



Standard Specification for Performance of Piping and Tubing Mechanically Attached Fittings¹

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1. Scope

1.1 This specification establishes the performance characteristics required for mechanically attached fittings (MAFs) for use in piping and tubing systems. These fittings directly attach to pipe or tube by mechanical deformation of the pipe or tube or fitting, or a combination thereof, creating a seal and a restrained joint. The seal may be created via the mechanical deformation or created independently. Successful completion of the tests described constitutes completion of the technical portion of the qualification process.

1.2 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified in part or whole by the purchaser in the order. Unless otherwise specified, U.S. Navy contracts shall invoke the supplementary requirements in whole.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 The following safety hazards caveat applies only to the tests listed in Section 13 and the tests described in the Supplementary Section and the Annex of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.5 Unless specific MAF types are specified, the term “MAF” shall apply to all types described herein.

1.6 The tests specified in Section 13 and described in Annex A1 and Supplementary Requirements are applicable only to ascertain the performance characteristics of MAFs. These tests are not intended for use in the evaluation of non-MAF products.

1.7 A fire performance test is specified in Supplementary Requirement S7. This test provides general guidelines to

determine the responsiveness of MAFs when subjected to fire. This test should not be considered for use to evaluate non-MAF products.

2. Referenced Documents

2.1 ASTM Standards:

A 105/A 105M Specification for Carbon Steel Forgings for Piping Applications²

A 106 Specification for Seamless Carbon Steel Pipe for High-Temperature Service²

A 108 Specification for Steel Bars, Carbon, Cold-Finished, Standard Quality³

A 109/A 109M Specification for Steel, Strip, Carbon (0.25 Maximum Percent), Cold-Rolled⁴

A 167 Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip⁴

A 182/A 182M Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service²

A 213/A 213M Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes²

A 234/A 234M Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service²

A 240/A 240M Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels⁴

A 249/A 249M Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes²

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels⁴

A 269 Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service²

A 276 Specification for Stainless and Steel Bars and Shapes⁴

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² Annual Book of ASTM Standards, Vol 01.01.

³ Annual Book of ASTM Standards, Vol 01.05.

⁴ Annual Book of ASTM Standards, Vol 01.03.

- A 312/A 312M Specification for Seamless and Welded Austenitic Stainless Steel Pipes²
- A 380 Practice for Cleaning, Descaling, and Passivation Stainless Steel Parts, Equipment, and Systems⁴
- A 403/A 403M Specification for Wrought Austenitic Stainless Steel Piping Fittings²
- A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes²
- A 479/A 479M Specification for Stainless and Heat-Resisting Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels⁴
- A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe²
- A 564/A 564M Specification for Hot-Rolled and Cold-Finished Age-Hardening Stainless Steel Bars and Shapes⁴
- A 576 Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality³
- A 766/A 766M Specification for Forgings⁵
- B 16 Specification for Free-Cutting Brass Rod, Bar, and Shapes for Use in Screw Machines⁶
- B 21 Specification for Naval Brass Rod, Bar, and Shapes⁶
- B 111 Specification for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock⁶
- B 117 Practice for Operating Salt Spray (Fog) Apparatus⁷
- B 122/B 122M Specification for Copper-Nickel-Tin Alloy, Copper-Nickel-Zinc Alloy (Nickel Silver), and Copper-Nickel Alloy Plate, Sheet, Strip, and Rolled Bar⁶
- B 124 Specification for Copper and Copper Alloy Forging Rod, Bar, and Shapes⁶
- B 154 Method for Mercurous Nitrate Test for Copper and Copper Alloys⁶
- B 164 Specification for Nickel-Copper Alloy Rod, Bar, and Wire⁸
- B 251 Specification for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube⁶
- B 371 Specification for Copper-Zinc-Silicon Alloy Rod⁶
- B 564 Specification for Nickel Alloy Forgings⁸
- B 633 Specification for Electrodeposited Coatings of Zinc on Iron and Steel⁹
- B 696 Specification for Coatings of Cadmium Mechanically Deposited⁹
- B 766 Specification for Electrodeposited Coatings of Cadmium⁹
- E 511 Test Method for Measuring Heat Flux Using a Copper-Constantan Circular Foil, Heat Flux Gage¹⁰
- E 1529 Test Methods for Determining Effects of Large Hydrocarbon Pool Fires on Structural Members and Assemblies¹¹

2.2 Federal Specifications:¹²

- QQ-P-35 Passivation Treatments for Corrosion-Resisting Steels
- QQ-N-281 Nickel-Copper Alloy Bar, Rod, Plate, Sheet, Strip, Wire, Forgings and Structural and Special Shaped Sections
- QQ-N-286 Nickel-Copper-Aluminum Alloy, Wrought (UNS N05500)
- QQ-P-416 Plating, Cadmium (Electrodeposited)
- QQ-B-626 Brass, Leaded and Nonleaded Rods, Shapes, Forgings and Flat Product, TH Finished Edges (Bar and Strip)
- QQ-S-763 Steel Bars, Wire, Shapes, and Forgings, Corrosion Resisting

2.3 Military Specifications:¹²

- MIL-S-901 Shock Tests, H.I. (High Impact) Shipboard Machinery, Equipment, and Systems, Requirements for
- MIL-T-1368 Tube and Pipe, Nickel Copper Alloy Seamless and Welded
- MIL-H-5606 Hydraulic Fluid, Petroleum Based, Aircraft, Missile, and Ordinance
- MIL-L-7808 Lubricating Oil, Aircraft Turbine Engine, Synthetic Base, NATO Code Number O-148
- MIL-T-8606 Tubing, Steel Corrosion-Resistant (18-8 Stabilized and Extra Low Carbon)
- AND 10102 Tubing—Standard Dimensions for Round Alloy Steel
- MIL-C-15726 Copper-Nickel Alloy, Rod, Flat Products (Flat Wire, Strip, Sheet, Bar, and Plate) and Forgings
- DOD-P-16232 Phosphate Coatings, Heavy, Manganese or Zinc Base (for Ferrous Metals)
- MIL-T-16420 Tube, Copper Nickel Alloy, Seamless and Welded (Copper Alloy Numbers 715 and 706)
- MIL-F-18866 Fittings Hydraulic Tube, Flared, 37° and Flareless Steel
- MIL-C-20159 Copper-Nickel Alloy Castings
- MIL-T-24107 Tube, Copper, (Seamless) (Copper Numbers 102, 103, 108, 120, 122, and 142)
- MIL-P-24691/1 Pipe and Tube, Carbon Steel, Seamless
- MIL-P-24691/2 Pipe and Tube, Chromium-Molybdenum Steel, Seamless
- MIL-P-24691/3 Pipe and Tube, Corrosion-Resistant, Stainless Steel, Seamless or Welded
- MIL-R-83248/1 Rubber, Fluorocarbon Elastomer, High Temperature, Fluid and Compression Set Resistant, O-Rings, Class 1, 75 Hardness
- MIL-H-83282 Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft, Metric, NATO Code Number H-537

2.4 Military Standards:¹²

- MIL-STD-105 Sampling Procedures and Tables for Inspection by Attributes
- MIL-STD-167 Mechanical Vibration of Shipboard Equipment
- MIL-STD-271 Nondestructive Testing Requirements of Metals
- MIL-STD-278 Welding and Casting Standard
- MIL-STD-753 Corrosion-Resistant Steel Parts, Sampling, Inspection and Testing for Surface Passivation

⁵ Discontinued. See *Annual Book of ASTM Standards*, Vol 01.01 (1991 Edition).

⁶ *Annual Book of ASTM Standards*, Vol 02.01.

⁷ *Annual Book of ASTM Standards*, Vol 03.02.

⁸ *Annual Book of ASTM Standards*, Vol 02.04.

⁹ *Annual Book of ASTM Standards*, Vol 02.05.

¹⁰ *Annual Book of ASTM Standards*, Vol 15.03.

¹¹ *Annual Book of ASTM Standards*, Vol 04.07.

¹² Available from Standardization Documents Order Desk, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

MIL-STD-777 Schedule of Piping Valves, Fittings, and Associated Piping Components for Naval Surface Ships
 MIL-STD-889 Dissimilar Metals
 MIL-STD-1235 Single- and Multi-Level Continuous Sampling Procedures and Table for Inspection by Attributes
 MIL-STD-2175 Castings, Classification and Inspection of MS 33531 Tolerances, Welded Corrosion-Resistant Steel Tubing
 MIL-STD-45662 Calibration System Requirements
 2.5 *American National Standards Institute (ANSI)*:¹³
 B 36.10 Welded and Seamless Wrought Steel Pipe
 B 46.1 Surface Texture (Surface Roughness, Waviness and Lay)
 2.6 *Society of Automotive Engineers (SAE)*:¹⁴
 AMS 5643 Bars, Forgings, Tubing and Rings—16 Cr 4.0 Ni 0.30 (Cb + Ta) 4.0 Cu
 J 514 Hydraulic Tube Fittings
 J 515 Hydraulic “O” Ring
 SAE 1010 Carbon Steel: Nonsulfurized Manganese 10 % Minimum
 2.7 *American Society of Mechanical Engineers (ASME)*:¹⁵
 ASME Code, Section IX

3. Terminology

3.1 Definitions:

3.1.1 *class, n*—a group of MAFs of a particular design with the dimensions proportional to pipe or tube outside diameters, made from the same material grade (or combination of grades), for the same rated pressure, or for a rated pressure inversely proportional to the diameter.

3.1.1.1 *Discussion*—Class designation for MAF is assigned based upon the rated pressure used to test the MAF design.

3.1.2 *failure, n*—any leakage or joint separation unless otherwise determined to be due to a tubing/pipe or fitting defect.

3.1.3 *fitting, n*—connecting device used to join multiple pipes or tubes or other MAFs together to create a working system.

3.1.3.1 *Discussion*—Shapes such as couplings, unions, elbows, tees, crosses, plugs, adapters, reducers, flanges, and special shapes are used as needed to fulfill MAF system design specifications.

3.1.4 *joint, n*—interface between pipe or tube and MAFs where the seal is maintained or mechanical holding strength is applied or maintained within the overall MAF design.

3.1.5 *leakage, n*—the escape of fluid or gas from any point of the MAF, including the MAF joint interface, sufficient to drop or flow from the point of formation or gas bubbles rising to the surface after the first minute of submersion.

3.1.6 *mechanically attached fitting (MAF), n*—a fitting that is directly attached to pipe or tube by mechanical deformation of the pipe/tube or fitting, or both, creating a seal and a

restrained joint. The seal may be created via the mechanical deformation or created independently.

3.1.7 *penalty run, n*—a penalty run is performed with penalty run MAF specimens when the original MAF test specimen leaks or separates during testing as a result of any cause that is not related to the design of the MAF being qualified.

3.1.8 *penalty run MAF specimens, n*—additional specimen(s) that are tested in the place of the original specimen(s) (see 3.1.7).

3.1.8.1 *Discussion*—These additional MAF specimen(s) are assembled using the same methods along with additional MAFs of the same type, grade, class, and configuration and additional pipe or tube with the same wall thickness and material conditions as the original test specimen.

3.1.9 *permanent MAF, n*—a fitting whose joint(s) attach directly to the pipe or tube to join two or more pipes or tubes or other MAFs in a combination of pipes or tubes and components. In either case, the permanent MAFs cannot be disassembled and reused after initial assembly.

3.1.10 *pipe, n*—hollow round product conforming to the dimensional requirements for nominal pipe size (NPS) as tabulated in ANSI B36.10, Table 2.

3.1.11 *rated pressure, n*—the manufacturer’s recommended in-service pressure assigned to the MAF (see 3.1.15).

3.1.12 *separable MAF, n*—a fitting whose joint(s) attach directly to the pipe or tube to join two or more pipes or tubes or other MAFs in a combination of pipes or tubes and components. Once assembled, the separable MAFs can be disassembled and reassembled a multiple number of times.

3.1.12.1 *Discussion*—Some subcomponents of separable MAFs may become permanently attached to the pipe or tube without affecting the function of the joint.

3.1.13 *specimen, n*—a prepared assembly consisting of a MAF assembled onto a preselected pipe or tube. The specimen is placed into a controlled environment and tested to determine if the MAF assembly meets the requirements specified in the test being performed.

3.1.14 *test pressure, n*—a selected pressure used during testing, which is based upon the rated pressure (see 3.1.13) of the MAF or pipe or tube, whichever is lower, times the factor specified for each test (that is, 1.25, 1.50, 2.00, 4.00, and so forth).

3.1.15 *tube, n*—hollow round product which is usually specified with respect to outside diameter and wall thickness.

4. Classification

4.1 MAFs are classified into the following design types:

NOTE 1—Each MAF type may consist of more than one material and class.

4.1.1 *Type I: Radially Swaged MAF (Permanent)*—A portion of the MAF diameter is reduced mechanically by means of an installation tool through radial compression to provide an intimate joint. The properly installed MAF has a circumferential deformation of predetermined dimensions.

4.1.2 *Type II: Flared MAF (Separable)*—An assembly that consists of a body, nut, and sleeve. The MAF is designed to mate with a tube or other component which has been flared or

¹³ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

¹⁴ Available from Society of Automotive Engineers, 400 Commonwealth Dr., Warrendale, PA 15096.

¹⁵ Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

machined to a specific angle. The flared tube end is positioned onto the MAF body cone or seat. The nut is then tightened to the body thread, thus providing a tube-to-MAF seal through mechanical retention.

4.1.3 *Type III: Flareless (Bite-Type) MAF (Separable)*—An assembly having a ferrule, nut, and body. The ferrule penetrates the outside of the tubing, thus providing a pressure seal and holding mechanism.

4.1.4 *Type IV: Grip-Type MAF (Separable)*—An assembly having one or two ferrules that are compressed into the surface of the tube. In the case of the two-ferrule MAF, the forward ferrule provides the primary seal through radial compression around the outer diameter of the tube. The rear ferrule acts as the primary mechanical holding device. In the case of the single-ferrule design, the ferrule is used to seal and act as the primary mechanical holding device.

4.1.5 *Type V: Shape Memory Alloy (SMA) MAF (Permanent)*—Mechanically attached fittings that use SMA to provide the mechanical force required to produce a metal-to-metal seal between the pipe or tube and the MAF. The metal-to-metal seal that is formed is a “live crimp” since the pipe or tube and the SMA are in a state of dynamic equilibrium. The SMA maintains a permanent inward radial force on the pipe or tube at all times. The MAF body itself may be manufactured from a nonshape memory metal and used in conjunction with a driver made from SMA.

4.1.6 *Type VI: Axially Swaged MAF (Permanent)*—Mechanically attached fittings that have machined swaging rings telescopically “press fit” from the extremities toward the center of the MAF body. An installation tool advances the swaging rings axially over the MAF body into a seated and locked position. The swage rings compress the MAF body onto the pipe or tube forming a metal-to-metal seal. The seal is permanently maintained by the force radially exerted by the swaging rings onto the sealing interface.

4.2 The MAFs shall be made from one or more of the following material grades:

NOTE 2—When multiple components resulting in more than one material grade are specified within a MAF assembly, the combination of grades used shall be galvanically compatible.

- 4.2.1 *Grade A*—Carbon steel.
- 4.2.2 *Grade B*—Stainless steel.
- 4.2.3 *Grade C*—Nickel-copper.
- 4.2.4 *Grade D*—Copper-nickel.
- 4.2.5 *Grade E*—Brass.
- 4.2.6 *Grade F*—Nickel titanium.

4.3 The MAF rated pressure may be one of the following classes:

NOTE 3—The rated pressure may differ within the size range of a MAF being qualified (see 3.1.1).

