SAE International

SURFACE VEHICLE STANDARD

SAE J2045 NOV2012

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Superseding J2045 FEB1998

Performance Requirements for Fuel System Tubing Assemblies

RATIONALE

This revision is to encompass changes in fuel and emission technology and to clarify applicable test procedures.

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1. SCOPE

This SAE Standard encompasses the recommended minimum requirements for non-metallic tubing and/or combinations of metallic tubing to non-metallic tubing assemblies manufactured as liquid- and/or vapor-carrying systems designed for use in gasoline, alcohol blends with gasoline, or diesel fuel systems. This SAE Standard is intended to cover tubing assemblies for any portion of a fuel system which operates above –40 °C (–40 °F) and below 115 °C (239 °F), and up to a maximum working gage pressure of 690 kPa (100 psig). The peak intermittent temperature is 115 °C (239 °F). For long-term continuous usage, the temperature shall not exceed 90 °C (194 °F). It should be noted that temperature extremes can affect assemblies in various manners and every effort must be made to determine the operating temperature to which a specific fuel line assembly will be exposed, and design accordingly.

The applicable SAE standards should be referenced when designing liquid-carrying and/or vapor-carrying systems which are described in this document.

Wherever possible or unless stated otherwise, systems tested to this document shall be in the final design intent configuration.

2. REFERENCES

2.1 Applicable Documents

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

2.1.1 SAE Publications

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

SAE J30 Fuel and Oil Hoses, Sections 10 and 11

SAE J517 Hydraulic Hose

SAE J526 Welded Low Carbon Steel Tubing

SAE J1645 Fuel System Electrostatic Charge

SAE J1681 Gasoline/Oxygenate Mixtures for Materials Testing

SAE J1737 Procedure/Fuel Permeation Losses

SAE J2027 Protective Covers for Non-metallic Gasoline Fuel Injection Tubing

SAE J2044 Quick Connect Coupling Specification for Liquid and Vapor/Emissions Systems

SAE J2260 Non-Metallic Fuel System Tubing with 1 or More Layers

SAE J2587 Optimized Fuel Sender Closure

2.1.2 ASTM Publication

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 B117 Method of Salt Spray (Fog) Testing

2.1.3 Other Publications

Code of Federal Regulations (CFR) 40 (Protection of Environment), part 86 (Control of Emissions from New and In-Use Highway Vehicles and Engines).

FMVSS 301 (Fuel Systems Integrity).

California Code of Regulation Title 13, Division 3 (ARB), Chapter 1, Article 1, section 1976 (Standards and Test Procedures for Motor Vehicle Fuel Evaporative Emissions).

3. ROUTING RECOMMENDATIONS

Fuel tube/hose assemblies shall be routed and supported as to;

a. Prevent chafing, abrasion, kinking, or other mechanical damage.

b. Be protected against road hazards or provided with adequate shielding in locations that are vulnerable to physical and/or chemical hazards.

c. Be protected where temperatures may exceed the limits of –40 °C to +90 °C by the addition of adequate insulation and/or shielding.

d. To assure maintenance of design intent routings of liquid fuel and/or fuel vapor assemblies, appropriate retaining/mounting devices must be incorporated for proper assembly and subsequent vehicle service operation, maintaining interfaces for temperature and environmental control for durability.

e. Route tube assemblies in an environment which minimizes heat input to the assemblies and the liquid fuel and/or fuel vapor which they contain.

4. TECHNICAL REQUIREMENTS

4.1 Leak Tightness

In accordance with stringent emissions regulations, including CARB PZEV, and safety regulations, fuel line assemblies must be free of leaks and micro-leaks. Production leak testing is performed to assure conformance to the requirement. Compressed air leak testing is a proven technique which provides required leak sensitivity as well as a proof test for pressure resistance.

4.1.1 Testing Device

A device capable of applying the recommended internal pressure specified for both liquid fuel and fuel vapor line assemblies. Test is intended to be performed on liquid fuel/fuel vapor assemblies that duplicate the design intended for vehicle application, including applicable end fittings and/or connections (see Appendic A).

4.1.2 Sample Preparation

All test samples to be at room temperature.

