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AEROSPACE STANDARD

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Superseding AS1650

Coupling Assembly, Threadless, Flexible, Fixed Cavity, Self-Bonding, Procurement Specification

1. SCOPE:

This aerospace specification defines the requirements for a threadless, flexible, self-bonding coupling assembly which, when installed on machined fixed cavity ferrules, provides a flexible connection for joining tubing and components in aircraft fuel, vent or other systems. This assembled coupling, hereafter referred to as the assembly, is designed for use from -65 to +400 °F and at 125 psig nominal operating pressure.

1.1 Product Classification:

The coupling assembles shall be of the integral electrical bonding type.

2. REFERENCES:

2.1 Applicable Documents:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

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

AS568	Aerospace Size Standard for O-Rings
AS1055	Fire Testing of Flexible Hose, Tube Assemblies, Coils, Fittings and Similar System Components
AS1651	Assembled Coupling, Threadless - Flexible, Fixed Cavity, Self Bonding, Envelope Dimensions
AS1652	Assembly, Coupling Body and Sleeve, Threadless - Flexible, Fixed Cavity, Self Bonding
AS1653	Ferrule, Male, Threadless - Flexible, Fixed Cavity, Self Bonding, Swaged
AS1654	Sleeve, Threadless - Flexible, Fixed Cavity, Female Ferrule Type
AS1655	Coupling Body, Threadless - Flexible, Fixed Cavity, Self Bonding
AS1656	Fitting End, Threadless - Flexible, Fixed Cavity, Self Bonding, Male and Female Ferrule Design Standard
AS4060	Tube Fitting Swaged Joint, Roller Expander, Manual Process, Requirements For
AS4734	Ferrule, Male, Threadless - Flexible, Fixed Cavity, Self Bonding, Butt Welded
AS4735	Ferrule, Female, Threadless - Flexible, Fixed Cavity, Self Bonding, Swaged
AS4736	Ferrule, Female, Threadless - Flexible, Fixed Cavity, Self Bonding, Butt Welded
AMS 3331	Fluorosilicone Rubber, Fuel and Oil Resistant, 65-75

2.1.2 U.S. Government Publications: Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

VV-P-236	Petrolatum, Technical
P-D-680	Petroleum Naphtha (Stoddard Solvent)
WW-T-700	Tube, Aluminum Alloy, Drawn, Seamless, 6061
TT-S-735	Standard Test Fluids; Hydrocarbon
MIL-PRF-7024	Calibrating Fluids, Aircraft Fuel System Components (Stoddard Solvent)
MIL-R-25988	Rubber, Fluorosilicone Elastomer, Oil & Fuel Resistant, O-Rings, Class 1, Grade 70
MIL-STD-129	Military Marking
MIL-STD-130	Identification Marking of U.S. Military Property
MIL-STD-464	Electromagnetic Environmental Effects Requirements for Systems
MIL-STD-810	Environmental Test Methods
MIL-STD-831	Test Reports, Preparation of
MIL-STD-889	Dissimilar Metals

2.1.3 NAS Standards: Available from Aerospace Industries Association, 1250 Eye Street NW, Washington, DC 20005.

NAS1787	Clamp, Tube Mounting

2.1.4 Uniform Classification Committee Publications: Available from Uniform Classification Committee, 202 Chicago Union Station, Chicago, IL 60606.

Uniform Freight Classification Rules

2.2 Definitions:

ASSEMBLED COUPLING: The completed coupled connection, utilizing a coupling assembly to connect two ferrules which are attached to tube ends.

COUPLING ASSEMBLY: The connecting device which constrains the ferrules and provides a pressure seal and electrical continuity path across the ferrules.

3. TECHNICAL REQUIREMENTS:

3.1 Qualification:

Assemblies furnished under this specification shall be products which are qualified by meeting all of the requirements covered by this document. Manufacturers choosing to produce only a part or parts of the assembled coupling shall qualify the part or parts by complying with the requirements and performing all tests of this specification. The test specimens for qualification of a part or parts shall be tested with a qualified part or parts made by other qualified manufacturers whenever possible.

3.2 Materials and Finishes:

Materials and finishes for the components shall be those designated on the applicable AS standard drawing. The assembly materials and finish shall be uniform in quality, free from defects, suitable for service, consistent with good manufacturing practice and in conformance with the applicable specifications and requirements stated herein.

3.2.1 Dissimilar Materials: Materials shall possess adequate corrosion resistance characteristics or shall be suitably protected by the use of finishes to resist corrosion caused by such conditions as dissimilar metal combinations, moisture, salt spray and high-temperature deterioration. Dissimilar materials are defined by MIL-STD-889.

3.3 Design and Fabrication:

The assembly shall be a lightweight flexible connection for fuel, vent and other system lines using the basic principles of O-ring sealing. It shall be capable of a 125 psig nominal operating pressure at temperatures from -65 to +200 °F in aluminum and -65 to +400 °F in CRES and titanium. The assembly shall function at a maximum angular misalignment of 4° or a maximum axial gap of 0.250 in or, in combination, a minimum axial gap of 0.063 in at a maximum angular misalignment of 3°. If a component uses an AS1656-2-(Size) sleeve end, the maximum angular misalignment is 2° or a maximum axial gap of 0.250 in. The AS1656-3-(Size) sleeve end is intended for hose end applications with no angular misalignment or axial gap except for clearances required to permit assembly.

3.3.1 Assembled Coupling Components: The assembled coupling shall consist of ferrules, O-ring seals and a coupling assembly as specified in the following standards (Reference AS1651):

TABLE 1

Quantity	Description	AS Standard Number
2	Ferrule	AS1653 or AS4734, ends per AS1656-1-(Size)
2	O-ring seal	User defined compound, sizes per AS568
1	Coupling assembly	AS1652

3.3.2 Ferrule: Ferrules shall contain the fixed O-ring cavity. The design of the O-ring groove shall be per AS1656-1-(Size) for standard sizes as specified in Table 2. Attachment of the ferrule to the tubing shall be by mechanical roller swaging, draw bar swaging or welding. Roller swaging shall conform to AS4060. Ferrule material shall be compatible with the tubing to which it is attached and shall comply with MIL-STD-889.

3.3.3 Coupling Assembly: Coupling assemblies (AS1652) are provided to simplify drawing callouts. Ferrules are not considered integral to the coupling assembly because they are usually specified on tubing fabrication drawings and vary according to the attachment method.

3.3.3.1 Sleeve: The sleeve shall conform to AS1654 and is designed to carry only hoop stresses and to effect sealing. A portion of the sleeve outside surfaces shall be circumferentially grooved or knurled to facilitate gripping by hand during installation and removal.

