COMPANY STANDARD PROCEDURE

FLANGE CONNECTIONS

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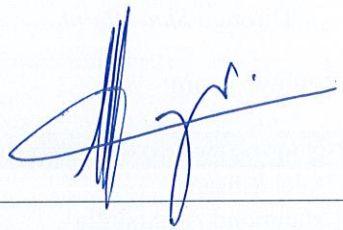
Approved by	Name	Vincent Raymond Magne	
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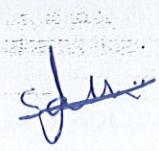
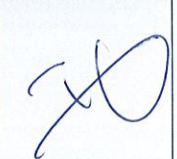
00	06 /June / 2020					
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1. OBJECTIVE

This procedure describes the requirements for assembling bolted flange connections in a way that follows best practice and helps to ensure lasting leak free joints.

2. SCOPE

This procedure applies to bolted flange joints in all piping and equipment for existing installations and new construction, except where there are specific OEM procedures that must be followed.

3. PROCEDURE SUMMARY

This procedure describes the requirements for assembling bolted flange connections following the best practices with respect to

- Identification of critical flanged connections
- requirement for each critical flanged connection
- inspection and administration of critical flanged connections
- requirements with respect to training and re-training for bolting technicians

4. ABBREVIATIONS / DEFINITIONS

#	Abbreviation / Key word	Definition summary
1	FRP	Fiber Reinforced Plastic
2	OEM	Original Equipment Manufacturer
3	PPE	Personal Protective Equipment
4	LMRA	Last Minute Risk Assessment
5	PTW	Permit to Work
6	MOC	Management of Change
7	ASME	American Society of Mechanical Engineers
8	PTFE	Polytetrafluoroethylene
9	LMRA	Last Minute Risk Assessment
10	LOTO	lockout/tagout
11	P&ID	piping and instrumentation diagram
12	HOI	Head of Integrity
13	RM	Reliability Manager
14	MM	Maintenance Manager
15	IIM	Inspection and Integrity Manager
16	HSEQGM	HSE Group Manager

5. DOCUMENT REFERENCES

#	Document ID	Document name	Summary of dependency or use
1	--	Quality Check Sheet	Quality control of bolted connection
2	--	ASME PCC-1	Guidelines for Pressure Boundary Bolted Flange Assemblies
3	--	ASME PCC-2	Repair of Pressure Equipment and Piping
4	--	ASME Section II	Materials
5	--	ASME Section VIII	Boiler and Pressure Vessel Code (BPVC)
6	--	ASME B16.5	Pipe Flanges and Flanged Fittings
7	--	ASME B16.47	Pipe Flanges and Flanged Fittings
8	--	API RP 570	Piping Inspection Code (Recommended practice)
9	--	ASTM D-3517	GRP Pipelines
10	PR-PSS-114	Permit to work procedure	QAPCO Permit to work procedure

5.1 Risk Register Reference

#	Risk ID	Risk Description	Remarks
1	NA	NA	NA
2			

6. IT SYSTEM REQUIREMENTS

#	IT system module name	Summary of IT system module use
1	SAP PM	Identify pipeline and connection, spare parts, link to procedure, link to quality check sheet

7. RASI SUMMARY

#	Procedure chapter	Integrity Engineer	Technician	Bolting Technician	Maintenance Supervisor	Maintenance Planner	Operator	Static Engineer	Inspector	Process Engineer
1	Tightening Procedure	A/R (critical)	--	--	--	I	--	A/R (non-critical)	C	C
2	Gasket Removal	--	R	C	S	S	A	I	S	--
3	Prepare for tightening	S	--	R	A (non-critical)	S	--	S	A (critical)	--
4	Tightening Bolted Flanged Connection	S	--	R	A (non-critical)	--	I	S	A (critical)	--

Legend:

R = Responsible (the class of people who are ultimately responsible for getting the work done)

A = Accountable (the position that is accountable to oversee that the work gets done)

S = Support (the person who supports by providing information and suggest any deviations from the Procedure)

C = Consulted (the person who can advise when needed)

I = Informed (concerned persons who are required to be informed or communicate to)

8. PROCEDURE METHOD

SAFETY, HEALTH, AND ENVIRONMENT PRECAUTIONS

Before breaking existing joints and removing the gasket, the system must be properly isolated, drained and depressurized as per QAPCO Permit to Work procedure. After receipt of the Permit to Work, performing the LMRA and validate the LOTO, the work can commence.

Before loosening the bolts, the flanges must be supported adequately. Where possible, first loosen the bolts on the side of the flange away from the technician so that any residual pressure is relieved away from the technician's body. The use of "flogging" wrenches, adjustable spanners, and wrench extenders are not permitted. These practices have frequently led to injuries and tend to overtighten joints causing damage to flanges, gaskets, and bolts.

8.1 TIGHTENING PROCEDURE

Identification of critical flanged connections and creation of a tightening procedure for each critical flange as well as generic procedure for non-critical flanges.

INPUTS SUMMARY

Bolted Flange Connection marked on P&ID together with the engineering data and process information to determine the criticality of the flange.

