$S_a =$ allowable stress for the material of the tubesheet extension at ambient temperature (see UG-23)

$S_{fe} =$ allowable stress for the material of the tubesheet extension at tubesheet extension design temperature (see UG-23)

$W =$ flange design bolt load from eq. 2-5(e)(5) considering UHX-4(b)

$W_{m1} =$ flange design bolt load from eq. 2-5(c)(1)(1) considering UHX-4(b)

### UHX-9.4 Design Considerations

(a) The designer shall take appropriate consideration of the stresses resulting from the pressure test required by UG-99 or UG-100 [see UG-99(b) and UG-99(d)]. Special consideration shall be required for tubesheets that are gasketed on both sides when the pressure test in each chamber is conducted independently and the bolt loading is only applied to the flanged extension during the pressure test.

(b) If the tubesheet is grooved for a peripheral gasket, the net thickness under the groove or between the groove and the outer edge of the tubesheet shall not be less than $h_r$. Figure UHX-9 depicts thickness $h_r$ for some representative configurations.

### UHX-9.5 Calculation Procedure

(a) For flanged extensions that have bolt loads applied to them [Configurations b, d (extended for bolting), e, and B], the procedure for calculating the minimum required thickness of the extension, $h_r$, is as follows:

$$h_r = \text{MAX} \left[ \frac{1.9W_G}{S_a G}, \frac{1.9W_{m1}h_G}{3.2S_{fe}} \right]$$

(b) For unflanged Configurations c and f, the minimum required thickness of the extension, $h_r$, shall be calculated in accordance with Mandatory Appendix 2, 2-8(c) for loose-type flanges with laps.

(c) For unflanged Configurations d and C and for flanged Configuration d having no bolt loads applied to the extension, the minimum required thickness of the extension, $h_r$, shall be the maximum of the values determined for each design loading case as follows:

$$h_r = \left( \frac{D_G}{3.2S_{fe}} \right) P_b - P_t$$

### UHX-10 GENERAL CONDITIONS OF APPLICABILITY FOR TUBESHEETS

(a) The tubesheet shall be flat and circular.

(b) The tubesheet shall be of uniform thickness, except that the thickness of a tubesheet extension as determined in UHX-9 may differ from the center thickness as determined in UHX-12, UHX-13, and UHX-14. The outside diameter, $A$, used for the tubesheet calculations shall not exceed the diameter at which the thickness of the tubesheet extension is less than the minimum of 0.75$h$ or $h - 0.375$ in. ($h - 10$ mm).

(c) The tubesheet shall be uniformly perforated over a nominally circular area, in either equilateral triangular or square patterns. However, untubed lanes for pass partitions are permitted.

(d) The channel component integral with the tubesheet (UHX-12.5, UHX-13.5, and UHX-14.5; configurations a, e, f, and A) shall be either a cylinder or a hemispherical head (see Figure UHX-10). The hemispherical head rules shall be used when the head is attached directly to the tubesheet and there are no cylindrical sections between the head and the tubesheet.

If a hemispherical head is attached to the hub of a tubesheet, the hub may be considered part of the hemispherical head and not require an intervening cylinder, provided the hub:
1. is shaped as a continuation of the head in accordance with Figure UHX-10(b), or
2. meets the requirements of Figure UHX-10(c)

For both cases, the tangent line of the head is coincident with the adjacent face of the tubesheet.
(e) The tube side and shell side pressures are assumed to be uniform. These rules do not cover weight loadings or pressure drop.

(f) The design pressure or operating pressure defined in the nomenclature is the applicable pressure in the shell side or tube side chamber, including any static head, not the coincident pressure defined in UG-21. For the design-pressure-only conditions (design loading cases), the design pressure shall be used. For the operating-thermal-pressure conditions (operating loading cases), the operating pressure shall be used. If the operating pressure is not available, the design pressure shall be used for all loading cases.

(g) The design rules in UHX-12, UHX-13, and UHX-14 are based on a fully assembled heat exchanger. If pressure is to be applied to a partially assembled heat exchanger having a Configuration d tubesheet that is extended for bolting, special consideration, in addition to the rules given in UHX-9, UHX-12, UHX-13, and UHX-14, shall be given to ensure that the tubesheet is not overstressed for the condition considered.

UHX-11 TUBESHEET CHARACTERISTICS

UHX-11.1 Scope

These rules cover the determination of the ligament efficiencies, effective depth of the tube side pass partition groove, and effective elastic constants to be used in the calculation of U-tube, fixed, and floating tubesheets.

UHX-11.2 Conditions of Applicability

The general conditions of applicability given UHX-10 apply.

UHX-11.3 Nomenclature

The symbols described below are used for determining the effective elastic constants.

- \( A_L \) = total area of untubed lanes
- \( c_t \) = tubesheet corrosion allowance on the tube side
- \( d \) = diameter of tube hole
- \( d_t \) = nominal outside diameter of tubes
- \( d^* \) = effective tube hole diameter
- \( E \) = modulus of elasticity for tubesheet material at tubesheet design temperature
- \( E_{ET} \) = modulus of elasticity for tube material at tubesheet design temperature
- \( E^* \) = effective modulus of elasticity of tubesheet in perforated region
- \( h \) = tubesheet thickness
- \( h_{g} \) = tube side pass partition groove depth
- \( h'_{g} \) = effective tube side pass partition groove depth

Figure UHX-10

Integral Channels

NOTES:
(1) Length of cylinder shall be \( \geq 1.8 \sqrt{D_{c} t_{c}} \).
(2) Head shall be 180 deg with no intervening cylinders.