4.1.3 Procedure

a. Leak tests are to be conducted at room temperature.

b. Attach tube assemblies to test fixture that simulates vehicle installation where at all possible.

c. Apply internal gas pressure (see Appendix A) at one end of the assembly, allowing sufficient time for system to stabilize before determining leak rate.

d. At test completion, test gas media should be exhausted through opposite end of assembly to which it was pressurized to insure obstruction and/or blockage was not present in the liquid fuel/fuel vapor line assembly, as well as blowout any potential residue which may have been present.

e. After test, remove assembly from test fixture.

4.1.4 Acceptance Criteria

No leak paths greater than 15µm X 3mm long for fuel lines and 20µm X 3mm long for vapor lines(see graphs figure A1 and A2). If otherwise required, final acceptance criteria to be jointly determined by producer and end user.

4.2 Fitting Pull-Off

(room temperature and elevated temperature)

4.2.1 Testing Device

A device suitable for applying a tensile load at a constant rate of 50 mm/min, elongating tube or hose assemblies up to 400% of their initial length, and measuring the maximum load achieved up to a load of 900 N minimum.

4.2.2 Sample Preparation

All tests are to be conducted at room temperature (room temperature fitting pull-off) and at 115 °C for high-temperature fitting pull-off.

4.2.3 Procedure

a. The test specimen shall consist of a direct connection coupling between the flexible tubing/hose and fitting or tube with enough length of hose and/or tube on either side of specimen to permit adequate gripping in the test apparatus. Specimens may be cut from the production intent part or made for this test utilizing production intent product and processes, such as component assembly devices and tube forming techniques.

b. Grip the test specimen in the tensile-loading device and apply a tensile load at a speed of 50 mm/min until one of the following events occur;

    1. The fitting or tube separates from the flexible tubing

    2. One of the test specimen components break, fracture, or rupture

    3. A maximum load is reached whereby the flexible tubing reaches its maximum tensile/elongation load capability

c. For elevated temperature pull-off tests, grip the test specimen in the tensile-loading device and heat test specimen to 115 °C (239 °F) for (15) minutes prior to applying the 50 mm/min tensile load. Test chamber should be instrumented with a thermocouple to insure test environment reaches 115 °C prior to applying the tensile load.

d. Measure and record the greatest load achieved before one of the events listed (2) occurs, and the type of event (failure mode).

4.2.4 Acceptance Criteria

a. Room Temperature - 450 N minimum (fuel assemblies) or 222 N minimum (vapor assemblies)

b. 115 °C Temperature - 115 N minimum (fuel assemblies) or 65 N minimum (vapor assemblies)

4.3 Formed Bend Restriction. (for Production Validation (PV) only).

4.3.1 Testing Device - A spherical ball half the diameter of the nominal flexible tubing material inner diameter.

4.3.2 Sample Preparation

Testing is to be performed at room temperature.

4.3.3 Procedure

a. Bend or preform tubing, utilizing intended production processing method, to the shape and contour required by its design application. It is not recommended to include connectors or tubing ends for this test since geometry constraints of these components may interfere with performing this test (i.e., lack of flow through feature, restrictions, etc.)

b. Pass the spherical ball through the preformed tube.

4.3.4 Acceptance Criteria

The spherical ball must pass freely through the Inside Diameter of the preformed tube.

4.4 Internal Cleanliness (for Production Validation (PV) only).

4.4.1 Testing Device(s)

a. Testing devices must be utilized which can safely and accurately flush the interior of the tubing assembly with solvent, effectively remove any contaminants and foreign material from the interior surface, and accurately measure that material and its weight. (See Figure 1.)

b. Test solvent to be a reagent grade stoddard solvent or equivalent which is capable of effectively removing all contaminants and foreign material from interior surface of test assembly.

