

**KSC-SPEC-Z-0008**  
**Revision D Change 1**  
October 18, 2019

# **FABRICATION AND INSTALLATION OF FLARED TUBE ASSEMBLIES AND INSTALLATION OF FITTINGS AND FITTING ASSEMBLIES, SPECIFICATION FOR**

**OCTOBER 18, 2019**

**ENGINEERING DIRECTORATE**

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National Aeronautics and  
Space Administration

**John F. Kennedy Space Center**

KSC FORM 16-12 (REV. 6/95) PREVIOUS EDITIONS ARE OBSOLETE (CG 11/95)  
KDP-T-5411\_Basic





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Approved by:



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Shawn M. Quinn  
Director, Engineering

**OCTOBER 18, 2019**

**JOHN F. KENNEDY SPACE CENTER, NASA**

**RECORD OF REVISIONS/CHANGES**

<b>REV. LTR.</b>	<b>CHG. NO.</b>	<b>DESCRIPTION</b>	<b>DATE</b>
-		Basic issue.	February 14, 1968
A			March 10, 1969
B			January 17, 1977
C			June 13, 1978
D		Updated document.	August 7, 2019
	D-1	Updated sections 2.2, 3.2.2.1, 3.3, 3.4.5, 3.5.1, 3.5.3, 3.5.4, 3.6, 4.7.2, 4.10.3, and 4.11.1; updated Tables 3, 4, 6, and 10.	October 18, 2019

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## ABBREVIATIONS, ACRONYMS, AND SYMBOLS

Units of measure and some terms commonly understood within the subject disciplines have been abbreviated in the body of this document without callout but are included among the following.

°	degree
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
F	Fahrenheit
ft	foot
in	inch
in-lb	inch-pound
KSC	John F. Kennedy Space Center
max.	maximum
MIL	military
min.	minimum
MSFC	George C. Marshall Space Flight Center
OD	outer diameter
psid	pound per square inch differential
psig	pound per square inch gauge
PTFE	polytetrafluoroethylene
SAE	Society of Automotive Engineers
SPEC	specification
STD	standard
UNS	unified numbering system

## DEFINITIONS

For the purposes of this document, the following definitions apply.

**automatic welding:** welding with equipment that performs the welding operation without adjustment of the controls by the operator. The equipment may or may not perform the loading and unloading of work.

**fabrication:** the preparation of tubing for assembly, including cutting, grooving, forming, bending, and joining of components into subassemblies. Fabrication may be performed in the shop or in the field.

**manual welding:** a welding operation performed and controlled completely by hand.

**solution heat treatment:** heating an alloy to a suitable temperature, holding at that temperature long enough to allow one or more constituents to enter into solid solution, and then cooling rapidly enough to hold the constituents in solution.



This specification revision has been approved by the Engineering Directorate of the John F. Kennedy Space Center (KSC) and is mandatory for use at KSC.

## 1. SCOPE

### 1.1 Purpose

This specification covers the requirements for the fabrication and the installation of 37-degree flared tube assemblies and the installation of 37-degree flared tube fitting assemblies used in fluid pressure systems of KSC.

*NOTE: The requirements in this specification do not apply to tubing designated as being in High Pressure Fluid Service by the Engineering Technical Authority per ASME B31.3, Chapter IX.*

### 1.2 Applicability

These requirements apply to new equipment that has not been verified to meet requirements of a previous revision of this specification. Equipment designed or fabricated prior to the effective date of this specification may be verified as acceptable for use against the requirements of a previous revision of this specification. Existing equipment may be modified or repaired to meet this or a previous revision of this specification.

## 2. APPLICABLE DOCUMENTS

The following documents of the issue in effect on date of invitation for bids or requests for proposal form a part of the specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

*NOTE: Copies of the documents are available from the NASA Technical Standards website (<http://standards.nasa.gov>), any NASA installation library or documentation repository, or from the procuring activity.*

### 2.1 Government Documents

75M04185	Identification Tag, Tubing and Hose Lines
A-A-3041	Commercial Item Description, Wrench, Open End Ratchet (Tac Pattern) for Tube Fitting, Electrical Cable Terminals, and Stuffing Tube Gland Nuts
K0000382480-RPT	KSC-SPEC-Z-0008 Tubing Installation Standard Companion Analysis for Tubing Spacing Between Consoles/Modules
KSC-GP-425	Fluid Fitting Engineering Standards

KSC-SPEC-P-0027	Tubing, Superaustenitic Steel, Corrosion Resistant, UNS N08367 and UNS S31254, Seamed, Bright Annealed, Passivated
KSC-SPEC-Z-0007	Tubing, Steel, Corrosion Resistant, Seamless, Types 304 and 316
KSC-SPEC-Z-0009	Lubrication, Thread, Corrosion-Resistant Steel Tube Fittings
KSC-STD-E-0015	Marking of Ground Support Equipment
MIL-L-25567	Leak Detection Compound, Oxygen Systems
MSFC-SPEC-384	Leak Test Compound, LOX Compatible
NAS1149	Washer, Flat

## **2.2 Non-Government Documents**

ASME BPVC-VIII	ASME Boiler & Pressure Vessel Code, Section VIII Division 1, Rules for Construction of Pressure Vessels
ASME B31.3	ASME Code for Pressure Piping, Process Piping
ASME B107.300	Torque Instruments
ASTM A249	Standard Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes
ASTM A269	Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service
ASTM E2428	Standard Practice for Calibration and Verification of Torque Transducers
ASTM F2215	Standard Specification for Balls, Bearings, Ferrous and Nonferrous for Use in Bearings, Valves, and Bearing Applications
AWS D17.1	Specification for Fusion Welding for Aerospace Applications
SAE AS1097	Seal Ring, 37° Flared Tube Fitting End
SAE AS1098	Fitting End, Flared Tube, for Seal Ring, Standard Dimensions for, Design Standard
SAE AS1099	Fitting End, Bulkhead Flared Tube, for Seal Ring, Standard Dimensions for, Design Standard
SAE AS28778	O-Ring, Straight Thread Tube Fitting Boss Molded from AMS-P-5510 Rubber

SAE AS4330	Tubing, Flared, Standard Dimensions
SAE AS4326	Nut, Coupling
SAE AS4327	Sleeve, Flared Tube Fitting
SAE AS5178	Nut, Fitting, Bulkhead
SAE AS5202	Port or Fitting End, Internal Straight Thread, Design Standard
SAE AS9956	Packing, Preformed (PTFE) – AMS3668, Seal

### **3. FABRICATION OF TUBE ASSEMBLIES**

#### **3.1 General Process Requirements**

##### **3.1.1 Tubing**

- a) Tubing shall be UNS S30400 or S31600 stainless steel in accordance with ASTM A269.
- b) Tubing shall be seamless, or welded with 100% radiographic inspection of the longitudinal welds.
- c) Tubing shall have a wall thickness tolerance of +10/-0%.
- d) Tubing shall have mechanical properties verified by tensile testing in accordance with ASME B31.3.
- e) Tubing shall be subjected to an intergranular corrosion test in accordance with supplementary requirement S4 of ASTM A269.
- f) Tubing shall be marked with the tubing specification (e.g, “A269”), the specific alloy (e.g., 316), and the wall thickness tolerance (+10/-0%).

*NOTE: Tubing that conforms to KSC-SPEC-Z-0007 meets the requirements of this section. Requirements b), c), and d) are needed to satisfy ASME B31.3 requirements for ASTM A269 tubing at the pressure ratings specified herein.*

- g) When directly exposed to a corrosive environment, tubing shall be one of the following:
  - i. UNS N08367 (trade name AL6XN) stainless steel in accordance with ASTM A269 and requirements d), e), and f) of this section;
  - ii. UNS S31254 (trade name 254SMO) stainless steel in accordance with ASTM A249 and requirements d), e) and f) of this section; or
  - iii. UNS S31600/S31603 (316/316L) dual-certified stainless steel in accordance with ASTM A269 and requirements b) through f) of this section.

*NOTE: Tubing that conforms to KSC-SPEC-P-0027 meets the requirements of this section. The mechanical properties of AL6XN and 254SMO allow for reduced wall thickness and a weld joint efficiency reduction while maintaining the pressure ratings specified herein. 316/316L dual-certified tubing provides the mechanical strength of 316 and the welding/corrosion advantage of 316L.*

### **3.1.2 Fittings**

Unless otherwise specified by the KSC Engineering Technical Authority, connections to tube assemblies shall be made by fittings selected from KSC-GP-425 or seal ring fittings with flared tube ends conforming to SAE AS1098/KC105.

## **3.2 Flared Tube Ends**

Ends of tubing shall be flared either by forming the tube ends or by welding a machined fitting (buttweld spud) per KSC-GP-425 with the basic flare shape to a plain tube end.

### **3.2.1 Formed Flares**

A formed flare shall be made by deforming the end of the tubing in accordance with SAE AS4330. Each formed flare necessitates the use of a coupling nut (SAE AS4326/KC142) and sleeve (SAE AS4327/KC143). For new design, flare forming on tubing with a wall thickness greater than 0.109 inch requires approval of the KSC Engineering Technical Authority.

#### **3.2.1.1 Flared Tubing Preparation**

Tubing shall be cut to required length with a saw or tubing cutter. Cut end roundness (ovality) shall be maintained per KSC-SPEC-P-0027 or KSC-SPEC-Z-0007 as applicable. Work-hardened ends resulting from the cutting process shall be removed. Prior to flaring, tube ends shall be squared, deburred, and chamfered in accordance with SAE AS4330.

