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BSI Standards Publication

Twin ferrule connectors and associated tubing for 316 stainless steel systems – Specification and test methods

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Publishing and copyright information

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Contents

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 54, an inside back cover and a back cover.

Foreword

Publishing information

This British Standard is published by BSI and came into effect on 31 July 2011. It was prepared by Panel MCE/18/-/4, *Connectors and associated components*, under the authority of Technical Committee MCE/18, *Fluid power systems and components*. A list of organizations represented on these committees can be obtained on request to their secretary.

Information about this document

***Product certification/inspection/testing*.** Users of this British Standard are advised to consider the desirability of third-party certification/inspection/witness of testing of product conformity with this British Standard. Users seeking assistance in identifying appropriate conformity assessment bodies or schemes may ask BSI to forward their enquiries to the relevant association.

Users of this standard are also advised to consider the desirability of requesting conformity to BS EN ISO/IEC 17025 and BS EN 45011.

***Assessed capability*.** Users of this British Standard are advised to consider the desirability of quality system assessment and registration against the appropriate standard in the BS EN ISO 9000 series by an accredited third-party certification body.

Hazard warnings

WARNING. This British Standard calls for the use of substances and/or procedures that can be injurious to health if adequate precautions are not taken. It refers only to technical suitability and does not absolve the user from legal obligations relating to health and safety at any stage. Attention is particularly drawn to the danger of bursts, fine jets (which can penetrate the skin), energy release of expanding gases and the use of accumulators.

WARNING. Where tests are performed, the maximum working pressure connector (MWPC) or maximum working pressure tube (MWPT) should not exceed the manufacturer's maximum pressure rating.

WARNING. Do not bleed off air under pressure by undoing connector nuts, as they might separate and cause injury.

The practice(s) of intermixing and/or interchanging are not condoned or recommended within the remit of this British Standard. However, it is recognized that, in practice, system interfaces, modification requirements etc., can make these practices necessary, and for this purpose, this British Standard requires suitable instructions to be made available to the user (see Clause **11**).

Use of this document

This British Standard is intended for use by manufacturers of connectors and designers of systems that use connector assemblies.

BSI permits the reproduction of BS 7993:2011, Table A.3. This reproduction is only permitted where it is necessary for the user to work/record findings on the table during each application of the standard.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its requirements are expressed in sentences in which the principal auxiliary verb is "shall".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Requirements in this standard are drafted in accordance with *The BSI guide to standardization – Section 2: Rules for the structure, drafting and presentation of British Standards*, subclause **11.3.1**, which states, "Requirements should be expressed using wording such as: 'When tested as described in Annex A, the product shall ...'". This means that only those products that are capable of passing the specified test will be deemed to conform to this standard.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Introduction

Twin ferrule connectors provide metal-to-metal seal connections, non-elastomeric seals for leak-free connections to annealed stainless steel tubes. They are for use in applications where operating conditions do not allow elastomeric seals.

Twin ferrule connectors are used to connect tube-to-tube and tube-to-system components, the latter through standardized ports such as pipe threads. This British Standard provides external envelope and tube-end-to-port dimensions that facilitate designing systems that use twin ferrule connectors. It also provides material specifications and minimum performance requirements to ensure the integrity and consistency expected from this type of connector.

This British Standard does not provide detailed descriptions of the contours of connector components. Individual manufacturers determine the fine details of their connector components, and they are continually improving their designs. The nature of these metal-to-metal seals requires consistently compatible components.

The twin ferrule tube connector is designed to have a maximum allowable working pressure that is higher than that of any tubing, as shown in Tables 1 to 22 of this British Standard.

In the case of an all tube-ended connector, such as a union tee, the properly selected tube is the limiting factor in the system. A connector may, however, combine a twin ferrule connector end with another end of different form, such as male or female pipe thread. Pressure ratings for other ends are determined in accordance with applicable standards and may, in fact, be lower than the rating for the twin ferrule tube connector end. The raw material from which the connector is manufactured, either bar stock or a forging may also affect those ratings. As a result, the rating for such other forms is generally the limiting factor for the rating of the entire connector.

1 Scope

This British Standard specifies the characteristics of, and performance requirements for, the tube connector (compression) end(s) of twin ferrule connectors made of 316 stainless steel. It also specifies requirements for 316 stainless steel tubes.

The twin ferrule connectors in this standard are suitable for use with annealed stainless steel tubes with outside diameters from 2 mm to 38 mm and $^{1}/_{16}$ in to 2 in.

This British Standard is applicable to twin ferrule connectors that are intended for the connection of plain end tubes to other tubes and to ports in accordance with BS EN ISO 6149-1, BS EN ISO 1179 and BS EN ISO 9974-1, and other ports agreed between the purchaser and manufacturer. It provides external envelope, tube-end-to-tube-end and tube-end-to-port dimensions that facilitate designing systems that use twin ferrule connectors.

NOTE These twin ferrule connectors can also be used with other austenitic stainless steel tubes, typically 304, 316L, 321, etc.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ANSI B1.20.1, *Pipe threads, general purpose (inch)*

ASME/ANSI B1.1, *Unified inch screw threads (UN and UNR thread form)*

ASME B31.3, *Process piping* [1)]

ASTM A182/A182M, *Standard specification for forged or rolled alloy and stainless steel pipe flanges, forged fittings, and valves and parts for high-temperature service*

ASTM A213/A213M-10, *Standard specification for seamless ferritic and austenitic alloy-steel boiler, superheater, and heat-exchanger tubes*

ASTM A249-10, *Standard specification for welded austenitic steel boiler, superheater, heat exchanger, and condenser tubes*

ASTM A262 *Standard practices for detecting susceptibility to intergranular attack in austenitic stainless steels*

ASTM A269-10, *Standard specification for seamless and welded austenitic stainless steel tubing for general service*

ASTM A276, *Standard specification for stainless steel bars and shapes*

ASTM A351/A351M-10, *Standard specification for castings, austenitic, for pressure-containing parts*

ASTM A479, *Standard specification for stainless steel bars and shapes for use in boilers and other pressure vessels*

ASTM A632-4(2009), *Standard specification for seamless and welded austenitic stainless steel tubing (small-diameter) for general service*

ASTM E18, *Standard test methods for Rockwell hardness of metallic materials*

ASTM E140, *Standard hardness conversion tables for metals (relationship among Brinell hardness, Vickers hardness, Rockwell hardness, Rockwell superficial hardness, Knoop hardness, and Scleroscope hardness)*

BS 1580, *Unified screwed threads*

BS 3643, *ISO metric screw threads*

BS 2000-2 (ISO 2977), *Method of test for petroleum and its products – Part 2: Petroleum products and hydrocarbon solvents – Determination of aniline point and mixed aniline point*

BS 2000-15 (ISO 3016), *Methods of test for petroleum and its products – Part 15: Petroleum products – Determination of pour point*

BS 2000-71.2 (ISO 3105), *Method of test for petroleum and its products – Part 71: Kinematic viscosity – Section 2: Specifications and operating instructions for glass capillary kinematic viscometers*

BS EN 837-1, *Pressure gauges – Part 1: Bourdon tube pressure gauges – Dimensions, metrology, requirements and testing*

BS EN ISO 228-1, *Pipe threads where pressure-tight joints are not made on the threads – Part 1: Dimensions, tolerances and designation*

[1)] This standard also gives an informative reference to ASME B31.3:2008.

BS EN ISO 1179, *Connections for general use and fluid power – Ports and stud ends with ISO 228-1 threads with elastomeric or metal-to-metal sealing*

BS EN ISO 2719 (BS 2000-34), *Determination of flash point – Pensky-Martens closed cup method*

BS EN ISO 6149-1, *Connections for hydraulic fluid power and general use – Ports and stud ends with ISO 261 metric threads and O-ring sealing – Ports with truncated housing for O-ring seal*

BS EN ISO 9227:2006, *Corrosion tests in artificial atmospheres – Salt spray tests*

BS EN ISO 9974-1, *Connections for general use and fluid power – Ports and stud ends with ISO 261 threads with elastomeric or metal-to-metal sealing – Threaded ports*

BS ISO 261, *ISO general purpose metric screw threads – General plan*

BS ISO 5598, *Fluid power systems and components – Vocabulary*

BS ISO 19921, *Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Test methods*

ISO 7-1, *Pipe threads where pressure-tight joints are made on the threads – Part 1: Dimensions, tolerances and designation*

3 Terms and definitions

For the purposes of this British Standard, the terms and definitions given in ISO 5598 and the following apply.

3.1 certification of conformity
action by a third party, demonstrating that adequate confidence is provided that a duly identified product, process or service is in conformity with a specific standard or other normative document

3.2 connector
leak-proof device to connect tubes to one another, or to equipment

3.3 face-to-centre dimension
distance from the face of an outlet to the centre axis of an angularly disposed outlet

3.4 face-to-face dimension
distance between the two parallel faces of axially aligned outlets of a fitting

3.5 fire resistance
ability of a connector to fulfil for a stated period of time the required stability, integrity, thermal insulation and/or expected duty specified in a standard fire resistance test

3.6 interchanging
using one manufacturer's assembled nut and ferrule system with another manufacturer's body

NOTE This practice usually arises where there is a similarity of key body elements among certain manufacturers.

3.7 intermixing
random mixing of components, particularly nuts and ferrules including materials and dimensions, which might or might not be compatible

3.8 maximum working pressure connector (MWPC)
maximum permissible working pressure at which a connector is rated

NOTE See Tables 23 to 26.

3.9 maximum working pressure tube (MWPT)
maximum permissible working pressure at which a tube is rated against a stated bending allowance and stated factor of safety

NOTE See Tables 23 to 26.

3.10 proof pressure
pressure, applied after assembly, in excess of maximum working pressure, which causes no damage or subsequent malfunction

3.11 test assembly
assembly of tube and connectors intended for use in tests

NOTE Test assemblies are shown in Figures A.1, A.2 and A.3.

3.12 test connector
twin ferrule connector under test

3.13 test manifold block
part of the test rig possessing port arrangements to accept test connector assemblies

4 Design

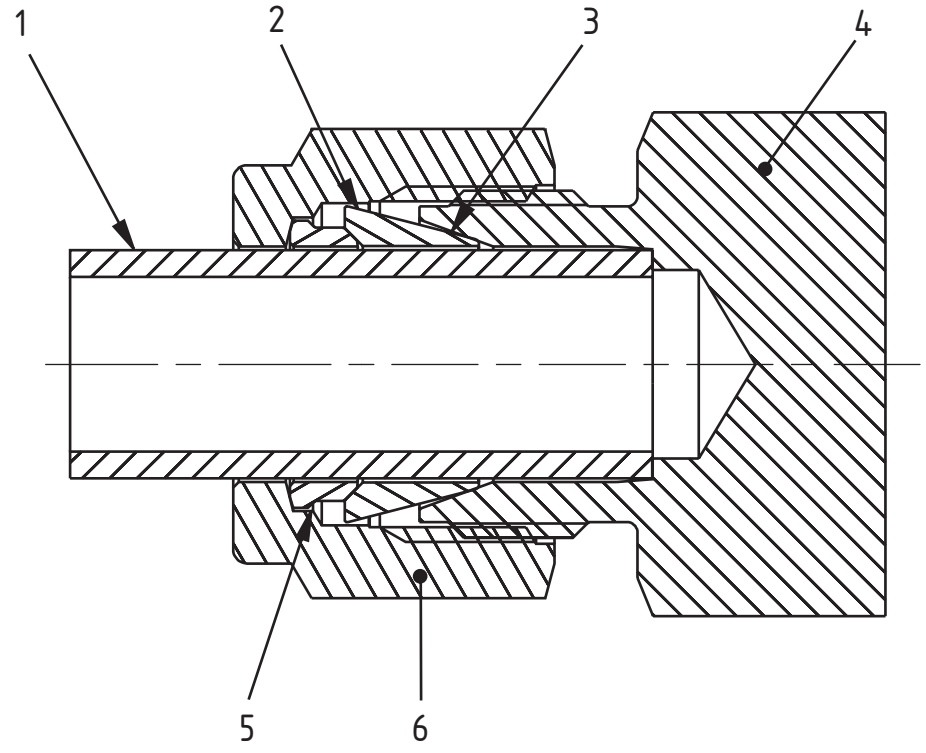
NOTE 1 Twin ferrule connectors are separable and are mechanically attached to squarely cut, deburred plain-end tubes. The components of the connector comprise a body, two ferrules and a threaded nut. The front ferrule provides the primary seal through radial compression around the outer diameter of the tube and axial interface with the connector body. The rear ferrule acts as the primary mechanical holding device for gripping the tube, and the nut screws onto the body to hold the assembly together.

NOTE 2 This clause provides a description of the contours and dimensions of the bodies and their principal nominal included angle of 40° (see Figure 1), whilst the ferrule and mating nut design is left to the manufacturers to determine the fine details of these components. They are thus unrestricted to allow continual improvement of their designs.

NOTE 3 Figure 1 shows the cross-section and component parts of a typical twin ferrule connector.

NOTE 4 By convention, NPT threaded components are not marked. Non-NPT threaded products should carry markings on the bodies only. The thread form of stud ends should be marked on the bodies and optionally with the tube size on any nuts.

Figure 1 **Cross-section of a typical twin ferrule connector**



Key
1 Tube
2 Front ferrule
3 40° inc. cone angle (ref)
4 Connector body
5 Rear ferrule
6 Nut

4.1 Connectors

Twin ferrule connectors shall be in accordance with the appropriate figure and table as follows:

NOTE The designated tube size numbers for metric and imperial tube outside diameters are shown in Table 1 and Table 2 respectively.

- metric tube ends shall be in accordance with Figure 2 and Table 1;
- fractional tube ends shall be in accordance with Figure 3 and Table 2;
- compression end nuts shall be in accordance with Figure 4, and Table 3 or Table 4;
- union connectors shall be in accordance with Figure 5, and Table 5 or Table 6;
- male bulkhead connectors shall be in accordance with Figure 6, and Table 7 or Table 8;
- equal elbows shall be in accordance with Figure 7, and Table 9 or Table 10;
- equal tees shall be in accordance with Figure 8, and Table 11 or Table 12;
- equal crosses shall be in accordance with Figure 9, and Table 13 or Table 14;
- male stud connectors (NPT) shall be in accordance with Figure 10, and Table 15 or Table 16;
- male stud connectors (BSPT) shall be in accordance with Figure 11, and Table 17 or Table 18;
- male stud connectors (BSPP) shall be in accordance with Figure 12, and Table 19 or Table 20;
- bulkhead connectors shall be in accordance with Figure 13, and Table 21 or Table 22.

4.2 Dimensions of finished parts

NOTE In Tables 1 to 22, C is a face-to-face dimension and N is a face-to-centre dimension. All the specified dimensions apply to finished parts, including any plating or other treatments. The values of dimensions C, D and L are given for the finger-tight position.

Dimensions shall be subject to a general tolerance of $\pm 1/16$ in (1.6 mm) where not otherwise specified. Dimension C shall be subject to an abutment length tolerance of $\pm 1/6$ in (0.4 mm).

4.3 Dimensions of across-flats

The across-flats dimensions for nuts of the connectors shall be in accordance with the values specified in Table 1 and Table 2.

NOTE Where across-flats dimensions are quoted, imperial sizes may be replaced by the nearest metric equivalent and vice versa.

4.4 Passage tolerances

Where internal body passages are machined from opposite ends, the offset at the meeting point shall not exceed 0.4 mm. No cross-sectional area at a junction of passages shall be less than that of the smallest passage.

