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REVISION 2

TECHNICAL MANUAL

DESCRIPTION, DESIGN
AND MAINTENANCE

SUBMARINE FASTENING CRITERIA (NON-NUCLEAR)

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FOREWORD

This manual is intended to serve as a compendium of information and techniques associated with submarine fasteners in pressure containing systems and structural bolted joints. It shall be treated as a specification when referenced in other documents or used for the resolution of problems, development of procedures and writing of process instructions.

Nuts and bolts as threaded fasteners are so integral to mechanical assembly that their fundamental importance is often overlooked.

Tightening the fastener is the primary problem. No matter how initially strong the fastener, proper tightening is still the key to a good fastening system. While the mechanic with his wrench remains a surprisingly accurate preload control machine, there are instances requiring more than simple judgement, including those where the tightness of a nut is determined by the clamping force the designer wants exerted on the joint. This clamping force must be closely controlled to prevent the joint from loosening when it is subjected to forces caused by pressure, temperature, hull movements, or shock. Since there is little room for error, it is imperative that the mechanic employ an accurate method of tightening fasteners within a specified range. These problems and others are identified and their solutions offered herein.

The manual is arranged in six major sections:

General Information

Geometry of Fasteners

Geometry of Joints

Methods for Obtaining Clamping Loads

Typical Joint Assembly

Appendices

The following general guidelines were used in preparing the manual:

Fasteners, as discussed in the manual, tend to emphasize threaded fasteners used with flanged joints, except as noted below. However, the principles and techniques apply to all bolted joints, whether on submarines or elsewhere.

The fasteners covered, and methods of tightening fasteners, are restricted to those applicable to submarines. Procedures and problems unique to or particularly applicable to submarines are stressed, but again, the principles and techniques apply to all bolted joints, whether on submarines or elsewhere.

Although primary interest has been slanted toward joints in submarine material certification boundaries, other pressure containing systems such as steam, air, feed water and hydraulics have been included. Appendix A lists relevant references which may assist the user, Appendix B discusses, briefly, the general use of threaded fasteners in applications other than joints in pressure containing systems, Appendix C gives guidance for determining where a specific torque must be applied and Appendix D contains guidance for the assembly of O-ring union mechanical joints. Appendix E (NAVSEA 0900-LP-091-6010) is a computer program for calculating the required torque and Appendix F (NAVSEA 0900-LP-091-6020) is a compendium of the torque tables from this manual repro-

FOREWORD - Continued

duced in a format suitable for field use. Appendix E and Appendix F are provided under separate cover, available from: Commander, Naval Sea Systems Command, Submarine Directorate, Washington, D.C. 20362

Custodianship and responsibility for maintaining the technical content of this manual to meet the Navy's needs rests with the Submarine Directorate of Naval Sea Systems Command (NAVSEA). Changes and/or recommendations to improve the content of this manual should be directed to Commander, Naval Sea Systems Command, Submarine Directorate, Washington, D.C. 20362.

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CHAPTER 1

GENERAL INFORMATION

1-1. INTRODUCTION.

Of all the elements normally dealt with in pressure-containing and structural assemblies, the fastener is the one to which little thought is given and, in most cases, the fastener is taken for granted. Because of the extensive use of bolts, studs, and nuts as fastening elements, and the large number of parameters that influence their design and selection, proper tightening of fasteners is essential. The following sections contain generalized guidance information for achieving proper clamping loads on submarine mechanical joints (non-nuclear) in pressure-containing systems and structural assemblies.

1-2. PURPOSE.

The purpose of this manual is to present general fastener guidelines for the shipbuilding activities engaged in the overhaul, repair, and conversion of combatant submarines. It contains the basic techniques that are currently used for tightening threaded fasteners used in mechanical joints aboard combatant submarines. For the purposes of this manual, representative pressure-containing systems are listed in Table 2-1. This manual should not be construed as providing rigid procedures for tightening fasteners or to discourage initiative and innovation in the use of new methods or techniques for obtaining properly tightened fastening systems. Nor should the torque values given in various tables herein be construed as superseding the fastener torque values listed in applicable drawings and technical manuals. The tables in this manual give acceptable torque values for use when none are stated in applicable drawings and technical manuals (see section 5 for further discussion). The principles put forth in this manual apply whether the fasteners in question are sized by the English or metric systems of measure- ment. To establish torques for metric fasteners, use Appendix E of this manual.

1-3. GLOSSARY OF TERMS.

An alphabetical list of terms appearing throughout this manual is contained in Table 1-1. The definitions given for these terms are not necessarily the most widely accepted but are applicable to their use in the manual.

Table 1-1 GLOSSARY OF TERMS

TERM	DEFINITION
Alloy Steel	A steel containing elements other than carbon which have been added to obtain definite mechanical or physical properties, (e.g., higher strength at elevated temperatures, toughness, etc.).
Bearing Surface	The supporting or locating surface of a fastener with respect to the part which it fastens (mates). The area under the nut or head of a bolt.
Body Bound	More commonly called ″Fitted Body″ - refer to that term. Not to be confused with ″Interference Fit″
Bolt	A fastener with a head on one end and the body threaded as required.
Bolt-stud	A fastener threaded with the same form and fit of thread on both ends or throughout its length. It is generally used with a nut on each end.
Bottoming	In bottom tapped holes, the contact between the bottom of the threaded piece and the bottom of the tapped hole. Bottoming threaded fasteners should be avoided since tremendous forces can be generated at this contact point and can crack material sections.

Table 1-1 GLOSSARY OF TERMS - Continued

TERM	DEFINITION
Cap Screw	A cap screw is a screw having all surfaces machined or of an equivalent finish, closely controlled body diameter and a flat, chamfered point. It has a wrench, slotted, recessed, or socket head of proportions and tolerances designed to assure full and proper loading when wrenched or driven into a tapped hole.
Clamping Force	The force that actually holds the parts together, created by applying tension or preload on the fastening system by tightening.
Class 5 Interference Fit	See ″Interference Fit″.
Clearance Fit	A fit that has limits of size so prescribed that a clearance always results when mating parts are assembled.
Cold Forming	A metal forming process that employs high impact force instead of heat to cause metal to flow and produce a head or other geometrical shapes. Commonly known as cold heading when applied to bolts and screws.
Extensometer	An instrument used for measuring minute distances.
Fastener	A mechanical device for holding two or more main bodies in definite positions with respect to each other.
Fastener Body	The unthreaded portion of the shank.
Fitted Body	The body of a stud or bolt which has definite interference or extremely small clearance with its mating hole. Not to be confused with ″Interference Fit″.
Flange	A rib or rim designed to aid attachment to another object.
Galling	An abrasive condition on the rubbing surfaces of a fastener where excessive friction causes chipping, fragmentation or deformation of the threads.
Grip Length	The distance between the gripping surfaces of the bolt head and the nut.
Interference Fit	Interference-fit threads are threads in which the externally threaded member is larger than the internally threaded member when both members are in a free state and which, when assembled, become the sane size and develop a high resistance to any applied backout torque through elastic compression, plastic movement of material, or both. By FED-STD-H28, these threads are designated Class 5.
Length of Thread Engagement	Applicable specification governs the length of thread engagement, but, in any case, engagement should not be less than one diameter.
Loose Fastener	A fastener is loose if a light to medium pressure, greater than the locking element (e.g., plastic insert self-locking nut) prevailing torque, on a standard length wrench allows the fastener to turn in either direction.
Machined Threads	Threads that are formed by cutting away material.
Peening	A means of locking a recessed screw or bolt by forcing some of the thread working surface material over the head, preventing it from backing out. Also used on the threaded end to lock fastener in place. A generally unacceptable practice for locking fasteners.
Prestress (Preload)	To introduce internal stresses in the fastener to counteract the forces on the clamped elements of the joint that result from pressure, temperature hull movements, or shock loads.
Prevailing-torque Locknut	A nut in which the locking feature is self-contained, resists loosening, and does not depend upon bolt or stud load for locking.
Proof Load	A specified test load which a fastener must withstand without any indication of failure. The proof load is approximately equivalent to the yield strength of the fastener or the load causing 0.2% offset.
Rolled Threads	Threads made by squeezing a blank rod between rotating or reciprocating dies.
Self-locking Fastener	A fastener with a thread-locking feature that resists rotation by gripping the mating thread and does not depend upon bolt, nut, or stud load for locking.

Table 1-1 GLOSSARY OF TERMS - Continued

TERM	DEFINITION
Shouldering	Shouldering occurs in studs when the thread runout engages the top of the threaded hole forcing the material at the top of the hole to distort and destroy the flat surface.
Slugging	To strike a wrench heavily with a hammer (in fastener tightening)
Staking	The forcing of material from a working surface into the threads of a fastener, or the deformation of threads by means of a punch or ball peen hammer.
Stud or stud bolt	A headless fastener threaded on each end. It has conventional threads on the nut end and threads on the stud end that give an interference fit in the hole in which it is installed.
Tap Bolt	A bolt where the threaded portion is turned into a tapped hole other than a nut.
Tensile Strength	The greatest longitudinal stress (e.g., pounds per square inch) a substance can bear without tearing apart.
Tensile Stress Area	The cross-sectional metal area of an externally threaded part, used for the purpose of computing the tensile strength of the fastener.
Threaded Fastener	A threaded device (e.g., bolt, stud, bolt-stud, or nut) intended specifically to join or assemble multiple components.
Through Bolt	A bolt with a head on one end which uses a nut on the threaded portion.
Tolerance	The total permissible variation of a size. The tolerance is the difference between the limits of size.
Torque	A twisting force exerted, multiplied by the distance through which the force acts. In the Navy, torque is usually measured in foot-pounds or inch-pounds.
Transition Fit	A fit that has limits of size so prescribed that either a clearance or an interference may result when mating parts are assembled.
Water Hammer	The pressure pulsation which results from a sudden stoppage of relatively high velocity flow (hydraulic shock).
Yield Strength	A measure of resistance to plastic deformation of a material subjected to axial loading. It is the point at which the material exhibits a specified, limited, permanent deformation.

1-4. JOINT DESIGN

1-5. PURPOSE OF PROCEDURE

To establish the method for flange and fastener analysis of bolted, flanged connections within the SUBSAFE Design Review (SSDR) boundary (as defined in SUBSAFE Design Review Procedure Manual). This procedure is required by section 5.7.2 of SUBSAFE Design Review Procedure Manual and shall be used unless otherwise specified by applicable technical manuals or system/component drawings per procurement specifications. While the method for flange and fastener analysis of bolted, flanged connections which follows is tailored to joints within the SUBSAFE Design Review boundary, the rules and procedures used are generally applicable to any bolted joint, and may be applied outside that boundary, except as noted in 1-7 below.

1-6.

This document contains specific rules for the design of bolted closures within the SUBSAFE boundary which are either; (1) circular raised face flanges with ring type gaskets that are entirely within the circle enclosed by the bolt holes and with no contact outside of this circle, (2) flat covers with contact outside of the bolt circle and (3) spigoted closures. The user is referred to Appendix Y of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2, for circular flat face flanges with metal-to-metal contact outside of the bolt circle, and to paragraph UG-34 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2 for the design of flat covers with no contact outside of the bolt circle.

1-7.

This document is not intended to be used for the design of closures within components for which other structural specifications dictate closure design.

1-8.

This document does not contain rules to cover all details of design. Where complete details are not given, it is intended that the engineer shall provide details of design which will be as safe as those provided by the rules of this document.

1-9.

Fastener and flange material, configuration, thread form, testing and identification shall be in accordance with the documents specified by the applicable system diagrams, piping drawings and shipbuilding specification section.

1-10. APPLICABILITY

For components previously qualified, the rules of the appropriate paragraph of the Class Submarine Safety Design Review Procedures Booklet apply.

1-11.

The analysis of fasteners for flanged joints shall be performed using parameters defining design conditions. This analysis shall include the bolts/stud pre-stress and allowable tolerances under tensile loading. The amount of bolt/stud pre-stress shall be determined using the requirements herein.

1-12.

This standard is intended to cover the design of:

a. Raised face flanges (i.e., flange, with gaskets that are entirely within the circle enclosed by the bolt holes and with no contact outside of the bolt circle).

b. Bolting for raised face flanges.

c. Flat covers both with and without metal-to-metal contact outside bolt circle.

d. Bolting for flat covers.

e. Spigoted closure.

f. Bolting for spigoted closure.

1-13.

The design of flanged connections with metal-to-metal contact outside of the bolt circle (i.e., flat face flanges) shall be in accordance with Appendix Y of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2.

1-14.

Special rules are provided in paragraph 1.13 for the design of bolting in spigoted connections that have metal-to-metal contact outside of the bolt circle. It is noted that the flange design procedures presented here, like those of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2 do not include effects of pipe load. Code flange rules, largely in their present form, have been used for the design of commercial pressure vessels for more than fifty years. Like other parts of the Code, the flange design rules would have been modified years ago if there was any evidence that there is insufficient conservatism to account for the effects of pipe loads on structural adequacy.

1-15. APPROACH

Determine the total design pressure load on the joint (i.e., not hydro).

1-16.

Determine a set of allowable stresses for your fasteners. For cold applications (applicable to most SSDR closures), the single allowable stress (Sb) will be the lower of 2/3 yield or 1/4 ultimate. The 1/4 ultimate usually governs for high strength materials.

1-17.

Select a number of bolts and bolt size such that the design pressure load divided by Sb gives the required root area.

1-18.

Now follow the detailed rules presented herein for the design of the flanges.

1-19.

Table 1-4 outlines several bolt and flange design examples using PC-Bolts, TK-Solver, and hand calculations.

1-20. DETAILED METHODS

Flat circular plates thickness - The thickness of flat circular cover plates and heads shall be determined using equation 2 of paragraph UG-34 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2.

Where:

F = a factor which depends on the bolted connection.
F shall be taken as 0.3 when there is no contact outside of the bolt circle and F shall be 0.25 for metal-to-metal contact outside of the bolt circle.

P = design pressure for the closure (i.e., not hydro), psi.

S = allowable stress for the cover plate material. This will be taken as the lower of 2/3 yield or 1/4 ultimate at room temperature, psi.

1-21. BOLTS FOR FLAT COVER PLATES

The minimum required bolt area (at root of thread or section of least diameter) for bolts on flat cover plates with self-energizing gaskets which have metal-to-metal contact outside of the bolt circle shall be determined as follows:

(2) $A_{m1} = [\pi P(R_b)(R_p)^2/S)(R_o - 0.75R_p)]/[R_o(R_o - R_b)]$

(2A) $A_{m2} = 15.7 \cdot R_P{}^2 \cdot P_C / S_Y$

Where:

A_m = minimum required area of bolts (i.e., number of bolts times area per bolt), square inches.

NOTE

For hull integrity fasteners only, A_m equals greater of A_{m1} or A_{m2}.

A_{m1} = minimum required area of bolts fasteners, based on design pressure.

A_{m2} = minimum required area of bolts based on a hydrostatic pressure of 5 times collapse depth (for hull integrity fasteners only), square inches.

S_y = minimum yield strength of bolt material, psi.

P = design pressure for the closure (i.e., not hydro), psi.

P_c = ship's collapse depth pressure, psi.

S = allowable stress for the bolt material. This will be taken as the lower of 2/3 yield or 1/4 ultimate at room temperature, psi.

R_p = radius over which pressure acts on the gasket, inches.

R_o = outside radius of the contact surface between the cover plate and adjacent flange, inches.

R_b = bolt circle radius, inches.

1-22. FLANGE DESIGN

For flanges with gaskets contained entirely within the bolt circle and no metal contact beyond the bolt circle, paragraph 2.4 through 2.8 of Appendix 2 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 shall apply.

1-23. NOTATION

The symbols described below are used in the formulas for the design of flanges and fasteners. (Refer to Fig 2-4 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2).

A = outside diameter of flange or, where slotted holes extend to the outside of the flange, the diameter to the bottom of the slots, in.

A_b = cross-sectional area of the bolts using the root diameter of the thread or least diameter of unthreaded portion, if less, square inches.

A_m = total required cross-sectional area of bolts, taken as the greater of A_{m1} and A_{m2}, square inches.

NOTE

For hull integrity fasteners only, taken as the greater of A_{m1}, A_{m2}, or A_{m3}, square inches.

A_{m1} = total cross-sectional area of bolts at root of thread or section of least diameter under stress, required for the operating conditions, square inches.
= W_{m1}/S_b

A_{m2} = total cross-sectional area of bolts at root of thread or section of least diameter under stress, required for gasket seating, square inches.
= W_{m2}/S_o

A_{m3} = total cross-sectional area of bolts at root of thread or section of least diameter under stress, required for hull integrity fasteners based on a hydro-static pressure of 5 times collapse depth, square inches.
= $3.93 \cdot G^2 P_C/S_y$

B = inside diameter of flange, in. When B is less than 20·g1, it will be optional for the designer to substitute B_1 for B in the formula for longitudinal stress S_H.

B_1 = $B + g_1$, in., for loose type flanges and for integral type flanges that have calculated values h/h_o and g_1/g_o which would indicate an f value of less than 1.0, although the minimum value of f permitted is 1.0.

B_1 = $B + g_o$, in., for integral type flanges when f is equal to or greater than one.

b = effective gasket or joint-contact-surface seating width, in.

b_o = basic gasket seating width, in. (from Table 2-5.2 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2).

C = bolt circle diameter, in.

c = basic dimension used for the minimum sizing of welds, in., equal to t_n or t_x, whichever is less.

d = factor, in_3

d =$(U/V)\, h_O\, g_O^{\,2}$ for integral type flanges

d = $(U/V_L)\, h_O\, g_O^{\,2}$ for loose type flanges

e = factor, in^{-1}

e = F/h_o for integral type flanges

e = F_L/h_o for loose type flanges

F = factor for integral type flanges (from Figure 2-7.2 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2).

F_L = factor for loose type flanges (from Figure 2-7.4 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2).

f = hub stress correction factor for integral flanges from Figure 2-7.6 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2 (When greater than one, this is the ratio of the stress in the small end of hub to the stress in the large end). (For values below limit of figure, use f = 1).

G = diameter, in., at location of gasket load reaction. Except as noted in sketch (1) of Figure 2-4 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2. G is defined as follows (Refer to Table 2-5.2 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2).
When $b_o \leq 1/4$ in., G = mean diameter of gasket contact face, in.
When $b_o > 1/4$ in., G = outside diameter of gasket contact face less 2b, in.

g_o = thickness of hub at small end, in.

g_1 = thickness of hub at back of flange, in.

H = total hydrostatic end force, lb.
= $0.785G^2 P$

H_D = hydrostatic end force on area inside of flange, lb.
= $0.785B^2 P$

H_G = gasket load (difference between flange design bolt load and total hydrostatic end force), lb.
= W-H

H_p = total joint contact-surface compression load, lb.
= $2b \cdot 3.14$ GmP

H_T = difference between total hydrostatic end force and the hydrostatic end force on area inside of flange, lb.
= $H-H_D$

h = hub length, in.

h_D = radial distance from the bolt circle, to the circle on which H_D acts, as prescribed in Table 2-6 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2.

h_G = radial distance from gasket load reaction to the bolt circle, in.
= (C-G)/2

h_o = factor, in.
= square root of Bg_o

h_T = radial distance from the bolt circle to the circle on which H_T acts as prescribed in Table 2-6 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2.

K = ratio of outside diameter of flange to inside diameter of flange.
= A/B

L = factor
=$(t_e + 1)/T + t^3 /d$

M_D = component of moment due to H_D, in-lb.
= $H_D h_D$

M_G = component of moment due to H_G, in-lb.
= $H_G h_G$

M_O = total moment acting upon the flange, for the operating conditions or gasket seating as may apply, in-lb.

M_T = component of moment due to H_T, in-lb.
= $H_T h_T$

m = gasket factor, obtain from Division 1, Appendix 2; refer to Note 1, 2-5 (c) (1).

N = width, in., used to determine the basic gasket seating with b_O based upon the possible contact width of the gasket. Table 2-5.2 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2.

P = internal design pressure, psi.

P_c = ship's collapse depth pressure, psi.

R = radial distance from bolt circle to point of intersection of hub and back of flange, in. For integral and hub flanges.

R = $(C - B)/2 - g_1$

S_a = allowable bolt stress at atmospheric temperature, psi.

S_b = S_a

S_f = allowable design stress for material of flange at design temperature (operating condition) or atmospheric temperature (gasket seating), as may apply, psi.

S_n = allowable design stress for material of nozzle neck, vessel or pipe wall, at design temperature (operating condition) or atmospheric temperature (gasket seating), as may apply, psi.

S_H = calculated longitudinal stress in hub, psi.

S_R = calculated radial stress in flange, psi.

S_T = calculated tangential stress in flange, psi.

S_y = minimum yield strength of bolt material, psi.

T = factor involving K (from Figure 2-7.1 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2).

t = flange thickness, in.

t_n = nominal thickness of shell or nozzle wall to which flange or lap is attached, in.

t_x = two times the thickness g_O, when the design is calculated as an integral flange, in., or two times the thickness, in., of shell nozzle wall required for internal pressure, when the design is calculated as a loose flange, but not less than 1/4 in.

U = factor involving K (from Figure 2-7.1 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2).

V = factor for integral type flanges (from Figure 2-7.3 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2).

V_L = factor for loose type flanges (from Figure 2-7.5 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2).

W = flange design bolt load, for the operating conditions or gasket seating, as may apply, lb. (Refer to para. 2-5(e) of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2).

W_{m1} = minimum required bolt load for the operating conditions. lb. (Refer to para. 2-5 (c) of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2). For flange pairs used to contain a tubesheet for a floating head for a U-tube type of heat exchangers, or for any other similar design, W_{m1} shall be the larger of the value as individually calculated for each flange, and that value shall be used for both flanges.

W_{m2} = minimum required bolt load for gasket seating, lb. (Refer to para. 2-5 (c) of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2).

w = width. in., used to determine the basic gasket seating width b_o, based upon the contact width between the flange facing and the gasket (Refer to Table 2-5.2 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2).

Y = factor involving K (from Figure 2-7.1 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2).

y = gasket or joint-contact-surface unit seating load, psi (Refer to Note 1, para. 2-5 (c) of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2).

Z = factor involving K (from Figure 2-7.1 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2).

1-24. SPIGOTED METAL-TO-METAL BOLTED CONNECTIONS WITH O-RING SEAL ON SPIGOT

The minimum required bolt area (at root of thread or section of least diameter) and flange thickness for spigoted bolted connections shall be determined as follows:

If the ratio of the thickness of the spigoted section to that of the flange edge (T_s / T_f) is equal to or greater than 2.0 then: (refer to Figure 1-1).

$A_{m1} = \pi R_p^2 P/S$

$A_{m2} = 15.7 R_p^2 P_c / S_y$

Where:

A_m = minimum required area of bolts (i.e. number of bolts times area per bolt), square inches.

NOTE

For hull integrity fasteners only.

A_m = greater of A_{m1} or A_{m2} .

A_{m1} = minimum required area of the non hull integrity fasteners, square inches

A_{m2} = minimum required area of bolts based on a hydrostatic pressure of 5 times collapse depth (for hull integrity fasteners only), square inches.

S_y = minimum yield strength of bolt material, psi.

P = design pressure for the connections (i.e. not hydro), psi.

S = allowable stress of bolt material. This will be taken as the lower of 2/3 yield or 1/4 ultimate at room temperature, psi.

P_c = ship's collapse depth pressure, psi.

R_p = radius over which pressure acts on the gasket or O-ring, inches.

$$S_r = \frac{3W}{2\pi T_f^2} \left[\frac{2(D_f / 2)^2 (M + 1) Ln(D_f / D_s) + (D_f / 2)^2 (M - 1) - (D_s / 2)^2 (M - 1)}{(D_f / 2)^2 (M + 1) + (D_s / 2)^2 (M - 1)} \right]$$

Where:

S_r = maximum radial flange bending stress, psi shall be less than allowable stress in flange material. This will be taken as the lower of 2/3 yield or 1/4 ultimate at room temperature. Formula obtained from Roark, Formulas for Stress And Strain, 5 th Edition.

W = $\pi R_p^2 P$ for non-hull integrity.

T_f = thickness of flange, in.

D_f = diameter of flange at bolt circle, in.

D_s = diameter of spigot, in.

M = 1/u, reciprocal of Poisson's Ratio.

1-25.

If the ratio T_s/T_f is less than 2.0, (refer to Figure 1-1) size the fasteners and flange thickness in accordance with paragraph 1.7 and paragraph 1.8 of this procedure.

1-26. BOLT/STUD PRE-STRESS AND TORQUE REQUIREMENTS

For SUBSAFE joints, it is recommended that the resulting pre-stress should fall between 50% and 66 2/3% of the fastener minimum yield strength. The resulting compressive stress in the clamped material should not exceed 150% of the material minimum yield strength.

1-27.

After the required pre-stress has been calculated, the torque to produce this pre-stress shall be determined. There are three options that may be used to determine the required torque. For self-locking fasteners, the average running Torque per specification shall be added to the calculated pre-stress Torque to obtain the Total Torque to be applied to the fastener.

a. The PC-BOLTS computer program from Appendix E may be used. Appendix E represents the user's manual for the PC-BOLTS computer program. It is a NAVSEA approved method for determining required bolt torque.

b. The following formulas from the PC-Bolts program may be used by hand:

$T = K_t \cdot P \cdot D$

$K_t = [E_m (\tan \Psi + \mu \sec \alpha)]/[2D(1 - \mu \tan \Psi \sec \alpha)] + D_{cm} \mu_c / 2D \sin ø$

$P = A_t \cdot \% \cdot S_Y$

Where:

T	= applied torque, in-lbs.
K_t	= torque coefficient
P	= preload, lbs.
A_t	= bolt tensile area, in ^{2}
%	= percent of bolt material yield strength, 1/2 Sy to 2/3 Sy.
S_y	= bolt material yield strength, psi.
D	= nominal bolt diameter, in.
E_m	= mean thread pitch diameter, in.
Ψ	= helix angle of thread.
α	= 1/2 angle between threads (30° for standard threads).
μ	= thread friction coefficient (refer to Table 1-2).
μc	= collar friction coefficient (refer to Table 1-2).
D_{cm}	= mean collar diameter of the nut or bolt (whichever is turned), in.
ø	= 1/2 included bolt head/nut angle of contact with pint (90° for all fastener types except countersunk head machine screws which are at 40°).

c. The following simplified equation developed from the results of a and b above may be used. The results of this Formula agree within ∀ 3% of those of a and b above for thread sizes between 1/2 inch and 2 inches.

$T = (1.21 \mu + 0.02) C D^{0.94} P$

Where:

C = fastener configuration factor.
= 1.0 for plain or self-locking heavy hex nuts.
= 0.960 for plain or self-locking regular hex nuts.
= 0.943 for cap screws.
= 1.28 for machine screws.

1-28. MINIMUM THREAD ENGAGEMENT

The minimum acceptable thread engagement for the setting end of a stud or bolt shall be that which will develop the minimum strength of the assembly, as calculated by formulas given in FED-STD-H28.

1-29.

For hull integrity fasteners unless otherwise approved by NAVSEA, nuts shall be NiCu of the self-locking type, in accordance with MIL-N-25027 and MS17828 or MIL-N-25027/1, except that those nuts which shall attach equipment to the hull or hull insert shall be in accordance with MIL-N-25027/1.

1-30.

For non-hull integrity fasteners, the nuts shall be selected such that the stripping strength (proof load) of the nut exceeds the operational load including preload of the externally threaded fastener on which it is used.

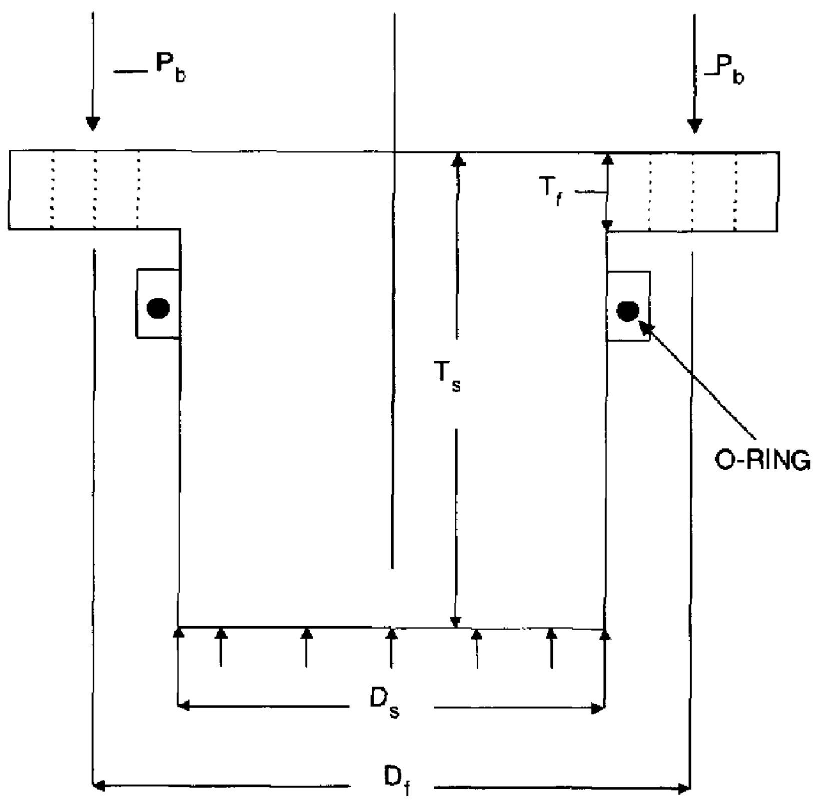

Figure 1-1 SPIGOTED BOLTED CONNECTION

NOTE

$$R_p = D_s/2 \text{ (inches)}$$

D_f = Diameter of bolt Circle (inches).

P_b = Total bolt load due to hydrostatic pressure acting over diameter D_s, lbs.

Table 1-2 FRICTION COEFFICIENTS OF VARIOUS LUBRICANTS

LUBRICANT	AVERAGE COEFFICIENT OF FRICTION
A-A-59004, MOLYKOTE P37 (OTHER THAN ALLOY 625) (REFER TO NOTE 3)	.10
A-A-59004, MOLYKOTE P37 (ALLOY 625) (REFER TO NOTE 3)	.11
MIL-G-27617, GREASE, TYPE III, FLUORO CARBON BASED	.10
MIL-L-24131, GRAPHITE IN ISOPROPANOL (NEOLUBE)	.11

NOTE

(1) Friction values for all of the lubricants were obtained from Appendix E of this manual.

(2) Calculate torque values from preloading fasteners using average coefficient of friction values. This approach is consistent with Appendix E of this manual.

(3) For fasteners larger than 1.5 inches diameter, coefficients of friction shall be increased by 20%.

1-31.

Design the flange of a pressure vessel in accordance with this standard. A 20 in. I.D. cylindrical vessel with a 1 in. wall is to be made of annealed Monel. The design pressure is to be 700psi. A commercially pure Titanium cover will be attached to the cylinder with K-Monel bolts. A rubber O-ring (self energizing) will be included, as shown;

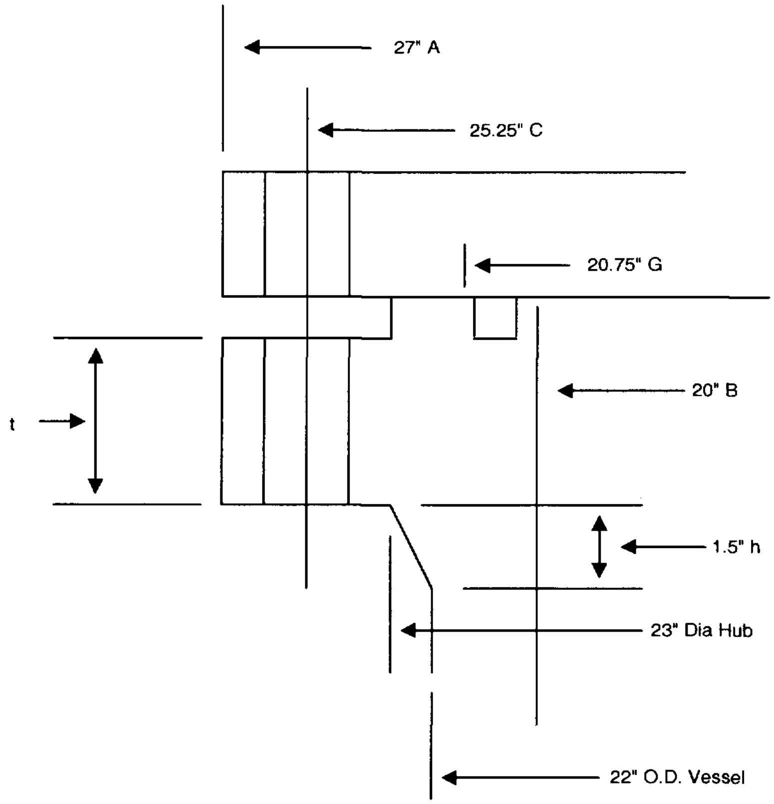

Figure 1-2 PRESSURE VESSEL FLANGE DESIGN

Material properties are taken as follows:

Table 1-3 MATERIAL PROPERTIES

MATERIAL ULTIMATE	KSI	YIELD (KSI)	ALLOWABLE (S) (KSI)
CP Ti Gr.2	50	40	12.5
Annealed Monel	70	25	16.6
K-Monel	130	85	32.5

a. Determine bolt area: W_{m1} (from ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2) = $.785\ G^2\ P = .785\ (20.75)^2\ (700) = 237,000$
$A_m = A_{m1} = W_{m1}/S_b = 237,000/32,500 = 7.29\ in^2$
Say we use 7/8 in. bolts at $0.419 in^2$ bolt, therefore need 7.29/.419 = 18 bolts.

b. Across corner diameter of 7/8 in. heavy nuts is about 1.64 in., so let the bolt circle diameter be the sum of the diameter to thick end of hub +1/2 in. fillet +1.64 in. = about 25.25 in. = C.

c. The O.D. of the flange will be C + 1.64 in. = about 27 in. = A

d. The thickness of the flange is then determined using the rules of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2. The next page shows a TK-Solver calculation which shows that a 1.82 in. thick flange satisfies all code allowables in that all stresses (the bottom of page) are less than the 16,000psi allowable of the flange material, except for the longitudinal hub stresses which are allowed to be 1.5 times that value. The flange with say, 2 inch thickness is acceptable.

NOTE

The next 2 pages show TK-Solver input and output parameters. Included is also hand calculation verifying the TK-Solver program.

Table 1-4 TK-SOLVER INPUT AND OUTPUT PARAMETERS

ST INPUT	NAME	OUTPUT	unit	COMMENT
				WELD NECK FLANGES
				GEOMETRY INPUTS
1	g^o		in	Thickness at top of hub
1.5	g^1		in	Thickness at base of hub
1.5	h		in	Length of hub
	t	1.8160672	in	FLG thickness
27	A		in	OD of FLG
20	B		in	ID of FLG
25.25	C		in	Bolt circle diameter
20.75	G		in	Eff pressure dia.
	R	1.125	in	Dist bolt hub to bolt circle
	E	0.875	in	Dist bolt circle to outer Rad.
0.419	A_{b1}		sq. in.	Str area per bolt
18	NB			Number bolts
.875	c		in	Nom bolt dia.
				1. DESIGN CONDITIONS
700	P		psi	Design pressure
32500	S_c		psi	Bolt Allow, (@ ATM temp)
32500	S_c		psi	Bolt allow, (@ design temp)
				3. GASKET CHARACTERISTICS
	b0		in	Basic gasket seat width
	b	0	in	Eff. Gasket seat width
0	m			Gasket factor
0	y			Gasket seating load
				8. STRESS CALC. (OPERATING)
	SH	14182.885	psi	Long. Hub (<1.5 SF_o)
	SR	13580.286	psi	Radial FLG (<SF_o)
	ST	4024.0528	psi	TANG. FLG (<SF_o)
16600	int1	13881.585	psi	Average 1 (<SF_o)
	int2	9103.4888	psi	Average 2 (<SF_o)
				9. STRESS CALC (SEATING)
	SHsect	16960.303	psi	Long hub (<1.5 SF_o)
	SRsect	16239.697	psi	Radial FLG (<SF_o)
	STsect	4812.0784	psi	Tang. FLG (<SF_o)
	int1sec		psi	Average 1 (<SF_o)
	int2sec	10886.19	psi	Average 2 (<SF_o)
				4. LOAD AND BOLT CALCULATIONS
	W_{m2}	0	lb	
	H_p	0	lb	

Table 1-4 TK-SOLVER INPUT AND OUTPUT PARAMETERS - Continued

ST INPUT	NAME	OUTPUT	unit	COMMENT
	H	236714.1	lb	
	W_{m1}	236714.1	lb	
	A_b	7.542	sq. in.	
	A_m	7.2835107	sq. in.	
	W	240914.55	lb	
				5. MOMENT CALCULATIONS
	HD	219911.49	lb	
	HG	0	lb	
	HT	16802.612	lb	
	hD	1.875	in	
	hG	2.25	in	
	hT	2.4375	in	
	MD	412334.04	in-lbs	
	MG	0	in-lbs	
	MT	40956.367	in-lbs	
	MO	453290.4	in-lbs	
	MGSEAT	542057.73	in-lbs	
				6. K AND HUB FACTORS
	K	1.35		
	U	7.2824509		
	Z	3.4316109		
	Y	6.6270303		
	T	1.7759167		
	hO	4.472136		
	F	0.87362861		
	V	0.35762069		
	f	1.0495037		
	e	0.1953493		
	d	91.068866		
				7. FORMULA FACTORS STRESS
	Alpha	1.3547674		
	Beta	1.4730233		
	Gamma	.76285528		
	Delta	.06576969		
	Lambda	.82862497		
	mo1	22664.52	lb	
	mG1	27102.887	lb	
	Space	4.4069564		
	Factor	1.1116667		
	mo	25195.393	lb	
	mG	30129.378	lb	

Table 1-5

1	**DESIGN CONDITIONS**					**2 GASKETS**	**FACE**		**3 FROM Fig UA-49**
Design Pressure, *P*				700		RUBBER O-RING	RAISED		N = 18
Design Temperature				70					B = 0
Flange Material				MONEL					G = 20.75
Bolting Material				K-MONEL					Y = 0
									M = 0
Corrosion Allowance				0		**4 LOAD AND BOLT CALCULATIONS**			
Allow. Stress	Flange		Design Temp., S_{fo}		16600	$W_{m2} = b\pi G_y = 0$		A_m = greater or W_{m2}/S_a OR $W_{m1}/S_b = 7.28357$	
			Atm. Temp., S_{fo}			$H_p = 2b\pi GmP = 0$		$A_b = 7.542$	
	Bolting		Design Temp., S_b		32500	$H = G^2 \pi P/4 = 236714$		$W = .5(A_m + A_b)S_a = 240914$	
			Atm. Temp., S_a			$W_{m1} = H_p + H = 236714$			
CONDITION			**LOAD**		**X**	**LEVER ARM**		**=**	**MOMENT**
5 OPER-ATING		$H_D = \pi B^2 P/4 = 219911$				$h_D = R + .5_{g1} = 1.875$		$M_D = H_D h_D = 412334$	
		$H_G = W_{m1} - H = 0$				$h_G = .5(C-G) = 2.25$		$M_G = H_G h_G = 0$	
		$H_T = H - H_D = 16802$				$h_T = .5(R+g1+h0) = 2.4375$		$M_T = H_T h_T = 40956$	
								$M_O = 453290$	
SEAT-ING		$H_G = W = 240915$				$h_G = .5(C-G) = 2.25$		$M_G = 542058$	
8 Allow-able Stress		**STRESS CALCULATION - Operating**					**6**	**K AND HUB FACTOR**	
1.5 S_{fo}		Long. Hub, $S_H = fm_O/\lambda g_1^2 = 14182$					K=A/B= 1.35		$h/h_O = 335$
S_{fo}		Radial Flg., $S_R = \beta m_O/\lambda t^2 = 13580$					T=1776		F= .874
S_{fo}		Tang. Flg., $S_T = m_O Y/t^2 - ZS_R = 4024$					Z=3.432		V= .358
S_{fo}		Greater of $.5(S_H + S_R)$ OR $.5(S_H + S_T) = 13881$					Y=6.627		f=1.049
9 Allow-able Stress		**STRESS CALCULATION-Seating**					U=7.282		$e = F/h_o = .195$
1.5 S_{fo}		Long. Hub, $S_H = fm_G/\lambda g_1^2 = 16980$					$g_1/g_O = 1.5$		$d = U/V\, h_O\, g_o^2 = 91.069$
S_{fo}		Radial Flg., $S_R = \beta m_G/\lambda t^2 = 16238$					h_O = square root of B_{go} =4.472		
S_{fo}		Tang. Flg., $S_T = m_G Y/t^2 - ZS_R = 1812$					**7**	**STRESS FORMULA FAC-TORS**	
S_{fo}		Greater of $.5(S_H + S_R)$ OR $.5(S_H + S_T) = 16600$					t = 1.816		
							$\alpha = t_e + 1 = 1.335$		
							$\beta = 4/3\, t_e + 1 = 1.473$		
							$Y = \alpha/T = .763$		
							$\nabla = t^3/d = .066$		
							$\lambda = Y + \nabla = .829$		
							$m_O = M_O/b$ = operating = 25195		
							$m_O = M_G/B$ = seating = 30129		
							If bolt spacing exceeds. 2a+t, multiply m_O and m_G in the above equations by:		square root (Boltspacing/2a + t)

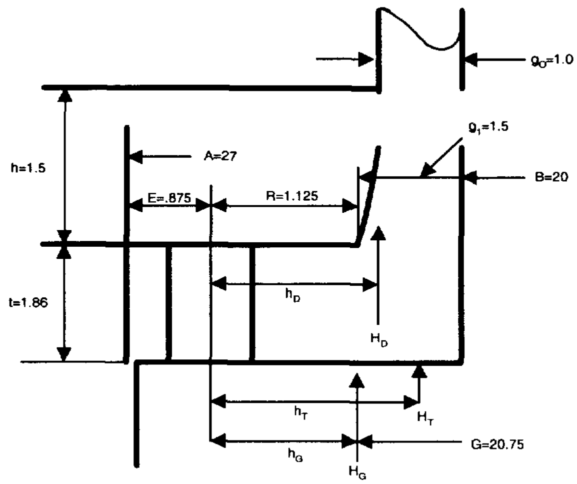

Figure 1-3 (18-7/8 in. Ø Bolts) Cover Plate Design

1-32.

