SAE Aerospace An SAE International Group	AEROSPACE INFORMATION REPORT	SAE AIR1529	REV. A
		Issued 1978-03 Revised 1989-10 Reaffirmed 2013-01 Superseding AIR1529	

Flexure Testing of Hydraulic Tubing Joints and Fittings by Planar Resonant Vibration (Free-Free Beam)

RATIONALE

AIR1529A has been reaffirmed to comply with the SAE five-year review policy.

1. SCOPE:

1.1 This Aerospace Information Report (AIR) 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 steel, AMS 4944 titanium and MIL-T-7081 aluminum alloy, mounted as free-free resonant beams.

Of particular advantage are the inherent simplicity of test setup, minimum restraint from a test fixture, low power requirements, short test duration, and ease of varying stress level.

1.2 Classification:

1.2.1 Type:

Type I Tests to be conducted with full cyclic bending stress reversal without simultaneous application of internal pressure

Type II Tests to be conducted with full cyclic bending stress reversal with a constant mean stress applied by imposing system pressure during cycling

2. REFERENCES:

2.1 Issues of Documents:

The following documents of the issue in effect on date of invitation for bids or request for proposal form a part of this document to the extent specified herein.

TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada)
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: http://www.sae.org

SAE values your input. To provide feedback on this Technical Report, please visit http://www.sae.org/technical/standards/AIR1529A

2.2 Military Specifications:

MIL-T-7081 Tube, Aluminum Alloy, Seamless, Round, Drawn, 6061, Aircraft Hydraulic Quality

2.3 SAE Publications:

Available from Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096.

AMS 4944 Titanium Alloy Tubing, Seamless, Hydraulic, 3.0Al - 2.5V, Cold Worked, Stress Relieved
AMS 5561 Steel Tubing, Welded and Drawn, Corrosion Resistant, 9.0Mn - 20Cr - 6.5Ni - 0.28N, High Pressure Hydraulic
ARP1185 Flexure Testing of Hydraulic Tubing Joints and Fittings

3. REQUIREMENTS:

3.1 Flexure Test Device:

The test device should be capable of testing in-line or bulkhead union fittings and other configurations such as tees. The device should consist of a vibration generator similar to an MB Calibrator/Exciter system on which the test specimen is mounted in the manner shown in Figures 1 and 2 using a vibration yoke assembly in accordance with Figures 7 and 8. In this configuration the test specimen is caused to vibrate as a free-free beam in its first resonant mode at an amplitude which provides the desired stress level. Until fracture occurs, the resonant frequency remains constant regardless of the stress level selected. Under Type II test conditions, pressure may be applied using a simple hand pump. Each device is capable of testing one specimen.

3.2 Flexure Test Specimen:

The specimen shall consist of a straight length of tubing that mounts a test fitting in a manner which places the center of mass of the entire test specimen at midspan. Type I specimens do not require end fittings (Figure 1). Type II specimens are provided with end fittings to contain the internal pressure (Figure 2).

3.3 Specimen Length and Deflection:

3.3.1 Specimen Length: Type I specimen lengths are given in Figure 1. These will resonate at approximately 150 Hz. Type II specimen lengths and recommended end fittings are given in Figure 2. These will resonate at approximately 100 Hz. Shorter specimens resonating at higher frequencies may be used but present a disadvantage because of relatively less deflection and consequent inherent increase of calibration errors.

3.3.2 Stress Determination: The desired bending stress for each set of specimens shall be induced by deflection during resonant vibration. The bending stress levels corresponding to various amplitudes of deflection can be determined through use of strain gages and the procedures outlined in 4.1.4. Strain gages should always be used to calibrate the stress-deflection of at least one specimen of each new configuration of tube material, type of fitting or line size.

3.3.3 Deflection: The approximate deflection corresponding to 30 000 psi bending stress at midspan for various tube materials is given in Figures 1 and 2. Deflections for other bending stresses are proportionate. The exact deflection for a given stress level on a given specimen configuration is determined during stress-deflection calibration.

3.4 Classification of Fittings:

Fitting and tubing combinations shall be classified according to the S/N flexure performance method specified in ARP1185 paragraph 3.4.

3.5 Deflection/Fatigue Strength:

The deflection/fatigue strength shall be determined by the method specified in ARP1185 paragraph 3.5.