Historic information on leakages of this bolted flange connection if available

FLANGED CONNECTION TIGHTENING PROCEDURE

ID	Activity	Document reference	Responsible org. position
8.1.1	List flanged connections.	N/A	Static Engineer
8.1.2	Identify critical flanged connections based on process medium, pressure, temperature cycles, and historic data.	N/A	Static Engineer
8.1.3	Validate critical flanged connections.	N/A	Integrity Engineer
8.1.4	For each critical flanged connection, a separate tightening procedure must be available.	N/A	Integrity Engineer
8.1.5	For all non-critical flanged connection, a generic tightening procedure must be available.	N/A	Static Engineer
8.1.6	In SAP reference to be made to tightening procedure based on pipeline number.	N/A	Planner Static
8.1.7	Flange criticality and respective tightening procedure to be reviewed every 7 years or when leakage occurs.	N/A	Integrity Engineer

PROCEDURE COMMENTARY

The output of this process is a tightening procedure which includes whether the bolts need replacement, type and size of gasket, number of bolts, tightening sequence and passes, and the torque for each pass. This sheet must be readily available for each critical bolted flanged connection and given to the bolting technician for use in the field when a connection needs to be made.

The level of integrity of the bolted flanged connections can only be guaranteed when the practice is followed rigorously.

OUTPUTS SUMMARY

For each critical bolted flanged connection, a tightening procedure must be available, including the right gasket, bolts, and torque or tensioning values, see Appendix 5: Recommended Torque Values

For all non-critical bolted flanged connections, a generic procedure is available including the right gasket, bolts and torque or tensioning values grouped on process medium and pressure rating of the flanges.

8.2 GASKET REMOVAL

Loosening of the bolts, spreading of the flanges and removal of the gasket

INPUTS SUMMARY

Operations to clearly identify with proper identification Tags, which flange to be opened, including applying LOTO for the system and a suitable Permit to Work for Line Breaking. The Work permit shall clearly identify the risk of the process medium and related applicable PPE to be used.

LINE BREAKING AND GASKET REMOVAL

ID	Activity	Document reference	Responsible org. position
8.2.1	Clearly identify flanged connection(s) to be opened	N/A	Operations
8.2.2	Validate the LOTO performed by Operations	N/A	Technician
8.2.3	Perform last minute risk assessment	N/A	Technician
8.2.4	Sign Permit to Work	N/A	Technician
8.2.5	Ensure pipeline is suitably supported before first loosening	N/A	Technician
8.2.6	Loosen first bolts, if possible, away from technician.	N/A	Technician
8.2.7	Relief remaining pressure and / or residual product	N/A	Technician
8.2.8	Loosen and remove all bolts, bolts to be cleaned and properly stored next to the flanged connection	N/A	Technician

ID	Activity	Document reference	Responsible org. position
8.2.9	Separate the flange faces using a joint breaker or wedges; for FRP joints a plastic scraper is recommended and remove the gasket	N/A	Technician
8.2.10	Inspect the flange face to ensure all old gasket material is removed	N/A	Technician

PROCEDURE COMMENTARY

Separate the flange faces using a joint breaker or wedges, if required. Do not drive wedges, chisels, or screwdrivers between the laps. Remove the gasket completely and do not reuse. A heavy-duty scraper can be used to remove gasket fragments from flange faces that can be separated only slightly; however, care must be used to prevent scoring or scratching the flange faces. For FRP (Fibre Reinforced Plastic) joints a plastic scraper is recommended.

Inspect flange faces to assure complete removal of old gasket materials. Complete removal of all residues from the old gasket is essential for the successful performance of the new gasket. Gasket material can, and does, become lodged into the flange serrations and this will adversely affect the leak tightness of the new gasket. Cleaning of the serrations with a brass wire brush in the direction of the serrations, followed by a solvent type cleaner and cotton cloth is recommended. Use a stainless-steel wire brush for stainless steel and higher alloy flanges.

OUTPUTS SUMMARY

Opened flanged connection with clean flange faces ready for inspection, preparation, and tightening when required.

8.3 PREPARE FOR TIGHTENING

Inspection and preparation of the bolted flanged connection before tightening which includes flange alignment, flange face, gasket, bolts, stud bolts, and nuts. In case the flange surface is damaged then the damaged surface can be refaced following ASME PCC-1 (See Appendix)

INPUTS SUMMARY

Opened bolted flanged connection and tightening procedure including size and quality of bolts and nuts, requirements for washers, grease to be used

PREPARE FOR TIGHTENING

ID	Activity	Document reference	Responsible org. position
8.3.1	Inspect flange surface for surface finishing of critical flanges and evidence of scoring, gouges, or abrasions.	N/A	Inspector
8.3.1	Inspect flange surface for surface finishing of non-critical flanges and evidence of scoring, gouges, or abrasions.	N/A	Supervisor
8.3.2	If flange surface is not right then the surface to be refaced, or flange to be replaced following repair procedure.	N/A	Static Engineer
8.3.3	Inspect bolts and nuts for worn or damaged threads, corrosion, or stretched. Replace bolts where required.	N/A	Bolting Technician
8.3.4	Check flange alignment and resolve when required.	N/A	Bolting Technician
8.3.5	Check if new bolts, nuts, washes, studs, and gasket are right material and type.	N/A	Bolting Technician
8.3.6	Insert greased bolts at the 3, 6, and 9 o'clock position and insert the gasket and for spiral wound gaskets ensure that the inner diameter of the centering ring is at all points within the outside diameter of the raised face.	N/A	Bolting Technician
8.3.7	Insert the remaining greased bolts and nuts and hand gently tighten them to secure the nuts, bolts and gaskets in place.	N/A	Bolting Technician
8.3.8	Ensure that a minimum of 3 threads protrude through the nuts, and with studs on both sides. When hydraulic tensioning is to be used then a treaded length of 1 to 1.5 times the bolt diameter must protrude at the end where the tensioner is to be placed.	N/A	Bolting Technician
8.3.9	Check that the gap between the flanges around the circumference is uniform and the flanges are parallel, measure the gap at 8 points around the circumference. The difference should be within 0.25mm.	N/A	Bolting Technician
8.3.10	In case the flange is defined as a critical flange then inspection to be done before tightening of the bolts on alignment, gasket position, bolt condition and greasing. The inspector will give approval for tightening in case all is found in good condition	N/A	Inspector

PROCEDURE COMMENTARY

Alignment of the flange faces is necessary to ensure uniform gasket loading and to ensure mechanical strain is not placed on the bolted assembly that will act to unload the gasket. In the appendix the guidelines for flange alignment and surface condition consistent with ASME PCC-1 are included.