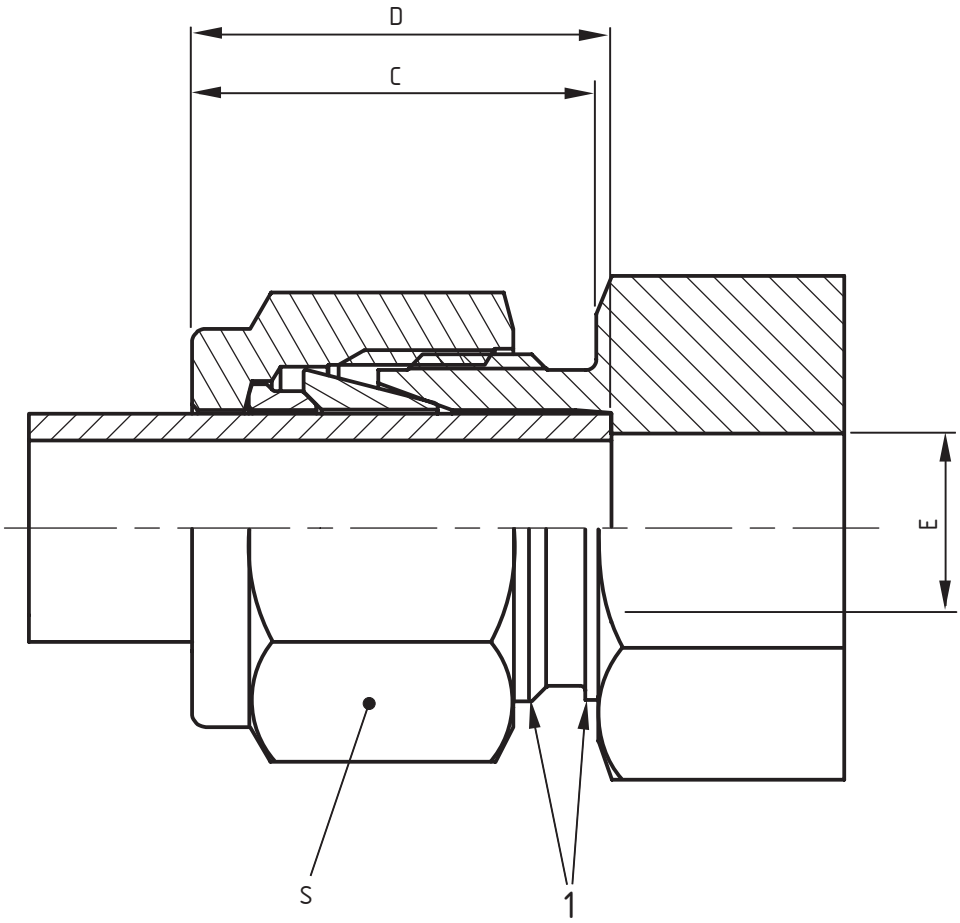
4.5 Angular tolerances

Angular tolerances on axes of ends of elbows, tees and crosses shall be ±1.5° for all connectors.

4.6 Contour details

Details of non-critical contours shall be chosen by the manufacturer. However, abrupt reduction of sections shall be avoided and junctions of small external sections and adjoining sections that are relatively heavy shall be blended by means of ample fillets where possible.

Figure 2 **Cross-section of a metric tube end**



Key
1 Metric identification shoulder on nut and body
C Back of nut to body hexagon face
D Tube insertion depth from back of nut
E Through hole diameter
S Across flats hexagon

Table 1 **Requirements for tube ends for tubes with metric outside diameter sizes**

Designated tube size number [A]	Tube O.D. [B]	Requirements					
		Straight thread for nut end of tube fitting [C]	C [D] ±0.4 mm	S	S	E	D [D]
	mm	in/mm	mm	mm	in	mm	mm
M2	2	$^{5}/_{16}$ in × 20 UN	15.3	12.0	$^{1}/_{2}$	1.7	12.9
M3	3	$^{5}/_{16}$ in × 20 UN	15.3	12.0	$^{1}/_{2}$	2.4	12.9
M4	4	$^{3}/_{8}$ in × 20 UN	16.1	12.0	$^{1}/_{2}$	2.4	13.7
M6	6	$^{7}/_{16}$ in × 20 UN	17.7	14.0	$^{9}/_{16}$	4.8	15.3
M8	8	$^{1}/_{2}$ in × 20 UN	18.6	16.0	$^{5}/_{8}$	6.4	16.2
M10	10	$^{5}/_{8}$ in × 20 UN	19.5	19.0	$^{11}/_{16}$	7.9	17.2
M12	12	$^{3}/_{4}$ in × 20 UN	22.0	22.0	$^{7}/_{8}$	9.5	22.8
M14	14	$^{7}/_{8}$ in × 20 UN	22.0	25.0	1	11.1	24.4
M15	15	$^{7}/_{8}$ in × 20 UN	22.0	25.0	1	11.9	24.4
M16	16	$^{7}/_{8}$ in × 20 UN	22.0	25.0	1	12.7	24.4
M18	18	1 in × 20 UN	22.0	30.0	$1^{1}/_{8}$	15.1	24.4
M20	20	$1^{1}/_{8}$ in × 20 UN	22.0	32.0	$1^{1}/_{4}$	15.9	26.0
M22	22	$1^{1}/_{8}$ in × 20 UN	22.0	32.0	$1^{1}/_{4}$	18.3	26.0
M25	25	$1^{5}/_{16}$ in × 20 UN	26.5	38.0	$1^{1}/_{2}$	21.8	31.3
M28	28	M37 × 1.5 mm	36.6	46.0	$1^{7}/_{8}$	21.8	36.6
M30	30	M40 × 1.5 mm	39.2	50.0	$2^{1}/_{4}$	26.2	39.6
M32	32	M42 × 1.5 mm	41.6	50.0	$2^{1}/_{4}$	28.6	42.0
M38	38	M50 × 1.5 mm	47.9	60.0	$2^{3}/_{4}$	33.7	49.4

NOTE All tolerances are ±1.6 mm ($^{1}/_{16}$ in) unless otherwise stated.

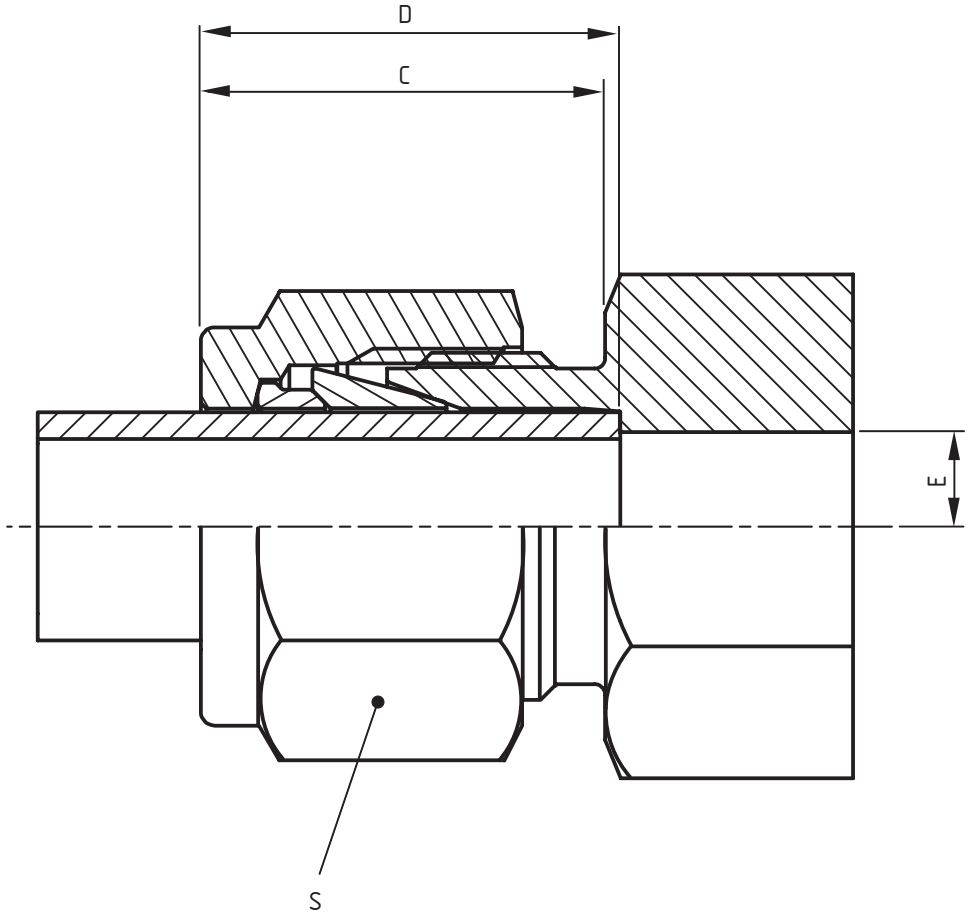
[A] See **6.9**.

[B] Tolerances for the tube outside diameter shall be in accordance with ASTM A269.

[C] UN = Unified thread conforming to BS 1580; M = metric thread conforming to BS 3643.

[D] Average value.

Figure 3 **Cross-section of a fractional tube end**



Key
C Back of nut to body hexagon face
D Tube insertion depth from back of nut
E Through hole diameter
S Across flats hexagon

Table 2 **Requirements for tube ends for tubes with imperial outside diameter sizes**

Designated tube size number [A]	Tube O.D. [B]	Requirements					
		Straight thread for nut end of tube fitting [C]	C [D] ±1/64 in	S	S	E	D [D]
	in	in	in	in	mm	in	in
1	1/16	No. 10 × 32 UN	0.43	5/16	8	0.052	0.34
2	1/8	5/16 in × 20 UN	0.60	7/16	12	0.093	0.50
3	3/16	3/8 in × 20 UN	0.64	1/2	12	0.125	0.54
4	1/4	7/16 in × 20 UN	0.70	9/16	14	0.187	0.60
5	5/16	1/2 in × 20 UN	0.73	5/8	16	0.250	0.64
6	3/8	9/16 in × 20 UN	0.76	11/16	19	0.281	0.67
8	1/2	3/4 in × 20 UN	0.87	7/8	22	0.406	0.90
10	5/8	7/8 in × 20 UN	0.87	1	25	0.500	0.96
12	3/4	1 in × 20 UN	0.87	1 1/8	30	0.625	0.96
14	7/8	1 1/8 in × 20 UN	0.87	1 1/4	32	0.750	1.03
16	1	1 5/16 in × 20 UN	1.05	1 1/2	38	0.875	1.24
20	1 1/4	1 5/8 in × 20 UN	1.52	1 7/8	46	1.090	1.61
24	1 1/2	1 5/16 in × 20 UN	1.77	2 1/4	60	1.340	1.96
32	2	2 5/8 in × 20 UN	2.47	3	76	1.810	2.65

NOTE All tolerances are ±1.6 mm (1/16 in) unless otherwise stated.

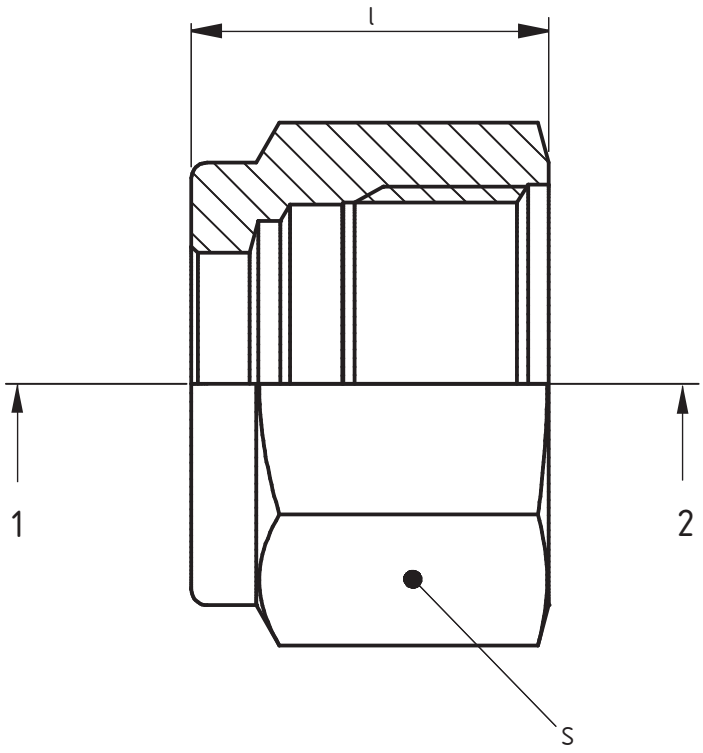
[A] See **6.9**.

[B] Tolerances for the tube outside diameter shall be in accordance with ASTM A269.

[C] UN = Unified thread conforming to BS 1580.

[D] Average value.

Figure 4 **Compression end nut**



Key
1 Tube outside diameter
2 Thread
l Back of nut to centre line (shapes)
S Across flats hexagon

Table 3 **Requirements for compression end nuts for tubes with metric outside diameter sizes**

Tube O.D. [A]	Requirements			
	Straight thread [B]	l	S	S
mm	in/mm	mm	mm	in
2	$^{5}/_{16}$ in × 20 UN	11.9	12.0	$^{7}/_{16}$
3	$^{5}/_{16}$ in × 20 UN	11.9	12.0	$^{7}/_{16}$
4	$^{3}/_{8}$ in × 20 UN	11.9	12.0	$^{1}/_{2}$
6	$^{7}/_{16}$ in × 20 UN	12.7	14.0	$^{9}/_{16}$
8	$^{1}/_{2}$ in × 20 UN	13.5	16.0	$^{5}/_{8}$
10	$^{5}/_{8}$ in × 20 UN	15.1	19.0	$^{3}/_{4}$
12	$^{3}/_{4}$ in × 20 UN	17.5	22.0	$^{7}/_{8}$
14	$^{7}/_{8}$ in × 20 UN	17.5	25.0	$^{15}/_{16}$
15	$^{7}/_{8}$ in × 20 UN	17.5	25.0	$^{15}/_{16}$
16	$^{7}/_{8}$ in × 20 UN	17.5	25.0	1
18	1 in × 20 UN	17.5	30.0	$1^{3}/_{16}$
20	$1^{1}/_{8}$ in × 20 UN	17.5	32.0	$1^{1}/_{4}$
22	$1^{1}/_{8}$ in × 20 UN	17.5	32.0	$1^{1}/_{4}$
25	$1^{5}/_{16}$ in × 20 UN	20.6	38.0	$1^{1}/_{2}$
28	M37 × 1.5 mm	30.6	46.0	$1^{7}/_{8}$
30	M40 × 1.5 mm	32.7	50.0	2
32	M42 × 1.5 mm	34.4	50.0	2
38	M50 × 1.5 mm	40.6	60.0	$2^{3}/_{8}$

NOTE All tolerances are ±1.6 mm ($^{1}/_{16}$ in) unless otherwise stated.

[A] Tolerances for the tube outside diameter shall be in accordance with ASTM A269.

[B] UN = Unified thread conforming to BS 1580; M = metric thread to conforming to BS 3643.

Table 4 **Requirements for compression end nuts for tubes with imperial outside diameter sizes**

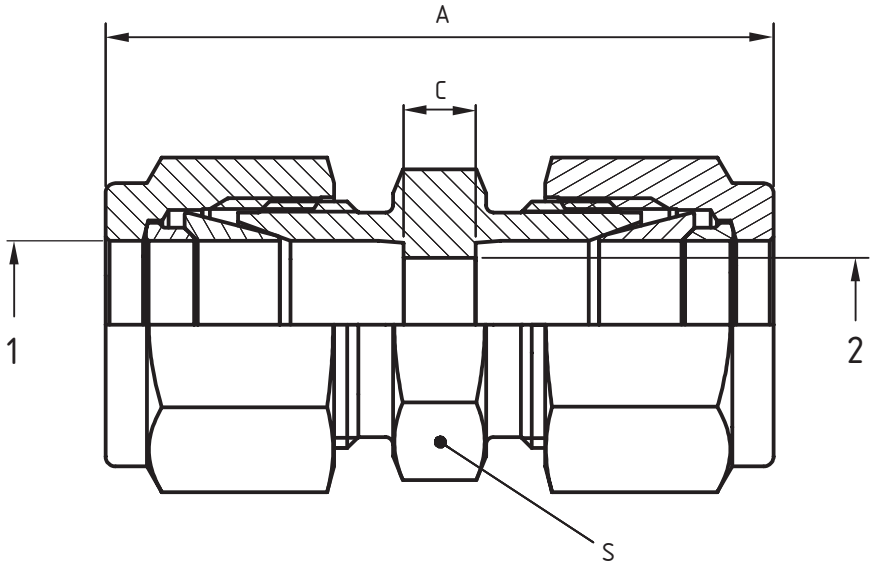
Tube O.D. [A]	**Requirements**			
	Straight thread [B]	**l**	**S**	**S**
In	in	in	in	mm
1/16	No. 10 × 32 UN	0.310	5/16	8.0
1/8	5/16 × 20 UN	0.470	7/16	12.0
3/16	3/8 × 20 UN	0.470	1/2	12.0
1/4	7/16 × 20 UN	0.500	9/16	14.0
5/16	1/2 × 20 UN	0.530	5/8	16.0
3/8	9/16 × 20 UN	0.560	11/16	19.0
1/2	3/4 × 20 UN	0.690	7/8	22.0
5/8	7/8 × 20 UN	0.690	1	25.0
3/4	1 × 20 UN	0.690	1 1/8	30.0
7/8	1 1/8 × 20 UN	0.690	1 1/4	32.0
1	1 5/16 × 20 UN	0.810	1 1/2	38.0
1 1/4	1 5/8 × 20 UN	1.250	1 7/8	46.0
1 1/2	1 15/16 × 20 UN	1.500	2 1/4	57.0
2	2 5/8 × 20 UN	2.062	3	76.0

NOTE All tolerances are ±1.6 mm (1/16 in) unless otherwise stated.

