SAE Aerospace An SAE International Group	AEROSPACE RECOMMENDED PRACTICE	SAE ARP1185	REV. B
		Issued 1978-12 Revised 1993-09 Reaffirmed 2013-01 Superseding ARP1185A	

Flexure Testing of Hydraulic Tubing Joints and Fittings

RATIONALE

ARP1185B has been reaffirmed to comply with the SAE five-year review policy.

1. SCOPE:

This SAE Aerospace Recommended Practice (ARP) 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 AMS 5561 (21Cr-6Ni-9Mn) steel or AMS 4944 (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:

The following publications form a part of this specification to the extent specified herein. The latest issue of all SAE Technical Reports shall apply.

2.1 SAE Publications:

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

AMS 4944	Titanium Alloy Tubing Seamless, Hydraulic 3Al-2.5V, Cold Worked, Stress Relieved
AMS 5561	Steel Tubing, Seamless or Welded, Corrosion Resistant 21Cr-6Ni-9Mn, High Pressure Hydraulic
ARP1258	Qualification of Hydraulic Tube Joints to Specified Flexure Fatigue Requirements

2.2 Military Publications:

Available from Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

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
MIL-H-83282	Hydraulic Fluid, Fire Resistant Synthetic Hydrocarbon Base, Aircraft

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 may be similar to that shown in Figure 1. However, optional equipment designs may be used. 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 8000 psi in the test specimen. The hydraulic fluid may be a system fluid such as MIL-H-5606, MIL-H-83282 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 1 in and a constant rotational frequency within the range of 1500 to 3600 rpm. Planar flexure machines should be capable of testing at 1500 to 8400 cpm. 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. See also ARP1258 for test specimens employing elbows and tees.

