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STANDARD, THREADED FASTENERS, TORQUE LIMITS FOR

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B	1		Replaces Previous Revision in its entirety.

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NOTE: After revising the document, file this sheet in document preceeding Table of Contents

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MSFC STANDARD, THREADED FASTENERS, TORQUE LIMITS FOR

1. SCOPE

1.1 Scope. This standard establishes acceptable torque limits for threaded fasteners used in space vehicles and support equipment, methodology for establishing acceptable torque limits for same, and criteria for the use of torque wrenches and other torque indicating devices on such fasteners.

1.2 This standard has been completely revised.

2. APPLICABLE DOCUMENTS

2.1 The following documents form a part of this standard to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

SPECIFICATIONS/STANDARDS

Federal

FED-STD-H28/2A	Screw Thread Standards for Federal Services Section 2, Unified Inch Screw Threads-UN and UNR Thread Forms
GGG-W-686	Wrench, Torque
QQ-P-416	Plating, Cadmium (Electrodeposited)

Military

MIL-HDBK-5F	Metallic Materials and Elements for Aerospace Vehicle Structures
MIL-STD-1312 Test 8 Test 15	Fastener Test Methods Tensile Strength Torque-Tension
MIL-T-5544	Thread Compound, Antiseize, Graphite-Petrolatum
MIL-N-25027	Nut, Self-Locking, 250°F, 450°F, and 800°F
MIL-L-46010 Type 1	Lubricant, Solid Film, Heat Cured, Corrosion Inhibiting
MIL-L-87132	Lubricant, Cetyl Alcohol, 1-Hexadecanol, Application to Fasteners

MS14183	Washer, Countersunk and Plain, For Use With Bolts and Nuts Up to and Including 220 ksi F_{tu}
MS33540	Safety Wiring and Cotter Pinning, General Practice For

National Aeronautics and Space Administration

NHB 8060.1	Flammability, Odor, and Offgassing Requirements and Test Procedures for Materials in Environments that Support Combustion
NASA TM-86556	Lubrication Handbook for The Space Industry
SP-R-0022A	Vacuum Stability Requirements of Polymeric Material for Spacecraft Applications

George C. Marshall Space Flight Center

10A00527	Sealing of Fasteners Subject To Seawater Exposure on the SRB, Excluding the SRM
40M39581	Connectors, Electrical, Circular Miniature, Installation and Mounting, Procedure For

Lyndon B. Johnson Space Center

NSTS 08307	Criteria For Preloaded Bolts

(Copies of specifications, standards, drawings and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer).

OTHER PUBLICATIONS

National Aerospace Standards

NAS 1587	Washer, Plain and Countersunk, 1200° F

(Applications for copies should be addressed to:

Aerospace Industries Association of America, Inc.
1250 Eye Street, NW
Washington, D.C. 20005)

Aerospace Standards

AS 1310 Fastener Torque for Threaded Applications, Definitions of

(Applications for copies should be addressed to:

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

American Institute of Steel Construction

Specification for Structural Joints Using ASTM A 325 or A 490 Bolts

(Applications for copies should be addressed to:

American Institute of Steel Construction
1 East Wacker Drive
Chicago, IL 60601)

3. DEFINITIONS

The torque definitions provided herein are those which are commonly used in the aerospace industry (reference AS 1310).

3.1 Breakaway Torque: The torque required to overcome static friction when 100 percent of the locking feature is engaged and the fastener is unseated. Breakaway torque shall not contain any component of torque required to produce an axial load in the fastener assembly. Breakaway torque can be prefixed with the words MAXIMUM or MINIMUM and can be measured in either a loosening or tightening direction.

3.2 Fastening System: An installed fastener, its component parts (structural elements, nut, nutplate, insert, washer, lubricant, fastener coating, etc.), the geometry of the hole where it affects the performance of the system, and installation and removal tooling and procedures.

3.3 Free Running Torque: This shall be the torque required to overcome kinetic friction between mating threads. This torque can be measured in either a loosening or tightening direction. Free running torque shall not include any component of torque required to overcome a self-locking feature or axial load in a fastener assembly.

3.4 Installation torque: The designed torque applied at final assembly. It shall include the net effect of the following:

a) The torque required to overcome kinetic friction between mating bearing faces and between mating threads, plus;

b) The torque required to overcome the self-locking feature (if any), plus;

c) The torque required to apply the desired axial load to a fastener assembly.

The installation torque may be prefixed by the words MAXIMUM or MINIMUM when referring to the toleranced torque values of the nominal installation torque. The installation torque shall be measured only in the tightening direction.

3.5 Locking device: A part or mechanism designed to prevent loss of preload or disengagement of a fastener.

3.6 Self-Locking: An attribute of a fastener or fastener assembly having an integral locking element to impede relative rotation of mating components.

3.7 Self-Locking Torque (Running Torque): This shall be the torque required to overcome kinetic friction of the mating threads plus the torque required to overcome the locking feature when 100 percent of the locking feature is engaged and fastener is unseated. The word "self-locking" shall be understood as the average locking torque when it is not prefixed by the words MAXIMUM or MINIMUM. Self locking torque shall not contain any torque component for axial load in the fastener assembly. The self-locking torque can be measured in either a loosening or a tightening direction while the fastener is in motion.

3.8 Shear application: Shear application in this standard refers to that application in which the applied tensile loads are low and the shear ultimate strength (F_{su}) of the part is used to determine the installation torque value.

3.9 Tensile application: Tensile application in this standard refers to that application in which the applied tensile loads are not low and the tensile ultimate strength (F_{tu}) of the part is used to determine the installation torque value.

3.10 Torque Installation Sequence: A method indicating sequence of assembling fasteners in a prescribed pattern.

3.11 Verification Torque: This shall be the torque required to initially move the wrenched fastener from the assembled condition. Verification torque is always measured in the tightening direction and it usually exceeds the maximum limit of the desired installation torque. It is normally used to: (1) break loose the net seizure effects before encountering the corrosive effects when the fastener assembly is disassembled, (2) initially

deform the captive internal thread element on blind fasteners with threaded cores, or, (3) to determine the magnitude of the installation torque after a given span of time, after cylic thermal or vibration loading, etc.

4. REQUIREMENTS

4.1 Torque Limits.

4.1.1 Acceptable torque limits for threaded fasteners for use in space vehicles are tabulated for specific materials, conditions and strength levels in **Appendix A.**

4.1.2 Torque-tension data and proposed torque values used for unique fastener systems not represented in Appendix A shall be submitted to the procuring activity prior to use. A tolerance of plus zero (+) 0, minus fifteen (-) 15 percent shall be applicable to all torque-tension data and torque values obtained. Torque-tension data and torque values submitted shall be determined by using one of the following methods:

4.1.2.1 Torque-tension testing. Torque tension testing is the **preferred method** and shall be used for determining torque-tension data and torque values to the **maximum extent possible.** Torque-tension testing shall be conducted in accordance with the test methods described in Appendix B. Torque-tension data and torque values which meet the testing requirements of Appendix B shall be incorporated in Appendix C, and allowed for use on appropriate fastener system designs.

For typical preloaded structural assembly tension applications, the torque shall not exceed a value which will result in a tensile preload greater than 65 percent of the tensile yield strength as determined by MIL-STD-1312-8A (Johnson's 2/3 approximate method for determination of yield strength; Figure 1). Torque values based on lower percentages of tensile yield strength shall be permitted based on the specific application and procuring activity approval. For shear applications, the torque shall not exceed 60 percent of the tensile application torque determined by MIL-STD-1312-8A.

For critical preloaded structural assembly tension and shear applications, torque values based on higher percentages of tensile yield strength shall be permitted based on procuring activity approval.

Where the ultimate tensile load levels of the internally and externally threaded members' (bolts, screws, nuts, nutplates, inserts, etc.) are different, the torque requirement corresponding to the lower allowable tensile load level shall apply.

4.1.2.2 Analysis. Preload torque may be determined by analysis (e.g. NSTS 08307) as the torque value required to ensure joint assembly integrity, considering all loading, thermal, and operational environments and applicable safety factors, where torque-tension testing is not justifiable, or where data exists with similar design configuration which supports the analyis. Determination by analysis is subject to procuring activity approval.

Analysis shall be based on the material minimum or A-Basis (ref. MIL-HDBK-5F) tensile yield strength and the thread minimum tensile stress area (e.g. formulas in FED-STD-H28/2A, Table II.B.1, etc.), or the minimum shank cross sectional area, whichever is least.

