AEROSPACE RECOMMENDED PRACTICE

Society of Automotive Engineers, Inc.
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FLEXURE TESTING OF HYDRAULIC TUBING JOINTS AND FITTINGS

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1. SCOPE

This recommended practice establishes flexure test procedures to determine and classify the fatigue strengths of reconnectable or permanent hydraulic tube joints.

The procedure is intended for conducting flexure tests of fittings and joints for hydraulic tubing materials such as AM 350, 21Cr-6Ni-9Mn steel, or 3Al-2.5V titanium.

A mean stress is applied by holding system pressure in the specimens and flexing in a rotary or planar bending test machine.

2. APPLICABLE DOCUMENTS

AMS 5561	Steel Tubing, Seamless or Welded, Corrosion Resistant 21Cr-6Ni-9Mn, High Pressure Hydraulic
MIL-H-5606	Hydraulic Fluid, Petroleum Base, Aircraft and Ordnance
MIL-T-6845	Tubing, Steel, Corrosion Resistant, (304) Aerospace Hydraulic System, 1/8 Hard Condition
MIL-F-18280	Fittings, Flareless Tube, Fluid Connection
ARP 1258	Qualification of Hydraulic Tube Joints to Specified Flexure Fatigue Requirements
AM 350	Corrosion Resistant Steel Tubing—Company specifications available
3Al-2.5V	Titanium Tubing—Company specifications available

3. REQUIREMENTS

3.1 Flexure Test Device: The test device should be capable of testing in-line or bulkhead union test specimens and other configurations such as elbows and tees. The rotary flexure test device should be similar to that shown in Figure 1. Each rotary flexure test device should be capable of testing one specimen, but several specimens may be tested in parallel at one time.

The device should be capable of maintaining constant pressures of up to 5000 psi (34.47 M Pa) in the test specimen. The hydraulic fluid may be a system fluid such as MIL-H-5606 or the phosphate ester fluids used in commercial jet airplanes. A typical pressurization and automatic shutdown system is shown in Figure 2. The shutdown should be automatic in the event of failure or pressure drop. The device should be capable of testing at controlled constant temperature, if specified by the procuring agency. The tailstock of the test device should be designed to permit alignment during initial installation and specimen mounting, and to serve as a pressure manifold. The rotating headstock should have a low-friction, self-aligning bearing and should be designed to permit total deflections of up to one inch, and a constant rotational frequency within the range of 1500 to 3600 rpm (i.e. 1500 to 8400 cycles per minute for planar flexure). The base should be of rigid construction. Design suggestions are shown in Section 6.

3.2 Flexural Test Specimen: The test specimen should consist of an adapter fitting (headstock end), a section of straight tubing, and a test fitting at the tailstock end. Typical test specimens are shown in Figure 3. The tubing shall be of a size and wall thickness as specified by the user or procuring agency.

