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TUBE CONNECTOR DEVELOPMENT

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TECHNICAL REPORT NO. AFRPL-TR-69-98

JULY 1969

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AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
EDWARDS, CALIFORNIA

AFRPL-TR-69-98

TUBE CONNECTOR DEVELOPMENT

Albert B. Spencer, Jr., Lt, USAF

FOREWORD

This report summarizes research conducted during a USAF In-House Applied Research Program under Project 305802ERB, Tube Connector Development. The program was conducted from September 1964 through December 1968, by the Liquid Rocket Division of the Air Force Rocket Propulsion Laboratory at Test Area 1-14, pneumatics laboratory. Work described in this report was performed under the direction of Captain John L. Feldman, Fluid Components Section Chief, Lt Albert B. Spencer, Jr., Project Engineer, and Mr. Dennis Lank, Engineering Technician. Personnel participating in the research described include Mr. Edward E. Stein, Propulsion Subsystems Branch Chief, and Captain George N. Graves.

This technical report has been reviewed and is approved.

EDWARD E. STEIN
Chief, Propulsion Subsystems Branch
Liquid Rocket Division
Air Force Rocket Propulsion Laboratory

ABSTRACT

Families of threaded connectors consisting of unions, elbows, tees, and crosses, were designed for Type 347 CRES and 6061-T6 aluminum in the sizes of 1/8- to 1-inch tube diameter. A laboratory evaluation of Type 347 CRES unions in all sizes was conducted along with a field installation study. The laboratory evaluation consisted of the following qualification tests: thermal gradient, stress-reversal bending, vibration, pressure impulse, and repeated assembly. Based on the successful laboratory evaluation of the connector, in the sizes of 1/8-, 1/4-, 3/8-, and 1/2-inch tube diameters, fabricated in accordance with the detail designs and M. S. Specifications and Standards, these connector sizes were qualified for production. The 3/4- and 1-inch-tube-diameter connector experienced problems in thermal gradient conditions and further work is being done to correct this problem.

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SECTION I

INTRODUCTION

A. BACKGROUND

During the development of rocket propulsion systems, it became evident to the Air Force that separable connectors adapted from those used in the aircraft industry could not satisfy the requirements imposed by new rocket fluid systems. The prospect of significantly improving existing connectors to fulfill the needs of these systems appeared to be slight unless a better understanding and comprehension of connector design criteria existed.

A contract was initiated with Battelle Memorial Institute to develop new concepts for separable connectors. Battelle's work resulted in an advanced threaded fitting that could effectively perform in rocket-system environments (1). This connector was designated as the AFRPL connector.

B. OBJECTIVE

The AFRPL Tube Connector Evaluation Program, Project 305802ERB, was established with the general objective of providing an independent evaluation of the fitting concepts developed under contracted programs and to evaluate field service problems and skill levels required for connector fabrication and installation. The specific objectives of the program as related to the evaluation of threaded separable connectors were as follows:

1. To develop testing procedures, techniques, and equipment to evaluate the performance of tubing connectors.

2. To establish a standard of comparison with which to evaluate fitting designs and concepts.

3. To verify the performance of the AFRPL connector developed by Battelle Memorial Institute under Contracts AF04(611)-8176 and AF04(611)-9578.

4. To determine the skill level and assembly limitations to install mechanical fittings in the field.

C. APPROACH

The basic approach of this program was divided into a three-part effort. The initial phase involved building a complete tube connector test facility. In the second phase, baseline tests were conducted to establish data to be used in a comparative manner with the AFRPL connector test results. The final phase was to conduct qualification tests to verify that the AFRPL connector could meet the extreme requirements of rocket fluid systems. This report is concerned with the third phase of the program. The first and second phases are reported respectively in AFRPL-TM-66-8, "Fittings Evaluation Test Requirements and Facilities Design", and AFRPL-TR-69-127, "Performance Analysis of Flared Connectors".

The design procedure makes possible the design of connectors to operate under various service conditions; therefore, a sufficient number of specimens had to be tested to demonstrate that the AFRPL connectors will respond to each set of operational conditions as the design procedure indicated they should. Performance evaluations were conducted in the laboratory environment per MIL-F-27417 (USAF) as well as test stand operational systems. The connector was tested under conditions of thermal shock, vibration, stress-reversal bending, repeated assembly, pressure impulse, and misalignment.

SECTION II

AFRPL CONNECTOR DESIGN

The AFRPL connector (Figures 1 and 2) is an all-metal, high-performance, separable-tube connector capable of meeting present and advanced system requirements. The family of connectors consist of unions, elbows, tees and crosses which were designed for Type 347 CRES in sizes from 1/8- to 1-inch tube diameter.

The maximum allowable assembly torque ranges from 2580 in-lb for the 1-inch connector to 90 in-lb for the 1/8-inch connector. The upper torque limit is based on a reasonable assembly requirement which permits a mechanic to assemble the connector without the aid of a wrench handle extension. The connector is capable of sealing helium to 10^{-7} atm cc/sec at 4000 psi and in a temperature range from $-320^{\circ}F$ to $+600^{\circ}F$.

The temperature effects and leakage requirements have a great deal of influence on the seal design. Because of transient thermal gradients, the resulting differential expansion of the connector parts causes a reduction in seal contact stress which results in leakage. To compensate for these effects, additional payload may be applied through a load path parallel to the seal. The bobbin seal design allows a constant sealing load. Geometrical arrangement of the seal design allows the seal to act radially rather than axially, which provides a seal less affected by dimensional changes due tc thermal coefficients of expansion.

Recent research (2) in sealing phenomena has shown that to provide seals with essentially zero leakage, one of the seal interface materials must be plastically yielded. To provide this sealing load with the minimum stress in the structural members of the connector, a mechanical-toggle, force-amplifying mechanism is incorporated into the seal action. The

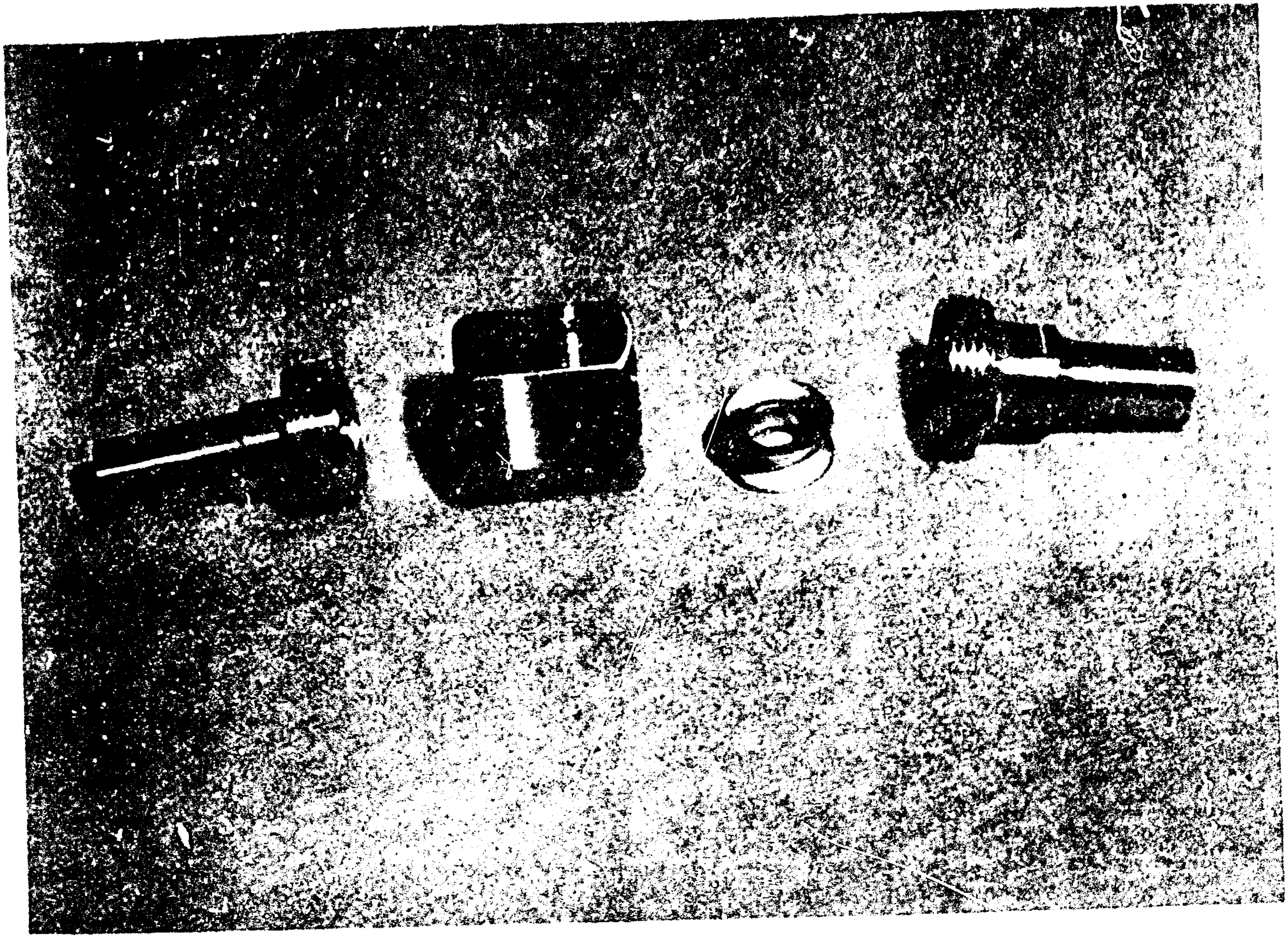


Figure 1. AFRPL Connector

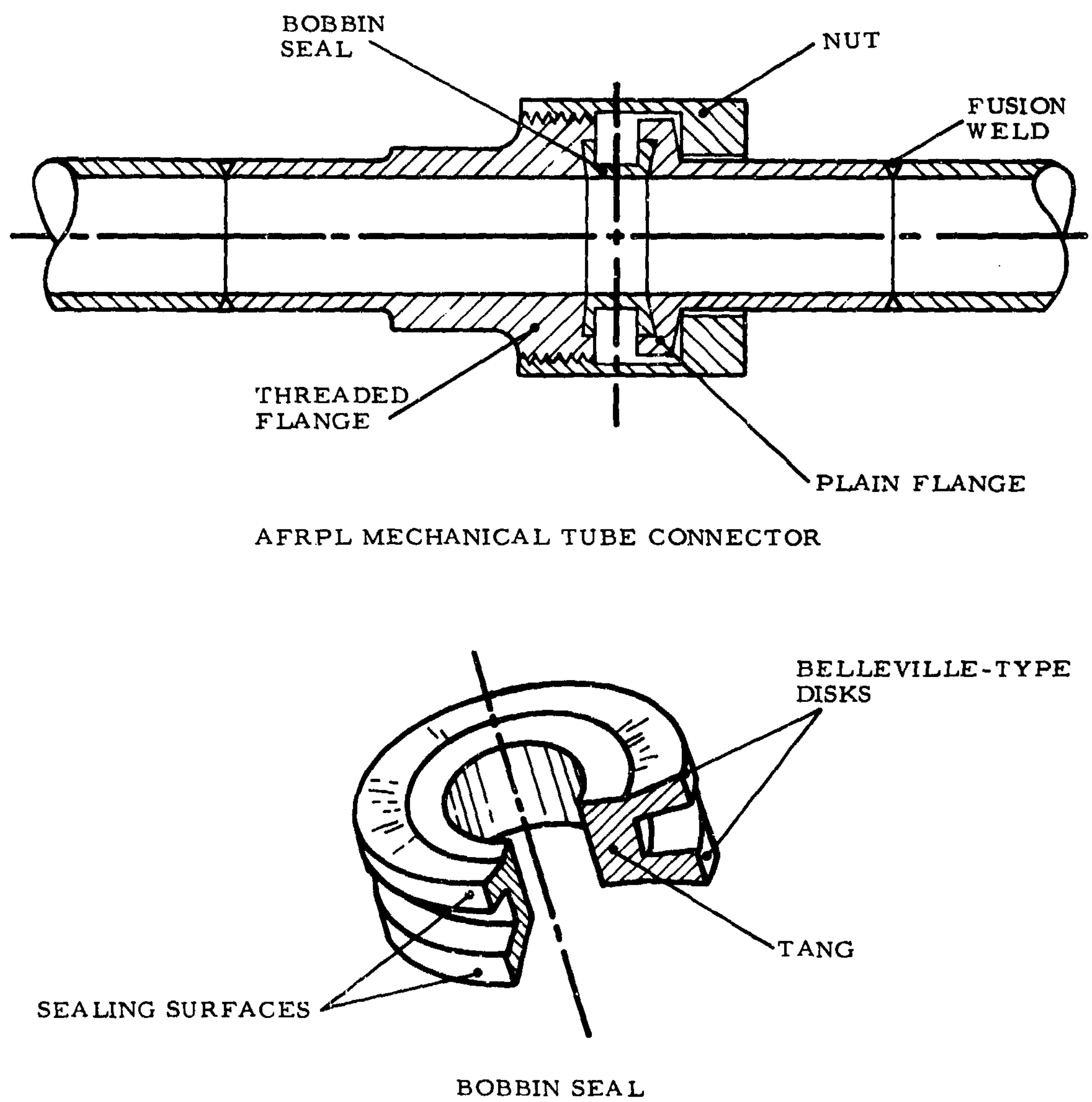


Figure 2. AFRPL Connector Parts

stainless steel seals are plated with soft nickel which further lowers the contact stress required for plastic deformation.

Operationally, the flanges are brought together by turning the nut which deflects the sealing legs until the outside diameter of the seal contacts the inside diameter of the seal cavity in the restraining flanges. Further deflection causes an interference fit between the seal and flanges and a rapid increase in contact stress, but because of slight dimensional differences between the legs resulting from the machining process, one sealing leg generally tends to respond sooner than the other. Elastic strain increases until the elastic limit of the tang is exceeded. The axial force drops when the tang yields. However, because of the mechanical advantage developed by the deflecting legs and the fact that the seal is firmly wedged in the flange cavity, the contact stress at the sealing surface does not decrease. Also, the radial sealing force and the contact stress remain constant because the tang yields. Continued application of force causes the other side of the seal to respond in a like manner. At this point, the seal is in place--the nickel coating has been plastically deformed at the sealing surfaces, the legs have been deflected, the seal is completely restrained, and the flange faces are in contact with the tang faces. In essence, the process of creating a seal is complete. Axial force, when applied, is not transmitted to the sealing surfaces, but rather is transmitted through the tang, from one flange to the other, permitting proper preloading of the connector structure. It is worthy of note that the bobbin seal is permanently deformed during the assembly of the AFRPL connector, and upon disassembly, the seal must be replaced with a new bobbin seal for each additional assembly. This bobbin seal replacement assures an effective, reliable, helium leak-tight seal after each assembly. The sealing force mechanics are graphically depicted in Figure 3.

The method presently used in attaching the tube connector to the tubing is Tungsten Inert Gas (TIG) welding. This can be done manually, with any

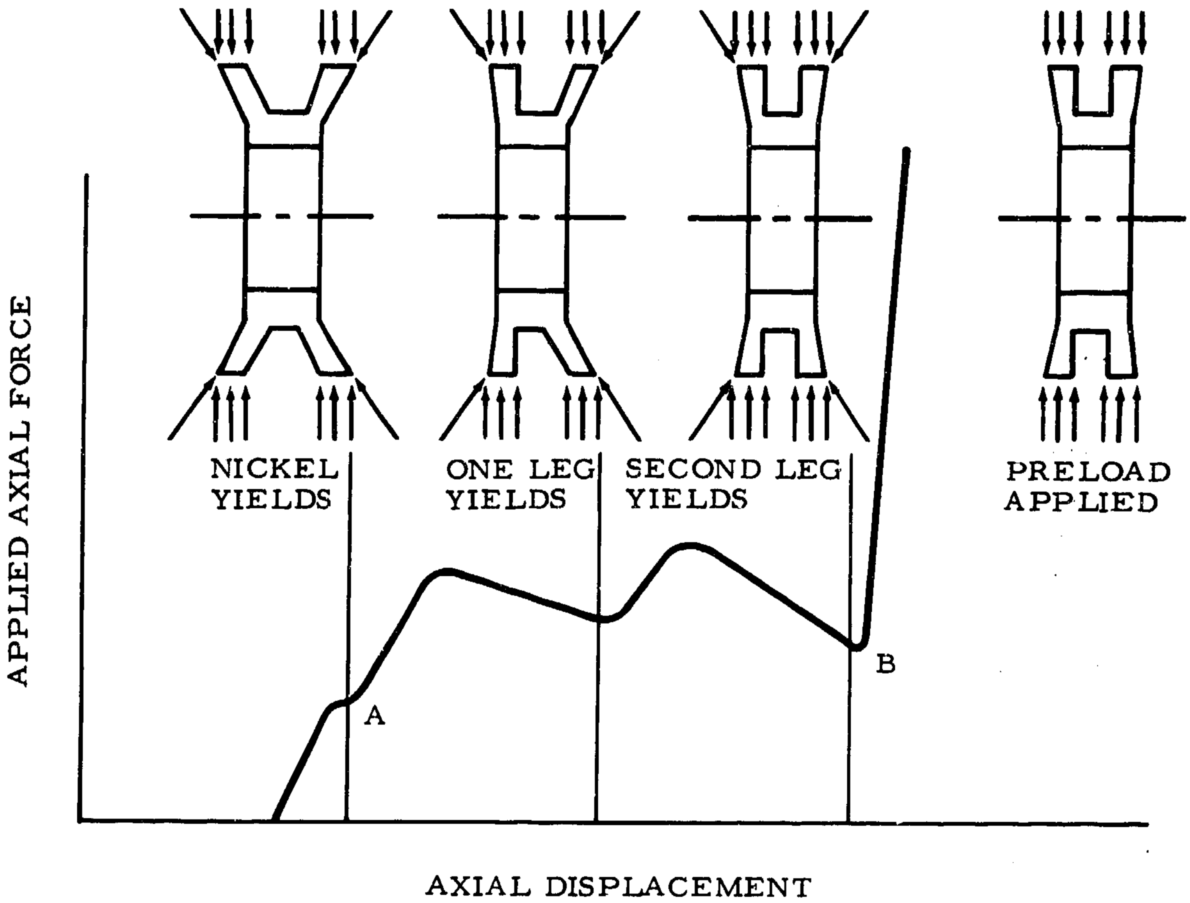


Figure 3. Sealing Force Mechanics of The Bobbin Seal

of the commercially available semi-automatic tube welders, or with fully automatic welding equipment.

This connector was designed as an advanced high-performance connector for rocket propulsion systems. It has reliably demonstrated zero-leakage performance over a service range of -450°F to 600°F at 1000 psia and 4000 psia under severe operating conditions of vibration, stress-reversal bending, and thermal gradients. The connector was designed to maintain zero leakage (defined as 7×10^{-7} cubic centimeters helium per second at atmospheric conditions).

SECTION III

TEST FACILITIES AND PROCEDURES

A. LEAKAGE AND PRESSURE

The requirements placed on each test system were the most important step in planning evaluation of the performance of a tubing connector. The following paragraphs describe the requirements for the six test systems.

Leakage measurements were one of the most important requirements throughout the tests. Leakage may be measured in several different manners, depending on the rate and leaking media. The measurement of liquid media is very difficult if the leakage rate is less than 1 cc/min. Nuclear, ultrasonic, and chemical techniques are being developed but are handicapped by high cost or low sensitivity. Therefore, most leakage measurements are made with a gas as the working fluid.

Water displacement is a technique that has been used successfully. The leaking gas is captured in a container under water. The system is generally made so that the captured gas may be maintained at a constant pressure. The volume of water displaced equals the volume leakage of the gas. This system will measure leaks from high rates down to about 10^{-3} atm cc/sec.

The leakage measurement limits of the water displacement method are three to six orders of magnitude greater than that expected of the AFRPL connector. For these leakage requirements and measurements, a helium mass spectrometer leak detector was used. This technique uses helium as a pressurizing gas and a vacuum chamber to surround the fitting and collect all leaking helium gas. Conventional mass spectrometer techniques are used to sense the helium.

Leakage rates were the prime method of determining failure of connectors, both welded and separable. Leakage could not exceed 10^{-7} atm cc/sec or the seal was considered to be a failure. The maximum acceptable leakage for flared connectors was 10^{-5} atm cc/sec. All test systems had leak-detecting chambers integrated in the system around the test connector.

Pressure operating conditions are an important part of each test. A separate test was devoted to testing the connector's ability to perform under pressurized conditions. Both proof-pressure and burst-pressure tests were conducted. Proof pressure is defined as 1.5 times the working pressure. This test was an inspection test to insure that no gross defects existed in the connector seal or mechanical structure. This test system is shown in Figure 4.

Burst-pressure tests are structural tests based on the ultimate strength of the structural members of the connector. Burst pressure is defined as two times working pressure without catastrophic failure. The burst pressure generally will yield structural members of the connector and cause large leaks. These leaks are not measured because they have no relation to designed performance. A burst-pressure test not only identifies weak connector structural members, it also demonstrates the actual factor of safety of the connector.

B. STRESS-REVERSAL BENDING

It is highly likely that in rocket propulsion applications tubing lines containing connectors will be subjected to dynamic loading. These loads may be caused by vehicle deflection, installation forces, vibration, acceleration, etc. The dynamic aspect of these forces generally occurs during rocket engine operation. Thus, the total duration is generally less than 5 minutes. For dynamic loading, only low total cycle life is required and high stress levels may be imposed on the fitting structure.

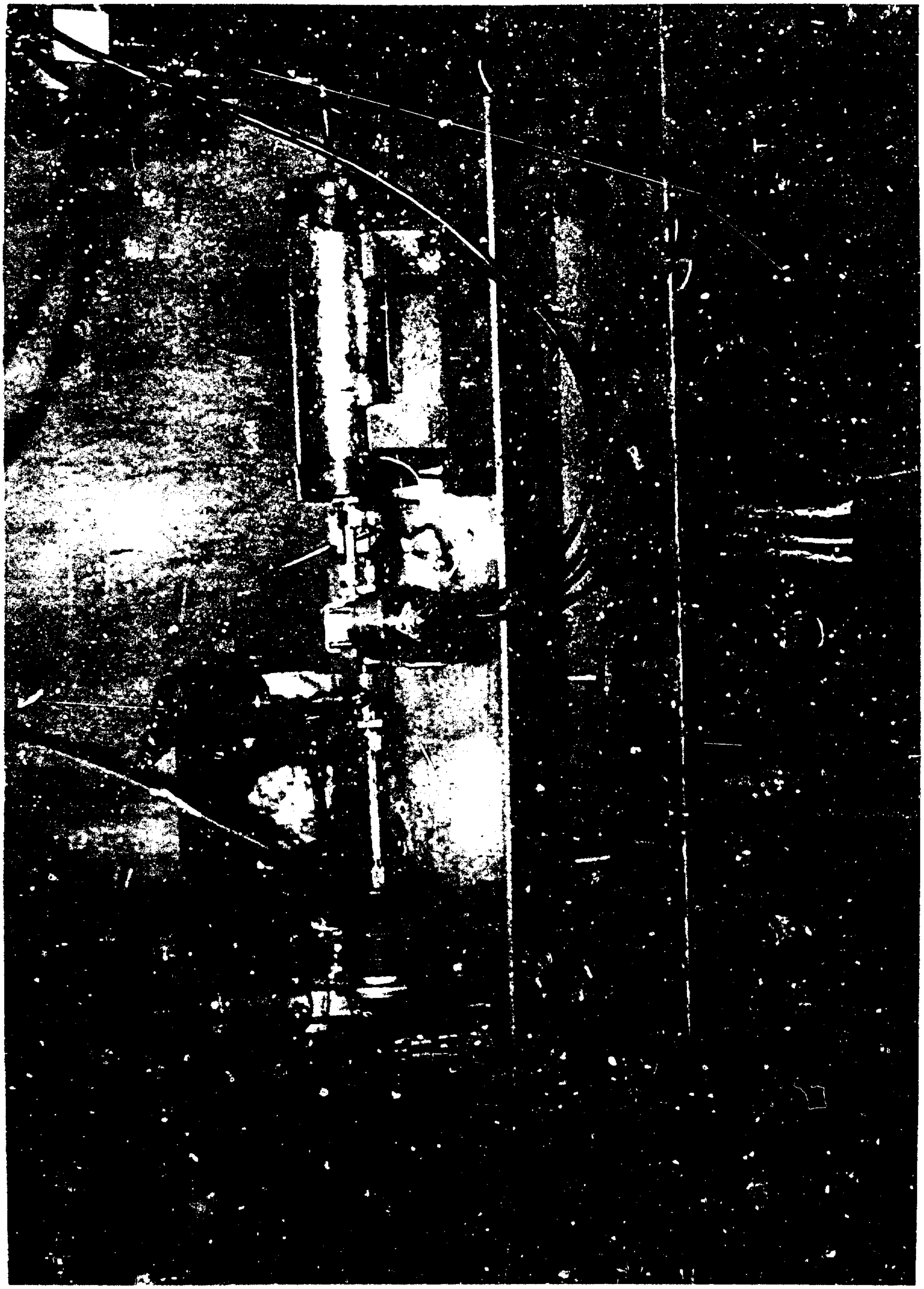


Figure 4. Proof-Pressure Test System

Stress-reversal bending tests were conducted on all connectors from the 1-inch-diameter to the one-quarter-inch diameter. The equipment used to simulate stress-reversal conditions in the connectors is shown in Figure 5. The evaluation procedure consisted of the following steps:

1. The plain flange was welded to the connecting rod, and the threaded flange was welded to the rigid support.

2. The seal was inserted and the connector was assembled.

3. The bellows vacuum chamber was assembled.

4. The connecting rod was inserted in the bearing, and the entire assembly was bolted to the fixture.

5. The eccentric was set to the proper offset as measured by the strain gage.

6. The connector was pressurized to proof pressure and heated to maximum operating temperature. The leakage was measured.

7. The bending moment was applied by means of the rotating eccentric for at least 300,000 cycles at a rate of 1,500 cycles per minute. The operating pressure and maximum operating temperature were maintained. Leakage was continuously monitored during the test with the helium mass spectrometer.

C. THERMAL GRADIENT

Between temperature of exhaust products and cryogenic propellants, large temperature gradients may be caused in tubing line connectors. The temperature differences can have two deleterious effects. High temperature gradients on the tension member (nut) cause relaxation of the sealing load. Thermal gradients in the negative direction raise the stress level in the nut

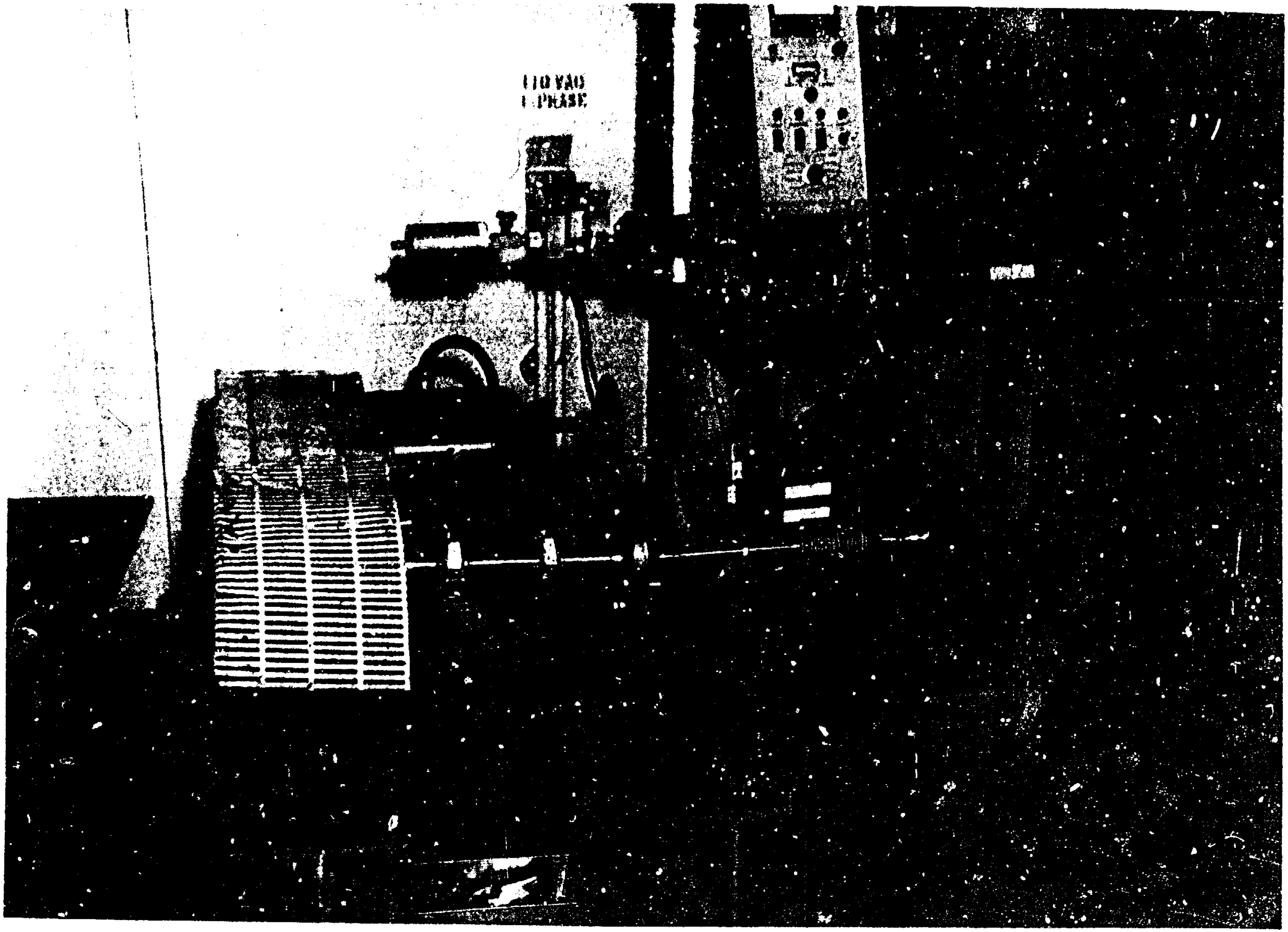


Figure 5. Stress-Reversal Bending Test System

with the possibility of causing yielding or failure. If the nut yields, the sealing load will be reduced upon return to assembly temperature.