OUTPUTS SUMMARY

Bolted Flange Connection fully prepared for tightening following the pre-defined torqueing or tensioning procedure for respective flange.

8.4 TIGHTENING BOLTED FLANGED CONNECTION

Tightening of the bolted flanged connection following the torqueing or tensioning procedure and record actual passes and torqueing values for each pass and bolt.

INPUTS SUMMARY

Flanged connection prepared for tightening and the tightening procedure for respective flange.

TIGHTENING

ID	Activity	Document reference	Responsible org. position
8.4.1	Number the bolts so that torqueing requirement can be followed.	N/A	Bolting Technician
8.4.2	Tighten the bolts in the cross-pattern bolt-tightening sequence as per procedure and record the actual torqueing figures.	N/A	Bolting Technician
8.4.3	After each incremental stage the gap around the circumference is to be measured for uniformity and record the measured gap.	N/A	Bolting Technician
8.4.4	If the difference in gap is too large, then the connection needs to be disassembled to locate and solve the source of the problem.	N/A	Bolting Technician
8.4.5	Continue tightening the bolts following the procedure and record the torque after each pass.	N/A	Bolting Technician
8.4.5	In case of a critical flange the inspector is to perform final inspection before final tightening and check sheet signed	N/A	Inspector
8.4.6	Once all bolts are tightened according to the procedure all bolts need to be continued tightening rotation clockwise until no further nut rotation occurs and record the final torque for each bolt.	N/A	Bolting Technician
8.4.7	Flange to be tagged with respective technician label.	N/A	Bolting Technician
8.4.8	Retighten following step 8.5.6 again after 4 hours.	N/A	Bolting Technician
8.4.9	For PTFE type gaskets and lined pipes it is recommended to retighten again after 24 hours and after every thermal cycle and decompression.	N/A	Bolting Technician
8.4.10	Quality Check Sheet to be handed over to maintenance planning.	Quality Check Sheet	Bolting Technician

ID	Activity	Document reference	Responsible org. position
8.4.11	Check sheet to be uploaded into SAP at respective pipeline and / or flange.	Quality Check Sheet	Maintenance Planner

PROCEDURE COMMENTARY

This procedure shall be aligned /made applicable for Flanged connection jobs executed by Contractor personnel including General shutdowns.

Each joint assembled using this procedure, except those done using conventional manual wrenches must have a joint certificate completed and signed by the lead technician performing the work and a tag attached to the flange. Use Appendix 3 for torqued joints and Appendix 4 for tensioned joints.

Quality control checks should be performed by QAPCO inspector during periods of intense maintenance activity by contractors e.g. turnarounds. Checks should include but are not limited to:

- Joint certificate completed in full, with signatures and accurate torque values
- Metallic Tag fitted to joint
- Checking before tightening that the correct gasket has been fitted
- Checking flanges for indications that bolts have been numbered to assist in torque sequencing.

OUTPUTS SUMMARY

High Quality Tightened and recorded Bolted Flange Connection, fit for service

9. RECORDS

The owner / executor of change shall maintain the following, but not limited to, records / documents for reference:

#	Document / Record ID	Document / Record name	Responsible department or section
1	Quality Check Sheet	Quality Check Sheet critical flanged connections	Bolting Technician
2	Quality Check Sheet	Tightening inspection form in SAP	Planning Department
3			

10. APPENDIX

10.1 SERVICE LEVEL DEFINITION

The key services and service levels listed below are required to complete the activities contained within this procedure.

#	Service	Service level	Service provider	Service customer
1	Flange -Line Breaking and Gasket removal	Zero Safety Incident	Maintenance Static	Operations
2	Flange Tightening	Zero Leak Zero Safety incident	Maintenance Static	Operations

10.2 TRAINING REQUIREMENTS

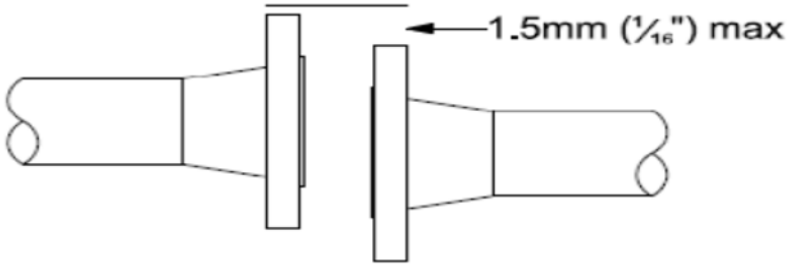
Tightening of Bolted Flanged Connections is, from an integrity point of view, a highly critical task since it has a direct relation to the integrity of the facility. Specific training therefore is required for every employee and contractor working for QAPCO and who regularly works on bolted flanged connections, this includes but is not limited to, operators, static and rotating technicians, instrument technicians, and inspectors. The training requirements depend on the criticality of the flange and the tightening method to be uses.

