

Bolt Torque For Polyethylene Flanged Joints TN-38/July 2011



**LAP-JOINT STYLE FLANGE ASSEMBLY
(Based on ASME B16.5)
24-Inch Dia. Polyethylene Flange Adapters, Metal Lap-Joint Flanges, and Bolt Set**

Foreword

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CAUTION

FLANGES IN NATURAL GAS PIPELINES

Note: In jurisdictional installations any metallic pipeline components must be protected from corrosion as prescribed in US CFR Title 49, Part 192, Subpart I, sections 451-491. Furthermore, Part 195 Subpart H, sections 551-589 applies to steel pipelines used in the transport of Hazardous Liquids.

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Preface:

Based on ASME B16.5 flange styles, the polyethylene **Lap-Joint Flange Assembly** is a three component device consisting of:

1. Polyethylene flange adapter (stub-end).
2. A loose, metal, Lap-Joint Flange (LJF).
3. The bolt set.

The metal Lap-Joint Flange (LJF) cross-section geometry may be a rectangular solid or a contoured cross-section. The rectangular cross-section typically is machined from metal plate; the contoured cross-section is typically cast using molten ductile-iron or stainless-steel.

The LJF is typically in flat-face contact with the polyethylene flange adapter hub, and has a radius on the contact side of the LJF ID which mates with the fillet radius of the matching polyethylene flange-adapter (stub-end). The LJF slips over the pipe; is not welded to the pipe; is loose until bolted; and is free to rotate into bolt-hole alignment with another flange. The bolt-load is transferred to the sealing face by the pressure of the LJF against the back-face of the HDPE hub.

Two methods are commonly used to seal polyethylene Lap Joint Flange assemblies between various combinations of pipe materials such as HDPE to HDPE; HDPE to Steel; HDPE to Ductile-Iron; HDPE to PVC; HDPE to Fiberglass.

The first method, (non gasketed), uses the specified HDPE seating torque initially applied to the HDPE flange adapters, followed by a mandatory re-torque applied 4-hours to 24-hours after completion of the initial torque application

The second method, (gasketed), uses a low gasket seating bolt torque, applied to a soft elastomeric gasket, for lower pressure applications (like landfill gas collection or use with torque-limited PVC or fiberglass flanges), followed by the mandatory re-torque 4 hours to 24-hours after the initial torque.

PPI strongly recommends that each flanged joint be independently analyzed by the project engineer for sealing capacity when subjected to all expected operating and installation loads.

By applying the higher initial seating torque to seat the un-marred HDPE faces, without gaskets, the final residual bolt torque (RBT) at the HDPE sealing stress is sufficient to contain flow-stream pressure under operating conditions.

As is discussed later, the mandatory re-torquing to the initial target torque after a 4 hour to 24 hour creep-relaxation period is done to compensate for possible bolt-creep, nut embedment, and, gasket compression-set (if gaskets are used).

- Consult the individual HDPE flange manufacturers for their recommended protocol.
- Flange-Adapter Manufacturers should verify their flange assemblies are performance rated when used with a specific style or manufacturer's LJF.
- LJF (lap-joint flange) manufacturers should verify the maximum allowable torque that can be applied to their product, and that their LJF's provide "disk" deformation in excess of the polyethylene flange-adapter's expected service life's visco-elastic creep deformation, at low residual compressive stress.

CAUTION: When bolting to fiberglass, cast iron, PVC pipe flanges, or PVC flanged valves, the "brittle" flange typically bolts to a special HDPE full-face flange adapter using lower bolt torque. Hence a soft gasket is frequently also used with "brittle" pipes. Over-tightening, misalignment, or uneven tightening can break brittle material flanges. Extreme care is advised. Refer to Appendix C, and consult with the sensitive, low-strain product manufacturer for its maximum torque limits, when bolting to "raised-face" HDPE flange adapters. When gaskets

are to be considered, review [Appendix C](#) very carefully, to perform calculations using the seating stress, blow-out resistance, crush resistance, and other performance values obtained from the gasket manufacturer. This Tech-Note does not provide guidance on gasket selection; consult with the gasket designer to discuss the parameters outlined in [Appendix C](#).

