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	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E	REV. F	REV. G	REV. H
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FORM OWNED TO PETROBRAS N-381 REV. L.

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1 INTRODUCTION

1.1 GENERAL

1.1.1 The purpose of this specification is to ensure the proper assembly of bolts, either for pressure retaining application or structural purposes.

1.1.2 For structural bolts, the assembly and the applicable requirements shall be as indicated in Appendix B and C of this specification. Only the requirements therein listed need to be followed (e.g., joint classification and joint data sheets are not required).

1.1.3 For pressure retaining purposes, the proper technique will guarantee that all bolted joints are consistently leak-free during testing and operation. The requirements herein cited are applicable for all bolted joints, including those within process or power piping, their connections to valves, pressure vessels, boilers, tanks, rotating equipment, as well as bolted joints that are part of the pressure retaining parts of the cited equipment.

1.1.4 This technical specification defines the bolt tightening general requirements for bolted joint assemblies based on ASME B16.5/B16.47 flanges and ASME PCC-1.

1.1.5 Additional requirements shall be evaluated and included in specific assembly procedures to be issued by SELLER for the following cases:

a) API 6A and API 17D flanges.

b) Compact flanges as per NORSOK L-005 and ISO 27509.

c) GRP flanges (manufacturer's recommendations supersede this specification).

d) Flanges made from polymers, composite materials, or other brittle materials (manufacturer's recommendations supersedes this specification).

e) Clamp type and other proprietary connections (manufacturer's recommendations supersedes this specification).

1.1.6 Bolted joints that are part of pressure containing equipment (pressure vessels, heat exchangers and rotating equipment pressure-boundary bolted joints) may also be subjected to different quality requirements. The manufacturer of the equipment shall be consulted before applying the requirements of this specification.

1.1.7 Bolted joints which connect to pumps and rotating equipment (compressors and so on) are usually subject to special requirements when it comes to the alignment of the flanges prior to bolting. The manufacturer manual for equipment installation shall always be checked, and the restrictions therein cited shall always be adhered to this document.

1.1.8 Written procedures, incorporating all features of this technical specification, shall be issued by the SELLER.

1.2 DEVIATIONS

1.2.1 Alternative techniques and/or methods for specific applications may be used but shall be subject to prior approval from BUYER through a formal Technical Query.

1.2.2 Failure to observe this requirement may result in remedial work at SELLER's expenses.

1.3 SAFETY

1.3.1 SELLER shall ensure that all hand tools and hydraulic equipment are supplied with comprehensive instruction and operating manuals. Hydraulic equipment can be dangerous, particularly as high pressures are often required.

1.3.2 All involved personnel shall be trained and shall follow all safety precautions to avoid personal injury. Work permits shall be issued and strictly adhered to. Striking wrenches as it is represented in Figure 1 and spanner wrench extension tools are not allowed on the assembly of bolted joints.



Figure 1 – Striking Wrench

2 NORMATIVE REFERENCES AND DESIGN SPECIFICATIONS

Applicable codes and standards, rules and project specifications as defined in the contract are to be considered as part of this specification.

2.1 CLASSIFICATION SOCIETY RULES

2.1.1 Classification Society (CS) rules shall be observed. In case there is any conflict between CS rules and the requirements of this technical specification the more stringent shall usually apply. SELLER is recommended to submit Technical Queries to BUYER to solve the conflicts, if any.

2.1.2 Failure to observe this requirement may result in remedial work at SELLER's expense.

2.2 CODES AND STANDARDS

The following standards include provisions which, through reference in this text, constitute provisions of this technical specification. The latest issue of the references shall be used unless otherwise agreed. Other recognized standards may be used provided it can be shown that they meet or exceed the requirements of the standards referenced in this specification.

API 6A - Specification for Wellhead and Christmas Tree Equipment

API 6BX - Ring-Joint Flanges for Drilling and Production Service for Extreme Pressures

API 17D - Design and Operation of Subsea Production Systems - Subsea Wellhead and Tree Equipment

ASME B1.1 - Unified Inch Screw Threads (UN and UNR Thread Form)

ASME B1.20.1 - Pipe Threads, General Purpose (Inch)

ASME B16.5 - Pipe Flanges and Flanged Fittings

ASME B16.20 - Metallic Gaskets for Pipe Flanges – Ring Joint, Spiral Wounds and Jacketed

ASME B16.21 - Nonmetallic Flat Gaskets for Pipe Flanges

ASME B16.47 - Large Diameter Steel Flanges, NPS 26 Through NPS 60

ASME B31.1 - Power Piping

ASME B31.3 - Process Piping

ASME Boiler and Pressure Vessel Code Section VIII.

ASME PCC-1:2022 - Guidelines for Pressure Boundary Bolted Flange Joint Assembly

ASME PCC-2:2022 - Repair of Pressure Equipment and Piping

NORSOK L-005 - Compact Flanged Connections.

ISO 27509 - Compact Flanged Connections with IX Seal Ring

I-ET-3010.00-1200-431-P4X-001 THERMAL INSULATION FOR MARITIME INSTALLATIONS

I-ET-3010.00-1200-970-P4X-003 REQUIREMENTS FOR PERSONNEL QUALIFICATION AND CERTIFICATION

3 GENERAL REQUIREMENTS

3.1 COMPETENCE / TRAINING

3.1.1 Assembly and tightening of bolted joints shall only be performed by people with training and qualification in accordance with I-ET-3010.00-1200-970-P4X-003.

3.1.2 In order to assembly GRP bolted joints, bolted joint assembly personnel shall also be trained by the GRP manufacturer.

3.2 FLANGED JOINTS CLASSIFICATION

3.2.1 Joints shall be classified in either **ordinary joints** (for which assembly reports are not considered necessary) or **special joints** (for which assembly reports shall be issued). As a minimum the following features shall be considered when classifying the joints:

a) System service (type of conveyed fluid, pressure rating, design temperature).

b) Past performance of the selected joint (or joints in similar service, likelihood of a leak).

c) Inventory loss in case a leak occurs.

d) Safety and environmental consequences of a leak.

e) Access for remedial work once asset is in service.

f) Local factors – vibration, temperature cycles, slug flow, hazardous duty, etc.

g) Exposure to external fatigue loads.

3.2.2 In the absence of any BUYER's complementary document indicating the classification of the bolted joints, the following shall be considered as **special joints**:

a) Lines and equipment that will contain flammable gases and/or CO2 with pressure class above 600.

b) Lines and equipment DN> 2" and pressure class 2500 and above (as per ASME B16.5) for all fluids.

c) All flanged joints with API 6A, API 17D, NORSOK L-005 or ISO 27509 flanges.

d) Flanges connecting to load sensitive equipment (such as rotating equipment).

e) Hard pipes, riser lines, production lines.

3.2.3 Bolted joints that are part of the hull package or part of marine systems may be considered ordinary (except hard pipes and other riser related lines).