Method	Manual	Manual Torqueing	Hydraulic Tensioning
Flange Criticality			
Critical	--	EN 1591 certified or similar	EN 1591 certified or similar and Specialist training & certification
Non-Critical	Training in accordance with EN 1591	Training in accordance with EN 1591	

10.3 ASME PCC-1 FLANGE ALIGNMENT

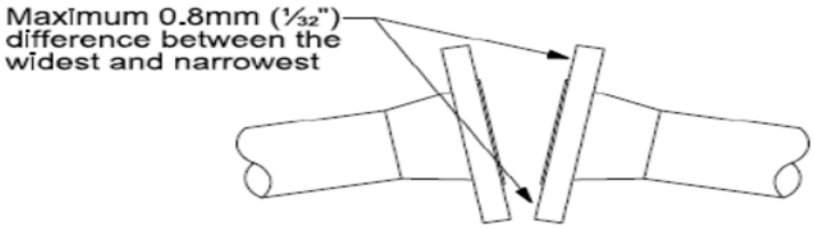
Alignment of the flange faces is necessary to ensure uniform gasket loading and to ensure mechanical strain is not placed on the bolted assembly that will act to unload the gasket. The following are guidelines for flange pair alignment consistent with ASME PCC-1:

Centerline offset (high/low) – the flange faces should come together with the outer and inner edge of the flanges coming together at the same location. Excessive offset can pinch the gasket causing mechanical damage. Acceptable high/low offset is 1.5mm or 1/16” at any point measured at 4 locations around the flange



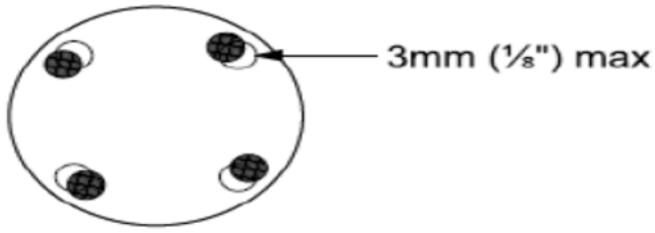
Centerline offset (high/low)

Angular – during the assembly process the flange should come together square. Just before contact the maximum gap between flange sealing surfaces at all points around the flange is 0.8mm or 1/32” using a force no greater than 10% of the maximum torque or bolt load.



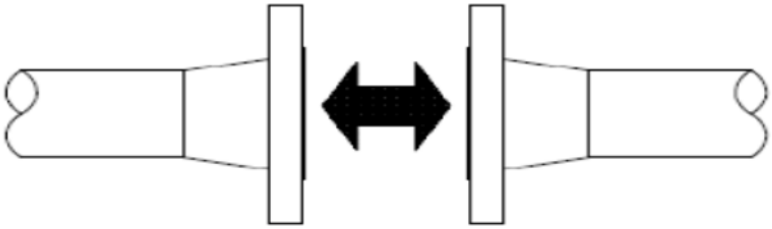
Angular

Rotational – the flange pair must be aligned so that the bolt holes between mating flanges allows fasteners to pass through the flange pair without binding. Bolt holes shall be aligned to within 3mm or 1/8” maximum offset.



Rotational – Two Hole

Excessive Spacing – flanges must be brought sufficiently close together to ensure adequate gasket compression. Spacing is "excessive" when the flanges are separated by a distance greater than twice the thickness of the gasket when the flanges are at rest. When no external alignment devices are used to bring the flange pair together the flanges must be brought together with less than 10% of the target preload. When external devices are used the flanges must be brought together with less than 20% of the target preload.



Excessive Spacing or Gap

10.4 ASME 16-5: FLANGE FACE ROUGHNESS

The ASME B16.5 code requires that the flange face (raised face and flat face) has a specific roughness to ensure that this surface be compatible with the gasket and provide a high-quality seal. In case of any damage to the surface there is an increased risk of flange leakage. ASME PCC-1 describes the different types of damages and what is regarded as an acceptable damage.

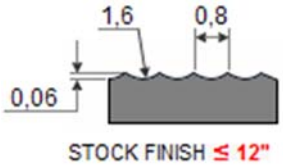
The most common types of damage which can be found are

1. Scratches - narrow and elongated damage with sharp, shallow bottoms. However, depending on the force that created them, they can be deep. Frequently, this type damage is created by a sharp object dragging across the flange face. These objects may include the bristles of a wire brush or a tool, such as a chisel.
2. Gouges - wide and elongated with blunt, rounded bottoms and are created by a dull object dragging across the flange face. Gouges can be caused by objects—such as a screwdriver, flange jack or chisel.
3. Pits - small, somewhat rounded areas of concentrated material loss created by corrosion. Often, pits occur in clusters or groups.
4. Dents - sharp or blunt on elongated areas caused by some form of impact. Dents sometimes result from equipment collisions caused by positioning the mating flanges WHEN using cables and rigging

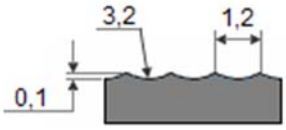
The most used flange finishes are shown in the graph and described in the next paragraphs.

Serrated Finish

A serrated finish, either concentric or spiral, is required with 30 to 55 grooves per inch and a resultant roughness between 125 and 500 micro inches. This allows for various grades of surface finish to be made available by flange manufactures for the gasket contact surface of metal flanges.