Experiments were conducted to evaluate the capability of the connector to function satisfactorily at maximum expected temperature gradients with the equipment shown in Figures 6 and 7. The hot thermal gradient was achieved with an induction generator and coil. This procedure closely simulated actual service conditions where the connector is subjected to external heat. The cold thermal gradient was achieved by flowing cryogenic fluid through the connector. This procedure accurately simulates the actual thermal conditions encountered by the connector and the heat conduction paths are distributed in the same pattern encountered during actual operation.

The test procedure consisted of the following steps:

1. Connector flanges were welded to the tubing.

2. The connector was assembled with the prescribed preload torque.

3. A thermocouple was attached to the outside surface of the nut, and the pyrex vacuum chamber was assembled.

4. After the vacuum chamber was evacuated, the connector was pressurized to the proof pressure at maximum operating temperature.

5. The temperature was cycled between room temperature and -320°F three times at operating pressure. Both temperature extremes were maintained for 5 minutes during each cycle.

6. The temperature was cycled between room temperature and the upper temperature limit, 600°F, three times at operating pressure. Both temperature extremes were maintained for 5 minutes during each cycle.

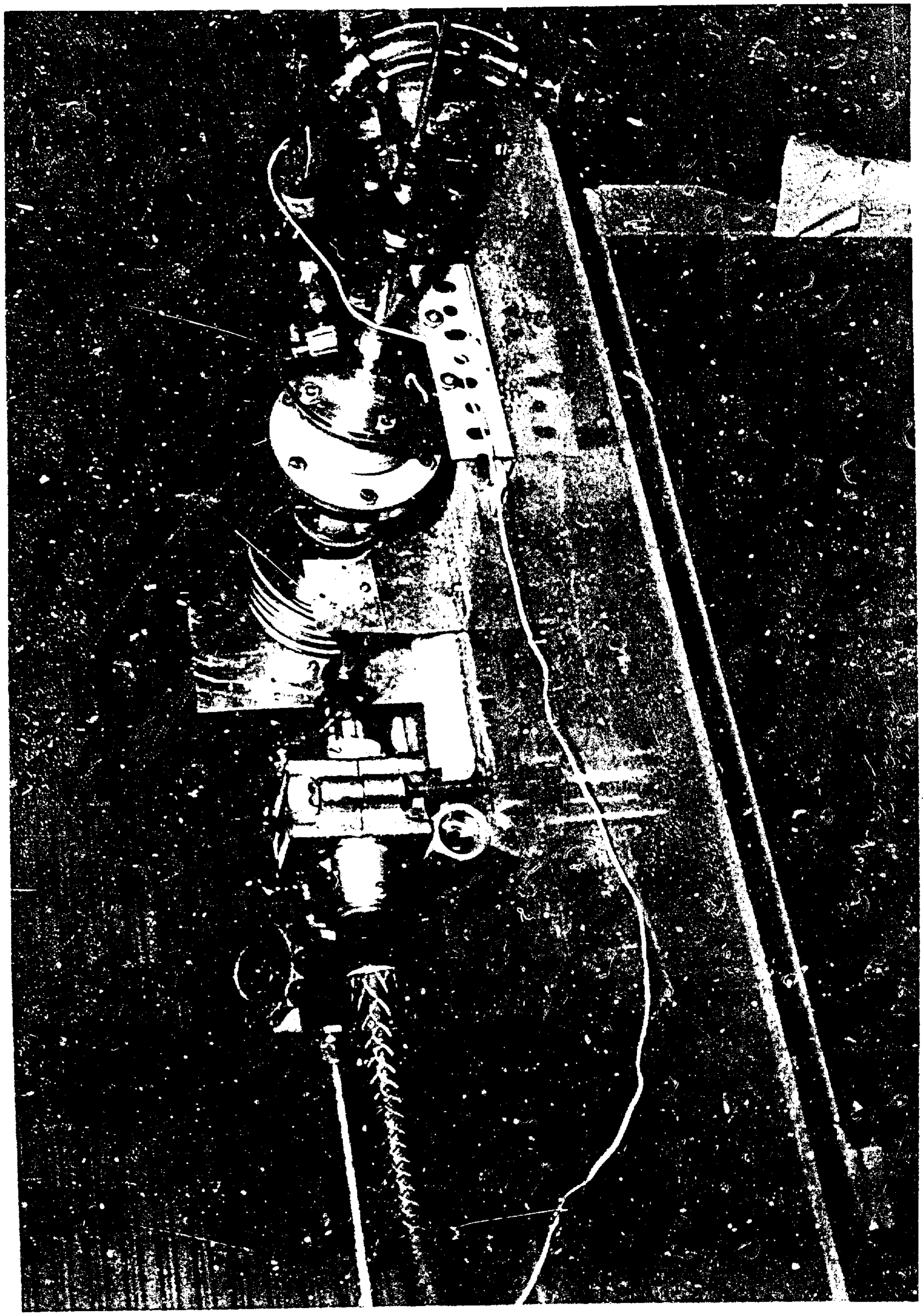


Figure 6. Thermal Gradient Test System

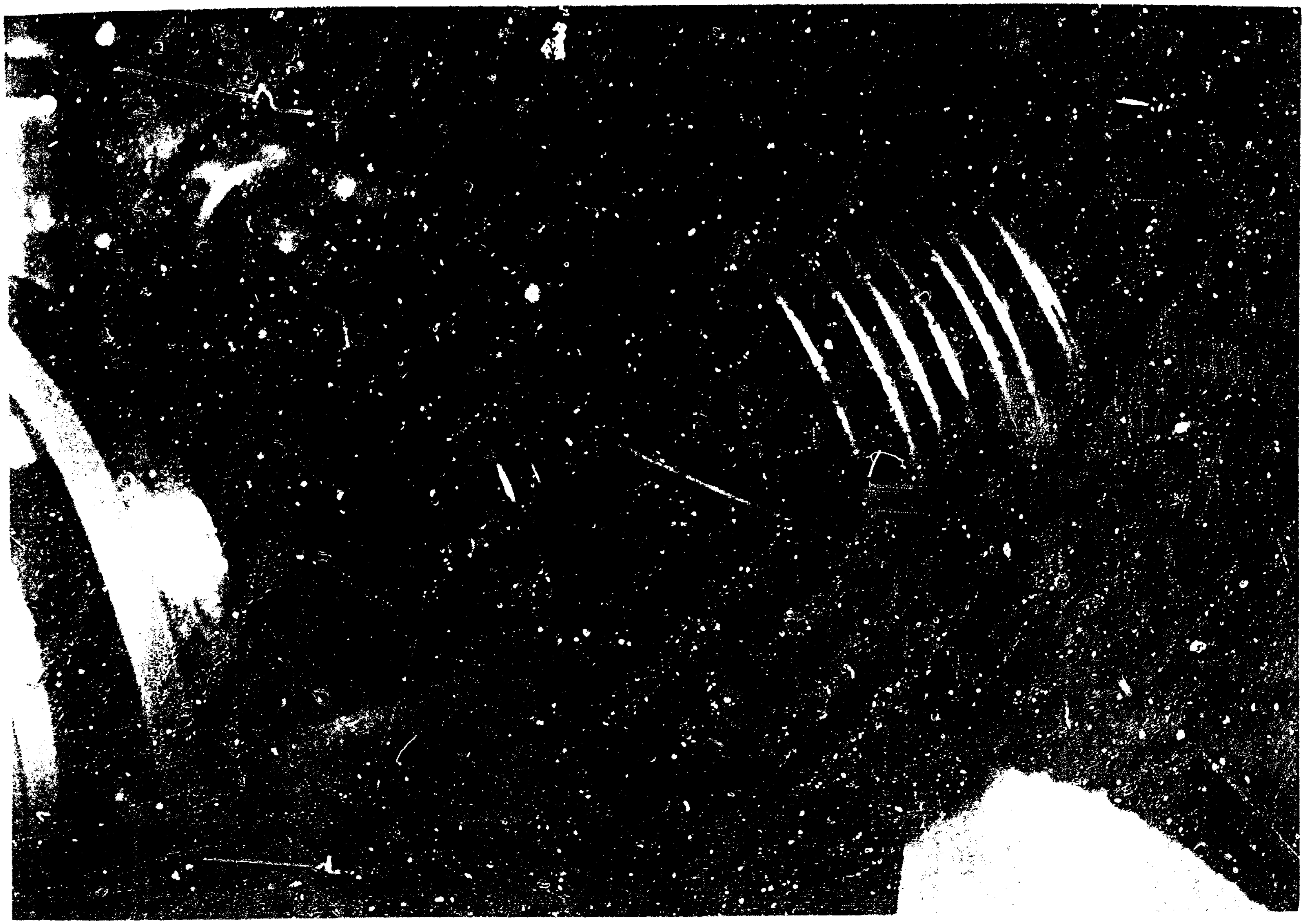


Figure 7. Heating Coil for the Thermal Gradient Test

7. The temperature was cycled between $-320^{\circ}F$ and $600^{\circ}F$ three times at operating pressure. Both temperature extremes were maintained for 5 minutes during each cycle.

8. The leakage was continuously monitored during the test with the helium mass spectrometer.

D. REPEATED ASSEMBLY

The advantage of a separable connector is its ability to be disassembled and reassembled easily. Although it is difficult to estimate the number of times a connector will be reassembled, it was agreed that the AFRPL connector should be capable of being reassembled 20 times.

In conducting the repeated assembly experiments, the following trouble areas were monitored:

1. Deterioration of the flange sealing surface.

2. Deformation or distortion of the flanges.

3. Damage to the wrenching surface.

4. Galling of bearing surfaces.

The experiment was performed by clamping the plain flange in a rigidly mounted fixture. The threads and back face were lubricated with a molydisulfide lubricate mixture. A bobbin seal was placed in the seal cavity and the connector was tightened by hand. An open-end wrench was placed on the wrench flats of the threaded flange to prevent it from turning during the torquing operation. The nut was then tightened with a torque wrench to the desired torque level.

The critical dimensions as shown in Figure 8 were measured after every fifth increment in the testing operation. Leakage was measured after the test was completed by hydrostating the connector at 8000 psi burst pressure.

E. VIBRATION

High-frequency loads are potentially more troublesome than the lower frequency stress-reversal bending. Tubing systems resonating at their natural frequency at stress levels near the yield point of the tubing material may quickly fatigue and fail. Vibrational loads also accelerate the relaxation of residual stresses, which contributes to loosening of the nut, loss of preload, and movement of the seal. The primary purpose of this test was to evaluate the structural effects on the connectors in the vibration environment.

The connectors were evaluated by the indeterminant-beam method illustrated in Figure 9. The connectors were pressurized to maximum operating pressure and heated by an induction heating coil (Figure 7) to the upper temperature limit. All connectors were vibrated for at least 300,000 cycles, at the lowest resonant frequency. The amplitude was statically determined so that the bending stress at the connector was equal to that applied during the stress-reversal bending test. Static deflection was measured optically, and the amplitude was adjusted so that the dynamic deflection was identical to the measured static deflection.

The actual setup was accomplished as follows:

1. The plain flange was welded to a plugged tube and the threaded flange was welded to a pressure-line tube.

2. Strain gages were attached to the nut.

3. The seal was inserted and the connector was assembled to minimum torques.

4. The bellows vacuum chamber and blanket heater were assembled.

5. The connector was pressurized to maximum operating pressure and heated to maximum operating temperature.

6. The leakage was measured.

7. The flexing frequency was the lowest resonant frequency of the fitting.

8. Duration of the test was 300,000 cycles.

9. Leakage was measured upon test completion.

F. MISALIGNMENT

The misalignment of the AFRPL connector's seal was a problem which was identified while the connector was being used during the field evaluation portion of this program. This problem area was then looked at more closely and the misalignment condition was simulated (Figure 10) in the laboratory using the following procedures:

1. The connector was welded in place and connected to a helium pressure line.

2. The connector seal was inserted.

3. The connector was assembled to maximum torque.

4. The bellows vacuum chamber was assembled.

5. The connector was pressurized to maximum operating pressure.

6. Leakage was checked.

7. The vacuum chamber and connector were disassembled.

8. Incremental axial displacements of 0.125 inch were imposed on the plain flange until 1 inch total displacement was obtained. Then the threaded flange was displaced by an angular displacement of 1/2 degree for the next axial displacement cycle of incremental displacements up to 1 inch. This process was continued until the stress exceeded 20,000 psi or until assembly became impossible.

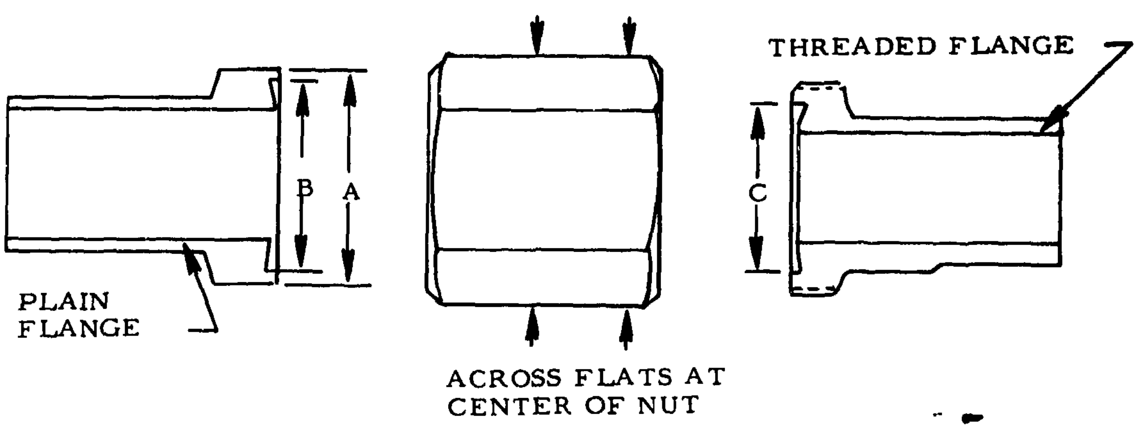


Figure 8. Repeated Assembly Test Measurement Locations

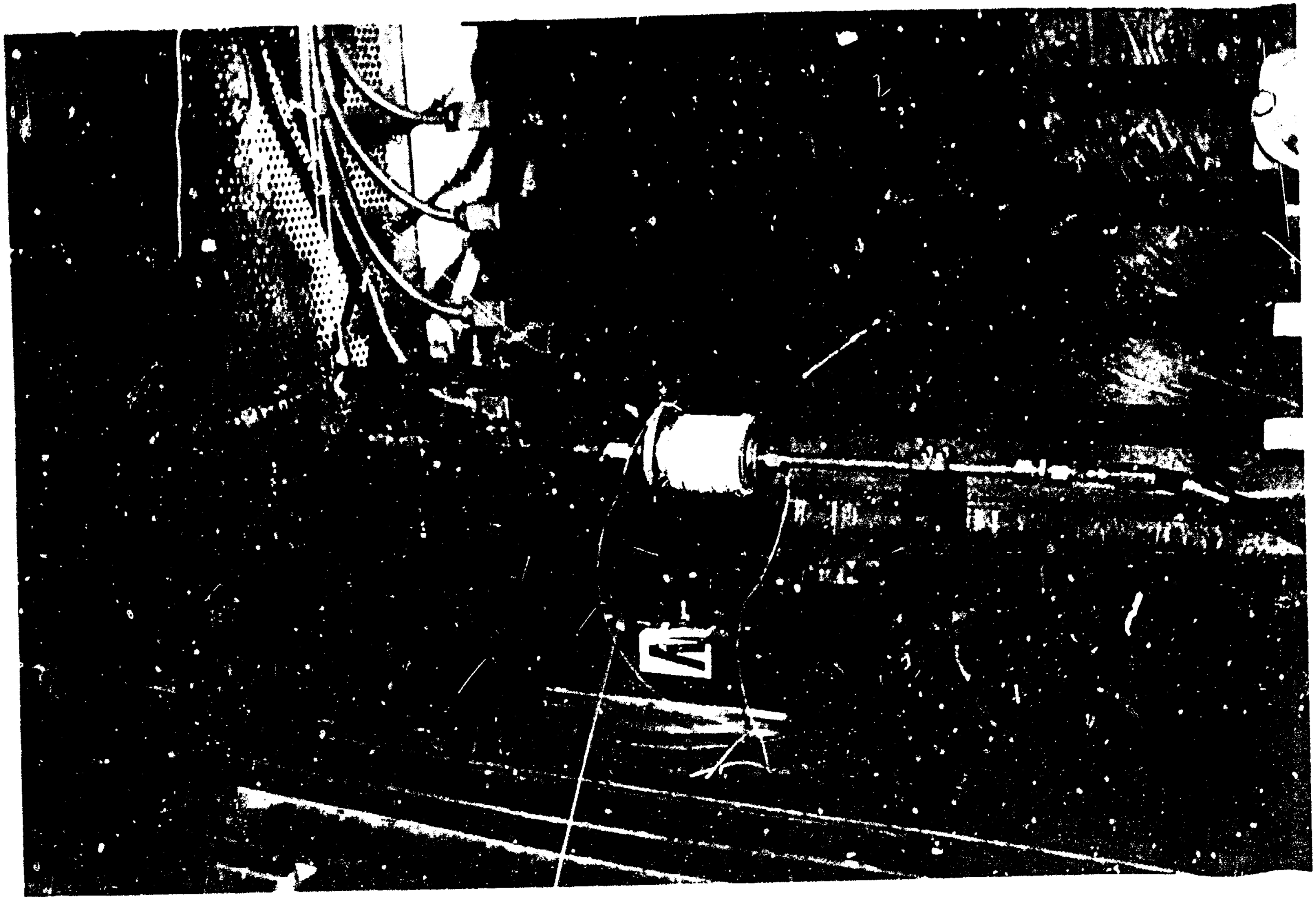


Figure 9. Vibration Test System

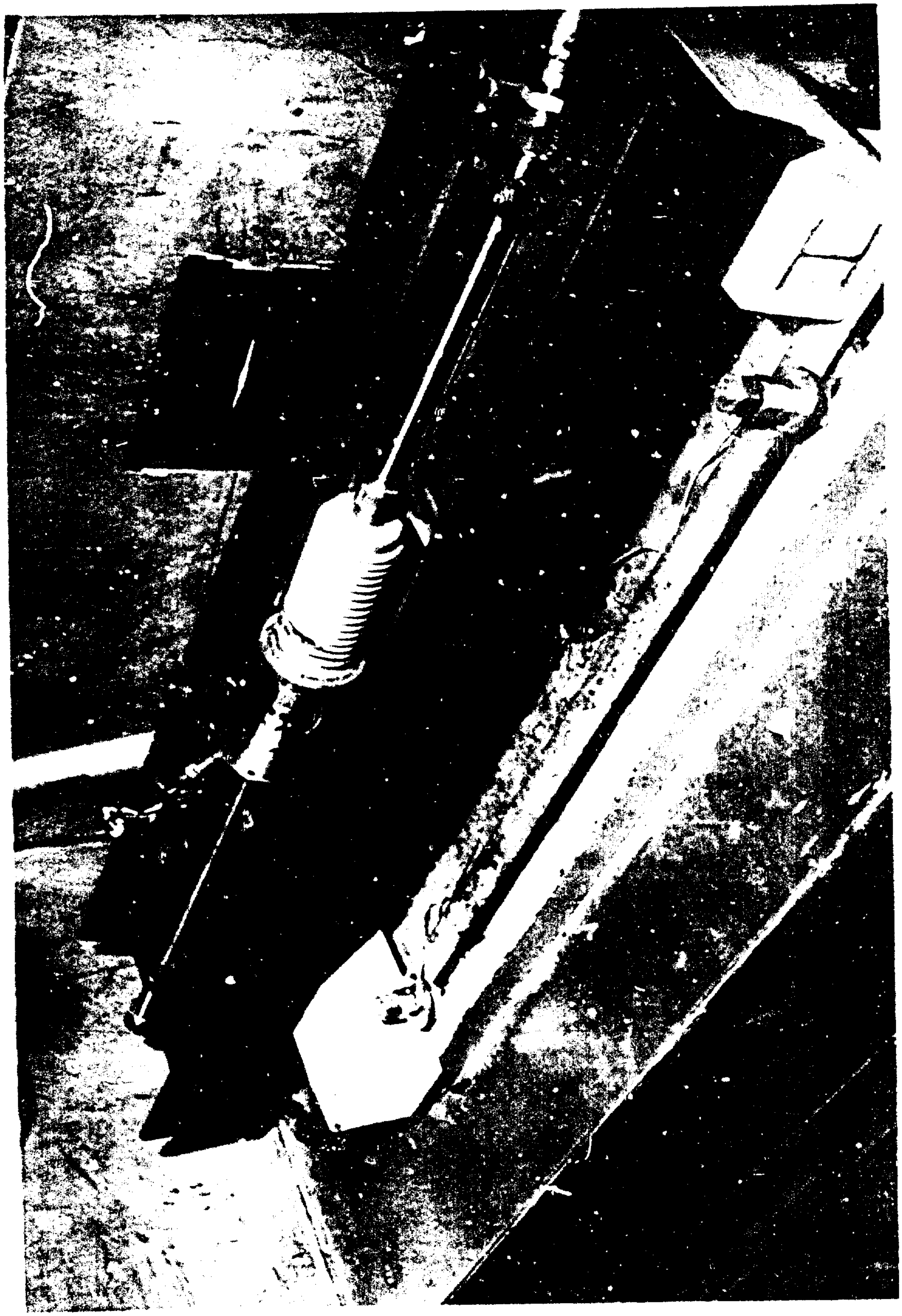


Figure 10. Misalignment Test System

SECTION IV

TEST RESULTS

The experimental program was conducted to verify the AFRPL connector design. The experimental program also provided insight and guidelines for necessary design modifications.

A. STRESS-REVERSAL BENDING

The stress-reversal bending tests were conducted with six 3/8-inch unions, six 1/2-inch unions, and three 3/4-inch unions. A complete record of the results is given in Table I.

All of the connectors were subjected to at least 300,000 cycles. Failure occurred in the weld joint of a 3/4-inch setup, but the weld was repaired and the connector completed 300,000 cycles. Excessive bending movements caused the weld failure, but the connector did not leak. Maximum leakage recorded throughout these tests was 7×10^{-7} atm cc/sec.

Bending movements of 50.6 in-lbs full reversal were applied to the 3/8-inch connectors, 126.4 in-lbs full reversal were applied to the 1/2-inch connectors, and 427 in-lbs were applied to the 3/4-inch connectors. Leakage was continuously monitored by a mass spectrometer.

TABLE I. STRESS-REVERSAL BENDING TEST LEAKAGE DATA

FITTING*	R6U4	R6U5	R6U6	R6U7	R6U8
TORQUE IN-LBS	380	380	380	435	435
BENDING MOMENT, IN-LBS	50.6	50.6	50.6	50.6	50.6
LEAKAGE AT TEST CONDITIONS:					
4000 psi at RT	3.0×10^{-8}	4.4×10^{-8}	4.7×10^{-8}	2.6×10^{-7}	7.1×10^{-8}
4000 psi at 600°F	4.1×10^{-8}	6.5×10^{-8}	5.2×10^{-8}	2.8×10^{-7}	7.2×10^{-8}
LEAKAGE AT END OF TEST	6.0×10^{-8}	3.8×10^{-8}	2.7×10^{-8}	2.0×10^{-7}	4.6×10^{-8}
FITTING*	R6U9	R8U4	R8U5	R8U6	R8U7
TORQUE IN-LBS	435	490	490	490	555
BENDING MOMENT, IN-LBS	50.6	126.4	126.4	126.4	126.4
LEAKAGE AT TEST CONDITIONS:					
4000 psi at RT	9.8×10^{-10}	4.4×10^{-8}	1.3×10^{-8}	9.0×10^{-9}	3.1×10^{-7}
4000 psi at 600°F	4.2×10^{-8}	6.2×10^{-9}	1.1×10^{-8}	0.0×10^{-9}	3.3×10^{-7}
LEAKAGE AT END OF TEST	3.72×10^{-8}	1.1×10^{-8}	1.4×10^{-8}	9.1×10^{-9}	7.0×10^{-7}
FITTING*	R8U8	R8U9	R12U7	R12U8	R12U9
TORQUE IN-LBS	555	555	1240	1240	1240
BENDING MOMENT, IN-LBS	126.4	126.4	427	427	427
LEAKAGE AT TEST CONDITIONS:					
4000 psi at RT	1.2×10^{-8}	1.2×10^{-8}			
4000 psi at 600°F	1.4×10^{-8}	3.1×10^{-8}	0.60×10^{-8}	0.80×10^{-8}	0.30×10^{-8}
LEAKAGE AT END OF TEST	6.8×10^{-8}				

*NOTE CODE:

R = Connector Type R-AFRPL Connector F-Flared, etc.
6 - Nominal Tubing OD in 1/16th of an inch
U = Configuration U-Union L-Elbow T-Tee X-Cross
4 = Sequential Test Item Numbers

R6U4 indicates the fourth, union type
AFRPL connector tested in the 3/4-inch size.

B. THERMAL GRADIENT

The thermal shock tests were performed with three 3/8-inch unions, six 1/2-inch unions, three 3/4-inch unions. The results are recorded in Table II.

The maximum transient time recorded for the thermal shock test was 8 minutes. The average time was about 6 minutes except in the 3/4-inch size which failed. Failures resulted from a combination of low radial sealing loads and the quality of the seal plating and sealing surface finish. These problem areas are discussed in more detail in Section V.

TABLE II. THERMAL SHOCK TEST DATA*

Connector	Maximum Leakage 10^{-7} ctm cc/sec	Low Temp. (°F)	High Temp. (°F)
R6U51	1.70	-295	600
R6U52	0.39	-295	600
R6U53	0.76	-295	520
R8U50	0.37	-270	600
R8U52	1.0	-270	540
R8U53	2.2	-270	400
R8U61	0.76	-290	475
R8U62	0.76	-290	475
R8U63	0.99	-280	600
R12U2	**	-100	175
R12U3	**	-120	200
R12U4	**	-110	180

*All data indicate 6 thermal cycles

**Leaked greater than 7 x 10^{-7} atm cc/sec after first thermal cycle.

C. REPEATED ASSEMBLY

The repeated assembly test results are shown in Table III. Procedures for this test were as described in Section III. This evaluation demonstrated that the limit placed on the number of recommended assemblies was probably below the actual number of assemblies that could be accomplished and still retain the good performance of the connector. The dimensional variances were not enough to be judged as detrimental to the performance. These dimensions never varied over 0.002 inch during this test. The measurements were taken as shown in Figure 8.