3.3 PROCEDURES, DATA SHEETS AND RECORDS

3.3.1 Bolted Joint Assembly Procedure

SELLER shall submit a detailed **Bolted Joint Assembly Procedure** for review and approval prior to commencing of work. The following special requirements shall be detailed in the procedure:

a) Specific requirements for flanges designed as per API 6A, API 17D and Compact flanges.

b) Additional features and care for Clamp Type and other proprietary connections.

c) Additional features and care for GRP (Glass Reinforced Piping), and any other composite or polymeric materials, as well as any other materials that may show brittle behavior.

d) Specific requirements for bolted joints that are part of pressure containing equipment.

e) Specific requirements for bolted joints connecting equipment with pre-determined maximum load limits (load sensitive equipment).

3.3.2 Joint Data Sheets

3.3.2.1 Besides the Bolted Joint Assembly Procedure, which shall contain all general information applicable to the assembly of all bolted joints, SELLER shall also issue **Joint Data Sheets** for all flanges that will be assembled.

3.3.2.2 These **Joint Data Sheets** shall be available at site for the bolted joint assembly team before the commencing of the assigned work, so that it will help them check the specified materials and the calculated torque and tension for each and every joint.

3.3.2.3 **Joint Data Sheets** shall follow the model included in Appendix A.

3.3.3 Joint Assembly Records

3.3.3.1 SELLER shall issue a **Joint Assembly Record** for each assembled joint classified as **special joint** (see item 3.2).

3.3.3.2 Joint Assembly Records shall include the following information:

a) Joint identification (TAG) and location.

b) Joint Data Sheet number.

c) Pressure class and diameter of the joint.

d) Dimensional check of the joint alignment prior to assembly (must include the values obtained during inspection). If the aid of alignment devices was deemed necessary, include illustration (photos) of the joint preparation showing the application of all the alignment devices. The recommendations of Appendix E of ASME PCC-1 shall be followed.

e) Material specification and preservation conditions of the joint components (bolts, nuts, washers, flanges, gaskets, bonding jumpers etc.).

f) Lubricant used.

g) Assembly procedure, tightening method and applied torque/tension.

h) Information on the tightening tools and applicable calibration certificates.

i) Quality control applied (if any).

j) Electric resistance measured in between flanges.

k) Date of assembly.

l) Name of the professionals who performed the assembly.

m) Name and signature of the Bolting Assembler/Bolting Inspector.

3.3.3.3 The Joint Assembly Records shall have the minimum content of the figure R-2.2-1 of ASME PCC-1 Revision 2022. All records shall be submitted to the BUYER in electronic format.

3.3.4 Qualification of Powered Equipment

3.3.4.1 Powered equipment (torque tools or tension tools as opposed to hand operated tools) shall be qualified prior to its use.

3.3.4.2 SELLER shall qualify the equipment torque or tension values with a calibrated hollow load cell in accordance with ISO 27509:2020 item D.11.

3.3.4.3 This qualification shall indicate that torque values applied are in line with the calculated tensions and forces. Bolts, nuts, and lubricants used shall be of the same type as those used in field. After this qualification, a report shall be issued for each bolt size, and torque values of bolting procedure shall be updated if necessary.

3.3.4.4 BUYER shall be invited at least 30 days in advance to witness bolt torque and tension qualifications.

3.4 BOLTED JOINT TAGS AND LOCKOUT

3.4.1 General

3.4.1.1 In order to record all applicable data and plan the activities each joint needs to be clearly and uniquely identified. This requires the joint to be physically tagged so that its identity is clear and visible at the joint location including a unique joint TAG number.

3.4.1.2 The flange joint TAG number shall be the same as established in the 3D model.

3.4.1.3 **Permanent TAG:** The purpose of a Permanent TAG is to uniquely identify a joint throughout its life cycle, enabling all activities and data on that joint to be recorded. Permanent Tags shall be securely attached to the joint and may hold no other data than its unique TAG number.

3.4.1.4 **Temporary TAG:** The purpose of a Temporary TAG is to uniquely indicate the status of the joint during the work scope of special joints.

3.4.1.5 Both Permanent and Temporary tags shall be durable and waterproof and shall be securely fastened to the flanges. Temporary TAG shall be perforated so that the colored parts can be teared off.

3.4.1.6 Temporary TAGS shall be similar to the ones described in items 3.4.2 and 3.4.3.

3.4.2 Mechanical Completion TAG

3.4.2.1 The Mechanical Completion TAG shall be added to the special joint as soon as it is first assembled in the field. It shall be in accordance with the following suggested model (Figure 2).

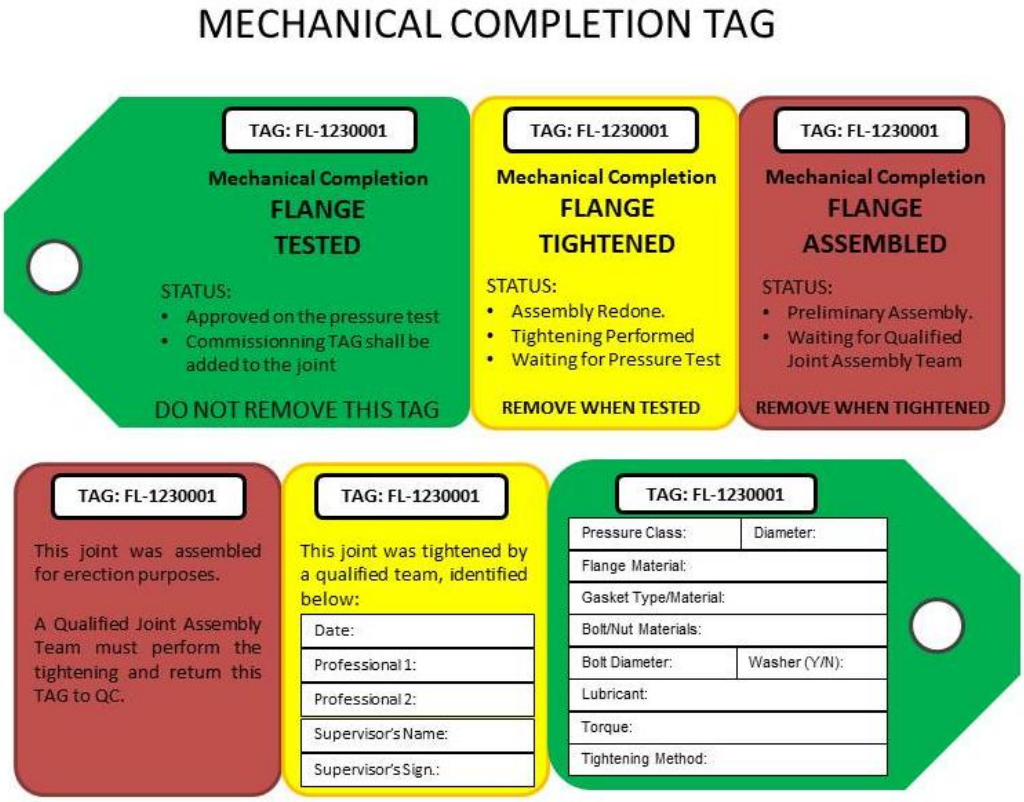


Figure 2 - Model for the Mechanical Completion TAG

3.4.2.2 It shall include the following information:

a) Joint identification (TAG number).

b) Pressure Class and diameter of the flanged joint.

c) Material specifications of the components (bolts, nuts, washers, flanges, gaskets, etc.).

d) Bolt diameters and the need of washers.

e) Lubricant to be used.

f) Torque to be applied and the tightening method.