STOCK FINISH ≤ 12"

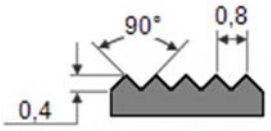


STOCK FINISH ≥ 14"

Stock Finish

The most widely used of any flange surface finish, because practically, is suitable for all ordinary service conditions. Under compression, the soft face from a gasket will embed into this finish, which helps create a seal, and a high level of friction is generated between the mating surfaces.

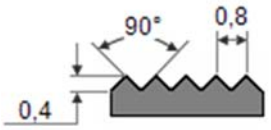
The finish for these flanges is generated by a 1.6 mm radius round-nosed tool at a feed rate of 0.8 mm per revolution up to 12 inch. For sizes 14 inch and larger, the finish is made with 3.2 mm round-nosed tool at a feed of 1.2 mm per revolution.



SPIRAL SERRATED
OR PHONOGRAPHIC

Spiral Serrated Finish

This is also a continuous or phonographic spiral groove, but it differs from the stock finish in that the groove typically is generated using a 90-° tool which creates a "V" geometry with 45° angled serration.



CONCENTRIC SERRATED

Concentric Serrated

As the name suggests, this finish is comprised of concentric grooves. A 90° tool is used and the serrations are spaced evenly across the face.


SMOOTH FINISH

Smooth Finish

This finish shows no visually apparent tool markings. These finishes are typically utilized for gaskets with metal facings such as double jacketed, flat steel and corrugated metal. The smooth surfaces mate to create a seal and depend on the flatness of the opposing faces to effect a seal. This is typically achieved by having the gasket contact surface formed by a continuous (sometimes called phonographic) spiral groove generated by a 0.8 mm radius round-nosed tool at a feed rate of 0.3 mm per revolution with a depth of 0.05 mm. This will result in a roughness between Ra 3.2 and 6.3 micrometers (125 - 250 micro inch).

10.5 GUIDE TO SELECT BOLT TIGHTENING METHOD

Fluids and Services	Bolt Diameter	Tightening Method
All service/utility fluids at ≤ class 150, design temp ≤ 186 ºC and fluid temp ≥ -29 ºC. Category D fluids in ASME B31.3 and PCC-1	≤ 1”	Std Manual Wrench
	> 1”	Hydraulic Torque or tension
All process/hazardous fluids, plus all services/utility fluids at ≥ class 150, design temp ≥ 186 ºC. Normal fluids in ASME B31.3 and PCC-1	≤ 1”	Manual torque wrench
	> 1”	Hydraulic torque or tension
All highly toxic services. Category M in ASME B31.3 and PCC-1	≤ 1”	Manual torque wrench
	> 1”	Hydraulic tension

10.6 RECOMMENDED TORQUE VALUES

Introduction

Many factors affect the performance of a bolted flange assembly. The initial intended bolt preload can be dramatically affected by installation/assembly problems. Even with proper assembly procedures the flanges can and will relax due to mechanical relaxation, thermal cycling, and supplemental loads. The optimum pre-load for a flange assembly is the maximum pre-load the assembly can take without damaging the gasket, bolt, or flange. By maximizing the pre-load for the flange, there is greater margin to allow for the assembly uncertainty and mechanical relaxation. The intent of the torque tables in this section is to provide the user with optimal preloads for standard flanges.

Scope

The torque tables in this section are intended for standard ASME pipe flanges (Class 150, 300 and 600) using standard sheet ring gaskets (ASME B16.21) and standard spiral wound gaskets (ASME B16.20). Flanges can be fabricated in many ways. The most mechanically robust design is the weld neck flange. This flange design can withstand the highest bolt pre-load and hence creates the tightest joint. The lap joint flange is unable to transmit the pre-load through the pipe/nozzle neck and as a result is significantly less robust. To optimize the pre-loads separate torque tables for lap joint and weld neck flanges have been created.

The torque tables in this section are for Carbon Steel flanges (weld necks and lap joint) at temperatures up to 200°C.

Tightness Considerations

The values listed in the torque tables are intended to provide the highest preload to the gasket without over-stressing and/or deflecting any of the components. In general, the higher the gasket pre-load the tighter the seal on the gasket. The tightness of a flanged assembly as a function of gasket stress has been quantified

through a procedure developed by the PVRC (Pressure Vessel Research Council) using gasket test data from the ROTT (Room Temperature Tightness Test).

The PVRC procedure has established three levels of tightness (Class 1,2,3). Class 1 tightness is for non-critical service, Class 2 is for "normal" service, while Class 3 is for "tight" or hazardous service. The torque required to achieve a "tight" (T3) seal was determined for each flange size in the torque tables. These values were calculated for two representative gaskets (spiral wound, filled PTFE) at the maximum pressure limit in the flange class. A review of this data shows that T3 seals can be achieved with either gasket when weld neck flanges are used since these flanges can handle a relatively high bolt pre-load. However, for lap joint flanges a T3 seal can only be accomplished with the filled PTFE gaskets. The pre-load required to achieve a T3 seal on Spiral Wound gaskets overstresses the lap joint flange.

Screening Criteria

The following torque tables are suggested values for standard Class 150, Class 300, and Class 600 carbon steel flanges. Additional considerations may need to be considered based on operating conditions. In general, the following conditions apply:

- Must use high strength bolting (yield strength greater than 80 ksi, B7, B7M, L7, B8 Class 2….). For low strength bolting (A307, B8 Class 1…) use the torque values in Attachment 8.8 corresponding to 20 ksi bolt stress
- Operating Temperature does not exceed 200°C
- Flanges are assumed to be in good condition and in compliance with ASME B16.5 or B16.47 specifications
- Flanges not subject to extreme mechanical or thermal cycling

Tables are for non-elastomeric sheet gaskets (minimum crush strength of 15,000 psi) and metal gaskets (spiral wound, corrugated graphite, KAMM profile).