[A] Tolerances for the tube outside diameter shall be in accordance with ASTM A269.

[B] UN = Unified thread conforming to BS 1580.

Figure 5 **Union connector**



Key
1 Tube outside diameter
2 Through-bore
A Overall length
C Back of nut to body hexagon face
S Across flats hexagon

Table 5 **Requirements for union connectors for tubes with metric outside diameter sizes**

Tube O.D. [A)]	**Requirements**			
	Through bore	**A**	**C ±0.4 mm**	**S**
mm	mm	mm	mm	mm
2	1.7	35.6	9.8	12
3	2.4	35.3	9.5	12
4	2.4	37.4	10.0	12
6	4.8	41.2	10.6	14
8	6.4	43.2	10.8	15
10	7.9	46.2	11.8	18
12	9.5	51.2	5.6	22
14	11.1	52.0	3.2	24
15	11.9	52.0	3.2	24
16	12.7	52.0	3.2	24
18	15.1	53.5	4.7	27
20	15.9	55.0	3.0	30
22	18.3	55.0	3.0	30
25	21.8	65.1	2.5	35
28	21.8	85.0	11.8	41
30	26.2	92.7	13.5	46
32	28.6	97.3	13.3	46
38	33.7	113.6	14.8	55

NOTE All tolerances are ±1.6 mm (1/16 in) unless otherwise stated.

[A)] Tolerances for the tube outside diameter shall be in accordance with ASTM A269.

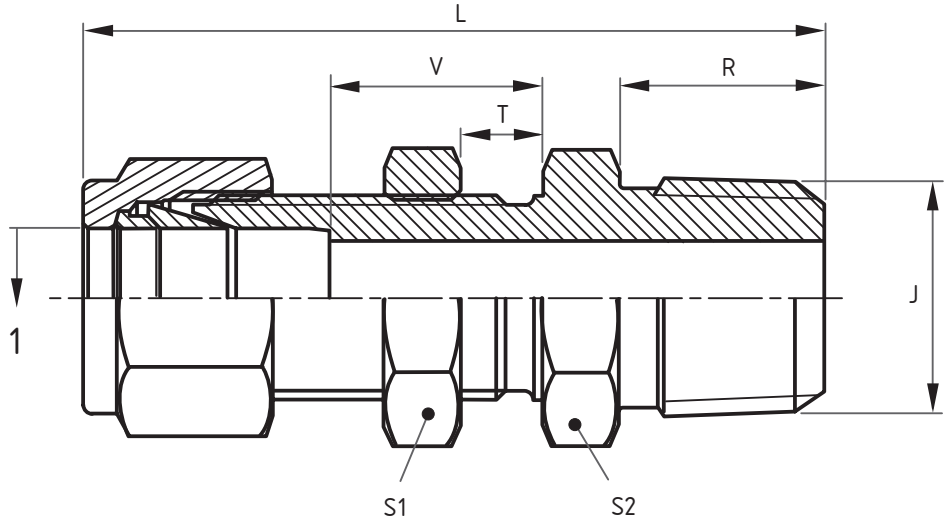
Table 6 **Requirements for union connectors for tubes with imperial outside diameter sizes**

Tube O.D. [A)]	**Requirements**			
	Through bore	**A**	**C ±1/64 in**	**S**
in	in	in	in	in
1/16	0.052	0.990	0.310	5/16
1/8	0.093	1.390	0.390	7/16
3/16	0.125	1.480	0.400	7/16
1/4	0.187	1.620	0.420	1/2
5/16	0.250	1.700	0.420	9/16
3/8	0.281	1.770	0.430	5/8
1/2	0.406	2.020	0.220	13/16
5/8	0.500	2.050	0.130	15/16
3/4	0.625	2.110	0.190	1 1/16
7/8	0.750	2.180	0.120	1 3/16
1	0.875	2.570	0.090	1 3/8
1 1/4	1.090	3.610	0.370	1 3/4
1 1/2	1.340	4.230	0.290	2 1/8
2	1.810	5.880	0.560	2 3/4

NOTE All tolerances are ±1.6 mm (1/16 in) unless otherwise stated.

[A)] Tolerances for the tube outside diameter shall be in accordance with ASTM A269.

Figure 6 **Male bulkhead connector**



Key
1 Tube outside diameter
J Pipe thread size
L Back of nut to centre line (shapes)
R Pipe thread length
S1 Across flats hexagon (lock nut)
S2 Across flats hexagon (body)
T Maximum bulkhead thickness
V Tube abutment face to hexagon face on bulkhead

Table 7 **Requirements for male bulkhead connectors for tubes with metric outside diameter sizes**

Tube O.D. [A]	**Requirements**							
	J NPT thread [B]	**L**	**R**	**V ±0.4 mm**	**S1**	**S2**	**Bulk-head hole drill size**	**T**
mm	in	mm	mm	mm	mm	mm	mm	mm
6	1/8	49.6	9.5	18.4	16	16	11.5	10.2
6	1/4	53.5	14.3	18.4	16	16	11.5	10.2
8	1/8	52.3	9.5	19.8	18	17	13.1	11.2
8	1/4	57.5	14.3	19.8	18	17	13.1	11.2
10	1/4	58.4	14.3	19.8	22	21	16.3	11.2
10	3/8	58.4	14.3	19.8	22	21	16.3	11.2
10	1/2	63.1	19.0	19.8	22	21	16.3	11.2
12	1/4	63.3	14.3	19.1	24	24	19.5	12.7
12	3/8	64.5	14.3	19.1	24	24	19.5	12.7
12	1/2	67.5	19.0	19.1	24	24	19.5	12.7

NOTE All tolerances are ±1.6 mm (1/16 in) unless otherwise stated.

[A] Tolerances for the tube outside diameter shall be in accordance with ASTM A269.

[B] NPT threads shall conform to ANSI B1.20.1.

Table 8 **Requirements for male bulkhead connectors for tubes with imperial outside diameter sizes**

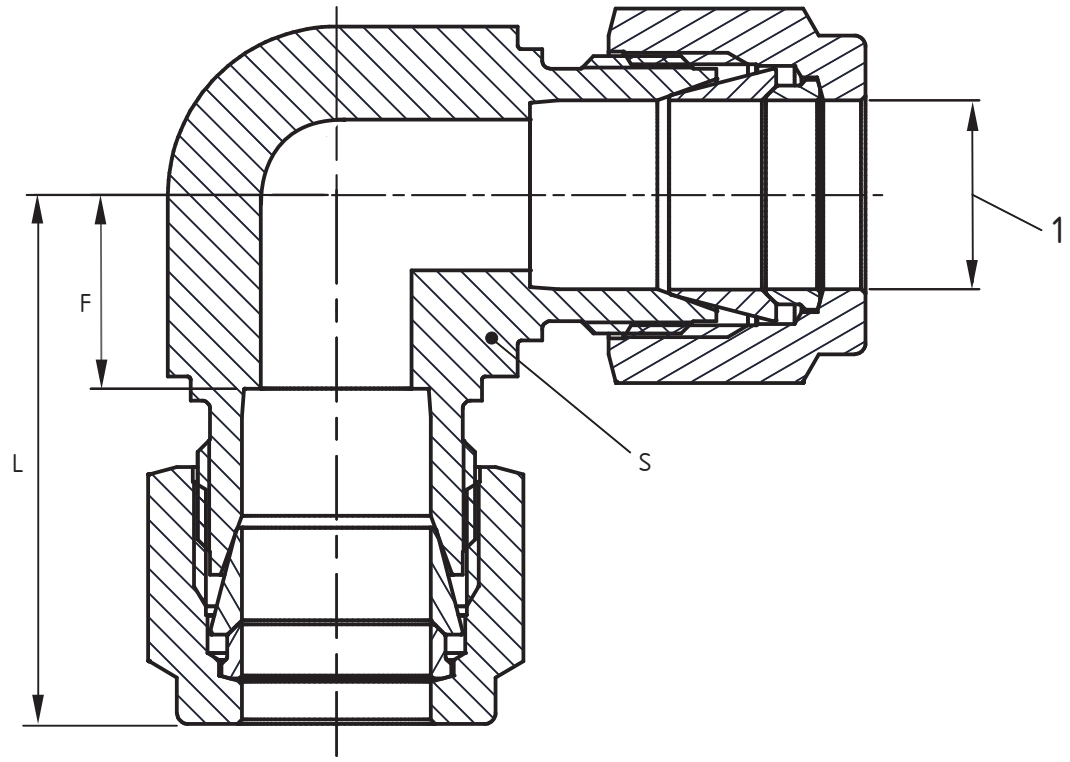
Tube O.D. [A]	Requirements							
	J NPT thread [B]	L	R	V $\pm 1/64$ in	S1	S2	Bulkhead hole drill size	T
in	in	in	in	in	in	in	in	in
$1/16$	$1/8$	1.270	0.380	0.340	$15/16$	$15/16$	$13/64$	$1/2$
$1/8$	$1/8$	1.830	0.380	0.730	$1/2$	$1/2$	$21/64$	$1/2$
$1/4$	$1/8$	1.950	0.380	0.710	$5/8$	$5/8$	$29/64$	$17/32$
$1/4$	$1/4$	2.132	0.560	0.710	$5/8$	$5/8$	$29/64$	$17/32$
$1/4$	$3/8$	2.162	0.560	0.710	$5/8$	$5/8$	$29/64$	$17/32$
$1/4$	$1/2$	2.374	0.750	0.710	$7/8$	$5/8$	$29/64$	$17/32$
$3/8$	$1/4$	2.265	0.560	0.770	$3/4$	$3/4$	$37/64$	$9/16$
$3/8$	$3/8$	2.265	0.560	0.770	$3/4$	$3/4$	$37/64$	$9/16$
$3/8$	$1/2$	2.480	0.750	0.770	$7/8$	$3/4$	$37/64$	$9/16$
$1/2$	$3/8$	2.494	0.560	0.750	$15/16$	$15/16$	$49/64$	$19/32$
$1/2$	$1/2$	2.712	0.750	0.750	$15/16$	$15/16$	$49/64$	$19/32$

NOTE All tolerances are ±1.6 mm ($1/16$ in) unless otherwise stated.

[A] Tolerances for the tube outside diameter shall be in accordance with ASTM A269.

[B] NPT threads shall conform to ANSI B1.20.1.

Figure 7 **Equal elbow**



Key
1 Tube outside diameter
F Tube abutment face to centre line (shapes)
L Back of nut to centre line (shapes)
S Across flats hexagon

Table 9 **Requirements for equal elbows for tubes with metric outside diameter sizes**

Tube O.D. [A)]	**Requirements**		
	L	**F** ±0.4 mm	**S**
mm	mm	mm	in/mm
3	22.3	9.4	$^{3}/_{8}$ in
4	25.4	11.7	$^{1}/_{2}$ in
6	27.0	11.7	$^{1}/_{2}$ in
8	28.8	12.6	$^{9}/_{16}$ in
10	31.5	14.3	$^{11}/_{16}$ in
12	36.0	13.2	$^{13}/_{16}$ in
14	38.1	13.7	$^{15}/_{16}$ in
15	38.0	13.6	$^{15}/_{16}$ in
16	38.0	13.6	$^{15}/_{16}$ in
18	39.8	15.4	$1^{1}/_{16}$ in
20	44.6	18.6	$1^{3}/_{8}$ in
22	44.6	18.6	$1^{3}/_{8}$ in
25	49.1	17.8	$1^{3}/_{8}$ in
28	64.0	27.4	41 mm
30	69.9	30.3	46 mm
32	72.3	30.3	46 mm
38	84.0	34.6	55 mm

NOTE All tolerances are ±1.6 mm ($^{1}/_{16}$ in) unless otherwise stated.

[A)] Tolerances for the tube outside diameter shall be in accordance with ASTM A269.

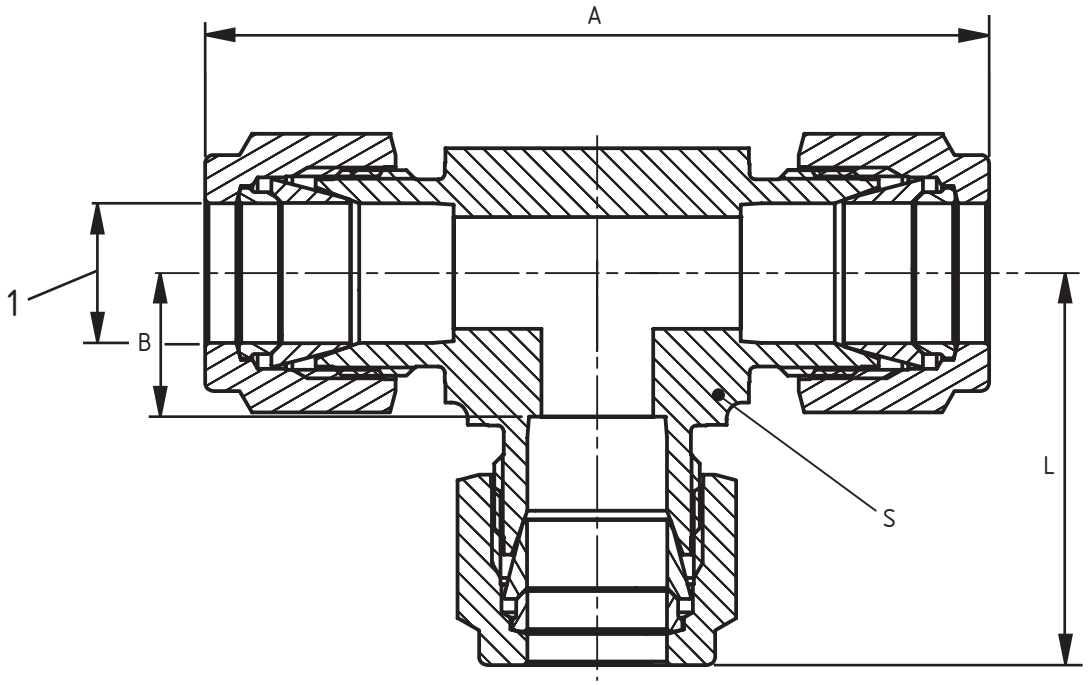
Table 10 **Requirements for equal elbows for tubes with imperial outside diameter sizes**

Tube O.D. [A)]	**Requirements**		
	L	**F** ±$^{1}/_{64}$ in	**S**
in	in	in	in
$^{1}/_{16}$	0.710	0.370	$^{3}/_{8}$
$^{1}/_{8}$	0.880	0.380	$^{3}/_{8}$
$^{3}/_{16}$	1.000	0.460	$^{1}/_{2}$
$^{1}/_{4}$	1.060	0.460	$^{1}/_{2}$
$^{5}/_{16}$	1.170	0.530	$^{5}/_{8}$
$^{3}/_{8}$	1.200	0.530	$^{5}/_{8}$
$^{1}/_{2}$	1.420	0.520	$^{13}/_{16}$
$^{5}/_{8}$	1.430	0.470	$^{7}/_{8}$
$^{3}/_{4}$	1.560	0.600	$1^{1}/_{16}$
$^{7}/_{8}$	1.760	0.730	$1^{3}/_{8}$
1	1.940	0.700	$1^{3}/_{8}$
$1^{1}/_{4}$	2.610	0.990	$1^{5}/_{8}$
$1^{1}/_{2}$	3.060	1.090	$1^{7}/_{8}$
2	4.220	1.560	$2^{13}/_{16}$

NOTE All tolerances are ±1.6 mm ($^{1}/_{16}$ in) unless otherwise stated.

[A)] Tolerances for the tube outside diameter shall be in accordance with ASTM A269.

Figure 8 **Equal tee**



Key
1 Tube outside diameter
A Overall length
B Tube abutment face to tube abutment face
L Back of nut to centre line (shapes)
S Across flats hexagon

Table 11 **Requirements for equal tees for tubes with metric outside diameter sizes**

Tube O.D. [A]	**Requirements**			
	A	**L**	**B** ±0.4 mm	**S**
mm	mm	mm	mm	in/mm
2	44.7	22.3	18.9	$^{3}/_{8}$ in
3	44.7	22.3	18.9	$^{3}/_{8}$ in
4	50.8	25.4	23.4	$^{1}/_{2}$ in
6	53.9	27.0	23.3	$^{1}/_{2}$ in
8	59.7	29.9	27.3	$^{9}/_{16}$ in
10	63.0	31.5	28.6	$^{11}/_{16}$ in
12	72.0	36.0	26.4	$^{13}/_{16}$ in
14	77.6	38.8	28.8	$^{15}/_{16}$ in
15	77.6	38.8	28.8	$^{15}/_{16}$ in
16	77.6	38.8	28.8	$^{15}/_{16}$ in
18	79.5	38.8	30.7	$1^{1}/_{16}$ in
20	89.3	44.6	37.3	$1^{3}/_{8}$ in
22	89.3	44.6	37.3	$1^{3}/_{8}$ in
25	98.3	49.1	35.7	$1^{3}/_{8}$ in
28	128.0	64.0	54.8	41 mm
30	139.7	69.9	60.5	46 mm
32	144.6	72.3	60.6	46 mm
38	168.0	84.0	69.2	55 mm

NOTE All tolerances are ±1.6 mm ($^{1}/_{16}$ in) unless otherwise stated.

