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	CLIENT: SRGE		SHEET: 1 of 20
	PROGRAM:		-
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SRGE	TITLE: **REQUIREMENTS FOR BOLTED JOINTS ASSEMBLY AND MANAGEMENT**		INTERNAL / ESUP

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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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1 INTRODUCTION

1.1 GENERAL

The purpose of this specification is to ensure 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, its 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.

This technical specification defines the bolt tightening requirements for flanged joint assemblies based on ASME B16.5/B16.47 flanges.

For the assembly of API 6A flanges, API 17D and Compact flanges additional requirements from the applicable design standards shall apply. These requirements must also be fulfilled and therefore shall be contemplated on the specific assembly procedure to be issued by the CONTRACTOR.

For the assembly of other types of bolted connections (clamp type and other proprietary connections) specific manufacturer's requirements may apply. These requirements must also be fulfilled and therefore shall be contemplated on the specific assembly procedure to be issued by the CONTRACTOR.

Bolt tightening for GRP (Glass Reinforced Piping) and other composite and polymeric materials shall be in accordance with manufacturer's recommendations.

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.

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

Bolted joints applied to structural components, including piping and equipment supports, are not within the scope of this technical specification.

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

1.2 DEVIATIONS

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

Failure to observe this requirement may result in remedial work at CONTRACTOR expense.

1.3 SAFETY

Contractor 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.

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.

Impact wrenches and spanner wrench extension tools are not allowed on the assembly of bolted joints.

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

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. CONTRACTOR is recommended to submit Technical Queries to OWNER in order to solve the conflicts, if any.

Failure to observe this requirement may result in remedial work at CONTRACTOR expense.

2.2 CODES AND STANDARDS

The following standards include provisions which, through reference in this text, constitute provisions of this technical specification. 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
- 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

3 GENERAL REQUIREMENTS

3.1 COMPETENCE / TRAINING

Assembly and tightening of bolted joints shall only be performed by people with training and qualification as herein defined. Bolted joints that were assembled in order to enable the erection of the spools into the piping system shall be completely dismantled by the bolted joint assembly team in order to verify its alignment and cleanliness before performing the complete tightening procedure.

Training and qualification of bolted joint assembly personnel shall be as detailed in Appendix A of ASME PCC-1 or EN 1591-4. Only personnel who has attended the training and passed practical and written examinations as therein stated shall be allowed to train the assembly of bolted special joints.

In order to assembly GRP piping joints, bolted joint assembly personnel shall be trained by the vendor.

Each special joints bolted joint assembly team shall have at least one personnel internal trained by a Qualified Bolting Specialist. Competence and qualification of these specialist shall be in accordance with Appendix A of ASME PCC-1 or EN 1591-4.

The internal qualification process shall have written and practical examinations.

Alternatively, special joints bolted assembly team may be a recognized specialized contractor with experience in more than 10 similar FPSO projects to be approved by PETROBRAS.

3.2 FLANGED JOINTS CLASSIFICATION

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:

- System service (type of conveyed fluid, pressure rating, design temperature);
- Past performance of the selected joint (or joints in similar service, likelihood of a leak);
- Inventory loss in case a leak occurs;
- Safety and environmental consequences of a leak;
- Access for remedial work once asset is in service;
- Local factors – vibration, temperature cycles, slug flow, hazardous duty, etc.;
- Exposure to external fatigue loads.

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

- Lines and equipment that will contain flammable gases and process CO2 pressure class above 600
- Lines and equipment DN> 2" and pressure class 2500 and above (as per ASME B16.5) for all fluids;
- All flanged joints with API 6A, API 17D, NORSOK L-005 or ISO 27509 flanges,;
- Flanges connecting to load sensitive equipment (such as rotating equipment);
- Hard pipes, riser lines, production lines;
- Hull bolted joints may be considered as ordinary (except hard pipes and riser related lines).

3.3 PROCEDURES, DATA SHEETS AND RECORDS

3.3.1 Bolted Joint Assembly Procedure

CONTRACTOR performing the work 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:

- Specific requirements for flanges designed as per API 6A, API 17D and Compact flanges;
- Additional features and care for Clamp Type and other proprietary connections;
- 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;
- Specific requirements for bolted joints that are part of pressure containing equipment;
- Specific requirements for bolted joints connecting equipment with pre-determined maximum load limits (load sensitive equipment).

3.3.2 Joint Data Sheets

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

This **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.