TABLE III. REPEATED ASSEMBLY TEST DATA

	R4U1	R4U2	R6U1
Temperature, ^{o}F	600	600	600
Pressure Each Cycle, psi	5900	5900	5900
Pressure for Leak Test, psi	4300	4350	4400
Size	-04	-04	-06
Torque, in-lbs	200	225	380
Leak Rate at Start, atm cc/sec	1.8×10^{-8}	7.1×10^{-8}	2.0×10^{-8}
Leak Rate after 5th Assembly, atm cc/sec	2.1×10^{-9}	6.5×10^{-8}	2.5×10^{-8}
Leak Rate after 10th Assembly, atm cc/sec	2.3×10^{-9}	9.5×10^{-8}	5.2×10^{-8}
Leak Rate after 15th Assembly, atm cc/sec	7.4×10^{-9}	1.3×10^{-7}	8.2×10^{-9}
Leak Rate after 20th Assembly, atm cc/sec	8.4×10^{-9}	7.8×10^{-7}	8.1×10^{-9}
Dimension A at Start, in.	.453	.452	.565
Dimension A after 5th Assembly, in.	.454	.452	.563
Dimension A after 10th Assembly, in.	.453	.452	.565

TABLE III. REPEATED ASSEMBLY TEST DATA (Cont'd)

	R4U1	R4U2	R6U1
Dimension A after 15th Assembly, in.	.455	.451	.566
Dimension A after 20th Assembly, in.	.454	.453	.655
Dimension B at Start, in.	.453	.453	.565
Dimension B after 5th Assembly, in.	.453	.454	.566
Dimension B after 10th Assembly, in.	.452	.453	.565
Dimension B after 15th Assembly, in.	.453	.454	.566
Dimension B after 20th Assembly, in.	.453	.453	.565
Dimension C at Start, in.	.574	.573	.688
Dimension C at Finish, in.	.576	.577	.688
Dimension D at Start, in.	.688	.688	.813
Dimension D at Finish, in.	.688	.688	.813

	R6U2	R8U1	R8U2
Temperature, ^{o}F	600	600	600
Pressure Each Cycle, psi	5900	5900	5900
Pressure for Leak Test, psi	4350	4350	4350
Size	-06	-08	-08
Torque, in-lbs	430	490	555

TABLE III. REPEATED ASSEMBLY TEST DATA (Cont'd)

	R6U2	R8U1	R8U2
Leak Rate at Start, atm cc/sec	9.5×10^{-8}	5.3×10^{-8}	2.5×10^{-9}
Leak Rate after 5th Assembly, atm cc/sec	Weld broke	5.9×10^{-8}	3.2×10^{-9}
Leak Rate after 10th Assembly, atm cc/sec		3.5×10^{-8}	4.6×10^{-9}
Leak Rate after 15th Assembly, atm cc/sec		1.2×10^{-8}	1.3×10^{-9}
Leak Rate after 20th Assembly, atm cc/sec		5.7×10^{-8}	2.9×10^{-9}
Dimension A at Start, in.	.565	.668	.668
Dimension A after 5th Assembly, in.		---	---
Dimension A after 10th Assembly, in.		.668	.668
Dimension A after 15th Assembly, in.		.668	.667
Dimension A after 20th Assembly, in.		.667	.667
Dimension B at Start, in.	.565	.667	.665
Dimension B after 5th Assembly, in.		---	---
Dimension B after 10th Assembly, in.		.667	.667
Dimension B after 15th Assembly, in.		.668	.667
Dimension B after 20th Assembly, in.		.669	.667
Dimension C at Start, in.	.689	.800	.801
Dimension C at Finish, in.		.800	.800

TABLE III. REPEATED ASSEMBLY TEST DATA (Cont'd)

	R6U2	R8U1	R8U2
Dimension D at Start, in.	.813	.934	.935
Dimension D at Finish, in.		.935	.935
	R12U1	**R12U2**	**R16U1**
Temperature, ^{o}F	600	600	600
Pressure Each Cycle, psi	5900	5900	5900
Pressure for Leak Test, psi	4350	4350	4350
Size	-12	-12	-16
Torque, in-lbs	1240	1400	2580
Leak Rate at Start, atm cc/sec	7.6×10^{-9}	1.1×10^{-8}	
Leak Rate after 5th Assembly, atm cc/sec	Leak in weld	5.8×10^{-8}	
Leak Rate after 10th Assembly, atm cc/sec		7.8×10^{-8}	
Leak Rate after 15th Assembly, atm cc/sec		1.3×10^{-8}	
Leak Rate after 20th Assembly, atm cc/sec		1.7×10^{-8}	
Dimension A at Start, in.	.892	.890	1.228
Dimension A after 5th Assembly, in.	.892	.890	1.228
Dimension A after 10th Assembly, in.		.890	1.228
Dimension A after 15th Assembly, in.		.890	1.228
Dimension A after 20th Assembly, in.		.891	1.228

TABLE III. REPEATED ASSEMBLY TEST DATA (Cont'd)

	R12U1	R12U2	R16U1
Dimension B at Start, in.	.892	.890	1.104
Dimension B after 5th Assembly, in.	.892	.890	1.105
Dimension B after 10th Assembly, in.		.890	1.104
Dimension B after 15th Assembly, in.		.890	1.105
Dimension B after 20th Assembly, in.		.890	1.105
Dimension C at Start, in.	1.040	1.040	1.103
Dimension C at Finish, in.		1.040	1.105
Dimension D at Start, in.	1.188	1.188	1.434
Dimension D at Finish, in.		1.188	1.433

There was no evidence of thread galling, distortion, or damage of any kind; neither was there evidence of degradation of the flange-cavity sealing surfaces. In all respects the connector was as usable after 20 assemblies as it was after the first.

D. VIBRATION

Six 3/8-inch unions and four 1/2-inch unions were evaluated under vibration conditions. The results are presented in Table IV.

TABLE IV. VIBRATION TEST DATA

Specimen No.	10	11	12	13	10	11	12	13
Tube Size, in.	3/8	3/8	3/8	3/8	1/2	1/2	1/2	1/2
Torque, 16-in.	380	380	380	380	490	490	490	490
Frequency, cps	70	70	70	70	115	115	115	115
No. of Cycles Completed in 1000's	252*	300	144*	220*	300	200*	275*	207*
Max. Leakage 10^{-7} atm cc/sec	1.70	2.50	3.10	0.06	0.04	0.30	0.20	0.08

*Test discontinued after tubing broke.

All of the connectors were vibrated at the natural frequency, which varied from 70 to 115 cps. A bending movement of 41.5 in-lb was applied to the 3/8-inch connectors, and a bending movement of 98.5 in-lb was applied to the 1/2-inch connector. When the tubing failed at one of the supports, the test was terminated. In all cases the maximum leakage measured was less than 3.1×10^{-7} atm cc/sec.

SECTION V

MISALIGNMENT AND SEAL LOAD INVESTIGATION

The 3/4-inch AFRPL connectors were used in a field installation (Figures 11 and 12) during the program. The connectors were installed per Military Standard, MS 27850 (USAF), which governs installation procedures. All of the connectors which were in the system were leak-checked, and five leaked. Two of these were disassembled and it was found that one seal leg was formed into the seal cavity in the normal manner, however, the other seal leg was only partially contained in the seal cavity. Measurements were made between the nut thread diameter and nut hub diameter. This identified the misaligned condition which the connector and seal experienced.

While the remaining AFRPL connectors were still in place in the environmental chamber, they were welded at the hub and threads (Figure 13), then they were removed from the facility and sent to Battelle Memorial Institute (BMI) for investigation. The three assembled connectors and two seals from the disassembled connectors were included.

The separate seals were examined first. The disks appeared to have been fully deflected, the tang had apparently been satisfactorily yielded, and a seal seating surface approximately 0.010 inch wide was visible on the four sealing disks. Under a medium-power microscope, the sealing surface of one disk was seen to have a pronounced ridge where the seal had apparently been pressed against the edge of the flange cavity during an improper partial assembly prior to final assembly. The ridge was sufficiently large so that the seal could not have sealed properly even in an aligned connector. The other seal showed no obvious cause of leakage. The only visible differences between this seal and seals from past Battelle work were (1) tool marks were visible in the nickel plating, indicating that the surface finish of the machined seals was rougher than Battelle's seals

Figure 11. AFRPL Connector Field Installation

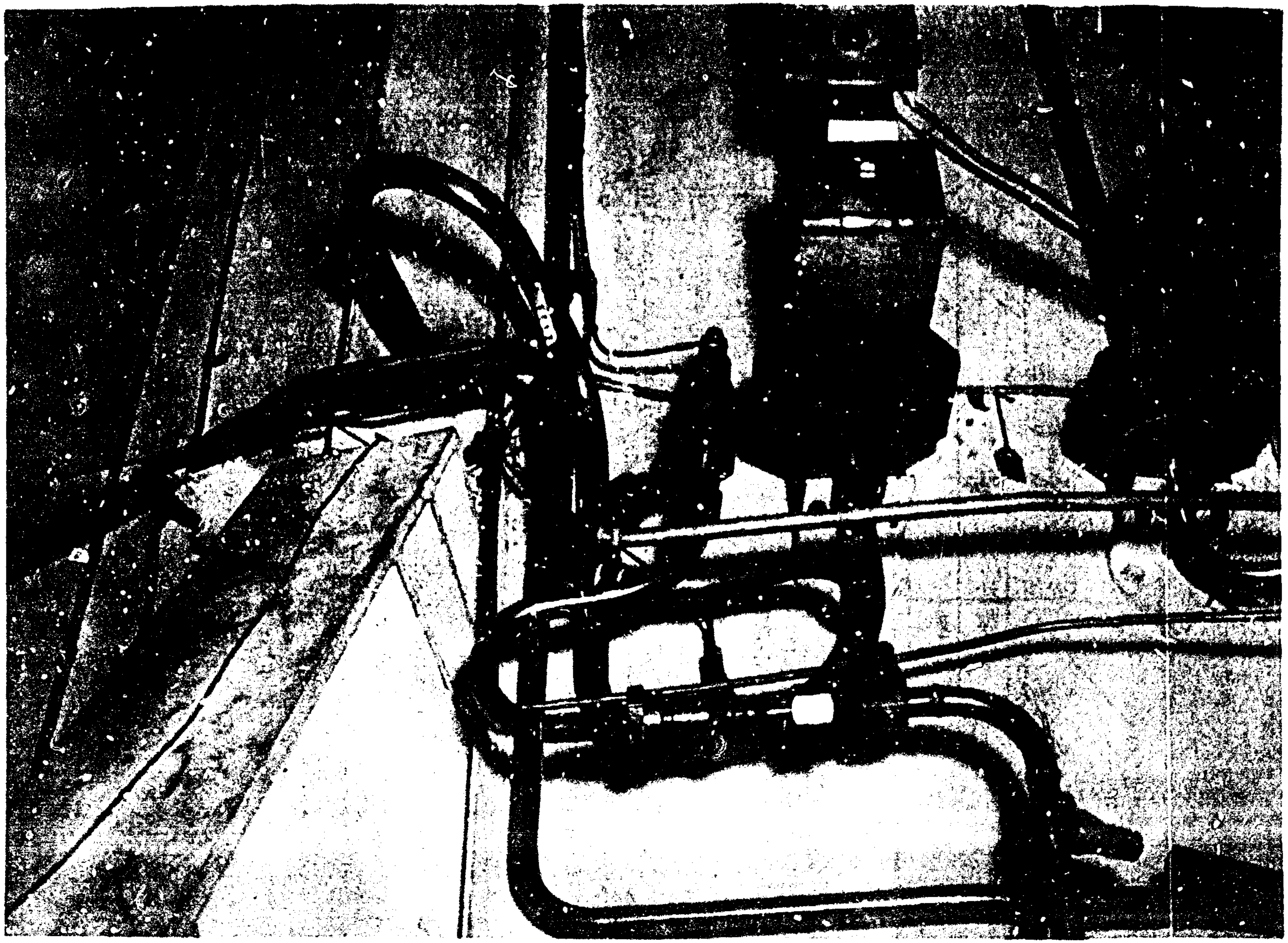


Figure 12. AFRPL Connector Field Installation

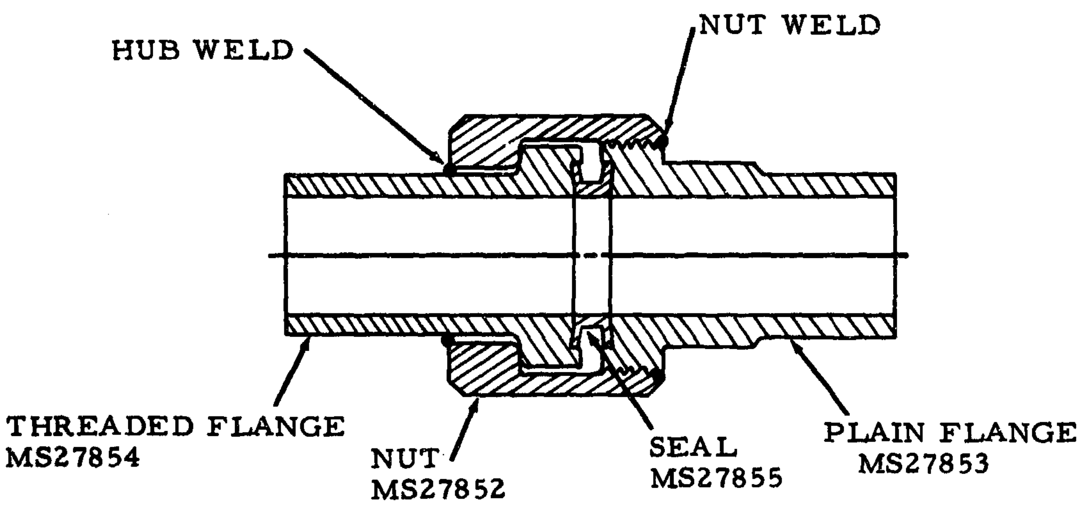


Figure 13. Connector Hub and Nut Weld Positions

had been, and (2) the nickel on the yielded surfaces had a mat finish, while past Battelle seals showed a very shiny surface where the nickel was yielded.

The absence of structural abnormalities in the separate seals indicated that it was necessary to examine the sealing surfaces at the source of leakage in the three connectors. To find the leaks in these connectors, three corners of the hex nuts of each connector which had been welded at the hub and threads were machined away. This exposed the outside of the seals but left the connectors held together by the three remaining nut corners. An O-ring-sealed plug was made to fit inside the connectors, and the inside of each connector was pressurized with helium. Soap solution was used to locate the sources of leakage.

The three connectors were then cut in half so that each connector half was still held together by 1-1/2 corners of the nuts. The connectors were cut so the leak was contained in one half. This half was then separated so the sealing surfaces at the leak could be examined. The other half was encapsulated, polished, and etched so the cross sections of the assembled connectors could be examined and the hardnesses of the nickel plating could be measured.

An examination of the leakage area in one connector showed that the edge of the flange cavity had been nicked by a sharp object, causing a peened, inward protrusion of the metal. This protrusion scratched the nickel plating on the sealing surface during assembly of the seal. It was believed that this seal could not have sealed satisfactorily even if the connector had been aligned.

The other two connectors showed no obvious cause of leakage. The general appearance of the seals was identical to that of the separate seals. The surfaces of the flange cavity did not exhibit abnormalities, although it appeared that the seals had not pressed as tightly against the flange surface in the general area of leakage as they had against other areas and against the flange which did not show a leak. Although the disk edges in one connector showed a somewhat different type of deformation, in general it was concluded that the seal structures had deformed normally. The coined sealing surfaces were approximately 0.010 inch wide. The seals were compared to seals that had previously performed satisfactorily.

The shiny appearance of the sealing surfaces on the Battelle seals indicated that the nickel had yielded more than was indicated by the mat sealing surface of the leaking seals. It was suspected that the plating of the leaking seals might be too hard. However, hardness readings showed that the hardness of the plating on the leaking seals was within specifications and was similar to the hardness readings taken on a cross sectioned seal.

Consideration was then given to the possibility that the seal was not providing sufficient resistance to yielding. This could have been caused by the material in the seals having a low yield strength, or by interaction between the two sides of the seal. Thus, if one disk grossly yielded the seal structure, this might have significantly reduced the resistance of yielding in the other disk-tang area.

Scientific Advances, Inc. (the seal manufacturer) had made tensile specimens from the material used for the seal. The Company records showed that the yield strength of the material in the 3/4-inch seals was approximately 35,000 psi. This was within the specifications and compared favorably with the yield strength of the Type 310 stainless steel seals of the same dimensions tested at Battelle-Columbus.

However, the difference in appearance of the nickel between the leaking seals and Battelle's past seals had not been explained. Battelle's Laboratory record books and reports for all of the work on stainless steel seals were reviewed. Two aspects of the past work seemed to be pertinent.

First, it appeared that higher radial sealing pressures had probably been attained during the early research on separable connectors. It was not possible to compare the values directly because so many different seal dimensions had been used, and most of the radial seal-seating loads were not measured directly. The axial seal-seating loads were always measured, but these included the force necessary to rotate the disks, and the mechanical advantage of the rotating disks was difficult to estimate. However, the axial-load peaks of early seals with dimensions similar to the leaking seals were generally about 30 percent higher than the axial-load peaks of the leaking seals. In addition, the thickness of the disks at the hinge line of the final seals (0.027 inch) was about 30 percent higher than the thickness (0.020 inch) of most of the disks of the early seals. Thus, a greater amount of the axial load required to seat the leaking seals was needed to rotate the disks (this force does not contribute to the radial seal-seating force) than was the case with the seals with thinner disks. In conclusion, it was estimated that the radial seal-seating pressure on the leaking seals was probably significantly lower than the radial seal-seating pressure on the early seals.

The second aspect was the difference in appearance of the axial seal-seating-load curve for the early seals and for the seals made to dimensions in the specifications. Most of the early curves showed two distinct humps. Each hump represented the seating action of a seal disk. Two humps were created because one disk was always stronger than the other disk. Many of the curves for the specification seals had one full hump and a partial hump. It was believed that the absence of a full second hump may have resulted from the first disk causing the tang to yield sufficiently that the second disk was not supported as much as normal by the tang. The possibility of interaction between the two sides of the tang was increased for the larger seals because the tang was shorter in relation to the tang thickness than was the case for the 3/8-inch seals (Table V). This interaction might explain the failure of the seals to function satisfactorily in the misaligned connectors despite the fact that all the seals functioned satisfactorily in the aligned connectors.

TABLE V. SEAL TANG LENGTH-TO-THICKNESS RATIOS

Tubing Size, in.	Seal Tang Thickness, in.	Seal Tang Length, in.	L/t Ratio
3/8	0.043	0.154	3.50
1/2	0.053	0.154	2.91
3/4	0.069	0.154	2.23
1	0.089	0.154	1.73

The need existed to perform additional tests to determine the radial sealing force of the 3/4-inch stainless steel. Strain-gaged rings were fabricated at Battelle from high-strength steel to replace the retaining lip of the 3/4-inch connector flanges. Plugs were machined to fit inside the rings so the seal tang could be compressed between the plugs and the seal disks would press outwardly against the load rings. These components were calibrated and then forwarded to the AFRPL. Axial load tests (Figure 14) were conducted using the seals supplied under contract from Scientific Advances, Inc. (SAI) for the 3/4-inch-O.D. connectors. These investigations were conducted to determine if the present seal load was marginal as suspected and to determine if a toggling interaction existed between the seal legs.

The assembled connector was placed into a tensile test machine and displacement was recorded along with the axial load which was being applied to the connector as a result of increasing the torque on the connector nut.

Load distribution inconsistencies in the seal legs were observed. Figure 15 illustrates that as the seals were loaded, one leg began to deform into the seal cavity, which is the first noticeable slope change (hump) of the curves; then the second leg deformed into its seal cavity, which is the next noticeable slope change.

The maximum radial sealing loads were measured for seven seals. The first two seals were seated normally with the disks both being seated in one loading. The next five seals were loaded to seat only one disk at a loading. The results of the load tests with these seals are shown in Table VI. Also shown are the measured maximum axial loads, the original seal disk diameters, and the percent of sealing surface that was matted, or did not seem to be as shiny as desired. Figure 16 shows a plot of the maximum measured radial load as a function of the maximum measured axial load. This confirmed the theoretical rule of thumb that the radial sealing load is approximately twice as great as the axial seating load.

From the studies, a model of the seal leg interaction was developed (Figure 17). As the seal loads increase, the first leg will start to deform and seal in the seal cavity. Then the second leg begins to deform. As the

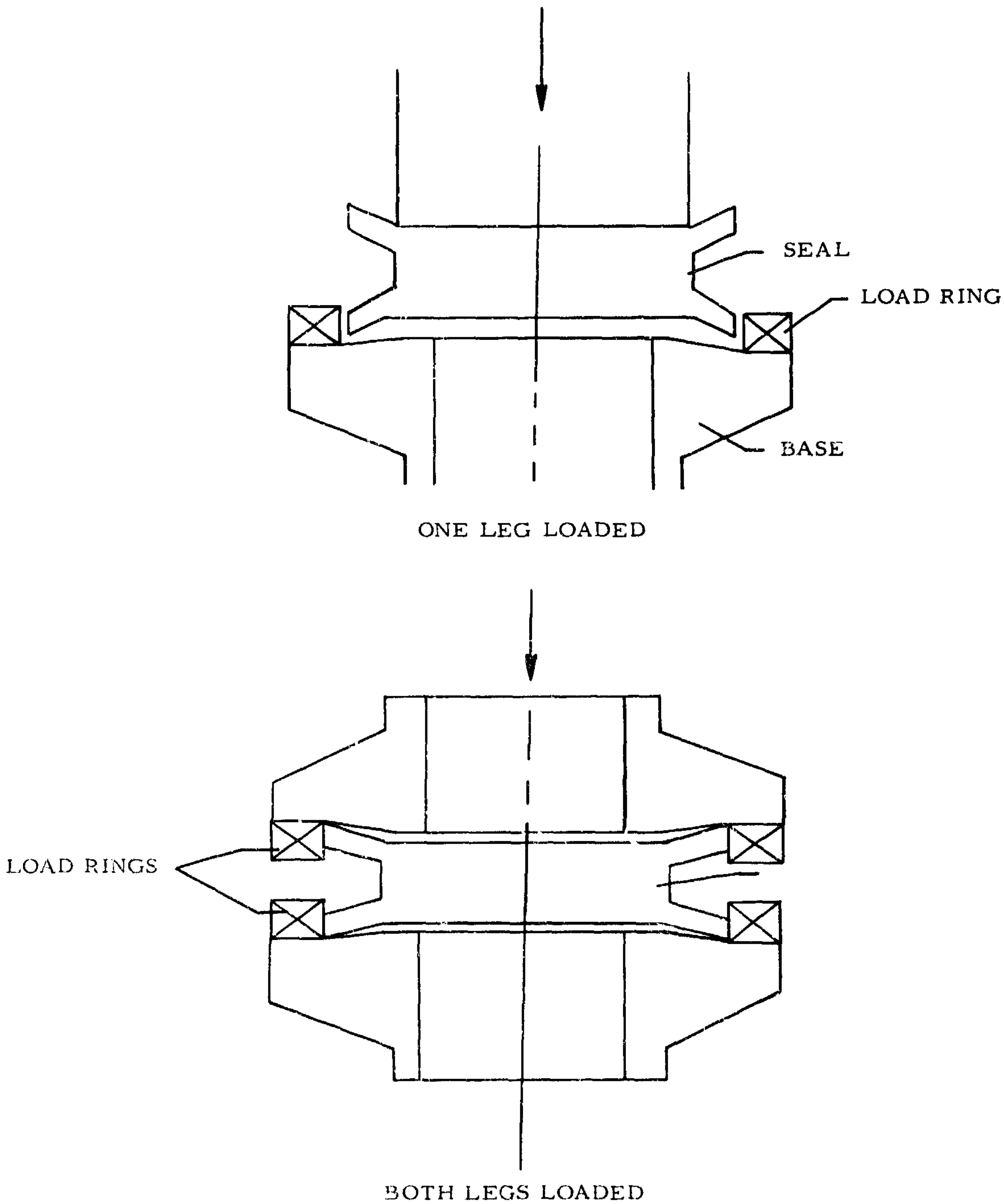


Figure 14. Seal Load Test Schematic

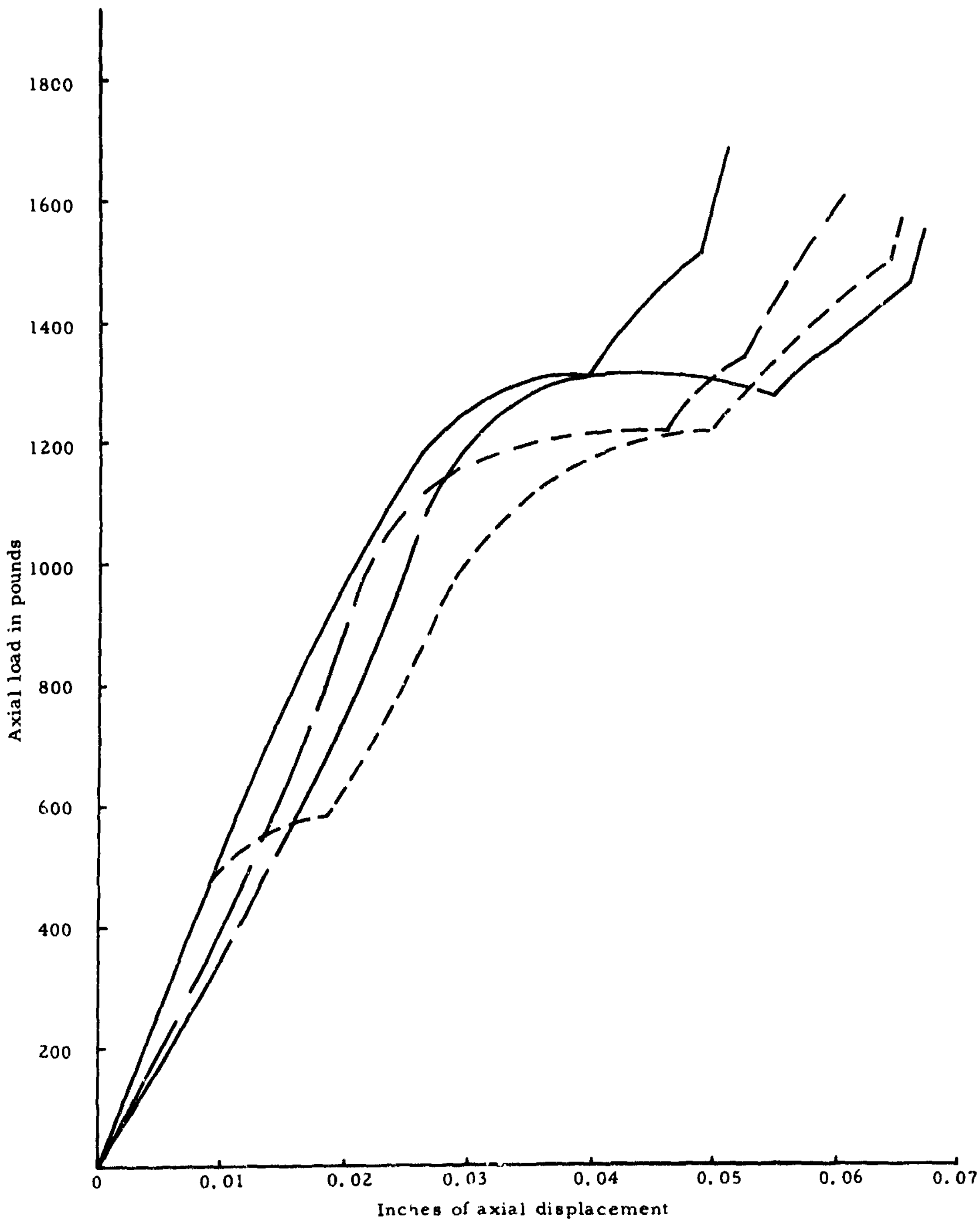


Figure 15. Axial Seal Displacement as a Function of Axial Seal Load

TABLE VI. LOAD TESTS MADE WITH SAI 3/4-INCH SEALS

Specimen No.	(a) Seal Disk Diameter/in.	(b) Max Axial Load, lb	Maximum Load Per In. of Seal Circumference: Axial Load lb/in.	Maximum Load Per In. of Seal Circumference: Radial Load lb/in.	(c) Percent of Matted Sealing Surface
1	0.884	1260	452	965	33
	0.887	1740	623	1275	33
2	0.885	1135	407	790	25
	0.887	1480	530	1174	10
3	0.882	1380	495	935	33
	0.887	2280	817	1385	None
4	0.887	1400	502	880	None
	0.887	1485	533	900	33
5	0.885	1330	477	885	50
	0.887	1580	567	1065	25
6	0.886	1410	506	990	25
	0.887	1775	637	1380	33
7	0.885	1400	502	1050	33
	0.881	1480	530	940	75

(a) Disks of specimens 1 and 2 seated during one loading. Disks of specimens 3 to 7 seated one at a time.

(b) ID of flange lip = 0.888 in.

(c) Based on ID of flanged lip.