[A] Tolerances for the tube outside diameter shall be in accordance with ASTM A269.

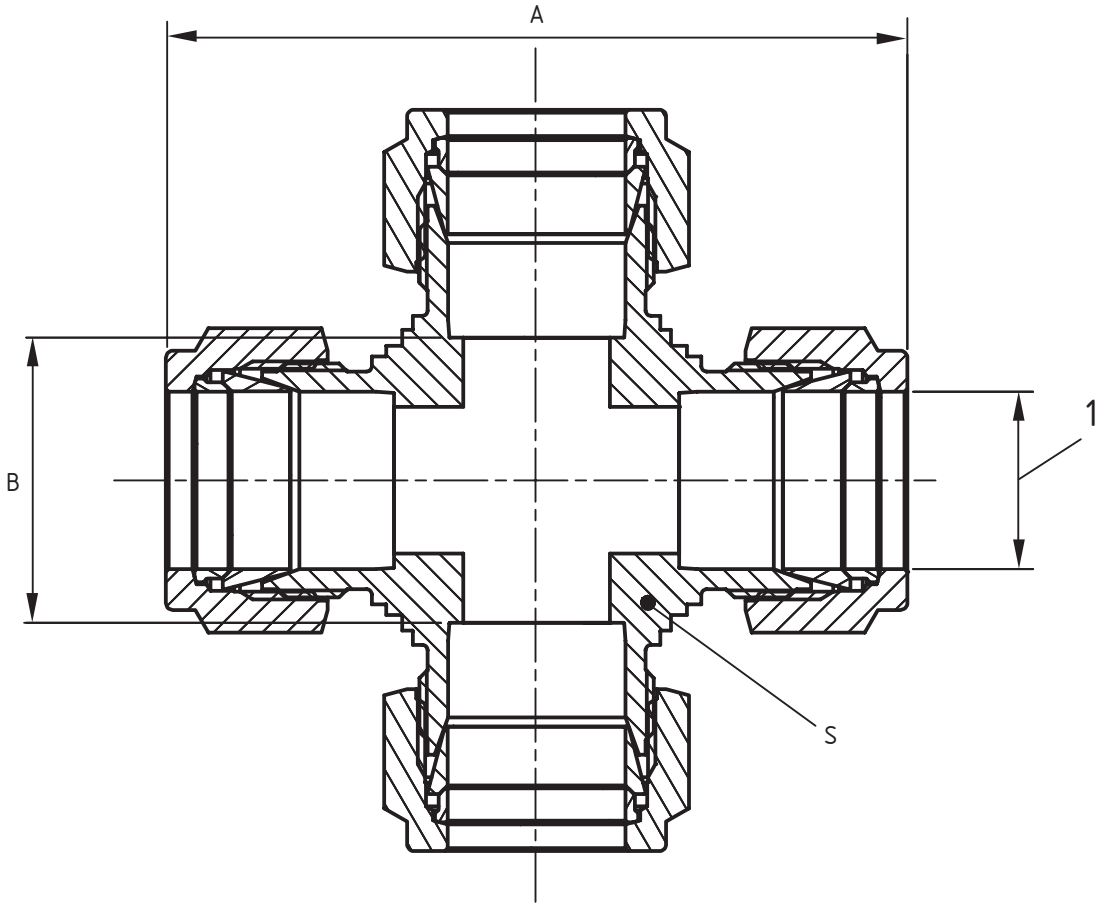
Table 12 **Requirements for equal tees for tubes with imperial outside diameter sizes**

Tube O.D. [A]	**Requirements**			
	A	**L**	**B** ±$^{1}/_{64}$ in	**S**
in	in	in	in	in
$^{1}/_{16}$	1.420	0.710	0.720	$^{3}/_{8}$
$^{1}/_{8}$	1.760	0.880	0.760	$^{3}/_{8}$
$^{3}/_{16}$	1.920	0.960	0.840	$^{1}/_{2}$
$^{1}/_{4}$	2.120	1.060	0.920	$^{1}/_{2}$
$^{5}/_{16}$	2.340	1.170	1.060	$^{5}/_{8}$
$^{3}/_{8}$	2.400	1.200	1.080	$^{5}/_{8}$
$^{1}/_{2}$	2.840	1.420	1.040	$^{13}/_{16}$
$^{5}/_{8}$	3.060	1.530	1.140	$^{7}/_{8}$
$^{3}/_{4}$	3.140	1.570	1.220	$1^{1}/_{16}$
$^{7}/_{8}$	3.520	1.760	1.480	$1^{3}/_{8}$
1	3.860	1.930	1.400	$1^{3}/_{8}$
$1^{1}/_{4}$	5.240	2.610	2.000	$1^{5}/_{8}$
$1^{1}/_{2}$	6.140	3.070	2.200	$1^{7}/_{8}$
2	8.440	4.220	3.120	$2^{13}/_{16}$

NOTE All tolerances are ±1.6 mm ($^{1}/_{16}$ in) unless otherwise stated.

[A] Tolerances for the tube outside diameter shall be in accordance with ASTM A269.

Figure 9 **Equal cross**



Key
1 Tube outside diameter
A Overall length
B Tube abutment face to tube abutment face
S Across flats hexagon

Table 13 **Requirements for equal crosses for tubes with metric outside diameter sizes**

Tube O.D. [A)]	**Requirements**		
	A	**B** **±0.4 mm**	**S**
mm	mm	mm	in
3	44.7	18.9	$^{7}/_{16}$
4	50.8	23.4	$^{1}/_{2}$
6	53.9	23.3	$^{1}/_{2}$
8	59.7	27.3	$^{5}/_{8}$
10	67.0	32.6	$^{13}/_{16}$
12	72.0	26.4	$^{13}/_{16}$
16	74.0	25.2	$^{15}/_{16}$
18	76.6	27.8	$1^{1}/_{16}$
20	89.3	37.3	$1^{3}/_{8}$
25	98.3	35.7	$1^{3}/_{8}$

NOTE All tolerances are ±1.6 mm ($^{1}/_{16}$ in) unless otherwise stated.

[A)] Tolerances for the tube outside diameter shall be in accordance with ASTM A269.

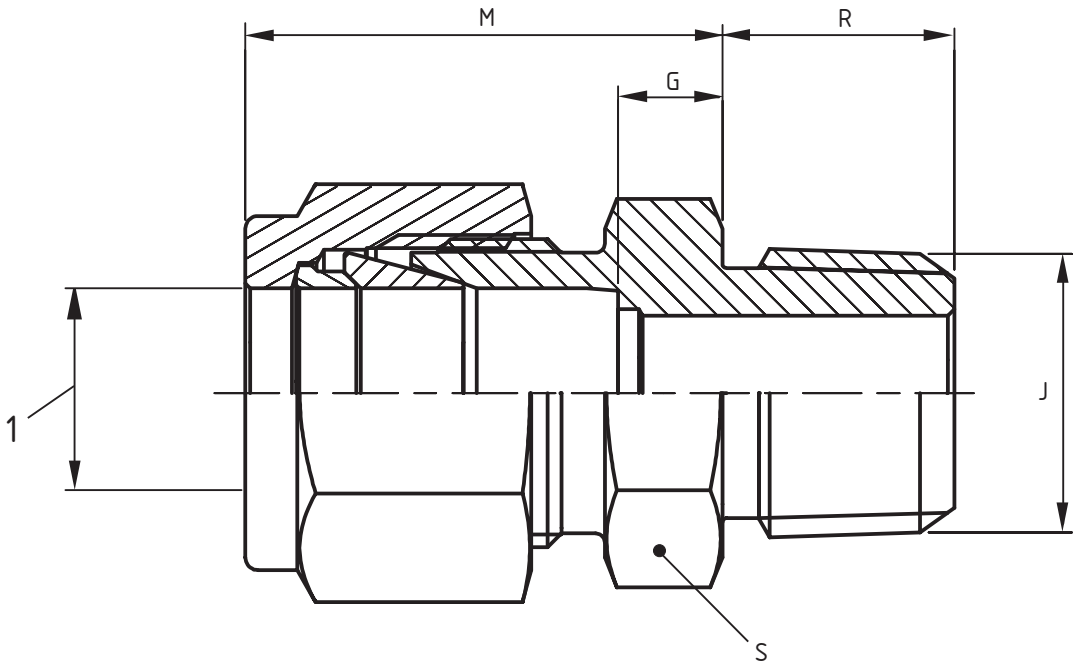
Table 14 **Requirements for equal crosses for tubes with imperial outside diameter sizes**

Tube O.D. [A]	**Requirements**		
	A	**B** $\pm 1/64$ **in**	**S**
in	in	in	in
$1/8$	1.760	0.760	$7/16$
$3/16$	1.920	0.840	$7/16$
$1/4$	2.120	0.920	$7/16$
$5/16$	2.340	1.060	$9/16$
$3/8$	2.400	1.080	$9/16$
$1/2$	2.840	1.040	$3/4$
$5/8$	2.860	0.940	$1\,1/16$
$3/4$	3.140	1.220	$1\,1/16$
$7/8$	3.520	1.460	$1\,5/16$
1	3.860	1.400	$1\,5/16$

NOTE All tolerances are ±1.6 mm (1/16 in) unless otherwise stated.

[A] Tolerances for the tube outside diameter shall be in accordance with ASTM A269.

Figure 10 **Male stud connector (NPT)**



Key
1 Tube outside diameter
G Tube abutment face to hexagon face of pipe thread end
J Pipe thread size
M Back of nut to hexagon face of pipe thread end
R Pipe thread length
S Across flats hexagon

Table 15 **Requirements for male stud connectors (NPT) for tubes with metric outside diameter sizes**

Tube O.D. [A]	Requirements				
	J NPT thread [B]	M	R	G ±0.4 mm	S
mm	in	mm	mm	mm	mm
2	1/8	20.2	9.5	7.3	12
3	1/8	20.2	9.5	7.3	12
4	1/8	21.7	9.5	8.0	12
6	1/4	23.8	14.3	8.5	14
8	1/4	24.5	14.3	8.3	15
10	3/8	26.6	14.3	9.4	18
12	1/2	29.9	19.1	7.1	22
14	1/2	29.9	19.1	5.5	24
15	1/2	29.9	19.1	5.5	24
16	1/2	29.9	19.1	5.5	24
18	3/4	31.5	19.1	7.1	27
20	3/4	33.2	19.1	7.2	30
22	3/4	33.2	19.1	7.2	35
25	1	38.5	23.8	7.2	35
28	1	48.6	23.8	12.0	41
30	1 1/4	53.4	23.8	13.8	46
32	1 1/4	55.8	23.8	13.8	46
38	1 1/2	65.4	26.2	16.0	55

NOTE All tolerances are ±1.6 mm (1/16 in) unless otherwise stated.

[A] Tolerances for the tube outside diameter shall be in accordance with ASTM A269.

[B] NPT threads shall conform to ANSI B1.20.1.

Table 16 **Requirements for male stud connectors (NPT) for tubes with imperial outside diameter sizes**

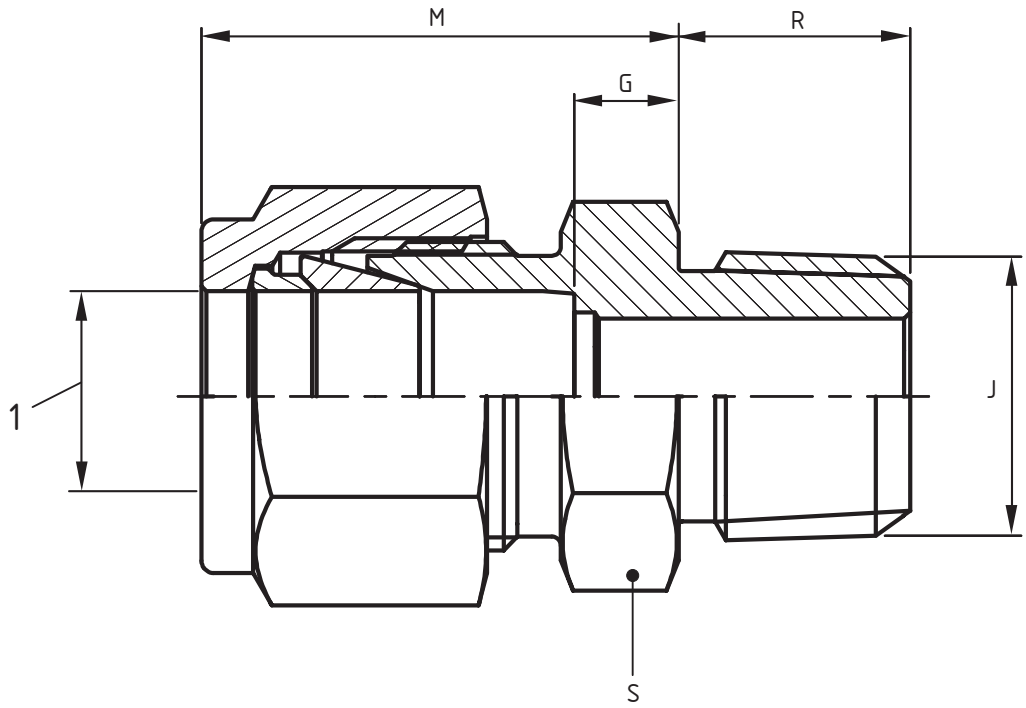
Tube O.D. [A]	**Requirements**				
	J NPT thread [B]	**M**	**R**	**G ±1/64 in**	**S**
in	in	in	in	in	in
1/16	1/16	0.550	0.380	0.210	5/16
1/8	1/8	0.820	0.380	0.320	7/16
3/16	1/8	0.850	0.380	0.310	7/16
1/4	1/4	0.930	0.560	0.330	9/16
5/16	3/8	0.960	0.560	0.320	11/16
3/8	3/8	1.010	0.560	0.340	11/16
1/2	1/2	1.180	0.750	0.280	7/8
5/8	1/2	1.180	0.750	0.220	15/16
3/4	3/4	1.240	0.750	0.280	1 1/16
7/8	3/4	1.240	0.750	0.210	1 3/16
1	1	1.520	0.940	0.280	1 3/8
1 1/4	1 1/4	2.060	0.970	0.440	1 3/4
1 1/2	1 1/2	2.500	1.000	0.530	2 1/8
2	2	3.430	1.040	0.770	2 3/4

NOTE All tolerances are ±1.6 mm (1/16 in) unless otherwise stated.

[A] Tolerances for the tube outside diameter shall be in accordance with ASTM A269.

[B] NPT threads shall conform to ANSI B1.20.1.

Figure 11 **Male stud connector (BSPT)**



Key
1 Tube outside diameter
G Tube abutment face to hexagon face of pipe thread end
J Pipe thread size
M Back of nut to hexagon face of pipe thread end
R Pipe thread length
S Across flats hexagon

Table 17 **Requirements for male stud connectors (BSPT) for tubes with metric outside diameter sizes**

Tube O.D. [A]	**Requirements**				
	J **BSPT thread** [B]	**M**	**R**	**G** **±0.4 mm**	**S**
mm	in	mm	mm	mm	mm
2	$^{1}/_{8}$	20.2	9.5	7.3	12
3	$^{1}/_{8}$	20.2	9.5	7.3	12
4	$^{1}/_{8}$	21.7	9.5	8.0	12
6	$^{1}/_{4}$	23.8	14.3	8.5	14
8	$^{1}/_{4}$	24.5	14.3	8.3	15
10	$^{3}/_{8}$	26.6	14.3	9.4	18
12	$^{1}/_{2}$	29.9	19.1	7.1	22
14	$^{1}/_{2}$	29.9	19.1	5.5	24
15	$^{1}/_{2}$	29.9	19.1	5.5	24
16	$^{1}/_{2}$	29.9	19.1	5.5	24
18	$^{3}/_{4}$	31.5	19.1	7.1	27
20	$^{3}/_{4}$	33.2	19.1	7.2	30
22	$^{3}/_{4}$	33.2	19.1	7.2	35
25	1	38.5	23.8	7.2	35
28	1	48.6	23.8	12.0	41
30	$1^{1}/_{4}$	53.4	23.8	13.8	46
32	$1^{1}/_{4}$	55.8	23.8	13.8	46
38	$1^{1}/_{2}$	65.4	26.2	16.0	55

NOTE All tolerances are ±1.6 mm ($^{1}/_{16}$ in) unless otherwise stated.