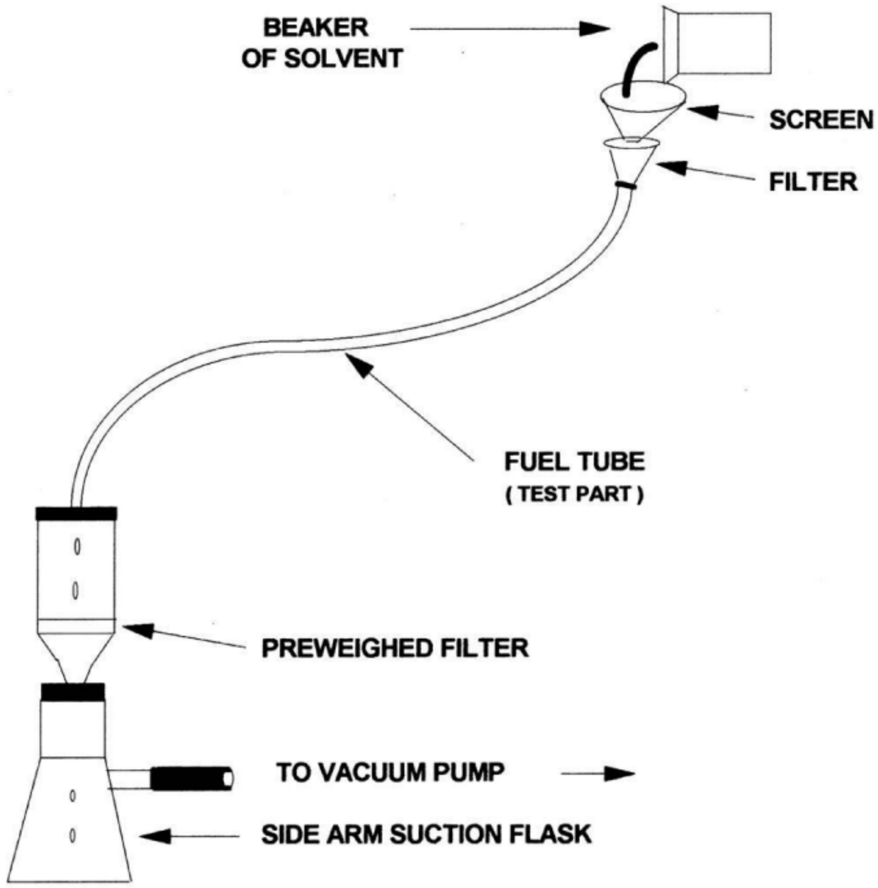

FIGURE 1 - EXAMPLE

4.4.2 Sample Preparation

Testing is to be performed at room temperature.

4.4.3 Procedure

a. Pre-dry filter device, then cool in a desiccant cabinet.

b. Pre-weigh filter device which will be used in collecting potential contaminants and foreign material in fuel line assembly. Filter must be capable of collecting a contaminant which is 240 micron in size or larger.

c. Set up test specimen in test device/apparatus.

d. Turn on vacuum pump (if applicable or utilized).

e. Pour an amount of solvent (equivalent to at least the volume of the assembly) through the tube assembly. Solvent which is dispensed into the fuel line assembly should be pre-filtered.

f. Dispense solvent which has passed through the fuel line assembly into a pre-weighed filter, followed by a collection device to contain the solvent. Dry filter to dissipate solvent absorbed by filter.

g. Weigh filter to determine weight gain, which is an indicator of contaminant and/or foreign material collected from tube assembly. Record value obtained in grams per tube.

4.4.4 Acceptance Criteria

Total contaminant collection should not exceed 0.15 g/m^2 (flexible tubing assembly) or 0.25 g/m^2 (flexible tubing assembly with steel tubing attached) of interior surface area.

4.5 Internal Fuel Resistance

4.5.1 Testing Device(S), Sample, Preparion, and Test Procedure

As described in SAE J2260, Fuel Exposure-Preconditioning per the following.

Soak Fuel Type	Time of Soak	Temperature
CE-10	1000 Hours	60 ℃
CM-15	1000 Hours	60 ℃
Fuel C (Auto Oxidized)	1000 Hours	40°C

4.5.2 Acceptance Criteria

All post testing is conducted at room temperature. Assemblies must meet 4.1, 4.2, and 4.8. Additionally, complete 4.9 on fuel C (auto oxidized) perconditions samples. SAE J1645 does not recommend using alcohol fuels for conductivity testing. End user should be consulted for any potential additional requirements beyond SAE J2260 baseline fuels and soak duration.

4.6 Life Cycle

4.6.1 Testing Device

Life cycle test chamber capable of performing the pressure, vibration, and temperature cycles with test fluid as outlined in SAE J2044, Life Cycle requirement.

4.6.2 Sample Preparation

Prepare samples as described in Life Cycle requirement of SAE J2044 on finished assemblies or samples which consist of production intent interfaces and components.