TABLE 2 - Physical Requirements

Dash Size Ref.	Tube Size Inches Ref.	Operating Pressure Nominal Negative (-) in-Hg	Operating Pressure Nominal Positive (+) psig	Proof Pressure Minimum Negative (-) in-Hg	Proof Pressure Minimum Positive (+) psig	Burst/ Rupture Pressure Minimum psig	AS568 O-Ring Dash Size Ref.
-08	0.500	24	125	28	250	375	-015
-10	0.625	24	125	28	250	375	-017
-12	0.750	24	125	28	250	375	-117
-16	1.000	24	125	28	250	375	-214
-20	1.250	24	125	28	250	375	-218
-24	1.500	24	125	28	250	375	-222
-28	1.750	24	125	28	250	375	-224
-32	2.000	24	125	28	250	375	-226
-36	2.250	10	125	12	250	375	-228
-40	2.500	10	125	12	250	375	-230
-48	3.000	10	125	12	250	375	-234
-56	3.500	10	125	12	250	375	-238
-64	4.000	10	125	12	250	375	-242

3.3.3.2 Coupling: The coupling shall automatically lock when manually closed and shall be structurally capable of withstanding both the axial and bending moment loads transmitted by the system tubing when using the tubing wall thickness as specified in Table 3. The closure shall have clear indication of a locked condition both visually and by feel. Quick connect or disconnect action of the latch shall be utilized to allow assembly and removal with one hand. The coupling assembly shall provide electrical bonding means which will produce a maximum of 1 Ω resistance from tube to tube across the coupling assembly. The coupling assembly is allowed to rotate around the ferrules when installed.

3.3.4 Seals: O-ring seals are not considered a part of this specification except for coupling qualification test requirements. Sizes per AS568 are given in Table 2.

3.3.5 Dimensions: The assembly envelope dimensions shall be as specified in AS1651. Part dimensions shall be as specified in applicable AS part standards.

3.3.6 Weights: The individual components of the coupling shall meet the weight requirements listed on the applicable AS part standards.

TABLE 3 - Tube Size and Wall Thickness

Coupling Dash Size Ref.	Tube Size Inches Ref. /1/	Tube Wall Thickness /2/
-08	0.500	0.035
-10	0.625	0.035
-12	0.750	0.035
-16	1.000	0.035
-20	1.250	0.035
-24	1.500	0.035
-28	1.750	0.035
-32	2.000	0.035
-36	2.250	0.042
-40	2.500	0.042
-48	3.000	0.042
-56	3.500	0.049
-64	4.000	0.049

/1/ All sizes listed are not required for qualification testing but are included in the event that the user specifies additional testing.
/2/ Aluminum drawn tubing, 6061-T6 in accordance with WW-T-700/6.

3.4 Performance:

The assembled coupling shall meet the following performance requirements.

3.4.1 Proof Pressure: The assembled coupling shall meet the negative and positive proof pressures listed in Table 2 without leakage as specified or evidence of other malfunction. Testing is specified in 4.6.2.

3.4.1.1 Negative Pneumatic Leakage: The assembled coupling shall not exhibit a decrease in negative pressure exceeding 0.5 in Hg within a period of 5 min when subjected to the Table 2 negative proof pressure. Testing is specified in 4.6.2.1.

3.4.1.2 Positive Pneumatic Leakage: The assembled coupling shall withstand pneumatic pressure equal to the Table 2 positive proof pressure for 3 min at room temperature without any visible bubbles starting after 1 min at proof pressure. Testing is specified in 4.6.2.2.

3.4.1.3 Positive Hydraulic Leakage: The assembled coupling shall withstand hydraulic pressure equal to the Table 2 positive proof pressure for 3 min at room temperature without external wetting from any point of the assembly. Testing is specified in 4.6.2.3.

3.4.2 Fuel Resistance (Aging): The assembled coupling shall not show evidence of malfunction or leakage in excess of 3.4.1.3 when subjected to high temperature fuel aging at +200 °F, low temperature fuel aging at -65 °F and air dry out at +200 °F. Testing is specified in 4.6.3.

3.4.3 Vibration: The assembled coupling shall show no evidence of malfunction or structural failure and no leakage in excess of 3.4.1.3 after exposure to vibration levels in accordance with 4.6.4. The electrical resistance across the assembled coupling shall not exceed 1 Ω.

3.4.4 Repeated Assembly: There shall be no evidence of deformation, damage or degradation in latching ability and the assembled coupling shall show no evidence of leakage in excess of 3.4.1.3 when subjected to the burst pressure requirements of 3.4.9 following 100 repeated assembly operations. The electrical resistance across the assembled coupling shall not exceed 1 Ω. Testing is specified in 4.6.5.

3.4.5 Salt Fog: The assembled coupling shall show no evidence of leakage in excess of 3.4.1.3 when subjected to the Table 2 positive proof and burst/rupture pressures and shall show no evidence of excessive corrosion, peeling, chipping or blistering of the finish nor exposure of base metal under plated surfaces after being subjected to salt fog test. The electrical resistance across the assembled coupling shall not exceed 1 Ω. Testing is specified in 4.6.6.

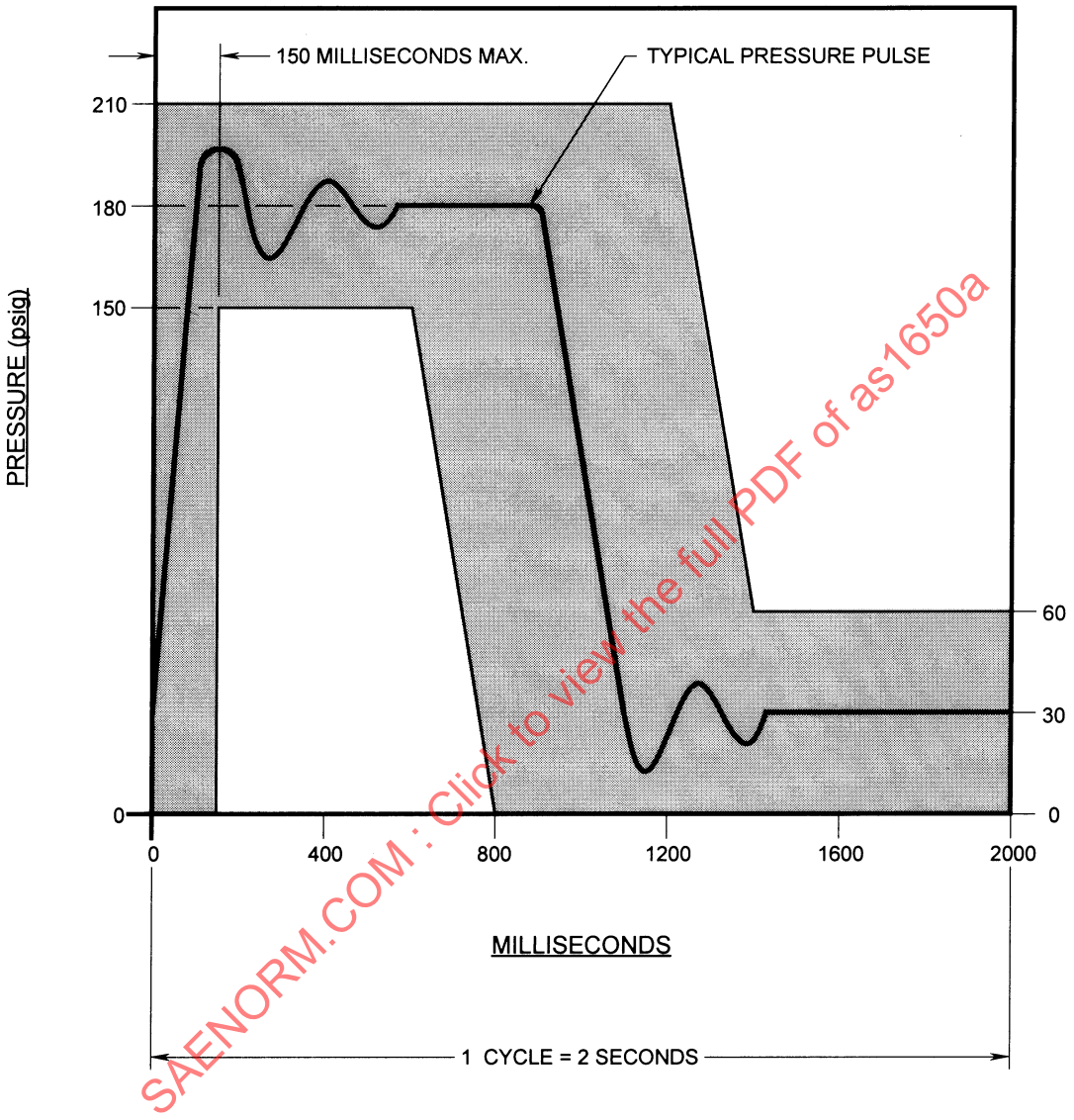
3.4.6 Dust Resistance: The assembled coupling shall show no damage such as fouling of parts and no evidence of malfunction and shall be capable of withstanding Table 2 positive proof pressures without evidence of leakage in excess of 3.4.1.3 after being subjected to the dust resistance test. The electrical resistance across the assembled coupling shall not exceed 1 Ω. Testing is specified in 4.6.7.