#### **3.2.1.2 Flaring Equipment**

The choice of method and flaring equipment shall be left to the discretion of the performing activity, except that all tube flaring equipment using split dies shall have provisions for die adjustments. Such adjustments shall provide alignment within 0.001 inch in the vertical, horizontal, and longitudinal axes.

### **3.2.1.3 Formed Flare Configuration**

The completed formed flare shall conform in every respect to the design requirements of SAE AS4330/KC154. The finished flare shall be free from fins on the back side, cracks, or other defects that would prevent a fluid-tight seal. Fins resulting from the use of split die flaring machines may be removed, but the contour of the back of the flare must not be distorted.

### **3.2.1.4 Minimum Straight Tube Dimensions**

The minimum straight tube lengths for tubes with formed flares are shown on Table 1. Minimum Lengths of Straight Formed Flare Tube Assemblies

### **3.2.2 Buttweld Flares**

Buttwelded flares shall be made using machined fittings with the flare form similar to that made on ends of tubing but designed to be welded to tubing ends by automatic welding equipment.

#### **3.2.2.1 Welded Tubing Preparation**

Tubes shall be squared (for automatic welding) or chamfered (for manual welding), as applicable, and deburred in accordance with SAE AS4330 prior to the welding operation. Additionally, approximately 3 inches of the end shall be degreased.

#### **3.2.2.2 Machined Flare Fittings**

Machined flare fittings shall conform to KC145 or KC151.

#### **3.2.2.3 Welding Process**

Machined flares shall be joined to tube ends by gas tungsten arc welding. Welding shall be accomplished by automatic welding in accordance with ASME B31.3. Manual welding may be performed with prior approval of the KSC Engineering Technical Authority.

*NOTE: The tube assembly requires the installation of both coupling nuts prior to welding the second flare. Sleeves are not required.*

#### **3.2.2.4 Minimum Straight Tube Dimensions for Welded Flares**

The minimum straight tube lengths for tubes with welded flares are shown in Table 2.

### **3.3 Dimensions of Bent-Tube Assemblies**

- a) The minimum dimensions for bent-tube assemblies shall be in accordance with Table 3.
- b) Bent-tube assemblies made from N08367 or S31254 stainless steel shall be designed in accordance with Table 4.

*NOTE: UNS N08367 and S31254 tubing is more difficult to bend than 300-series stainless steel tubing, so console and module designs utilizing these tubing materials need to allow for larger bend radii if needed during fabrication. The values in Table 3 may still be used for fabrication if the resultant bent-tube assemblies meet all other acceptance criteria.*

- c) Bent-tube assemblies to be used between consoles and modules should be in accordance with Table 4.

*NOTE: The minimum values in Table 4 are recommended for all tubing between consoles and modules. Where it is impractical to bend tubing to these values, the minimum values in Table 3 may be used if the resultant bent-tube assemblies meet all other acceptance criteria.*

### 3.3.1 Tube Flatness (Ovality)

Tube flatness along the length of the bend shall not be greater than 5 percent of the tube diameter for tubing to be used in ground support equipment systems. Tube flatness shall be determined by the following formula:

$$F = \frac{D_1 - D_2}{N} \times 100$$

where:

- F = Flatness or ovality (percent)
- D<sub>1</sub> = Maximum tube outside diameter
- D<sub>2</sub> = Minimum tube outside diameter
- N = Nominal tube outside diameter

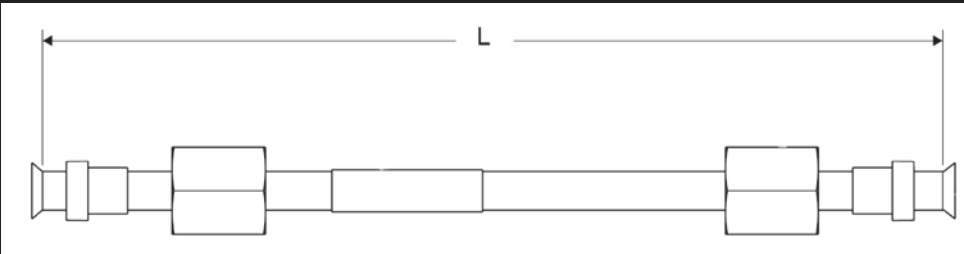
### 3.3.2 Wrinkle Depth

Wrinkle depth on the inside of a bend shall be considered as the perpendicular distance measured from a point on an arc that connects two adjacent crests to the bottom of a wrinkle (see Figure 1). Wrinkle depth shall not be greater than 2 percent of tube outside diameter for sizes up to 3/4 inch and 1 percent of outside diameter for tubes 1 inch and larger.

### 3.3.3 Scratch Depth

The depth of any scratch or die marks along the length of the bend shall be not greater than 5 percent of the tube wall thickness.

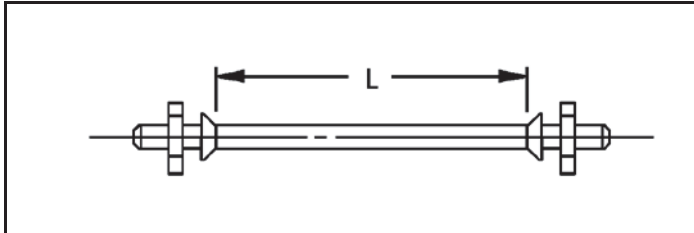
**Table 1. Minimum Lengths of Straight Formed Flare Tube Assemblies**



Tube OD	L
1/4	1-3/4
3/8	2
1/2	2-1/4
3/4	2-1/2
1	2-3/4
1-1/4	4-3/4
1-1/2	4-3/4
2	4-3/4

*Dimensions are in inches*  
*“L” dimension is measured from the base of flared ends*

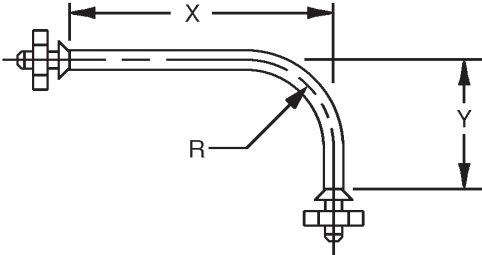
**Table 2. Minimum Lengths of Straight Tube Assemblies (Buttweld Flares)**



Tube OD	L
1/4	3
3/8	3-1/4
1/2	3-1/2
3/4	4
1	4-1/4
1-1/4	4-1/2
1-1/2	5
2 × 0.065	5-1/2
2 × 0.188	8

*Dimensions are in inches*  
*“L” dimension is measured between the noses of fittings*

**Table 3. Minimum Dimensions for Tube Assemblies with a 90-Degree Bend**



Tube OD	X		Y		R
	Formed Flares	Buttweld Flares	Formed Flares	Buttweld Flares	
1/4	1-5/8	2-3/4	1-1/8	2-3/4	9/16
3/8	2-1/4	3-1/4	1-5/8	3-1/4	15/16
1/2	2-3/4	3-5/8	2-3/4	3-5/8	1-1/4
3/4	3-3/8	4-3/8	3-3/8	4-3/8	1-3/4
1	4-3/4	5-3/4	4-3/4	5-3/4	3
1-1/4	5-5/8	6-1/2	5-5/8	6-1/2	3-3/4
1-1/2	7-3/8	7-1/2	7	7-1/2	4-1/2
2 × .065	8-3/4	9-1/4	7-3/4	9-1/4	6
2 × .188	8-3/4	13-1/2	7-3/4	13-1/2	6

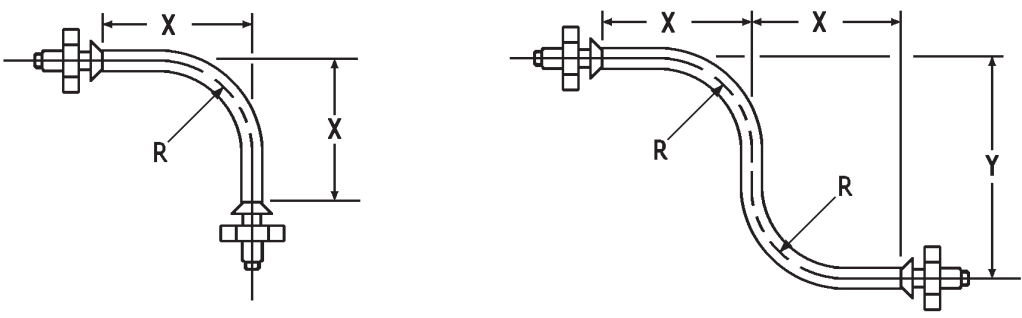
*Dimensions are in inches*

*X and Y dimensions on tubes with formed flares are from base of flared end to extended centerline of tube leg*

*X and Y dimensions on tubes with buttweld flares are from the nose of the fitting to the extended centerline of the tube leg*



**Table 4. Recommended Dimensions for Tube Assemblies with a 90-Degree Bend or S-Bend for Use with N08367/S31254 Tubing or Interconnecting Consoles and Modules**