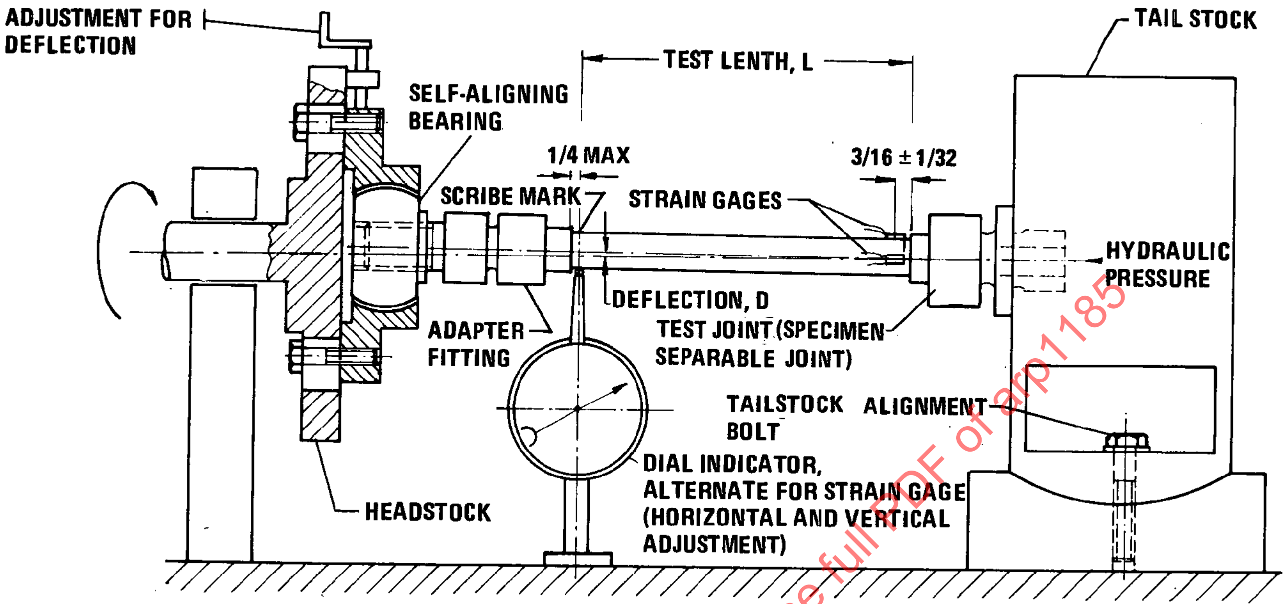


FIGURE 1 - ROTARY FLEXURE TEST SCHEMATIC

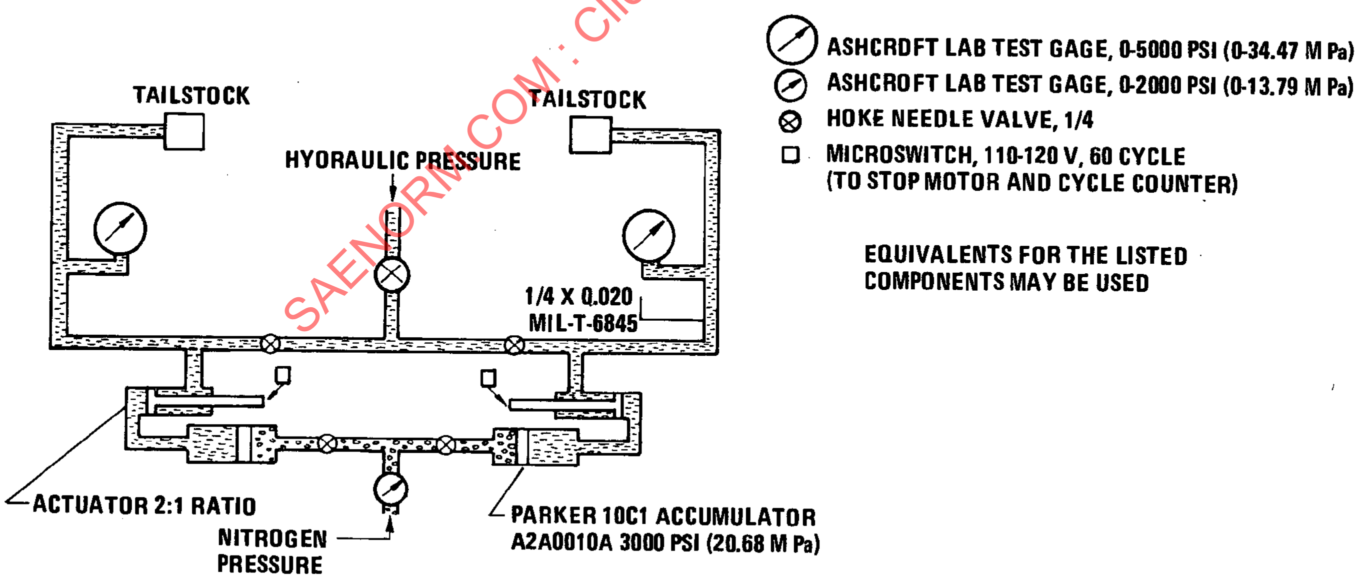


FIGURE 2 - ROTARY FLEXURE TEST HYDRAULIC SCHEMATIC

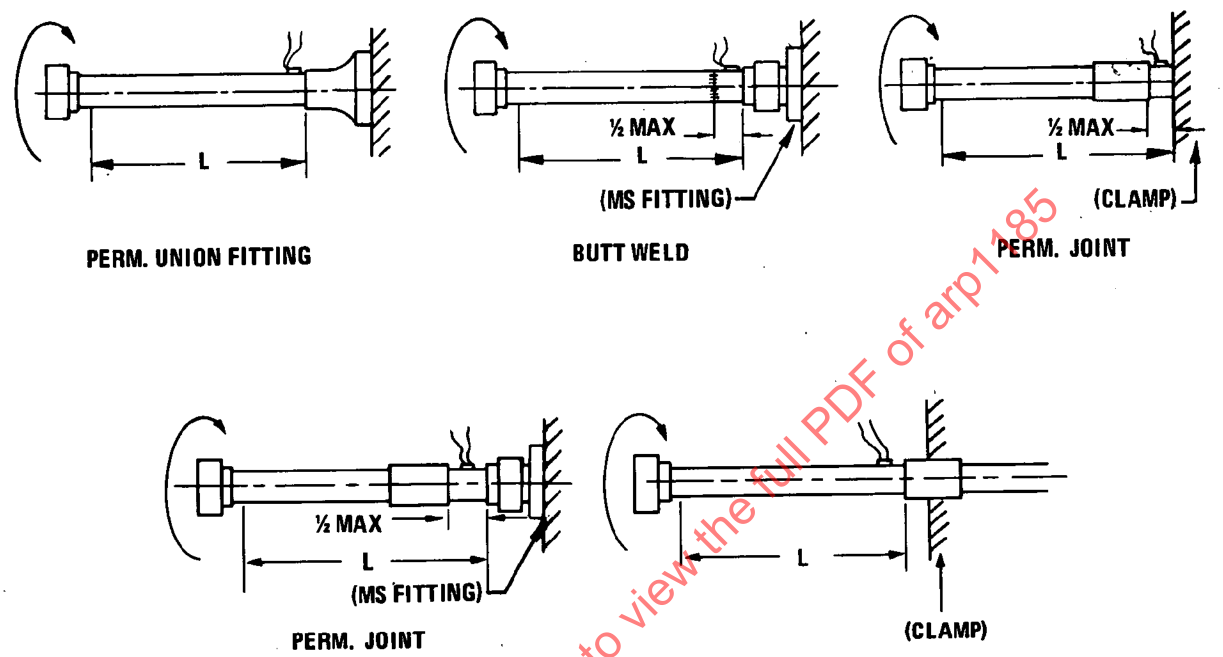


FIGURE 3 - ALTERNATE SPECIMEN MOUNTING FOR PERMANENT JOINTS

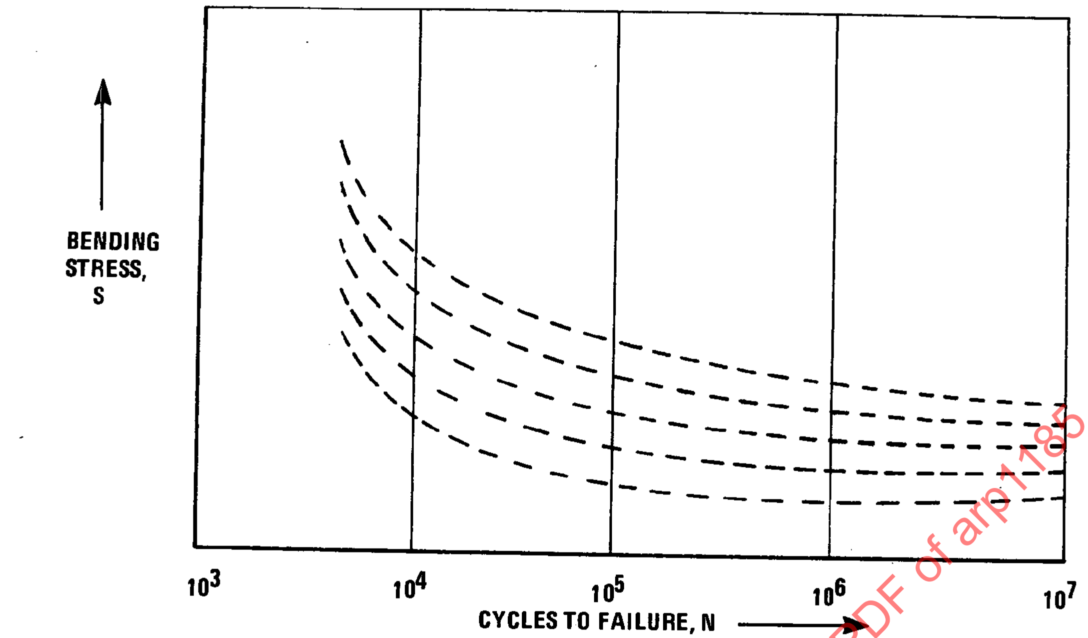


FIGURE 4 - S/N CURVES FOR CHARACTERIZING VARIOUS TYPES OF TUBING OR FITTING JOINTS

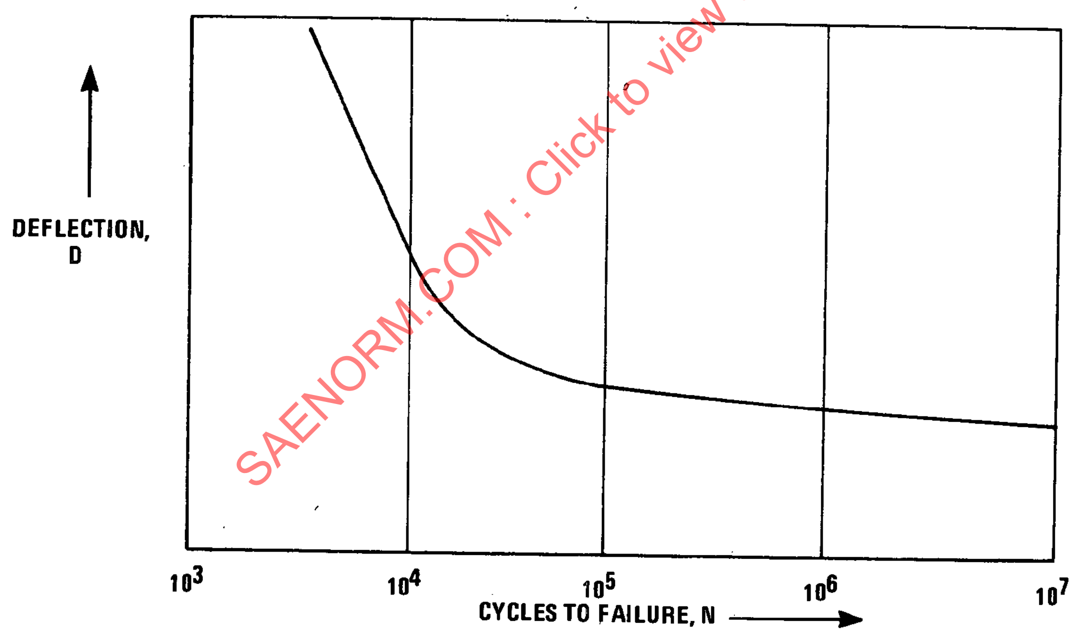


FIGURE 5 - D/N CURVE, DEFLECTION/FATIGUE DETERMINATION

Note: The correlation between the strain gage reading and deflection may vary for different fitting designs. For example, a flareless fitting will sh ow some movement in the fitting, whereas a weld joint will be rigid. Also, a significant difference is noted if the S/N and D/N curves are compared for different tubing such as titanium and CRES. Figures 4 and 5 will be revised to reflect actual data when such data become available.

3.3 Specimen Length and Deflection Requirements:

3.3.1 Specimen Length: The length "L" of the specimens for rotary flexure testing shall be per Table I and measured as shown in Figures 1 or 3, depending on the fitting design.

TABLE 1.- TEST SPECIMEN LENGTH

TUBE SIZE	-4	-5	-6	-8	-10	-12	-16	-20	-24
LENGTH "L" (INCHES)	6	7	7.5	9	10	11	12	14	15
LENGTH "L" (MM)	152.4	177.8	190.5	228.6	254	279.4	304.8	355.6	381

3.3.2 Stress Determination: The desired strain or bending stress level for each set of specimens is induced by deflection of the specimen in the headstock. The bending stress levels for the various deflection settings and combined stresses due to bending and pressure should be determined using strain gages and procedures as outlined in Section 4. Strain gages should always be used unless continual use of the same specimens and equipment makes settings by dial indicator acceptable. Such settings by dial indicator, however, must be established in prior testing by the use of strain gages. Strain gages should be used whenever new test equipment is used or new tubing materials or tubing walls tested.

