unusual restraint such as may occur at points of stress concentration and also because of metallurgical changes occurring at high temperatures.

WC-2126 Ductile Cast Iron for Containment

The containment body shall be cast by a single pouring controlled by a casting plan to ensure reproducibility. The casting plan shall be agreed upon between the manufacturer and purchaser and shall become a lifetime quality assurance record in accordance with WA-4134.

WC-2127 Additional Requirements When Strain-Based Acceptance Criteria Have Been Implemented

In order to satisfy the strain-based acceptance criteria of WC-3700 regarding sufficient ductility, all material specified to be used in the construction of the containment and implementing the strain-based acceptance criteria shall meet the requirements of Section III Appendices, Nonmandatory Appendix FF, FF-1122 and FF-1140(a) or FF-1140(b). Assurance of satisfying these requirements shall be documented in the final Design Report. Per Section III Appendices, Nonmandatory Appendix FF, FF-1140(a), when temperature-dependent material test data are not available, the Certified Material Test Report(s) shall include reduction of area values in order to have the necessary data to ensure sufficient material ductility. This requirement is only necessary when strain-based acceptance criteria have been employed in the design of the containment.

WC-2128 Bolting Material

(a) Material for bolts and studs shall conform to the requirements of one of the specifications listed in Section II, Part D, Subpart 1, Table 4. Material for nuts shall conform to SA-194 or to the requirements of one of the specifications for nuts or bolting listed in Section II, Part D, Subpart 1, Table 4.

(b) The use of washers is optional. When used, they shall be made of wrought material with mechanical properties compatible with the nuts with which they are to be employed.

WC-2129 Fabricated Hubbed Flanges

Fabricated hubbed flanges shall be in accordance with the following:

(a) Hubbed flanges may be machined from a hot rolled or forged billet. The axis of the finished flange shall be parallel to the long axis of the original billet. (This is not intended to imply that the axis of the finished flange and the original billet must be concentric.)

(b) Hubbed flanges, except as permitted in (a) above, shall not be machined from plate or bar stock material unless the material has been formed into a ring, and further provided that:

(1) in a ring formed from plate, the original plate surfaces are parallel to the axis of the finished flange (this is not intended to imply that the original plate surface must be present in the finished flange);

(2) the joints in the ring are welded butt joints that conform to the requirements of this Division. Thickness to be used to determine postweld heat treatment and radiography requirements shall be the lesser of t, or $(A - B)/2$, where these symbols are as defined in Section III Appendices, Mandatory Appendix XI, XI-3130.

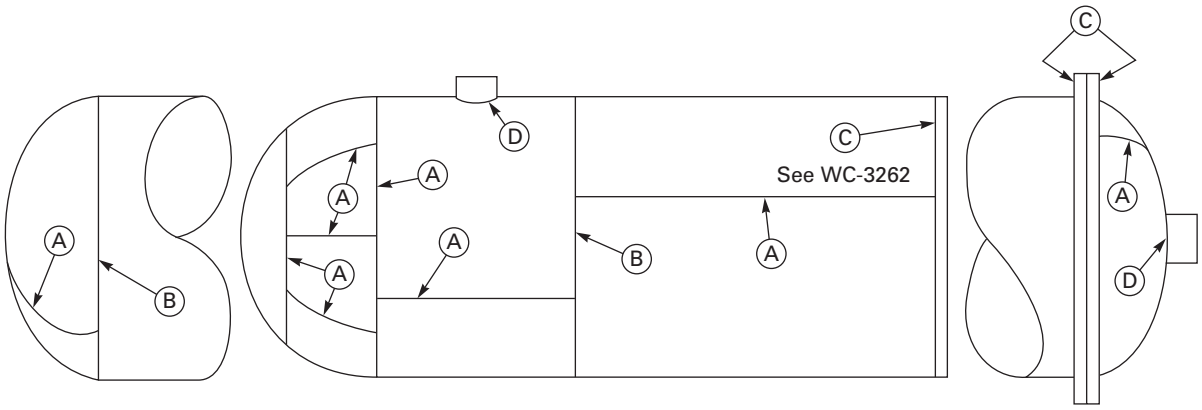
(3) The back of the flange and the outer surface of the hub shall be examined by the magnetic particle method or the liquid penetrant method in accordance with WC-2540 to ensure that these surfaces are free from defects.