For typical preloaded structural assembly tension applications, the torque shall not exceed a value which will result in a tensile preload greater than 65 percent of the tensile yield strength as determined by tensile testing of the fastener. Torque values based on lower percentages of tensile yield strength shall be permitted based on the specific application and procuring activity approval. For shear applications, the torque shall not exceed 60 percent of the tensile application torque, determined by MIL-STD-1312-8A.

For critical preloaded structural assembly tension and shear applications, torque values based on higher percentages of tensile yield strength shall be permitted based on procuring activity approval.

Where the ultimate tensile load levels of the internally and externally threaded members' (bolts, screws, nuts, nutplates, inserts, etc.) are different, the torque requirement corresponding to the lower allowable tensile load level shall apply.

4.1.3 Automatic Preload Indicating Fastening Systems. Fastening systems which employ special features to provide and/or indicate predetermined preload levels upon installation shall meet the preload tolerance requirements of 4.1.2 when tested in accordance with 4.1.2.1. Manufacturers' torque-tension data or equivalent shall be submitted to demonstrate compliance.

4.1.4 High Strength Fasteners. Methodologies other than torquing should be utilized to determine fastener preload where there is a concern with fastener materials which have high yield strength to ultimate tensile strength ratios, and/or low ductilities. Preload can be more accurately determined with hydraulic tensioners, preload indication washers, ultrasonic devices, instrumented bolts, etc.

4.1.5 Support Equipment Structural Steel Applications. Steel construction for ground support equipment applications (ASTM

A307, A325, A354, A490, etc. bolts) shall conform to the requirements of the AMERICAN INSTITUTE OF STEEL CONSTRUCTION SPECIFICATION FOR Structural Joints Using ASTM A325 or A490 Bolts. Structural steel applications are not covered in this document.

4.2 Torque Wrenches. Unless otherwise specified, torque shall be applied to fasteners using torque wrenches which conform to Specification GGG-W-686. The torque wrench to be used shall be chosen such that the specified torque values for a particular fastener shall be between 20 and 80 percent of the full scale torque.

4.2.1 Calibration. Unless otherwise specified, torque wrench calibration shall be checked prior to the first use and thereafter at intervals not to exceed 30 calendar days. A dated certification of such check shall be securely attached to the wrench.

4.2.1.1 Sealing and Marking. Torque presetting wrenches shall be sealed after adjustment and calibration check with a suitable tamperproof material. The torque to which the wrench is set shall be clearly and conspicuously marked on the wrench.

4.2.1.2 Recalibration. If a torque wrench is dropped, struck or otherwise damaged, or suspected of being out of calibration, the wrench shall be checked before further use and, if found to be out of calibration, the wrench shall not be used until recalibrated.

4.2.2 Adapters. Adapters or extensions shall be used with torque wrenches only when necessary. Adapters or extensions shall be used only with wrenches designed for their use and the wrench or adapter combination shall be calibrated prior to use or correction made for actual torque by an acceptable analytical method.

4.3 Installation.

a. Use sockets and wrenches that have no sharp edges or burrs that could damage the fastener plating or coating.

b. Torque shall be applied from the nut of the fastening system to the maximum extent possible when a nut is present. Whenever clearance is a problem, torque may be applied from the bolt head of the fastening system, to the high side of the torque range specified in the torque tables of Appendix A.

c. The nut, nutplate, insert, etc., shall not engage any incomplete threads adjacent to the bolt or screw shank.

d. Any identification mark in the washer used under the nut shall be placed opposite the face of the nut.

e. When a self-locking screw thread fastening system is being installed or removed, the locking or break-away torque shall comply with the applicable torque values shown in TABLE XI, Appendix A.

f. Install fastener threads to extend through nuts, or nutplates to comply with the thread minimum protrusion requirements shown in TABLE XII, Appendix A. [Depth of fastener threads into tapped holes or free running inserts shall be one diameter minimum. Depth of fastener threads into locking inserts shall be as above or a minimum of 1.5 threads through the locking element, whichever is greater.]

g. For grip length adjustment, bolt length can be changed as necessary. The number of washers used on a fastener shall be limited to three, with one countersunk washer and one plain washer under the bolt head, or one countersunk washer under the bolt head and two plain washers under the nut.

h. Countersunk washers shall be installed under bolt heads with the countersink facing the bolt head of the joint.

4.4 Lubricants: Lubricants shall be specified on installation drawings when necessary to prevent galling or other damage to fastener threads or bearing surfaces. Lubricants used in LOX systems shall meet the compatibility requirements of Specification NHB 8060.1. Lubricants used in space vacuum shall meet the requirements of SP-R-0022A. Lubricants used for fastening systems on space vehicles and support equipment and method of application are subject to procuring activity approval.

(Sources of lubricants include NASA TM-86556: Lubrication Handbook for The Space Industry, The Marshall Space Flight Center, Materials and Processes Technical Information System (MAPTIS), as well as technical literature from lubricant manufacturers).

4.5 Designer Information.

a. Torque values for installing threaded fasteners shall be shown on drawings by providing specific values including applicable tolerances for bolts, nuts and other threaded fasteners. Lubricants and method of installation shall be shown on the installation drawing.

NOTICE: When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished or in any way supplied the said drawings, specifications or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

Copies of specifications, standards and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.

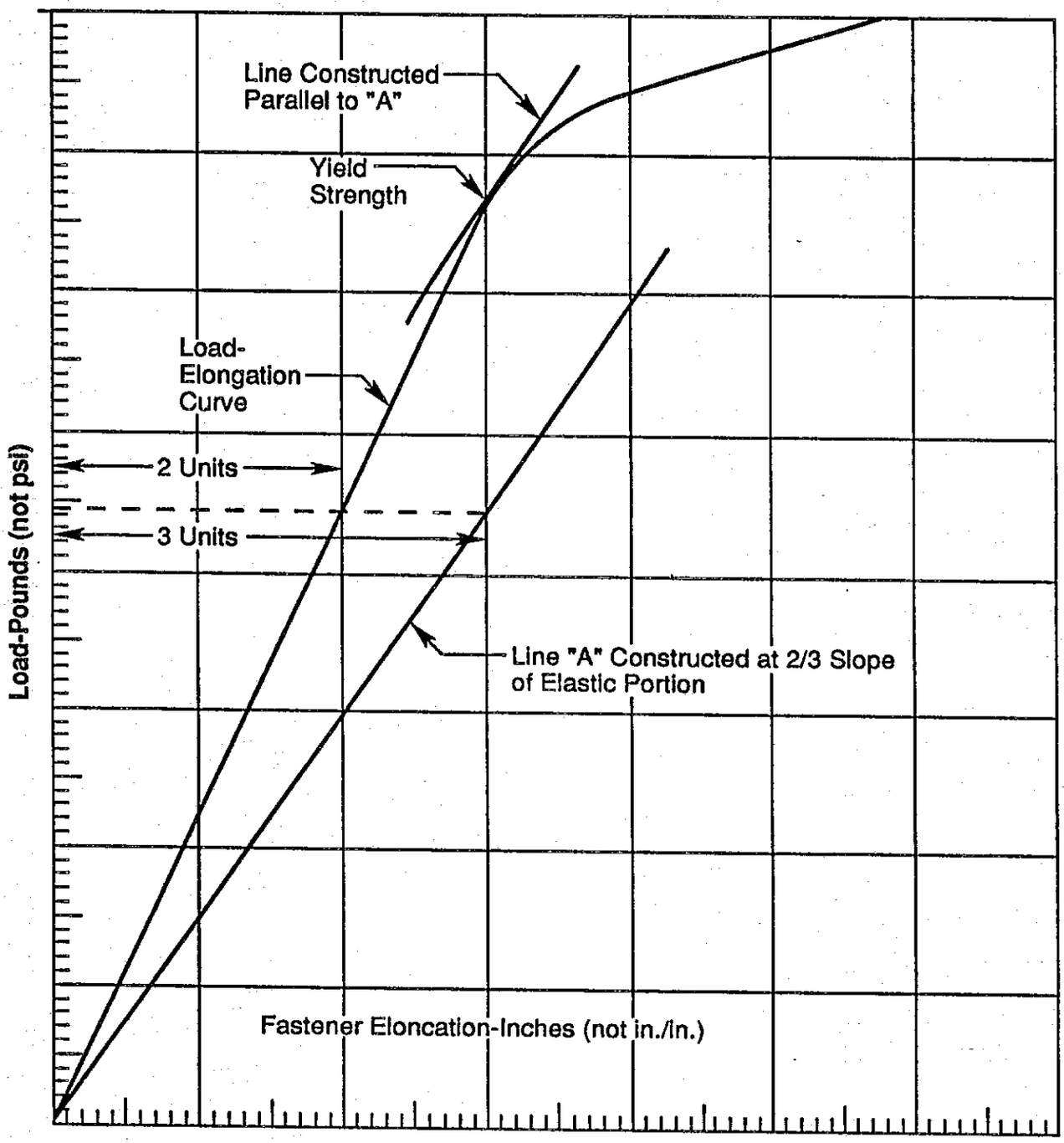

Figure 1. Johnson's 2/3 Approximate Method for Determination of Yield Strength

APPENDIX A

TABULATED TORQUE DATA
(HISTORICAL DATA)
(TABLES I-XII)

A1. SCOPE: This appendix contains a historical background, and the Detailed Requirements in their entirety as contained in MSFC-STD-486A. Tables I-XII are applicable as written.

