SAE International™

SURFACE VEHICLE STANDARD

SAE J2260

REV. NOV2004

Issued 1996-11
Revised 2004-11

Superseding J2260 NOV1996

Nonmetallic Fuel System Tubing with One or More Layers

1. Scope

This SAE Standard presents the minimum requirements for nonmetallic tubing with one or more layers manufactured for use as liquid-carrying or vapor-carrying component in fuel systems for gasoline, or alcohol blends with gasoline. Requirements in this document also apply to monowall tubing (one layer construction). When the construction has one or more layers of polymer-based compounds in the wall, the multilayer constructions are primarily for the purpose of improvement in permeation resistance to hydrocarbons found in various fuels. The tube construction can have a straight-wall configuration, a wall that is convoluted or corrugated, or a combination of each. It may have an innermost layer with improved electrical conductivity for use where such a characteristic is desired. The improved electrical conductivity can apply to the entire wall construction, if the tubing is a monowall. (For elastomeric based MLT constructions, refer to SAE J30 and SAE J2405).

Unless otherwise agreed to by suppliers and users this document applies to tubing for any portion of the fuel system that might operate continuously at temperatures above -40 °C and below 90 °C and up to a maximum working gage pressure of 450kPa. The tubing can be used at the peak intermittent temperature up to 115 °C.

This document can apply to systems that operate at higher pressures and/or are exposed to higher temperatures. For higher pressures, the acceptance criteria of section 7.2 must be correspondingly changed. For higher temperatures, the acceptance criteria of sections 7.2 and 7.14 remain the same, but apply at the higher temperature. The selection of higher temperatures and pressures that could be used for this document would be the decision of the end user and supplier of the specific fuel/fuel vapor system in question.

There are three types of tubing covered by this specification, based on the type of application for which the tubing is intended to be used:

- <u>High pressure, liquid fuel line</u> is tubing that handles liquid fuel at pressures up to 450 kPa pressure, and can handle the maximum pressure requirements identified in sections 7.1 and 7.2. These are typically the smaller diameter tubes identified in Table A1.

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- Low pressure, liquid fuel line is tubing that is regularly exposed to liquid fuel, but is subjected to pressures that are under 50 kPa (e.g. fuel filler pipes). These are typically the larger diameters identified in Table A1.
- Fuel vapor tubing is tubing that handles fuel in vapor form or some liquid condensed from vapor, and operates at a working gauge pressure that does not exceed 20 kPa.

In some cases, a distinction is made in the criteria that apply to tubing used to carry liquid fuel compared to tubing used to carry fuel vapor. These are identified separately in each section.

2. References

2.1 Applicable Publications

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 Publications

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

SAE J30—Fuel and Oil Hoses (R11: Low Permeation Fuel Fill and Vent Hose and R12: Low Permeation Fuel Feed and Return Hose)
SAE J1645—Recommended Practice Covering Electrostatic Charge in Fuel Systems
SAE J1681—Gasoline, Alcohol and Diesel Surrogates for Material Testing
SAE J1737—Recommended Practice for Measurement of Permeation Resistance by the Recirculation Technique
SAE J1960—Accelerated Exposure of Automotive Exterior Materials Using a Controlled Irradiance Water-Cooled Xenon-Arc Apparatus
SAE J2027—Standard for Protective Covers for Gasoline Fuel Lines
SAE J2044—SAE Quick Connector Specifications for Liquid Fuel Systems
SAE J2045—Tube/Hose Assemblies
SAE J2405—Low Permeation Fuel Fill and Vent Tube (Elastomer Hose)
SAE J2663—Test Procedure to Measure Permeation of Elastomeric Hose by Reservoir Weight Loss Method

2.1.2 ISO Publications

Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002.

ISO 527—Plastics—Determination of tensile properties
ISO 4639-3—Rubber tubing and hoses for fuel circuits for internal combustion engines specification—Part 3: Oxidized fuels

2.2 Related Publications

The following publications are for information purposes only and are not a required part of this document.

2.2.1 ASTM Publications

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 412—Test Methods for Rubber Properties in Tension
ASTM D 4000—Classification System for Specifying Plastic Materials
ASTM D 4066—Specification for Nylon Injection and Extrusion Materials

3. Installation, Assembly, and Handling Recommendation

3.1 End Fittings

End fittings can be assembled to the tubing providing that they do not cause mechanical damage to the tubing that results in decreased performance. Assemblies manufactured with tubing described in this document and end fittings must meet all of the requirements of SAE J2045.

3.2 Support and Routing

When installed in a vehicle this tubing shall be routed and supported so as to:

a. Prevent chafing, abrasion, kinking, or other mechanical damage.
b. Be protected against road hazards by installation in a protected location or by providing adequate shielding in vulnerable areas.
c. Be protected from heat by proper clearance or the addition of insulation and/or heat shielding (refer to SAE J2027), for use in applications where temperatures exceed the upper limits of 115 °C.

3.3 Handling

Tubing ends should be protected during handling and storage to prevent internal contamination.

4. Construction

Tubing shall consist of an extrudate of one or more layers within the body of the wall. The dimensions and tolerances of the one or various layers shall be expressed in millimeters and the material name should be called out on the drawing.

4.1 Materials

The requirements of this document apply to the tubing as a whole and not necessarily to the individual materials used in the construction of the tubing

For monowall tubing, the material used must meet all applicable exposure criteria described in this document.

4.1.1 OUTER LAYER

If the tubing in question must be conductive (as described in section 7.9), the outer layer material should not be the one that has that characteristic. The only exception would be if the innermost layer were at least equally conductive and the two layers are bonded as defined in SAE J1645. Refer to 4.3 for comments on color.

4.1.2 INNER LAYER

If tubing must be conductive as described in section 7.9, the innermost layer must have that characteristic.

The materials used in the inner layer must be able to withstand contact with road chemicals. The inner layer of the tubing can be exposed to such an environment at the "ends" that are attached to the various connection points in a fuel system. It is for this reason that the ends of the tubing are also exposed to the environmental stress crack resistance test in 7.12.

4.2 Regrind

Tubing may be manufactured using regrind within the limits specified in this section and providing the tubing produced will meet all the performance requirements of this document.

4.2.1 REGRIND LIMITATIONS

4.2.1.1 Regrind of a specific resin can only be blended with identical virgin resin.

4.2.1.2 Regrind must be free from contamination from other resins or foreign matter except as allowed in 4.2.1.4.

4.2.1.3 Regrind from one layer of a multilayer tube must only be blended and used in the same layer.

4.2.1.4 Regrind created by grinding up a specific multilayer tube construction can only be used as a separate layer within a specific multilayer construction provided:

4.2.1.4.1 The multi-resin regrind layer is not the outer or inner layer of the tube wall.

4.2.1.4.2 The multi-resin regarding layer thickness does not exceed 10% of the tube wall thickness.

4.2.2 REGRIND QUALIFICATION

4.2.2.1 Tubing whose wall or a layer in the wall is manufactured from regrind blends must meet all the requirements of this document. Qualification consists of demonstrating and documenting the capability of such tubing by passing all the test requirements of this document.

4.2.2.2 A single blend of regrind and virgin resin must be qualified. Once qualified, any blend of regrind less than the amount qualified may be used. Any blend of regrind greater than the amount qualified must be fully qualified separately.

4.2.2.3 A single construction of multilayer tubing in which one layer is regrind must be qualified. Once qualified, the thickness and position of the regrind layer is fixed but any blend of regrind less than the amount qualified may be used in the regrind layer.

4.2.2.4 Qualification of a regrind/virgin resin blend applies only to the manufacturer who developed the regrind blend and tubing construction and obtained the qualification.

4.2.3 REGRIND GUIDELINES

4.2.3.1 If single resin regrind is used to produce monowall tubing or the inner or outer wall of multilayer constructions the amount of regrind in the blend shall be limited to 10% max.

4.2.3.2 Use of regrind might have an effect on the long term capability of tubing to resist exposure to long term heat aging or zinc chloride. The end user should be consulted to determine if more aggressive testing is necessary than listed in this document.

4.3 Color

The outside layer of the tubing constructions is usually black although, alternative colors are permissible, if necessary, for purposes of color-coding. The following criteria must be met:

a. The tubing color and the label color must be such that there is sufficient contrast to achieve easy readability.
b. Material used in outside layer of the MLT or as the material of the monowall tubing should be U.V. stabilized to withstand expected exposure (either with an additive or by the inherent characteristics of the material). Requirements necessary to adequately resist sunlight exposure will depend strongly on the application. The end user must be consulted for specific standards to be met. As a general guideline, also refer to SAE J1960.

4.4 Identification

4.4.1 The following minimum information, in the order listed, is required. Additional information and/or another lay line may be added: SAE J2260 – L-D-Type-XX/YY-P.

a. L refers to the construction of the tubing: (S for single layer and M for more than one layer)
b. D refers to the reference size in mm from Tables A1 located in the Appendix.
c. TYPE refers to the type of tube as indicated by two descriptions.
    1. The first description (xx) refers to conductivity and has 2 options:
        C: This is a tubing that is conductive as defined by Section 7.9
        N: This is a tubing that is non-conductive (the requirements of section 7.9 do not have to be met)
    2. The second description is (YY) refers to pressure application and has 3 options:
        HPF: This is a type of tubing described in the scope as high-pressure liquid fuel line.
        LPF: This is a type of tubing described in the scope as low-pressure liquid fuel line.
        V: This is a type of tubing described in the scope as one that handles fuel vapor or evaporative emissions.

    These two descriptions are included by printing them with a “slash” line separating them. Two examples of this “type” as printed on the tubing would be:
    C/HPF and N/V

d. P refers to the permeation category as determined by the procedures described in 7.10. It shall be a single digit that is identified from 7.10.5.

   If it is not practical to print on the outside of the tubing (convoluted tubing or tubing with an outside surface that is not smooth, for example), then the labeling will be done by a tag or loop of tape permanently attached to the outside circumference of the tubing. Such labeling must be repeated every 500 mm or less along the entire length.

   For convoluted or corrugated tubing, the necessary printing can be done by the labeling or tagging procedure that is described. An acceptable alternative is to print the necessary wording only on each straight end section.