4. PROCEDURE:

4.1 Preparation for Test:

4.1.1 Instrumentation Strain Gages: Two strain gages should be mounted on each side of the test fitting as shown in Figures 1 and 2. The leads may be taped to the test specimen and taken off conveniently at the nodes. It is important to use strain gages of a size that will properly identify maximum bending stress. The following gage sizes are recommended:

a. For tube sizes through -6: 1/8 in gage
b. For tube sizes -8 and -10: 1/8 or 1/4 in gage
c. For tube sizes -12 and larger: 1/4 in gage

Suitable gages are recommended in ARP1185 paragraph 6.2.

4.1.2 Instrumentation Deflection Target: Deflection may be conveniently read on a paper deflection target constructed as shown in Figure 4, attached at the tube end, the location of greatest deflection excursion. The target may be constructed to be read from the side or the end. When the tube is vibrating, retention of vision presents a shadowed triangle, the apex of which is an accurate measure of the excursion double amplitude. Targets may be photographically reproduced in quantity.

4.1.3 Test Setup: The test specimen is mounted, as shown in Figures 1 and 2, in a vibration yoke assembly near one of the two node points; the yoke, in turn, being attached to the armature of the exciter. It is horizontally supported at the other node point by a loop of string attached to a fixed bracket, suspended essentially as a free body with very little mounting restraint in the plane of vibration. The Type II test setup is made flexible by providing several spring-like loops in the connecting pressure line. The two nodes are points of zero amplitude. The yoke assembly is positioned slightly off-node to impart a force input through a small amplitude at low power at resonant frequency. The string at the other node carries no dynamic load, but only its share of the test specimen static weight. The specimen resonates as quietly and regularly as a tuning fork.

4.1.4 Stress-Deflection Calibration: Values of the desired maximum bending stress shall be determined by varying the gain of the vibration input and obtaining corresponding strain gage readings. Simultaneously, as the tube end deflects, the deflection target measures the double amplitude associated with the maximum bending stress. Bending stress deflection data shall be obtained and recorded as shown in Figure 5. The resultant plot is always linear and an appropriate straight line may be faired in from a few plotted points. If the stress-deflection plot is not approximately linear, improper mounting or reading of strain gages must be suspected. Each different configuration of test specimen, size, material or type of connector, requires its own initial stress-deflection calibration. Thereafter, all succeeding similar test specimens may use deflection target data for adjusting maximum bending stress levels. The stress-deflection calibration is always determined without internal pressure.

NOTE: Exercise caution to not overshoot desired stress level during startup as it is easy to do and will seriously affect validity of the results.

4.1.5 Failure of Test Specimen: If a test specimen detunes and thereafter cannot be made to resonate at its original natural frequency, even though leakage due to internal pressure may not be immediately apparent, a change in elastic continuity has occurred, indicating a fracture. The nature and location of the failure may be determined by a convenient method such as air pressure test under water, in the case of nonpressurized tubing. It may be helpful to establish a new resonant frequency and continue cycling for a short time to open the fractures still further.

NOTE: A slight shift in resonant frequency is normal, therefore failure is defined as a 10% reduction in resonant frequency.

4.1.6 Optional Automatic Control: A piezoelectric accelerometer may be utilized in conjunction with a control circuit in order to provide automatic resonant frequency tracking, amplitude control, and automatic shut-down when a failure has occurred. The addition of this equipment will not basically alter the equipment and procedure described above. The schematic of this system is shown in Figure 3.

4.1.6.1 Frequency and Level Control: Regulation of the vibration amplitude is achieved by electronic control circuitry shown in the functional block diagram of Figure 3. The accelerometer signal is amplified by the signal conditioner and sent to the bandpass filter. The filter passband is centered around the tubing first bending mode resonant frequency and provided 90° of phase lag. The filter output is amplified by the multiplier and sent to the shaker electronics. This signal path closes a positive feedback loop on the tube causing divergent oscillations at the first bending mode resonant frequency. If left unattended, the divergent oscillations would increase to destructive levels. To prevent this from happening, an automatic gain control is provided to maintain the oscillations at the desired amplitude. An rms circuit calculates root mean square acceleration. This circuit consists of an analog absolute value circuit and low pass filter. The rms acceleration is compared to the desired amplitude setpoint and fed to the multiplier. If the oscillation amplitude is too high, the multiplier gain is reduced, lowering the loop gain below unity and causing the oscillations to subside until the rms amplitude is equal to the setpoint. Likewise, if the amplitude is too low, the loop gain is automatically increased by the multiplier until the rms amplitude is equal to the setpoint.