A2. HISTORICAL BACKGROUND:

The proposed MSFC-STD-486 was first distributed for comments on May 28, 1968 and again on August 30, 1968 by the Chairman of the Specification Coordination Board, R-P&VE-VNR, Mr. F. V. McDaniel, under the direction of R-P&VE-V, Mr. Aberg (Vehicle Systems Engineering Division). The development of this standard was a combined effort of the Vehicle System Engineering Division, the Materials Division under the direction of Dr. W. R. Lucas, Director of Propulsion and Vehicle Engineering Laboratory, and the Manufacturing Engineering Laboratory, under the direction of Mr. Werner R. Kuers.

The Proposed MSFC-STD-486 torque limits were initially taken from the Sturdevant, "Proposed Standard Torque Values for Industrial Fasteners (Metal)", dated August 1964. An extensive review of industry torque procedures revealed that Chrysler, Douglas, and IBM used the ABMA-STD-18, dated July 7, 1958; Boeing used BAC 5009; and NAR used MA0601-002. The Torque values from Sturdevant, industry, and MSFC (actual torque-tension tests) were compared to values published in WADC Technical Report 57-330, ASTIA Document No. AD131039, dated July 1957, entitled, "Investigation for Determining the Torque-Tension Relationship of Screw Threaded Fasteners Used on Aircraft."

The Materials Division submitted comments concerning the Proposed MSFC-STD-486 to Dr. Lucas, R-P&VR-DIR, in memos R-P&VE-MMM-68-68 on July 19, 1968 and R-P&VE-MMM-68-82 on Sept. 3, 1968. Detailed comments were submitted to Mr. Aberg, R-P&VE-V, in memo R-P&VE-MMM-68-89 dated Oct. 7, 1968. The contents of that memo are summarized as follows:

"Data from torque-tension tests made jointly by the Materials Division and the Manufacturing Engineering Laboratory on 1/4, 3/8, and 5/16-inch diameter fastener systems (160 ksi and lower strength levels), indicate that the proposed torque values in the subject standard for cadmium plated systems should be reduced to approximately 80 percent of the proposed values.

Our data also indicates that the effect of torquing from the head of the bolt (as opposed to torquing of the nut) results in less tension load for a given amount of torque.

Among the numerous variables which can significantly influence the torque induced tensile load in a fastener system are the number and type of washers used and the type of nut used.....Our tests were made in accordance with actual installation procedures, a process which is not taken into account in previously published torque tension charts. As previously stated, the use of different washers and nuts significantly influence the actual tensile load realized.

Torque-tension tests made with a Skidmore-Wilhelm machine are limited to specific fastener diameters and lengths. Variables associated with different length fasteners cannot be easily correlated by this method of testing. We have made tests on 1/4, 3/8, and 5/16-inch diameter fastener systems of 160 ksi and lower strength levels. To make tests on stronger, larger, longer, or shorter fasteners would require extensive fixturing and additional calibrated gages, which are not readily acquired, and the procurement of many sizes and designs of fasteners for testing. This division is currently not in a position to handle such an extensive test program in-house; however, a Manufacturing Engineering Laboratory contract, currently in force, with the Almay Testing Corporation may provide additional data that could be of value to this specification. Therefore, other than the changes specified above, we believe that the torque values proposed in the subject specification represent the best knowledge that we have available. As additional data are obtained, amendments to this specification may be necessary."

Major additions, based on torque-tension data generated under contract NAS8-32525 (completed 11-14-77) with SPS Technologies and torque tension tests performed at MSFC, were made to MSFC-STD-486 as Amendment 2, dated July 21, 1978. At that time Tables IV, V, VI, and VII containing torque values for 140, 160, 180, and 200 ksi UTS A286 CRES fasteners were added as well as Table VIII which contained torque values for 260 ksi UTS MP35N Multiphase fasteners.

Paragraph 4.1.1 was also added to specify that tension nuts must have an axial tensile strength equal to or greater than that of the bolt for the torque values specified in Tables I through III to apply. Another addition specified the use of one countersunk washer under the bolt head and one flat washer under the rotating elements for the 160 and 180 ksi UTS bolts.

Notice 1, published Jan. 5, 1981, added among other items, MIL-L-8937 Lubricant, 10A00527 (PR1422) Sealant Procedure, and NAS1587 Washers for 1200^{O}F application. Tables IX and X, based on MSFC torque-tension data, were added to specify torque values for A286

CRES fasteners lubricated with Conoco HD-2 grease and Tables XI and XII were added to specify torque values for A286 CRES fasteners sealed with PR1422. Table XIII incorporated torque values for MP35N fasteners lubricated with MIL-L-8937. Table XIV and XV specify locking torque and minimum bolt or screw thread protrusion respectively.

Paragraph 4.1.5 was added which states; "In circumstances where the nut strength varies from the bolt strength, the torque requirement of the lower strength component shall apply." This paragraph was intended to preclude the type of failures which occurred in 1980 [Memo EH44(80-15)] and later in 1982 [Memo EH22(83-39)] with 140 ksi UTS A286 CRES nut cages and anchor nuts being utilized with 180-200 ksi UTS, Inconel 718 bolts.

The addition of paragraph 4.1.5 was to preclude overtorquing of the weaker component of a fastener system which inadvertently contained a mismatch of components. The paragraph was not added to give license to poor engineering practices such as the utilization of lower strength shear nuts on high strength tensile bolts. When the practices of installing shear nuts on tensile bolts is permitted, the chances for overtorque and failure of the nut are greatly increased. A technician is more likely to note the strength of the bolt and not the mating element and to apply a torque value in accordance with the bolt strength. In addition, the strength of the bolt can never be fully utilized as it is when the correct strength tension nut is properly used.

In Dec. 1987, a completely revised MSFC-STD-486A was published which was a major improvement in organization. This revision was approved by the Materials and Processes Laboratory, the Structures and Dynamics Laboratory, the Test Laboratory, and the Quality Assurance Office. This revision contained the important paragraph 6.2, DESIGNER INFORMATION:stating that "Torque values for installing threaded fasteners shall be shown on drawings by providing specific values including applicable tolerances for bolts, nuts, and other threaded fasteners." With the addition of this paragraph, the drawing should also state that the torquing procedures are in accordance with MSFC-STD-486.

MSFC-STD-486 was completely revised again in 1992 by a continuous improvement team composed of Materials and Processes Laboratory, Structures and Dynamics Laboratory, and contractor personnel. This revision expanded the scope of the standard to include torque-tension testing methodologies, updated the applicable documents section of the standard, added a definitions section to the standard, completely revised the Requirements section of the document, added an Appendix A providing a historical background to the document and added notes to this appendix to clarify the existing standard torque tension tables, and added an Appendix B to the document providing torque-tension testing procedures.

The MSFC-STD-486 has evolved over a period of twenty years and the revised Requirements of Paragraph 4 are applicable, especially concerning torque wrenches and their calibration. It is therefore considered mandatory to follow the Requirements and Detailed Requirements of MSFC-STD-486, unless otherwise approved.

A3. DETAILED REQUIREMENTS. The detailed requirement information contained herein is from MSFC-STD-486A, dated December 1987, and establishes acceptable torque limits for threaded fasteners.

A3.1 Torque Values for Standard and High Strength Steel Threaded Fastener Systems. The torque values specified in Table I are applicable to the specified materials and conditions in tension applications using nuts having an axial tensile strength equal or greater than that of the bolt and with one flat washer under the rotating element. The 160 and 180 ksi bolt and nut tensile strength levels shown shall be assembled with one countersunk washer under the bolt head and one plain washer under the nut. Unless otherwise specified, torque values for fastener systems used in shear applications shall not exceed 60 percent of the values shown in Table I.