WC-2130 CERTIFICATION OF MATERIAL

All materials used in the construction of containments shall be certified as required in NCA-3862 and NCA-3861. Certified Material Test Reports are required for containment material except as provided by NCA-3861. A Certificate of Compliance may be provided in lieu of a Certified Material Test Report for all other material. Copies of all Certified Material Test Reports and Certificates of Compliance applicable to material used in a component shall be furnished with the material.

1

Figure WC-3251-1
Welded Joint Locations Typical of Categories A, B, C, and D



WC-5230. Minimum dimensions of corner welded joints and throat

WC-3252.3 Joints of Category C. All welded joints of Category C, except for final closure welds (WC-3262), shall meet the fabrication requirements of WC-4265 and shall be capable of being examined in accordance with WC-5230. Minimum dimensions of welds and throat thickness shall be as shown in Figure WC-4265-1 where

(a) Figure WC-4265-1, sketches (a) and (b)

(1) for forged flat heads and forged flanges with the weld preparation bevel angle not greater than 45 deg. Measured from the face:

b = $t_s/2$ or $T/4$, whichever is less
c = $0.7t_s$ or $\frac{1}{4}$ in. (6 mm), whichever is less
T, t_s = nominal thickness of welded parts

(2) for all other material forms and for forged flat heads, and forged flanges with the weld preparation bevel angle greater than 45 deg. Measured from the face:

b = t_s or $T/2$, whichever is less
c = $0.7t_s$ or $\frac{1}{4}$ in. (6 mm), whichever is less
T, t_s = nominal thickness of welded parts

(b) Figure WC-4265-1, sketches (c) and (d)

c = $0.7t_s$ or $\frac{1}{4}$ in. (6 mm), whichever is less
T, t_s = nominal thickness of welded parts

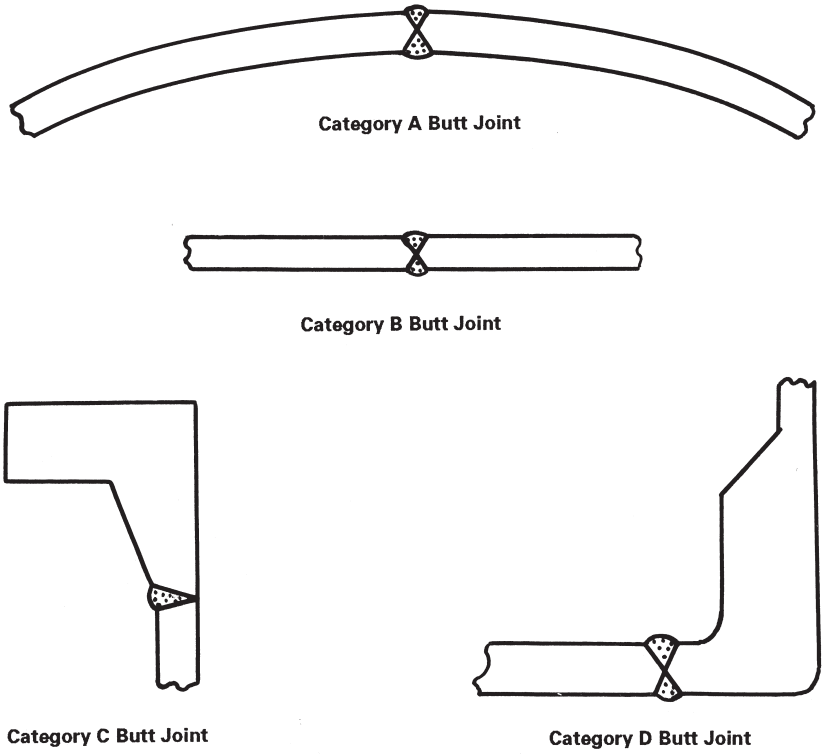
(c) Figure WC-4265-1, sketch (e)

$a + b$ = not less than $2t_s$
b = not less than t_s
t_p = not less than t_s
t_s = actual thickness of shell

EDITOR:
Please delete this entire (d) paragraph and move to a new location as indicated on page 4 with a new numbered header.