4.4.2 EXAMPLES OF IDENTIFICATION

The following are examples of appropriate identification of a tubing

a. SAE J2260 – M-8-C/HPF-2: This is a multilayer tubing construction with an 8mm nominal O.D. It is conductive and is targeted toward a high pressure liquid fuel application; permeation category is 2.
b. SAE J2260 – M-28-C/LPF-1: This is a multilayer tubing construction with a 28mm nominal O.D. It is conductive and is targeted toward a low-pressure liquid fuel application; permeation category is 1.
c. SAE J2260 – S-14-N/V-4: This is a monowall tubing with a 14mm nominal O.D. It is non-conductive and is targeted toward a fuel vapor application; permeation category is 4.

5. Dimensions

5.1 Tubing Sizes and Dimensions

5.1.1 DIAMETERS

Tubing diameters refer to outside diameter (O.D.); standard sizes and their tolerances are listed in Tables A1 and A2 in the Appendix.

5.1.2 WALL THICKNESS

There are numerous factors that can have an influence on the wall thickness that is selected; for example:

a. The burst pressure of a given tube construction and diameter is a function of its wall thickness.
b. As walls become thicker, the minimum bend radius increases for a given tube diameter (for a free-form bend).
c. For MLT constructions with elastomeric covers, the critical dimension is the ID. The wall thickness is determined by the materials utilized and the requirements of the application
d. Tubing wall thickness may differ for convoluted/corrugated wall (refer to Section 6.3)

The result of all these factors is that the end user must be consulted to determine all requirements. The wall thickness is then determined by those requirements and the materials selected for the various layers of the multilayer tubing or for the monowall tubing.

Details on available standard wall thicknesses and their tolerances are found in Tables A1 and A2.

5.2 Minimum Bend Radius

When a tubing is routed as part of a vehicle system, there are occasional "free-state" bends that occur. Care must be taken to ensure that such bends do not attempt to create radii that are so tight that the inside dimensions of the tubing distort excessively. Minimum bend radius details for tubing conforming to this Recommended Practice are described in 7.3.1. Tubing may be qualified to minimum bend radii smaller than indicated by the appropriate table referenced in 7.3.1, using the procedure of 7.3.2.

If it is known that the tubing under consideration will be used only as a CVT (refer to section 6) or only in a formed state, then the minimum bend radius requirements of this section do not apply.

5.3 Test Specimen Considerations

5.3.1 MULTILAYER/MONOWALL TUBING TEST SPECIMENS

5.3.1.1 The wall thickness and tubing diameter used for the test specimens needed for the procedures should correspond to those required for each application (consult the end user). Refer to tables A1and A2 in the Appendix for standard tubing dimensions.

5.3.1.2 If a set of required tubing dimensions is not known or not specified by the end user, then the basic tubing size to be used for test specimens is 8mm O.D. and 1mm wall thickness (see Table A1).

5.3.1.3 For some test requirements, results for a single tube diameter can be used to qualify many diameters (e.g. permeation resistance). Use of a substitute or surrogate diameter for a test specimen is acceptable only if the layer configuration and thickness of the wall is identical. (Note: This does not apply to the CVT … see section 6).

5.3.1.4 Length of tubing specimen shall be a minimum of 200mm unless otherwise *specified.*

5.3.1.5 Refer to sections 6.3 and 6.4 for details on CVT test specimens.

5.3.1.6 No preformed tubing – All test specimens to be tested will be straight tube (no preforming of any kind). This applies to both straight wall tubing and CVT.

5.3.1.7 Table 1 shows a complete summary of the number of test specimens needed for each of the tests called out in J2260. Ten (10) are needed for initial cold impact test of section 7.5. All other tests require five (5) test specimens.

TABLE 1—NUMBER OF TEST SPECIMENS NEEDED FOR EACH TEST REQUIREMENT OF SECTION 7 (SEE NOTES 1 AND 2)

	Tubing Property	Burst Test at 23 °C	Burst Test at 115 °C	Ovality	Cold Impact Resistance at -40 °C	Electrical Resistance	Permeation Resistance CE10		Mandrel Insertion	Layer Adhesion
	Section	7.1	7.2	7.3	7.5	7.9	7.10		7.11	7.13
as extruded (no preconditioning needed)		5	5	5xL (see note 3)	10	5	5		5	5 (see note 4)
PRECONDITIONING PROCEDURE										
after kinking	7.4	5				5				
after cold impact test	7.5	5				5				
after fuel exposure preconditioning (CE10, 60 °C, 5000h)	7.6				5					5 (see note 4)
after fuel exposure preconditioning (CE10, 60 °C, 5000 h) and cold impact test	7.6	5	← See note 5		5					
after fuel exposure preconditioning (Fuel C, 60 °C, 1000 h)	7.6					5				
after methanol resistance (CM15, 60 °C, 1000h)	7.7				5					5 (see note 4)
after methanol resistance (CM15, 60 °C, 1000h) and cold impact test	7.7	5	← See note 5		5					
after auto-oxidized fuel exposure test (base fuel C, 50 millimols/1 of TBHP as described in J1681; 40 °C, 1000h)	7.8				5					5 (see note 4)
after auto-oxidized fuel exposure test (base fuel C, 50 millimols/1 of TBHP as described in J1681; 40 °C, 1000h)and cold impact test	7.8	5	← See note 5		5					
after immersion in 50wt% ZnC12 solution, 200h at RT and 24 hour air dry @ 23 °C	7.12				5					
after heat aging (@ 90 °C for 1000 hrs)	7.14	5	← See note 5		5					
after heat aging (1000h at 90 °C + 48 h at 115 °C) and cold impact test	7.14	5	← See note 5		5					

NOTE 1—Length of all test specimens is 200mm minimum except where otherwise specified (see 5.3.1.4).
NOTE 2—O.D. of tubing identified in Section 5.3.1.1 or 5.3.1.2.
NOTE 3—L = length identified for test of Section 7.3 as 1.2π minimum bend radius.
NOTE 4—For layer adhesion, 5 test specimens are needed for each interface.
NOTE 5—This arrow means that the 5 test specimens that have completed the cold impact test are the ones used in the burst test.

5.3.2 CONNECTORS, PLUGS, MANDRELS

For the various tests that are done, there are a variety of connectors, plugs, and mandrels that are used for the various exposure testing. The material from which those are made shall be a type 300 stainless steel or equivalent (as agreed to by end user and producer).

6. Convoluted or Corrugated Tubing (CVT)

6.1 Criteria

Some applications may require tubing with flexibility beyond the capability of straight wall tubing. Tubing with a wall that has a convoluted or corrugated configuration for all or portions of its length can resolve this concern. A CVT may not have the same performance level as the equivalent straight-wall tube but still it must meet the pertinent acceptance criteria for all sections of this specification appropriate to it's end use.

6.2 Test Considerations

The convoluted or corrugated shape of the wall can effect how the CVT is handled as the tests are conducted. Some of these are identified in section 6.4; some others are mentioned in the sections that discuss a particular test. They can have an effect on how specific tests are conducted or results are reported.

6.3 Dimensional Considerations for CVT

6.3.1 The CVT shall be identified by its nominal ID; this is the same as ID of the straight wall section at each end (known as the cuff of the CVT), see Table A1). In most cases, the inner diameter of the straight-wall portion is not exactly the same as the inner diameter of the corrugated area. Due to the manner in which most CVT is produced (with the so called “over-pressure-technique”), the diameter of the corrugated area has an inner diameter which is a little bit smaller than the inner diameter of the cuff ends. If the diameter of the cuff ends and the corrugated area are exactly the same, the sealing plug can touch the inner surface of the cuff ends and causes scratches and core “smear-marks” which then can cause leaks (when the connectors are inserted). Therefore, the inner diameter of the convoluted area typically ends up being about 0.1 mm smaller than the inner diameter of the cuff ends. When the tubes are produced with the “vacuum-technique” the inner diameter of the straight-wall can be exactly the same as in the corrugated portion of the tube.

6.3.2 At each end of the convoluted or corrugated tubing, there will be a straight section (known as the cuff) used to join the tubing to connectors, nipples, and other attachment elements. The dimensions of this cuff will correspond to those identified on Tables A1and A2 unless a non standard size has been specified.

6.3.3 Wall thickness of the convoluted/corrugated portions of the tubing may differ from those indicated in Table A1 due to the manufacturing process. Performance tests results will be used to establish that such “routinely occurring” variations in wall thickness are acceptable.

NOTE—For dimensional considerations of sections 6.3 refer to tables A2-1 and A2-3 in Appendix.

6.4 Test Considerations for CVT

6.4.1 When a test is performed on CVT type tubing, the required procedure can be conducted on either the convoluted portion of the tube or on the straight sections (cuff, for example). These tests are identified in each test description where it is appropriate.

6.4.2 Wherever possible, tests should focus on the convoluted sections of the tubing. This can be an application of the procedure directly to the convoluted or corrugated wall (example is cold impact and kink test). For layer adhesion, the procedure of 7.13.2 should be followed using the CVT section for all testing after fuel exposures. For determination of initial layer adhesion, the cuff section should be used. (Section 7.13.1)

6.5 Consideration for Liquid Fuel Line Applications

Any CVT used in liquid fuel applications must meet the conductivity requirements called for in 7.9. In addition, the end user must have the final application carefully tested to determine that unacceptable electrostatic charging is avoided (refer to SAE J1645) during usage and when it's being tested (such as during fuel recirculation or during permeation measurements (SAE J1737).

7. Performance Requirements

a. All tests described in this standard are to be performed on the completed product (tubing) that has not been formed (all tests are done on straight tubing). Differences in performance criteria between high pressure liquid fuel, low pressure liquid fuel, and fuel vapor applications are indicated in the procedure or acceptance criteria of each section. If no distinction is made, all types of tubing must meet the entire requirement as written.
b. The dimensions and configurations of test specimens used must conform to the guidelines of sections 5.3 and 6.3, unless there are specific length or other criteria identified for a specific test.
c. Tubing shall be allowed to equilibrate at 23 °C and 50% Relative Humidity for a minimum of 24 h after production before it is subjected to any tests.
d. For all testing in this section, there shall be a quantity of test specimens used as shown in Table 1. The result of testing each specimen must meet the acceptance criteria. When comparison are made from one section to another, the numeric value used in those comparisons shall be the average of the values obtained for the number of specimens of the specific test procedure.
e. All test temperatures specified may vary by ± 2 °C, unless otherwise specified. All times are minimum unless otherwise specified.
f. For testing that is done involving flowing fuel (fuel exposure-testing and permeation measurements), there is a possibility of electrostatic charge build up. This is more likely when the wall of the tubing is corrugated or convoluted and/or the material used in the innermost layer is not conductive. Steps should be taken to minimize the occurrence of electrostatic charges. These steps can include (but are not limited to) the following:
    - reduce flow of fuel to a very low rate
    - substitute weight loss procedures where such alternative test methods are acceptable
    - use conductive fittings for the testing and bond them to the appropriate ground plane

    It is recommended that pertinent sections of the Recommended Practice SAE J1645 be consulted.