Design The Cover Plate In The Above Sketch:

$t = G[(FP/S)+1.9\ W\ h_G/(SG^3)]^{.5}$

The value of F is taken as 0.3 (because there is no contact outside of the bolt circle). G is 20.75 in., P is 700psi, S is 12,500psi, $h_C = (C-G)/2 = (25.25 - 20.75)/2 = 2.25$ in. The value of W is determined from formula (4) of Appendix 2 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.

$W = (A_m + A_b)\ S_O/2$

Where:

A_m is the required bolt area, 7.28 in^2 from the above calculation

A_b is the actual bolt area = (18)(.419) = 7.55 in^2

S_o is 32,500psi

So, W is 241,000 pounds and $t = (20.75)[(.3)(700)/12{,}500 + 1.9(241{,}000)(2.25)/(12{,}500)(20.75^3)]^{.5}$

So, t = 3.55 inches.

It is pointed out that this is a much thicker plate than would be required by calculation procedures which would base the allowable stress for the CP material on yield rather than on ultimate, if 2/3 yield governed the value of S the resulting thickness would be about 2.3 in. The code requires that extra protection be provided for materials in which there is not much difference between yield and ultimate.

1-33.

Design the bolts and a titanium cover plate, but now let the plate be bolted to a thick reinforced region as shown:

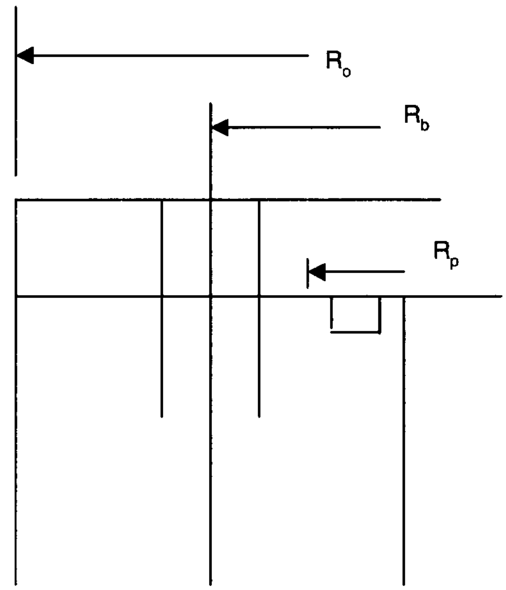

Figure 1-4 THICK PLATE BOLTING

Now the bolts can be moved in closer to the groove.

$$A_m = [\pi P(R_b)(R_p)^2/S]\,(R_O - 0.75\,R_p)/[R_p(R_O - R_b)]$$

R_p = 20.75/2 = 10.375 in.
R_o = 12.5 in. (as a trial)
R_b = 11.375 in. (as a trial)
P = 700psi
S = 32,500psi

So, A_m = 30.55 square inches.

Now if 18 bolts are used, area/bolt = 30.55/18 = 1.697, so use 1 3/4 in. bolts. This result is typical of what happens when the bolts are called upon to clamp the O.D. of the plate: bolt size increases.

1-34.

Now design the cover plate, again:

$$t = G[(FP/S) + 1.9W\,h_G/(SG^3)]^{.5}$$

But now h_G is taken as zero, and F = .25, so t = 20.75 [(.25)(700) /12,500 $^{.5}$], so t= 2.46 in. and this is another typical result: bolt size increases but required plate thickness is decreased by the clamped edge.

1-35.

Derivation of Bolt Size For Flat Cover Plates - Visualize the closure as broken at the O-ring groove, so that pressure acts out to R_p . There is a bolt at R_b and the outside radius is R_O . The portion out to the O-ring is taken as thin plate with radius R_p . The portion outside of R is taken as a ring (i.e. an axisymmetric structural element which can rotate and translate, but does not deform within its own section) . A shear force per inch, V, and a moment per inch, M, are set up at junction of two bodies.

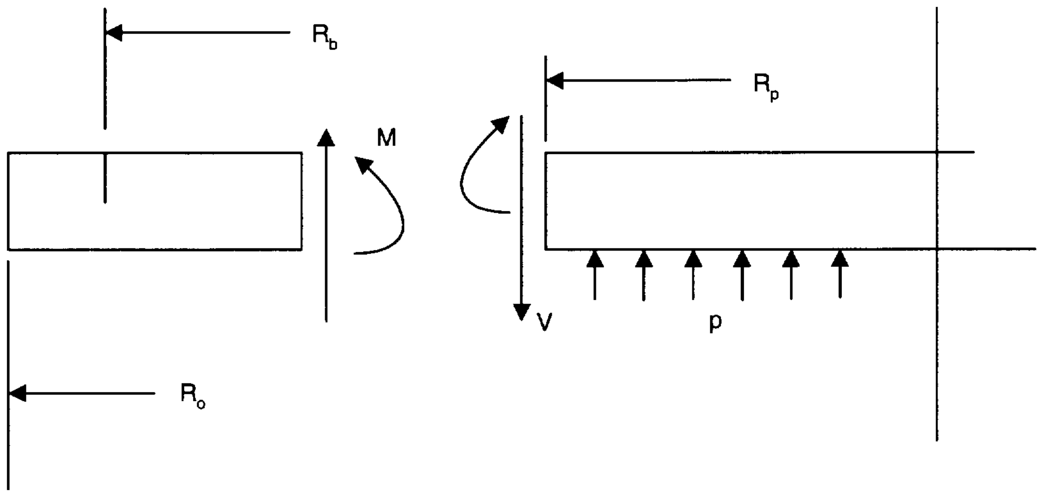

Figure 1-5 SHEAR FORCE CALCULATION

We can calculate the shear force from equilibrium of the plate: $V = p \cdot R_p /2$

Now we will assume that the outer portion completely clamps the plate, so that $M = p \cdot R_p^2 /8$. (say, from ROARK 6 th ED., Table 24, Case 10b.)

Now considering radius ratios, find the load/inch F_b applied at R_b which will put the ring into equilibrium;

$$(R_o - R_p) \cdot R_p \cdot V + R_p \cdot M = (R_o - R_b) \cdot R_b \cdot F_b$$

So, $F_b = [(R_o - R_p) \cdot R_p \cdot V + R_p \cdot M] / [(R_o - R_b) \cdot R_b]$

Plugging in: $F_b = [(R_o - R_p) \cdot R_p \cdot (p \cdot R_p /2) + R_p \cdot (p \cdot R_p^2 /8)]/[(R_o - R_b) \cdot R_b]$

Or, $F_b = \{p \cdot R_p^2 /[R_b (R_o - R_b)]\} \cdot [(R_o - R_b)/2 - R_p /8]$

$= p \cdot R_p^2 / [2 \cdot R_b \cdot (R_o - R_b)] \cdot (R_o - .75 R_p)$

Now, the total bolt load is $2\pi \cdot R_b \cdot F_b = A_m \cdot S$, where S is the allowable stress and A is the required bolt area. Plugging in and solving for A_m gives:

$$A_m = [\pi \cdot P \cdot R_p^2 \cdot (R_o - 0.75 \cdot R_p)] / [S \cdot (R_o - R_b)]$$

Which is the same as equation (2) in paragraph 1.11.1 of the procedure except that an R_b which appears in both the numerator and denominator is cancelled out here. It is the same numerically.

1-36. REVERSE ENGINEERING OF JOINTS FOR DETERMINATION OF PROPER TORQUE

There are several reasons for having a procedure to reverse engineer a joint from the standpoint of determination of proper torque/preload and resulting stresses. Typical cases are:

a. Determination of the validity of the torque given in the applicable document.

b. When circumstances require the use of a thread lubricant other than that specified in the applicable document.

c. When a torque is given in an applicable document, but it is not clear if the torque is based on the use of a thread lube or unlubricated assembly, or what thread lube or friction coefficient formed the basis for the given torque.

To analyze any of these situations quickly requires the use of PC Bolts, Appendix E of this manual, or laborious hand calculations. If you are not comfortable with this computer program, seek assistance from an activity or individual experienced in its use.

1-37.

For case a. the first step is the same as any PC Bolts calculation; gather the necessary information from the applicable sources and input it into PC Bolts so that Bolts can make the calculation. For the first iteration, input the supplied torque from the applicable document. Compare the stresses which result from this calculation with the default values used by PC Bolts to see if the results are reasonable from a stress standpoint (for guidance in judging what are acceptable deviations from the default values, see 1-40.e and 1-40.f below). If they are reasonable, this is all that is required for case a. above. If they deviate too much from the default values, reduce the torque until the stresses are within the correct range.

1-38.

For case b. the first step is to make the normal calculation as in case a., using the originally specified thread lubricant and inputting the specified torque. Again, analyze the stresses and if they are acceptable, proceed. If they are too high, reduce the torque as before, until the stresses fall within the acceptable range. With the proper stresses established, write down the value for the preload that goes with the torque and stresses; go to the ″Lubricant″ box and change the thread lubricant from the original lube to the one you desire to use. Go to the ″Preload″ box on the computer screen and manually input the preload that gives the proper stresses, and complete the calculation to get the new torque. Note that the preload and stresses will be the same, but the torque will be different due to the change in friction coefficient for the new thread lube.

1-39.

For case c., it is necessary to assume a thread lube by specifying it in the ″Lubricant″ box in the program (choose the one you intend to use, or choose ″Unlubricated ″), then complete the calculation as before. Again, compare the resulting stresses to the defaults used by the program and the guidance in paragraph 1.40 below. If the stresses are not in the acceptable range, alter the torque until they fall within the acceptable range. If ″Unlubricated″ was chosen, once the previous actions have been completed and the stresses are shown to be within the acceptable range, write down the resulting preload, choose the desired thread lubricant, and proceed as for case b. above.

1-40.

Historically, there are several reasons why we have needed to reverse engineer joints as described above, to determine the proper torque, or if the given torque is acceptable. It helps to be familiar with some of these reasons and what the acceptable limits are.

a. We know a lot more about the friction coefficients of various thread lubricant and material combinations now than we knew as recently as ten years ago. Twenty-five to thirty-five years ago, when most of these torques were calculated for inclusion in drawings and technical manuals for hulls prior to the SEAWOLF Class, all an engineer could do was make a guesstimate as to friction coefficient. Now there is a significant body of research results from both the Navy and the private sector to refine such calculations.

b. We now recommend using a thread lubricant on essentially all bolted joints; sometimes, the requirement to use a thread lubricant was added to a joint without suitable revision to the torque requirement, or the thread lubricant was changed without suitable torque revision.

c. Prior to the advent of the computer program we now use to calculate torque, the calculation of the various stresses in a joint was cumbersome and time consuming at best. Because of this, bearing stress (under the nut or under the bolt head, as appropriate) was often ignored as a way to shorten the process. With some material combinations, this means that we would now specify a lower torque because the bearing stress limit is exceeded even though tensile and shear stresses aren't.

d. Prior to the use of 2/3 of yield as a stress limit for the primary stresses in a bolted joint, 75 percent of yield was a commonly used standard for these stresses, in the absence of other guidance. Depending on a number of variables, either number is technically defensible. For the above and other legitimate (though annoying) reasons, we are now discovering these variations from present stress limits, and they must be dealt with.

e. By direction from NAVSEA the following guidelines have been used by SUBMEPP and the Design Divisions of the Naval Shipyards to reduce the number of joints submitted for off yard evaluation (via LAR) by the Planning Yard and/or NAVSEA when reverse engineering of a joint is necessary to verify the suitability of a specified torque:

e.1 Any joint is acceptable without further action by the Shipyard if the verification calculation shows the stresses which default to 2/3 of yield in the PC Bolts computer program are less than 80 percent of yield with the currently specified torque. The currently specified torque doesn't need to be revised downward or further guidance sought via LAR.

e.2 Where bearing stress exceeds 150 percent of yield (whether based on the other principle stresses meeting the default limit of 2/3 of yield or the extended limit of 80 percent of yield per 3.a above), the excessive bearing stress situation may be ignored, as it was in the original calculation.

f. Where the guidance values of e. through e.2 above are exceeded when the verification calculation is complete, continue to submit the results to the Planning Yard for evaluation, via LAR, as is already done. If the verification calculations show that the stresses are considerably less than the default values of PC Bolts, no further action is necessary unless operational history indicates tendencies toward loose fasteners, leakage or unacceptable movement of the mating surfaces. In this case, again, the results should be submitted to the Planning Yard via LAR for resolution. Where there are differing torques cited for the same joints in multiple sources, torques given in a Maintenance Standard (MS), or in SHAPEC packages developed by the SHAPEC Planning Yard, shall take precedence. These torques have been developed after extensive review and reverse engineering and do not require further review by the user activity.

CHAPTER 2

GEOMETRY OF FASTENERS

2-1. INTRODUCTION.

This section identifies the configuration of threaded fasteners used on board submarines in non-nuclear pressure-containing systems. For information concerning fastener materials used in pressure-containing systems, see Table 2-1 or refer to MIL-STD-438, Schedule of Piping, Valves, Fittings, and Associated Piping Components for Submarine Service.

2-2. THREADED FASTENERS.

The types of threaded fasteners covered in this section include bolts, studs or stud-bolts, bolt-studs, and nuts. Additional coverage of nuts is included in paragraph 2-8 under self-locking nuts. The type of threaded fastener to be used in a specific application is determined by the equipment designer and is found in the parts lists, drawings, and/or equipment manual. (See Table 1-1 for definitions.)

2-3. BOLTS.

Hexagon-head bolts are the most commonly used bolts in pressure containing systems. Through bolting is used whenever possible. When the use of such bolting is not possible, studs are used in preference to tap bolts.

2-4. STUDS.

The two different type studs (stud-bolts) used in pressure-containing systems are the reduced-body and full-body studs. Reduced-body studs have an unthreaded section smaller than the major diameter of the threaded portion of the stud (see paragraph 2-6). Full-body studs have no reduction in size in the unthreaded portion.

2-5. BOLT-STUDS.

Bolt-studs are used with a nut on each end. They are threaded with the same form and fit throughout their length.

2-6. CONSTANT STRENGTH STUDS.

To evenly distribute shock loads and preserve integrity of the joint, energy absorption is provided by making the studs of essentially constant strength throughout their length. This is achieved by reducing the unthreaded shank diameter to approximately the pitch diameter or by threading the stud throughout its entire length.

2-7. STEPPED STUDS.

This type stud is used only as a repair when the setting end threads have been stripped or damaged and that end of the stud no longer mates with the damaged threads. The hole is then drilled and tapped to the next larger diameter and the setting end of the stud is also stepped up one size larger. The essentially constant strength feature may be restored by removing metal through appropriate axial drilling of the enlarged end of the stud, thereby restoring a more uniform stress area throughout its length. Stepped studs may not be used in submarine hull integrity joints without prior approval of NAVSEA.

2-8. SELF-LOCKING NUTS.

The primary function of the self-locking nut is to prevent the fastener from loosening once preload has been lost. The nonmetallic and metallic types are the two most commonly used self-locking nuts in submarine pressure containing systems (see Figure 2-1) . Nonmetallic nuts are commonly known as elastic stop nuts and consist of the plastic insert ring, plastic plug, and the plastic patch types. The metallic nuts consist of the distorted thread and collar nuts and the spring beam nut.

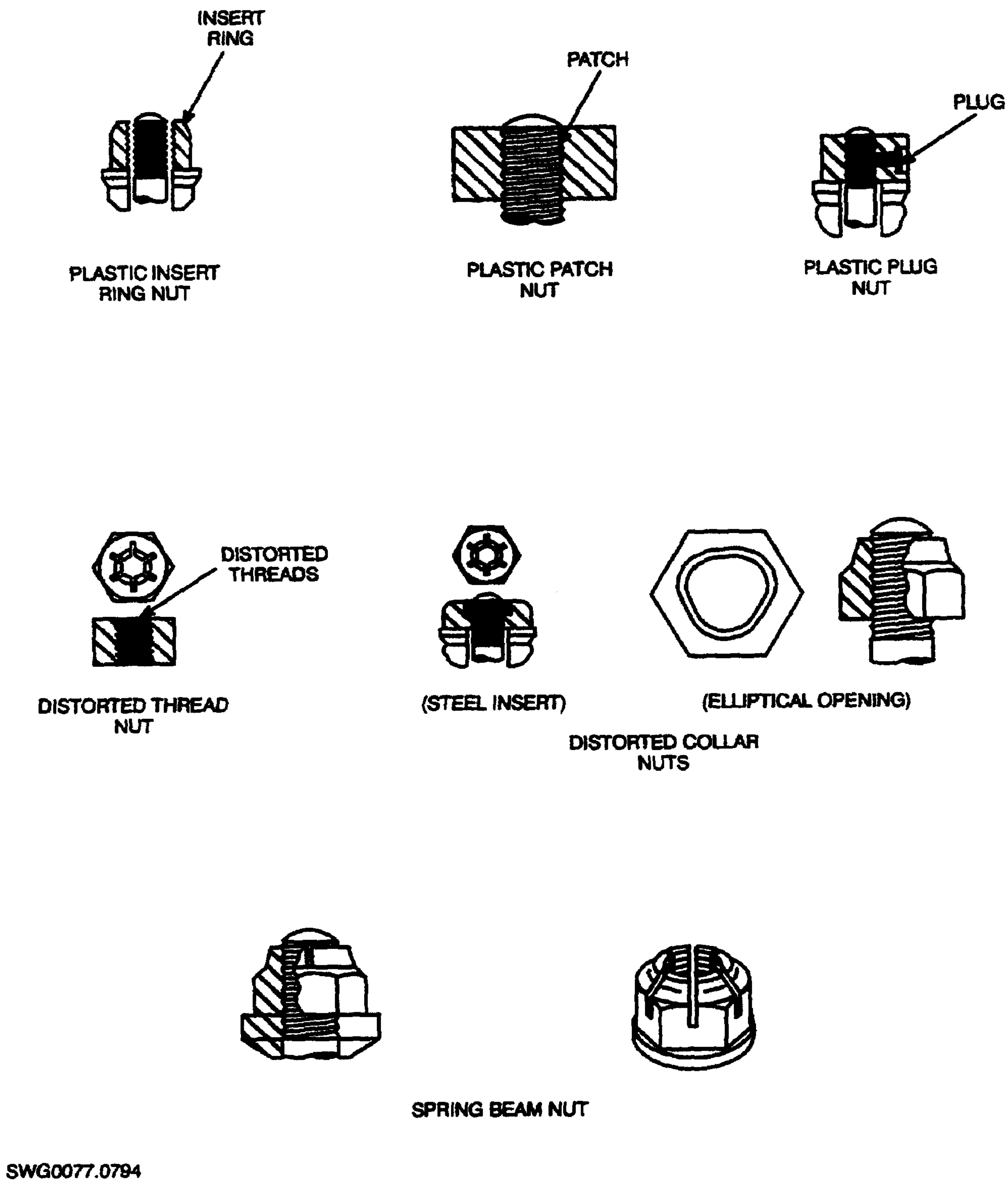

Figure 2-1 COMMONLY USED SELF-LOCKING NUTS

2-9. PLASTIC INSERT RING NUT.

A plastic (nylon) insert ring in the top of this nut provides the necessary locking action. When assembled, the plastic is forced to assume the shape of the mating threads and produces the locking action. This is the most commonly used self-locking nut in submarine pressure containing systems.

2-10. PLASTIC PLUG NUTS.

The plastic (nylon) plug inserts which do not extend completely around the internal circumference of the nut force the nut to the side, cocking it slightly. This causes a wedge locking action between the mating threads.

2-11. PLASTIC PATCH NUTS.

The plastic patch is permanently fused to an area of the nut. As the mating threads fully engage the plastic locking patch, the plastic is gradually compressed, completely filling in all axial tolerances between the male and female threads. This action forces a strong metal-to-metal contact between mating threads, opposite the locking patch, which produces the locking action.

2-12. PLASTIC INSERT RINGS OR PLUG NUTS

Plastic insert ring or plug nuts do not deform bolt or stud threads and are used when frequent removal is necessary. They should not be used in areas where the temperature exceeds 250°F. These are the most commonly used nonmetallic self-locking nuts in pressure-containing systems. For further information concerning self-locking nuts and their temperature ratings, see MIL-N-25027.

2-13. DISTORTED THREAD NUTS.

Distorted thread nuts have either depressions in the face of the nut distorting a few threads or they have a number of deflected threads in the center of the nut. In either case, forcing the threads on the bolt or stud deforms the threads toward the angle of the bolt threads. This deforms the bolt threads in the direction of the nut threads and high interference frictional forces are created. These nuts tend to deform the threads of the bolt or stud and should not be used when frequent removal is necessary.

2-14. DISTORTED COLLAR NUTS.

Distorted collar nuts, commonly referred to as distorted top nuts, have either an oval steel insert or the nut is formed with an elliptical opening. As the nut is threaded on a bolt or stud, the bolt forces the nut or collar into a round shape. The nut threads tend to return to the oval shape causing high frictional forces to be exerted on two sides of the bolt. This nut deforms the bolt threads and is not used when frequent removal is necessary.

2-15. SPRING BEAM NUT.

The spring beam nut is formed with a slight taper in the threads toward the upper portion of the nut. Slots are cut in the outer portion forming segments that are forced outward when the nut is installed. Elastic reaction causes the segments to push inwards gripping the bolt or stud. This nut does not deform the bolt or stud threads and can be used on frequently removed items. Before reusing, check the nut for loss of elasticity of the segments by installing nut on lightly oiled clean threads. If the nut can be threaded past the deflection segments without a wrench, discard the nut and replace with a new one.

2-16. MISCELLANEOUS NUTS.

Locking nuts that do not fall into the self-locking class are jam nuts and castellated nuts (see Figure 2-3).

2-17. JAM NUTS.

Jam nuts are thin nuts used under full-sized nuts to develop locking action. The thin nut is deformed by the wider nut and is pressed against the working surface and the bolt threads. Thus, a considerable resistance against loosening is built up. This nut is ideal for assemblies where long travel of the nut on the bolt under load is necessary to bring mating parts into location.

2-18. CASTELLATED NUTS WITH COTTER PINS.

Castellated nuts have slots to receive a cotter pin which passes through a drilled hole in the bolt, serving as the locking member. Although these nuts will be encountered aboard submarines, they represent an outmoded type of locking fastener and their use is discouraged because the pin may be inadvertently removed and lost thereby eliminating the locking-safety feature.

2-19. MULTI-JACKBOLT TENSIONER.

A tensioning system consisting of a hardened washer and a Cylindrical nut with several small bolts (jackbolts) installed around the circumference of the nut (see Figure 2-2). Multi-jackbolt tensioners (MJTs) are preloaded by seating the cylindrical nut snug against the washer and extending the jackbolts instead of tightening the nut. SUPERBOLT() is one brand of these tensioners. While conventional fasteners are preloaded by tightening the nut, which can be difficult when the fastener is large or the access is restricted, multi-jackbolt tensioners are preloaded by extending the jackbolts. Since this can be done using hand tools, the rigging, interference removal, etc. required where hydraulic wrenches, multipliers or long cheater bars must be used is eliminated. Multi-jackbolt tensioners also resist loosening better than conventional hex nuts (especially under vibration) and are more shock resistant than the heavy hex nuts they are designed to replace. For more detailed information concerning the use of multi-jackbolt tensioners, see NSTM Chapter 075.

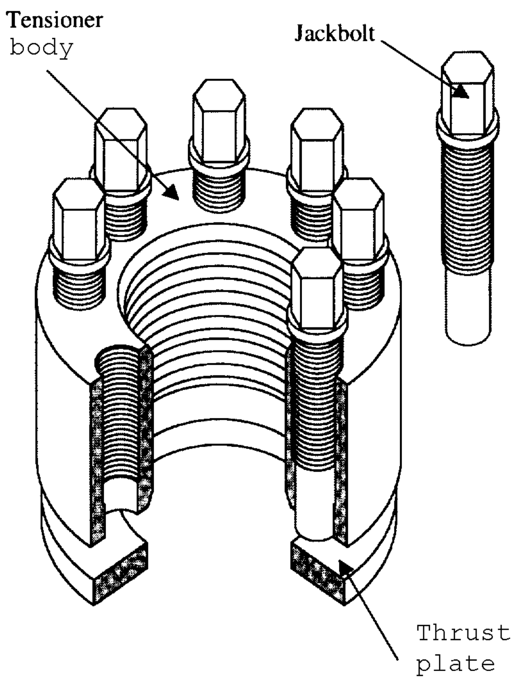

Figure 2-2 MULTI-JACKBOLT TENSIONER

2-20. NUT SEALANT.

There are instances where an anaerobic compound (Loctite or equivalent) is used as a sealant on nut threads.

2-21. LOCKWASHERS.

Although lockwashers will be encountered, their use should be limited wherever possible. Whenever possible, self-locking nuts should be used in place of lockwashers.

2-22. TAB WASHERS.

Tab washers are flat washers that have a combination of long and short protruding tabs. The long tabs are bent downward against the flange and the short tabs are bent upward against the flat of the nut to prevent fastener movement. The ″pant leg″ washer is one type of tab washer. Tab washers may be encountered but are not authorized for new construction. When these washers are removed, in connection with repairs or inspections, they should be replaced with self-locking fasteners.

2-23. THREADS

2-24. THREAD SERIES.

Thread series are groups of diameter-pitch combinations distinguished from each other by the number of threads per inch for a specific diameter. The basic dimensions and limits of size for all thread series are listed in General Services Administration FED-STD-H28, Screw-Thread Standards for Federal Services, Part 1, Section 2.

2-25. THREAD CLASSES AND FITS.

The function of thread classes is to assure the interchangeability of threaded components. The required assembly fit may be obtained by selecting the proper thread class for each threaded component. Thread series Classes 2, 3, and 5 are the most commonly used fits aboard submarines in pressure-containing systems.

2-26. CLASS 3 FIT VERSUS CLASS 5 FIT.

Studs normally come with a Class 5 fit on the setting end and a Class 3 fit on the nut end. However, it has been found in submarine service that assemblies using Class 5 fit interference studs require precise tolerances and selective fitting. Such precision is expensive to maintain particularly if the stud has to be disassembled and if the fit is too tight. In these instances, the casting may split, distort, or the stud may break. If the fit is too loose, the assembly may fail in service. Using Class 3 studs with the proper grade of anaerobic sealant (see MIL-S-22473 or MIL-S-46163 and paragraph 4-23), it is possible to develop a greater breakaway torque than that of a Class 5 force fit on the setting end of the stud. (Also see paragraph 4-23.) The use of Class 3 studs with anaerobic sealant is preferable to the use of Class 5 studs with an interference fit for this reason.

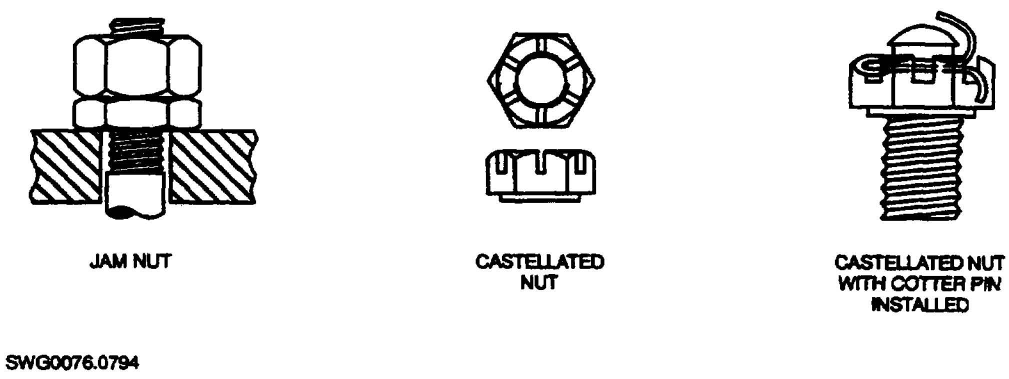

Figure 2-3 MISCELLANEOUS NUTS

2-27. TYPES OF THREADS.

The most common methods of forming external screw threads are by rolling and cutting. Although threads manufactured in the United States are generally rolled, cut threads are used, when required, in specific applications.

2-28. ROLLED THREADS.

Rolled threads are cold formed when the bolt or other cylindrical part has threads formed on its external surface by means of squeezing between rotating or reciprocating dies. The action of the dies on the metal displaces material radially and causes the surface to be indented by the crest of the die threads while the metal between the die threads is forced outward to form the apex of the thread. Because metal is not removed from the blank, but only displaced, the original blank diameter must be slightly undersize (approximately equal to the thread pitch diameter) to allow for the material at the thread root to be squeezed up into the thread apex. Rolled threads have a definite advantage in increased strength over cut threads.

2-29. CUT THREADS.

In forming threads by cutting, the threads are actually machine cut from the solid blank. Because there is a removal of metal, the original blank must always be full size (equal to the major diameter of thread).

2-30.

Tests have proved that rolled threads under straight tension loads, as a result of cold-working, average ten to twenty-five percent stronger than cut threads of corresponding size and material. Cold-forging the threads during the rolling process strengthens them in tension, shear, and fatigue. Torque requirements for rolled threads and cut threads will differ because rolled threads have smoother burnished thread flanks and have more generously radiused roots providing for a lower coefficient of friction. Less torque is required to tighten rolled threaded fasteners when considering only the lesser coefficient of friction than that required in the case of a cut threaded fastener. However, the physical properties of the fastener material are improved during the thread rolling process by cold-working. This enables the rolled threaded fastener to have a higher allowable stress level (two-thirds yield strength) which increases the amount of torque the fastener can withstand. While the lesser coefficient of friction for rolled threads enables less torque to be applied to obtain a given preload (and corresponding stress level), the rolled threaded fastener is able to withstand greater loading (torque). This is one reason why fastener torque tables do not distinguish between cut and rolled threads when listing torque values.

2-31. THREAD PROTRUSION.

Equipment component drawings normally specify the type, length, and size of bolt, stud, bolt-stud, etc., used. If not specified on the drawings, threaded fasteners of commercially stocked lengths should be used. Threaded fasteners, when installed and tightened, should protrude a distance of at least one thread beyond the top of the nut or plastic insert. Excessive protrusion should be avoided, particularly when necessary clearances, accessibility, and safety are important. Where practicable, the number of threads protruding should not exceed five. In no case should thread protrusion exceed ten threads. In the case of a stud, excessive thread protrusion may indicate that the stud has not been properly driven in the blind hole. In self-locking nuts, where the distance from the top of the nut to the locking element (plastic insert) is equal to or greater than the chamfer, the bolt or stud end may be flush with the top of the nut. For existing or reused fasteners, no maximum amount of thread protrusion is established except where excessive protrusion could cause damage to machinery or harm to personnel.

2-32. THREAD INSERTS.

Thread inserts (Helicoils and thin-wall inserts) should not be used in submarine material certification envelope applications without NAVSEA approval. For further guidance concerning their use, see NSTM Chapter 075.

2-33. LENGTH OF THREAD ENGAGEMENT.

The preferred design of most mechanically fastened assemblies is one in which the bolt or stud fractures before the threads shear in the tapped hole or on the bolt or stud. An adequate length of thread engagement ensures that the stud fractures rather than the threads shearing. There should be full threads for the entire length of engagement. Where studs are used, the length of engagement should be compatible with the shear strength of the material. Appendix 5 of FED-STD-H28 lists an acceptable method of determining required length of thread engagement. It is also one of the outputs of the PC Bolts computer program (Appendix E).

2-34.

Tapped holes for studs or tap bolts in thin material may be bottom tapped where necessary to obtain sufficient thread engagement. Where the material into which the stud is engaged is as hard as, or harder than, the stud, strength calculations are not required, provided the length of engagement is not less than the thickness of the corresponding size of a type I hexagon nut as given in the MIL-S-1222 series. If applicable specifications do not specify thread engagement, thread engagement should not be less than one diameter.

2-35. BOTTOMING AND SHOULDERING.

In bottom-tapped holes, contact between the bottom of the threaded piece and the bottom of the tapped hole should be avoided as tremendous forces can be generated at this contact point and can crack the material sections. The proper fastener length should be used to avoid bottoming. Shouldering occurs in studs when the thread runout engages the top of the threaded hole forcing the material at the top of the hole to distort and deform the flat surface. Shouldering should also be avoided by ensuring that an adequate length of thread engagement is provided.

2-36. FASTENER MATERIALS.

Fasteners are manufactured in a variety of ferrous and nonferrous metals. They are subjected to a variety of conditions (e.g., static and dynamic loads, corrosion, elevated temperatures, abrasion, etc.). The key to material selection of fasteners is in knowing what job the fastener has to do. Table 2-1 lists flange, gasket, and fastener recommendations for flanged joints used in submarine pressure-containing systems. To attain the ultimate in hull integrity and shock hardening, mechanically fastened piping connections, in the hull integrity area, are normally fitted with properly age-hardened K-monel bolts, studs, and bolt-studs with monel nuts.

NOTE

Hydraulic component fasteners shall be in accordance with NAVSEA S9086-S4-STM-000/Chapter - 556, Section 10.

Table 2-1 FLANGE, GASKET, and FASTENER RECOMMENDATIONS

Joint					
SERVICES	**FLANGE**	**GASKET**	**FASTENER**	**FASTENER MATERIAL**	**FASTENER SPECIFICATIONS/STANDARDS**
Steam, High Pressure Steam Drains, and Feed Water	Raised Face to Raised Face	Spiral Wound - Metallic Flexible Graphite	Bolt-Studs	Alloy Steel	MIL-S-1222, Type 1
			Nuts	Carbon Steel	MIL-S-1222, Type III Symbol 2H or 4
			Bolts	K-Monel	MIL-S-1222, Type III MS18116
			Studs		MIL-S-1222, Type I
			Bolt-Studs		MIL-S-1222, Type IV
			Nuts	Monel	MIL-S-1222, Type III
Steam and Low Pressure Steam Drains at 400°F	Flat Face to Flat Face	Non-Asbestos Sheet Gasket per MIL-Q-24696	Bolts	Steel, Zinc	MIL-S-1222, Type II or Type III, Grade 2
			Nuts	Coated	Zinc Coating per MIL-C-87115, Class 3
					MIL-S-1222, Type III, Grade 2
	Raised Face to Raised Face	Spiral Wound - Metallic Flexible Graphite	Bolts and Studs (in bilge)	Monel or K-Monel	MIL-S-1222, Type II
			Nuts (in bilge)	Monel	MIL-S-1222, Type II
					MIL-S-1222, Type III
Steam and Low Pressure Steam Drains at 300°F, Condensate and other Fresh Water Services	Raised Face to Flat Face	Cloth or Sheet Rubber Cloth Impregnated Rubber			
Seawater (main, auxiliary, trim, and drain)	Flat Face to Flat Face	Sheet - Synthetic Rubber, Cloth Inserted, Non-Asbestos Sheet Gasket per MIL-Q-24696 (for low pressure only) and O-rings, as approved	Bolts	Monel or K-Monel	MIL-S-1222, Type II or Type III
			Nuts	Monel	MIL-S-1222, Type I
					MIL-S-1222, Type III
	Raised Face to Flat Face	O-ring			

Table 2-1 FLANGE, GASKET, and FASTENER RECOMMENDATIONS - Continued

Joint					
SERVICES	**FLANGE**	**GASKET**	**FASTENER**	**FASTENER MATERIAL**	**FASTENER SPECIFICATIONS/STANDARDS**
Oil Systems, High Pressure (other than hydraulic)	Raised Face to Flat Face	Spiral Wound - Metallic Graphite and O-ring, as approved	Bolts	Carbon Steel, Monel or K-Monel	MIL-S-1222, Type II or III, Grade 2
			Nuts		MIL-S-1222, Type III, Grade 2
			Bolts and Nuts (in bilge)		MIL-S-1222, Type II or III (used with spiral wound gaskets)
			Nuts (in bilge)	Monel	MIL-N-25027 or MS17828 (used with all gaskets); QQ-N-281; QQ-N-281
Oil System, Low Pressure (other than hydraulic)	Flat Face to Flat Face	Sheet - Asbestos or Fiber			
Hydraulic Service Inside Pressure Hull	Raised Face to Flat Face	O-Ring - Nitrile, Fluorocarbon, or Elastomer, as approved	Bolts (not in bilge)	Carbon Steel, Monel or K-Monel	MIL-S-1222, Type II or III, Grade 2
			Nuts (not in bilge)		MIL-S-1222, Type III, Grade 2
			Bolts (in bilge)	Monel or K-Monel	MIL-S-1222, Type II or III
			Nuts (in bilge)	Monel	MIL-S-1222, Type III, QQ-N-281
Hydraulic Service Outside Pressure Hull	Raised Face to Flat Face	O-Ring - Nitrile, Fluorocarbon, or Elastomer, as approved	Bolts	Monel or K-Monel	MIL-S-1222, Type II or III
			Nuts	Monel	MIL-S-1222, Type III
Hydraulic Systems, Low Pressure Inside Pressure Hull (including return lines)	Raised Face to Flat Face	O-Ring - Nitrile	Bolts	Carbon Steel	MIL-S-1222, Type II or III, Grade 2
			Nuts		MIL-S-1222, Type III, Grade 2
Refrigerant Plants (R-12 refrigerant)	Flat Face to Flat Face	Sheet - Asbestos	Bolts	Copper - Silicon	MIL-S-1222, Type III ([1])
					Material UNS C64700, C65100, C655000, C66100 ([2]) ([3])
			Bolts	Aluminum	

Table 2-1 FLANGE, GASKET, and FASTENER RECOMMENDATIONS - Continued

Joint					
SERVICES	**FLANGE**	**GASKET**	**FASTENER**	**FASTENER MATERIAL**	**FASTENER SPECIFICATIONS/STANDARDS**
				Bronze	QQ-C-450 ([2]) MIL-S-1222, Type III ([1])
			Bolts	Phosphor	
				Bronze	MIL-S-1222, Type III ASTM B-139
Note: For guidance concerning the use of cadmium plated fasteners, see Section 2 and Section 3 of NSTM Chapter 075.					

[1]Use MIL-S-1222 for dimensions & handling only.

[2]See the applicable material specification for mechanical & chemical properties in lieu of MIL-S-1222.

[3]The UNIFIED Numbering System (UNS) is not in itself a specification, since it establishes no requirements for form, condition, properties, or qualities. It is a unified identifier of a metal or an alloy for which controlling limits have been established in specifications published elsewhere.

CHAPTER 3

GEOMETRY OF JOINTS

3-1. FLANGED JOINTS.