[A] Tolerances for the tube outside diameter shall be in accordance with ASTM A269.

[B] BSPT threads shall conform to ISO 7-1.

Table 18 **Requirements for male stud connectors (BSPT) for tubes with imperial outside diameter sizes**

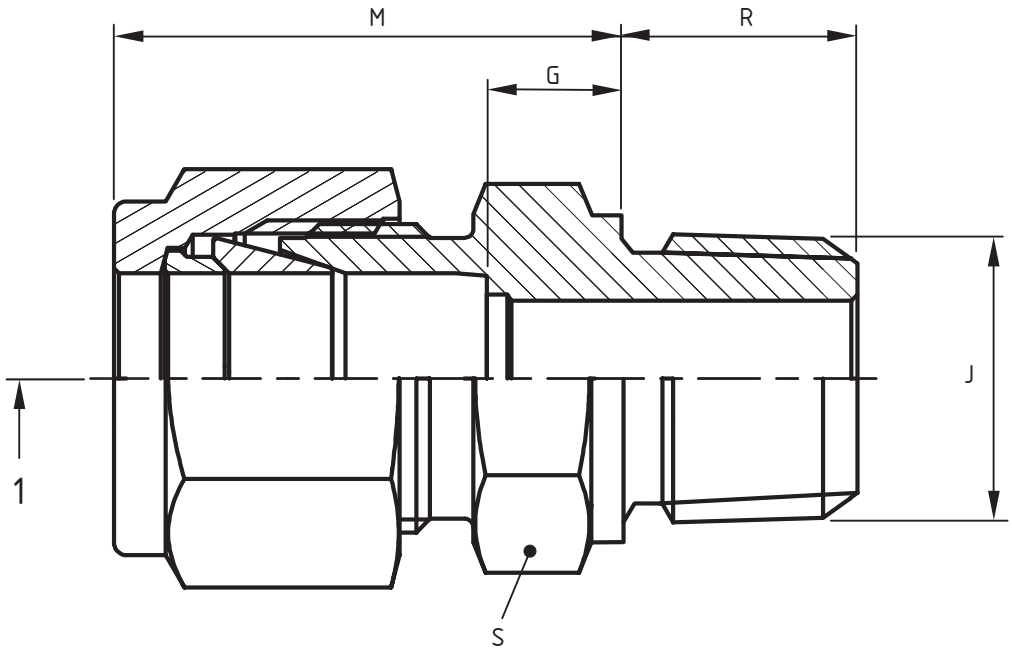
Tube O.D. [A]	**Requirements**				
	J **BSPT thread** [B]	**M**	**R**	**G** $\pm 1/64$ **in**	**S**
in	in	in	in	in	in
$1/16$	$1/16$	0.550	0.380	0.210	$5/16$
$1/8$	$1/8$	0.820	0.380	0.320	$7/16$
$3/16$	$1/8$	0.850	0.380	0.310	$7/16$
$1/4$	$1/4$	0.930	0.560	0.330	$9/16$
$5/16$	$3/8$	0.960	0.560	0.320	$11/16$
$3/8$	$3/8$	1.010	0.560	0.340	$11/16$
$1/2$	$1/2$	1.180	0.750	0.280	$7/8$
$5/8$	$1/2$	1.180	0.750	0.220	$15/16$
$3/4$	$3/4$	1.240	0.750	0.280	$1\,1/16$
$7/8$	$3/4$	1.240	0.750	0.210	$1\,3/16$
1	1	1.520	0.940	0.280	$1\,3/8$
$1\,1/4$	$1\,1/4$	2.060	0.970	0.440	$1\,3/4$
$1\,1/2$	$1\,1/2$	2.500	1.000	0.530	$2\,1/8$
2	2	3.430	1.040	0.770	$2\,3/4$

NOTE All tolerances are ±1.6 mm (1/16 in) unless otherwise stated.

[A] Tolerances for the tube outside diameter shall be in accordance with ASTM A269.

[B] BSPT threads shall conform to ISO 7-1.

Figure 12 **Male stud connector (BSPP)**



Key
1 Tube outside diameter
G Tube abutment face to hexagon face of pipe thread end
J Pipe thread size
M Back of nut to hexagon face of pipe thread end
R Pipe thread length
S Across flats hexagon

Table 19 **Requirements for male stud connectors (BSPP) for tubes with metric outside diameter sizes**

Tube O.D. [A]	**Requirements**				
	J **BSPP thread** [B]	**M**	**R**	**G** **±0.4 mm**	**S**
mm	in	mm	mm	mm	mm
3	$^{1}/_{8}$	22.9	7.1	10.0	14
6	$^{1}/_{4}$	26.5	11.2	11.1	19
8	$^{1}/_{4}$	27.3	11.2	11.1	19
10	$^{3}/_{8}$	29.4	11.2	12.2	22
12	$^{1}/_{2}$	34.8	14.2	12.0	27
16	$^{1}/_{2}$	34.8	14.2	10.4	27
20	$^{3}/_{4}$	36.8	16.0	10.8	35
22	$^{3}/_{4}$	36.8	16.0	10.8	35
25	1	41.8	18.3	10.5	41

NOTE All tolerances are ±1.6 mm ($^{1}/_{16}$ in) unless otherwise stated.

[A] Tolerances for the tube outside diameter shall be in accordance with ASTM A269.

[B] BSPP threads shall conform to BS EN ISO 228-1.

Table 20 **Requirements for male stud connectors (BSPP) for tubes with imperial outside diameter sizes**

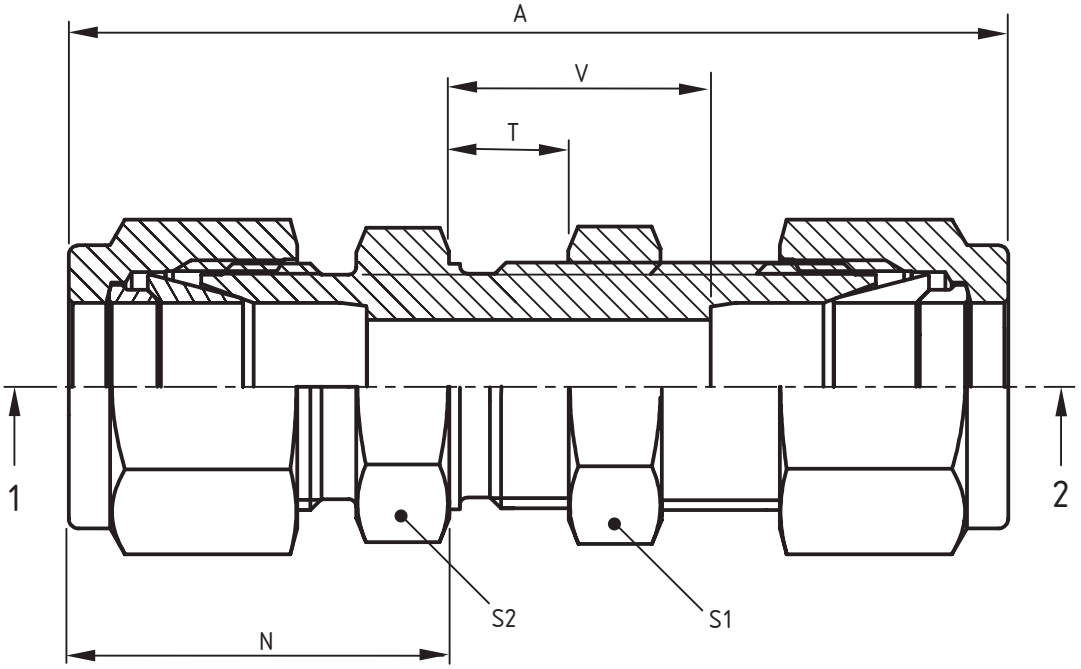
Tube O.D. [A]	Requirements				
	J BSPP thread [B]	M	R	G $\pm 1/64$ in	S
in	in	in	in	in	in
$1/8$	$1/8$	0.900	0.280	0.400	$9/16$
$1/4$	$1/4$	1.040	0.440	0.440	$3/4$
$3/8$	$3/8$	1.130	0.440	0.490	$7/8$
$1/2$	$1/2$	1.370	0.560	0.470	$1\,1/16$
$3/4$	$3/4$	1.450	0.630	0.500	$1\,5/16$
1	1	1.630	0.720	0.410	$1\,5/8$

NOTE All tolerances are ±1.6 mm (1/16 in) unless otherwise stated.

[A] Tolerances for the tube outside diameter shall be in accordance with ASTM A269.

[B] BSPP threads shall conform to BS EN ISO 228-1.

Figure 13 **Bulkhead connector**



Key
1 Tube outside diameter
2 Through-bore
A Overall length
N Back of nut to hexagon face of bulkhead end
S1 Across flats hexagon (lock nut)
S2 Across flats hexagon (body)
T Maximum bulkhead thickness
V Tube abutment face to hexagon face on bulkhead

Table 21 **Requirements for bulkhead connectors for tubes with metric outside diameter sizes**

Tube O.D. [A)]	Requirements								
	Through bore	N	A	G	V ±0.4 mm	S1	S2	Bulkhead hole drill size	T
mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
3	2.400	20.100	51.300	7.200	25.5	13	14	8.3	12.7
4	2.400	21.700	53.700	8.000	26.2	14	14	9.9	12.7
6	4.800	24.200	57.800	8.900	27.2	16	16	11.5	10.2
8	6.400	25.000	61.000	8.800	28.6	17	18	13.1	11.2
10	7.900	26.600	63.600	9.400	29.3	21	22	16.3	11.2
12	9.500	29.100	71.000	6.300	25.4	24	24	19.5	12.7
15	11.900	29.900	72.500	5.500	23.7	27	27	22.5	12.7
16	12.700	30.000	72.600	5.600	23.7	27	27	22.5	12.7
18	15.100	31.500	78.900	7.100	30.1	30	30	26.0	16.8
20	15.900	33.500	84.500	7.500	32.5	33	35	29.0	19.0
25	21.800	41.400	95.800	10.100	33.2	41	41	33.8	19.0
30	26.200	53.500	123.700	13.900	44.5	50	50	40.5	19.0
32	28.600	55.800	128.300	13.800	44.3	50	50	42.5	19.0
38	33.700	65.500	144.600	16.100	45.8	60	60	50.5	19.0

NOTE All tolerances are ±1.6 mm (1/16 in) unless otherwise stated.

[A)] Tolerances for the tube outside diameter shall be in accordance with ASTM A269.

Table 22 **Requirements for bulkhead connectors for tubes with imperial outside diameter sizes**

Tube O.D. [A)]	Requirements								
	Through bore	N	A	G	V ±1/64 in	S1	S2	Bulkhead hole drill size	T
in	in	in	in	in	in	in	in	in	in
1/16	0.052	0.550	1.230	0.210	0.560	5/16	5/16	13/64	1/8
1/8	0.093	0.790	2.020	0.290	1.020	1/2	1/2	21/64	1/2
3/16	0.125	0.850	2.110	0.310	1.030	9/16	9/16	25/64	1/2
1/4	0.187	0.960	2.270	0.360	1.070	5/8	5/8	29/64	17/32
5/16	0.250	0.980	2.400	0.340	1.110	11/16	11/16	33/64	9/16
3/8	0.281	1.020	2.460	0.350	1.130	3/4	3/4	37/64	9/16
1/2	0.406	1.150	2.800	0.250	1.000	15/16	15/16	49/64	19/32
5/8	0.500	1.180	2.860	0.220	0.940	1 1/16	1 1/16	57/64	19/32
3/4	0.625	1.240	3.110	0.280	0.960	1 3/16	1 3/16	1 1/64	25/32
1	0.875	1.510	3.780	0.270	1.310	1 5/8	1 5/8	1 21/64	15/16
1 1/4	1.090	2.100	4.850	0.480	1.610	1 7/8	1 7/8	1 41/64	15/16
1 1/2	1.340	2.470	5.480	0.500	1.540	2 1/4	2 1/4	1 61/64	15/16
2	1.810	3.410	7.100	0.750	1.780	2 3/4	2 3/4	2 41/64	15/16

NOTE All tolerances are ±1.6 mm (1/16 in) unless otherwise stated.

[A)] Tolerances for the tube outside diameter shall be in accordance with ASTM A269.

5 Requirements for construction and materials

5.1 General

All machined surfaces shall have a surface finish roughness value of R_a<6.3 µm, except sealing surfaces which shall have a maximum roughness of 0.8 µm.

Metric tube connectors shall have an identifying spigot machined on the nuts and bodies.

The connectors shall be free from cracks and porosity and shall have any sharp edges removed to a depth of not more than 0.15 mm unless otherwise specified.

5.2 Components

Each twin ferrule connector shall contain a body, two ferrules and a nut manufactured from 316 stainless steel materials, as specified in **5.3**, or their national or international equivalents.

5.3 Materials

NOTE Austenitic stainless steel components manufactured by hot-forge or other sensitizing processes may be stress-relieved or solution-annealed. When specified by the purchaser, practices such as those found in ASTM A262 should be used to evaluate carbide precipitation in stainless steels.

5.3.1 Bodies

Connector bodies shall be made of 316 stainless steel material as follows.

a) Bodies that are machined directly from bar stock shall be of austenitic stainless steel conforming to ASTM A276 or ASTM A479.

b) Bodies that are machined from forgings shall be of austenitic stainless steel conforming to ASTM A182.

c) Bodies that are machined from castings shall be of austenitic stainless steel conforming to ASTM A351/A351M-10, grade CF3M or CF8M.

Connector bodies shall be permanently marked with the manufacturer's name or trademark, material and traceable material heat code.

5.3.2 Nuts

Nuts shall be manufactured from austenitic stainless steel conforming to ASTM A276, ASTM A479 or ASTM A182.

Nuts shall be permanently marked with the manufacturer's name or trademark, material and traceable material heat code.

5.3.3 Ferrules

Ferrules shall be manufactured from austenitic stainless steel bar stock conforming to ASTM A276, ASTM A479, ASTM A182 or ASTM 182M.

5.4 Flow of grain or grain direction

The longitudinal axis of components machined from hot-or-cold drawn bar stock shall be parallel to the longitudinal axis of the bar.

NOTE It is recommended that elbows and tees machined from blanks cut from bar stock be verified by non-destructive testing.

5.5 Additional surface applications, coatings and heat treatments

Where any surface applications, coatings or heat treatments are applied to a twin ferrule connector, the connector shall conform to the requirements specified in Clause **9**.

NOTE 1 Any heat treatment or hardening operations performed should take into consideration the effects of potentially corrosive operating conditions.

NOTE 2 Lubricants and/or coatings may be applied during manufacture to mating surfaces to prevent galling, reduce friction and aid in the proper assembly of the connector whilst ensuring system contamination from the applied lubricants and/or coatings is eliminated.

5.6 Gauging devices

Gauging devices shall be made available with connectors to enable users to verify whether the connectors have been properly assembled onto the tubes.

NOTE Measurement devices from one manufacturer might not operate properly with connectors from another manufacturer.

5.7 Packaging

Finished products shall be packaged to protect them from contamination and damage during shipping and storage.

Exposed male threads shall be protected, e.g. by use of a cap.

Connectors and associated products shall be packed in protective boxes with suitable protective material. Boxes shall be identified with the part number, quantity and packaging date code.

6 Pressure/temperature requirements

6.1 Pressure ratings for combinations of tube and connector

NOTE 1 The working pressure ratings for stainless steel tube in Tables 23 to 26 are derived from stress values and methodologies listed in ASME B31.3.

The pressure rating of a twin ferrule connector end shall be that of the tube with the highest pressure rating to which it can be attached as specified in Tables 23 to 26 (pressure ratings shall be in accordance with Table 23 or Table 24 for metric tube sizes, and Table 25 or Table 26 for imperial tube sizes).

NOTE 2 In the case of an all tube-ended connector, such as a union tee, the properly selected tube is the limiting factor in the system. A connector may, however, combine a twin ferrule connector end with another end of different form, such as male or female pipe thread. Pressure ratings for other ends are determined in accordance with applicable standards and may, in fact, be lower than the rating for the twin ferrule tube connector end. The raw material, from which the connector is manufactured, either from bar stock or a forging can also affect the ratings of those other ends. As a result, the rating for such other forms is generally the limiting factor for the rating of the entire connector.

6.2 Pressure rating and wall thickness of tubes

The pressure ratings for type 316 stainless steel seamless tubes for temperatures up to 93 °C (200° F) shall normally be in accordance with Tables 23 to 26. The minimum and maximum wall thickness of tubes for each size of twin ferrule connector shall also be in accordance with Tables 23 to 26.