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

3.3.3 Joint Assembly Records

CONTRACTOR shall issue a **Joint Assembly Record** for each assembled joint classified as **special joint** (see item 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, 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) Date of assembly;

k) Name of the professionals who performed the assembly;

l) Name and signature of the Qualified Bolting Specialist.

The Joint Assembly Records shall be in accordance with Figure 7 of ASME PCC-1. All records shall be submitted to the CLIENT in electronic format.

3.3.4 Bolt torque and tension qualification

When assembling special joints CONTRACTOR shall qualify torque and tension values with a calibrated hollow load cell in accordance with ISO 27509:2020 item D.11.

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 lot 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.

PETROBRAS 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

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.

The flange joint TAG shall be the same as stablished in the 3D model.

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.

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

Both Permanent and Temporary tags shall be durable and water proof, and shall be securely fastened to the flanges. Temporary TAGS shall be perforated so that the colored parts can be teared off.

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

3.4.2 Mechanical Completion TAG

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 1).

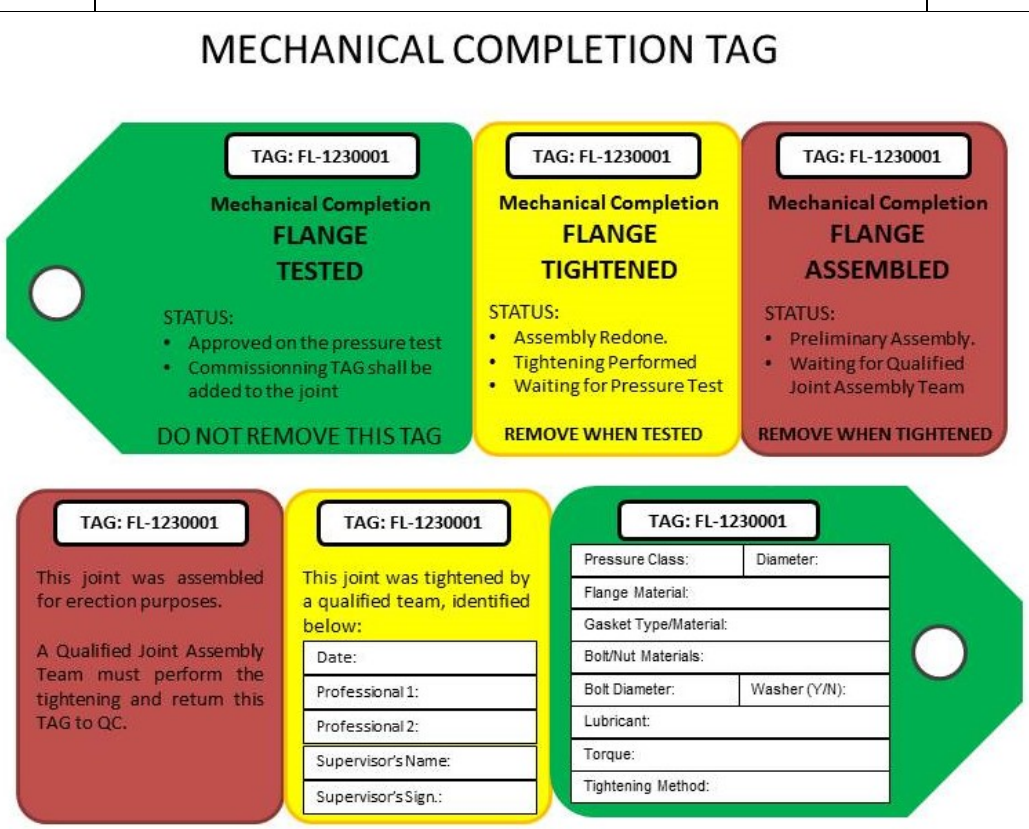


Figure 1 – Model for the Mechanical Completion TAG

It shall include the following information:

a) Joint identification (Permanent 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.

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.

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

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.

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 yellow tag shall be filled by the team supervisor.

Pressure test can only be performed on systems with no red tags left on the joints.

Once the pressure test has been performed and approved the yellow tags 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.

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

3.4.3 Commissioning TAG

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 2).