3.4.2.3 The above listed information shall be printed to the TAG, reflecting all the information as has been previously determined in the design of the joint.

3.4.2.4 Only the information concerning the actual tightening of the joint (yellow TAG) shall be hand filled at site.

3.4.2.5 The TAG still with a red end indicates that only a preliminary assembly was performed, and most likely this assembly was not performed by a qualified team.

3.4.2.6 Once the qualified bolt joint assembly team performs the inspection and the tightening of the joint, the red TAG shall then be detached and delivered to QC. The team supervisor shall fill the yellow TAG.

3.4.2.7 Pressure tests can only be performed on systems with no red TAG left on the joints.

3.4.2.8 Once the pressure test has been performed and approved the yellow TAG may be detached and delivered to QC (the information therein contained shall be properly registered for quality and traceability purposes). The green TAG shall not be removed.

3.4.2.9 Upon approval of the pressure test a Commissioning TAG shall then be added to the joints.

3.4.3 Commissioning TAG

3.4.3.1 The Commissioning TAG shall be added to the special joints as soon as they are approved on the pressure test. It shall be in accordance with the following suggested model (Figure 3).

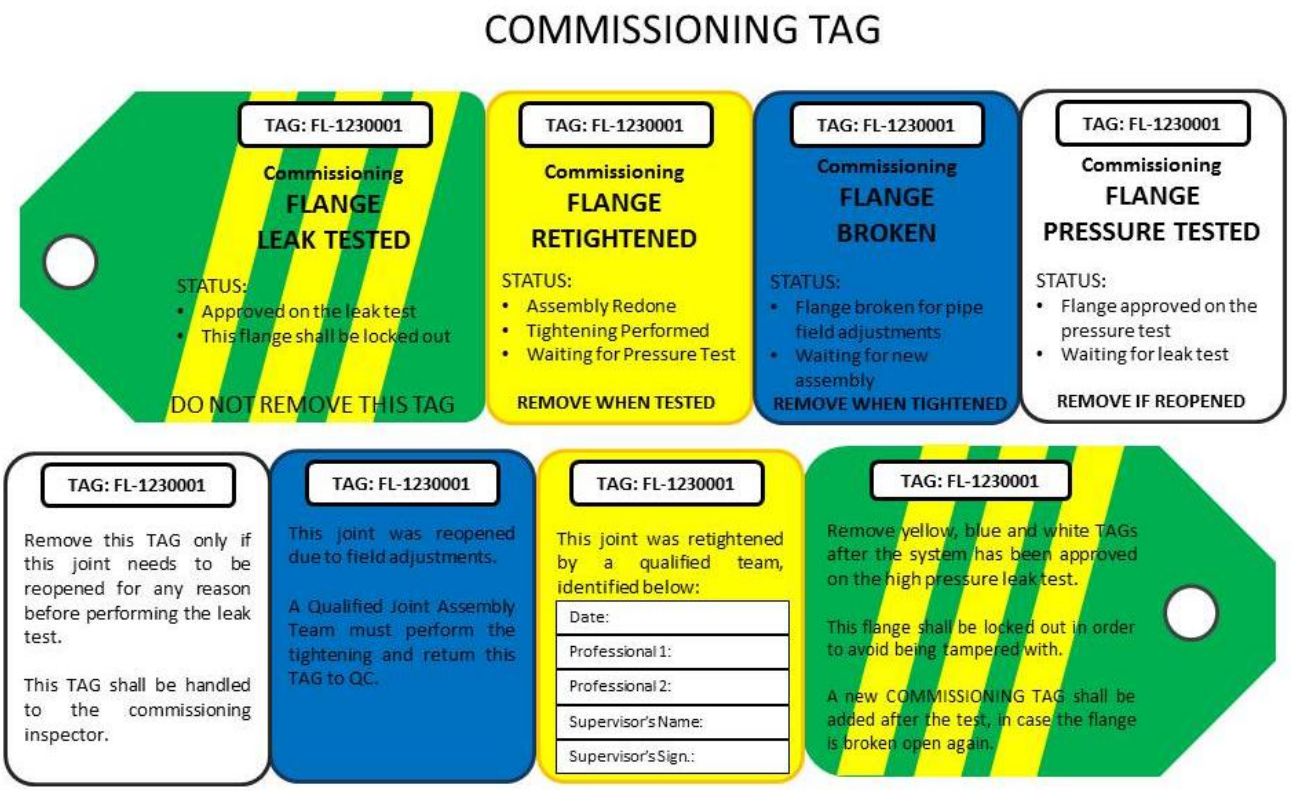


Figure 3 - Model for the Commissioning TAG

3.4.3.2 If the flange is disassembled at any moment before the final leak test the white TAG shall be detached and delivered to the Commissioning Inspector. It means that the flange tightness may be impaired, and that a new assembly by a qualified team must be performed.

3.4.3.3 Once the qualified bolt joint assembly team performs the inspection and the tightening of the joint, the blue TAG shall then be detached and delivered to the Commissioning Inspector. The yellow TAG shall be filled by the team supervisor.

3.4.3.4 The system leak test can only be performed on systems with no blue end TAGS (TAGS must be white end or yellow end).

3.4.3.5 Once the leak test has been performed and approved the yellow, blue, and white TAGS may be detached and delivered to Commissioning Inspector (the yellow TAGS information shall be properly registered for quality and traceability purposes). The green and yellow striped TAG shall not be removed.

3.4.3.6 A new Commissioning TAG shall be added to the joint at any time if the joint is reopened after the leak test.

3.4.4 Flange Lockout

3.4.4.1 All flanges after the leak test shall be locked out to avoid being tampered with.

3.4.4.2 This lockout may be performed by:

a) Metallic cable and a metallic seal.

b) Metallic cable and a plastic compression seal.

c) Plastic fastening (e.g., hellermann type fasteners).

d) Any other means that will promptly reveal whether a joint has been broken.

3.4.4.3 The lockout method shall be submitted for BUYER's approval. Metallic lockout devices must be compatible with the flange, bolt, and nut materials (e.g., galvanized wires shall not be used for stainless steel parts).

3.5 BOLTED JOINT MANAGEMENT SYSTEM

3.5.1 All bolted joints shall be managed in a similar fashion as the piping welded joints, with due traceability to the professionals involved in the assembly (all joints) and the Joint Assembly Records (critical joints).

3.5.2 Besides been given a TAG, a Bolted Joints Management System shall be implemented, and it shall be able to keep the required traceability for all the technical requirements herein listed.