4.6.3 Test Procedure

Per SAE J2044, Life Cycle requirement (both liquid-fuel and/or fuel-vapor applications)

4.6.4 Acceptance Criteria

Test assemblies must exhibit no fluid leaks through entire test duration. At completion of test, visually inspect assemblies and components to insure no fractures, cracks, or unusual wear has occurred. Test assemblies must then meet the following tests at room temperature, 4.1, 4.2, and 4.8 of SAE J2045.

4.7 Coverstock Flame/Heat Resistance –See SAE J2027

4.8 Burst

(room temperature and elevated temperature)

4.8.1 Testing Device

A test apparatus capable of applying a pulse free hydrostatic pressure at a uniform rate of increase of 7000 kPa/min (1000 psig/min).

For high-temperature burst testing, test apparatus must also be capable of heating test fluid to the test temperature of 115 °C (239 °F) and maintaining test temperature to within ±3 °C (±5 °F).

Fluid bath (silicon oil or equivalent) or hot-air exposure are recommended means to employ in conducting this test.

Test apparatus must also be capable of filling test specimens with hydraulic fluid to conduct room and high-temperature burst testing.

4.8.2 Sample Preparation

Sample tubing, representative of the production design intent, shall be cut to a length 31 to 46 cm (12 to 18 in) and assembled with the proper, production design intent connectors. Test assemblies shall be processed and assembled in the manner applicable to the production design intent process. Samples are then conditioned for 24 h minimum at room temperature.

4.8.3 Test Procedure

a. Room Temperature

1. Fill burst test apparatus and test specimen with burst fluid.
2. Secure test assembly to burst test apparatus in the same manner that the test assembly will be secured for end use.
3. Apply pressure at a 7000 kPa/min rate of increase until the test specimen fails.

b. Elevated Temperature (115 °C)

1. Fill burst test apparatus and test specimen with burst fluid.
2. Secure test assembly to burst test apparatus in the same manner that the test assembly will be secured for end use.
3. Heat both the test specimen and test fluid to 115 °C (bath chamber or oven) and allow to stabilize at 115 °C.
4. Once the test specimen and test fluid have reached a stabilized temperature of 115 °C, apply pressure at a 7000 kPa/min rate of increase until the test specimen fails.

4.8.4 Acceptance Criteria

1. Room Temperature Liquid Fuel - Minimum burst value must equal 3500 kPa.(508 psig) (vehicle application).
2. Room Temperature Vapor - Minimum burst value must equal 345 kPa (50 psig) (vehicle application).
3. 115 °C Temperature Liquid Fuel - Minimum burst value must equal 1350 kPa (196 psig) (vehicle application).
4. 115 °C Temperature Liquid Vapor - Minimum burst value must equal 150 kPa (22 psig).

4.9 Electrostatic Charge Mitigation Requirements.

4.9.1 Background

Test per SAE J1645 on virgin components and components that have been exposed to 4.5 Fuel C (Auto Oxidized) only.

This test not intended for components preconditioned in Alcohol based test fuels.

4.10 Assembly Hydrocarbon Loss (Mini-S.H.E.D.)

Perform test only when end user specifies an acceptance criteria and requests data. This test procedure measures diurnal emissions from fuel line assembiles by subjecting them to a hot soak and diurnal test sequence.

4.10.1 Test Devices

A testing device/set-up capable of provideing a Sealed Housing for Evaporative Determination (SHED) is used to measure diurnal emissions. This method subjects test samples to a preprogrammed temperature profile while maintaining a constant pressure and continuously sampling for hydrocarbons with a Flame Ionization Detector (FID).

4.10.2 Sample Preparation

Test assemblies shall be representative of the production intent design, utilizing the appropriate flexible tubing, connectors, and rigid tubing, along with the appropriate connecting interfaces to the connectors.

Vapor line soak: Precondition for vapor lines is done by attaching the line to the vapor side of a fuel reservior. The line should vent through the opposite end of the resevior to allow complete migation of vapors through the line.

Fuel Line soak: Perconditioning of fuel line is to be perform by attaching the line to a fuel resevior such that the line is completely filled with fuel.

4.10.3 Test Procedure

a. Testing to be conducted with fuel composition and test temperature conditions as determined and agreed to by the end item user for both pre-conditioning and mini-S.H.E.D. requirements.

b. Test assemblies shall be representative of the production intent design however, can be made in a straight length configuration whereby entire test assembly and connector interface(s) can be contained within test cell.

c. Conduct an assembly leak test as described in SAE J2045,4.1.

d. Pre-condition (i.e., soak) test assemblies as listed under sample preparation

e. Following pre-condition (soak) portion of test, conduct the hydrocarbon loss portion of test (mini-S.H.E.D.) S.H.E.D. test fuel, temperature, and test duration conditions are to be jointly determined between producer and end user.