(d) Hubs for butt welding to the adjacent shell, head, or other containment part, as in Figure WC-4265-3, shall not be machined from rolled plate. The component having the hub shall be forged in such a manner as to provide in the hub the full minimum tensile strength and elongation specified for the material, in a direction parallel to the axis of the vessel. Proof of this shall be furnished by a tension

Figure WC-3251-2
Typical Butt Joints



test specimen (subsize if necessary) taken in this direction and as close to the hub as is practical. In Figure WC-4265-3, the minimum dimensions are as follows:

(1) sketch (a), r not less than $1.5t_s$

(2) sketch (b), r not less than $1.5t_s$ and e not less than t_s

(3) sketch (c), r not less than $1.5t_s$

(4) sketch (d), t_f not less than $2t_s$ and r not less than $3t_f$

(5) sketch (e), t_f not less than $2t_s$, r not less than $3t_f$, and e not less than t_f

EDITOR:
Please delete this entire (d) paragraph and move to a new location as indicated on page 4 with a new numbered header.

WC-3252.4 Joints of Category D. All welded joints of Category D, as defined in WC-3251, shall be in accordance with the requirements of (a) through (e).

(a) Butt-Welded Nozzles. Nozzles shall meet the fabrication requirements of WC-4266(a) and shall be capable of being examined in accordance with WC-5242. The minimum dimensions and geometrical requirements of Figure WC-4266(a)-1 shall be met, where

r_1 = $\frac{1}{4}$t or $\frac{3}{4}$ in. (19 mm), whichever is less
r_2 = $\frac{1}{4}$ in. (6 mm) min.
t = nominal thickness of part penetrated
t_n = nominal thickness of penetrating part

WC-3262.2 For welds in the end closures using two cover plates [Figure WC-4265-3, sketch (b)] and made after the containment is loaded, the following apply:

(a) The inner cover plate weld shall use a design stress reduction factor of 0.9. The root and final layers shall be examined by the liquid penetrant or magnetic particle method in accordance with Article WC-5000, and shall be tested in accordance with WC-6720.

(b) The outer cover plate weld shall use the stress reduction factors of Table WC-3262-1 and shall be examined to the requirements of Table WC-3262-1.

WC-3262.3 Vent and drain cover plate welds may be full penetration welds examined in accordance with WC-5250 partial penetration welds using the examination and stress reduction factors of Table WC-3262-1.

WC-3262.4 For partial penetration closure welds, a fatigue strength reduction factor of not less than 4.0 shall be used when fatigue analysis is required.

WC-3700 STRAIN-BASED ACCEPTANCE CRITERIA

The strain-based acceptance criteria are applicable only to the metallic portions of storage containments subject to energy-limited dynamic events. It is not the intent of this subarticle to permit significant regions or major portions of the containment to experience strains at or near the limits of these strain-based acceptance criteria without consideration of the overall component deformation. These strain-based acceptance criteria are established to address the regions of the containment that experience high strains due to the effects of direct impacts. Deformation limits, if any, provided in the Design Specification shall be satisfied.

Section III Appendices, Nonmandatory Appendix FF provides the strain-based acceptance criteria.

WC-3263 Category C Weld Joints for Flat Heads with Hubs

Hubs for butt welding to the adjacent shell, head, or other containment part, as in Figure WC-4265-3, shall not be machined from rolled plate. The component having the hub shall be forged in such a manner as to provide in the hub the full minimum tensile strength and elongation specified for the material, in a direction parallel to the axis of the vessel. Proof of this shall be furnished by a tension test specimen (subsize if necessary) taken in this directionand as close to the hub as is practical. In Figure WC-4265-3, the minimum dimensions are as follows:

(1) sketch (a), r not less than $1.5t_s$

(2) sketch (b), r not less than $1.5t_s$ and e not less than t_s

(3) sketch (c), r not less than $1.5t_s$

(4) sketch (d), t_f not less than $2t_s$ and r not less than $3t_f$

(5) sketch (e), t_f not less than $2t_s$, r not less than $3t_f$, and e not less than t_f

EDITOR:
Please make sure fonts and subscripts match that shown in the original WC-3252.3(d)

Table WC-3262-1
Stress Reduction Factors and Examinations for Closure Welds

Examination Requirements [Note (1)]	Stress Reduction Factors
Volumetric Examination	1.00
Liquid Penetrant or Magnetic Particle Examination: Root and each successive 1/4 in. (6 mm) of weld thickness and the final layer	0.90
Liquid Penetrant or Magnetic Particle Examination: Root, mid, and final layer [Note (2)]	0.80

NOTES:
(1) All examinations shall be performed and accepted to the requirements of Article WC-5000.
(2) Mid layer is defined as approximately one-half of the maximum weld thickness.