3.5.3 This system shall be able to handle properly the following information:

a) Joint identification (TAG) and location.

b) Joint classification (ordinary / special).

c) Joint material specifications for all components (bolts, nuts, washers, flanges, gaskets, etc.).

d) Joint main features (pressure class, diameter of the flange, diameter of the bolts, number of bolts, and so on).

e) Joint tightening method, assembly target torque / tension, and the applicable lubricant.

f) Applicable Joint Data Sheet number.

g) Quality controls to be applied after assembly (if any).

h) Tightening Teams involved in assembly.

i) Applicable Joint Assembly Record (special joints).

3.5.4 The Bolted Joint Management System shall also be able to keep track of the following:

a) Status of the joint (assembled / tightened / pressure tested / broken / leak tested).

b) Dates for all relevant events: assembly, tightening, pressure test, leak test.

c) Professional involved in the applicable events (qualified team identification).

4 TIGHTENING METHODS

4.1 SELECTION

4.1.1 The choice of the tightening method is dependent upon the criticality of each joint, as follows:

a) Striking wrenches and spanner wrench extension tools ARE NOT ALLOWED. Striking wrenches are prone to accidents and expose the worker to a risk that is not considered justifiable. Extension tools may subject the joint to excessive stress which may cause the failure of its components.

b) Hand wrenches are not recommended. Hand tightening may subject the joint to excessive stress and deformation. When approved by BUYER this method may be used only in Category D service (see definition in ASME B31.3 Process Piping Code).

c) Controlled torque bolt tightening using manual or hydraulic torque tools shall be used for all ordinary and special bolted joints. Manual torque tools shall only be applied to a maximum calculated torque of 700 N.m, above which hydraulic torque tools shall be applied.

d) Hydraulic bolt tensioning shall be used on all bolts greater than 2" diameter, unless specified otherwise.

4.1.2 Controlled torque bolt tightening method (as in (c) above) associated with bolt elongation measurement or load-control techniques (see item 9.3) may be used as a substitute for hydraulic bolt tensioning when approved by BUYER.

4.2 CONTROLLED TORQUE BOLT TIGHTENING

4.2.1 Torque tightening of bolts shall be performed with calibrated manual tools or with calibrated hydraulic torque tools.

4.2.2 SELLER shall calculate the torque and load to be applied in each assembly, considering the specificities of each bolted joint. These values shall be included in the Bolted Joint Assembly Procedure, on the Joint Data Sheets and on the Joint Assembly Records (where applicable).

4.2.3 For GRP flanges the tightening torque shall be calculated and informed by the flange manufacturer.

4.2.4 Hydraulic torque wrench shall have their torque tables informed by the equipment vendor. Yearly, the equipment shall be calibrated to ISO 17025. The certificate shall compare applied pressure and torque in at least 10 points. The torque accuracy shall be not more than 5%. The pressure gauge used in hydraulic pump shall also be calibrated yearly and its accuracy considered for the torque verification.

4.3 BOLT TENSIONING

4.3.1 Hydraulic bolt tensioning shall have load tables informed by the equipment vendor. Yearly, the equipment shall be calibrated to ISO 17025. The certificate shall compare applied pressure and load in at least 10 points. The load accuracy shall be not more than 5%. The pressure gauge used in hydraulic pump shall also be calibrated yearly and its accuracy considered for the load verification.

4.3.2 Load tables shall clearly indicate the calculated load transfer loss, which depends on the effective length to bolt diameter ratio.

4.3.3 The CONTRACTOR shall calculate the tension and the equivalent pressure to be applied in each assembly, considering the specificities of each bolted joint. These values shall be included in the Bolted Joint Assembly Procedure and on the Joint Assembly Records.

5 CALCULATED BOLT LOAD AND TORQUE

5.1 Bolt assembly loads shall be established with due consideration of the following joint integrity issues:

a) Sufficient Gasket Stress to Seal the Joint.

b) Avoid damage to the Gasket (over-compression).

c) Avoid damage to the Bolts.

d) Avoid damage to the Flange.

e) Tension due to overcoming Hydrostatic Test internal pressure.

f) External loads.

g) Vibration.

h) Cyclic service.

i) Thermal expansion differences between bolts and flanges.

j) Temperature gradients within the flanges.

k) Lubricant characteristics.

l) Use of washers or other accessories.

5.2 The torque determination shall be performed as detailed in ASME PCC-1 standard, Appendix O, joint component approach, with the exception that for GRP flanges the tightening torque shall be calculated and informed by the flange manufacturer.

5.3 The CONTRACTOR shall issue torque tables that are in close agreement with the bolted joint assembly procedure, with special attention to possible variations of the specified lubricant and the applicable friction coefficient. Torque tables shall indicate the torques and tensions to be applied for each size and pressure class for specific combination of lubricant, flange, gasket and bolt materials.

5.4 The gaskets constants used in the calculations shall be listed, and its values shall be as determined by the gasket manufacturers. As a minimum the following values are required for calculating the desired assembly torque:

a) Maximum permissible gasket stress.

b) Minimum gasket operating stress.

c) Minimum gasket seating stress.

d) Maximum flange rotation permitted by the gasket.

e) Fraction of gasket load remaining after relaxation.

5.5 Gaskets with high relaxation factors (such as PTFE gaskets) require the flanged joints to be retightened after 48 hours of initial tightening.

5.6 Retightening of bolted joints after more than 240 hours of initial tightening or after the system has been put to service is not recommended, since the initial lubrication condition may no longer be valid. In this case a new torque calculation may be needed, or the joint may require to be fully disassembled, so that it can be again lubricated and retightened.

6 INSPECTION PRIOR TO TIGHTENING

6.1 GENERAL

6.1.1 Proper alignment of all joint members is an essential element of flange joint assembly. It results in maximum seating surface contact, maximum opportunity for uniform gasket loading, and improves the effectiveness of all bolt tightening methods. The following guidelines apply for aligning mating flanges.

IMPORTANT: If a joint assembly team is assigned to tighten a joint that has already been preassembled by unqualified professionals, first this joint must be completely disassembled to perform the inspection activities herein cited. After that, the joint may be reassembled and finally tightened.

6.1.2 All materials shall be inspected before commencing the work. As a minimum the following shall be checked:

a) Flanges and gaskets shall be well preserved, with no corrosion, and flanges shall present no mechanical damage on the sealing surfaces according to ASME PCC-1 Revision 2022 NONMANDATORY APPENDIX D GUIDELINES FOR ALLOWABLE GASKET SEATING SURFACE FLATNESS AND DEFECT DEPTH sections D-3 and D-4. These guidelines shall be implemented in the Bolted Joint Tightening Procedure issued by the CONTRACTOR. For flanges that are not designed and manufactured according to ASME standards, SELLER shall follow the guidelines for discontinuities evaluation according to specific standard of these flanges.

b) Bolts and nuts shall be well preserved, with no corrosion or mechanical damage to the threads.

c) Flanges, bolts, nuts, washers, and gaskets are of the correct material specification, with the applicable manufacturers markings as required by the specification.

d) Flanges, gaskets, bolts, and nuts are within the dimensions established by the applicable standards.

