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INTERIM REPORT ON AFRPL CONNECTOR TESTS

G. N. GRAVES, CAPT, USAF

TECHNICAL REPORT NO. AFRPL-TR-69-105

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DIRECTORATE OF LABORATORIES
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
EDWARDS, CALIFORNIA

AFRPL-TR-69-105

INTERIM REPORT ON AFRPL CONNECTOR TESTS

George N. Graves, Capt, USAF

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FOREWORD

This report covers the work on Project 305802ERB, Tube Connector Development, by the Propulsion Subsystems Branch in the Liquid Rocket Division of the Air Force Rocket Propulsion Laboratory from 1 March to 1 November 1967. The project engineer was George N. Graves, Capt, USAF, and the engineering technician was Dennis L. Lank.

This Technical Report has been reviewed and approved for publication.

E. E. STEIN, Chief
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ABSTRACT

A family of threaded fittings was developed which would withstand the stringent operating conditions imposed on a fluid-line connector by a liquid rocket. Qualification and verification testing of this connector family was conducted and the results evaluated in a program at the Air Force Rocket Propulsion Laboratory (AFRPL). The tests included repeated assembly, thermal gradient, stress-reversal bending, and pressure impulse. Connectors which were tested and qualified were fabricated from type 347 CRES in the 1/4-, 3/8-, and 1/2-inch O. D. sizes. The complete family of connectors includes a 3/4- and 1-inch O.D. size.

A complete test system was developed for qualifying and testing any threaded connector. The qualification and verification test data substantiated the integrity of the AFRPL connector design and provides qualification of the connector through 1/2-inch sizes. Additional testing and data will be generated at the completion of the test program and will be reported in the final report.

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INTERIM REPORT ON AFRPL CONNECTOR TESTS

I. INTRODUCTION

In October 1960, the Air Force Rocket Propulsion Laboratory (AFRPL) was requested to initiate a program to develop advanced fittings. Connections being used on Atlas, Thor, and Titan were not capable of meeting propulsion system requirements. As a result of this request, design studies for separable and permanent fittings were initiated with industry. One contract was initiated with North American Rockwell, Los Angeles Division (NAR/LAD), to develop brazed and welded tube joint and tooling concepts. This work was based on similar B-70 and X-15 efforts but oriented to rocket propulsion requirements. A second contract was initiated with Battelle Memorial Institute (BMI) to develop new concepts for separable fittings.

The NAR/LAD Program resulted in brazed and welded joint designs, and tooling concepts to perform these operations in the field. A performance test program was conducted to demonstrate the capability of the developed joints to meet rocket propulsion system environmental requirements. The BMI Program resulted in an advanced threaded fitting concept and the development of a computerized flange design procedure. Follow-on efforts have been contracted with both companies. NAR/LAD has expanded the welding work on the previous program to include weldability data on representative tube materials, weld tooling concepts for large-diameter tubing (to 16 inches), and tubing cutoff and weld joint preparation tools. BMI has developed a complete family of threaded fittings for use on tubing systems up to 1 inch in diameter. BMI is also working on bolted connectors for use on up to 16-inch-diameter tubing. The advanced threaded connector developed under Air Force Rocket Propulsion Laboratory (AFRPL) sponsorship became known as the AFRPL connector. A detailed description of the design and development of the AFRPL connector appears in References 1, 2, and 3. The connector design has also been incorporated into a series of

Military Standards. The Military Standards describing the stainless steel unions which have been tested and which this document reports are shown in Appendix A. The Air Force Rocket Propulsion Laboratory has conducted an in-house evaluation of several tube connector designs. The purpose of this report is to provide a summary of the test work conducted on the AFRPL connector during the period of 1 March 1967 to 1 November 1967.

II. THE AFRPL CONNECTOR DESIGN

The AFRPL 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° to 600°F at 1000 and 4000 psi under severe operating conditions of vibration, stress reversal bending and thermal gradients. A family of 1000 and 4000 psi connectors have been designed for fluid-line joints of $1/8$ to 1 inch diameter, including unions, elbows, "tee" and "crosses". The all-metal connector was designed to maintain zero leakage (defined as 7×10^{-7} cubic centimeter helium per second at atmospheric conditions (atm cc/sec.)).

The temperature effects and leakage requirement had a great importance in 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, a large preload may be applied through a load path parallel to the seal. This design allows a constant sealing load. Also, the seal is geometrically arranged so the seal acts radially rather than axially, which provides a seal less affected by dimensional changes due to thermal coefficients of expansion.

Recent research 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 was incorporated into the seal action. The stainless

steel seal, are plated with soft nickel which further lowers the contact stress required for plastic deformation. The resulting seal design is shown in Figure 1.

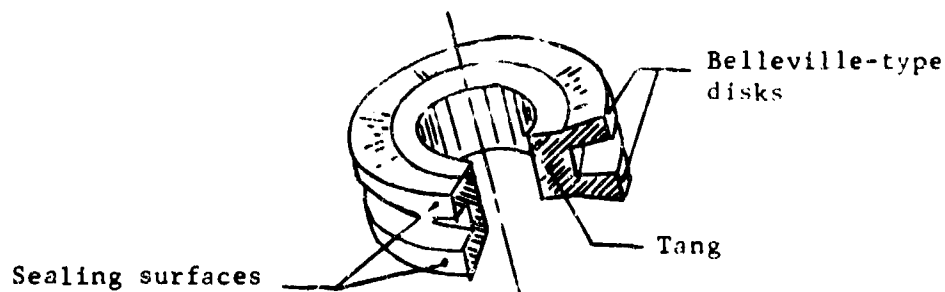


Figure 1. The AFRPL Connector Seal

To determine the prelaod required to insure sealing, a graphical design technique, utilizing a preload diagram, was developed. The technique simply plots the load versus deflection (spring rate) of the compression members of an assumed connector, and establishes variations and limits caused by thermal gradients and material properties. This allows determination of the load deflection relation of the tension members. Following a few iterations (3 to 5), dimensions are achieved which give reasonable spring rates. Once the required spring rate of the tension member, i. e., the nut, is known, it can be designed by common techniques. In reality, the actual preload calculations and nut design were computerized so that variation in the nut design could be made and weight optimized for the performance requirements. The requirements for wrench flats, seal cavity, and structural integrity dictated most of the remaining design, which is shown in Figure 2.

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 of the commercially available semi-automatic tube welders, or with the fully automatic equipment developed by North American Rockwell, Los Angeles Division.

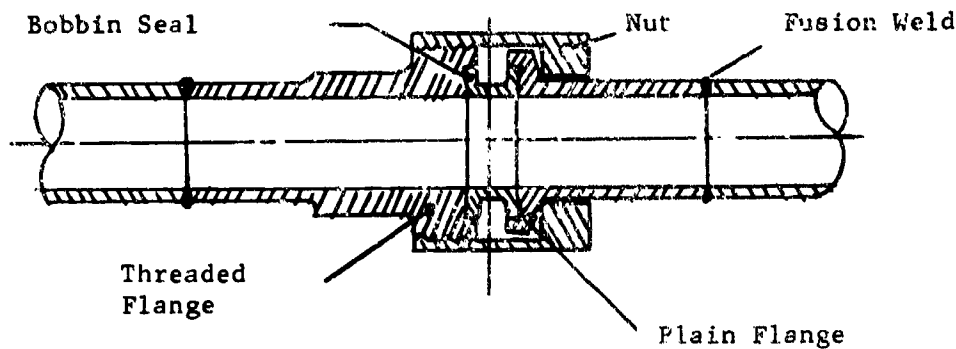


Figure 2. The AFRPI Connector

The sealing force mechanics are graphically depicted in Figure 3. Initially, 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 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.

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.