3.4.7 Flexure: The assembled coupling shall withstand Table 2 burst pressure without evidence of leakage in excess of 3.4.1.3 with no binding or galling of parts after being subjected to 28,800 flexure cycles with the assembled coupling at an offset of 3°. Testing is specified in 4.6.8.

3.4.8 Pressure Surge: The assembled coupling shall withstand 100,000 pressure surge cycles as defined in Figure 1 without evidence of malfunction or leakage in excess of 3.4.1.3. Testing is specified in 4.6.9.

3.4.9 Burst/Rupture: The assembled coupling shall not rupture nor show evidence of leakage in excess of 3.4.1.3 at any pressure up to the Table 2 burst/rupture pressures. Testing is specified in 4.6.10.

3.4.10 Electrical Bonding: The electrical resistance of the assembled coupling, when measured from tube to tube, shall not exceed 1 Ω at any time. Testing is specified in 4.6.11.



/3/ The pressure-time curve for the pressure surge test shall be within the shaded area of the curve shown. Pressure trace recordings shall be made at start, middle and end of each run of 50,000 pressure surge cycles.

FIGURE 1 - Pressure Surge Curve

3.5 Identification of Product:

Coupling assembly parts and ferrules shall be marked for identification in accordance with MIL-STD-130 as specified on the applicable AS standard or drawing.

3.6 Workmanship:

Coupling components shall be manufactured and finished in accordance with commercially accepted practices and processes.

3.7 Cleaning:

The coupling components as supplied shall be free of oil, grease, dirt or any other foreign material both internally and externally.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:

Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection and test requirements as specified herein. Except as otherwise specified, the supplier may utilize his/her own facilities or any commercial laboratory acceptable to the procuring activity for the performance of the inspection and test requirements. The procuring activity reserves the right to perform any of the inspections and tests set forth in the specification, where such inspections and tests are deemed necessary to assure that supplies and services conform to prescribed requirements.

4.2 Classification of Inspections:

The examining and testing of assemblies shall be classified as:

a. Qualification inspections (4.3)
b. Quality conformance inspections (4.4)

4.3 Qualification Inspections:

4.3.1 Qualification Test Specimens: Aluminum test specimens in accordance with Figure 2A or 2B and Table 4 shall be used for all tests specified herein. The number of specimens are specified in 4.3.2. Tubing for fabrication of test specimens shall be 6061-T6 aluminum in accordance with WW-T-700/6 with dimensions as shown in Table 3. Attachment of ferrules to tubing shall be in accordance with AS4060 and/or user specifications.

Qualification of CRES and titanium couplings shall be by similarity, subject to approval by the user.

TABLE 4 - Test Schedule and Sequence

Specimen Numbers	1	2	3	4	5	6	/4/ 7
Applicable test paragraphs	4.6.1	4.6.1	4.6.1	4.6.1	4.6.1	4.6.1	4.6.1
	4.6.2	4.6.2	4.6.2	4.6.2	4.6.2	4.6.2	4.6.2
	4.6.11	4.6.11	4.6.11	4.6.11	4.6.1	4.6.11	4.6.11
	4.6.3	4.6.3	4.6.7	4.6.7	4.6.5	4.6.5	4.6.4
	4.6.4 /4/	4.6.4 /4/	4.6.11	4.6.11	4.6.6	4.6.6	4.6.2
	4.6.2	4.6.2	4.6.8	4.6.8	4.6.9	4.6.9	4.6.11
	4.6.11	4.6.11	4.6.2	4.6.2	4.6.2	4.6.2	
	4.6.10		4.6.11	4.6.11	4.6.11	4.6.11	
			4.6.10		4.6.10		

/4/ Specimen 1 and 2 will not be subjected to the vibration tests of 4.6.4 in sizes -08, -16, -24, -32 and -40. All other tests are applicable. Specimen 7 will be used for vibration testing of these sizes. Specimens 1 and 2 in sizes -48 and -64 will be subjected to the vibration tests of 4.6.4.

4.3.2 Test Schedule and Sequence: Seven test specimens each for coupling sizes -08, -16, -24, -32 and -40, and six test specimens each for coupling sizes -48 and -64 shall be subjected to qualification tests in the order indicated in Table 4. MIL-R-25988/1 O-ring seals or seals per AMS 3331 with sizes per AS568 shall be used for all test specimens. Sizes other than those listed above and smaller than size -64 are considered qualified by design similarity.