6.2 DIMENSIONAL CHECK

6.2.1 A dimensional check shall be performed prior to the assembly of the bolted joint.

6.2.2 For GRP flanges and flanges other than ASME B16.5/B16.47, specific more stringent dimensional requirements may be needed. In these cases, the flange manufacturer's recommendations or the flange design standard recommendations shall be followed.

6.2.3 For ASME B16.5/B16.47 flanges tolerances shall be as indicated in accordance with ASME PCC-1 Revision 2022. Out-of-tolerance conditions shall be corrected before the gasket is installed to avoid damaging it. Only minimum or reasonable adjustments should be made after the gasket is installed. Aligning shall not require more force than can be exerted by hand or common hand and hammer alignment tools such as spud wrenches and alignment pins.

6.2.4 Bolting to pumps and rotating equipment (compressors and so on) is usually subject to special requirements, such as API RP 686, when it comes to the alignment of the flanges prior to bolting. The manual of equipment issued by the manufacturer shall always be checked, and the restrictions therein cited shall always be adhered to.

6.2.5 Proper alignment will result in the bolts passing through the flanges at right angles and the nuts resting flat against the flanges prior to tightening.

6.2.6 If the flanges that need alignment are connected to pumps or rotating equipment (or any other load sensitive equipment), great care must be taken to prevent introducing a strain into the equipment housing or

bearings. Measuring the movement in the equipment to ensure that its aligned condition is not disturbed is a mandatory practice.

6.2.7 Once the flanges are aligned, install the gasket, and tighten the bolts completely, and then release the aligning devices.

6.2.8 Centerline (CL) tolerance should be measured at four locations, each approximately 90 deg apart on the flange (Figure 4). Hold a straight edge parallel to the axis of one flange and flush with the outside diameter (0.0.). Extend the straight edge to the adjoining flange and measure the distance from the straight edge surface to the same surface on the adjoining flange.

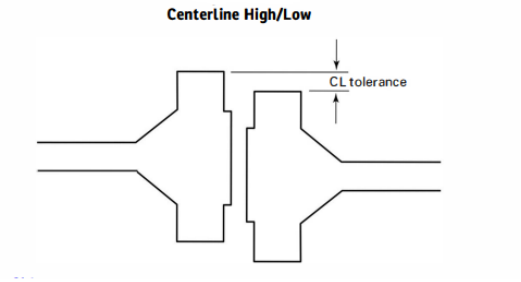


Figure 4 – Centerline High/Low

6.2.9 Gap (GP) tolerance is a measurement of the spacing between the seating surfaces (Figure 5).

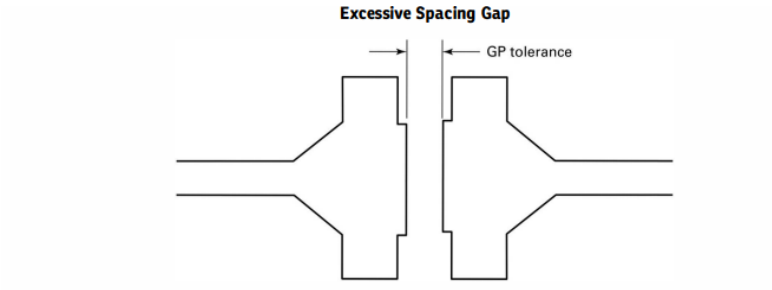


Figure 5 – Excessive Spacing Gap

6.2.10 Parallelism (PRL) tolerance is a measurement defining the uniformity of distance between the sealing surfaces of two flange faces. PRL tolerance is calculated as the difference between the largest and smallest distance between the two sealing surfaces at the sealing surface outside diameter (Figure 6).

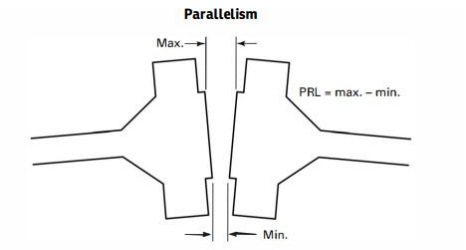


Figure 6 – Parallelism

6.2.11 Rotational two-hole (RTH) ensures the flange holes are rotationally aligned to one another such that fasteners can be installed perpendicular to both flanges. Measure RTH by confirming the hole centers are aligned (Figure 7).

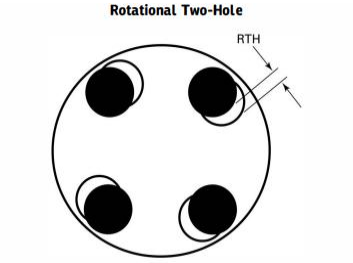


Figure 7 – Rotational Two-Hole

6.2.12 Alignment tolerances shall be as presented on Table 1.

Table 1 – Alignment Tolerances

Property	Maximum Tolerance, mm (in)
CL	1.5 (1/16)
GP	Gasket thickness x 2
PRL	0.8 (1/32)
RTH	3 (1/8)

6.3 CLEANING AND EXAMINATION

6.3.1 Before assembly starts, flange and fasteners contact surfaces shall be cleaned and inspected.

6.3.2 The nut seating surface (at the back of the flanges) shall be free from organic coatings (a primer layer is allowed).

6.3.3 Remove all dirt and indications of any previous gasket installation from the gasket contact surfaces. Use approved solvents and/or soft-wire brushes for cleaning to prevent surface contamination and damage to existing surface finish. Do not use carbon steel brushes on stainless steel flanges.

6.3.4 Examine the gasket contact surfaces of both mating joint flanges for compliance with recommended surface finish and for damage to surface finish such as scratches, nicks, gouges, and burrs. Any questionable imperfections shall be reported (see item 6.1).

6.3.5 For ASME B16.5/B16.47 flanges, damage to the sealing surfaces may be repaired according to Article 305 Flange Repair and Conversion guidelines of the ASME PCC-2 Revision 2022.

6.3.6 For flanges other than ASME B16.5/B16.47 damages to the sealing surfaces may only be repaired when permitted by the flange standard and shall follow the requirements therein stated.

6.3.7 Examine bolts and nut threads and washer faces of nuts for damage such as rust, corrosion, and burrs.

6.3.8 Damaged components shall be replaced/corrected. Likewise, bolt/nut combinations for which the nuts will not turn freely by hand past where they will come to rest after tightening shall be replaced/corrected.

6.4 INSTALLATION OF GASKET

6.4.1 Place a new gasket in position after determining the absence of (or having made correction for) unacceptable gasket sealing surface imperfections and flatness tolerance deviations, as well as joint alignment considerations.

6.4.2 Reuse of a gasket is not allowed.

6.4.3 Verify that the gasket complies with the dimensional (O.D., I.D., thickness) and material specifications. Position the gasket to be concentric with the flange I.D., taking suitable measures to ensure that it is adequately supported during the positioning process. No portion of the gasket shall project into the flow path.