NOTE 1 If a wall thickness is used that is not specified in Tables 1 to 4, the supplier should be consulted.

For welded-and-drawn tube, a derating factor shall be applied for weld integrity. For double-welded tube, the pressure ratings in Tables 23 to 26 shall be multiplied by a factor of 0.85, and for single-welded tube the ratings shall be multiplied by a factor of 0.80. The pressure rating at elevated temperatures shall be not greater than the appropriate working pressure from Tables 23 to 26 multiplied by the appropriate factor given in Table 27.

The wall thickness of connectors used for gas service shall be not less than the value shown in the unshaded areas of Tables 23 to 26.

NOTE 2 The reason for this is that heavy wall tube resists ferrule action more than thin wall tube, allowing the ferrules to coin out minor surface imperfections.

7 Requirements for tubes

7.1 Tube for fluid-conducting systems

NOTE 1 Stainless steel tube is critical to the performance of twin ferrule connector connections. Design criteria are based on a minimum safety factor of 4:1.

Tube for service with 316 twin ferrule connectors shall be annealed austenitic stainless steel of grades 316/316L, 304 or 321, as defined in ASTM A632-4(2009), ASTM A269-10, ASTM A249-10 or ASTM A213/A213M-10.

NOTE 2 The preferred grade is 316/316L.

The tube shall be either seamless or welded-and-drawn, and cold finished in accordance with ASTM A632-4(2009), ASTM A269-10, ASTM A249-10 or ASTM A213/A213M-10. If welded tube is used, it shall be processed in accordance with **7.2**.

The outer surface of the tube shall be free of imperfections such as irregularities, discontinuities, or scratches that are readily visible.

7.2 Welded-and-drawn-tube

After welding, and prior to annealing, tube shall be drawn through a die that contacts the entire 360° of the outer periphery. During drawing, the inside diameter of the tube shall be supported at all points where the outside diameter passes through the die. The stainless steel within the weld zone shall be in the recrystallized structure, not the cast structure. The weld seam on finished tube shall not be readily visible.

7.3 Tube hardness

When measured on the outside diameter of tube, in accordance with ASTM E18 and ASTM E140, on a 25 mm long sample cut from the tube length at least 25 mm from one of its ends, the hardness of the tube shall be not greater than 85 HRB.

Table 23 **Working pressure rating for metric size stainless steel tube (bar)**

Tube O.D.	Pressure rating, in bar														
	W/t 0.5 [A)]	W/t 0.7 [A)]	W/t 0.8 [A)]	W/t 1.0 [A)]	W/t 1.2 [A)]	W/t 1.5 [A)]	W/t 1.8 [A)]	W/t 2.0 [A)]	W/t 2.2 [A)]	W/t 2.5 [A)]	W/t 2.8 [A)]	W/t 3.0 [A)]	W/t 3.5 [A)]	W/t 4.0 [A)]	W/t 4.5 [A)]
mm	bar	bar	bar	bar	bar	bar	bar	bar	bar	bar	bar	bar	bar	bar	bar
2	600	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	—	575	670	—	—	—	—	—	—	—	—	—	—	—	—
4	—	425	490	630	765	—	—	—	—	—	—	—	—	—	—
6	—	270	315	405	500	635	—	—	—	—	—	—	—	—	—
8	—	—	—	295	360	465	—	—	—	—	—	—	—	—	—
10	—	—	—	235	285	360	—	—	—	—	—	—	—	—	—
12	—	—	—	190	235	300	365	410	—	—	—	—	—	—	—
14	—	—	—	175	210	270	330	370	410	—	—	—	—	—	—
15	—	—	—	160	195	250	300	340	380	—	—	—	—	—	—
16	—	—	—	—	180	230	280	320	350	—	—	—	—	—	—
18	—	—	—	—	160	205	250	280	310	355	—	—	—	—	—
20	—	—	—	—	145	180	225	250	280	320	360	—	—	—	—
22	—	—	—	—	130	165	200	225	250	285	325	—	—	—	—
25	—	—	—	—	—	—	180	200	220	250	280	305	—	—	—
28	—	—	—	—	—	—	160	175	195	220	250	270	320	—	—
32	—	—	—	—	—	—	140	150	170	190	220	235	275	320	—
38	—	—	—	—	—	—	—	—	140	160	180	195	230	265	300

NOTE The shaded areas represent combinations of tube outside diameter and wall thickness that are not recommended for gas applications.

[A)] Wall thickness, in millimetres (mm).

Table 24 **Working pressure rating for metric size stainless steel tube (psi)**

Tube O.D.	Pressure rating, in pounds per square inch (psi)														
	W/t 0.5 [A)]	**W/t 0.7** [A)]	**W/t 0.8** [A)]	**W/t 1.0** [A)]	**W/t 1.2** [A)]	**W/t 1.5** [A)]	**W/t 1.8** [A)]	**W/t 2.0** [A)]	**W/t 2.2** [A)]	**W/t 2.5** [A)]	**W/t 2.8** [A)]	**W/t 3.0** [A)]	**W/t 3.5** [A)]	**W/t 4.0** [A)]	**W/t 4.5** [A)]
mm	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi
2	8 810	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	—	8 350	9 675	—	—	—	—	—	—	—	—	—	—	—	—
4	—	6 140	7 120	9 110	11 110	—	—	—	—	—	—	—	—	—	—
6	—	3 950	4 570	5 850	7 200	9 220	—	—	—	—	—	—	—	—	—
8	—	—	—	4 280	5 230	6 745	—	—	—	—	—	—	—	—	—
10	—	—	—	3 375	4 110	5 250	—	—	—	—	—	—	—	—	—
12	—	—	—	2 785	3 380	4 305	5 260	5 920	—	—	—	—	—	—	—
14	—	—	—	2 520	3 055	3 880	4 735	5 320	5 920	—	—	—	—	—	—
15	—	—	—	2 345	2 840	3 605	4 390	4 930	5 485	—	—	—	—	—	—
16	—	—	—	—	2 655	3 365	4 100	4 595	5 105	—	—	—	—	—	—
18	—	—	—	—	2 345	2 970	3 610	4 045	4 490	5 170	—	—	—	—	—
20	—	—	—	—	2 100	2 660	3 225	3 610	4 005	4 605	5 220	—	—	—	—
22	—	—	—	—	1 905	2 405	2 920	3 265	3 615	4 150	4 700	—	—	—	—
25	—	—	—	—	—	—	2 550	2 850	3 155	3 620	4 090	4 410	—	—	—
28	—	—	—	—	—	—	2 265	2 530	2 800	3 205	3 620	3 900	4 610	—	—
32	—	—	—	—	—	—	1 970	2 200	2 430	2 780	3 140	3 380	3 990	4 610	—
38	—	—	—	—	—	—	—	—	2 030	2 320	2 620	2 815	3 315	3 830	4 355

NOTE The shaded areas represent combinations of tube outside diameter and wall thickness that are not recommended for gas applications.

[A)] Wall thickness, in millimetres (mm).

Table 25 **Working pressure rating for imperial size stainless steel tube (bar)**

Tube O.D.	Pressure rating, in bar															
	W/t 0.010 [A)]	W/t 0.012 [A)]	W/t 0.014 [A)]	W/t 0.016 [A)]	W/t 0.020 [A)]	W/t 0.028 [A)]	W/t 0.035 [A)]	W/t 0.049 [A)]	W/t 0.065 [A)]	W/t 0.083 [A)]	W/t 0.095 [A)]	W/t 0.109 [A)]	W/t 0.120 [A)]	W/t 0.134 [A)]	W/t 0.156 [A)]	W/t 0.188 [A)]
in	bar	bar	bar	bar	bar	bar	bar	bar	bar	bar	bar	bar	bar	bar	bar	bar
1/16	390	480	570	660	840	1145	—	—	—	—	—	—	—	—	—	—
1/8	—	—	—	—	—	550	705	—	—	—	—	—	—	—	—	—
3/16	—	—	—	—	—	355	460	660	—	—	—	—	—	—	—	—
1/4	—	—	—	—	—	260	335	490	665	—	—	—	—	—	—	—
5/16	—	—	—	—	—	—	260	380	520	—	—	—	—	—	—	—
3/8	—	—	—	—	—	—	215	310	430	—	—	—	—	—	—	—
1/2	—	—	—	—	—	—	170	240	330	430	—	—	—	—	—	—
5/8	—	—	—	—	—	—	—	190	260	340	395	—	—	—	—	—
3/4	—	—	—	—	—	—	—	160	215	280	320	375	—	—	—	—
7/8	—	—	—	—	—	—	—	135	180	235	270	315	—	—	—	—
1	—	—	—	—	—	—	—	—	160	205	235	275	305	—	—	—
1 1/4	—	—	—	—	—	—	—	—	—	160	185	215	240	270	320	—
1 1/2	—	—	—	—	—	—	—	—	—	—	155	180	200	220	260	320
2	—	—	—	—	—	—	—	—	—	—	—	130	145	165	195	235

NOTE The shaded areas represent combinations of tube outside diameter and wall thickness that are not recommended for gas applications.

[A)] Wall thickness, in inches (in).

Table 26 **Working pressure rating for imperial size stainless steel tube (psi)**

Tube O.D.	Pressure rating, in pounds per square inch (psi)															
	W/t 0.010 [A]	**W/t 0.012** [A]	**W/t 0.014** [A]	**W/t 0.016** [A]	**W/t 0.020** [A]	**W/t 0.028** [A]	**W/t 0.035** [A]	**W/t 0.049** [A]	**W/t 0.065** [A]	**W/t 0.083** [A]	**W/t 0.095** [A]	**W/t 0.109** [A]	**W/t 0.120** [A]	**W/t 0.134** [A]	**W/t 0.156** [A]	**W/t 0.188** [A]
in	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi
1/16	5 670	6 985	8 285	9 600	12 195	16 640	—	—	—	—	—	—	—	—	—	—
1/8	—	—	—	—	—	8 000	10 230	—	—	—	—	—	—	—	—	—
3/16	—	—	—	—	—	5 145	6 635	9 620	—	—	—	—	—	—	—	—
1/4	—	—	—	—	—	3 780	4 825	7 050	9 635	—	—	—	—	—	—	—
5/16	—	—	—	—	—	—	3 800	5 500	7 565	—	—	—	—	—	—	—
3/8	—	—	—	—	—	—	3 130	4 505	6 200	—	—	—	—	—	—	—
1/2	—	—	—	—	—	—	2 460	3 520	4 790	6 300	—	—	—	—	—	—
5/8	—	—	—	—	—	—	—	2 780	3 760	4 910	5 710	—	—	—	—	—
3/4	—	—	—	—	—	—	—	2 300	3 100	4 030	4 670	5 440	—	—	—	—
7/8	—	—	—	—	—	—	—	1 960	2 635	3 415	3 950	4 590	—	—	—	—
1	—	—	—	—	—	—	—	—	2 290	2 970	3 425	3 970	4 410	—	—	—
1 1/4	—	—	—	—	—	—	—	—	—	2 345	2 700	3 130	3 470	3 905	4 610	—
1 1/2	—	—	—	—	—	—	—	—	—	—	2 230	2 580	2 855	3 210	3 780	4 635
2	—	—	—	—	—	—	—	—	—	—	—	1 910	2 110	2 370	2 780	3 395

NOTE The shaded areas represent combinations of tube outside diameter and wall thickness that are not recommended for gas applications.

[A] Wall thickness, in inches (in).

Table 27 **Factors used to determine tube pressure ratings at elevated temperatures**

Temperature	Derating factor	
°C	304 stainless steel	316 stainless steel
93	1.00	1.00
204	0.93	0.96
315	0.82	0.85
426	0.76	0.79
537	0.69	0.76

NOTE 1 These factors are based on ASME B31.3 derating factors for ASTM A269 tube. They are derived from ASME B31.3:2008, Table A.1 (basic allowable stresses in metals).

NOTE 2 For temperatures above 537 °C, the possibility of carbide precipitation has to be considered. However, this is beyond the scope of this British Standard.

8 Requirements for screw threads

Screw threads associated with tube ends shall be in accordance with Figure 4. Screw threads associated with stud ends shall be in accordance with ASME/ANSI B1.1 for UN threads and BS ISO 261 for metric threads.

9 Performance requirements

9.1 Hydraulic proof pressure

When a hydraulic proof pressure test is carried out as specified in Annex A:

a) the connector shall conform to the dimensional requirements specified in Tables 23 to 26 as appropriate;

b) there shall be no alteration in the dimensions as measured;

c) there shall be no leakage.

Any leakage shall be deemed to constitute a failure of the test.

9.2 Dismantling and reassembly

When a dismantling and reassembly test is carried out as specified in Annex A, there shall be no leakage. Any leakage shall be deemed to constitute a failure of the test.

9.3 Minimum hydrostatic pressure

When a minimum hydrostatic pressure test is carried out as specified in Annex A:

a) the connector shall conform to the dimensional requirements specified in Tables 23 to 26 as appropriate;

b) there shall be no alteration in the dimensions as measured;

c) there shall be no leakage.

Any leakage shall be deemed to constitute a failure of the test.

9.4 Vacuum

When a vacuum test is carried out as specified in Annex A, the leak rate shall be not greater than 1×10^{-8}.

If the leak rate is greater than 1×10^{-8}, the connector shall be deemed to have failed the test.

9.5 Over-tightening

When an over-tightening test is carried out as specified in Annex A:

a) the connector shall conform to the dimensional requirements specified in Tables 23 to 26 as appropriate;

b) there shall be no alteration in the dimensions as measured;

c) there shall be no leakage.

Any leakage shall be deemed to constitute a failure of the test.

9.6 Maximum static gas pressure

When a maximum static gas pressure test is carried out as specified in Annex A:

a) no visible bubbles shall appear from the test assembly when it is pressurized under water for 10 min at each of the gas cycles;

b) if any bubble appears from anywhere other than the test assembly within the 10 min test time, a second bubble shall not appear within 60 s.

9.7 Hydraulic impulse and vibration

When a hydraulic impulse and vibration test is carried out as specified in Annex A, there shall be no leakage. If leakage occurs from any one assembly, the connector shall be deemed to have failed the test.

9.8 Thermal cycle

When a thermal cycle test is carried out as specified in Annex A:

a) the assembly tree shall show no evidence of leakage or any other malfunction;

b) the connector shall conform to the dimensional requirements specified in Tables 1 to 22 as appropriate;

c) there shall be no alteration in the dimensions of the tree assembly or its component parts.

9.9 Pneumatic pressure vibration

When a pneumatic pressure vibration test is carried out as specified in Annex A, a minimum of (20×10^6) cycles shall be completed without failure.

If failure occurs, the position of the failure with respect to the ferrule shall be recorded in the test report.

9.10 Fire

When a fire test is carried out as specified in Annex A, there shall be no leakage. Any leakage shall be deemed to constitute a failure of the test.

9.11 Corrosion resistance

When a corrosion resistance test is carried out as specified in Annex A:

a) there shall be no visible evidence of corrosion following the test exposure;

NOTE Staining and superficial surface discolouring is deemed to be acceptable.

b) there shall be no corrosion defects, such as pits, cracks, blisters or rusting, which result in weight loss when removed from the specimens following test exposure.

9.12 Deep water submersion

When a deep water submersion test is carried out as specified in Annex A, there shall be no helium detected on the mass spectrometer.

9.13 Additional pass/fail criteria

If any one of the test connectors that have been subjected to the proof test (**A.8**) subsequently leaks at the tube/connector interface on being subjected to one of the further tests described for either hydraulic fluid (**A.14**) or gas (**A.13**), the connector shall be deemed to have failed the test.

If an assembly leaks due to tube fracture or rupture outside the envelope of the test connectors, a further test shall be conducted as appropriate.

The connectors shall be deemed to have failed the test if any of the following are evident

- the nut cannot be removed by hand after breakaway;
- the nut cannot swivel freely by hand;
- the nut will not retract to its original position by hand;
- any visible cracks in the sealing surface or nut that would render the nut unusable appear.

10 Marking

10.1 Traceability

Connector bodies and nuts shall be permanently marked with the manufacturer's name or trademark, material designation and traceable material heat code (HCT).

10.2 Designation of connectors

Twin ferrule connectors shall be designated by an alphanumeric code to facilitate ordering. The code shall begin with the number of this British Standard, i.e. BS 7993[2)]. This shall be followed by a hyphen, and then the connector style designation letter symbols (see Table 29), then a hyphen, immediately followed by the outside diameter of the tube (see Table 1 and Table 2) to which they are to be connected. For stud ends (connector ends), another hyphen followed by the thread designation of the stud end and the sealing type shall be added.