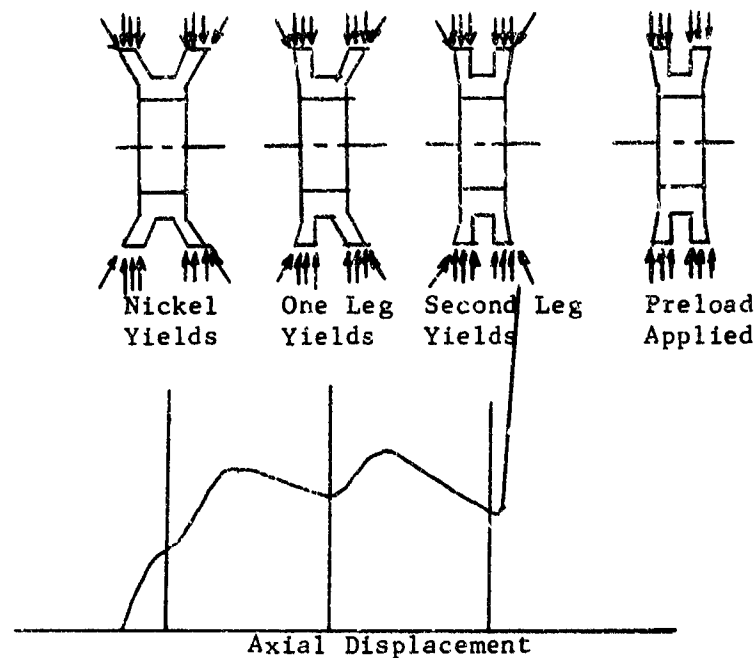


Figure 3. Sealing-Force Mechanics of Bobbin Seal

III. TEST SYSTEM DESCRIPTIONS

The test systems that have been used for testing the AFRPL connector at the Air Force Rocket Propulsion Laboratory are described in detail in Reference 4. The proof- and burst-pressure tests and the stress-reversal bending test systems which were used for tests described in this report will be described briefly. The proof-pressure test is an integral part of the stress-reversal bending and repeated assembly tests. The proof-pressure test is an inspection test to insure that no gross defects exist in

the connector seal or mechanical structure. Proof pressure is defined as 1.5 times the working pressure. Leakage during this test for the AFRPL connector should be less than 7×10^{-7} atm cc/sec as measured by a helium mass spectrometer leak detector.

The burst-pressure test is a structural test 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.

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, 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 maintained.

A stress-reversal bending test system was designed to conduct these low-cycle, high-stress tests. The connector was mounted near the fixed end of a shaft and a small vacuum chamber was built around the fitting to collect leakage which was measured with the leak detector. A bellows was used for the vacuum chamber so that it would not affect the stress transmitted to the connector. The stress resulting is from pressure, and bending was measured by a strain gage on the nonrotating shaft in the plane of maximum stress (see Figure 4). The bending moment applied to the fitting was set and periodically monitored from these strain gages. Frequency of flexing was 25 Hz. Half the mechanical tube connectors were

assembled with minimum torque. The connector was tested for 300,000 cycles. The test stress level was based on a total combined equivalent stress of 29,000 psi.

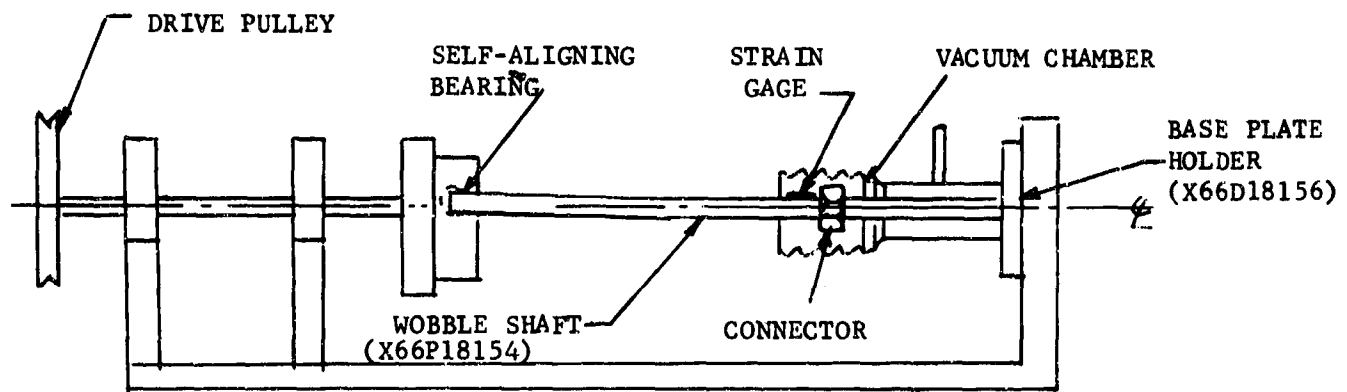


Figure 4. Stress-Reversal Bending Test System Schematic

In addition to the above test, the connectors were tested for the ability to be reassembled a number of times. Reference 4 established the requirement that the connector be able to be reassembled 25 times without damage to the wrenching or thread surfaces or excessive leakage. For each of the 25 assemblies, the same flanges and nut were used with a new nickel-plated seal.

IV. EVALUATION OF STAINLESS STEEL AFRPL CONNECTORS

The connectors which have been evaluated were manufactured by Scientific Advances, Inc., 1400 Holly Avenue, Columbus, Ohio, and were procured on Contract AF04(611)-11565. All the connectors were rated for service at 4000 psi and 600°F. The procurement specifications were the same as those shown in Appendix 1 of Reference 2. A total of 5425 connector parts manufactured from austenitic and iron-nickel-chromium-molybdenum stainless steel alloys were ordered. Table I shows the numbers of parts made.

TABLE I - CONNECTOR PART FABRICATION

	DASH SIZE (TUBE O. D.)				
	-4(1/4)	-6(3/8)	-8(1/2)	-12(3/4)	-16(1)
MS 27852 - Nut	200	300	200	175	200
MS 27853 - Plain Flange	200	250	200	175	200
MS 27854 - Threaded Flange	75	75	75	50	75
MS 27855 - Seal	500	700	500	400	600
MS 27866 - 90° Elbow	25	25	25	25	25
MS 27867 - Tee	25	25	25	25	25
MS 27868 - Cross	--	25	--	--	--

Each part was inspected at the laboratory for conformance to the procurement specification. The parts were accepted or rejected on the basis of the measured dimensions. Generally these dimensions were not recorded. To obtain an understanding of the quality of the parts that were inspected, 25 threaded flanges in the 1/4-inch tube size (MS 27854-04) were measured and the dimensions recorded. The distribution of dimensions is shown in Figure 5. The specification dimensions can be found on the military standard (MS 27854) in Appendix A. The large variation in dimension "F" resulted in a change from $0.208 \pm \begin{smallmatrix} .005 \\ .000 \end{smallmatrix}$ to $0.213 \pm .005$ in final specification. Experience has shown that in tubing connectors the full-cycle stress-reversal bending flexure test is the most strenuous structural test. The full-cycle flexure test loads the connector nearer the designed limits than any other type of test. For this reason the stress-reversal bending test was conducted first.

The stress-reversal bending test was conducted by having a threaded flange welded to the base plate holder (X66D18156) and the plain flange welded, with the nut in position, to the wobble shaft (X66D18154). (The fitting must be concentric to the centerline of the shaft within 0.010 inches.) A copper constantan thermocouple was welded to the threaded flange. A strain gage was bonded to the tube section behind the weld on the wobble shaft. Micromasurement's SK-09-125AD-350 and Budd C9-624-350 strain

