(b) Openings in a definite pattern, such as tube holes, may be designed in accordance with the rules for ligaments in HG-350 provided the diameter of the largest hole in the group does not exceed that permitted by the equation in (d).

(c) No calculations need be made to determine the availability of reinforcement for single openings in boilers not subject to rapid fluctuations in pressure or temperature and in which the outside diameter of the opening does not exceed one-fourth of the inside diameter of the boiler, provided the diameter of the finished opening as defined in HG-321.2 does not exceed the following sizes:

1. NPS 2 (DN 50) for welded connections in boiler walls over 3/8 in. (10 mm) thick and for all threaded, studded, or expanded connections.

2. NPS 3 (DN 80) for welded connections in boiler walls 3/8 in. (10 mm) thick and under.

(d) No calculations need be made to demonstrate compliance with HG-321 for single openings not covered in (c) when either the diameter of the opening in the shell or header does not exceed that permitted in the following equation or the calculated $K$ value is less than 50%.

\[
\begin{align*}
\text{U.S. Customary Units} & \\
& \frac{d}{2} = 2.75 \left[ D (1 - K) \right]^{1/3} \\
\text{SI Units} & \\
& \frac{d}{2} = 8.08 \left[ D (1 - K) \right]^{1/3}
\end{align*}
\]

where:

- $D$ = outer diameter of the shell, in. (mm)
- $d$ = maximum allowable diameter of opening, in. (mm)
- $K = PD/2St$
- $P$ = design pressure
- $S$ = maximum allowable stress value taken from Table HF-300
- $t$ = nominal thickness of the shell, in. (mm)

Three significant figures shall be employed for the variables in the equation and in the resulting value of $d$. Additional significant figures are permitted but not required. $K$ as used in the equation is limited to a maximum of 0.990.

HG-321 REINFORCEMENT REQUIRED FOR OPENINGS IN SHELLS AND FORMED HEADS

HG-321.1 General. The rules in this subparagraph apply to all openings other than those openings in a definite pattern covered by HG-320.3(b), openings covered by HG-320.3(c) and HG-320.3(d), flanged-in openings in formed heads covered by HG-323, and openings in flat heads covered by HG-325.

Reinforcement shall be provided in such amount and distribution that the requirements for area of reinforcement are satisfied for all planes through the center of the opening and normal to the boiler surface. For a circular opening in a cylindrical shell, the plane containing the axis of the shell is the plane of greatest loading due to pressure.

HG-321.2 Design for Internal Pressure. The total cross-sectional area of reinforcement $A$ required in any given plane for a boiler under internal pressure shall be not less than

\[
A = \frac{d_t F}{2} + 2t_r F (1 - f_r)
\]

where

- $d$ = the diameter in the given plane of the finished opening (as depicted in Figure HG-326.1)
- $F = a$ correction factor that compensates for the variation in pressure stresses on different planes with respect to the axis of a vessel. A value of 1.00 shall be used for all configurations except that Figure HG-321 may be used for integrally reinforced openings in cylindrical shells.
- $t_r = \text{the required thickness of a seamless shell or head computed by the rules of the Code for the designated pressure except that}$
- \(a\), when the opening and its reinforcement are in a torispherical head and are entirely within the spherical portion, $t_r$ is the thickness required for a seamless hemispherical head of the same radius as that of the spherical portion.
- \(b\), when the opening is in a cone, $t_r$ is the thickness required for a seamless cone of diameter $D$ measured where the nozzle axis pierces the inside wall of the cone.
- \(c\), when the opening and its reinforcement are in an ellipsoidal head and are located entirely within a circle the center of which coincides with the center of the head and the diameter of which is equal to 80% of the shell diameter, $t_r$ is the thickness required for a sphere of radius $K_1 D$ where $D$ is the shell diameter and $K_1$ is given by Table HG-321.

HG-323 FLANGED-IN OPENINGS IN FORMED HEADS

HG-323.1 Reinforcement Requirements. Flanged-in openings in torispherical, ellipsoidal, and hemispherical heads shall be provided with reinforcement in accordance with HG-321, except for heads that meet the requirements in HG-323.2, HG-323.3, and HG-323.4.

HG-323.2 Restrictions on Location. The flanged-in opening and its reinforcement shall be entirely within the spherical portion of torispherical heads, and within a circle the center of which coincides with the center of
the head and the diameter of which equals 80% of the shell diameter for ellipsoidal and hemispherical heads. The center line of the opening shall not be closer to the above boundary circle than the diameter of the opening.

HG-323.3 Minimum Thickness Requirements of Flanged-in Openings.

(a) For flanged-in openings that do not exceed 6 in. (150 mm) in any dimension and for flanged-in openings of any dimension that are stayed by an attached flue, the thickness of the head shall not be less than that required by HG-305 for a blank head, nor less than that required by HG-305 for torispherical heads.

(b) For unstayed flanged-in openings that exceed 6 in. (150 mm) in any inside dimension, the head thickness shall be increased 15% but not less than \( \frac{t}{h} \) in. (3 mm) greater than that required by (a) above.

HG-323.4 Minimum Flange Depth. The minimum depth of flange of a flanged-in opening, when not stayed by an attached flue, shall equal 3\( t \) or \( t + 3 \) in., whichever is less, where \( t \) is the required head thickness. The depth of flange shall be determined by placing a straightedge across the outside of the opening along the major axis and measuring from the straightedge to the edge of the flanged opening.

HG-323.5 Minimum Gasket Bearing Surface. The minimum width of bearing surface for a gasket on a flanged-in manhole opening shall be \( \frac{11}{16} \) in. (17 mm).

HG-325 REINFORCEMENT REQUIRED FOR OPENINGS IN FLAT HEADS

HG-325.1 General. The rules in this paragraph apply to all openings other than small openings covered by HG-320.3(c).

HG-325.2 Specific Requirements. Flat heads that have an opening with a diameter that does not exceed one-half of the head diameter or shortest span, as defined in HG-307, shall have a total cross-sectional area of reinforcement not less than that given by the formula:

\[
A = 0.5dt
\]

where

- \( d \) = diameter of the finished opening
- \( t \) = minimum required thickness of plate

As an alternative, the thickness of flat heads may be increased to provide the necessary opening reinforcement as follows:

(a) in eq. HG-307.2(b)(1) or eq. HG-307.3(a)(3) by using 2\( C \) or 0.75 in place of \( C \), whichever is less.

(b) in eq. HG-307.2(b)(2) or eq. HG-307.3(b)(5) by doubling the quantity under the square root sign. Except for the types of construction shown in Figure HG-307, sketches (j) and (k), the value of 2\( C \) to be used in the equations need not exceed 0.75.