Tables assume a “nut factor” of .2. Significant difference in the nut factor can be experienced. Low nut factors can be applied for “coated” studs/nuts or wit use of special lubricants. Higher “nut factors” may be attributed to poor lubrications, fastener corrosion or fastener reuse.

The torque values in the table are specifically for Carbon Steel Flanges (specifically SA 105 forged flanges). The values in the table can be used for other materials where the yield stress at the design/pipe code temperature limit is at least 30000 psi.

Nut Factors

Bolted flange assemblies achieve their clamping force through the stored potential energy that is imparted to the studs during the assembly process. Unfortunately, most of the energy imparted to the nut/stud is converted to heat loss caused by frictional energy losses between the nut/stud threads and the nut/flange surface.

The Nut Factor "K" also known as the torque coefficient accounts for how efficiently the torque applied to the nut is transmitted to the bolt stretch. The Nut Factor includes all inefficiencies including the friction factor between the internal/external threads and the friction losses between the nut face and the flange/washer face. The actual value of the Nut Factor depends on many factors including the type of lubrication, method of bolt elongation, presence of hardened washers, and the number of times the studs/nuts have been reused.

For new installations, the Nut Factor typically varies from .15-.20 depending on type of lubrication and use of washers. However, when stud/nuts are reused the nut factor can increase significantly. Studies have shown the Nut Factor can double (.4) within 6 uses/reuses. The effect of doubling the "Nut Factor" is to drop the clamping force in half. In critical service applications (hazardous service, higher pressures) where a significant reduction in clamping force cannot be tolerated, new bolts/nuts should be installed with every installation. In applications where bolts/nuts must be reused care must be taken to verify the condition and functionality of the fastener. ASME PCC-1 (Appendix N) provides guidelines on the reuse of fasteners. In these cases, the fasteners must go through a “controlled” reuse. A “controlled” reuse will include the following; specifying and applying a defined preload, defining lubrication, tracking the number of uses and inspection/verifying the condition of the fasteners.

Fluoropolymer-coated nuts/bolts have low nut factors (approximately 0.125) and do not require the use of lubricants. The use of lubricants will have the effect of raising the nut factor.

Torque Tables

For Critical Assets like Tubular Reactor similar equipment the OEM or Vendor recommended Torque values must be applied.

Table 4: Torque Values for ASME B16.5 Class 150 Lap Joint Flanges

Nominal Pipe Size	Size of Bolts (in)	# of Bolts	Lightly lubricated, studs and nuts, K=0.2 (ft-lbs)	Well Lubricated studs and nuts with hardened washers, K=0.15 (ft-lbs)	Teflon coated Fasteners, K=0.125 (ft-lbs)
0.5	0.5	4	20	15	13
0.75	0.5	4	20	15	13
1	0.5	4	25	20	16
1.5	0.5	4	45	35	30
2	0.63	4	65	50	45
2.5	0.63	4	85	65	55
3	0.63	4	125	95	80
4	0.63	8	60	45	40
6	0.75	8	105	80	70
8	0.75	8	135	105	85
10	0.88	12	125	95	80
12	0.88	12	125	95	80
14	1	12	190	145	120
16	1	16	190	145	120
18	1.13	16	280	210	175
20	1.13	20	280	210	175
24	1.25	20	400	300	250

Exceptions:

- Must use high strength bolting only (B7, B7M, L7, B8 Class 2)
- Operating temperatures not to exceed 400F
- Flanges are assumed to be in good condition (per ASME B16.5)
- Flanges are not subject to extreme mechanical or thermal cycling
- Tables are for non-elastomeric sheet gaskets and semi-metallic gaskets
- Torque values in the table are specifically for carbon steel flanges. The tables can be used for other materials (i.e. stainless) provided the yield stress at the design temperature must be at least 30,000 psi.

Table 5: Torque Values for ASME B16.5 Class 300 Lap Joint Flanges

Nominal Pipe Size	Size of Bolts (in)	# of Bolts	Lightly lubricated, studs and nuts, K=0.2 (ft-lbs)	Well Lubricated studs and nuts with hardened washers, K=0.15 (ft-lbs)	Teflon coated Fasteners, K=0.125 (ft-lbs)
0.5	0.5	4	25	20	16
0.75	0.63	4	40	30	25
1	0.63	4	45	35	30
1.5	0.75	4	80	60	50
2	0.63	8	45	35	30
2.5	0.75	8	80	60	50
3	0.75	8	85	65	55
4	0.75	8	115	90	75
6	0.75	12	100	75	65
8	0.88	12	150	115	100
10	1	16	185	140	120
12	1.13	16	275	210	175
14	1.13	20	275	210	175
16	1.25	20	390	300	250
18	1.25	24	390	300	250
20	1.25	24	390	300	250
24	1.5	24	700	525	450

Exceptions:

- Must use high strength bolting only (B7, B7M, L7, B8 Class 2)
- Operating temperatures not to exceed 400F
- Flanges are assumed to be in good condition (per ASME B16.5)
- Flanges are not subject to extreme mechanical or thermal cycling
- Tables are for non-elastomeric sheet gaskets and semi-metallic gaskets
- Torque values in the table are specifically for carbon steel flanges. The tables can be used for other materials (i.e. stainless) provided the yield stress at the design temperature must be at least 30,000 psi.