- 4.3.1 *Class 1*—1.38 MPa (200 psi) maximum.
- 4.3.2 *Class 2*—2.76 MPa (400 psi) maximum.
- 4.3.3 *Class 3*—4.83 MPa (700 psi) maximum.
- 4.3.4 *Class 4*—6.90 MPa (1000 psi) maximum.
- 4.3.5 *Class 5*—10.34 MPa (1500 psi) maximum.
- 4.3.6 *Class 6*—13.79 MPa (2000 psi) maximum.
- 4.3.7 *Class 7*—20.69 MPa (3000 psi) maximum.

- 4.3.8 *Class 8*—25.86 MPa (3750 psi) maximum.
- 4.3.9 *Class 9*—34.48 MPa (5000 psi) maximum.
- 4.3.10 *Class 10*—41.37 MPa (6000 psi) maximum.

5. Ordering Information

5.1 Orders for MAFs under this specification shall include the following:

- 5.1.1 ASTM designation, title, number, and year of issue;
- 5.1.2 Quantity of fittings (MAF);
- 5.1.3 Size, nominal pipe size (NPS), or outer diameter (OD);
- 5.1.4 Type (I, II, III, IV, V, or VI);
- 5.1.5 Material grade (see 4.2, 6.1, or Table 1),
- 5.1.6 Class (see 3.1.1 and 4.3);
- 5.1.7 MAF shape (that is, straight, elbow, cross, union, coupling, and so forth) (see 3.1.3);
- 5.1.8 Supplementary requirements, if any;
- 5.1.9 Other requirements agreed to between the purchaser and the manufacturer; and
- 5.1.10 Inspection and acceptance of MAFs as agreed upon between the purchaser and the supplier (see Section 14).

5.2 Optional Ordering Requirements:

- 5.2.1 Certification (see Section 15).
- 5.2.2 Special marking requirements (see Section 16 and S1.5).

6. Materials and Manufacture

6.1 *MAF Material*—The MAF material used may be as specified in Table 1 or may be other materials not specified in Table 1, as agreed to between the manufacturer and the purchaser.

6.1.1 All types may be manufactured from wrought bars, forgings, castings, pipe, or tube.

6.1.2 *Flow of Grain*—MAFs machined from hot- or cold-drawn bars shall have their longitudinal axis parallel to the longitudinal axis of the bar with at least the center one third of the bar removed during the manufacturing process unless testing shows the center material to be free of injurious defects.

6.2 *Material Quality*—The material shall be of such quality and purity that the finished product shall have the properties and characteristics to meet the performance requirements of this specification.

6.2.1 The manufacturer is encouraged to use materials produced from recovered materials to the maximum extent practicable without jeopardizing the intended use. Used or rebuilt products shall not be used.

NOTE 4—The term “recovered materials” is interpreted as those materials that have been collected or recovered from solid waste and reprocessed to become a source of raw material, as opposed to extra virgin raw materials.

6.3 *Seal Materials*—Seals used with MAFs shall be as specified in Table 1.

6.4 *Surface Applications and Coatings*—Surface applications and coatings if applicable, shall be applied and tested in accordance with the requirements specified in Table 2.

6.5 *MAF Fabrication*—MAFs fabricated from two or more parts may be welded. The use of brazing or soldering is not permitted.

TABLE 1 Material Specifications for MAFs

Type	Straight	Shape	Nut/Ring (Body, Lock, Jam)	Sleeve or Ferrule	Backup Washer	Seal Material
Grade A: Carbon Steel						
I	A 108 ^A	A 576	A 108	...	...	MIL-R-83248/1
II	A 108	A 576	A 576 ^B	A 108	A 109/A 109M	^C
III	A 108	A 576	A 576	A 108	A 109/A 109M	^D
IV	A 108	A 576 ^B	A 576	A 108	A 109/A 109M	^D
VI	A 108 ^A	A 576 ^E	A 108 ^A	...	...	^D
Grade B: Stainless Steel						
I	A 312/A 312M ^F	QQ-S-763 ^G	A 312/A 312M ^F	...	...	MIL-R-83248/1
II	A 479/A 479M	A 182/A 182M	A 479/A 479M ^H	A 479/A 479M ^H	A 167 ^I	^C
III	A 479/A 479M	A 182/A 182M	A 479/A 479M ^H	A 564/A 564M ^J	A 167 ^I	^D
IV	A 479/A 479M	A 182/A 182M	A 479/A 479M	A 276	A 167 ^I	^D
VI	A 312/A 312M ^F	A 182/A 182M ^K	A 312/A 312M ^F	A 240/A 240M	...	^D
Grade C: Nickel Copper						
II	B 164	B 564	B 164	B 164	A 167 ^I	^C
III	B 164	A 564/A 564M	B 164	B 164	A 167 ^I	^D
IV	B 164 ^L	B 564 ^L	B 164 ^L	B 164 ^L QQ-N-286	A 167 ^I	^D
Grade D: Copper Nickel						
I	MIL-C-15726 ^M	MIL-C-20159 ^M	MIL-C-15726 ^M	...	...	MIL-R-83248/1
II	B 122/B 122M	B 122/B 122M	B 122/B 122M	B 122/B 122M	A 167 ^I	^C
III	B 122/B 122M	B 122/B 122M	B 122/B 122M	A 564/A 564M ^I	A 167 ^I	^D
VI	MIL-C-15726 ^M	MIL-C-20159 ^M	MIL-C-15726 ^M	...	...	^D
Grade E: Brass						
II	B 16	B 124	B 16 ^N	B 111 ^O	...	^C
IV	B 16 ^P	B 124 ^P	B 16 ^P	B 16 ^P	...	^D
Grade F: Nickel Titanium						
V	Q	Q	Q	...	...	^D

^AAlternate material in conformance to Specification A 106 (Grade B) may be used.

^BAlternate material in conformance to Specification A 108 may be used.

^CWhen required by the MAF design, O-rings in accordance with SAE J515 shall be used to connect the MAF end.

^DNo O-rings used to connect the MAF end.

^EAlternate material in conformance to Specification A 234/A 234M may be used.

^FAlternate material in conformance to MIL-P-24691/3 may be used.

^G304, 304L or 316, 316L material may be used.

^HAlternate material in conformance to Specification A 276 may be used.

^IGrade 302.

^JAlternate material in conformance to AMS 5643 may be used.

^KAlternate material in conformance to Specification A 403/A 403M may be used.

^LAlternate material in conformance to QQ-N-281 may be used.

^MAlternate material in conformance to MIL-T-16420 may be used.

^NAlternate material in conformance to Specification B 21 may be used.

^OAlternate material in conformance to Specification B 371 may be used.

^PAlternate material in conformance to QQ-B-626 may be used.

^QIn accordance with the manufacturer's specification.

6.5.1 Welding procedure qualification and welding operator performance qualification shall be in accordance with ASME Section IX. Welding process shall be in accordance with MIL-STD-278. Welded MAFs shall be tested in accordance with the requirements as specified in 13.4.3.

6.5.2 The welding procedure qualification test shall duplicate the joint configuration to be used in production.

6.6 *Processing Stainless Steel Forgings*—Austenitic stainless steel components manufactured by hot forge or other sensitizing processes shall be solution annealed and certified

free of intergranular precipitation. Practice A 262 shall be used to evaluate carbide precipitation in stainless steels.

7. Performance Requirements

7.1 *Testing Requirements*—MAFs shall be subjected to the standard performance tests specified in 13.1 and Table 3. The tests are described in the Annexes. Supplementary tests specified in 13.2 and Table S1.1 shall be performed when invoked in the order or contract by the purchaser.

TABLE 2 Finishes and Coatings Applied to MAFs^A

Material Grade	Type of Finish or Coating	Applicable Document	Test Requirement	Applicable Document	Test Results
A	Cadmium Coating ^{B,C}	B 766 ^D	Salt Spray (Fog)	B 117	72 h before red rust
A		B 696 ^D			
A	Zinc Coating ^B Type II, Surface Condition 1	B 633	Salt Spray (Fog)	B 117	72 h before red rust
A	Phosphate Coat ^B Class 1	DOD-P-16232	Salt Spray (Fog)	B 117	32 h before red rust
B	Passivation	A 380 QQ-P-35	Copper Sulphate Test	MIL-STD-753 Method 102	pass copper sulphate test

^AOther finishes or coatings not specified herein may be used upon mutual agreement between the manufacturer and the purchaser.

^BCoating shall be a minimum of 0.0002 followed by a chromate treatment or with a phosphate coating with oil finish.

^CCadmium plating shall not be used on MAFs intended for use on U.S. Navy vessels.

^DFederal Specification QQ-P-416 plating may also be used.

TABLE 3 Specimen Geometry and Testing Requirements^A

Description of Test	Number of Specimens		Applicability of Test	
	Permanent	Separable	Permanent	Separable
Examination of specimen	22	28	yes	yes
Pneumatic proof test	22	28	yes	yes
Hydrostatic proof test	22	28	yes	yes
Impulse test ^B	6	6 ^C	yes	yes
Flexure fatigue test ^B	6	6 ^C	yes	yes
Tensile test	6	6	yes	yes
Burst test ^{B,D}	4	4	yes	yes
Repeat assembly test ^B	...	^C	no	yes
Rotary flexure test ^B	...	6	no	yes
Mercurous nitrate test	2	2	... ^E	... ^E

^A Number of specimens does not include any specimens for supplementary tests (see Table S1.1). When supplementary requirements in S1.3.8 are invoked, the number of specimens for all tests (annex and supplementary) shall be as specified in the supplementary requirements section.

^B Specimens can be reused for other primary tests as long as all requirements herein are complied with for each test.

^C A minimum of 50 % of specimens selected for impulse and flexure fatigue testing shall be subjected to repeat assembly testing.

^D When the Supplementary Requirements of this standard are invoked, burst test specimens shall be comprised only with passed specimens from elevated temperature soak (see S3) and shock test (see S6). When the Supplementary Requirements are not invoked, new or passed specimens from other tests in the Annex can be used. In any event, the minimum quantity of specimens used for this test shall be as specified.

^E Two MAFs from each size and shape made from either copper zinc alloys containing more than 15 % zinc or copper-aluminum alloys shall be tested. These specimens shall be assembled onto pipe or tube, but do not have to be capped for pneumatic and hydrostatic testing before performing the mercurous nitrate test.

7.1.1 These tests shall be repeated any time changes are made in the design, material, or manufacturing process, which in the opinion of the purchaser, may degrade the performance of MAFs.

7.2 *Intermixing of MAF Subcomponents*—The intermixing by the purchaser of subcomponents of the same design, but of different brands or trade names, is not permitted unless specifically authorized by the manufacturer.

7.2.1 When subcomponents of different brands, trade names, or manufacturers are used, the manufacturer testing the MAF design shall specify this information in the test report.

7.3 *Qualification Requirements*—MAFs shall be tested using specimens of the same type, grade (or combination of

grades), and class. The pipe or tube selected for the technical qualification to this specification shall meet the requirement specified in 7.3.4. Technical qualification of the MAF assembly shall be based upon successful completion of all required testing. Each MAF design is only qualified for use with the pipe or tube material and minimum to maximum wall thickness tested or extended by interpolation (see 7.3.2 and 7.3.3).

7.3.1 Except as required by Annex A11 (Mercurous Nitrate Test), all MAFs tested shall be comprised of an equal number of specimens from the smallest and largest sizes within the size range of the MAF type, grade, and class being tested.

7.3.1.1 Test one or more intermediate sizes if the ratio of the minimum and maximum pipe or tube outside diameter to be tested is equal to or more than five.

7.3.2 Through reasonable interpolations between the MAF sizes tested, all other sizes of MAFs within the same type, grade (or combination of grades), and class, will be considered acceptable if the MAF specimens pass all of the testing requirements specified by the purchaser. Extrapolation is not acceptable.

7.3.3 Acceptance of tees, elbows, and other shapes within the same class, may be accomplished by parametric analysis (see 7.3.3.1), as agreed to between the manufacturer and the purchaser based on the acceptance of couplings.

7.3.3.1 If tees, elbows, and other shapes are made from a different raw material form than the coupling (for example, tees and elbows manufactured from castings versus couplings manufactured from solid bar or round tube), this alternate material form shall undergo the same test regimen as the coupling. Once this is complete, parametric analysis may be used to qualify the remainder of the shapes as agreed to between the purchaser and the manufacturer.

7.3.4 Recommended pipe or tube for use with MAFs may be qualified throughout its wall thickness range, when pipe or tube of a minimum and maximum wall thickness are used within the test specimens being qualified.

7.3.5 The MAFs may incorporate non-MAF features (that is, bolted flanges, and so forth). Those non-MAF features that are part of a MAF configuration shall meet the current issue of existing military and commercial documents (as applicable). Qualification of the non-MAF features are not within the scope of this specification.

7.4 *Test Report*—Upon completion of testing, a test report shall be written and maintained on file during the life cycle of

the design. A copy of this report shall be made available upon request from the purchasing activity.

7.4.1 A failure during testing shall be analyzed and the failure analysis (see 11.3.1 and 11.3.2) and corrective action shall be included in the test report.

7.4.2 A retest as specified in Section 11 may be allowed when failure of the original assembly occurs during testing. When retesting is permitted, the failure analysis and corrective action shall be included in the test report as specified in 7.4.1.

7.5 *Test Equipment and Inspection Facilities*—The manufacturer shall ensure that test equipment and inspection facilities of sufficient accuracy, quality, and quantity are established and maintained to permit the performance of required inspections.

7.5.1 *Calibration System Requirements*—The manufacturer shall maintain a calibration system for all measuring and test equipment (M & TE) in accordance with MIL-STD-45662 with traceability to the National Institute of Standards and Technology (NIST).

7.5.1.1 Accuracy of the M & TE used to measure allowable variables during testing shall be within one third of the tolerances permitted (see 7.6).

7.6 *Test Conditions*—Unless otherwise specified in the test, the following tolerances shall be used to control conditions of the tests specified in the Annex:

7.6.1 *Ambient Conditions*—When ambient is specified, standard ambient conditions shall be maintained at $25 \pm 10^\circ\text{C}$ ($77 \pm 18^\circ\text{F}$).

7.6.2 *Pressure*—Unless otherwise specified, the tolerance for the internal pressure applied to the test specimen during testing shall be maintained at $\pm 5\%$.

7.6.3 *Test Fluids*—Unless otherwise specified, the test fluids used in the testing of MAF shall include those fluids specified within the test. Water and other fluids such as SAE Grade 10W, MIL-H-5606, MIL-L-7808, or MIL-H-83282 may be used without affecting the validity of the test.

7.6.4 *Temperature*—Unless otherwise specified, the allowable tolerance for temperature applied to the test specimen during testing shall be $\pm 5^\circ\text{C}$ ($\pm 10^\circ\text{F}$).

7.7 *Pass or Fail Criteria*—Pass or fail criteria for each test shall be based upon meeting or exceeding the performance requirements specified in each test.

8. Dimensions

8.1 MAF Dimensions:

8.1.1 Type I MAF dimensions shall be as specified by the manufacturer.

8.1.2 Types II and III MAF dimensions shall be as specified in MIL-F-18866 or SAE J514 or as agreed to between the manufacturer and the purchaser.

8.1.3 Type IV MAF dimensions shall be as specified by the manufacturer.

8.1.4 Type V MAF dimensions shall be as specified by the manufacturer.

8.1.5 Type VI MAF dimensions shall be as specified by the manufacturer.

9. Workmanship, Finish, and Appearance

9.1 *Machined Surfaces*—Machined surfaces shall be free from burrs, cracks, laps, or seams which would affect the suitability for the intended service.