7.1 Room Temperature Burst Test

7.1.1 Initial Burst Test Measurement

The tubing specimens shall be stabilized for ½ to 3 hrs at 23 °C and tested by increasing pressure of a suitable liquid fluid inside the tubing at a rate of 7 MPa/min ± 1 MPa/min. Continue at that rate until tubing bursts. Any type of fitting can be used during this burst test as long as it does not effect the burst capability of the tubing and meets the criteria of 5.3. If the connectors blow out of the tubing before the required level of burst pressure is reached, the data from that particular sample should be discarded. Additional clamps over the existing connectors or fittings may be utilized, if necessary, to ensure that the tubing sample fails by bursting.

The initial value for room temperature burst for 5 test specimens must be recorded. The average of those test results will be used as the baseline for comparison of burst tests done on tubing that has been subjected to certain procedures and test fluid exposures (see 7.1.2).

7.1.2 Burst Test Measurements After Exposures

There are 5 sections of the performance requirements that include a subsequent burst test measurement (7.4, 7.5, 7.7, 7.8, and 7.14). After each of the steps described in each section, the tubing specimen subjected to the particular procedure/exposure is tested by the room temperature burst procedure described in section 7.1.1.

NOTE—If the connectors blow out of the “exposed” tubing before the required level of pressure is reached, the result of that particular test should be discarded. The sample can be used again (another connector inserted) to avoid having to conduct the exposure test all over again.

7.1.3 Acceptance Criteria

7.1.3.1 For all test specimens that are exposed under the 5 identified sections, the measured burst test result shall not be less than 75% of the measured initial burst test result on unexposed tubing (initial value obtained in section 7.1.1.).

7.1.3.2 It is possible for a tube to have a decrease greater than the level indicated in section 7.1.3.1 and still be acceptable. For that to be the case, the following criteria must to met:

a. After the initial drop off of greater than 25%, the performance of the tube can be proven to level off and to not drop below the minimum burst pressure of section 7.2.1.1 for the expected life of the application.
b. Acceptance of such a construction shall be by a specific end user and for a specific producer. (Acceptance by one end user does not imply acceptance by any other end user and acceptance for one producer does not imply acceptance for any other producer).

7.2 High Temperature Burst Test

7.2.1 The test procedure described in 7.1.1 shall be performed at a temperature of 115 °C. The tubing shall be stablized at the test temperature for 2 hours prior to conducting the test. A minimum of 5 test specimens are to be used; test results of those 5 will be averaged.

NOTE—The liquid used in this burst test shall also be at the same temperature.

The end user shall be consulted to establish the maximum pressure that can possibly be encountered in the specific liquid or vapor system in which the tubing will be used.

7.2.1.1 Normal Acceptance Criteria

Minimum burst pressure shall be three times the maximum pressure that can be encountered in the system in which the tubing will be used. Additionally, the burst pressure shall not be less than the level shown in Table 2.

This will depend on the type of application for which the tubing is targeted.

TABLE 2—MINIMUM HIGH TEMPERATURE BURST PRESSURE ACCEPTANCE CRITERIA

Type of Application	Minimum Burst Pressure of Any One Sample Tested
High pressure liquid fuel line (HPF)	1350 kPa
Low pressure liquid fuel line (LPF)	150 kPa
Fuel vapor tubing (V)	60 kPa

7.2.1.2 Exception to Section 7.2.1.1 (for CVT)

For CVT used in high pressure liquid fuel applications, there is an exception allowed for situations where it can be proven that the temperature of the application does not reach the 115 °C level identified in section 7.2.1. An example of this is a CVT that is used as part of a fuel delivery module inside of the fuel tank. For a case such as that, the temperature used for the procedure of section 7.2.1 should be the maximum that could be encountered in the specific location where it will be used. This temperature level is to be agreed upon between the end user and the fuel system supplier/tubing producer.

7.3 Ovality Requirement

This requirement is not required for convoluted/corrugated tubing (CVT) or for tubing that will be used only in a formed state (no free bend).

7.3.1 CALCULATION OF MINIMUM BEND RADIUS

The formulae shown in Table A3 (in the Appendix) shall be used to determine the minimum bend radius for tubing.

7.3.2 PROCEDURE TO DETERMINE MINIMUM BEND RADIUS

The following procedure is used to determine if a tubing can be bent in a tighter radius than is indicated by the formula in Table A3 and to approximate what that bend radius may be. Figure 1 illustrates some aspects of the procedure.

The tubes are to be bent in a free state until they form a coil, the free ends are then grasped, wrapped over the first loop of tubing to form a two-layered coil of tubing. The tubing is drawn down to the smallest coil diameter possible within 1 min and without kinking the tubing. The measurement of the minimum bend radius is made by taking 1/2 the measured value of the inside diameter (inside wall to inside wall of coil of tubing). The length of tubing used for this test shall vary with different diameters of the tubing. The length shall be enough so that the procedure shown in Figure 1 can be accomplished with at least 100 mm of tubing extending beyond the circle on both sides.

It is important to note that the radius measured by this procedure is an approximation. The performance test of 7.3.3 must be passed to confirm that the estimated bend radius can be achieved without kinking.

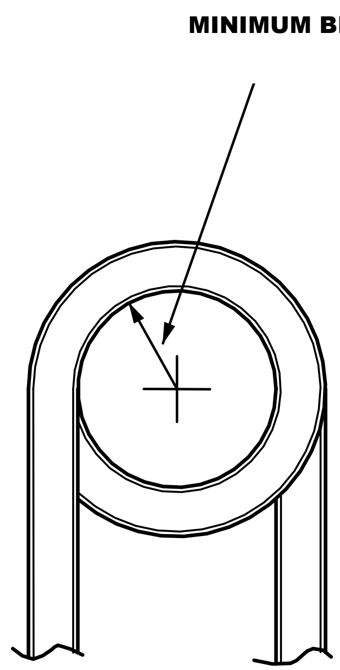


FIGURE 1—ILLUSTRATION OF PROCEDURE FOR DETERMINING MINIMUM BEND RADIUS

7.3.3 OVALITY REQUIREMENT—TEST PROCEDURE

This test procedure is to determine if a tube can meet the minimum bend radius dimensions from Table A3, or from the procedure of 7.3.2., or from the requirement of the actual application.

The first step is to identify the minimum bend radius dimension that is to be tested for a specific tubing diameter. A tubing test specimen shall then be cut to length equal to: (1.2xπ) x minimum radius.

The tubing specimen shall then be placed in a fixture as shown in Figure 2. When installing the tube, it shall be bent in the same plane and direction as its free state curvature. Place the tube, installed on the fixture, into an oven at 115 °C and soak for 1 h. Remove the fixture from the oven and pass the specified ball through the tube on the fixture. Tubing and fixture can be allowed to cool to room temperature for easier handling.

The diameter of the ball shall be determined by Equation 1:

$$\text{Ball diameter (mm)} = 0.4 \times \text{minimum tubing ID} \pm 0.05 \text{ mm} \qquad \text{(Eq. 1)}$$

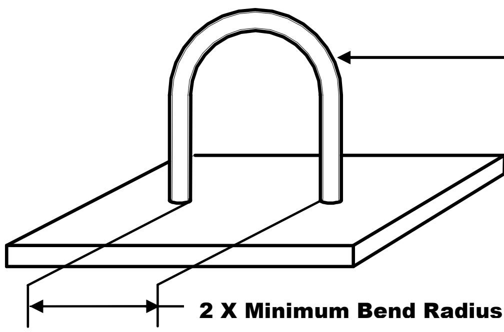


FIGURE 2—KINKING RESISTANCE TEST FIXTURE

7.3.3.1 Acceptance Criteria

Restriction of the passage of the ball constitutes a failure.

7.4 Burst Test on Kinked Tubing

For the procedures of this section, the tubing shall be stabilized for 1/2 to 3 h at 23 °C. Completely bend tubing so it is kinked and two lengths of tubing on either side of the kink touch along entire length. Straighten tubing completely. Repeat the procedure so that the kink occurs at the same position on the specimen (total of 2 complete kinks in the same direction).

7.4.1 ACCEPTANCE CRITERIA

Tubing must meet all requirements of the Room Temperature Burst Test (see 7.1).

7.5 Cold Temperature Impact

The Impact Test Apparatus is pictured in Figure 3. The impact head weighs 0.912 kg ± 0.003 kg and is in the form of bar with a diameter of 31.75 mm and its end has a spherical radius of 15.88 mm. The test apparatus allows the impact head to fall 305 mm ± 3 mm. The 305 mm ± 3 mm distance is measured from the bottom of the weight to the center of the tube specimen. When the mass is released, it must fall freely in the fixture. The maximum radius of curvature of the inner edge of the opening of the supporting platform is 2.0 mm. The supporting platform is 10 mm ± 1 mm thick.

NOTE—For cold impact testing of CVT, it is the convoluted or corrugated wall section that should be the impact point of the test. The energy of impact for the CVT is not the same as for the straight wall tubing; instead, it is half the level. (This means for the impact on the CVT section, the weight of the impact apparatus is dropped from 153 ± 3mm).