Flanges are installed in piping systems for ready removal of piping to provide for portability of machinery and equipment, to facilitate inspection and cleaning, and to avoid in-position welding or heat treatment. Flanged joints should be kept at a minimum for operating and maintenance conditions and, insofar as possible, located in the most advantageous position with respect to applied moments. They must be designed to withstand the longitudinal forces and bending of torsional moments due to weight, thermal expansion, and shock to which they will be subjected, and to maintain a tight seal. Also, certain flanges must be designed to maintain a tight seal when the joint is subjected to high fluid pressures as a result of underwater explosions. Standard flange types are contained in American National Standards Institute (ANSI) Standard B16.5, Steel Pipe Flanges. Flanged Valves and Fittings. An excellent discussion of the design of flanges is contained in Taylor Forge & Pipe Works' Modern Flange Design. Flange material and component selection for submarine piping systems are in accordance with MIL-STD-438 (see Table 2-1). NSTM Chapter 505 (paragraph 505-6.3) has additional information on this subject.

3-2. TYPES OF FLANGES.

Flat-face and raised-face flanges are the two flange types generally used in submarine joints for pressure-containing systems. Flanges are manufactured with or without an O-ring groove. Flanges without an O-ring groove are considered plain-face flanges. In addition to the flat-face and raised-face flanges, a special clamping ring joint has been used for limited applications, in lieu of flanges, on certain submarines built at Portsmouth Naval Shipyard (see Figure 3-1). In general, material and component selection, including gaskets, for submarine piping systems should be in accordance with MIL-STD-438. (See Table 2-1 for reference.) Material and components not covered therein require specific NAVSEA approval unless they are prescribed elsewhere in specifications for the applicable component.

3-3. FLANGED JOINT CONFIGURATIONS.

The three different flanged joint configurations generally used in submarine joints are raised face to raised face, flat face to flat face, and raised face to flat face (see Figure 3-1). Male and female flanged joints are no longer standard equipment for steam piping, because of the high initial cost and the difficulty in breaking a joint when necessary to replace a gasket. They are still used for hydraulic and other high pressure lines, and for steel piping connections for high temperature turbine lubricating oil lines.

3-4. FLAT-FACE FLANGE CONFIGURATION.

There are two flange configurations normally used in submarine seawater systems. The flat face to flat face flanges are most commonly used on hull-mounted components and the flat face to raised face flanges (NAVSEA Drawing 803-1385861) are usually used in line joints. Flanges in seawater line joints and hull-mounted flanges use O-rings. (See Table 2-1 for flange and gasket requirements.)

3-5. RAISED-FACE FLANGE CONFIGURATION.

On raised-face flanges, the face of the flange is raised slightly on the inner diameter of the flange extending out, in some cases, to the inner edge of the bolt holes. Normally, a raised-face flange is used against a flat-face

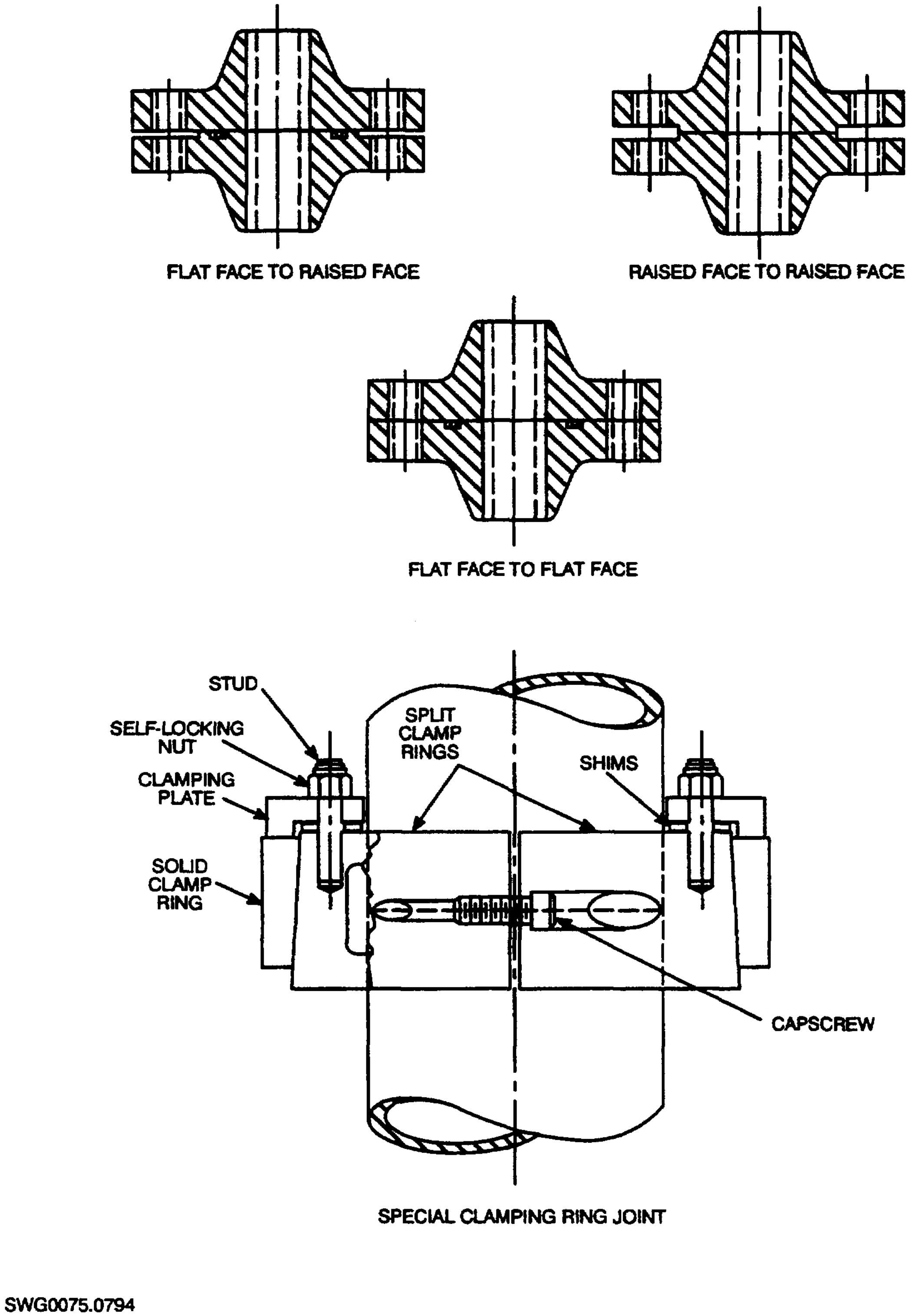

Figure 3-1 REPRESENTATIVE FLANGES

flange. Raised-face flanges permit higher gasket pressure for the same bolt stresses as compared to flat-face flanges, but result in increased flange stresses as discussed in paragraph 3-16. Raised-face flanges (raised face to raised face) in steam systems are usually made of steel, while copper-nickel flanges are normally used in seawater systems. Raised-face flanges are not usually used against bronze or relatively low strength composition valves, fittings, or flanges.

3-6. SPECIAL CLAMPING RING JOINTS.

Special clamping ring joints have been used in lieu of flange bolting on hull valves on certain submarines built at Portsmouth Naval Shipyard. These special joints consist of a solid clamping ring that is placed over a split clamping ring (halves). The split ring is placed over the valve or insert flange under the tailpiece elbow extension, and held in place with two capscrews. Eighty percent or more of the tapered surfaces of each split clamp ring must be in contact with the valve or insert flange to assure a properly assembled joint. The solid ring is then placed against this half, tilting up sufficiently to allow the other split ring half to be slipped over the flange. The shims and clamping plates are then assembled over both studs and held in place with two self-locking nuts (see Figure 3-1). For further information on the special clamping ring, see Portsmouth Naval Shipyard Drawing 593-515-2161619 or consult manufacturer.

3-7. GASKETS.

Gaskets are divided into two general categories according to materials.

a. SOFT MATERIALS Sheet rubber, sheet (non-asbestos) over 1/8-inch thick, and nonmetallic O-rings.

b. HARD MATERIALS Graphite-inserted spiral wound metallic, metallic flexible graphite, sheet (non-asbestos) less than 1/8-inch thick, and other gaskets requiring comparable or higher compression for sealing.

3-8. FLANGE GASKET/O-RING SELECTION.

Gasket selection for a specific type of flange depends on several considerations (e.g., gasket characteristics, operating conditions, mechanical features) of the flanged joint. The most common types of gaskets used in submarine pressure-containing systems are sheet, spiral wound (Flexitallic), and O-ring gaskets. Sheet gaskets are made of asbestos, asbestos metallic cloth, compressed metallic, fiber, or rubber. Sheet asbestos gaskets are gradually being replaced with improved non-asbestos sheet gaskets, such as MIL-G-24696. Spiral wound gaskets are made of metallic-flexible graphite, and MIL-G-24716 lists the only spiral wound gaskets authorized for submarine use. O-rings are made of nitrile, fluorocarbon, or other elastomer. All gasket selections for flanged joints should be as specified on the applicable system drawing (see Table 2-1). System design is governed by MIL-STD-438. Gaskets should be compatible with the service and flushing fluid.

3-9. JOINT MAKE-UP.

An ideal flanged joint should have two characteristics: low flange stress as a result of limiting fastener preload and high fastener preloads to minimize fatiguing due to cyclic loading and to provide the maximum clamping force in anticipation of the potentially high loads tending to open the joint as a result of shock loading. Note that, as is often the case with ″ideal″ items, there is some conflict between the two characteristics.

3-10.

When a flange joint is made up and is not under internal pressure, the bolt load is balanced by the gasket reaction. As internal pressure is applied the bolt load is balanced by the sum of the gasket reaction, pressure load on flange face, and hydrostatic end load. The flanges, which transmit the bolt tension to the gasket, may be more or less flexible, and this property affects the bolt load either adversely or favorably, respectively. The gasket likewise affects the efficiency of the bolt tension by its composition, dimensions, and location. The compressive load on the gasket is reduced as the internal pressure increases until the added internal pressure reduces the compression in the gasket to the point where leakage occurs. It is generally necessary to apply prestress to bolts in order to provide a clamping force sufficient to seat the gasket properly in the make-up condition and to maintain a net unit gasket compression of two to three times the internal fluid pressure, to prevent leakage across the joint surfaces. This bolt tension required to produce the above gasket compression must be in addition to the bolt tension required to resist the tendency of the joint to separate due to internal fluid pressures, expansion, and other external forces. Also, bolts must be spaced closely enough to assure adequate gasket pressure between bolts.

3-11.

In flanged joints in a pipe line conveying heated fluids, the forces resulting from temperature are usually far greater than those which result from pressure. All of these forces must be considered in any bolt stress calculations. Additional bolt stresses result from the following:

a. Bending moments due to pipe line expansion

b. Nonuniform joint temperatures

c. Water hammer

d. Temperature differential between joint body and bolts

e. High shock

f. Hydraulic shock

3-12. GASKET JOINTS.

In gasketed joints other than O-rings, the performance of a gasketed surface depends not only on the elastic properties of the gasket material, but also upon the following

a. Surfaces must be in intimate contact at all points with no avenue for the escape of the fluid.

b. The unit pressure between the faces must be in excess of the unit internal fluid pressure.

c. The material of the faces must neither corrode nor distort under the action of the fluid, its pressure or temperature, and shock.

3-13.

Where elastic conditions are maintained, leakage of a properly fabricated and assembled flange should not occur if the initial bolt load is sufficient to perform the following:

a. Maintain the required gasket load above the longitudinal loads developed by pressure and structural effects.

b. Compensate for the expected reductions in bolt load due to flange deflections and change in elastic modulus.

3-14. O-RING JOINTS.

An O-ring is a circular ring with a circular cross section confined in a recess. O-rings are automatic seals because they deform under pressure to block passage of the fluid to be sealed through the joint. This sealing action is caused by the pressure from the confined or excluded fluid, plus the initial squeezing of the compressible elastomer into the recess, which is usually five to ten percent shallower than the cross-sectional diameter of the O-ring.

3-15.

When an O-ring is installed, it is deformed (squeezed) to a dimension smaller than its cross-sectional diameter, in one direction, causing the cross-sectional diameter to assume an oval shape. This deformation requires the expenditure of energy which the O-ring can store for a long time. Because of its memory property, the O-ring uses this stored energy to try to regain its original circular cross-section. The ability to conform allows the O-ring surface to mate with the surfaces in contact. This combination of events produces an initial, and automatic seal. Once an O-ring is installed, operating pressure keeps it sealed against the metal clearance areas. O-rings permit wider tolerance and rougher surface finishes on metal mating members. Table 2-1 lists flange and O-ring requirements for pressure-containing systems.

3-16. FASTENER PRESTRESS LOADING.

It is desirable to have high elastic strains in bolts coupled with high creep resistance; however, these two properties are in opposition since high stresses cause accelerated creep. Tests were conducted by the Naval Ship Research and Development Center (NSRDC) Annapolis with seawater flanges, to determine if flange studs relaxed. These tests indicated that an immediate decrease in the load occurred in the first minute or so, but a very insignificant decrease occurred after the initial one minute time frame. This decrease was attributed to plastic flow in the threads and redistribution of the load to less highly loaded areas. The decrease was small, being about one percent for K-monel and two percent for monel, with the monel being loaded nearly to yield while the K-monel was loaded to two-thirds of yield. In these tests, using a lubricant as discussed in paragraph 4-22, the torsional strains were low in all cases, indicating that very little twisting of the stud occurred. This prestress of two-thirds of yield strength should be used except in those few cases where the gasket may be overcompressed or extruded, such as in a low pressure system with a sheet gasket material (for installation of sheet gaskets that may become overcompressed or extruded, see NSTM Chapter 078, Vol. 2, paragraph 078-8.7.4.1 through paragraph 078-8.7.4.2.1), or with certain raised-face flanges as discussed in paragraph 3-18. This is not a concern in flanges where O-ring gaskets are used, because of the metal-to-metal flange contact.

3-17.

Flange-bolting tests show that in some cases extensive yielding of the flange may result from bolt preload. Lack of parallelism and surface finish increase the stresses in the flange due to bolting forces. Badly scarred or irregular faces of flat-face flanges cause the equivalent of a raised-face flange, resulting in high flange stresses.

3-18.

Good engineering practice dictates the use of high preloads on flanged joints and normally this should be the governing criterion in assigning the stud preload, not the flange stresses. However, we cannot completely disregard flange stresses, especially when bolt preload can induce stresses in excess of the flange material's yield stress. This situation exists with raised-face flanges. With raised-face flanges of the type currently shown on NAVSHIPS standard drawing 810-1385861, it is desirable to limit the flange stresses to the minimum yield strength of the material (18 ksi). In these cases, a maximum stud prestress of 2/3 of the stud minimum yield strength or a maximum stud prestress based upon the minimum yield strength of the flange should be used, whichever is less. Maximum yield strength of the studs assumed was 40 ksi for monel and 90 ksi for K-monel. The same principle applies to other raised-face flange designs, such as those covered in ANSI B16.5.

3-19.

It has been shown that a hydrostatic end force may either increase or decrease the initial bolt load, depending upon the relative position of the gasket reaction and the elastic properties of the assembly. With customary flanges, established by ANSI Standard B16.5, the bolt load decreases slightly with application of internal pressure as the net amount on the flange increases, causing increased flange rotation and a decrease in the distance between flanges at the bolt circle. The bolt load will also decrease as the temperature of the assembly is uniformly raised, since the elastic modulus of the bolt decreases with temperature rise.

3-20. PRELOADING.

Joint strength is affected by the amount of preloading in the bolt, which is proportional to tightening torque. Therefore, it is necessary that the preload be as high as possible, but within proper limits. If the preload is excessive, yielding of the flanges and/or fasteners can produce relaxation that might result in leakage or gasket extrusion. At the same time, preload must be adequate to resist all conditions that tend to produce a leaking joint. This is critical for compression type gaskets where the gasket must be seated properly by applying a minimum load in the cold condition while maintaining a minimum unit load over the effective contact area of the gasket under operating conditions. High preload has the added advantage of making the fastener self-locking. Research has established a connection between the stresses in a fastener (from both preload and residual stresses left from manufacturing processes) and susceptibility to hydrogen embrittlement in embrittlement prone materials, such as K-monel and high strength steels (steels with yield strengths of 130 ksi or greater) . This involves a metallurgical characteristic called threshold stress level and means that the higher the preload, the more likely embrittlement is to occur. For this reason, it is especially important that care be taken in the selection of torques for fasteners made from embrittlement prone materials. This is one of the reasons our torques are usually based on generation of a nominal preload of two-thirds of yield.

3-21.

Because of the danger of over-stressing smaller size bolts in tightening, a minimum bolt size of 0.5 inch is usual in most piping and pressure vessel work.

3-22. FLANGE ALIGNMENT.

Flanges must line up in a parallel plane and as close together as possible. They are considered parallel when checked with feeler gauges and the clearances at points diametrically opposite on the gasket seating surfaces are within the tolerances specified in Table 3-1. Concentricity is satisfactory when the fasteners, of the specified diameter, can be pushed (by hand) through the holes in the mating faces or when visual inspection ensures that installed studs have not been pushed into hard contact with the holes in the mating flange. Flange holes should not be elongated to achieve flange concentricity. See also paragraph 5-2 for Flange Joint Fit-Up.

3-23. STUD AND BOLT ALIGNMENT.

Bolt and stud holes are sufficiently aligned when bolts can pass freely through the holes of both flanges or when flanges can be assembled freely with studs. Stud misalignment (perpendicularity) should not exceed 0.50 degree from the perpendicular with respect to flange surfaces. Drilling of oversize holes to provide stud clearance is not permitted without specific approval from NAVSEA. See also paragraph 3-30.

3-24. FLANGED JOINTS IN STEAM PLANT FLUID SYSTEMS.

Pressure-containing joints in steam plant fluid systems are normally designed with raised-face flanges and made up with spiral wound metallic asbestos or metallic flexible graphite (Flexitallic) gaskets. In these steam plant joints, the controlling factor in the tightening of fasteners is the designed compression of the gasket rather than the prestressing of the fasteners. NSTM Chapter 505 (S9086-RK-STM-010/CH-505) paragraph 505-6.4.2 discusses these gaskets and their installation. Shipyards have established procedures for the installation of spiral wound gaskets in raised-face joints, which have been approved by NAVSEA, and a representative sample is provided in paragraph 3-25. Each such flanged joint should be checked for proper assembly and fastener tightness in accordance with the official shipyard procedures. The applicable shipyard inspection department should confirm proper assembly and fastener tightness of each flanged joint or use a sampling procedure to confirm these attributes if each flanged joint is specifically checked by the installation department. Official shipyard procedures should provide controls so that flanged joints opened during construction, repairs, or testing are inspected after restoration to ensure the joints are properly assembled and fasteners tightened. Further assurance of proper assembly and fastener tightness is provided if the joint satisfactorily passes the applicable system hydrostatic test.

3-25. SPIRAL WOUND GASKET INSTALLATION.

Spiral wound gaskets may be installed according to the following steps and the joints made up in accordance with the alternate methods of paragraph 3-26, paragraph 3-27 or paragraph 3-28.

a. Ensure the sealing surfaces are free from grease, loose particles, nicks, gouges, burrs, etc. Ensure that the proper gasket has been selected, that it is undamaged and that the gasket rotates freely within the metal outer ring (free movement may require removal of a short length of spiral wrap from the gasket outside diameter).

b. Position gasket in joint and assemble bolts (or studs) and nuts hand tight (assure that the threads and the bearing face of all nuts (or bolts, if applicable) are lubricated with the proper thread lubricant. The bearing face of a bolt only needs to be lubricated if installation requires that the nut be held stationary while the bolt is rotated).

c. Ensure the gasket and flange faces are aligned.

Table 3-1 FLANGE ALIGNMENT PARALLELISM TOLERANCES

PIPE SIZE IN INCHES	FLANGE O.D. IN INCHES	MAXIMUM ALLOWABLE DIFFERENCE (INCHES) AT OUTSIDE DIAMETER OF SEATING SURFACE	
		* Raised Face Flanges	** Flat Face Flanges
1/2	3-9/16	0.030	0.067
1/2	3-3/4	0.030	0.067
3/4	3-13/16	0.030	0.062
3/4	4-5/8	0.035	0.072
1	4-1/4	0.035	0.066
1	4-7/8	0.035	0.066
1-1/4	4-1/2	0.035	0.063
1-1/4	5-1/4	0.040	0.072
1-1/2	5-1/16	0.040	0.065
1-1/2	6-1/8	0.045	0.073
2	5-9/16	0.040	0.065
2	6-1/2	0.045	0.073
2-1/2	6-1/8	0.045	0.070
2-1/2	7-1/2	0.050	0.078
3	7-7/16	0.050	0.082
3	8-1/4	0.055	0.091
3-1/2	8	0.055	0.088
3-1/2	9	0.060	0.096
4	(NAVSEA) 8-11/16	0.060	0.095
4	(USA) 10	0.065	0.102
5	(NAVSEA) 9-3/4	0.065	0.097
5	(USA) 11	0.065	0.097
6	(NAVSEA) 10-7/8	0.065	0.094

Table 3-1 FLANGE ALIGNMENT PARALLELISM TOLERANCES - Continued

PIPE SIZE IN INCHES	FLANGE O.D. IN INCHES	MAXIMUM ALLOWABLE DIFFERENCE (INCHES) AT OUTSIDE DIAMETER OF SEATING SURFACE	
		* Raised Face Flanges	** Flat Face Flanges
6	(USA) 12-1/2	0.070	0.101
8	(NAVSEA) 13-1/8	0.070	0.098
8	(USA) 15	0.075	0.105
10	(NAVSEA) 15-3/4	0.075	0.104
10	(USA) 17-1/2	0.080	0.111
12	(NAVSEA) 18-1/8	0.090	0.121
12	(USA) 20-1/2	0.095	0.127
14	(NAVSEA) 19-1/4	0.095	0.126
14	23	0.095	0.126
Over 14	Over 23	0.095	0.126

*For raised face to raised face and raised face to flat face.

**For flat face to flat face.

3-26. JOINT MAKE-UP (METAL-TO-METAL).

a. Make up joint evenly by sequentially tightening diametrically opposed fasteners (e.g., star pattern) in increments (use of at least 4 passes is recommended) until the flanges are in contact with the gasket outer ring. This would normally be accompanied by a noticeable increase in torque when metal-to-metal contact is made. To the maximum extent practical, flange faces should be maintained parallel during tightening of fasteners. Do not continue to tighten bolts after metal-to-metal contact is made, since excessive torque may distort the flanges or overstress the bolt. Use of a torque wrench is not required, unless special torque requirements are specified in technical manuals or drawings. See 3-31 below if the use of temporary fasteners is necessary to achieve adequate gasket compression.

b. Check all fasteners in the joint to ensure that no fasteners are loose following completion of joint pull-up. If no other special minimum torque requirements exist, tight is defined as less than 1/6 turn movement. Check passes should be made in either a clockwise or counter clockwise direction (technician's choice), rather than in the normal tightening pattern. Start and complete each check pass by attempting to tighten the fastener designated as number 1. This reduces the chances of skipping a fastener and results in higher initial preload and reduced preload variation.

CAUTION

To avoid flange distortion, do not contact the raised faces of both flanges with the gasket outer ring at any single point. Maintain even contact around flange faces to the maximum possible extent to avoid the effects of prying loads due to premature pull-up of fasteners on one side.

3-27. JOINT MAKE-UP (CONTROLLED GAP).

Where gasket compressibility will not permit the raised face of the flange to go metal-to-metal with the gasket metal outer ring as described above, do not continue to tighten fasteners after firm metal-to-metal contact is made, since excessive torque may distort the flanges or overstress the bolts. Instead, proceed as follows:

a. Make up the joint evenly using the procedure described in 3-26.a above, except that when the noticeable increase in torque occurs, there will still be gaps between the raised faces and the gasket outer ring. Joint make-up is acceptable if the gaps (the sum of the distances from the metal outer ring to the raised face on each side of the gasket at a point of measurement) measured at four points spaced 90 degrees apart around the flange circumference, with bolts tightened as specified, do not exceed 0.010 in. In addition, to ensure parallelism, the total gap measurements at 90 degree intervals should all be within a range of 0.005 in. See 3-28 below if the use of temporary fasteners is necessary to achieve adequate gasket compression.

b. Where the total gap exceeds the above requirements, waiting before retightening may result in enough gasket relaxation to reduce the gap.

c. Check all fasteners in the joint to ensure that no fasteners are loose following completion of joint pull-up. Be sure to observe the caution following step b. paragraph 3-26. After final tightening of fasteners, check passes should be made in either a clockwise or counter clockwise direction (technician's choice), rather than in the normal tightening pattern. Start and complete each check pass by attempting to tighten the fastener designated as number 1. This reduces the chances of skipping a fastener and results in higher initial preload and reduced preload variation.

3-28. JOINT MAKE-UP (TEMPORARY FASTENERS).

In order to achieve proper gasket compression, the joint may be assembled using temporary high strength steel (170+ KSI) fasteners. These fasteners can be torqued to the maximum torque values listed in Table 3-5. When using temporary fasteners it is recommended that washers be used under the nuts because the preloads reached at these torque levels exceed the bearing stress limit of the flange material. This condition will result in galling of the flange bearing surface. When the gasket is satisfactorily compressed in accordance with 3-27 or 3-28, as appropriate, the high strength fasteners should be removed and replaced, one at a time, with the permanent fasteners preloaded in accordance with 3-27. One at a time replacement results in changeout without disturbing joint integrity.

3-29. ADDITIONAL INFORMATION ON MAKE-UP OF JOINTS WITH SPIRAL WOUND GASKETS.

These notes will be of assistance in making up and inspecting this type of joint (or in development of the necessary process instructions for their make-up) . They are specifically applicable to ANSI B16.5 CL 600 steel raised face flanges assembled with spiral wound gaskets. The principles are generally applicable to similar joints regardless of pressure class:

a. If a torque wrench is used to establish preload, or for inspection purposes, the applied torque should fall within the range established for each size bolt on the detailed drawing or in Table 3-6, as applicable. When metal-to-metal contact with the outer ring is established, all fasteners in the bolt circle may be checked to approximately the same torque value within the listed range. When using the gap method (3-27), the torque on each individual fastener must fall within the range of values listed on the applicable detailed drawing or in Table 3-6, but the torque for each fastener does not have to be the same as that of the other fasteners in the bolt circle. This allows for maintenance of parallelism while dealing with the differences in coefficient of friction which occur from fastener to fastener.

b. The torques listed in Table 3-6 push preload to the limit for bearing stress under the nut with ANSI B16.5

flanges. Both theory and practice have shown that, even when properly lubricated, there is often galling between the bearing face of the nut and the flange at these loads. Substitution of heavy hex nuts of the same material and grade (instead of regular hex nuts) is permissible in this case, without further approval. This, together with proper lubrication, greatly reduces the potential for galling.

c. The use of a torque wrench on these joints is not mandatory unless the drawing lists a specific torque for a joint. Instead, good shop practice and the appropriate box end or combination wrenches may be used. A torque wrench would, however, be required for inspection if the controlled gap method of 3-27 is used or if Table 3-1 is to be used to supply inspection criteria at the time of original joint makeup.

d. When inspecting fasteners in these joints for preload, the torques listed on applicable detail drawings or in Table 3-6 are valid at the time of installation, but thereafter, both short term and long term relaxation occur. Subsequent to installation (as few as 5 minutes) , and for in-service joints, measurable relaxation will have occurred. For in-service joints, there are two requirements: the joint must not leak, and the fasteners must be tight. Once a joint has been placed in service, due to the cumulative effects of both short term and long term relaxation, ″tight″ is defined as at least 50% of the minimum torque value listed in Table 3-6 for joints assembled and/or inspected using that table. This 50% rule may also be applied to in-service joints for which the torque applied at assembly is known, whether or not the source of the torque was Table 3-6.

e. During joint assembly or inspection, the onset of fastener yielding is identified by a sudden decrease in the resistance to applied torque. If yielding occurs, the joint shall be disassembled and remade with a new gasket and fastener(s).

3-30. STUD INSTALLATION PROCEDURES

Installation procedures for various types of studs are given in the following paragraphs. (Refer to Uniform Method and Standard No. 5307-104, Studs; Manufacture and Installation.)

3-31. INSTALLATION OF HULL INTEGRITY AND OTHER LEVEL I NEW CONSTRUCTION SERIES STUDS.

The procedure for installing hull integrity and other level I new construction series studs is as follows:

a. Jig drill/index drill and ream to the tap drill size for interference fit studs; countersink all holes. Ensure that holes are perpendicular to within one-half of one degree. Use tap marked HY-80 for tapping HY-80 material; use tap marked Monel for tapping NICO, CUNI, and CRES. Tap by drill press or by hand with a T-wrench. Do not use air power for tapping. Pack Crisco, or an approved lubricant such as Rapid Tap, or equivalent, into the hole. Turn the tap in continually until the threads are complete. Do not back off the tap to break the chip. Crisco is recommended as a lubricant where holes must be tapped overhead.

b. Draw and install the studs in accordance with, and to the standout specified by, the applicable installation drawing. Avoid shouldering or bottoming. Lubricate the threads with Molykote or equivalent. Maintain stud perpendicularity within one-half of one degree without bending, and request inspection. Protect the studs and mounting surfaces until the component is ready for installation.

3-32. INSTALLATION or HULL INTEGRITY AND OTHER LEVEL I REWORK SERIES STUDS.

The procedure for installing hull integrity and other level I rework series studs is as follows:

a. Remove existing studs when directed by work authorization and retap the stud hole threads. Retapping is required for stud holes in HY-80, HTS, CUNI, and NICU, but not for holes in grade 5 steel or softer.

b. When material is removed by retapping, request that replacement studs be provided.

c. When no material is removed by the retapping process, clean the hole thoroughly by repeated flushing with detergent Formula 409, or equivalent, and a soft wire brush. Blow out all liquid, and dry with oil-free compressed air. Measure the hole at three places: near the bottom, midway, and three threads from the top. Take thread gage readings to the nearest 0.001 inch. If gage readings vary but stud dimensions are within the setting end tolerance, request that studs be manufactured for sealant installation in accordance with paragraph 3-34.

d. When the largest measurement taken in step c. above is the same or exceeds the applicable stud size plus the tolerance from Table 3-3, custom studs are required (see paragraph 3-33).

e. After the holes have been retapped, install the studs to the proper dimensions, without shouldering or bottoming, as specified in the applicable installation drawing. Lubricate the threads with Molykote, or equivalent. Maintain stud perpendicularity within one-half of one degree without bending and request inspection. Protect the studs and mounting surfaces until the component is ready for installation.

3-33. INSTALLATION OF LEVEL I CUSTOM STUDS.

The procedure for installing custom studs is as follows:

a. Remove existing studs when directed by work authorization, and retap the stud hole threads in accordance with the applicable installation drawing. Retapping is required for stud holes in HY-80, HTS, CUNI, and NICU, but not for holes in grade 5 steel or softer.

b. When stud hole measurements taken in step c. of paragraph 3-32 are the same as or exceed the applicable stud size plus the tolerance from Table 3-3, custom studs are required for those stud holes.

c. Obtain the appropriate tap(s), and retap all holes. Provide the pitch diameter of the retapped holes and request replacement studs to the thread gage pitch diameter reading plus 0.002 inch. Standardization of all holes to the largest measured size is optional.

d. Whenever only one or two holes of an installation exceed the tolerance, custom studs are required for these holes. Provide a sketch of the installation with each location numbered and the setting end pitch diameter readings specified for the required custom studs.

e. After the holes have been retapped, install the studs to the proper dimensions, without shouldering or bottoming, as specified in the applicable installation drawings. Lubricate the threads with Molykote, or equivalent. Maintain stud perpendicularity within one-half of one degree without bending and request inspection. Protect the studs and mounting surfaces until the component is ready for installation

3-34. INSTALLATION OF STUDS WITH ANAEROBIC LOCKING COMPOUND.

The installation of studs with anaerobic locking compound as described below is preferable to the use of studs manufactured for a class 5 interference fit as described in the previous paragraphs, especially for repair/refit activities below the depot level. Properly executed, it yields an installation which is more resistant to stud breakaway torque than an interference fit and generally does so with the expenditure of fewer manhours. It is suitable for use with newly manufactured components or as a repair procedure. The procedure for installing studs with anaerobic sealant is as follows;

Table 3-2 RESISTANCE TEST BREAKAWAY TORQUE VALUES FOR SEALANTS

STUD SIZE	TORQUE IN FT LB	STUD SIZE	TORQUE IN FT LB
1/4 - 20	2	3/4 - 10	30
5/16 - 18	3	7/8 - 9	45
3/8 - 16	5	1 - 8	63
7/16 - 14	7	1-1/8 - 7	78
1/2 - 13	10	1-1/4 - 7	105
9/16 - 12	15	1-3/8 - 6	125
5/8 - 11	19	1-1/2 - 6	163

Table 3-3 PITCH DIAMETER TOLERANCE

NOM SIZE	MAX PD DIFF	NOM SIZE	MAX PD DIFF
1/4 - 20	0.0064	3/4 - 10	0.0101
5/16 - 18	0.0069	7/8 - 9	0.0108
3/8 - 16	0.0076	1 - 8	0.0117
7/16 - 14	0.0081	1-1/8 - 7	0.0125
1/2 - 13	0.0085	1-1/4 - 7	0.0127
9/16 - 12	0.0090	1-3/8 - 6	0.0138
5/8 - 11	0.0095	1-1/2 - 6	0.0140

Table 3-4 RECOMMENDED MINIMUM BREAKAWAY TORQUES FOR PREVIOUSLY USED SELF-LOCKING NUTS

SIZE	TORQUE (IN-LB)	TORQUE (FT-LB)
1/4 - 20	3.5	
5/16 - 18	6.0	
3/8 - 16	9.5	
7/16 - 14	13.0	
1/2 - 13	19.0	
9/16 - 12	24.0	
5/8 - 11	32.0	
3/4 - 10	48.0	
7/8 - 9	65.0	
1 - 8	88.0	
1 1/8 - 7	110.0	9.0
1 1/4 - 7	132.0	11.0
1 3/8 - 6	160.0	13.0
1 1/2 - 6	184.0	15.0
1 3/4 - 5	240.0	20.0
2 - 4 1/2	288.0	24.0
2 1/4 - 4 1/2	344.0	28.0
2 1/2 - 4	400.0	33.0

NOTE

Breakaway torque is the torque required to start the nut moving on the male thread when the locking element is fully engaged and there is no axial load on the nut.

Table based on loss of 1/5 of the breakaway torque required by MS 17828 for new nuts.

Table 3-5 TEMPORARY FASTENERS (STEEL - 170+ KSI) *

BOLT SIZE (INCH)	MAX TORQUE (FT-LB)
1/2	75 **
5/8	130
3/4	220
7/8	365
1	540
1-1/8	750
1-1/4	1050

*NOTE: ABOVE TABLE BASED ON USE OF A THREAD LUBRICANT WITH A FRICTION COEFFICIENT OF 0.11, SUCH AS FEL-PRO C5-A.

**NOTE: FOR 150 LB FLANGES USE A MAXIMUM TORQUE OF 60 FT-LB. DO NOT OVER TORQUE 150 LB FLANGES.

NOTE

TO ADJUST FOR THREAD LUBRICANTS WITH FRICTION COEFFICIENTS OTHER THAN 0.11, CALCULATE THE PRELOAD FOR THE TORQUE GIVEN IN THIS TABLE USING THE PC BOLTS COMPUTER PROGRAM. INPUT THIS PRELOAD MANUALLY IN THE "PRELOAD" BOX, SELECT THE NEW LUBRICANT (OR INPUT THE FRICTION COEFFICIENT MANUALLY) AND READ OUT THE NEW TORQUE REQUIRED TO ACHIEVE THIS SAME PRELOAD WITH THE NEW LUBRICANT.

Table 3-6 PERMANENT FASTENERS (STEEL, B7 OR B16) *

BOLT SIZE (INCH)	MAX TORQUE (FT-LB)
1/2	30 - 45 **
5/8	60 - 105
3/4	100 - 165
7/8	160 - 260
1	250 - 390
1-1/8	375 - 550
1-1/4	550 - 900

*NOTE: ABOVE TABLE BASED ON USE OF A THREAD LUBRICANT WITH A FRICTION COEFFICIENT OF 0.11, SUCH AS FEL-PRO C5-A

**NOTE: FOR 150 LB FLANGES USE A MAXIMUM TORQUE OF 60 FT-LB. DO NOT OVER TORQUE 150 LB FLANGES.

NOTE

TO ADJUST FOR THREAD LUBRICANTS WITH FRICTION COEFFICIENTS OTHER THAN 0.11, CALCULATE THE PRELOAD FOR THE

TORQUE GIVEN IN THIS TABLE USING THE PC BOLTS COMPUTER PROGRAM. INPUT THIS PRELOAD MANUALLY IN THE ″PRELOAD″ BOX, SELECT THE NEW LUBRICANT (OR INPUT THE FRICTION COEFFICIENT MANUALLY) AND READ OUT THE NEW TORQUE REQUIRED TO ACHIEVE THIS SAME PRELOAD WITH THE NEW LUBRICANT. TO ADJUST FOR DIFFERENT FASTENER MATERIALS MAKE THE SAME INITIAL PRELOAD CALCULATION AS ABOVE, THEN SELECT THE NEW FASTENER MATERIAL, STILL USING THE TORQUE FROM THE TABLE. REVIEW THE RESULTS TO ASSURE THAT THE LISTED TORQUE DOES NOT OVERSTRESS THE FASTENERS.

NOTE

Temperature of joints assembled with locking compound must not exceed 300°F. Install Class 3A bolt studs in Class 3B tapped holes with locking compound. Use this method when it has been determined that it is feasible to install studs with locking compound.

a. Determine the clearance at the thread pitch diameter with a thread gage midway in the tapped holes. Then determine the grade of locking compound to be applied, which will be determined by the installing activity and MIL-S-22473 or MIL-S-46163 (see paragraph 4-23).

b. Scrub the hole and stud threads with detergent Formula 409, or equivalent, and a soft wire brush. Do not use Stoddard Solvent or other oil base cleaners. Blow dry with oil-free compressed air, wash sparingly with a primer of a grade in accordance with the locking compound manufacturer's instructions, and allow to air dry for the prescribed time (at least five minutes). Avoid touching the cleaned surface.

c. Apply the proper grade of locking compound to the mating threads. Where brushing is employed, a camel's hair brush is recommended. Avoid using more locking compound than the surface will retain.

d. Install the studs in accordance with, and using the standout specified by, the installation drawing. Do not use a lubricant. Maintain perpendicularity to within one-half of one degree. Do not disturb the studs until the end of the required curing time, which should be in accordance with the manufacturer's instructions.

e. After curing is completed, ensure that the studs are properly bonded by applying resistance test breakaway torque (Table 3-2) to at least one stud of the joint installed with locking compound. Details for conducting this test, including allowable stud rotation, are contained in SAE J2270. The breakaway torque values listed in Table 3-2 may be used for the test, or the values in SAE J2270 or a NAVSEA approved process instruction may be substituted for the values in Table 3-2. Wipe off excess locking compound and request inspection.

f. Inspect the installed studs to the requirements of the applicable installation drawing. Prior to joint makeup, periodically check that the proper grade of locking compound has been used for hull integrity stud installation. They should appear as a red dye when viewed under ultraviolet light (″black light″). The dye should encircle the stud.

g. When installing studs with anaerobic locking compound in accordance with the above guidance, the following is an acceptable alternate method for choosing the correct grade of thread locking compound only if the required thread pitch diameter gages are not available:

(1) Select grade AV/AVV locking compound (Loctite 271 or equivalent) for fasteners through one inch in diameter. Select grade AVV locking compound (Loctite 277 or equivalent) for fasteners over one inch in diameter (see also paragraph 4-23 and MIL-S-46163 for alternate locking compounds.

(2) After complete curing, apply the resistance test breakaway torque to a least one stud of the joint, per paragraph e. above, just as would normally be done.