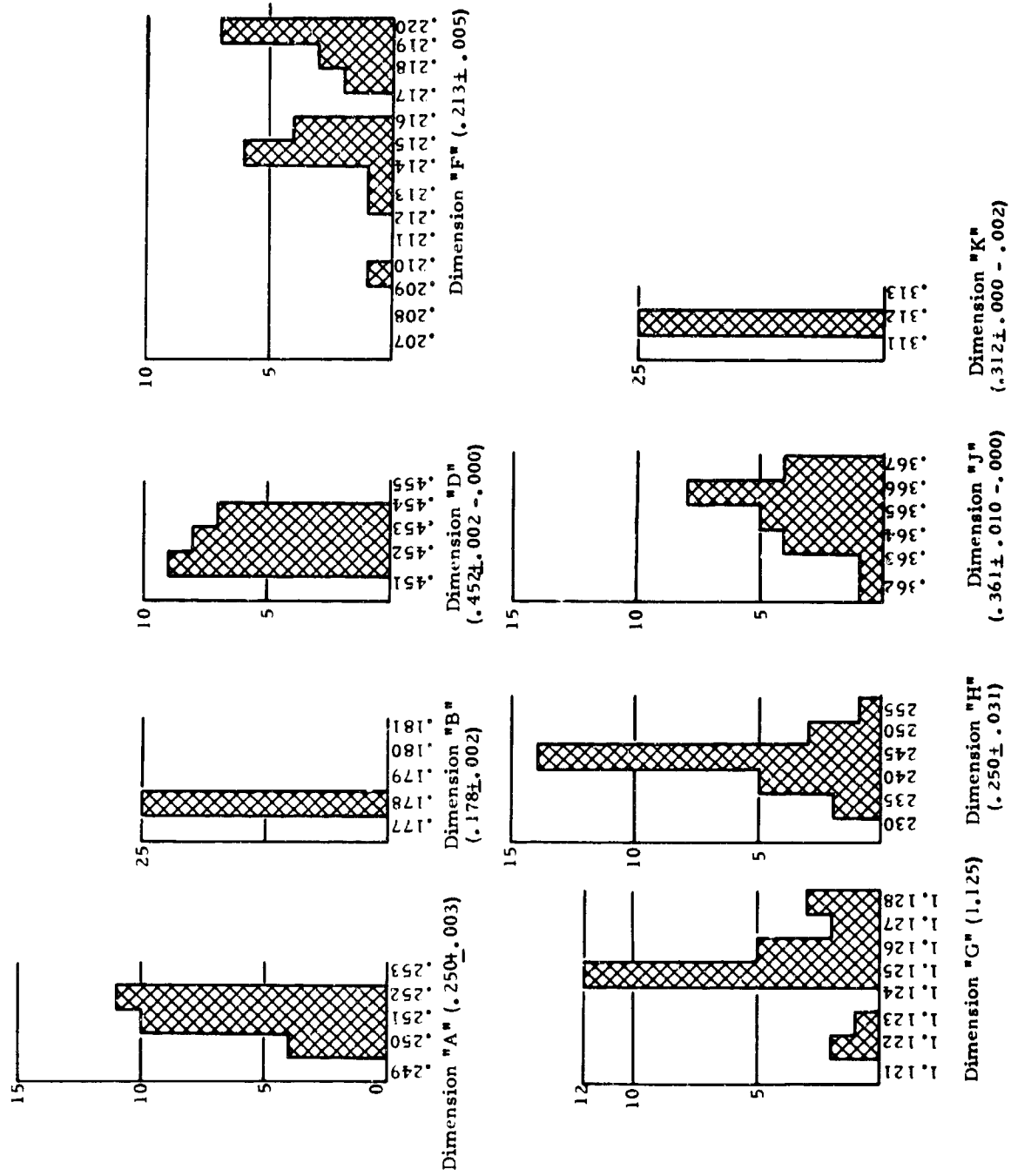


Figure 5. Measured Dimensions of 25 Threaded Flanges, MS 27854-04

gages were found to perform in the extreme test environment. These were bonded to the tubing using Budd-type GA61 strain-gage cement. High-temperature lead wire was soldered with a 0.035-inch-diameter 95% cadmium, 5% silver soldering alloy. The strain readings were calculated using the procedure in Appendix B. The connector was assembled according to the requirements of MS 27850 (Fittings, Installation of Straight Threaded Fluid Connection). The connector, ready for test, is shown in Figure 6. The connectors were proof-pressure-tested with as high a line pressure as was available. The available pressure was generally 4700 to 5100 psi, but never exceeded 6000 psi. The test was conducted at 4000 psi. The connector was heated to 600°F with a 400 watt (3/16-inch diameter by 18-inch long) special sheath heater made by Pyro Electric, Walkerton, Indiana, and controlled by a model Pc 230-85-1-DC (Research, Incorporated) solid-state power controller. The measured leakage rate of the tested connectors is shown in Table II. The highest measured leakage rate was 7.0×10^{-7} cc/sec. This level is the maximum level allowed by the performance specification. The smallest leakage was less than 9.8×10^{-10} cc/sec which was the sensitivity limit of the mass spectrometer at the time of measurement.

Two connectors of the -04, -06, -08, and -12 sizes were tested for their ability to be assembled repeatedly. One connector in each size was assembled each time at the minimum recommended torque; and one in each size was assembled at the maximum assembly torque. A new seal was installed for each assembly.

The repeated assembly test was conducted using available high-pressure gas supplies. The proof-pressure cycles were conducted with nitrogen, which was available at 5900-psi pressure, the leakage tests were conducted with helium (4300 psi). The nitrogen was purged before the leak test. The threads and nut hub bearing areas were lubricated with a 50/50 mixture of "Kel-F" grease and MoS_2 . The seal cavities, the plain flange