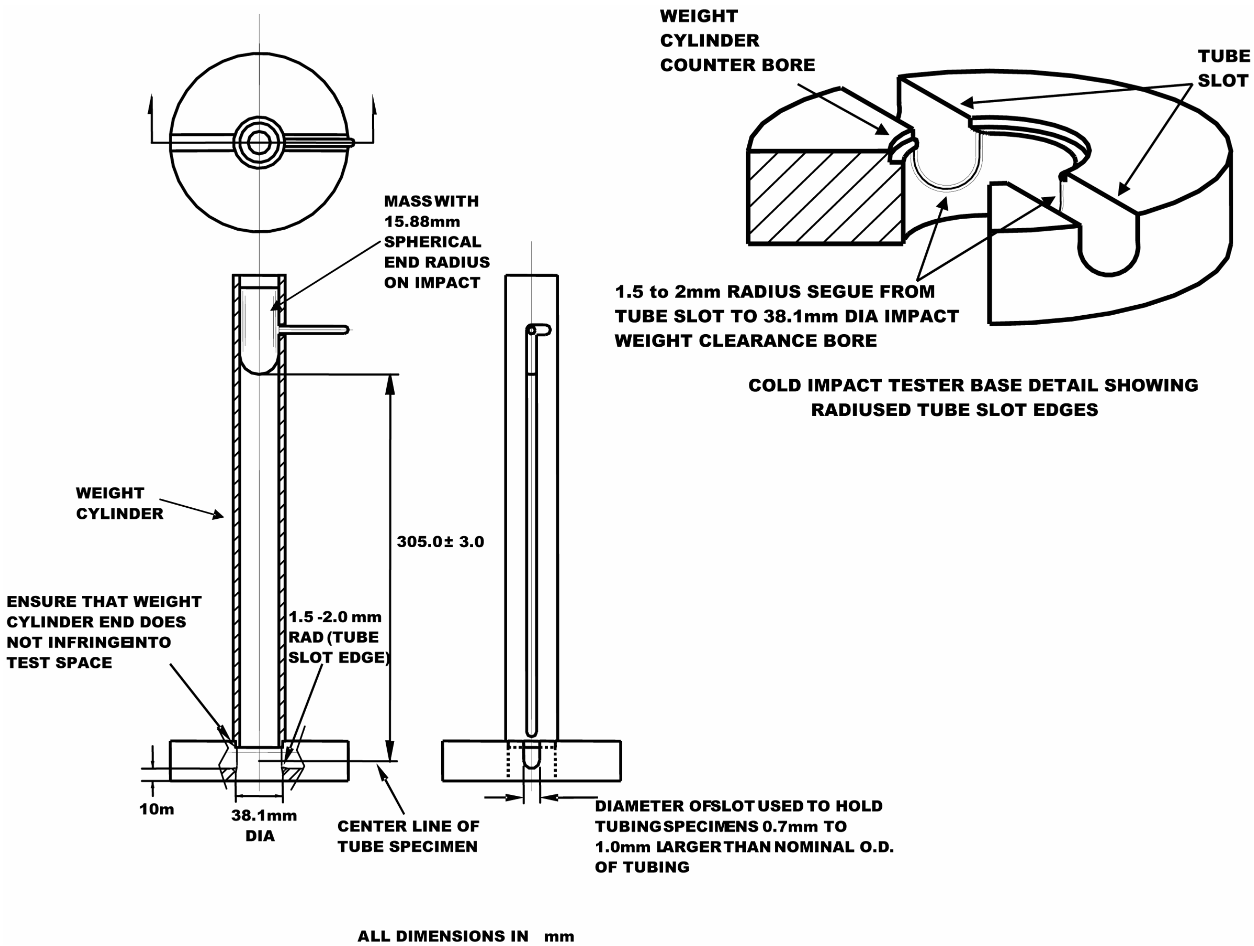


FIGURE 3—COLD IMPACT TEST FIXTURE

7.5.1 PREFERRED PROCEDURE

Expose the test samples and the impact test apparatus to –40 °C for 4 h. Place each sample in the supporting platform of the apparatus and allow the impact head to fall on it. Impact should occur with both apparatus and specimens inside the cold chamber.

7.5.2 OPTIONAL PROCEDURE

If the impact test cannot be done inside the cold chamber, the apparatus and the specimens can be removed from the chamber by the following procedure:

a. The apparatus is removed from the chamber for up to a 3 min period. During that period, impact tests of several tubing specimens can be completed. At the end of the 3 min period, the apparatus is returned to the chamber for additional temperature soak (–40 °C) of at least 25 min duration. After the additional soak at temperature, the apparatus can be removed again for an additional set of cold impact of tubing specimens (within a 3 min period). This procedure is repeated until all test specimens have been impacted properly.

b. All test specimens are kept in the cold chamber until immediately before impact in the apparatus. When a tubing specimen is removed, it must be impacted in the apparatus within 5 s of its removal from the cold temperature environment.

NOTE—The temperature of the ambient air where these impacts occur shall not be higher than 23 °C.

7.5.3 ACCEPTANCE CRITERIA

Several types of specimens are tested by this impact procedure (after exposures of sections 7.6, 7.7, 7.8, 7.12 and 7.14). In each case, after impact of a tubing specimen, it is allowed to return to 23 °C. The tubing specimen is then subjected to Room Temperature Burst per (see 7.1). All criteria of that section must be met. The sample must be free of visible cracks and fractures (after impact and before burst test).

7.6 Fuel Exposure-Preconditioning

This is a long-term fuel exposure procedure designed to provide a pre-conditioning step to test specimens that are used in sections 7.5 (cold impact), 7.13 (layer adhesion) and the “C” test fluid exposure for section 7.9 (electrical resistance).

This procedure is not intended as a routinely required test because it takes too much time. It is for the initial qualification for each particular wall configuration of a given type of tubing.

7.6.1 The two test fluids for this procedure shall be “C” and “CE-10”, as described in SAE J1681.

7.6.1.1 For test fluid C, its composition should remain constant during the full time of exposure. The important consideration is to maintain appropriate fluid levels.

7.6.1.2 For test fluid CE-10, the composition of the fluid can change with time (especially alcohol content). Besides maintaining the appropriate fluid levels, the alcohol content must be maintained as described in sections 7.6.4.1 (recirculation method) and sections 7.6.4.2 (reservoir/tubing method).

7.6.2 The temperature of test fluid used in the exposure shall be 60 °C.

7.6.3 TEST SPECIMENS

7.6.3.1 For the recirculation method of 7.6.4.1, the tubing can be exposed to the test fluids before it is cut to length (as specified in 5.3.1) for the subsequent tests.

7.6.3.2 For the reservoir method of 7.6.4.2, the length of test specimens being exposed to the test fluids shall be as specified in 5.3.1.

7.6.3.3 For each specific, defined configuration of layers in the wall construction, only one diameter should be tested for a given wall thickness. Separate tests must be done on tubes having the same ID, but wall thicknesses or layer configurations that are different.

7.6.4 PROCEDURES

There are two procedures described here for exposing the test specimens to each of the two test fluids: Recirculation method (7.6.4.1) and Reservoir/tubing method (7.6.4.2) The procedure of section 7.6.4.1 shall be followed for tubing intended for high pressure liquid fuel applications. For tubing intended for low pressure liquid fuel applications and fuel vapor applications, the procedure of 7.6.4.1 is recommended; however, the optional procedure of section 7.6.4.2 may be followed.

7.6.4.1 Recirculation Method

7.6.4.1.1 For test fluid C, follow the recirculation procedure of SAE J1737.

7.6.4.1.2 For test fluid CE-10, the same procedure of SAE J1737 is followed; however steps must be taken to maintain the alcohol content as described in the following paragraph.

Composition of the fuel should be measured and adjusted periodically to ensure that the alcohol content of the fuel is maintained at 10% ± 2% (frequency of the checking of the composition is determined primarily by the size of the liquid fuel reservoir used in the recirculation process). Alcohol content shall be measured every day after the start of test until it is established that the rate of alcohol content change is less than + 2% over a longer period of time. The frequency of checking alcohol content can then be decreased. If these tests are done frequently and a history of how often the alcohol should be checked can be substantiated from previous test specimens, then that established schedule can be utilized. Alcohol content shall always be checked at least once per week. If the alcohol content of the fuel goes outside of the limits, the test fuel must be replaced with a new mixture with the correct level or alcohol.

7.6.4.2 Reservoir/Tubing Method

7.6.4.2.1 For test fluid "C", follow the procedure as described in SAE J2663.

7.6.4.2.2 For test fluid CE-10, follow the procedure as described in SAE J2663. Steps must be taken to maintain the alcohol content of the test fluid (7.6.4.1.2 procedure can be followed).

7.6.5 PROCEDURES

7.6.5.1 For "C" Test Fluid

7.6.5.1.1 Using recirculation method continuously expose a length of tubing (1.0 meters or more) to ASTM fuel C for 1000 hrs @ 60 °C. At the end of the exposure, five (5) specimens are cut to length (200mm minimum) and used in the procedure of section 7.9.

7.6.5.1.2 Using reservoir method, continuously expose a minimum of 5 test specimens to ASTM fuel C for 1000 hrs @ 60 °C. At the end of that period, the other 5 specimens (200 mm minimum length) are used in the procedures of section 7.9 (electrostatic charge procedures).

7.6.5.2 CE-10 Test Fluid

7.6.5.2.1 It can be confusing to determine the exact quantity of test specimens to use in this fuel exposure. The following 2 sections illustrate how the sequence of tests that would be done and the number of specimens involved for an MLT with 4 layers. (The number of test specimens needed for an MLT with a different number of layers would be different than this example because of needs of section 7.13 … 5 test specimens for each layer interface).

7.6.5.2.2 Using recirculation method, continuously expose a length of tubing (4.0 meters or more) to ASTM fuel CE-10 for 5000 hrs @ 60 °C. At the end of the full 5000 hrs of fuel exposure 20 test specimens are then cut (200mm minimum length) and used in the procedures of section 7.5 (5 specimens) and 7.13 (15 specimens).

7.6.5.2.3 Using reservoir method continuously expose a minimum of 20 test specimens to ASTM fuel CE-10 for 5000 hrs @ 60 °C. At the end of the full 5000 hrs of fuel exposure, the 20 specimens are then used in the procedures of sections 7.5 (5 specimens) and 7.13 (5 specimens for each interface) … or a total of 15 in this example.

7.6.6 Acceptance criteria of the sections 7.5, 7.10, and 7.13 apply to the “exposed” specimens that are tested.

7.7 Methanol Resistance

7.7.1 PROCEDURES

The fuel exposure/preconditioning steps of section 7.6 shall be followed for the following conditions:

Test temperature	60 °C
Test exposure time	1000 hrs.
Test fluid	CM-15 as described in SAE J1681. Methanol content is to be maintained at 15 ± 2% in a manner similar to that described in 7.6.4.1.2 or 7.6.4.2.2 (whichever is appropriate).
Test specimens	Quantity needed depends on number of layer interfaces that are in the MLT being tested (refer to section 5.3 as well as 7.6.3 for details). The specimens can be exposed individually or in a full length, then cut-to-size as needed.