(3) If the stud(s) checked fails the resistance test breakaway torque check, apply the breakaway torque test to all studs in the joint. Remove, clean arid reinstall any studs which fail the resistance test breakaway torque check.

h. For installation of studs for repairs to components in high temperature systems (main steam, auxiliary steam, high pressure steam drains, turbine throttles, etc.), the above procedures may be followed substituting Copaltite (MIL-S-15204) for anaerobic locking compound, rather than manufacturing a custom stud for a class 5 fit. Note that it may be necessary to apply heat to the stud or set end material or both to facilitate proper curing of the Copaltite. Where this option is used, the resistance test breakaway torque check of paragraph e. above shall be applied to all the re-set studs in the bolt circle.

3-35. REMOVAL AND REUSE OF LOCKING COMPOUND ASSEMBLED STUDS.

The procedure for removal and reuse of locking compound assembled studs is as follows:

a. To remove studs, apply torque not in excess of values shown in Table 5-3. Heat may be applied if necessary. If the stud does not break away readily within the torque limits, heat to about 200°F but not more than 400°F. Undamaged studs may be reused after they are thoroughly cleaned.

b. Inspect the installed studs to the requirements of the applicable installation drawing.

3-36. INSTALLATION OF NON-LEVEL I STUDS.

The procedure for installation of non-level I studs is as follows:

a. Install studs in accordance with the applicable drawing. Install studs which do not meet the required thread class minimum fit requirements with sealant in accordance with paragraph 3-34 if temperatures at the joints do not exceed 300°F.

b. Inspect the installed studs for conformance with the requirements of the installation drawing.

3-37. REPLACEMENT OF FASTENERS WITHOUT DISTURBING JOINT INTEGRITY.

Should it be necessary to rework or replace flange joint fasteners (including studs) in piping systems after completion of the hydrostatic tests, such rework and or replacement may be carried out without disturbing joint integrity by accomplishing the requirements of the appropriate paragraphs of this manual one fastener at a time. It should be emphasized that no more than one fastener should be removed and reinstalled/replaced at one time, so that joint integrity will remain intact and further hydrostatic testing won't be required. When overhauling a joint requiring studs, fit up dimensions for establishing required stud size may be established one stud at a time also, rather than going around the flange circle to find the largest stud and retapping all holes to standardize the installation.

3-38. REUSED FASTENER INSPECTION PROCEDURE.

The following procedure applies to level I and level NA used threaded fasteners.

a. Definitions of terms used in this procedure are as follows:

(1) FASTENER THREAD. Specifically refers to the threads on a stud, bolt, or nut, but will include the threads on a mating part when appropriate for inspection purposes.

(2) ENGAGED THREAD. All external and internal fastener threads that are subjected to stresses due to fastener torquing preload or to the external loads applied to a mechanical joint in service, which means all mated threads and all threads below the nut or fastener head.

(3) NONENGAGED THREAD. All external and internal fastener threads that are not subjected to loads or stresses, such as the threads protruding beyond the top of a nut or the unused threads in a threaded hole.

(4) ONE COMPLETE THREAD OR ONE THREAD LENGTH. The thread length of one complete rotation **(360** ° on a single thread), starting at any point along the thread.

(5) MINOR DEFECT. A single nick, gouge, or flattened thread (after removal of sharp edges and raised metal) that has a depth greater than 1/64 inch but less than 1/2 the thread height (depth) and a width less than the thread spacing (pitch). Defects less than 1/64 inch deep may be ignored.

(6) MAJOR DEFECT. A single defect (after removal of sharp edges and raised metal) that has a depth over 1/2 the thread depth.

b. PROCEDURE

(1) Ensure thread surfaces are clean and free of dirt, scale, rust, etc.

(2) Review definitions and acceptance criteria.

(3) Examine parts visually, including use of 5x magnification to investigate suspected cracks.

(4) Determine defect sizes and the total length of defects in one thread length by visual estimation or use of simple linear scales.

(5) When determining the total length of defects in one thread length, the starting point shall be set or adjusted to enclose the maximum or worst case number of defects.

(6) When reporting a nonconforming condition for engineering evaluation, identify the nonconformance (such as, major defect exceeds allowable depth, etc.

(7) Perform pitch diameter measurement on mating threads when required, such as when needed to confirm suspected nonconforming thread condition or to determine thread clearance for selecting the proper grade of anaerobic sealant

(8) When fasteners are to be reused, a suitable system for control, handling and storage of existing fasteners shall be used (i.e., ″Tag and Bag″).

c. ENGAGED THREAD ACCEPTANCE CRITERIA

(1) Cracks are not acceptable.

(2) Broken, chipped, or missing threads, or other indications of brittle material failure, are not acceptable.

(3) Galling is not acceptable.

(4) Major defects are not acceptable.

(5) Isolated Minor Defects are acceptable.

(6) An isolated Minor Defect that exceeds the width criteria (see definition) is acceptable when the total length of the defect does not exceed 15 percent of one thread length in any one complete thread.

(7) Any combination of Minor Defects are acceptable when the total combined length of the defects do not exceed 15 percent of one thread length in any one complete thread.

(8) Repaired threads which engage with a non-self locking nut of Class 3A fit, turned with the fingers, are acceptable.

(9) Cuts or tears in self-locking elements which are deeper than the existing thread impressions are not acceptable.

d. NON-ENGAGED THREAD ACCEPTANCE CRITERIA

(1) Cracks are not acceptable.

(2) For externally threaded fasteners, no minimum thread form is required, except as needed to provide initial engagement and passing of the nut.

e. SPECIAL INSTRUCTIONS FOR NUTS

(1) SELF-LOCKING NUTS. Replace self-locking nuts that have looseness in the plastic (nylon) insert ring element or cracks in the element or metal surrounding the element. Replace self-locking nuts which are known to have been used more than five times or which do not provide a positive locking torque. Table 3-4 provides minimum recommended torques for previously used UNC self-locking nuts up to 2-1/2 inches in diameter.

(2) STANDARD NUTS. Replace nuts which are damaged or deformed to the extent that they interfere with ready installation.

f. SPECIAL INSTRUCTIONS FOR MIL-F-18240 SELF-LOCKING FASTENERS

3-39.

These are externally threaded male fasteners (capscrews/bolts) with plug, patch or chemical patch type locking inserts. The locking portion is supposed to be replaced at each reuse. If logistic problems prohibit such replacement, they may be reused if the locking element generates a breakaway torque of at least 25 percent of the value listed for the appropriate size in Table 3-4. They may also be reused by applying an anaerobic thread locking compound chosen to allow their future removal (such as grade C or CVV of MIL-S-22473)

3-40. TIGHTENING OF ZINC ANODE PLUGS.

″Good shop practice″ is sufficient for tightening zincs when new ones are installed. No specific torque is required unless one is specified on a drawing or in a technical manual for the installation of a specific zinc anode plug or plugs.

CHAPTER 4

METHOD FOR OBTAINING CLAMPING LOADS

4-1. INTRODUCTION.

Threaded fasteners are used to mechanically hold together a joint with a force sufficient to prevent the joint from leaking when subjected to various service conditions (e.g., temperature, pressure, shock, vibration, etc.).

4-2.

The proper amount of tightening (or preload) is important. Fasteners that are installed with excessive clamping loads may exceed the yield of the fastener material and loosen in service. If insufficient clamping load is applied, the surface may leak or may cause excessive vibration with ultimate fastener failure.

4-3. TORQUE-TENSION RELATIONSHIP.

In any fastening situation, the basic problem is to determine the optimum fastener that meets design and environmental considerations, and which when properly tightened, will secure a joint so it will not fail or loosen in service. Fastener determination is affected by the torque-tension relationship, because tightening of a flanged joint is normally accomplished through the application of torque to fasteners. It is tension, however, not torque, that is the goal in fastener tightening. Although there is a definite relationship between torque and tension (clamping force), this relationship is highly variable because of the variety of tightening methods and factors of friction, thread fit, etc. The geometry of some flanged joints (i.e., certain valve body to bonnet joints) results in a mix of studs and through-bolts (with nuts) to complete the fastener system for the joint. In order to keep clamping force as equal as possible around the bolt circle of the joint, through-bolts with nuts should be torqued to the same value as the nuts on the studs, per Table 5-5.II. This procedure should also be followed if the fastener system is a mixture of studs and capscrews (see Table 5-5.II). There is still the probability of significant variation in the actual clamping force from fastener to fastener, again due to factors of friction, thread fit, etc.; but selecting torque values from table 5-5 for all the fasteners in the situations cited above minimizes this variation to the greatest extent possible.

4-4. TIGHTENING FASTENERS TO PROPER TENSION.

To ensure that the required tension is actually produced in a bolt or stud when the joint is assembled requires a tightening method that either directly or indirectly measures or determines the amount of tension. In the practical application of threaded fasteners used in submarine services, the following methods for setting bolt tension are used:

a. Torque measurement

b. Angular turn-of-the-nut

c. Feel

d. Micrometer (not normally used in shipboard applications)

e. Ultrasonic (measurement of change of length or direct stress measurement)

4-5.

Before using any of the tightening methods listed above, the following should be performed:

a. Examine fasteners for compliance with marking requirements.

b. Examine the internal and external thread for burrs, nicks, metallic slivers, etc., that could cause jamming or excessive resistance to tightening. Remove or correct as necessary.

c. Ensure the threads and mating bearing surfaces are clean and free of rust, chips, or other foreign matter.

d. Ensure the nut seating surface is flat and contacts the mating surface all around.

e. Lightly lubricate the threads and bearing surface with applicable lubricant (paragraph 4-22) and remove excess lubricant to permit air to escape from under the nut. Flange spot facing should also be lubricated. When the temperature of the installation may exceed 300°F and the thread surfaces may require disassembly in service, assure that the lubricant chosen is suitable for use at elevated temperatures. Anti-galling compound A-A-59004 is suitable for applications to 1050°F.

f. If using torque measurement method, ensure the torque wrench has a current calibration sticker. Select a torque wrench such that the required torque is between 20% and 90% of the full scale range of the torque wrench selected.

4-6. TORQUE MEASUREMENT METHOD.

The torque measurement method requires that the torque-tension relationship be established for the specific conditions of assembly. In most applications of threaded fasteners, it is not practicable to measure directly, during assembly, the tension required in each fastener to produce a desired clamping force. However, for many applications the tension (or stress level) may be controlled within satisfactory limits by applying measured torques in tightening the threaded fastener. Torque-tension relationships may be established for a given set of conditions, but the change of any one variable may alter the relationship markedly. Since most of the applied torque is absorbed by an indeterminate mount of friction (approximately 90 percent), factors such as a change in the surface roughness of the bearing surfaces or the threads, or a change in lubrication, will drastically affect the friction and thus the torque-tension relationship. It must be recognized that a given torque will not always produce a definite stress value, but can be expected to induce a stress that lies within a required range that is satisfactory.

4-7.

The torque-tension relationship for a given set of conditions may be established by means of a torque wrench in combination with a tensile testing machine or by the micrometer method described in paragraph 4-18. When both ends of a fastener are not accessible to permit micrometer (caliper) measurement and if the bolt end area will permit an axial hole to be drilled sufficiently larger for the insertion of a micrometer depth gage, a change in the depth of the hole or strain can be determined during tightening of the fastener.

4-8. TORQUE PRINCIPLES.

Torque is based on the fundamental law of the lever (i.e., force times distance equals the moment or torque about a point) . If this law is fully understood, the problems of torque values relative to torque wrenches and adapters can be solved.

4-9.

There is a maximum limit to the size of wrench which is practical for use. Beyond this limit, either the wrench becomes too cumbersome, because of its weight and length, or the pull that must be applied to obtain the desired torque becomes excessive. These inherent limitations can be improved by the use of extensions or handle elongations. Extensions are used for the purposes of increased leverage. When a minimum amount of space is available and the development of torque in higher ranges is necessary, multipliers, adapters, and drive extensions may be required.

4-10.

The primary purpose of an adapter is to make torque wrench use possible beyond applications where an ordinary socket or attachment can be used. Curved or angular adapters can be used in order to reach a nut or bolt head that is behind an obstruction. This in no way alters the calculations if the axis of the nut or bolt head intersects the extended centerline of the torque wrench. Most adapters must not be used in combination with a torque multiplier. An adapter that will keep the center of the multiplier over the center of the nut being tightened is the only adapter that should be used.

4-11.

Even with the use of these torque wrench accessories, there are many cases of submarine joint tightening when the required torque cannot be measured at the installation location because of the confined space. In this case, the joint assembly should be duplicated in an area where a pilot assembly (sample fastener) may be tightened to the correct torque value. The torque required to turn this sample fastener prior to contact with the bearing surface should be observed. An abrupt change in torque value indicates metal-to-metal contact has been made. The fastener should be marked in some manner so its rotational movement (turning) can be measured, when final torque value is applied. This exact measurement of turn may then be applied to the fasteners (after metal-to-metal contact is made) on the shipboard installation location (on board submarine) by some other means other than a torque wrench (e.g., slugging wrench adapter).

4-12. IMPACT WRENCH.

In the past, impact wrenches have been commonly used to install high strength bolts and nuts in the torque range of 100 to 700 foot-pounds. The following are three accepted methods of using impact wrenches to control the amount of torque applied to fasteners:

a. Operation judgement/feel method (±35 percent torque accuracy)

b. Turn-of-the-nut method (±15 percent torque accuracy)

c. Torque control impact wrench with automatic shutoff (±10 percent torque accuracy)

4-13.

Generally, impact wrenches are used because they are the only practical method of multiplying torque and eliminating dangerous torque reaction, even though these wrenches are self-destructive and inaccurate in controlling torque output. Impact wrenches apply very high loads to the threads during the tightening process, introduce secondary stresses in the stud or bolt due to torsion and bending, and are time consuming when used.

4-14. POWER TORQUE WRENCH.

The National Aeronautics and Space Administration (NASA) designed a reactionless power torque wrench for use by astronauts during space walks. Through NASA's design, a nonimpacting, reactionless power torque wrench that accurately controls torque to within ±5 percent with a ±1 percent repeatability has been designed and developed for shipboard use. It consists of a drive socket, a reaction socket, a reaction washer or reaction bar, and a nut and bolt. Accessories are also available (e.g., paint spray attachment that spot-marks fasteners to visually indicate that torque has been applied, reaction arm assembly that allows torquing of fasteners where reaction washers are not used) for various applications.

4-15. ANGULAR TURN-OF-THE-NUT METHOD.

The angular turn-of-the-nut tightening method is routinely used in the installation of high strength bolts. This method is not influenced by variations in thread conditions, lubrication of bolts, efficiency of air tools, or air pressure. In addition, the possibility of human error is reduced to a minimum. Turn-of-the-nut method results in a safe, strong joint because it eliminates the effect of variations in coefficient of friction due to the presence or absence of lubrication on threads or bearing surfaces. The following step-by-step procedures should be followed when using the angular turn-of-the-nut method for high strength bolts.

a. Calculate the angle which the subject nut will be turned through. This is accomplished by the following formula:

Angular Turn Of The Nut = (L + 1.5D) (N)/K

where

L	fastener length under tension (grip length)
D	fastener nominal diameter
K	mechanical property coefficient (K = 1.28 for K-Monel, 2.72 for Monel, 3.40 for CRES 300 series, 1.01 for Alloy steel)
N	Threads Per Inch (pitch)

b. Torque all fasteners to 10% of required torque. If 10% of the required torque cannot be achieved, tighten all fasteners to the highest torque that all fasteners can be torqued to. All fasteners should be torqued to the same value using a crossing pattern.

c. Rotate all fasteners (using a crossing pattern) through the angle determined using the above formula. This is in addition to the amount the nuts were tightened in step b. above.

d. On a one-for-one basis, loosen each fastener completely, retorque to 10% of the required torque, then rotate the nut through the angle determined above. This retorquing process is accomplished on each fastener, in its entirety, before proceeding to the next fastener. Follow the same crossing pattern as in step b. and step c..

4-16. TORQUE AND TURN-OF-THE-NUT METHOD.

There will be instances where torquing of all nuts is not practicable. In this case, torque as many as possible while observing the amount of turns of the nut after contact. Tighten the rest of the nuts by rotating them the same average amount of turn (e.g., nut torque 20 foot-pounds may be applied with a 10^{o} turn).

4-17. FEEL METHOD.

The feel method is applicable only when the desired tensile stress is just beyond the yield point of the bolt material. When an assembly has been properly designed, the yield point of the bolt may be slightly exceeded without harmful results. When an experienced workman is tightening a nut, he can feel a very slight yield in the bolt when the yield point has been reached. He then stops tightening when he feels this yield. This method should never be applied to critical joints.

4-18. MICROMETER METHOD.

Tightening by bolt extension (elongation) is one of the most precise assembly method available, but it is also the slowest and most expensive method. For these reasons, it is usually confined to unusual situations, such as the assembly of bolts or studs of a very large diameter where torque or turn data are impractical to develop or in cases where preload control is extremely critical. Techniques to measure bolt elongation vary. To use the micrometer method both ends of the bolt must be accessible to measure the change in overall bolt length. As a bolt is tightened, it elongates as the tension in the bolt is increased. To apply the micrometer method, the length of the bolt is measured by a micrometer or a bolt strain indicator (extensometer) prior to assembly. The bolt is then tightened, and measurements are made periodically with a micrometer, until the predetermined elongation is attained or until the predetermined elongation is indicated on the extensometer dial. The amount of elongation required for proper preload is determined from a load extension diagram or by calculations.

4-19. ULTRASONIC STRESS MEASUREMENT.

In lieu of tightening to a predetermined torque value, the fastener may be tightened to a predetermined stress level. This is accomplished by using specially designed ultrasonic instruments to measure actual stress levels. Appendix E may be used to determine proper preload stress level or to convert torques given in other sources to the proper tensile stress value.

4-20. LOCKWIRING.

Although lockwiring will probably be encountered in some areas, it should be avoided whenever possible. If lockwiring is used and the fasteners are taken down for any reason, usually the holes may not align properly when reassembled. Self-locking nuts should be used in place of lockwiring. The purpose of lockwiring is to prevent the nut, bolt, stud, or any other threaded part from backing off. This is done by installing the wires through the hole in the nut so the wire will tend to tighten by pulling against the untorquing direction. For more detailed information on lockwiring, see NAVSEA S9086-CJ-STM-000/CH-075, NSTM Chapter 075, Locking procedures and Torque Wrenches for Threaded Fasteners.

4-21. STAKING AND PEENING.

Staking and peening are also methods of achieving a thread lock. Both methods distort the material (destroy the threads) and should be avoided whenever possible. Staking includes the forcing of material from a working surface into the threads or head of a screw or stud, or the forcing of material from the head into the working surface, and deformation of threads by means of a punch. Peening is a means of locking a recessed screw or bolt by forcing some of the working surface material over the screw or bolt head to prevent it from backing out. NAVSEA S9086-CJ-STM-000/CH-075, NSTM Chapter 075 contains detailed information on staking and peening.

4-22. THREAD LUBRICANTS.

Torsional stresses caused by thread and nut bearing-surface friction must be considered in establishing torque requirements. These stresses do not contribute to the useful tensile strain or clamping force. Torsional stresses can be reduced by the use of a thread lubricant such as anti-galling compound A-A-59004 on all friction surfaces (when a sealant is not used) . The reduction in torsional stress makes practical the use of bolt elongation or torque values to obtain predictable total stress range levels in threaded fasteners. Another major advantage of using a lubricant is that a bolt and nut combination may be reused without any changes in torque-versus-load characteristics. For a list of thread lubricants and applications for their use, see the appropriate tables in NSTM Chapter 075 (NAVSEA S9086-CJ-STM-000/CH-075). If drawings, technical manuals, or operating instructions specify the use of a specific lubricant, that lubricant should be used. Anti-galling compound A-A-59004 should be used as a lubricant for fastener installations where temperatures exceed 300°F and for threaded fasteners that require removal in service.

NOTE

Thread lubricants containing molybdenum disulfide (Molykote or equivalent) should not be used in areas where the fastener will be immersed in water or regularly wetted by splashing or periodic flooding of the bilges. Bacteria in the water, especially seawater, cause the molybdenum disulfide to break down. The by-products of the breakdown (especially the sulfur) form compounds which attack the fasteners. Use anti-galling compound A-A-59004 (or copper or nickel based anti-sieze compounds if A-A-59004 is not available).

4-23. THREAD LOCKING COMPOUNDS AND SEALANTS.

NOTE

Paragraph 4-24 below is carried over in its entirety from the 6 February 1995 edition of this manual for historic reference as no more definitive information is available. The MIL-SPECs discussed have been or are being cancelled as a result of Acquisition Reform actions mandated by the Secretary of Defense without regard for the fact that there is no approved substitute. If an existing commercial document is approved, it will very likely be ASTM D 5363-93, Standard Specification for Anaerobic Single Component Adhesives (AN). The most commonly used thread locking compounds (grades A, AV and AVV below, Loctite 271 or 277 or equivalent) fall under AN0121, AN0123 and AN0124 of ASTM D 5363-93. For small fasteners or other applications where a lesser degree of locking strength is desired, grades C and CVV (Loctite 242 or equivalent), AN0141 and AN0143 of ASTM D 5363-93 are satisfactory. Until the situation is officially resolved, this interim guidance is the best that can be offered.

4-24.

The most commonly used sealant on threaded fasteners in pressure containing systems is an anaerobic compound, grade A, AV or AVV, (e.g., Loctite or equivalent), in accordance with MIL-S-22473. This sealant is used for sealing threaded fasteners against fluid pressure and for locking threaded fasteners under shock and vibration. It is used primarily for setting studs, particularly where the Class 5 interference thread fit may be eliminated, where the Class 5 thread fit has been tapped slightly oversize, and for locking and sealing studs with radial clearances, depending on grade used. When properly applied, it forms a mechanical lock between the mating threads over their engaged length. This lock results in breakaway torques equal to or greater than torques for interference fits. When the lock has been ruptured, the hardened Loctite acts as a mechanical obstruction in the threads. This obstruction develops a prevailing torque locking action that persists for several full turns. Loctite is not to be used on fasteners in services where temperatures reach below -65°F or exceed 300°F. Studs can be removed by the application of heat before applying torque, to remove lockout resistance. Thread locking/sealing compound in accordance with MIL-S-46163, type I, grade J, K or L may be used as a substitute for compounds in accordance with MIL-S-22473, grade A, AV or AVV. Anaerobic compounds must be used in accordance with an approved procedure.

4-25. RUNNING TORQUE.

Running torque, also called prevailing torque, is the amount of torque required to cause rotation of a self locking nut (threads of the nut, including the locking feature, fully engaged on a bolt or stud, but bearing surface not contacting the clamped material) on a threaded fastener. Note that running torque is a measurement of dynamic friction so its value will be less than the value of breakaway torque (a static friction situation) for the same nut. When we use a torque wrench to apply a specified torque from an approved source, any running torque developed by the locking feature will reduce the expected preload by the amount of the specified torque minus the running torque. This causes the actual preload developed to be less than the amount theory says is generated by our chosen torque. If the running torque is a large enough percentage of the total applied torque, this reduction can be significant. For this reason, it is logical to add running torque to the specified applied torque to compensate for the difference, and this is, in fact, often done. On the other hand, determination of running torque and the extra record keeping generated by recording its use on joint records has been identified as both an annoyance and a major cost driver in joint assembly where torque measurement is used to establish preload. For this reason, it is necessary to establish policy concerning when it is necessary to apply running torque and when it may be ignored, and how to determine running torque most economically.

4-26.

The most expensive way to determine running torque is to measure the running torque of each nut in a bolt circle, record that value, then add that value to the specified torque for that nut. This results in several different torques around the bolt circle, along with the cost of the labor to determine each individual value and separately record it each time a joint is assembled. This method is always technically acceptable. A better method, from an economic standpoint, is for an activity to develop a table, by diameter, for running torques. The table can be built over time as joints with different diameter fasteners are assembled; it doesn’t have to have all the values filled in at once. To do this, record the running torques of 7 to 10 used self locking nuts of a given diameter, and the running torques of an equal number of new self locking nuts, add them all up, and divide by the total number of new and used fasteners checked and determine the average running torque. This average running torque becomes the value to be added for that diameter self locking nut for any future work packages; no more individual measurement of running torque for each individual nut is necessary. Simply add the value given in the table to the specified torque and assemble the joint using that total as the applied torque. This method is also always technically acceptable. Finally, for a specific diameter nut (if no locally developed table exists from which to get an average running torque) , the assembling activity can add the minimum acceptable breakaway torque test value for reuse of self locking nuts found in Table 3-4 of this volume to the specified torque to arrive at the applied torque. While this is the least accurate method, the final applied torque will be well within acceptable limits, so it, too, is always technically acceptable.

4-27.

The question of when the running torque must be added to the specified torque with use of a self locking nut hinges upon a number of factors. The most important are the diameter of the fastener and whether the nut is new or reused. With small diameter fasteners the running torque is a much larger component of the applied torque (if no adjustment for the presence of the self locking feature is made) than it is with large diameter fasteners. New self locking nuts tend to exhibit higher running torques, when tested, than do reused self locking nuts, especially after the nut is reused multiple times, so new self locking nuts will exhibit a larger component of the applied torque (again, if no adjustment is made for the presence of the self locking feature) than reused nuts. But, as stated elsewhere in this manual, the actual preload achieved by the application of a specific torque varies considerably from fastener to fastener within any given bolt circle, so there is actually a considerable range of acceptable preloads and the running torque is just one more factor in the range. Since the range is relatively large, once fasteners get large enough, it doesn’t make economic sense to adjust for running torque because its effect is lost in the magnitude of the dozens of other items causing preload variation. For this reason, once the fastener diameter is big enough, ignoring the running torque will not cause the final preload to fall outside the acceptable range.

4-28.

To determine the final torque to be applied when assembling joints containing self locking nuts, the following rules apply for the addition of running torque to the specified torque:

a. It is never technically incorrect to add the running torque to the specified torque, even if the specific joint does not require it to be added, it just adds expense.

b. The running torque must be added to the specified torque from a torque table or PC Bolts calculation if the self-locking nut is 5/8″ or less in diameter.

c. The addition of running torque to the specified torque from a torque table or a PC bolts calculation is not required for self-locking nuts greater than 5/8″ in diameter. However, such addition is technically correct and acceptable if the assembling activity chooses to do so.

4-29. HEAVY HEX NUTS.

Because nut dilation is a significant contributor to failure of nuts in shear (stripping), and because resistance to nut dilation (and hence stripping) is directly proportional to the width across the flats dimension of a nut (among other things), heavy hex nuts are often used in place of regular hex nuts to increase the stripping resistance of the fasteners in a joint. A secondary benefit is that their use often forces the theoretical joint failure mode to be bolt/stud failure, saving the cost of complex Finite Element Analysis of joint designs to verify the probable failure mode. Heavy hex nuts, with their larger width across the flats, are common in joints within the hull integrity boundary, and are often used in the body to bonnet joints on Standard Navy Valves. Whether the correct nut to use in a given joint is a regular hex nut or a heavy hex nut is not always obvious from the material list of a drawing; all notes referenced in the line item for a specific nut must be read and understood to make sure that the correct replacement nut is procured or that the correct nut was installed the last time a joint was reassembled.

4-30.

The installation of regular hex nuts where heavy hex nuts are required is an error that occurs during maintenance operations with varying degrees of regularity. The use of regular hex nuts where heavy hex nuts are required reduces the strength during extreme conditions, such as high shock/Undex situations. It does not reduce the strength to levels below the specified design minimums used for subject joints, but it significantly reduces the strength margin built into the joints during the design process, degrading performance under extreme conditions. The situation presents no threat during normal (and most abnormal) day to day operations, therefore, when regular hex nuts are found installed in joints which are supposed to have heavy hex nuts installed, the proper nuts should be procured and installed as soon as possible, on a not to delay the ship basis.

4-31. CHECK PASSES.

When all the fasteners in a joint have been pulled up tight, one or more check passes (depending on whether the joint passes the first check pass) are required to verify that all the fasteners in the joint are tight. Rather than following the specified tightening pattern (e.g. ″star″ pattern), check passes should be made in either a clockwise or counter clockwise direction (technician’s choice). Start and complete each check pass by attempting to tighten the fastener designated as number 1. This reduces the chances of skipping a fastener and results in higher initial preload and reduced preload variation.

CHAPTER 5

TYPICAL JOINT ASSEMBLY

5-1. INTRODUCTION.

This section contains information required to properly assemble a SUBSAFE mechanical joint and the applicable inspections and tests that should be performed on the assembled joint. Information required to check flange alignment and flange line fits is provided in paragraph 5-2. Paragraph 5-3 provides bolt-tightening procedures for flat-face flanges and raised-face flanges manufactured in accordance with NAVSEA drawings 803-1385861, 803-1385947, and 803-1385949. These procedures use the torque wrench method to obtain the desired preload. Instructions on obtaining the correct torque value from the torque tables are given in paragraph 5-4. The effect of varying length of thread engagement is discussed in paragraph 5-5. Mechanical joint acceptance and system tests are provided in paragraph 5-6 through 5-9.

5-2. FLANGE JOINT FIT-UP.

The following procedures provide methods for checking flange alignment and flange and liner fits for bolted-flange connections using O-rings or flat gaskets:

a. Ensure the flange faces are on a plane perpendicular to the longitudinal centerline of the pipe tube, or fitting, to which they are attached.

b. Check all flanges, gaskets, fasteners, and other material to ensure they are as specified by the applicable plan or specification.

c. Ensure flange faces are parallel, as close together as possible, and bolt holes are in alignment before assembling bolted joint. (See paragraph 3-22 and Table 3-1 for flange parallelism criteria.) In order to ensure against O-ring blowout from internal pressure, the mating flange surfaces should be parallel and as close together as possible.

d. Check bolt or bolt-stud holes of the mating flanges for concentricity. Misalignment of holes, without the application of external forces to align the flanges, should be no more than that which would allow a bolt or bolt-stud of the specified diameter to pass freely through the holes of the mating flanges and still remain parallel to the axis of the flange. Ensure that bolt hole spot facing on the rear side of the flange is of adequate diameter and parallel to the flange face.

NOTE

External forces may be applied to compensate for minor misalignments, provided the forces do not result in permanent deformation of piping and do not overstress adjacent piping hangers. In cases where rotating equipment is connected to its affiliated piping without resilient piping connections (e.g., risic couplings or hose connections), no external forces shall be applied to joints at the equipment or to joints nearer the equipment than ten (10) feet, or the second hangar, away from the equipment, whichever is least.

e. Ensure that all bolt holes have been deburred.

f. To check hull liner fit for valve and pipe joints using O-ring gaskets, perform the following:

(1) Inspect hull liner for damage due to handling. Acceptance criteria for surface defects should be in accordance with MS 7650-081-001, General Acceptance Criteria.

(2) The part of the liner surface inside the bolt circle is defined as the critical area for the purpose of inspected flatness of the liner. Inspect hull liner surface flatness as follows:

(a) Manufacture a doughnut shape surface plate of proper size for the valve or pipe flange liner in question.

(b) Inspect the plate and edges for freedom from burrs and mechanical irregularities.

(c) Hold the plate against the liner with the hole in the plate matching the hole in the liner. Insert feelers between the plate and the critical area of the liner, from the inside of the hole toward the bolt circle. If a 0.005-inch feeler will not go in as far as the O-ring seat, at any point around the hole, this edge of the critical area is satisfactory.

(d) Slide the plate toward one side of the liner until the outer edges of the plate are tangent to the line at the bolt circle. Insert feelers at point of tangency toward center of liner. Take feeler clearances all around bolt circle, swinging surface plate to new points of tangency as readings are taken. If a 0.005 inch-feeler gage cannot be inserted between flange mating surfaces at any point, the critical area outside of the O-ring is satisfactory.

NOTE

Blueing should not be used on the critical area as a criterion for acceptance of this surface.

g. To check flat-face and raised-face flanges for flange-to-flange and flange-to-liner fit for valves and pipe flanges, perform the following:

(1) Inspect flanges for damage due to handling. Defects forming a path for leakage should be reworked. Isolated defects or scars that do not provide a path for leakage do not require reworking.

(2) Check flanges with a straight edge and feelers. Surface plate should not be used. Openings of more than 0.003 inch require reworking of flange face.

NOTE

Raised faces in accordance with NAVSEA Drawing 803-1385861 are one sixty-fourth inch (approximately 0.015 inch) above the normal machined flange face.

(3) On raised-face flanges only, ensure that there is at least a 0.005-inch clearance around the outer periphery of the pipe flanges after tightening. Inspect the feeler readings on four points, 90 degrees apart, to ensure the required clearance is maintained.

h. Perform stud installation inspection required by SAE J2270 when anaerobic sealant is used for stud installations.

5-3. FASTENER TIGHTENING PROCEDURES.

The following procedures are applicable to nuts, through bolts, studs, capscrews, and set-studs used on flat-face and raised-face flanges:

a. Prior to applying final torque, perform the prerequisites described in paragraph 4-5, steps a. through f.

b. For flange joint fit-up, follow the procedures in paragraph 5-2.

c. Where the application requires O-ring or gaskets, ensure the O-ring or gasket is in its proper position. Make up the joint evenly by tightening diametrically opposite fasteners until the flanges contact each other. This will normally be accompanied by a noticeable increase in torque when metal-to-metal contact is made. Check all fasteners to ensure that no fasteners are loose. Continue to tighten fasteners sequentially. Apply approximately ten percent of the specified torque to ensure solid part contact. Finish torquing the joint in 25 percent increments of the specified torque.

d. For determining torque values used in this procedure, refer to paragraph 5-4 or use Appendix E (PC Bolts)

e. When tightening nuts, check stud rotation by marking with a felt-tip marker on the nut end of each stud in a direction toward the center of the flange. Check the mark on each stud after tightening to ensure the stud did not rotate.

NOTE

All class 5 interference fit threads should be in accordance with General Services Administration FED-STD-H28, Part III, Appendix 11.

f. Check nut torque for any rotational movement of the stud (rotational movement indicates the installation is not satisfactory). If the torque reading stops increasing as fastener is being tightened, replace fastener as it has yielded. Rotation of stud is cause for rejection. Examine internal threads for damage prior to replacing stud.

g. In instances where it is not possible to torque all nuts or bolts due to interferences or lack of space for the torque wrench, tighten as many as possible. Observe the amount of turns of the nut after contact and tighten the remaining nuts or bolts the same average amount of turns; e.g., nut torque 20 foot-pounds and 10 degrees turn (see paragraph 4-16).

h. Record actual torque values and the torque value source and retain with the joint record.

NOTE

Step i. applies to raised-face flanges only.

i. If a joint becomes overtightened, as indicated by flange distortion resulting in flange contact, disassemble and retighten (see step h.) to the proper value. Examine the parts, including the gasket or O-rings, etc., for damage and replace as required. Depending on the amount of over-torquing examine the parts; parts may or may not be reusable. If necessary, retest the joint.

j. Should it become necessary to replace flange joint fasteners after completion of hydrostatic test, replacement may be accomplished by one at a time removing the existing fasteners, installing the replacement fasteners, and tightening to the required torque.

5-4. LOCATING A CORRECT TORQUE VALUE FROM THE TORQUE TABLES.

a. When a torque value is specified on the drawing, Maintenance Standard, or technical manual, the fasteners should be torqued to that value. In those instances when a torque value is not provided, the torque values provided herein should be used.

b. The torque tables in this manual are categorized into three basic fastener assembly configurations as follows:

TYPE I:	Through bolts/bolt-studs, Flat Face Flanges and Plates (See Figure 5-1 and Figure 5-2)
TYPE II:	Studs, Cap Screws, Flat-Face Flanges and Plates (See Figure 5-3 and Figure 5-4)
TYPE III:	Through bolts, Bolt-Studs, Raised Face Flanges (See Figure 5-5)

c. Fastener types, specifications and materials represented in these tables are detailed in Table 5-1 and Table 5-2. The various fastener materials are grouped according to yield strength and are detailed in Table 5-3 and Table

5-4. The tables are further broken down according to thread lubricant used, flange and clamped plate materials, and flange design type. Figure 5-6 below illustrates a typical table designation and the significance of each table identifier:

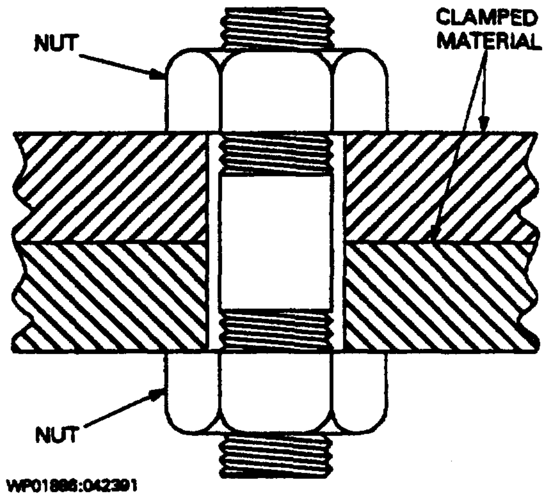

Figure 5-1 Type I Assembly: Bolt-Stud/Nut, Flat Face Flange or Plate

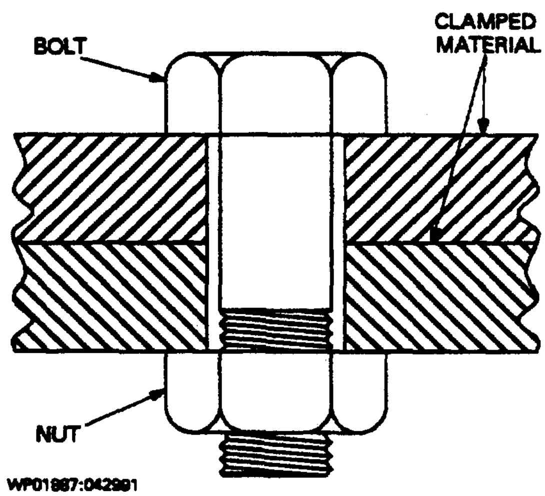

Figure 5-2 Type I Assembly: Through Bolt/Nut, Flat Face Flange or Plate

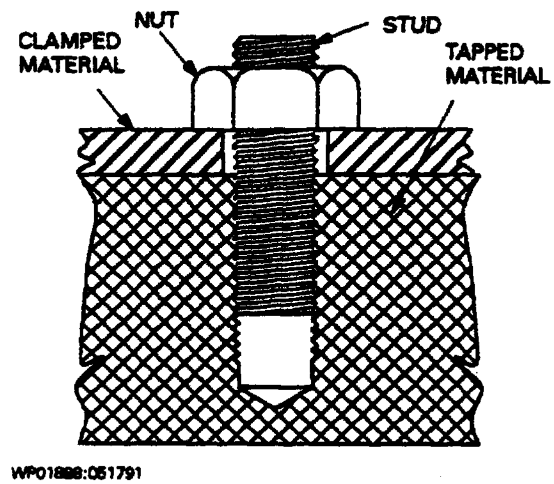

Figure 5-3 Type II Assembly: Set Stud, Flat Face Flange or Plate

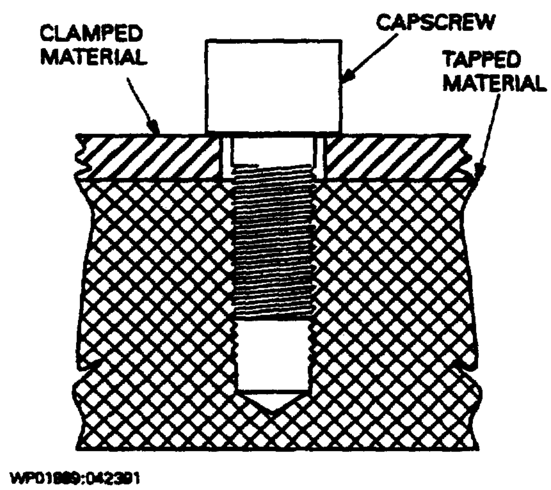

Figure 5-4 Type II Assembly: Cap Screw, Flat Face Flange or Plate

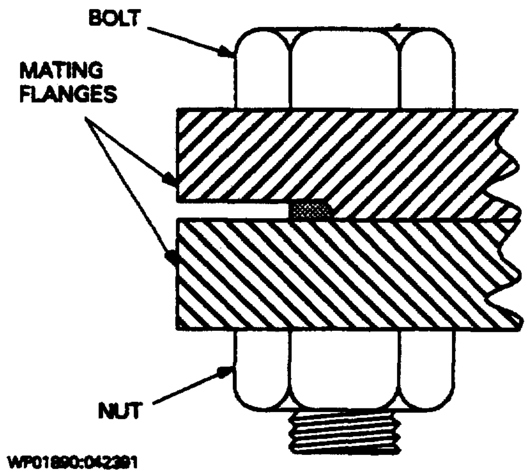

Figure 5-5 Type III Assembly: Through Bolts/Studs, Raised Face Flange

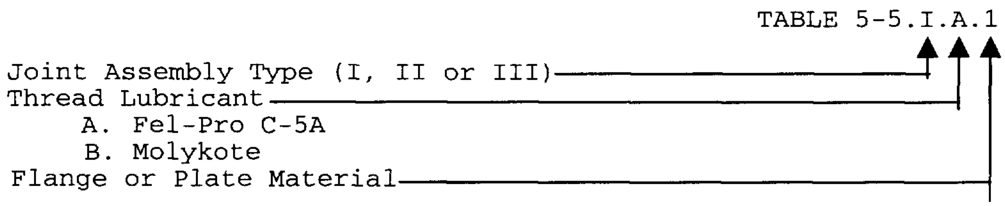

Figure 5-6 Table Designators.

d. To locate the correct torque value, first identify the flange material, type and size, and the strength of the fastener being assembled. Choose the applicable strength group for the fasteners used from Table 5-3 and Table 5-4. Next, identify the lubricant used for the particular application. The tables in this manual give torque values for two of the most commonly used thread lubricants: MIL-A-907 (Fel-Pro C-5A) and MIL-L-24478 (Molykote). Once this information is known, determine the correct table using Figure 5-6, above. Once the correct table is found, locate the strength group in the vertical column and the fastener size in the horizontal row; at the intersection is the correct torque value.

e. For raised face flanges in accordance with NAVSEA drawings 803-1385861, 803-1385947, and 803-1385949 design, use the torque values from Table 5-5.III. For other raised face flange designs, see Table 5-6.

f. For Class 5 interference fit stud torque values, refer to Table 5-7.