A3.1.1 Cadmium Plated Steel Fasteners. Torque values for tightening clean cadmium plated unlubricated steel fasteners shall be in accordance with DRY values in Table I.

A3.1.2 Lubricated. Torque values for tightening cadmium plated or not plated steel fasteners lubricated with an approved lubricant (see A4.1) shall be in accordance with the LUBE values in Table I.

A3.2 Torque Values for 300 Series Corrosion Resistant Steel (CRES) Threaded Fastener Systems.

The torque values specified in Table II are applicable to the specified materials and conditions in tension applications using nuts having an axial tensile strength equal or greater than that of the bolt and with one flat washer under the rotating element. Unless otherwise specified, torque values for fastener systems used in shear applications shall not exceed 60 percent of the values shown in Table II.

A3.2.1 Passivated. Torque values for tightening clean passivated 300 series CRES threaded fasteners shall be in accordance with Table II, Column A.

A3.2.2 Plated. Torque values for tightening clean silver plated CRES 300 series threaded fasteners shall be in accordance with Table II, Column B.

A3.2.3 Lubricated. Torque values for tightening 300 series CRES

threaded fasteners lubricated with an approved lubricant (see A4.1) shall be in accordance with Table II, Column C.

A3.3 Torque Values for 62,000 psi (62 ksi) Tensile Strength Aluminum Alloy Threaded Fasteners (2024-T4 and 7075-T6). The torque values specified in Table II are applicable to the specified materials and conditions in tension applications using nuts having an axial tensile strength equal or greater than that of the bolt and with one flat washer under the rotating element. Unless otherwise specified, torque values for fastener systems used in shear applications shall not exceed 60 percent of the values shown in Table II.

A3.3.1 Anodized. Torque values for tightening clean anodized aluminum threaded fasteners shall be in accordance with Table II, Column D.

A3.3.2 Lubricated. Torque values for tightening clean anodized aluminum threaded fasteners with an approved lubricant shall be in accordance with Table II, Column E.

A3.4 Torque Values for UNS K66286 (A286) Fastener Systems. Unless otherwise specified, torque values shall be in accordance with paragraphs A3.4.1 through A3.4.5.

A3.4.1 Cadmium Plated Nuts. Torque values for installing A286 bare/passivated bolts, cadmium plated nuts and MS14183/NAS 1587 washers shall be in accordance with Table III.

A3.4.2 Cadmium Plated Nuts Coated with Cetyl Alcohol. Torque values for installing A286 bare/passivated bolts, cadmium plated nuts coated with cetyl alcohol per MIL-L-87132, Type I, Grade A, and MS14183/NAS 1587 washers shall be in accordance with Table IV.

A3.4.3 Fastener Systems Coated with Dry Film Lubricant. Torque values for installing A286 bolts and nuts coated with dry film lubricant per MIL-L-46010 and MS14183/NAS 1587 washers shall be in accordance with Table V.

A3.4.4 Fastener Systems Lubricated with Continental Oil Company (Conoco) HD Calcium Grease No. 2. Torque values for installing A286 bare/passivated bolts, cadmium plated nuts, and MS14183/NAS1587 washers lubricated with Continental Oil Company HD Calcium Grease No. 2 shall be in accordance with Table VI. Grease shall be applied to the structure, bolt shank, threads, and washers of the fastener system. After torquing, excess grease shall be removed with a lint-free cloth or paper towel.

A3.4.5 Fastener Systems Sealed with PR-1422. (Product Research Co.). Torque values for installing A286 bare/passivated bolts, cadmium plated nuts and MS 14183/NAS1587 washers sealed with PR-

1422 shall comply with Table VII. PR-1422 shall be applied to holes, under bolt head, on bolt shank, on threads, and to the nut face per MSFC Drawing No. 10A00527.

A3.5 Torque Values for UNS N07718 (Alloy 718*) Fastener Systems. Unless otherwise specified, torque values shall be in accordance with paragraph A3.5.1.

A3.5.1 Fastener Systems Coated with Dry Film Lubricant. Torque values for installing Alloy 718 bolts and nuts coated with dry film lubricant per MIL-L-46010 and MS 14183 washers shall be in accordance with Table VIII.

A3.6 Torque Values for UNS R30035 (MP35N) Fastener Systems.** Unless otherwise specified, torque values shall be in accordance with paragraphs A3.6.1 and A3.6.2.

A3.6.1 Cadmium Plated Nuts. Torque values for installing MP35N bare/passivated bolts, cadmium plated nuts and SPS No. 75708 washers or equal shall be in accordance with Dry Bolt and Cadmium Plated Nut Column, Table IX.

A3.6.2 Dry Film Lubricated Nuts. Torque values for installing MP35N bare/passivated bolts, dry film lubricated nuts and SPS No. 75708 washers or equal shall be in accordance with Lube Bolt and Dry Film Lubed Nut Column, Table IX.

A3.7 Torque Values for #2 Through #10 Thread Sizes.

A3.7.1 Unless otherwise specified, torque values for #2 through #10 thread sizes shall be in accordance with Table X.

A3.8 Table Torque Values. Table torque values are the net effect of installation torque (a) + (c) components. The measured self-locking torque (running torque) of self-locking fasteners shall be added to the specified torque to obtain the final applied torque.

A3.9 Safety Wiring and Cotter Pinning. When securing fasteners with safety wire or cotter pins in accordance with MS33540, tightening may continue beyond the specified torque to permit slot and hole alignment provided that the final torque does not exceed the specified torque by more than 10 percent. [When cutting off excess lengths of safety wire or cotter pins, capture and properly dispose of the removed pieces. This is required to eliminate free floating debris on orbit which may jam mechanisms, short circuit electrical contacts, etc.]

* Registered Trademark of Huntington Alloys, Inc.
** Registered Trademark of SPS Technologies, Inc.

A4. NOTES

A4.1 Approved Lubricants. Unless otherwise specified, the following lubricants have been approved for use:

(a)	MIL-T-5544	Thread Compound, Antiseize graphite-petrolatum
(b)	MIL-L-46010 Type 1	Lubricant, Solid Film, Heat Cured, Corrosion Inhibiting
(c)	MIL-N-25027	Nut, Self-locking, 250°F, 450°F, and 800°F (Lubricants shall be qualified and listed in QPL 25027)
(d)	Conoco HD #2	Continental Oil Company HD Calcium Grease NO. 2.
(e)	PR-1422	Products Research & Chemical Corp. Temperature Resistant Sealing Compound

A4.2 Retorquing/Reuse: The effect of retorquing/reuse on a fastener's torque-load relationship can be significant, and has been shown to be significant for specific fastening systems. All activities which install fasteners should consider the potential effects on preload that retorquing fasteners can have on installed hardware. Appendix B covers procedures for determining retorque-tension curves.

A4.3 Tables III-IX: Tables III-IX specify torque values based on headings which specify the bolt and nut type for tensile and shear. The intent of the tables is to provide torque values based on tensile or shear applications. However, tension and shear type fasteners should be used for tensile and shear applications, respectively, to the maximum extent possible. The use of low profile shear fastener elements with tensile fasteners is allowed if the design dictates, but is discouraged. For tensile bolts used with shear nuts, torque values from the appropriate shear column must be used. Torque values for shear columns are based on using shear type nuts. When shear nuts are used, the torque is a maximum of 60 percent of tensile column values.

A4.4 Table XI: Table XI is taken from MIL-N-25027. The minimum breakaway and maximum locking torque values shown represent acceptable limit values of these parameters for self-locking nuts during durability tests conducted per MIL-N-25027. This table may also be used to determine acceptable running torque values. Running torque values that fall between the minimum breakaway and maximum locking torque values listed are acceptable.

A4.5 Electrical Connectors: MSFC Drawing 40M39581 provides standard methods for installing and mounting circular miniature electrical connectors conforming to MSFC Specifications 40M38277, 40M38298 and 40M39569.