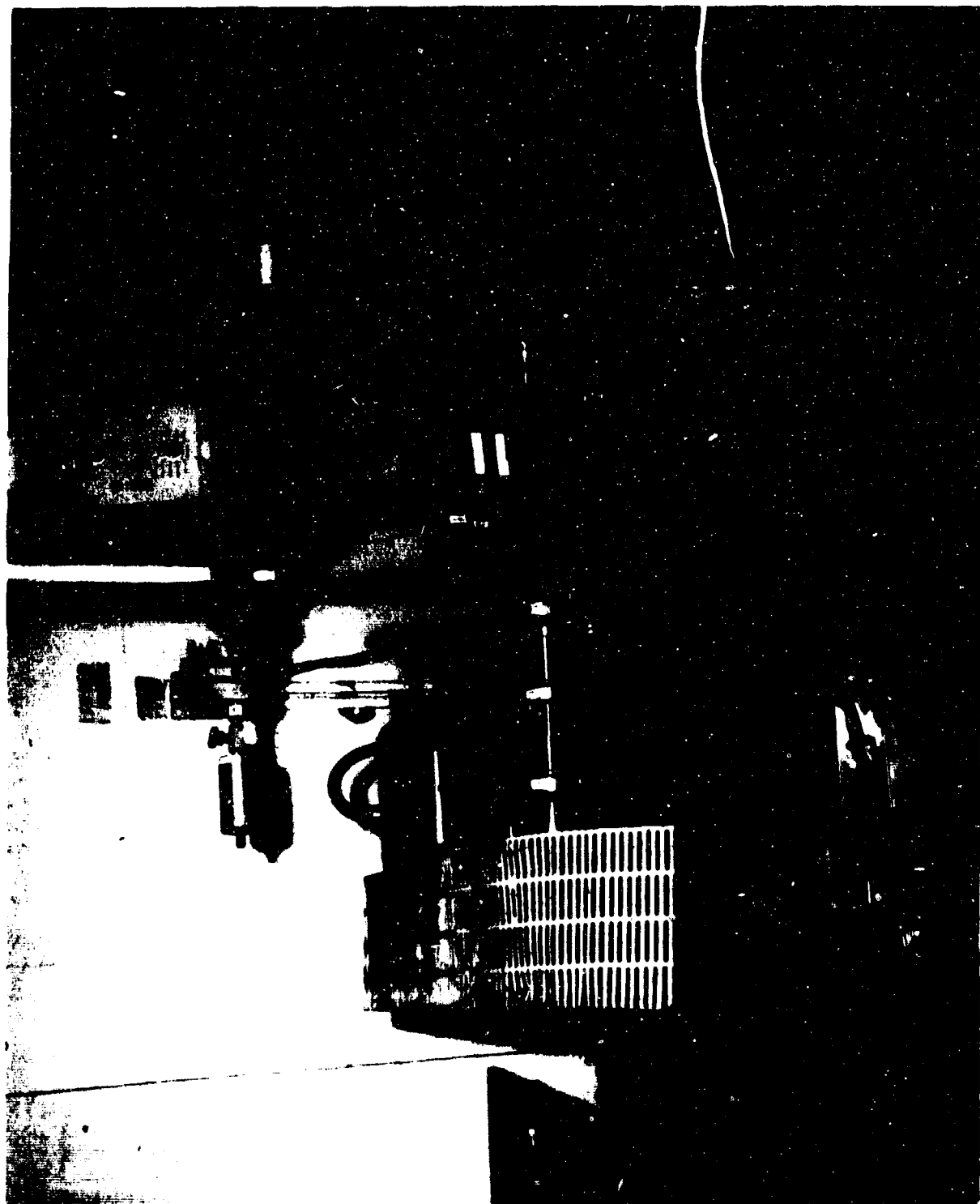


Figure 6. Stress-Reversal Bending Test Fixture

TABLE II. STRESS-REVERSAL BENDING LEAKAGE DATA

FITTING:	R6U4	R6U5	R6U6	R6U7	R6U8	R6U9	R6U4	R6U5	R6U6	R6U7	R6U8	R6U9	R6U7	R6U8	R6U9
Torque in-lbs	380	380	380	435	435	435	490	490	490	490	490	555	555	555	555
Bending Moment, in-lbs	50.6	50.6	50.6	50.6	50.6	50.6	126.4	126.4	126.4	126.4	126.4	126.4	126.4	126.4	126.4
Proof Pressure psi	5600	4400	5800	5400	5400	5400	4500	4800	5100	4400	5300	5100	4400	5300	5100
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}	9.8×10^{-10}	4.4×10^{-9}	1.2×10^{-8}	9.0×10^{-9}	3.1×10^{-7}	1.2×10^{-8}	1.2×10^{-8}	3.1×10^{-7}	1.2×10^{-8}	1.2×10^{-8}
PP at RT	3.0×10^{-8}	4.4×10^{-8}	4.9×10^{-8}	2.6×10^{-7}	7.2×10^{-8}	9.8×10^{-10}	5.1×10^{-9}	1.3×10^{-8}	9.0×10^{-9}	3.3×10^{-7}	1.2×10^{-8}	1.2×10^{-8}	3.3×10^{-7}	1.2×10^{-8}	1.2×10^{-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}	4.2×10^{-8}	6.2×10^{-9}	1.1×10^{-8}	9.0×10^{-9}	3.3×10^{-7}	1.4×10^{-8}	3.1×10^{-8}	3.3×10^{-7}	1.4×10^{-8}	3.1×10^{-8}
PP at 600°F	5.0×10^{-8}	9.0×10^{-8}	5.2×10^{-8}	2.8×10^{-7}	7.8×10^{-8}	4.2×10^{-8}	6.2×10^{-9}	1.2×10^{-8}	9.0×10^{-9}	3.2×10^{-7}	1.4×10^{-8}	3.5×10^{-8}	3.2×10^{-7}	1.4×10^{-8}	3.5×10^{-8}
Leakage During Test	6.2×10^{-8}	9.0×10^{-8}	5.6×10^{-8}	2.8×10^{-7}	1.2×10^{-8}	1.2×10^{-8}	1.1×10^{-8}	1.4×10^{-8}	9.1×10^{-9}	7.0×10^{-7}	6.8×10^{-8}	8.0×10^{-8}	7.0×10^{-7}	6.8×10^{-8}	8.0×10^{-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}	3.72×10^{-8}	1.1×10^{-8}	1.4×10^{-8}	9.1×10^{-9}	7.0×10^{-7}	6.8×10^{-8}	7.2×10^{-8}	7.0×10^{-7}	6.8×10^{-8}	7.2×10^{-8}

*NOTE CODE:

R - Connector Type R-AFRPL Connector F-Flared, etc.

6 - Nominal Tubing OD in 1/16 inch

U - Configuration U-Union L-Elbow T-Tee X-Cross

4 - Sequential Numbers

R6U4 indicates the fourth, union-type AFRPL connector tested in the 3/8-inch size.

outside diameter, and the nut wrench flats were measured to detect possible distortion during repeated assembly.

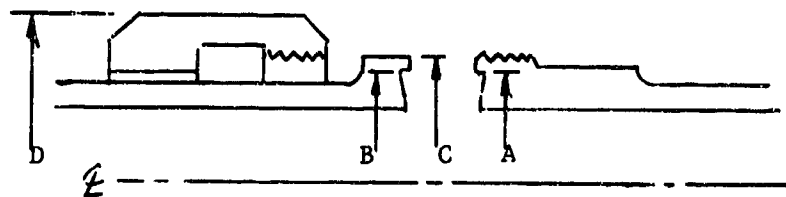


Figure 7. Repeated-Assembly Test Measurements

The location of the dimensions monitored during the repeated assembly tests are indicated in Figure 7. The leakage and dimensional measurements taken during the repeated assembly tests are shown in Table III.

Over 150 seals have been assembled with leakage measurements made on 44 different joints. Over 100 leakage measurements were made. A distribution chart of the maximum leakages measured and test condition is presented in Figure 8. The mean leakage was 3.5×10^{-8} atm cc/sec. This correlates well with the 2.6×10^{-8} atm cc/sec reported in Reference 8.

V. CONCLUSIONS AND RECOMMENDATIONS

This report does not include the results of all the testing that is planned; however, the following conclusions and recommendations can be made on the basis of the data available.

Conclusions

1. The AFRPL connector successfully met all leakage requirements during all leakage tests.
2. The AFRPL connector demonstrated that it can be manufactured at reasonable cost within present tolerances.

TABLE III. REPEATED-ASSEMBLY TEST DATA

	R4U1	R4U2	R6U1	R6U2	R8U1	R8U2	R12U1	R12U2
Temperature. °F	600	600	600	600	600	600	600	600
Pressure Each Cycle psi	5900	5900	5900	5900	5900	5900	5900	5900
Pressure for Leak Test psi	4300	4350	4400	4350	4350	4350	4350	4350
Size	-04	-04	-06	-06	-08	-08	-12	-12
Torque IN-LBS	200	225	380	430	490	555	1240	1400
Leak Rate At Start. atm cc/sec	1.8×10^{-8}	7.1×10^{-8}	2.0×10^{-8}	9.5×10^{-8}	5.3×10^{-8}	2.5×10^{-9}	7.6×10^{-9}	1.1×10^{-8}
Leak Rate After 5th Assembly atm cc/sec	2.1×10^{-9}	6.5×10^{-8}	2.5×10^{-8}	Weld Broke	5.9×10^{-8}	3.2×10^{-9}	Leak in Weld	5.8×10^{-8}
Leak Rate After 10th Assembly atm cc/sec	2.3×10^{-9}	9.5×10^{-8}	5.2×10^{-8}		3.5×10^{-8}	4.6×10^{-9}		7.8×10^{-8}
Leak Rate After 15th Assembly atm cc/sec	4×10^{-9}	1.3×10^{-7}	8.2×10^{-9}		1.2×10^{-8}	1.3×10^{-9}		1.3×10^{-8}
Leak Rate After 20th Assembly atm cc/sec	8.4×10^{-9}	7.8×10^{-7}	8.1×10^{-9}		5.7×10^{-8}	2.9×10^{-9}		1.7×10^{-8}
Dimension A at Start. in.	0.453	0.452	0.565	565	0.668	668	892	890
Dimension A After 5th Assembly. in.	0.454	0.452	0.563		X	X	841	890
Dimension A After 10th Assembly. in.	0.453	0.452	565		0.668	668		890
Dimension A After 15th Assembly. in.	0.455	0.451	566		0.668	667		890
Dimension A After 20th Assembly. in.	0.454	0.453	655		0.667	667		891
Dimension B at Start. in.	0.453	0.453	565	565	0.667	0.665	892	890
Dimension B After 5th Assembly. in.	0.453	0.454	566		X	X	892	890
Dimension B After 10th Assembly. in.	0.452	0.453	565		0.667	0.667		890
Dimension B After 15th Assembly. in.	0.453	0.454	566		0.668	0.667		890
Dimension B After 20th Assembly. in.	0.453	0.453	565		0.669	0.667		890
Dimension C at Start. in.	574	573	688	689	0.800	0.801	1.040	1.040
Dimension C at Finish. in.	576	577	688		0.800	0.800		1.040
Dimension D at Start. in.	688	688	0.813	0.813	934	935	1188	1.188
Dimension D at Finish. in.	688	688	0.813		935	935		1.188

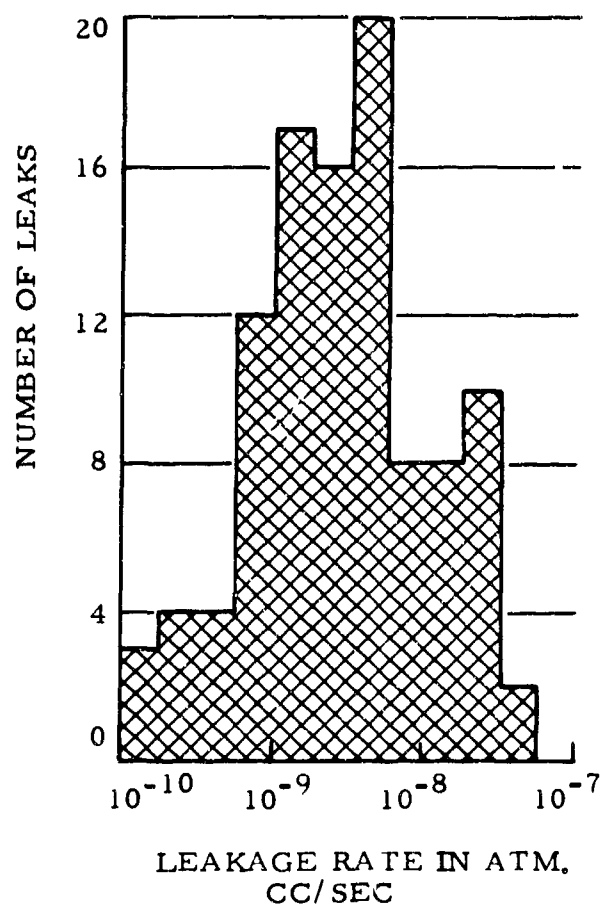


Figure 8. Leakage Rate Distribution For The Connector

3. The AFRPL connector demonstrated that it is structurally able to carry design loads.

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

5. The MoS_2 /grease mixture was an adequate lubricant.

Recommendations

1. Continue with the testing of the AFRPL connector in the remaining sizes and other tests (i. e. , vibration and temperature shock).