EXAMPLE A male stud connector (SDM), straight (S), for use with tube with an outside diameter of 12 mm and a half-inch NPT thread, conforming to BS 7993, is designated as follows:

BS 7993-SDMS-M12-8N

An example of a male stud connector is shown in Figure 10.

The letter symbol designation of the connector style (see Table 29) shall have two parts: the connector end type, immediately followed by the shape of the connector.

[2)] Marking BS 7993:2011 on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is solely the claimant's responsibility. Such a declaration is not to be confused with third-party certification of conformity.

Reducing connectors and reducing elbows shall be designated by specifying the larger tube end first.

Stud connectors (Figures 10 to 12) shall be designated by specifying the tube end first, then the thread size for the stud end.

For tee connectors (Figure 8), the order of designation of the connector ends shall be from larger to smaller on the run, followed by the branch end.

For cross connectors, the order of designation of the connector ends shall be from left to right, followed by top to bottom, with the larger ends on the left and at the top. If the connector has a tube union connection, it shall be designated first, and then the designation shall proceed clockwise (Figure 9).

The letter symbols specified in Table 29 shall be used.

Table 29 – Letter symbols for connectors

Category	Type	Letter
Connector end type	Bulkhead	BH
	Socket weld	CSW
	Butt weld	CBW
	Port	P
	Stud male	SDM
	Stud female	SDF
	Reducing	RE
Shape	Straight	S
	Elbow	E
	45° elbow	E45
	Tee	T
	Run tee	RT
	Branch tee	BT
	Cross	K
Component type	Nut	N
	Union twin ferrule × twin ferrule	U
	Reducing union – twin ferrule × smaller twin ferrule	RU
	Bulkhead union	BU
	Bulkhead stud	BCM and BCF
	Bulkhead tube end – also known as adapter	BAU
	Flange connector	CFL [A)]
	Positionable	SW
	Ferrule	F
	Front ferrule	FF
	Rear ferrule	RF
	Locknut	LN
	Plug	PL
	Cap	CP
	Metric	M
	Inch	— [B)]
Thread type	NPT to ANSI B1.20.1	N
	BS PP to BS EN ISO 228-1	G
	BS PT to ISO 7-1	R

[A)] Flange specification to be designated.

[B)] Intentionally left blank.

Tube sizes shall be designated as follows.

a) Metric tube sizes shall be designated with a capital M, followed by the outside diameter of the tube in millimetres.

EXAMPLE 1 A tube with an outside diameter of 20 mm would be designated M20, as shown in Table 1.

b) Imperial tube sizes shall be designated in increments of $^{1}/_{16}$ in.

EXAMPLE 2 A tube with an outside diameter of ¾ in would be designated 12, as shown in Table 2.

11 Documentation

Manufacturers shall provide assembly and installation instructions detailing how to prepare tubes and correctly assemble the connectors for installation and use with every connector assembly or part-assembly issued, the instructions shall be provided within the packaging of each individual product issued. These instructions shall also explain how the installer can verify whether the correct insertion depth and nut tightness have been achieved.

The assembly instructions shall include:

- an instruction not to intermix or interchange component parts of one manufacturer's product with another manufacturer's product (see sample wording in Figure 14);
- a note informing the user how the ferrules fit into the connector;
- instructions for using the gauging device (**5.6**);
- installation diagrams;
- advice on installation of connectors near tube bends;
- retightening instructions;
- instructions on how many times the connector can be made and re-made, together with advice to keep a record of the number of times this has been done.

Figure 14 **Assembly instructions regarding intermixing and interchanging**

Intermixing and interchanging component parts of connector assemblies

The mixing of component parts of different manufacturers' products is potentially hazardous. Component parts from different manufacturers should not be intermixed or interchanged.

Intermixing is random mixing of components, particularly nuts and ferrules including materials and dimensions, which might or might not be compatible. Interchanging is using one manufacturer's assembled nut and ferrule system with another manufacturer's body.

The issues of training, stock control, full traceability and record keeping will need to be considered such that intermixing or interchanging of products does not occur.

A record should be kept on the number of times a connector has been re-made.

As the training of staff in the safe use of these products lies with the users of the connectors, the instructions shall also include a recommendation for users of the product to have a system in place to ensure all staff that will use the connectors have completed the necessary training and testing, such that they are deemed competent in their installation and use.

Annex A (normative) Test procedures

A.1 General

The tests shall be carried out using the apparatus specified in **A.2** and the generic procedures specified in **A.3** to **A.7**. The following specific tests shall then be carried out in the order shown:

a) hydraulic proof pressure test (**A.8**);

b) dismantling and reassembly (**A.9**);

c) minimum hydrostatic pressure test (**A.10**);

d) vacuum test (**A.11**);

e) over-tightening test (**A.12**);

f) maximum static gas pressure test (**A.13**);

g) hydraulic impulse and vibration test (**A.14**);

h) thermal cycle test (**A.15**);

i) pneumatic pressure vibration test (**A.16**);

j) fire test (**A.17**);

k) corrosion resistance test (**A.18**);

l) deep water submersion test (**A.19**).

WARNING. These tests call for the use of substances and/or procedures that can be injurious to health if adequate precautions are not taken. It refers only to technical suitability and does not absolve the user from legal obligations relating to health and safety at any stage. Attention is particularly drawn to the danger of bursts, fine jets (which can penetrate the skin), energy release of expanding gases and the use of accumulators.

A test report (**A.20**) shall be produced for each test carried out.

A.2 Apparatus

A.2.1 *Pressure gauge*, having an accuracy of measurement in accordance with class 1 industrial gauges specified in BS EN 837-1.

A.2.2 *Test rig for hydraulic proof pressure test*, capable of raising the pressure of the test fluid to 4 times the MWPC or MWPT at a rate of 200 bar/min.[3)]

A.2.3 *Test rig for hydraulic impulse and vibration test*, capable of generating and repeating pressure impulse and vibration cycles simultaneously, and of applying a pressure impulse at between 0.5 Hz and 1.7 Hz and vibrations at between 23 Hz and 47 Hz.

A.2.4 *External and wall thickness micrometers*.

A.2.5 *Vernier callipers*.

A.2.6 *Bell jar*.

A.2.7 *Vacuum pump*, capable of causing a depression of (1×10^{-4}) mbar [3)] at the test component.

A.2.8 *Test regulator*.

[3)] 1 bar = 10^5 N/m^2 = 100 kPa.

A.2.9 *Apparatus for the detection of gas leakage*.

A.2.10 *Static torque transducer and readout*.

A.2.11 *Thermometer or thermocouple and readout*.

A.2.12 *Crack detection equipment*.

A.2.13 *Mass spectrometer*, with a sensitivity not less than (1×10^{-8}) cm^3/s.

A.2.14 *Test manifold blocks*, manufactured from carbon steel having a surface finish in accordance with the supplier's recommendations.

A.2.15 *Electromagnetic vibration rig*.

A.2.16 *Accelerometer*.

A.2.17 *Strain gauge*.

A.2.18 *UV recorder*.

A.2.19 *Oscilloscope*.

A.2.20 *Precision resistor decade box*.

A.2.21 *Barometric chamber*.

A.2.22 *Apparatus for fire test* as specified in BS ISO 19921.

A.2.23 *Apparatus for corrosion resistance test* as specified in BS EN ISO 9227.

A.3 Test temperatures

All tests shall be carried out at an ambient temperature of (20 ± 5) °C, unless otherwise specified.

A.4 Wall thickness

Connectors shall be tested with both minimum and maximum wall thickness for each tube size as detailed in Tables 23 to 26.

A connector that meets the specified requirements when tested at the working pressures of the minimum and maximum wall thickness of a range as detailed in Tables 23 to 26 shall be deemed to meet those requirements for the entire range.

EXAMPLE If a 6 mm connector meets the specified requirements when tested at the working pressures of a 6 mm tube with a wall thickness of 0.8 mm and a 6 mm tube with a wall thickness of 1.5 mm, the connector is deemed to meet those requirements for the calculated working pressures of a 6 mm tube with a wall thickness between 0.8 mm and 1.5 mm.

A.5 Test fluid

The test fluid for tests shall be a fully fortified mineral oil, having the properties specified in Table A.1 when tested in accordance with the appropriate British Standard.

Table A.1 **Test fluid properties**

Property	Value	Test method
Viscosity at 50 °C	22 cSt [A] to 32 cSt	BS 2000-71.2
Viscosity at 20 °C	85 cSt to 140 cSt	BS 2000-71.2
Pour point	–28 °C	BS 2000-15
Flash point closed	>190 °C	BS EN ISO 2719
Aniline point	(100 ±10) °C	BS 2000-2

[A] 1 cSt = 10^{-15} m^2/s.

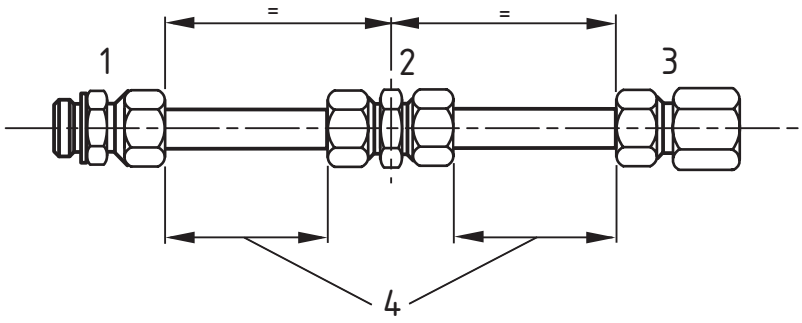
A.6 Selection and preparation of specimens for testing

The connectors and tubes used for testing shall be selected at random from a batch that is deemed to be representative of normal manufacture.

Unless otherwise stated in the test method, the threaded port components shall be tightened in accordance with the manufacturer's published tightening instructions (see Clause **11**).

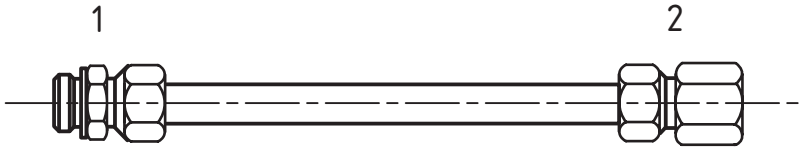
The test connectors shall be assembled as shown in Figure A.1, Figure A.2 and Figure A.3, in accordance with the manufacturer's published assembly instructions (see Clause **11**).

Figure A.1 **Test assembly for pressure tests**



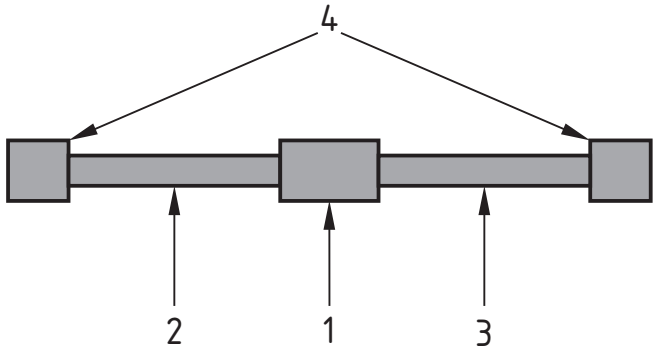
Key
1 Male stud coupling
2 Straight coupling
3 Blanking end
4 Maximum length (five times the outside diameter of the tube)

Figure A.2 **Test assembly for dismantling and reassembly test**



Key
1 Male stud coupling
2 Blanking end

Figure A.3 **Salt spray test**



Key
1 Union coupling
2 Thin wall tubing. Maximum length (five times the outside diameter of the tube)
3 Thick wall tubing. Maximum length (five times the outside diameter of the tube)
4 Blanking end × 2

A.7 Visual and dimensional inspection

Before any connector or part of a connector is used in any test, it shall be dismantled, visually inspected, and measured, and the measurements shall be recorded.

Only connectors that meet the dimensional requirements specified in Tables 1 to 22 shall be used in the tests.

Only tubes that meet the requirements specified in Clause **7** shall be used in the tests.

Before any tube is cut for the test assemblies, it shall be visually inspected and the outside diameter and wall thickness measured.

A.8 Hydraulic proof pressure test

Before starting a hydraulic test, bleed the system of air in order to minimize the energy released in the event of failure.

WARNING. Do not bleed off air under pressure by undoing the connector nut.

After proof testing a connector assembly, re-tighten the connector in accordance with the manufacturer's re-tightening instructions (see Clause **11**) before carrying out subsequent tests.

Attach three test assemblies, as shown in Figure A.1 or Figure A.2 as appropriate, to a test manifold block manufactured from carbon steel having a surface finish in accordance with the fitting manufacturers recommendation, and subject them to a hydraulic pressure of 1.5 times the maximum permissible working pressure of the connector as detailed in Tables 23 to 26. Apply the pressure at a rate not exceeding 200 bar/min[4)], isolate the test assembly and leave for a period of not less than 5 min.

Record the test pressure in bar that the test assemblies were subject to, at the start of the test and after 5 min.

NOTE *During this period a slight drop in indicated gauge pressure might be observed due to a possible temperature drop in the test fluid. This should not be interpreted as evidence of leakage.*

Examine for leakage.

[4)] 1 bar = 10^5 N/m^2 = 100 kPa.

On removal of the test pressure, carry out a visual check of the connector, and measure and record its dimensions.

A.9 Dismantling and reassembly test

If there are no signs of leakage following the test described in **A.8**, subject the same three test assemblies (as shown in Figure A.2) to a dismantling and reassembly test. Dismantle and remake each connector ten times, in accordance with the manufacturer's published re-tightening instructions.

After each of the first nine re-tightenings, subject the assembly to a proof pressure test in accordance with **A.8** but for a minimum period of 5 min. After the tenth re-tightening, subject the test assembly to a further proof pressure test in accordance with **A.8**.

A.10 Minimum hydrostatic pressure test

If there are no signs of leakage following the tests described in **A.8** and **A.9**, subject the same three test assemblies to a hydraulic pressure four times the maximum permissible ambient pressure rating. Apply the pressure at a rate not exceeding 200 bar/min and maintain it for 5 min.

Examine for leakage.

NOTE These test assemblies should not be used for further testing, and are unsuitable for further use.

A.11 Vacuum test

Subject three test assemblies, as shown in Figure A.1, that have passed the proof pressure test described in **A.8** to the following procedure.

a) Place the test assembly in a bell jar.

b) Evacuate both the bell jar and the test sample to (1×10^{-4}) mbar or greater.

c) Pressurize the bell jar with helium to one atmosphere.

d) Measure the leak rate using a mass spectrometer.

e) Record the leak rate after 5 min.

NOTE The degreasing agent and the method of degreasing should be compatible with the material from which the test connectors are manufactured.

A.12 Over-tightening test

Take three test connector assemblies as shown in Figure A.1 and repeat the tests described in **A.8** and **A.9**, but with the assembly of the test connector and tube tightened and subsequently re-tightened to 125% of the manufacturer's published tightening criteria (see Clause **11**).

A.13 Maximum static gas pressure test

Subject three test assemblies, as shown in Figure A.1, that have passed the proof pressure test described in **A.8** to a further pressure test using an inert gas to 150% of system working pressure.

a) Make up test assembly to manufacturer's instructions (see Clause **11**).

b) Pressurize each connector with nitrogen gas to 150% of pressure rating for each tube. Test to be performed under water for 10 min.

c) Disassemble and reassemble each connector ten times as per manufacturer's instructions. In addition, each time rotate the tube ferrule assemblies with respect to the body seat 60° to 90° from its previous seated position. Rotation to be performed while the connector is in disassembled condition. This simulates random seat/front ferrule contact, typical of real life use.

d) Tighten to manufacturer's instructions and gas leak test connectors each fifth remake as [evacuate both the bell jar and the test sample to (1×10^{-4}) mbar or greater].

A.14 Hydraulic impulse and vibration test

The temperature of the test fluid shall be in the range 15 °C to 60 °C.

Take three test assemblies, as shown in Figure A.1, that have satisfactorily passed the proof pressure test described in **A.8**, followed by the tests described in **A.9**, **A.10**, **A.11** and **A.12**, and connect them to a hydraulic pressure impulse and vibration rig, either as shown in Figure A.4 or to a rig of equivalent design.

Before any tube is cut for the test assemblies, it shall be visually inspected and the outside diameter and wall thickness measured. The quality and measurements shall be in accordance with the requirements specified in Clause **7**.

Apply pressure impulses and vibration simultaneously to the assemblies, the pressure impulses at between 0.5 Hz and 1.7 Hz (30 cycles/min to 100 cycles/min) and the vibration at between 23 Hz and 47 Hz (1 380 cycles/min to 2 820 cycles/min).

Run the pressure impulses for a minimum of (5×10^5) cycles and the vibration for a minimum of (20×10^6) cycles. Choose the impulse and vibration frequencies so that they conclude simultaneously.