Table I (5, 6)

Torque Values for Steel Screw Thread Fastening System Cadmium Plated or Lubricated

Fastener Size	Grade or Ultimate Tensile Strength, KSI					
	SAE2		SAE5		125	
	Dry	Lube	Dry	Lube	Dry	Lube
	Torque, Inch Pounds (4)					
1/4	55	42	80	72	90	78
5/16	105	78	150	132	155	144
3/8	180	135	265	228	275	240
7/16	275	210	480	360	500	390
1/2	420	315	610	540	690	576
9/16	620	470	900	790	1,000	860
5/8	880	660	1,224	1,080	1,296	1,200
3/4	1,380	1,080	2,340	1,620	2,496	1,920
7/8	1,860	1,440	2,820	2,760	3,840	3,060
1	2,820	2,160	5,220	4,200	5,520	4,620
1-1/8	4,500	3,300	7,560	5,640	7,980	7,200
1-1/4	6,300	4,740	10,440	7,920	11,040	10,080

Fastener Size	Grade or Ultimate Tensile Strength, KSI					
	SAE8		160		180	
	Dry	Lube	Dry	Lube	Dry	Lube
	Torque, Inch Pounds (4)					
1/4	102	90	115	99	145	103
5/16	225	198	238	210	320	240
3/8	375	330	405	360	530	396
7/16	610	540	750	576	860	648
1/2	905	790	950	830	1,260	940
9/16	1,344	1,080	1,404	1,200	1,920	1,440
5/8	1,836	1,620	2,100	1,728	2,520	1,920
3/4	3,000	2,640	4,500	2,880	4,200	3,180
7/8	4,800	4,200	6,300	4,500	6,720	5,040
1	7,236	6,360	9,000	6,912	10,320	7,800
1-1/8	11,520	10,200	13,920	10,800	16,320	12,240
1-1/4	15,840	14,100	21,000	15,120	22,680	17,040

Notes:
1. These torque values apply to UNC and UNF threads.
2. DRY torque values are to be used for steel, cadmium plated but not lubricated.
3. LUBE torque values are to be used for steel, plated or unplated with lubricants per Par. A4.1.
4. A tolerance of (+) 0% and (–) 15% is applicable.
5. Add locking torque of self-locking devices to torque values specified on the drawing.
6. Torque values are for tension applications. Torque values for shear applications shall not exceed 60% of the values shown unless otherwise specified.

Table II (5, 6)

Torque Values for Corrosion Resistant Steel and Aluminum Alloy Screw Thread Fastening Systems

Fastener Size	Screw Thread Fastening System				
	CRES 300 Series (3)			Aluminum Alloy (4)	
	A Passivated	B Ag Plated	C Lubricated	D Anodized	E Lubricated
	Torque, Inch Pounds (2)				
1/4	70	56	42	45	25
5/16	130	104	78	80	45
3/8	225	180	135	145	85
7/16	375	300	225	230	135
1/2	500	400	300	320	190
9/16	700	560	420	460	250
5/8	1,000	800	600	655	430
3/4	1,440	1,150	860	940	580
7/8	2,280	1,800	1,368	1,440	860
1	3,120	2,520	1,860	1,920	1,150
1-1/8	4,680	3,720	2,820	2,880	1,680
1-1/4	5,760	4,620	3,480	3,600	2,160

Notes:
1. These torque values apply to UNC and UNF threads.
2. A tolerance of (+) 0% and (–) 15% is applicable.
3. 300 Series CRES bolts have 80 KSI minimum UTS.
4. Aluminum alloy bolts have 62 KSI minimum UTS.
5. Add locking torque of self-locking devices to torque values specified on the applicable drawing.
6. Torque values are for tension applications. Torque values for shear applications shall not exceed 60% of the values shown unless otherwise specified.

Table III (3)

Torque Values for A–286 Screw Thread Fastening System With Nut Cadmium Plated Per QQ–P–416, Type II, Class 3

Bolt Type, (1) KSI @ RT (min)	Tensile 200 (Ftu)	Shear 110 (Fsu)	Tensile 180 (Ftu)	Shear 100 (Fsu)
Nut Type, (2)	Tensile	Shear	Tensile	Shear
Washer	MS 14183C and MS 14183 –			(4)
Fastener Size	Torque, Inch Pounds			
0.1900–32	46–54	27–32	38–45	23–27
0.2500–28	110–130	70–80	90–110	55–65
0.3125–24	230–270	135–160	195–230	120–140
0.3750–24	450–530	270–320	385–455	235–275
0.4375–20	725–855	435–515	625–735	375–440
0.5000–20	1,145–1,345	685–805	995–1,170	595–700
0.5625–18	1,625–1,910	975–1,145	1,415–1,665	850–1,000
0.6250–18	2,270–2,670	1,360–1,600	1,975–2,325	1,185–1,395
0.7500–16	3,950–4,645	2,365–2,785	3,450–4,060	2,070–2,435

Bolt Type, (1) KSI @ RT (min)	Tensile 160 (Ftu)	Shear 95 (Fsu)	Tensile 140 (Ftu)	Shear 84 (Fsu)
Nut Type, (2)	Tensile	Shear	Tensile	Shear
Washer	NAS1587–C and NAS1587–			(4)
Fastener Size	Torque, Inch Pounds			
0.1900–32	30–36	19–22	22–26	14–17
0.2500–28	75–90	45–55	55–65	35–40
0.3125–24	160–190	95–115	125–145	80–95
0.3750–24	320–375	190–225	250–295	160–190
0.4375–20	525–620	315–370	415–490	270–320
0.5000–20	840–990	505–595	670–790	435–515
0.5625–18	1,200–1,410	720–845	960–1,130	580–680
0.6250–18	1,680–1,975	1,005–1,185	1,350–1,590	810–955
0.7500–16	2,935–3,455	1,765–2,075	2,370–2,790	1,425–1,675

Notes:
1. Bolts are furnished with bare/passivated finish.
2. Nuts are plated per QQ–P–416, Type II, Class 3, and USE IS LIMITED TO 450 °F.
3. Add locking torque of self-locking devices to torque values specified on the applicable drawing.
4. Alternate washers based on equivalent fastener strength levels and corrosion resistant materials may be used.

Table IV (3)

Torque Values for A–286 Screw Thread Fastening System With Nut Cadmium Plated Per QQ–P–416, Type II, Class 3 and Coated With Cetyl Alcohol Per MIL–L–87132, Type I, Grade A

Bolt Type, (1) KSI @ RT (min)	Tensile 200 (Ftu)	Shear 110 (Fsu)	Tensile 180 (Ftu)	Shear 100 (Fsu)
Nut Type, (2)	Tensile	Shear	Tensile	Shear
Washer	MS 14183C and MS 14183–			(4)
Fastener Size	Torque, Inch Pounds			
0.1900–32	36–43	22–26	30–36	18–22
0.2500–28	90–105	55–65	75–90	45–55
0.3125–24	170–200	100–120	145–170	85–100
0.3750–24	325–385	195–230	285–335	170–200
0.4375–20	525–620	315–370	460–540	275–325
0.5000–20	815–960	490–575	710–835	425–500
0.5625–18	1,150–1,350	690–810	1,000–1,175	600–705
0.6250–18	1,590–1,870	950–1,120	1,380–1,625	830–975
0.7500–16	2,720–3,200	1,630–1,920	2,365–2,780	1,420–1,670

Bolt Type, (1) KSI @ RT (min)	Tensile 160 (Ftu)	Shear 95 (Fsu)	Tensile 140 (Ftu)	Shear 84 (Fsu)
Nut Type, (2)	Tensile	Shear	Tensile	Shear
Washer	NAS1587–C and NAS1587–			(4)
Fastener Size	Torque, Inch Pounds			
0.1900–32	25–30	15–18	18–22	11–13
0.2500–28	65–75	40–45	45–55	30–35
0.3125–24	120–140	70–85	95–110	55–65
0.3750–24	240–285	145–170	190–225	115–135
0.4375–20	385–455	235–275	305–360	180–215
0.5000–20	605–710	360–425	485–570	290–340
0.5625–18	850–1,000	510–600	685–805	410–485
0.6250–18	1,175–1,380	705–830	935–1,105	565–665
0.7500–16	2,000–2355	1,200–1,415	1,600–1,885	960–1,130

Notes:
1. Bolts are furnished with bare/passivated finish.
2. Nuts are plated per QQ–P–416, Type II, Class 3, and USE IS LIMITED TO 450 °F.
3. Add locking torque of self-locking devices to torque values specified on the applicable drawing.
4. Alternate washers based on equivalent fastener strength levels and corrosion resistant materials may be used.