3.3.3 Deflection: The specimen deflections required to induce the stress levels indicated in 4.2, or as specified in ARP 1258, are measured by dial indicator at the length "L" as shown in Figure 1 or 3. Established deflection settings per Table I and ARP 1258 may be used in lieu of stress determination by strain gage whenever qualification tests are being conducted, or when deflection plotting is of particular interest, for example, to compare steel and titanium tubing.

3.4 Method of Classification of Fittings According to S/N Flexure Performance: Fitting/tubing combinations should be classified by the characteristic curves as shown in Figure 4, above which all S/N failure data points lie. Characteristic curves should be established per 4.2, showing cycles to failure for various bending stress levels.

3.5 Method of Determining Deflection/Fatigue Strength: Cycles to failure should be plotted as shown in Figure 5, showing cycles to failure for various deflection settings (deflection settings may correspond with bending stress levels used per 3.4).

Note: Plotting of deflection in lieu of stress over cycles may be of interest to evaluate rigidity of fittings or compare the flexibility of different tubing materials such as corrosion-resistant steel and titanium.

4. PROCEDURE

4.1 Preparation for Test:

4.1.1 Instrumentation, Strain Gages: Strain gages should be mounted on each test specimen. The strain gage type and location should be as follows:

Types – For tube sizes through -10: 1/8 inch gage
For tube sizes -12 and above: 1/4 inch gage