4.1.6.2 Automatic Shutdown: An amplitude monitoring function is provided by the window comparator, which detects a specimen failure when the acceleration amplitude is above or below the present value. When the rms amplitude deviates from the setpoint, the window comparator generates a logic signal to shut down the test.

4.1.6.3 Accelerometer Mounting: The accelerometer location shown in Figure 3 is the result of considerable experimentation. A location near the tube center was found to alter the tube mode shape due to the added mass, and the mounting saddle also caused local stiffening of the tube. Both resulted in alteration of the stress distribution and resulted in premature failures. The prescribed location has the advantages of being in an area of low stress and low amplitude, which greatly reduces the mass effect. However, low mass is still an important consideration. Although a clamp-on type mount may be acceptable, a saddle-type bonded to the tube is preferred. Small lightweight piezoelectric accelerometers are readily available. The exciter drive may be placed inboard of the node, as shown in Figures 1 and 2, but the accelerometer connections must then be reversed.

4.2 S/N Testing:

The requirements for S/N testing shall conform to 4.2 of ARP1185. Tube stresses must be kept below the endurance strength of the material to prevent charging a tube failure unjustly to the fitting.

4.3 Deflection/Fatigue Testing:

This testing shall conform to 4.3 of ARP1185.

5. BACKGROUND AND PHILOSOPHY OF S/N TESTING:

For background and S/N flexure test philosophy see Section 5 of ARP1185.

6. EQUIPMENT:

6.1 Vibration Yoke Assemblies:

Detail drawing of suggested yoke assemblies are given in Figures 7 and 8. A uniform design should be agreed upon by all users, although an equivalent yoke design that does not affect test results would be acceptable. To permit maximum freedom, the yoke is approximately knife-edged where it grips the tube. There are two sets of matched rate springs that are lightly loaded and seldom need replacing. A simplified vibration yoke known to have been used successfully consists of lightly clamping over an O-ring that fits over the tube o.d.

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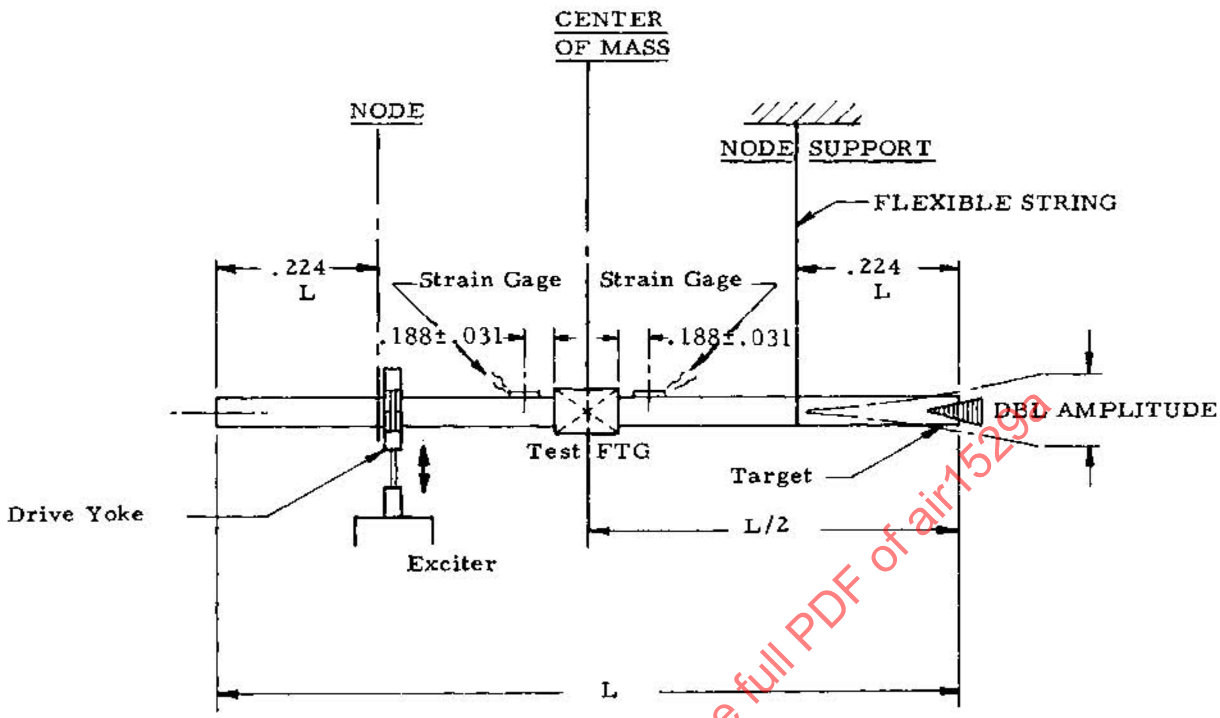