6.4.4 Ensure that the gasket will remain in place during the joint assembly process. A very light dusting of spray adhesive on the gasket (not the flange) may be used. Particular care shall be taken to avoid adhesive chemistry that is incompatible with the process fluid or could result in stress corrosion cracking or pitting of the flange surfaces. Do not use tape strips to hold it in position. Do not use grease.

6.4.5 Ring gaskets installed in API and Compact flange connections shall be lightly lubricated prior to assembly. Appropriate lubricants include mineral-base oil (20 W or higher), synthetic motor oil (5W or higher) or a general-purpose grease suitable for high-pressure metal-to-metal application. Greases or thread compounds with metallic additives shall not be used. Lubricant shall be applied as a thin film, never in sufficient amount to have any possibility of filling the grooves.

6.5 BOLTING LUBRICATION

6.5.1 No bolted connection shall be assembled and tightened without appropriate lubrication applied. Fasteners that are coated with Teflon or any other self-lubricated coating shall be assembled as prescribed by the manufacturer.

6.5.2 Ensure that the lubricant is chemically compatible with the bolt/nut/washer materials. Particular care shall be taken to avoid lubricant chemistry that could contribute to stress corrosion cracking, galvanic corrosion, oxygen auto-ignition, etc. Also ensure that the lubricant has proven to be suitable for the expected range of service temperature(s) and anti-seize requirements. For stainless steel components the lubricant shall not contain Zinc in its composition.

6.5.3 Before lubricant is applied to the bolt and nut threads, nuts must run freely by hand past where they will come to rest after tightening. If nuts will not turn freely by hand, check for cause, and make necessary corrections/replacements.

6.5.4 Apply lubricant liberally and completely to the nut contact faces and to the threads on both ends of the bolts past where the nuts will come to rest after tightening (Figure 8 - Surfaces to be lubricated). The lubricant shall be applied after the bolts are inserted through the flange bolt holes to avoid possible contamination with solid particles that could create unwanted reaction torque. Lubrication shall be applied irrespective of the tightening method used.

6.5.5 For new self-lubricated coated bolts and nuts, free-running nut checks are required. On the second and subsequent tightening operations, apply lubricant as described above.

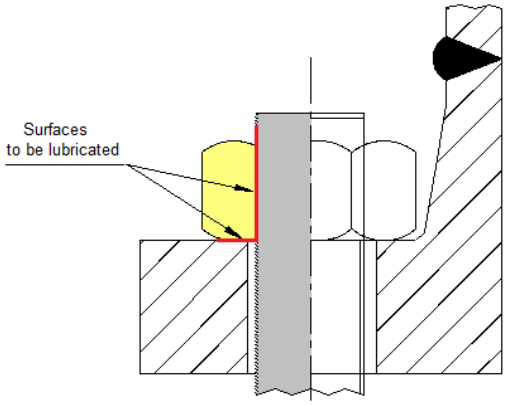


Figure 8 - Surfaces to be lubricated

6.6 INSTALLATION OF BOLTS

6.6.1 Install bolts and nuts so they are hand-tight with the marked ends of the bolts and nuts located on the same side of the joint and facing outward to facilitate inspection; then snug up to 15 N·m (10 ft-lb) to 30 N·m (20 ft-lb), but not to exceed 20% of the Target Torque. If nuts do not hand tighten, check for cause, and make necessary corrections.

6.6.2 Verify compliance with bolt and nut specifications (materials, diameter, thread pitch, and nut thickness equal to the nominal bolt diameter).

6.6.3 Check bolts for adequate length. This length shall consider the presence of washers, nut height, and required thread protrusion. Nuts shall engage the threads for the full depth of the nut plus at least one thread.

6.6.4 The use of bolt tensioners requires that the threaded portion of the bolt extends beyond the outside nut face on the tensioner side of the joint. The length of the bolt extension shall be verified with the manufacturer of the tensioner.

6.6.5 Excess thread protrusion can hinder joint disassembly due to corrosion, paint, or damage. A practice that facilitates joint disassembly is to fully engage the nut on one end (just one bolt thread projection beyond the nut) so that all remaining excess threads are located on the opposite end. Excess thread protrusion beyond the nut should be minimized.

7 TIGHTENING OF BOLTED JOINTS

7.1 TIGHTENING STAGES

Once determined the final torque value for the stud or bolt to be tightened (Section 5) the following tightening stages shall be followed:

a) First tightening stage shall be limited to a maximum of 30% of the final torque setting.

b) Second tightening stage shall be limited to a maximum of 60% of the final torque setting.

c) Third tightening stage shall be carried out at the 100% of the final torque setting.

Note: The stages above shall be tightened using the diagonal bolt sequence (Legacy Pattern) as described on item 7.2.

d) On the Fourth and Fifth tightening sequence, change from diagonal tightening to adjacent bolt-to-bolt tightening clockwise using the 100% torque setting and chase around flange until all bolts are equally tightened.

7.2 TIGHTENING SEQUENCE

Use the Legacy cross-pattern to mark the correct tightening sequence around the flange (as required by ASME PCC-1). Alternative tightening sequences predicted by ASME PCC-1 may be used, as long as they are included in the Bolted Joint Tightening Procedure issued by the SELLER.

7.3 HYDRAULIC BOLT TENSIONERS

SELLER shall follow the equipment manufacturers instructions for assembly of the bolted joint and a specific procedure shall be issued with all applicable information for operation and quality control of the joint.

7.4 TIGHTENING SUPERVISION

7.4.1 A survey of the bolted flanges shall periodically be performed by the Bolting Supervisor. This evaluation shall be done on a daily basis, so that the work performed by all assembly teams is sampled.

7.4.2 The Bolted Joint Assembly Procedure issued by SELLER shall detail the systematics for this evaluation.

8 PRESERVATION

8.1 Preservation of the bolted joints is crucial to its long-life performance, and therefore it shall be applied right after the bolted joint has been assembled.

8.2 The general preservation method shall be agreed with BUYER. It is usually on the form of a thick fill corrosion protection product applied to all unpainted surfaces from flanges, bolts, and nuts (not related to the mandatory lubricant product applied to the contact surfaces before tightening).

8.3 This preservation scheme shall be maintained and repaired (wherever and whenever needed) at all times during the following assembly, test and preservation stages of the bolted joints and the related piping system.

8.4 On areas of the platform with higher environmental corrosivity (such as the Riser Balcony and the Fire Main Ring) the preservation method shall be changed after the final leak test of the system has been performed and approved (but never before). This new preservation scheme for high corrosivity areas shall be in the form of wax based dry corrosive preventive coatings. Product to be applied shall be approved under at least 1000 hours salt spray test as per ASTM B117.

8.5 Other high corrosivity areas, such as those subjected to the prevalent wind incidence, according to geographic orientation and meteoceanographic data, may require this change in the preservation method upon agreement with buyer.