Location – In rotary flexure the gages should be mounted per Figure 1, 90° apart. In planar flexure the gages should be mounted in the plane of maximum strain, and, as a minimum, one gage per specimen.

Note: Mounting of four gages, in pairs on the X and Y axis, for rotary, and of two gages for planar flexure testings is optional.

Suitable gages are suggested in Section 6.

4.1.2 Rotary Flexure Test Setup, Centering: The exact outside diameter and wall thickness of the test specimen should be measured and recorded before the test. It is also recommended to check straightness, and if not straight, to reject or at least to mark the specimen in the plane where the tube end is not aligned.

The tube assembly should be installed into the tailstock and the separable fittings hand tightened to permit subsequent adjustments. The setup procedure is detailed as follows:

- Free-state microstrain readings should be measured and recorded.
- The self-aligning bearing at the headstock end should be roughly centered and the adapter inserted. The tailstock end should then be carefully tightened so as to avoid moving the test specimen out of line.
- The symmetry of the specimen should be maintained during the tightening procedure with the assistance of one, preferably two, dial indicators positioned on the driven end of the tube. After tightening the adjustment bolts in the centered position, the symmetry must be checked in the horizontal and vertical positions. While turning the headstock by hand, each dial indicator should indicate less than ±0.003 inch (0.076 mm) nonsymmetrical deflection. For strain gaged specimens the microstrain reading should deviate no more than ±20 microstrain from the free state microstrain reading referred to above.
  For easy checking the headstock shaft may be moved back and forth in its bearing. The shaft will move freely for properly aligned specimens.