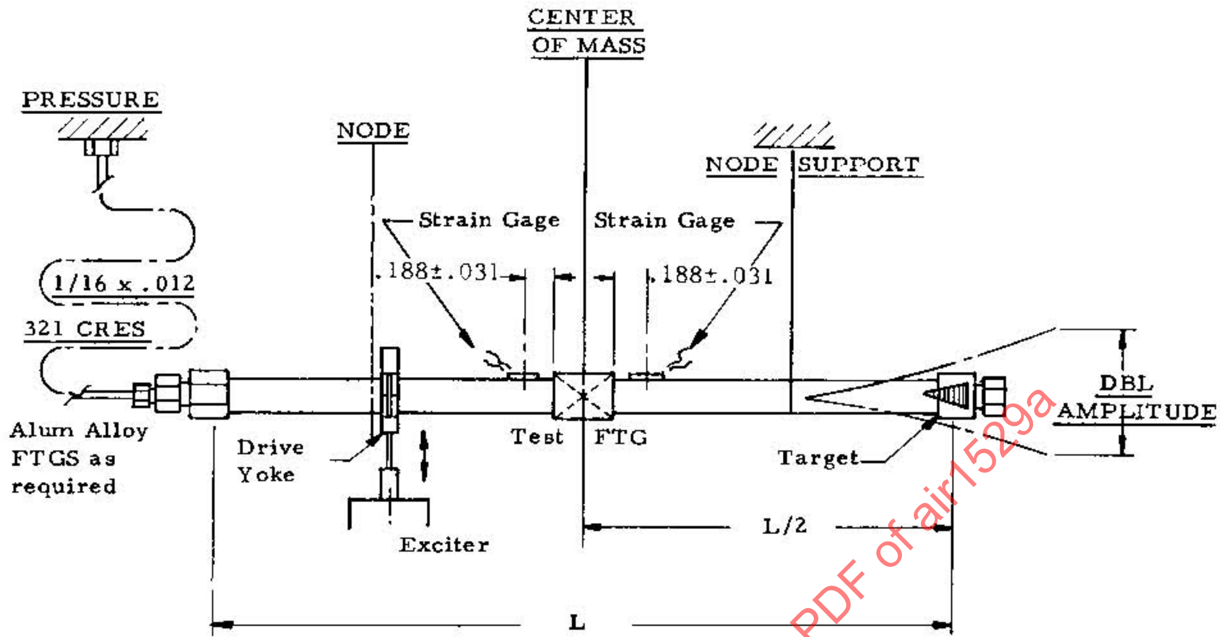
TUBE SIZE	LENGTH L INCHES	DOUBLE AMPLITUDE: INCHES (1) 21-6-9 CRES	TITANIUM ALLOY	ALUMINUM ALLOY
-4	20	0.38	0.70	1.05
-5	22			
-6	24			
-8	28			
-10	31			
-12	35			
-16	40			
-20	45			
-24	50			

(1) Young's Modulus: CRES, 28.5×10^6; Ti (3Al-2.5V), 15×10^6; Al, 10×10^6

The tabulated lengths will resonate at approx 150 Hz, and will produce 30 000 psi bending stress near midspan when adjusted to vibrate through the end double amplitudes indicated. For thin wall tubing, wall thicknesses may be neglected.