2. Test AFRPL connectors submitted by manufacturer for the purpose of placing manufacturer on the Qualified Producers List of MIL-F-27417.

3. Test aluminum AFRPL connectors and develop QPL sources.

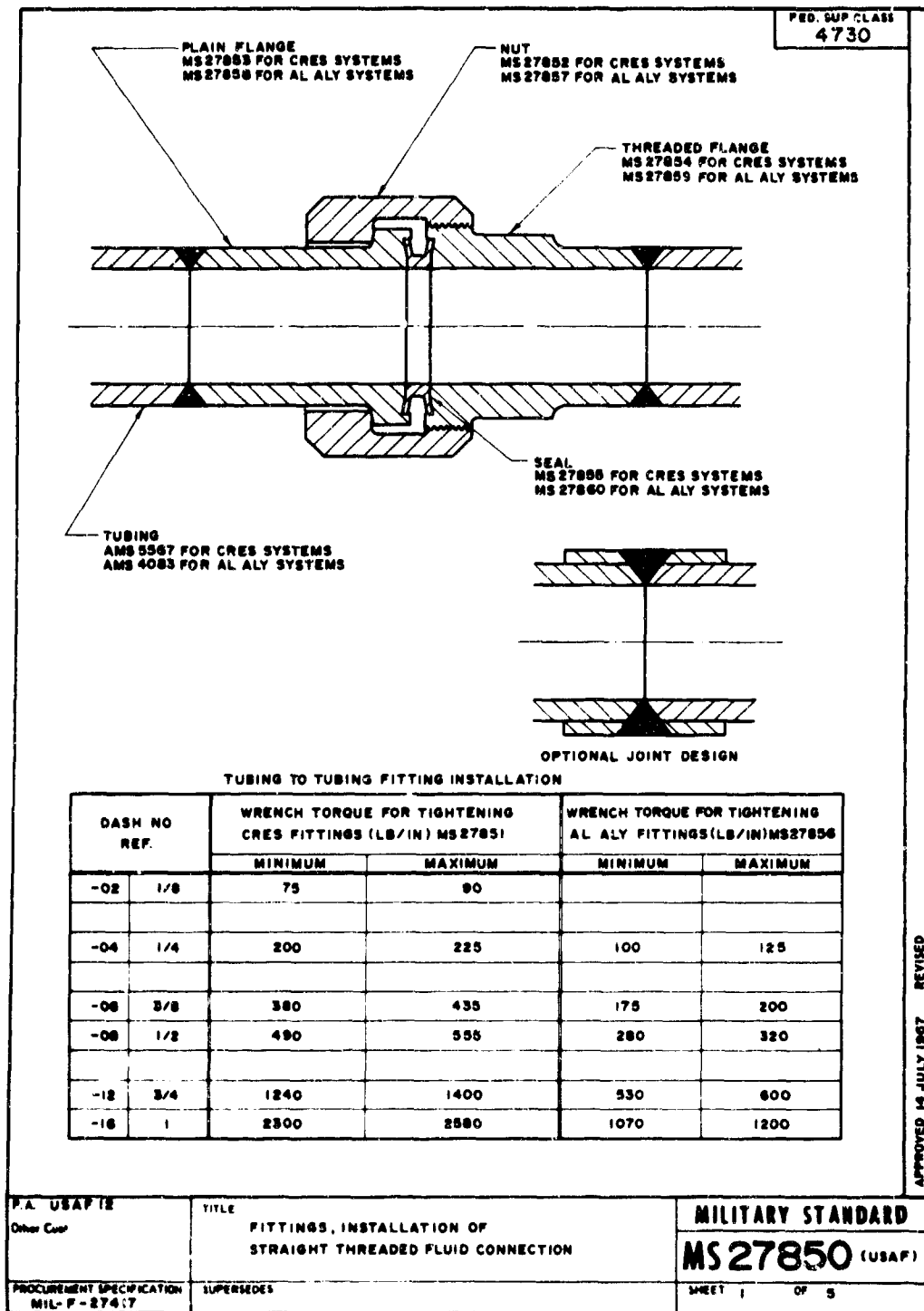
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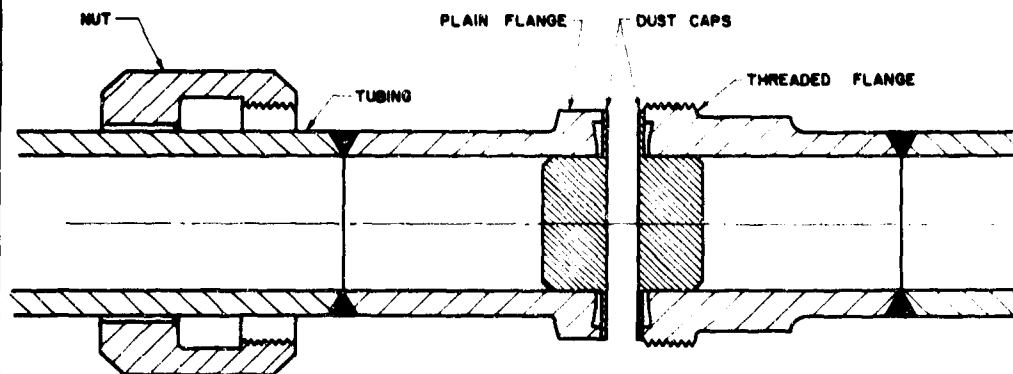
APPENDIX A

AFRPL CONNECTOR MILITARY STANDARDS

APPENDIX A AFRPL CONNECTOR MILITARY STANDARDS

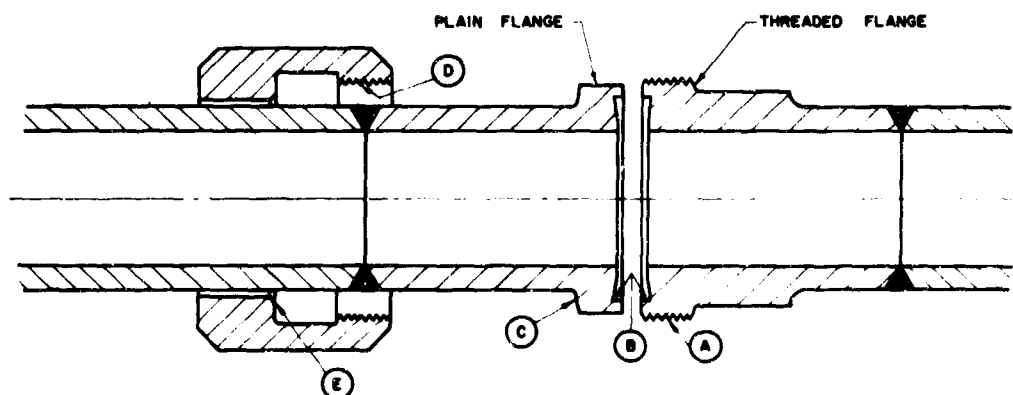


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STEP 1

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



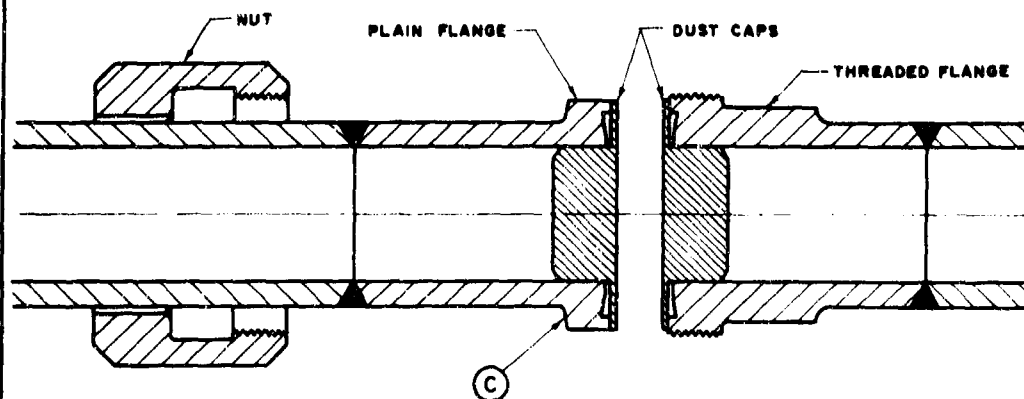
STEP 2

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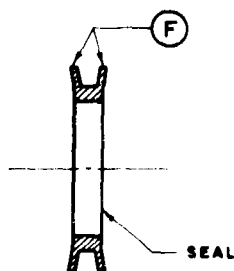
P.A. USAF 12 Other Code	TITLE FITTINGS, INSTALLATION OF STRAIGHT THREADED FLUID CONNECTION	MILITARY STANDARD MS27850 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES	SHEET 2 OF 5

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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.