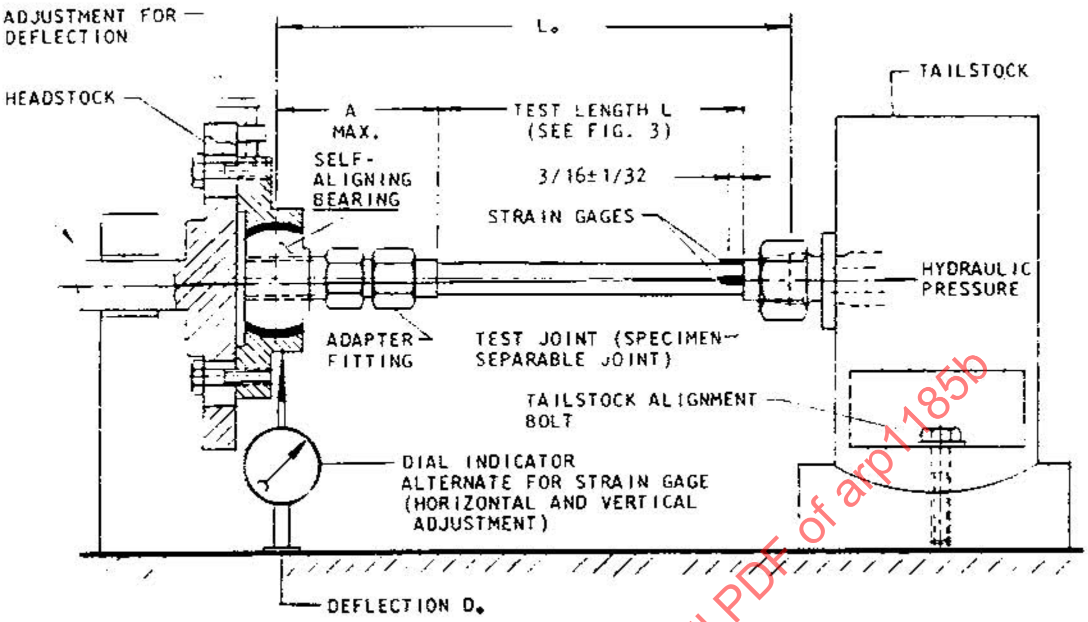


FIGURE 1 - Rotary Flexure Test Schematic

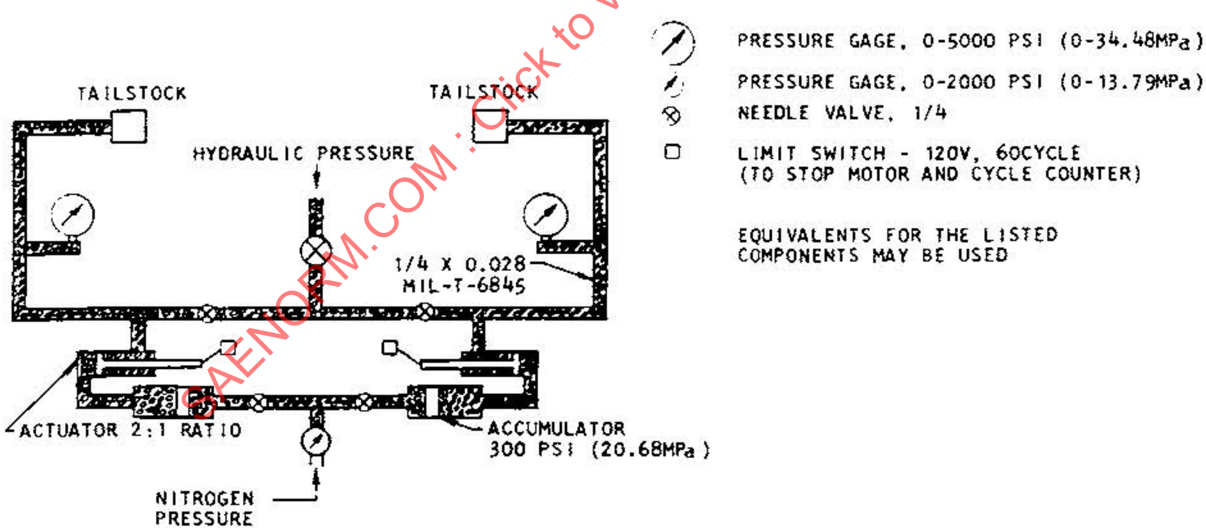


FIGURE 2 - Rotary Flexure Test Hydraulic Schematic

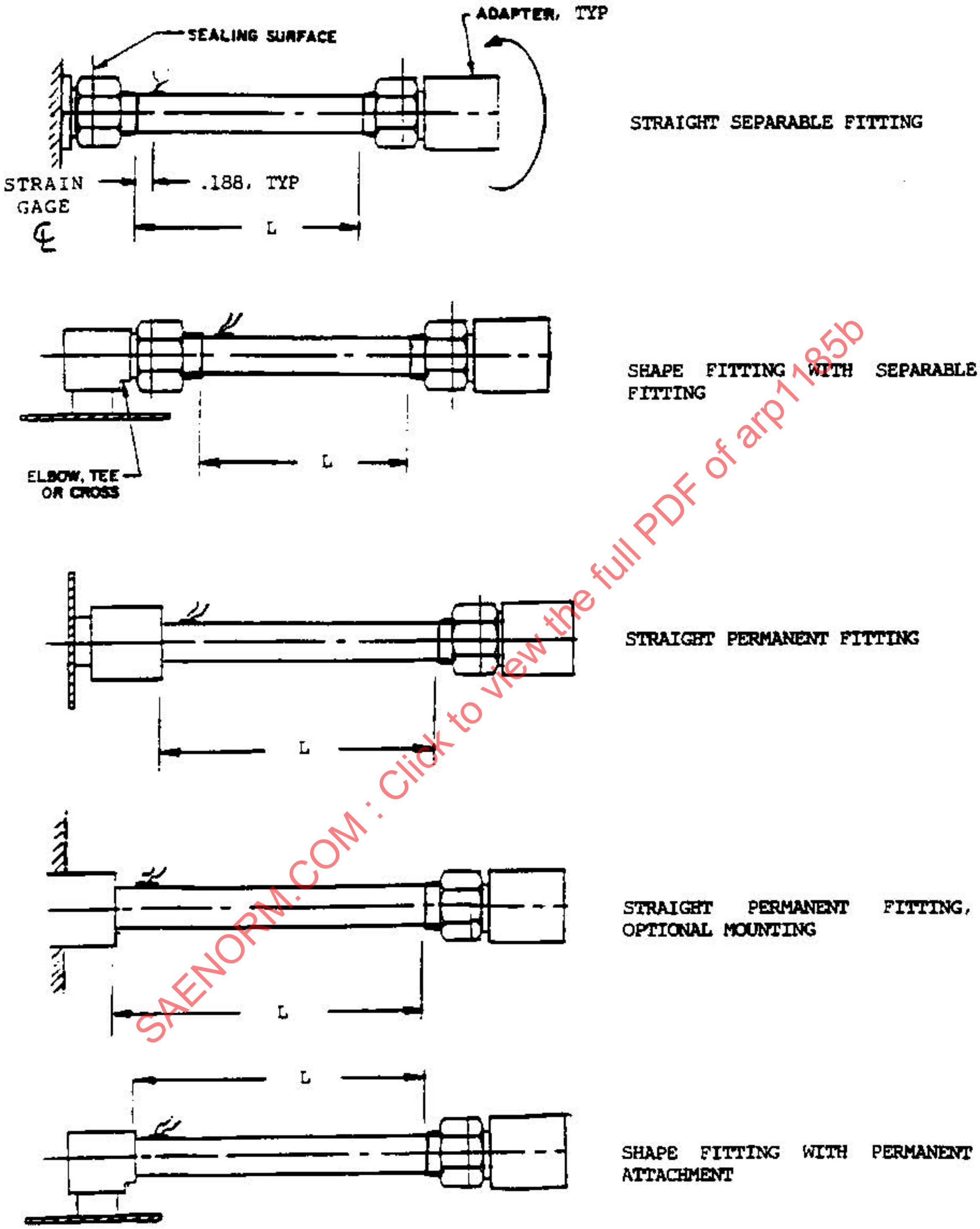


FIGURE 3 - Specimen Configuration

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 1 and measured as shown in Figures 1 or 3, depending on the fitting design.

TABLE 1 - Test Specimen Length

Tube Size	Length, Maximum "A" (Inches)	Length, Maximum "L" (Inches)	Tube Size	Length, Maximum "A" Inches	Length, Maximum "L" (Inches)
-3	1.69	5	-11	3.62	11
-4	2.91	6	-12	3.62	11.5
-5	1.85	7	-13	3.65	12
-6	2.96	7.5	-14	3.66	12
-7	2.96	9	-15	3.70	12.5
-8	2.96	9	-16	3.71	12.5
-9	3.50	10	-20	4.33	14
-10	3.56	10	-24	4.36	15

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 ARP1258, are measured by dial indicator at the length "L_o" as shown in Figure 1. Established deflection settings per AIR1418 and ARP1258 may be used in lieu of stress determination by strain gage, when done consistant with 3.3.2, 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.