4.10.4 Acceptance Criteria

Final acceptance criteria to be jointly determined by producer and end user. Test values to be expressed in total grams of hydrocarbron loss per 24 h period.

4.11 Chemical Resistance

Components may be exposed to a range of chemicals typical of the automotive environment. This chemical resistanse test is performed to assure that the components will meet their functional requirements after exposure to typical automotive fluids.

4.11.1 Test Device

A testing device/set-up capable of performing external chemical resistance exposure tests as outlined in SAE J2044 listed under External Chemical and Environmental Resistance.

4.11.2 Sample Preparation

Samples are to be tested as described in Table 1 on production design intent test assemblies.

4.11.3 Test Procedure

a. Assemble test assemblies with production design intent flexible tubing, along with production design intent quick connectors, rigid tubing, etc. Test assemblies may be constructed on short lengths to accommodate testing with various test fluids.

b. Insert mating tube ends to quick connectors and/or cap mating tube ends (for rigid tubing attachments).

c. Expose test assembly externally in the test fluids for the described exposure durations as specified in Table 1. Submerge a portion of the sample such that all the desired test materials are completely exposed to the test fluids. Note that Zinc Chloride is an environmental stress-cracking agent to which some hygroscopic polymers are sensitive. Therefore the end of hose/tubes and any applicable location should be inspected for crack conditions.

d. Fluid or Medium – See Table 1.

4.11.4 Acceptance Criteria

Test assemblies must meet 4.1 and 4.8 at the completion of each fluid exposure.

TABLE 1 – FLUID OR MEDIUM

Fluid or Medium	Exposure Time	Procedure
Automatic Transmission Fluid	60 Days	Soak @ room temp
Motor Oil	60 Days	Soak @ room temp
Brake Fluid (Dot3)	60 Days	Soak @ room temp
Ethylene Glycol (50% Water)	60 Days	Soak @ room temp
Propylene Glycol (50% Water)	60 Days	Soak @ room temp
Diesel Fuel	60 Days	Soak @ room temp
Engine Degreaser	60 Days	Soak @ room temp
Zinc Chloride	168 Hours/24 Hour Dry	Soak @ room temp

5. VALIDATION TESTING RECOMMENDATIONS

See Table 2.

TABLE 2 - SAE J2045 TABLE SUMMARY

Section	Requirement	Acceptance Criteria	Suggested Sample Size D.V.(1)	Suggested Sample Size P.V.(2)	Suggested Sample Size I.P.(3)
4.1	LEAK RESISTANCE	maximum leakage as described in SAE J2045 Appendix A (Leak Resistance Guidelines)	30	100%	100%
4.2	FITTING PULL-OFF (room temperature and 115 °C)	Liquid Fuel: 450 N (room temp.) and 155 N (115 °C elevated temp.) Fuel Vapor: 222 N (room temp.) and 65 N (115 °C elevated temp.)	30 30	10 10	1/lot/ connector (RT only)
4.3	FLOW RESTRICTION	ball size 1/2 the nominal inside hose diameter must pass freely through entire hose assembly	N/R	30	5/lot
4.4	INTERNAL CLEANLINESS	0.15 g/m^2 area max insolubles	N/R	10	1/lot
4.5	INTERNAL FUEL RESISTANCE	must meet 4.1, 4.2, 4.8, and 4.9 (conductive systems only) of SAE J2045 upon completion of SAE J2260 fuel exposures	10 per fluid	N/R	N/R
4.6	LIFE CYCLE	no leakage during life cycle test and meet 4.1, 4.2, and 4.8 of SAE J2045 at test completion	10	15(4)	N/R
4.7	FLAME/HEAT RESISTANCE	See SAE J2027 application reference	See SAE J2027	See SAE J2027	N/R
4.8	BURST	Room Temperature: 115 °C Elevated Temperature:	10 10	10(4) 10(4)	N/R N/R
4.9	Electrostatic Charge Mitigation Requirements	as described in SAE J1645	5	5(4)	N/R
4.10	ASSEMBLY HYDROCARBO N LOSS	to be jointly determined between producer and end user	6	6(4)	N/R
4.11	CHEMICAL RESISTANCE	meet 4.1 and 4.8 of SAE J2045 at completion of each exposure	10 Per fluid	10(4) Per fluid	N/R