Introduction:

Lap-Joint Flanges (LJF) have been used for decades. The typical polyethylene flange adapter with loose LJF is also known as a Van-Stone Flange joint. The HDPE flanged joint assembly is an engineered pressure containment connection subject to diverse forces. While simple in appearance, its design is complex due to the axial shear, radial dilation, disk-bending moments, residual interfacial sealing pressure, bolt-load versus bolt-torque, HDPE flange face creep-relaxation, LJF disc flexure, axial tension from thermal contraction of the pipe-line, some vibration, pressure-surge, pipe bending due to soil settlement, etc. The greatest contributors to flange leakage are insufficient torque, un-even torque, and flange misalignment. Written and correct bolt torque specifications and installation procedures will eliminate these problems. The flange assembly design, and written assembly specifications, are controlled by the pipeline design-engineer or project engineer-of-record.

The ideal flange-adapter joint should exhibit Compressibility, Resilience, and Creep-Resistance. The plastic flange-adapter face should be able to compress into any and all surface texture and imperfections of the mating flange. The plastic flange face should be sufficiently and elastically resilient to move with dynamic loadings to maintain seating stress. The flange-adapter face should exhibit sufficient creep-resistance so as not to permanently deform after bolt-up under varying load cycles of temperature and pressure.

The “memory” of pipe-grade HDPE makes it an ideal flange face sealing surface. It becomes its own “gasket flange”, and seals well when un-marred and torqued to meet or exceed the HDPE seating stress. When properly torqued with a flexible LJF, the HDPE flange-adapter becomes self-gasketing.

The LJF assembly is typically evaluated as a combined mechanical “spring” assembly. The torqued bolts are elastically stretched to initiate the sealing pre-load. The metal LJF (lap-joint flange) is elastically flexed (bent by the bolt-load) to maintain the pre-load and to transfer the load to the HDPE flange face. At small strains, the HDPE flange-face is elastically and visco-elastically deformed (axial compression and slight radial enlargement) so as to maintain pre-load sealing pressure on the flange-face surface. The HDPE flange face compressibility is the measure of its ability to deflect and conform to the mating flange face. This compressibility compensates for flange surface irregularities such as minor nicks, non-parallelism, metal corrosion, and variation in surface roughness or grooving depth. The HDPE flange face also exhibits Memory / Recovery / Resiliency which are measures of the elasticity of the HDPE material to recover shape and to maintain its deformation sealing pressure under varying loads across broad temperature ranges. Although the HDPE is a visco-elastic material that slightly creeps over time, at sufficient torque the flexure of the LJF and bolt stretch exceed the expected long-term compressive creep of the flange face, such that the residual sealing force exceeds the sum of the operating separation forces. In this way, the sealing pressure is maintained.

The combined “springs” of the stretched bolts, the flexed disc LJF, and the elastic component of the compressed flange-face, all serve to provide an elastic / visco-elastic, resilient “spring-seal” of the hydrostatically pressurized joint.

The key element to an effective sealing HDPE flanged joint, is to torque the bolts to a sufficiently high value to stretch the bolts, so that the LJF is flexurally distorted, and the HDPE flange-face sufficiently and continuously compressed. The joint is at equilibrium, with the compressive sealing force distributed across the sealing face and equal in magnitude to the pre-tension in the

bolts. The total bolt tension must be able to constrain the joint assembly against operating pressure, surge pressure, pipe-line axial thermal contraction, and pipe bending strain from soil settlement, and flange angular alignment; all with an applied safety factor.