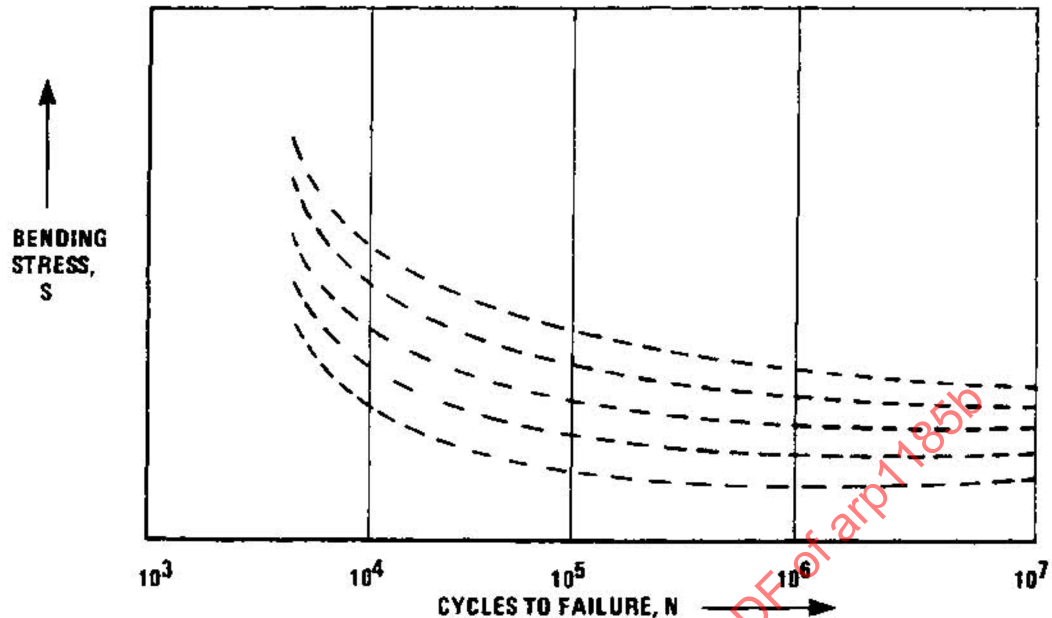


FIGURE 4 - S/N Curves for Characterizing Various Types of Tubing or Fitting Joints

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.

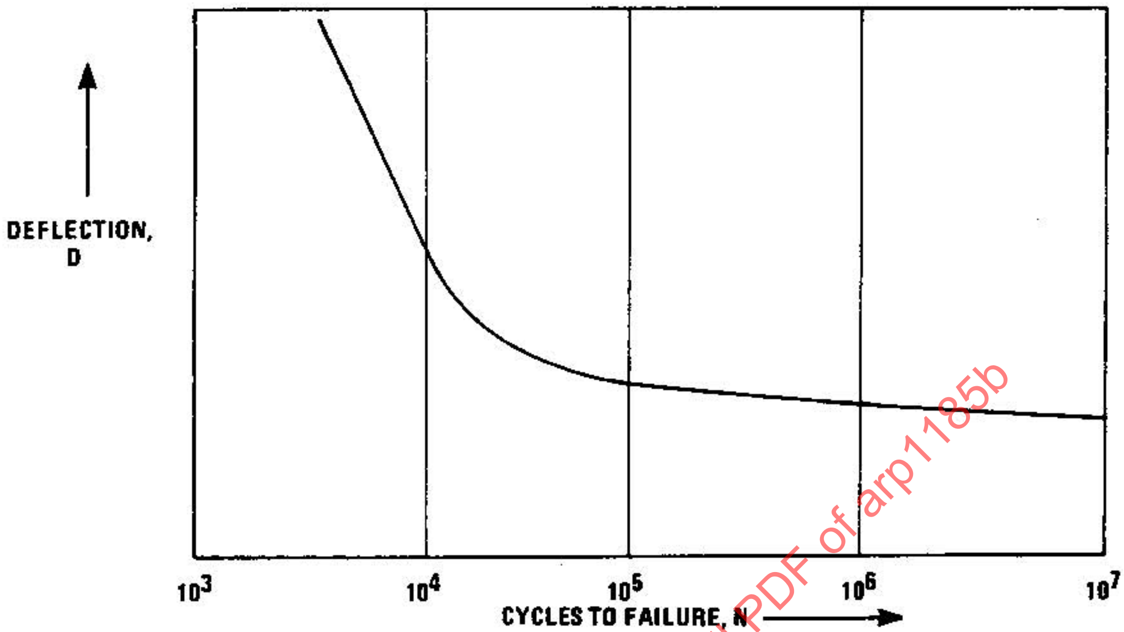
4. PROCEDURE:

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 in Table 2:

TABLE 2 - Type

Tube Size	Grid Width	Grid Length
3/16	.062	.125
1/4 thru 5/8	.125	.125 or .250
11/16 and larger	.188	.250



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.