9.1.1 All machined surfaces shall be 3.2- μm roughness, average (R_a) (125- $\mu\text{in. } R_a$) as specified in ANSI B46.1 or duplicate of that qualified.

9.1.1.1 External surfaces that do not affect the overall function of MAFs shall be excluded from the requirement specified in 9.1.1.

9.2 *Unmachined Surfaces*—Unmachined surfaces, such as forging or casting surfaces and bar stock flats, shall be free from scale, blisters, fins, folds, seams, laps, segregations, or cracks which may be injurious to personnel or equipment or affect MAF performance.

10. Sampling for Testing

10.1 *Inspection Sampling of Raw Material*—Except when specified herein, the number of samples required for inspection of raw materials for conformance of products during manufacturing and processing shall be in accordance with established quality assurance procedures maintained by the manufacturer and approved by the purchaser.

10.2 *In-Process Inspection Sampling of MAFs*—Inspection sampling plans of MAFs being manufactured or processed shall be mutually agreed upon between the manufacturer and the purchaser. MIL-STD-105 shall be used when specified in the purchase order or contract. Level of inspection and acceptable quality level (AQL) shall be in accordance with the manufacturer's quality assurance procedures.

10.3 *Lot Acceptance*—Lot acceptance sampling plans shall be mutually agreed upon between the manufacturer and the purchaser. MIL-STD-105 shall be used when specified in the purchase order or contract.

10.4 *Sampling for Inspection of Type III Ferrules*—A random sample of ferrules shall be selected from each lot in accordance with MIL-STD-105, Special Inspection Level S-2, AQL of 2.5, and tested in accordance with 13.4.1. Other inspection or sampling plans may be used upon mutual agreement between the manufacturer and the purchaser.

10.4.1 A minimum of five ferrules shall be randomly selected from each lot and subjected to the testing specified in 13.4.2.

10.5 *Sampling for Inspection of Fabricated MAFs*—A minimum of four samples shall be selected at random from each lot of welded products and subjected to the tests specified in 13.4.3.

11. Number of Tests and Retests

11.1 *Number of Test Specimens*—The tests used to qualify MAFs and the number of specimens required for each test shall be as specified in Table 3.

11.2 *Replacement of Test Specimens*—When untested specimens are rejected as a result of overtightening, inferior workmanship or materials, or assembly, the specimens shall be dispositioned in accordance with the manufacturer's quality assurance procedures.

11.2.1 The original unique numbers assigned in accordance with 12.3.1 shall be recorded in the test report along with the reason for rejection.

11.2.1.1 New test specimens with MAFs of the same type, grade, and class, and pipe or tube of the same outside diameter and wall thickness shall be prepared in accordance with Section 12.

11.3 *Penalty Runs*—In the event of a test failure, the manufacturer shall proceed with one of the following options:

11.3.1 If the failure is determined to be design related, the manufacturer shall redesign the MAF and start all tests from the beginning. The requirements in 11.3.2 shall not apply to redesigned MAF.

11.3.2 If the failure is determined to be unrelated to the design, the test specimen shall be rerun. A replacement test specimen shall be prepared in accordance with the requirements in 11.2 and Section 12.

11.3.3 If the failure cannot be determined to be either design related or not design related, the manufacturer shall test three additional penalty specimens. The requirements specified in 11.3.2 shall apply.

11.4 *Penalty Run Specimen Preparation*—Penalty run specimens shall be prepared when MAF has failed any of the tests specified in the Annexes.

11.4.1 The MAF used for penalty runs shall be of the same type, grade, and class as the failed MAF being replaced.

11.4.2 The pipe or tube used in penalty runs shall be of the same material (including form and condition), outer diameter, and wall thicknesses as the pipe or tube being replaced.

11.4.3 Preparation of the penalty run specimens shall be in accordance with Section 12.

11.4.4 Penalty run specimens shall be identified in accordance with 12.3 and 11.4.5.

11.4.5 In addition to the part number and test specimen number, a designator shall be placed after the test specimen number which would allow the specimen to be identified as a penalty run specimen. The method used to identify penalty run specimens shall be at the manufacturer's option.

12. Specimen Preparation

12.1 Specimen preparation and installation of MAFs on appropriate testing apparatus shall be in accordance with the manufacturer's recommended procedures.

12.1.1 Permanent MAFs shall be assembled at the minimum allowable insertion depth permitted by the manufacturer's recommended procedure.

12.1.2 Separable MAFs shall be assembled using the minimum value (that is, torque, nut rotation, and so forth) permitted by the manufacturer's recommended procedure.

12.2 *Assembly of Specimens*—MAFs qualified under the requirements of this specification shall be tested and qualified as a completed assembly. The acceptance of similar, but different, MAF designs shall not permit the intermixing of their subcomponents such as sleeves, nuts, and ferrules.

12.2.1 Test specimens used in testing shall be assembled using a MAF of a single type, grade (or combination of grades), and pipe or tube material.

12.2.2 The wall thickness and outer diameter size of the pipe or tube shall be selected in accordance with the MAF sizes (see 7.3.4) being qualified.

12.2.3 The test specimens shall be assembled using the specimen geometry specified in Fig. 1.

12.3 *Identification of Test Specimens*—Each test specimen shall be identified with a unique number to provide traceability back to the test records.

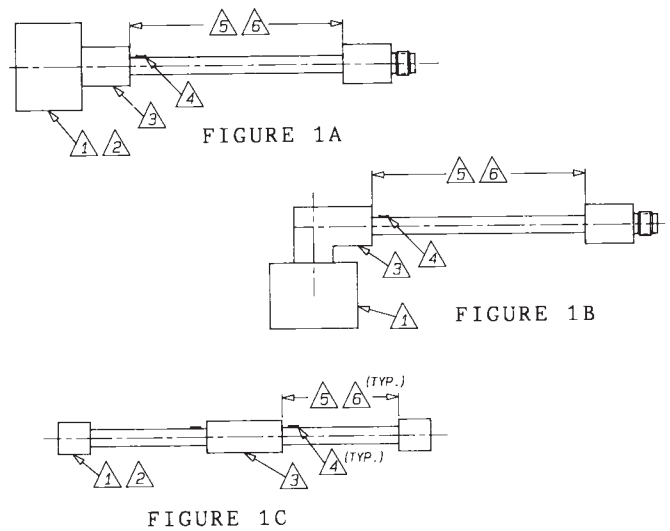
12.3.1 Identification of test specimens shall be permanent. In those cases in which size or design does not permit permanent markings, tagging or bagging may be used.

12.3.2 When, as a result of testing, a test specimen is sectioned into two or more pieces, the identification method shall be as specified in 12.3.1.

13. Test Methods

13.1 *Standard Qualification Tests*—All tests used to qualify MAFs shall be as specified in the Annexes. The following primary tests are described:

Name of Test	Section
Performance Tests for MAFs	A1
Examination of Specimen	A2
Pneumatic Proof Test	A3
Hydrostatic Proof Test	A4
Impulse Test	A5
Flexure Fatigue Test	A6
Tensile Test	A7
Hydrostatic Burst Test	A8
Repeated Assembly Test	A9
Rotary Flexure Test	A10
Mercurous Nitrate Test	A11



- 1 CAPPED END WITH PORT (2 PLACES TYP.)
- 2 TENSILE SPECIMENS DO NOT REQUIRE CAPPED ENDS
- 3 MAF TEST SPECIMEN
- 4 STRAIN GAGE LOCATED ON THE HIGH STRESS SIDE OF THE PIPE/TUBE 4.6 MM (.18 IN.) FROM MAF (2 PLACES) (AS REQUIRED)
- 5 FIRE TEST SPECIMENS SHALL BE A MINIMUM OF TEN TIMES (10X) PIPE/TUBE O.D. VIBRATION TEST SPECIMEN LENGTH SHALL BE AS SPECIFIED IN TABLE S8. SPECIMEN GEOMETRY SHALL BE AS SHOWN IN FIGURE S8.
- 6 FREE PIPE/TUBE LENGTH (MIN) FIVE TIMES (5X) PIPE/TUBE O.D.

FIG. 1 Typical Specimen Geometries

13.2 *Supplementary Tests*—When one or more of the supplementary requirements are requested by the purchaser (see 1.2), the following applicable test(s) shall also be performed:

Name of Test	Section
General Requirements	S1
Thermal Cycling Test	S2
Elevated Temperature Soak Test	S3
Stress Corrosion Test	S4
Torsion Test	S5
Shock Test	S6
Fire Test	S7
Vibration Test	S8

13.3 *Certification of Test Results*—If certified test results are required, a certification shall be provided to the purchaser as specified in the contract or purchase order.

13.4 *In-Process Inspection Tests*—The following tests shall be performed by the manufacturer in accordance with in-house practices and when specified in the contract or purchase order:

13.4.1 Metallographically prepare, microexamine, and test for hardness and microstructural conformance to the manufacturer's appropriate specification a random sample of Type III ferrules, as specified in 10.4.1. An appropriate specification is defined as the documented procedures that the manufacturer uses on a continuing basis to produce ferrules. Such ferrules shall be of the same quality as those used in the assemblies that were previously tested and found to satisfy the performance requirements of this specification.

13.4.2 Randomly select a minimum of five Type III ferrules from each lot as specified in 10.5 and test for cut bite quality.

13.4.2.1 Preset the Type III ferrules onto tubing as specified in 13.4.2.2. After disassembly, drive back each ferrule to expose the ring cut for examination. The cut bite shall completely encircle the periphery of the tube. The cut bite shall be clean, smooth, and uniform. A jagged irregular cut bite is unacceptable. There shall be no longitudinal or circumferential cracks on the ferrule before driving it back.

13.4.2.2 Use Type 304 tubing in accordance with Specifications A 213/A 213M, A 249/A 249M, or A 269 for testing corrosion-resistant steel MAFs. Use SAE 1010 tubing to test carbon steel MAFs. The tubing materials as specified will assure consistent results of testing. Preset Type III ferrules onto the tubing in accordance with the manufacturer's recommended procedures using either a presetting machine, presetting tool, or the MAF.

13.4.2.3 When the Type III ferrules are manufactured from materials other than those specified in 13.4.2.2, conduct the test using tubing material as recommended by the manufacturer.

13.4.3 Fracture test a minimum of four MAFs selected at random from each lot of welded MAFs as specified in 13.4.3.1 and then either crush test in accordance with 13.4.3.2 or macroexamine in accordance with 13.4.3.3.

13.4.3.1 Test two MAFs. Cut each MAF into two or more sections. Cut the sections so that the weld is perpendicular to the longitudinal axis of the section. The total width of the sections taken from each MAF shall be equal to or exceed one fourth of the circumference of the MAF. Remove all weld flashing. Load each section laterally in such a way that the root of the weld is in tension. Bend the section until it fractures or

is bent 90°. If the specimen fractures, the fractured surface shall show no evidence of preexisting cracks or incomplete fusion, and the sum of the lengths of inclusions and porosity visible on the fractured surface shall not exceed 10 % of the total area. Cracking or tearing of the parent material is acceptable.

13.4.3.2 Two MAFs shall be tested. Remove all weld flashing. Position each MAF between two parallel plates in a manual or hydraulic press, or between the jaws of a multiple-jaw hydraulic press. The weld shall be located 3.2 mm ($\frac{1}{8}$ in.) from the face of the plates or jaws. Flatten the MAF against itself between the parallel plates or crush the MAF to within 50 % of its original diameter between the multiple jaws. There shall be no indication of cracking or tearing in the weld joints. Cracking or tearing of parent material is acceptable.

13.4.3.3 Test two MAFs. Take a cross section of the weld from each MAF. Smooth and etch one face of each cross section to give a clear definition of the weld metal and heat-affected zone. When examined, the weld and the heat-affected zone shall show complete fusion and freedom from cracks.

14. Inspection

14.1 *Terms of Inspection*—Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection requirements (examination and tests) specified herein.

14.2 *Raw Material Inspection*—Each lot of raw material used to produce MAFs in accordance with this specification shall be inspected for conformance to the applicable material specification. A lot of raw material shall consist of bars, pipe, tube, forgings, or castings of the same heat, produced at essentially the same time and submitted for inspection at the same time.

14.3 *Quality Conformance Inspection*—MAFs shall be visually and dimensionally examined to verify compliance with the appropriate drawings. Quality conformance inspection shall be performed on each lot of MAFs produced under this specification.

14.3.1 The inspection lot of MAFs shall include MAFs of the same size and shape manufactured under essentially the same conditions from the same lot of material and submitted for inspection at one time.

14.4 *Process Control Inspection*—MAFs shall be inspected throughout the entire manufacturing and processing cycle. Methods of inspection shall be in compliance with the manufacturer's quality assurance procedures.

14.5 *Inspection Records*—Inspection records shall be maintained by the manufacturer. The length of time on file shall be in accordance with the manufacturer's quality assurance procedures.

14.6 *Performance Testing Records*—The manufacturer shall maintain a record of all performance tests throughout the life of the MAF design.

14.6.1 The original test specimens, as well as replacement or penalty run specimens, used in performance testing to meet qualification shall be maintained by the manufacturer for a minimum of two years.

14.6.2 Inspection records relating to the performance tests shall be maintained in accordance with 14.5.

15. Certification

15.1 *Certification of Testing or Inspection*—When requested by the purchaser, the manufacturer shall supply written certifications that the MAF has been tested and qualified in accordance with this specification.

15.2 *Certification of Raw Material*—A certificate of compliance or mill certificate shall be obtained from the material supplier. This certificate shall state that all applicable requirements of the raw material are met. As a minimum, the material specification shall specify the chemical and mechanical requirements of the material.

16. Product Marking

16.1 *Product Marking*—Each MAF shall be marked with the manufacturer’s name or trademark, size, and material

(material marking is not required for Type V MAF). When shape or size does not permit inclusion of all required markings, the information may be omitted in the reverse order presented.

16.1.1 When MAFs are comprised of multiple components that are assembled, the marking methods used to identify the assembly (and each of its components) shall be as agreed to between the manufacturer and the purchaser.

16.2 *Additional Markings*—When specified in the contract or purchaser order, additional markings other than those specified shall be applied.

17. Keywords

17.1 axially swaged; bite-type; elastic strain preload (esp); fittings; flared; flareless; grip type; mechanically attached fittings (MAFs); piping; radially swaged; shape memory alloy (SMA); tubing

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified in part or whole by the purchaser in the contract or purchase order.

S1. GENERAL REQUIREMENTS

S1.1 Scope

S1.1.1 This section covers the general requirements that, unless otherwise specified, apply to the Annex or this section whenever invoked individually or collectively by the purchaser of MAFs in the contract or purchase order. The testing requirements specified herein are applicable to all the tests described in Sections S2 through S8 (see Table S1.1). The requirements covered herein are outlined as follows:

- S1.3 Testing Requirements
- S1.4 Quality Assurance Requirements
- S1.5 Product Marking Requirements

TABLE S1.1 Supplementary Tests^A

Description of Test	Number of Specimens ^B
Examination of specimen (Annex A2)	40
Pneumatic proof test (Annex A3)	40
Hydrostatic proof test (Annex A4) ^C	40
Thermal cycling test (S2) ^{D,E}	10
Elevated temperature soak test (S3) ^C	5
Stress-corrosion test (S4)	5
Torsion test (S5)	5
Shock test (S6) ^C	5
Fire test (S7) ^C	5
Vibration test ^D	5

^A Passed specimens shall be used for burst testing (see Annex A8).
^B The number of specimens shown is the minimum amount required for each test per family of MAF. The number of specimens may increase when various pipe or tube grades, forms, conditions, and outer diameter wall thickness combinations are tested, unless exempted parametrically (see 7.3). The total minimum amount of specimens required for all tests (including Annex) shall be as specified in S1.3.8.
^C Fire test specimens shall be hydrostatically proof tested using water only.
^D Specimens may be reused for other primary tests as long as all requirements herein are complied with for each test (see S1.1.9).
^E An equal number of specimens (four minimum) shall be used for the high- and low-temperature cycle test.