1. D.V. = Design Validation (design proveout)
2. P.V. = Production Validation (production process proveout)
3. I.P. = In Process (ongoing process verification)
4. * = P.V. not required providing basic design features have not changed since D.V. which could influence performance features.
5. N/R = Not Required

6. NOTES

6.1 Marginal Indicia

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY THE SAE FUEL SUPPLY SYSTEMS COMMITTEE

APPENDIX A

TABLE A1 - FUEL SYSTEM COMPONENT LEAK TEST SPECIFICATION

Vehicle Compliance	System Description		Allowed Leak Tightness	Comments
Evaporative Emission per; - U.S. Tier 1 or Tier 2 - CARB LEV II	Fuel Vapor Line Assemblies	***	20 µm X 3mm max equivalent channel diameter	See graph figure A2
	Liquid Fuel Line Assemblies	***	15 µm X 3mm max equivalent channel diameter	See graph figure A1

A.1 PURPOSE:**

The purpose of this document is to define leak test parameters and procedures required to meet reduced

Hydrocarbon emission specifications.

A.1.1 It is important to note the difference between hydrocarbon permeation through materials and hydrocarbon emission through micro-leaks. Both of these factors contribute to total overall hydrocarbon emission level. Even when low permeation materials are used for component construction, one micro-leak can emit more hydrocarbon than is allowed for an entire vehicle. No production leak test method is capable of measuring hydrocarbon permeation through materials. However, it is possible to detect micro-leaks in components through leak testing. There is no hydrocarbon emission allowance for micro-leaks.

A.2 DEFINITIONS:**

A.2.1 Equivalent Channel (EC)

An equivalent channel is a smooth and round micro-channel where L>>d (L/d>~100). Diameter is specified in micrometers (microns), 1 micron is 3.94 x 10^{-5} inches. Roundness and diameter imperfection must be held to ± 10% of diameter. Tolerance on EC diameter must be held to ± 1 micron. One significant benefit of using an EC based leak tightness standard it that SHED test emission levels can be correlated to various production leak test methods (pressure decay, mass flow, He accumulation, or helium hard vacuum).

A.2.2 Unit Under Test (UUT)**

Component being leak tested for micro-leaks.

A.3 BACKGROUND: **

A.3.1 This specification is based on test data indicating that fuel system micro-leaks will plug over time. Effectively, micro-leaks plug to a near zero hydrocarbon emission level due to debris in fuel. The plugging phenomenon is dependent on leak path diameter and length. Micro-orifice geometry is critical when establishing an allowable leakage specification in terms of hole size. Micro-leak orifices can be produced using a wide variety of manufacturing processes and materials. Each process can result in very different orifice geometry. Equivalent channels (EC) have been adopted in an effort to standardize orifice geometry.

A.3.2 Micro-gas flow regime is dependent on test method. Complex formulas are required to calculate flow rates in different flow regimes. Helium hard vacuum testers operate in the molecular flow regime. Other test methods run low pressure at barometric conditions. Low pressure to atmosphere testing results in viscous and/or slip flow regimes. The implementation of EC prevents the need to use complex mathematical models to properly estimate gas micro leak flow rate for the various test methods.

A.4 TEST REQUIREMENTS: **

A.4.1 Detection Capability

Leak test must be statistically capable, as defined in A4.4, of detecting a 15 micron x 3 mm EC **for fuel lines and 20 micron x 3 mm EC for vapor lines.**

A.4.1.1 Nitrogen flow rate guidelines for positive pressure to atmosphere testing are included in Figure A1 and A2** for reference only.

A.4.1.2 Helium flow rate guideline for hard vacuum testing at 140 mbar to 2 mbar is 7.05 x 10-5 sccs (standard cubic centimeters per second). This flow rate has been included for reference only.

A.4.1.3 Failure specification must be qualified by testing an EC on the leak test system used for leak testing. This specification method facilitates maximum flexibility for test pressure and medium.

A.4.2 Pressure

UUT leak test pressure differential must be agreed upon by the manufacturer and OEM. Minimum pressure differential used for testing should be equal to, or higher than, component operating pressure.