Table V (2)

Torque Values for A-286 Screw Thread Fastening System Coated With Dry Film Lubricant Per MIL-L-46010, Type 1

Bolt Type, (1) KSI @ RT (min)	Tensile 200 (Ftu)	Shear 110 (Fsu)	Tensile 180 (Ftu)	Shear 100 (Fsu)
Nut Type, (1)	Tensile	Shear	Tensile	Shear
Washer	MS 14183C and MS 14183-			(3)
Fastener Size	Torque, Inch Pounds			
0.1900-32	34-40	20-24	30-35	18-21
0.2500-28	95-110	55-65	80-95	48-57
0.3125-24	205-240	120-145	175-205	105-125
0.3750-24	395-465	235-280	340-400	205-240
0.4375-20	685-805	410-485	585-690	355-415
0.5000-20	1,095-1,290	660-774	945-1,110	565-665
0.5625-18	1,610-1,895	965-1,135	1,380-1,625	830-975
0.6250-18	2,260-2,660	1,355-1,595	1,940-2,285	1,165-1,370
0.7500-16	4,025-4,735	2,415-2,840	3,470-4,085	2,080-2,450

Bolt Type, (1) KSI @ RT (min)	Tensile 160 (Ftu)	Shear 95 (Fsu)	Tensile 140 (Ftu)	Shear 84 (Fsu)
Nut Type, (1)	Tensile	Shear	Tensile	Shear
Washer	NAS1587-C and NAS1587-			(3)
Fastener Size	Torque, Inch Pounds			
0.1900-32	25-30	15-18	20-24	12-15
0.2500-28	65-75	38-45	50-60	30-36
0.3125-24	145-170	85-100	110-130	70-80
0.3750-24	280-330	170-200	215-255	130-155
0.4375-20	485-570	290-340	380-445	225-265
0.5000-20	785-925	470-555	615-725	370-435
0.5625-18	1,155-1,360	695-815	915-1,074	550-645
0.6250-18	1,630-1,915	980-1,150	1,285-1,510	770-905
0.7500-16	2,940-3,435	1,750-2,060	2,325-2,735	1,395-1,640

Notes:
1. Bolts and nuts shall be fully coated with MIL-L-46010, Type 1 lubricant and USE IS LIMITED TO 450 °F. LUBRICANT SHALL BE LISTED ON QPL 46010.
2. Add locking torque of self-locking devices to torque values specified on the applicable drawing.
3. Alternate washers based on equivalent fastener strength levels and corrosion resistant materials may be used.

Table VI (3)

Torque Values for A–286 Screw Thread Fastening System Lubricated With Continental Oil Company HD Calcium Grease No. 2

Bolt Type, (1) KSI @ RT (min)	Tensile 200 (Ftu)	Shear 110 (Fsu)	Tensile 180 (Ftu)	Shear 100 (Fsu)
Nut Type, (2)	Tensile	Shear	Tensile	Shear
Washer	MS 14183C and MS 14183–			(4)
Fastener Size	Torque, Inch Pounds			
0.1900–32	37–44	22–26	30–35	18–21
0.2500–28	85–100	50–60	70–85	42–50
0.3125–24	165–195	95–115	135–160	80–95
0.3750–24	305–360	180–215	255–300	150–180
0.4375–20	475–560	285–335	405–480	245–290
0.5000–20	720–850	435–510	620–730	375–440
0.5625–18	1,000–1,180	605–710	860–1,010	515–605
0.6250–18	1,360–1,600	815–960	1,165–1,370	695–820
0.7500–16	2,235–2,630	1,340–1,580	1,930–2,270	1,155–1,360

Bolt Type, (1) KSI @ RT (min)	Tensile 160 (Ftu)	Shear 95 (Fsu)	Tensile 140 (Ftu)	Shear 84 (Fsu)
Nut Type, (2)	Tensile	Shear	Tensile	Shear
Washer	NAS1587–C and NAS1587–			(4)
Fastener Size	Torque, Inch Pounds			
0.1900–32	23–28	14–17	17–20	10–12
0.2500–28	55–65	35–40	40–48	25–30
0.3125–24	110–130	65–80	80–95	45–55
0.3750–24	210–250	125–150	160–190	95–115
0.4375–20	335–395	200–235	260–305	155–185
0.5000–20	520–610	310–365	400–475	240–285
0.5625–18	715–840	430–505	560–660	335–395
0.6250–18	975–1,150	585–690	765–900	460–540
0.7500–16	1,615–1,900	970–1,140	1,285–1,510	765–905

Notes:
1. Bolts are furnished with a bare/passivated finish.
2. Nuts are plated per QQ–P–416, Type II, Class 3. CONOCO HD Calcium Grease No. 2 shall be applied to the structure and bolt threads, shank and washer of the fastener system. USE IS LIMITED TO 450 °F.
3. Add locking torque of self-locking devices to torque values specified on the applicable drawing.
4. Alternate washers based on equivalent fastener strength levels and corrosion resistant materials may be used.

Table VII (3)

Torque Values for A–286 Screw Thread Fastening System Sealed With PR–1422 In Accordance With MSFC DWG. 10A00527

Bolt Type, (1) KSI @ RT (min)	Tensile 200 (Ftu)	Shear 110 (Fsu)	Tensile 180 (Ftu)	Shear 100 (Fsu)
Nut Type, (2)	Tensile	Shear	Tensile	Shear
Washer	MS 14183C and MS 14183 –			(4)
Fastener Size	Torque, Inch Pounds			
0.1900–32	100–120	50–60	75–90	40–48
0.2500–28	230–275	120–145	185–220	95–115
0.3125–24	455–535	240–285	365–430	195–230
0.3750–24	860–1,015	460–540	700–825	375–445
0.4375–20	1,350–1,590	730–860	1,110–1,310	600–710
0.5000–20	2,075–2,440	1,135–1,335	1,725–2,030	945–1,110
0.5625–18	2,865–3,375	1,580–1,860	2,390–2,815	1,315–1,550
0.6250–18	3,900–4,595	2,160–2,540	3,260–3,835	1,805–2,125
0.7500–16	6,500–7,645	3,635–4,280	5,260–6,400	3,045–3,585

Bolt Type, (1) KSI @ RT (min)	Tensile 160 (Ftu)	Shear 95 (Fsu)	Tensile 140 (Ftu)	Shear 84 (Fsu)
Nut Type, (2)	Tensile	Shear	Tensile	Shear
Washer	NAS1587–C and NAS1587–			(4)
Fastener Size	Torque, Inch Pounds			
0.1900–32	60–70	30–36	39–46	20–24
0.2500–28	140–165	75–90	95–115	50–60
0.3125–24	285–335	145–175	200–235	105–125
0.3750–24	550–650	295–350	425–500	210–250
0.4375–20	885–1,045	480–565	650–765	350–415
0.5000–20	1,385–1,630	755–890	1,030–1,215	565–665
0.5625–18	1,925–2,265	1,060–1,250	1,445–1,700	845–995
0.6250–18	2,630–3,095	1,455–1,715	1,975–2,325	1,095–1,290
0.7500–16	4,410–5,190	2,470–2,905	3,330–3,920	1,865–2,195

Notes:
1. Bolts are furnished with a bare/passivated finish.
2. Nuts are plated per QQ–P–416, Type II, Class 3 and USE IS LIMITED TO 275 °F.
3. Add locking torque of self-locking devices to torque values specified on the applicable drawing.
4. Alternate washers based on equivalent fastener strength levels and corrosion resistant materials may be used.

Table VIII (2)

Torque Values for Inconel 718 Screw Thread Fastening System Coated With Dry Film Lubricant Per MIL–L–46010, Type 1

Bolt Type, (1) KSI @ RT (min)	Tensile 220 (Ftu)	Shear 132 (Fsu)	Tensile 180 (Ftu)	Shear 108 (Fsu)
Nut Type, (1)	Tensile	Shear	Tensile	Shear
Washer	MS 14183C and MS 14183= (3)			
Fastener Size	Lubed Bolt and Nut		Lubed Bolt and Nut	
	Torque, Inch Pounds			
0.1900–32	34–40	20–24	30–35	18–21
0.2500–28	95–110	55–65	80–95	48–57
0.3125–24	205–240	120–145	175–205	105–125
0.3750–24	395–465	235–280	340–400	205–240
0.4375–20	685–805	410–485	585–690	355–415
0.5000–20	1,095–1,290	660–774	945–1,110	565–665
0.5625–18	1,610–1,895	965–1,135	1,380–1,625	830–975
0.6250–18	2,260–2,660	1,355–1,595	1,940–2,285	1,165–1,370

Notes:
1. Bolts and nuts shall be fully coated with MIL–L–46010, Type 1 lubricant and USE IS LIMITED TO 450 °F. LUBRICANT SHALL BE LISTED ON QPL–46010.
2. Add locking torque of self-locking devices to torque values specified on the applicable drawing.
3. Alternate washers based on equivalent fastener strength levels and corrosion resistant materials may be used.