Subsequent procedures on tubing specimens that were exposed to methanol-blend fuels for the full 1000 @ 60 °C:

- Five (5) specimens will be needed to test for cold impact resistance per 7.5 (including the burst test). The cold soak must be started immediately after emptying the tubing of the methanol blend fuel (to avoid any drying out of the tubing).
- Test for layer adhesion per section 7.13.2 (need 5 test specimens for each layer interface)

7.7.2 ACCEPTANCE CRITERIA

All criteria of sections 7.5 and 7.13 shall be met for all tubing tested.

7.8 Resistance to Auto-Oxidized Fuel

7.8.1 The fuel exposure and preconditioning steps of section 7.6 shall be followed for the following conditions:

Test temperature	40 °C
Test exposure time	1000 hrs.
Test fluid	Auto oxidized test fluid uses a base fuel of ASTM Fuel C and has a concentration of 50 millimols/1 of tertiary-butyl-hydroperoxide (TBHP) (using copper additive) as described in SAE J1681. The concentration must be maintained ± millimols/liter throughout the entire exposure. A technique similar to the maintenance of alcohol percentage in 7.6.4.1.2 or 7.6.4.2.2 (whichever is pertinent) should be followed.
Test specimens	Quantity needed depends number of layer interfaces that are in the MLT being tested (refer to section 5.3 as well as 7.6.3 for details). The specimens can be exposed individually or in a full- length, then cut-to-size as needed.

Subsequent procedures on tubing that have been exposed to auto-oxidized test fluid for the full 1000 hrs @ 40 °C.

- Five (5) test specimens are needed to test for cold impact resistance per 7.5 (including the burst test). The cold soak must be started immediately after emptying the tubing of the sour gas fuel (to avoid any drying out of the tubing).
- Test for layer adhesion per section 7.13.2 (need 5 test specimens for each layer interface).

7.8.2 ACCEPTANCE CRITERIA

All criteria of sections 7.5 and 7.13 shall be met for all tubing tested.

7.9 Conductive Tubing

Liquid carrying fuel tubes (both high pressure and low pressure) designated as conductive per section 4.4 of this document shall have a conductive inner layer and meet the conductivity requirements of this test method. For monowall tubing, the whole tubing all meet those conductivity requirements.

For tubing used in fuel vapor and evaporative emissions systems, electrostatic charge is not an issue, so section 7.9 is not required for those applications. (Refer to SAE J1645 for details about this).

7.9.1 REFERENCE DOCUMENT FROM SAE

SAE J1645 is a Recommended Practice that addresses the issue of electrostatic charge that may develop in a flowing liquid fuel system. It gives guidelines that should be followed on liquid tube and how it should be integrated into a fuel system to minimize the adverse effects that can develop from an electrostatic charging condition. These guidelines include such matters as configuration of the tube, assembly issues, and bonding to the vehicle ground. When developing a system to carry liquid fuel, care must be taken to consider all aspects of the system from an electrostatic charge perspective

Liquid fuel line that is to be used on a vehicle should meet the criteria of the Component Requirements section of that J1645 Recommended Practice. The final system design should also be tested in close conjunction with the needs of the end user to insure that all of their necessary criteria are met.

7.9.2 INITIAL TESTING (BEFORE EXPOSURE)

Before any fuel exposure or any other testing described in this specification, the initial performance of the tubing must be tested by using the procedure described in section 7.9.3. Surface resistivity should be calculated and recorded. Acceptance Criteria for initial testing is identified in section 7.9.5.

7.9.3 TEST PROCEDURE

7.9.3.1 Test Apparatus Needed

The test apparatus consists of a resistance meter (MEG-CHECK 2100A R-meter from Associates Research Inc. or equivalent) and a set of copper pins (diameter approximately 0.1 mm larger than ID of tubing).

7.9.3.2 Test Procedure

a. All tests are conducted at 23 °C ± 2 °C and 50% ± 5% relative humidity.
b. Measure sample length. Record as 'L_o' (mm).
c. Measure inner diameter of sample. Record as 'd' (mm).
d. Insert the copper pins to full depth in ends of tube assuring a tight fit. Measure the depth of the copper pin 'a' (mm). Attach the leads to the resistance meter as shown in Figure 4.
e. Record the resistance R (ohms).
f. Calculate Equation 2:

$$\text{Surface Resistivity (ohms/sq)} = \frac{R(\pi d)}{L_o - 2a} \qquad \text{(Eq. 2)}$$

g. Measure the resistance and record the associated surface resistivity of tubing specimens before any exposure testing.

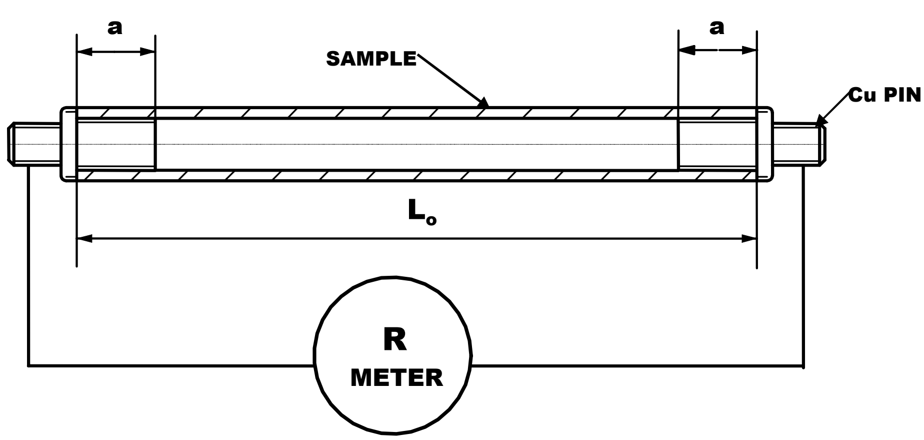


FIGURE 4—SCHEMATIC OF RESISTANCE MEASUREMENT FIXTURE

7.9.4 TESTING AFTER EXPOSURES

7.9.4.1 There are 3 sections in this specification where tubing samples have been subjected to other tests or preconditioning and then are to be tested to determine if they maintain their performance levels adequately.

Section 7.4—Kink Procedure: After two kinking steps are done, the surface resistivity is determined. (No subsequent burst test is done in this particular case)
Section 7.5—Cold Temperature Impact: After the tubing specimen has been impacted per section 7.5, it is allowed to return to 23 °C. (No subsequent burst test is done in this particular case)
Section 7.6—Fuel Exposure: After exposure to ASTM fuel C for 1000 hrs @ 60 °C as described in section 7.6.5, the surface resistivity of the 5 exposed test specimens is determined. NOTE: The test fluid used in this fuel exposure part of the testing does not contain any alcohol for reasons described in SAE J1645 (sections 5.3 and Appendix A1.7).

7.9.4.2 Test Procedure

For testing after exposures, the procedure of section 7.9.3. is used. For the fuel exposed specimens of section 7.6.5, the measurements shall be taken within 2 hours after the exposure fuel has been removed from the exposed test specimens. Acceptance criteria of section 7.9.5 applies to both procedures.

7.9.5 ACCEPTANCE CRITERIA

Surface Resistivity Level—The surface resistivity determined from measured resistance values measured on test specimens both before and after exposure testing shall not be greater than 10^6 Ω/square.

7.10 Permeation Test Procedure

7.10.1 TEST CONDITIONS

The test fluid shall be CE-10 as described in SAE J1681. For that test fluid, the temperature the test shall be 60 °C and the pressure of the circulating test fluid shall be 2 bar.

7.10.2 TEST SPECIMENS

The tubing used in this procedure shall conform to the requirements of SAE J1737 and the criteria of section 5.3 of this document.

7.10.3 PROCEDURE

The permeation measurement shall be done using the recirculation method of SAE J1737 and refer to section 7.6.4.4.2 for the reservoir tube method). The test shall be until steady state is achieved (as described in SAE J1737).

7.10.4 REPORTING RESULTS

The steady state permeation measurement results shall be recorded; all measurements are to be recorded in grams/meter^2·day of tubing.

7.10.5 GENERAL CLASSIFICATION OF PERMEATION RESISTANCE

No matter which of the two test procedures are used, the following steps must be done to determine the general category of permeation performance.

a. The permeation at 60 °C for test fluid CE-10 shall be the basis.
b. Units reported from the measurement shall be grams/(meter^2·day) and shall be reported as a whole number by following all the guidelines of 8.3 of SAE J1737.
c. For calculation of the permeation resistance (grams/meter^2·day), it is the ID of the tubing (wetted by the fuel) that is the basis of the calculation. For CVT, it is the nominal ID that is used (see section 6.3.1).
d. Care must be taken that the permeation rate measured is at steady-state as defined and discussed in 3.3 of SAE J1737.
e. A minimum of five specimens must be tested by this procedure. After the high and low value of those five separate measurements are discarded, the average measurements of the remaining 3 specimens shall be the number used to describe the permeation rate of the tubing being tested. The average shall be rounded off to a whole number by following the guidelines of 8.3 of SAE J1737.
f. The whole number value of permeation determined from the previous step shall be used to identify the permeation category from Table 3. That category number is the digit “P” that is marked on the tubing for identification purposes that is described in 4.4.

7.10.6 OTHER TESTS

Different temperatures and test fluids can be used for permeation measurement. Other combinations typically used are 40 °C/CE-10, 60 °C/fuel C, and 40 °C/fuel C. These other test fluids and temperatures are to be determined by the end user and tubing producer. If other combinations are used then, the procedures of 7.10.1 through 7.10.5 apply (adjusted for the new conditions).

TABLE 3—DETERMINING CATEGORY OF PERMEATION PERFORMANCE

Category Number	Permeation Measurement of Tubing as Determined by Steps of 7.10.5 (grams/m^2·day)
0	0-3
1	3- 10
2	10 – 20
3	20 – 40
4	40 – 80
5	80 – 160
6	over 160

7.11 Mandrel Insertion

Inserting a standard mandrel in the end of the tubing is done for several reasons:

a. simulates the stresses involved with connector insertion
b. provides a means to qualitatively measure weld line strength
c. provides a means to impart a stress in the wall of a tubing during certain exposure tests

7.11.1 MANDREL DESIGN

The size of the mandrel to be used is determined by the ID of the tubing (refer to Table 4 and to the tubing dimensions of tables A1and A2 in the appendix).