(17) ## WC-4265 Category C Weld Joints

Category C weld joints shall be as described in subparagraphs (a) through (d) below.

(a) Full Penetration Butt Joints. Category C welds shall be Type No. 1 or Type No. 2 butt joints.

(b) Full Penetration Corner Joints. Welds in full penetration corner joints shall be groove welds extending completely through at least one of the parts being joined and shall be fully fused to each part. Typical details for type No. 1 and No. 2 full penetration corner joints are shown in Figure WC-4265-1.

(c) Partial Penetration Closure Joints. Partial penetration joints are acceptable for flat head closure welds (per WC-3262). Typical details are shown in Figure WC-4265-2.

(d) Flat Heads With Hubs

Delete

(1) Hubs for butt welding to the adjacent shell, head, or other containment parts, as shown in Figure WC-4265-3, for flat heads, shall not be machined from flat plate. The hubs shall be forged in such a manner as to provide in the hub the full minimum tensile strength and elongation specified for the material in the direction parallel to the axis of the containment vessel. Proof of this shall be furnished by a tension test specimen (subsize, if necessary) taken in this direction and as close to the hubs as is practical. One test specimen may represent a group of forgings, provided they are of the same nominal dimensions, from the same heat material and the same heat treatment lot, and forged in the same manner. The minimum height of the hub shall be the lesser of $1\frac{1}{2}$ times the thickness of the containment part to which it is welded or $\frac{3}{4}$ in. (19 mm), but need not be greater than 2 in. (50 mm).

(2) Hubbed flanges shall not be machined from flat plate.

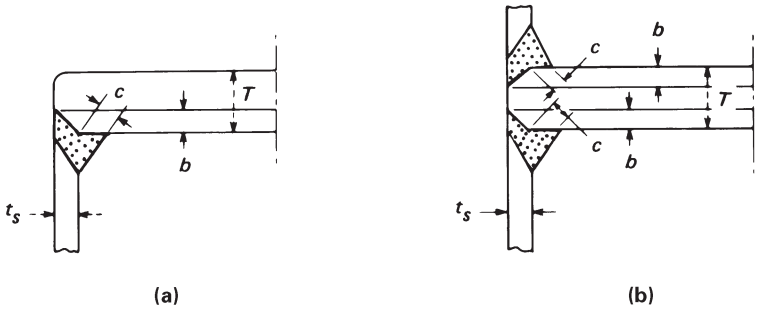
Delete

WC-4266 Category D Weld Joints

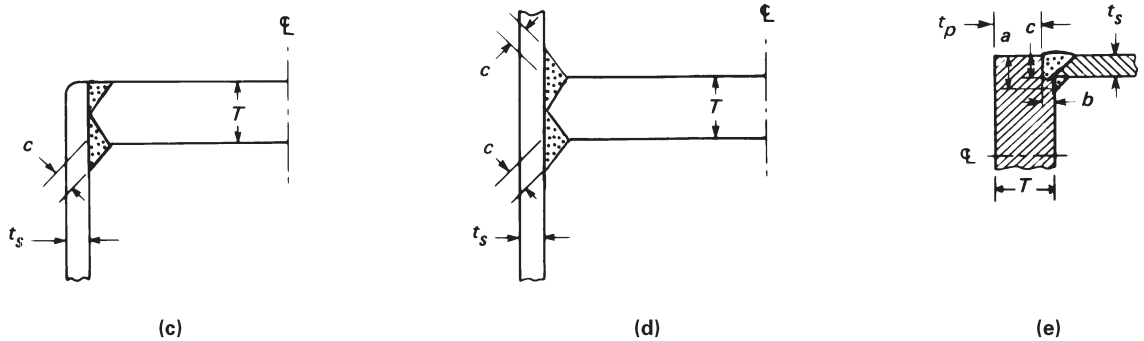
Category D and similar weld joints shall be welded using one of the details of (a) through (e) below.