S1.1.2 Cadmium plating shall not be used on MAFs intended for use on U.S. Navy vessels.

S1.1.3 This section is applicable to MAFs that are designed for the following pipe or tube sizes:

S1.1.3.1 This supplementary section is applicable to MAFs suitable for pipe outside diameters for NPS 3.2 mm (1/8 in.) through 63.5 mm (2 1/2 in.).

S1.1.3.2 This supplementary section is applicable to MAFs suitable for tube outside diameters from 6.4 mm (0.250 in.) to 73.0 mm (2.875 in.).

S1.1.3.3 Other pipe or tube sizes, with supporting data, may be submitted to the purchaser for evaluation and approval.

S1.1.4 The following supplementary tests listed herein are as follows:

Test	Section
Thermal Cycling Test	S2
Elevated Temperature Soak Test	S3
Stress-Corrosion Test	S4
Torsion Test	S5
Shock Test	S6
Fire Test	S7
Vibration Test	S8

S1.1.5 The sections listed below from the main body of this specification apply to the test specimens used to perform the tests specified in S1.5 (see S1.8). MAFs shall have met the requirements of Annex A1 and Annex A2 before performing any test, unless otherwise specified herein.

Title	Section
Scope	1
Referenced Documents	2
Terminology	3

Classification	4
Materials and Manufacture	6
Performance Requirements	7
Workmanship, Finish, and Appearance	9
Number of Tests and Retest	11
Specimen Preparation	12
Test Methods	13
Inspection	14
Certification	15
Performance Tests for MAFs	Annex A1
Examination of Specimen	Annex A2

S1.1.6 Unless otherwise specified, the requirements specified in the main body and Annex A1 and Annex A2 of this specification shall apply.

S1.1.6.1 In the event of a conflict between this supplement and the requirements specified in the main body of this specification and Annex A1 and Annex A2, or both, the requirements specified herein shall take precedence, unless otherwise invoked in the contract or purchase order by the purchaser.

S1.1.7 Before beginning performance testing, the manufacturer shall obtain approval from the purchaser of the test plan to be used. The plan shall include the following information:

S1.1.7.1 A matrix showing the MAF grade(s) (or different combination(s) of grades) (see 4.2) and MAF class(es) (see 4.3) to be qualified,

S1.1.7.2 MAF sizes selected to qualify every size within its range (see S1.1.3),

S1.1.7.3 Compatible pipe or tube materials to be in assembly with the MAFs to be tested (see Table S1.2),

S1.1.7.4 Pipe or tube wall thicknesses and sizes selected to qualify the pipe or tube throughout its range (see 7.3.5),

S1.1.7.5 The manufacturer's recommended procedure covering the assembly of the MAFs onto pipe or tube (see 12.1), and

S1.1.7.6 Test fluids used for each test (see 7.6.3).

S1.1.8 After verification, the purchaser shall approve the matrix or specify any additional tests required for each MAF family for the manufacturer to include in the program.

S1.2 Significance and Use

S1.2.1 The significance of this section allows the purchaser of MAFs to invoke those general, testing, or quality assurance requirements individually or collectively to meet their existing requirements. The purchaser may use this section as a guide to make out an agreement with the manufacturer to fulfill their requirements for MAFs.

TABLE S1.2 Pipe or Tube Material, Size, and Tolerances

Material Type	Material Specification	Material Size	Material Tolerance
Carbon steel	MIL-P-24691/1	ANSI B36.10	A 530/A 530M A 450/A 450M
Chromium molybdenum	MIL-P-24691/2	ANSI B 36.10	A 530/A 530M A 450/A 450M
Stainless steel	MIL-P-24691/3	ANSI B 36.10	A 530/A 530M A 450/A 450M
	MIL-T-8606	AND 10102	MS 33531
Copper-nickel	MIL-T-16420	MIL-T-16420	MIL-T-16420
Nickel-copper	MIL-T-1368	MIL-T-1368	MIL-T-1368
Copper	MIL-T-24107	MIL-T-24107	B 251

S1.3 Testing Requirements

S1.3.1 MAF test specimens shall be selected for qualification in accordance with the requirements specified herein and in 7.3.

S1.3.1.1 Each and every pipe or tube size (both outside diameter and wall thickness) and each and every material combination of both pipe or tube (including annealed and drawn conditions) and MAFs may be qualified in accordance with this specification. If the manufacturer can demonstrate by parametric or test data that some tests are not necessary, the purchaser may exempt the manufacturer from the test requirement on a case-by-case basis.

S1.3.2 The test MAFs shall be of the same base material as the pipe or tube. Other combinations of materials, approved for use by the purchaser, must be shown to be galvanically compatible, or in accordance with MIL-STD-889.

S1.3.2.1 MAFs shall be shown to meet the requirements of this specification over the full range of pipe or tube tolerances (see S1.3.3.1) either experimentally or by parametric.

S1.3.3 Pipe or tube materials used with MAFs shall conform to the specifications listed in Table S1.2.

S1.3.3.1 Pipe or tube tolerances shall be in accordance with the requirements specified in Table S1.2.

S1.3.3.2 In no case shall the pipe or tube used for testing be machined or otherwise changed from its original mechanical or chemical properties unless otherwise specified in the manufacturer's installation instructions.

S1.3.3.3 The cut pipe or tube ends may be deburred, but not tapered or otherwise reduced, below the minimum wall thickness.

S1.3.4 Strain gages (as required) shall be placed at a distance not to exceed 4.6 mm (0.18 in.) from the end(s) of the MAF pipe or tube joint (see Fig. 1).

S1.3.5 The test specimens shall be marked using the same methods which will be applied to MAFs sold subsequent to qualification.

S1.3.5.1 All test specimens shall be identified in accordance with the requirements specified in 12.3.

S1.3.6 A test specimen shall consist of one or several pipe(s) or tube(s) joined to MAFs.

S1.3.6.1 MAFs installed on the test apparatus shall be in accordance with the manufacturer's recommended procedures as approved by the purchaser. No other means of joining the test connector to the pipe shall be permitted.

S1.3.6.2 Unless otherwise specified in the individual test, (see S7) the specimen geometry (Fig. 1) shall be no less than five pipe or tube diameters (outside diameter) long on the end of the MAFs being tested.

S1.3.6.3 After approval of the test plan (see S1.1.7), the test specimens shall be assembled in accordance with the requirements specified in 12.2.

S1.3.7 The minimum amount of specimens required for each supplementary test shall be as specified in Table S1.1 (see S1.3.8). A family of MAFs shall consist of a manufacturer's single combination of: pressure rating (class), design (type), and material (grade) including form and condition. A family requires tests as follows:

S1.3.7.1 Test each MAF shape. Shapes may be test exempted only if it can be shown to the purchaser’s satisfaction that they are equivalent to those shapes tested.

S1.3.7.2 Test the range of MAF sizes, including the smallest and largest. Test one or more intermediate sizes if the ratio of the minimum to the maximum pipe or tube outside diameter to be tested is equal to or more than ten.

S1.3.7.3 Any nonproportional MAF sizes shall be tested unless they can be shown parametrically to be equivalent to the sizes tested.

S1.3.7.4 Test each pipe or tube material for all material conditions of intended use (that is, annealed and drawn).

S1.3.7.5 For each pipe or tube size being tested, test the minimum and maximum nominal wall thickness of pipe or tube materials selected from Table S1.2.

S1.3.8 A minimum of 60 specimens shall be prepared to cover the unique combinations of a MAF family (see S1.3.7). Each primary test shall have a minimum of five specimens representing all of the unique combinations of a MAF family. When the total amount of specimens (including Annex) is below 60, additional specimens shall be added to attain the minimum of 60 total specimens for all tests (see S1.3.8.5).

S1.3.8.1 The total number of test assemblies must each pass their designated tests successfully to meet the requirements of this performance specification.

S1.3.8.2 The proposed test plan covering unique combinations of test assemblies used in qualification testing shall be submitted to the purchaser for approval (see S1.1.7).

S1.3.8.3 The pneumatic test (see Annex A3), the hydrostatic test (see Annex A4), and the hydrostatic burst test (see Annex A8) (when performed separately or in combination before or after another primary test) are not to be used as a part of the total specimens used for testing because they are connected with the pass and fail criteria of the primary test. In all instances, they are considered to be a part of the primary test and not a separate mechanical test for this calculation.

S1.3.8.4 Also, comparison tests of pipe or tube without MAFs do not count as part of these totals.

S1.3.8.5 Specimens may be reused for other primary tests as long as all of the requirements herein are complied with for each test (see S1.1.7).

S1.3.9 In the event of a test failure, the manufacturer shall proceed in accordance with 11.3.

S1.3.10 At the option of the purchaser, the test laboratory shall cut open or otherwise prepare specimens for detailed examination following any failure.

S1.3.11 Unless otherwise specified within the test, the conditions for testing shall be as specified in 7.6 and as follows:

S1.3.11.1 Unless otherwise specified by the purchaser, the pressures applied during testing shall be calculated based upon the class (rated pressure) assigned by the manufacturer in the test plan (see 4.3). The purchaser may also designate a class not specified in 4.3 to fulfill end-system requirements (see 3.1.1).

S1.3.11.2 The test temperature shall be maintained to within $\pm 5^{\circ}\text{C}$ ($\pm 10^{\circ}\text{F}$), unless otherwise specified by the purchaser (see Table S1.3). The test temperature is maintained when the

TABLE S1.3 Test Temperatures

Test	Test Section	Low Temperature ^{A,B}	Ambient Temperature 21.1°C ^A (70°F)	High Temperature ^{A,B}
Thermal Cycling Test	S2	...	...	...
Thermal Cycling (high)	S2.4.1	...	...	X
Thermal Cycling (low)	S2.4.2	X	...	...
Elevated Temperature Soak	S3	...	...	X
Stress Corrosion Test	S4	3/	3/	3/
Torsion Test	S5	...	X	...
Shock Test	S6	...	X	...
Fire Test	S7	C	C	C
Vibration Test	S8	...	X	...

^AThe allowable tolerance for all test temperatures is $\pm 5^{\circ}\text{C}$ ($\pm 10^{\circ}\text{F}$).

^BThe temperatures given correspond to the category and group system temperatures specified in MIL-STD-777.

^CSee test procedure for test temperature requirements.

test specimen attains the temperature designated by the test. The temperature shall be stabilized for a period of 1 h or more.

S1.3.12 All testing shall be done at a test laboratory acceptable to the purchaser. The test laboratory shall verify that specimens to be tested are as identified and certify results.

S1.3.12.1 The test laboratory must establish a mutually convenient testing schedule when the purchaser specifies that a witness is to be present during testing.

S1.3.13 Unless otherwise specified, the test report shall contain the following information:

S1.3.13.1 Identification number, a description of each specimen, and the fabrication process.

S1.3.13.2 Description of the test apparatus including instrumentation and their settings during the test.

S1.3.13.3 Photographs of test setup including specimen.

S1.3.13.4 Graphical printout of all data for those tests that record a waveform (if requested by the purchaser).

S1.3.13.5 Leakage rate during testing, if any.

S1.3.13.6 Video tape(s) (fire test only).

S1.3.13.7 A record of any unusual observations during testing.

S1.3.13.8 Summary of test results, including but not limited to the following data in tabular form:

(1) A description of the specimen shape, pressure rating, material, and method of fabrication,

(2) Nominal size, actual pipe outside diameter, actual MAF inside diameter,

(3) Pipe material (condition and form), class, and wall thickness,

(4) Pressure and temperature, or both, applied during and at the completion of testing,

(5) Number of cycles or time at specific atmospheric conditions,

(6) Reason for termination of any test,

(7) Hydrostatic leakage rate and description, (if any),

(8) Summary of pass or fail results, and

(9) Calculations (only when requested) to support test data submitted in the test report.

S1.4 Quality Assurance Requirements

S1.4.1 *Mill Certification*—When specified in the contract or purchase order, a mill certification shall be obtained from the

suppliers of all raw materials used in the manufacturing or fabrication of MAFs. The raw material shall be impounded until required testing or verification, or both, is completed. The types of tests used to verify mechanical, chemical, and physical properties shall be at the option of the manufacturer.

S1.5 Product Marking Requirements

S1.5.1 Unless otherwise specified in the contract or purchase order, the rated pressure of MAFs shall be marked in addition to the markings specified in 16.1.1.

S1.6 Precision and Bias

S1.6.1 No statement is made about the precision or bias herein since the requirements only apply when invoked by the purchaser in the purchase order or contract.

S2. THERMAL CYCLING TEST

S2.1 Scope

S2.1.1 Unless otherwise specified, MAFs shall be subjected to a thermal cycling test. The number of specimens used shall be as specified in Table S1.1.

S2.2 Significance and Use

S2.2.1 This test determines the ability of MAFs to withstand changes in temperature while being pressurized to the rated pressure of the MAFs or pipe or tube, whichever is lower. The test is conducted in high temperature and low temperature. This test is used to duplicate conditions that could occur during in-service use.

S2.3 General Testing Requirements

S2.3.1 The test specimens may be tested pneumatically (see Annex A3) and hydrostatically (see Annex A4) at the option of the manufacturer.

S2.3.2 An equal number of specimens shall be used for high-temperature thermal cycling (see S2.4.1) and low-temperature thermal cycling (see S2.4.2).

S2.3.3 The tests shall be conducted using the temperatures specified in Table S1.3. The specimen may be tested in an environmental chamber held at test temperature.

S2.3.4 The rated test pressure selected for high- and low-temperature thermal cycling shall be as specified in S1.3.11.1.

S2.3.5 The time for the temperature of the test fluid to change from high or low to ambient conditions (and back again) shall be a maximum of 2 min.

S2.3.6 The test specimens shall be monitored continuously for leakage throughout the test.

S2.3.7 If there is any leakage during the thermal cycling tests or subsequent hydrostatic proof tests, the specimens fail and the test shall be discontinued at that point. If failure occurs, follow the instructions specified in S1.3.9.

S2.4 Procedure

S2.4.1 *High-Temperature Thermal Cycling:*

S2.4.1.1 Mount the test specimens in an environment suitable for the conditions stated herein.

S2.4.1.2 The duration of the test shall be three cycles as specified in S2.4.1.4 through S2.4.1.6.

S2.4.1.3 Fill the specimen with fluid (see 7.6.3) and pressurize it to the rated pressure specified in S1.3.11.1. Maintain this pressure throughout the test period.

S2.4.1.4 Increase the specimen temperature to the maximum specified in Table S1.3 within 1 h (see S2.3.5).

S2.4.1.5 Stabilize the specimen at the high temperature and rated pressure for a period of 2 h.

S2.4.1.6 At the conclusion of the high-stabilization period, lower the specimen temperature (while maintaining the rated pressure) to ambient conditions within 1 h and stabilize for an additional 2 h (see S2.3.5).

S2.4.1.7 The steps specified in S2.4.1.4 through S2.4.1.6 constitute one cycle. Repeat these steps until three cycles have been completed (see S2.4.1.2).

S2.4.1.8 After the completion of the third cycle, subject the test specimens to a hydrostatic proof test (see Annex A4).