TABLE 4—RECOMMENDED MANDREL SIZES FOR DIFFERENT SIZES OF TUBING

ID	Diameter of Mandrel
Up to 10mm	145% of ID
10mm ≤ ID < 16mm	135% of ID
16mm ≤ ID < 22mm	130% of ID
Over 22mm	125% of ID

The design of the mandrel should meet the following criteria:

a. The length of the constant diameter portion of the mandrel (L_C in Figure 5) shall be at least 2 times the I.D. of the tubing being tested.
b. The part of the mandrel that is inserted in the tubing first shall be tapered so that it increases from smaller than the ID of the tubing to the constant diameter within a length equal to 1.5 times the I.D. of the tubing being tested (L_T in Figure 5).
c. The mandrel shall be circular in cross section with a diameter determined by the guidelines from table 4. The mandrel size tolerance shall be ± 0.1mm (D in Figure 5).
d. The material from which the mandrel is made shall conform to the guidelines of section 5.3.2.

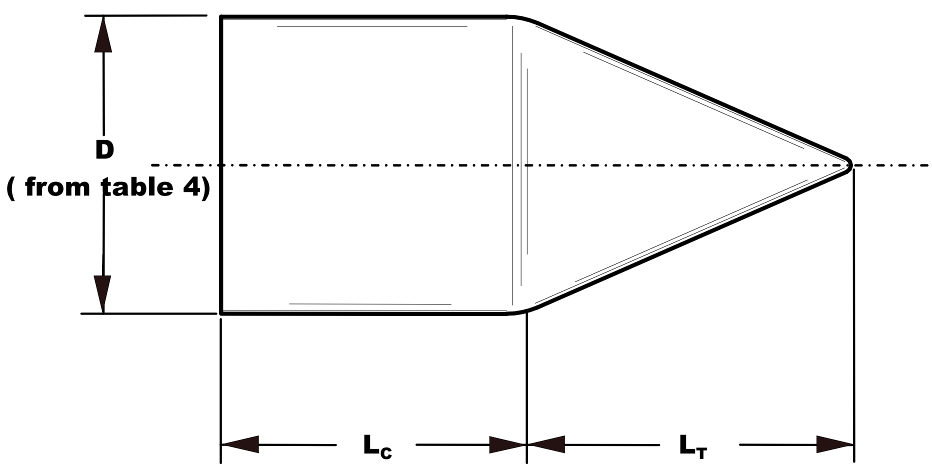


FIGURE 5—MANDREL CONFIGURATION

7.11.2 PROCEDURE

Tubing is conditioned in air at 23 °C for ½ hour to 3 hours. Then the mandrel is inserted in one end of the tubing within a 5 second time period.

NOTE—For CVT, the mandrel is inserted only in the cuff section (not the convoluted section).

7.11.3 ACCEPTANCE CRITERIA

The tubing end with the mandrel in place shall be examined visually at up to 5X magnification. There shall be no evidence of splitting, cracking, or layer separation.

7.12 Zinc Chloride Resistance

Environmental stress crack resistance of the tubing involves two options for exposure to zinc chloride solution described in sections 7.12.1 and 7.12.2. It is recommended that both be done, however, either is acceptable. (The mandrel insertion procedure may be more practical to do when larger tubing diameters are involved).

7.12.1 BENT TUBING EXPOSURE

Cut tubing specimen to be tested to a length as described in the second paragraph of 7.3.3. The connectors or fittings that will be used in the burst pressure testing of 7.1 are then inserted in at least one end of the tubing. If only 1 connector/fitting is used, then the other end shall be plugged or otherwise completely closed (and able to withstand the subsequent testing). The tubing is then bent in a half circle and mounted onto a fixture that is similar to that shown in Figure 2. The dimensions of the fixture, spacing of the means of mounting the connectors, radius of curvature are dependent on the diameter of the tubing (and are based on Appendix Tables … whichever applies). Other details described in 7.3 are to be used for guidance.

When the tubing specimen (and its connectors/fittings) is appropriately mounted in the fixture, invert it so the curved part is down and immerse the tubing specimen into a 50% (by weight) aqueous solution of zinc chloride at 23 °C for 200 h. The <u>entire</u> tubing specimen must be fully immersed; however, the connectors must not be fully immersed. The zinc chloride must be in contact with the <u>ends</u> of the tubing, but should not be able to enter the inside of the tube through the ends of the connectors. This level of immersion is to be maintained throughout the entire 200 h soaking time in the zinc chloride solution.

NOTE—Fresh, anhydrous zinc chloride should be used to make up a concentration of 50% (by weight) aqueous solution (specific gravity of 1.576 or a Baume rating of 53 at 15.5 °C). During the time that the bent tube is immersed in the solution, the concentration of the zinc chloride should be checked periodically to make sure the concentration stays at 50% ± 5%.

When the 200 h exposure is complete, remove the tubing specimen from the solution and allow it to dry for 24 h at 23 °C. Do not wipe off excess solution from any surface or the tubing ends. After drying, the tubing should be removed from the fixture so that all steps of the cold impact procedure of section 7.5 can be done (including the burst test). It’s important that the point of impact be on that part of the tube that had been exposed to the zinc chloride.

7.12.2 MANDREL INSERTION PROCEDURE

A mandrel shall be selected of the appropriate size and configuration as described in section 7.11.1. It must be of a design that fully plugs the tubing so no solution can enter the tubing. It is then fully inserted into one end of a tubing test specimen that has been cut to a length of at least 0.3 meter. The other end of tube shall have a connector or fitting appropriately inserted so the burst pressure test can be performed (part of acceptance criteria). When the mandrel and fitting are fully inserted in the tube, the mandrel end of the test specimen is then inserted into a 50% aqueous solution of zinc chloride at 23 °C for 200 hours. The entire tubing specimen must be fully immersed; however, the connector must not be fully immersed. The zinc chloride must be in contact with the ends of the tubing, but should not be able to enter the inside of the tube through the very ends of the connectors. This level of immersion is to be maintained throughout the entire 200 h soaking time in the zinc chloride solution. When the 200h exposure of the tubing specimen is complete, remove it from the solution and allow it to dry at 23 °C for 24 hours. Do not wipe off excess solution from any surface or from the tubing ends.

NOTE—Fresh, anhydrous zinc chloride should be used to make up a concentration of 50% (by weight) aqueous solution (specific gravity of 1.576 or a Baume rating of 53 at 15.5 °C). During the time that the mandrel end of the tubing is inserted in the solution, the concentration of the zinc chloride should be checked periodically to make sure the concentration stays at 50% ± 5%.

7.12.3 ACCEPTANCE CRITERIA

Tubing shall show no evidence of cracking on the outside diameter, tubing ends, or that part of the inner layer that is visible from the tubing ends. For tubing that also had a cold impact procedure, the specimens shall be cut open (lengthwise) and the area of impact shall also be examined. That area must also have no evidence of cracking. Also, all acceptance criteria of section 7.5 must be met.

7.13 Layer Adhesion

Tubing with 2 or more layers, must have adhesion between layers initially and after fuel exposure. The initial layer adhesion is measured by a quantitative test in section 7.13.1 to measure the ability of the layers to adhere to each other during the stress of initial assembly (particularly insertion of fittings). The test after fuel exposure is described in section 7.13.2; 7.13.2.2 is a qualitative method established to determine if the layers are prone to “internal collapse” during the stress of bending or short-term drying out after extended fuel exposure.

7.13.1 QUANTITATIVE METHOD FOR INITIAL LAYER ADHESION

This test procedure is used to measure layer adhesion between each interface of a multilayer tubing. For example, a 4 layer construction, therefore, requires 3 separate layer adhesion measurements on 5 test specimens for each measurement.

7.13.1.1 Strip Preparation

There are three methods recommended for obtaining a strip from the wall of the MLT. Each method minimizes the effects from the curvature of the tubing.

7.13.1.1.1 Spiral Strip

Cut a sample of tubing into a helical coil whose length is at least five times the circumference of the tubing. The width of the strip should be no less than 70% of the outer diameter of the tubing. (Figure 6 shows an example of a suitable tool for producing such a cut).

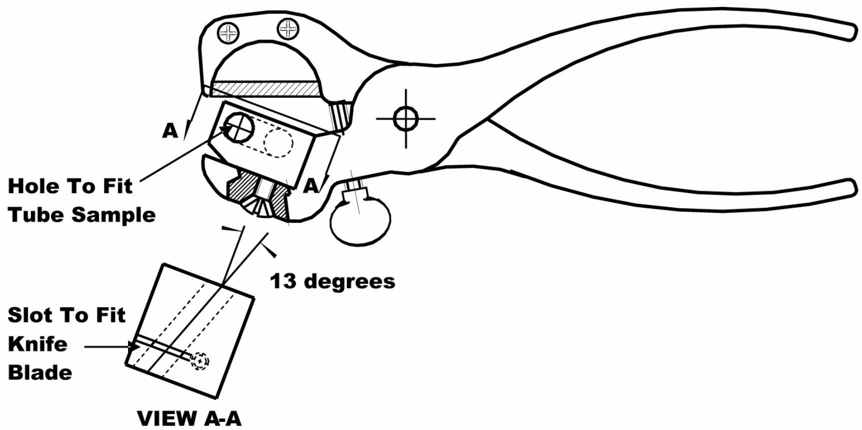


FIGURE 6—EXAMPLE OF SUITABLE TOOL FOR SPIRAL CUT ADHESION TEST

7.13.1.1.2 Longitudinally cut strips (two are described; either one is acceptable procedure).

7.13.1.1.2.1 Procedures

a. Tubing specimens shall be longitudinally cut by means of a suitable clamping jig and a sliding cutting fixture that holds parallel scalpel blades. This can be set up to cut more than one strip from the tube specimens at the same time. The resulting strips are sections of the circumference
b. An alternative technique is to use a modified microtome cutter to cut a strip from the tubing that has been placed in a holding fixture (see Figure 7 for an example of this).