5-5. EFFECT OF VARYING LENGTH OF THREAD ENGAGEMENT.

a. When designing a fastened connection, the goal is to fully develop the strength of the externally threaded male fastener by ensuring that the fastener breaks in tension before the internal or external threads fail in shear. This is accomplished by specifying an adequate length of thread engagement (LE). When the threaded joint members are of equivalent strengths, a good rule of thumb is to design the length of thread engagement to be at least 1.1 times the nominal diameter of the fastener. This relationship is supported by the thread engagement formulas in FED-STD-H28. The torque tables provided herein (Table 5-5) are based on an LE of 1.25 times the nominal diameter.

b. When the threaded members substantially differ in strength, a length of engagement of 1.25 times the nominal diameter may not be sufficient to develop the full male fastener strength. In these cases, fastener torque values are limited by thread shear. Table 5-8 and Table 5-9 were developed to illustrate the effect of LE on torque values for two fastened joint material combinations. It can be seen that for widely differing material strength combinations, torque changes significantly with changing LE. For these cages, and for cases where 1.25 times the fastener nominal diameter LE cannot be achieved, the designer should refer to PC Bolts computer program, Appendix E of this manual, to calculate the correct torque value.

5-6. MECHANICAL JOINT ACCEPTANCE.

Prior to final mechanical joint acceptance, in systems or parts of systems designated as SUBSAFE, joints should be visually inspected before hydrostatic and operational tests are performed. Visual inspection of a SUBSAFE hull integrity joint consists of the following, as applicable.

a. During joint assembly the following should be performed:

(1) Inspect installation of O-ring.

(2) Ensure flange alignment (parallel and concentric) is within proper limits (see paragraph 5-2, step c. and step d.).

(3) Ensure O-rings, gaskets, etc., are of proper material and meet the applicable specifications.

(4) Ensure Flexitallic gasket has the proper service rating, if applicable.

(5) Ensure all fasteners are properly marked, as applicable (e.g., .K. for K-monel) and ensure that all fasteners in a flange bolt circle are of the same material. However, nuts need not be of the same material as the mating externally threaded fastener.

(6) Ensure fasteners are the proper size, type, and configuration (e.g., size -3/4 inch x 4 inch; type - stud; configuration - continuous/relieved) Ensure fasteners are of the specified length or have the specified stud standout.

(7) Ensure joints are clean.

b. After joint make-up perform the following:

(1) Ensure nuts are installed so thread engagement is completely through the nut with a minimum of one thread protruding beyond the crown of the nut (maximum protrusion shall not exceed 10 threads for threaded fasteners not specified on the applicable drawings), see paragraph 2-31. Improper thread protrusion is cause for rejection of the joint.

(2) Ensure all fasteners are torqued to values (nut tightening torque values) specified on the applicable drawing and torque wrenches have current calibration stickers. If applicable drawing does not specify torque values, refer to table 5-5 through Table 5-7.

(3) Ensure joint assembly inspection of MIL-STD-1371 is performed when anaerobic sealant is used on studs.

5-7. HYDROSTATIC PRESSURE TESTS.

Hydrostatic pressure tests are conducted to determine joint strength and tightness. All hydrostatic tests should be satisfactorily completed before the system is operated. Deficiencies revealed during these tests should be corrected and followed by a repeat of the test. For system operations and hydrostatic test pressures for a specific system, refer to the applicable test pressure drawing or piping system diagram. In general, hydrostatic tests should be conducted in accordance with the guidance contained in the Submarine Nonnuclear Piping Systems Test Manual, NAVSEA S9505-AF-MMA-010/PIPING SYSTEMS, including (in the absence of other guidance), the length of time required to maintain a specified pressure while performing a hydrostatic test.

5-8. CONTROLLED ASSEMBLY TESTS.

For joints where hydrostatic testing is not feasible, joints may be tested to the following series of controlled assembly tests in lieu of hydrostatic tests:

a. Inspect and verify that surface finish of gasket or O-ring sealing surfaces are in accordance with applicable specifications.

b. Ensure that fastener material and installation are in accordance with applicable specifications.

c. Inspect to ensure that O-rings, gaskets, etc., are properly installed and in accordance with applicable specifications.

d. Ensure that fasteners in joints are adequately torqued (nut tightening torque values) in accordance with applicable specifications.

e. It is desirable to maintain objective evidence (documentation) verifying completion of above requirements.

5-9. OPERATIONAL TESTS.

Piping systems should be operationally tested after the systems have passed the hydrostatic pressure tests or controlled assembly tests. Joints which were blanked during the hydrostatic test should be inspected for tightness during the operational test. Deficiencies detected during the tests should be corrected, followed by a repeat of the test. All testing should be accomplished in accordance with NAVSEA 0902-018-2010, General Overhaul Specifications for Deep Diving Submarines.

Table 5-1 FASTENER MATERIAL/MARKING CROSS REFERENCE

FASTENER MATERIAL	APPLICABLE SPECIFICATION	MARKING SYMBOL
Steel Grade 5	MIL-B-857 MIL-S-1222	
Steel Grade 8	MIL-B-857 MIL-S-1222	
Steel Grade 2	MIL-B-857 MIL-S-1222	None Required
Steel Grade B7	MIL-S-1222	B7
Steel Grade B16	MIL-S-1222	B16
NiCuAl	MS18116	· K · or Ni-Cu K
NiCuAl	MIL-S-1222	· K ·
NiCu	MIL-S-1222	NC
Alloy Steel, Grade 4340	MIL-S-1222	4340
Titanium, Grade T7	MIL-S-1222	T7
NiCrMoCuSi Alloy 625	MIL-S-1222 Modified by SEAWOLF Specification 075	625
CRES 300 Series	MIL-S-1222	300 Series No. Equals Symbol No.

Table 5-2 THREADED FASTENER TYPES

FASTENER TYPES	SPECIFICATIONS
Hex Head Bolt	MIL-B-857, MIL-S-1222
Stud	MIL-B-857, MIL-S-1222
Cap Screw	FF-S-86, MIL-S-1222
Nut (Regular)	MIL-B-857, MIL-S-1222 MS17828, ESNA Type NE (or equivalent)
Nut (Heavy)	MIL-H-25027/1(SH), ESNA Type NU (or equivalent)

Table 5-3 FASTENER STRENGTH MATRIX THROUGH BOLTS AND STUDS

FASTENER STRENGTH GROUP	MALE FASTENER MATERIALS	DIAMETER SIZE RANGE (INCHES)	YIELD STRENGTH (KSI)	TENSILE STRENGTH (KSI)	CORRESPONDING NUT MATERIALS	YIELD STRENGTH RANGE (KSI)
1	CRES Grade 300 Series Annealed	1/4 to 2-1/2	30	75	CRES Grade 300 Series Annealed	30
2	Grade 400 NiCu Grade 2 Steel	1/4 to 2-1/2 7/8 to 2-1/2	40 35	80 60	Grade 400 NiCu	35 - 40
3	UNS N06625 Grade 2 Steel Grade 5 Steel	1/4 to 2-1/2 1/4 to 3/4 1-1/2 to 2-1/2	60 55 58	120 75 90	UNS N06625 Grade 2 Steel Grade 5 Steel	55-60
4	Grade 5 Steel	1/4 to 1 >1 to 1-1/2	92 81	120 105	Grade 5 Steel	81 - 92
5	Grade B7 and B16 steel Gr T7 Titanium	1/4 to 2 2-1/8 to 2-1/2	105 105	125 115	Grade 2H, 4, 7 Steel Gr T7 Titanium	105 - 115
6	Grade 8 Steel	1/4to 2-1/2	130	150	Grade 8 Steel	130
7	NiCuAl NiCuAl	1/4to 7/8 1 to 2-1/2	90 85	130 130	NiCu	85 - 90

Table 5-4 FASTENER STRENGTH MATRIX CAP SCREWS AND SET STUDS

FASTENER STRENGTH GROUP	MALE FASTENER MATERIALS	DIAMETER SIZE RANGE (INCHES)	YIELD STRENGTH (KSI)	TENSILE STRENGTH (KSI)	CORRESPONDING NUT MATERIALS	NUT PROOF STRENGTH RANGE (KSI)
1	CRES Grade 300 Series Annealed [1] & [2]	1/4 to 5/8 >5/8	30 26	80 70	CRES Grade 300 Series Annealed	75
2	NiCuAl Grade 500 [1] & [2]	<1 >1	90 85	110 130	Grade 400 NiCu	80
3	NiCU Grade 400 Grade 2 Steel	1/4 to 2-1/2 7/8 to 2-1/2	40 35	80 60	Grade 400 NiCu Grade 2 Steel	80-90
	UNS NO6625 Grade 2 STL Grade 5 STL	1/4 to 2-1/2 1/4 to 3/4 >1-1/2 to 2-1/2	60 55 58	120 75 90	UNS N06625 Grade 2 STL Grade 5 STL	90-105
	Grade 5 Steel	1/4 to 1 >1 to 1-1/2	92 81	120 105	Grade 5 Steel	105-120
6	Grade B7 and B16 steel	1/4 to 2-1/2	105	125	Steel Gr 2H, 4, 7	150
	Gr T7 Titanium Annealed	1/4 to 1-1/2 >1-1/2 to 2 > 2	115 110 1OS	125 120 115	Gr T7 Titanium Annealed	120
7	Grade 8 Steel	1/4 to 2-1/2	130	150	Grade 8 Steel	150
8	Alloy Steel [2]	1/4 to 1/2 > 1/2	155 150	180 170	NOT APPLICABLE	
	Alloy Steel Grade 574 and 4340 [1]	1/4 to 1/2 > 1/2	155 153	180 170	NOT APPLICABLE	

[1]Per MIL-S-1222

[2]Per FF-S-86

Table 5- 5.I.A.1 TORQUE VALUES FOR THROUGH BOLTS/BOLT-STUDS FLAT FACE FLANGES OR PLATES (TYPE I)

FLANGE OR CLAMPED PLATE MATERIAL: NiCu PLATE, QQ-N-281							
MATING FLANGE OR CLAMPED PLATE MATERIAL: NiCu PLATE, QQ-N-281							
THREAD LUBRICANT: Fel-Pro C5-A, MIL-A-907							
TOLERANCE ON TORQUE VALUES: +/-5%							
FASTENER SIZE UNC	**FASTENER TORQUE (FT-LBS)**						
	STRENGTH GROUP 1	**STRENGTH GROUP 2**	**STRENGTH GROUP 3**	**STRENGTH GROUP 4**	**STRENGTH GROUP 5**	**STRENGTH GROUP 6**	**STRENGTH GROUP 7**
1/4 - 20	2	3	4	7	8	10	6 **
5/16 - 18	4	6	9	13	15	19	12 **
3/8 - 16	8	10	14	23	25 *	25 *	20 **
7/16 - 14	12	16	22	36	42	49~	32’
1/2 - 13	18	24	33	54	61 **	61 *	48 **
5/8 - 11	36	48	66	108	120 *	120 *	96 **
3/4 - 10	62	83	114	150 *	150 *	150 *	150 *
7/8 - 9	100	116	199	250 *	250 *	250 *	250 *
1 - 8	149	174	299	390 *	390 *	390 *	390 *
1 1/8 - 7	212	248	425	566	574 *	574 *	566 **
1 1/4 - 7	297	346	593	791 *	797 *	797 *	791 **
1 3/8 - 6	392	457	784	1045 *	1046 *	1046 *	1044 **
1 1/2 - 6	516	602	1032	1370 *	1370 *	1370 *	1370 *
1 3/4 - 5	834	972	1612	N/A	2917	3185 *	2223 **
2 - 4.5	1247	1455	2412	N/A	4366	4623 *	3327 **
2 1/4- 4.5	1804	2104	3487	N/A	6313	6388 *	4810 **
2 1/2 - 4	2491	2906	4815	N/A	8717	9190 *	6641 **

**denotes Nut Proof stress as limiting factor

*denotes Bearing Stress under nut as limiting factor

Table 5- 5.I.A.2 TORQUE VALUES FOR THROUGH BOLTS/BOLT-STUDS FLAT FACE FLANGES OR PLATES (TYPE I)

FLANGE OR CLAMPED PLATE MATERIAL: CuNi 70-30 CAST, MIL-C-20159							
MATING FLANGE OR CLAMPED PLATE MATERIAL: CuNi 70-30 CAST MIL-C-20159							
THREAD LUBRICANT: Fel-Pro C5-A, MIL-A-907							
TOLERANCE ON TORQUE VALUES: +/-5%							
FASTENER SIZE UNC	**FASTENER TORQUE (FT-LBS)**						
	STRENGTH GROUP 1	**STRENGTH GROUP 2**	**STRENGTH GROUP 3**	**STRENGTH GROUP 4**	**STRENGTH GROUP 5**	**STRENGTH GROUP 6**	**STRENGTH GROUP 7**
1/4 - 20	2	3	4	7	8	10	6 **
5/16 - 18	4	6	8	13	15	16	12 **
3/8 - 16	8	10	14	20 *	20 *	20 *	20 **
7/16 - 14	12	16	22	37	39 *	39 *	32 **
1/2 - 13	18	24	33	49 *	49 *	49 *	48 **
5/8 - I1	36	48	66	96 *	96 *	96 *	96 **
3/4 - 10	62	83	114	120 *	120 *	120 *	120 *
7/8 - 9	100	116	199	200 *	200 *	200 *	200 *
1 - 8	149	174	299	312 *	312 *	312 *	312 *
1 1/8 - 7	212	248	425	459 *	459 *	459 *	459 *
1 1/4 - 7	297	346	593	638 *	637 *	637 *	638 *
1 3/8 - 6	392	457	784	837 *	837 *	837 *	837 *
1 1/2 - 6	516	602	1032	1096 *	1096 *	1096 *	1096 *
1 3/4 - 5	834	972	1612	N/A	2548 *	2548 *	2223 **
2 - 4.5	1247	1455	2412	N/A	3699 *	3699 *	3327 **
2 1/4- 4.5	1804	2104	3487	N/A	5110 *	5110 *	4810 **
2 1/2 - 4	2491	2906	4815	N/A	7352 *	7352 *	6641 **

**denotes Nut Proof stress as limiting factor

*denotes Bearing Stress under nut as limiting factor

Table 5- 5.I.A.3 TORQUE VALUES FOR THROUGH BOLTS/BOLT-STUDS FLAT FACE FLANGES OR PLATES (TYPE I)

FLANGE OR CLAMPED PLATE MATERIAL: INCONEL 625 ASTM B443-75

MATING FLANGE OR CLAMPED PLATE MATERIAL: INCONEL 625 ASTM - B443-75

THREAD LUBRICANT: Fel-Pro C5-A, MIL-A-907

TOLERANCE ON TORQUE VALUES: +/-5%

FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)						
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7
1/4 - 20	2	3	4	7	8	10	6 **
5/16 - 18	4	6	8	13	15	19	12 **
3/8 - 16	8	10	14	23	26	33	20 **
7/16 - 14	12	16	22	36	42	53	32 **
1/2 - 13	18	24	33	54	63	79	48 **
5/8 - 11	36	48	66	108	125	155	96 **
3/4 - 10	62	83	114	186	217	225 *	165 *
7/8 - 9	100	116	199	299	349	376 *	266 **
1 - 8	149	174	299	448	523	585 *	398 **
1 1/8 - 7	212	248	425	566	743	860 *	566 **
1 1/4 - 7	297	346	593	791	1039	1196 *	791 **
1 3/8 - 6	392	457	784	1045	1372	1569 *	1045 **
1 1/2 - 6	516	602	1032	1377	1807	2055 *	1377 *
1 3/4 - 5	834	972	1612	N/A	2917	3612	2223 **
2 - 4.5	1247	1455	2412	N/A	4366	5406	3327 **
2 1/4 - 4.5	1804	2104	3487	N/A	6313	7816	4810 **
2 1/2 - 4	2491	2906	4815	N/A	8717	10792	6641 **

**denotes Nut Proof stress as limiting factor

*denotes Bearing Stress under nut as limiting factor

Table 5- 5.I.A.4 TORQUE VALUES FOR THROUGH BOLTS/BOLT-STUDS FLAT FACE FLANGES OR PLATES (TYPE I)

FLANGE OR CLAMPED PLATE MATERIAL: BRONZE, CAST VALVES, MIL-B-16541B							
MATING FLANGE OR CLAMPED PLATE MATERIAL: BRONZE, CAST VALVES, MIL-B-16541B							
THREAD LUBRICANT: Fel-Pro C5-A, MIL-A-907							
TOLERANCE ON TORQUE VALUES: +/-5%							
FASTENER SIZE UNC	**FASTENER TORQUE (FT-LBS)**						
	STRENGTH GROUP 1	**STRENGTH GROUP 2**	**STRENGTH GROUP 3**	**STRENGTH GROUP 4**	**STRENGTH GROUP 5**	**STRENGTH GROUP 6**	**STRENGTH GROUP 7**
1/4 - 20	2	3	4	6 *	6 *	6 *	6 *
5/16 - 18	4	6	8	9 *	9 *	9 *	9 *
3/8 - 16	8	10	11 *	11 *	11 *	11 *	11 *
7/16 - 14	12	16	22 *	22 *	22 *	22 *	22 *
1/2 - 13	18	24	28 *	28 *	28 *	28 *	28 *
5/8 - 11	36	48	54 *	54 *	54 *	54 *	54 *
3/4 - 10	62	67 *	67 *	67 *	67 *	67 *	67 *
7/8 - 9	100	113 *	113 *	113 *	113 *	113 *	113 *
1 - 8	149	174	176 *	176 *	176 *	176 *	176 *
1 1/8 - 7	212	248	258 *	258 *	258 *	258 *	258 *
1 1/4 - 7	297	346	359 *	359 *	359 *	359 *	359 *
1 3/8 - 6	392	457	471 *	471 *	471 *	471 *	471 *
1 1/2 - 6	516	602	616 *	616 *	616 *	616 *	616 *
1 3/4 - 5	834	972	1433 *	N/A	1433 *	1433 *	1433 *
2 - 4.5	1247	1455	2081 *	N/A	2081 *	2081 *	2081 *
2 1/4 - 4.5	1804	2104	2875 *	N/A	2875 *	2875 *	2875 *
2 1/2 - 4	2491	2906	4135 *	N/A	4135 *	4135 *	4135 *

*denotes Bearing Stress under nut as limiting factor

Table 5- 5.I.A.5 TORQUE VALUES FOR THROUGH BOLTS/BOLT-STUDS FLAT FACE FLANGES OR PLATES (TYPE I)

FLANGE OR CLAMPED PLATE MATERIAL: CRES 304 ANN, QQ-S-766C							
MATING FLANGE OR CLAMPED PLATE MATERIAL: CRES 304 ANN, QQ-S-766C							
THREAD LUBRICANT: Fel-Pro C5-A, MIL-A-907							
TOLERANCE ON TORQUE VALUES: +/-5%							
FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)						
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7
1/4 - 20	2	3	4	7	8	10	6 **
5/16 - 18	4	6	8	13	15 *	15 *	12 **
3/8 - 16	8	10	14	19 *	19 *	19 *	19 **
7/16 - 14	12	16	22	37 *	37 *	37 *	32 **
1/2 - 13	18	24	33	46 *	46 *	46 *	46 *
5/8 - 11	36	48	66	90 *	90 *	90 *	90 *
3/4 - 10	62	83	114	112 *	112 *	112 *	112 *
7/8 - 9	100	116	199	188 *	188 *	188 *	188 *
1 - 8	149	174	299	293 *	293 *	293 *	293 *
1 1/8 - 7	212	248	425	430 *	430 *	430 *	430 *
1 1/4 - 7	297	346	593	598 *	598 *	598 *	598 *
1 3/8 - 6	392	457	784	784 *	784 *	784 *	784 *
1 1/2 - 6	516	602	1032	1027 *	1027 *	1027 *	1027 *
1 3/4 - 5	834	972	1612	N/A	2389 *	2389 *	2223 **
2 - 45	1247	1455	2412	N/A	3468 *	3468 *	3327 **
2 1/4 - 4.5	1804	2104	3487	N/A	4791 *	4791 *	4810 **
2 1/2 - 4	2491	2906	4815	N/A	6892 *	6892 *	6641 **

**denotes Nut Proof stress as limiting factor

*denotes Bearing Stress under nut as limiting factor

Table 5- 5.I.A.6 TORQUE VALUES FOR THROUGH BOLTS/BOLT-STUDS FLAT FACE FLANGES OR PLATES (TYPE I)

FLANGE OR CLAMPED PLATE MATERIAL: HY-80 PLATE, MIL-S-21952C

MATING FLANGE OR CLAMPED PLATE MATERIAL: HY-80 PLATE, MIL-S-21952C

THREAD LUBRICANT: Fel-Pro C5-A, MIL-A-907

TOLERANCE ON TORQUE VALUES: +/-5%

FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)						
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7
1/4 - 20	2	3	4	7	8	10	6 **
5/16 - 18	4	6	8	13	15	19	12 **
3/8 - 16	8	10	14	23	26	33	20 **
7/16 - 14	12	16	22	36	42	53	32 **
1/2 - 13	18	24	33	54	63	79	48 **
5/8 - 11	36	48	66	108	125	155	96 **
3/4 - 10	62	83	114	186	217	269	165 **
7/8 - 9	100	116	199	299	349	432	266 **
1 - 8	149	174	299	448	523	647	398 **
1 1/8 - 7	212	248	425	566	743	920	566 **
1 1/4 - 7	297	346	593	791	1039	1286	791 **
1 3/8 - 6	392	457	784	1045	1372	1698	1045 **
1 1/2 - 6	516	602	1032	1376	1807	2237	1377 **
1 3/4 - 5	834	972	1612	N/A	2917	3612	2223 **
2 - 4.5	1247	1455	2412	N/A	4366	5406	3327 **
2 1/4 - 4.5	1804	2104	3487	N/A	6313	7816	4810 **
21/2 - 4	2491	2906	4815	N/A	8717	10792	6641 **

**denotes Nut Proof stress as limiting factor

Table 5- 5.I.B.1 TORQUE VALUES FOR THROUGH BOLTS/BOLT-STUDS FLAT FACE FLANGES OR PLATES (TYPE I)

FLANGE OR CLAMPED PLATE MATERIAL: NiCu PLATE, QQ-N-281							
MATING FLANGE OR CLAMPED PLATE MATERIAL: NiCu PLATE, QQ-N-281							
THREAD LUBRICANT: MOLYKOTE M-77, MOLYKOTE Gn, MIL-L-24478							
TOLERANCE ON TORQUE VALUES: +/-5%							
FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)						
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7
1/4 - 20	2	3	3	5	6	7	4 **
5/16 - 18	3	5	6	9	11	13	8 **
3/8 - 16	6	9	10	16	18 *	18 *	14 **
7/16 - 14	9	14	16	26	30	34 *	23 **
1/2 - 13	14	20	23	39	43 *	43 *	34 **
5/8 - 11	28	40	45	76	83 *	83 *	66 **
3/4 - 10	48	70	78	103 *	103 *	103 *	103 *
7/8 - 9	76	89	137 *	172 *	172 *	172 *	172 *
1 - 8	114	133	205	267 *	267 *	267 *	267 *
1 1/8 - 7	162	189	291	393	393 *	393 *	388 *
1 1/4 - 7	226	263	404	543 *	543 *	543 *	539 **
1 3/8 - 6	299	349	536	715 *	715 *	715 *	714 **
1 1/2 - 6	392	458	702	931 *	931 *	931 *	931 *
1 3/4 - 5	633	739	1096	N/A	1983	2166 *	1511 **
2 - 4.5	947	1105	1637	N/A	2964	3139 *	2258 **
2 1/4 - 4.5	1363	1590	2352	N/A	4259	4309 *	3245 **
2 1/2 - 4	1883	2197	3249	N/A	5881	6200 *	4481 **

**denotes Nut Proof stress as limiting factor

*denotes Bearing Stress under nut as limiting factor

Table 5- 5.I.B.2 TORQUE VALUES FOR THROUGH BOLTS/BOLT-STUDS FLAT FACE FLANGES OR PLATES (TYPE I)

FLANGE OR CLAMPED PLATE MATERIAL: CuNi 70-30 CAST, MIL-C-20159							
MATING FLANGE OR CLAMPED PLATE MATERIAL: CuNi 70-30 CAST, MIL-C-20159							
THREAD LUBRICANT: MOLYKOTE M-77, MOLYKOTE Gn, MIL-L-24478							
TOLERANCE ON TORQUE VALUES: +/-5%							
FASTENER SIZE UNC	**FASTENER TORQUE (FT-LBS)**						
	STRENGTH GROUP 1	**STRENGTH GROUP 2**	**STRENGTH GROUP 3**	**STRENGTH GROUP 4**	**STRENGTH GROUP 5**	**STRENGTH GROUP 6**	**STRENGTH GROUP 7**
1/4 - 20	2	3	3	5	6	7	4 **
5/16 - 18	3	5	6	9	11	11	8 **
3/8 - 16	6	9	10	14 *	14 *	14 *	14 **
7/16 - 14	9	14	16	26	27 *	27 *	23 **
1/2 - 13	14	20	23	34 *	34 *	34 *	34 **
5/8 - 11	28	40	45	66 *	66 *	66 *	66 **
3/4 - 10	48	70	78	82 *	82 *	82 *	82 *
7/8 - 9	76	89	137	137 *	137 *	137 *	137 *
1 - 8	114	133	205	214 *	214 *	214 *	214 *
1 1/8 - 7	162	189	291	315 *	315 *	314	4314 *
1 1/4 - 7	226	263	404	434 *	434 *	434 *	434 *
1 3/8 - 6	299	349	536	572 *	572 *	572 *	572 *
1 1/2 - 6	392	458	702	745 *	745 *	745 *	745 *
2 - 4.5	947	1105	1637	N/A	2511 *	2511 *	2258 **
2 1/4 - 4.5	1363	1590	2352	N/A	3447 *	3447 *	3245 **
2 1/2 - 4	1883	2197	3249	N/A	4960 *	4960 *	4481 **

** denotes Nut Proof stress as limiting factor

* denotes Bearing Stress under nut as limiting factor

Table 5- 5.I.B.3 TORQUE VALUES FOR THROUGH BOLTS/BOLT-STUDS FLAT FACE FLANGES OR PLATES (TYPE I)

FLANGE OR CLAMPED PLATE MATERIAL: INCONEL 625, ASTM B443-75							
MATING FLANGE OR CLAMPED PLATE MATERIAL: I NCONEL 625, ASTM B443-75							
THREAD LUBRICANT: MOLYKOTE M-77, MOLYKOTE Gn, MIL-L-24478							
TOLERANCE ON TORQUE VALUES: +/-5%							
FASTENER SIZE UNC	**FASTENER TORQUE (FT-LBS)**						
	STRENGTH GROUP 1	**STRENGTH GROUP 2**	**STRENGTH GROUP 3**	**STRENGTH GROUP 4**	**STRENGTH GROUP 5**	**STRENGTH GROUP 6**	**STRENGTH GROUP 7**
1/4 - 20	2	3	3	5	6	7	4 **
5/16 - 18	3	5	6	9	11	13	8 **
3/8 - 16	6	9	10	16	18	23	13 **
7/16 - 14	9	14	16	25	30	37	23 **
1/2 - 13	14	20	23	38	44	55	34 **
5/8 - 11	28	40	45	74	87	107	66 **
3/4 - 10	48	70	78	128	149	155 *	114 **
7/8 - 9	76	89	137	205	239	257 *	182 **
1 - 8	114	133	205	307	358	401 *	273 **
1 1/8 - 7	162	189	291	388	509	590 *	388 *
1 1/4 - 7	226	263	404	539	707	814 *	539 **
1 3/8 - 6	299	349	536	714	937	1072 *	714 **
1 1/2 - 6	392	458	702	936	1228	1397 *	936 **
1 3/4 - 5	633	739	1096	N/A	1983	2456	1511 **
2 - 4.5	947	1105	1637	N/A	2964	3670	2258 **
2 1/4 - 4.5	1363	1590	2352	N/A	4259	5273	3245 **
2 1/2 - 4	1883	2197	3249	N/A	5881	7281	4481 **

**denotes Nut Proof stress as limiting factor

*denotes Bearing Stress under nut as limiting factor

Table 5- 5.I.B.4 TORQUE VALUES FOR THROUGH BOLTS/BOLT-STUDS FLAT FACE FLANGES OR PLATES (TYPE I)

FLANGE OR CLAMPED PLATE MATERIAL: BRONZE, CAST, VALVES MIL-B-16541B							
MATING FLANGE OR CLAMPED PLATE MATERIAL: BRONZE, CAST, VALVES MIL-B-16541B							
THREAD LUBRICANT: MOLYKOTE M-77, MOLYKOTE Gn, MIL-L-24478							
TOLERANCE ON TORQUE VALUES: +/-5%							
FASTENER SIZE UNC	**FASTENER TORQUE (FT-LBS)**						
	STRENGTH GROUP 1	**STRENGTH GROUP 2**	**STRENGTH GROUP 3**	**STRENGTH GROUP 4**	**STRENGTH GROUP 5**	**STRENGTH GROUP 6**	**STRENGTH GROUP 7**
1/4 - 20	2	3	3	4 *	4 *	4 *	4 **
5/16 - 18	3	5	6	6 *	6 *	6 *	6 *
3/8 - 16	6	9	8 *	8 *	8 *	8 *	8 *
7/16 - 14	9	14	15 *	15 *	15 *	15 *	15 *
1/2 - 13	14	20	19 *	19 *	19 *	19 *	19 *
5/8 - 11	28	40	37 *	37 *	37 *	37 *	37 *
3/4 - 10	48	57 *	46 *	46 *	46 *	46 *	46 *
7/8 - 9	76	86 *	77 *	77 *	77 *	77 *	77 *
1 - 8	114	133	120 *	120 *	120 *	120 *	120 *
1 1/8 - 7	162	189	177 *	177 *	177 *	177 *	177 *
1 1/4 - 7	226	263	244 *	244 *	244 *	244 *	244 *
1 3/8 - 6	299	349	322 *	322 *	322 *	322 *	322 *
1 1/2 - 6	392	458	419 *	419 *	419 *	419 *	419 *
1 3/4 - 5	633	739	975 *	N/A	975 *	975 *	975 *
2 - 4.5	947	1105	1412 *	N/A	1412 *	1412 *	1412 *
2 1/4 - 4.5	1363	1590	1939 *	N/A	1939 *	1939 *	1939 *
2 1/2 - 4	1883	2197	2790 *	N/A	2790 *	2790 *	2790 *

*denotes Bearing Stress under nut as limiting factor

**denotes Nut Proof stress as limiting factor

Table 5- 5.I.B.5 TORQUE VALUES FOR THROUGH BOLTS/BOLT-STUDS FLAT FACE FLANGES OR PLATES (TYPE I)

FLANGE OR CLAMPED PLATE MATERIAL: CRES 304 ANN, QQ-S-766C							
MATING FLANGE OR CLAMPED PLATE MATERIAL: CRES 304 ANN, QQ-S-766C							
THREAD LUBRICANT: MOLYKOTE M-77, MOLYKOTE Gn, MIL-L-24478							
TOLERANCE ON TORQUE VALUES: +/-5%							
FASTENER SIZE UNC	**FASTENER TORQUE (FT-LBS)**						
	STRENGTH GROUP 1	**STRENGTH GROUP 2**	**STRENGTH GROUP 3**	**STRENGTH GROUP 4**	**STRENGTH GROUP 5**	**STRENGTH GROUP 6**	**STRENGTH GROUP 7**
1/4 - 20	2	3	3	5	6	7	4 **
5/16 - 18	3	5	6	9	10 *	10 *	8 **
3/8 - 16	6	9	10	13 *	13 *	13 *	13 *
7/16 - 14	9	14	16	25 *	25 *	25 *	23 **
1/2 - 13	14	20	23	32 *	32 *	32 *	32 *
5/8 - 11	28	40	45	62 *	62 *	62 *	62 *
3/4 - 10	48	70	77 *	77 *	77 *	77 *	77 *
7/8 - 9	76	89	129 *	129 *	129 *	129 *	129 *
1 - 8	114	133	200 *	200 *	200 *	200 *	200 *
1 1/8 - 7	162	189	291	295 *	295 *	295 *	295 *
1 1/4 - 7	226	263	404	407 *	407 *	407 *	407 *
1 3/8 - 6	299	349	536	536 *	536 *	536 *	536 *
1 1/2 - 6	392	458	698 *	698 *	698 *	698 *	698 *
1 3/4 - 5	633	739	1096	N/A	1624 *	1624 *	1511 **
2 - 4.5	947	1105	1637	N/A	2354 *	2354 *	2258 **
2 1/4 - 4.5	1363	1590	2352	N/A	3232 *	3232 *	3231 *
2 1/2 - 4	1883	2197	3249	N/A	4650 *	4650 *	4481 *

**denotes Nut Proof stress as limiting factor

*denotes Bearing Stress under nut as limiting factor

Table 5- 5.I.B.6 TORQUE VALUES FOR THROUGH BOLTS/BOLT-STUDS FLAT FACE FLANGES OR PLATES (TYPE I)

FLANGE OR CLAMPED PLATE MATERIAL: HY-80 PLATE, MIL-S-21952C							
MATING FLANGE OR CLAMPED PLATE MATERIAL: HY-80 PLATE, MIL-S-21952C							
THREAD LUBRICANT: MOLYKOTE M-77, MOLYKOTE Gn, MIL-L-24478							
TOLERANCE ON TORQUE VALUES: +/-5%							
FASTENER SIZE UNC	**FASTENER TORQUE (FT-LBS)**						
	STRENGTH GROUP 1	**STRENGTH GROUP 2**	**STRENGTH GROUP 3**	**STRENGTH GROUP 4**	**STRENGTH GROUP 5**	**STRENGTH GROUP 6**	**STRENGTH GROUP 7**
1/4 - 20	2	3	3	5	6	7	4 **
5/16 - 18	3	5	6	9	11	13	8 **
3/8 - 16	6	9	10	16	18	23	13 **
7/16 - 14	9	14	16	25	30	37	23 **
1/2 - 13	14	20	23	38	44	55	34 **
5/8 - 11	28	40	45	74	87	107	66 **
3/4 - 10	48	70	78	128	149	185	114 **
7/8 - 9	76	89	137	205	239	296	182 **
1 - 8	114	133	205	307	358	443	273 **
1 1/8 - 7	162	189	291	388	509	631	388 **
1 1/4 - 7	226	263	404	539	707	876	539*
1 3/8 - 6	299	349	536	714	937	1160	714 **
1 1/2 - 6	392	458	702	936	1228	1520	936 **
1 3/4 - 5	633	739	1093	N/A	1983	2456	1511 **
2 - 4.5	947	1105	1637	N/A	2964	3670	2258 **
2 1/4 - 4.5	1363	1590	2352	N/A	4259	5273	3245 **
2 1/2 - 4	1883	2197	3249	N/A	5881	7281	4481 **

** denotes Nut Proof stress as limiting factor

Table 5- 5.I.C.1 TORQUE VALUES FOR THROUGH BOLTS/BOLT-STUDS FLAT FACE FLANGES OR PLATES (TYPE I)

FLANGE OR CLAMPED PLATE MATERIAL: NiCu PLATE, QQ-N-281							
MATING FLANGE OR CLAMPED PLATE MATERIAL: NiCu PLATE, QQ-N-281							
THREAD LUBRICANT: P37 PASTE, A-A-59004							
TOLERANCE ON TORQUE VALUES: +/-5%							
FASTENER SIZE UNC	**FASTENER TORQUE (FT-LBS)**						
	STRENGTH GROUP 1	**STRENGTH GROUP 2**	**STRENGTH GROUP 3**	**STRENGTH GROUP 4**	**STRENGTH GROUP 5**	**STRENGTH GROUP 6**	**STRENGTH GROUP 7**
1/4 - 20	2.1	2.7	3.8	6.3	7.2	8.9	5.5
5/16 - 18	4.0	5.4	7.4	12	14	17	11
3/8 - 16	6.9	9.2	13	21	23	23	18
7/16 - 14	11	15	21	34	39	45	30
1/2 - 13	17	22	31	51	55	55	45
5/8 - 11	33	44	61	101	107	107	88
3/4 - 10	58	77	106	169	169	169	155
7/8 - 9	93	124	108	266	266	266	248
1 - 8	139	186	162	396	396	396	371
1 1/8 - 7	198	264	231	534	564	564	527
1 1/4 - 7	276	368	322	744	764	764	735
1 3/8 - 6	364	485	424	982	1030	1030	970
1 1/2 - 6	478	638	558	1290	1320	1320	1280
1 3/4 - 5	756	1010	882	1460	2100	2100	2020
2 - 4.5	1130	1510	1320	2190	3130	3130	3020
2 1/4 - 4.5	1640	2190	1910	3170	4400	4400	4370
2 1/2 - 4	2250	2990	2620	4340	6040	6040	5990

Table 5- 5.I.C.2 TORQUE VALUES FOR THROUGH BOLTS/BOLT-STUDS FLAT FACE FLANGES OR PLATES (TYPE I)

FLANGE OR CLAMPED PLATE MATERIAL: CuNi 70-30 CAST, MIL-C-20159							
MATING FLANGE OR CLAMPED PLATE MATERIAL: CuNi 70-30 CAST, MIL-C-20159							
THREAD LUBRICANT: P37 PASTE, A-A-59004							
TOLERANCE ON TORQUE VALUES: +/-5%							
FASTENER SIZE UNC	**FASTENER TORQUE (FT-LBS)**						
	STRENGTH GROUP 1	**STRENGTH GROUP 2**	**STRENGTH GROUP 3**	**STRENGTH GROUP 4**	**STRENGTH GROUP 5**	**STRENGTH GROUP 6**	**STRENGTH GROUP 7**
1/4 - 20	2.1	2.7	3.8	6.3	7.2	8.9	5.5
5/16 - 18	4.0	5.4	7.4	11	14	14	11
3/8 - 16	6.9	9.2	13	14	18	18	18
7/16 - 14	11	15	21	28	36	36	30
1/2 - 13	17	22	31	34	44	44	44
5/8 - 11	33	44	61	67	86	86	85
3/4 - 10	58	77	105	105	135	135	135
7/8 - 9	93	124	108	166	213	213	213
1 - 8	139	186	162	247	317	317	317
1 1/8 - 7	198	264	231	352	451	451	451
1 1/4 - 7	276	368	322	478	611	611	611
1 3/8 - 6	364	485	424	641	820	820	820
1 1/2 - 6	478	638	558	824	1050	1050	1050
1 3/4 - 5	756	1010	882	1310	1680	1680	1680
2 - 4.5	1130	1510	1320	1950	2500	2500	2500
2 1/4 - 4.5	1640	2190	1910	2750	3520	3520	3520
2 1/2 - 4	2250	2990	2620	3780	4830	4830	4830

