Remove the tube from the oven and allow to cool to room temperature for a minimum of 2 hours. Bend it over a mandrel having a diameter of ten times the nominal OD within 4 seconds. Examine it, both inside and outside. The tube shall show no cracks or breaks.

7.6 Electrical Conductivity (Inspection Test on All Sizes)

The purpose is to provide a conductive pathway to dissipate any static electrical buildup. This test is required only for tube that will be designated as electrically conductive.

The length of tube for the test shall be 610 mm, unless the part length is shorter than 610 mm, in which case the entire part shall be used for the test. Insert a brass, steel, or copper plug or fitting into each end. Place clamps on each end of the tube and firmly tighten. Attach the ohmmeter electrodes to the plugs at each end. Measure the resistance between the plugs while applying 550 VDC (±50 V). The maximum resistance allowable is 10 MΩ.

NOTE 1: The diameter of the plug or fitting should be close to the ID of the tube.

NOTE 2: The tube while under test should be placed on a nonconductive surface.

NOTE 3: Ohmmeter must have the capability of measuring resistance from 10^{-1} to 10^{3} MΩ at 550 VDC.

7.7 Oil Resistance (Qualification Test)

After immersion in IRM 903 oil for 70 hours, at 125 °C per ASTM D471, the volume change of a sample taken from the outer layer (or tube, in the case of a monolayer tube) shall not exceed +60%.

7.8 Fuel Resistance (Qualification Test)

After immersion in ASTM Reference Fuel C for 48 hours at 23 °C per ASTM D471, the physical properties of the specimens taken from the tube or inner tube (when taken from a laminated tube), shall not exceed the change limits as follows:

a. Tensile change: -45% max

b. Elongation change: -45% max

c. Volume change: 0 to 50%

NOTE: If a laminated tube is used, the inner tube must be separated and tested alone. If a satisfactory test specimen cannot be provided from the inner tube, then a lab prepared test slab is acceptable.

7.9 Test for Extractables in Tube (Qualification Test)

a. Apparatus and Reagents

ASTM Reference Fuel C (50% Toluene—50% Isooctane by volume)
Methanol, 99% minimum purity
Gooch crucible
Glass fiber filter, Grade 934AH
Beaker—100 mL
Heating unit
Metal (aluminum or steel) plugs

b. Specimens: Tube under test shall be 300 mm long; plugged at both ends with metal (aluminum or steel) plugs to retain the fluid. Calculate inside surface area based on the actual inside diameter of the tube for its total effective length between the inner ends of the inserted end plugs.

c. Procedure: Record tube actual inside diameter, length, and inside surface area. Preferred method is with plug gauges to nearest 0.025 mm.

NOTE: Solubility of waxy hydrocarbon is affected by temperature.

- Fill hose with ASTM Fuel C.
- Allow to stand for 24 hours at temperature of 23 °C ± 2 °C with both ends sealed. (Solubility of waxy hydrocarbons is affected by temperature.)
- Drain fluid from hose into a tared beaker.
- Rinse inside of the specimen with an amount of fresh ASTM Fuel C approximately equal to the volume of the original filling and add to the original extraction.
- Remove solvent by evaporation by heating at 80 to 95 °C until no fuel odor is detectable, and then store sample at room temperature of 23 °C ± 2 °C under a fume hood for a minimum of 16 hours.
- Take up residue with 30 mL of room temperature, 23 °C ± 2 °C, methanol.
- Filter this solution on the tared crucible, rinsing beaker twice with 10 mL of room temperature, 23 °C ± 2 °C (73 °F ± 3.6 °F), methanol.
- Place crucible in beaker and dry in a 65 to 90 °C (149 to 194 °F) oven to ensure complete evaporation of methanol.
- Weigh the Gooch crucible and tared beaker and determine mass of extractables expressed as g/m^2 using surface area of hose in contact with ASTM Fuel C.
- Value for total waxy extractables shall be less than 2.50 g/m^2.

7.10 Ozone Resistance

The test procedure and apparatus shall be in accordance with ASTM D1149, where applicable.

a. Sample preparation: For straight tube, sufficient length shall be bent around a mandrel with OD eight times the nominal OD of the specimen. The two ends shall be tied at their crossing with enameled copper or aluminum wire.

b. For preformed parts, prepare a specimen by cutting a strip of tube 12.7 x 100 mm long and tie specimen (cover out) around a 12.0 mm diameter mandrel.

c. After mounting, the specimen shall be allowed to rest in an ozone-free atmosphere for 24 hours at 23 °C. The mounted specimen shall be placed in a test chamber containing ozone at 100 mPa ± 5 mPa at a temperature of 40 °C for 70 hours. Remove the specimen from the chamber, allow to cool to a temperature of 23 °C. The specimen cover shall be visually inspected under 7X magnification and must meet a “0” rating except for the area immediately adjacent to the wire, which shall be ignored.

NOTE: This test applies to the cover only and cracks in the exposed tube or cut edges of the cover shall be ignored.

7.11 Adhesion

7.11.1 Original Adhesion (Inspection Test on All Sizes)

Cut 25 mm samples out of the tube in the transverse direction. The number of samples to be tested is dependent on the construction of the tube but should be enough to test the adhesion between all adjacent layers. When tested in accordance with ASTM D413, Machine Method, Strip Specimen—Type A, 180 degree Peel, the minimum force required to separate the two layers shall be 1.4 N/mm or stock tear.

7.11.2 Aged Adhesion (Qualification Test)

a. Sample conditioning:

1. Use tube from the permeation test (7.13).

2. Alternate method:

Plug one end of the tube to be tested. Fill with test fuel CM15.

Plug the other end in such a manner that it can be periodically removed. Expose the filled tube to a temperature of 40 °C for 1000 hours continuously. Change the fuel every 168 hours.

b. Cut 25 mm samples in the transverse direction. The number of samples to be tested is dependent on the construction but should be enough to test the adhesion between all adjacent layers.

c. Condition the test samples in a 70 °C oven for 24 hours followed by 2 hours at 23 °C.

d. Test for adhesion in accordance with ASTM D413, Machine Method, Strip Specimen—Type A, 180 degree Peel, the minimum force required to separate the two layers shall be 1.0 N/mm or stock tear.

7.12 Kink Resistance (Inspection Test on All Applicable Sizes)

NOTE: This test is not applicable for tube sizes greater than 12.7 mm ID, nor for formed tube.

This test should be performed on a straight length of tube. When tested to the following procedure, a ball having a diameter equal to one-half the nominal inside diameter of the tube shall pass freely through the tube. Use a fixture consisting of a 19 mm thick board or plate with holes and center distances shown in Table 4. Condition 300 mm long specimens of tube for 2 hours at room temperature (23 °C). Insert one end of tube into board with end flush with opposite side of board. Carefully bend tube along its natural curvature and insert the other end carefully into the second hole until it projects 63 mm out the other side. After tube has been in this position for 5 minutes, insert a steel ball having a diameter equal to one-half the tube nominal ID. The ball must pass freely from one end to the other.