FIGURE 5 - D/N Curve, Deflection/Fatigue Determination

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

NOTE: Mounting of two gages, 180° apart or mounting of four gages, in pairs on the X and Y axis, for rotary, and two gages for planar flexure testing is optional.

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:

4.1.2.1 Free-State microstrain readings should be measured and recorded.

4.1.2.2 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.

4.1.2.3 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 in 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.

4.1.2.4 For each 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 Stress Measurement: After the specimen is zeroed as described, the headstock should be initially adjusted to produce a strain gage reading about 5% below the required bending stress value. The machine should be briefly turned on and the dynamic reading (i.e., strain gage reading at full test revolutions per minute) recorded. This reading should be within ±10 microstrain of the test specified value. Some readjustment is usually necessary.

4.1.4 Flexure Deflection Measurement: The deflection setting is measured by dial indicator as shown in Figure 1.

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

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), a bending stress of 35 000 psi should be applied to the first set of specimens.

For low-strength tubing (aluminum) a bending stress of 20 000 psi 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 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 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 in 4.2, except that the deflection settings are plotted over cycles to failure, as shown in Figure 5.

4.4 Minimum Endurance Stress Level Method:

When specified, fittings may be qualified per ARP1258 by the minimum stress method. In this procedure, six test specimens of the straight configuration in each size are tested at the required endurance stress. All samples must complete 10 X 10° cycles without failure. Failures attributable to tube defects may be replaced with new samples.

5. FORMULA:

See Figure 1.

5.1 Total Combined Stress (see Equation 1):

$$S = (e_{max})(E) + \frac{P d_i^2}{d_o^2 - d_i^2} \quad \text{(Eq. 1)}$$

where:

S = Maximum apparent total axial stress
e_{max} = Maximum measured axial unit bending strain
E = Modulus of elasticity for the tube material
P = Internal pressure
d_o = Tube outside diameter
d_i = Tube inside diameter

5.2 Deflection (see Equation 2):

The deflection of the flexure test specimen is predictable by the cantilever beam formula.

$$D = \frac{P(Lo)^3}{3EI} \quad \text{(Eq. 2)}$$

where:

Do = Deflection of load point, single amplitude
P = Load, lb
E = Modulus of elasticity of tube
I = Moment of inertia of tube
Lo = Distance from load point to seal face of test fitting - see Figure 1

For plotting deflections, the double amplitude value is used. Per AIR1418, the deflection at length L is required. This deflection can be measured directly by using a dial indicator positioned within 0.25 in maximum of the adaptor fitting (location L, in Figure 1) or can be calculated using Equation 3.

$$D = \frac{DoL^2}{Lo^2} \quad \text{(Eq. 3)}$$

where:

D = Double ampltiude deflection at L
L = Length per Figure 1
Lo = Assembly length to point of measurement
Do = Measured double amplitude deflection at Lo

6. EQUIPMENT:

6.1 Suggested Test Fixtures:

Photographs of suggested fixtures are shown in Figures 6 through 10.

NOTE: The test fixture described by the detail drawings is suitable for high-pressure line sizes up to 0.625 in maximum. Larger line sizes require heavier equipment and improved adjustability as shown in Figure 7.