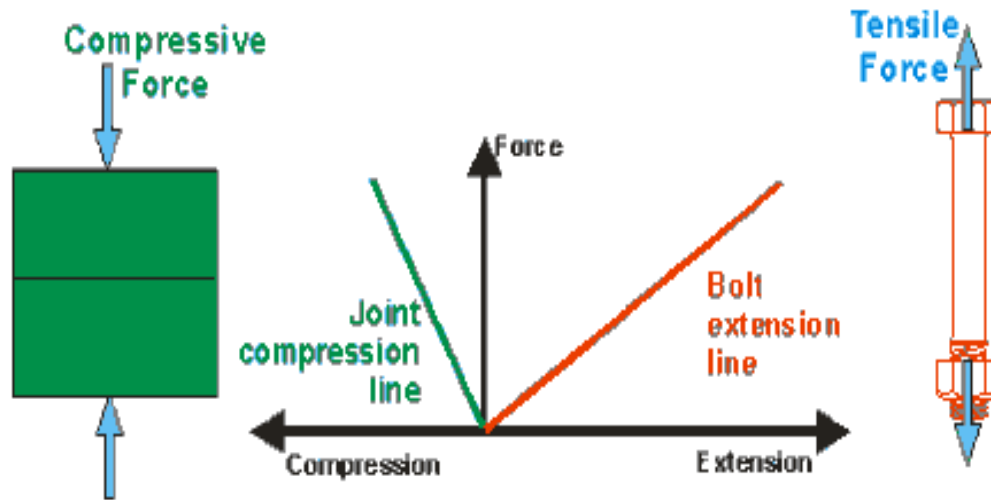


Figure 1

The total possible force required from bolting torque should equal and exceed the sum of applicable separation forces:

$$F_{\text{Total}} > \{ F_{\text{Press}} + F_{\text{Surge}} + F_{\text{Therm.Contr.}} + F_{\text{Pipe-Bend}} + F_{\text{Flng-Alignment}} + F_{\% \text{ Variance}} \}$$

Equation # 1

Caution: The component, $F_{\text{pipe-bend}}$ (forces from pipe beam-bending), in the above equation can sometimes exceed thermal contraction and hydraulic forces. HDPE flange joints are geometrically rigid assemblies, unlike the flexible HDPE pipe ring “hoop”. The rigid flanged joint cannot shed stress by ring deformation. Localized HDPE pipe beam-bending at a flanged joint due to soil settlement, water buoyancy or wave action, pipe “snaking” above ground, etc, must be managed so as to isolate the flange from beam-bending strain. External installation measures to protect PE flange joints from beam-bending strain are necessary. While additional torque can maintain the pressure seal, bending strain across the HDPE flange adapter should be limited to prevent flange adapter fracture.

NOTE:

Appendix “A” provides the method for calculation and determination of specified bolt torque at the required seating stress. Proceed to Appendix “A” to perform the required engineering calculations to determine the required target torque to be used in the Checklist following on the next page.

CHECKLIST and FLANGE TORQUE RECORD:

Project: _____ Flange Set Location : _____
Connecting HDPE Flange to _____ Flange.
Bolt Dia & Grade : _____ Nut Diameter & Grade : _____
Lap-Joint Flange Dia. & Pressure Rating : _____
Lubricant Used: _____ Flange Temp: _____
Torque Wrench ID #: _____ Calibration Date: _____
If Specified: Full-face Gasket Info: Material: _____ Thickness: _____
Deep-Well Socket / Heavy-Hex Nut Wrench Size Used : _____

Axis off-set: _____ Angular & Facial Gap: Top _____ Bottom _____ L _____ R _____

“Initial” Each Step Upon Completion:

- _____ 1. Visually examine and clean both flanges, bolts and nuts. Replace damaged units.
- _____ 2. Liberally Lubricate bolt threads & nut threads & flange surface under nut.
- _____ 3. If gasket is specified, insert full-face gasket. Do not use wrinkled or damaged gaskets.
- _____ 4. Number the bolt-holes in circumferential sequence stating at 12:00 position.
- _____ 5. Check Flange alignment, concentricity, angularity, and gap for acceptability.
- _____ 6. To firm the flanges squarely together, Hand Tighten, then pre-tighten all bolts in proper sequence to 10-20 foot-pounds torque, but do not exceed 20% of the TARGET TORQUE.
- _____ 7. Re-check any flange-adapter face gap and LJF gap for uniformity. ****
- _____ 8. Use the appropriate criss-cross pattern tightening in numerical sequence for Rounds 1, 2, 3, and 4 (tightening all bolts once in sequence constitutes a “round”).

**** Note: Check LJF gap around the flange circumference between each of these rounds, measured at every other bolt. If any gap is not reasonably uniform around the circumference, make the appropriate adjustments by selective bolt tightening before proceeding.