A.4.2.1 MASKING LEAKS

Care must be taken to ensure that by pressurizing the UUT operating pressure leaks are not masked. This can occur from over pressurizing or under pressurizing.

A.4.2.2 Test Medium

UUT can be pressurized with air, nitrogen, or helium. Any concentration of gas is acceptable, as long as,the test is capable and calibration is completed using the same leak test gas concentration.

A.4.3 Capability

Test method must prove statistically capable.

A.1.1.1~100 piece (minimum) capability study.
A.1.1.2~Minimum of 1.33 CPk using ±15% specification limits.

Upper Specification Limit = *Target Leak Rate + 15% of Target Leak Rate*
Lower Specification Limit = Target Leak Rate – 15% of Target Leak Rate
CP (upper) = (Upper Specification Limit – Average)/ 3 σ
CP (Lower) = (Average-Lower Specification Limit – Average)/ 3 σ
CPk = smaller of the calculated CP values

The following graphs identify leak rate in cubic centimeters per minute (cc/m), verses standard cubic centimeters per minute (scc/m). The term "standard" indicates that the given flow rate assumes a standard temperature and pressure, but cubic centimeters per minute define the volume of air at the unique test pressure and temperature at the point of measurement. Since there no real uniform global standard for temperature and pressure, the user can utilize standard formulas to convert from cc/m to scc/m.

