(c) Damage to the Bolts. The specified bolt stress should be below the bolt yield point, such that bolt failure does not occur. In addition, the life of the bolt can be extended by specifying an even lower load.

(d) Damage to the Flange. The assembly bolt stress should be selected such that permanent deformation of the flange does not occur. If the flange is deformed during assembly, then it is likely that it will leak during operation or that successive assemblies will not be able to seal due to excessive flange rotation. Leakage due to flange rotation may be due to concentration of the gasket stress on the gasket outer diameter causing damage or additional relaxation. Another potential issue is the flange face outer diameter touching, which reduces the effective gasket stress.

However, it is also important to consider the practicalities involved with the in-field application of the specified bolt stress. If a different assembly stress is specified for each flange in a plant, including all variations of standard piping flanges, then it is unlikely, without a significant assembly quality assurance plan, that success will actually be improved in the field by comparison to a simpler method. Depending on the complexity of the joints in a given plant, a simple approach (standard bolt stress per size across all standard flanges, for example) may actually be more effective in preventing leakage than a more complex approach that includes consideration of the integrity of all joint components.

This Appendix outlines two approaches: the simpler single-assembly bolt stress approach (which is simpler to use, but may result in damage to joint components); and a more complex joint component-based approach that considers the integrity of each component.

O-3 SIMPLE APPROACH

O-3.1 Required Information

In order to determine a standard assembly bolt stress across all flanges, it is recommended that, as a minimum, the target gasket stress, \( S_{gT} \), for a given gasket type be considered. Further integrity issues, as outlined in the following section on the joint component approach, may also be considered, as deemed necessary.

O-3.2 Determining the Appropriate Bolt Stress

The appropriate bolt stress for a range of typical joint configurations may be determined via eq. (O-1).

\[
S_{bolT} = S_{gT} \frac{A_s}{m_d A_b}
\]  

(O-1)

The average bolt stress across the joints considered may then be selected and this value can be converted into a torque table using eq. (O-2M) for metric units or eq. (O-2) for U.S. Customary units.

\[
T_b = S_{bolT} K A_b \phi_b / 12
\]  

(O-2)

An example of the type of table produced using this method is given in Table 1, which was constructed using a bolt stress of approximately 50 ksi and a nut factor, \( K \), of approximately 0.20 with adjustments made based on industry experience. If another bolt stress or nut factor is required, then the table may be converted to the new values using eq. (O-3), where \( S'_{bolT} \), \( T'_{b} \) and \( K' \) are the original values.

\[
T_b = \frac{K'}{K} \frac{S'_{bolT}}{S_{bolT}} \frac{T'_{b}}{T_b}
\]  

(O-3)

O-4 JOINT COMPONENT APPROACH

O-4.1 Required Information

There are several values that must be known prior to calculating the appropriate assembly bolt stress using the joint component approach.

(a) The maximum permissible flange rotation (\( \theta_{f_{\text{max}}} \)) at the assembly gasket stress and the gasket operating temperature must be obtained from industry test data or from the gasket manufacturer. There is presently no standard test for determining this value; however, typical limits vary from 0.3 deg for expanded PTFE gaskets to 1.0 deg for typical graphite-filled metallic gaskets (per flange). A suitable limit may be determined for a given site based on calculation of the amount of rotation that presently exists in flanges in a given service using the gasket type in question.

(b) The maximum permissible bolt stress (\( S_{b_{\text{max}}} \)) must be selected by the user. This value is intended to eliminate damage to the bolt or assembly equipment during assembly and may vary from site to site. It is typically in the range of 40% to 70% of ambient bolt yield stress (see section 10).

(c) The minimum permissible bolt stress (\( S_{b_{\text{min}}} \)) must be selected by the user. This value is intended to provide a lower limit such that bolting inaccuracies do not become a significant portion of the specified assembly bolt stress, \( S_{bolT} \). The value is typically in the range of 20% to 40% of ambient bolt yield stress.

(d) The maximum permissible bolt stress for the flange (\( S_{f_{\text{max}}} \)) must be determined, based on the particular flange configuration. This may be found using either elastic closed-form solutions or elastic-plastic finite element analysis, as outlined in section O-5. In addition, when the limits are being calculated, the flange rotation at that load should also be determined (\( \theta_{f_{\text{max}}} \)). Example flange limit loads for elastic closed-form solutions and elastic-plastic finite element solutions are outlined in Tables O-1 through O-7.

(e) The target assembly gasket stress (\( S_{gT} \)) should be selected by the user in consultation with the gasket manufacturer. The target gasket stress should be selected to be towards the upper end of the acceptable gasket