TARGET TORQUE (and 4 to 24-HOUR RE-TORQUE): _____ foot-pounds

_____ For 4-bolt, 8-bolt, 12-bolt Flanges

_____ For Large Flanges > 16 + Bolts

_____ Lubricate, Hand tight, Pre-tighten
_____ Round 1 – Tighten to _____ ft.lbs. (30%)
_____ Round 2 – Tighten to _____ ft.lbs. (60%)
_____ Round 3 – Tighten to _____ ft.lbs. (100%)
_____ Rotational (clockwise) Round

_____ Lubricate, hand tighten, Pre-tighten
_____ Round 1 – Tighten to _____ ft.lbs. (25%)
_____ Round 2 – Tighten to _____ ft.lbs. (50%)
_____ Round 3 – Tighten to _____ ft.lbs. (75%)
_____ Round 4 – Tighten to _____ ft.lbs. (100%)
_____ Rotational (clockwise) Round

_____ Rotational (clockwise) Round: 100% of Target Torque. Use rotational clockwise tightening sequence, starting with bolt #1, for one complete round, and continue until no further bolt or nut rotation occurs at 100% of the target torque value for each nut.

_____ 4- Hour Re-Torque & Inspection :
Re-torque to target torque value using one or two sequence-rounds, followed by one rotational round at the target torque value.

Documentation Recorded By : _____ Date: _____

Joint Technician/Mechanic: _____ Date: _____

Tightening Sequence:

Number the bolts in rotation around the Lap-Joint Flange circumference in a clockwise order, beginning with the first bolt at the top in the nominal 12:00 position, the second being the next bolt to the right, the third being the next bolt to the right, etc, until all bolts are numbered sequentially.

Following the table below, tighten the given bolt number to the desired torque value for the given round of tightening as specified on the Torque Record Checklist.

TABLE 1 [refer to ASME Document PCC-1 for Bolt Sequences]

NUMBER OF BOLTS	CRISS-CROSS PATTERN TIGHTENING 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 >> 5-10-15-20 >> 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

The criss-cross bolt tightening sequence and multi-round tightening are necessary to counteract the flange / bolt elastic interaction.

TABLE 2

EXAMPLES OF ESTIMATED BOLT TORQUE TO “SEAT” HDPE FLANGE FACES:

The **engineer of record** is usually responsible for establishing each flange joint criteria, and performing the required calculations to determine the initial and residual torque values.

These estimated values are based on non-plated bolts and studs, using a nut factor of $K=0.16$ for lightly greased bolts and nuts. The calculations uses a HDPE flange face seating stress of **1200-psi** as a minimum and **1800-psi** as a maximum, and assumes the flanged joint is between two HDPE flange adapters (in which the contact area is largest), without a rubber gasket.

NOTE: For bolting to ductile-iron pipe, steel flanges or butterfly valves, the flange face contact area is about half, so bolt torque for that flange pair will be measurably less (refer to Table #3).

IPS Nominal Pipe Size	LJF Bolt Diameter	Initial Number of Bolts	Minimum Lubed Torque (Ft-Lbs)	Initial Maximum Lubed Torque (Ft-Lbs)	Flange OD/ ID (Inches)
2"	0.625	4	23	35	3.9 / 1.94
3"	0.625	4	33	50	5.0 / 2.86
4"	0.625	8	33	50	6.6 / 3.68
5"	0.75	8	44	66	7.5 / 4.40
6"	0.75	8	50	75	8.5 / 5.42
8"	0.75	8	80	120	10.63 / 6.76
10"	0.875	12	80	120	12.75 / 8.79
12"	0.875	12	105	160	15.00 / 10.43
14"	1.000	12	180	270	17.50 / 11.45
16"	1.000	16	180	270	20.00 / 13.09
18"	1.125	16	200	300	21.12 / 14.73
20"	1.125	20	200	300	23.50 / 16.36
22"	1.25	20	260	390	25.60 / 18.00
24"	1.25	20	290	435	28.00 / 19.64
26"	1.25	24	290-	435	30.00 / 21.27
28"	1.25	28	290	435	32.30 / 22.91
30"	1.25	28	325	488	34.30 / 24.54
32"	1.50	28	425	640	36.50 / 26.18
34"	1.50	32	425	640	38.50 / 27.82
36"	1.50	32	460	690	40.80 / 29.45
40"	1.50	36	460	690	46.00 / 35.29
42"	1.50	36	460	690	47.50 / 37.06
48"	1.50	44	460	690	54.00 / 43.43
54"	1.75	44	560	840	60.00 / 48.86