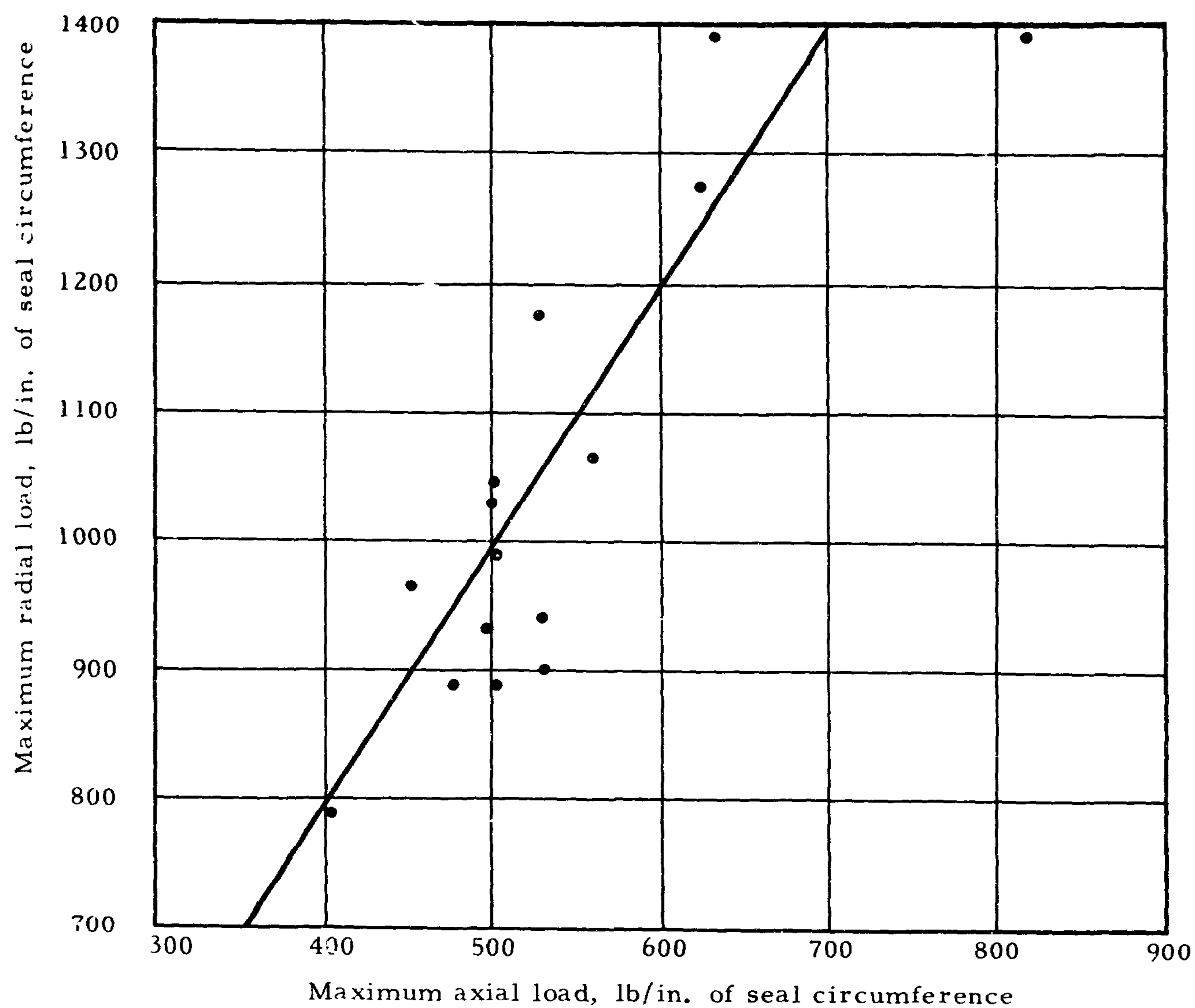


Figure 16. Comparison of Maximum Radial and Axial Seal-Seating Loads

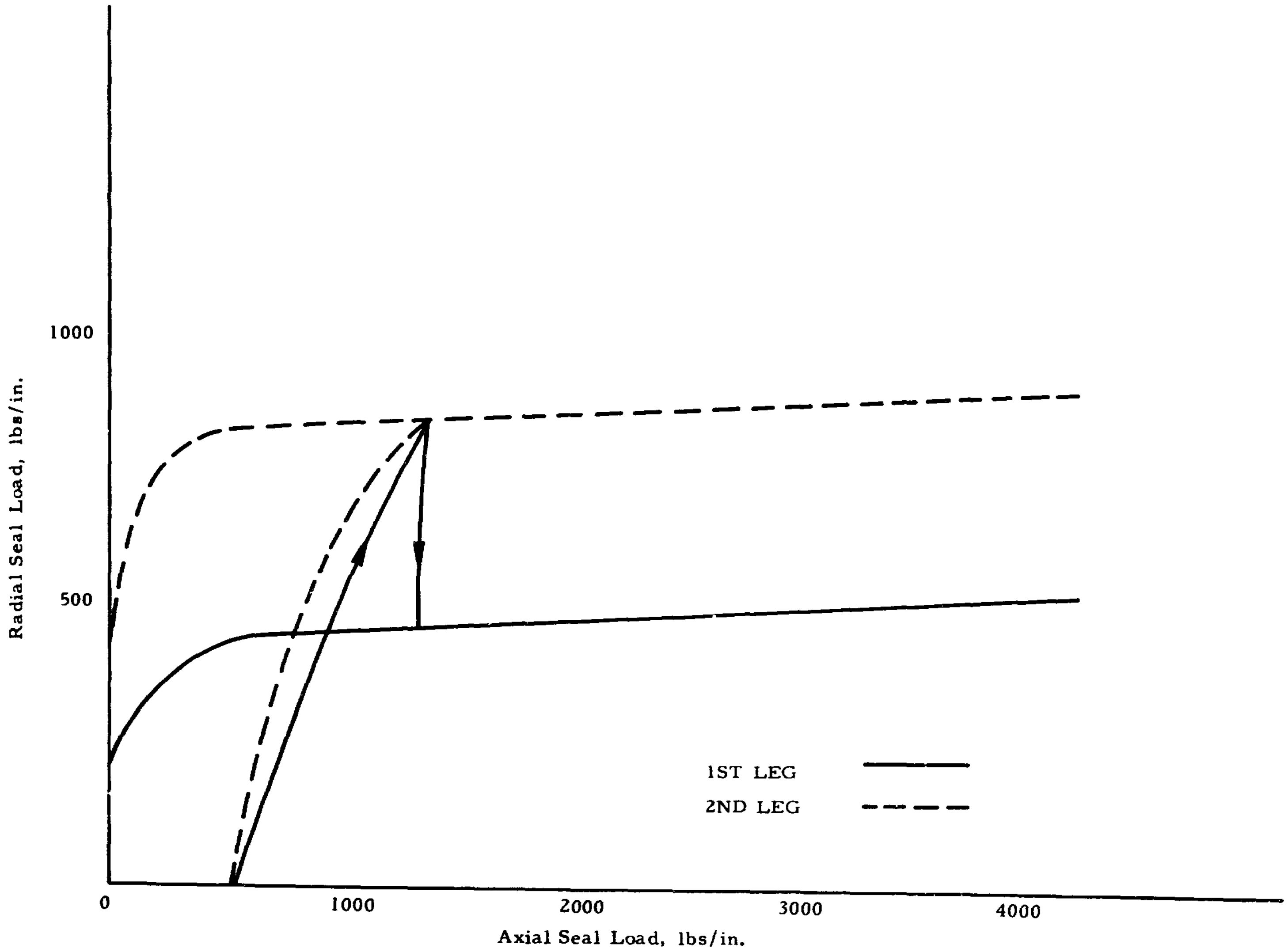


Figure 17. Seal Leg Interaction Model

second leg seal load approaches the seal load of the first leg, the seal load on the first leg is reduced and assumes a more constant load as the second leg continues to load until it has completely deformed, and seals in the seal cavity. That is to say, when the hinging effect of the second leg occurs, the radial seal load on the first leg is reduced and gives a portion of its load value to the second leg until it has sealed; then both legs assume a constant radial seal load, regardless of the increasing axial loads applied.

To demonstrate that this interaction between the seal legs can be eliminated and that there was a need to redesign the connector's seal, radial-seal-load tests were conducted using a longer tang length seal.

As a result of this testing, it was found that the toggling interactions were eliminated in a test run with a 0.300-inch tang length seal. The toggling effect can be eliminated by increasing the radial seal loads to the point that when the second leg hinges up into the seal cavity, the radial seal load assumed by the first leg is not subtracted away. With this in mind, using the 0.300-inch tang length seal, radial seal loads were obtained which were 400 lbs/in above the radial seal loads of the presently used 0.154-inch tang length seal. Figures 18 and 19 illustrate this condition for the different seals with different Rockwell hardness numbers. The increase in seal tang length is about 2.50% increase in radial seal load for the 3/4- and 1-inch-O.D. sizes. This increase apparently did not result in significant compression yielding at the base of the legs; however, a substantial increase in radial load at the seal surface was seen. Therefore, any desired increase in radial load would require an increase in seal leg thickness if the tang length were increased above 0.380 inches for 3/4-inch seals as shown in Figures 18 and 19.

Results obtained from tests utilizing the redesigned seal indicated that the connector will perform in a misaligned condition up to 3° angular displacement. The connector can be expected not to perform, and may therefore leak if during assembly operations any portion of the seal leg is

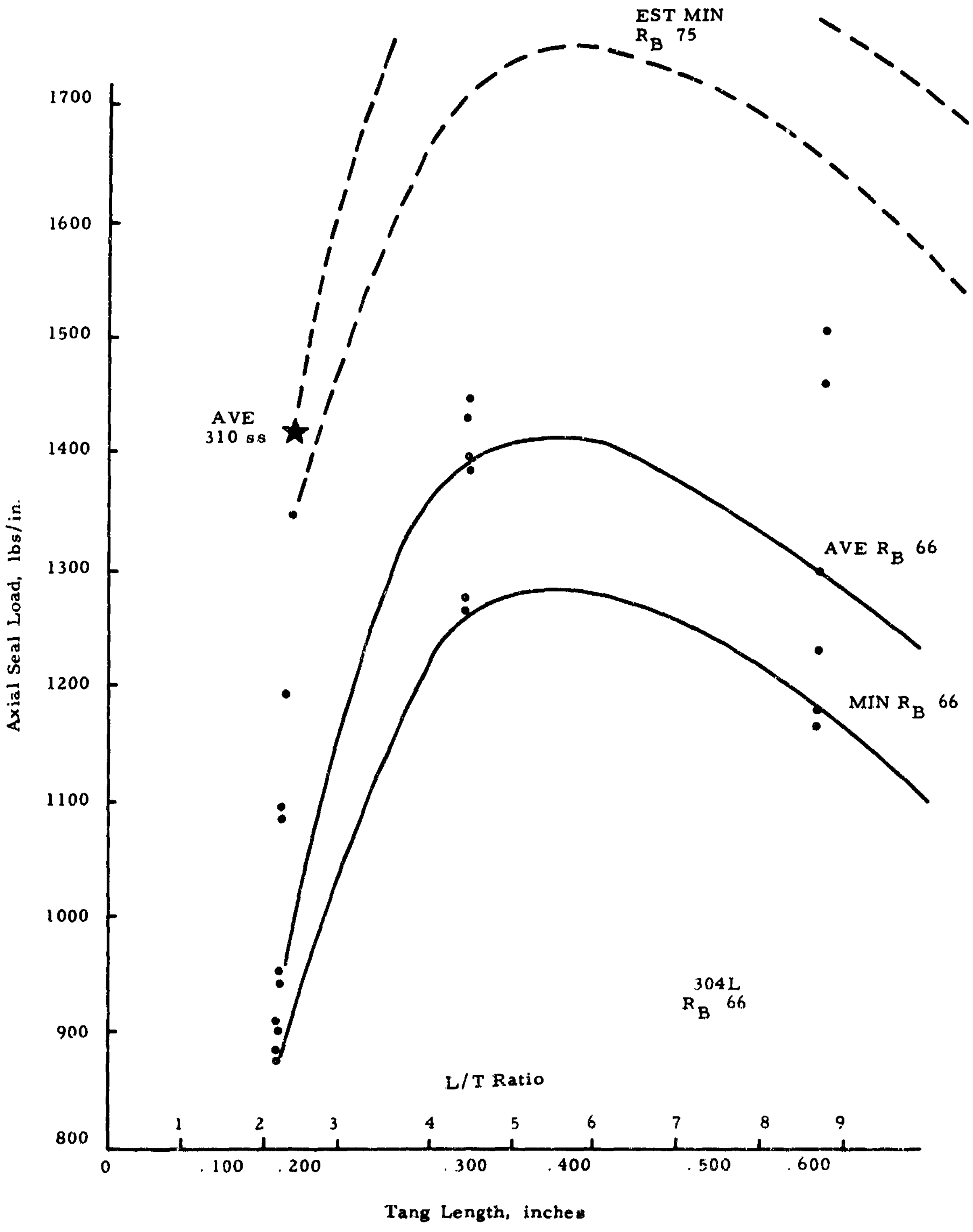


Figure 18. Seal Leg Thickness-to-Tang-Length Ratio Variations as a Function of Axial Seal Load.

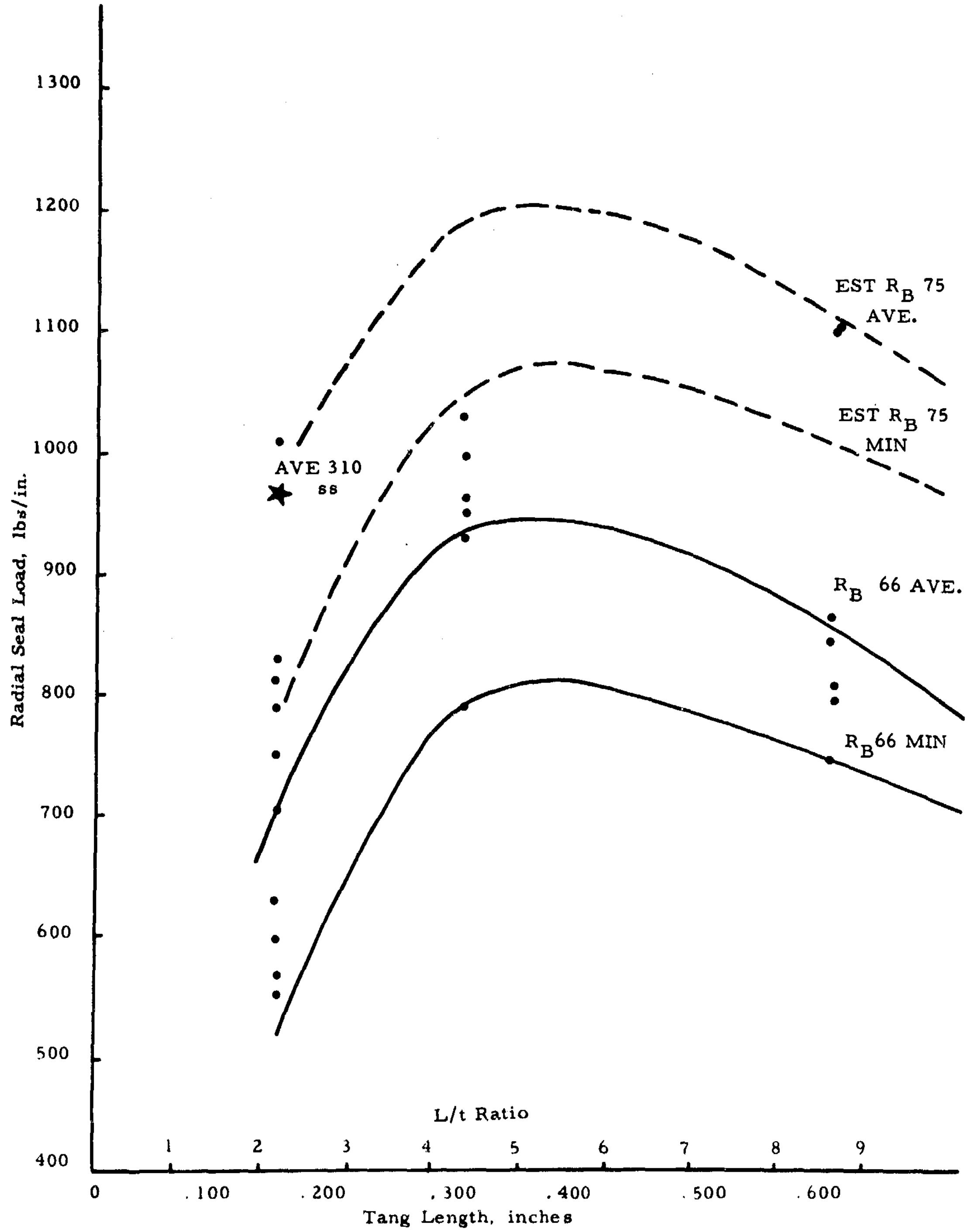


Figure 19. Leg Thickness-to-Tang-Length Ratio versus Radial Seal Load.

not completely engaged into the seal cavity. If the seal is not engaged into the seal cavity, damage to the sealing surface of the seal occurs during the assembly of the connector, thus leakage will develop almost immediately upon pressurizing the connector. Table VII shows the resultant leakage for the various misaligned conditions imposed upon the connector.

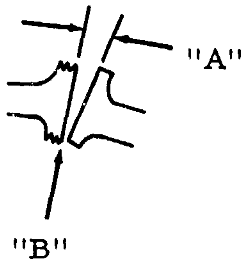
The major conclusion from this work was that the radial sealing load varied much more than was anticipated for seals made by the same manufacturer from one bar of material. Tentative conclusions were: (1) the initial fit of the seal was not a major load-determining factor; (2) dimensional variations within the seal probably were a major load-determining factor; and (3) the prevalence of the mat surface indicated the need for increased seal strength; and (4) the rule-of-thumb estimate that the radial sealing force was twice the axial sealing force was an effective approximation.

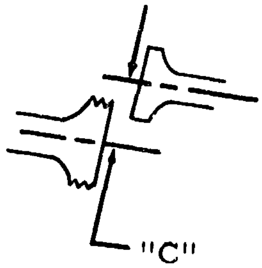
TABLE VII. MISALIGNMENT TE.'T RESULTS

Angle (degrees)	Offset in.	"A" in.	"B" in.	"C" in.	Leakage	Max. Torque in-lbs
1	.125	.032	.00	- **	**	1240
1 1/2	--	.057	.00	--	**	1240
2	.00	.053	.00	--	**	1240
2 1/2	.00	.042	.00	3/4	**	1240
3	.00	*	*	1- 1/8	--	1240

*The leg of the seal was not completely engaged in the seal cavity.

**Leakage was less than 10^{-7} atm cc helium/sec as measured with a mass spectrometer.





In the second series of tests it was shown that significant interaction existed between the seal disks. In essence it was shown that the radial load established by the first disk to seat could be reduced as much as 50 percent when the second disk was seated.

In the third series of tests, 3/4-inch seals were machined to the dimensions in the specifications from Type 304L stainless steel. Radial sealing forces from five seals varied fairly uniformly from 520 lb/in. to 830 lb/in. of seal circumference. It was thus shown that the introduction of a material-properties variation created a set of readings almost completely below those obtained from the SAI seals. It was also shown, however, that the lowest sealing load was still very close to the original design minimum of 600 lb/in.

In the fourth series of tests, 3/4-inch seals were made from Type 304L stainless steel with different tang lengths. These seals were seated to determine the effect of increased tang length on the radial sealing load and on disk interaction. It was found that a 100 percent increase in tang length resulted in a 50 percent increase in radial sealing load. A greater increase in tang length did not increase the radial sealing load significantly because the seal disks were not strong enough to yield a stronger tang.

Based on the work conducted at the AFRPL, it was concluded that the radial sealing load of the 3/4- and 1-inch stainless steel seals should be increased and that the increased load should be accomplished by lengthening the seal tang since this would tend to separate the seating action of the seal disks (Table VIII).

The successful operation of the bobbin seal depends upon achieving and maintaining metal-to-metal contact between the seal outside diameter and periphery of the flange seal cavity. Intimate metal-to-metal contact is obtained by creating radial contact stresses at the seal surface interface on the order of three times the yield strength of the seal surface material. The minimum radial loading that is required to achieve this contact stress level is about 1200 to 1500 pounds per lineal inch of seal circumference based on sealing material compressive yield strength of 10,000 psi, and seal contact width of 0.020 in.

In previous analysis of the seal, it was assumed that the seal legs made no significant contribution to the radial load; the radial load was determined by the strength of the tang.

To determine the design parameters that have significant effects on seal operation, additional seal analysis was conducted to include calculations for the radial load contribution by the seal legs.

It was assumed that the seal leg is a truncated conical element that, on assembly of the seal, is rotated or flattened to approach the shape of a disk. This action is illustrated by Figure 20.

After rotation, if the seal leg is not restrained radially, the outside diameter increases and the inside diameter decreases. Internal stresses

TABLE VIII. REDESIGNED AFRPL CONNECTOR DIMENSIONS AND DETAIL DRAWINGS

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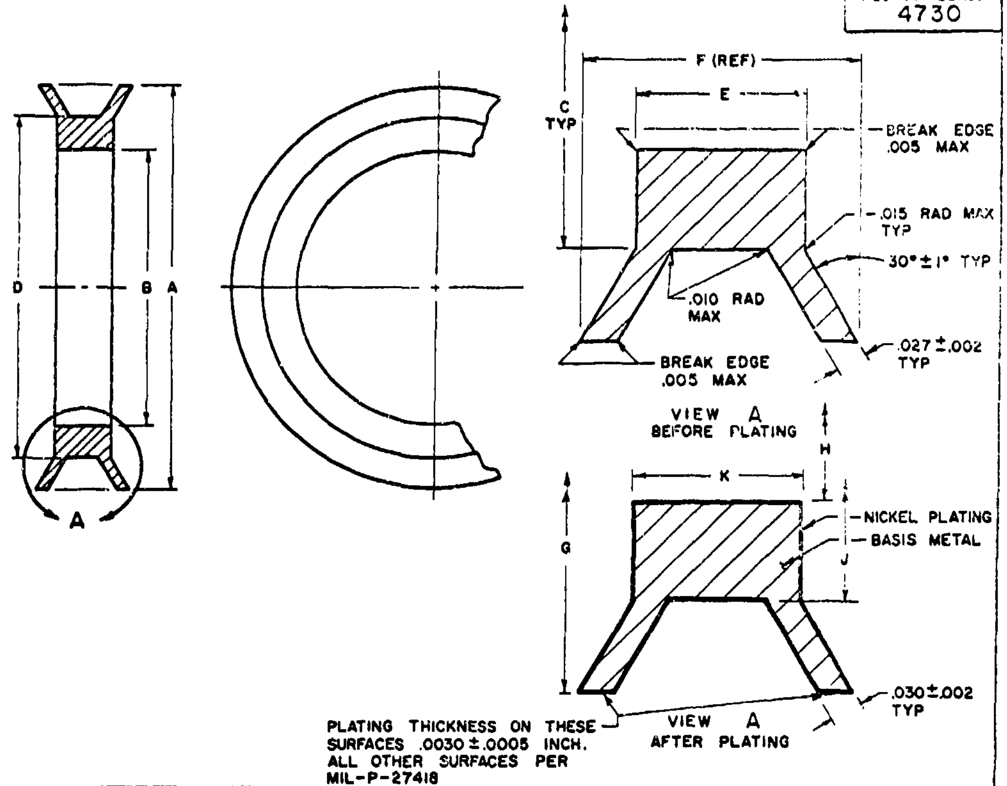


MS PART NO.	TUBE O.D.	A DIA +.000 -.002	B DIA +.002 -.000	C DIA +.010 -.000	D DIA +.000 -.005	E ±.004	F REF	G DIA +.001 -.003	H DIA +.002 -.000	J DIA +.000 -.005	K ±.004	APPROX. WEIGHT LB/100
MS27855-12	3/4	.880	.572	.710	.713	.195	.293	.886	.568	.717	[illegible]	.990
MS27855-16	1	1.092	.744	.922	.925	.195	.293	1.098	.740	.929	[illegible]	1.550

1. ALL DIAMETERS SHALL BE CONCENTRIC WITHIN .002 FIR.
2. MATERIAL: CORROSION-RESISTANT STEEL, AMS 5639, AMS 5650 OR AMS 5651.
3. FINISH: NICKEL PLATING PER MIL-P-27418.
4. CLEANING: FINISHED PARTS SHALL BE CLEANED PER MIL-F-27417.
5. SURFACE TEXTURE IN ACCORDANCE WITH USAS B46.1, UNLESS OTHERWISE SPECIFIED, SURFACES TO BE 32 MICROINCHES BEFORE PLATING.
6. BREAK SHARP EDGES .003 - .015 UNLESS OTHERWISE SPECIFIED.
7. DIMENSIONS IN INCHES. UNLESS OTHERWISE SPECIFIED, TOLERANCES: LINEAR DIMENSIONS ±.010, ANGULAR DIMENSIONS ± 5°.
8. RUBBER STAMP P/N AND MFR IDENT ON CONTAINER OR PACKAGING PER AS 478-30.
9. DO NOT USE UNASSIGNED PART NUMBERS.
10. REFER TO MS27851 FOR ASSEMBLY.

FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCURMENT DOCUMENTS REFERENCED HEREIN.
REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

APPROVED 14 JULY 1967 REVISED

exist in the flattened disk. Tensile hoop stresses exist around the outside diameter of the seal leg disk and compressive hoop stresses exist around the inside diameter of the seal leg disk.

Physical constraints are imposed on the seal leg disk by the seal cavity in the flange which limits the seal O.D. growth from about 0.001 to 0.007 inch plus any compression or distortion at the seal-to-flange contact area. A radial load is imposed on the inside of the seal leg disk by the inward deflection of the seal-to-tang joint, resulting in radial inward deflection of the tang.

A stress model for the seal leg disk can be constructed as illustrated in Figure 21. The assembled seal leg disk is now a completely flattened cone with loads and dimensions as shown in Figure 21.

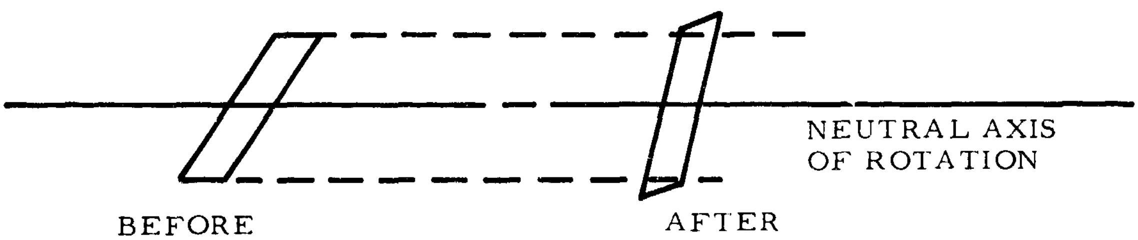


Figure 20. Seal Disk Rotation During the Seal Seating Operation

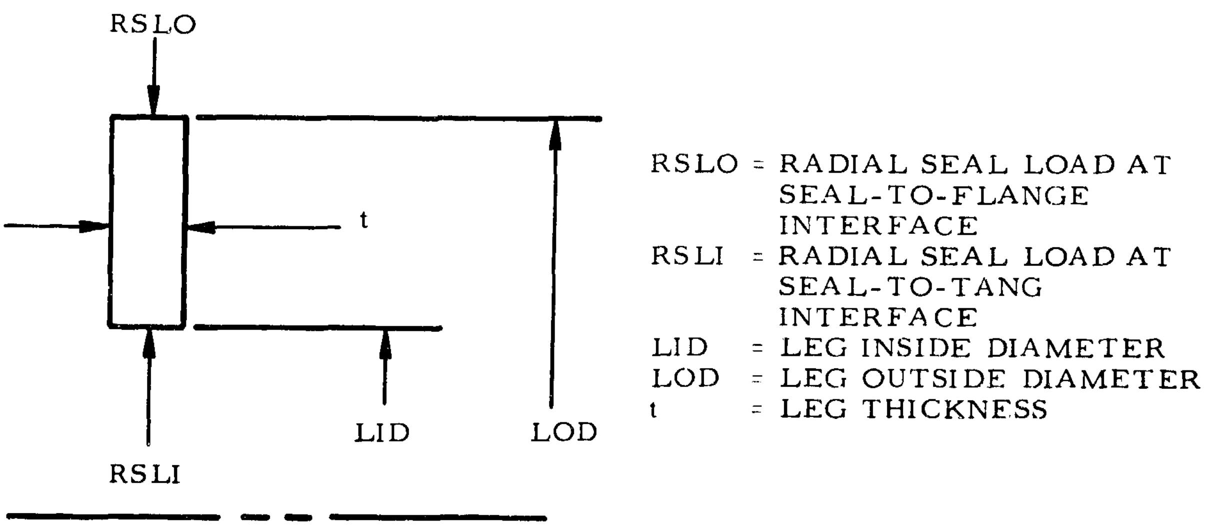


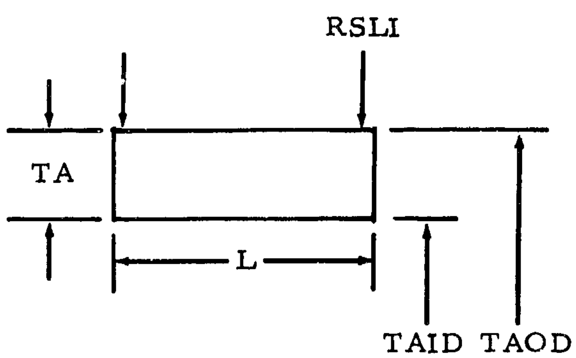
Figure 21. Seal Leg Stress Model

Radial seal load at seal-to-flange interface (RSLO) results from the effect of flattening the disk and the radial load contributed by the tang. The loop or circumferential stress at the leg inside diameter (LID) is limited by the material yield strength. Also, the direct radial stress resulting from the radial seal load at seal-to-tang interface (RSLI) is limited by the material yield.

Similarly, a model can be constructed for the seal tang as shown in Figure 22.

For this model, the load RSLI is limited by the loop strength of the tang material.

The radial load contributed at the inside diameter of the seal leg is distributed radially to the sealing surface.



RSLI = Radial Seal Load at Seal-to-Tang Interface
TA = Tang Thickness
L = Tang Length
TAID = Tang Inside Diameter
TAOD = Tang Outside Diameter

Figure 22. Seal Tang Stress Model

Examination of the physical dimensions of the seal elements before and after seal seating illustrates that some plastic deformation exists in the seal legs, particularly at the inside diameter, and definite plastic deformation exists for the seal tang element.

As observed before, the radial load available from seals fabricated from Type 347 CRES, which have been used, is apparently more than 600 lb/in. The 3/4- and 1-inch-size seals have less radial sealing load than the smaller sizes. An increase in seal tang length of about 30%, to 0.195 inch, for the 3/4- and 1-inch-size seal was to increase the radial load on these seals to approximately the same as for the 3/8- and 1/4-inch sizes. A greater increase was thought to result in significant compression yielding at the base of the legs with no substantial increase in radial load at the seal surface. Any further increase in radial load may require as increase in-seal leg thickness

A summary of seal load calculations is presented in Table IX. The detailed calculations are available in Appendix A.