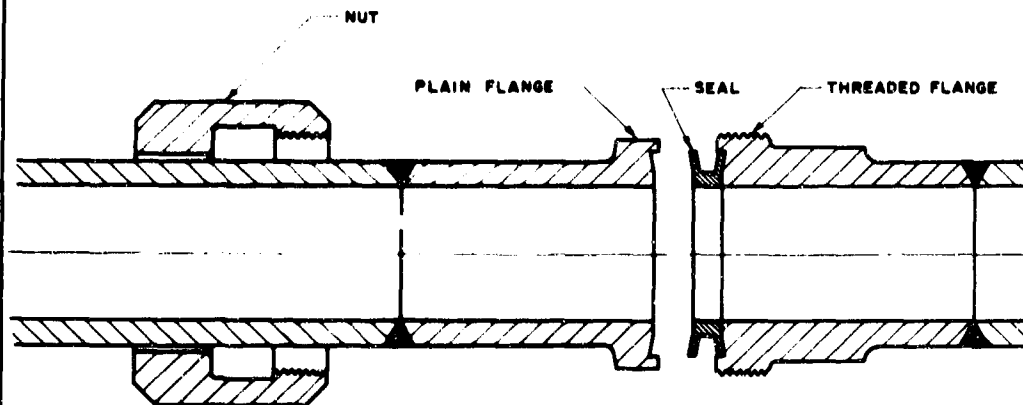


STEP 4

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

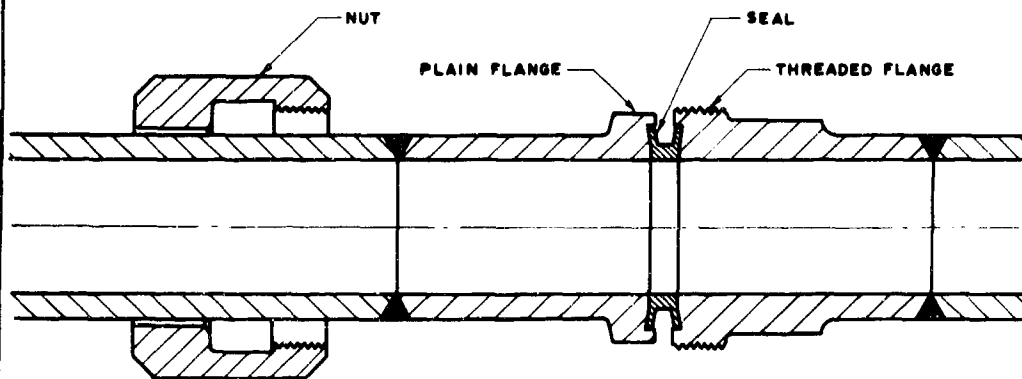
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P.A. USAF 12 Other Cost	TITLE FITTINGS, INSTALLATION OF STRAIGHT THREADED FLUID CONNECTION	MILITARY STANDARD MS 27850 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES	SHEET 3 OF 3



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.



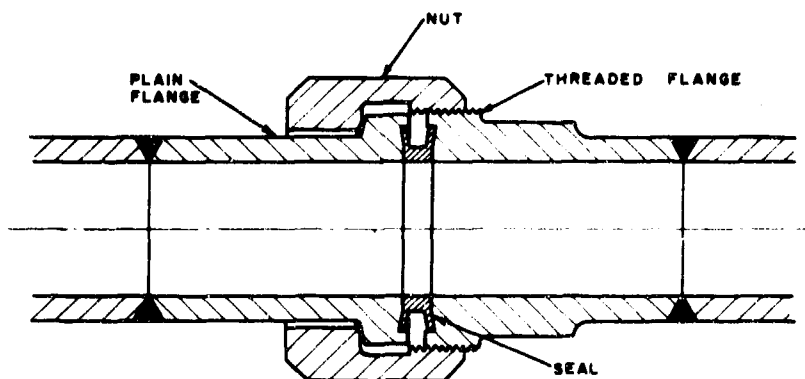
STEP 6

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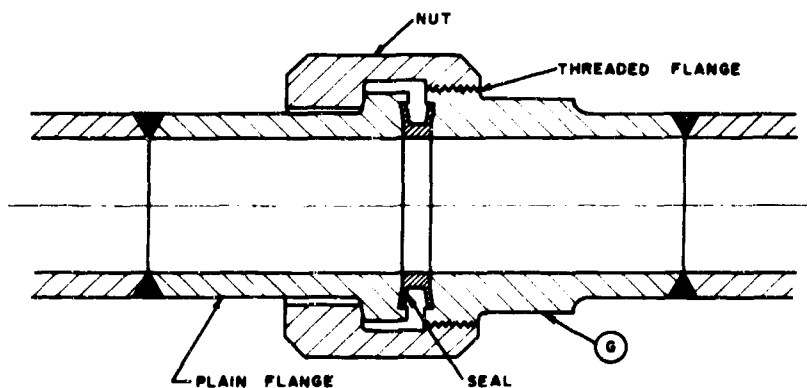
P.A. USAF 12 Other Code	TITLE FITTINGS, INSTALLATION OF STRAIGHT THREADED FLUID CONNECTION	MILITARY STANDARD MS 27850 (USAF)
PROCUREMENT SPECIFICATION MIL-P-27417	SUPERSEDES	
		SHEET 4 OF 5