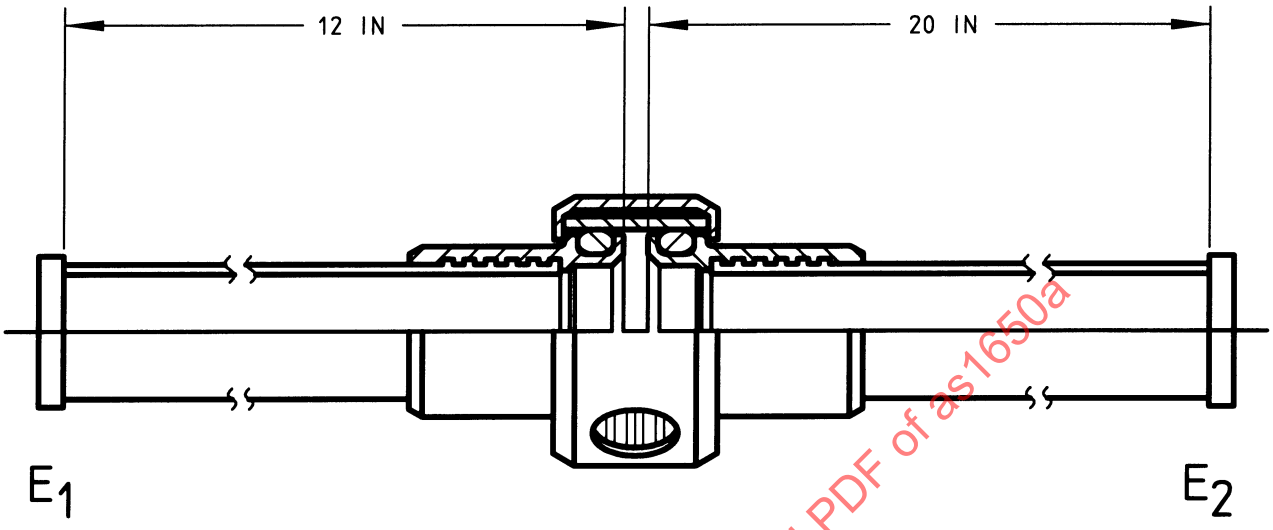
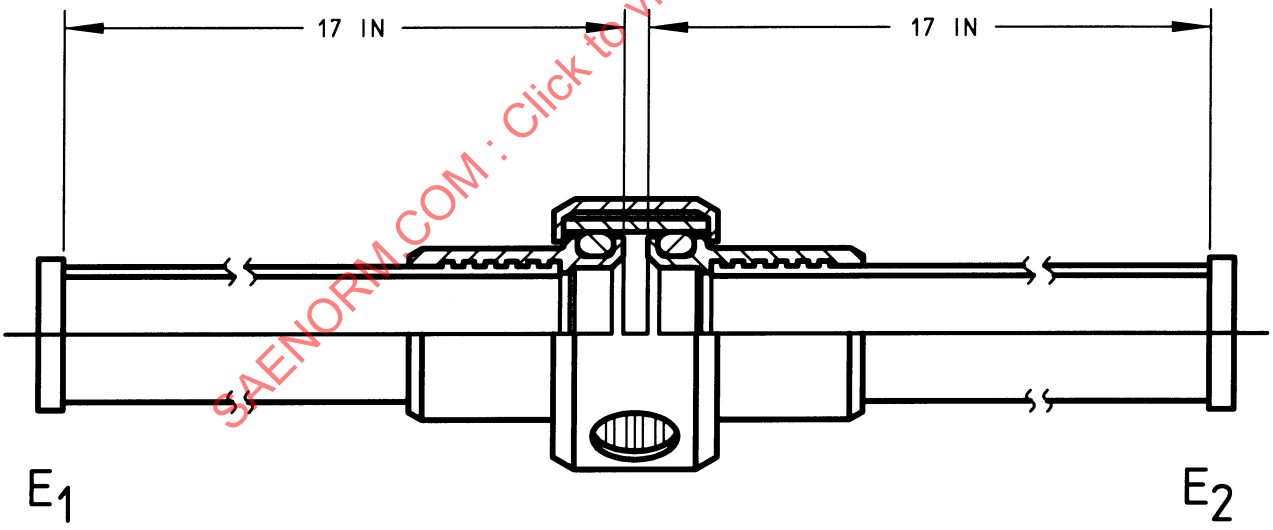


FIGURE 2A - Test Specimens 1 Thru 6



/5/ End caps E1 and E2 to be compatible with test requirements.

FIGURE 2B - Test Specimen 7

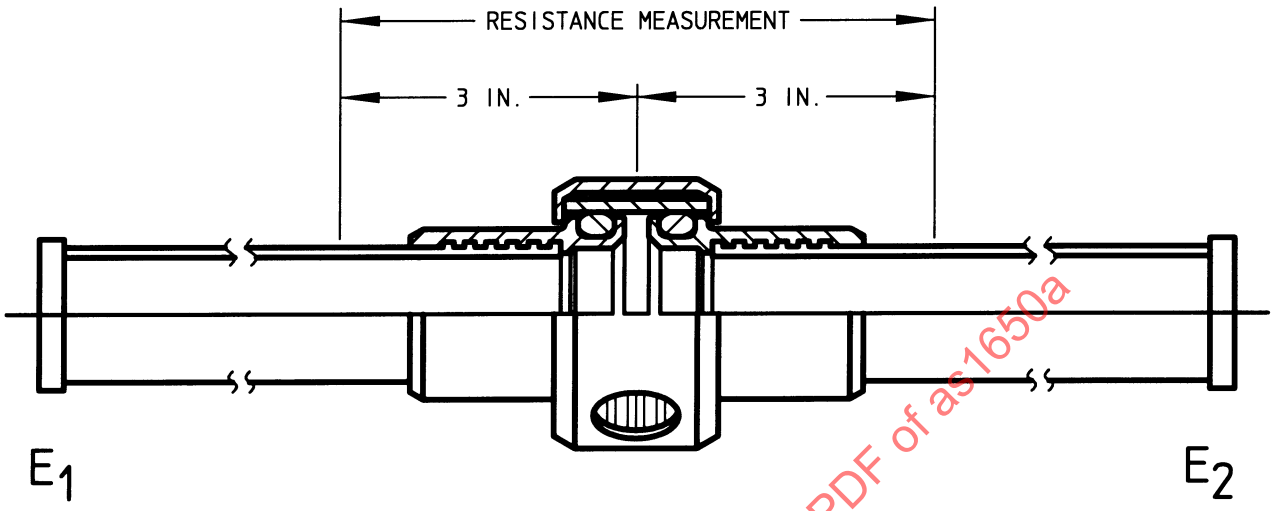


FIGURE 2C - Electrical Resistance Measurement, Typical

4.3.3 Test Report, Test Samples and Data for the Procuring Activity: When the tests are conducted at a location other than the laboratory of the procuring activity, the following shall be required:

a. Test Report: A minimum of three copies of a test report in accordance with MIL-STD-831, which shall include a report of all tests and outline description of the test setup and test conditions.

b. Test Sample: The test sample which was tested, when requested by the procuring activity.

c. Test Data: A minimum of three sets of engineering data in the form of assembly drawings. The assembly drawings shall have a cut-away section showing all details in their normal assembled position and shall carry part numbers of all details and subassemblies.

NOTE: Log sheets containing the required test data shall remain on file at the supplier's test facility and shall be made available upon request.

4.3.4 Qualification Inspection Methods: Qualification inspection methods shall consist of all the examinations and tests specified in 4.6.

4.4 Quality Conformance Inspections:

Each coupling component shall be subjected to examination of product as specified in 4.6.1.

4.4.1 Rejection and Retest: Where one or more items selected from a lot fails to meet the specification, all items in the lot shall be inspected for the particular characteristic that failed.

4.4.1.1 Resubmitted Lots: Once a lot (or part of a lot) has been rejected by a procuring activity (government or industrial), before it can be resubmitted for tests, full particulars concerning the cause of previous rejection and the action taken to correct the defects in the lot shall be furnished in writing, by the manufacturer to the procuring activity.

4.5 Test Conditions:

4.5.1 Assembly of Test Specimens: O-ring seals shall be lubricated with petrolatum per VV-P-236 or equivalent.

4.5.2 Test Fluids: Test fluids shall be TT-S-735, Type I or Type III, or Stoddard Solvent per P-D-680 or MIL-PRF-7024, or as specified for each test.