Table 5- 5.I.C.3 TORQUE VALUES FOR THROUGH BOLTS/BOLT-STUDS FLAT FACE FLANGES OR PLATES (TYPE I)

FLANGE OR CLAMPED PLATE MATERIAL: INCONEL 625 ASTM B443-75

MATING FLANGE OR CLAMPED PLATE MATERIAL: INCONEL 625 ASTM B443-75

THREAD LUBRICANT: P37 PASTE, A-A-59004

TOLERANCE ON TORQUE VALUES: +/-5%

FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)						
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7
1/4 - 20	2.1	2.7	3.8	6.3	7.2	8.9	5.5
5/16 - 18	4.0	5.4	7.4	12	14	17	11
3/8 - 16	6.9	9.2	13	21	23	23	18
7/16 - 14	11	15	21	34	39	45	30
1/2 - 13	17	22	31	51	55	55	45
5/8 - 11	33	44	61	101	107	107	88
3/4 - 10	58	77	106	169	169	169	155
7/8 - 9	93	124	108	266	266	266	248
1 - 8	139	186	162	396	396	396	371
1 1/8 - 7	198	264	231	534	564	564	527
1 1/4 - 7	276	368	322	744	764	764	735
1 3/8 - 6	364	485	424	982	1030	1030	970
1 1/2 - 6	478	638	558	1290	1320	1320	1280
1 3/4 - 5	756	1010	882	1460	2100	2100	2020
2 - 4.5	1130	1510	1320	2190	3130	3130	3020
2 1/4 - 4.5	1640	2190	1910	3170	4400	4400	4370
2 1/2 - 4	2250	2990	2620	4340	6040	6040	5990

Table 5- 5.I.C.4 TORQUE VALUES FOR THROUGH BOLTS/BOLT-STUDS FLAT FACE FLANGES OR PLATES (TYPE I)

FLANGE OR CLAMPED PLATE MATERIAL: BRONZE, CAST VALVES, MIL-B-16541B							
MATING FLANGE OR CLAMPED PLATE MATERIAL: BRONZE, CAST VALVES, MIL-B-16541B							
THREAD LUBRICANT: P37 PASTE, A-A-59004							
TOLERANCE ON TORQUE VALUES: +/-5%							
FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)						
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7
1/4 - 20	2.1	2.7	3.8	5.9	5.9	5.9	5.9
5/16 - 18	4.0	5.4	7.4	7.9	7.9	7.9	7.9
3/8 - 16	6.9	9.2	10	10	10	10	10
7/16 - 14	11	15	20	20	20	20	20
1/2 - 13	17	22	25	25	25	25	25
5/8 - 11	33	44	48	48	48	48	48
3/4 - 10	58	76	76	76	76	76	76
7/8 - 9	93	120	108	120	120	120	120
1 - 8	139	178	162	178	178	178	178
1 1/8 - 7	198	254	231	254	254	254	264
1 1/4 - 7	276	344	322	344	344	344	344
1 3/8 - 6	364	462	424	462	462	462	462
1 1/2 - 6	478	593	558	593	593	593	593
1 3/4 - 5	756	946	882	946	946	946	946
2 - 4.5	1130	1410	1320	1410	1410	1410	1410
2 1/4- 4.5	1640	1980	1910	1980	1980	1980	1980
2 1/2 - 4	2250	2720	2620	2720	2720	2720	2720

Table 5- 5.I.C.5 TORQUE VALUES FOR THROUGH BOLTS/BOLT-STUDS FLAT FACE FLANGES OR PLATES (TYPE I)

FLANGE OR CLAMPED PLATE MATERIAL: CRES 304 ANN, QQ-S-766							
MATING FLANGE OR CLAMPED PLATE MATERIAL: CRES 304 ANN, QQ-S-766							
THREAD LUBRICANT: P37 PASTE, A-A-59004							
TOLERANCE ON TORQUE VALUES: +/-5%							
FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)						
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7
1/4 - 20	2.1	2.7	3.8	6.3	7.2	8.9	5.5
5/16 - 18	4.0	5.4	7.4	12	13	13	11
3/8 - 16	6.9	9.2	13	17	17	17	17
7/16 - 14	11	15	21	34	34	34	30
1/2 - 13	17	22	31	41	41	41	41
5/8 - 11	33	44	61	81	81	81	81
3/4 - 10	58	77	106	126	126	126	126
7/8 - 9	93	124	108	199	199	199	199
1 - 8	139	186	162	297	297	297	297
1 1/8 - 7	198	264	231	423	423	423	423
1 1/4 - 7	276	368	322	573	573	573	573
1 3/8 - 6	364	485	424	769	769	769	769
1 1/2 - 6	478	638	558	989	989	989	989
1 3/4 - 5	756	1010	882	1460	1580	1580	1580
2 - 4.5	1130	1510	1320	2190	2340	2340	2340
2 1/4 - 4.5	1640	2190	1910	3170	3300	3300	3300
2 1/2 - 4	2250	2990	2620	4340	4530	4530	4530

Table 5- 5.I.C.6 TORQUE VALUES FOR THROUGH BOLTS/BOLT-STUDS FLAT FACE FLANGES OR PLATES (TYPE I)

FLANGE OR CLAMPED PLATE MATERIAL: HY-80 PLATE, MIL-S-21952C

MATING FLANGE OR CLAMPED PLATE MATERIAL: HY-80 PLATE, MIL-S-21952C

THREAD LUBRICANT: P37 PASTE, A-A-59004

TOLERANCE ON TORQUE VALUES: +/-5%

FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)						
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7
1/4- 20	2.1	2.7	3.8	6.3	7.2	8.9	5050
5/16 - 18	4.0	5.4	7.4	12	14	17	11
3/8 - 16	6.9	9.2	13	21	24	30	18
7/16 - 14	11	15	21	34	39	49	30
1/2 - 13	17	22	31	51	59	73	45
5/8 - 11	33	44	61	101	116	143	88
3/4 - 10	58	77	106	178	203	252	155
7/8 - 9	93	124	108	285	325	403	248
1 - 8	139	186	162	427	487	603	371
1 1/8 - 7	198	264	231	534	692	857	527
1 1/4 - 7	276	368	322	744	965	1190	735
1 3/8 - 6	364	485	424	982	1270	1580	970
1 1/2 - 6	478	638	558	1290	1670	2070	1280
1 3/4 - 5	756	1010	882	1460	2650	3280	2020
2 - 4.5	1130	1510	1320	2190	3970	4910	3020
2 1/4- 4.5	1640	2190	1910	3170	5740	7100	4370
2 1/2 - 4	2250	2990	2620	4340	7860	9730	5990

Table 5- 5.II.A.1 TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: NiCu PLATE, QQ-N-281

CLASS A FLANGE OR CLAMPED PLATE MATERIAL: NiCu PLATE, QQ-N-281 CLASS A

THREAD LUBRICANT: Fel-Pro C5-A, MIL-A-907

TOLERANCE ON TORQUE VALUES: +/-5%

FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)							
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7	STRENGTH GROUP 8
1/4 - 20	2	6	3	4	6	7	8 *	8 *
5/16 - 18	4	13	6	8	13	15	15 *	15 *
3/8 - 16	8	23	10	14	23	26	27 *	27 *
7/16 - 14	12	36	16	22	36	42	43 *	43 *
1/2- 13	18	54	24	33	54	63	64 *	64 *
5/8 - 11	36	107	48	65	107	125	125 *	125 *
3/4- 10	54	188	83	115	188	216 *	216 *	216 *
7/8 - 9	87	302	118	202	302	346 *	346 *	346 *
1 - 8	131	427	176	301	452	518 *	518 *	518 *
1 1/8 - 7	185	605	249	427	569	743 *	743 *	743 *
1 1/4 - 7	258	844	347	596	794	1014 *	1014 *	1014 *
1 3/8 - 6	340	1111	458	785	1046	1361 *	1361 *	1361 *
1 1/2 - 6	447	1462	602	1032	1376	1761 *	1761 *	1761 *
1 3/4 - 5	706	2309	951	1575	N/A	2819 *	2819 *	2819 *
2 - 4.5	1058	3458	1424	2360	N/A	4219 *	4219 *	4219 *
2 1/4- 4.5	1530	5003	2060	3414	N/A	5982 *	5982 *	5982 *
2 1/2 - 4	2095	6848	2820	4672	N/A	8243 *	8243 *	8243 *

*Denotes Shear Stress of tapped hole as limiting factor

Table 5- 5.II.A.1.a TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: CuNi 70-30 PLATE, MIL-C-20159

FLANGE OR CLAMPED PLATE MATERIAL: NiCu PLATE, QQ-N-281 CLASS A

THREAD LUBRICANT: Fel-Pro C5-A, MIL-A-907

TOLERANCE ON TORQUE VALUES: +/-5%

FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)							
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7	STRENGTH GROUP 8
1/4 - 20	2	6 *	3	4	6 *	6 *	6 *	6 *
5/16 - 18	4	12 *	6	8	12 *	12 *	12 *	12 *
3/8 - 16	8	21 *	10	14	21 *	21 *	21 *	21 *
7/16 - 14	12	34 *	16	22	34 *	34 *	34 *	34 *
1/2 - 13	18	51 *	24	33	51 *	51 *	51 *	51 *
5/8 - 11	36	100 *	48	65	100 *	100 *	100 *	100 *
3/4 - 10	54	173 *	83	115	173 *	173 *	173 *	173 *
7/8 - 9	87	277 *	118	202	277 *	277 *	277 *	277 *
1 - 8	131	415 *	176	301	415 *	415 *	415 *	415 *
1 1/8 - 7	185	594 *	249	427	594 *	594 *	594 *	594 *
1 1/4 - 7	258	811 *	347	596	811 *	811 *	811 *	811 *
1 3/8 - 6	340	1089 *	458	785	1089 *	1089 *	1089 *	1089 *
1 1/2 - 6	447	1409 *	602	1032	1409 *	1409 *	1409 *	1409 *
1 3/4 - 5	706	2255 *	951	1575	N/A	2255 *	2255 *	2255 *
2 - 4.5	1058	3375 *	1424	2360	N/A	3375 *	3375 *	3375 *
2 1/4 - 4.5	1530	4786 *	2060	3414	N/A	4786 *	4786 *	4786 *
2 1/2 - 4	2095	6595 *	2820	4672	N/A	6595 *	6595 *	6595 *

*Denotes Shear Stress of tapped hole as limiting factor

Table 5- 5.II.A.1.b TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: HY-8O, MIL-S-16216								
FLANGE OR CLAMPED PLATE MATERIAL: NiCu PLATE, QQ-N-281 CLASS A								
THREAD LUBRICANT: Fel-Pro C5-A, MIL-A-907								
TOLERANCE ON TORQUE VALUES: +/-5%								
FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)							
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7	STRENGTH GROUP 8
1/4 - 20	2	6	3	4	6	7	10	8 **
5/16 - 18	4	13	6	8	13	15	19	17 **
3/8 - 16	8	23	10	14	23	26	25 *	31 **
7/16 - 14	12	36	16	22	36	42	50 *	51 **
1/2 - 13	18	54	24	33	54	63	59 *	77 **
5/8 - 11	36	107	48	65	107	125	116 *	155 **
3/4 - 10	54	188	83	115	188	219	183 *	271 **
7/8 - 9	87	302	118	202	302	353	288 *	408 **
1 - 8	131	427	176	301	452	527	430 *	620 **
1 1/8 - 7	185	605	249	427	569	747	612 *	898 **
1 1/4 - 7	258	844	347	596	794	1042	831 *	1325 **
1 3/8 - 6	340	1111	458	785	1046	1372	1114 *	1670 **
1 1/2 - 6	447	1462	602	1032	1376	1806	1433 *	2168 **
1 3/4 - 5	706	2309	951	1575	N/A	2852	2285 *	3498 **
2 - 4.5	1058	3458	1424	2360	N/A	4272	3398 *	5260 **
2 1/4 - 4.5	1530	6003	2060	3414	N/A	6180	4785 *	7470 **
2 1/2 - 4	2095	6848	2820	4672	N/A	8459	6575 *	10323 **

**Denotes Bearing Stress under cap screw head as limiting factor

*Denotes Bearing Stress under nut as limiting factor

Table 5- 5.II.A.1.c TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: Bronze, Cast Valves, MIL-B-16541								
FLANGE OR CLAMPED PLATE MATERIAL: NiCu PLATE, QQ-N-281 CLASS A								
THREAD LUBRICANT: Fel-Pro C5-A, MIL-A-907								
TOLERANCE ON TORQUE VALUES: +/-5%								
FASTENER SIZE UNC	**FASTENER TORQUE (FT-LBS)**							
	STRENGTH GROUP 1	**STRENGTH GROUP 2**	**STRENGTH GROUP 3**	**STRENGTH GROUP 4**	**STRENGTH GROUP 5**	**STRENGTH GROUP 6**	**STRENGTH GROUP 7**	**STRENGTH GROUP 8**
1/4 - 20	2	4 *	3	4 *	4 *	4 *	4 *	4 *
5/16 - 18	4	7 *	6	7 *	7 *	7 *	7 *	7 *
3/8 - 16	8	12 *	10	12 *	12 *	12 *	12 *	12 *
7/16 - 14	12	19 *	16	19 *	19 *	19 *	19 *	19 *
1/2 - 13	18	29 *	24	29 *	29 *	29 *	29 *	29 *
5/8 - 11	36	56 *	48	56 *	56 *	56 *	56 *	56 *
3/4 - 10	54	97 *	83	97 *	97 *	97 *	97 *	97 *
7/8 - 9	87	156 *	118	156 *	156 *	156 *	156 *	156 *
1 - 8	131	233 *	176	233 *	233 *	233 *	233 *	233 *
1 1/8 - 7	185	334 *	249	334 *	334 *	334 *	334 *	334 *
1 1/4 - 7	258	456 *	347	456 *	456 *	456 *	456 *	456 *
1 3/8 - 6	340	613 *	458	613 *	613 *	613 *	613 *	613 *
1 1/2 - 6	447	793 *	602	793 *	793 *	793 *	793 *	793 *
1 3/4 - 5	706	1268 *	951	1268 *	N/A	1268 *	1268 *	1268 *
2 - 4.5	1058	1896 *	1424	1898 *	N/A	1896 *	1896 *	1898 *
2 1/4 - 4.5	1530	2692 *	2060	2692 *	N/A	2692 *	2692 *	2692 *
2 1/2 - 4	2095	3709 *	2820	3709 *	N/A	3709 *	3709 *	3709 *

*Denotes Shear Stress of tapped hole as limiting factor

Table 5- 5.II.A.2 TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: CuNi 70-30 PLATE, MIL-C-20159

FLANGE OR CLAMPED PLATE MATERIAL: CuNi 70-30 PLATE, MIL-C-20159

THREAD LUBRICANT: Fel-Pro C5-A, MIL-A-907

TOLERANCE ON TORQUE VALUES: +/-5%

FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)							
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7	STRENGTH GROUP 8
1/4 - 20	2	6 *	3	4	6 *	6 *	6 *	6 *
5/16 - 18	4	12 *	6	8	12 *	12 *	12 *	12 *
3/8 - 16	8	21 *	10	14	21 *	21 *	21 *	21 *
7/16 - 14	12	34 *	16	22	34 *	34 *	34 *	34 *
1/2 - 13	18	51 *	24	33	51 *	51 *	51 *	51 *
5/8 - 11	36	100 *	48	65	100 *	100 *	100 *	100 *
3/4 - 10	54	173 *	83	115	173 *	173 *	173 *	173 *
7/8 - 9	87	277 *	118	202	277 *	277 *	277 *	277 *
1 - 8	131	415 *	176	301	415 *	415 *	415 *	415 *
1 1/8 - 7	185	594 *	249	427	569	594 *	594 *	594 *
1 1/4 - 7	258	811 *	347	596	794	811 *	811 *	811 *
1 3/8 - 6	340	1089 *	458	785	1046	1089 *	1089 *	1089 *
1 1/2 - 6	447	1409 *	602	1032	1376	1409 *	1409 *	1409 *
1 3/4 - 5	706	2255 *	951	1575	N/A	2255 *	2255 *	2255 *
2 - 4.5	1058	3375 *	1424	2360	N/A	3375 *	3375 *	3375 *
2 1/4 - 4.5	1530	4786 *	2060	3414	N/A	4786 *	4786 *	4786 *
2 1/2 - 4	2095	6595 *	2820	4672	N/A	6595 *	6595 *	6595 *

*Denotes Shear Stress of tapped hole as limiting factor

Table 5- 5.II.A.2.a TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: HY-80, MIL-S-16216								
FLANGE OR CLAMPED PLATE MATERIAL: CuNi 70-30 PLATE, MIL-C-20159								
THREAD LUBRICANT: Fel-Pro C5-A, MIL-A-907								
TOLERANCE ON TORQUE VALUES: +/-5%								
FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)							
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7	STRENGTH GROUP 8
1/4 - 20	2	6	3	4	6	10	10	7 **
5/16 - 18	4	13	6	8	13	15 *	15 *	14 **
3/8 - 16	8	23	10	14	23	20 *	20 *	25 **
7/16 - 14	12	36	16	22	36	40 *	40 *	41 **
1/2 - 13	18	54	24	33	54	48 *	48 *	62 **
5/8 - 11	36	107	48	65	107	93 *	93 *	124 **
3/4 - 10	54	188	83	115	188	146 *	146 *	217 **
7/8 - 9	87	302	118	202	302	231 *	231 *	326 **
1 - 8	131	427	176	301	452	344 *	344 *	496 **
1 1/8 - 7	185	605	249	427	569	490 *	490 *	719 **
1 1/4 - 6	258	844	347	596	794	664 *	664 *	988 **
1 3/8 - 6	340	1111	458	785	1046	891 *	891 *	1336 **
1 1/2 - 6	447	1462	602	1032	1376	1147 *	1147 *	1735 **
1 3/4 - 5	706	2309	951	1575	N/A	1828 *	1828 *	2799 **
2 - 4.5	1058	3458	1424	2360	N/A	2718 *	2718 *	4208 **
2 1/4 - 4.5	1530	5003	2060	3414	N/A	3828 *	3828 *	5976 **
2 1/2 - 4	2095	6848	2820	4672	N/A	5260 *	5260 *	8258 **

**Denotes Bearing Stress under cap screw head as limiting factor

*Denotes Bearing Stress under nut as limiting factor

Table 5- 5.II.A.3 TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: INCONEL 625, ASTM B443-75								
FLANGE OR CLAMPED PLATE MATERIAL: INCONEL 625, ASTM B443-75								
THREAD LUBRICANT: Fel-Pro C5-A, MIL-A-907								
TOLERANCE ON TORQUE VALUES: +/-5%								
FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)							
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7	STRENGTH GROUP 8
1/4 - 20	2	6	3	4	6	7	9	11
5/16 - 18	4	13	6	8	13	15	19	22
3/8 - 16	8	23	10	14	23	26	33	39
7/16 - 14	12	36	16	22	36	42	52	62
1/2 - 13	18	54	24	33	54	63	78	93
5/8 - 11	36	107	48	65	107	125	154	178
3/4 - 10	54	188	83	115	188	219	271	313
7/8 - 9	87	302	118	202	302	353	437	504
1 - 8	131	427	176	301	452	527	652	753
1 1/8 - 7	185	605	249	427	569	747	925	1068
1 1/4 - 7	258	844	347	596	794	1042	1290	1489
1 3/8 - 6	340	1111	458	785	1046	1373	1700	1961
1 1/2 - 6	447	1462	602	1032	1376	1806	2236	2580
1 3/4 - 5	706	2309	951	1575	N/A	2852	3531	4074
2 - 4.5	1058	3458	1424	2360	N/A	4272	5289	6103
2 1/4 - 4.5	1530	5003	2059	3414	N/A	6180	7651	8828
2 1/2 - 4	2095	6848	2820	4672	N/A	8459	10473	12084

Table 5- 5.II.A.4 TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: BRONZE, CAST VALVES, MIL-B-16541								
FLANGE OR CLAMPED PLATE MATERIAL: BRONZE, CAST VALVES, MIL-B-16541								
THREAD LUBRICANT: Fel-Pro C5-A, MIL-A-907								
TOLERANCE ON TORQUE VALUES: +/-5%								
FASTENER SIZE UNC	**FASTENER TORQUE (FT - LBS)**							
	STRENGTH GROUP 1	**STRENGTH GROUP 2**	**STRENGTH GROUP 3**	**STRENGTH GROUP 4**	**STRENGTH GROUP 5**	**STRENGTH GROUP 6**	**STRENGTH GROUP 7**	**STRENGTH GROUP 8**
1/4 - 20	2	4 *	3	4 *	4 *	4 *	4 *	4 *
5/16 - 18	4	7 *	6	7 *	7 *	7 *	7 *	7 *
3/8 - 16	8	12 *	10	12 *	12 *	12 *	12 *	12 *
7/16 - 14	12	19 *	16	19 *	19 *	19 *	19 *	19 *
1/2 - 13	18	29 *	24	29 *	29 *	29 *	29 *	29 *
5/8 - 11	36	56 *	48	56 *	56 *	56 *	56 *	56 *
3/4 - 10	54	97 *	83	97 *	97 *	97 *	97 *	97 *
7/8 - 9	87	156 *	118	156 *	156 *	156 *	156 *	156 *
1 - 8	131	233 *	176	233 *	233 *	233 *	233 *	233 *
1 1/8 - 7	185	334 *	249	334 *	334 *	334 *	334 *	334 *
1 1/4 - 7	258	456 *	347	456 *	456 *	456 *	456 *	456 *
1 3/8 - 6	340	613 *	458	613 *	613 *	613 *	613 *	613 *
1 1/2 - 6	447	793 *	602	793 *	793 *	793 *	793 *	793 *
1 3/4 - 5	706	1268 *	951	1268 *	N/A	1268 *	1268 *	1268 *
2 - 4.5	1058	1899 *	1424	1899 *	N/A	1899 *	1899 *	1899 *
2 1/4 - 4.5	1530	2692 *	2060	2692 *	N/A	2692 *	2692 *	2692 *
2 1/2 - 4	2095	3710 *	2820	3710 *	N/A	3710 *	3710 *	3710 *

*Denotes Shear Stress of tapped hole as limiting factor

Table 5- 5.II.A.4.a TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: HY-80, PLATE, MIL-S-16216								
FLANGE OR CLAMPED PLATE MATERIAL: BRONZE, CAST VALVES, MIL-B-16541								
THREAD LUBRICANT: Fel-Pro C5-A, MIL-A-907								
TOLERANCE ON TORQUE VALUES: +/-5%								
FASTENER SIZE UNC	**FASTENER TORQUE (FT-LBS)**							
	STRENGTH GROUP 1	**STRENGTH GROUP 2**	**STRENGTH GROUP 3**	**STRENGTH GROUP 4**	**STRENGTH GROUP 5**	**STRENGTH GROUP 6**	**STRENGTH GROUP 7**	**STRENGTH GROUP 8**
1/4 - 20	2	6 *	3	4	6 *	6 *	6 *	4 **
5/16 - 18	4	9 *	6	8	9 *	9 *	9 *	8 **
3/8 - 16	8	11 *	10	11 *	11 *	11 *	11 *	14 **
7/16 - 14	12	23 *	16	22	23 *	23 *	23 *	23 **
1/2 - 13	18	27 *	24	27 *	27 *	27 *	27 *	35 **
5/8 - 11	36	52 *	47	52 *	52 *	52 *	52 *	70 **
3/4 - 10	54	82 *	83	82 *	82 *	82 *	82 *	121 **
7/8 - 9	87	130 *	118	130 *	130 *	130 *	130 *	183 **
1 - 8	131	193 *	176	193 *	193 *	193 *	193 *	279 **
1 1/8 - 7	185	275 *	249	275 *	275 *	275 *	275 *	404 **
1 1/4 - 7	258	374 *	347	374 *	374 *	374 *	374 *	556 **
1 3/8 - 6	340	501 *	458	501 *	501 *	501 *	501 *	751 **
1 1/2 - 6	447	645 *	602	645 *	645 *	645 *	645 *	976 **
1 3/4 - 5	706	1028 *	951	1028 *	N/A	1028 *	1028 *	1574 **
2 - 4.5	1058	1529 *	1424	1529 *	N/A	1529 *	1529 *	2367 **
2 1/4 - 4.5	1530	2153 *	2060	2153 *	N/A	2153 *	2153 *	3362 **
2 1/2 - 4	2095	2959 *	2820	2959 *	N/A	2959 *	2959 *	4645 **

*Denotes Bearing Stress under nut as limiting factor

**Denotes Bearing Stress under cap screw head as limiting factor

Table 5- 5.II.A.5 TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: CRES 304, ANNEALED, QQ-S-766								
FLANGE OR CLAMPED PLATE MATERIAL: CRES 304, ANNEALED, QQ-S-766								
THREAD LUBRICANT: Fel-Pro C5-A, MIL-A-907								
TOLERANCE ON TORQUE VALUES: +/-5%								
FASTENER SIZE UNC	**FASTENER TORQUE (FT-LBS)**							
	STRENGTH GROUP 1	**STRENGTH GROUP 2**	**STRENGTH GROUP 3**	**STRENGTH GROUP 4**	**STRENGTH GROUP 5**	**STRENGTH GROUP 6**	**STRENGTH GROUP 7**	**STRENGTH GROUP 8**
1/4 - 20	2	6 *	3	4	6 *	6 *	6 *	6 *
5/16 - 18	4	12 *	6	8	12 *	12 *	12 *	12 *
3/8 - 16	8	20 *	10	14	20 *	20 *	20 *	20 *
7/16 - 14	12	32 *	16	22	32 *	32 *	32 *	32 *
1/2 - 13	18	48 *	24	33	48 *	48 *	48 *	48 *
5/8 - 11	36	94 *	48	65	94 *	94 *	94 *	94 *
3/4 - 10	54	162 *	83	115	162 *	162 *	162 *	162 *
7/8 - 9	87	259 *	118	202	259 *	259 *	259 *	259 *
1 - 8	131	389 *	176	301	389 *	389 *	389 *	389 *
1 1/8 - 7	185	557 *	249	427	557 *	557 *	557 *	557 *
1 1/4 - 7	258	761 *	347	596	761 *	761 *	761 *	761 *
1 3/8 - 6	340	1021 *	458	785	1021 *	1021 *	1021 *	1021 *
1 1/2 - 6	447	1321 *	602	1008	1321 *	1321 *	1321 *	1321 *
1 3/4 - 5	706	2114 *	951	1575	2114 *	2114 *	2114 *	2114 *
2 - 4.5	1058	3164 *	1424	2360	3164 *	3164 *	3164 *	3164 *
2 1/4 - 4.5	1530	4487 *	2060	3414	4487 *	4487 *	4487 *	4487 *
2 1/2 - 4	2095	6182 *	2820	4672	6182 *	6182 *	6182 *	6182 *

*Denotes Shear Stress of tapped hole as limiting factor

Table 5- 5.II.A.6 TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: HY-80 PLATE, MIL-S- 16216								
FLANGE OR CLAMPED PLATE MATERIAL: HY-80 PLATE, MIL-S-16216								
THREAD LUBRICANT: Fel-Pro C5-A, MIL-A-907								
TOLERANCE ON TORQUE VALUES: +/-5%								
FASTENER SIZE UNC	**FASTENER TORQUE (FT-LBS)**							
	STRENGTH GROUP 1	**STRENGTH GROUP 2**	**STRENGTH GROUP 3**	**STRENGTH GROUP 4**	**STRENGTH GROUP 5**	**STRENGTH GROUP 6**	**STRENGTH GROUP 7**	**STRENGTH GROUP 8**
1/4 - 20	2	6	3	4	6	7	9	11
5/16 - 18	4	13	6	8	13	15	19	22
3/8 - 16	8	23	10	14	23	26	33	39
7/16 - 14	12	36	16	22	36	42	52	62
1/2 - 13	18	54	24	33	54	63	78	93
5/8 - 11	36	107	48	65	107	125	154	178
3/4 - 10	54	188	83	115	188	219	271	313
7/8 - 9	87	302	118	202	302	353	467	504
1 - 8	131	427	176	301	452	527	652	753
1 1/8 - 7	185	605	249	427	569	747	925	1068
1 1/4 - 7	258	844	347	596	794	1042	1290	1489
1 3/8 - 6	340	1111	458	785	1046	1373	1700	1961
1 1/2 - 6	447	1462	602	1032	1376	1806	2236	2580
1 3/4 - 5	706	2309	951	1575	N/A	2851	3531	4074
2 - 4.5	1058	3458	1424	2360	N/A	4272	5289	6103
2 1/4 - 4.5	1530	5003	2060	3414	N/A	6180	7651	8828
2 1/2 - 4	2095	6848	2820	4672	N/A	8459	10473	12084

Table 5- 5.II.B.1 TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: NiCu PLATE, QQ-N-281, Class A								
FLANGE OR CLAMPED PLATE MATERIAL: NiCu PLATE, QQ-N-281, Class A								
THREAD LUBRICANT: MOLYKOTE M-77/MOLYKOTE Gn, MIL-L-24478								
TOLERANCE ON TORQUE VALUES: +/-5%								
FASTENER SIZE UNC	**FASTENER TORQUE (FT-LBS)**							
	STRENGTH GROUP 1	**STRENGTH GROUP 2**	**STRENGTH GROUP 3**	**STRENGTH GROUP 4**	**STRENGTH GROUP 5**	**STRENGTH GROUP 6**	**STRENGTH GROUP 7**	**STRENGTH GROUP 8**
1/4 - 20	2	6	2	3	5	6	6 *	6 *
5/16 - 18	4	9	5	6	10	12	12 *	12 *
3/8 - 16	6	16	9	11	17	20	21 *	21 *
7/16 - 14	10	25	14	17	28	32	33 *	33 *
1/2 - 13	15	38	20	26	42	49	49 *	49 *
5/8 - 11	30	74	40	50	82	96	96 *	96 *
3/4 - 10	46	129	70	88	144	165 *	165 *	165 *
7/8 - 9	74	207	90	138	231	264 *	264 *	264 *
1 - 8	110	292	134	206	345	396 *	396 *	396 *
1 1/8 - 7	156	414	190	293	435	567 *	567 *	567 *
1 1/4 - 7	217	574	264	405	604	771 *	771 *	771 *
1 3/8 - 6	286	769	349	536	797	1038 *	1038 *	1038 *
1 1/2 - 6	376	994	457	701	1045	1338 *	1338 *	1338 *
1 3/4 - 5	594	1572	723	1198	N/A	2144 *	2144 *	2144 *
2 - 4.5	888	2351	1082	1793	N/A	3206 *	3206 *	3206 *
2 1/4 - 45	1282	3379	1558	2582	N/A	4525 *	4525 *	4525 *
2 1/2 - 4	1755	4628	2134	3636	N/A	6239 *	6239 *	6239 *

*Denotes Shear Stress of tapped hole as limiting factor

Table 5- 5.II.B.1.a TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: CuNi 70-30 PLATE, MIL-C-20159								
FLANGE OR CLAMPED PLATE MATERIAL: NiCu, QQ-N-281, Class A								
THREAD LUBRICANT: MOLYKOTE M-77/MOLYKOTE Gn, MIL-L-24478								
TOLERANCE ON TORQUE VALUES: +/-5%								
FASTENER SIZE UNC	**FASTENER TORQUE (FT-LBS)**							
	STRENGTH GROUP 1	**STRENGTH GROUP 2**	**STRENGTH GROUP 3**	**STRENGTH GROUP 4**	**STRENGTH GROUP 5**	**STRENGTH GROUP 6**	**STRENGTH GROUP 7**	**STRENGTH GROUP 8**
1/4 - 20	2	5 *	2	3	5 *	5 *	5 *	5 *
5/16 - 18	3	9 *	4	6	9 *	9 *	9 *	9 *
3/8 - 16	5	15 *	7	10	15 *	15 *	15 *	15 *
7/16 - 14	8	24 *	11	15	24 *	24 *	24 *	24 *
1/2 - 13	13	35 *	17	23	35 *	35 *	35 *	35 *
5/8 - 11	25	69 *	33	45	69 *	69 *	69 *	69 *
3/4 - 10	38	119 *	57	79	119 *	119 *	119 *	119 *
7/8 - 9	60	190 *	81	138	190 *	190 *	190 *	190 *
1 - 8	89	284 *	120	206	284 *	284 *	284 *	284 *
1 1/8 - 7	127	407 *	171	293	390	407 *	407 *	407 *
1 1/4 - 7	176	552 *	237	405	540	552 *	552 *	552 *
1 5/8 - 6	232	744 *	313	536	715	744 *	744 *	744 *
1 1/2 - 6	304	958 *	409	701	935	958 *	958 *	958 *
1 3/4 - 5	481	1535 *	647	1073	N/A	1535 *	1535 *	1535 *
2 - 4.5	719	2294 *	968	1604	N/A	2294 *	2294 *	2294 *
2 1/4 - 4.5	1034	3232 *	1391	2305	N/A	3232 *	3232 *	3232 *
2 1/2 - 4	1416	4457 *	1906	3158	N/A	4457 *	4457 *	4457 *

*Denotes Shear Stress of tapped hole as limiting factor

Table 5- 5.II.B.1.b TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: HY-80, MIL-S-16216								
FLANGE OR CLAMPED PLATE MATERIAL: NiCu, QQ-N-281, Class A								
THREAD LUBRICANT: MOLYKOTE M-77/MOLYKOTE Gn, MIL-L-24478								
TOLERANCE ON TORQUE VALUES: +/-5%								
FASTENER SIZE UNC	**FASTENER TORQUE (FT/LBS)**							
	STRENGTH GROUP 1	**STRENGTH GROUP 2**	**STRENGTH GROUP 3**	**STRENGTH GROUP 4**	**STRENGTH GROUP 5**	**STRENGTH GROUP 6**	**STRENGTH GROUP 7**	**STRENGTH GROUP 8**
1/4 - 20	2	5	2	3	5	5	7	6 **
5/16 - 18	3	9	4	6	9	11	13	12 **
3/8 - 16	5	16	8	10	16	18	17 *	22 **
7/16 - 14	8	25	12	15	25	29	35 *	36 **
1/2 - 13	13	38	19	23	38	44	41 *	54 **
5/8 - 11	25	74	37	45	74	86	80 *	107 **
3/4 - 10	37	129	64	79	129	151	126 *	186 **
7/8 - 9	56	207	81	138	207	242	198 *	279 **
1 - 8	89	292	120	206	309	361	294 *	424 **
1 1/8 - 7	127	414	171	293	390	512	419 *	615 **
1 1/4 - 7	176	574	237	405	541	709	565 *	841 **
1 3/8 - 6	232	759	313	536	715	938	761 *	1141 **
1 1/2 - 6	304	994	409	704	935	1227	974 *	1473 **
1 3/4 - 5	481	1572	647	1072	N/A	1942	1555 *	2382 **
2 - 4.5	719	2351	968	1604	N/A	2904	2308 *	3576 **
2 1/4 - 4.5	1034	3379	1391	2305	N/A	4174	3230 *	5045 **
2 1/2 - 4	1416	4628	1906	3158	N/A	5717	4441 *	6977 **

**Denotes Searing Stress under cap screw head as limiting factor

*Denotes Bearing Stress Under nut as limiting factor

Table 5- 5.II.B.1.c TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: Bronze, Cast Valves, MIL-B-16541

FLANGE OR CLAMPED PLATE MATERIAL: NiCu, PLATE, QQ-N-281, Class A

THREAD LUBRICANT: MOLYKOTE M-77/MOLYKOTE Gn, MIL-L-24478

TOLERANCE ON TORQUE VALUES: +/-5%

FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)							
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7	STRENGTH GROUP 8
1/4 - 20	2	3 *	2	3 *	3 *	3 *	3 *	3 *
5/16 - 18	3	5 *	4	5 *	5 *	5 *	5 *	5 *
3/8 - 16	5	8 *	7	8 *	8 *	8 *	8 *	8 *
7/16 - 14	8	13 *	11	13 *	13 *	13 *	13 *	13 *
1/2 - 13	13	20 *	17	20 *	20 *	20 *	20 *	20 *
5/8 - 11	25	39 *	33	39 *	39 *	39 *	39 *	39 *
3/4 - 10	37	67 *	57	67 *	67 *	67 *	67 *	67 *
7/8 - 9	56	107 *	81	107 *	107 *	107 *	107 *	107 *
1 - 8	89	160 *	120	160 *	160 *	160 *	160 *	160 *
1 1/8 - 7	127	229 *	171	229 *	229 *	229 *	229 *	229 *
1 1/4 - 7	176	311 *	237	311 *	311 *	311 *	311 *	311 *
1 3/8 - 6	232	419 *	313	419 *	419 *	419 *	419 *	419 *
1 1/2 - 6	304	539 *	409	539 *	539 *	539 *	539 *	539 *
1 3/4 - 5	481	862 *	647	862 *	N/A	862 *	862 *	862 *
2 - 4.5	719	1291 *	968	1291 *	N/A	1291 *	1291 *	1291 *
2 1/4 - 4.5	1034	1818 *	1391	1818 *	N/A	1818 *	1818 *	1818 *
2 1/2 - 4	1416	2507 *	1906	2507 *	N/A	2507 *	2507 *	2507 **

*Denotes Shear Stress of tapped hole as limiting factor

**Denotes Bearing Stress under cap screw head as limiting factor

Table 5- 5.II.B.2 TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: CuNi 70-30 PLATE, MIL-C-201 59

FLANGE OR CLAMPED PLATE MATERIAL: CuNi 70-30 PLATE, MIL-C-20159

THREAD LUBRICANT: MOLYKOTE M-77/MOLYKOTE Gn, MIL-L-24478

TOLERANCE ON TORQUE VALUES: +/-5%

FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)							
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7	STRENGTH GROUP 8
1/4 - 20	2	5 *	2	3	5 *	5 *	5 *	5 *
5/16 - 18	3	9 *	4	6	9 *	9 *	9 *	9 *
3/8 - 16	6	15 *	7	10	15 *	15 *	15 *	15 *
7/16 - 14	9	24 *	11	15	24 *	24 *	24 *	24 *
1/2 - 13	14	35 *	17	23	35 *	35 *	35 *	235 *
5/8 - 11	27	69 *	33	45	69 *	69 *	69 *	69 *
3/4 - 10	42	119 *	57	79	119 *	119 *	119 *	119 *
7/8 - 9	67	190 *	81	138	190 *	190 *	190 *	190 *
1 - 8	100	284 *	120	206	284 *	284 *	284 *	284 *
1 1/8 - 7	141	407 *	171	293	390	407 *	407 *	407 *
1 1/4 - 7	196	552 *	237	405	541	552 *	552 *	552 *
1 3/8 - 6	259	744 *	313	536	715	744 *	744 *	744 *
1 1/2 - 6	340	958 *	409	701	935	958 *	958 *	958 *
1 3/4 - 5	537	1535 *	647	1073	N/A	1535 *	1535 *	1535 *
2 - 4.5	804	2294 *	968	1604	N/A	2294 *	2294 *	2294 *
2 1/4 - 4.5	1158	3232 *	1391	2305	N/A	3232 *	3232 *	3232 *
2 1/2 - 4	1585	4457 *	1906	3158	N/A	4457 *	4457 *	4457 *

*Denotes Shear Stress of tapped hole as limiting factor

Table 5- 5.II.B.2.a TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: HY-80, MIL-S-16216

FLANGE OR CLAMPED PLATE MATERIAL: CuNi 70-30 PLATE, MIL-C-20159

THREAD LUBRICANT: MOLYKOTE M-77/MOLYKOTE Gn, MIL-L-24478

TOLERANCE ON TORQUE VALUES: +/-5%

FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)							
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7	STRENGTH GROUP 8
1/4 - 20	2	5	2	3	5	7	7	5 **
5/16 - 18	3	9	4	6	9	11 *	11 *	10 **
3/8 - 16	5	16	8	10	16	14 *	14 *	18 **
7/16 - 14	8	25	12	15	25	28 *	28 *	29 **
1/2 - 13	13	38	19	23	38	33 *	33 *	43 **
5/8 - 11	25	74	37	45	74	64 *	64 *	86 **
3/4 - 10	37	129	64	79	129	101 *	101 *	149 **
7/8 - 9	60	207	81	138	207	158 *	158 *	223 **
1 - 8	89	292	120	206	309	235 *	235 *	339 **
1 1/8 - 7	127	414	171	293	390	335 *	335 *	492 **
1 1/4 - 7	176	574	237	405	541	452 *	452 *	673 **
1 3/8 - 6	232	759	313	536	715	609 *	609 *	913 **
1 1/2 - 6	304	994	409	701	935	779 *	779 *	1179 **
1 3/4 - 5	481	1572	647	1073	N/A	1244 *	1244 *	1905 **
2 - 4.5	719	2351	968	1604	N/A	1847 *	1847 *	2861 **
2 1/4 - 4.5	1034	3379	1391	2305	N/A	2584 *	2584 *	4036 **
2 1/2 - 4	1416	4628	1906	3158	N/A	3553 *	3553 *	5581 **