S2.4.1.9 After completing the hydrostatic proof test, and if there was no leakage during the test period, the specimens have passed the high-temperature cycling test.

S2.4.2 *Low-Temperature Cycling Test:*

S2.4.2.1 Mount the test specimens in an environment suitable for the conditions stated herein.

S2.4.2.2 The duration of the test shall be three cycles as specified in S2.4.2.4 through S2.4.2.6.

S2.4.2.3 Pressurize the specimen with a fluid that will meet the low-temperature requirements for this test. The fluid shall be maintained at the rated pressure as specified in S1.3.11.1 throughout the test period.

S2.4.2.4 Lower the specimen temperature to the temperature specified in Table S1.3 within 1 h (see S2.3.5).

S2.4.2.5 Stabilize the specimen at the low temperature and rated pressure for a period of 2 h.

S2.4.2.6 At the conclusion of the low-stabilization period, raise the specimen temperature (while maintaining the rated pressure) to ambient conditions within 1 h and stabilize for an additional 2 h (see S2.3.6).

S2.4.2.7 The steps specified in S2.4.2.4 through S2.4.2.6 constitute one cycle and shall be repeated until three cycles have been completed (see S2.4.2.2).

S2.4.2.8 After the completion of the third cycle, subject the test specimens to a hydrostatic proof test (see Annex A4).

S2.4.2.9 After completing the hydrostatic proof test, and if there was no leakage during the test period, the specimens have passed the low-temperature cycling test.

S2.5 Precision and Bias

S2.5.1 The precision of the high- and low-temperature cycling test is established by the accuracy of the measuring and test equipment (M & TE) and their permissible tolerances

during the test (see 7.5). There is no bias in the high- and low-temperature cycling test when the M & TE used is calibrated properly.

S3. ELEVATED TEMPERATURE SOAK TEST

S3.1 Scope

S3.1.1 Unless otherwise specified, MAFs shall be subjected to an elevated temperature soak test. The number of specimens used shall be as specified in Table S1.1. A minimum of two passed specimens must be submitted for burst test (see Annex A8).

S3.2 Significance and Use

S3.2.1 This test determines the ability of MAFs to withstand a constant temperature level while pressurized to the rated pressure of the MAFs or pipe or tube, whichever is lower. After 100 h, the specimens are cooled to ambient temperature and subjected to further tests. This test is used to duplicate conditions which could occur during in-service use.

S3.3 General Testing Requirements

S3.3.1 The test specimens may be tested pneumatically (see Annex A3) and hydrostatically (see Annex A4) at the option of the manufacturer.

S3.3.2 The tests shall be conducted using the temperatures specified in Table S1.3 for this test.

S3.3.3 The test pressure selected for the elevated temperature soak test shall be as specified in S1.3.11.1.

S3.3.4 The specimen shall be filled with fluid (see 7.6.3) and pressurized to the rated pressure specified in S1.3.11.1. This pressure shall be maintained throughout the test period.

S3.3.5 If there is any leakage during the elevated temperature soak test, or hydrostatic proof or burst tests, the specimens fail and the test shall be discontinued at that point. If failure occurs, follow the instructions specified in S1.3.9.

S3.4 Procedure

S3.4.1 Maintain the test specimens at the rated pressure and at the temperatures specified in Table S1.3 for the material being tested, for a minimum of 100 h, in an air environment.

S3.4.2 At the completion of 100 h, air-cool the test specimen to ambient temperature.

S3.4.3 After ambient temperature is attained, subject the test specimens to a hydrostatic proof test as specified in Annex A4.

S3.4.4 Upon completion of the hydrostatic proof test, subject a minimum of two test specimens to a hydrostatic burst test in accordance with the requirements specified in Annex A8.

S3.4.5 The specimens successfully pass when there is no visible evidence of leakage during the elevated temperature soak test or during the hydrostatic proof and burst test.

S3.5 Precision and Bias

S3.5.1 The precision of the elevated temperature soak test is established by the accuracy of the measuring and test equipment (M & TE) and their permissible tolerances during the test (see 7.5). There is no bias in the elevated temperature soak test when the M & TE used is properly calibrated.

S4. STRESS-CORROSION TEST

S4.1 Scope

S4.1.1 Unless otherwise specified, MAFs shall be subjected to a stress-corrosion test. The number of specimens used shall be as specified in Table S1.1.

S4.2 Significance and Use

S4.2.1 This test determines the ability of MAFs to withstand the effects of corrosion while being subjected to a bending stress. Upon completion of 50 h, the specimens are examined and then subjected to a hydrostatic proof test (see Annex A4). This test is used to duplicate conditions that could occur during in-service use.

S4.3 General Testing Requirements

S4.3.1 The test specimens may be tested pneumatically (see Annex A3) and hydrostatically (see Annex A4) at the option of the manufacturer.

S4.3.2 The tests shall be conducted using the temperatures specified in Test Method B 117 for this test.

S4.3.3 The performance test pressure selected for the stress-corrosion test shall be as specified in S1.3.11.1.

S4.3.4 A combined axial stress (bending and internal pressure) applied during the test shall be a minimum of two thirds of the yield strength of the pipe or tube materials specified in Table S1.2. The axial stress as a result of the applied internal pressure shall be calculated using the following formula:

$$S = \frac{Pd^2}{D^2 - d^2}$$

where

S = stress,

P = pressure,

D = outside diameter, and

d = inside diameter.

S4.3.4.1 When other materials are used, cite reference used for yield strength values.

S4.3.5 The apparatus shall be equipped with calibrated gages (see 7.5.1) which permit visual readings of the strain being applied. The apparatus shall be designed to shut down in the event that pressure is lost during the period of the test.

S4.3.6 Calibrated strain gages shall be located on the high stress side of the pipe or tube as shown in the geometries in Fig. 1.

S4.3.7 If there is any leakage during the stress-corrosion test or hydrostatic proof test, the specimens fail and the test shall be discontinued at that point. If failure occurs, follow the instructions specified in S1.3.9.

S4.4 Procedure

S4.4.1 Install the test specimens in a test fixture which can impose a stress level equivalent to two thirds of the yield strength of the pipe or the tube material less the axial stress as a result of the internal pressure (see S4.3.4).

S4.4.2 Apply bending stress to the MAF and pipe or tube interface. Take and record a strain gage reading.

S4.4.3 Pressurize the test specimen to the rated pressure (see S1.3.11.1).

S4.4.4 With the applied stress locked into place, subject the specimen to the standard salt spray test in accordance with Test Method B 117 for 50 h.

S4.4.5 After testing, subject the test specimen to a hydrostatic proof test (see Annex A4).

S4.4.6 Clean and metallurgically examine the test specimen including sectioning of the MAF and pipe or tube throughout the high-stress area. The following conditions shall be checked and shall not have occurred:

S4.4.6.1 Indication of cracking or pitting of the exposed surfaces of MAF and tubing within one diameter of the MAF greater than that exhibited on the remainder of the tubing when visually examined with 10× power magnification.

S4.4.6.2 Leakage or burst at a value less than the specified test pressure (see S4.4.3).

S4.4.6.3 Indications of inter- or trans-granular stress corrosion paths during metallurgical examination of longitudinal and transverse sections of the MAF and pipe or tube junction.

S4.4.7 The specimens successfully pass this test when they complete the stress-corrosion test without showing any of the indications specified in S4.4.6 and successfully complete the hydrostatic proof test requirements specified in Annex A4.

S4.5 Precision and Bias

S4.5.1 The precision of the stress-corrosion test is established by the accuracy of the measuring and test equipment (M & TE) and their permissible tolerances during the test (see 7.5). There is no bias in the stress-corrosion test when the M & TE used is calibrated properly.

S5. TORSION TEST

S5.1 Scope

S5.1.1 Unless otherwise specified, MAFs shall be subjected to a torsion test. The number of specimens used shall be as specified in Table S1.1.

S5.2 Significance and Use

S5.2.1 This test determines the ability of MAFs to withstand displacement of the MAFs and pipe or tube joint through the application of torque. After creating this displacement between the MAF and the pipe or tube, the test assembly is subjected to a hydrostatic proof test in accordance with the requirements specified in Annex A4. This test is used to simulate environmental conditions that could occur during end-service use.

S5.3 General Testing Requirements

S5.3.1 The test specimens may be tested pneumatically (see Annex A3) and hydrostatically (see Annex A4) at the option of the manufacturer.

S5.3.2 The tests shall be conducted at ambient temperature as specified in Table S1.3 for this test.

S5.3.3 If there is any leakage during the hydrostatic proof test, the specimen fails and the test shall be discontinued at that point. If failure occurs, follow the instructions specified in S1.3.9.

S5.4 Procedure

S5.4.1 Draw a straight line from end to end on the specimen to be tested.

S5.4.2 Secure one end of the specimen in a vise. Do not pressurize the specimen.

S5.4.3 Using an appropriate tool, clamp onto the specimen and rotate the opposite end until permanent deformation or displacement of the pipe or tube occurs relative to the MAF. Deformation or displacement occurs when:

S5.4.3.1 The spring-back position shows permanent angular deflection of the straight line. The line should deflect no less than 1.6 mm (0.0625 in.) at four pipe or tube diameters from near the end of the MAF joint or,

S5.4.3.2 Relative displacement occurs between the MAF and the pipe or tube when the line remains straight but rotates with respect to MAF. The pipe or tube shall be rotated a minimum of 30° from the original position in the MAF joint or,

S5.4.3.3 In any event, the maximum torque applied shall be 542 N·m (400 ft-lbf).

S5.4.4 After displacement or deformation has occurred, or maximum torque has been applied, subject the test specimen to a hydrostatic proof test in accordance with the requirements specified in Annex A4.

S5.4.5 The specimens successfully pass when the following conditions are met:

S5.4.5.1 Permanent MAF completes the hydrostatic proof test without any leakage. If leakage occurs see S5.3.3.

S5.4.5.2 Separable MAF completes the hydrostatic proof test without any leakage. If leakage occurs in the initial test, the specimen may be tightened no more than one-fourth turn (record this occurrence in accordance with S1.3.13.8, (7) and

(8). After tightening, the hydrostatic proof test shall be performed from the beginning without any leakage. If leakage occurs during the secondary test, see S5.3.3.

S5.5 Precision and Bias

S5.5.1 The precision of the torsion test is established by the accuracy of the measuring and test equipment (M & TE) and

their permissible tolerances during the test (see 7.5). There may be bias in the results of the torsion test if the line drawn has irregular edges or is too thick or is thick and thin, which may make it difficult to measure the amount of actual displacement.

S6. HIGH IMPACT SHOCK TEST

S6.1 Scope

S6.1.1 Unless otherwise specified, MAFs shall be subjected to a high impact shock test. The number of specimens used shall be as specified in Table S1.1. A minimum of two passed specimens shall be used for burst test (see Annex A8).

S6.2 Significance and Use

S6.2.1 This test verifies the ability of MAFs to withstand a series of impacts while being pressurized to the rated pressure of the MAFs or pipe or tube, whichever is lower. This test is used to duplicate in-service conditions that could occur.

S6.3 General Testing Requirements

S6.3.1 The test specimens may be tested pneumatically (see Annex A3) and hydrostatically (see Annex A4) at the option of the manufacturer.

S6.3.2 The tests shall be conducted using the temperatures specified in Table S1.3 for this test.

S6.3.3 The rated pressure selected for the high-impact shock test shall be as specified in S1.3.11.1.

S6.3.4 If there is any leakage during the high-impact shock test or subsequent hydrostatic proof test, the specimens fail and the test shall be discontinued at that point. If failure occurs, follow the instructions specified in S1.3.9.

S6.4 Procedure

S6.4.1 Fill each test specimen with fluid in accordance with 7.6.3 before installation onto the shock test fixture.

S6.4.2 Pressurize the test specimens to the rated pressure of the MAF or pipe or tube, whichever is lower (see S1.3.11.1).

S6.4.3 With the test specimen pressurized, subject it to impacts from hammer drop heights of 304.8 mm (1 ft), 914.4 mm (3 ft), and 1524 mm (5 ft). The test criteria shall be in conformance with MIL-S-901 (for Grade A, Class I, Type A, lightweight hull-mounted equipment).

S6.4.4 After completion of high-impact shock test, subject the specimens to a hydrostatic proof test (see Annex A4) followed by a burst test (see Annex A8).

S6.4.5 The test specimens successfully pass high-impact shock testing when they do not show evidence of leakage during the shock test, hydrostatic proof test, and burst test.

S6.5 Precision and Bias

S6.5.1 The precision of the high-impact shock test is established by the accuracy of the measuring and test equipment (M & TE) and their permissible tolerances during the test (see 7.5). There is no bias in the high-impact shock test when the M & TE used is calibrated properly.

S7. FIRE TEST

S7.1 Scope

S7.1.1 Unless otherwise specified, MAFs shall be subjected to a fire test. The amount of specimens required for testing shall be as specified in Table S1.1 (see S1.3.7).

S7.1.2 This test should be used to measure and describe the response of materials, products, or assemblies to heat and flame under controlled conditions and should not be used to describe or appraise the fire hazard or the fire risk of materials, products, or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire hazard assessment or a fire risk assessment which takes into account all the factors that are pertinent to an assessment of the fire hazard or the fire risk of a particular end use.

S7.1.3 *Limitation*—This fire test is a part of a set of tests used for evaluating the performance characteristics of MAFs. It is not intended for use independently in part or whole (see 1.7).

NOTE S7.1—High pressures created during this test can result in

catastrophic failure of the test specimen. Precautions shall be taken to protect personnel and facilities.

S7.2 Significance and Use

S7.2.1 This test establishes a combined exposure of internal pressure and external heat flux to determine the ability of MAFs to withstand a 30-min simulated fire condition. Heat flux instead of temperature was selected because it is a better measure of fire exposure. The pressure and heat flux exposure specified herein represents a specific fire condition that could occur on board ship. The specified exposure is not sufficient to predict the survival of MAFs during all types and sizes of shipboard fires. After the fire test, MAF specimens are subjected to hydrostatic proof tests. MAFs are graded according to the amount of leakage during the hydrostatic tests. The fire test may be used to determine the acceptability of MAFs for use in fire hazardous areas on board ship where fire conditions such as those caused by a flammable liquid fire could occur.

S7.3 General Testing Requirements

S7.3.1 The test specimens may be pneumatically tested (see Annex A3) and hydrostatically tested with water (see Annex A4) at the option of the manufacturer.

S7.3.2 All testing shall be done at a test laboratory acceptable to the purchaser (see S1.3.12).

S7.3.2.1 The fitting manufacturer must submit advance proof of ability of the independent test laboratory to meet the requirements specified by the purchaser (including: facilities, equipment, personnel, instrumentation, and sample data).

S7.3.3 The fire test laboratory shall verify that specimens to be tested are identified properly, conduct all tests, and certify results.

S7.3.3.1 Fire test laboratory personnel shall witness test specimen installation and provide certification of fabrication in accordance with approved written fabrication techniques and procedures.

S7.3.4 After verification of the unique combinations of the fitting family (see S1.3.7), the purchaser may specify one additional random fire test for each manufacturer to include in its test plan.

S7.3.5 The specimens to be tested shall be assembled in accordance with the geometries shown in Fig. 1, except that the minimum pipe or tube length shall be as specified in S7.4.2.

S7.3.5.1 Connection of each MAF to pipe or tube shall be done using the manufacturer's approved assembly procedures (see S1.3.6).

S7.3.5.2 The MAFs assembled into fire test specimens shall be the same in all respects as the MAFs subjected to other tests herein and in the Annex.