NOTE: Uniform bolt pre-load (torque), without large “scatter”, is as useful as the target pre-load. Within the limits of the HDPE flange adapter, gasket, or metal LJF, higher pre-load is desirable. The higher the pre-load safely achievable, the more closely the assembly will behave like the theoretical model and seal well. Higher pre-load means that a given internal pressure will result in the least possible change in contact sealing pressure. Be consistent (avoid changes) with materials and tools when following written assembly procedures.

Train and supervise the bolting personnel. Tell the crew what is to be accomplished, why, and explain that good results are not automatically achieved. Skill and care are essential. Bolted Joint assembly is a technical skill that is not common in the construction and maintenance profession, being considered more like a specialty. There is no universally accepted testing, nor certification, of bolted-joint assembly mechanics. With no common training, certification, nor standards, it is no surprise there is +/- 25% variability in assembly torque. Specifications and instructions by the engineer, followed by trained mechanics, help to solve the dilemma.

(NOTE: Consult ASME Document PCC-1, Appendix A for training and certification of bolted joint assemblers)

TABLE 3

Examples of Estimated Bolt Torque to “Seat” the HDPE Flange Face To
A Butterfly-Valve, Steel Pipe Flange, or Ductile Iron Flange.

The engineer of record is usually responsible for establishing each flange joint criteria, and performing the required calculations to determine the initial and residual torque values.

These estimated liberally lubricated torque values assume the flanged joint connects one HDPE flange-adapter to a Butterfly-Valve or Steel Pipe flange of Schedule 40 ID, or a Ductile-Iron flange. For bolting to steel flanges or butterfly valves, the flange face contact area is just over half that of HDPE to HDPE flanges, so calculated bolt torque for this flange pair will be measurably less than the values listed in Table #2.

Dimensional flange data should be obtained for each case from the pipe flange suppliers, so as to be able to calculate the face contact area.

These estimated values are based on non-plated bolts and studs, using a K=0.16 for lightly greased bolts and nuts. These calculations use an HDPE material minimum and maximum compressive seating stress of **1200-psi to 1800-psi**.

IPS Nominal Pipe Size	LJF Bolt Dia. (inches)	Initial Number of Bolts	Minimum Lubed Torque (Ft-Lbs)	Initial Maximum Lubed Torque (Ft-Lbs)	HDPE Flange OD Steel Pipe ID (inches)
2"	0.625	4	22	32	3.90 / 2.067
3"	0.625	4	30	45	5.00 / 3.068
4"	0.625	8	30	45	6.60 / 4.026
5"	0.75	8	44	66	7.50 / 4.40
6"	0.75	8	44	66	8.50 / 6.06
8"	0.75	8	58	88	10.63 / 7.98
10"	0.875	12	58	88	12.75 / 10.02
12"	0.875	12	75	114	15.00 / 11.94
14"	1.000	12	140	210	17.50 / 13.13
16"	1.000	16	140	210	20.00 / 15.00
18"	1.125	16	140	210	21.12 / 16.88
20"	1.125	20	140	210	23.50 / 18.81
22"	1.25	20	160	240	25.60 / 21.25
24"	1.25	20	180	270	28.00 / 23.25
26"	1.25	24	180	270	30.00 / 25.25
28"	1.25	28	180	270	32.30 / 27.25
30"	1.25	28	180	270	34.30 / 29.25
32"	1.50	28	240	360	36.50 / 31.00
34"	1.50	32	240	360	38.50 / 33.00
36"	1.50	32	260	390	40.80 / 35.00
40"	1.50	36	310	465	46.00 / 39.00
42"	1.50	36	310	465	47.50 / 41.00
48"	1.50	44	310	465	54.00 / 47.00
54"	1.75	44	365	550	60.00 / 53.00