Notes (2) and (3)
Floating Tubesheet Heat Exchanger - A heat exchanger with one stationary tubesheet attached to the shell and channel, and one floating tubesheet that can move axially. The heat exchanger contains a bundle of straight tubes connecting both tubesheets [see Figure 4.18.1, sketch (c)].

4.18.3 GENERAL DESIGN CONSIDERATIONS

(a) The design of all components shall be in accordance with the applicable rules of all Parts of this Division.

(b) The design of flanges shall consider the effects of pass partition gasketing in determining the minimum required bolt loads, \( W_a \) and \( W_g \), of 4.16. When the tubesheet is gasketed between the shell and channel flanges, the shell and channel flange bolt loads are identical and shall be treated as flange pairs in accordance with 4.16.

(c) Rules for U-tube heat exchangers are covered in 4.18.7.

(d) Rules for fixed tubesheet heat exchangers are covered in 4.18.8.

(e) Rules for floating tubesheet heat exchangers are covered in 4.18.9.

(f) Distribution and vapor belts shall be designed in accordance with the following:

1. Where the shell is not continuous across the belt, the design shall be in accordance with 4.18.12.

2. Where the shell is continuous across the belt, the design shall be in accordance with 4.11 for Type 1. The longitudinal stress in the shell section with openings (for flow into the shell) shall be based on the net area of the shell (the shell area less that removed by the openings) and shall not exceed the applicable allowable stress criteria. For U-tube and floating head exchangers, the allowable axial stress is \( S \) (see 4.1.12) for the shell material, and for fixed tubesheet exchangers, the allowable stress is as defined in 4.18.8.4, Step 10.

(g) Requirements for tubes shall be as follows.

1. The allowable axial tube stresses in fixed and floating tubesheet heat exchangers shall be in accordance with 4.18.8 and 4.18.9.

2. The thickness of U-tubes after forming shall not be less than the design thickness.

NOTE: Tubesheet deflection, especially when the tubesheet thickness is less than the tube diameter, may contribute to tube-to-tubesheet joint leakage; likewise, deflection of a tubesheet or flat bolted cover may result in fluid leakage across a gasketed pass partition plate. Such leakages can be detrimental to the thermal performance of the heat exchanger and deflection may need to be considered by the designer.

4.18.4 GENERAL CONDITIONS OF APPLICABILITY FOR TUBESHEETS

(a) The tubesheet shall be flat and circular.

(b) The tubesheet shall be of uniform thickness, except that the thickness of a tubesheet extension as determined in 4.18.5 may differ from the center thickness as determined in 4.18.7, 4.18.8, and 4.18.9. The outside diameter \( A \) used for the tubesheet calculations shall not exceed the diameter at which the thickness of the tubesheet extension is less than the minimum of 0.75\( h \) or \( h - 10 \text{ mm} \) (\( h - 0.375 \text{ in.} \)).

(c) The tubesheet shall be uniformly perforated over a nominally circular area, in either equilateral triangular or square patterns. However, untubed lanes for pass partitions are permitted.

(d) The channel component integral with the tubesheet (Configurations a, e, f and A for U-Tube, Fixed, and Floating Tubesheets) shall be either a cylinder or a hemispherical head (see Figure 4.18.15). The hemispherical head rules shall be used when the head is attached directly to the tubesheet and there are no cylindrical straight sections between the head and the tubesheet.

(e) The tube side and shell side pressures are assumed to be uniform. These rules do not cover weight loadings or pressure drop.

(f) For the design pressure-only conditions (design loading cases), the design pressure shall be used. For the operating thermal-pressure conditions (operating loading cases), the operating pressure shall be used. If the operating pressure is not available, the design pressure shall be used for all loading cases.

(g) The design rules in 4.18.7, 4.18.8, and 4.18.9 are based on a fully assembled heat exchanger. If pressure is to be applied to a partially assembled heat exchanger having a Configuration “d” tubesheet that is extended for bolting, special consideration, in addition to the rules in 4.18.5, 4.18.7, 4.18.8, and 4.18.9, shall be given to ensure that the tubesheet is not overstressed for the condition considered.

4.18.5 TUBESHEET FLANGED EXTENSION

4.18.5.1 Scope.

(a) A tubesheet extension, if any, is an attached flat plate (flanged tubesheet) or an extended ring (unflanged tubesheet).

If a hemispherical head is attached to the hub of a tubesheet, the hub may be considered part of the hemispherical head and not require an intervening cylinder, provided the hub:

1. is shaped as a continuation of the head in accordance with Figure 4.18.15(b), or
2. meets the requirements of Figure 4.18.15(c).

For both cases, the tangent line of the head is coincident with the adjacent face of the tubesheet.
Figure 4.18.15
Integral Channels

(a) Cylindrical Channel
NOTE: Length of Cylinder Shall Be \( \geq 1.8 \sqrt{D_c t_c} \)

(b) Hemispherical Channel
NOTE: Head Shall Be 180 Degrees With No Intervening Cylinders

Figure 4.18.16
Some Representative Configurations Describing the Minimum Required Thickness of the Tubesheet Flanged Extension, \( h_r \)

These rules also apply to channels integral with tubesheets having extensions.

(a) Raised Face

(b) Grooved for Ring Gasket
(c) Hemispherical Channel with tubesheet hub thicker than channel