S7.3.6 Any furnace or other apparatus large enough to expose the minimum length of specimen (see 7.4.2) to the required heat flux may be used.

S7.3.6.1 If an electric furnace is used, a thin coat of flat black paint must be applied to each specimen before the fire test.

S7.3.6.2 Multiple specimens may be tested at the same time if the required heat flux exposure of each specimen is assured.

S7.3.7 Any fuel that achieves the required heat flux may be used.

S7.3.8 Install sufficient total heat-flux gages within a 15-cm (6-in.) radial distance of each specimen centerline to measure a spatial average of the total cold wall heat flux at all exposed surfaces of each specimen during all tests. Alternatively, precalibrate the furnace or other apparatus as specified in S7.3.11.

S7.3.8.1 Measure the required heat flux using circular foil heat-flux gages (often call Gardon gages after the developer). The gage must be calibrated and water cooled and must sense total heat flux (radiant and convective).

NOTE S7.3—Test Methods E 511 and E 1529 describe the design and use of circular foil heat flux gages.

S7.3.9 Furnace thermocouples, if used, are to be fabricated by fusion welding the twisted ends of 1.63-mm (0.064-in.) diameter chromel-alumel wires having a time constant of 2 min or less and mounting the wires in porcelain insulators.

S7.3.9.1 The furnace thermocouple assembly is to be inserted through a standard weight 12.7-mm (½-in.) steel or chrome-nickel alloy pipe. The thermocouple junction is to protrude 12.7 mm (½ in.) from the open end of the pipe.

S7.3.10 Heat flux (or temperature) and pressure shall be monitored continuously and recorded at intervals not exceeding 10 s during the first 5 min and every 30 s thereafter.

S7.3.10.1 Measure the internal pressure of MAF specimens with transducers appropriate to each specimen's test pressure.

S7.3.11 Instead of continuous heat-flux measurement, the furnace or other apparatus may be calibrated to establish a time-temperature curve that provides the required heat flux to each specimen. The calibrated time-temperature conditions must be measured and successfully reproduced in every subsequent material test. Measure temperature and heat flux and follow:

S7.3.11.1 For each specimen location, measure a spatial average of the total cold wall heat flux that would exist at all exposed surfaces of the longest specimen to be tested in that location. Position the heat-flux gages within a 115-cm (6-in.) radial distance of the specimen centerline.

S7.3.11.2 Measure the heating environment temperature with not less than six furnace thermocouples as specified in S7.3.9 symmetrically distributed at the outer boundaries of, but not in contact with, the test specimen(s). Any cage or other safety barrier must be included in the calibration test.

S7.3.11.3 If the furnace or other apparatus has provision for multiple specimens, calibrate each position with all other positions occupied to assure specimens are not shielded from direct impingement of the required flux.

S7.3.11.4 The furnace or apparatus must be recalibrated each time it is repaired or modified or once per year or every 300 test h, whichever is first.

S7.4 Procedure

S7.4.1 Pressurize and instrument each specimen separately, except that the specimens requiring the same test pressure may be manifolded. When a manifold is used, any leakage invalidates the fire test for all specimens manifolded. See S1.3.9 for further instructions.

S7.4.1.1 Specimens shall be unrestrained at one end to allow for expansion.

S7.4.1.2 Assembly supports shall be beyond the minimum specimen exposure length specified in S7.4.2.

S7.4.2 Expose a fitting with pipe or tube length at each outlet as follows:

S7.4.2.1 If the entire pipe or tube length is exposed to the required heat flux, the minimum length of that pipe or tube shall be three outside diameters.

S7.4.2.2 If any pipe or tube extends beyond the area of required heat flux, the length of the pipe or tube actually exposed to the required heat flux shall be a minimum of ten outside diameters.

S7.4.2.3 Less pipe or tube length may be exposed if screening tests prove that the fitting heats at the same rate with less pipe exposed to the required heat flux.

S7.4.3 The specimen test pressure shall be the rated pressure of the MAF or the temperature-adjusted rated pressure (P_{TEMP}) of the pipe or tube, whichever is lower.

S7.4.3.1 Calculate the temperature-adjusted rated pressure for the appropriate pipe or tube material being tested using the following formula:

$$P_{TEMP} = F_s \times \frac{2t_{min} \sigma_{TEMP}}{OD} = \frac{t_{min} \sigma_{TEMP}}{OD}$$

where

- F_s = 0.5 factor of safety,
- t_{min} = minimum wall thickness,
- σ_{TEMP} = temperature-adjusted yield strength of the pipe or tube at 927°C (1700°F) (see S7.4.3.2), and
- OD = outside diameter of pipe or tube.

S7.4.3.2 Use the following temperature-adjusted yield strength (σ_{TEMP}) values for the calculation of P_{TEMP} specified in S7.4.3.1:

Material	σ_{TEMP}
Carbon steel	14.00 MPa (2.000 ksi)
CRES (3xx/3xxL)	41.00 MPa (6.000 ksi)
CUNI (70/30)	11.00 MPa (1.600 ksi)
CUNI (90/10)	8.00 MPa (1.200 ksi)
Copper	1.00 MPa (0.150 ksi)

S7.4.4 Pressurize the specimens with nitrogen (N₂) or dry air. Control the pressure of the gas as follows:

S7.4.4.1 Before the fire exposure, precharge each specimen with an estimated mass of gas such that after 5 min the total pressure of expanding gas inside the heated specimen will reach 100 ± 10 % of the specimen test pressure. Verify there is no leakage.

S7.4.4.2 During the first 5 min of fire exposure, allow specimen pressure to rise uncontrolled up to 110 % of the test pressure. If necessary, bleed out gas to maintain 100 ± 10 % of the test pressure.

S7.4.4.3 After 5 min of fire exposure, control specimen pressure to maintain 100 ± 5 % of the test pressure until 20 min of fire exposure.

S7.4.4.4 After 20 min of fire exposure, close the valves controlling specimen pressure to seal the specimens.

S7.4.4.5 A safety relief valve may be used throughout the fire exposure. If a relief valve is used, the opening pressure setting shall be at least 10 % above the test pressure. Instrument the relief valve and record the opening times.

S7.4.4.6 After 20 min of fire exposure, pressure variations within each MAF specimen as a result of variations in specimen gas temperature or specimen volume shall be within ±10 % of the specimen test pressure.

S7.4.5 Conduct the fire test in a manner that will allow for a rapid temperature rise to attain the required heat flux.

NOTE S7.4—See Test Method E 1529 for background information on the fire exposure.

S7.4.5.1 The fire exposure shall provide a spatial average total cold wall heat flux of at least 120 kW/m² within 3 min to all exposed surfaces of each specimen and maintain +20 and –0 % of that flux throughout the remainder of the test.

S7.4.5.2 Expose each specimen in an environment meeting the fire requirements (see S7.4.5) for 30 min.

S7.4.6 If there is any leakage during the 30-min fire period, the fire test is invalid. See S1.3.9 for further instructions.

S7.4.7 Immediately after completing the fire exposure, allow the test specimens to cool to ambient temperature. Upon attaining room temperature, subject the test specimens to a hydrostatic proof test.

S7.4.7.1 Conduct the hydrostatic proof test in accordance with the requirements specified in Annex A4 except for the following:

- (1) Fill the specimens with clean fresh water.
- (2) Pressurize the test specimen to 150 % of rated pressure and maintain pressure for at least 30 min.
- (3) Perform the hydrostatic proof test in the same test laboratory as the fire test.
- (4) Measure the total accumulated leakage of the hydrostatic proof test.

S7.4.7.2 Total accumulated leakage from the fitting for the duration of the hydrostatic proof test shall be classified with the following grades:

Grade	Amount of Leakage, mL ^A
L-0	0 (None)
L-10	>0 and <10 ^B
L-50	>10 and <50
Failure	>50

^A Total accumulated leakage for the duration of the postfire hydrostatic test.

^B Symbol ">" means "greater than." Symbol "<" means "less than or equal to."

S7.4.8 The test specimen fails if there is leakage greater than or equal to 50 mL at the fitting joint or within one diameter of the fitting joint during the post-fire or hydrostatic test.

S7.4.8.1 Failure of the pipe away from the fitting does not disqualify a fitting. Failure within one diameter of the fitting constitutes failure of the fitting unless it is shown by tests of pipe alone that the fitting is not likely to have contributed to the pipe failure.

S7.4.9 Complete the test report for the fire test in accordance with S1.3.13.

S7.5 Precision and Bias

S7.5.1 The precision of the fire test is established by the accuracy of the test equipment (see 7.5) and permissible tolerances used during the test. There is no bias when the equipment used is properly calibrated to measure accurate results.

S8. VIBRATION TEST

S8.1 Scope

S8.1.1 When invoked by the purchaser, MAFs shall be subjected to a vibration test. The number of specimens used shall be as specified in Table S1.1.

S8.2 Significance and Use

S8.2.1 This test determines the ability of MAFs to withstand the effects of vibration while being pressurized. After completion of this test, the specimen is subjected to a hydrostatic proof test. This test is used to duplicate conditions that could occur during in-service use.

S8.3 General Testing Requirements

S8.3.1 The test specimen geometry may be in accordance with Fig. 1. The location of strain gages shall be on the high side of the specimen to within 4.6 mm (0.18 in.) as shown in Fig. 1.

S8.3.2 Before beginning the vibration test, the test specimens may be tested pneumatically (see Annex A3) and hydrostatically (see Annex A4) at the option of the manufacturer.

S8.3.3 The selected specimens shall be filled with fluid in accordance with 7.6.3 before being placed onto the appropriate test fixture.

S8.3.3.1 The test fixture shall be equipped with supports to be attached to the test specimen during testing. The supports shall be spaced as shown in Fig. S8.1. The distance between supports shall be as specified in Table S8.1.

S8.3.4 The testing frequency ranges applied and vibration amplitudes attained shall be recorded in the test report for each of the tests performed.

S8.3.5 The specimens shall show no evidence of leakage during or at the completion of the test.

S8.3.6 At completion of testing, the test specimens shall be subjected to a hydrostatic proof test in accordance with the requirements specified in Annex A4.

S8.3.7 The specimens successfully pass the vibration test after meeting the test requirements herein and passing the subsequent hydrostatic proof test (see Annex A4).

TABLE S8.1 Distance Between Supports

Designation OD/NPS	OD, in.	OD, mm	F, in.	F, mm
¼ OD	0.250	6.35	16.4	417
¾ OD	0.375	9.53	18.0	457
⅛ NPS	0.405	10.29	18.0	457
½ OD	0.500	12.70	19.0	483
¼ NPS	0.540	13.72	19.0	483
⅝ OD	0.625	15.88	21.0	533
⅜ NPS	0.675	17.15	21.0	533
¾ OD	0.750	19.05	23.0	584
½ NPS	0.840	21.34	23.0	584
1 OD	1.000	25.40	25.0	635
¾ NPS	1.050	26.67	25.0	635
1¼ OD	1.250	31.75	28.0	711
1 NPS	1.315	33.40	28.0	711
1½ OD	1.500	38.10	31.0	787
1¼ NPS	1.660	42.16	31.0	787
1½ NPS	1.900	48.26	34.0	864
2 OD	2.000	50.80	39.0	991
2 NPS	2.375	60.33	39.0	991
2½ NPS	2.875	73.66	44.0	1118

S8.4 Procedure

S8.4.1 Subject MAF to a vibration test in accordance with MIL-STD-167 (Type I: Environmental).

S8.4.2 Conduct the test in each of the three principle directions (X, Y, and Z).

S8.4.3 Conduct and complete testing in one direction before proceeding to the other.

S8.4.4 Pressurize the specimens to 100 % of the rated pressure of the pipe or tube or fitting, whichever is lower (see S1.3.11.1).

S8.4.5 The test apparatus shall be able to record any drop in pressure throughout the duration of the test. If pressure is lost at any time during the test and is due to leakage at the MAF joint, the specimens have failed (see S1.3.9).

S8.4.5.1 If there is a loss of pressure through faulty equipment or on the test specimen in any area other than the MAF joint, note this occurrence in the test report, but it is not to be considered as a failure of the MAF.

S8.4.6 Perform the following tests: exploratory vibration test, variable frequency test, and endurance test.

S8.5 Precision and Bias

S8.5.1 The precision of the vibration test is established by the accuracy of the test equipment (7.5.1.1) and permissible tolerances used during the test. There is no bias when the equipment used is calibrated properly to measure accurate results.

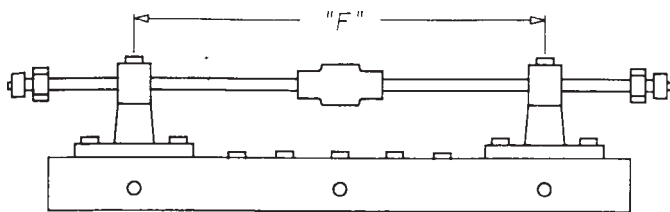


FIG. S8.1 Vibration Test Specimen Geometry

ANNEXES
(Mandatory Information)
A1. PERFORMANCE TESTS FOR MAF
A1.1 Scope

A1.1.1 This section lists the tests to be used to verify whether MAFs meet the performance characteristics of this specification. In addition, any statements that would apply to all tests are specified in this section to minimize redundancy.

A1.1.2 The test procedures appear in the following order:

Procedure	Section
Examination of Specimen	Annex A2
Pneumatic Proof Test	Annex A3
Hydrostatic Proof Test	Annex A4
Impulse Test	Annex A5
Flexure Fatigue Test	Annex A6
Tensile Test	Annex A7
Hydrostatic Burst Test	Annex A8
Repeated Assembly Test	Annex A9
Rotary Flex Test	Annex A10
Mercurous Nitrate Test	Annex A11

A1.1.3 The sections of the main body of this specification listed below apply to the test specimens used to perform the tests listed in A1.1.2.

Title	Section
Scope	1
Referenced Documents	2
Terminology	3
Classification	4
Materials and Manufacture	6
Performance Requirements	7
Workmanship, Finish, and Appearance	9
Number of Tests and Retest	11
Specimen Preparation	12
Test Methods	13
Inspection	14
Certification	15

A1.2 Significance & Use

A1.2.1 *List of All Tests*—Section A1.1.3 and Table 1 provide a listing of all tests specified herein. The requirements for each test are as specified in Annex A2-Annex A11.

A1.2.2 *General Information*—All of the general information which applies to the tests described shall be as specified in A1.3.

A1.3 General Testing Requirements

A1.3.1 The test temperatures shall be as specified in each individual test.

A1.3.2 Tests may be performed by the manufacturer or by a test facility designated by the manufacturer and approved by the purchaser. In all cases, the testing apparatus used to test MAFs shall be calibrated in accordance with the requirements specified in 7.5.1.

A1.3.3 End caps or adapters used to connect the test specimen assembly to the test apparatus, or plugs used to block off a specimen end, shall be an optional design designated by the manufacturer. The end caps or adapters shall be constructed as to prevent their failure during testing.

A1.3.4 Failure of any test specimen which is related to separation or leakage at the joint of the end cap or adapter and pipe or tube shall be recorded in the test report but shall not be considered a failure of the MAF pipe or tube combination being tested. Replacement test specimens shall be prepared in accordance with Section 12.

A1.3.5 Failure of the MAF during testing through causes which are determined to be related to the MAF design shall be dispositioned in accordance with the requirements specified in 11.3.1. When penalty specimens are used, they shall be prepared and identified in accordance with 11.3.2. If the penalty specimens successfully pass all required testing, the initial failure shall be reported but shall not be considered an issue against the approval for technical qualification of the MAF design.