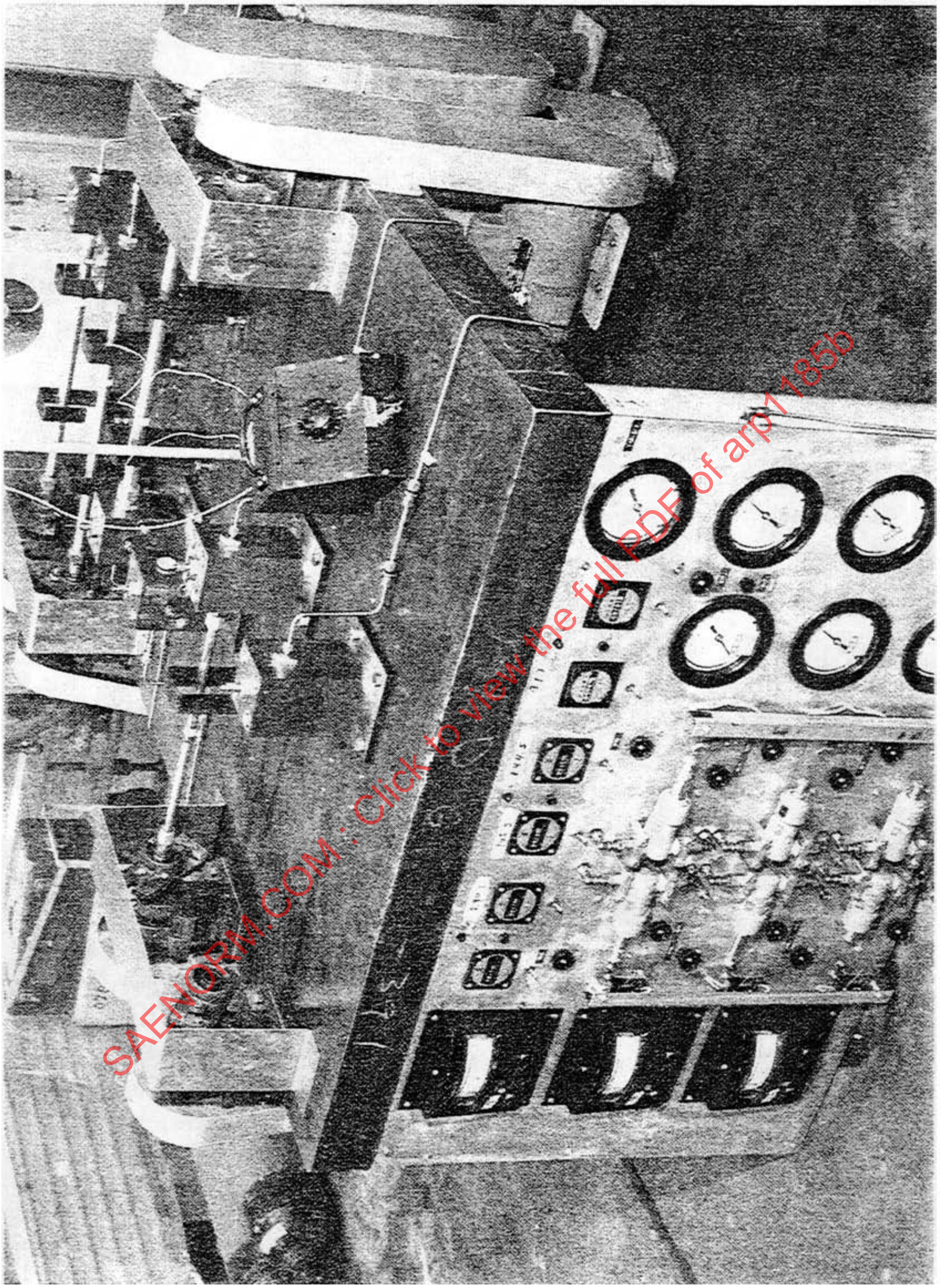


FIGURE 6 - Example of Possible Flexure Stand for Tube Sizes to 0.625 in