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STEP 7

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

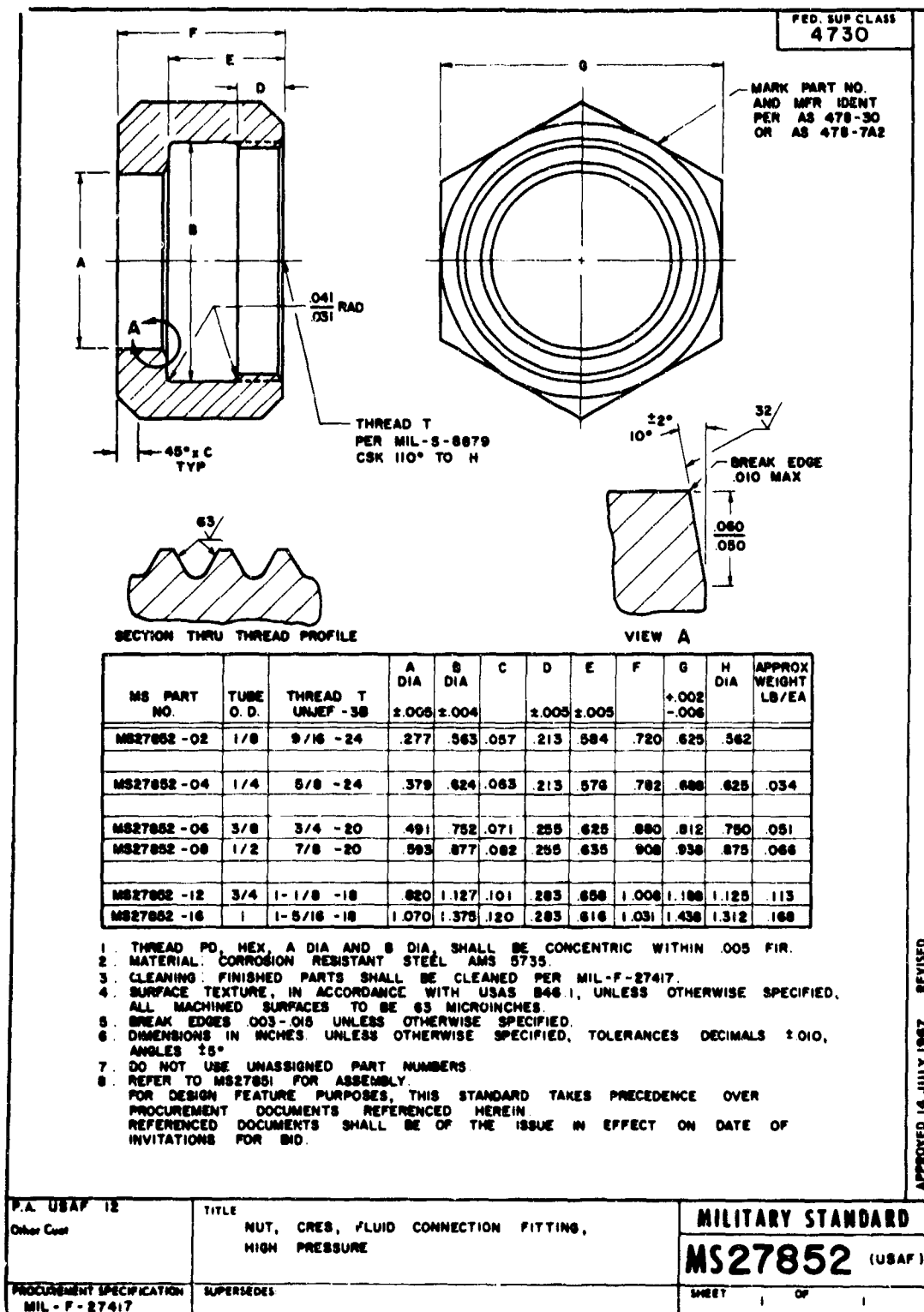


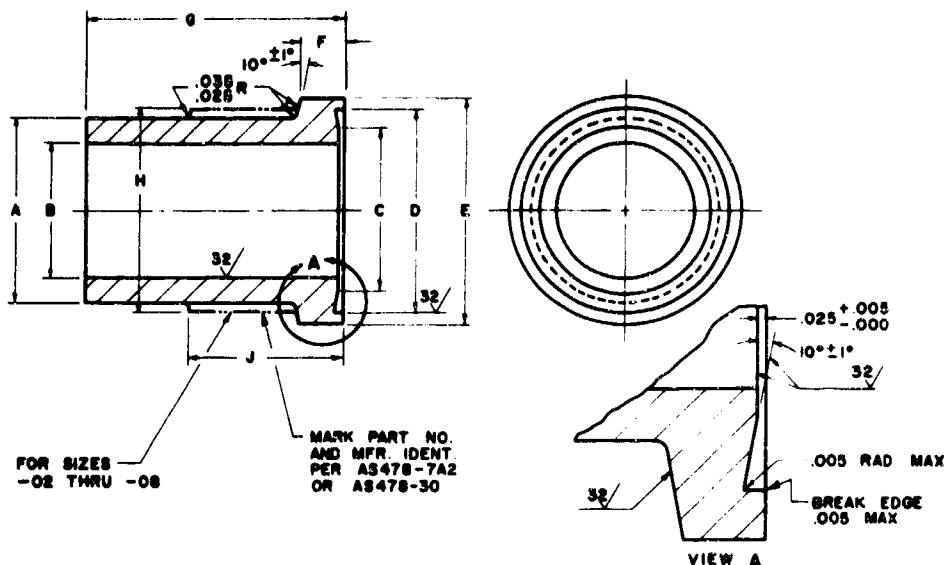
STEP 8

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

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



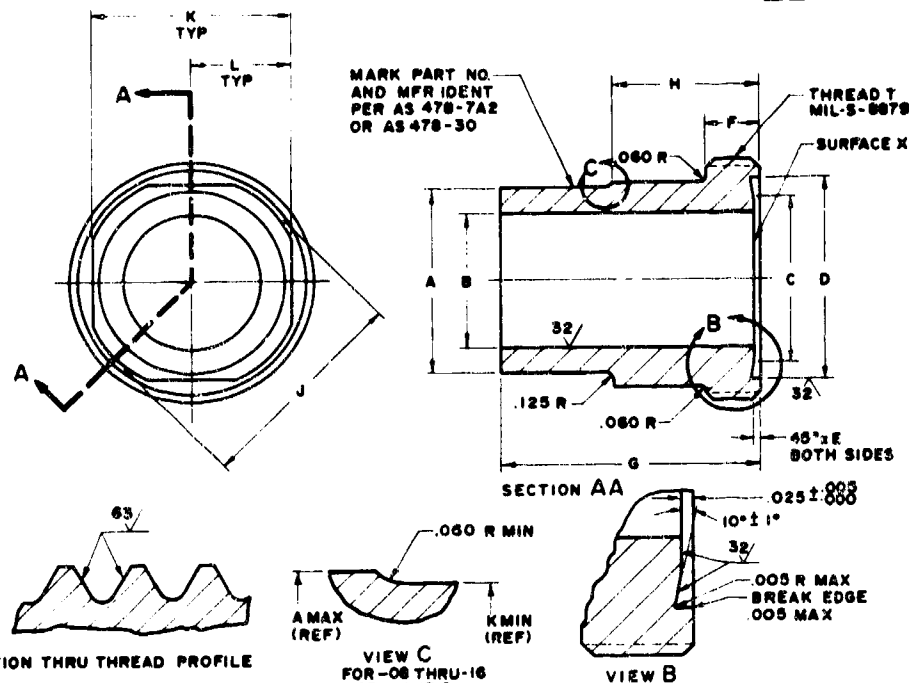


MS PART NO.	TUBE O.D.	A DIA	B DIA ±.002	C DIA +.000 -.010	D DIA +.002 -.000	E DIA +.002 -.007	F	G	H DIA +.005 -.000	J ±.031	APPROX. WEIGHT LB/EA
MS27853-02	1/8	.125 ± .002	.083	.156	.350	.500	.313	1.125	.217	.440	
MS27853-04	1/4	.250 ± .003	.178	.260	.482	.582	.280	1.125	.319	.467	.027
MS27853-06	3/8	.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 Cost	TITLE FLANGE, PLAIN, CRES, FLUID CONNECTION FITTING, HIGH PRESSURE	MILITARY STANDARD MS27853 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES	SHEET 1 OF 1