A1.3.6 MAF test specimen(s) shall be assembled in accordance with the manufacturer's recommended procedures.

A1.3.7 When multiple tests are performed on individual specimens, the sequence of testing shall be as specified in the test description.

A1.3.8 MAFs meet the requirements of this specification after successfully passing all of tests described in Annex A2-Annex A10. When required, the mercurous nitrate test specified in Annex A11 shall also be passed.

A1.4 Precision and Bias

A1.4.1 No statement is made about either the precision or bias of Annex A1, since the result merely states whether there is conformance to the criteria for success specified in the procedure.

A2. EXAMINATION OF SPECIMEN
A2.1 Scope

A2.1.1 This procedure covers the inspection and examination of test specimens prepared in accordance with the requirements specified in Section 12.

A2.2 Significance and Use

A2.2.1 MAFs are attached to and onto pipe(s) or tube(s), or both, using a variety of methods (see 1.1). To ascertain the integrity of each MAF type covered, it becomes important to

subject all types of MAFs to essentially the same tests. When the same tests are used, the assembly of the test specimens becomes critical to the results of each test performed. The usefulness of this procedure lies in the examination of MAF test specimens to ensure that resulting geometries duplicate appropriate stresses on all types of MAFs qualified using the tests specified herein.

A2.3 Procedure

A2.3.1 Assemble MAF test specimens in accordance with the manufacturer's assembly procedures as approved by the purchaser (see 12.1).

A2.3.2 Inspect the test specimen dimensionally to ensure that it is in compliance with the specimen geometry specified in Fig. 1.

A2.3.3 Inspect strain gages (when required) to ensure their location on the test specimen as shown in Fig. 1. They shall be calibrated to assure their ability to transmit accurate readings and data to the equipment being used during the appropriate test.

A2.3.4 The materials used to assemble the test specimens shall be in accordance with Section 12. The schedule or the nominal wall thickness of the pipe or tube may vary as recommended by the manufacturer for a single MAF size. This

will permit the compatible pipe or tube throughout its given size range to be qualified along with the MAF.

A2.3.5 Quality and workmanship of the test specimens shall be in accordance with the requirements specified in Section 9.

A2.3.6 End caps or adapters used to connect the test specimen to subsequent testing apparatus shall be designed by the manufacturer or its designated testing facility.

A2.3.6.1 MAF specimens prepared for mercurous nitrate testing do not require end caps to be installed.

A2.3.7 During visual examination of the test specimens, record any unusual circumstances in accordance with the requirements specified in 14.6.

A2.3.8 Record the following information in the test report (or form) at the time of examination: date examined, MAF part number, specimen part number, pipe or tube material, outside diameter, wall thickness, and intended use.

A2.4 Precision and Bias

A2.4.1 Precision is based upon the accuracy of the MAF dimensions in accordance with applicable drawings. The pipe or tube used in conjunction with MAF must be in accordance with the raw material specification recommended by the manufacturer. There may be bias for the examination of specimens based upon the human elements involved in the visual inspection methods used.

A3. PNEUMATIC PROOF TESTING (OPTIONAL)¹⁶

A3.1 Scope

A3.1.1 This section covers pneumatic proof testing of all MAF test specimens (except mercurous nitrate) as specified in Table 3. All specimens approved for testing shall be subjected to this test.

A3.2 Significance and Use

A3.2.1 This test is the initial test of all MAF specimens prepared for testing. The test is performed by pressurizing the test specimen(s) using dry air or nitrogen (N₂). The initial pressure of 0.690 MPa (100 psi) is applied. If there is no leakage, the pressure is gradually increased to 125 % rated pressure of the pipe or tube or 3.45 MPa (500 psi), whichever is lower. If the specimen still shows no evidence of leakage after the second pressurization period, the specimen has successfully passed the test. This test is useful in determining if the MAF pipe or tube connection has been assembled correctly or if the MAF design performs as intended at elevated pressure.

A3.3 Procedure

A3.3.1 Place the test specimen in an appropriate chamber and secure it in place in accordance with the manufacturer's recommended procedures.

A3.3.2 Equip the chamber with calibrated pressure gages (see 7.5.1) to permit visual readings of the actual pressure being applied.

A3.3.3 Completely submerge the test specimen in water (H₂O) before beginning the test.

A3.3.4 Perform the pneumatic proof test at ambient temperature.

A3.3.5 Initially use nitrogen (N₂) or dry air to pressurize the test specimens to 0.690 MPa (100 psi) ± 5 % (shedding of surface bubbles during the first 1 min is acceptable) for a total period of 5 min. There shall be no evidence of leakage during the remaining 4-min period. If leakage occurs during the last 4 min of this pressurized period, discontinue the test. The affected specimens have failed. Fill out the test report noting the reason for discontinuing the test. See A1.3.4 and A1.3.5 for further information.

A3.3.6 If there is no evidence of leakage after the initial pressurization period (see A3.3.5) gradually increase the pressure to 125 % of the rated pressure of the pipe or tube or MAF or 3.45 MPa (500 psi) ± 5 %, whichever is lower. Maintain this pressure for an additional period of 5 min. There shall be no evidence of leakage during this 5-min period. If leakage occurs, discontinue the test. The affected specimens have failed the test. Fill out the test report noting the reason for discontinuing the test. See A1.3.4 and A1.3.5 for further information.

A3.3.7 If there is no evidence of leakage during both pressurized periods (except allowable shedding of surface

¹⁶ This test is optional as to whether it is performed before all other testing.

bubbles during initial pressurization), the test specimens have passed the pneumatic proof test.

A3.4 Precision and Bias

A3.4.1 The precision of the pneumatic proof test is established by the accuracy of the measuring and test equipment (M

& TE) and their permissible tolerances during the test (see 7.5). There is no bias in the pneumatic proof test when the M & TE used is calibrated properly.

A4. HYDROSTATIC PROOF TESTING (OPTIONAL)¹⁶

A4.1 Scope

A4.1.1 This section covers hydrostatic proof testing of selected MAF test specimens (except mercurous nitrate) as specified in Table 3. All specimens prepared for testing shall be subjected to this test.

NOTE A4.1—**Caution:** Those specimens selected for fire testing shall be hydrostatically proof tested using water only.

A4.2 Significance and Use

A4.2.1 This test is performed by pressurizing the test specimens using hydraulic fluid or water (see Note A4.1). The initial pressure applied, 0.690 MPa (100 psi), tests the assembled specimen to determine if it can retain fluid without leakage at the pipe or tube and MAF joint. If there is no leakage, the pressure is gradually increased to a second pressurization period of 150 % rated pressure of the pipe or tube or MAF, whichever is lower. This elevated pressure level tests the ability of the specimens to hold fluid without leakage.

A4.2.2 If the specimen still shows no evidence of leakage after the second pressurization period, the specimens have passed the test. This test is useful in determining the integrity of the MAF joint to hold fluid at an elevated pressure without leakage. After successful completion of this test, the test specimens are ready for additional testing.

A4.3 Procedure

A4.3.1 Fill the test specimens with fluid which meets the requirements of 7.6.3 before installation onto the appropriate testing apparatus.

A4.3.2 Place the test specimens in a burst chamber and secure into place in accordance with the manufacturer's recommended procedures. One end of the test specimen shall be free to move.

A4.3.3 Equip the chamber with calibrated pressure gages (see 7.5.1) to permit visual readings of actual pressure being applied.

A4.3.4 Perform the hydrostatic proof test at ambient temperature.

A4.3.5 Initially pressurize the test specimens to 0.690 MPa (100 psi) $\pm 5\%$ for a total period of 5 min. There shall be no evidence of leakage during this 5-min period. If leakage occurs, discontinue the test. The affected specimens have failed the test. Fill out the test report noting the reason for discontinuing the test. See A1.3.4 or A1.3.5 for further information.

A4.3.6 If there is no evidence of leakage after the initial 5-min period (see A4.3.5), gradually increase the pressure at an average rate not to exceed 172 MPa/min (25 000 psig/min) to $150 \pm 5\%$ of the rated pressure of the pipe or tube or MAF, whichever is lower. Maintain this pressure for an additional period of 5 min. There shall be no evidence of leakage during this 5-min period. If leakage occurs, discontinue the test. The affected specimens have failed the test. Fill out the test report noting the reason for discontinuing the test. See A1.3.4 and A1.3.5 for further information (as applicable).

A4.3.7 If there is no evidence of leakage within the MAF or MAF joint during both pressurized periods, the test specimens have passed the hydrostatic proof test. The specimens are ready for further testing.

A4.4 Precision and Bias

A4.4.1 The precision of the hydrostatic proof test is established by the accuracy of the measuring and test equipment (M & TE) and their permissible tolerances during the test (see 7.5). There is no bias in the hydrostatic proof test when the M & TE used is calibrated properly.

A5. IMPULSE TESTING

A5.1 Scope

A5.1.1 This section covers impulse testing of selected MAF test specimens. The number of specimens tested shall be as specified in Table 3 using the applicable specimen geometries shown in Fig. 1.

A5.1.1.1 At least 50 % of the separable specimens (Types II, III, and IV) shall be used for repeat assembly testing before testing begins, during the testing period, and after the test is concluded (see Annex A9).

A5.2 Significance and Use

A5.2.1 This test is performed by filling the test specimens with hydraulic fluid or water. The maximum pressure attained during the impulse cycle shall be 133 % of the performance pressure. The specimen is then depressurized to a pressure not greater than $20 \pm 5\%$ of the performance pressure. Each period of pressurization/depressurization is equal to one impulse cycle. The test specimens must be subjected to one million (10⁶) cycles without leakage.

A5.2.2 If the test specimens show no evidence of leakage after completion of the impulse testing, they have passed. If any specimens fail during the course of this test, the test for the failed specimens must be discontinued and the reason for the failure noted in the test report (see A1.3.5).

A5.2.3 All passed specimens shall then be subjected to a hydrostatic proof test as specified in Annex A4. This impulse test is useful to verify the ability of the MAF joint to maintain integrity in the presence of fluctuating system pressure. The occurrences during impulse testing simulate environments that may exist in hydraulic or hydrostatic piping or tubing systems for which MAF is designed.

A5.3 Procedure

A5.3.1 Fill the test specimens with hydraulic fluid which meets the requirements of 7.6.3 before installation onto the appropriate test apparatus.

A5.3.2 Perform the test at ambient conditions throughout the testing period.

A5.3.3 Connect the test specimens onto a testing apparatus that is capable of applying a pressure of $133 \pm 5\%$ of the performance pressure of the pipe or tube or MAF, whichever is lower, followed by a depressurization to a pressure not greater than $20 \pm 5\%$ of the performance pressure.

A5.3.4 Equip the apparatus with calibrated instruments (see 7.5.1) which permit visual readings of the actual pressures being applied to the specimens throughout the test period.

A5.3.5 Subject the test specimens to impulse pressures at the range specified in A5.3.3. Each application of maximum and minimum pressure shall be equal to one impulse cycle.

A5.3.6 The duration of impulse testing shall be 10^6 cycles at a rate not to exceed 75 cycles per minute (CPM).

A5.3.7 After the completion of the impulse test, hydrostatically proof test the test specimens in accordance with the requirements specified in Annex A4.

A5.3.8 There shall be no evidence of leakage during impulse testing or hydrostatic proof testing. If leakage occurs during either testing period, discontinue the test. The affected specimens have failed the test. Fill out the test report noting the reason for discontinuing the test. See A1.3.4 and A1.3.5 for further information.

A5.3.9 If there is no evidence of leakage at the conclusion of impulse or hydrostatic proof testing, the specimens have passed.

A5.4 Precision and Bias

A5.4.1 The precision of the impulse test is established by the accuracy of the measuring and test equipment (M & TE) and their permissible tolerances during the test (see 7.5). There is no bias in the impulse test when the M & TE used is calibrated properly.

A6. FLEXURE FATIGUE TEST

A6.1 Scope

A6.1.1 This section covers the requirements for flexure fatigue testing of selected test specimens as specified in Table 3. The specimen geometry used shall be as selected from Fig. 1.

A6.1.1.1 At least 50 % of the separable specimens (Types II, III, and IV) shall be used for repeat assembly testing specified in Annex A9.

A6.2 Significance and Use

A6.2.1 The significance of this test is to verify the capability of the MAF joint to perform adequately at rated pressure in a flexure environment. The test specimen is subjected to flexure while being pressurized to the maximum rated pressure of the pipe or tube or MAF, whichever is lower. The specimen is subjected to a bidirectional flexure whose plus (+) and minus (-) magnitudes are equal to within 2 %. This test is useful in simulating environmental conditions which may exist in fluid systems for which MAF is designed.

A6.2.2 If the specimens do not show signs of leakage, they are subjected to a hydrostatic proof test as specified in Annex A4. The specimen passes when there is no evidence of leakage after the flexure fatigue test and hydrostatic proof test.

A6.3 Procedure

A6.3.1 Fill the test specimens with hydraulic fluid which meets the requirements of 7.6.3 before installation onto the appropriate testing apparatus.

A6.3.2 Equip the apparatus with calibrated gages (see 7.5.1) which permit visual readings of the actual pressures being applied. The apparatus shall be designed to shut down in the event that pressure is lost during the period of the test.

A6.3.3 Locate calibrated strain gages on the high stress side of the pipe or tube as shown in the geometries in Fig. 1. They shall be able to transmit accurate data to calibrated equipment which will be capable of displaying visual data or recording physical data, or both, throughout the period of the test.

A6.3.4 Conduct the test at ambient conditions throughout the testing period.

A6.3.5 Calculate the axial stress introduced as a result of the internal pressure to be applied using the following formula:

$$S = \frac{Pd^2}{D^2 - d^2}$$

where

S = stress,

P = pressure,

D = outside diameter (OD), and
 d = inside diameter.

A6.3.6 Introduce a bending moment which will obtain an average strain gage reading across the unpressurized specimen equivalent to the stress level specified in Table A6.1 less the axial stress calculated (see A6.3.5).

A6.3.7 After the bending moment is established, pressurize the specimen to the rated pressure of the MAF or pipe or tube, whichever is lower. The total axial stress (as a result of bending and internal pressure) shall be a minimum of the values specified in Table A6.1.

A6.3.7.1 The flexure rate during the test shall be at the option of the manufacturer.

A6.3.8 One cycle shall consist of an excursion from neutral (zero strain) to the maximum positive strain position, to the maximum negative strain position, and return to neutral. Maximum positive strain and maximum negative strain shall be equal to within 2 %.

A6.3.9 Subject the specimens to a minimum of 80 000 total cycles (30 000 total cycles for stainless steel (CRES) speci-

mens). Record the average cycle rate used on the test report. Leakage during the test shall result in the automatic shut down of the apparatus.

A6.3.10 If there is no evidence of leakage at the conclusion of flexure fatigue testing, subject the passed specimens to a hydrostatic proof test as specified in Annex A4.

A6.3.11 There shall be no evidence of leakage during flexure fatigue testing or hydrostatic proof testing. If leakage occurs, discontinue the test. The affected specimens have failed the test. Fill out the test report noting the reason for discontinuing the test. See A1.3.4 and A1.3.5 for further information.

A6.3.12 The specimens pass when there is no evidence of leakage during the flexure fatigue test and hydrostatic proof test.