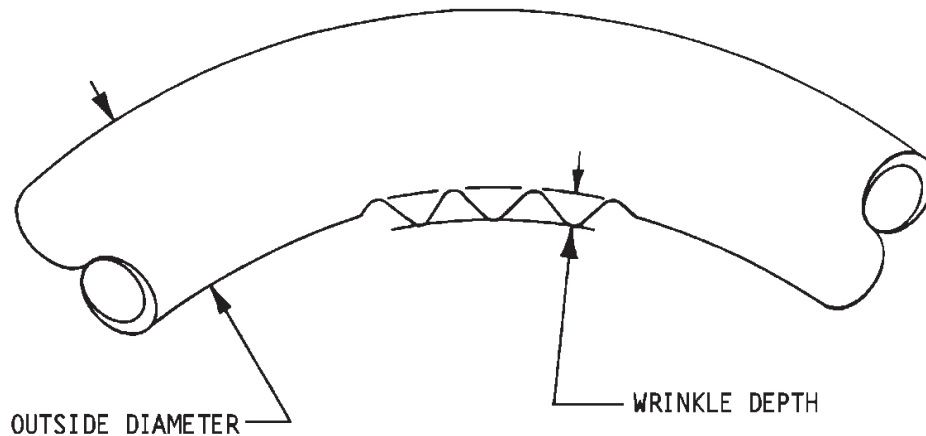


Tube OD & Wall	X		Y		R
	Formed Flares	Buttweld Flares	Formed Flares	Buttweld Flares	
1/4 × 0.035	2	2-3/4	2-3/4	2-3/4	3/4
3/8 × 0.035	2-1/2	3-1/4	3-7/8	3-7/8	1-1/4
3/8 × 0.058	2-3/4	3-1/4	3-7/8	3-7/8	1-1/4
1/2 × 0.049	3-5/16	3-5/8	5-3/8	5-3/8	2
1/2 × 0.072	4-5/16	3-5/8	5-3/8	5-3/8	2
3/4 × 0.065	4-9/16	4-3/8	8	8	4
3/4 × 0.109	5-11/16	4-3/8	8	8	4
1 × 0.095	8-1/32	5-3/4	10-1/16	10-1/16	4
1 × 0.120	9-1/4	5-3/4	10-1/16	10-1/16	4
1-1/4 × 0.049	7-21/32	6-1/2	13-3/4	13-3/4	5
1-1/4 × 0.134	8-7/8	6-1/2	13-3/4	13-3/4	5
1-1/2 × 0.049	8-7/8	7-1/2	16-1/2	16-1/2	6
1-1/2 × 0.188	10-3/8	7-1/2	16-1/2	16-1/2	6
2 × 0.065	11	9-1/4	24-1/2	24-1/2	8
2 × 0.188	12-1/2	13-1/2	24-1/2	24-1/2	8

*Dimensions are in inches.*

*X and Y dimensions on tubes with formed flares are from base of flared end to extended centerline of tube leg*

*X and Y dimensions on tubes with buttweld flares are from nose of fitting to extended centerline of tube leg*



**Figure 1. Wrinkle Depth**

### **3.4 Welded Fitting Operations**

#### **3.4.1 Welded Fittings**

In addition to the welded fittings referred to in 3.2.2, tubes may be joined by welded fittings and they may be used wherever fluid flow or pressure permits, if allowed in lieu of threaded flared fittings by the drawings, specification, or contract.

#### **3.4.2 Weld Fitting Sizes**

Buttweld fittings, unions, elbows, tees, and crosses should only be used with the standard tube sizes shown in Table 6.

#### **3.4.3 Tubing Preparation**

Tube ends shall be prepared as specified in 3.2.2.1.

#### **3.4.4 Pressure Limitations**

Welded fittings shall have the same pressure limitations as those applied to tubing (see 3.5.1).

#### **3.4.5 Weld Filler**

Welded fittings typically provide the weld filler material when fittings are welded to tubing. Welded fittings may be used as-is without additional weld filler, or the fittings may be chamfered so that welding can be performed with additional weld filler.

### 3.4.6 Weld Inspection

- a. With the exception of welds in pneumatic systems, welds in pressurized piping and tubing shall be inspected in accordance with the applicable fluid service classification in AWS D17.1, Clause 9 (rate of weld inspection), and in ASME B31.3 (fluid service weld acceptance criteria).

*NOTE: Hypergolic, cryogenic, and ammonia systems are classified as Category M (lethal service) per ASME B31.3.*

- b. Welds in pneumatic systems shall be subjected to 100% radiographic testing in accordance with ASME B31.3 for normal fluid service.

*NOTE: Meeting the AWS D17.1 requirement for in process examination of automatic gas tungsten arc welding may be substituted for the required 100% radiographic testing.*

### 3.4.7 In-Place Welding

The welding head of automatic welding equipment shall have the capability of encircling in-place fluid lines to produce the welded joint. In-place welding may be used for both normal installation of tubes and fittings and for repair work. Table 5 defines typical space allocation around various tube sizes for in-place welding.

## 3.5 Pressure/Temperature Requirements – Tubes and Fittings

### 3.5.1 Maximum Allowable Working Pressure

The maximum allowable working pressure (MAWP) for standard sizes of tube and fittings for continuous use at temperatures indicated in 3.5.2 is tabulated in Table 6.

*NOTE: Tube assemblies fabricated and installed in accordance with this specification are also rated to external pressure up to 15 psid (full internal vacuum) in accordance with ASME BPVC-VIII.1, paragraph UG-28.*

### 3.5.2 Temperature Range

The working temperature range shall be from minus 320 to plus 300°F. Use at temperatures beyond these limits requires KSC Engineering Technical Authority approval on a case-by-case basis.

### 3.5.3 Hydrostatic Test Pressure

- a) Each completed tube assembly shall be hydrostatically tested to the pressures listed in Table 6.
- b) A tube size used for replacement in an existing system shall be tested at its respective test pressure listed in Table 6 regardless of the test pressure specified in the system drawing.

- c) Buttweld tube assemblies comprised of more than one tubing size shall be hydrostatically tested to the test pressure of the lowest rated tube size.
- d) Tubing permanently installed in vent systems that discharge directly to atmosphere do not require hydrostatic testing; such tubing shall be tagged in accordance with section 3.6 with “NOT HYDRO TESTED” in place of the identification information.

#### **3.5.4 Leak Checking**

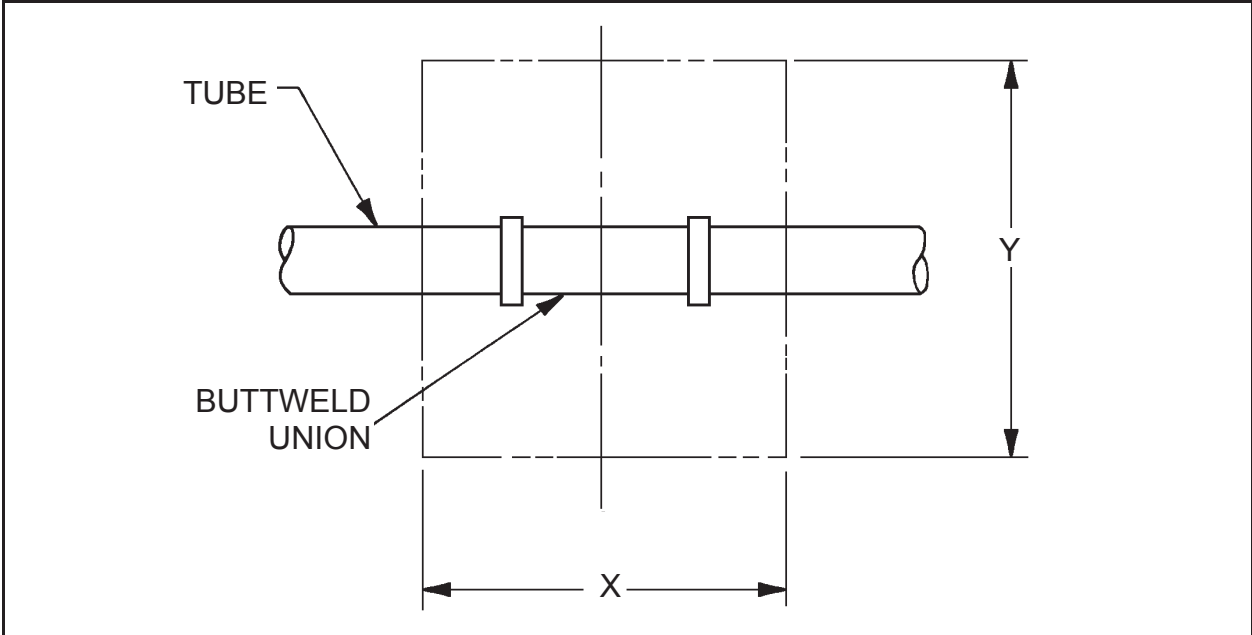
- a) Fluid mechanical joints shall be leak checked in accordance with ASME B31.3, based on the design pressure specified by the engineering drawing, statement of work, or specification.
- b) Unless otherwise specified on the design drawings, pneumatic systems shall be tested with MIL-L-25567 Type I leak detection compound.
- c) MSFC-SPEC-384 leak detection compound shall be used for oxygen systems requiring oxygen compatibility.
- d) If the fitting leaks, vent line pressure and tighten nut to maximum torque. If leakage continues, the joint is defective and must be reworked.