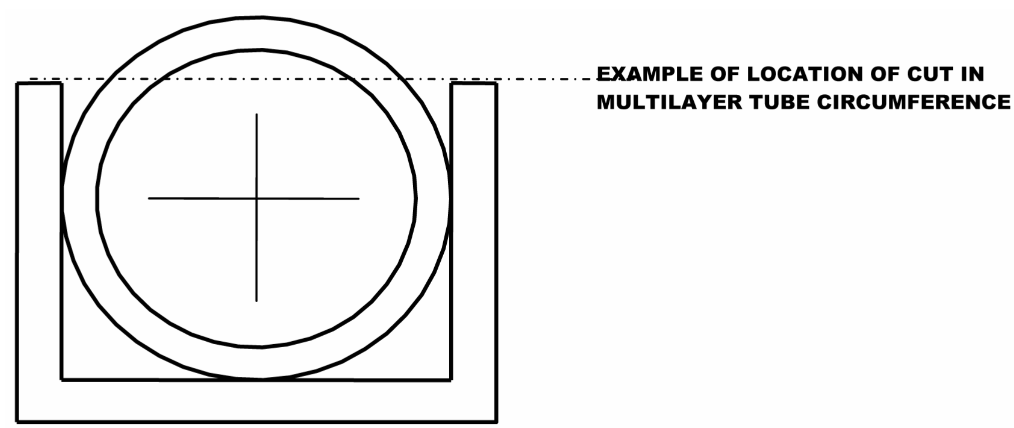


FIGURE 7—ILLUSTRATION OF PROCEDURE FOR CUTTING STRIP FOR LAYER ADHESION TEST

7.13.1.1.2.2 Strip Characteristics for Longitudinally Cut Strips

Length of strip obtained by procedure A or B above shall be at least 5 times the circumference of the tubing being tested. The width of the strip should be at least 3 times the thickness of the tubing and not more than 25% of the total circumference of the tubing). Three strips shall be taken from evenly spaced positions around the circumference. Those three strips can be taken from either the same length region or at different regions along the length (as long as the exposures of the regions have been the same).

7.13.1.2 Test Procedure

The adhesion between each layer of the multilayer tubing must be measured separately.

1. Test shall be done within 1 hour of removal from the test fluid.
2. Measure the width of the strip in millimeters at the I.D. surface
3. Mechanically initiate separation of the layers by using a scalpel (or similar hand-held instrument) or a fixed blade that is part of a fixture designed to initiate the layer separation required
4. Further separate the layers by using two sets of pliers. The amount of separation of the ends should be sufficient to easily grip them in a tensile tester
5. Install the separated layers in the opposing grips of a tensile machine
6. The layer being separated from the strip should be pulled as close to 90° from the strip as can be practically done. A rotating fixture or support wheel can be used to support the strip to prevent chatter or random fluctuations as the separation process occurs.
7. Pull the layers apart at a crosshead speed 50mm/minute Record the forces required to separate the layers along as much of the specimen length as possible:
   - The first 25mm of the strip length are not be included in the measurement process for the longitudinal strip
   - For the spiral strip, the length of strip to be tested shall not be less than 4 times the circumference of the tube from which the spiral was taken
   - The length of specimen along which the adhesion of the individual layers shall not be less than two times the circumference of the tubing from which the strips were taken
8. Measured force of peel strength should be calculated on a basis of force (Newtons) per millimeter of width of the strip used in the measurement process.
9. The force of separation will vary through the length of the strip being tested. In each case, the high and low values shall be recorded.
10. The force of separation will be the average of the high and low values that are obtained for each strip.
11. For the spiral strip, that average of high and low will be the force of layer adhesion for the tubing from which the spiral was taken.
12. For the longitudinal strips, the average for each strip taken from the circumference shall be average together to give the force of layer adhesion for the whole tubing from which the strips were taken.

7.13.1.3 Acceptance Criteria

For the strips prepared in sections 7.13.1.1.1 and 7.13.1.1.2 the average of all layer adhesion measurements of the strip or strips taken from tubing specimen shall be $\geq$ 1.0 N/mm. There shall be no minimum force value $\leq$ 0.5 N/mm.

7.13.2 ADHESION TEST AFTER FUEL EXPOSURE

7.13.2.1 Straight-Wall Tubing

After each of the three fuel exposure procedures described in 7.6, 7.7, and 7.8, each specimen must be tested using the quantitative method described in section 7.13.1. Acceptance criteria are the same as indicated at the end of section 7.13.1.2.

7.13.2.2 Convoluted Tubing

After each of the three fuel exposures described in section 7.6, 7.7, and 7.8, each specimen is tested using the following length change procedure for examining layer adhesion.

7.13.2.2.1 Procedure

Place a test specimen that has been exposed to fuel per 7.6 in a hot-air recirculating oven at 40 °C for a period of not less than 48 hours. Remove it and allow to cool to room temperature.

7.13.2.2.2 Acceptance Criteria

Examine the ends of the tubing speciman after it has cooled. There shall be no evidence of delamination or any sort of length change differences among any of the layers that are present.

7.14 Heat Aging Resistance

7.14.1 A minimum of 10 tubing specimens shall be prepared so that it can be tested in the room temperature burst test procedure (of section 7.1). This includes making the specimen of sufficient length so that the cold impact procedure that is part of section 7.1 can also be adequately conducted. The length must not be excessive; the whole specimen must be exposed in the manner described here.

7.14.2 When the tubing specimens have been appropriately cut to length, the test specimen shall then be placed in a recirculating hot air oven. (Note: Fittings for the burst test can be inserted before or after the heat exposure). They shall be continuously exposed to a constant temperature of 90 °C for a period of not less than 1000 hours.

7.14.3 When the exposure to 90 °C is completed, 5 of the 10 specimens shall then be tested by procedure of section 7.5. The other 5 test specimens shall then be exposed to a second temperature level of 115 °C 48 hrs. ± 2 hours. When the second set of 5 specimens have completed the second temperature exposure, they shall then be tested by the procedure of section 7.5.

7.14.4 ACCEPTANCE CRITERIA

Requirements of section 7.5 shall be met by exposed specimens.

PREPARED BY THE SAE FUEL LINES AND FITTINGS STANDARDS COMMITTEE

APPENDIX A

A.1 Dimension and Tolerances

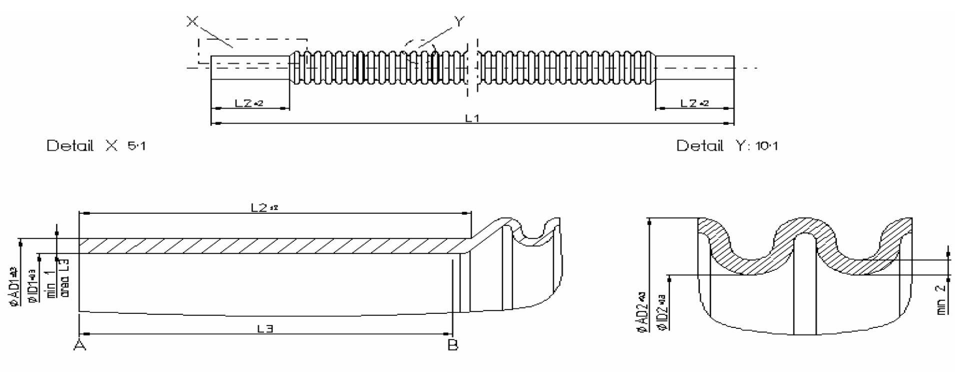
Tables A1 and A2 are listings of the various tubing sizes, wall thicknesses, and tolerances that should be used for the tubing covered in this document.

TABLE A1—TUBING DIMENSIONS (METRIC SIZES)(1)

Reference Sizes OD Dimension (mm)	ID of Tubing (mm)	Wall Thickness
5	3.0	1.0
6	4.0	1.0
8	6.0	1.0
10	8.0	1.0
12	9.0	1.5
15	12.0	1.5
18	14.0	2.0
20	16.0	2.0
22	18.0	2.0

1. Tolerances are ±0.1 mm for reference sizes 10 mm and less. For over 10 mm reference size, the tolerance is ±0.15 mm.

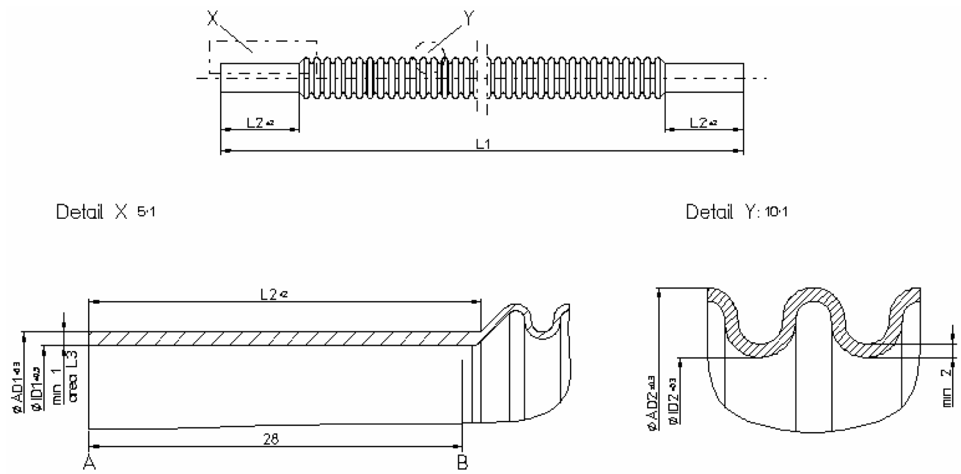
A.2



Ref.	AD1 (mm)	ID1 (mm)	min 1 (mm)	AD2 (mm)	ID2 (mm)	min 2 (mm)
5x1	5,0	3,0	0,7	7,6	4,0	0,3
6x1	6,0	4,0	0,7	8,6	5,1	0,3
8x1	8,0	6,0	0,7	10,6	6,9	0,3
10x1	10,0	8,0	0,7	14,2	9,0	0,3
12x1,5	12,0	9,0	1,0	16,2	10,5	0,4
15x1,5	15,0	12,0	1,0	19,2	13,5	0,4
18x2	18,0	14,0	1,2	22,6	15,8	0,6
20x2	20,0	16,0	1,2	24,6	17,8	0,6
22x2	22,0	18,0	1,2	26,6	19,8	0,6

FIGURE A1—TYPICAL DIMENSIONS AND TOLERANCES FOR CVT FUEL LINE

NOTE—Lengths of cuff sections (L_2 and L_3) are not specifically identified because they vary among the end users and are dependent on the specific mold blocks used in production. (For general reference, however, they can be in the range of 28 to 30 mm).