8.6 Flange wrap preservation schemes for high corrosivity areas may be applied when permitted by BUYER.

8.7 Bolt preservation method may be changed from grease to painting where this is considered feasible, see 8.8. This is especially advantageous where it is predicted that the bolted joints will not be disassembled on further commissioning stages, since preservation with painting lasts longer than the preservation with grease, and thus it will significantly reduce the amount of preservation activities, especially for joints with difficult access.

8.8 The preservation of bolting by painting shall be agreed between BUYER and SELLER during C&A early stage and revised when deemed necessary. The following premises shall be considered:

a) Bolted connections of CRA piping and fittings shall not be preserved by painting or varnish.

b) Painting as a preservation method can only be applied after leak test.

c) Preparation for painting will require that the excess bolt lubricant/preservation grease be removed prior to painting.

8.9 For CRA materials to which a long-lasting preservation alternative is sought, VCI impregnated bolt caps and flange band protector may be used in lieu of the constant grease application.

8.10 The coating scheme for the painting preservation method shall be as follows:

a) One epoxy adhesion primer with a topcoat (recommended).

b) Flange original paint system or repair/touch-up system.

9 ADDITIONAL INFORMATION

9.1 THERMAL INSULATION

Bolted joints shall never be thermally insulated, unless for cold conservation purposes as stablished in I-ET-3010.00-1200-431-P4X-001 – THERMAL INSULATION FOR MARITIME INSTALLATIONS. When applied, flange insulation for thermal or fire protection shall be designed to be easily removed such as Velcro types.

9.2 DISASSEMBLY OF BOLTED JOINTS

The disassembly of bolted joints shall also be performed in a cross-pattern. An intermediate stage at 50% of the calculated torque shall be applied during disassembly.

9.3 LOAD CONTROL SYSTEMS

Several techniques are commercially available to control and assure bolt load, as set out below.

9.3.1 Direct length measurement

This method uses mechanical extensometer to measure the bolt extension. Accuracy is dependent on the level of physical load test calibration carried out. A readily available technique is the indicating rod bolt type. A rod is inserted into a drill hole in the bolt that runs the fastener's complete length. The rod is anchored at the opposite end to where the measurement takes place. At the measuring end a precise datum face is machined leaving the rod end flush with the bolt face. Relative displacement of the rod compared to the bolt face is

measured and calibrated against bolt load by physical load test.

9.3.2 Ultrasonic direct length measurement

This method determines the stress by measuring the time of flight of an acoustic pulse travelling from one end of the stud or bolt to the other. The time will vary depending on the extension and the stress in the stud or bolt. The monitored time is proportional to the bolt extension and stress and can be converted to provide an output as a bolt tension or stress as required. The pulse is generated by a hand-held processing unit and is independent of the tightening method.

9.3.3 Load monitoring sensors

9.3.3.1 There are several load monitoring sensors commercially available. These include capacitance, fiber optic and strain gauge techniques that take the form of sensor inserts placed into a converted bolt. Another type is the compression load cell that fits like a washer under the nut or bolt head.

9.3.3.2 One load cell monitors any change in the nut face stress using an amorphous material. Other types use strain gauges in the cell structure. Signals from all types of sensors can be read by a hand-held device or hardwired logging systems; they have future potential for remote signal monitoring. The sensors are particularly useful where there is a need to continuously monitor bolt load in service.

9.3.4 Mechanical load indicating bolts

These comprise standard bolts converted to monitor bolt load. The bolt has a pin with a rotor attached, anchored in an axial drill hole. The rotor air gap is set to rotate freely until a specified bolt load is achieved. The indicator is enclosed in a protective cap. Simple finger feel of this cap determines bolt load status. Tension is indicated at make-up and throughout the life of the joint. Variations of this technique include a dual indicating maximum/minimum load range system as well as a visual indication system.

APPENDIX A - JOINT DATA SHEET

Joint Data Sheet NUMBER: _____

PROJECT DETAILS	TRACEABILITY
CLIENT:	BASE PROCEDURE:
PROJECT:	PREPARED BY:
LOCATION:	DATE PREPARED:

JOINT DETAILS	BOLT DETAILS
STANDARD:	BOLT SIZE:
DIAMETER:	MIN. BOLT LENGTH:
PRESSURE CLASS:	NUMBER OF BOLTS:
FLANGE MATERIAL:	BOLT MATERIAL:
GASKET MATERIAL:	NUT MATERIAL:
JOINT TYPE:	LUBRICANT:

TIGHTENING VALUES	
BOLT STRESS:	% YIELD:
BOLT LOAD:	TIGHTENING METHOD:

TENSION INFORMATION	TORQUE INFORMATION
TOOL:	TORQUE STEP 1 (30%):
MAX WP:	TORQUE STEP 2 (60%):
MAX LOAD:	TORQUE STEP 3 (100%):
EQUIVALENT TORQUE:	

PUMP PRESSURE	RETORQUE AFTER 48 HOURS
STEP 1:	( ) YES ( ) NO
STEP 2:	
STEP 3:	BONDING JUMPER
STEP 4:	( ) YES ( ) NO

RESISTIVITY MEASUREMENT

NOTES

APPENDIX B – BOLT ASSEMBLY FOR STRUCTURAL APPLICATIONS

B.1 GENERAL REQUIREMENTS

B.1.1 Cleaning, examination, lubrication and installation of bolts shall be performed as described in Section 6.

B.1.2 Appropriate lubrication shall be applied to the bolt's threads, and to the nut surfaces. Dry assembly is not acceptable.

B.1.3 Alternate the tightening sequence around the bolts involved in the assembly, in a similar fashion as applied to flanged connections.

B.1.4 After assembly, all bolting shall be field painted, as described in 8.10.

B.1.5 Bolt torque for structural applications shall be calculated as follows.

B.2 TORQUE FOR EQUIPMENT FOUNDATION

B.2.1 Bolt torque for equipment fixed supports (skirts, lugs, legs and fixed saddle) shall be calculated as to achieve at least 50% of the bolt yield strength.

B.2.2 If double nuts or jam nuts are used, they shall be tightened as described in Appendix C.

B.2.3 For sliding saddle type supports, the use of double or jam nut is mandatory. In this case the tightening sequence described in Appendix C shall not be used.

B.2.4 For sliding saddle type supports, the first nut shall not be given any torque, as it shall be snug tight only. The second nut is then placed on top of the first nut while the first nut shall be held in place to prevent its rotation. A spanner may be used for this purpose. While the first nut is locked, the second nut is then tightened to the full calculated torque value (at least 50% of the bolt yield strength).

B.3 TORQUE FOR OTHER STRUCTURAL APPLICATIONS

For other structural applications, unless otherwise stated the torque shall be calculated as to achieve at least 70% of the bolt yield strength.

APPENDIX C – JAM NUT / DOUBLE NUT TECHNIQUE

C.1 GENERAL

C.1.1 For applications to which the risk of self-loosening is deemed high, or to which the consequences of losing the applied assembly load are considered dangerous, the use of a locking nut is sometimes recommended. On some cases this may appear as a double heavy hex nut, but in many cases the recommendation would go towards the use of a smaller "jam" nut. They are illustrated in Figure C.1 and Figure C.2.