*NOTE: Liquid systems do not require special equipment or compounds to detect leaks. Inert media may be used in lieu of hazardous media for shop leak tests when safety requirements would be compromised. Sensitive detection devices such as mass spectrometers or halogen detectors need not be used unless they are required by the drawings or the acceptance checkout procedure for the equipment under test.*

#### **3.6 Identification of Tube Assemblies**

- a) Fabricated tube assemblies shall be identified by an attached metal band per 75M04185 and die stamped or electrochemically etched per KSC-STD-E-0015, with 1/8 inch lettering.
- b) Tube assemblies that will be installed in a launch environment or any environment in which foreign object debris is a concern shall be identified by an attached metal band per 75M04185-10.
- c) Identification shall include the tube assembly part number or the performing activity's tracking number, tube outer diameter and wall thickness, material designator, hydrostatic test pressure, and date of test.
- d) Buttweld tube assemblies that extend over 100 feet in length must have additional metal identification bands spaced at intervals of 100 feet.

**Table 5. In-Place Welding Space Allowances**



Tube OD	Welding Tool Envelope	
	X	Y
1/4	3-1/2	4
3/8	3-1/2	4
1/2	3-1/2	4
3/4	3-3/4	4
1	3-3/4	4
1-1/4	4-3/8	5-7/8
1-1/2	4-3/8	5-7/8
2	4-3/8	5-7/8

*Dimensions are in inches*

**Table 6. Maximum Allowable Working Pressures for Tubes and Fittings**

<b>Tube O.D. (in)</b>	<b>Tube Wall Thickness (in)</b>	<b>Tube MAWP (psig)</b>	<b>Tube Hydrostatic Test Pressure (psig)</b>	<b>Flared Tube Fittings MAWP* (psig)</b>
1/4	0.035	6200	9300	9900
3/8	0.035	4000	6000	6900
	0.058	6900	10300	
1/2	0.049	4200	6300	7400
	0.072	6400	9600	
3/4	0.065	3700	5600	7000
	0.109	6500	9800	
1	0.095	4100	6300	6500
	0.120	5300	8000	
1-1/4	0.049	1600	2400	6300
	0.134	4600	6900	
1-1/2	0.049	1300	2000	5600
	0.188	5500	8300	
2	0.065	1300	2000	5500
	0.188	4000	6000	

*\* Per 01/24/2007 memo, Pressure Rating for Flared Tube Fittings per GP-425 and TR-324 (Appendix A). Flared tube fitting MAWP are listed for reference; hydrostatic test pressures are limited by the tube MAWP.*

*NOTE: Tube MAWP is calculated using ASME B31.3 equation 3a for seamless type 304 (UNS S30400) and 316 (UNS S31600) stainless steel tubing. While these values are conservative for welded AL6XN (UNS N08367) and 254SMO (UNS S31254) stainless steel tubing, these MAWP values are applied to all tubing so that materials can be considered interchangeable.*

#### **4. INSTALLATION OF TUBE ASSEMBLIES, FITTINGS, FITTING ASSEMBLIES, AND COMPONENTS**

##### **4.1 Examination of System Components**

Prior to installation in a system, sleeves, nuts, tubes, and fittings shall be examined to determine that they are free from damage and that they are properly marked and packaged to maintain the appropriate cleanliness requirements.

##### **4.2 Cleanliness**

###### **4.2.1 Cleanliness of Tube Assemblies and Fittings**

Tube assemblies and fittings (including seal rings and O-rings) shall be cleaned to the requirements on the design drawings. Any protective closures (caps, plugs, etc.) shall remain in place after cleaning until the part or assembly is installed.

###### **4.2.2 Contamination**

To prevent contamination of a system when an assembly or part is disconnected, all openings shall be capped or plugged immediately.

*NOTE: Care must be exercised in removing or replacing closures to prevent depositing plug or cap material in a system.*

##### **4.3 Installation Clearances**

###### **4.3.1 Clearance Between Tubing Runs and Stationary Components**

Clearance between tubing outside diameter and stationary components shall be 1/8 inch minimum.

###### **4.3.2 Clearance Between Tubing Runs and Moving Components**

Clearance between tubing and moving components shall be at least 1/2 inch between the tubing outside diameter and the maximum clearance envelope of the moving component.

###### **4.3.3 Clearance Between Multiple Tubing Runs**

For multiple formed flare tube runs, the minimum dimension centerline of tube to centerline of adjacent tube shall be as specified in Table 7 or Table 8. Use Table 5 for butt-welded welding head and repair tool clearances.

#### **4.4 Tube and Fitting Assembly Fit-Up**

##### **4.4.1 Alignment**

The tube assembly shall be placed and aligned so that the flare on the tubing (machined or formed) and the fitting sealing surfaces will meet squarely. Figure 2 illustrates two sources of misalignment.

##### **4.4.2 Length**

In addition to the requirement for flare and fitting to meet squarely, the tube length shall be sufficient to allow contact between flare and fitting sealing surfaces. Figure 3 illustrates undesirable gap between tube and fitting.

##### **4.4.3 Tightness**

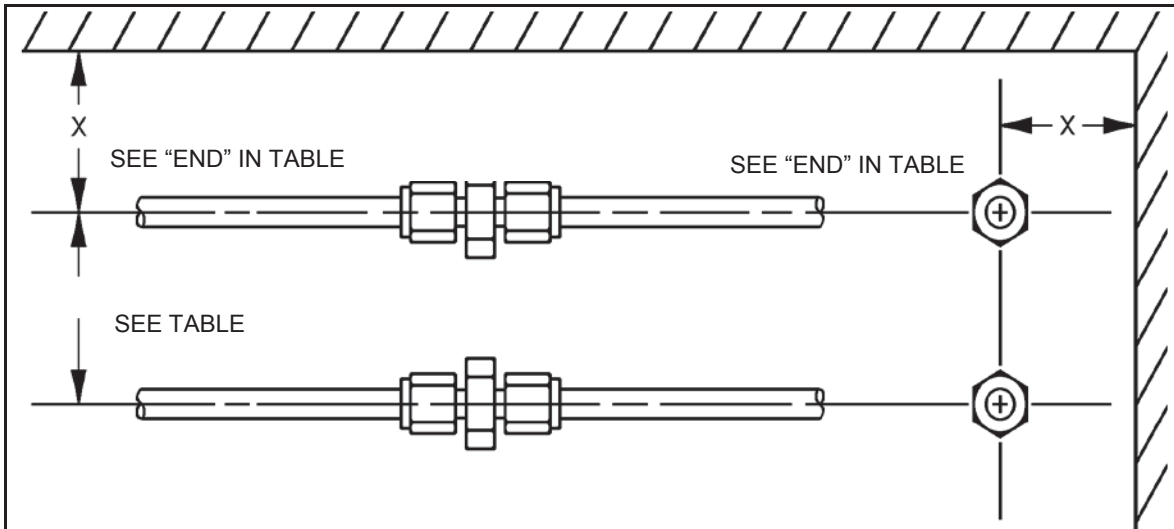
If properly fitted, the coupling nut shall be moved to the tube end and turned on the fitting to a finger-tight position. The fitting shall be held stationary while torque is applied to the nut per 4.7.

##### **4.4.4 Visual Check**

A visual check shall be made to determine whether any mismatch exists between flare and fitting as described in 4.4.1 and 4.4.2. If the assembly is questionable, a mechanical check as specified in 5.3 shall be performed.



**Table 7. Minimum Spacing of Tubes with Formed Flares for Parallel Coplanar Tube Runs with Adjacent Unions**

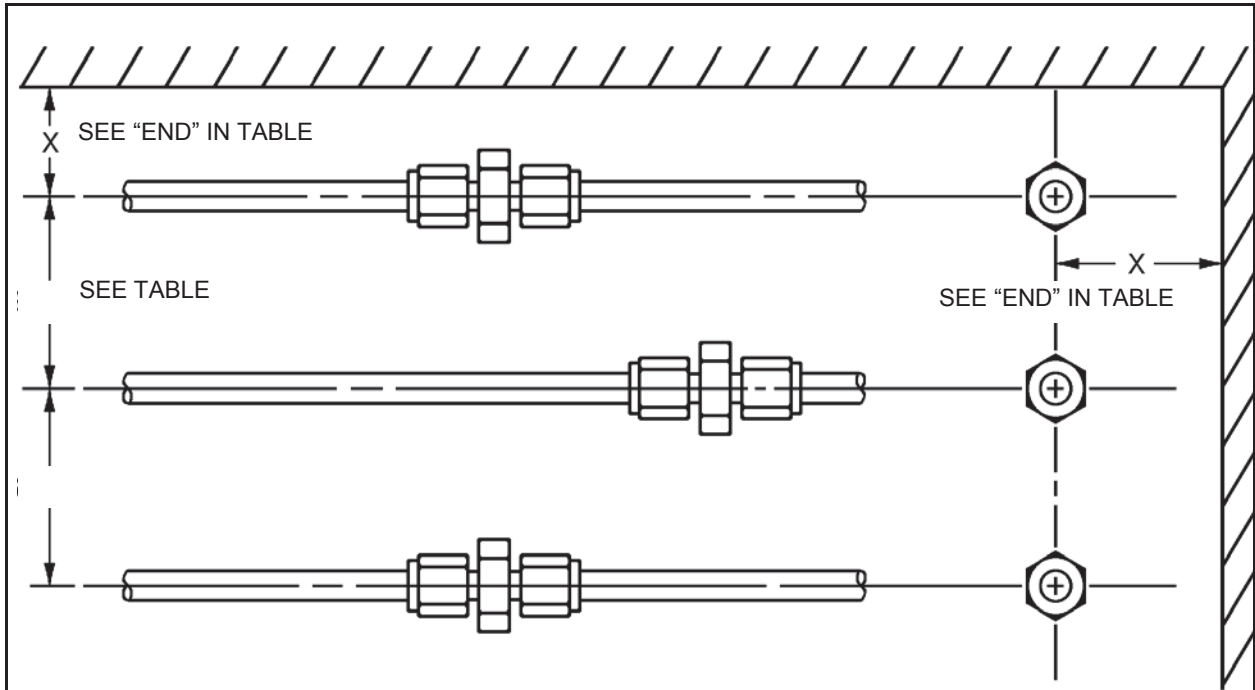


Tube O.D.	1/4	3/8	1/2	3/4	1	1-1/4	1-1/2	2	End*
1/4	1-3/8								11/16
3/8	1-1/2	1-9/16							3/4
1/2	1-5/8	1-3/4	1-13/16						7/8
3/4	2-1/8	2-3/16	2-5/16	2-1/2					1-3/16
1	2-5/16	2-3/8	2-1/2	2-3/4	2-7/8				1-3/8
1-1/4	2-11/16	2-3/4	2-7/8	3-1/8	3-1/4	3-3/8			1-5/8
1-1/2	3-1/4	3-5/16	3-7/16	3-11/16	3-3/4	3-15/16	4-1/8		1-15/16
2	4	4-1/16	4-3/16	4-3/8	4-9/16	4-11/16	5	5-5/8	2-9/16

