

POLYETHYLENE FLANGED JOINTS

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1.0 EXECUTIVE SUMMARY

The design and selection of components for flanged joints connecting PE pipe to PE pipe, or PE pipe to metal pipe are based on lower interfacial pressures than those used for metal flanged joints. The initial interfacial pressure is limited by the allowable short duration stress of the PE flange adapter. To establish higher long term interfacial stress, retorquing is suggested to compensate for the visco-elastic stress relaxation in the PE flange adapter.

The mating interfacial surface area of a metal flange to PE flange adapter is significantly less than that between PE-to-PE flange adapters since the bore of the metal flange / pipe is larger than the bore of the PE flange adapter. The bore of PE flange adapters can also vary depending on whether or not a pipe 'toe-in' allowance has been included in the bore of the flange adapter. Regardless, the required bolt and nut 'proof' strength of a PE-to- PE flanged joint is more than for PE to metal flanged joints due to the larger interfacial surface area. See Section 6.2 for additional discussion about this topic.

The lower flange face interfacial pressures associated with PE flange adapters necessitates careful selection of the gasket materials. Compressed fiber gaskets (CFG) and PTFE gaskets tend to be the better option with HDPE flanged connections. Not only do these products have much higher crush and extrusion resistance than elastomeric materials, but the products are also designed to handle higher pressures.

While retightening of the bolts is recommended for all flanged joints, the creep relaxation of the PE flange adapter can significantly reduce the stress between the mating faces and loosen the bolts. Consequently, retightening is more important with PE flanged joints.

When the PE flanged joint is mated to a flanged butterfly valve, it may be necessary to provide a spacer ring with a tapered bore to provide clearance for the disk.

Hydrotesting of PE piping systems is described in ASTM F2164 (ASTM F2164 Standard Practice for Field Leak Testing).

2.0 PREFACE

Polyethylene pressure pipe is usually joined by butt fusion or electrofusion. Flanged connections are used as transitions to pipes of other materials, connections to flanged fittings, or as 'end connections' on fused PE pipe strings.

Flanged joints prevent leakage by compressing a deformable material into irregularities in a less deformable material to 'seal' possible leak paths. The 'mating faces' of flanged joints are the surface area that needs to be sealed. The deformation characteristics of the deformable material are the primary determinant of the amount of compression (force per unit area) required to seal a flanged joint.

It is desirable to utilize common bolting patterns in order to facilitate connections to readily available flanged fittings and valves. Flanges used in North America generally conform to ASME B16.5 (ASME B16.5), ASME B16.47 Series A (ASME B16.47), or AWWA C207 (AWWA C207-18 STEEL PIPE FLANGES FOR WATERWORKS SERVICE—SIZES 4 IN. THROUGH 144 IN. (100 MM THROUGH 3,600 MM)) bolting patterns.

3.0 PE FLANGED JOINT PRESSURE RATINGS

ASME B16.5/B16.47 provides pressure ratings for metal flanges that vary by flange material type. The standard does not provide pressure ratings for flanges made of non-metallic materials such as polyethylene (PE).

Class 150 ASME B16.5 and B16.47 Series A flanges made of forged carbon steel (material group 2-1.1), are rated for a maximum operating pressure of 285 psi at temperatures ranging from ambient up to 38°C (100°F). 304(L) & 316(L) stainless steel flanges (material group 2-2.3) are rated for a maximum operating pressure of 235 psi at service temperatures from ambient up to 38°C (100°F).

The pressure-temperature ratings of ASME Class 150 metal flanges usually exceeds that which is permissible for most PE pressure pipe. For example, PE4710 pressure pipe with bore of DR 9 has a pressure rating of 250 psi at service temperatures up to 80°F. Consequently, ASME B16.5 / B16.47 Series A Class 150 flanges in material group 2-1.1 (A105 or A350LF2) are suitable for connection to this pipe.

However, low DR PE pipe with high pressure ratings may exceed the pressure rating of the ASME B16.5 / B16.47 Series A metal flange. For example, Class 150 flanges in material group 2-2.3 (e.g., 304(L), 316(L)), are theoretically not suitable since they are limited to pressures of 235 psi. Class 150 flanges in material group 2-1.1 (A105 and A350 LF2) are theoretically limited to service pressures of 285 psi. This is less than the 335 psi pressure rating of a DR 7 PE4710 pipe.

In a metal piping system with flanged connections, Class 300 flanges would be used at 'higher' service conditions. The geometry of a Class 300 flange has a bolt circle

diameter (BCD) that is larger than the Class 150 BCD. The geometry of a Class 300 rated metal flange makes sense with metal flanges because of the rigidity of these materials. However, the increase in BCD with a Class 300 pattern will make it more difficult to seal a flanged joint involving a PE flange adapter. Deformation of the flange face reduces the interfacial pressure near the ID. In some instances, deformation of the flange face will separate the faces (Jacobsson, 2011).