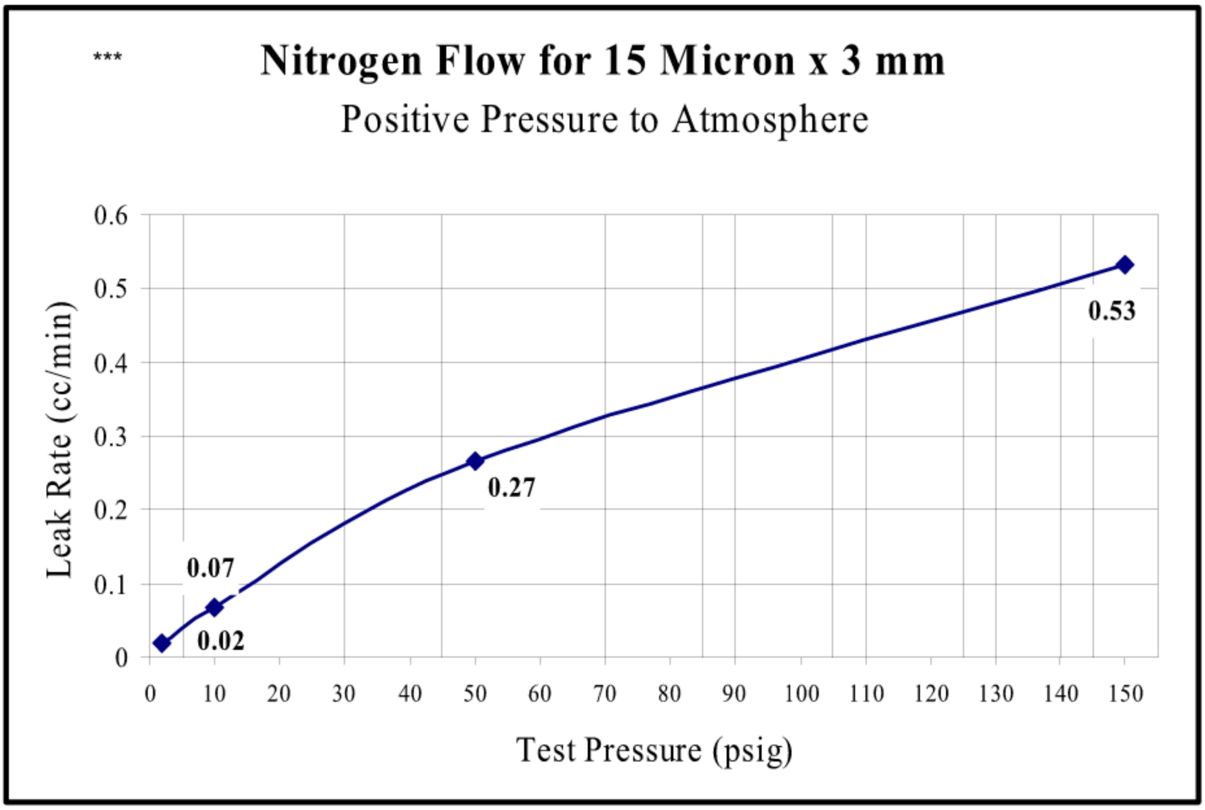

FIGURE A1 TYPICAL 15 MICRON X 3MM FLOW RATES VS.
PRESSURE THROUGH A CALIBRATED LEAK CHANNEL

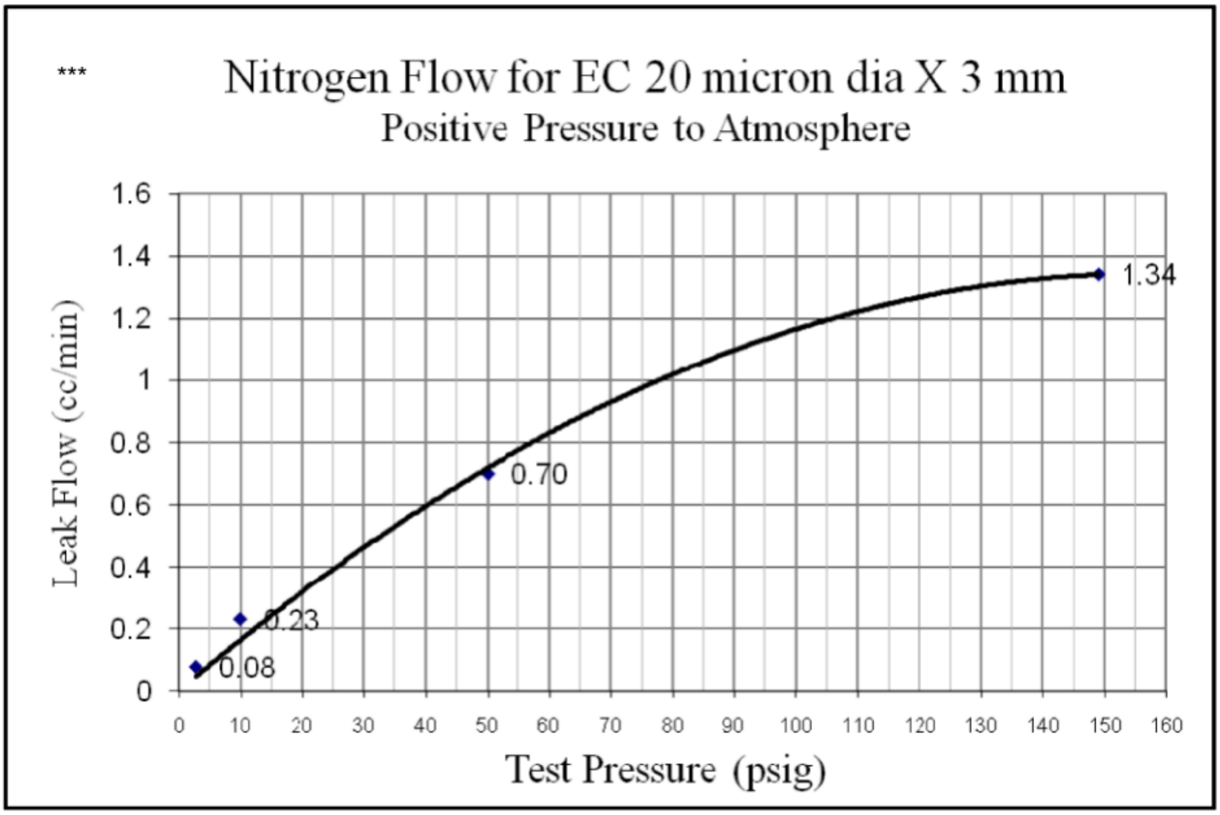

FIGURE A2 TYPICAL 20 MICRON X 3MM FLOW RATES VS. PRESSURE THROUGH A CALIBRATED LEAK CHANNEL

**Note: Section A.1 through A.4.4 taken from SAE J2587 Appendix C. 20 micron x 3mm data has been added and is directly related to the context within this specification.

*** The earths atmosphere is approximately 80% Nitrogen, therefore, nitrogen or air may be used as the test medium when identifying leak rates.

Leak Flow Units: Actual cubic centimeter per minute (cc/m) and not scc/m.