Table 6: Torque Values for ASME B16.5 Class 150 Weld Neck Flanges

Nominal Pipe Size	Size of Bolts (in)	# of Bolts	Lightly lubricated, studs and nuts, K=0.2 (ft-lbs)	Well Lubricated studs and nuts with hardened washers, K=0.15 (ft-lbs)	Teflon coated Fasteners, K=0.125 (ft-lbs)
0.5	0.5	4	20	15	13
0.75	0.5	4	20	15	13
1	0.5	4	30	25	20
1.5	0.5	4	55	45	35
2	0.63	4	85	65	55
3	0.63	4	135	105	90
4	0.63	8	100	75	65
6	0.75	8	175	135	110
8	0.75	8	220	165	140
10	0.88	12	300	225	200
12	0.88	12	340	255	220
14	1	12	465	350	300
16	1	16	450	350	300
18	1.13	16	680	510	425
20	1.13	20	680	510	425
24	1.25	20	1000	750	625

Note:

This torque table may be used for ASME B16.5 slip-on flanges provided the flange is attached to the pipe with an inside and outside weld (i.e. double welded).

Exceptions:

- Must use high strength bolting only (B7, B7M, L7, B8 Class 2)
- Operating temperatures not to exceed 400F
- Flanges are assumed to be in good condition (per ASME B16.5)
- Flanges are not subject to extreme mechanical or thermal cycling
- Tables are for non-elastomeric sheet gaskets and semi-metallic gaskets
- Torque values in the table are specifically for carbon steel flanges. The tables can be used for other materials (i.e. stainless) provided the yield stress at the design temperature must be at least 30,000 psi.

Table 7: Torque Values for ASME B16.5 Class 300 Weld Neck Flanges

Nominal Pipe Size	Size of Bolts (in)	# of Bolts	Lightly lubricated, studs and nuts, K=0.2 (ft-lbs)	Well Lubricated studs and nuts with hardened washers, K=0.15 (ft-lbs)	Teflon coated Fasteners, K=0.125 (ft-lbs)
0.5	0.5	4	30	25	20
0.75	0.63	4	40	30	25
1	0.63	4	55	45	35
1.5	0.75	4	115	90	75
2	0.63	8	70	55	45
3	0.75	8	140	105	90
4	0.75	8	200	150	125
6	0.75	12	200	150	125
8	0.88	12	325	250	205
10	1	16	450	340	290
12	1.13	16	590	450	375
14	1.13	20	600	450	375
16	1.25	20	660	495	412.5
18	1.25	24	700	525	450
20	1.25	24	700	525	450
24	1.5	24	850	650	550

Note:

This torque table may be used for ASME B16.5 slip-on flanges provided the flange is attached to the pipe with an inside and

outside weld (i.e. double welded).

Exceptions:

- Must use high strength bolting only (B7, B7M, L7, B8 Class 2)
- Operating temperatures not to exceed 400F
- Flanges are assumed to be in good condition (per ASME B16.5)
- Flanges are not subject to extreme mechanical or thermal cycling
- Tables are for non-elastomeric sheet gaskets and semi-metallic gaskets
- Torque values in the table are specifically for carbon steel flanges. The tables can be used for other materials (i.e. stainless) provided the yield stress at the design temperature must be at least 30,000 psi.

- ***Table 8: Torque Values for ASME B16.5 Class 600 Weld Neck Flanges***

Nominal Pipe Size	Size of Bolts (in)	# of Bolts	Lightly lubricated, studs and nuts, K=0.2 (ft-lbs)	Well Lubricated studs and nuts with hardened washers, K=0.15 (ft-lbs)	Teflon coated Fasteners, K=0.125 (ft-lbs)
0.5	0.5	4	30	25	20
0.75	0.63	4	40	30	25
1	0.63	4	55	45	35
1.5	0.75	4	130	100	85
2	0.63	8	85	65	55
3	0.75	8	150	115	100
4	0.88	8	250	200	160
6	1	12	370	280	240
8	1.13	12	550	420	350
10	1.25	16	650	500	425
12	1.25	20	690	525	450
14	1.38	20	760	570	475
16	1.5	20	1050	800	675
18	1.63	20	1450	1100	925
20	1.63	24	1475	1125	950
24	1.88	24	2100	1575	1325

Note:

This torque table may be used for ASME B16.5 slip-on flanges provided the flange is attached to the pipe with an inside and

outside weld (i.e. double welded).

Exceptions:

- Must use high strength bolting only (B7, B7M, L7, B8 Class 2)
- Operating temperatures not to exceed 400F
- Flanges are assumed to be in good condition (per ASME B16.5)
- Flanges are not subject to extreme mechanical or thermal cycling
- Tables are for non-elastomeric sheet gaskets and semi-metallic gaskets
- Torque values in the table are specifically for carbon steel flanges. The tables can be used for other materials (i.e. stainless) provided the yield stress at the design temperature must be at least 30,000 psi.