4.1.3 Flexure Deflection Measurement: The deflection setting is measured by dial indicator as shown in Figure 1 and Table I.

4.1.4 Operating Pressure: The static operating pressure is introduced after the deflection settings are completed by the strain gage or dial indicator methods described above.

4.2 S/N Testing:

4.2.1 Four sets of two specimens (specimen pairs) in each size should be subjected to flexure testing and the test results plotted on a semi-log plot, over a grid of S/N characteristic curves, as shown in Figure 4.

4.2.2 For high-strength tubing (defined here as having an ultimate tensile strength over 100,000 psi or 689.4 M Pa), a bending stress of 35,000 psi (241.29 M Pa) should be applied to the first set of specimens.

For low-strength tubing (aluminum) a bending stress of 20,000 psi (137.88 M Pa) should be applied to the first set of test specimens.

4.2.3 If the failure point for the first set lies between 5000 and 50,000 cycles, the bending stress should be reduced by approximately 10,000 psi (68.9 M Pa) for the second test set.

4.2.4 If the failure point for the second set lies between 200,000 and 1 million cycles, the bending stress should be lowered by approximately 2000 psi (13.79 M Pa) for the third set.

4.2.5 After two sets of data points are plotted, an examination of the data will indicate the probable stress level for test sets number three and four. These levels should be selected to complete the S/N curve form, with one test set completing or exceeding 10 million flexure cycles. At least three sets should fail at less than 10 million cycles. In some cases, additional test sets may be required to obtain the required data points, i. e., one set exceeding 10 million and three sets to fail under 10 million cycles.

Note: After a failure, deflection and B-nut torque should be checked and recorded.

4.3 Deflection/Fatigue Testing: The same basic procedure should be followed as outlined under 4.2 above, except that the deflection settings are plotted over cycles to failure, as shown in Figure 5.

5. BACKGROUND AND PHILOSOPHY OF FLEXURE TESTING

5.1 Background: The requirement for flexure testing is based on MIL-F-18280, which originally specified comparative flexure test of the MS flareless fitting and the AN flared fitting. This flexure test required that the flareless fitting perform as well as or better than the flared fitting. It specified deflection settings at which flared fittings failed at no less than 500,000 cycles, and subsequent testing of the flareless fitting to the same deflection.

With the A revision to MIL-F-18280 this requirement was altered to specify a bending stress level of 40,000 psi (274.76 M Pa) for tube sizes -3 through -8, 25,000 psi (172.35 M Pa) for size -10, and 20,000 psi (137.88 M Pa) for size -12. With the B revision to MIL-F-18280 a combined stress level of 35,000 psi (241.29 M Pa) was specified for steel fittings on all sizes of 3000 psi (20.682 M Pa) MIL-T-6845 tubing and 15,000 psi (103.41 M Pa) for aluminum fittings.

ARP 1258 describes how fatigue test data generated by this ARP may be used as a basis for qualification approval.

5.2 S/N Flexure Test Philosophy: In the interest of evaluating the component parts of fluid power transmission circuits in a manner that permits a quantitative determination of tubing and joint fatigue life over the full spectrum of possible bending stresses, it is desirable to generate classical S/N fatigue data during the course of a qualification effort. The S/N data so generated can then serve as a baseline against which candidate tube joints can be rated in future design evaluations.

The S/N validation method verifies the performance of the fitting at both high and low stresses. There are numerous areas in a high-performance plumbing system where a particular fitting/joint will be subjected to a discrete (but small) number of high-stress cycles. A typical case might be fittings associated with the landing gear retract-extension system. In this case the system is quiescent for most of the aircraft's operational life but will go through a stress cycle each time the gear is extended or retracted. For a typical aircraft, this would be on the order of 20,000 cycles for military aircraft and up to 100,000 cycles for some commercial aircraft. The tube joint could be operated at 150% of the endurance limit stress for this discrete number of cycles and survive for the life of the aircraft. In many instances, significant weight savings can be achieved if this characteristic has been verified through qualification and thus can be used to advantage.

The present validation methods (MIL-F-18280C) fail to differentiate between fitting joints barely able to qualify and fitting joints whose deflection endurance limit is significantly greater.

It is, therefore, desirable to classify fittings in terms of bending endurance according to "S/N Characteristic Curve Numbers." The fitting can then be classified based on the highest curve above which all failure points lie.

6. EQUIPMENT

6.1 Suggested Test Fixtures: Photographs of a suggested fixture are shown in Figures 6 through 9. Detailed drawings are also provided.

Note: The test fixture described by the detail drawings is suitable for high-pressure line sizes up to 5/8 inch maximum. Larger line sizes require heavier equipment and improved adjustability as shown in Figure 7.