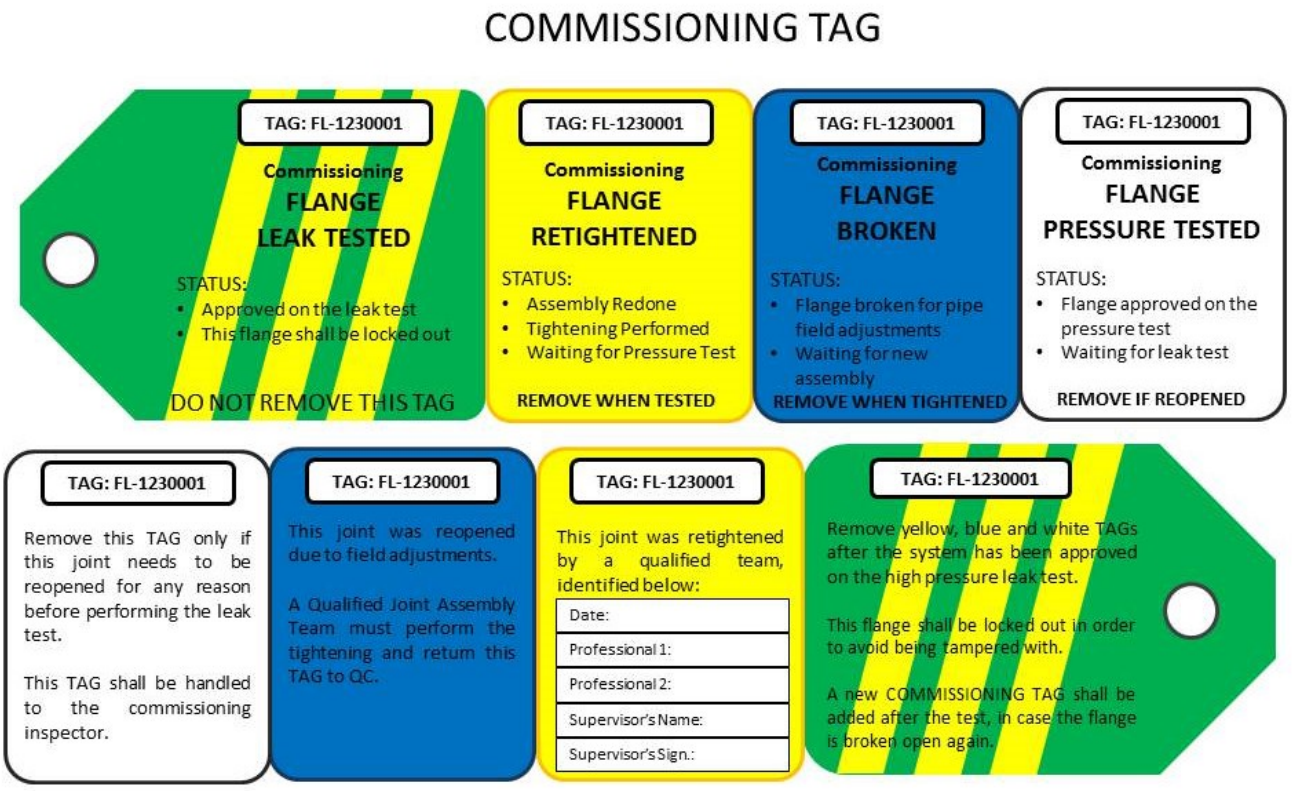


Figure 2 – Model for the Commissioning TAG

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.

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.

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

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.

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

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

This lockout may be performed by:

- Metallic cable and a metallic seals;
- Metallic cable and a plastic compression seals;
- Plastic fastening (p.e. hellermann type fasteners);

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

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

3.5 BOLTED JOINT MANAGEMENT SYSTEM

All bolted joints shall be managed in a similar fashion as the piping welded joints.

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 herein listed technical requirements.

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

- Joint identification (TAG) and location;
- Joint classification (ordinary / special);
- Joint material specifications for all components (bolts, nuts, washers, flanges, gaskets, etc.);
- Joint main features (pressure class, diameter of the flange, diameter of the bolts, number of bolts, and so on);
- Joint tightening method, assembly target torque / tension, and the applicable lubricant;
- Applicable Joint Data Sheet number;
- Quality controls to be applied after assembly (if any);
- Tightening Teams and Bolting Specialists involved in assembly;
- Applicable Joint Assembly Record (special joints).

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

- Status of the joint (assembled / tightened / pressure tested / broken / leak tested);
- Dates for all relevant events: assembly, tightening, pressure test, leak test;
- Professional involved in the applicable events (qualified team identification).

4 TIGHTENING METHODS

4.1 SELECTION

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

a) Impact wrenches and spanner wrench extension tools ARE NOT ALLOWED. Impact 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 stresses which may cause the failure of its components;

b) Hand wrenches are not recommended. Hand tightening may subject the joint to excessive stresses and deformation. When approved by OWNER 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.