Misalignment tests were performed on three 3/4-inch redesigned AFRPL connector seals with an L/t ratio of 2.88. These seals were fabricated from 304L stainless steel stock. The 304L steel was thought to have been a possible solution to the low radial seal load problem because of a higher yield strength than 310 stainless steel. This was found to be a false assumption after the seals had been tested unsuccessfully in the misalignment fixture. From a recent handbook, the yield strength for 310 was found to be 45,000 psi, and for 304L stainless steel, 33,000 psi, which is considerably lower. Increasing the tang length of the seal and fabricating these seals from 304L stainless steel raised the radial seal load but did not raise it above that of the regular Type 310 CRES seal design. The redesigned seals, therefore, did not perform as expected. They were found to be very temperature sensitive. The sensitivity of the connector seal regarding thermal cycling was determined to be a characteristic of low radial sealing loads.

TABLE IX. SUMMARY OF SEAL CALCULATIONS

Connector Size, in.	Connector OD (Approx. Installed), in.	Connector ID (Approx. Installed), in.	Connector Leg Thickness, in.	Connector Tang Thickness, in.	Connector Length, in.	Calculated Radial Seal Load - Lame Formulas Only, lb/ circumf. in. of sealing surface.	Calculated Radial Seal Load - Lame for Legs, Plastic for Tang, lb/ circumf. in. of sealing surface.
3/8	.564	.275	.027	.043	.150	705	759
						382	382
						1087	1142
1/2	.666	.368	.027	.053	.150	531	695
						332	332
						863	1028
3/4	.888	.558	.027	.069	.150	420	672
						260	260
						680	932
1	1.100	.730	.027	.089	.150	439	683
						215	215
						644	898

Six redesigned seals were tested to determine if the radial sealing loads were low. The indication of low radial seal loads in the thermal shock test were confirmed. Table X shows the results obtained from the axial load tests run on the six redesigned seals. Two of the seals were loaded with both seal disks being seated, and the remaining four were loaded with one leg being seated (see Figure 14).

TABLE X. EXPERIMENTAL RADIAL SEALING LOADS FOR THE INCREASED TANG-LENGTH-TO-TANG-THICKNESS RATIO SEALS

L/t = 2.88, 3/4-inch seals

BOTH LEGS SEATED				
Specimen No.	Maximum Axial Load lb.		Maximum Radial Load lb/in.	
	1st Leg	2nd Leg	1st Leg	2nd Leg
1	2,000	2,400	945	846
2	2,000	3,000	767	713

ONE LEG SEATED		
Specimen No.	Maximum Axial Load lb	Maximum Radial Load lb/in.
3	2,400	705
4	2,200	885
5	2,200	815
6	1,800	671

The work on the misalignment problem of the threaded connector led to a more intensive investigation of the radial sealing loads of the stainless steel connector seals. Increasing the seal tang length had more disadvantages than advantages. Most importantly, the increase in tang length would result in an increase in the size and weight of the connector. Related to these problems were problems associated with specification changes. Changing the size of the connector would result in revisions to the parts standards for the plain and threaded flanges, the nut, and the seal. The most desirable approach was considered to be limiting these changes to the seal part standard only.

Radial sealing loads were calculated for all the Type 310 stainless steel seals in the specifications. It was expected that this calculation would illustrate that the radial seal load was constant for all seal sizes. In fact, considerable variation in radial seal load was calculated. The radial sealing loads for the 3/8-inch seals were significantly higher than the loads calculated for the 3/4-inch seals of the specification dimensions and the loads calculated for the 3/4-inch seal with increased tang dimensions.

The 3/8-inch seals were seated in a connector and examined. The sealing surfaces of the 3/8-inch SAI seals seemed to be consistently shiny, and appeared to have a better sealing surface than the 3/4-inch or 1-inch SAI seals. This study resulted in defining the radial sealing load estimate required for the threaded connector seals. Table XI shows the radial sealing loads calculated for the specification seals using 40,000 psi and 50,000 psi yield strengths.

TABLE XI. CALCULATED RADIAL SEALING LOADS
FOR SPECIFICATION SEALS

Tubing Size, in.	Radial Sealing	Load, lb/in.
	Sy = 40,000 psi	Sy = 50,000 psi
3/8	913	1142
1/2	822	1028
3/4	745	932
1	718	898

The 3/8-inch sealing load was satisfactory and it appeared that this load would be defined minimum. Seal load tests were conducted with three 3/8-inch SAI seals. The disks of the first specimen were seated one at a time, while the disks of the second and third specimens were seated during one assembly. Table XII shows calculated and experimental loads for the 3/8-inch seals.

TABLE XII. EXPERIMENTAL RADIAL SEALING LOADS
FOR 3/8-INCH SPECIFICATION SEALS

BOTH LEGS SEATED				
Specimen No.	Maximum Axial Load lb		Maximum Radial Load lb/in.	
	1st Leg	2nd Leg	1st Leg	2nd Leg
1	1200	1310	1150	1150
2	1260	1490	1490	1230
ONE LEG SEATED				
3	1235		1410	

NOTE: Calculated radial sealing loads for the 3/8-inch specification seal are 1142 lb/in.

From this data a revised radial sealing load of 1200 to 1500 lb/in was determined to be the load value that the seal should be designed to meet.

Secondary to the marginal sealing load was a problem of the plating quality. This area was investigated by using a microscope and noting defective areas of seals before and after seating. Typical types of variations included pits, plating modules, grain surfaces, edge nicks, scratches, inclusions, and machining marks under the plating. Although various steps could be taken to improve the plating, these would result in substantial increase in plating costs. Therefore, it was determined that by increasing the radial sealing load sufficiently, the plating quality would be acceptable. Some seals were tested with higher radial sealing loads and the plating inadequacies were overcome and a good sealing surface was obtained.

The ideal approach to eliminating the problem of low radial sealing load was to develop a seal which could be fabricated to the present seal specifications. Several higher strength materials seemed to be capable of producing the required increase in radial sealing load within the specification seal dimensions (Table XIII). Such a material would provide greater spring-back in the seal and would minimize the problem of disk interaction because of the higher seal material yield strength properties.

Two basic approaches have been developed to accomplish the increase in radial seal loading. The use of a higher strength material for the entire seal, and the use of an insert ring of higher strength material in the tang of an austenitic stainless steel seal, are the two basic approaches which were formulated. The one-metal seal approach offered lower production costs and better production control than the two-metal seal approach.

The candidate materials (3) for a one-metal seal which show the most potential are: (1) cold-worked Type 304 CRES; (2) 19-9DL stainless steel; and (3) Armco 21-6-9 stainless steel (Table XIV).

TABLE XIII. HIGHER STRENGTH CANDIDATE SEAL MATERIALS

	SEAL MATERIAL						
Feature	Cold Rolled Austenitic S.ST.	A-286	21-6-9	19 9DL	400 Series S.ST.	AM 350	Decaloy
Thermal Expansion	8.8	10.3	9.3	8.6	6.0	6.3	8.5
Yield Strength (KSI)	35.95	85-100	57	70	60-145	173	85
Corrosion Compatibility	Acceptable	Unacceptable			Unacceptable	Acceptable	
Machining Index	50	27	50	40	50	50	30
Cost ($/LB)	.50	2.28	.60	1.00	.75	1.48	

TABLE XIV. MAJOR CANDIDATES FOR SEAL MATERIALS

Approach	Material	Load Capability	Design Change	Problems to Investigate
1	19-9DL	1500	Unchanged	1. Corr. Comp 2. Strength Variance 3. Plating 4. Flange Deformation
2	21-6-9	1500	Major Change	1. Corr. Comp 2. Strength Variance 3. Plating
3	Type 304 CRES	1500	Unchanged	1. Strength Variance 2. Flange Deformation

The one-metal seal approach is being investigated more extensively at the present. A concentrated effort is being made to solve the problems of low radial sealing load and associated problems by the one-metal approach. The progress at the writing of this report has advanced to a more extensive literature survey and design analysis of the major candidate seal materials. The results from the investigation should provide a seal material and design which will meet performance specifications in the 3/4- and 1-inch-size connectors.

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Leakage requirements were successfully met in the AFRPL connector sizes up to and including 1/2-inch O.D. The leakage requirements were not met with sufficient consistency in the 3/4- and 1-inch-O.D. connectors to conclude that they were acceptable for low-leakage gaseous system application.

The connector demonstrated that it was able to be repeatedly assembled without deforming the nut, galling threads, or deforming the seal cavity area.

Radial sealing loads are not sufficient in the 3/4- and 1-inch-size connectors to allow positive assurance of sealing helium at 400 psi with a maximum leak rate of 7×10^{-7} atm cc/sec. The 3/4- and 1-inch-size connector redesigned seals (tang length dimension increased) did not provide for a sufficiently high radial seal load to allow the connector to seal successfully under thermal gradient and structural integrity tests.

The AFRPL threaded connector will perform in a misaligned condition up to and including a 3° angular displacement.

All connectors demonstrated that they were structurally able to withstand the design loads. The 1/2-inch and smaller sized connectors demonstrated this better than the 3/4- and 1-inch size.

The 3/8- and 1/2-inch-size connectors are capable of withstanding vibration frequencies comparable to those encountered during a rocket firing. The 3/4-inch seal failed to meet the thermal gradient test of the performance specification. However, the connector did meet the performance specification in all other qualification tests. It can be concluded that the present 3/4-inch-specification connector would perform adequately in an aligned condition and when it is not subjected to high thermal gradient changes over very short transient time periods. The 3/4-inch and 1-inch connector is adaptable for liquid use but in a hot-gas application its performance is questionable.

An adequate lubricating grease is the MoS_2/Lubriseal mixture used during this program. It works very well and holds up under the extreme conditions imposed on the connector during testing.

The AFRPL connector in the size range for 1/8-, 1/4-, 3/8- and 1/2-inch tube diameters passed the qualification tests.

The one-metal seal approach appears to be the solution to the low radial seal load problem. Radial seal loads of 1200 to 1500 lb/in. appear to be good values for the threaded connector seals. Each candidate material meets the requirements for a seal to meet performance parameters and provide the increase in radial sealing loads that are desired.

B. RECOMMENDATIONS

The 1/8-, 1/4-, 3/8- and 1/2-inch AFRPL connectors produced by Scientific Advances, Inc. and tested during the 1 March to 1 November 1967 time period should be approved for the Qualified Producers List.

Testing of aluminum AFRPL connectors to develop QPL sources should be initiated.

An effort must be made to demonstrate an adequate seal design in the 3/4- and 1-inch sizes which will exhibit sufficient radial seal loads.

Testing of AFRPL connectors submitted by manufacturers for the purpose of placing the manufacturer on the Qualified Producers List of MIL-F-27417 should be continued.

REFERENCES

1. B. Goobich, et al; "Development of AFRPL Threaded Fittings for Rocket Fluid Systems"; Final Report; AFRPL-TR-65-162, AD 474789; Battelle Memorial Institute, Columbus, Ohio; November 1965; Unclassified Report.

2. Paul Bauer, et al; "Analytical Techniques for the Design of Seals for Use in Rocket Propulsion Systems, Vol I, Static Seals", and "Vol II, Dynamic Seals", AFRPL-TR-65-61, Vol I, AD 464958; Vol II, AD 464959; IIT Research Institute, Chicago, Illinois; May 1965; Unclassified Report.

3. Aerospace Structural Metals Handbook, Volume I, Ferrous Alloys, Syracuse University Research Institute, Syracuse, New York.

4. T.M. Trainer et al; "Development of AFRPL Flanged Connectors for Rocket Fluid Systems"; AFRPL-TR-69-97; Battelle Memorial Institute, Columbus, Ohio; July 1969; Unclassified Report.

5. S. Timoshenko and J.N. Goodier; "Theory of Elasticity"; McGraw-Hill Book Company, Inc., 1959, Chapter 4.

APPENDIX A

SEAL DESIGN CALCULATIONS

A new design procedure was developed which includes the material in the seal disks as well as the material in the seal tang. Although the calculation (4) is an approximation, the results of the procedure agreed with the experimental results for threaded seals, and was judged to be acceptable for large as well as small seals. The loads and dimensions for the seal tang and disk model are shown in Figure 23. The seal-design procedure is described below.

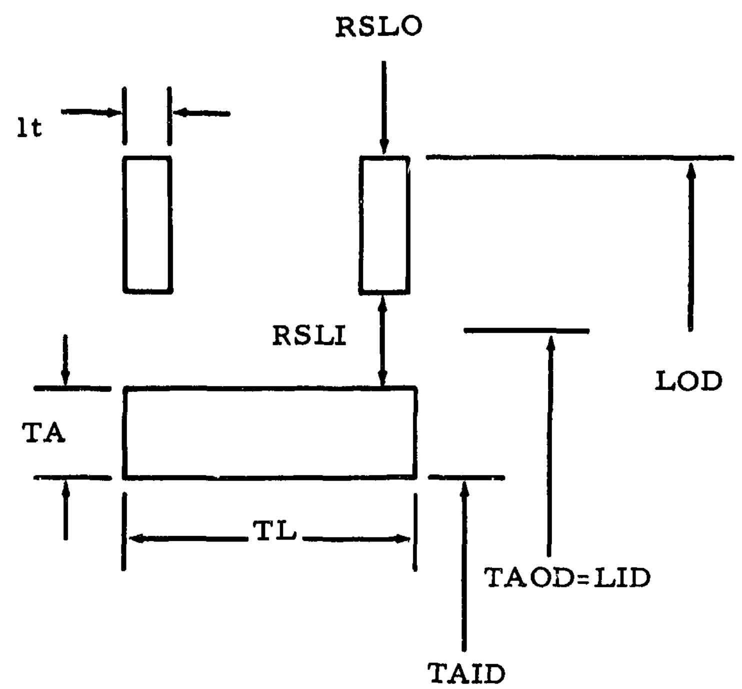
TAOD = tang outside diameter
TAID = tang inside diameter
T1 = tang length
TA = tang thickness.

Based on elastic stress/strain theory for thick-walled cylinders, (5) circumferential stress was related to radial loads as follows:

$$\sigma_\theta = -\frac{a^2 b^2 (p_o - p_i)}{(b^2 - a^2)} \cdot \frac{1}{r^2} + \frac{p_i a^2 - p_o b^2}{b^2 - a^2}$$

Where:

σ_θ = circumferential stress
a = inner radius
b = outer radius
p_i = inside pressure
p_o = outside pressure
r = location of stress.



RSLO = RADIAL SEAL LOAD AT SEAL-TO-FLANGE SURFACE
RSLI = RADIAL SEAL LOAD AT SEAL-TO-TANG INTERFACE
LOD = SEAL DISK OUTSIDE DIAMETER
LID = SEAL DISK INSIDE DIAMETER
lt = SEAL DISK THICKNESS

Figure 23. Seal Disk and Tang Stress Model

Considering the seal disk first, if the circumferential stress at LID equalled the yield strength of the material, the radial seal load increment contributed by the seal disk,

$$\Delta RSLO = \frac{S_y\ (b^2 - a^2) \times lt}{2b^2}$$

Where:

ΔRSLO = radial seal load, lb/in.

Similarly, the radial seal load increment contributed to each seal disk by the tank was calculated:

$$\Delta RSLI = \frac{S_y (b^2 - a^2)}{2b^2} \times \frac{Tl}{2}$$

Where:

ΔRSLI = radial load, lb/in. contributed to each seal disk by the tang.

It was assumed that the radial load at the inside diameter of the seal disk was distributed radially to the sealing surface. Thus:

$$RSLO = \Delta RSLO + \Delta RSLI \times \frac{LID}{LOD} .$$

The foregoing calculations were based on limits from idealized elastic seal elements. Examinations of the dimensions of typical seals showed that sufficient radial compression existed to create plastic deformation at the inside diameter of the seal disks and in the seal tang. Using plastic theory for the seal tang, the seal tang radial load contribution was calculated.

$$\Delta RSLIP = \frac{TL}{2} \times S_y \ln \frac{TAOD}{TAID}$$

and then

$$RSLO = \Delta RSLO + \Delta RSLIP \times \frac{LID}{LOD} .$$

APPENDIX B

MILITARY SPECIFICATIONS AND STANDARDS FOR THE AFRPL THREADED FITTING

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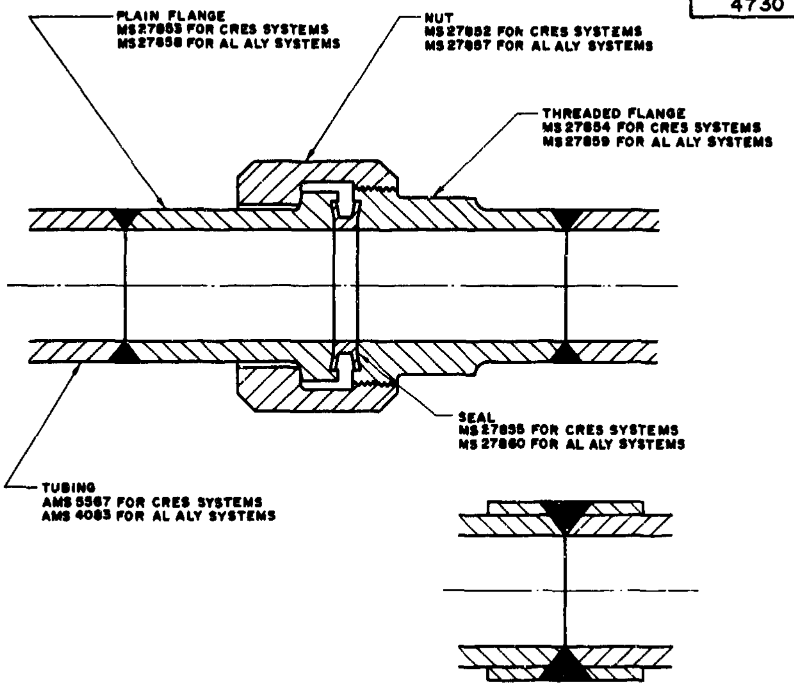

TUBING TO TUBING FITTING INSTALLATION

DASH NO. REF.		WRENCH TORQUE FOR TIGHTENING CRES FITTINGS (LB/IN) MS27851		WRENCH TORQUE FOR TIGHTENING AL ALY FITTINGS (LB/IN) MS27856	
		MINIMUM	MAXIMUM	MINIMUM	MAXIMUM
-02	1/8	75	90		
-04	1/4	200	225	100	125
-06	3/8	380	435	175	200
-08	1/2	490	555	280	320
-12	3/4	1240	1400	530	600
-16	1	2300	2580	1070	1200

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE FITTINGS, INSTALLATION OF STRAIGHT THREADED FLUID CONNECTION	MILITARY STANDARD MS 27850 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 1 OF 5

FED. SUP CLASS
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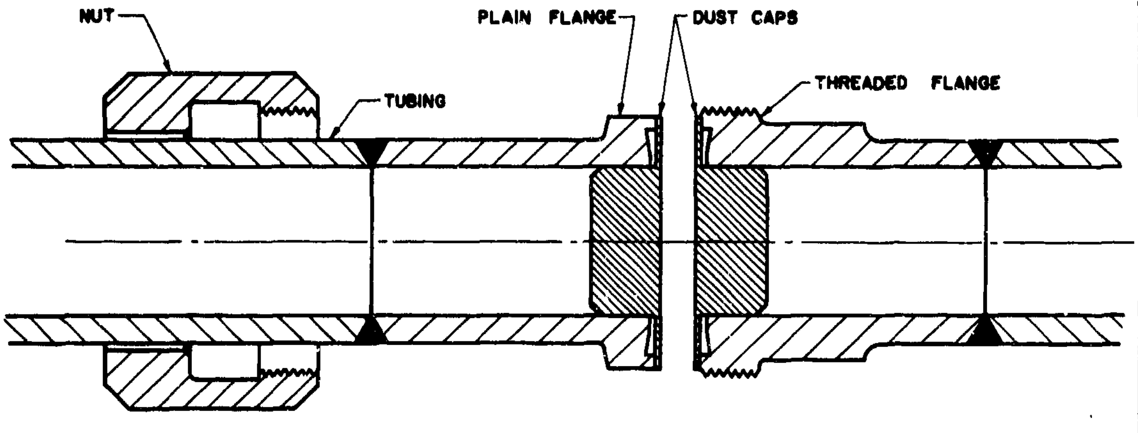
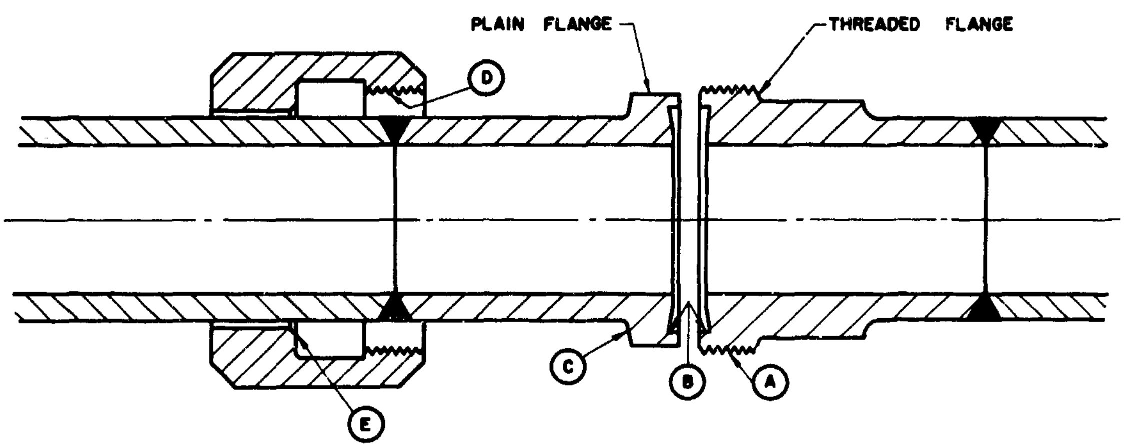


STEP 1

PLACE THE NUT ON THE TUBING TO BE ATTACHED TO PLAIN FLANGE. WELD PLAIN AND THREADED FLANGES TO TUBING.



STEP 2

REMOVE DUST CAPS. INSPECT SURFACES A, B, C, D, AND E FOR DIRT, CONTAMINATION, OR SURFACE IRREGULARITIES. IF NECESSARY RINSE SURFACES WITH METHYLETHYLKETONE AND DRY PARTS WITH FILTERED AIR STREAM OR WIPE PARTS WITH CLEAN PAPER TISSUE MOISTENED WITH METHYLETHYLKETONE. REPLACE DUST CAPS.

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P.A. USAF 12 Other Cust	TITLE FITTINGS, INSTALLATION OF STRAIGHT THREADED FLUID CONNECTION	MILITARY STANDARD MS27850 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 2 OF 5

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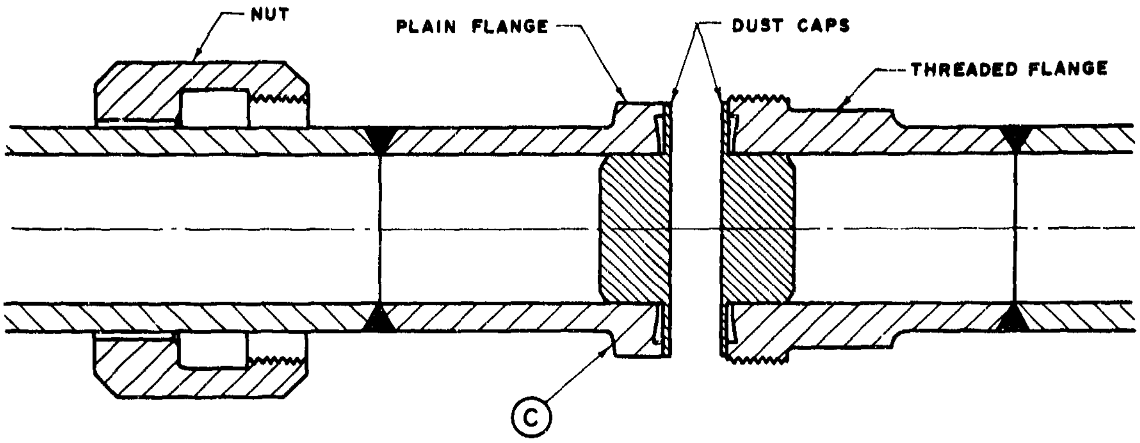
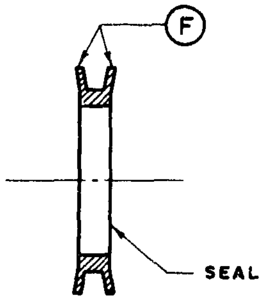


STEP 3

COAT MALE THREADS AND SURFACE C WITH LUBRICANT. APPLY LUBRICANT SPARINGLY. WORK THE NUT ONTO THE MALE THREADS AND AGAINST SURFACE C BY HAND. RETRACT NUT AND INSPECT SURFACES FOR EVEN COATING OF LUBRICANT. REMOVE EXCESS LUBRICANT FROM NONLUBRICATED SURFACES.



STEP 4

REMOVE SEAL FROM PROTECTIVE WRAPPING. INSPECT SURFACES F WITH 10 POWER LENS. DISCARD IF SURFACES ARE SCRATCHED OR IRREGULAR. CLEAN WITH METHYLETHYLKETONE IF DIRTY.

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P.A. USAF 12 Other Cust	TITLE FITTINGS, INSTALLATION OF STRAIGHT THREADED FLUID CONNECTION	MILITARY STANDARD MS 27850 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 3 OF 5

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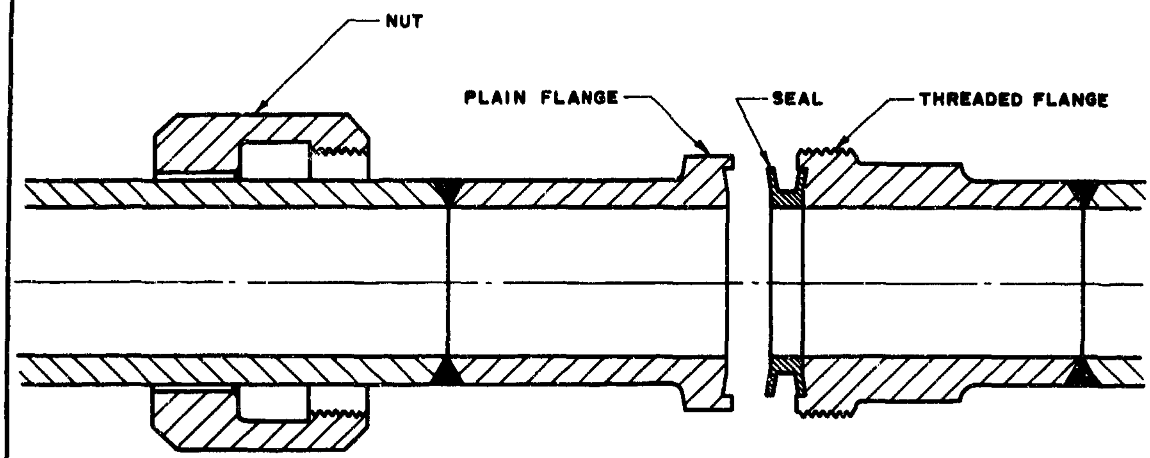
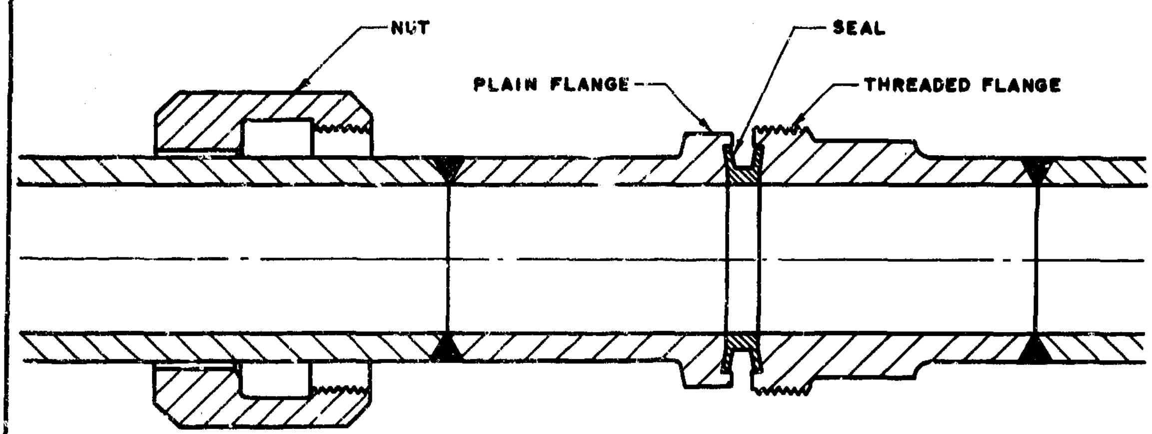


STEP 5

REMOVE DUST CAPS FROM PLAIN AND THREADED FLANGE AND INSERT SEAL. HANDLING WITH CLEAN HANDS IS PERMISSIBLE BUT CARE MUST BE EXERCISED TO AVOID GETTING LUBRICANT OR DIRT ON THE SEALING SURFACES.



STEP 6

LOCATE PLAIN FLANGE SO SEAL IS RETAINED IN THE SEAL CAVITY OF BOTH FLANGES. MAKE CERTAIN SEAL IS COMPLETELY INSERTED INTO BOTH PLAIN AND THREADED FLANGE SEAL CAVITIES.