Train and supervise the bolting personnel. Tell the crew what is to be accomplished, why, and explain that good results are not automatically achieved. Skill and care are essential. Bolted Joint assembly is a technical skill that is not common in the construction and maintenance profession, being considered more like a specialty. There is no universally accepted testing, nor certification, of bolted-joint assembly mechanics. With no common training, certification, nor standards, it is no surprise there is +/- 25% variability in assembly torque. Specifications and instructions by the engineer, followed by trained mechanics, help to solve the dilemma. (Note: Consult ASME PCC-1, Appendix A)

APPENDIX A

Calculations, Considerations, and Guidelines

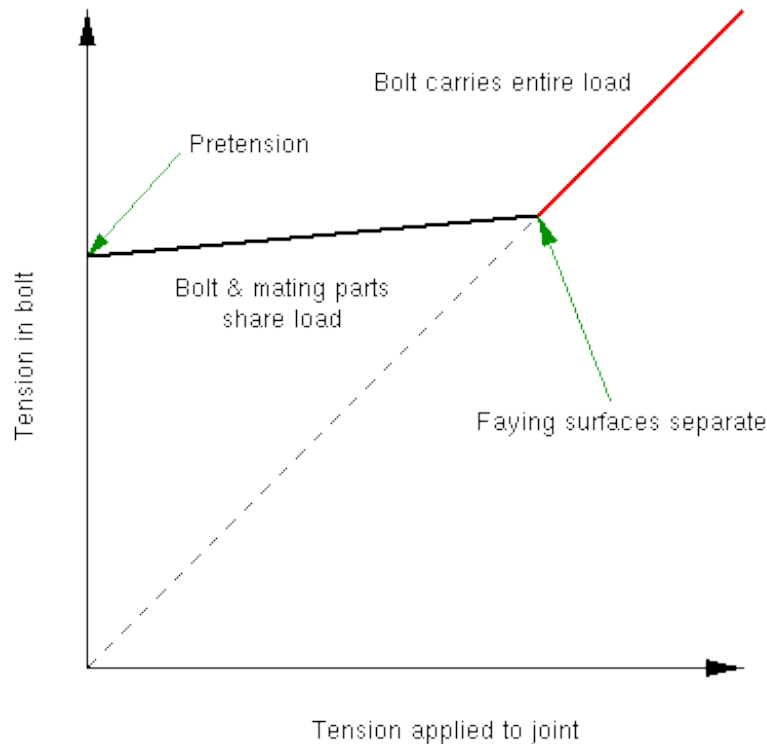


Figure 2

Bolt Pre-Load:

Within its proportional limit, the metal bolt tension is linearly related to the applied torque. A two dimensional graph plotting Total Applied Torque (y-axis) versus measured Bolt Load (x-axis) , displays a linear slope up-wards to the right. The bolt tension transmitted to the flange joint is directly dependent upon applied torque. The mechanical advantage of the torque-wrench lever and the helical threads enables one to stretch the length of the bolt between the head and the nut (this length is known as the *grip-length*), thus creating elongation (mechanical strain) resulting in tension stress in the bolt cross-section.

However, when using Torque-Control as the method for establishing flange assembly pre-load, one must understand there is a measurable variance between applied torque and theoretical bolt tension. Typically, only about 10% to 20 % of the applied torque is actually transmitted into bolt elongation. From tests, it is known that about 50% of the bolt torque is consumed by friction from the bolt-head contact face or the nut-face being rotated against its mating part. About 10% is used up in reversible twist of the bolt length. About another 30% is dissipated to overcome the friction in the bolt/nut threads. When more torque is needed to overcome friction, then less remains for bolt extension pre-load. Hence, small changes to reduce friction on the bolt-threads and under the rotating nut-face, will significantly increase the torque transmitted to bolt-extension pre-load. This is the reason a light duty grease or 30 weight motor oil should be sparingly applied to the bolt-thread and nut-thread before assembly. Metal or mineral filled lubricating greases are not usually used, because they may also enable nut loosening when subject to some vibration or repetitive pressure surge. The correct lubricant enables more bolt