Table IX (3, 4)

Torque Values for MP 35N Screw Thread Fastening System With Cadmium Plated Or Dry Film Lubricated Nuts

Bolt Type, (1) KSI @ RT (min)	Tensile 260 (Ftu)	Shear 145 (Fsu)	Tensile 260 (Ftu)	Shear 145 (Fsu)
Nut Type, (2)	Tensile	Shear	Tensile	Shear
Washer	75708C and 75708P			(5)
Fastener Size (In)	B/P Bolt and Cadmium Plated Nut		B/P Bolt and Dry Film Lubed Nut	
	Torque, Inch Pounds			
0.1900–32	68–80	40–48	46–55	28–33
0.2500–28	155–185	95–110	110–130	65–80
0.3125–24	305–360	185–215	220–260	130–155
0.3750–24	575–675	345–405	425–500	255–300
0.4375–20	890–1,050	535–630	670–790	400–475
0.5000–20	1,355–1,595	810–955	1,030–1,215	620–730
0.5625–18	1,910–2,245	1,145–1,345	1,480–1,740	885–1,040
0.6250–18	2,645–3,110	1,585–1,865	2,080–2,445	1,240–1,460
0.7500–16	4,530–5,330	2,720–3,200	3,650–4,295	2,185–2,570
0.8750–14	7,110–8,365	4,265–5,020	5,840–6,870	3,500–4,120

Notes:
1. Bolts have a bare/passivated (B/P) finish.
2. Nuts are plated per QQ–P–416, Type II, Class 2 or dry film lubricated per MIL–L–46010, Type1 and USE IS LIMITED TO 450 °F. LUBRICANT SHALL BE LISTED ON QPL–46010.
3. Add locking torque of self-locking devices to torque values specified on the applicable drawing.
4. Standard Pressed Steel Part Number or EQUAL.
5. Alternate washers based on equivalent fastener strength levels and corrosion resistant materials may be used.

Table X (1, 2, 3, 4, 5)

Threaded Fastener Tightening Torque

Thread Size	Minimum Ultimate Tensile Strength, ksi			
	60	80	125	160
	Torque, Inch Ounces			
#2—56/64	21–26	26–33	42–53	53–66
#4—40/48	45–56	56–70	90–112	112–140
#6—32/40	83–104	104–130	166–208	208–260
	Torque, Inch Pounds			
#8—32/36	10–12	11–15	19–24	24–30
#10—24/32	16–20	20–25	32–40	39–49

Notes:
1. When threaded fasteners are self-locking, tighten to the maximum torque value in the table.
2. When lubricants per Par. A4.1 are used, tighten to the minimum value in the table.
3. Add locking torque of self-locking devices to torque values specified on the applicable drawing.
4. Engineering drawings shall show the specific torque value including applicable tolerances for a fastener.
5. The tolerance for tightening to either the minimum or maximum torque value is plus (+) or minus (–) two (2) inch ounces or plus (+) or minus (–) one (1) inch pound as applicable.

Table XI (1, 3)

Required Locking Torque at Room Ambient Temperature (inch pounds)

Thread Size Diameter-UNC/UNF	Maximum Locking Torque, Installation or Removal	Minimum Breakaway Torque
0.0860–56/64	2.5/2.5	–/–(2)
0.1120–40/48	5/5	–/–(2)
0.1380–32/40	10/10	1.0/1.0
0.1640–32/36	15/15	1.5/1.5
0.1900–24/32	18/18	2.0/2.0
0.2500–20/28	30/30	4.5/3.5
0.3125–18/24	60/60	7.5/6.5
0.3750–16/24	80/80	12.0/9.5
0.4375–14/20	100/100	16.5/14.0
0.5000–13/20	150/150	24.0/18.0
0.5625–12/18	200/200	30.0/24.0
0.6250–11/18	300/300	40.0/32.0
0.7500–10/16	400/400	60.0/50.0
0.8750– 9/14	600/600	82.0/70.0
1.0000– 8/12	800/800	110.0/90.0
1.1250– 7/12	900/900	137.0/117.0
1.2500– 7/12	1,000/1,000	165.0/143.0

Notes:
1. For inspection of maximum locking torque or minimum breakaway torque values, the nut shall be engaged on a clean bolt with at least two thread lengths protruding beyond the locking device of the nut. Maximum locking torque shall be checked at a rate slow enough to obtain a dependable measure of torque and the nut shall be rejected if the locking torque at installation or removal exceeds the above limits. The minimum breakaway torque shall be checked after the nut has been installed with two thread lengths exposed and at a rate slow enough to obtain a dependable measure of torque between the limits of a minimum of one thread length and a maximum of two thread lengths extending beyond the nut end.
2. Must have some indication of torque.
3. Thread sizes 0.0860–64, 0.1120–48, 0.1380–40, 0.1640–36, 0.1900–24, and UNC (coarse) thread fasteners from size 0.2500–20 through 1.2500–7 are not preferred for spacecraft design.

Table XII (1)

Minimum Thread Protrusion

Threads Per Inch	Protrusion (inch)
64	0.031
56	.035
48	.042
40	.050
36	.056
32	.062
28	.071
24	.083
20	.100
18	.111
16	.125
14	.143
13	.154
12	.167
11	.182
10	.200
9	.222
8	.250
7	.286

Notes: 1. The thread protrusion after the nut is torqued shall be no less than as shown above.

APPENDIX B

TORQUE - TENSION TESTING METHODOLOGY

B1. SCOPE

B1.1 This test method describes standard procedures for determining the room temperature torque-tension relationship for threaded fasteners. It is not limited by configuration or size. The following methods are specified:

(a) Hand torque method using torque wrenches.
(b) Machine torque method using torsion machine.

B2. REFERENCED DOCUMENTS

B2.1 Government Documents

B2.1.1 Specifications, standards, and handbooks: Unless otherwise specified, the following specifications, standards and handbooks form a part of this appendix to the extent specified herein.

STANDARD

FEDERAL

GGG-W-686 Wrench, Torque

(Copies of specifications, standards, handbooks, drawings and publications required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer).

B2.2 Other publications: The following document(s) forms a part of this appendix to the extent specified herein.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E 74 Verification of Calibration Devices for Verifying Testing Machines

(Applications for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187).

B3. DEFINITIONS

B3.1 Abutment: The place at which adjoining or bordering occurs. The part of a structure that directly receives thrust or pressure.

B4. GENERAL REQUIREMENTS

B4.1 Test Apparatus

B4.1.1 Hand Torque Method: Torque wrenches calibrated for accuracy within the limits specified by GGG-W-686 will be required as well as the necessary adapters to fit the configuration of the fastener under test. A suitable method conforming to B4.1.3 shall be used to determine the tension. Fixtures shall conform to B4.1.4.

B4.1.2 Machine torque method: A torsion machine capable of measuring and indicating within an accuracy of 2 percent of the scale employed shall be required as well as the necessary adapters to fit the configuration of the fastener under test. A suitable method (see B4.1.3) shall be used to determine the tension. Fixtures shall conform to B4.1.4.

B4.1.3 Tension: The induced tensile load shall be measured by one of the following instruments, which shall have been verified for accuracy not more than 3 months before being used.

B4.1.3.1 Load cell system: A precision load cell, which has been calibrated in accordance with ASTM E 74 in a universal testing machine, and of sufficient capacity to develop the full tensile load of the fastener under test shall be used. Appropriate strain gages shall be fastened by standard approved methods to the load cell.

B4.1.3.2 Tensile Machine: A tension or universal tension machine capable of measuring and indicating the induced tension to within 1 percent of the test load shall be used. The machine shall be capable of maintaining the induced load upon cessation of the torque process.

B4.1.3.3 Bolt tension calibrator: A bolt tension calibrator of the closed hydraulic system type (e.g. Skidmore-Wilhelm Mfg. Co. or equivalent calibrator) with suitable dials to read the induced loading directly shall be used. The calibrator shall be accurate to within 4 percent of the test load and shall be capable of maintaining the induced load upon cessation of the torque process.

B4.1.3.4 Strain gage: A precision strain gaged bolt or stud calibrated in a tensile machine shall be used, together with an accurate strain indicator. The complete system shall be accurate within 2 percent of the test load.

B4.1.3.5 Ultrasonic bolt gage: An ultrasonic bolt gage (e.g. Ultrasonic Boltmaster bolt gage or equivalent) calibrated in a

tensile machine shall be used. The ultrasonic bolt gage system shall be accurate within 10 percent of the test load.