(a) Butt-Welded Attachments. Nozzles shall be attached by Type No. 1 butt welds through either the containment or the nozzle wall as shown in Figure WC-4266(a)-1.

Figure WC-4265-1
Acceptable Full Penetration Weld Details for Category C Joints



Type No. 1 Corner Welded Joints

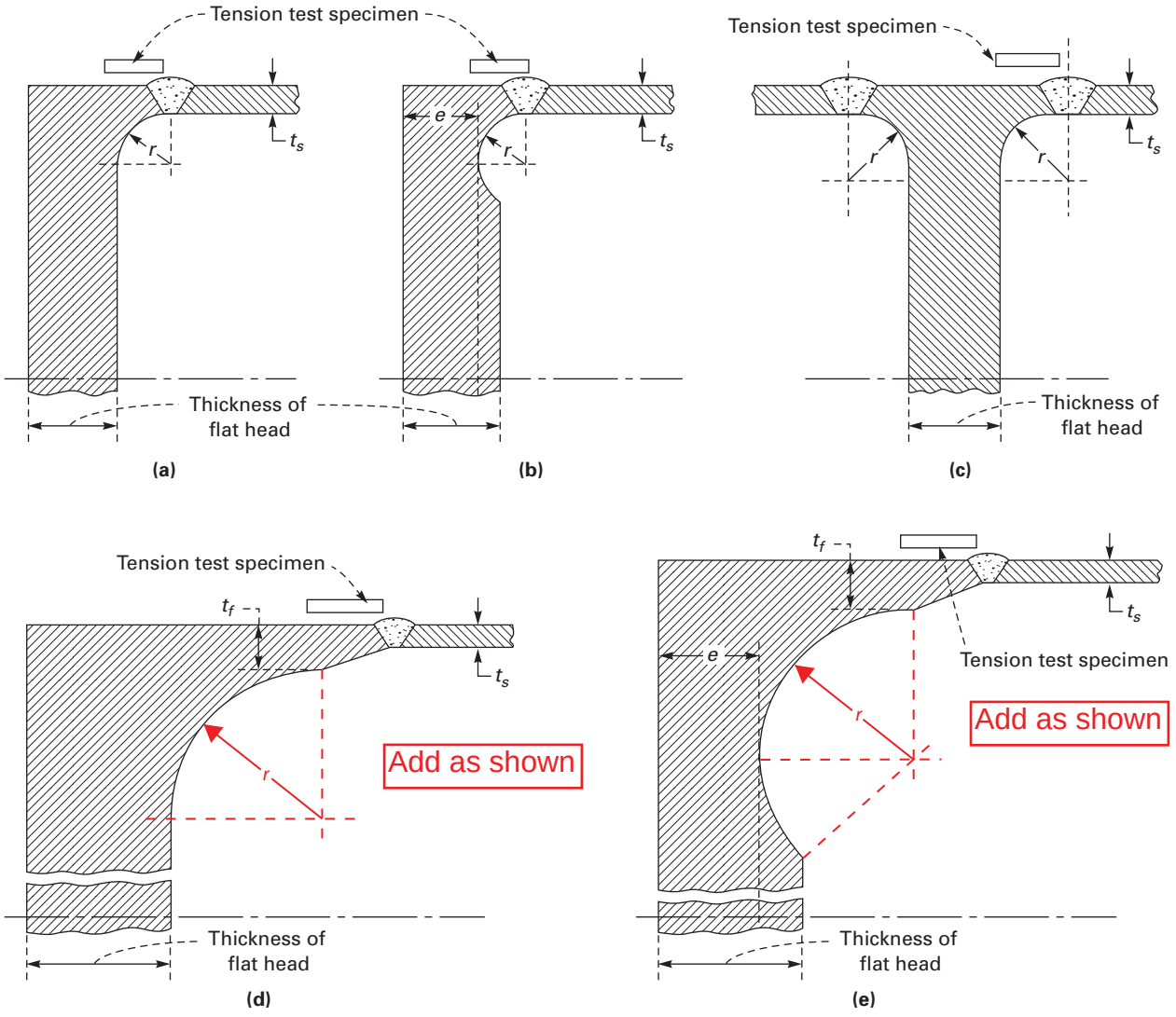


Type No. 2 Corner Welded Joints

GENERAL NOTE: For definitions of nomenclature, see WC-3252.3.