A6.4 Precision and Bias

A6.4.1 The precision of the flexure fatigue test is established by the accuracy of the measuring and test equipment (M & TE) and their permissible tolerances during the test (see 7.5). There is one area of bias for this test. If there is equipment malfunction, or leakage in the facility, or leakage in an area of the specimen other than the MAF or MAF joint, which results in loss of pressure and the automatic shutdown does not occur, it may be possible to achieve a given amount of cycles before the loss of pressure is detected. If this occurs, replacement test specimens (see A1.3.4) shall be required. The affected test specimens cannot be considered for further testing and must be discarded. The reason for this is because the original specimens may have completed the test. If the same specimens were used and cycled an additional 80 000 cycles (30 000 cycles for stainless steel (CRES)) and failure occurred, absolute verification of whether it was because of the design or overstress could not be determined clearly.

TABLE A6.1 Minimum Combined Total Axial Stress Values^A

Material	Temper	Test Stress Value, ksi
CRES (Type 3XX)		259 MPa (38.00)
CRES (Type 3XXL)		259 MPa (38.00)
CuNi (70-30)		124 MPa (18.00)
CuNi (90-10)	annealed	83 MPa (12.00)
CuNi (90-10)	light drawn	72 MPa (10.50)
Copper	annealed	93 MPa (13.50)
Copper	drawn	41 MPa (6.00)
Carbon steel		152 MPa (22.00)
Chromium-molybdenium		152 MPa (22.00)

^ATotal axial stress as a result of combined pressure and bending.

A7. TENSILE TEST

A7.1 Scope

A7.1.1 This section covers the requirements for tensile testing selected specimens as specified in Table 3. The number of specimens for this test shall be as specified in Table 3, using the specimen geometries as shown in Fig. 1.

A7.2 Significance and Use

A7.2.1 The significance of this test is to apply a tensile load at a controlled separation speed to establish how much load is needed to separate the test specimen. The minimum tensile load occurs during separation of the pipe or tube and MAF joint. The amount of tensile load applied depends upon the cross-section area and the yield strength of the pipe or tube. The formula specified in A7.3.3 constitutes the criterion for the pass or fail requirements of this test. When the minimum tensile load is calculated, the result should be equal to or less than the minimum tensile load required to achieve separation of the specimen joint. Failure occurs when separation takes place at a point before the calculated tensile load is applied. If failure occurs, the test shall be discontinued, and the test report shall be noted with the reason for discontinuing the test.

A7.2.2 The specimens pass this test when the calculated tensile load is achieved without separation of the joint. Movement within the area of the joint is acceptable as long as actual separation does not occur. This test is useful in determining the strength of the pipe or tube or MAF joint. Based upon the strength of the joint, the pipe or tube material and wall thickness can be tailored to withstand failure within the adverse environments present in fluid systems for which MAF is designed.

A7.3 Procedure

A7.3.1 Before tensile testing, the specimens may be subjected to a pneumatic test (see Annex A3) and a hydrostatic test (see Annex A4) at the option of the manufacturer.

A7.3.2 Install each test specimen in a constant strain rate tensile machine. The gripping jaws shall be located a minimum of three pipe or tube diameters from the MAF joint.

A7.3.3 The constant strain rate tensile machine shall have the capability to apply a constant tensile load which will result in establishing a speed of approximately 1.3 mm/min (0.05 in./min) at which cross head minimum tensile pull out force (as separation occurs) will be attained. Minimum allowable tensile

load is based upon being equal to or greater than the values stated in the following formula:

$$\text{Calculated tensile load} = (Kt) \times (Ap) \times (Sy)$$

where

Kt = tensile constant of 1.0;

Ap = actual cross-section area of the pipe, mm² (in.²) based on wall thickness; and

Sy = minimum specified yield strength of pipe or tube.

A7.4 Precision and Bias

A7.4.1 The precision for the tensile test is established by the accuracy of the measuring and test equipment (M & TE) and

their permissible tolerances during the test (see 7.5). There may be bias in the tensile test when separation occurs at a point other than at the MAF joint. If the pipe or tube were to yield before the MAF pipe or tube joint, this would establish that the pipe or tube is weaker than the MAF. In this case, a stronger yield of pipe or tube may be needed to determine the strength of the joint. In another instance, the MAF may yield before the joint or pipe or tube. If this is the case, reevaluation of the pipe or tube selected may have to be reconsidered to establish the true strength of the MAF joint.

A8. HYDROSTATIC BURST TEST

A8.1 Scope

A8.1.1 This section covers the test requirements for burst testing. The number of specimens to be tested shall be as specified in Table 3.

A8.1.1.1 When the Supplementary Section is invoked, passed specimens from the elevated temperature soak test (S3) and shock test (S6) shall be used instead of new or previously tested specimens from tests specified in the Annex.

A8.2 Significance and Use

A8.2.1 The significance of this test is two-fold. The first significant aspect is the burst test itself. This test verifies the integrity of the pipe or tube and MAF joint to withstand, without leakage or burst, a minimum pressure equal to four times the rated pressure of the pipe or tube or MAF, whichever is lower. To pass this test, the pipe or tube and MAF joint cannot leak or burst below four times the rated pressure.

A8.2.2 The second significant aspect of this test is the test specimens used. All test specimens are comprised of those specimens which have passed other tests as specified in A8.1.1. The use of this test determines whether the MAF design may ultimately receive technical approval for in-service systems by the purchaser.

A8.3 Procedure

A8.3.1 Fill the test specimens with water or hydraulic fluid which meets the requirements of 7.6.3 before installation onto the appropriate testing apparatus.

A8.3.2 Place the test specimens into a burst chamber and secure them into place in accordance with the manufacturer's recommended procedures. One end must be free to move.

A8.3.3 Equip the chamber with calibrated pressure gages (see 7.5.1) to permit visual readings of actual pressure being applied.

A8.3.4 Perform the hydrostatic burst test at ambient temperature.

A8.3.5 Subject the test specimens to a gradual increase of pressure at an average rate not to exceed 127 MPa/min (25 000 psig/min) to four times the rated pressure of the specimen assembly and hold for a minimum of 1 min. If leakage or burst occurs below four times the rated pressure of the specimen assembly, discontinue the test. The affected test specimens have failed the test. Fill out the test report noting the reason for discontinuing the test. See A1.3.4 and A1.3.5 for further information.

A8.3.6 The test specimens have passed the hydrostatic burst test when four times the rated pressure of the specimen assembly has been attained.

A8.4 Precision and Bias

A8.4.1 The precision of the hydrostatic burst test is established by the accuracy of the measuring and test equipment (M & TE) and their permissible tolerances during the test (see 7.5). There may be bias in this test if the pipe or tube selected burst below four times its rated pressure. If this should occur, the test specimens shall be replaced in accordance with A1.3.4. There may be no bias in this test if the precision of the gages used is the only determining factor. The gages used to apply a gradual increase pressure to a maximum of four times the rated pressure of the specimen assembly, can be read accurately during the test period.

A9. REPEATED ASSEMBLY TEST

A9.1 Scope

A9.1.1 This section covers the requirements for repeat assembly testing of selected test specimens as specified in Table 3. This test is only applicable to separable MAFs, Types II, III, and IV. Test specimens selected for repeat assembly shall be comprised of at least 50 % of the specimens from impulse (see Annex A5) and flexure fatigue (see Annex A6) tests.

A9.2 Significance and Use

A9.2.1 The significance of this test is to verify the integrity of the separable MAF joint to withstand ten repeated assemblies. The disassembly and reassembly shall be performed using the manufacturer's recommended assembly procedures. The test specimens used for repeat assembly shall be selected from the impulse and flexure tests. An equal amount of specimens shall be selected from each of these tests. Scoring, distortion, damage, or modification of the mating parts of the MAF joint as a result of repeated assembly shall not be cause for failure.

A9.2.2 If the specimens show no evidence of leakage during impulse and flexure testing (or their posttest requirements), they pass the repeat assembly test.

A9.3 Procedure

A9.3.1 Before beginning the impulse or flexure fatigue test, disassemble and reassemble the separable MAF assembly one time.

A9.3.1.1 Each assembly shall have the sealing face rotated by hand 60 to 90° before each reassembly.

A9.3.1.2 Retighten each assembly within the minimum and maximum values recommended by the manufacturer's assembly procedure.

A9.3.2 At the conclusion of 25 % of the test cycles for impulse and flexure fatigue test, interrupt the test and disassemble and reassemble the test specimens two more times (see A9.3.1.1).

A9.3.3 At the conclusion of 50 % of the test cycles for impulse and flexure fatigue test, interrupt the test and disassemble and reassemble the test specimens two more times (see A9.3.1.1).

A9.3.4 At the conclusion of 75 % of the test cycles for impulse and flexure fatigue test, interrupt the test and disassemble and reassemble the test specimens two more times (see A9.3.1.1).

A9.3.5 At the conclusion of the impulse and flexure fatigue test (before post testing), disassemble and reassemble the test specimens an additional two times (see A9.3.1.1).

A9.3.6 If the test specimens show no evidence of leakage after the post-test requirements for impulse and flexure fatigue, they have passed the repeated assembly test.

A9.3.7 If the specimens leak any time during the test, discontinue the test. The affected specimens have failed the test. Note the reason for discontinuing the test in the test report. See A1.3.4 and A1.3.5 for further information (as applicable).

A9.4 Precision and Bias

A9.4.1 There is no precision and bias for the repeated assembly test because scoring, distortion, damage, or modification of the sealing surfaces are not causes for failure of this test. The precision and bias statements for subsequent hydrostatic proof, impulse, and flexure fatigue tests apply.

A10. ROTARY FLEX TEST

A10.1 Scope

A10.1.1 When invoked by the purchaser, Types II, III, and IV MAFs shall be subjected to a rotary flex test. This test shall only apply to MAFs with tube diameters of 25.4 mm inclusive (1 in. inclusive) or less. The number of specimens used shall be as specified in Table 3.

A10.2 Significance and Use

A10.2.1 This test determines the ability of separable MAFs to withstand the effects of rotary flex while being pressurized. After completion of this test, the specimen is subjected to a hydrostatic proof test. This test is used to duplicate conditions that could occur during in-service use.

A10.3 General Testing Requirements

A10.3.1 The test specimen geometry shall be in accordance with Fig. 1. The location of strain gages shall be on the high side of the specimen to within 4.6 mm (0.18 in.) as shown.

A10.3.2 Before beginning the test, the specimens may be tested pneumatically (see Annex A3) and hydrostatically (see Annex A4) at the option of the manufacturer.

A10.3.3 The selected specimens shall be filled with fluid in accordance with 7.6.3 before being placed onto the appropriate test fixture.

A10.3.4 The testing frequency ranges applied and amplitudes attained shall be recorded in the test report for each of the tests performed.

A10.3.5 The specimens shall show no evidence of leakage during or at the completion of the test.

A10.3.6 At completion of testing, the test specimen shall be subjected to a hydrostatic proof test in accordance with the requirements specified in Annex A4.

A10.3.7 The specimens successfully pass after meeting the rotary flex test requirements and passing the hydrostatic proof test (see Annex A4).

A10.4 Procedure

A10.4.1 Subject selected separable test specimens to a rotary flexure test. The general test requirements specified in A10.3 apply before beginning the test.

A10.4.2 Fill the specimen with fluid in accordance with 7.6.3, and install the specimen onto the appropriate test apparatus which will allow for a bending moment to be introduced along with the application of pressure (see Fig. A10.1).

A10.4.3 With the specimen unpressurized, a bending moment equivalent to a minimum of 35 % of the ultimate tensile strength (of the tubing material) shall be introduced and locked into place. Record the bending moment selected in the test report.

A10.4.4 With the bending moment locked into place, pressurize the specimen to a static pressure of 3.45 MPa (500 psi) minimum. Maintain the bending moment and pressure for the duration of the test.

A10.4.5 Select the amplitude to be used and record it in the test report.

A10.4.6 Flex the specimen in a rotary motion at a minimum of 1750 rpm for a minimum of 1×10^6 cycles maintaining the specified bending stress level (see A10.4.3) and pressure (see A10.4.4) at all times.

A10.4.7 The test apparatus shall be able to record any loss of pressure throughout the duration of the test.

A10.4.8 If pressure is lost at any time during the test, the specimen has failed. See A1.3.4 and A1.3.5 for further instructions (as applicable).

A10.4.9 At the conclusion of the rotary flex test, subject the specimens to a hydrostatic proof test (see Annex A4) as specified in A10.3.6. Specimens pass the test upon successfully completing the rotary flex test and the hydrostatic test without any leakage.

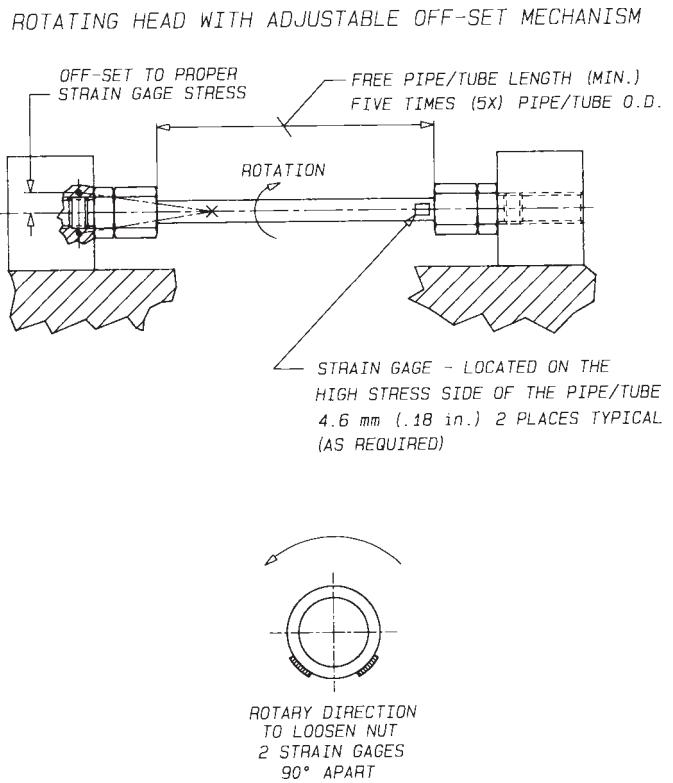


FIG. A10.1 Test Setup for Rotary Flex (MAF Types II, III, and IV)

A10.5 Precision and Bias

A10.5.1 The precision of the rotary flexure test is established by the accuracy of the measuring and test equipment (M & TE) and their permissible tolerances during the test (see 7.5). There is no bias in the rotary flexure test when the M & TE used is calibrated properly.

A11. MERCUROUS NITRATE TEST

A11.1 Scope

A11.1.1 This section covers the requirements for conducting a mercurous nitrate test of selected MAF specimens as specified in Table 3. The selection of specimens for this test is restricted to those specimens that are manufactured using either copper-zinc (containing more than 15 % zinc) or copper-aluminum alloys.

NOTE A11.1—**Warning:** All appropriate safety precautions, such as the use of rubber gloves, should be taken while handling and testing with mercury. Care should be taken to prevent mercury contamination of other test specimens.

A11.2 Significance and Use

A11.2.1 The significance of this test is to determine the susceptibility to stress-corrosion cracking of MAFs manufactured from materials specified in A11.1.

A11.3 Procedure

A11.3.1 Use two MAFs from the same material lot from which the specimens are selected to conduct this test.

A11.3.2 Assemble the specimens onto pipe or tube to duplicate the geometries shown in Fig. 1. End caps are not required.

A11.3.3 Immerse the MAF specimen for 30 min in a standard mercurous nitrate solution as specified in Test Method B 154.

A11.3.4 Rinse and dry the MAF before immediate examination. There shall be no cracks.

A11.3.5 MAFs successfully pass this test when no cracks are observed during the examination.

A11.4 Precision and Bias

A11.4.1 The precision of this test is the solution and the material tested. There may be bias if the solution is not properly mixed in accordance with Method B 154.

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