Consequently, the designer should consider using ASME B16.5 or B16.47 Series A Class 150 flanges when the service pressures exceed the pressure rating of the metal flange since there is a high factor of safety associated with metal flanges.

Other flange standards use the face dimension and BCD's of ASME Class 150 flanges. For example, AWWA C207 flanges used extensively in the waterworks industry makes use of the ASME B16.5 and B16.47 Series A bolting patterns. When welded to metal pipe, pressure ratings of 86 psi (Class B flanges), 175 psi (Class D $\leq 12"$), 150 psi (Class D $> 12"$), and 275 psi (Class E) have been established by AWWA for these waterworks' flanges. AWWA C207 Class D or E geometries are often used as Backup Rings (BUR) with PE flange adapters at lower working pressures. Determination of the pressure ratings of flanged joints with AWWA C207 geometry BUR's is beyond the scope of this document.

A 'PE pressure pipe to PE pressure pipe flanged joint' will consist of: (see figure 1)

- Two Polyethylene flange adapters or stub-ends.
- Two Loose metal backup rings (BUR) often called Lap-Joint Flanges (LJF).
- Optional gasket
- Bolt set (bolts or studs and nuts).

A 'flanged PE pressure pipe to metal flange joint' will consist of: (see figure 2)

- One Polyethylene flange adapter or stub-end.
- One loose metal backup rings (BUR) often called a Lap-Joint Flange (LJF).
- PE spacer (if valve disk requires clearance)
- Optional gasket
- Metal flange or flanged fitting
- Bolt set (bolts or studs and nuts).

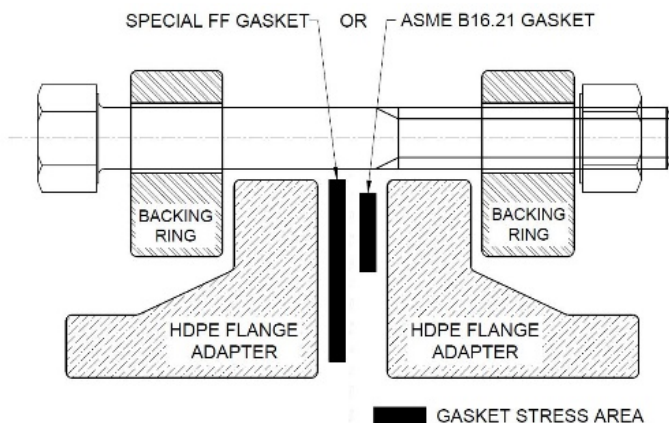


FIG. 1 PE FLANGE ADAPTER TO PE FLANGE ADAPTER

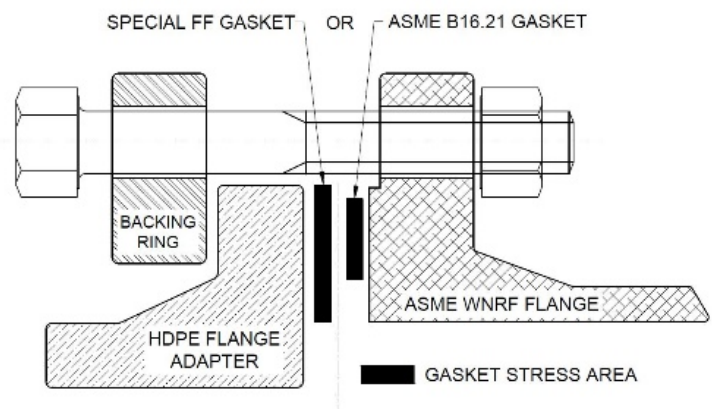


FIG. 2 PE FLANGE ADAPTER TO METAL FLANGE

A 'flanged PE pressure pipe to flanged plastic or FRP flanged joint' will consist of:

- One Polyethylene flange adapter or stub-end.
- One loose metal backup ring (BUR) often called a Lap-Joint Flange (LJF).
- Optional gasket
- Plastic or FRP flange or flanged fitting
- Bolt set (bolts or studs and nuts).
- Flange Spacer (if plastic or FRP flange is full flat face)

The interfacial (mating) surface of a 'PE to PE' flanged joint is significantly larger than the interfacial surface of the 'PE to Metal raised face (RF) mating flange face. This is because the bore of a PE pipe and a PE flange adapter are smaller than a metal pipe with the same OD and pressure rating. The short-term allowable stress of PE determines the force required to seat/seal the flange. Consequently, a 'PE to PE' flanged joint requires significantly more bolt torque to 'seat' than a 'PE to Metal RF' flanged joint. This will be discussed further in the section describing bolt torque calculations.