NOTE: In some materials, the resonant frequency can cause heating due to strain energy hysteresis which can affect the desired stress level. In this case, ambient cooling, or the selection of new tube lengths will be required.

FIGURE 1 - Type I Flexure Setup: Without Internal Pressure



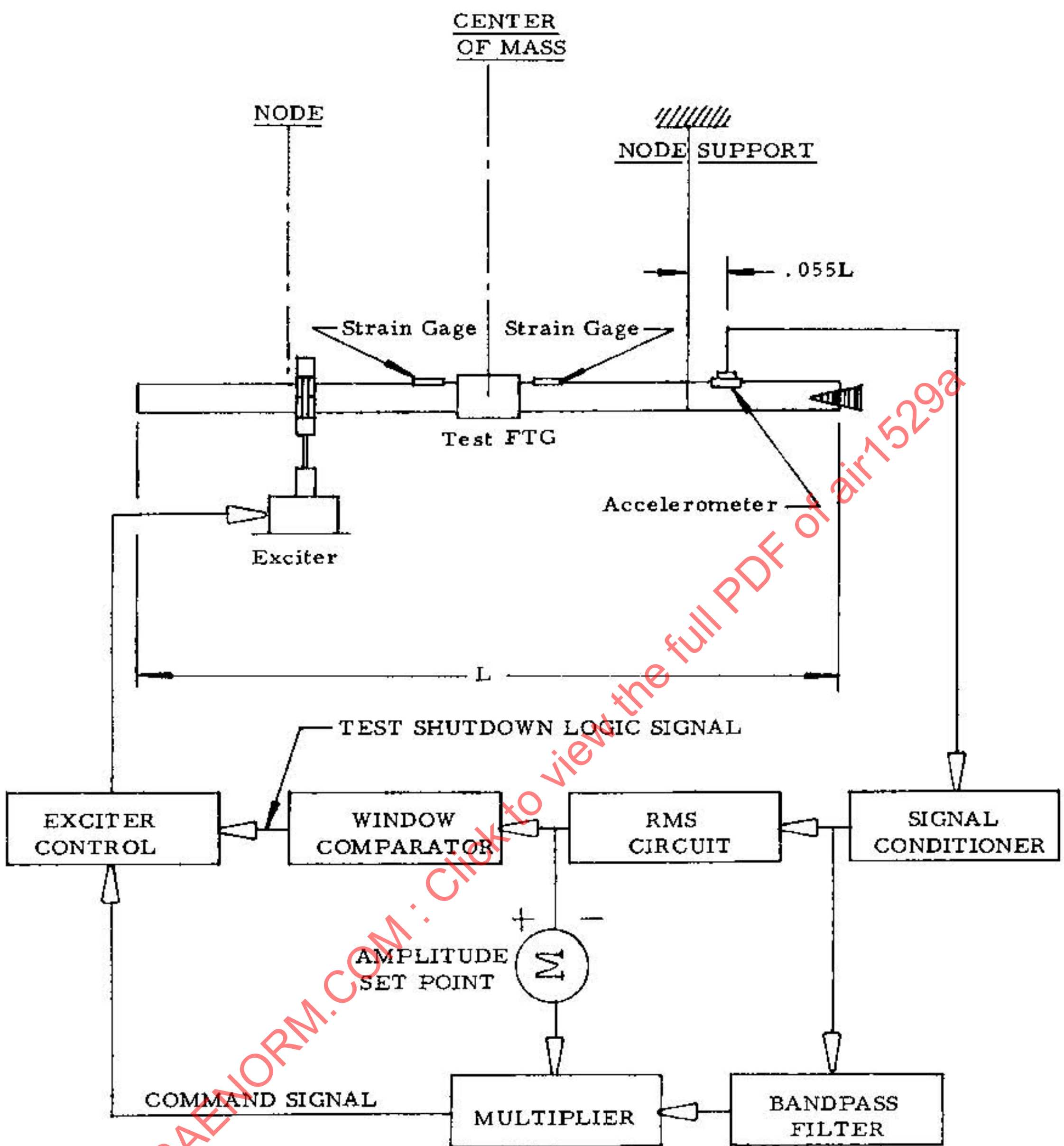
NOTE: In order to eliminate possible damping by the coiled tube, a hose may be connected to a valve at the end of the specimen. After pressurizing, the hose may then be disconnected. However, the mass of the valve must be balanced by an equivalent mass at the opposite end of the specimen. The total increased mass will affect the amplitude. Therefore new tube lengths must be calculated.