B4.1.4 Test fixtures: Unless otherwise specified, all fixtures shall meet the following requirements:

B4.1.4.1 Test fixtures shall reflect end item design joint configurations. Testing parameters to be identified and recorded during testing are identified in Table BI.

B4.1.4.2 All fixtures and washers shall be retained in such a manner that they are not permitted to rotate.

B4.1.4.3 Bearing surfaces shall be free of dirt or lubricant.

B4.2 Test Specimens: A minimum of six fasteners shall be tested for each unique end item design joint configuration. Individual fasteners shall be tested once for each joint configuration, unless otherwise specified. If tested beyond their yield strength, fasteners shall not be retested.

B5. DETAILED REQUIREMENTS

B5.1 Test procedures: Torque-tension tests may be performed using any of the indicated methods to determine the torque and tension provided they can satisfactorily accommodate end item design joint configurations. In the event of controversy, the hand torque method (see B 4.1.1) in conjunction with a tensile machine (see B4.1.3.2) shall be used as the referee method. Automatic recording devices may be used provided system accuracy is maintained.

B5.1.1 Assembly: Assemble the fastener in the simulated end item design joint configuration for testing. (Reference Table BI, Joint configuration sketch). (Unless otherwise specified, assemble the fasteners with two to three full form threads disengaged between the nut or internal thread bearing face and the external thread run-out. When nuts are used, a minimum of one complete thread shall extend beyond the top of the nut).

B5.1.2 Loading: Unless otherwise specified in Table BI, the externally threaded member should be fixed with torque applied through the nut. Torque shall be applied at a rate of approximately 5 RPM (a rate that will permit the torque readings to be read while the fastener or nut is in motion). The induced load shall be read simultaneously with the torque. Loading shall continue to approximately 90 percent of the fastener's minimum ultimate tensile load (lbs) capability for each separate torque-tension test conducted. (Fasteners' ultimate load capabilities are provided in fastener part number standards and/or fastener procurement specifications).

CAUTION: Appropriate shielding of the torqued fastener assembly and additional eye protection shall be provided during loading.

B5.2 Retorquing:

Installation torque values must be established for joint configurations subjected to more than one complete installation cycle (e.g. full thread engagement of locking feature, or full clamp-up torque attained in free running nuts). Torque-tension relationships used for multiple installation cycles must accurately predict fastener preload within acceptable limits determined by unique configuration strength analysis.

B5.2.1 Test Procedures: Test procedures shall be per the requirements of B5.1.

B5.2.2 Assembly: Assembly shall be per B5.1.1.

B5.2.3 Loading: Loading for retorque cycles shall be per the requirements of B5.1.2 except as noted. For retorque cycles:

(1) Load to 65% of the fastener's minimum ultimate tensile load (lbs) capability,
(2) Unload to zero tensile load (lbs),
(3) Continue (1-2) above for the desired number of retorque cycles.

B6. REPORTS

B6.1 Test reports: Test reports shall be submitted through appropriate channels for review by MSFC Structures and Dynamics and Materials and Processes Laboratories. Test reports shall include the following data:

B6.1.1 Joint configuration parameters: All end item design joint configuration parameters identified in Table BI shall be provided.

B6.1.2 Torque-load diagram: The test data shall be plotted as an induced load versus torque curve. The induced load in pounds (or psi as applicable) shall be plotted on the y-axis, and the torque values on the x-axis (Figure B1).

For each specific end item design joint configuration, one load-torque curve shall be generated from the six individual load-torque curves generated for that configuration. (One retorque cycle load torque curve shall be generated for each specific retorque cycle). This shall be done by determining a least squares fit of the appropriate order binomial (2nd, 3rd, etc.) based on the data from the individual tests.

APPENDIX B, TABLE BI

END ITEM DESIGN JOINT CONFIGURATION PARAMETERS

BOLT PART NUMBER_____
BOLT MATERIAL_____
BOLT STRENGTH LEVEL_____
BOLT FINISH_____

NUT PART NUMBER_____
NUT MATERIAL_____
NUT STRENGTH LEVEL_____
NUT FINISH_____

NUTPLATE PART NUMBER_____
NUTPLATE MATERIAL_____
NUTPLATE STRENGTH LEVEL_____
NUTPLATE FINISH_____

INSERT PART NUMBER_____
INSERT MATERIAL_____
INSERT STRENGTH LEVEL_____
INSERT FINISH_____

WASHER(S) PART NUMBERS_____
WASHER(S) MATERIALS_____
WASHER(S) STRENGTH LEVELS_____
WASHER(S) FINISHES_____

JOINT MATERIAL #1_____
JOINT MATERIAL #1 STRENGTH LEVEL_____
JOINT MATERIAL #1 FINISH_____
JOINT MATERIAL #2_____
JOINT MATERIALS #2 STRENGTH LEVEL_____
JOINT MATERIAL #2 FINISH_____

LUBRICANTS_____
TORQUE APPLICATION_____

_____

_____

JOINT CONFIGURATION SKETCH

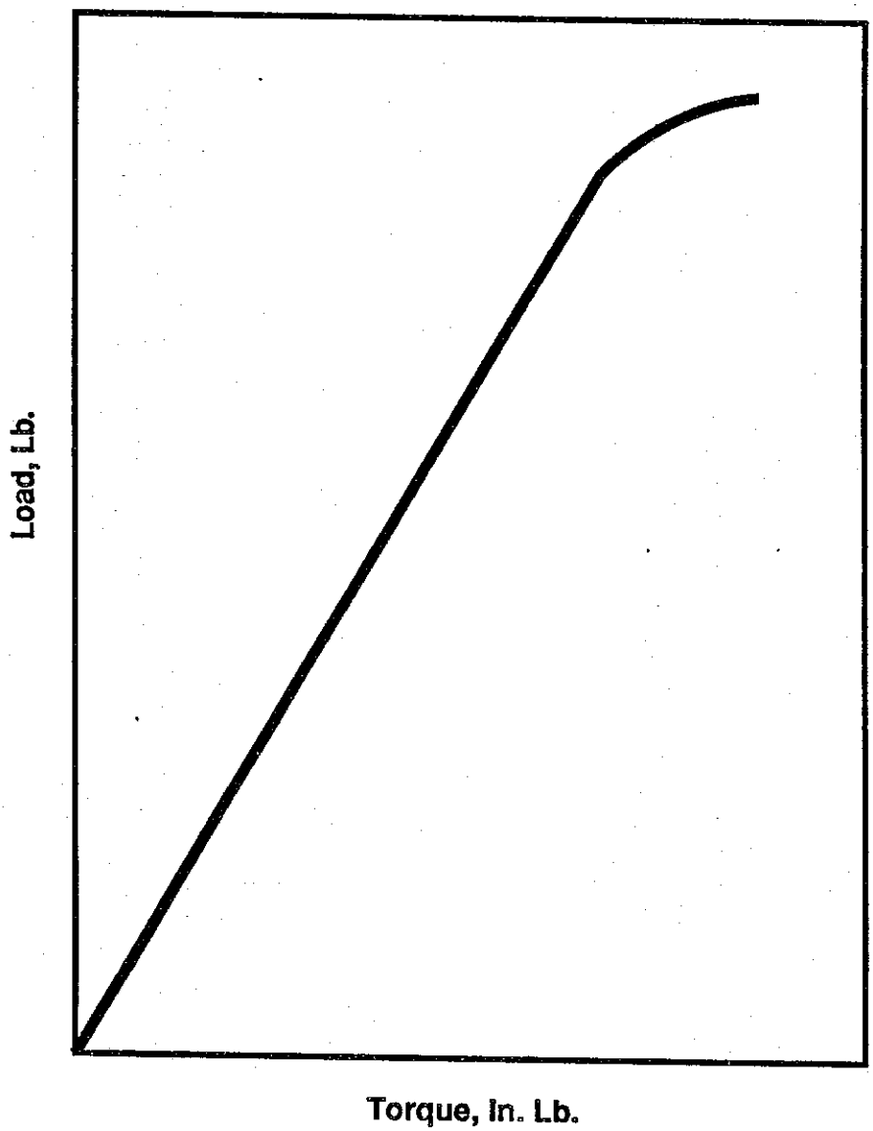

Figure B1. Load-torque diagram.

APPENDIX C

TORQUE - LOAD DIAGRAMS

C1. SCOPE

C1.1 This appendix contains torque - load diagrams generated using the torque - tension testing methodology described in Appendix B. Included with each torque - load diagram are all joint configuration parameters (reference Table BI) used to generate them. Appendix C torque - load diagrams may be used to establish acceptable torque limits for threaded fasteners used in space vehicles and support equipment.