Controlled torque bolt tightening method (as in (c) above) associated with bolt elongation measurement or load-control techniques (see item 10.3) may be used as a substitute for hydraulic bolt tensioning when approved by OWNER.

4.2 CONTROLLED TORQUE BOLT TIGHTENING

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

The CONTRACTOR 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).

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

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.

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 STRESS AND TORQUE

Bolt assembly stresses 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 overcome Hydrostatic Test internal pressure;

f) Compensation due to increased temperature during operation.

g) External loads;

h) Vibration;

i) Cyclic service;

j) Thermal expansion differences between bolts and flanges;

k) Temperature gradients within the flanges;

l) Lubricant characteristics;

m) Use of washers or other accessories;

The torque determination shall be performed as detailed in ASME PCC-1 standard, Appendix O, Joint Component Approach.

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.

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:

- Maximum permissible gasket stress;
- Minimum gasket operating stress;
- Minimum gasket seating stress;
- Maximum flange rotation permitted by the gasket;
- Fraction of gasket load remaining after relaxation.

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

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

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 in order to perform the inspection activities herein cited. After that the joint may be reassembled and finally tightened.

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

- Flanges and gaskets shall be well preserved, with no corrosion or mechanical damages to the sealing surfaces;
- Bolts and nuts shall be well preserved, with no corrosion or mechanical damages to the threads;
- Flanges, bolts, nuts, washers and gaskets are of the correct material specification, with the applicable manufacturers markings as required by the specification;
- Flanges, gaskets, bolts and nuts are within the dimensions stablished by the applicable standards.

6.2 DIMENSIONAL CHECK

A dimensional check shall be performed prior to the assembly of the bolted joint. Tolerances shall be as indicated in Table 1 below (in accordance with ASME PCC-1). 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.

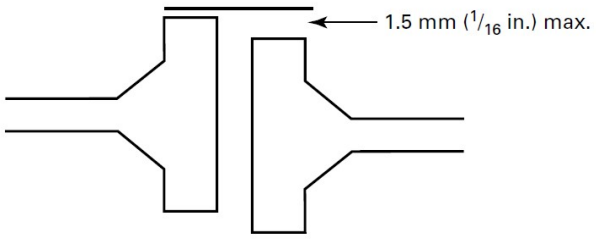
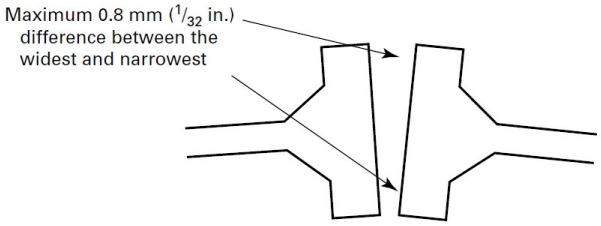
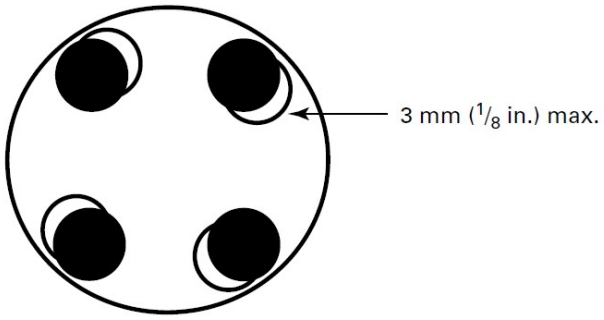
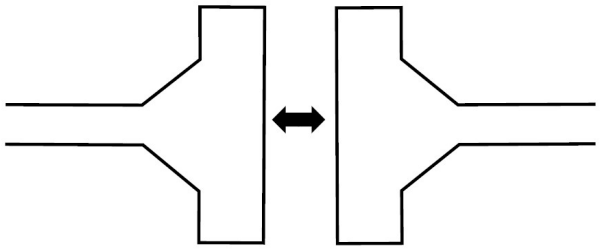
Bolting to pumps and rotating equipment (compressors and so on) is usually subject to special requirements when it comes to the alignment of the flanges prior to bolting. The equipment manufacturer installation manual shall always be checked and the restrictions therein cited shall always be adhered to.

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.

If the flanges that are in need of aligning 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 necessary practice.