Ref.	AD1 (mm)	ID1 (mm)	min 1 (mm)	AD2 (mm)	ID2 (mm)	min 2 (mm)
5x1	5.0	3.0	0.7	7.6	4.0	0.3
6x1	6.0	4,0	0.7	8.6	5,1	0.3
8x1	8.0	6,0	0.7	10.6	6,9	0.3
10x1	10.0	8.0	0.7	14.2	9.0	0.3
11x1	11.0	9,0	0.7	15.2	10,0	0.3
14x1	14.0	12.0	0.7	18.2	13.0	0.3
17x1.5	17.0	14.0	1.0	21.6	15.4	0.5
19x1,5	19.0	16,0	1.0	23.6	17,3	0.5
21x1.5	21.0	18.0	1.0	25.6	19.3	0.5

FIGURE A2—TYPICAL DIMENSIONS AND TOLERANCES FOR CVT LOW PRESSURE VAPOR LINE

NOTE—Lengths of cuff sections (L_2 and L_3) are not specifically identified because they vary among the end users and are dependent on the specific mold blocks used in production. (For general reference, however, they can be in the range of 28 to 30 mm).

A.3 Bend Radius for Freeform Bending

Table A3 shows the formulae that shall be used to determine the minimum bend radius for tubing with dimensions shown in Tables, A1,and A2.

TABLE A3—MINIMUM BEND RADII FOR VARIOUS MLT SIZES

Reference Size of Tubing (From Table A1)	Minimum Bend Radius
<8 mm	6 X Reference Size OD
8mm ≤ OD < 12 mm	7.5 X Reference Size OD
12mm ≤ OD < 18 mm	8.5 X Reference Size OD
18 mm ≤ OD <24 mm	10 X Reference Size OD
24 mm ≤ OD	11 X Reference Size OD

A.4 Optional Procedures

A.4.1 Tensile Strength, Elongation

The acceptance criteria are to be agreed upon by producer and end user.

The procedure to be followed is described in A3.1 through A3.3. The gripping procedure that is suggested for use in the tests is described in A3.2.1. Other gripping fixtures/procedures may be used provided that the resulting breakage during the tensile elongation test is in the approximate center of the test specimen. If breakage occurs outside the gage length (see A3.2.2) the elongation test result will be considered invalid.

A.4.1.1 TEST METHODS SUMMARY

This test method covers tension testing of plastic fuel tubing. It follows the general practices of ISO 527. Method “A” of ISO 527 for dumbbell and straight specimens with the modifications listed in A.3.2.1 is preferred.

A.4.1.2 MODIFICATION TO ISO 527

A.4.1.2.1 Grips and Fixtures

Any grip procedure of fixture for holding the tubing may be used to conduct the elongation test described in ISO 527, as long as the resulting breakage does not occur in an area of the tubing within 25 mm of either grip.

A.4.1.2.2 Gage Length and Distance Between Grips

The gage length between benchmarks shall be 50 mm ± 2 mm. An extensiometer may be used as an alternative to benchmarks. The distance between grips shall be not less than 100 mm ± 2 mm.

A.4.1.2.3 Crosshead Travel Speed

The crosshead travel speed shall be set at 50 mm/min ± 5 mm/min.

A.4.1.3 SUMMARY

The method of gripping tubing when testing in tension is critical to optimizing repeatabillity. The previous modification to ISO 527 listed in A3.2, enhance this repeatability.

A.4.2 Procedure to Check Solid Particle Contamination from Plastic Fuel Lines.

A.4.2.1 All tests should be based on a minimum of three test specimens.

A.4.2.2 Specimen:

tube 8x1 mm, length 1500 mm
inner volume of tube appr. 42 ml
inner surface area exposed to fuel appr. 0.0283m^2

A.4.2.3 HEAT EXPOSURE PROCEDURE

Test fuel:	CE 10
Soak Temperature:	60 °C
Exposure Time:	48 hours

1. Plug tube at one and fill completely with test fuel. Plug the other end and store tube in a hot air oven (explosion security) under defined conditions.
2. Remove test specimens from the oven and wait app. 1 minute to let samples cool at ambient temperature (23 °C).
3. Remove one plug and pour the liquid contents into a 100 ml test flagon.
4. Remove the second plug and wash the inside of the tube 3 times with 10ml fresh CE 10 collecting the wash solution in the same 100ml test flagon.
5. Close the test flagon and allow to rest 24 hours at 0 °C.

A.4.2.4 FILTRATION EQUIPMENT

Filter medium:	0.45 µm pore size filter (filter should be PES (polyethersulfone) not paper e.g. from company Pall/Gelmann, 600 South Wagner Road, Ann Arbor, Michigan 48103-9019, Type SUPOR 450, d=47 mm, 0.45 µm pore size, code (order): 60110 or similar
Filtration construction:	ceramic filter nutsche, d=47 mm, vacuum bottle 250 ml, water jet pump, separation unit 500 ml, electr. Pressure gage (1-1050 mbar) (see figure 9)

A.4.2.5 FILTRATION PROCEDURE:

1. Weight filter medium with accuracy of 0.1 mg accuracy (m_0).
2. The filter medium is applied to the ceramic nutsche and wetted by a small amount of fresh CE 10 (to enhance vacuum sealing).
3. The water jet pump is started waiting to develop sufficient vacuum conditions (app. 500 mbar absolute pressure).
4. Pour the liquid contents from the flagon into the nutsche.

5. Let the liquid completely pass the filter medium (pressure drops to app. 80 mbar or less).
6. Apply vacuum for at least 5 minutes (decrease of vacuum to appr. 400 mbar indicates that filtration procedure can be terminated).
7. Remove the filter medium from the nutsche (e.g. using a spatula) and put in a petri dish (that had been weighed previously). Heat the petri dish/filter medium combination @ 40 °C in a recirculating oven for 8 hours, then weigh it. Subtract the weight of the petri dish and record the weight of the filter medium as m_1.

A.4.2.6 EVALUATION

Amount of Contaminant = $(m_1 - m_0)$/inside tube area is recorded. Note that this is a test used for comparative purposes; there is no numeric acceptance criteria.

Rationale

There were many changes to the document to accomplish several purposes:

- To incorporate tubing requirements for another application area: low pressure, liquid fuel line.
- To expand reference documents.
- To far better summarize test procedures and to more readily show the number and type of test specimens to use.
- To better describe requirements of convoluted tubing.
- To change burst pressure requirement and how these results are utilized.
- To change fuel exposure test procedures involving ASTM fuel C and CE-10 to reflect long exposure time and different test procedures after the exposure.
- To change the basis of permeation comparison to CE-10 fuel.
- To completely change the layer adhesion measurement procedure from qualitative to quantitative.
- To add two new procedures (mandrel insertion, hot air aging resistance).
- To update the tolerances and dimension guidelines to reflect the current industry experience.

These are only the most critical changes; there were also a large number of editorial changes that played a role as well.

Relationship of SAE Standard to ISO Standard

Not applicable.

Application

This SAE Standard presents the minimum requirements for nonmetallic tubing with one or more layers manufactured for use as liquid-carrying or vapor-carrying component in fuel systems for gasoline, or alcohol blends with gasoline. Requirements in this document also apply to monowall tubing (one layer construction). When the construction has one or more layers of polymer-based compounds in the wall, the multilayer constructions are primarily for the purpose of improvement in permeation resistance to hydrocarbons found in various fuels. The tube construction can have a straight-wall configuration, a wall that is convoluted or corrugated, or a combination of each. It may have an innermost layer with improved electrical conductivity for use where such a characteristic is desired. The improved electrical conductivity can apply to the entire wall construction, if the tubing is a monowall. (For elastomeric based MLT constructions, refer to SAE J30 and SAE J2405).

Unless otherwise agreed to by suppliers and users this document applies to tubing for any portion of the fuel system that might operate continuously at temperatures above -40 °C and below 90 °C and up to a maximum working gage pressure of 450kPa. The tubing can be used at the peak intermittent temperature up to 115 °C.

This document can apply to systems that operate at higher pressures and/or are exposed to higher temperatures. For higher pressures, the acceptance criteria of section 7.2 must be correspondingly changed. For higher temperatures, the acceptance criteria of sections 7.2 and 7.14 remain the same, but apply at the higher temperature. The selection of higher temperatures and pressures that could be used for this document would be the decision of the end user and supplier of the specific fuel/fuel vapor system in question.

There are three types of tubing covered by this specification, based on the type of application for which the tubing is intended to be used:

- High pressure, liquid fuel line is tubing that handles liquid fuel at pressures up to 450 kPa pressure, and can handle the maximum pressure requirements identified in sections 7.1 and 7.2. These are typically the smaller diameter tubes identified in Table A1.

- Low pressure, liquid fuel line is tubing that is regularly exposed to liquid fuel, but is subjected to pressures that are under 50 kPa. (e.g. fuel filler pipes). These are typically the larger diameters identified in Table A1.
- Fuel vapor tubing is tubing that handles fuel in vapor form or some liquid condensed from vapor, and operates at a working gauge pressure that does not exceed 20 kPa.

In some cases, a distinction is made in the criteria that apply to tubing used to carry liquid fuel compared to tubing used to carry fuel vapor. These are identified separately in each section.

References

SAE J30—Fuel and Oil Hoses (R11: Low Permeation Fuel Fill and Vent Hose and R12: Low Permeation Fuel Feed and Return Hose)

SAE J1645—Recommended Practice Covering Electrostatic Charge in Fuel Systems

SAE J1681—Gasoline, Alcohol and Diesel Surrogates for Material Testing

SAE J1737—Recommended Practice for Measurement of Permeation Resistance by the Recirculation Technique

SAE J1960—Accelerated Exposure of Automotive Exterior Materials Using a Controlled Irradiance Water-Cooled Xenon-Arc Apparatus

SAE J2027—Standard for Protective Covers for Gasoline Fuel Lines

SAE J2044—SAE Quick Connector Specifications for Liquid Fuel Systems

SAE J2045—Tube/Hose Assemblies

SAE J2405—Low Permeation Fuel Fill and Vent Tube (Elastomer Hose)

SAE J2663—Test Procedure to Measure Permeation of Elastomeric Hose by Reservoir Weight Loss Method

ASTM D 412—Test Methods for Rubber Properties in Tension

ASTM D 4000—Classification System for Specifying Plastic Materials

ASTM D 4066—Specification for Nylon Injection and Extrusion Materials

ISO 527—Plastics—Determination of tensile properties

ISO 4639-3—Rubber tubing and hoses for fuel circuits for internal combustion engines specification—Part 3: Oxidized fuels

Developed by the SAE Fuel Lines and Fittings Standards Committee