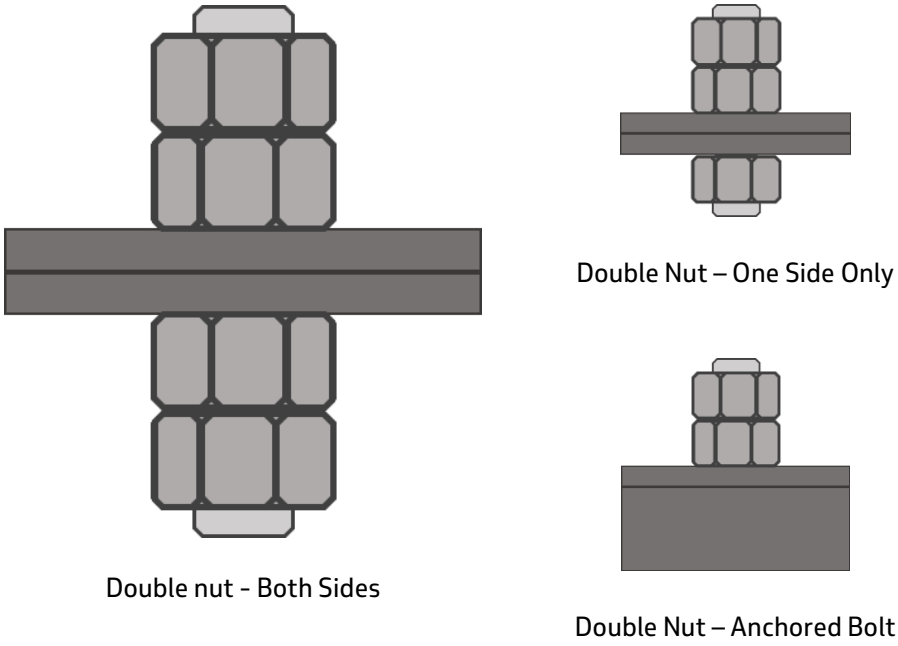


Figure C.1 – Double nut technique

C.1.2 The procedure for assembling this arrangement of nuts shall be performed as described herein. Attention shall be brought that the jam nut shall be placed first (below), and the regular heavy hex nut after it (on top of the jam nut) as shown in Figure C.2.

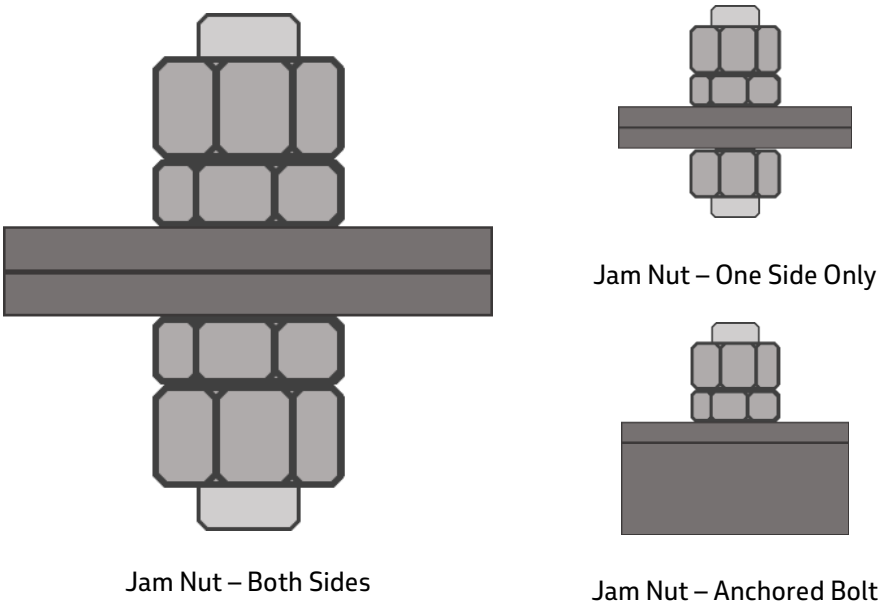


Figure C.2 – Jam nut technique

C.2 TIGHTENING SEQUENCES

C.2.1 Double nut – Single sided arrangement (one side only, or anchored bolt)

If the double nut (Figure C.1) is applied to one side only, the first nut shall be assembled and then tightened to 50% of the calculated tightening torque. The second nut is then placed on top of the first nut and the first nut shall be held in place to prevent its rotation. A spanner may be used for this purpose. While the first nut is locked, the second nut is then tightened to the full calculated torque value.

C.2.2 Double nut –Double sided arrangement

If the double nut (Figure C.1) is applied to both sides of the assembly, the first nut shall be assembled on both sides and then one of them is tightened to 50% of the calculated tightening torque (this can be made to either nut). The second nut is then placed on top of the first nut (on the first side) and the first nut (on the same side) shall be held in place to prevent its rotation while the second nut is then tightened to the full calculated torque value. This procedure is then repeated on the second side, keeping the first nut locked (also on the second side) while the second nut is being tightened to the full calculated torque.

C.2.3 Jam nut – Single sided arrangement (one side only, or anchored bolt)

If the jam nut (Figure C.2) is applied to one side only, the procedure is the same as described in C.1.1 above, taking care to apply the jam nut first (below) and the regular nut on top of it.

C.2.4 Jam nut –Double sided arrangement

C.2.4.1 If the jam nut (Figure C.2) is applied to both sides of the assembly, the first (jam) nut shall be assembled on both sides and then one of them is tightened to 50% of the calculated tightening torque (this can be made to either nut).

C.2.4.2 The second nut is then placed on top of the first jam nut on the first side, but in this case this second nut shall not be initially tightened to the full calculated torque, as this would cause excessive shear stresses on the jam nut of the opposite side. This second nut of the first side shall be tightened to 50% of the calculated

torque, while keeping the jam nut on the same side locked in place.

C.2.4.3 After that, the second top nut is applied to the jam nut on the second side. While keeping the second jam nut locked in place, the second top nut is tightened to the full calculated toque.

C.2.4.4 After the top nut of the second side has been fully tightened, the first top nut (on the first side) shall be finally tightened to the full calculated torque (as it was at 50% only).

C.3 ADDITIONAL REQUIREMENTS

C.3.1 Cleaning, examination, lubrication and installation of bolts shall be performed as described in Section 6.

C.3.2 Appropriate lubrication shall be applied to the bolt's threads, and to the nut surfaces (in between the nut and the substrate, and in between the first and the second nuts). Dry assembly is not acceptable.

C.3.3 Alternate the tightening sequence around the bolts involved in the assembly, in a similar fashion as applied to flanged connections. Apply the first nut and the first torque to all bolts, before applying the second nut and the second torque.

C.3.4 Preservation shall be applied after assembly, as described in Section 8.