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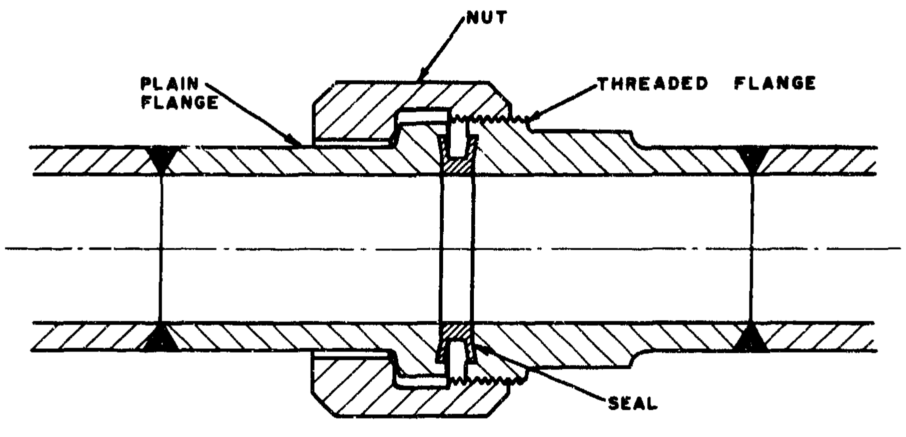
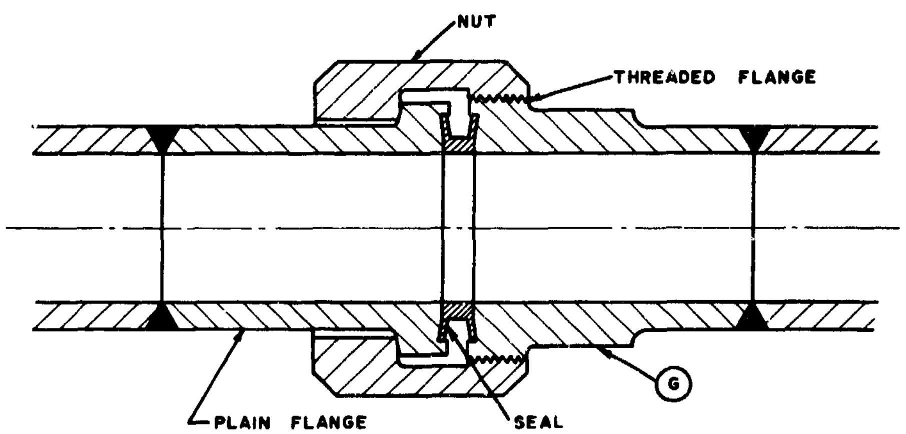
P.A. USAF 12 Other Cust	TITLE FITTINGS, INSTALLATION OF STRAIGHT THREADED FLUID CONNECTION	MILITARY STANDARD MS 27850 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 4 OF 5



STEP 7

TIGHTEN NUT HAND-TIGHT WHILE MAINTAINING LIGHT, FIRM PRESSURE ALONG AXIS OF FITTING TO PREVENT SEAL FROM SLIPPING OUT OF FLANGE CAVITIES.



STEP 8

PLACE OPEN-END WRENCH ON THREADED FLANGE, SURFACES G AND HOLD OR ALLOW TO BEAR AGAINST RIGID STRUCTURE TO PREVENT ROTATION. TIGHTEN NUT WITH CALIBRATED TORQUE WRENCH TO RECOMMENDED TORQUE. IF EITHER FLANGE HAS RELATIVE ROTATION MORE THAN 1/16 TURN, DISASSEMBLE AND REPLACE SEAL. PROPER ASSEMBLY IS INDICATED BY THREAD ENGAGEMENT. NO MORE THAN ONE THREAD OF EITHER THE THREADED FLANGE OR NUT SHOULD BE EXPOSED.

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE FITTINGS, INSTALLATION OF STRAIGHT THREADED FLUID CONNECTION	MILITARY STANDARD MS 27850 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 5 OF 5

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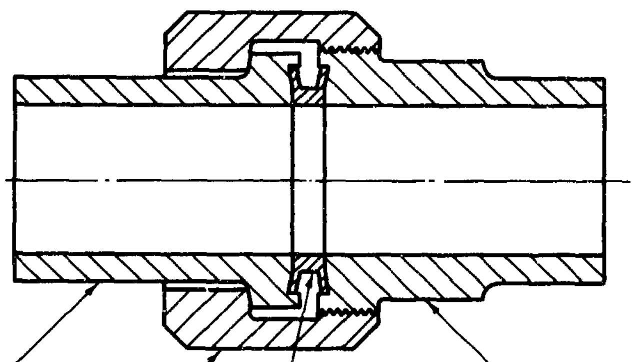

MS ASSEMBLY NO.	TUBE O.D.	NUT	PLAIN FLANGE	THREADED FLANGE	SEAL
MS 27851-02	1/8	MS 27852-02	MS 27853-02	MS 27854-02	MS 27855-02
MS 27851-04	1/4	MS 27852-04	MS 27853-04	MS 27854-04	MS 27855-04
MS 27851-06	3/8	MS 27852-06	MS 27853-06	MS 27854-06	MS 27855-06
MS 27851-08	1/2	MS 27852-08	MS 27853-08	MS 27854-08	MS 27855-08
MS 27851-12	3/4	MS 27852-12	MS 27853-12	MS 27854-12	MS 27855-12
MS 27851-16	1	MS 27852-16	MS 27853-16	MS 27854-16	MS 27855-16

1. DO NOT USE UNASSIGNED PART NUMBERS.
2. REFER TO MS 27850 FOR INSTALLATION INSTRUCTIONS.

FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCUREMENT DOCUMENTS REFERENCED HEREIN.
REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE FITTING ASSEMBLY, STRAIGHT THREADED, FLUID CONNECTION, 4000 PSI	MILITARY STANDARD MS 27851 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 1 OF 1

FED. SUP CLASS
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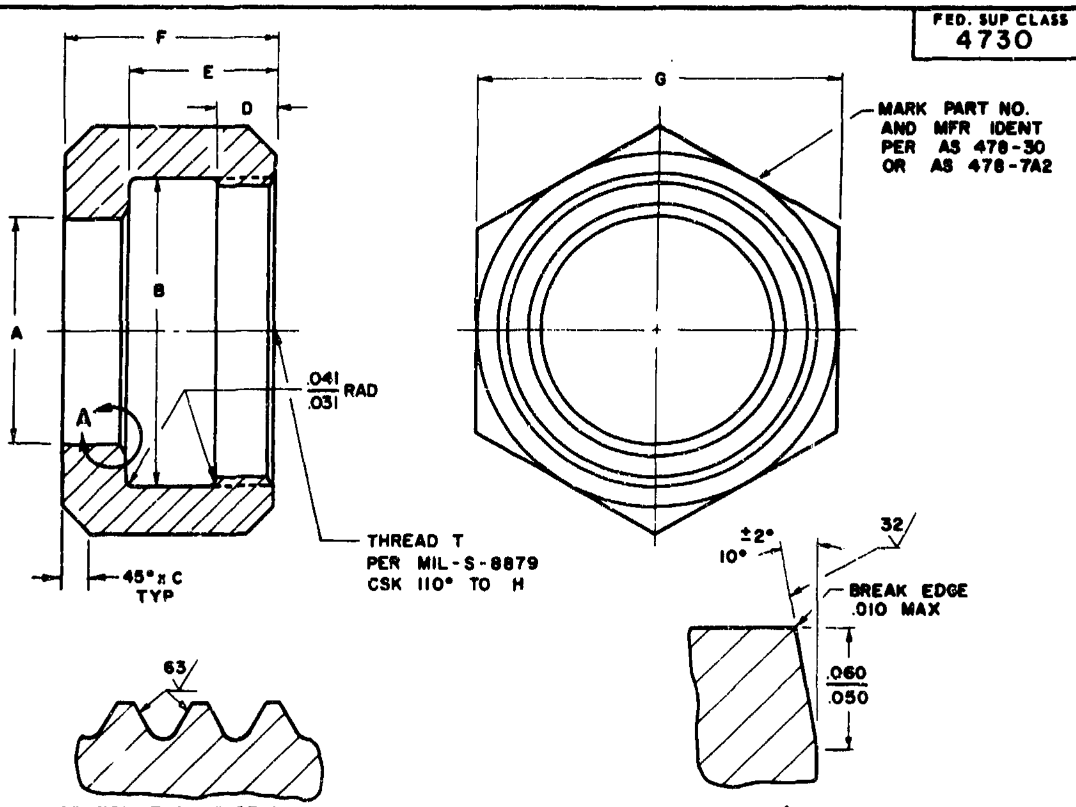


SECTION THRU THREAD PROFILE

VIEW A

MS PART NO.	TUBE O.D.	THREAD T UNJEF - 3B	A DIA ±.005	B DIA ±.004	C	D ±.005	E ±.005	F	G +.002 -.006	H DIA	APPROX WEIGHT LB/EA
MS27852-02	1/8	9/16 -24	.277	.563	.057	.213	.584	.720	.625	.562	
MS27852-04	1/4	5/8 -24	.379	.624	.063	.213	.576	.782	.688	.625	.034
MS27852-06	3/8	3/4 -20	.491	.752	.071	.255	.625	.880	.812	.750	.051
MS27852-08	1/2	7/8 -20	.593	.877	.082	.255	.635	.906	.938	.875	.066
MS27852-12	3/4	1-1/8 -18	.820	1.127	.101	.283	.658	1.008	1.188	1.125	.113
MS27852-16	1	1-5/16 -18	1.070	1.375	.120	.283	.616	1.031	1.438	1.312	.168

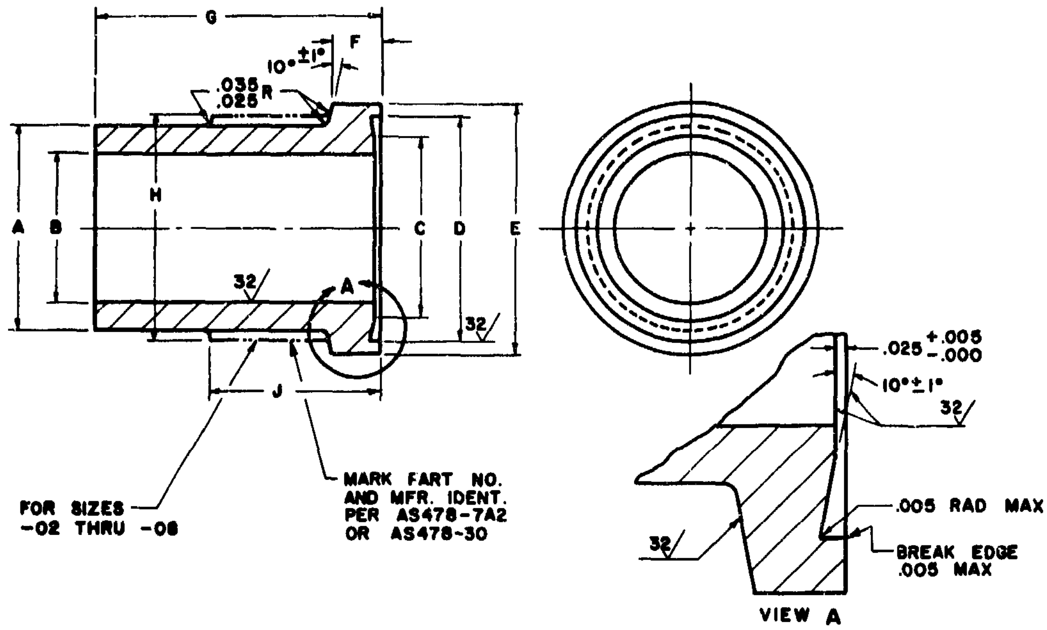
1. THREAD PD, HEX, A DIA AND B DIA, SHALL BE CONCENTRIC WITHIN .005 FIR.
2. MATERIAL: CORROSION RESISTANT STEEL AMS 5735.
3. CLEANING: FINISHED PARTS SHALL BE CLEANED PER MIL-F-27417.
4. SURFACE TEXTURE, IN ACCORDANCE WITH USAS B46.1, UNLESS OTHERWISE SPECIFIED, ALL MACHINED SURFACES TO BE 63 MICROINCHES.
5. BREAK EDGES .003-.015 UNLESS OTHERWISE SPECIFIED.
6. DIMENSIONS IN INCHES. UNLESS OTHERWISE SPECIFIED, TOLERANCES: DECIMALS ±.010, ANGLES ±5°.
7. DO NOT USE UNASSIGNED PART NUMBERS.
8. REFER TO MS27851 FOR ASSEMBLY.

FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCUREMENT DOCUMENTS REFERENCED HEREIN.
REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE NUT, CRES, FLUID CONNECTION FITTING, HIGH PRESSURE	MILITARY STANDARD MS27852 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 1 OF 1

FED. SUP CLASS 4730



MS PART NO.	TUBE O.D.	A DIA	B DIA ±.002	C DIA +.000 -.010	D DIA +.002 -.000	E DIA +.002 -.007	F ±.005	G	H DIA +.005 -.000	J ±.031	APPROX. WEIGHT LB/EA
MS27853-02	1/8	.125±.002	.083	.156	.350	.500	.313	1.125	.217	.440	
MS27853-04	1/4	.250±.003	.178	.260	.452	.582	.280	1.125	.319	.467	.027
MS27853-06	3/8	.375±.003	.275	.372	.564	.694	.258	1.250	.431	.503	.039
MS27853-08	1/2	.500±.004	.368	.470	.666	.805	.267	1.250	.533	.531	.057
MS27853-12	3/4	.750±.004	.558	.694	.888	1.045	.263	1.375	—	—	.104
MS27853-16	1	1.000±.005	.730	.904	1.100	1.235	.225	1.375	—	—	.163

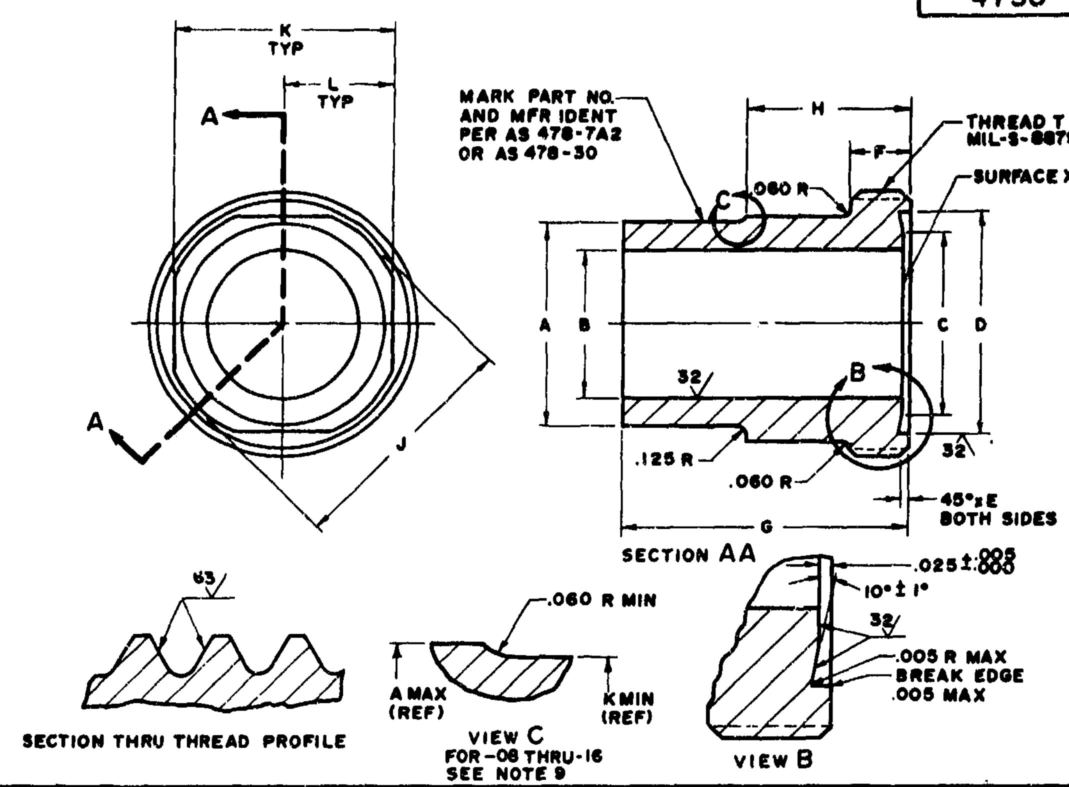
1. ALL DIAMETERS SHALL BE CONCENTRIC WITHIN .005 FIR.
2. MATERIAL: CORROSION RESISTANT STEEL AMS 5646.
3. CLEANING: FINISHED PARTS SHALL BE CLEANED PER MIL-F-27417.
4. SURFACE TEXTURE IN ACCORDANCE WITH USAS B46.1, UNLESS OTHERWISE SPECIFIED, ALL MACHINED SURFACES TO BE 63 MICROINCHES.
5. BREAK EDGES .003-.015 UNLESS OTHERWISE SPECIFIED.
6. DIMENSIONS IN INCHES, UNLESS OTHERWISE SPECIFIED, TOLERANCES: DECIMALS ±.010, ANGLES ±5°.
7. DO NOT USE UNASSIGNED PART NUMBERS.
8. REFER TO MS27851 FOR ASSEMBLY.

FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCUREMENT DOCUMENTS REFERENCED HEREIN.
REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE FLANGE, PLAIN, CRES, FLUID CONNECTION FITTING, HIGH PRESSURE	MILITARY STANDARD MS27853 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 1 OF 1

FED. SUP CLASS
4730



MS PART NO.	TUBE O.D.	THREAD T UNJEF-3A	A DIA	B DIA ±.002	C DIA +.000 -.010	D DIA +.002 -.000	E	F ±.005	G	H ±.031	J DIA	K +.002 -.006	L	APPROX WEIGHT LB/EA
MS 27854-02	1/8	9/16-24	.125±.002	.003	.156	.350	.030	.213	1.125	.463	.300	.250	.125	
MS 27854-04	1/4	5/8-24	.250±.003	.178	.260	.452	.030	.213	1.125	.463	.361	.312	.156	.024
MS 27854-06	3/8	3/4-20	.375±.003	.275	.372	.564	.035	.255	1.250	.567	.505	.437	.218	.046
MS 27854-08	1/2	7/8-20	.500±.004	.368	.470	.666	.035	.255	1.250	.630	.577	.500	.281	.066
MS 27854-12	3/4	1-1/8-18	.750±.004	.558	.694	.888	.040	.283	1.375	.720	.866	.750	.406	.128
MS 27854-16	1	1-5/16-18	1.000±.005	.730	.904	1.100	.040	.283	1.375	.783	1.155	1.000	.531	.161

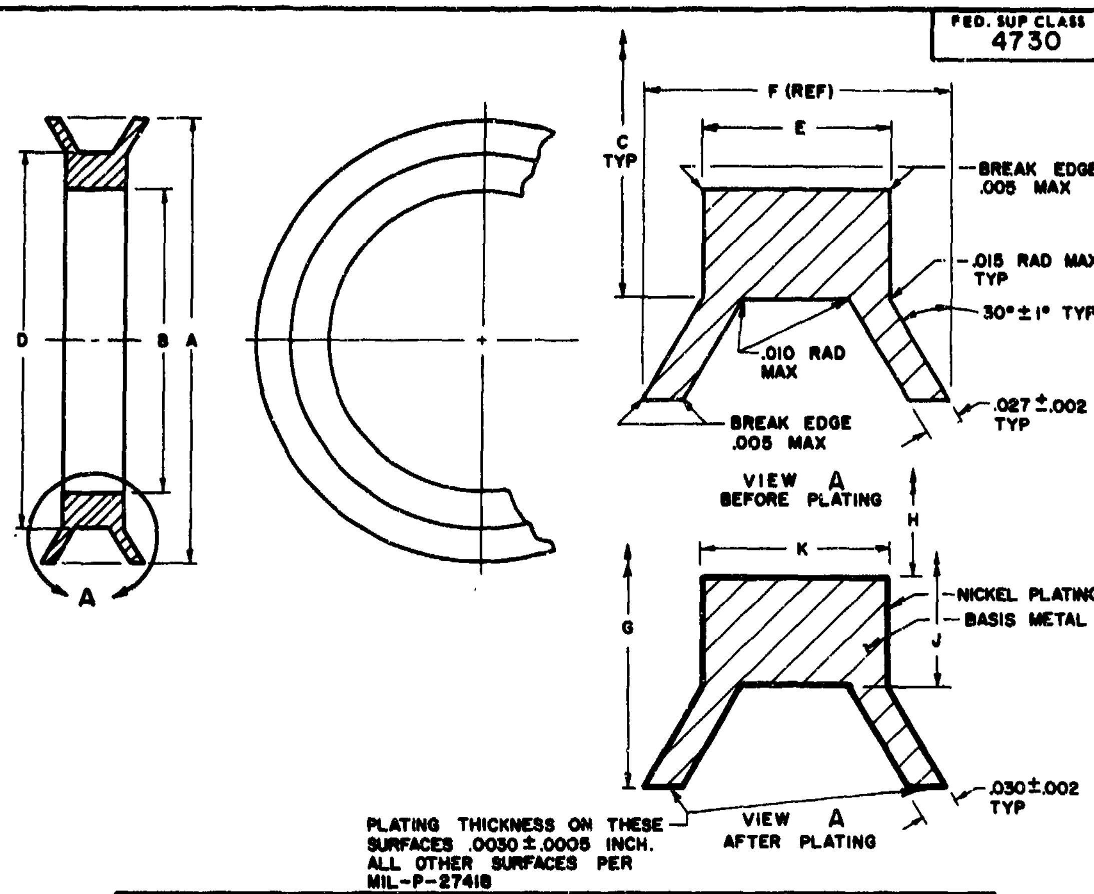
1. THREAD PD SHALL BE SQUARE WITH SURFACE X WITHIN .005 FIR AND CONCENTRIC WITH DIA D WITHIN .005 FIR.
2. MATERIAL: CORROSION-RESISTANT STEEL, AMS 5646.
3. CLEANING: FINISHED PARTS SHALL BE CLEANED PER MIL-F-27417.
4. SURFACE TEXTURE, IN ACCORDANCE WITH USAS B46.1, UNLESS OTHERWISE SPECIFIED, ALL MACHINED SURFACES TO BE 63 MICROINCHES.
5. BREAK EDGES .003-.015 UNLESS OTHERWISE SPECIFIED.
6. DIMENSIONS IN INCHES, UNLESS OTHERWISE SPECIFIED, TOLERANCES: DECIMALS ±.010, ANGLES ±5°.
7. DO NOT USE UNASSIGNED PART NUMBERS.
8. REFER TO MS27851 FOR ASSEMBLY.
9. BLEND WRENCH FLATS K INTO DIA A AS SHOWN IN VIEW C, WHEN K IS LESS THAN A.

FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCUREMENT DOCUMENTS REFERENCED HEREIN.
REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE FLANGE, THREADED, CRES., FLUID CONNECTION FITTING, HIGH PRESSURE	MILITARY STANDARD MS 27854 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 1 OF 1

FED. SUP CLASS
4730



MS PART NO.	TUBE O.D.	A DIA +.000 −.002	B DIA +.002 −.000	C DIA +.010 −.000	D DIA +.000 −.005	E ±.004	F REF	G DIA +.001 −.003	H DIA +.002 −.000	J DIA +.000 −.005	K ±.004	APPROX. WEIGHT LB/100
MS27855-02	1/8	.342	.100	.172	.174	.095	.193	.348	.096	.178	.099	
MS27855-04	1/4	.444	.190	.274	.276	.120	.218	.450	.186	.280	.124	.220
MS27855-06	3/8	.556	.290	.386	.389	.180	.248	.562	.286	.393	.154	.440
MS27855-08	1/2	.658	.382	.488	.491	.150	.248	.664	.378	.495	.154	.500
MS27855-12	3/4	.880	.572	.710	.713	.150	.248	.886	.568	.717	.154	.990
MS27855-16	1	1.092	.744	.922	.925	.150	.248	1.098	.740	.929	.154	1.550

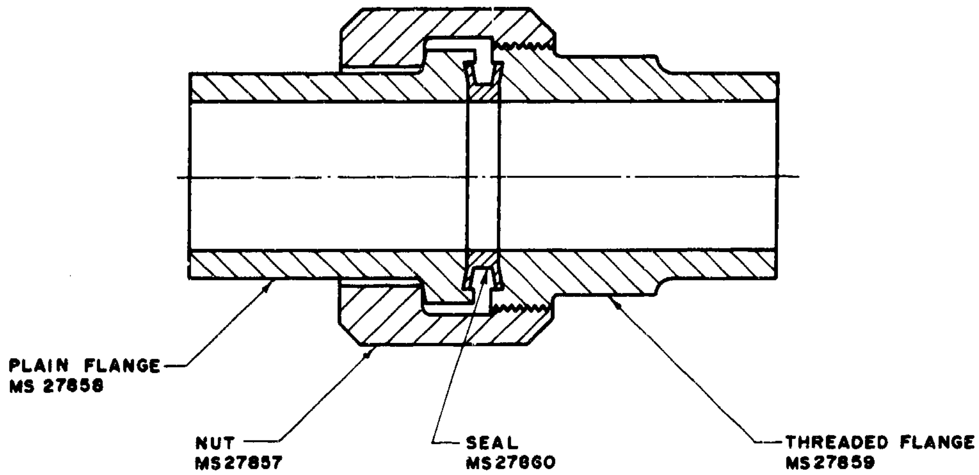
1. ALL DIAMETERS SHALL BE CONCENTRIC WITHIN .002 FIR.
2. MATERIAL: CORROSION-RESISTANT STEEL, AMS 5639, AMS 5650 OR AMS 5651.
3. FINISH: NICKEL PLATING PER MIL-P-27418.
4. CLEANING: FINISHED PARTS SHALL BE CLEANED PER MIL-F-27417.
5. SURFACE TEXTURE IN ACCORDANCE WITH USAS B46.1, UNLESS OTHERWISE SPECIFIED, SURFACES TO BE 32 MICROINCHES BEFORE PLATING.
6. BREAK SHARP EDGES .003 - .015 UNLESS OTHERWISE SPECIFIED.
7. DIMENSIONS IN INCHES. UNLESS OTHERWISE SPECIFIED, TOLERANCES: LINEAR DIMENSIONS ±.010, ANGULAR DIMENSIONS ± 5°.
8. RUBBER STAMP P/N AND MFR IDENT ON CONTAINER OR PACKAGING PER AS 478-30.
9. DO NOT USE UNASSIGNED PART NUMBERS.
10. REFER TO MS27851 FOR ASSEMBLY.

FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCURMENT DOCUMENTS REFERENCED HEREIN.
REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE SEAL, CRES, NICKEL PLATED, FLUID CONNECTION FITTING, HIGH PRESSURE	MILITARY STANDARD MS27855 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 1 OF 1

FED. SUP CLASS
4730



MS ASSEMBLY NO.	TUBE O.D.	NUT	PLAIN FLANGE	THREADED FLANGE	SEAL
MS 27856-04	1/4	MS 27857-04	MS 27858-04	MS 27859-04	MS 27860-04
MS 27856-06	3/8	MS 27857-06	MS 27858-06	MS 27859-06	MS 27860-06
MS 27856-08	1/2	MS 27857-08	MS 27858-08	MS 27859-08	MS 27860-08
MS 27856-12	3/4	MS 27857-12	MS 27858-12	MS 27859-12	MS 27860-12
MS 27856-16	1	MS 27857-16	MS 27858-16	MS 27859-16	MS 27860-16

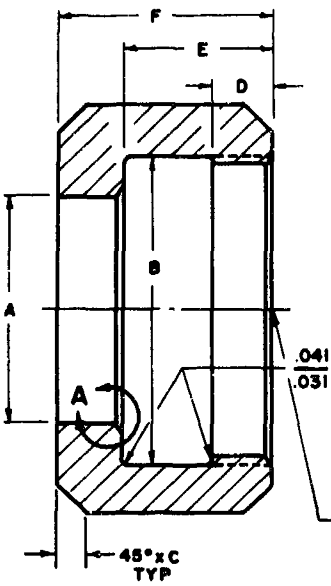
1. DO NOT USE UNASSIGNED PART NUMBERS.
2. REFER TO MS27850 FOR INSTALLATION INSTRUCTIONS.