*Dimensions are in inches*

*\* "End" is defined as the minimum distance from a wall or component to the centerline of an adjacent tube run where wrench clearance is required*

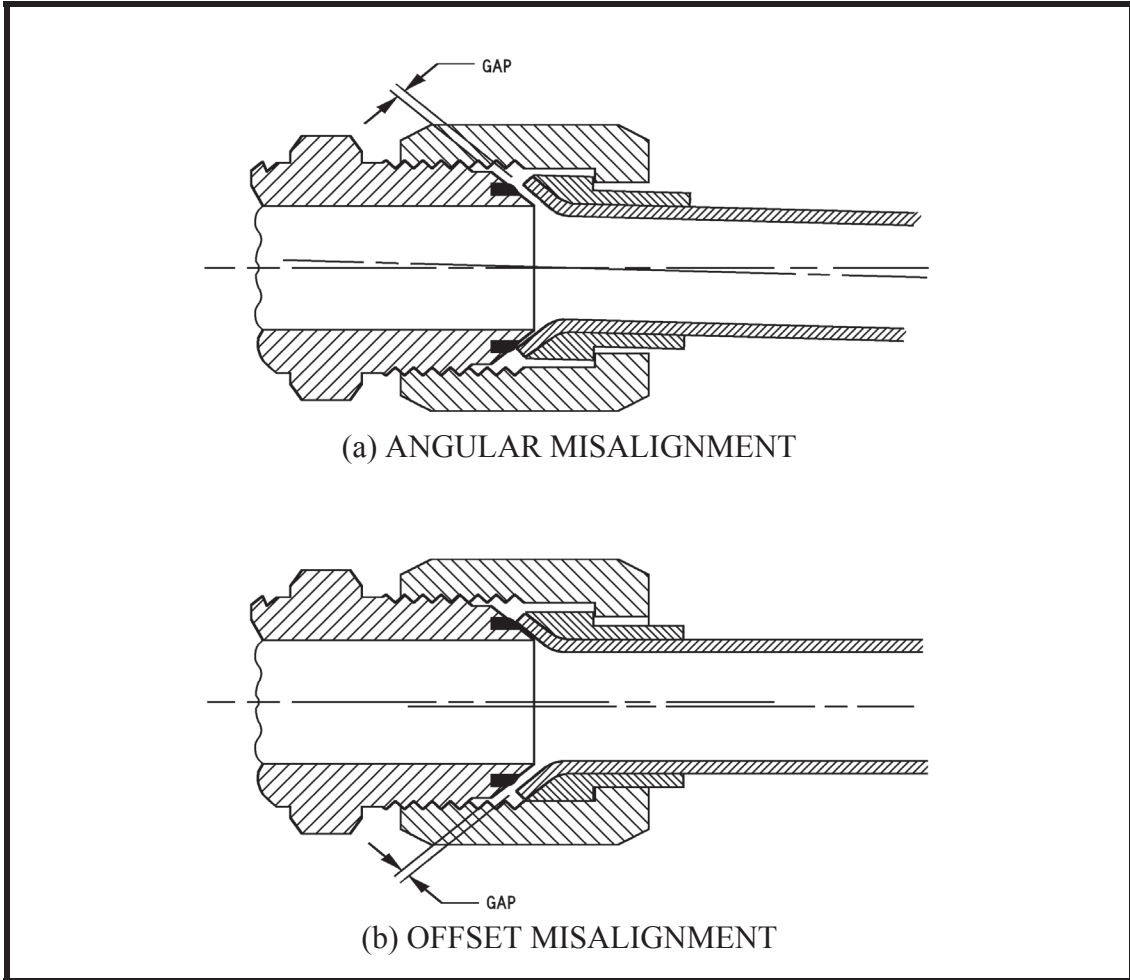
**Table 8. Minimum Spacing of Tubes with Formed Flare for Parallel Coplanar Tube Runs With Staggered Unions**



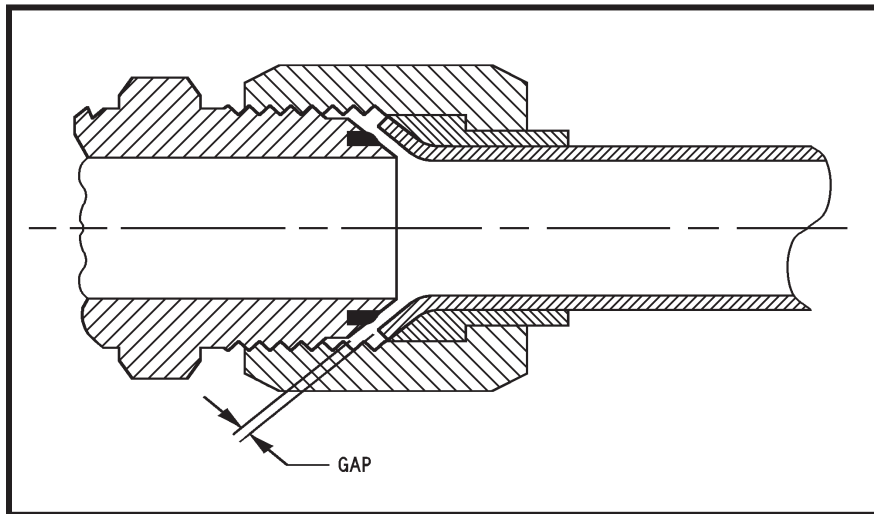
Tube O.D.	1/4	3/8	1/2	3/4	1	1-1/4	1-1/2	2	End*
1/4	13/16								11/16
3/8	7/8	15/16							3/4
1/2	1	1-1/8	1-3/16						7/8
3/4	1-3/8	1-7/16	1-9/16	1-11/16					1-3/16
1	1-1/2	1-9/16	1-5/8	1-3/4	1-7/8				1-3/8
1-1/4	1-3/4	1-13/16	1-7/8	2	2-1/8	2-1/4			1-5/8
1-1/2	2-1/16	2-1/8	2-3/16	2-5/16	2-7/16	2-9/16	2-11/16		1-15/16
2	2-11/16	2-3/4	2-13/16	2-15/16	3-1/16	3-3/16	3-5/16	3-7/16	2-9/16

*Dimensions are in inches*

*\*"End" is defined as the minimum distance from a wall or component to the centerline of an adjacent tube run where wrench clearance is required*



**Figure 2. Tube-to-Fitting Misalignment**



**Figure 3. Short Tube Gap**

## 4.5 Tube Supports

### 4.5.1 Support of Tube Assemblies and Fittings

All rigid tubing and fitting assemblies shall be supported by suitable holding devices, such as clamps and single- or multi-line blocks. Tube support location and spacing other than as specified herein shall require approval of the KSC Engineering Technical Authority, and shall require detailed stress and flexibility analysis in accordance with ASME B31.3, paragraphs 319 and 321.

*NOTE: Design of tubing supports and locations should consider forces at joints and thermal expansion/contraction effects in accordance with applicable design requirements and standards. Flexibility may be provided by changes of direction or by the use of bends, loops, or offsets.*

### 4.5.2 Support Installation

The installation of clamps and supports shall be specified on design drawings.

*NOTE: Where the routing and support locations are not explicitly identified on the design drawings, the installation of clamps and supports are to be field located and installed in accordance with section 4.5 of this specification.*

### 4.5.3 Tube Support Spacing

#### 4.5.3.1 Support Spacing

Tube supports shall be spaced in accordance with Table 9.