4.5.3 Pressure Measurements: Unless otherwise specified, positive pressure measurements shall have a tolerance of ±10 psig. Negative pressures (in-Hg) shall be equal to or greater than the specified value.

4.5.4 Temperature Measurements: Unless otherwise specified, the test specimens and fluid shall be maintained within ±5 °F. Ambient temperature measurements shall be taken within 6 in of the test specimen.

4.6 Inspection Methods:

4.6.1 Examination of Product: Each assembly or part shall be visually and dimensionally inspected to determine compliance with this specification and applicable standard or drawing with respect to material, size and workmanship.

4.6.2 Proof Pressure: Test specimens shall be installed in the test fixture as shown in Figure 3 and subjected to Table 2 negative and positive proof pressures in conjunction with and as specified in other tests.

4.6.2.1 Negative Pneumatic Proof Pressure: Test specimens shall be dry and free of fuel or test fluid vapors. The connection between the test specimen and vacuum pump shall be 0.500 in nominal hose or tube size minimum and shall not exceed a length of 10 ft. A stop valve shall be installed between the test specimen and the vacuum pump. Pressure shall be measured within 6 in of the test specimen. A negative proof pressure equal to or greater than the Table 2 specified negative proof pressure value shall be maintained for 15 min minimum. The stop valve shall then be closed and the pressure shall be monitored for 5 min minimum while maintaining the specimen temperature constant within a total range of 5 °F.

4.6.2.2 Positive Pneumatic Proof Pressure: Test specimens shall be immersed in water and pressure tested to the Table 2 positive proof pressure value for a minimum of 3 min. Measurements shall begin after a 1 min stabilization period. The test fluid shall be dry compressed air or gaseous nitrogen.

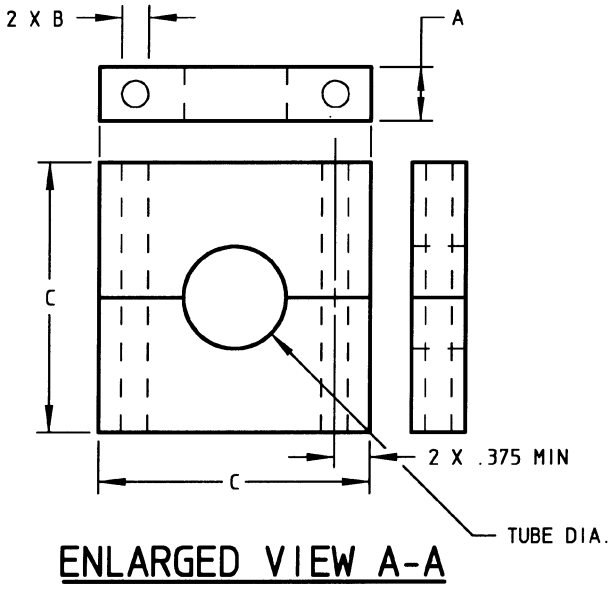
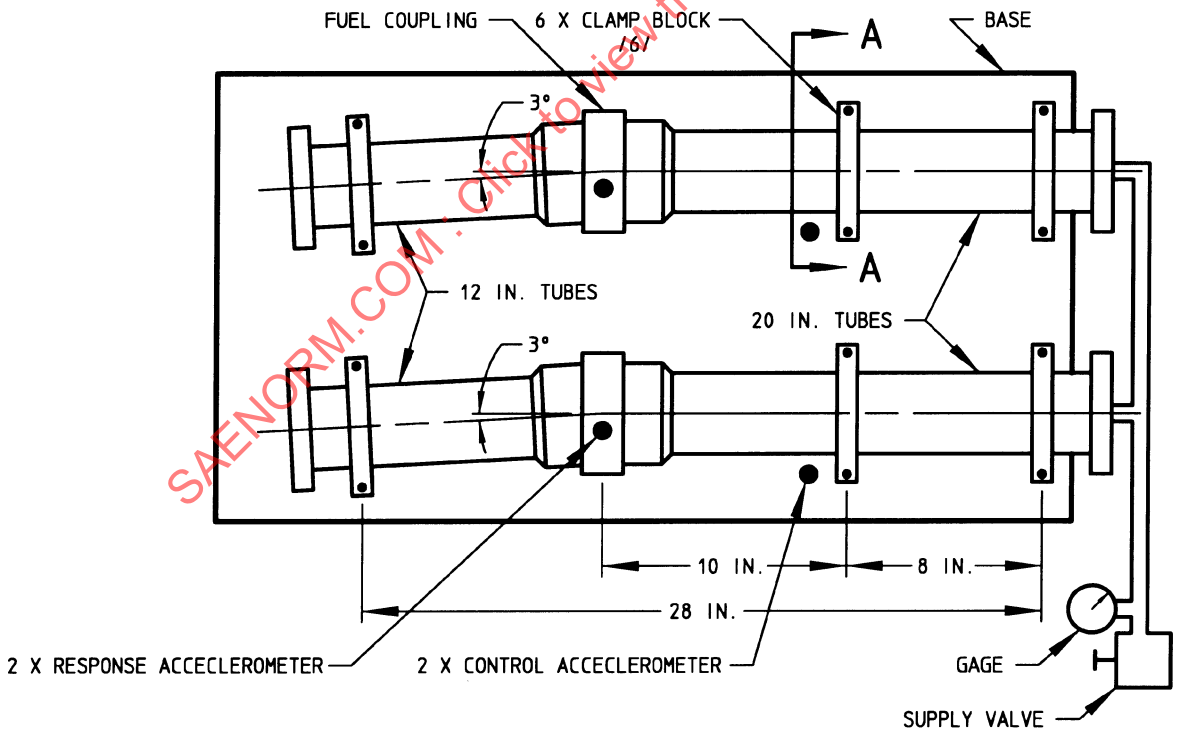


TABLE 5 - Clamp Block Dim's.
Material: Aluminum Alloy

TUBE DIA.	A	B	C
.50	1.0	.375	2.00
1.00	1.0	.375	2.50
1.50	1.0	.375	3.00
2.00	1.0	.50	3.50
2.50	1.0	.50	4.00
3.00	1.0	.50	4.50
4.00	1.0	.50	5.50



/6/ Clamp blocks shall clamp tightly on the 20 in tubes (E2) and on the 12 in tubes (E1) for the vibration tests only. For all other tests, the clamp blocks shall be a sliding fit on the 12 in tubes (E1) to allow load restraint by the coupling only.

FIGURE 3 - Fuel Resistance, Vibration (Sizes -48 and -64 Only) and Burst Pressure Test Setup

4.6.2.3 Positive Hydraulic Proof Pressure: Test specimens shall be wiped dry and pressure tested to the Table 2 positive proof pressure value for not less than 3 min and not more than 5 min. The test fluid shall be as specified in other tests or may be water.