6.2 Strain Gages: The following strain gages, or equivalent, are recommended. For tube sizes -4 through -10: Baldwin Lima Hamilton Electronics, part number FAE 12-12S6-ES, nominal gage factor 210, 120 ohms. For tube sizes -12 and larger: Baldwin Lima Hamilton Electronics, part number DLB-PT-354A, nominal gage factor 4.0, 350 ohms.

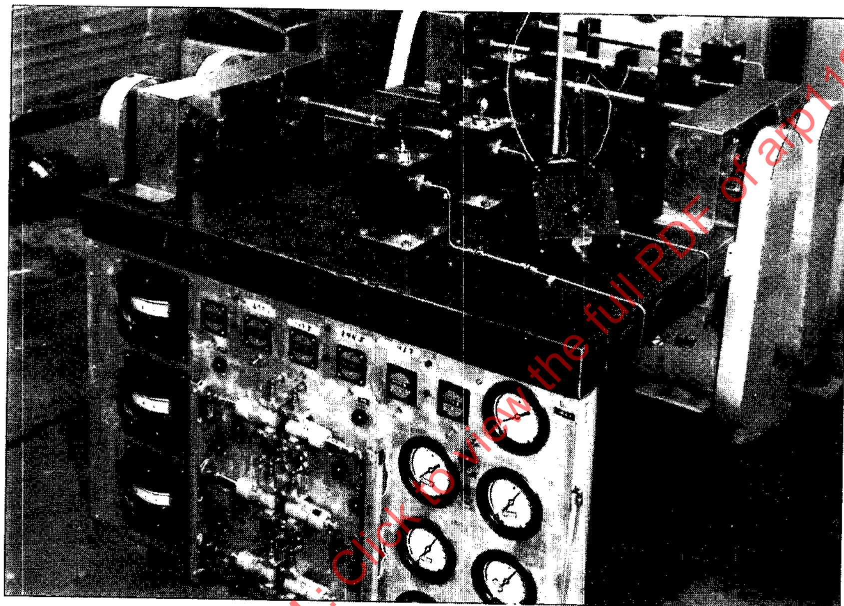


FIGURE 6 - FLEXURE TEST SETUP FOR TUBE SIZES UP TO 5/8 INCH (15.875 MM)