10.7 TORQUE AND LOAD VALUES FOR STRESS BOLTS (TABLE 9)

Load in pounds on bolts when torque loads are applied														
Nominal diameter of stud (in)	Number of threads (per in)	Area at root of thread (in^2)	7,500 psi		15,000 psi		20,000 psi		30,000 psi		45,000 psi		60,000 psi	
			Torque ft·lb	Bolt load, lb	Torque ft·lb	Bolt load, lb	Torque ft·lb	Bolt load, lb	Torque ft·lb	Bolt load, lb	Torque ft·lb	Bolt load, lb	Torque ft·lb	Bolt load, lb
3/8	16	0.068	3	510	6	1020	8	1360	12	2040	18	3060	24	4080
1/2	13	0.126	8	945	15	1890	20	2520	30	3780	45	5670	60	7560
5/8	11	0.202	15	1515	30	3030	40	4040	60	6060	90	9090	120	12120
3/4	10	0.302	25	2265	50	4530	70	6040	100	9060	155	13590	200	18120
7/8	9	0.419	40	3143	80	6285	110	8380	160	12570	250	18855	320	25140
1	8	0.551	62	4133	123	8265	165	11000	245	16530	375	24795	490	33060
1-1/8	8	0.728					240	14600	355	21840	540	32760	710	43680
1-1/4	8	0.929					335	18600	500	27870	755	41805	1000	55740
1-3/8	8	1.155					455	23100	680	34650	1020	51975	1360	69300
1-1/2	8	1.405					535	28100	800	42150	1200	63225	1600	84300
1-3/4	8	1.980					1000	39600	1500	59400	2250	89100	3000	118800
2	8	2.652					1470	53000	2200	79560	3300	119340	4400	159120
2-1/4	8	3.423							3180	102690	4770	154035	6360	205380
2-1/2	8	4.292							4400	128760	6600	193140	8800	257520
2-3/4	8	5.259							5920	157770	8880	236655	11840	315540
3	8	6.324							7720	189720	11580	284580	15440	379440

Values are based on lubricated threads and nut faces.

10.8 TORQUE SEQUENCES

Number of Bolts	**Sequence** (See Figure 1 for Illustration of Cross Pattern Sequence)
4	1-3-2-4
8	1-5-3-7 > 2-6-4-8
12	1-7-4-10 > 2-8-5-11 > 3-9-6-12
16	1-9-5-13 > 3-11-7-15 > 2-10-6-14 > 4-12-8-16
20	1-11-6-16 > 3-13-8-18 > 5-15-10-20 > 2-12-7-17 > 4-14-9-19
24	1-13-7-19 > 4-16-10-22 > 2-14-8-20 > 5-17-11-23 > 3-15-9-21 > 6-18-12-24
28	1-15-8-22 > 4-18-11-25 > 6-20-13-27 > 2-16-9-23 > 5-19-12-26 > 7-21-14-28 > 3-17-10-24
32	1-17-9-25 > 5-21-13-29 > 3-19-11-27 > 7-23-15-31 > 2-18-10-26 > 6-22-14-30 > 4-20-12-28 > 8-24-16-32
36	1-2-3 > 19-20-21 > 10-11-12 > 28-29-30 > 4-5-6 > 22-23-24 > 13-14-15 > 31-32-33 > 7-8-9 > 25-26-27 16-17-18 > 34-35-36
40	1-2-3-4 > 21-22-23-24 > 13-14-15-16 > 33-34-35-36 > 5-6-7-8 > 25-26-27-28 > 17-18-19-20 > 37-38-39-40 9-10-11-12 > 29-30-31-32
44	1-2-3-4 > 25-26-27-28 > 13-14-15-16 > 37-38-39-40 > 5-6-7-8 > 29-30-31-32 > 17-18-19-20 >41-42-43-44 9-10-11-12 > 33-34-35-36 > 21-22-23-24
48	1-2-3-4 > 25-26-27-28 > 13-14-15-16 > 37-38-39-40 > 5-6-7-8 > 29-30-31-32 > 17-18-19-20 > 41-42-43-44 9-10-11-12 > 33-34-35-36 > 21-22-23-24 > 45-46-47-48
52	1-2-3-4 > 29-30-31-32 > 13-14-15-16 > 41-42-43-44 > 5-6-7-8 > 33-34-35-36 > 17-18-19-20 > 45-46-47-48 21-22-23-24 > 49-50-51-52 > 25-26-27-28 > 9-10-11-12 > 37-38-39-40
56	1-2-3-4 > 29-30-31-32 >13-14-15-16 > 41-42-43-44 > 21-22-23-24 > 49-50-51-52 > 9-10-11-12 > 37-38-39-40 > 25-26-27-28 > 53-54-55-56 > 17-18-19-20 > 45-46-47-48 > 5-6-7-8 > 33-34-35-36
60	1-2-3-4 > 29-30-31-32 > 45-46-47-48 > 13-14-15-16 > 5-6-7-8 > 37-38-39-40 > 21-22-23-24 > 53-54-55-56 9-10-11-12 > 33-34-35-36 > 49-50-51-52 > 17-18-19-20 > 41-42-43-44 > 57-58-59-60 > 25-26-27-28
64	1-2-3-4 > 33-34-35-36 > 17-18-19-20 > 49-50-51-52 > 9-10-11-12 > 41-42-43-44 > 25-26-27-28 > 57-58-59-60 > 5-6-7-8 > 37-38-39-40 > 21-22-23-24 > 53-54-55-56 > 13-14-15-16 > 45-50-51-52 29-30-31-32 > 61-62-63-64
68	1-2-3-4 > 37-38-38-40 > 21-22-23-24 > 53-54-55-56 > 9-10-11-12 > 45-46-47-48 > 29-30-31-32 > 61-62-63-64 > 17-18-19-20 > 57-58-59-60 > 33-34-35-36 > 5-6-7-8 > 41-42-43-44 > 13-14-15-16 > 49-50-51-52 > 25-26-27-28 > 65-66-67-68