4.6.3 Fuel Resistance: Test specimens 1 and 2 as specified in Figure 2A, shall be mounted on a test fixture as shown in Figure 3 with 3° misalignment between tube centerlines for each size coupling to be qualified. Tube end (E2) shall be rigidly clamped and tube end (E1) shall be clamped with clearance to allow axial movement of the tube until it is restrained by the assembled coupling. Clamp blocks adjacent to the assembled coupling shall be spaced 20 in apart. The assembled coupling shall be centered between clamp blocks. The electrical resistance across the assembled coupling shall be measured before and after each step of the fuel resistance test per 4.6.11.

4.6.3.1 High Temperature Aging: The test specimens shall be proof pressure tested in accordance with 4.6.2.3 and Table 2 positive proof pressure using TT-S-735, Type III test fluid. The pressure shall then be reduced to 125 psig and the ambient and fluid temperatures shall be increased to +200 °F. After temperature stabilization, the test shall be continued for a minimum of 72 h maintaining a fluid and ambient temperature of +200 °F. Upon completion and while at +200 °F, the specimens shall be subjected to a positive hydraulic proof pressure test in accordance with 4.6.2.3. Electrical resistance across the assembled coupling shall be measured in accordance with 4.6.11. The ambient and fluid temperatures shall then be reduced to room temperature condition.

4.6.3.2 Low Temperature Aging: The TT-S-735, Type III test fluid shall be removed from the test specimens and refilled with TT-S-735, Type I test fluid. The test specimens shall be proof pressure tested in accordance with 4.6.2.3. The pressure shall then be reduced to Table 2 positive operating pressure and the ambient and fluid temperatures shall be lowered and stabilized at -65 °F. The test shall be continued for a minimum of 72 h maintaining a fluid and ambient temperature of -65 °F. Upon completion and while at -65 °F, the specimens shall be subjected to a positive proof pressure test in accordance with 4.6.2.3. Electrical resistance across the assembled coupling shall be measured in accordance with 4.6.11. The ambient and fluid temperatures shall then be increased to room temperature conditions, the test fluid drained, and the specimens dried without disassembly or removal from the test fixture.

4.6.3.3 High Temperature Drying: The test specimens while vented to the atmosphere shall be maintained for a minimum of 168 h at +200 °F. Upon completion, the specimens shall be filled with TT-S-735, Type I test fluid and the low temperature test in accordance with 4.6.3.2 shall be repeated one additional time except upon completion the test fluid will not be drained. Electrical resistance across the assembled coupling shall be measured in accordance with 4.6.11. Without disassembly of the assembled couplings or removal from the test fixture, the test specimen shall be subjected to vibration testing in accordance with 4.6.4.

4.6.4 Vibration:

4.6.4.1 Line Sizes -48 and -64 Only: At the completion of the fuel resistance test in accordance with 4.6.3 and without disassembly or removal from the test fixture, test specimens 1 and 2 shall be subjected to vibration testing at room temperature. The vibration time shall be divided equally between the specimen pressurized with TT-S-735, Type I or Stoddard Solvent per P-D-680 or MIL-PRF-7024 test fluid at 125 psig and empty at 10 in Hg minimum negative operating pressure. The electrical resistance across the assembled coupling shall be monitored periodically in accordance with 4.6.11.

a. Input: Plots of the actual vibration input spectra for each axis and test level shall be recorded.

b. Response: Frequency response plots of transmissibility (response/input) versus frequency for the equipment response points. Frequencies associated with minimum performance or other frequencies selected for resonance dwell points shall be identified on response points.

c. Chronological Log: The log shall contain clear description of test being performed and shall include all pertinent information concerning conduct of test, equipment performance, identification and description of failures and/or degradations during the vibration testing shall be fully documented as well as the remedial action taken.

4.6.4.1.1 Resonance Survey: A sinusoidal resonance survey shall be made in each of the three orthogonal axis noted in Figure 4A. The frequency sweep shall be made slowly from 5 to 2000 Hz. At 0.024 in double amplitude minimum or ±2.0 G, whichever is less. Resonance points shall be noted and resonance recorded and the modes of each resonance described. Resonant points used for resonance vibration shall be determined by input versus output levels as obtained per 4.6.4.1.b. A resonance is defined as a magnification of the output to input level by a factor of two or more.

4.6.4.1.2 Sinusoidal Vibration Test: The test specimens shall be vibrated in each of the three orthogonal axis as shown in Figure 4A, with up to two resonance dwells in the 5 to 2000 Hz range for the test times specified in Table 6 for each axis. If more than two resonance frequencies are noted, only the most severe points shall be used for resonance dwell. The double amplitudes or acceleration levels shall be in accordance with Table 7.

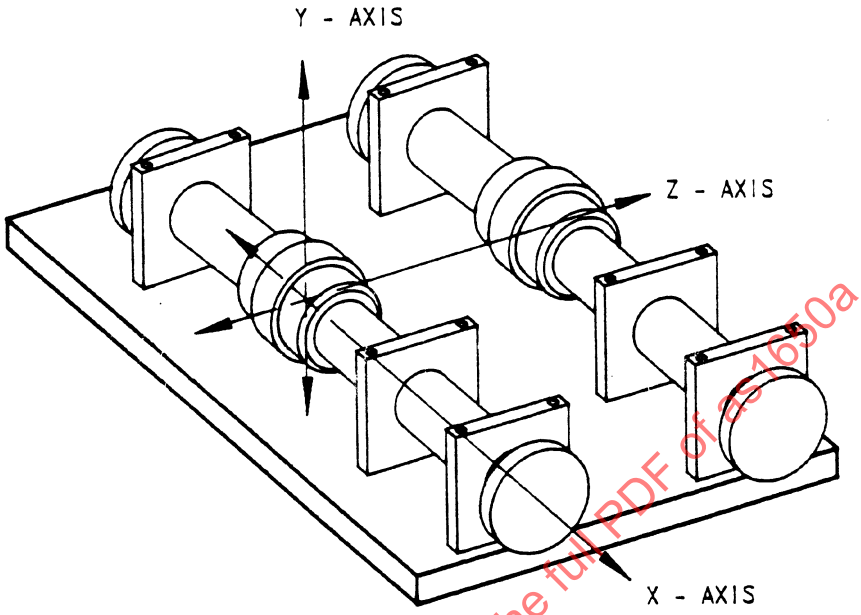


FIGURE 4A - Vibration Axes, Specimens 1 and 2 (Sizes -48 and -64)