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

Table 1 – Dimensional Tolerance (as per ASME PCC-1)

 Centerline High Low	The alignment of piping or vessel flanges so that the seating surfaces, the inside diameter of the bore, or the outside diameter of the flanges match or meet with the greatest amount of contact surface. Tolerance is usually measured by placing a straight edge on the outside diameter of one flange and extending it to or over the mating flange. This is done at four points around the flange, approximately 90 degrees from each other. The tolerance is 1.5 mm (1⁄16 in.) at any point.
 Parallelism	The alignment of piping or vessel flanges so that there are equal distances between the flange faces at all points around the circumference of the joint, therefore making the flange faces parallel to each other. The tolerance is usually determined by measuring the closest and farthest distance between the flanges and comparing. An acceptable practice is a difference no greater than 0.8 mm (1⁄32 in.) at the O.D. of the sealing surface, achieved using a force of no greater than 10% of the maximum torque or bolt load for any bolt.
 Rotational-Two Hole	The alignment of piping or vessel flanges so that the bolt holes align with each other, allowing the fasteners to pass through perpendicular to the flanges. The tolerance is measured by observing a 90-deg angle where the fastener passes through the flanges or the holes are within 3 mm (1⁄8 in.) of perfect alignment.
 Excessive Spacing or Gap	A condition where two flanges are separated by a distance greater than twice the thickness of the gasket when the flanges are at rest and the flanges will not come together using reasonable force. When no external alignment devices are used, the flanges should be brought into contact with the uncompressed gasket uniformly across the flange faces using less than the equivalent of 10% of the total target assembly bolt load. When aligning the flanges, no single bolt shall be tightened above 20% of the single bolt maximum torque or target bolt load. When external alignment devices are used, the flanges should be brought to the compressed gasket thickness uniformly across the flange faces using an external load equivalent to less than 20% of the total target assembly bolt load.

6.3 CLEANING AND EXAMINATION

Before assembly is started, flange and fasteners contact surfaces shall be cleaned and inspected.

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.

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.

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

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

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.

Reuse of a gasket is not allowed.

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.

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.

6.5 LUBRICATION

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.

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.

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.

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 3). 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.

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.

Do not apply either approved lubricant or unapproved compounds to the gasket or gasket-contact surfaces.

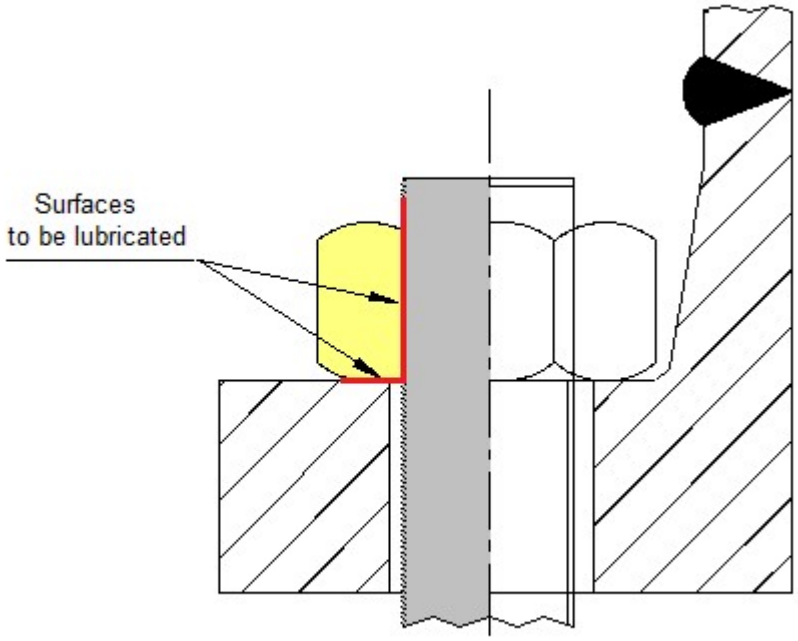


Figure 3 - Surfaces to be lubricated

6.6 INSTALLATION OF BOLTS

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.

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

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.

The use of bolt tensioners requires that the threaded portion of the bolt extend 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.

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 (item 5 above) 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 CONTRACTOR.

7.3 HYDRAULIC BOLT TENSIONERS

The CONTRACTOR 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

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

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

8 CANCELLED

9 PRESERVATION

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.

The general preservation method shall be agreed with OWNER. 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).

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.

On areas of the platform with a 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). Other high corrosivity areas may require this change in the preservation method upon agreement with OWNER.

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.

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

10 ADDITIONAL INFORMATION

10.1 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.

10.2 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.

10.3 LOAD CONTROL SYSTEMS

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

10.3.1 Direct length measurement

This method uses mechanical extensometry 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.

10.3.2 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.

10.3.3 Load monitoring sensors

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.

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.

10.3.4 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:	
STEP 4:	

NOTES