The pressure cycle shall be as shown in Figure A.5 and the displacement force applied at the position shown in Figure A.4 shall be sufficient to produce a displacement within 5% of the figure calculated from the following formula for a simple cantilever:

$$\Delta = \frac{2SL^2}{3ED}$$

where:

Δ is the displacement (in mm) of the assembly from rest, measured at the point of application of the vibrational force (half total amplitude);

L is the distance (in mm) from the connector nut on the male stud connector to the point of application of the vibrational force on the blanking end (see Figure A.6);

S is the bending stress (in kN/mm^2) based on 0.25 of the tensile yield or 0.25 of the 0.2% proof stress of the tube material at the point of entry into the nut of the fixed stud connector shown in Figure 5;

NOTE 1 This stress figure is only to be used as a basis for calculating the deflection.

NOTE 2 The tubes should be of a wall thickness such that the sum total of all applied loads does not reach the maximum permissible stress for the section of tube employed.

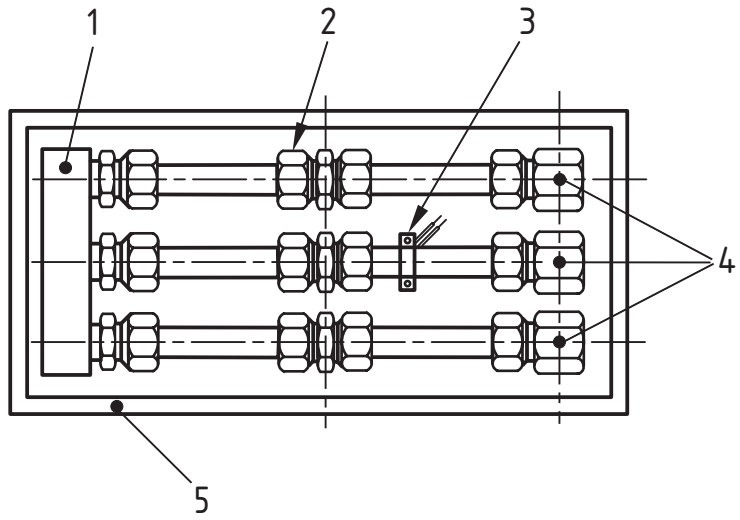
E is the Modulus of Elasticity of the tube material (e.g. for stainless steel, E = 193 kN/mm^2);

D is the outside diameter of the tube (in mm).

NOTE 3 Owing to the possibility of bedding-in of some types of connector, it is permissible to retighten once during the first 1 000 cycles of pressure impulse.

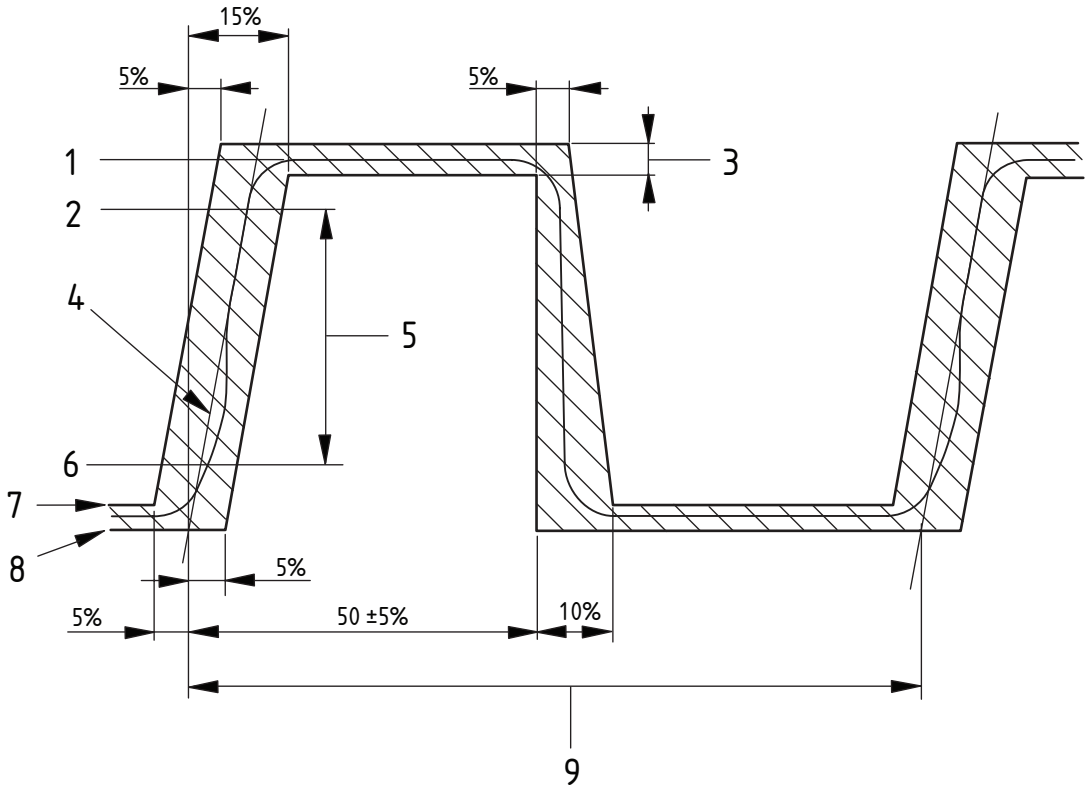
NOTE 4 Do not use test components that have been subjected to this test for any further test; clearly mark them as being unsuitable for further use.

Figure A.4 **Hydraulic impulse and vibration rig – Plan view**



Key
1 Pressure manifold
2 Test assembly as shown in Figure 5
3 Temperature sensor
4 Points of application of vibrational forces
5 Test chamber

Figure A.5 **Hydraulic impulse test cycle**



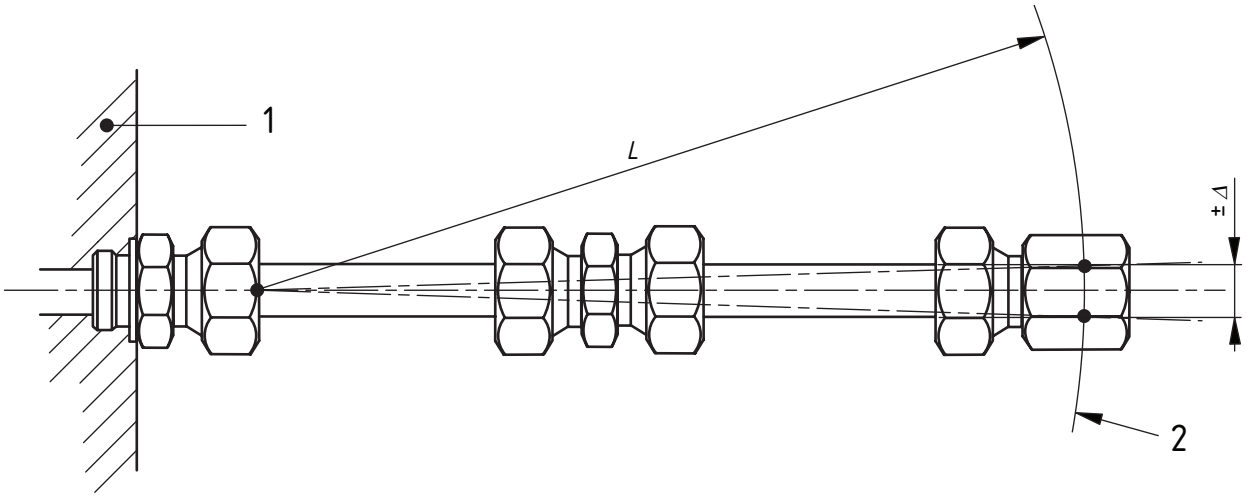
NOTE 1 Rate of rise of impulse test pressure to be between 3 000 bars/s and 6 000 bars/s.

NOTE 2 Impulse test pressure to equal 1.33 times the maximum working pressure.

Key

1 Test pressure
2 85% of test pressure
3 ±5% of test pressure
4 Secant pressure rise
5 Rate of rise of pressure to be determined between these points
6 15% of test pressure
7 10 bar (1.0 Mpa)
8 0 bar (0 Mpa)
9 One impulse cycle

Figure A.6 **Geometry of hydraulic impulse and vibration test – Side elevation showing simple cantilever**



Key

1 Pressure manifold

2 Axis of displacement in vibration test

A.15 Thermal cycle test

Two test assembly trees for each tube size shall be assembled according to the manufacturer's recommendations as shown in Figure A.7. Each test assembly tree shall consist of a male stud connector, a "T" piece, two elbows and two straight connectors with plugs. The first assembly tree shall be assembled using the thinnest wall tube whilst the second shall be assembled using the thickest wall tube. Each assembly shall then be subjected to the following test.

a) The assembly shall be proof pressure tested to 1.5 times the maximum recommended working pressure of the tubing as described in **9.1.**

b) The assembly shall then be subjected to a temperature cycle of; ambient to +80 °C and then to –25 °C with a hydrostatic pressure equal to the maximum working pressure allowed for the tube.

NOTE The temperature probe should be attached to the "T" piece.

c) The assembly shall be held at each extreme of the temperature cycle for sufficient time to enable the temperature of the assembly to stabilize.

d) This shall be repeated for a total of five cycles.

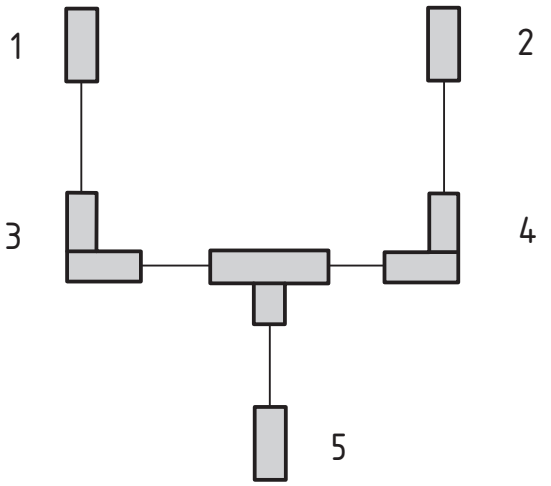
e) Following the completion of five cycles the assembly shall be subjected to a water immersion leak test with a gas pressure test of 68 bar.

A.16 Pneumatic pressure vibration test

Three specimens consisting of a male stud connector, tube and blanking end shall be made up and assembled on the vibration rig. An internal pneumatic pressure of 100 bar shall be applied to the specimens, and each connector shall be leak tested using soapy water. The pressure shall be maintained during the test.

A strain gauge shall be fixed to the central specimen at the entry point of the tube to the fixed stud connector, oriented to measure the strains induced by the vibrated and cantilevered specimen (specimens shall be oriented such that they each see the same stress levels). The strain levels shall be recorded on a UV recorder and monitored on an oscilloscope. The UV recorder shall be calibrated via a precision resistor decade box inserted in the circuit.

Figure A.7 **Thermal cycle test assembly**



Key
1 Straight connector with plug
2 Straight connector with plug
3 Elbow
4 "T" piece
5 Male stud connector

The electromagnetic vibrator shall be controlled at constant displacement through an accelerometer mounted on the vibration platform. The frequency of vibration shall be set at 45 Hz.

NOTE 1 This frequency is not expected to give any problems of resonance within the specimens, or any heating effects at the point of bending.

Each specimen shall be lubricated and assembled as specified by the manufacturer.

NOTE 2 Care is required to ensure that little or no residual static stress is incorporated in the assembly during make up and connection into the test rig.

The rig shall be operated until one of the specimens fails or twenty million cycles have been completed. The duration of the test, together with the test frequency, shall be used to obtain the total number of cycles.

NOTE 3 Failure can be detected when the internal pneumatic pressure drops, thus operating a trip, which isolates the vibration machine and stops the event timer.

The assemblies of three specimens shall be tested at superimposed bending stress levels of 30 N/mm^2, 60 N/mm^2, 90 N/mm^2 and 150 N/mm^2 (i.e. twelve specimens in all) or until sufficient information is gained from the test.

The test shall continue running until all three specimens fail or complete (20×10^6) cycles.

A.17 Fire test

Two test pieces of each tube size shall be tested in accordance with BS ISO 19921. The thickest and thinnest wall tubing shall be selected for each tube size from Tables 23 to 26.

If the tube diameters shown in the first column of Table A.2 pass the test, the suitability of the range of diameters shown in the second and third columns shall be deemed to have passed the test.

NOTE A selection of representative tubing diameters may be tested in order to evaluate the fire resistance of a series of twin ferrule connectors components, if applicable. Depending on the design of the tubing system and which connectors are used, different tube diameters might be necessary in each case.

Table A.2 **Range of tube diameters deemed to passed the fire test**

Tube diameter tested	Range deemed to have been passed	
	mm	in
2 mm ($^1/_{16}$ in)	2, 3, 4	$^1/_{16}$, $^1/_8$, $^3/_{16}$
4 mm ($^3/_{16}$ in)	4, 6, 8	$^3/_{16}$, $^1/_4$, $^5/_{16}$, $^3/_8$
8 mm ($^3/_8$ in)	8,10, 12	$^3/_8$, $^1/_2$
12 mm ($^1/_2$ in)	12, 14, 15, 16, 18, 20	$^1/_2$, $^5/_8$, $^3/_4$
20 mm ($^3/_4$ in)	20, 22, 25, 28, 30, 32	$^3/_4$, $^7/_8$, 1, $1^1/_4$
32 mm ($1^1/_4$ in)	32, 38	$1^1/_4$, $1^1/_2$, 2

A.18 Corrosion resistance test

A neutral salt spray corrosion resistance test shall be carried out in accordance with BS EN ISO 9227, using the test assembly shown in Figure A.3. The test shall be the NSS 6.5 to 7.2 ph test as specified in BS EN ISO 9227:2006, **5.2** and Table 2.

The duration of exposure for the test shall be at least 168 h.

Tests shall be carried out on connector assemblies made up onto the thinnest and thickest wall tube for each connector size as recommended by the connector manufacturer. Each assembly shall have a union in the middle joining the two tube lengths and each end

A test report shall be compiled as described in BS EN ISO 9227:2006, Clause **12**, and the results shall be recorded using Table A.3 below.

Table A.3 **Results of corrosion resistance test**

Test no:		**Start date:**		**Time:**		**Test piece details:**		
Test piece angle:		**Finish date:**		**Time:**		**Duration: hours**		
Weight before:		**Weight after:**		**Salt concentration:**		**Solution pH:**		
Date	**Time**	**Air line pressure**	**Jet pressure**	**Humidifier tower temperature**	**Cabinet temperature**	**Fallout (ml/h)**	**PH collected**	**Signature**
COMMENTS:								

A.19 Deep water submersion test

Place the connector assembly in a barometric chamber and pressurize the chamber to 138 bar with helium gas. Raise the pressure using nitrogen to 303 bar, which is equivalent to 3 048 m of sea water.

Evacuate the connector assembly to (1×10^{-3}) mbar or greater. Attach a mass spectrometer with detection rate greater than (1×10^{-8}) atmosphere c^3/s helium.

A.20 Test report

A test report shall be produced which includes at least the following information:

a) a full description of the test assemblies;

b) for the visual and dimensional inspection test, confirmation that only connectors that were found to meet the dimensional requirements specified in Tables 1 to 22 were tested;

c) for the hydraulic proof pressure test, the test pressure (in bar) that the assemblies were subject to at the start of the test and after 5 min;

d) for the dismantling and reassembly test, whether or not there are signs of leakage;

e) for the minimum hydrostatic pressure test, the test pressure (in bar) and whether or not there are signs of leakage;

f) for the vacuum test, any rise in pressure and whether or not there are signs of leakage;

g) for the over-tightening test, both tightening torques and whether or not there are signs of leakage;

h) for the maximum static gas pressure test, whether or not there are signs of leakage;

i) for the hydraulic impulse and vibration test, whether or not there are signs of leakage;

j) for the thermal cycle test, whether or not there are signs of leakage;

k) for the pneumatic pressure and vibration test, whether or not there are signs of leakage;

l) for the fire test, whether or not there are signs of leakage;

m) for the corrosion resistance test, details of any corrosion defects following the test exposure;

n) for the deep water submission test, whether or not helium is detected;

o) any observations of interest such as whether retightening was necessary;

p) the number and date of this British Standard, i.e. BS 7993:2011;[5)]

q) the name and company address of the testing facility;

r) the date when the test was performed;

s) the name and company address of the third-party witness, if third-party certification/inspection is undertaken (see Foreword).

[5)] Marking BS 7993:2011 on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is solely the claimant's responsibility. Such a declaration is not to be confused with third-party certification of conformity.

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