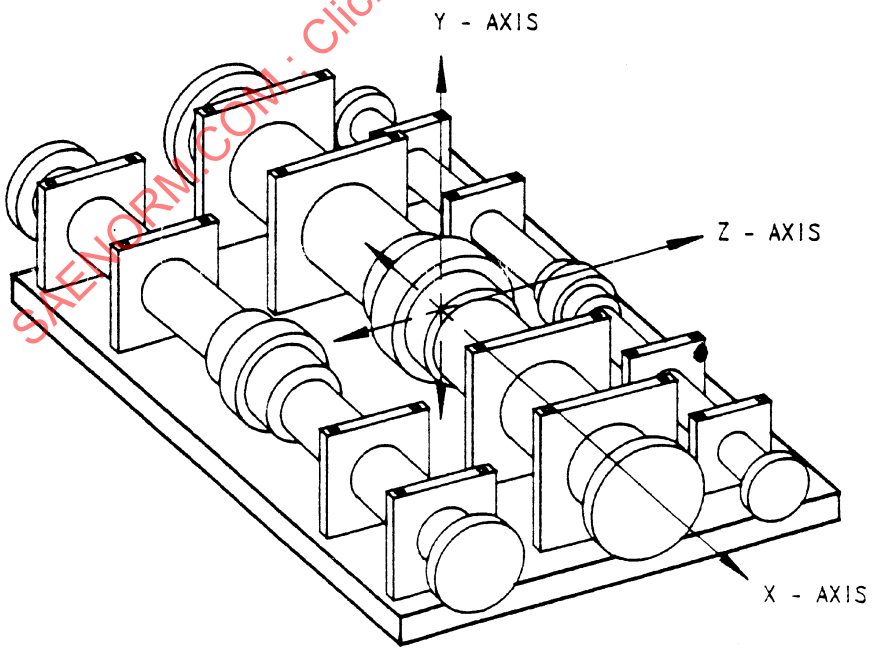


FIGURE 4B - Vibration Axes, Specimen 7 (Sizes -08 Thru -40)

TABLE 6 - Vibration Test Times

Number of Resonance	0	1	2
Total dwell times at resonance points minimum (minutes)	0	30	60
Total cycling time minimum (minutes)	90	60	30

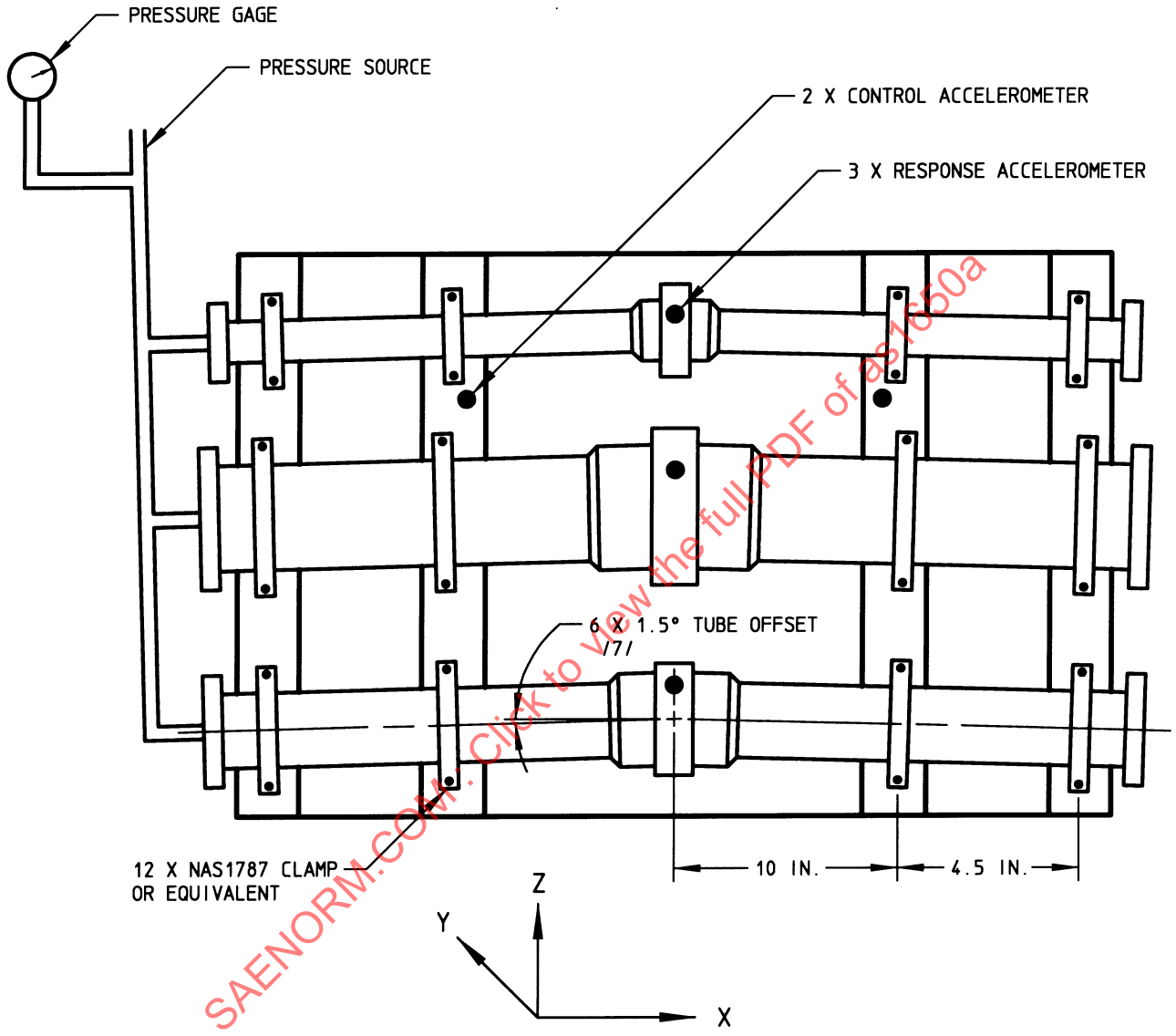
TABLE 7 - Vibration Levels (Sinusoidal)

Frequency	Amplitude or Acceleration Level
5 - 18 Hz	0.100 in double amplitude minimum
18 - 24 Hz	±1.5 G
24 - 50 Hz	0.036 in double amplitude minimum
50 - 1000 Hz	±5.0 G

4.6.4.2 Line Sizes -08 thru -40 Only:

4.6.4.2.1 General: All vibration testing on test specimen 7 as shown in Figure 2B shall be performed using the test fixture illustrated in Figure 5. Accelerometers rigidly mounted on the test fixture shall be used to control input acceleration forces. Response accelerometers rigidly mounted on each of the test specimens shall be used to monitor acceleration output forces on each of the test specimens. Each test specimen shall be mounted to the vibration test fixture at a minimum angular displacement of 3° between tube centerline (1.5° from the X axis for each tube) and free to move axially to accommodate end loads due to internal pressure prior to tightening. The distance between the inboard tube supports with the coupling mounted in the center shall be 20 in for all sizes. The distance between inboard and outboard tube supports shall be 4.5 in. Tube supports shall be NAS1787 or equivalent. The test setup shall be photographed showing the test specimens installed on the test fixture locating input and response accelerometers and direction of test axes.

Resonant modes shall be monitored aurally and visually by comparison of input versus output level and by waveform shape change. Input vibration spectrum shall be within the tolerance of +3.0/-1.5 dB below 500 Hz and within ±3.0 dB between 500 and 2000 Hz except that ±6.0 dB are permissible over a cumulative band width of 200 Hz maximum between 500 and 2000 Hz. Vibration frequency tolerance shall be ±2% or ±0.5 Hz below 25 Hz. Vibration amplitude tolerance shall be ±10% as used in sinusoidal vibration. A detailed chronological test log shall be maintained to verify conformance with test requirements.



/7/ All tubes are 1.5° offset from the X axis.