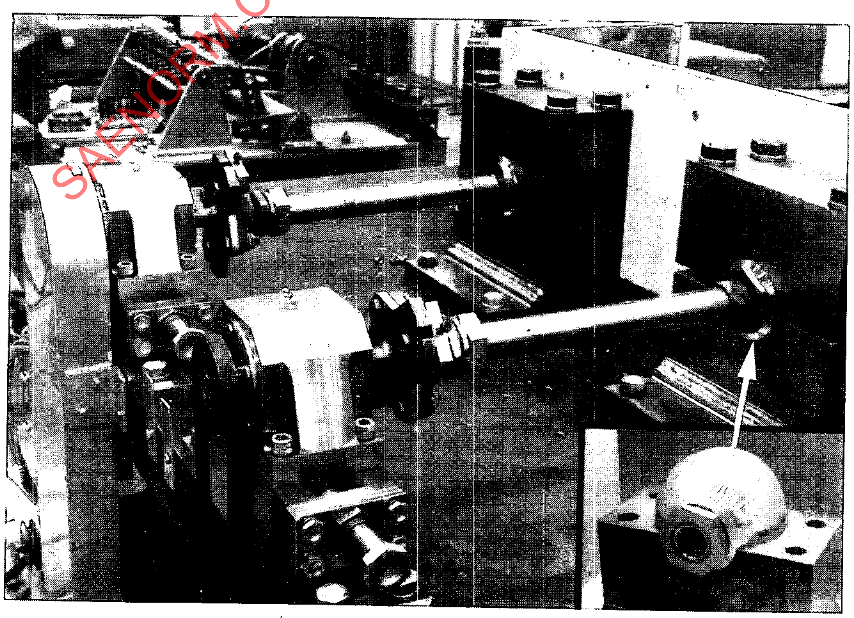


FIGURE 7 - HEAVY-DUTY FLEXURE TEST DEVICE, TUBE SIZES 3/4 INCH (19.05 MM) AND OVER

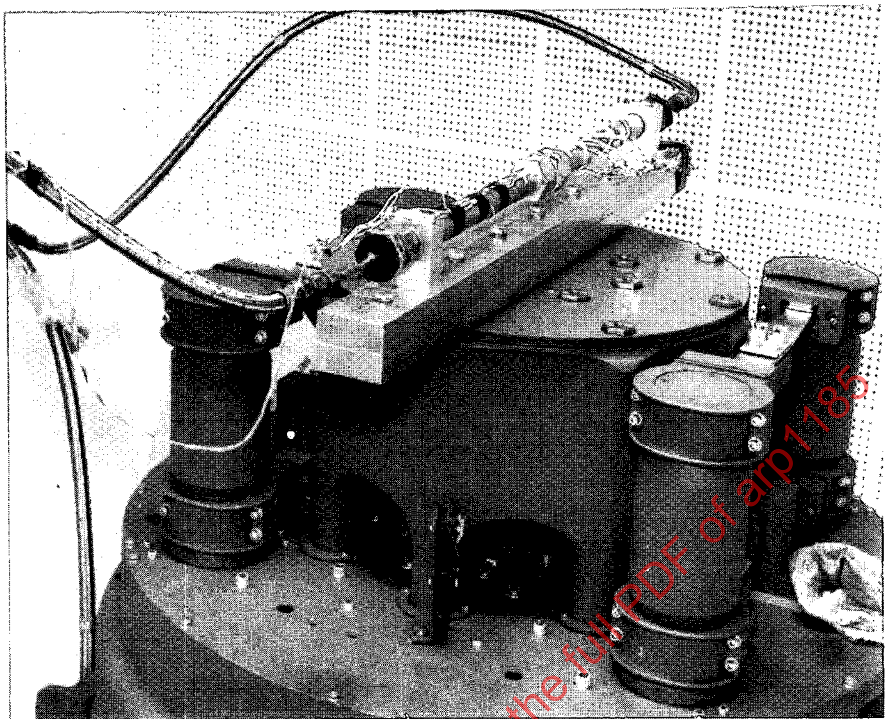


FIGURE 8 - PLANAR FLEXURE TEST. SPECIMEN MOUNTED ON SHAKER TABLE

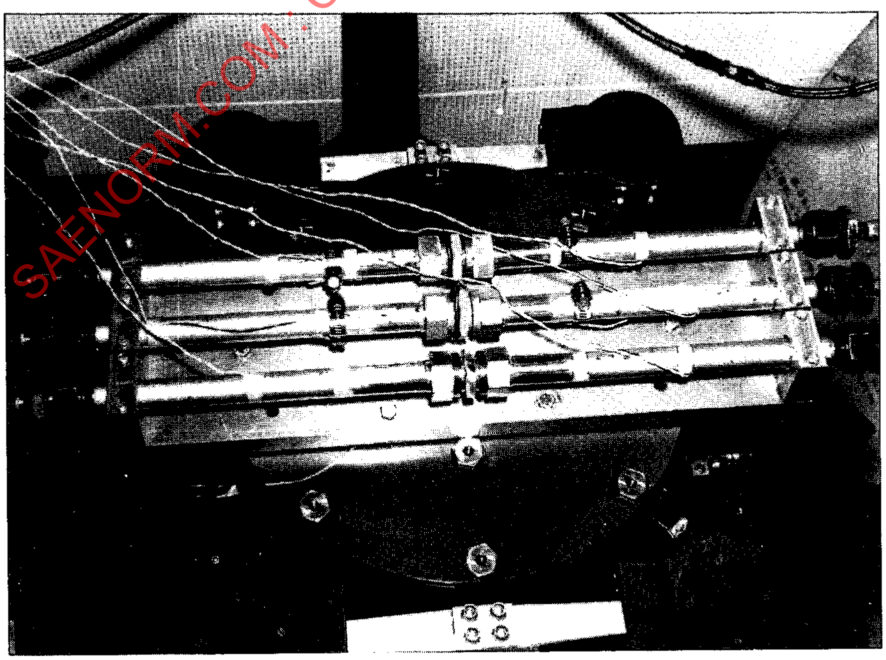
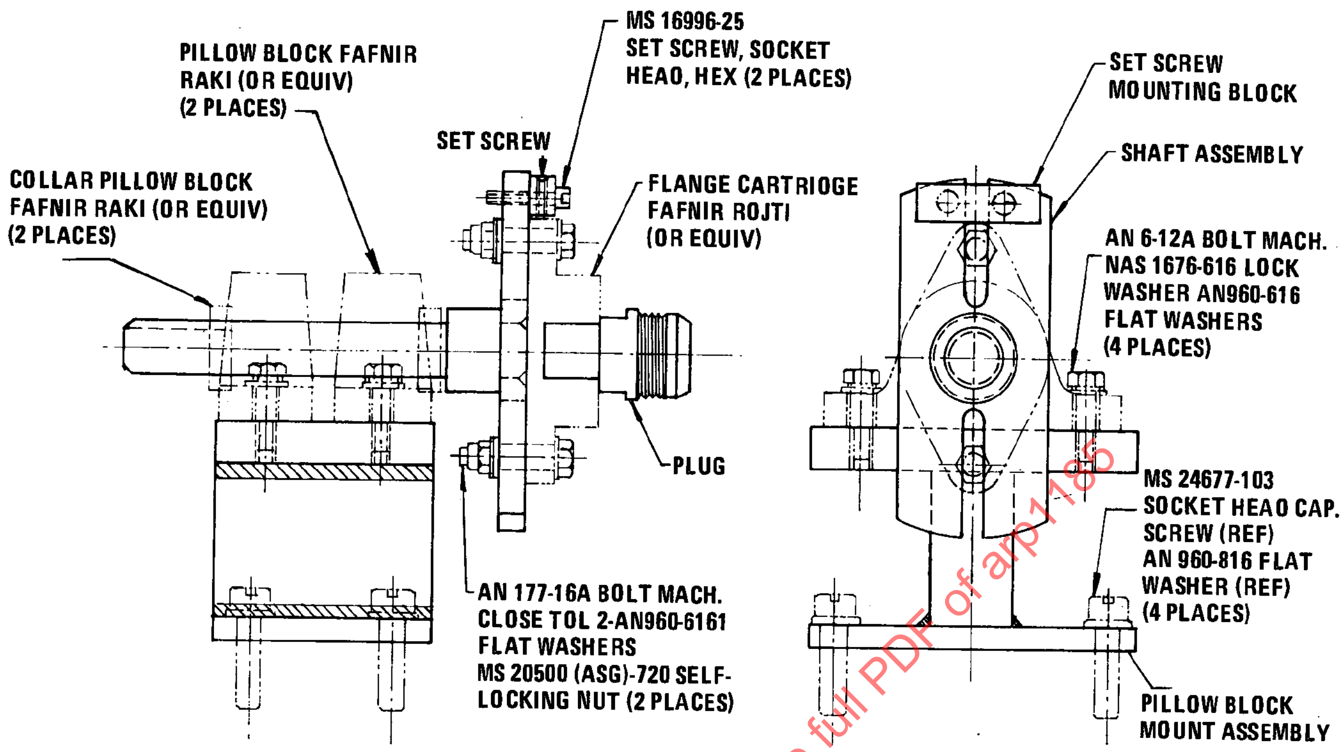
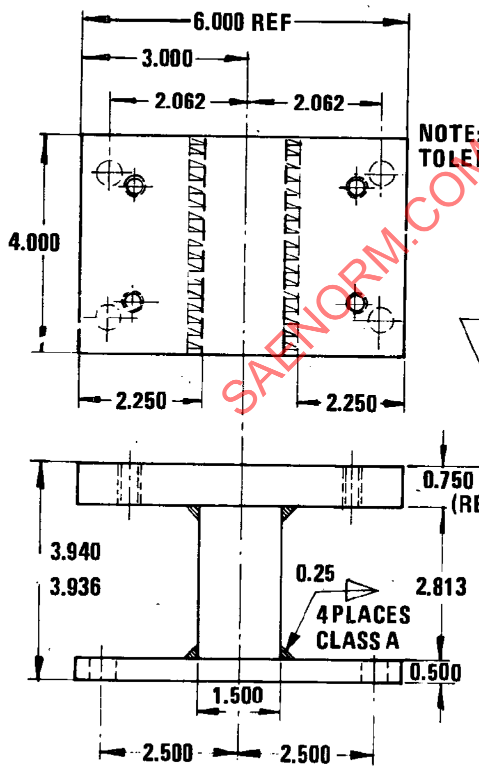