4.0 FLANGED JOINT COMPONENTS

4.1. Flange Adapters

Polyethylene flange adapters are often made to meet the dimensional and material (compound) requirements of ASTM F2880. (ASTM F2880 Standard Specification for Lap Joint Type PE Flange Adapters). The flange adapter consists of a neck (similar in ID and OD to the pipe to which it will be fused) and a hub (disk ring extending radially outward from the pipe OD). The neck of the flange adapter will be clamped during fusion by the standard clamps available on most butt fusion equipment.

ASTM F2880 indicates that the hub width may vary depending on the DR. Some FA's are produced with hub widths that vary from those specified in F2880. The FA associated with a lower DR (higher pressure rating) may be substituted if a FA for a specified DR is not readily available. The user is cautioned to confirm the hub width (flange thickness) dimension prior to purchasing the bolting hardware since the length of the bolts (studs) depends on the hub width.

The FA hub OD (see figure 3) matches the raised face dimension of standard ASME B16.5 and B16.47 Series A flanges. The ID of the neck and hub will either match the ID of the pipe to which is to be fused (i.e., it has the same DR), or the ID bore will be smaller to provide an allowance for toe-in on the matching pipe. ASTM F2880 neck dimensions (pipe end) may include a 10% allowance for toe-in and a 6% allowance for average wall over the required minimum wall (1.10 X 1.06 is approximately 1.17). The wall thickness of the neck (pipe end) of an F2880 flange adapter will be between 6% and 17% over the minimum wall of the PE pipe. The initial bolt torque required to seat the flange adapter or gasket with a larger

surface seating area (due to toe-in allowance) is higher than a FA with a wall thickness and gasket seating area based on the usual 6% allowance for average wall over minimum wall. Note: *Not all FA's are produced with a bore that includes the toe-in allowance indicated in F2880.*

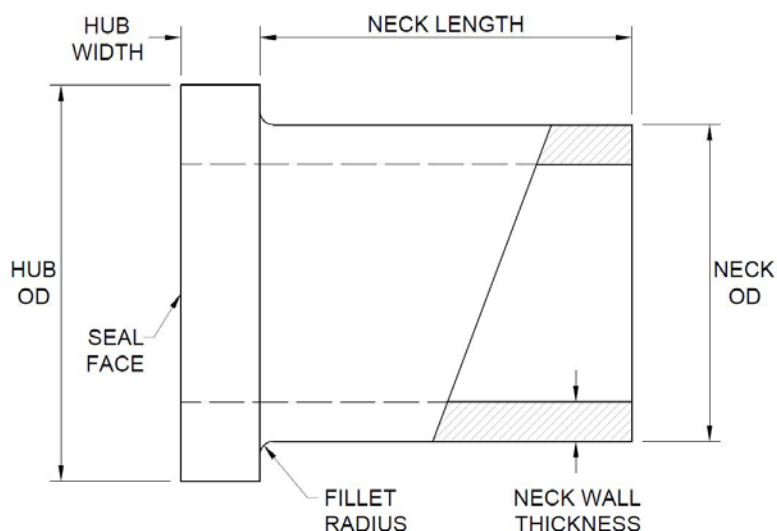


FIG. 3 POLYETHYLENE FLANGE ADAPTER GEOMETRY

The material (compound) requirements for flange adapters are similar to those of the pipe to which it is to be fused. Polyethylene has an apparent modulus that is 'duration-under-load' dependent. Stress in polyethylene that is caused by straining the material (compression due to tightening of the flange joint bolts), will 'relax' over time. If strain and temperature are constant, the compression stress in the flange adapter hub will decrease to about 50% of the originally applied stress in 60 hours, and approximately 35% in 1,000 hours. There is only a small loss in assembly stress thereafter. A number of sources for the determination of power law exponents for the relaxation of PE stresses are given in the final report of the PPI commissioned study Thermal Stress in HDPE Water Pipes (Bilgin, 2020).

The HDPE flange faces should be inspected to ensure they are free from radial gouges across no more than 1/3rd of the face width. Some surface marring or denting is acceptable. The flange sealing faces should be free from rust, weld spatter, dirt, debris, etc. HDPE flange-adapter faces exhibiting surface marring or dents should limit such defects to not more than 1/16" deep. Contact the supplier for assistance when minor defects are observed in HDPE adapter faces. The flange faces should be cleaned and installed per the manufacturer's recommendation. Flange faces should be uniformly flat and in consistent 90 degree orientation to the neck of the flange adapter.