FIGURE 5 - Vibration Test Setup (Sizes -08 Thru -40)

4.6.4.2.1 (Continued):

The outboard end of each tube shall be suitably plugged and ported to provide for test fluid filling and pressurization. Test fluid shall be Stoddard Solvent per P-D-680 or MIL-PRF-7024 pressurized to the Table 2 positive operating pressure for all testing.

The X and Y axis of vibration shall be performed horizontally with the fixture rigidly mounted to a slip plate. X axis vibration shall be along the axial centerline of the tube assemblies (disregarding the 1.5° per tube offset). Y axis vibration shall be perpendicular to the X axis. Z axis vibration shall be perpendicular to the tube centerline but mutually perpendicular to the X and Y axes. See Figure 4B.

All vibration testing shall be performed at room temperature. Electrical resistance across the assembled coupling shall be monitored periodically during this test in accordance with 4.6.11.

4.6.4.2.2 Non-Gunfire Vibration:

4.6.4.2.2.1 Sinusoidal Vibration:

4.6.4.2.2.1.1 Resonance Survey: A sinusoidal resonance survey shall be made in each orthogonal axis noted in Figure 4B. The frequency sweep shall be made slowly from 5 to 2000 Hz at 0.024 in double amplitude minimum, or ±2.0 G, whichever is less. Resonance points shall be noted and resonance recorded and the modes of each resonance described. Resonant points used for resonance vibration shall be determined by input versus output response levels.

4.6.4.2.2.1.2 Frequency Cycling and Resonance Dwell: Test specimens shall be vibrated in each of the three orthogonal axis as shown in Figure 4B, with up to two resonance dwells in the 5 to 50 Hz range, for test times specified in Table 6 for each axis. If more than two resonant frequencies are noted, only the most severe points shall be used for resonance dwell. The double amplitude and acceleration levels shall be in accordance with Table 8.

TABLE 8 - Vibration Levels (Non-Gunfire)

Frequency	Amplitude or Acceleration Level
5 - 9 Hz	0.200 in double amplitude minimum
9 - 17 Hz	0.100 in double amplitude minimum
17 - 29 Hz	±1.5 G
29 - 50 Hz	0.036 in double amplitude minimum

4.6.4.2.2.1.2 (Continued):

Logarithmic cycling sweep periods shall be a minimum of 7.5 min per 5-50-5 Hz, cycle. The actual input and response accelerations shall be plotted for one partial cycle, 5 to 50 Hz and selection of resonance from 4.6.4.2.2.1.1 shall be confirmed. If more than two resonance are encountered, the two most severe shall be utilized as evidenced by output versus input acceleration level. Double amplitudes and acceleration level shall be per 4.6.4.2.2.1.2. The test specimens shall not exhibit leakage during or subsequent to test. At each resonance, retuning shall be performed as necessary to maximize the response. Amplitude, response and frequency at the beginning and end of each dwell period shall be recorded.

4.6.4.2.2.2 Random Vibration: Prior to the test on each of the three orthogonal axes, the test fixture with specimens shall be equalized to provide conformance with the vibration levels specified below.

The test fixture with specimens shall be subjected to 180 min minimum on each axis of vibration testing utilizing the acceleration levels of Table 9.

TABLE 9 - Acceleration Levels (Non-Gunfire)

Frequency	Acceleration Power Spectral Density G^2/Hz
50 - 300 Hz	Beginning at 0.04 increasing at approximately +5.0 dB/Octave to 0.75 at 300 Hz
300 - 1000 Hz	Flat at 0.75
1000 - 2000 Hz	Beginning at 0.36 decreasing -6 dB/Octave to 0.09 at 2000 Hz
	(Overall = 28.1 G RMS)

The actual control input response levels shall be plotted from 50 to 2000 Hz as G^2/Hz versus frequency and the overall G RMS at start, 30 min, 90 min and 180 min into the test shall be recorded.

4.6.4.2.3 Gunfire Vibration:

4.6.4.2.3.1 Sunusoidal Vibration:

4.6.4.2.3.1.1 Resonance Survey: The data obtained in 4.6.4.2.2.1.1 shall be used to the extent applicable to conduct gunfire vibration testing.

4.6.4.2.3.1.2 Frequency Cycling and Resonance Dwell: Utilizing any resonance frequencies encountered in 4.6.4.2.2.1.1 above, resonance dwell times and cycling times in minutes on each orthogonal axis shall be per Table 10. Double amplitudes or accelerations shall be in accordance with Table 11.

Logarithmic cycling time from 50-500-50 Hz shall be a minimum of 7.5 min. The actual control input and response accelerations for one partial sweep from 50 to 500 Hz shall be plotted and selection of equipment resonance from 4.6.4.2.2.1.1 shall be confirmed. The fixed narrow band dwells shall be performed by sweeping the frequency about ±5% of the specified center frequency. For example, the 100 Hz dwell shall be performed from 95 to 105 Hz. The sweep rate shall be approximately the same as that used for the sweep testing in the same frequency range.

TABLE 10 - Vibration Test Times (Gunfire)

Number of resonance	0	1	2	3
Sweep time minimum (minutes)	30.0	22.5	15.0	7.5
Resonance dwell time minimum (minutes)	---	7.5	15.0	22.5
Fixed dwell time minimum (minutes) at the following center frequencies:				
F_D = 67 Hz	7.5	7.5	7.5	7.5
100 Hz	7.5	7.5	7.5	7.5
135 Hz	7.5	7.5	7.5	7.5
200 Hz	15.0	15.0	15.0	15.0
267 Hz	7.5	7.5	7.5	7.5
300 Hz	7.5	7.5	7.5	7.5
335 Hz	7.5	7.5	7.5	7.5
400 Hz	15.0	15.0	15.0	15.0
467 Hz	7.5	7.5	7.5	7.5
500 Hz	7.5	7.5	7.5	7.5
Total time minimum (minutes) each axis	120.0	120.0	120.0	120.0

TABLE 11 - Vibration Levels (Gunfire)

Frequency	Amplitude or Acceleration Level
50 - 81 Hz	0.036 in double amplitude minimum
81 - 210 Hz	±12.0 G
210 - 297 Hz	0.00532 in double amplitude minimum
297 - 500 Hz	±24.0 G

4.6.4.2.3.1.3 Selection of Resonance Dwells Bordering Fixed Dwells: When equipment resonance occurs within ±5% of a fixed dwell frequency, the fixed dwell period shall be omitted and only the resonance dwell performed. The omitted fixed dwell time shall then be added to the sweep time. Retuning shall be performed as necessary to maximize response at each equipment resonance.

4.6.4.2.3.2 Random Vibration: Prior to the test on each of the three orthogonal axes, the test fixture with specimens shall be equalized to provide conformance with the vibration levels below:

The test fixture with specimens shall be subjected to a minimum of 30 min on each axis of vibration testing utilizing the acceleration levels of Table 12.

TABLE 12 - Vibration Levels (Random)

Frequency	Acceleration Power Spectral Density G^2/Hz
500 - 1000 Hz	2.9
1000 - 2000 Hz	Decreasing -9.0 dB/Octave
	(Overall = 50.4 G RMS)

The actual control input and response levels from 500 to 2000 Hz shall be plotted as G^2/Hz versus frequency and overall G RMS at start and end of test shall be recorded.