TUBE SIZE	LENGTH (1) L INCHES	DOUBLE AMPLITUDE: INCHES (2)		
		21-6-9 CRES	TITANIUM ALLOY	ALUMINUM ALLOY
-4	15	0.25	0.48	0.72
-5	17			
-6	19			
-8	22			
-10	25			
-12	27			
-16	31			
-20	36			
-24	40			

(1) Tube length before flaring.
(2) Young's Modulus: CRES, 28.5×10^6; Ti (3Al-2.5V), 15×10^6; Al, 10×10^6.

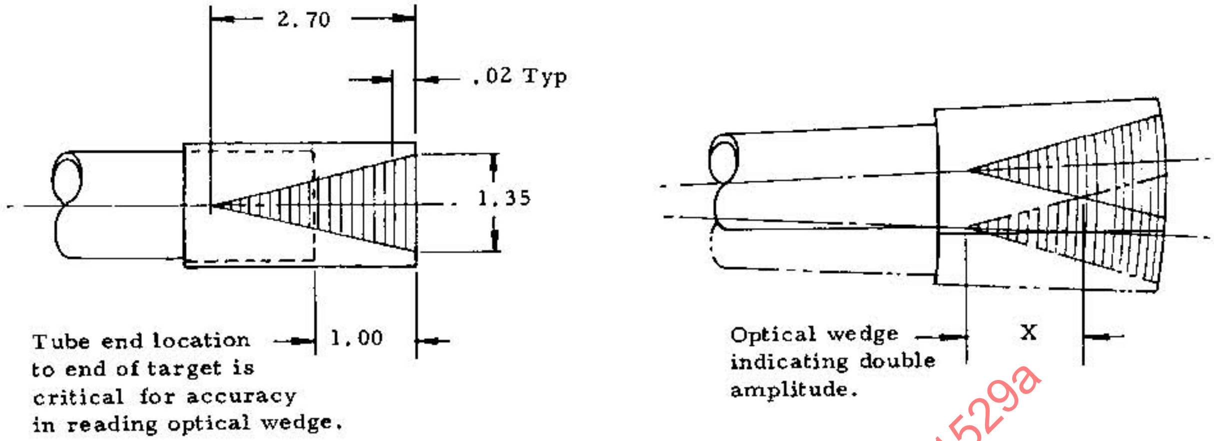
The tabulated lengths will resonate at approx. 100 Hz, and will produce 30 000 psi bending stress near midspan when adjusted to vibrate through the end double amplitudes indicated. Wall thickness may be neglected.

FIGURE 2 - Type II Flexure Setup: With Internal Pressure



NOTE: Tube lengths, strain gage location, and node position are the same as shown in Figures 1 and 2.

FIGURE 3 - Optional Automatic Control for Type I and II Flexure Test



a. Deflection Target Stationary

b. Deflection Target Vibrating

NOTE: An alternate method of measuring double amplitude is to paint a yellow dot at the apex of the optical wedge during the initial calibration run. Similar dots placed on the remaining targets will visually indicate the required double amplitude when the apex and the dot coincide.

TUBE SIZE	TUBE LENGTH	INDICATED DOUBLE AMPLITUDE "X" (INCHES)					
		WITHOUT PRESSURE			WITH PRESSURE		
		CRES	Ti	Al	CRES	Ti	Al
4	15				.29	.68	1.28
	20	.57	1.29	2.54			
5	17				.32	.72	1.32
	22	.59	1.31	2.47			
6	19				.34	.76	1.34
	24	.61	1.32	2.42			
8	22				.37	.79	1.36
	28	.64	1.33	2.35			
10	25				.38	.82	1.37
	31	.65	1.34	2.32			
12	27				.39	.83	1.38
	35	.66	1.35	2.29			
16	31				.41	.85	1.39
	40	.68	1.36	2.25			
20	36				.42	.87	1.40
	45	.69	1.36	2.24			
24	40				.43	.88	1.40
	50	.70	1.37	2.22			

FIGURE 4 - Deflection Target