*Denotes Bearing Stress under nut as limiting factor

Table 5- 5.II.B.3 TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: INCONEL 625, ASTM B443-75								
FLANGE OR CLAMPED PLATE MATERIAL: INCONEL 625, ASTM B443-75								
THREAD LUBRICANT: MOLYKOTE M-77/MOLYKOTE Gn, MIL-L-24478								
TOLERANCE ON TORQUE VALUES: +/-5%								
FASTENER SIZE UNC	**FASTENER TORQUE (FT-LBS)**							
	STRENGTH GROUP 1	**STRENGTH GROUP 2**	**STRENGTH GROUP 3**	**STRENGTH GROUP 4**	**STRENGTH GROUP 5**	**STRENGTH GROUP 6**	**STRENGTH GROUP 7**	**STRENGTH GROUP 8**
1/4 - 20	2	5	2	3	5	5	7	8
5/16 - 18	3	9	4	6	9	11	13	16
3/8 - 16	6	16	7	10	16	18	23	27
7/16 - 14	9	25	11	15	25	29	36	43
1/2 - 13	14	38	17	23	38	44	54	65
5/8 - 11	27	74	33	45	74	86	107	123
3/4 - 10	42	129	57	79	129	151	186	215
7/8 - 9	67	207	81	138	207	242	299	345
1 - 8	100	292	120	206	309	361	447	515
1 1/8 - 7	141	414	171	293	390	512	634	731
1 1/4 - 7	196	574	237	405	541	709	878	1014
1 3/8 - 6	259	759	313	536	715	938	1161	1340
1 1/2 - 6	340	994	409	701	935	1227	1520	1753
1 3/4 - 5	537	1572	647	1073	N/A	1942	2404	2774
2 - 4.5	804	2351	968	1604	N/A	2904	3596	4149
2 1/4- 4.5	1158	3379	1391	2305	N/A	4174	5167	5962
2 1/2 - 4	1585	4628	1906	3158	N/A	5717	7078	8167

Table 5- 5.II.B.4 TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: BRONZE, CAST VALVES, MIL-B-16541								
FLANGE OR CLAMPED PLATE MATERIAL: BRONZE, CAST VALVES, MIL-B-16541								
THREAD LUBRICANT: MOLYKOTE M-77/MOLYKOTE Gn, MIL-L-24478								
TOLERANCE ON TORQUE VALUES: +/-5%								
FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)							
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7	STRENGTH GROUP 8
1/4 - 20	2	3 *	2	3 *	3 *	3 *	3 *	3 *
5/16 - 18	3	5 *	4	5 *	5 *	5 *	5 *	5 *
3/8 - 16	6	8 *	7	8 *	8 *	8 *	8 *	8 *
7/16 - 14	9	13 *	11	13 *	13 *	13 *	13 *	13 *
1/2 - 13	14	20 *	17	20 *	20 *	20 *	20 *	20 *
5/8 - 11	27	39 *	33	39 *	39 *	39 *	39 *	39 *
3/4 - 10	42	67 *	57	67 *	67 *	67 *	67 *	67 *
7/8 - 9	67	107 *	81	107 *	107 *	107 *	107 *	107 *
1 - 8	100	160 *	120	160 *	160 *	160 *	160 *	160 *
1 1/8 - 7	141	229 *	171	229 *	229 *	229 *	229 *	229 *
1 1/4 - 7	196	311 *	237	311 *	311 *	311 *	311 *	311 *
1 3/8 - 6	259	419 *	313	419 *	419 *	419 *	419 *	419 *
1 1/2 - 6	340	539 *	409	539 *	539 *	539 *	539 *	539 *
1 3/4 - 5	537	864	647	864 *	N/A	864 *	864 *	864 *
2 - 4.5	804	1291 *	968	1291 *	N/A	1291 *	1291 *	1291 *
2 1/4- 4.5	1158	1818 *	1391	1818 *	N/A	1818 *	1818 *	1818 *
2 1/2 - 4	1585	2507 *	1906	2507 *	N/A	2507 *	2507 *	2507 *

*Denotes Shear Stress of tapped hole as limiting factor

Table 5- 5.II.B.4.a TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: HY-80, MIL-S-16216

FLANGE OR CLAMPED PLATE MATERIAL: BRONZE, CAST VALVES, MIL-B-16541

THREAD LUBRICANT: MOLYKOTE M-77/MOLYKOTE Gn, MIL-L-24478

TOLERANCE ON TORQUE VALUES: +/-5%

FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)							
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7	STRENGTH GROUP 8
1/4 - 20	2	4 ***	2	3	5 *	5 *	5 *	3 **
5/16 - 18	3	6 *	4	6	6 *	6 *	6 *	6 **
3/8 - 16	6	8 *	8	8 *	8 *	8 *	8 *	10 **
7/16 - 14	9	16 *	12	15	16 *	16 *	16 *	16 **
1/2 - 13	14	19 *	19	19 *	19 *	19 *	19 *	24 **
5/8 - 11	27	36 *	36	36 *	36 *	36 *	36 *	48 **
3/4 - 10	42	57 *	64	57 *	57 *	57 *	57 *	84 **
7/8 - 9	67	89 *	81	89 *	89 *	89 *	89 *	126 **
1 - 8	100	132 *	120	132 *	132 *	132 *	132 *	191 **
1 1/8 - 7	141	189 *	171	189 *	189 *	189 *	189 *	277 **
1 1/4 - 7	196	254 *	236	254 *	254 *	254 *	254 *	378 **
1 3/8 - 6	259	342 *	313	342 *	342 *	342 *	342 *	513 **
1 1/2 - 6	340	438 *	409	438 *	438 *	438 *	438 *	663 **
1 3/4 - 5	537	700 *	647	700 *	N/A	700 *	700 *	1072 **
2 - 4.5	804	1039 *	968	1039 *	N/A	1039 *	1039 *	1609 **
2 1/4 - 4.5	1158	1453 *	1391	1453 *	N/A	1453 *	1453 *	2270 **
2 1/2 - 4	1585	1999 *	1906	1999 *	N/A	1999 *	1999 *	3139 **

***Denotes Shear Stress of nut as limiting factor

*Denotes Bearing Stress under nut as limiting factor

**Denotes Bearing Stress under cap screw head as limiting factor

Table 5- 5.II.B.5 TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: CRES 304, ANNEALED, QQ-S-766

FLANGE OR CLAMPED PLATE MATERIAL: CRES 304, ANNEALED, QQ-S-766

THREAD LUBRICANT: MOLYKOTE M-77/MOLYKOTE Gn, MIL-L-24478

TOLERANCE ON TORQUE VALUES: +/-5%

FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)							
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7	STRENGTH GROUP 8
1/4 - 20	2	5 *	2	3	5 *	5 *	5 *	5 *
5/16 - 18	4	9 *	5	6	9 *	9 *	9 *	9 *
3/8 - 16	6	16 *	9	11	16 *	16 *	16 *	16 *
7/16 - 14	10	25 *	14	17	25 *	25 *	25 *	25 *
1/2 - 13	15	37 *	20	26	37 *	37 *	37 *	37 *
5/8 - 11	30	72 *	40	50	72 *	72 *	72 *	72 *
3/4 - 10	46	124 *	70	88	124 *	124 *	124 *	124 *
7/8 - 9	74	198 *	90	154	198 *	198 *	198 *	198 *
1 - 8	110	297 *	134	230	297 *	297 *	297 *	297 *
11/8 - 7	156	425 *	190	326	425 *	425 *	425 *	425 *
1 1/4 - 7	217	578 *	264	453	578 *	578 *	578 *	578 *
1 3/8 - 6	286	778 *	349	598	778 *	778 *	778 *	778 *
11/2 - 6	376	1004	457	784	1004	1004	1004	1004
13/4 - 5	594	1608 *	723	1198	N/A	1608 *	1608 *	1608 *
2 - 4.5	888	2404 *	1082	1792	N/A	2404 *	2404 *	2404 *
2 1/4 - 4.5	1282	3394 *	1558	2582	N/A	3394 *	3394 *	3394 *
2 1/2 - 4	1755	4679 *	2134	3536	N/A	4679 *	4679 *	4679 *

*Denotes Shear Stress of tapped hole as limiting factor

Table 5- 5.II.B.6 TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: HY-80 PLATE, MIL-S-16216								
FLANGE OR CLAMPED PLATE MATERIAL: HY-80 PLATE, MIL-S-16216								
THREAD LUBRICANT: MOLYKOTE M-77/MOLYKOTE Gn, MIL-L-24478								
TOLERANCE ON TORQUE VALUES: +/-5%								
FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)							
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7	STRENGTH GROUP 8
1/4 - 20	2	5	2	3	5	5	7	8
5/16 - 18	3	9	4	6	9	11	13	16
3/8 - 16	6	16	8	10	16	18	23	27
7/16 - 14	9	25	12	15	25	29	36	43
1/2 - 13	14	38	19	23	38	44	54	65
5/8 - 11	27	74	37	45	74	86	107	123
3/4 - 10	42	129	64	79	129	151	186	215
7/8 - 9	67	207	81	138	207	242	299	345
1 - 8	100	292	120	206	309	361	447	515
1 1/8 - 7	141	414	171	293	390	512	634	731
1 1/4 - 7	196	574	237	405	541	709	878	1014
1 3/8 - 6	259	759	313	536	715	938	1161	1340
1 1/2 - 6	340	994	409	701	935	1227	1519	1753
1 3/4 - 5	537	1572	647	1073	N/A	1942	2404	2774
2 - 4.5	804	2371	968	1604	N/A	2904	3596	4149
2 1/4 - 4.5	1158	3379	1391	2305	N/A	4174	5167	5962
2 1/2 - 4	1585	4628	1906	3157	N/A	5717	7078	8167

Table 5- 5.II.C.1 TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: CuNi 70-30 PLATE, MIL-C-20159

FLANGE OR CLAMPED PLATE MATERIAL: NiCu PLATE, QQ-N-281 CLASS A

THREAD LUBRICANT: P37 PASTE, A-A-59004

TOLERANCE ON TORQUE VALUES: +/-5%

FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)							
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7	STRENGTH GROUP 8
1/4 - 20	2	5.5	2.5	4	6	6	6	6
5/16 - 18	4	11	5.5	7.5	11	12	12	12
3/8 - 16	7	18	9	13	21	21	21	21
7/16 - 14	11	30	15	21	34	34	34	34
1/2 - 13	17	45	22	31	48	48	48	48
5/8 - 11	33	88	44	61	90	90	90	90
3/4 - 10	58	155	77	106	160	160	160	160
7/8 - 9	93	248	125	160	255	255	255	255
1 - 8	140	335	185	250	375	375	375	375
1 1/8 - 7	200	525	265	340	535	535	535	535
1 1/4 - 7	280	730	370	470	705	705	705	705
1 3/8 - 6	365	930	485	630	950	950	950	950
1 1/2 - 6	480	1280	640	1250	1250	1250	1250	1250
1 3/4 - 5	760	2020	1000	1460	1460	1950	1950	1950
2 - 4.5	1130	3000	1500	2200	2200	3100	3100	3100
2 1/4 - 4.5	1640	4200	2200	3200	3200	4300	4300	4300
2 1/2 - 4	2250	5750	3000	4350	4350	5900	5900	5900

Table 5- 5.II.C.2 TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: HY-80, MIL-S-16216								
FLANGE OR CLAMPED PLATE MATERIAL: HY-80, MIL-S-16216								
THREAD LUBRICANT: P37 PASTE, A-A-59004								
TOLERANCE ON TORQUE VALUES: +/-5%								
FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)							
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7	STRENGTH GROUP 8
1/4 - 20	2	5.5	2.7	4	6	7	9	9.5
5/16 - 18	4	11	5.5	7.5	12	14	17	18
3/8 - 16	7	18	9	13	21	23	23	23
7/16 - 14	11	30	15	21	34	39	47	47
1/2 - 13	17	45	22	31	51	55	55	55
5/8 - 11	33	88	44	61	101	107	107	107
3/4 - 10	58	155	77	106	169	169	169	169
7/8 - 9	93	248	124	160	266	266	266	266
1 - 8	139	371	186	240	396	396	396	396
1 1/8 - 7	198	527	264	330	534	564	564	564
1 1/4 - 7	276	735	368	460	744	764	764	764
1 3/8 - 6	364	970	485	610	982	1030	1030	1030
1 1/2 - 6	478	1280	638	1290	1290	1320	1320	1320
1 3/4 - 5	756	2020	1010	1460	1460	2100	2100	2100
2 - 4.5	1130	3020	1510	2190	2190	3130	3130	3130
2 1/4 - 4.5	1640	4370	2190	3170	3170	4400	4400	4400
2 1/2 - 4	2250	5990	2990	4340	4340	6040	6040	6040

Table 5- 5.II.C.3 TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: CuNi 70-30 PLATE, MIL-C-20159

FLANGE OR CLAMPED PLATE MATERIAL: CuNi 70-30 PLATE, MIL-C-20159

THREAD LUBRICANT: P37 PASTE, A-A-59004

TOLERANCE ON TORQUE VALUES: +/-5%

FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)							
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7	STRENGTH GROUP 8
1/4 - 20	2	5.5	3	4	6	7	7	7
5/16 - 18	4	11	5.5	7.5	11	12	12	12
3/8 - 16	7	18	9.5	13	18	18	18	18
7/16 - 14	11	30	15	21	30	30	30	30
1/2 - 13	17	44	22	31	44	44	44	44
5/8 - 11	33	86	44	61	86	86	86	86
3/4 - 10	58	135	77	100	135	135	135	135
7/8 - 9	93	213	124	160	215	215	215	215
1 - 8	139	317	186	240	320	320	320	320
1 1/8 - 7	198	451	264	340	450	450	450	450
1 1/4 - 7	276	611	368	475	610	610	610	610
1 3/8 - 6	364	820	485	625	820	820	820	820
1 1/2 - 6	478	1050	638	1050	1050	1050	1050	1050
1 3/4 - 5	756	1680	1010	1460	1460	1680	1680	1680
2 - 4.5	1130	2500	1510	2190	2190	2500	2500	2500
2 1/4 - 4.5	1640	3520	2190	3170	3170	3500	3500	3500
2 1/2 - 4	2250	4800	2990	4350	4350	4800	4800	4800

Table 5- 5.II.C.4 TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: HY-80, MIL-S-16216								
FLANGE OR CLAMPED PLATE MATERIAL: CuNi 70-30 PLATE, MIL-C-20159								
THREAD LUBRICANT: P37 PASTE, A-A-59004								
TOLERANCE ON TORQUE VALUES: +/-5%								
FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)							
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7	STRENGTH GROUP 8
1/4 - 20	2	5.5	3	4	6	7	9	9
5/16 - 18	4	11	5.5	8	12	14	14	14
3/8 - 16	7	18	9	13	18	18	18	18
7/16 - 14	11	30	15	21	34	37	37	37
1/2 - 13	17	44	22	31	44	44	44	44
5/8 - 11	33	86	44	60	86	86	86	86
3/4 - 10	58	135	77	110	135	135	135	135
7/8 - 9	93	215	125	160	215	215	215	215
1 - 8	139	320	186	235	320	320	320	320
1 1/8 - 7	198	450	265	330	450	450	450	450
1 1/4 - 7	276	610	368	460	610	610	610	610
1 3/8 - 6	364	820	485	610	820	820	820	820
1 1/2 - 6	478	1050	638	1050	1050	1050	1050	1050
1 3/4 - 5	756	1680	1010	1460	1460	1680	1680	1680
2 - 4.5	1130	2500	1510	2190	2190	2500	2500	2500
2 1/4 - 4.5	1640	3520	2190	3170	3170	3520	3520	3520
2 1/2 - 4	2250	4830	2990	4350	4350	4830	4830	4830

Table 5- 5.II.C.5 TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: INCONEL 625, ASTM B443-75								
FLANGE OR CLAMPED PLATE MATERIAL: INCONEL 625, ASTM B443-75								
THREAD LUBRICANT: P37 PASTE, A-A-59004								
TOLERANCE ON TORQUE VALUES: +/-5%								
FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)							
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7	STRENGTH GROUP 8
1/4 - 20	2	5.5	3	4	6	7	9	9.5
5/16 - 18	4	11	5.5	7	12	13	17	18
3/8 - 16	7	18	9	13	21	23	23	23
7/16 - 14	11	30	15	21	34	39	47	47
1/2 - 13	17	45	22	31	50	55	55	55
5/8 - 11	33	88	44	61	100	105	105	105
3/4 - 10	58	155	77	106	170	170	170	170
7/8 - 9	95	248	125	160	270	265	265	265
1 - 8	140	375	185	240	400	395	395	395
1 1/8 - 7	200	530	265	335	540	565	565	565
1 1/4 - 7	275	735	370	465	750	765	765	765
1 3/8 - 6	365	970	485	610	980	1030	1030	1030
1 1/2 - 6	480	1280	640	1290	1300	1320	1320	1320
1 3/4 - 5	760	2020	1010	1460	1460	2100	2100	2100
2 - 4.5	1130	3020	1510	2200	2200	3150	3150	3150
2 1/4 - 4.5	1640	4370	2200	3200	3200	4400	4400	4400
2 1/2 - 4	2250	6000	3000	4350	4350	6000	6000	6000

Table 5- 5.II.C.6 TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: BRONZE, CAST VALVES, MIL-B-16541								
FLANGE OR CLAMPED PLATE MATERIAL: BRONZE, CAST VALVES, MIL-B-16541								
THREAD LUBRICANT: P37 PASTE, A-A-59004								
TOLERANCE ON TORQUE VALUES: +/-5%								
FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)							
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7	STRENGTH GROUP 8
1/4 - 20	2	5	3	3.5	4	4	4	4
5/16 - 18	4	8	5.5	7	6	7	7	7
3/8 - 16	7	10	9	10	10	10	10	10
7/16 - 14	11	20	15	16	18	18	18	18
1/2 - 13	17	25	22	25	25	25	25	25
5/8 - 11	33	48	44	48	48	48	48	48
3/4 - 10	58	76	76	76	76	76	76	76
7/8 - 9	93	120	120	120	120	120	120	120
1 - 8	140	178	178	178	178	178	178	178
1 1/8 - 7	198	255	255	255	255	255	255	255
1 1/4 - 7	275	345	345	345	345	345	345	345
1 3/8 - 6	365	465	465	465	465	465	465	465
1 1/2 - 6	480	595	595	595	595	595	595	595
1 3/4 - 5	755	950	950	950	950	950	950	950
2 - 4.5	1130	1410	1410	1410	1410	1410	1410	1410
2 1/4 - 4.5	1650	1980	1980	1980	1980	1980	1980	1980
2 1/2 - 4	2250	2720	2720	2720	2720	2720	2720	2720

Table 5- 5.II.C.7 TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: HY-80, PLATE, MIL-S-16216								
FLANGE OR CLAMPED PLATE MATERIAL: BRONZE, CAST VALVES, MIL-B-16541								
THREAD LUBRICANT: P37 PASTE, A-A-59004								
TOLERANCE ON TORQUE VALUES: +/-5%								
FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)							
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7	STRENGTH GROUP 8
1/4 - 20	2	6	3	4	6	6	6	6
5/16 - 18	4	8	5.5	7.5	8	8	8	8
3/8 - 16	7	10	9	10	10	10	10	10
7/16 - 14	11	21	15	21	21	21	21	21
1/2 - 13	17	25	22	25	25	25	25	25
5/8 - 11	33	50	45	50	50	50	50	50
3/4 - 10	58	80	80	80	80	80	80	80
7/8 - 9	93	120	120	120	120	120	120	120
1 - 8	140	180	180	180	180	180	180	180
1 1/8 - 7	200	255	255	255	255	255	255	255
1 1/4 - 7	275	345	345	345	345	345	345	345
1 3/8 - 6	365	465	465	465	465	465	465	465
1 1/2 - 6	480	595	595	595	595	595	595	595
1 3/4 - 5	760	950	950	950	950	950	950	950
2 - 4.5	1130	1410	1410	1410	1410	1410	1410	1410
2 1/4 - 4.5	1650	1980	1980	1980	1980	1980	1980	1980
2 1/2 - 4	2250	2720	2720	2720	2720	2720	2720	2720

Table 5- 5.II.C.8 TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: CRES 304, ANNEALED, QQ-S-766								
FLANGE OR CLAMPED PLATE MATERIAL: CRES 304, ANNEALED, QQ-S-766								
THREAD LUBRICANT: P37 PASTE, A-A-59004								
TOLERANCE ON TORQUE VALUES: +/-5%								
FASTENER SIZE UNC	FASTENER TORQUE (FT-LBS)							
	STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUP 4	STRENGTH GROUP 5	STRENGTH GROUP 6	STRENGTH GROUP 7	STRENGTH GROUP 8
1/4 - 20	2	5.5	2.5	4	6	6	6	6
5/16 - 18	4	10	5.5	7.5	12	12	12	12
3/8 - 16	7	17	9	13	17	17	17	17
7/16 - 14	11	30	15	21	30	30	30	30
1/2 - 13	17	41	22	31	41	41	41	41
5/8 - 11	33	81	44	61	81	81	81	81
3/4 - 10	58	126	77	110	130	130	130	130
7/8 - 9	93	200	125	160	200	200	200	200
1 - 8	140	300	190	240	300	300	300	300
1 1/8 - 7	200	425	265	335	425	425	425	425
1 1/4 - 7	280	575	370	470	575	575	575	575
1 3/8 - 6	365	770	485	620	770	770	770	770
1 1/2 - 6	480	990	640	990	990	990	990	990
1 3/4 - 5	760	1580	1010	1460	1460	1580	1580	1580
2 - 4.5	1130	2340	1510	2190	2190	2340	2340	2340
2 1/4 - 4.5	1640	3300	2190	3170	3170	3300	3300	3300
2 1/2 - 4	2250	4530	2990	4350	4350	4530	4530	4530

Table 5- 5.II.C.9 TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: HY-80 PLATE, MIL-S-16126								
FLANGE OR CLAMPED PLATE MATERIAL: HY-80 PLATE, MIL-S-16126								
THREAD LUBRICANT: P37 PASTE, A-A-59004								
TOLERANCE ON TORQUE VALUES: +/-5%								
FASTENER SIZE UNC	**FASTENER TORQUE (FT-LBS)**							
	STRENGTH GROUP 1	**STRENGTH GROUP 2**	**STRENGTH GROUP 3**	**STRENGTH GROUP 4**	**STRENGTH GROUP 5**	**STRENGTH GROUP 6**	**STRENGTH GROUP 7**	**STRENGTH GROUP 8**
1/4 - 20	2	5.5	2.5	4	6	7	9	10
5/16 - 18	4	11	5.5	7.5	12	14	17	19
3/8 - 16	7	18	9	13	21	24	30	32
7/16 - 14	11	30	15	21	34	39	49	52
1/2 - 13	17	45	22	31	51	59	73	78
5/8 - 11	33	88	44	61	101	116	145	15
3/4 - 10	58	155	77	110	180	205	255	260
7/8 - 9	93	250	125	160	285	325	405	420
1 - 8	140	370	190	240	430	490	605	630
1 1/8 - 7	200	530	265	335	535	695	860	900
1 1/4 - 7	275	735	370	470	745	965	1190	1250
1 3/8 - 6	365	970	485	620	985	1270	1580	1650
1 1/2 - 6	480	1280	640	1290	1290	1670	2070	2150
1 3/4 - 5	760	2020	1010	1460	1460	2650	3280	3400
2 - 4.5	1130	3020	1510	2190	2190	3970	4900	5100
2 1/4 - 4.5	1640	4370	2190	3170	3170	5740	7100	7400
2 1/2 - 4	2250	5990	2990	4350	4350	7860	9750	10100

Table 5- 5.II.C.10 TORQUE VALUES FOR STUDS AND CAP SCREWS FLAT FACE FLANGES OR PLATES (TYPE II)

STUD SET END OR CAPSCREW SET END MATERIAL: BRONZE, CAST VALVES, MIL-B-16541								
FLANGE OR CLAMPED PLATE MATERIAL: NiCu PLATE, QQ-N-281 CLASS A								
THREAD LUBRICANT: P37 PASTE, A-A-59004								
TOLERANCE ON TORQUE VALUES: +/-5%								
FASTENER SIZE UNC	**FASTENER TORQUE (FT-LBS)**							
	STRENGTH GROUP 1	**STRENGTH GROUP 2**	**STRENGTH GROUP 3**	**STRENGTH GROUP 4**	**STRENGTH GROUP 5**	**STRENGTH GROUP 6**	**STRENGTH GROUP 7**	**STRENGTH GROUP 8**
1/4 - 20	2	4	2.7	4	4	4	4	4
5/16 - 18	4	7	5.5	7	7	7	7	7
3/8 - 16	7	12	9	12	12	12	12	12
7/16 - 14	11	20	15	20	20	20	20	20
1/2 - 13	17	26	22	26	26	26	26	26
5/8 - 11	33	50	44	50	50	50	50	50
3/4 - 10	58	90	77	90	90	90	90	90
7/8 - 9	93	135	124	135	135	135	135	135
1 - 8	139	200	186	200	200	200	200	200
1 1/8 - 7	198	290	264	290	290	290	290	290
1 1/4 - 7	276	390	368	390	390	390	390	390
1 3/8 - 6	364	500	485	500	500	500	500	500
1 1/2 - 6	478	640	638	640	640	640	640	640
1 3/4 - 5	756	1050	1010	1050	1050	1050	1050	1050
2 - 4.5	1130	1450	1450	1450	1450	1450	1450	1450
2 1/4 - 4.5	1640	1900	1900	1900	1900	1900	1900	1900
2 1/2 - 4	2250	2640	2640	2640	2640	2640	2640	2640

Table 5- 5.III.a.1 TORQUE VALUES FOR THROUGH BOLTS, RAISED-FACE FLANGES

NAVSEA DRAWING NO. - 1385861,700 psi WP						
MATERIAL - CUNI, MIL-C-15726 or NICU, QQ-C-281						
THREAD LUBRICANT: Fel-Pro C5-A, MIL-A-907						
TOLERANCE ON TORQUE VALUES: +/-5%						
FLANGE SIZE - IPS INCHES	NUMBER OF BOLTS	FASTENER SIZE-UNC INCHES	FASTENER TORQUE (FT-LBS)			
			STRENGTH GROUP 1	STRENGTH GROUP 2	STRENGTH GROUP 3	STRENGTH GROUPS 4-7
1/2	3	1/2 - 13	10 *	10	10	10
3/4	4	1/2 - 13	10 *	11	11	11
1	4	1/2 - 13	10 *	13 *	14	14
1 - 1/4	4	1/2 - 13	11 *	14 *	17	17
1 - 1/2	6	1/2 - 13	11 *	14 *	18	18
2	6	5/8 - 11	21 *	25	25	25
2 - 1/2	6	5/8 - 11	22 *	28 *	34	34
3	8	5/8 - 11	22 *	28 *	34	34
3 - 1/2	8	5/8 - 11	23 *	29 *	40	40
4	10	5/8 - 11	23 *	29 *	34	34
5	12	5/8 - 11	24 *	30 *	40	40
6	14	5/8 - 11	25 *	31 *	41	41
8	16	5/8 - 11	28 *	35 *	46 *	51
10	17	3/4 - 10	48 *	59 *	76	76
12	20	3/4 - 10	52 *	63 *	80	80
14	22	3/4 - 10	53 *	64 *	84 *	94

*Denotes Tensile Stress of bolt is the limiting factor. For all other torques, the allowable flange yield stress is the limiting factor.

Table 5- 5.III.a.2 TORQUE VALUES FOR THROUGH BOLTS, RAISED-FACE FLANGES

NAVSEA DRAWING NO. - 1385861,700 psi WP						
MATERIAL - CUNI, MIL-C-15726 or NICU, QQ-C-281						
THREAD LUBRICANT: MOLYKOTE M-77, Gn, MIL-L-24478						
TOLERANCE ON TORQUE VALUES: +/-5%						
FLANGE SIZE - IPS INCHES	**NUMBER OF BOLTS**	**FASTENER SIZE-UNC INCHES**	**FASTENER TORQUE (FT-LBS)**			
			STRENGTH GROUP 1	**STRENGTH GROUP 2**	**STRENGTH GROUP 3**	**STRENGTH GROUPS 4-7**
1/2	3	1/2 - 13	7 *	8	7	7
3/4	4	1/2 - 13	8 *	9	8	8
1	4	1/2 - 13	8 *	11 *	9	9
1 - 1/4	4	1/2 - 13	8 *	12 *	12	12
1 - 1/2	6	1/2 - 13	8 *	12 *	12	12
2	6	5/8 - 11	16 *	21	17	17
2 - 1/2	6	5/8 - 11	17 *	24 *	23	23
3	8	5/8 - 11	17 *	24 *	23	23
3 - 1/2	8	5/8 - 11	18 *	25 *	28	28
4	10	5/8 - 11	17 *	25 *	23	23
5	12	5/8 - 11	18 *	26 *	28	28
6	14	5/8 - 11	19 *	27 *	29	29
8	16	5/8 - 11	22 *	29 *	32 *	35
10	17	3/4 - 10	37 *	50 *	53	53
12	20	3/4 - 10	40 *	53 *	55	55
14	22	3/4 - 10	41 *	54 *	58 *	65

*Denotes Tensile Stress of bolt is the limiting factor. For all other torques. the allowable flange yield stress is the limiting factor.

Table 5- 5.III.a.3 TORQUE VALUES FOR THROUGH BOLTS, RAISED-FACE FLANGES

NAVSEA DRAWING NO. - 1385861,700 psi WP						
MATERIAL - CUNI, MIL-C-15726 or NICU, QQ-C-281						
THREAD LUBRICANT: P37 PASTE, A-A-59004						
TOLERANCE ON TORQUE VALUES: +/-5%						
FLANGE SIZE - IPS INCHES	**NUMBER OF BOLTS**	**FASTENER SIZE-UNC INCHES**	**FASTENER TORQUE (FT-LBS)**			
			STRENGTH GROUP 1	**STRENGTH GROUP 2**	**STRENGTH GROUP 3**	**STRENGTH GROUPS 4-7**
1/2	3	1/2 - 13	10 *	10	10	10
3/4	4	1/2 - 13	10 *	11	11	11
1	4	1/2 - 13	10 *	13 *	14	14
1 - 1/4	4	1/2 - 13	11 *	14 *	17	17
1 - 1/2	6	1/2 - 13	11 *	14 *	18	18
2	6	5/8 - 11	21 *	25	25	25
2 - 1/2	6	5/8 - 11	22 *	28 *	34	34
3	8	5/8 - 11	22 *	28 *	34	34
3 - 1/2	8	5/8 - 11	23 *	29 *	40	40
4	10	5/8 - 11	23 *	29 *	34	34
5	12	5/8 - 11	24 *	30 *	40	40
6	14	5/8 - 11	25 *	31 *	41	41
8	16	5/8 - 11	28 *	35 *	46 *	51
10	17	3/4 - 10	48 *	59 *	76	76
12	20	3/4 - 10	52 *	63 *	80	80
14	22	3/4 - 10	53 *	64 *	84 *	94

*Denotes Tensile Stress of bolt is the limiting factor. For all other torques, the allowable flange yield stress is the limiting factor.

Table 5- 5.III.b TORQUE VALUES FOR THROUGH BOLTS, RAISED-FACE FLANGES

NAVSEA DRAWING NO. - 1385947,700 psi WP				
MATERIAL - BRONZE, MIL-B-16541				
THREAD LUBRICANT: Fel-Pro C5-A, MIL-A-907 and P37 PASTE, A-A-59004				
TORQUE VALUES ARE VALID FOR ALL STRENGTH GROUPS (1-7)				
FLANGE SIZE - IPS INCHES	NUMBER OF BOLTS	FASTENER SIZE-UNC INCHES	TORQUE IN FOOT-POUNDS *	
			FEL-PRO C5-A	MOLYKOTE M-77, Gn
1/4	3	1/2 - 13	8	6±1
3/8	3	1/2 - 13	9	7±1
1/2	3	1/2 - 13	8	6±1
3/4	4	1/2 - 13	6	5±1
1	4	1/2 - 13	8	6±1
1 - 1/4	4	1/2 - 13	9	7±1
1 - 1/2	4	1/2 - 13	10	8±1
2	6	5/8 - 11	13	10±1
2 - 1/2	6	5/8 - 11	17	13±1
3	8	5/8 - 11	22	17±2
3 - 1/2	8	5/8 - 11	27	21±2
4	10	5/8 - 11	22	17±2
5	12	5/8 - 11	27	21±2
6	14	5/8 - 11	34	26±3
8	16	5/8 - 11	45	35±4

*All torques are ±5% unless otherwise stated.

Table 5- 5.III.c TORQUE VALUES FOR THROUGH BOLTS, RAISED-FACE FLANGES

NAVSEA DRAWING NO. - 1385949,700 psi WP				
MATERIAL - BRONZE, QQ-C-390, Alloy 903 or 922				
THREAD LUBRICANT: Fel-Pro C5-A, MIL-A-907 and P37 PASTE, A-A-59004				
TORQUE VALUES ARE VALID FOR ALL STRENGTH GROUPS (1-7)				
FLANGE SIZE - IPS INCHES	NUMBER OF BOLTS	FASTENER SIZE-UNC INCHES	TORQUE IN FOOT-POUNDS *	
			FEL-PRO C5-A	MOLYKOTE M-77, Gn
3	8	5/8 - 11	12	9±1
3 - 1/2	8	5/8 - 11	17	13±1
4	10	5/8 - 11	21	16±2
5	12	5/8 - 11	29	23±2
6	14	5/8 - 11	34	26±3
8	16	5/8 - 11	55	42±5

*All torques are ±5% unless otherwise stated.

Table 5-6 TORQUE VALUES FOR SUBMARINE VALVES AND FITTINGS WITH RAISED FACE TYPE JOINTS NOT CONFORMING TO DRAWING 1385961 DESIGN

DETAIL DWG	PC#	DETAIL DWG	PC#	SIZE (INCH IPS)	TORQUE (FT-LB)	TYPICAL APPLICATION (FOR INFO ONLY) 11/A
1889623	1109	1889817	ASSY G	2-1/2	24±4	F-9 AND F-37 TO F-10 OF 2117747
1889623	1308	98587-C1	34	2	15±2	F-40 TO SD-15 OF 2142258
1889627	103	2050596	TAILPIECE	1/2	3±1/2	FL-12 OF 2118325 TO TD-169/170
1889817	ASSY A	1889623	1103	1/2	12±2	F-3 TO F-7 OF 2117620
1889817	ASSY A	2180663	1403	1/2	12±2	F-3 TO F-8 OF 2117620
1889817	ASSY G	DISTILLER	CONDENSER	2-1/2	24±4	F-10 OF 2117747 TO DISTILLER CONDENSER
1889817	ASSY RK	2181201	R1112	4	18±3	F-1 TO F-2 OF 2118081
1889817	ASSY RK	1385861	-	4	18±3	F-1 TO FL-1 OF 2118081
1889817	ASSY RK	2118091	13	4	18±3	F-1 TO FL-3 OF 2118081
1889817	ASSY RK	2181201	R1112	4	18±3	F-1 TO F-2 OF 2118082
1889817	ASSY RK	2118091	16	4	18±3	F-1 TO FL-1 OF 2118082
1889817	ASSY RK	2181201	R1112	4	18±3	F-1 TO F-2 OF 2118075
1889817	ASSY RK	1385861	-	4	18±3	F-1 TO FL-1 OF 2118075
1889817	ASSY RK	1385681	-	4	18±3	F-13 TO FL-1 OF 4448348
1889817	ASSY RK	2621-166-01	R117A	4	18±3	F-13 TO FL-4 OF 4448348
1889817	ASSY RK	2621-166- 01	R178A	4	18±3	F-13 TO F-5 OF 4448348
1889817	ASSY RK	2621-166-01	R117A	4x5	18±3	F-13 TO F-8 OF 4448348
1889817	ASSY RK	2181201	R1112	4	18±3	F-13 TO F-12 OF 4448348
1889817	ASSY RK	2417743	1	4	18±3	F-13 TO F-15 OF 4448348
1889817	ASSY RK	2147743	2	4	18±3	F-13 TO F-16 OF 448348
1889817	ASSY RK	ASW PUMP		4	18±3	F-1 OF 2118081 TO ASW PUMP #1 AND #2 SUCTION
1889817	ASSY RK	ASW PUMP		4	18±3	F-1 OF 2118082 TO ASW PUMP #1 AND #2 DISCHARGE
1889817	ASSY RK	ASW PUMP	-	4	18±3	F-1 OF 2118075 TO ASW PUMP #3
1889817	ASSY RL	2621-166- 01	R118A	5	18±3	F-14 TO F-7 OF 4448348

Table 5-6 (CONT'D) TORQUE VALUES FOR SUBMARINE VALVES AND FITTINGS WITH RAISED FACE TYPE JOINTS NOT CONFORMING TO DRAWING 1385S61 DESIGN

DETAIL DWG	PC#	DETAIL DWG	PC#	SIZE (INCH IPS)	TORQUE (FT-LB)	TYPICAL APPLICATION (FOR INFO ONLY) 11/A
1889817	ASSY RL	1385861	-	5	18±3	F-8 TO FL-2 OF 2117621
1889817	ASSY RL	2181201	R1114	-	18±3	F-8 TO F-7 OF 2117621
1889817	ASSY RL	1385861	-	5	18±3	F-8 OF 2117621 TO FL-4 OF 2117622
1889817	ASSY RM	1385861	-	6	27±4	F-10 TO FL-3 OF 2117618
1889817	ASSY RM	2181201	R1115	6	27±4	F-10 TO F-5 OF 2117618
1889817	ASSY RM	2181201	R1115	6	27±4	F-10 TO F-37 OF 2117618
1889817	ASSY RM	1385861	-	6	27±4	F-12 OF 2117621 TO FL-1 OF 2117619
1889817	ASSY RM	1385861	-	6	27±4	F-12 TO FL-4 OF 2117621
1889817	ASSY RM	2181201	R1115	6	27±4	F-12 TO F-11 OF 2117621
1889817	204	2050874	ASSY CY 1	1/2	13±1	FL-1 OF 2120328 TO ALP-247/248
2046921	8	2620-622-41	PC1 MK2	2	79±4	FL-6 OF 2046473 TO HYDROGEN DIFFUSER
2046921	9	2180944	1	2	79±4	FL-5 OF 2046473 TO ASW-908
2046931	6	2180944	1	2	18±3	FL-4 OF 2046473 TO ASW-908
2050596	TAILPC	2050596	BODY	1/2	60±3	TAILPIECE TO BODY, HOV-21/23 OF 2142019
2050874	TAILPC	2050874	BODY	1	83±4	TAILPIECE TO BODY, ALP-277/278 OF 2142019
2050882	TAILPC	2050882	BODY	1-1/2	47±2	TAILPIECE TO BODY, TD-62/63 OF 2142019
2050886	TAILPC	2050886	BODY	2	100±5	TAILPIECE TO BODY, PL-200/201 OF 2568640
2050894	BODY	HULL INSERT	-	3	398±20	VALVE TO HULL, TD-18/65 OF 2142022
2050956	BODY	HULL INSERT	-	6	1382±70	VALVE TO HULL, ASW-63/202 OF 2142022
2109800	BODY	HULL INSERT	-	4	398±20	VALVE TO HULL, ASW-213/214 OF 2142022
2110262	20	2110262	8	1/2	12±1	BODY TO BONNET, DSW-41 OF 2142753
2110262	25	2110262	8	1/2	12±1	BODY TO BONNET, DSW-31 OF 2142019

Table 5-6 (CONT'D) TORQUE VALUES FOR SUBMARINE VALVES AND FITTINGS WITH RAISED FACE TYPE JOINTS NOT CONFORMING TO DRAWING 1385861 DESIGN