*NOTE: The rationale for tube support spacing can be found in K0000382480-RPT.*

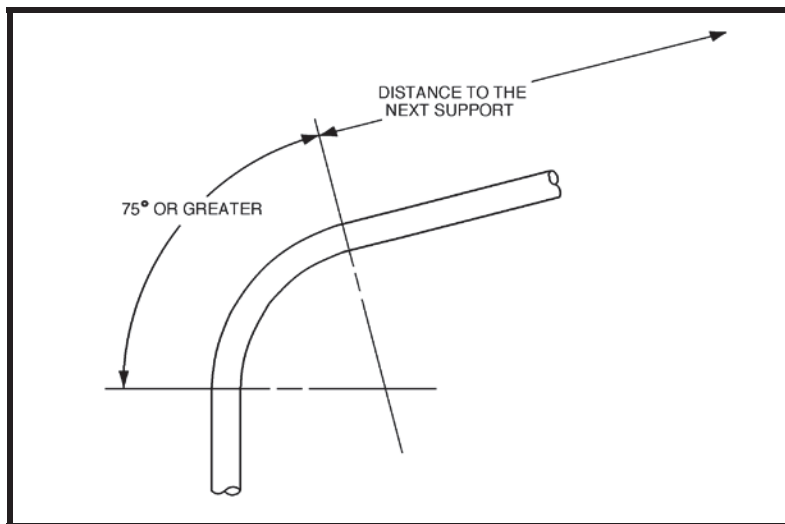
**Table 9. Tube Support Spacing**

Nominal Tube O.D. (Inches)	Maximum Tubing Length Between Supports (feet)	
	Horizontal Runs	Vertical Runs
1/4, 3/8	4	5
1/2, 3/4	6	7
1, 1-1/4, 1-1/2, 2	9	10

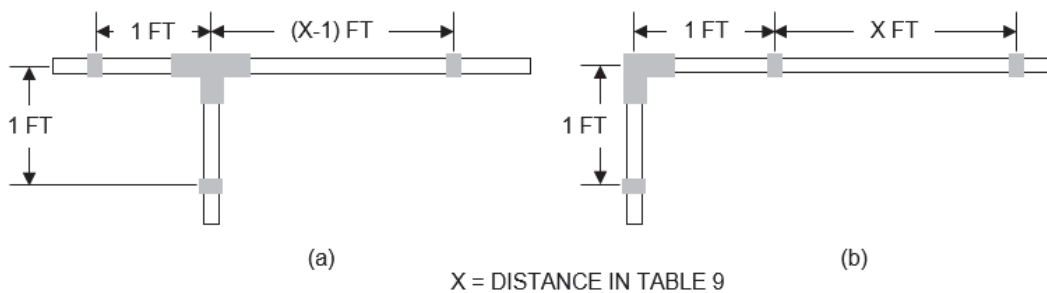
#### 4.5.3.2 Support Spacing Between Bends and Unsupported Fittings

- a) In all cases, one support shall be provided within one foot of all unsupported fittings (e.g., unions, tees, elbows) and tubing bends of greater than 75 degrees (see Figure 4 for guidance).
- b) For 1/4, 3/8, and 1/2 inch tubing in launch environments (e.g, launch pad or launch tower), a second support shall be provided within one foot of all unsupported tee fittings (i.e., one support is placed on the branch, and one support is placed on one of the runs; see Figure 5(a) for guidance).
- c) For 1/4 inch tubing in launch environments, a second support shall be provided within one foot of all unsupported elbow fittings (i.e., supports are placed on both sides of the elbow; see Figure 5(b) for guidance).
- d) Support spacing utilized for multiple tubing runs shall be based on the smallest tubing size used.

*NOTE: Additional supports should be considered for tubing that may be subject to loads imparted by personnel (e.g., tubing that may be used as a hand hold or may be stepped on).*



**Figure 4. Support Measurement Method for Bent Tube**



**Figure 5. Support Spacing for Tubing in Launch Environments**

#### **4.5.4 Support Alignment**

After the tube assembly is connected, the assembly shall be aligned by adjusting supports so it is strain free. No external force shall be applied to the tube assembly to correct such defects as described in 4.4.

#### **4.6 Component Mounting**

A component attached to a bulkhead fitting mounted through a supporting structure may not require any additional support. Components shall not be line mounted without approval of the KSC Engineering Technical Authority.

#### **4.7 Torque Requirements**

##### **4.7.1 Torque Application Devices**

Torque application devices shall conform to ASME B107.300, and shall be calibrated in accordance with ASTM E2428. It is recommended that wrench heads, adapters, plain hand wrenches, and other devices for applying torque conform to the open end box pattern defined by A-A-3041.

##### **4.7.2 Torque Application**

The specified torque values shall be applied slowly, smoothly, at a uniform rate after mating, to the midpoint of the values in Table 10. Fittings shall be backed off one-quarter turn and then retightened to the midpoint value.

##### **4.7.3 Erratic Indications**

When erratic torque indications are observed, the particular components shall be disassembled and checked for galling and other damage (cross-threading, broken coupling nuts, broken sleeves, foreign material, etc.).

**Table 10. Installation Torque**

	<b>Fittings</b>		<b>Fittings</b>		<b>Tube Assemblies</b>		<b>Bulkhead Fittings</b>	
	KC105 fitting end, KC136 fitting end, or KC138 fitting end with AN924 nut and KC140 washer installed with O-ring seal in SAE AS5202 boss		KC139 nut over KC137 or KC141 fitting end installed on fitting end per KC104 or KC105		Tube assembly coupling nuts per KC142 installed on fitting end per KC104 or KC105		AN924 locknuts installed on bulkhead fitting end KC104	
Applicable Fittings	KC108, 110, 111, 112, 113, 114, 115, 119, 120, 124, 125, 126, 127, 128, 129, 130, 133, 134, 135, 144, 164		KC106, 107, 109, 131, 132, 150		KC142		KC113, 114, 119, 120, 124, 127, 128, 134, 144	
Tube O.D.	Torque (inch-pounds)		Torque (inch-pounds)		Torque (inch-pounds)		Torque (inch-pounds)	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
1/4	55	80	135	185	135	185	75	100
3/8	100	150	270	345	270	345	150	200
1/2	180	230	450	525	450	525	200	250
3/4	420	600	900	1,100	900	1,100	450	650
1	600	840	1,200	1,400	1,200	1,400	650	900
1-1/4	720	960	1,500	1,800	1,500	1,800	800	1,000
1-1/2	840	1,080	2,000	2,300	2,000	2,300	900	1,100
2	1,000	1,300	3,200	3,600	3,200	3,600	900	1,100

## 4.8 Lubrication

### 4.8.1 Optional Requirement

If not prohibited by design documentation, fitting threads may be lubricated at the option of the installer. Fitting threads, when lubricated, shall be lubricated in accordance with KSC-SPEC-Z-0009.

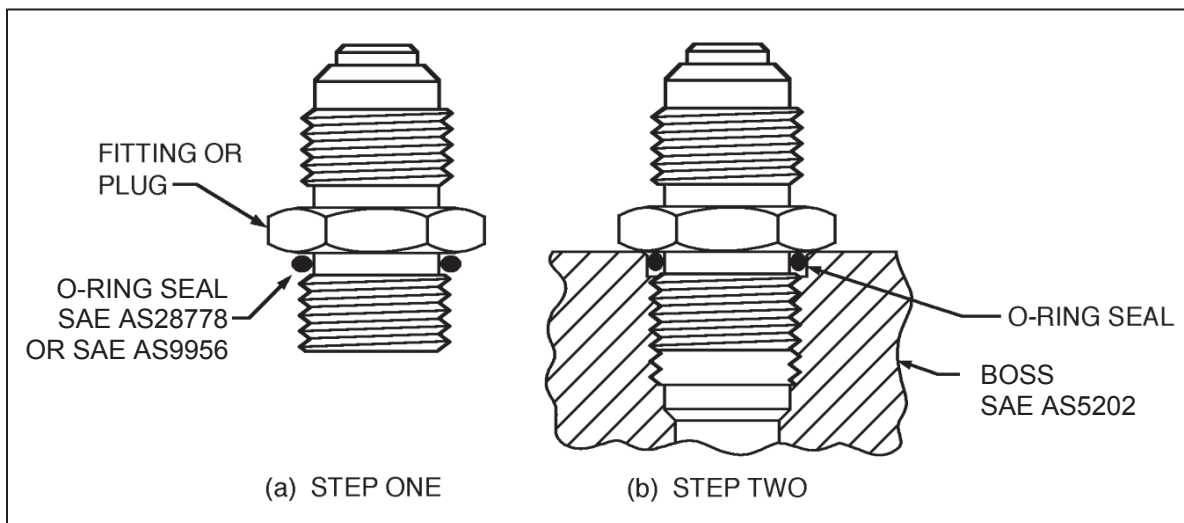
### 4.8.2 Documentation Requirement

New designs shall specify by general note or flag note: “Lubricate tube fitting threads per KSC-SPEC-Z-0009,” unless lubrication is not desired. If not desired, design documentation shall specify by general note or flag note: “Do not lubricate tube fitting threads.”

## 4.9 Fittings Into Bosses

### 4.9.1 Installation of Nonpositioning-Type Fittings

Nonpositioning-type fittings shall be those fittings that do not require specific orientation when installed in bosses. They employ an O-ring to provide a sealed joint. The O-ring seal shall be protected from damage and carefully installed on the fittings as shown in Figure 6(a). The fitting shall be screwed into the boss to the finger-tight position as shown in Figure 6(b). The fitting shall then be tightened to the applicable torque value specified in Table 10. The fitting hex must then be in contact with the surface of the boss.