Typical Flat Heads with Hubs

Figure WC-4265-3
Typical Flat Heads



GENERAL NOTE: For definition of nomenclature, see WC-3225.

For definition of nomenclature, see WC-3225 and WC-3263.

of curves; however, no extrapolation of the curves is permitted. For designs where $P/S > 0.08$, which is above the upper limit of Figure WC-3224.6-1, the thickness shall be set by the following equation:

$$t = \frac{D}{2}\left(e^{P/S} - 1\right)$$

where $t/L < 0.002$, which is below the lower limit of Figure WC-3224.6-1, the head design must be analyzed according to Section III Appendices, Mandatory Appendix II, or Mandatory Appendix XIII. The cylindrical shell to which the head is attached shall be equal to or greater in thickness than the required head thickness for a distance, measured from the tangent line along the cylinder, of not less than $\sqrt{Rt}$. Transition joints to shells of thickness less than the required head thickness shall not be located within this minimum distance. Transition joints to shells of thickness greater than the required head thickness may be located within this minimum distance and shall be in accordance with WC-3260 and Figure WC-3261-1.

WC-3224.8.1 Crown and Knuckle Radii. In connection with the design procedures of WC-3224.8 and Figure WC-3224.6-1, the inside crown radius to which an unstayed head is formed shall not be greater than the inside diameter of the skirt of the head. The inside knuckle radius of a torispherical head shall not be less than 6% of the outside diameter of the skirt nor less than three times the head thickness.

(17) **WC-3224.9 Loadings on Heads Other Than Pressure.** Provision shall be made for other loadings given in WC-3111. For torispherical and ellipsoidal heads, the effect of other loadings must be determined in accordance with Section III Appendices, Mandatory Appendix II, or Mandatory Appendix XIII. For the spherical portion of heads, the effect of composite loading may be treated as in WC-3224.3 and WC-3224.4.

WC-3225 Flat Heads and Covers

The minimum thickness of unstayed flat heads, cover plates, and blind flanges shall conform to the requirements given in this Paragraph. Some acceptable types of flat heads and covers are shown in Figures WC-3225-1, WC-3225-2, and WC-3225-3. The dimensions are exclusive of extra metal added for corrosion allowance.

WC-3225.1 Nomenclature. The notations used are defined as follows:

C = a factor depending upon the method of attachment of head, shell dimensions, and other items as listed in Figures WC-3225-1 through WC-3225-3, dimensionless
D = bolt circle diameter
d = diameter
h_G = gasket moment arm, equal to the radial distance from the centerline of the bolts to the line of the gasket reaction, (Figure WC-3225-2)
L = distance from centerline of the head to shell weld to tangent line on formed heads, as indicated in Figure WC-3225-2
m = the ratio t_r/t_s, dimensionless
P = Design Pressure, psi (MPa)
r = inside corner radius on a head formed by flanging or forging
S = design stress intensity S_m from Section II, Part D, Subpart 1, Tables 2A, 2B, and 4, multiplied by the k factor tabulated in Table WC-3217-1, psi (MPa)
T = minimum required thickness of flat head, cover, or flanges, exclusive of corrosion allowance
t_f = actual thickness of the flange on a formed head, at the large end, exclusive of corrosion allowance
t_p = the smallest dimension from the face of the head to the edge of the weld preparation
t_r = required thickness of shell or nozzle for pressure
t_s = actual thickness of shell or nozzle
W = total bolt load

WC-3225.2 Equations for Minimum Thickness. (17)

(a) The thickness of flat heads as shown in Figures WC-3225-1 through WC-3225-3, shall be not less than that calculated by the following equation:

$$T = d\sqrt{CP/S}$$

(b) The thickness of cover plates and blind flanges attached by bolts causing an edge moment as shown in Figure WC-3225-2 shall be not less than that calculated by the following equation:

$$T = d\sqrt{CP/S + 1.27\,Wh_G/Sd^3}$$

(c) The thicknesses determined in (a) and (b) above, address stress requirements. In some cases, greater thickness may be necessary if deflection would cause leakage of threaded or gasketed joints

NOTE: In some cases, the initial bolt load required to seat the gasket is larger than the operating bolt load. The thickness should be checked for both the operating condition and the initial bolt load required to seat the gasket.