DETAIL DWG	PC#	DETAIL DWG	PC#	SIZE (INCH IPS)	TORQUE (FT-LB)	TYPICAL APPLICATION (FOR INFO ONLY) 11/A
2117969	10	2119012	2	3	18±3	F-5 TO TD-5 OF 2117685
2117969	11	2180671	BODY	5	18±3	F-3 TO F-2 OF 2117685
2118093	R14	2180687	BODY	4	18±3	F-11 TO FW/SH HX #1 AND FL-1 OF 2118021
2118103	19	2119300	1	3	18±3	FL-3 OF 2117991 TO ALP-127 AND ALP-128
2119581	11	LIBR ABSORB	-	6	18±3	FL-6 OF 2117654 TO LIBR AC ABSORBER
2120327	R1	LIBR CONDSR	-	5	18±3	F-25 OF 2117654 TO LIBR AC CONDSR & FL-4 OF 2117654
2120473	3	1889817	5	2-1/2	24±4	F-38 TO F-10 OF 2117747
2142150	PC1 MK2	2180944	1	2	79±4	HYDROGEN DIFFUSER TO ASW-740 OF 2159819
2142150	PC1 MK2	2142150	15	2	55±3	HYDROGEN DIFFUSER TO FL-1 OF 2142141
2142150	12	2142150	PC1 MK1	1/2	219±10	HYDROGEN DIFFUSER TO PC-12 OF 2142150
2142700	1	MSW PUMP	-	12	105±5	FL-4 OF 2481278 TO MSW PUMP SUCTION
2142701	1	2143625	6	12	216±20	FL-2 OF 2481278 AND 2481280 TO MSW-1/5, 2/6, 3/7, AND 4/8 TAILPIECE OF 2143622
2144045	22	2144045	2	10	68±3	FLG TO TAILPIECE OF 2144044 (MSW-85)
2144045	4	2144045	1	10	68±3	FLG TO BODY OF 2144044 (MSW-85)
2145492	1	HULL INSERT	-	5	847±40	VALVE TO HULL, HOV-1/3 OF 2145492
2146281	15	2146281	18 MK1	1/2	219±10	DIFFUSER FLANGE TO DIF-FUSER
2146281	18 MK1	2146426	1	2	55±3	DIFFUSER OF 2146281 TO OG-64/65
2146281	18 MK2	2180944	1	2	79±4	DIFFUSER OF 2146281 TO ASW-740
2146329	R1	2050597	4	1/2	13±1	F-49 OF 2120328 TO ALP-255/256
2147743	1	2180756	22	4	18±3	F-15 TO ASW-625 OF 4448348

Table 5-6 (CONT'D) TORQUE VALUES FOR SUBMARINE VALVES AND FITTINGS WITH RAISED FACE TYPE JOINTS NOT CONFORMING TO DRAWING 1385861 DESIGN - Continued

DETAIL DWG	PC#	DETAIL DWG	PC#	SIZE (INCH IPS)	TORQUE (FT-LB)	TYPICAL APPLICATION (FOR INFO ONLY) 11/A
2147743	2	2180756	22	4	18±3	F-16 TO ASW-622 OF 4448348
2148876	1	TRASH EJCT	-	2-1/2	24±4	FL-10 OF 2117671 TO TRASH EJECTOR
2180663	1410	2180671	2810	3	18±3	F-2 TO F-7 OF 2117698
2180663	1507	1889793	1	1-1/2	10±1	F-12 OF 2118325 TO TD-37 & TD-23/187
2180663	1507	2050882	4	1-1/2	10±1	F-21 OF 2118325 TO TD-46/47
2180663	1508	2050886	TAILPC	2	14±2	F-9 OF 2568383 TO PL-200/201 OF 2568640
2180663	1508	2180939	1	2	14±2	F-12 TO TD-57 OF 2117664
2180663	1508	98587-C	34	2	14±2	F-34 TO SD-15 OF 2117747
2180663	1510	2050895	1	3	18±3	F-1 OF 2117698 TO TD-13/14
2180663	1510	5593	1	3	18±3	F-1 TO TD-135 OF 2095761 (SHT 148)
2180663	710	2119300	1	3	18±3	F-8 OF 2118333 TO ALP-128
2180663	910	2050894	BODY	3	18±3	F-14 OF 2142196 TO TD-18/65 OF 2142022
2180663	710	EX. GLAND CONDITION	-	3	18±3	F-1 OF 2117803 TO MN AIR EJECTOR & GLAND EXH. COND.
2180671	2810	SP1762200	1	3	18±3	F-7 TO F-6 OF 2117698
2180671	3110	2119012	1	3	18±3	F-6 TO TD-4 OF 2117685
2180671	3714	2119012	1	5	18±3	F-2 TO TD-5 OF 2117685
2180926	TAILPC	2180926	BODY	3/4	69±3	TAILPIECE TO BODY, MSW-105/ 106/107 OF 2142022
2181284	18	2181284	7	3/4	12±1	BODY TO BONNET, ASW-497 OF 2142336
2620-622-41	PC1 MK1	2620-622-41	-	1-1/2	32+3-0	HYD. DIFF. TO FL-7 OF 2046473
2621-092-01	R12A	2640-870-02	BODY	3	27±4	F-4 TO TD-225 OF 2437770
2621-166-01	R119A	R114 COND	-	5	18±3	F-4 OF 4850013 TO R114 CON-DENSER
2621-166-01	R154A	2621-927-09	4	4	18±3	F-10 TO ASW-292 OF 4527301
2621-166-01	R154A	2621-927-09	TAILPIECE	4	18±3	F-12 TO ASW-767 OF 4527161
2621-166-01	R154A	2621-927-09	TAILPIECE	4	18±3	F-4 TO ASW-276 OF 4527191

Table 5-6 (CONT'D) TORQUE VALUES FOR SUBMARINE VALVES AND FITTINGS WITH RAISED FACE TYPE JOINTS NOT CONFORMING TO DRAWING 1385861 DESIGN - Continued

DETAIL DWG	PC#	DETAIL DWG	PC#	SIZE (INCH IPS)	TORQUE (FT-LB)	TYPICAL APPLICATION (FOR INFO ONLY) 11/A
2621-166-01	R177A	CONDSR #1	R114	4	32±2	F-8 OF 4448348 TO R114 COND. #1
2621-166-01	102A	2119300	1	2	24±4	F-8 OF 4448933 TO ALP-127 AND ALP-128
2621-166-01	31A	2641-635-02	BODY	3	18±3	F-7 TO TD-224 OF 2437770
2621-166-02	R65A	2621-927-09	TAILPIECE	4	18±3	F-13 TO ASW-291 OF 4527301
2621-166-02	R83A	2621-927-09	TAILPIECE	4	18±3	F-12 TO ASW-291 OF 4527301
2621-166-02	R97A	R114 COND	-	5	18±3	F-5 OF 4850013 TO R114 CON-DENSER
2621-166-02	R97A	2621-027-09	TAILPIECE	5	18±3	F-22 TO ASW-692 OF 4527293
2621-288-01	58A	2109895	BODY	1	13±2	FL-2 OF 4448933 TO TD-24, 25, 26 & 27
2621-715-01	19A	2621-927-09	TAILPIECE	4	32±2	F-17 TO ASW-292 OF 4527301
2621-754-01	R35A	2119300	1	2	24±4	F-7 OF 4448933 TO ALP-128
2621-754-01	R55A	2621-166-01	R168A	4	18±3	F-8 TO F-9 OF 4527301
2621-754-01	25A	2621-635-02	BODY	3	18±3	F-3 TO F-20 & TD-224 OF 2437770

Table 5-7 CLASS 5 INTERFERENCE FIT STUD SETTING TORQUE VALUES IN FOOT-POUNDS

INSERTED INTO	MED STEEL		GUN METAL OR NAVAL BRASS		GUN METAL OR NAVAL BRASS		PHOS OR MANG BRONZE		PHOS OR MANG BRONZE	
	L = 1 1/4 D		L = 1 D		L = 1 1/2 D		L = 1 D		L = 1 1/2 D	
* STUD SIZE	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN
1/4 - 20	12	3	5	1	7	2	6	1	9	2
5/16 - 18	19	6	8	2	11	4	9	3	14	4
3/8 - 16	35	10	14	4	21	6	17	5	26	7
7/16 - 14	45	15	18	6	27	9	22	7	33	11
1/2 - 13	75	20	30	8	45	12	37	10	55	15
9/16 - 12	90	30	36	12	54	18	44	15	66	22
5/8 - 11	120	37	48	15	72	22	59	18	88	27
3/4 - 10	190	60	76	24	114	36	93	29	140	44
7/8 - 9	250	90	100	36	150	54	120	44	180	66
1 - 8	400	125	160	50	240	75	195	60	290	92
1 1/8 - 7	470	155	190	60	280	90	230	76	345	115
1 1/4 - 7	580	210	230	80	350	125	285	100	425	155
1 3/8 - 6	705	250	280	100	420	150	345	120	520	185
1 1/2 - 6	840	325	340	130	500	195	410	160	615	240
INSERTED INTO	70-30 CUNI		70-30 CUNI		MONEL, HTS, HARD AL BRZ		MONEL, HTS, HARD AL BRZ		NC5 HF STEEL HY-80	
	L = 1 D		L = 1 1/2 D		L = 1 D		L = 1 1/4 D		L = 1 1/4 D	
* STUD SIZE	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN
1/4 - 20	9	2	13	3	10	2	12	3	10	2
5/16 - 18	14	4	20	6	15	5	19	6	15	5
3/8 - 16	25	7	37	11	28	8	35	10	28	8
7/16 - 14	32	11	48	16	36	12	45	15	36	12
1/2 - 13	53	14	80	21	60	16	75	20	60	16
9/16 - 12	64	21	96	32	70	24	90	30	70	24
5/8 - 11	85	26	130	40	95	30	120	37	95	30
3/4 - 10	135	43	200	64	150	48	190	60	150	48
7/8 - 9	180	64	265	96	200	70	250	90	200	70
1 - 8	285	90	425	135	320	100	400	125	320	100
1 1/8 - 7	335	110	500	165	375	125	470	155	375	125
1 1/4 - 7	415	150	620	225	465	170	580	210	465	170
1 3/8 - 6	500	180	750	265	565	200	705	250	565	200
1 1/2 - 6	600	230	895	345	670	260	840	325	670	260

*Stud material - K-monel, monel, Chromium-molybdenum (CR-MO) steel, SAE grade 5 and grade 8 steel.

NOTE

Final length of engagement (L) is determined by the design agency.

Table 5-8 TORQUE VALUES FOR SET STUDS WITH VARYING LENGTHS OF ENGAGEMENT

STUD MATERIAL: NiCuAl, QQ-N-286

FLANGE OR CLAMPED PLATE MATERIAL: NiCu PLATE, QQ-N-281

STUD SET END MATERIAL: HY-80, MIL-S-16216

THREAD LUBRICANT: Fel-Pro C5-A, MIL-A-907

TOLERANCE ON TORQUE VALUES: +/-5%

FASTENER SIZE UNC	**LENGTH OF STUD ENGAGEMENT AND MAXIMUM FASTENER TORQUE (FT-LBS)**															
	0.250	**0.375**	**0.500**	**0.625**	**0.750**	**0.875**	**1.000**	**1.125**	**1.250**	**1.375**	**1.500**	**1.625**	**1.750**	**2.000**	**2.500**	**3**
1/4 - 20	7	7	7													
5/16 - 18	13	13	13													
3/8 - 16	21	22	22	22												
7/16 - 14	27	35	35	35												
1/2 - 13	34	54	54	54												
5/8 - 11		87	107	107	107	107										
3/4 - 10			176	188	188	188	188									
7/8 - 9			235	302	302	302	302	302								
1 - 8				395	452	452	452	452	452							
1 1/8 - 7					573	605	605	605	605	605	605					
1 1/4 - 7					702	844	844	844	844	844	844	844				
1 3/8 - 6						997	1111	1111	1111	1111	1111	1111	1111			
1 1/2 - 6							1386	1462	1462	1462	1462	1462	1462	1462		
1 3/4 - 5								2101	2309	2309	2309	2309	2309	2309	2309	
2 - 4.5									3044	3415	3458	3458	3458	3458	3458	
2 1/4 - 4.5										4284	4754	5003	5003	5003	5003	5003
2 1/2 - 4											5743	6324	6848	6848	6848	6848

Table 5-9 TORQUE VALUES FOR SET STUDS WITH VARYING LENGTHS OF ENGAGEMENT

STUD MATERIAL: Grade B16 Alloy Steel, MIL-S- 1222

FLANGE OR CLAMPED PLATE MATERIAL: CuNi Cast MIL-C-20159

STUD SET END MATERIAL: CuNi Cast, MIL-C-20159

THREAD LUBRICANT: Fel-Pro C5-A, MIL-A-907

TOLERANCE ON TORQUE VALUES: +/-5%

FASTENER SIZE UNC	LENGTH OF STUD ENGAGEMENT AND MAXIMUM FASTENER TORQUE (FT-LBS)															
	0.250	**0.375**	**0.500**	**0.625**	**0.750**	**0.875**	**1.000**	**1.125**	**1.250**	**1.375**	**1.500**	**1.625**	**1.750**	**2.000**	**2.500**	**3**
1/4 - 20	4	6	8	8												
5/16 - 18	6	9	13	15	15											
3/8 - 16	7	13	18	23	23	23										
7/16 - 14	10	17	24	30	30	30										
1/2 - 13	13	22	31	40	49	56	56									
5/8 - 11		33	47	61	75	88	101	110.2	110.2							
3/4 - 10			65	85	105	125	145	164.8	183.1	191	191					
7/8 - 9			96	114	141	168	196	223	250.3	275.2	287.9	287.9				
1 - 8				145	181	216	252	288	324	359.8	395.6	427.9	435.4			
1 1/8 - 7					224	270	316	361	407	453	498	543.8	585.2	627.8	627.8	
1 1/4 - 7						327	383	439	494	550	606	662	717.5	822.5	859.6	859.6
1 3/8 - 6							458	526	594	663	731	799	868	1004	1159	1159
1 1/2 - 6								617	697.6	778.3	858.9	939.5	1020	1181	1493	1500
1 3/4 - 5									930.9	1042	1152	1263	1374	1596	2039	2410
2 - 4.5										1333	1478	1623	1768	2057	2347	3216
2 1/4 - 4.5											1834	2015	2197	2560	3285	4011
2 1/2 - 4												2451	2676	3126	4026	4927

APPENDIX A

LIST OF REFERENCE MATERIAL

ANSI B1.1 Unified Inch Screw Threads (UN and UNR Thread Form) 1982

ANSI B4.1 - Preferred Limits and Fits for Cylindrical Parts

ANSI B16.5 - Steel Pipe Flanges, Flanged Valves and Fittings; 1973

ANSI B18.12 - Glossary of Terms for Mechanical Fasteners

Anti-Galling Compound per A-A-59004 (Molykote P37), Confirmatory (Phase III) Testing Scope of Work: DTD 22 Jan 1996

ASME Boiler and Pressure Vessel Code Section III, Nuclear Power Plant, Division 1

ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 2

FF-S-86 - Screw, Cap Socket-Head; 6 November 1972

Machinery's Handbook, 19th Edition, Industrial Press Incorporated

MIL-A-907 - Antiseize Compound, High Temperature (Navy); 22 June 1966

MIL-B-857A - Bolts, Nuts and Studs; 28 February 1969 (Cancelled and superseded by MIL-S-001222G)

MIL-F-18240 - Fastener, Externally Threaded, 250°F Self-Locking Element for; 25 February 1972

MIL-F-19700 - Fastener, Screw Threaded, and Related Items, Non-Magnetic; 8 May 1957

MIL-L-6082 - Lubricating Oil, Aircraft Reciprocating Engine (Piston); 21 October 1969

MIL-N-25027 - Nuts, Self-Locking, 250°F, 450°F, and 800°F, 125 KSI FTU, 60 KSI FTU, and 30 KSI FTU; 24 July 1969

MIL-S-001222G - Studs, Bolts, Hex Cap Screws, and Nuts, 13 January 1976

MIL-S-1222H - Studs, Bolts, Hex Cap Screws, Socket Head Cap Screws and Nuts, 21 October 1986

MIL-S-22473 - Sealing, Locking, and Retaining Compounds; Single Component; 11 September 1972

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MIL-STD-1371 - Inspection Procedure for Anaerobic Thread Locking Compounds; 30 April 1971

M517828 - Nut, Self-Locking, Hexagon, Regular-Height, (Nonmetallic Insert) 250°F, Nickel-Copper Alloy; 31 January 1974

MS18116 - Bolt, Bolt-stud, Stud, Stud-Bolt; Nickel-Copper-Aluminum Alloy; Special Requirements; 23 May 1969 (Superseded by MIL-S-1222)

MS24673 - Screw, Cap, Socket Head, Hexagon, Drilled Corrosion Resisting Steel, (UNF-3A); 27 January 1961

MS24677 - Screw, Cap Socket Head, Hexagon, Drilled Alloy Steel, Cadmium Coated, (UNC-3A); 27 January 1961

MS24678 - Screw, Cap Socket Head, Hexagon, Drilled Alloy Steel, Cadmium Coated, (UNF-3A); 21 November 1961

MS33540 - Safety Wiring and Cotter Pinning, General Practices for; 9 February 1973

Naval Shipboard Piping Structural Design Manual, October 1994

NAVSHIPS 0900-LP-038-8010 Ship Metallic Material Comparison and Use Guide

NAVSHIPS S9086-RX-STM-010 Chapter 505 - Piping Systems

NAVSHIPS 0902-018-2010, Section 9480 - General Requirements for Piping Systems

NAVSHIPS 0901-090-0001, Chapter 9090 - Locking Procedures and Torque Wrenches for Threaded Fasteners; September 1967

NSSN Class Submarine Safety Design Review Procedures Booklet

FED-STD-H28 - Screw-Thread Standards for Federal Services, General Services Administration

Process Instruction 5306-909-080, Hull Integrity Fasteners, Inspect and Reuse, Portsmouth Naval Shipyard

QQ-B-750 - Bronze, Phosphor, Bar, Plate, Rod, Sheet, Strip, Flat Wire, and Structural and Special Shaped Sections; 28 December 1966

QQ-C-450 - Copper-Aluminum Alloy (Aluminum Bronze) Plate, Sheet, Strip, and Bar (Copper Alloy Numbers 606, 612, 613, 614, and 628) ; 17 September 1974

QQ-C-591 - Copper-Silicon, Copper-Zinc-Silicon, and Copper-Nickel-Silicon Alloys; Rod, wire, Shapes, Forgings, and Flat Products, (Flat Wire, Strip, Sheet, Bar, and Plate); 18 April 1972

QQ-N-281 - Nickel-Copper Alloy Bar, Rod, Plate, Sheet, Strip, Wire, Forgings, and Structural and Special Shaped Sections; 26 August 1974

QQ-N-286 - Nickel-Copper-Aluminum Alloy, Wrought; 3 March 1975

Roark, Formulas for Stress and Strain, 5 th Edition

Submarine Safety (SUBSAFE) Design Review Procedure Manual, Change 7

Taylor Forge Bulletin 502 - Modern Flange Design; 1964

TRS 7650-086-001 - General Acceptance Criteria (for Surface Defects)

NSRDC Report 27-168 - Investigation of Bolting Procedures for Sea-Water Flanges; April 1972

NSRDC Report PAS-74-1 - Tightening Torque and Clamping Force Relationship for a Range of Threaded Fastener Sizes; April 1974

UM&S 5307-104 - Uniform Method & Standard, Studs, Manufacture and Installation; 1 November 1970, Naval Sea Systems Command, Prepared by Code 380, Portsmouth Naval Shipyard.

APPENDIX B

GENERAL FASTENER USAGE INFORMATION

B-1.

The subject of this manual has been limited to mechanical joints using threaded fasteners and located within the submarine material certification boundaries or the boundaries of other pressure containing piping systems such as steam, air, feedwater, and hydraulics. However, user input has established a need for some guidance in the use of threaded fasteners for general applications involving assembly of machinery, components, structural supports and their mounting systems. This need has been especially evident in the areas of fine thread (UNF) series fasteners and fasteners smaller than 1/4-20. This appendix has been developed to supply guidance in the use of threaded fasteners for applications other than mechanical joints in pressure containing systems. It is general in nature and intended for use only where specific directions are not available in applicable drawings, assembly instructions, or technical manuals. It applies to off-the-shelf commercial fasteners with class 2A/2B external/internal threads. For metric fasteners, use Appendix E of this manual.

B-2. THREAD SERIES.

While there are several different thread forms which may be encountered, only the two most common ones, the coarse thread series (UNC) and the fine thread series (UNF) will be discussed here.

a. COARSE THREADS. Threads in the coarse thread series extend from 1-64 UNC (0.0730 inches diameter) to 4-4 UNC (4 inches diameter). Coarse threads are used more often than fine threads and threads from this series are usually specified for naval shipboard machinery. They are easier to assemble, less likely to cross thread, less affected by burrs in assembly, have more thread clearance for plating, and are more desirable where corrosion or threads damage is possible. Coarse threads are recommended for threading into materials of a lower tensile strength, and are considered stronger than fine threads in sizes 1 inch and larger.

b. FINE THREADS. The fine thread series covers a range from 0-80 UNF (0.0600 inch diameter) to 1 1/2-12 UNF (1 1/2 inches diameter). Fine threaded fasteners are used widely in the aircraft and automotive industries. Since the threads are not as deep in this series, the tensile-stress area is larger than in coarse thread fasteners of the same size. For the same nominal bolt size, the clamping force which can (theoretically) be developed by a fine thread fastener is, for this reason, greater than that of a comparable coarse thread fastener, but this presupposes thread length engagement sufficient to prevent stripping and close control of all critical dimensions. Fine threads are used where length of thread engagement is short, where a small lead angle is desired for adjustment applications, or where wall thickness demands a fine pitch.

B-3.

Table B-1 and Table B-2 give suggested maximum torque values for fine (UNF) and coarse (UNC) series threaded fasteners, respectively. The torque values listed in Table B-2 also apply to fine thread fasteners larger than 5/16 inch. This is because the closer tolerances necessary for the engagement of fine thread fasteners all too often are not present at the point of assembly so that these fasteners frequently suffer through some loss of proper flank engagement.

B-4.

The values given in Table B-1 and Table B-2 are suggested maximum torque values and are based on dry fasteners (most other tables in this manual are based on the use of lubricated threads) torqued to 60 percent of yield strength (except for ferrous fasteners, which are listed at 60% of tensile strength). Note that when fasteners are lubricated, it is important to lubricate the mating face of the head or nut to be rotated, as well as the threads.

B-5. TESTING TO DETERMINE PROPER TORQUE VALUES.

A simple method is available to determine proper torque for a given fastener/joint configuration. The fastener in question is set up for tests just as torque will be applied on the job. The fastener is then stressed until some portion of the joint (usually the fastener) fractures or fails, while the peak torque to accomplish this is noted. The proper torque value is 50 to 60 percent of the fracture torque or joint failure torque. When this test method is used to establish required torque, a lot test, rather than a single article test, is recommended.

NOTE

APPLICABLE TO Table B-1 AND Table B-2

a. For fine thread (UNF) series fasteners larger than 5/16-24 use the coarse thread (UNC) series torque value from Table B-2.

b. If carbon steel fasteners are assembled without lubrication, reduce the torque figures in the tables by 10 percent when cap screws are cadmium plated. Reduce them by 20 percent when nuts and bolts are cadmium plated.

c. Reduce the torque figures in the tables by 25 to 50 percent when the fasteners are lubricated.

d. In cases where the fastener torque specified in the tables may cause a gasket to be overcompressed or extruded, fastener torque should be reduced as necessary.

Table B-1 FINE THREAD SERIES

BOLT SIZE	LOW Carbon STEEL (ASTM A 307 GR B)	18-8 St.StL. ASTM A 193 GR B8	BRASS (QQ-B-637, QQ-B-639, ASTM F-468)	SILICON BRONZE (QQ-C-591 ASTM F-468)	ALUMINUM 24ST-4 (QQ-200/3 QQ-A225/6, ASTM F-468)	316 St.StL. (QQ-S-763 MIL-S-862 ASTM A 193 GR B 9M/593	MONEL (QQ-N-281, MIL-N-24106)
	IN.-LBS	IN.-LBS	IN.-LBS	IN.-LBS	IN.-LBS	IN.-LBS	IN.-LBS
2-64	2.7	3.0	2.5	2.8	1.7	3.2	3.1
3-56	4.0	4.4	3.6	4.1	2.4	4.6	4.5
4-48	5.9	6.6	5.4	4.1	3.6	6.9	6.7
5-44	8.5	9.4	7.7	8.7	5.1	9.8	9.6
6-40	10.9	12.1	9.9	11.2	6.6	12.7	12.3
8-36	19.8	22.0	18.0	20.4	12.0	23.0	22.4
10-32	29.7	31.7	25.9	29.3	19.2	33.1	34.9
1/4-28	90	94	77	87	57	99	106
5/16-24	139	142	116	131	186	147	160

Table B-2 COARSE THREAD SERIES

BOLT SIZE	**Low Carbon STEEL (ASTM A 307) GR B)**	**18-8St.Stl. ASTM A 193 GR B8**	**BRASS (QQ-B-637, QQ-B-639, ASTM F-468)**	**SILICON BRONZE (QQ-C-591 ASTM F-468)**	**ALUMINUM 24ST-4 (QQ-200/3 Q-A225/6, ASTM F-468**	**316 St.StL. (QQ-S-763 MIL-S-862 ASTM A 193 GR B 8M/593**	**MONEL (QQ-N-281, MIL-N-24106)**
	IN.-LBS	**IN.-LBS**	**IN.-LBS**	**IN.-LBS**	**IN.-LBS**	**IN.-LBS**	**IN.-LBS**
2-56	2.2	2.5	2.0	2.3	1.4	2.6	2.5
3-48	3.5	3.9	3.2	3.6	2.1	4.0	4.0
4-40	4.7	5.2	4.3	4.8	2.9	5.5	5.3
6-32	8.7	9.6	7.9	8.9	5.3	10.1	9.8
8-32	17.8	19.8	16.2	18.4	10.8	20.7	20.2
10-24	20.8	22.8	18.6	21.2	13.8	23.8	25.9
1/4-20	65.0	75.2	61.5	68.8	45.6	78.8	85.3
5/16-18	129	132	107	123	80	138	149
3/8-16	212	236	192	219	143	247	266
7/16-14	338	376	317	349	228	393	427
1/2-13	465	517	422	480	313	542	584
9/16-12	613	682	558	632	413	713	774
5/8-11	1000	1110	907	1030	715	1160	1330
3/4-10	1259	1530	1249	1460	980	1582	1832
7/8-9	1919	2328	1905	2140	1495	2430	2775
	FT.-LBS	FT.-LBS	FT.-LBS	FT.-LBS	FT.-LBS	FT.-LBS	FT.-LBS
1 1/8-7	340	413	337	383	265	432	499
1 1/4-7	432	523	428	485	336	546	627
1 1/2-6	732	888	727	822	570	930	1064

APPENDIX C

SYSTEMS OR COMPONENTS REQUIRING SPECIFIC TORQUES (NON-NUCLEAR)

C-1.

The purpose of this appendix is to supply guidance concerning which systems and components, or portions thereof, require specific torque values when fasteners are made up. The following listing is not all-inclusive of areas which may require specific torque values (and where specific torque values are required, documentation of their application is also required), but it includes those areas where use of a specific torque is mandatory in accordance with NAVSEA requirements and practices.

NOTE

Where use of a torque wrench is not practical, alternate methods of applying a controlled preload (which also must be documented) are discussed in paragraph 4-11, paragraph 4-15, paragraph 4-16 and paragraph 4-19.

C-2.

All Hull Integrity Fasteners shall be tightened to the torque value specified on the appropriate drawing, Maintenance Standard, Technical Manual, or other applicable document. If torque values are not specified on the aforementioned documents, use torque values specified in the appropriate table or appendix of this manual.

C-3.

Seawater system flanges shall be tightened to the torque value specified on the appropriate drawing, Maintenance Standard, or other applicable document. If torque values are not specified on the aforementioned documents, use torque values specified in the appropriate table or appendix of this manual. Torque values are required for load carrying fasteners associated with the pressure containing parts of seawater system (and sea connected system) components and flange assemblies that are (or are the area equivalent of) NPS 1/2 and larger from the inboard joint of the backup valve (or equivalent) outboard and for NPS 4 and larger inboard of the backup valve. All other pressure containing seawater system (and sea connected system) and component bolted joints less than 4 NPS inboard of the backup valve shall be required to be wrench tight in accordance with a suitable installation procedure and its associated recording requirements.

NOTE

″seawater system″ is defined as, ″Any system that continuously draws suction from the sea, circulates sea water, and discharges into the sea.″ A ″sea connected system″ is defined as, ″Any system that can be open to sea in any mode of operation″.

C-4.

Submarine Steering and Diving Hydraulic Cylinders shall be assembled using the torque values specified on, in order of precedence, the applicable drawing, the applicable technical repair document (a Maintenance Standard, for example), NSTM Chapter 561, NSTM Chapter 556 or NSTM Chapter 075. Torque values are required for load carrying fasteners associated with the pressure containing parts of the hydraulic cylinders.

NOTE

The torquing of foundation hold down fasteners is required per the General Requirements invoked in Paragraph C–9, since a torque is required for them in NSTM Chapter 561.

C-5.

Hydraulic system fasteners, except those in portions of the hydraulic system that are classified ″Reduced Energy″ per the DDGOS, shall be tightened to the torque value specified on, in order of precedence, the applicable ship drawing, the applicable vendor drawing, the applicable technical repair document (a Maintenance Standard, for example), NSTM Chapter 556 or NSTM Chapter 075. Torque values are required for load carrying fasteners associated with pressure containing parts of hydraulic system components and flange assemblies not classified ″Reduced Energy″.

NOTE

″Reduced Energy″ systems are defined in NSTM Chapter 505 as systems operating at 200 psig or less and 200F or less.

C-6.

SSBN 640 Class and SSN 688 Class Shaft Seal Housing Fasteners shall be tightened to the torque values specified in TRS 0203-086-005 Rev. D.

C-7.

Main Feed, Main Steam, Auxiliary Steam, High Pressure Steam Drain, and Gland Seal and Exhaust System Fasteners, except those in portions of the systems specified above that are classified ″Reduced Energy″ per the DDGOS, shall be tightened to the torque value specified on the appropriate drawing, Maintenance Standard or other applicable document, if a torque value is specified. For joints requiring installation of a spiral wound gasket in system components and flange assemblies a controlled installation procedure is required for load carrying fasteners associated with the pressure containing parts, if not classified ″Reduced Energy″, of the systems specified above. This controlled installation procedure may require torque or gap readings, or both, to be taken; see paragraph 3-24, paragraph 3-25, and paragraph 3-29 of this manual.

NOTE

Shipyards have established procedures for the installation of spiral wound gaskets, which have been approved by NAVSEA, and these procedures would be an example of a controlled installation procedure.

C-8.

Fasteners in piping systems and components not identified in Paragraph C–2 through C-7 above shall be tightened using good shop practices to ensure a leaktight system. Note also that where fasteners not identified in paragraph C–2 through C-7 above specify a torque value for reasons such as use of a multiplier or a hydraulic wrench, the applied torque must be recorded per the requirements of paragraph C–1.

C-9.

For the systems identified in Paragraph C–2 through C-7 above, the following additional requirements apply. Fasteners in joints not part of a pressure containing boundary (structural supports and foundation hold down bolts, coupling bolts, etc.) should be torqued to a specific value when required by the applicable drawing, Maintenance Standard or technical manual.

C-10.

Assemble union joints in systems covered in paragraph C–1 through C-7 per Appendix D of this manual.

APPENDIX D

REQUIREMENTS FOR MAKE-UP OF SUBMARINE PIPING SYSTEM O-RING UNIONS (NONNUCLEAR)

D-1.

This appendix specifies the requirements for submarine piping system O-ring union joint assemblies and inspection procedures. Paragraph D–2, Paragraph D–3, and Paragraph D–4 cover, respectively, assembly of O-ring union joints in piping systems that operate at a pressure of 699 PSI or less; gas piping systems that operate at a pressure between 700 PSI and 2999 PSI and hydraulic systems that operate at pressures up to and including 3000 PSI; and gas piping systems that operate at a pressure of 3000 PSI and above. The alignment guidance given below applies only to newly installed unions. When remaking existing union joints, alignment is assumed to be correct if the union nut can be tightened most of the way by hand. Use of the torque tables in this appendix is optional. Good shop practice is generally sufficient for tightening unions. However, if it is desired to apply and document a specific torque where none is provided on drawings or other applicable documents, use the appropriate torque from the applicable table in this appendix. Other than items in this text specifically referring to O-rings, the guidance given is also generally applicable to non O-ring unions.

D-2.

This section specifies the requirements considered necessary to assemble O-ring union joints in systems that operate at a pressure of 699 PSI or less.

a. Material of union components and O-ring shall be specified by applicable drawings.

b. Surface finish of the O-ring sealing surfaces shall be as specified by applicable drawings/specifications; however, a finish of 63 RHR maximum in the O-ring groove and 125 RHR maximum on the surface areas shall not be exceeded.

c. Union joints shall be located where least affected by pipeline force due to thermal expansion or other causes. This requires that the joints be located away from pipe bends and offsets.

d. The piping shall be visually inspected to determine that the centerline of pipes joining at a union shall be parallel and intersecting.

e. To ensure that proper alignment exists, the following procedure shall be used:

   (1) Loosen the pipe hangers on sections of piping to be connected to ensure that piping lines up properly without being forced into position.

   (2) The O-ring union joint shall be checked to ensure that an angular alignment of joints is such that feeler gage dimensions taken at four equally spaced points around the circumference of the tailpiece is within 0.003 inches, measured between the tailpiece and threadpiece ends. If the variation exceeds 0.003 inches, the pipe shall be bent for correction.

   (3) Bending of piping to achieve proper alignment shall not exceed the ljmits/dimensions specified on the applicable drawings or other design documents. Honing or beat shrinking to achieve alignment is not allowed.

f. Caution shall be exercised during installation of the O-ring to prevent grit or other matter from coming in contact with the O-ring, since particulate contamination is the worst enemy of O-ring installation. All cloths used for cleaning shall be lint free, since one small thread across the O-ring can cause leakage.

Only approved system lubricants shall be used for O-ring joints; i.e., system fluid for hydraulic systems and an approved lubricant (see NSTM, NAVSEA S9086-H7-STM-000/Ch-262) for air and gas systems.

g. At assembly, lubricate the O-ring and spread lubricant lightly over the surfaces which will contact the O-ring.

Make up union joints by hand as far as possible.

WARNING

DO NOT OVERTIGHTEN UNIONS

Unions shall be tightened using a force no greater than that exerted by one man using a hand held 12 inch wrench. When tightening union nuts, it is understood that many times space is limited and a wrench of the specified length cannot be used; therefore good judgement must be used as to the correct force on the wrench. Union sealing characteristics are not affected by tightening beyond handtight. Further tightening only prevents loosening of the nut due to vibration.

If a drawing or other applicable documents specify torque requirements other than noted above, that document shall be used.

D-3.

This section specifies the requirements considered necessary to assemble O-ring union joints in submarine gas piping systems that operate at a pressure between 700 PSI and 2999 PSI and in hydraulic systems that operate at pressures up to 3000 PSI.

a. Perform steps D-2.a. through D-2.g above.

WARNING

DO NOT OVERTIGHTEN UNIONS

Tighten union nuts to the following torque values:

Size	**Torque (Foot-Pounds ±5%)**	
	Min.	**Max.**
1/8	10	25
1/4	10	25
3/8	12	30
1/2	15	40
3/4	20	50
1	25	60
1-1/4	30	75
1-1/2	35	90
2	45	120
2-1/2	60	150

D-4.

This section specifies the requirements for 3000 PSI or greater gas system O-ring union joint assemblies and inspection procedures.

NOTE

(3000 PSI hydraulic systems shall be per paragraph D–3).

a. Material of union components and O-ring shall be specified by applicable drawings.

b. Visual inspection shall be performed prior to proceeding with the union alignment, as follows:

(1) Perform inspection of the threads of the union nut and mating tailpiece to provide assurance that no galling or thread deformation exists.

(2) Inspect O-ring contact surface finish requirements.

(3) Inspect O-ring for signs of laps or cuts and certify O-ring to be 90 durometer or harder.

c. Alignment conditions shall be met when piping is supported by one man without the aid of mechanical devices, except for permanently installed hangers and foundations, as follows:

a. Maximum gap between faces shall be 0.060 inches.

b. Maximum angular displacement between faces shall be 0.010 inches.

c. Maximum axial misalignment shall be 0.050 inches.

d. The maximum allowable gap after assembly shall be 0.003 inches between O-ring contact faces. Suggested method for checking correct gap clearance is as follows:

(1) Place two 0.010 inch thick lead strips between the faces of the union joint oriented at 90° with the O-ring removed.

(2) Tighten the union nut to obtain a minimum squeeze of approximately 0.006 inches on the lead strips.

(3) Remove nut and measure lead strips to obtain maximum difference in thickness. Maximum permissible measured difference between thickness of lead strips shall be 0.003 inches.

e. When the requirements of paragraph D-4.d.3 above are met, joints shall be assembled and considered satisfactory with respect to alignment. Should measurement exceed 0.003 inches, joint must be reinspected to determine cause of deficiency.

f. Tighten union nuts to the following torque values:

Size	**Torque (Foot-Pounds ±5%)**	
	Min	**Max**
1/8	20	23
1/4	44	46
3/8	87	95
1/2	104	110
3/4	115	125
1	208	230
1-1/4	250	267
1-1/2	383	420
2	540	585
2-1/2	625	670

APPENDIX E

PC-BOLTS COMPUTER PROGRAM

Subj: PC-BOLTS COMPUTER PROGRAM

Encl: (1) PC-BOLTS User's Guide (provided under separate cover)

The PC-Bolts User's Guide provides instructions for use of PC-Bolts, a computer program for threaded fastener calculations. The program is for use on IBM Personal Computer (PC's) and compatibles. It provides a fast but thorough method of computing torque for fasteners on U.S. Naval submarines where no torque is specified on the applicable ship's drawing and technical manuals.

The result given by the PC-Bolts program are compatible with the tables in this manual, differing only when use of the program allows calculation to a more precise yield strength range than covered by the existing tables, especially Table 5-4. Whenever use of this manual is appropriate, torques calculated with the PC-Bolts program may be used.

The PC-Bolts User's Guide (Appendix E NAVSEA 0900-LP-091-6010) is provided under separate cover. It may be obtained from: Commander, Naval Sea Systems Command, Submarine Directorate, Washington, D. C. 20362.

APPENDIX F

TORQUE TABLES FOR BOLTED JOINTS

Subj: TORQUE TABLES FOR BOLTED JOINTS

Encl: Torque Tables for Bolted Joints (provided under separate cover)

Torque Tables for Bolted Joints is a compendium of torque tables from this manual with instructions for their use. It is reproduced in a 3-in. by 6-in. format designed for field use.

Torque Tables for Bolted Joints (Appendix F NAVSEA 0900-LP-091-6020) may be obtained from: Commander, Naval Sea Systems Command, Submarine Directorate, Washington D.C. 20362.

REAR SECTION

TECHNICAL MANUAL DEFICIENCY/EVALUATION REPORT(TMDER)

NOTE

Ships, training activities, supply points, depots, Naval Shipyards, and Supervisors of Shipbuilding are requested to arrange for the maximum practical use and evaluation of NAVSEA technical manuals. All errors, omissions, discrepancies, and suggestions for improvement to NAVSEA technical manuals shall be reported to the Commander, NAVSURFWARCENDIV, 4363 Missile Way, Port Hueneme, CA 93043-4307 in NAVSEA/SPAWAR Technical Manual Deficiency/ Evaluation Report (TMDER), NAVSEA Form 4160/1. To facilitate such reporting, print, complete, and mail NAVSEA Form 4160/1 below or submit TMDERS at web site http://nsdsa.phdnswc,navy.mil/tmder/tmder.htm. All feedback comments shall be thoroughly investigated and originators will be advised of action resulting therefrom. Extra copies of NAVSEA Form 4160/1 may be requisitioned from DDSP Susquehanna Pennsylvania, 05 E Street, Mechanicsburg, PA 17055-5003. (S/N 0116-LP-019-5300)

TMDER / MAILER