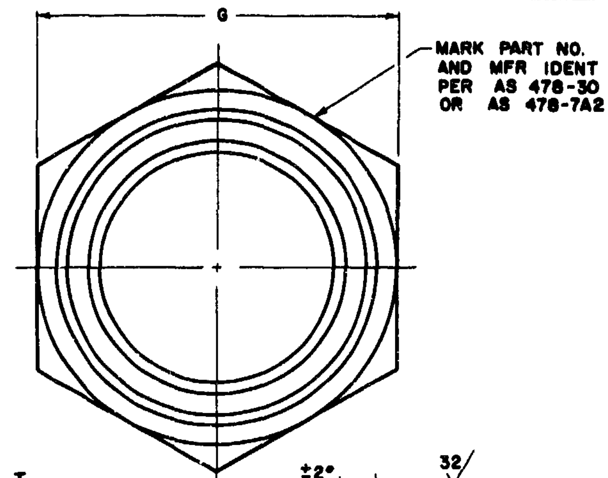
FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCUREMENT DOCUMENTS REFERENCED HEREIN.
REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

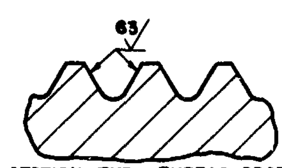
APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE FITTING ASSEMBLY, STRAIGHT THREADED, FLUID CONNECTION, LOW PRESSURE	MILITARY STANDARD MS27856 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 1 OF 1

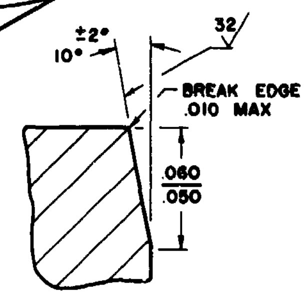
FED. SUP CLASS
4730







SECTION THRU THREAD PROFILE



VIEW A

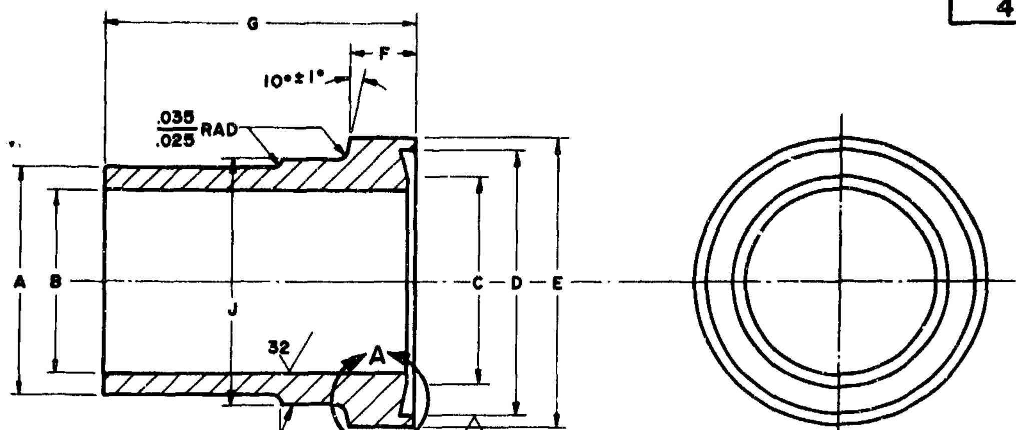
MS PART NO.	TUBE O. D.	THREAD T UNJEF - 3B	A DIA ±.005	B DIA ±.004	C	D ±.005	E ±.005	F	G +.004 -.003	H DIA	APPROX WEIGHT LB/EA
MS27857-04	1/4	11/16 - 24	.335	.697	.070	.213	.578	.771	.812	.688	
MS27857-06	3/8	13/16 - 20	.465	.822	.082	.255	.623	.851	.938	.812	
MS27857-08	1/2	15/16 - 20	.595	.947	.090	.255	.626	.876	1.062	.937	
MS27857-12	3/4	1-3/16 - 18	.845	1.197	.108	.263	.703	1.013	1.312	1.187	
MS27857-16	1	1-1/2 - 18	1.110	1.510	.132	283	.716	1.030	1.750	1.500	.056

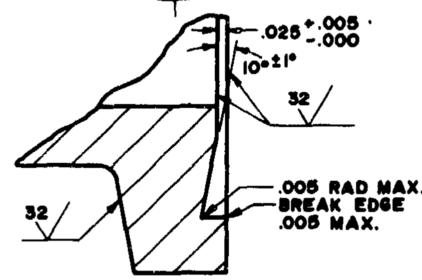
1. THREAD PD, HEX, A DIA AND B DIA, SHALL BE CONCENTRIC WITHIN .005 FIR.
2. MATERIAL: ALUMINUM ALLOY, AMS 4117.
3. CLEANING: FINISHED PARTS SHALL BE CLEANED PER MIL-F-27417.
4. SURFACE TEXTURE, IN ACCORDANCE WITH USAS B46.1, UNLESS OTHERWISE SPECIFIED, ALL MACHINED SURFACES TO BE 63 MICROINCHES.
5. BREAK EDGES .003-.015 UNLESS OTHERWISE SPECIFIED.
6. DIMENSIONS IN INCHES. UNLESS OTHERWISE SPECIFIED, TOLERANCES: DECIMALS ±.010, ANGLES ±5°.
7. DO NOT USE UNASSIGNED PART NUMBERS.
8. REFER TO MS27856 FOR ASSEMBLY.

FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCUREMENT DOCUMENTS REFERENCED HEREIN.
REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE NUT, ALUMINUM, FLUID CONNECTION FITTING, LOW PRESSURE	MILITARY STANDARD MS27857 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 1 OF 1





VIEW A

MS PART NO.	TUBE O. D.	A DIA ±.003	B DIA ±.003	C DIA +.000 -.010	D DIA +.002 -.000	E DIA +.002 -.007	F ±.005	G	H ±.015	J DIA +.005 -.000	APPROX WEIGHT LBS/EA
MS27858-04	1/4	.252	.204	.282	.470	.625	.248	1.125	.450	.275	
MS27858-06	3/8	.377	.317	.420	.608	.740	.251	1.187	.490	.405	
MS27858-08	1/2	.502	.428	.536	.724	.865	.255	1.250	.520	.535	
MS27858-12	3/4	.752	.678	.808	.986	1.110	.303	1.375	.630	.787	
MS27858-16	1	1.002	.900	1.090	1.282	1.420	.312	1.500	.640	1.050	.028

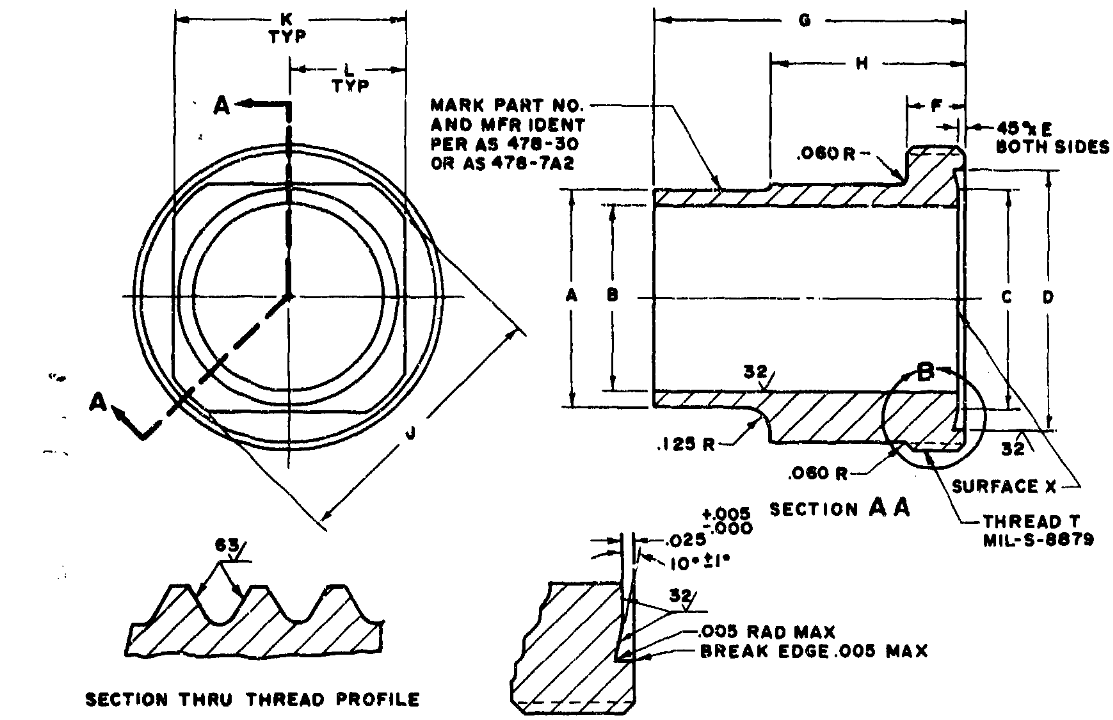
1. ALL DIAMETERS SHALL BE CONCENTRIC WITHIN .005 FIR.
2. MATERIAL: ALUMINUM ALLOY, AMS 4117.
3. CLEANING: FINISHED PARTS SHALL BE CLEANED PER MIL-F-27417.
4. SURFACE TEXTURE, IN ACCORDANCE WITH USAS B46.1, UNLESS OTHERWISE SPECIFIED ALL MACHINED SURFACES TO BE 63 MICROINCHES.
5. BREAK EDGES .003-.015 UNLESS OTHERWISE SPECIFIED.
6. DIMENSIONS IN INCHES. UNLESS OTHERWISE SPECIFIED, TOLERANCES: LINEAR DIMENSIONS, ±.010, ANGULAR DIMENSIONS ± 5°.
7. DO NOT USE UNASSIGNED PART NUMBERS.
8. REFER TO MS27856 FOR ASSEMBLY.

FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCUREMENT DOCUMENTS REFERENCED HEREIN.
REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE FLANGE, PLAIN, ALUMINUM, FLUID CONNECTION FITTING, LOW PRESSURE	MILITARY STANDARD MS27858 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES	SHEET 1 OF 1

FED. SUP CLASS
4730



SECTION THRU THREAD PROFILE

VIEW B

MS PART NO.	TUBE O.D.	THREAD T UNJEF-3A	A DIA ±.003	B DIA ±.003	C DIA +.000 -.010	D DIA +.002 -.000	E	F ±.005	G	H ±.031	J DIA	K +.002 -.006	L	APPROX WEIGHT LB/EA
MS 27859-04	1/4	11/16-24	.252	.204	.282	.470	.030	.213	1.125	.588	.608	.500	.250	
MS 27859-06	3/8	13/16-20	.377	.317	.420	.608	.035	.255	1.187	.692	.722	.625	.312	
MS 27859-08	1/2	15/16-20	.502	.428	.536	.724	.035	.255	1.250	.755	.848	.750	.375	
MS 27859-12	3/4	1-3/16-18	.752	.678	.808	.986	.040	.283	1.375	.814	1.088	.937	.468	
MS 27859-16	1	1-1/2-18	1.002	.900	1.090	1.282	.040	.283	1.500	.945	1.315	1.125	.562	.039

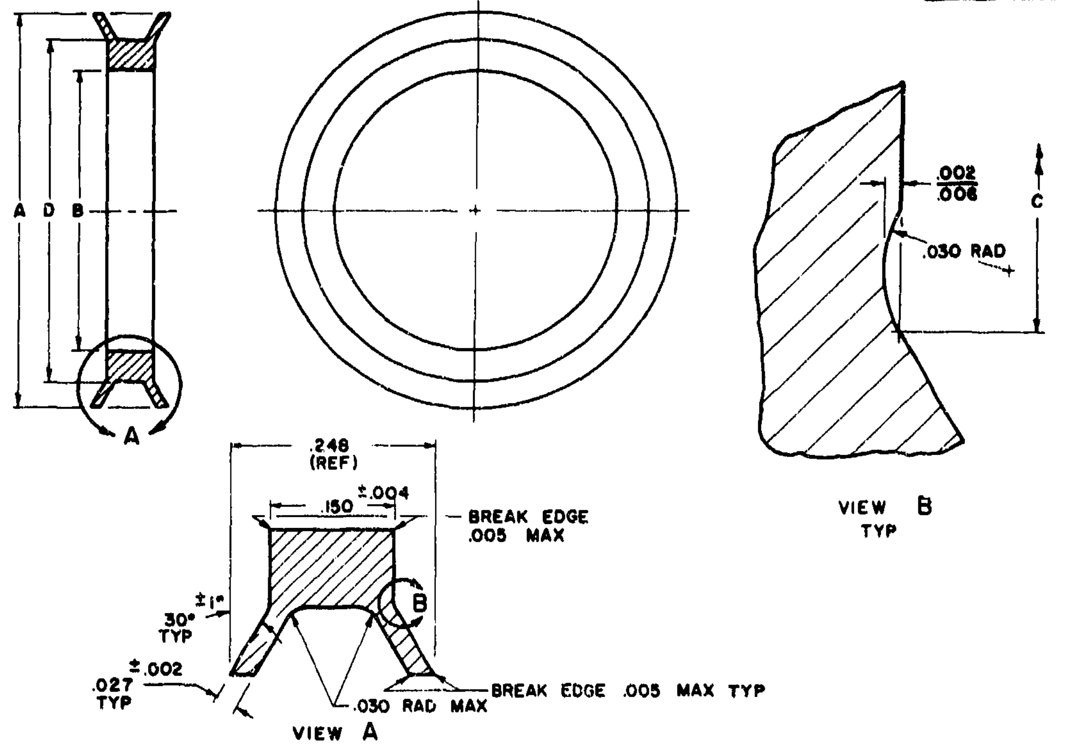
1. THREAD PD SHALL BE SQUARE WITH SURFACE X WITHIN .005 FIR AND CONCENTRIC WITH DIA D WITHIN .005 FIR.
2. MATERIAL: ALUMINUM ALLOY, AMS 4117.
3. CLEANING: FINISHED PARTS SHALL BE CLEANED PER MIL-F-27417.
4. SURFACE TEXTURE: UNLESS OTHERWISE SPECIFIED, SURFACES TO BE 63 MICROINCHES, USAS B46.1.
5. BREAK SHARP EDGES .003-.015 UNLESS OTHERWISE SPECIFIED.
6. DIMENSIONS IN INCHES, UNLESS OTHERWISE SPECIFIED, TOLERANCES: LINEAR DIMENSIONS ±.010, ANGULAR DIMENSIONS ± 5°.
7. DO NOT USE UNASSIGNED PART NUMBERS.
8. REFER TO MS27856 FOR ASSEMBLY.

FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCUREMENT DOCUMENTS REFERENCED HEREIN.
REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE FLANGE, THREADED, ALUMINUM, FLUID CONNECTION FITTING, LOW PRESSURE	MILITARY STANDARD MS 27859 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 1 OF 1

FED. SUP CLASS
4730



MS PART NO.	A DIA +.000 -.002	B DIA +.002 -.000	C DIA +.010 -.000	D DIA +.000 -.005	APPROX WEIGHT LB/100
MS27560-04	.468	.220	.298	.300	
MS27860-06	.606	.340	.436	.438	
MS27860-08	.722	.440	.522	.524	
MS27860-12	.984	.680	.824	.826	
MS27860-16	1.280	.920	1.110	1.112	.331

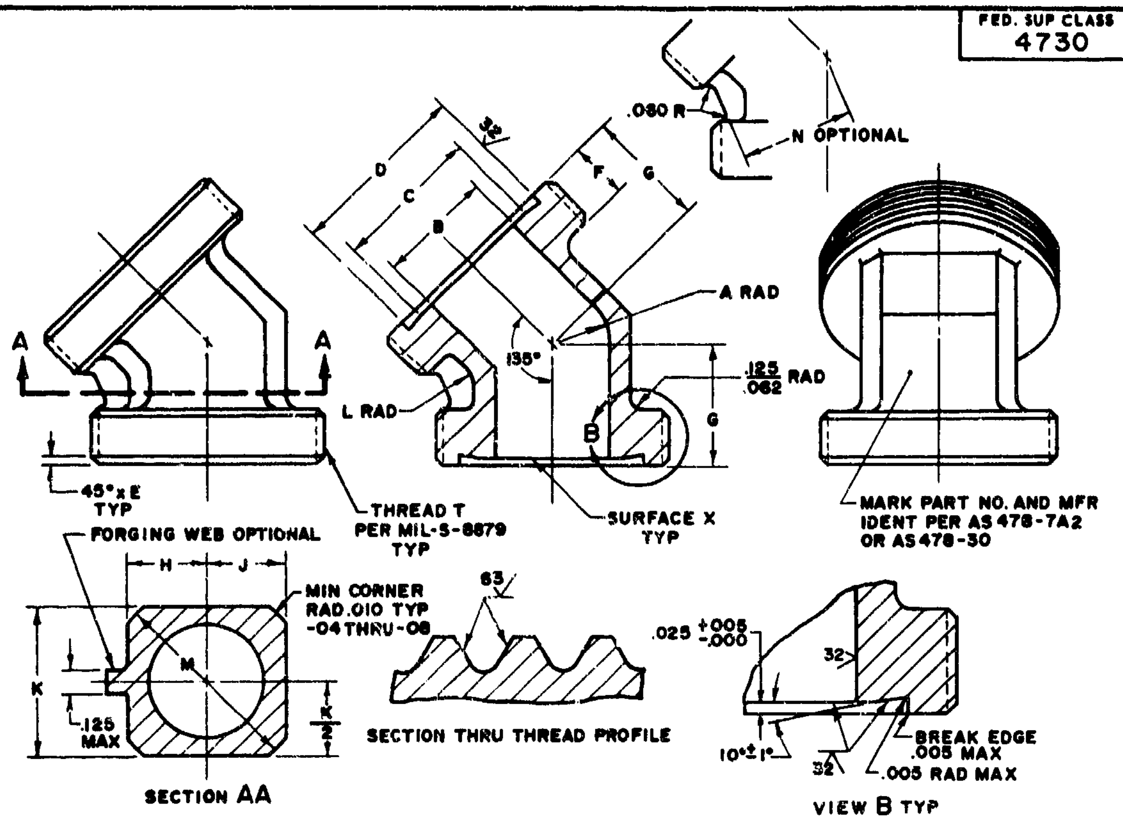
1. ALL DIAMETERS SHALL BE CONCENTRIC WITHIN .002 FIR.
2. MATERIAL: ALUMINUM ALLOY, AMS 4127, OVERAGED PER MIL-F-27417.
3. CLEANING: FINISHED PARTS SHALL BE CLEANED PER MIL-F-27417.
4. SURFACE TEXTURE: IN ACCORDANCE WITH USAS B46.1, UNLESS OTHERWISE SPECIFIED ALL SURFACES TO BE 32 MICROINCHES.
5. BREAK SHARP EDGES .003-.015 UNLESS OTHERWISE SPECIFIED.
6. DIMENSIONS IN INCHES. UNLESS OTHERWISE SPECIFIED, TOLERANCES: DECIMALS ±.010, ANGLES ±5°
7. RUBBER STAMP PART NO. AND MFR. IDENT ON CONTAINER OR PACKAGING PER AS 478-30.
8. DO NOT USE UNASSIGNED PART NUMBERS.
9. REFER TO MS27856 FOR ASSEMBLY.

FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCUREMENT DOCUMENTS REFERENCED HEREIN.
REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE SEAL, ALUMINUM, FLUID CONNECTION FITTING, LOW PRESSURE	MILITARY STANDARD MS27860 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 1 OF 1

FED. SUP CLASS
4730



MS PART NO.	TUBE O.D.	THREAD T UNJEF-3A	A RAD	B DIA ±.003	C DIA +.000 -.010	D DIA +.002 -.000	E	F +.031 -.000	G +.010 -.000	H +.015 -.000	J +.015 -.000	K +.002 -.006	L	M DIA	N OPT +.000 -.015	APPROX WEIGHT LB/EA
MS27861-04	1/4	11/16-24	.102	.204	282	.470	.030	.208	.412	.154	.164	.437	.093	—	.280	
MS27861-06	3/8	13/16-20	.158	.317	.420	.608	.035	.250	.488	.220	.220	.562	.093	—	.344	
MS27861-08	1/2	15/16-20	.214	.428	.536	.724	035	.250	.518	.288	.288	.687	.102	.860	.422	
MS27861-12	3/4	1-3/16-18	.339	.678	.808	.986	.040	.278	.608	.410	.410	.875	.102	1.062	.562	
MS27861-16	1	1-1/2-18	.450	.900	1.090	1.282	.040	.278	.683	.548	.548	1.125	.109	1.375	.750	

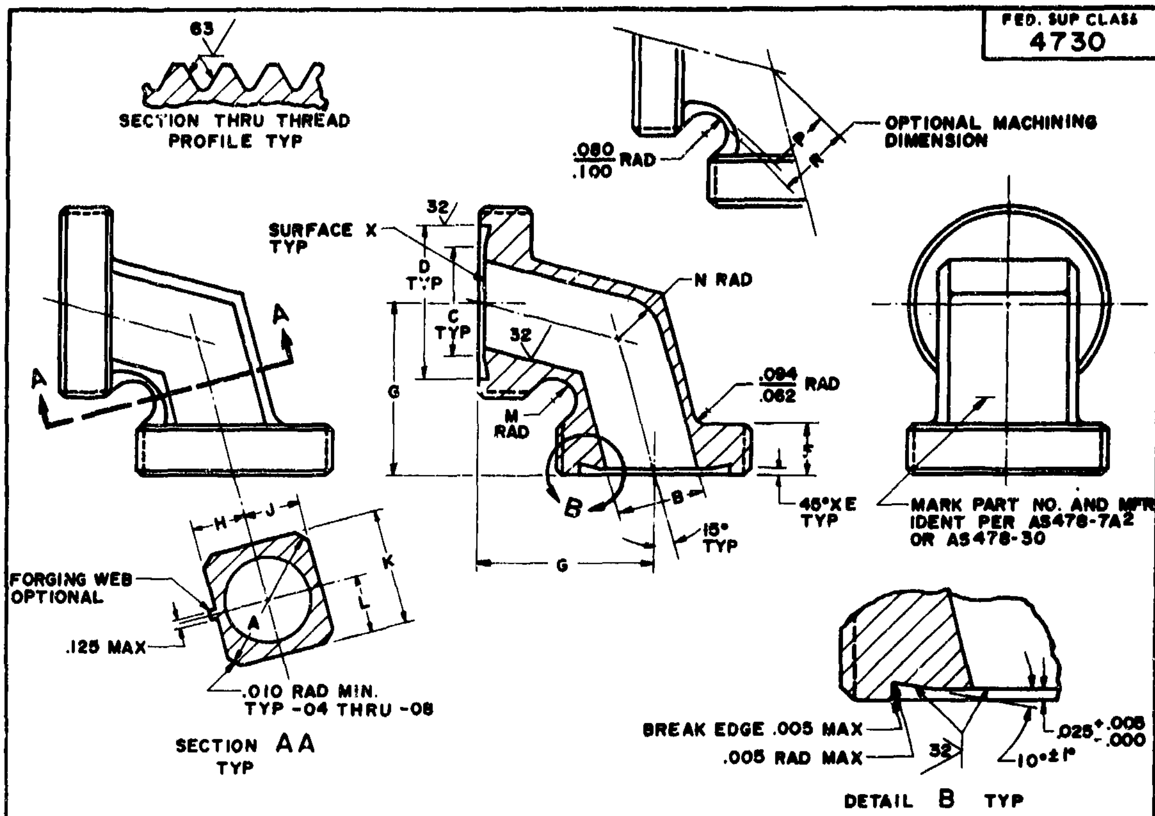
1. THREAD PD SHALL BE SQUARE TO SURFACE X WITHIN .005 FIR AND CONCENTRIC WITH DIA D WITHIN .005 FIR.
2. MATERIAL: ALUMINUM ALLOY, AMS 4127.
3. CLEANING: FINISHED PARTS SHALL BE CLEANED PER MIL-F-27417.
4. SURFACE TEXTURE: IN ACCORDANCE WITH USAS B46.1, UNLESS OTHERWISE SPECIFIED ALL MACHINED SURFACES TO BE 125 MICROINCHES.
5. BREAK EDGES .003-.015 UNLESS OTHERWISE SPECIFIED.
6. DIMENSIONS IN INCHES. UNLESS OTHERWISE SPECIFIED, TOLERANCES: DECIMALS ±.010, ANGLES ±5°.
7. DO NOT USE UNASSIGNED PART NUMBERS.
8. REFER TO MS27856 FOR ASSEMBLY.

FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCUREMENT DOCUMENTS REFERENCED HEREIN.
REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE ELBOW 45°, ALUMINUM, FLUID CONNECTION FITTING, LOW PRESSURE	MILITARY STANDARD MS27861 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 1 OF 1

FED. SUP CLASS
4730



MS PART NO.	TUBE O. D.	THREAD T UNJEF-3A	A DIA	B DIA ±.005	C DIA +.000 -.010	D DIA +.002 -.000	E	F +.031 -.000	G +.010 -.000	H +.015 -.000	J +.015 -.000	K +.002 -.006	L	M RAD	N RAD MAX	P	R +.000 -.015	APPROX WEIGHT LB/EA
MS27862-04	1/4	11/16-24	—	.200	.282	.47[illegible]	.030	.208	.665	.134	.164	.437	.218	.170	.100	.205	.250	
MS27862-06	3/8	13/16-20	—	.312	.420	.608	.035	.250	.786	.198	.208	.562	.281	.200	.156	.290	.315	
MS27862-08	1/2	15/16-20	—	.420	.536	.724	.035	.250	.849	.263	.263	.687	.344	.200	.210	.365	.390	
MS27862-12	3/4	1-3/16-18	1.110	.666	.808	.986	.040	.278	1.013	.386	.386	.875	.437	.226	.333	.505	.535	
MS27862-16	1	1-1/2-18	1.375	.884	1.090	1.282	.040	.278	1.169	.516	.515	1.125	.562	.219	.442	.590	.650	

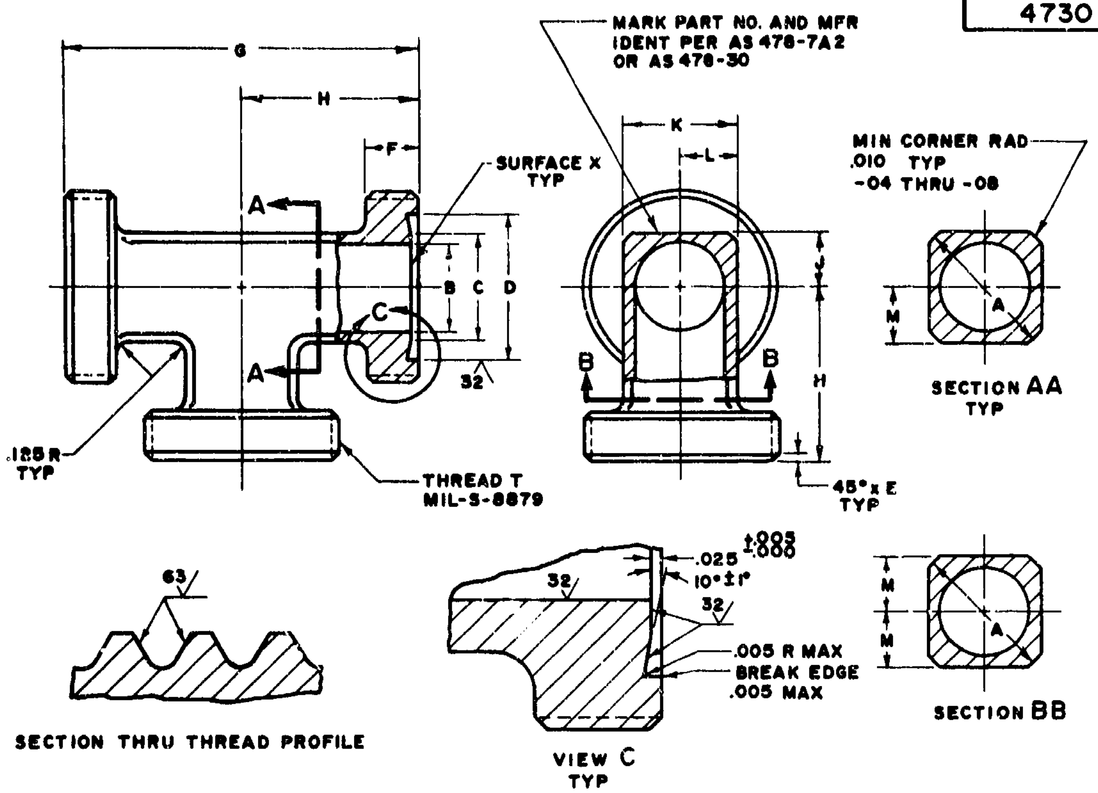
1. THREAD PD SHALL BE SQUARE TO SURFACE X WITHIN .005 FIR AND CONCENTRIC WITH DIA D WITHIN .005 FIR.
2. MATERIAL: ALUMINUM ALLOY, AMS 4127.
3. CLEANING: FINISHED PARTS SHALL BE CLEANED PER MIL-F-27417.
4. SURFACE TEXTURE: IN ACCORDANCE WITH USAS B46.1, UNLESS OTHERWISE SPECIFIED ALL MACHINED SURFACES TO BE 125 MICROINCHES.
5. BREAK EDGES .003-.015 UNLESS OTHERWISE SPECIFIED.
6. DIMENSIONS IN INCHES. UNLESS OTHERWISE SPECIFIED, TOLERANCES: DECIMALS ±.010, ANGLES ±5°.
7. DO NOT USE UNASSIGNED PART NUMBERS.
8. REFER TO MS27856 FOR ASSEMBLY.

FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCUREMENT DOCUMENTS REFERENCED HEREIN.
REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE ELBOW, 90°, ALUMINUM, FLUID CONNECTION FITTING, LOW PRESSURE	MILITARY STANDARD MS27862 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 1 OF 1

FED. SUP CLASS
4730



MS PART NO.	TUBE O.D.	THREAD T UNJEF-3A	A DIA	B DIA ±.003	C DIA +.000 -.010	D DIA +.002 -.000	E	F +.010 -.000	G +.010 -.000	H	J +.015 -.000	K +.002 -.006	L	M +.015 -.000	APPROX WEIGHT LB/EA
MS27863-04	1/4	11/16-24	—	.204	.282	.470	.030	.208	1.330	.665	.164	.438	.219	.135	
MS27863-06	3/8	13/16-20	—	.317	.420	.608	.035	.250	1.572	.786	.220	.562	.281	.202	.057
MS27363-08	1/2	15/16-20	—	.428	.536	.724	.035	.250	1.698	.849	.288	.688	.344	.268	
MS27863-12	3/4	1-3/16-18	1.110	.678	.808	.986	.040	.278	2.026	1.013	.410	.875	.438	.393	.117
MS27863-16	1	1-1/2-18	1.375	.900	1.090	1.282	.040	.278	2.338	1.169	.548	1.125	.562	.529	

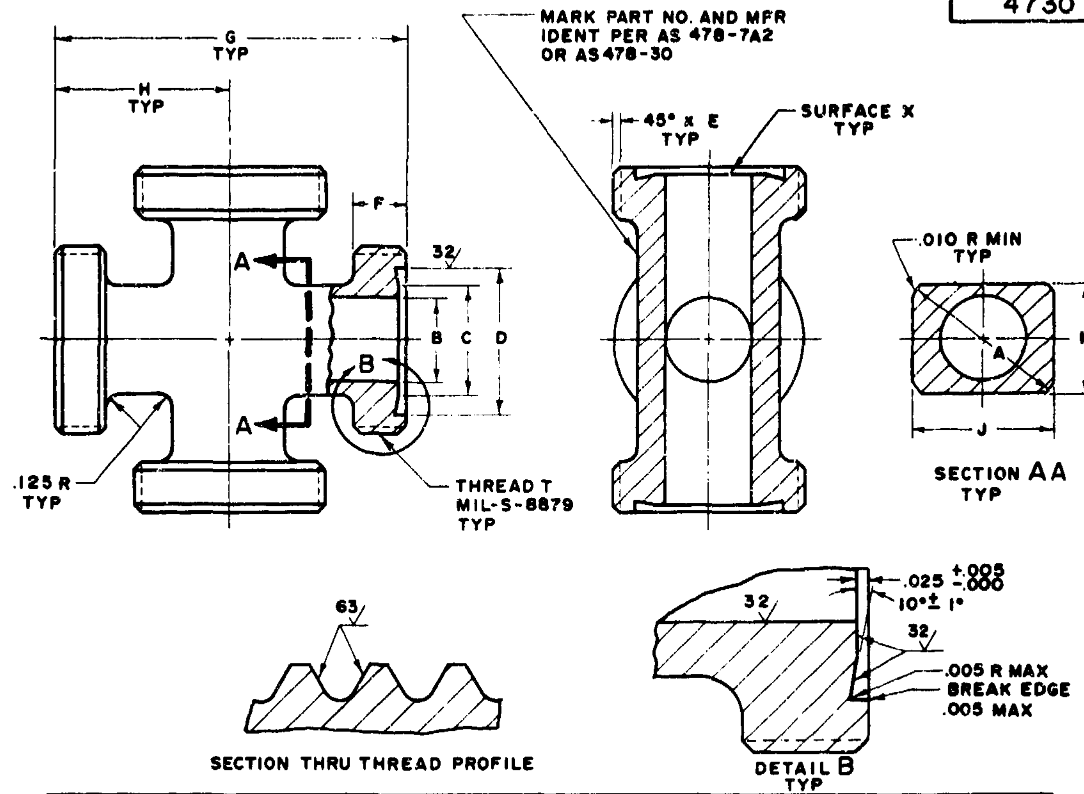
1. THREAD PD SHALL BE SQUARE TO SURFACE X WITHIN .005 FIR AND CONCENTRIC WITH DIA D WITHIN .005 FIR.
2. MATERIAL: ALUMINUM ALLOY, AMS 4127.
3. CLEANING: FINISHED PARTS SHALL BE CLEANED PER MIL-F-27417.
4. SURFACE TEXTURE: IN ACCORDANCE WITH USAS B46.1, UNLESS OTHERWISE SPECIFIED ALL MACHINED SURFACES TO BE 63 MICROINCHES.
5. BREAK EDGES .003-.015 UNLESS OTHERWISE SPECIFIED.
6. DIMENSIONS IN INCHES. UNLESS OTHERWISE SPECIFIED, TOLERANCES: DECIMALS ±.010, ANGLES ± 5°.
7. DO NOT USE UNASSIGNED PART NUMBERS.
8. REFER TO MS27856 FOR ASSEMBLY.

FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCUREMENT DOCUMENTS REFERENCED HEREIN.
REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE TEE, ALUMINUM, FLUID CONNECTION FITTING, LOW PRESSURE	MILITARY STANDARD MS 27863 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 1 OF 1

FED. SUP CLASS
4730



MS PART NO.	TUBE O.D.	THREAD T UNJEF-3A	A DIA	B DIA ±.003	C DIA +.000 -.010	D DIA +.002 -.000	E	F +.031 -.000	G +.010 -.000	H +.010 -.000	J +.002 -.006	K +.030 -.000	APPROX WEIGHT LBS/EA
MS27864-04	1/4	11/16-24	.514	.204	.282	.470	.030	.208	1.330	.665	.437	.272	
MS27864-06	3/8	13/16-20	.692	.317	.420	.608	.035	.250	1.572	.786	.562	.403	
MS27864-08	1/2	15/16-20	.871	.428	.536	.724	.035	.250	1.698	.849	.687	.536	
MS27864-12	3/4	1-3/16-18	1.110	.678	.808	.986	.040	.278	2.026	1.013	.875	.786	
MS27864-16	1	1-1/2-18	1.375	.900	1.090	1.282	.040	.278	2.338	1.169	1.125	1.057	

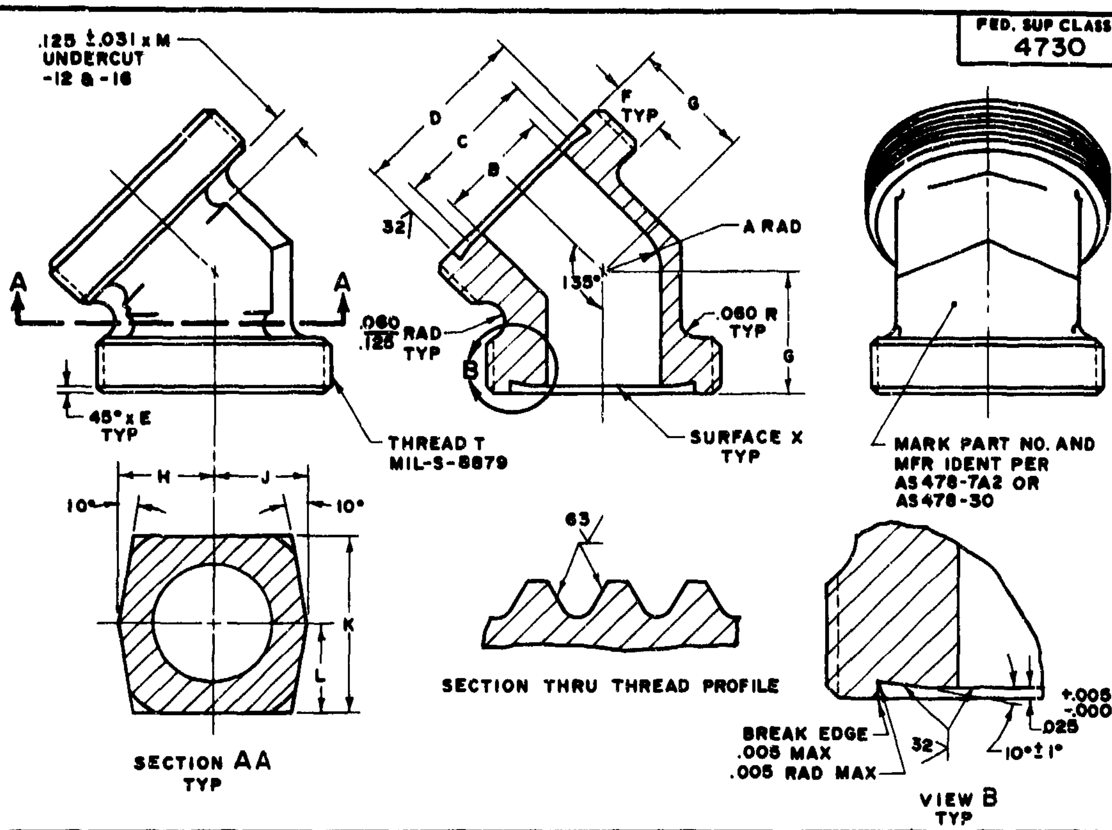
1. THREAD P.D. SHALL BE SQUARE WITH SURFACE X WITHIN .005 FIR AND CONCENTRIC WITH DIA B WITHIN .005 FIR.
2. MATERIAL: ALUMINUM ALLOY AMS 4127.
3. CLEANING: FINISHED PARTS SHALL BE CLEANED PER MIL-F-27417.
4. SURFACE TEXTURE: IN ACCORDANCE WITH USAS B46.1, UNLESS OTHERWISE SPECIFIED ALL MACHINED SURFACES TO BE 63 MICROINCHES.
5. BREAK EDGES .003-.015 UNLESS OTHERWISE SPECIFIED.
6. DIMENSIONS IN INCHES. UNLESS OTHERWISE SPECIFIED, TOLERANCES: DECIMALS ± .010, ANGLES ± 5°.
7. DO NOT USE UNASSIGNED PART NUMBERS.
8. REFER TO MS27856 FOR ASSEMBLY.

FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCUREMENT DOCUMENTS REFERENCED HEREIN.
REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE CROSS, ALUMINUM, FLUID CONNECTION FITTING, LOW PRESSURE	MILITARY STANDARD MS 27864 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES	SHEET 1 OF 1

FED. SUP CLASS
4730



MS PART NO.	TUBE O.D.	THREAD T UNJEF-3A	A RAD	B DIA ±.002	C DIA +.000 -.010	D DIA +.002 -.000	E	F +.031 -.000	G +.010 -.000	H +.015 -.000	J +.015 -.000	K +.002 -.006	L	M DIA +.000 -.015	APPROX WEIGHT LBS/EA
MS27865-02	1/8	9/16-24	.041	.083	.156	.350	.030	.208	.381	.130	.129	.312	.156	—	
MS27865-04	1/4	5/8 - 24	.089	.178	.260	.452	.030	.208	.397	.168	.168	.375	.188	—	
MS27865-06	3/8	3/4-20	.137	.275	.372	.564	.035	.250	.473	.215	.215	.437	.218	—	
MS27865-08	1/2	7/8-20	.184	.368	.470	.666	.035	.250	.503	.312	.249	.625	.312	—	
MS27865-12	3/4	1-1/8-18	.279	.556	.694	.888	.040	.278	.593	.464	.375	.875	.438	1.048	
MS27865-16	1	1-5/16-18	.365	.730	.904	1.100	.040	.278	.638	.621	.500	1.187	.594	1.235	

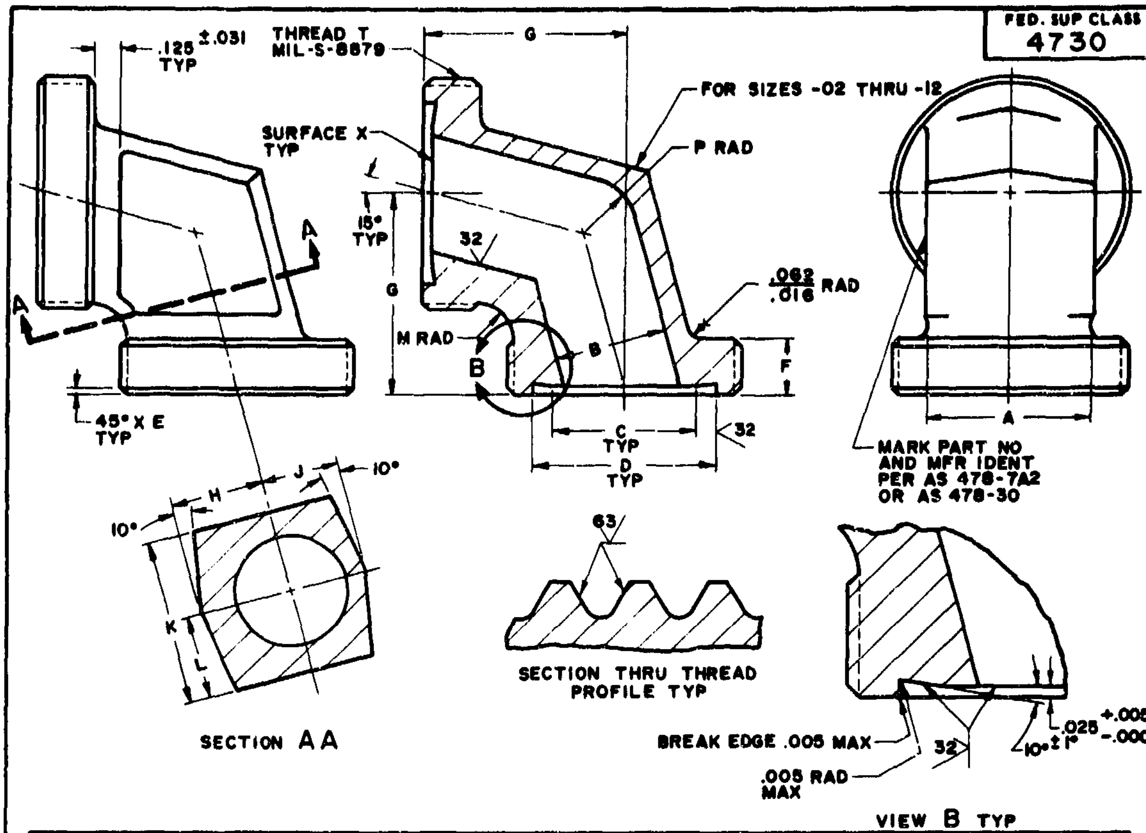
1. THREAD PD SHALL BE SQUARE TO SURFACE X WITHIN .005 FIR AND CONCENTRIC WITH DIA D WITHIN .005 FIR.
2. MATERIAL: CORROSION RESISTANT STEEL, AMS 5646.
3. CLEANING: FINISHED PARTS SHALL BE CLEANED PER MIL-F-27417.
4. SURFACE TEXTURE: IN ACCORDANCE WITH USAS B46.1, UNLESS OTHERWISE SPECIFIED, ALL MACHINED SURFACES TO BE 63 MICROINCHES.
5. BREAK EDGES .003-.015 UNLESS OTHERWISE SPECIFIED.
6. DIMENSIONS IN INCHES. UNLESS OTHERWISE SPECIFIED, TOLERANCES: DECIMALS ±.010, ANGLES ±5°.
7. DO NOT USE UNASSIGNED PART NUMBERS.
8. REFER TO MS 27851 FOR ASSEMBLY.

FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCUREMENT DOCUMENTS REFERENCED HEREIN.
REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE ELBOW, 45°, CRES, FLUID CONNECTION FITTING, HIGH PRESSURE	MILITARY STANDARD MS27865 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 1 OF 1

FED. SUP CLASS
4730



MS PART NO.	TUBE O.D.	THREAD T UNJEF-3A	A DIA +.031 -.000	B DIA ±.002	C DIA +.000 -.010	D DIA +.002 -.000	E	F +.031 -.000	G +.010 -.000	H +.015 -.000	J +.015 -.000	K +.002 -.006	L	M +.010 -.000	P	APPROX WEIGHT LB/EA
MS27866-02	1/8	9/16-24	.259	.081	.156	.350	.030	.208	.603	.130	.129	.312	.156	.155	.040	
MS27866-04	1/4	5/8-24	.336	.175	.260	.452	.030	.208	.634	.168	.168	.375	.188	.168	.088	.044
MS27866-06	3/8	3/4-20	.430	.270	.372	.564	.035	.250	.755	.215	.215	.437	.218	.207	.135	.070
MS27866-08	1/2	7/8-20	.576	.362	.470	.666	.035	.250	.818	.305	.271	.625	.312	.210	.181	.107
MS27866-12	3/4	1-1/8-18	.798	.548	.694	.888	.040	.278	.981	.424	.374	.812	.406	.240	.274	.204
MS27866-16	1	1-5/16-18	1.080	.730	.904	1.100	.040	.278	1.075	.535	.505	1.125	.562	.175	.365	.388

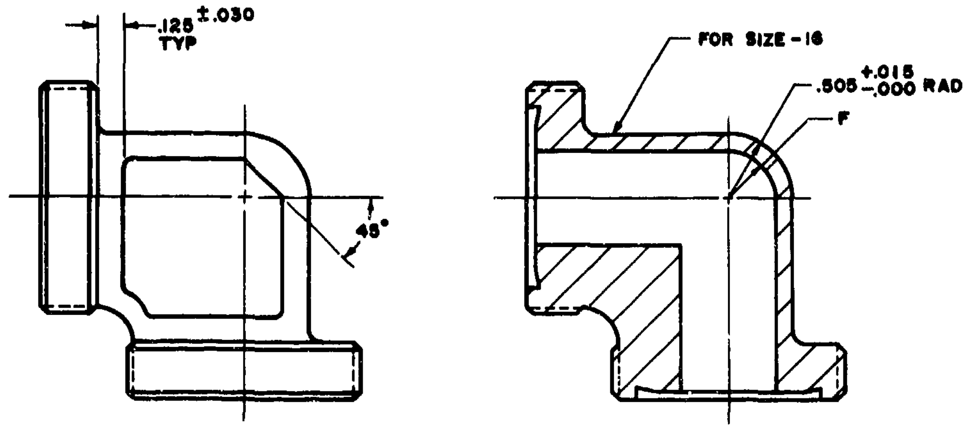
1. THREAD PD SHALL BE SQUARE TO SURFACE X WITHIN .005 FIR AND CONCENTRIC WITH DIA D WITHIN .005 FIR.
2. MATERIAL: CORROSION-RESISTANT STEEL, AMS 5646.
3. CLEANING: FINISHED PARTS SHALL BE CLEANED PER MIL-F-27417.
4. SURFACE TEXTURE: IN ACCORDANCE WITH USAS B46.1, UNLESS OTHERWISE SPECIFIED ALL MACHINED SURFACES TO BE 63 MICROINCHES.
5. BREAK EDGES .003-.015 UNLESS OTHERWISE SPECIFIED.
6. DIMENSIONS IN INCHES. UNLESS OTHERWISE SPECIFIED, TOLERANCES: DECIMALS ±.010, ANGLES ±5°.
7. DO NOT USE UNASSIGNED PART NUMBERS.
8. REFER TO MS27851 FOR ASSEMBLY.

FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCUREMENT DOCUMENTS REFERENCED HEREIN.
REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE ELBOW, 90°, CRES, FLUID CONNECTION FITTING, HIGH PRESSURE	MILITARY STANDARD MS27866 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 1 OF 2

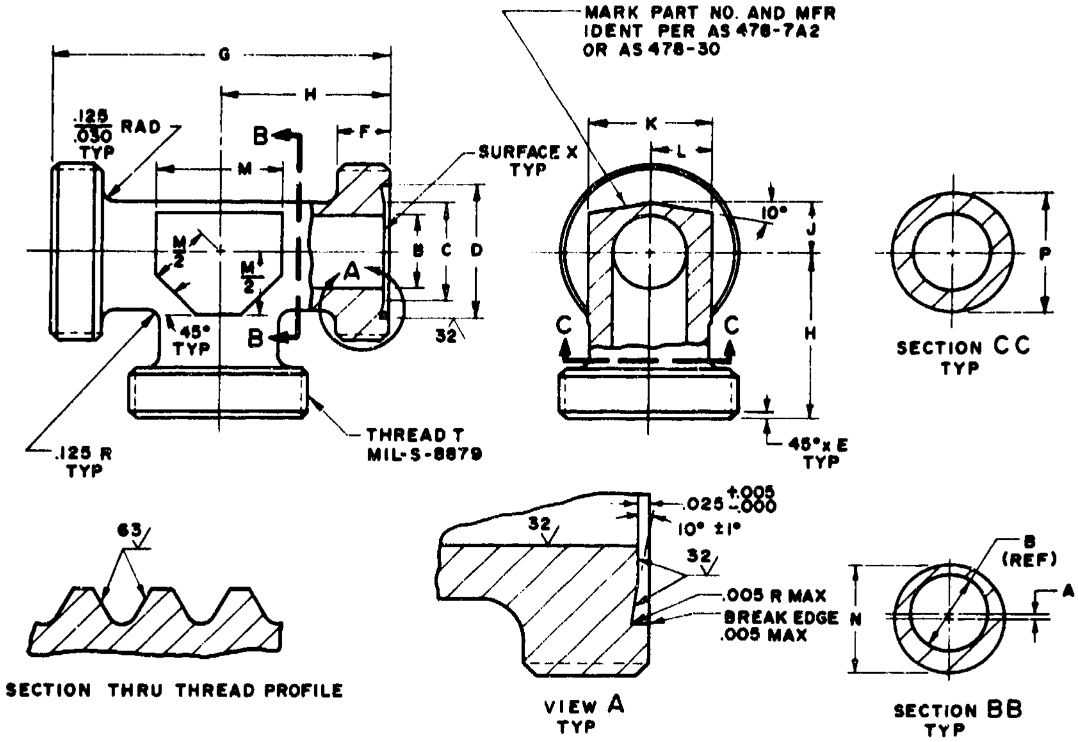
FED. SUP CLASS
4730



APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE ELBOW, 90°, CRES, FLUID CONNECTION FITTING, HIGH PRESSURE	MILITARY STANDARD MS27866 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 2 OF 2

FED. SUP CLASS 4730



MS PART NO.	TUBE O.D.	THREAD T UNJEF-3A	A	B DIA ±.002	C DIA +.000 -.010	D DIA +.002 -.000	E	F +.031 -.000	G +.010 -.000	H +.010 -.000	J +.015 -.000	K +.002 -.006	L	M +.060 -.000	N DIA +.030 -.000	P DIA +.030 -.000	APPROX WEIGHT LB/EA
MS27867-02	1/8	9/16-24	.000	.083	.156	.350	.030	.208	1.206	.603	.129	.312	.156	.312	.259	.259	
MS27867-04	1/4	5/8-24	.000	.178	.260	.452	.030	.208	1.268	.634	.168	.375	.188	.375	.336	.336	
MS27867-06	3/8	3/4-20	.000	.275	.372	.564	.035	.250	1.510	.755	.216	.437	.219	.437	.433	.433	
MS27867-08	1/2	7/8-20	.017	.368	.470	.666	.035	.250	1.636	.818	.250	.593	.296	.625	.535	.568	
MS27867-12	3/4	1-1/8-18	.024	.558	.694	.888	.040	.278	1.962	.981	.377	.875	.438	.875	.803	.851	
MS27867-16	1	1-5/16-18	.045	.730	.904	1.100	.040	.278	2.150	1.075	.500	1.187	.594	1.180	1.091	1.182	

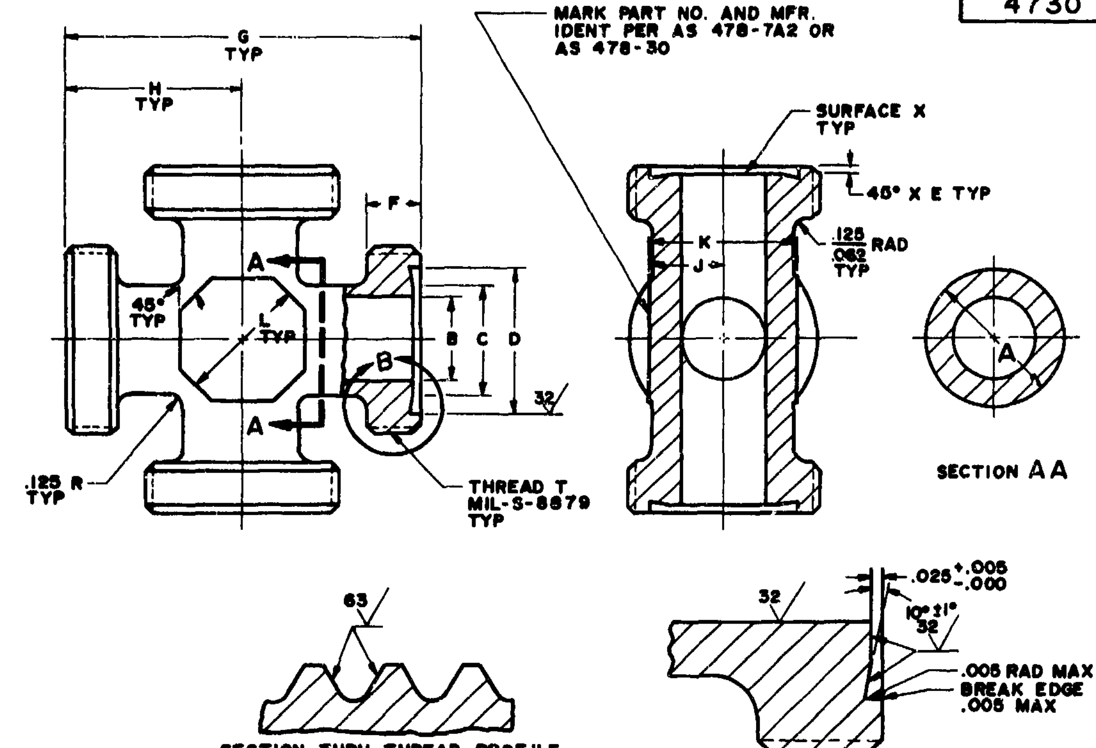
1. THREAD PD SHALL BE SQUARE TO SURFACE X WITHIN .005 FIR AND CONCENTRIC WITH DIA D WITHIN .005 FIR.
2. MATERIAL: CORROSION-RESISTANT STEEL, AMS 5646.
3. CLEANING: FINISHED PARTS SHALL BE CLEANED PER MIL-F-27417.
4. SURFACE TEXTURE: IN ACCORDANCE WITH USAS B46.1, UNLESS OTHERWISE SPECIFIED ALL MACHINED SURFACES TO BE 63 MICROINCHES.
5. BREAK EDGES .003-.015 UNLESS OTHERWISE SPECIFIED.
6. DIMENSIONS IN INCHES. UNLESS OTHERWISE SPECIFIED, TOLERANCES: DECIMALS ±.010, ANGLES ±5°.
7. DO NOT USE UNASSIGNED PART NUMBERS.
8. REFER TO MS27851 FOR ASSEMBLY.

FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCUREMENT DOCUMENTS REFERENCED HEREIN.
REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE TEE, CRES, FLUID CONNECTION FITTING, HIGH PRESSURE	MILITARY STANDARD MS 27867 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES	SHEET 1 OF 1

FED. SUP CLASS
4730



SECTION THRU THREAD PROFILE

VIEW B
TYP

MS PART NO.	TUBE O.D.	THREAD T UNJEF-3A	A DIA +.030 -.000	B DIA ±.005	C DIA +.000 -.010	D DIA +.002 -.000	E	F +.031 -.000	G +.010 -.000	H +.010 -.000	J	K +.002 -.006	L +.060 -.000	APPROX WEIGHT LBS/EA
MS27868-02	1/8	9/16-24	.259	.083	.156	.350	.030	.208	1.206	.603	.156	.312	.312	
MS27868-04	1/4	5/8-24	.336	.178	.260	.452	.030	.208	1.268	.634	.188	.375	.375	.148
MS27868-06	3/8	3/4-20	.433	.275	.372	.564	.035	.250	1.510	.755	.218	.438	.438	
MS27868-08	1/2	7/8-20	.568	.368	.470	.666	.035	.250	1.636	.818	.312	.625	.594	
MS27868-12	3/4	1-1/8-18	.851	.558	.694	.888	.040	.278	1.962	.981	.436	.875	.875	
MS27868-16	1	1-5/16-18	1.182	.730	.904	1.100	.040	.278	2.150	1.075	.594	1.187	1.875	

1. THREAD PD SHALL BE SQUARE TO SURFACE X WITHIN .005 FIR AND CONCENTRIC WITH DIA D WITHIN .005 FIR.
2. MATERIAL: CORROSION-RESISTANT STEEL, AMS 5646.
3. CLEANING: FINISHED PARTS SHALL BE CLEANED PER MIL-F-27417.
4. SURFACE TEXTURE: IN ACCORDANCE WITH USAS B46.1, UNLESS OTHERWISE SPECIFIED ALL MACHINED SURFACES TO BE 63 MICROINCHES.
5. BREAK EDGES .003-.015 UNLESS OTHERWISE SPECIFIED.
6. DIMENSIONS IN INCHES. UNLESS OTHERWISE SPECIFIED, TOLERANCES: DECIMALS ±.010, ANGLES ±5°.
7. DO NOT USE UNASSIGNED PART NUMBERS.
8. REFER TO MS27851 FOR ASSEMBLY.

FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCUREMENT DOCUMENTS REFERENCED HEREIN.
REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE CROSS, CRES, FLUID CONNECTION FITTING, HIGH PRESSURE	MILITARY STANDARD MS27868 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 1 OF 1

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

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13. ABSTRACT

Families of threaded connectors consisting of unions, elbows, tees, and crosses, were designed for Type 347 CRES and 6061-T6 aluminum in the sizes of 1/8- to 1-inch tube diameter. A laboratory evaluation of Type 347 CRES unions in all sizes was conducted along with a field installation study. The laboratory evaluation consisted of the following qualification tests: thermal gradient, stress-reversal bending, vibration, pressure impulse, and repeated assembly. Based on the successful laboratory evaluation of the connector, in the sizes of 1/8-, 1/4-, 3/8-, and 1/2-inch tube diameters, fabricated in accordance with the detail designs and M.S. Specifications and Standards, these connector sizes were qualified for production. The 3/4- and 1-inch-tube-diameter connector experienced problems in thermal gradient conditions and further work is being done to correct this problem.

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Unclassified

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Connector						
Fluid Coupling						
Threaded						
Vibration						
Thermal Gradient						
Pressure Impulse						
Repeated Assembly						
Stress-Reversal Bending						
Misalignment						
Qualified Producers List						
All-Metal Seal						