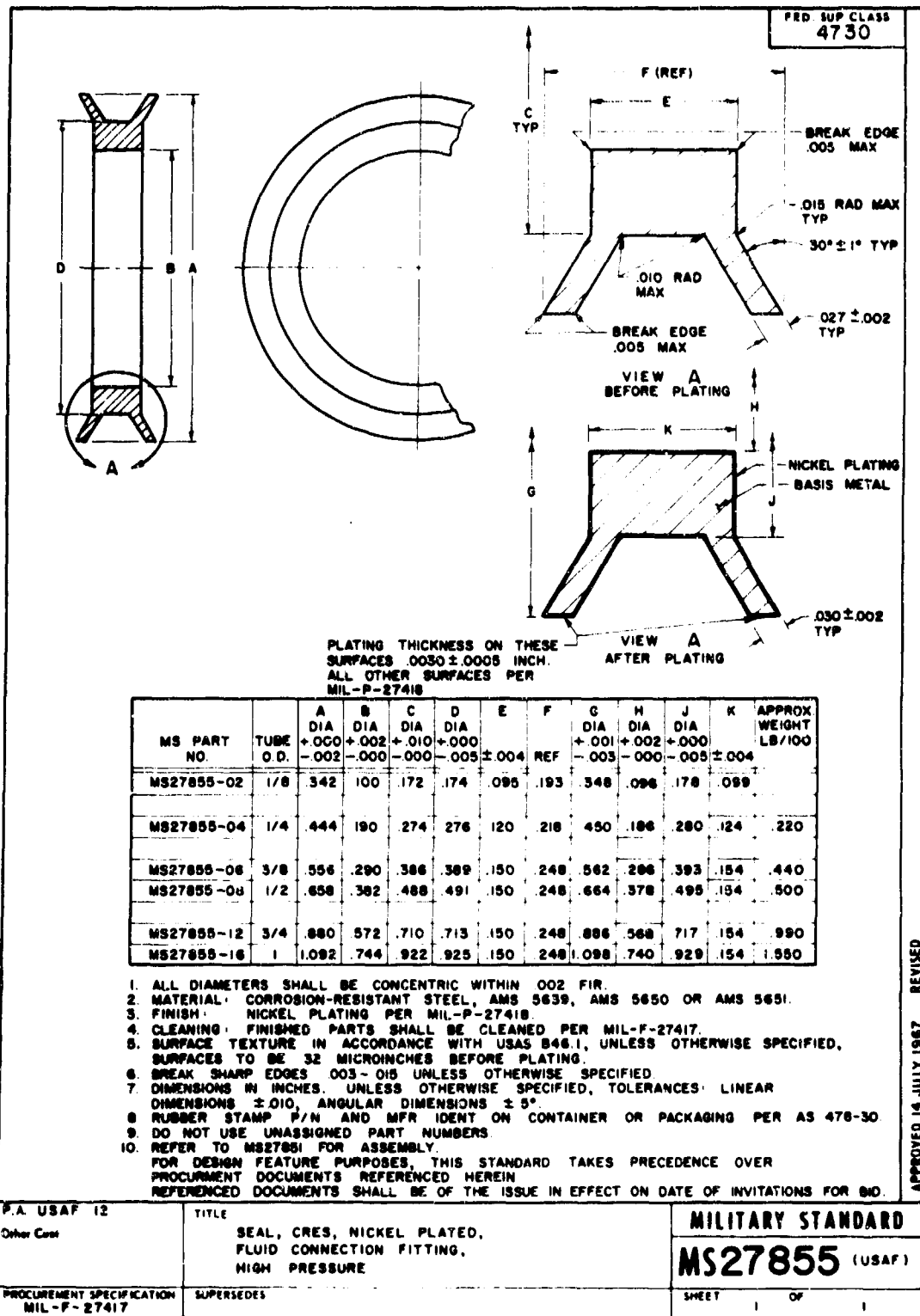
MS PART NO.	TUBE O.D.	THREAD UNJEF-3A	A DIA	B DIA ±.002	C DIA +0.000 -0.010	D DIA +0.002 -0.000	E	F ±.005	G	H ±.031	J DIA	K +0.002 -0.006	L	APPROX WEIGHT LB/EA
MS27854-02	1/8	9/16-24	.125±.002	.003	.156	.350	.030	.213	.1125	.463	.300	.250	.125	
MS27854-04	1/4	5/8-24	.250±.003	.178	.280	.452	.030	.213	.1125	.463	.361	.312	.156	.024
MS27854-06	3/8	3/4-20	.375±.003	.275	.372	.564	.035	.255	1.250	.567	.505	.437	.218	.046
MS27854-08	1/2	7/8-20	.500±.004	.368	.470	.666	.035	.255	1.250	.630	.577	.500	.281	.066
MS27854-12	3/4	1-1/8-18	.750±.004	.558	.694	.888	.040	.283	1.375	.720	.666	.750	.406	.128
MS27854-16	1	1-5/8-18	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.

P.A. USAF 12 Other Code	TITLE FLANGE, THREADED, CRES, FLUID CONNECTION FITTING, HIGH PRESSURE	MILITARY STANDARD MS27854 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES	SHEET 1 OF 1

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AFRPL Connector Specifications and Standards

MIL-F-27417	Fittings, Rocket Engine Fluid Connection
MIL-P-27418	Plating, Soft Nickel, (Electrodeposited, Sulfamate Bath)
*MS 27850	Fittings, Installation of Straight Threaded Fluid Connection
*MS 27851	Fitting Assembly, Straight Threaded, Fluid Connection, 4000 PSI
*MS 27852	Nut, CRES Fluid Connection Fittings, High Pressure
*MS 27853	Flange, Plain, CRES, Fluid Connection Fitting, High Pressure
*MS 27854	Flange, Threaded, Cres., Fluid Connection Fitting, High Pressure
*MS 27855	Seal, Cres., Nickel Plated, Fluid Connection Fitting, High Pressure
MS 27856	Fitting Assembly, Straight Threaded, Fluid Connection, Low Pressure
MS 27857	Nut, Aluminum Fluid Connection Fitting, Low Pressure
MS 27858	Flange, Plain Aluminum, Fluid Connection Fitting, Low Pressure
MS 27859	Flange, Threaded, Aluminum, Fluid Connection Fitting, Low Pressure
MS 27860	Seal, Aluminum, Fluid Connection Fitting, Low Pressure
MS 27861	Elbow 45°, Aluminum, Fluid Connection Fitting, Low Pressure
MS 27862	Elbow 90°, Aluminum, Fluid Connection Fitting, Low Pressure
MS 27863	Tee, Aluminum, Fluid Connection Fitting, Low Pressure
MS 27864	Cross, Aluminum, Fluid Connection Fitting, Low Pressure
MS 27465	Elbow 45°, CRES, Fluid Connection Fitting, High Pressure
MS 27866	Elbow 90°, CRES, Fluid Connection Fitting, High Pressure
MS 27867	Tee, Cres, Fluid Connection Fitting, High Pressure
MS 27868	Cross, CRES Fluid Connection Fitting, High Pressure

*These part numbers are included in the Military Standards shown previously in this Appendix.

APPENDIX B

SAMPLE STRAIN LEVEL CALCULATIONS FOR STRESS REVERSAL BENDING TESTS

APPENDIX B

SAMPLE STRAIN LEVEL CALCULATIONS
FOR STRESS REVERSAL BENDING TESTS

1. List following information:
 - a. Tubing Outside Diameter, D, in.
 - b. Tubing Inside Diameter, d, in.
 - c. Wall thickness, t, in.
 - d. Average of tube diameters, $D_a = \frac{D+d}{2}$, in.
 - e. Section Modulus of tubing ($I = .049 (D^4 - d^4)$), in⁴.
 - f. Youngs Modulus of Material, E, psi
 - g. Poisson's Ratio, ν
 - h. Test pressure, P, psi
 - i. Input stress, S, psi
2. Calculate longitudinal stress in the tube section due to pressure.

$$F = p_a = P \pi \frac{d^2}{4} \text{ Lbs}$$

$$\sigma_L = \frac{F}{\pi 4 (D^2 - d^2)} \text{ psi}$$

3. Calculate hoop stress due to pressure

$$\sigma_h = \sigma_L \text{ psi}$$

4. Calculate axial strain due to pressure

$$\epsilon = \frac{\sigma_L}{E} - \nu \frac{2 \sigma_L}{E} \text{ u-inches/in}$$

5. Calculate stress to be applied by bending

$$\sigma_b = 20,000 - \sigma_L \text{ psi}$$

6. Calculate strain due to bending

$$\epsilon = \frac{\sigma_b}{E}, \text{ u-inches/in}$$

This is the value to be indicated on the strain gauge mounted on the tube near the connector, when the correct bending moment input is applied.

7. A Shunt resistance to the circuit may be added for calibration. The value of this resistance is calculated as follows:

$$R_c = R_g$$

where R_c = calibration resistance

R_g = resistance of strain gage

E_B = as calculated above

GF = gage factor

8. Approximate AC strain reading

$$E_{AC} = 0.707 \times E$$

9. Bending moment resulting from bending stress

$$M = \frac{\sigma I}{D/2}, \text{ in-lbs}$$

10. Beam load due to bending moment

$$P = \frac{M}{10.25}, \text{ lbs}$$

(10.25 is length in inches of the wobble shaft from the center of the bearing to the strain gage)

11. The approximate deflection may be calculated from the following simplified equation.

$$\Delta = 10.75 \times 10^{-6} \frac{P}{I}$$

UNCLASSIFIED

Security Classification

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13. ABSTRACT A family of threaded fittings was developed which would withstand the stringent operating conditions imposed on a fluid line connector by a liquid rocket. Qualification and verification testing of this connector family was conducted and the results evaluated in a program at the AFRPL. The tests include repeated assembly, thermal gradient, stress-reversal bending, and pressure impulse. Connectors which were tested and qualified were fabricated from type 347 CRES in the 1/4, 3/8, and 1/2 inch O.D. sizes. The complete family of connectors includes a 3/4 and 1 inch O.D. size. A complete test system was developed for qualifying and testing any threaded connector. The qualification and verification test data substantiated the integrity of the AFRPL connector design and provides qualification of the connector through 1/2-inch sizes. Additional testing and data will be generated at the completion of the test program and will be reported in the final report.		

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Rocket Propulsion Threaded Connector Separable Connector Qualification Tests Repeated Assembly Tests Stress-Reversal Bending Tests Thermal Gradient Tests Vibration Tests Pressure Impulse Tests Fluid Line Connections Fluid Couplings Metallic Seals Helium Leakage						