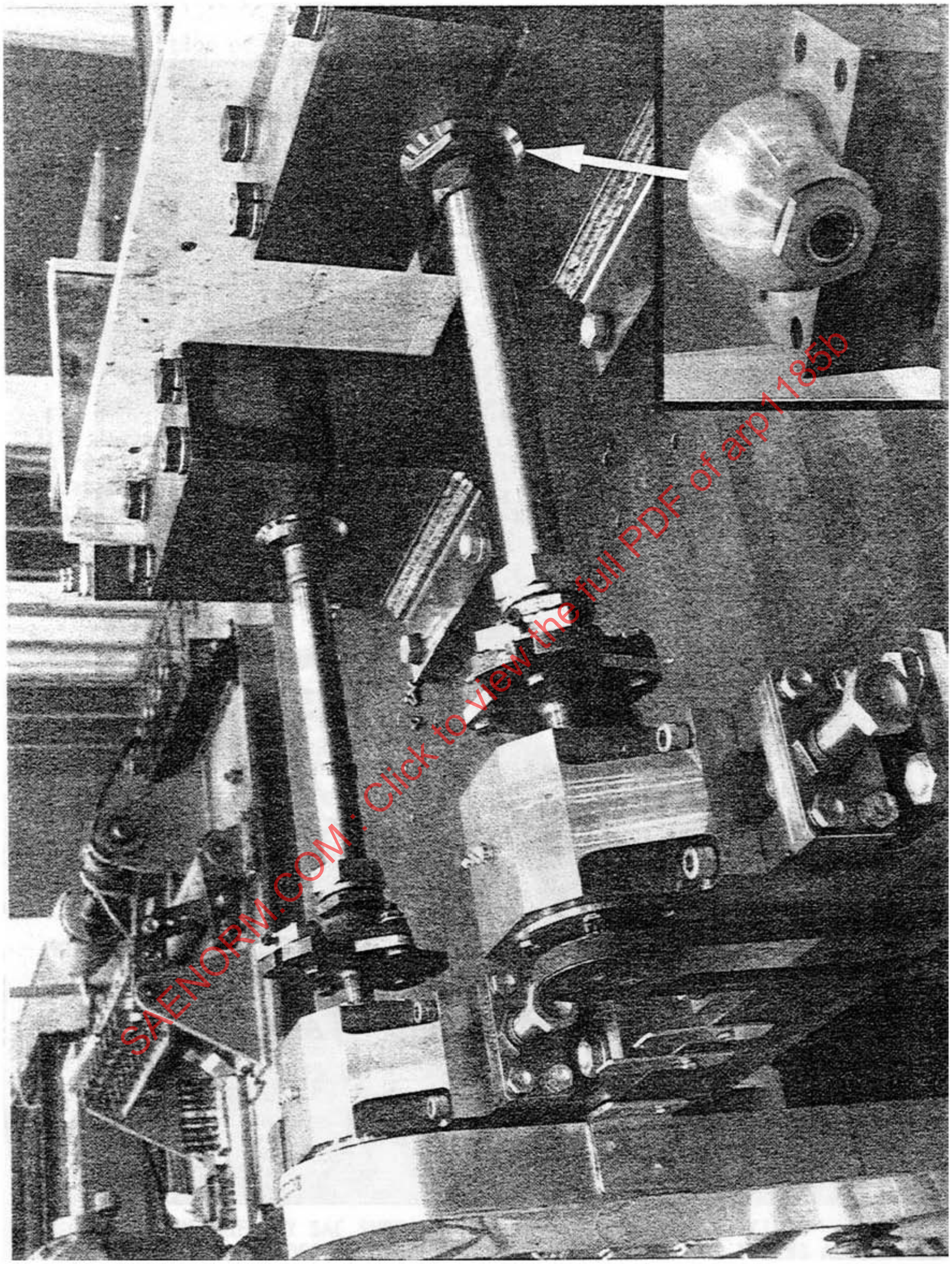


FIGURE 7 - Example of Possible Heavy Duty Machine for Tube Sizes 0.750 in and Larger