**Figure 6. Installation of Nonpositioning-Type Fitting Into Boss**



#### **4.9.2 Installation of Positioning-Type Fittings**

Positioning-type fittings are those fittings that require specific orientation when installed into threaded bosses. In addition to the O-ring seal, they employ a nut and a captive steel backup washer. The procedures as specified below shall be applicable to positioning-type fittings:

- a) Run the nut and the captive steel backup washer to the top of the seal groove. The O-ring shall be protected from damage and carefully installed and placed in firm contact with the backup washer (see Figure 7(a)).
- b) Screw the fitting-nut-washer-O-ring assembly into the boss as a unit until the O-ring contacts the boss. This point is determined by the sudden increase in torque (see Figure 7(b)).
- c) Set fitting direction by turning in as much as 3/4 turn (270 degrees) or backing out as much as 1/4 turn (90 degrees). Hold positioned fitting stationary and tighten the nut to the applicable torque value in Table 10. The backup washer must now be in contact with the surface of the boss (see Figure 7(c)).

#### **4.10 Bulkhead-Type Fittings**

##### **4.10.1 Fitting Styles**

Bulkhead-type fittings shall be those fittings that conform to style E or style S of SAE AS1099/KC104 in KSC-GP-425. For pressures up to 20000 psig in 1/4-inch outside diameter tubing, the bulkhead fittings shall be in accordance with KC169.

##### **4.10.2 Pass Throughs**

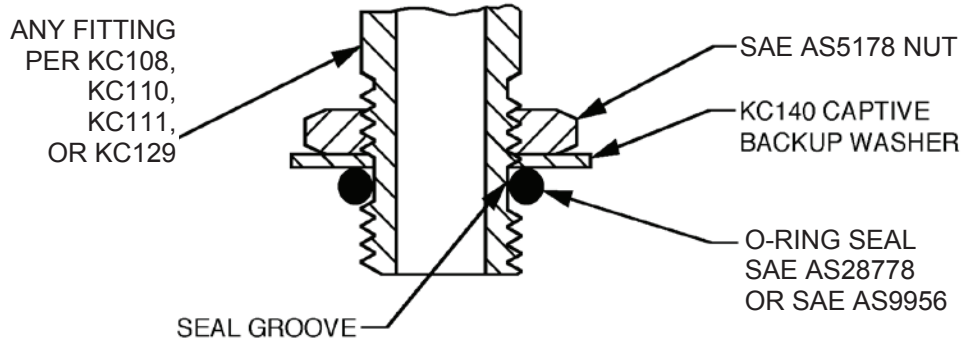
All bulkhead fittings used as “pass throughs” must be installed with the fixed hex (style E) or shoulder (style S) on the side of the least permanent joint; e.g., on the outside of consoles and modules or at a hose connection side.

##### **4.10.3 Bulkhead Holes**

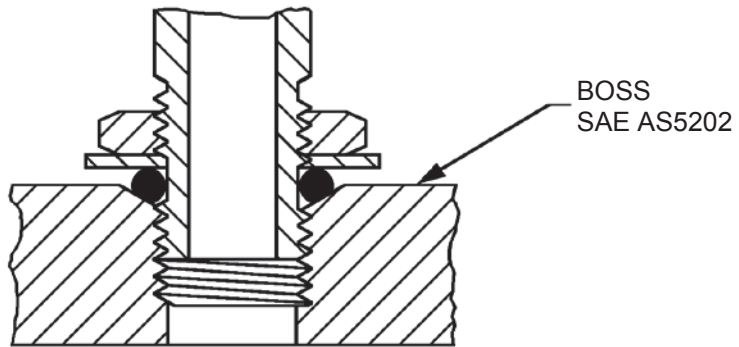
Holes made to accommodate bulkhead fittings shall be a maximum of 0.062 (1/16) inch over the basic thread diameter of the fittings.

##### **4.10.4 Mounting Bulkhead Fittings**

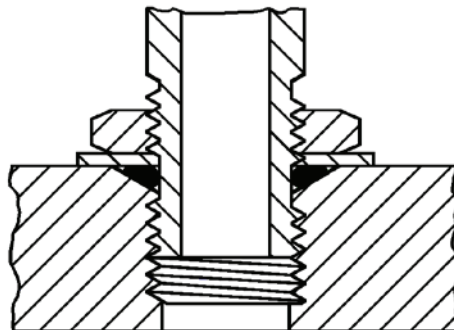
The fitting, washer(s), and nut shall be assembled to the bulkhead in the order shown in Figure 8. Only one washer is required for the connection if the bulkhead is over 0.125 inch thick. The fitting shall be positioned and held stationary while the nut is tightened to the applicable torque value specified in Table 10.



(a) STEP ONE



(b) STEP TWO



(c) STEP THREE

Figure 7. Installation of Positioning-Type Fitting Into Boss

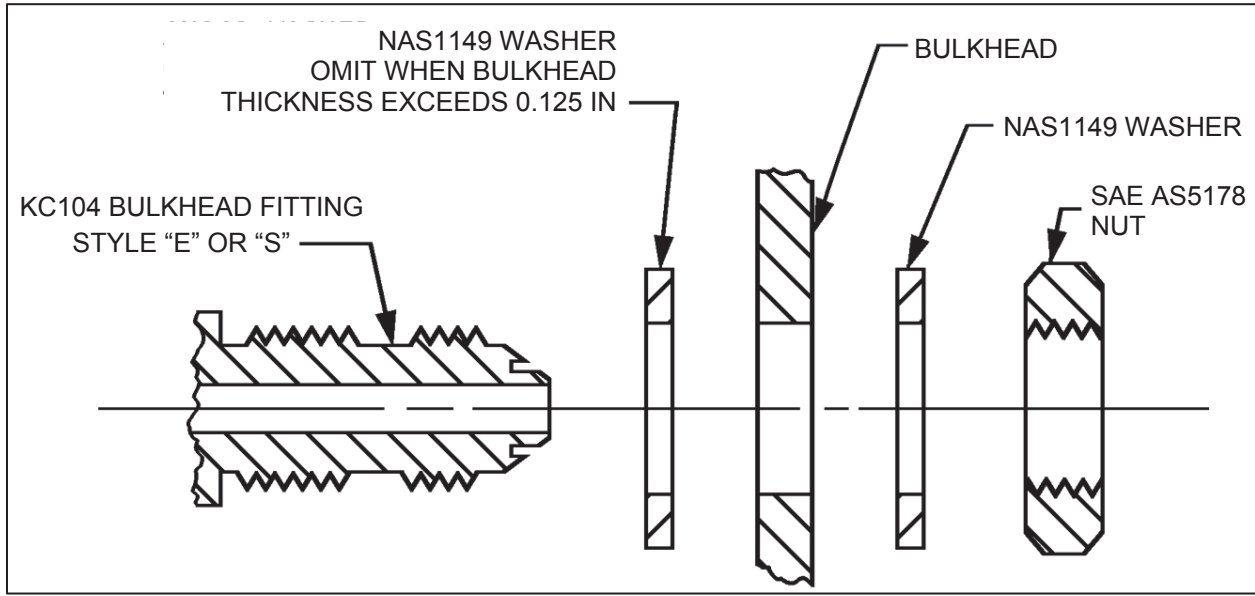


Figure 8. Bulkhead Fitting Installation

#### 4.11 Fitting and Seal Ring Assembly

##### 4.11.1 Assembly of New Parts

When practical, new tube fittings and seal rings should be preassembled from common stock fittings and SAE AS1097/KC103 seal rings as illustrated in Figure 9. Seal rings shall be cleaned to the same cleanliness level as the fitting. Use the following sequence:

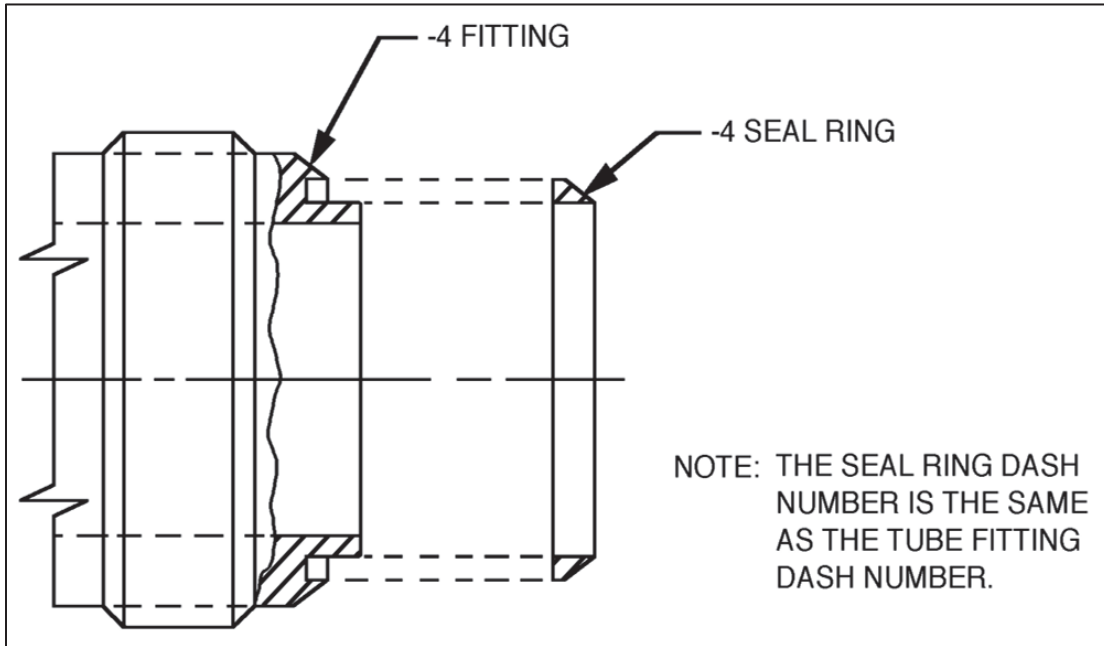
- a) With the fitting held firmly, select a SAE AS1097/KC103 seal ring of corresponding dash number to the fitting end and place it on the fitting's flared surface as indicated in Figure 9. Verify that the surfaces of the seal ring's chamfer and the fitting's flared surface are parallel and then attempt to manually press the seal ring into the groove using a slight rotary motion.