FIGURE 9 - PLANAR FLEXURE TESTING OF THREE SPECIMENS

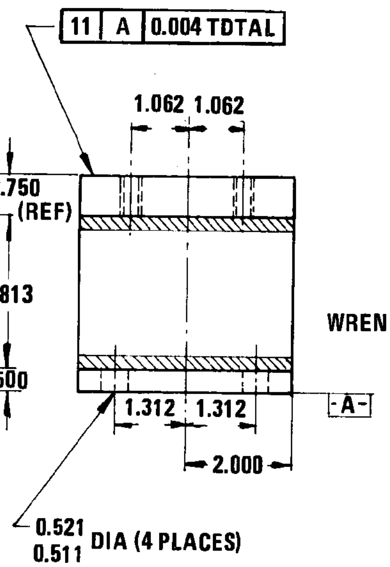


HEADSTOCK ASSEMBLY

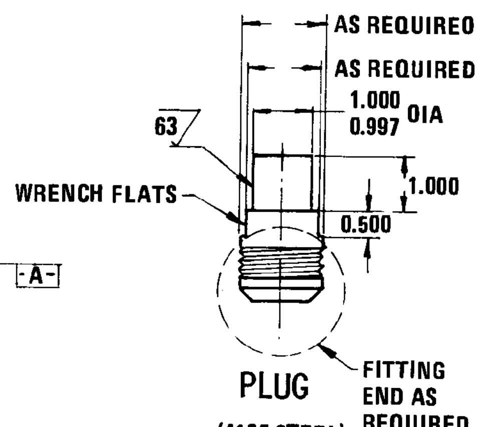
NOTE: DIMENSIONS IN INCHES
TOLERANCES: 0.030 UNLESS OTHERWISE NOTED
FINISH: 125√ UNLESS OTHERWISE NOTED



PILLOW BLOCK
(4130 STEEL)



MOUNT ASSEMBLY



PLUG
(4130 STEEL)