*NOTE: No tools or other devices are to be used to assist in the installation of seal rings.*

- b) If the seal ring fails to enter the groove with relative ease, remove it and repeat the procedure using another seal ring until one enters the groove properly and perceptibly seats against the bottom of the groove.

*NOTE: Seal ring removal is to be done manually, if possible. Non-metallic or soft metal (e.g., brass) instruments may be used to dislodge the seal ring and any particles lodged in the groove.*

- c) Visually examine the assembly to ensure the seal ring's chamfer projects uniformly above the groove around the entire circumference of the flared surface. If the ring cannot be properly seated, remove it and replace it with another seal ring using the above procedure until one is properly seated (see the note under 4.11.1(b)).



**Figure 9. Typical Tube Fitting Seal Ring Installation**

#### **4.11.2 Disassembly and Assembly for Maintenance, Repair, or Modification**

Tubing assemblies disconnected from KC fittings for any reasons such as maintenance, repair, or modification shall be handled as follows:

- a) Remove the SAE AS1097/KC103 seal ring (see the note under 4.11.1(b)).
- b) Carefully clean and inspect the groove to ensure that contaminants or particles that might interfere with a new seal ring installation are not present.
- c) Select and install a new SAE AS1097/KC103 seal ring as indicated in 4.11.1.

### **5. QUALITY ASSURANCE PROVISIONS**

#### **5.1 Responsibility for Inspection**

The performing activity shall be responsible for the performance of all inspection requirements as specified herein. The Government reserves the right to perform any of the inspections set forth in this specification to assure that the requirements specified herein have been met.

#### **5.2 Certification**

##### **5.2.1 Tube Bending, Flaring, and Welding**

The performing activity shall certify in writing that his personnel and procedures are capable of meeting the forming and welding requirements specified herein.

### **5.2.2 Torque Wrench Calibration**

Certification of conformance to the requirements of Section 4.7.1 shall be furnished in writing.

## **5.3 Examination of Fittings, Tubes, and Fitting Assemblies**

### **5.3.1 Alignment (Mechanical Check)**

It shall be determined by the following steps that the tube assembly is free of restraint so that relative movement of the ends can be observed:

- a) Disengage the coupling nuts at both ends, and disengage the flare from the fitting nose at one end.
- b) Tighten the coupling nut finger tight at the other end, allowing the tube assembly to seek its natural position.
- c) Observe the orientation of the free end relative to the proper location of the fitting with which it mates.

If the fitting at the free end can be moved and engaged with the tube assembly so that the fitting nose meets the flare squarely without any of the defects shown in Figure 2 and Figure 3, the tube assembly is acceptable. No force may be applied to the tube assembly to achieve alignment.

### **5.3.2 Tube Inside Diameter**

The inside diameter of form-flared and bent tubing shall be checked to determine conformance to tube flatness (see Section 3.3.1) and wrinkle depth (see Section 3.3.2). In addition, to assure other restrictions do not exist, a spherical ball shall be passed through the flared or bent tube. The ball diameter to be used for the specific size tubing undergoing testing shall be selected from Table 11 and be in accordance with ASTM F2215. For form-flared and bent-tube assemblies which also contain welded fittings, the ball check must be performed prior to welding.

### **5.3.3 Fittings and Bosses**

Nonpositioning and positioning-type fittings shall be examined for proper installation.

#### **5.3.3.1 Nonpositioning-Type Fittings**

Nonpositioning-type fittings installed into bosses shall be examined to determine conformance to the requirements of 4.9.1.

#### **5.3.3.2 Positioning-Type Fittings**

Positioning-type fittings installed into bosses shall be examined to determine conformance to 0.

### 5.3.4 Bulkhead-Type Fittings

Bulkhead-type fittings installed in brackets or bulkheads shall be examined to determine conformance to the requirements of 4.10.

### 5.3.5 Welded Fittings

The identification of a fitting weld, its inspection records, and its test records shall be provided by the performing activity per ASME B31.3. The method used for complying with this requirement shall provide a cross-reference that may be readily used for tracing weld to records or records to weld. X-rays shall be provided to KSC by the performing activity. A suggested method of marking the individual records and radiographs is with the X-ray code mark that is placed on the X-ray film and identifies an individual X-ray with the weld X-rayed.

## 5.4 Rejection Procedure

Nonconformance to the requirements of this specification shall be cause for rejection. Nonconforming articles shall be reviewed and approved by the KSC Engineering Technical Authority.

**Table 11. Test Ball Diameters**

Nominal Tube Size	Nominal I.D.	Test Ball Diameter $D_i = .949 \times \text{I.D. Nom.}$
1/4 × 0.035	0.180	0.156 (5/32)
3/8 × 0.035	0.305	0.281 (9/32)
3/8 × 0.058	0.259	0.219 (7/32)
1/2 × 0.049	0.402	0.375 (3/8)
1/2 × 0.072	0.356	0.313 (5/16)
3/4 × 0.065	0.620	0.562 (9/16)
3/4 × 0.109	0.532	0.500 (1/2)
1 × 0.095	0.810	0.750 (3/4)
1 × 0.120	0.760	0.719 (23/32)
1-1/4 × 0.049	1.152	1.094 (1-3/32)
1-1/4 × 0.134	0.982	0.906 (29/32)
1-1/2 × 0.049	1.402	1.312 (1-5/16)
1-1/2 × 0.188	1.126	1.031 (1-1/32)
2 × 0.065	1.870	1.750 (1-3/4)
2 × 0.188	1.626	1.500 (1-1/2)

## 6. NOTES

### 6.1 Intended Use

This specification is intended to cover the fabrication and the installation of tube assemblies and the installation of fittings and fitting assemblies for fluid pressure systems.

### 6.2 Citation Data

Contract documents should cite this specification by number, title, and date. Drawings should cite this specification by number in a general note.

**NOTICE:** When Government drawings, specifications, or other data are used for any purpose other than in connection with definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

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**APPENDIX A. PRESSURE RATING FOR FLARED TUBE FITTINGS PER GP-425 AND TR-324 (01/24/2007 MEMO)**

National Aeronautics and  
Space Administration  
**John F. Kennedy Space Center**  
Kennedy Space Center, FL 32899



January 24, 2007

Reply to Attn of: NE-D

TO: TA-E3/Raymond Norman  
SUBJECT: Pressure rating for Flared Tube Fittings per GP-425

This letter is in response to your request for approval to use a 1 1/4" KC-style 37-degree flared tube fitting at a pressure higher than the pressures listed in the released version of KSC-SPEC-Z-0008, *Fabrication and Installation of Flared Tube Assemblies and Installation of Fittings and Fitting Assemblies, Specification For*.

This series of fittings described in KSC-GP-425, *Fluid Fitting Engineering Standards*, were analyzed by NASA KSC Engineering in 1989 and approved for use at KSC by Walt Murphy, Director of Engineering Development, at that time. The allowable pressures are listed in KSC-SPEC-Z-0008. That specification was not updated to reflect the new pressure ratings. Allen Aircraft Products, Inc. (the principal fitting manufacturer) has been using the updated allowable pressures based on the NASA KSC analysis for the past 18 years.

The higher pressure rating has also been verified by a test arranged by TA-E3. Allen Aircraft Products, Inc. hired Consolidated Laboratories, Inc. to perform the testing. The subject fitting was pressurized to 25,200 pounds per square inch (PSI) and held for five minutes. This test provided an independent validation of the allowable pressures calculated in the 1989 analysis.

The new pressure rating for the KC-Series of flared tube fittings made from type 316 stainless steel (Unified Numbering System (UNS) S31600) in accordance with KSC-GP-425 are as follows:

Fitting Dash Number	Fitting size (inch)	Allowable Pressure (psi)
4	1/4	9,900
6	3/8	6,900
8	1/2	7,400
12	3/4	7,000
16	1	6,500
20	1 1/4	6,300
24	1 1/2	5,600
32	2	5,500



Prior to the NASA analysis, the allowable pressures were set by a pressure test in 1964. In that series of tests, the fittings were pressurized to the highest pressures the testers could achieve and the rating was that pressure divided by four (four to one factor of safety against burst). None of the fittings in the test actually burst. The maximum pressure for every size ended up being either the highest pressure they could generate with their equipment or the pressure when a leak occurred. The true factor of safety is much higher than four.

The allowable pressure for the 1 ¼" fitting size from the 1989 analysis and testing is 6,300 psig. That is based on the American Society of Mechanical Engineers Process Piping Code (ASME B31.3) requirements. ASME B31.3 is currently the basis for fluid systems design at KSC. These new ratings will be reflected in the next revision of KSC-SPEC-Z-0008.

If you have any questions, please contact Dr. Eric Thaxton at 321-867-8267 or by e-mail [Eric.A.Thaxton@nasa.gov](mailto:Eric.A.Thaxton@nasa.gov).



Oscar Toledo

cc:  
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