B_2 = factor for stress in uniformly loaded, simply supported, rectangular plate (see Tables 1A and 1B)

E = modulus of elasticity, psi

f = maximum fiber stress in bending, psi

H = uniform load, ft of water

L_s = stiffener spacing, in.

n = a/A or b/B

p = uniform load or pressure, psi

P = concentrated load, lb

r = radius, in., of central loaded area

r' = inside knuckle radius, in., for flat, unstayed, circular plates

R = radius, in., to support for circular plates

S = spacing, in., of adjacent staybolts at corners of square plates

t = plate thickness, in.

Δ = center deflection, in., of plate relative to supports

ϕ = factor for stress in circular flanged plate (see Table 1A)

ϕ_1 = factor for deflection of uniformly loaded, fixed-edge, rectangular plates (see Tables 1A and 1B)

ϕ_2 = factor for deflection of uniformly loaded, simply supported rectangular plates (see Tables 1A and 1B)

ϕ_3 = factor for deflection of fixed-edge, rectangular plates subjected to central concentrated load (see Tables 1A and 1B)

One of the most commonly encountered conditions is a uniformly loaded flat plate supported on uniformly spaced parallel stiffeners. In the absence of any code or specification requirement, assume an allowable bending stress of 20,000 psi in the plate for determination of stiffener spacing L_S, in.

The plate stress can be obtained from the formula in Table 1A for the case of a rectangle $b \times B$, where $B = \infty$ and b is taken as L_S. Thus, for the fixed condition (continuous over the supports), the maximum permissible spacing of stiffeners becomes:

$$L_s = \left(\frac{40,000\, t^2}{p}\right)^{1/2} \qquad (1)$$

For convenience in connection with tank bottoms, the load can be expressed in feet of water, rather than psi, in which case:

$$L_s = \left(\frac{92,308\, t^2}{H}\right)^{1/2} \qquad (2)$$

Figure 1 gives graphically stiffener spacing determined from Eqs. (1) and (2) for an allowable bending stress of 20,000 psi.

If deflection exceeds $t/2$, the plate will tend to act as a membrane in tension and exert a lateral pull on the outside support that must be taken into account. An alternative solution, therefore, is to assume that yielding does occur at the support and the plate acts as a catenary between supports. At intermediate supports, the tension in the plate will be balanced; but at the outside support, restraint must be provided to resist that tension. This is not always easily accomplished.

When the span is such that the profile of the plate approaches a catenary between supports, the support spacing is given approximately by the following formula:

$$L_s = \frac{tf}{p}\left(\frac{24f}{E}\right)^{1/2} \qquad (3)$$

Because of the approximate nature of the solution, a conservative value for f is indicated. Assuming f = 10,000 psi and E = 29,000,000 psi for mild carbon steel, the equation becomes:

$$L_s = 900\,\frac{t}{p} = 2,076\,\frac{t}{H} \qquad (4)$$

Figure 2 gives graphical solutions for Eqs. (3) and (4).

For the catenary approach, **it is essential that a lateral force of 10,000 psi be resisted at the peripheral support.** Since this is not always practicable, application of the catenary approach is limited. Similarly, it should not be used where pressure is reversible or where deflection is objectionable.

In the above discussion, only plate stresses have been considered, and it is assumed that any welded plate joints will develop the full strength of the plate. Also, the stiffener system should be in accordance with accepted structural design principles.

Protection against brittle failure of a structure should be considered at the time of design. Since environment extremes, design detail, material selection, fabrication methods and inspection adequacy are all interrelated in protecting a structure from such failure, these factors should be evaluated.

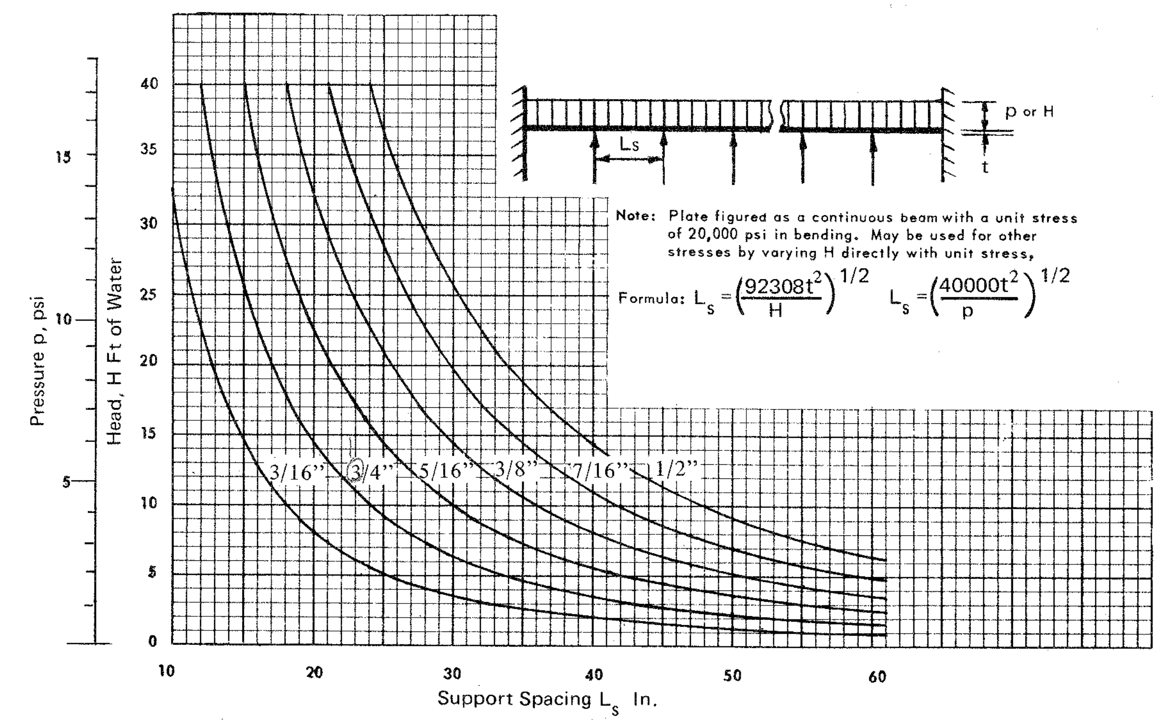

Figure 1. Stiffener Spacing for Flat Plate Acting as Continuous Beam

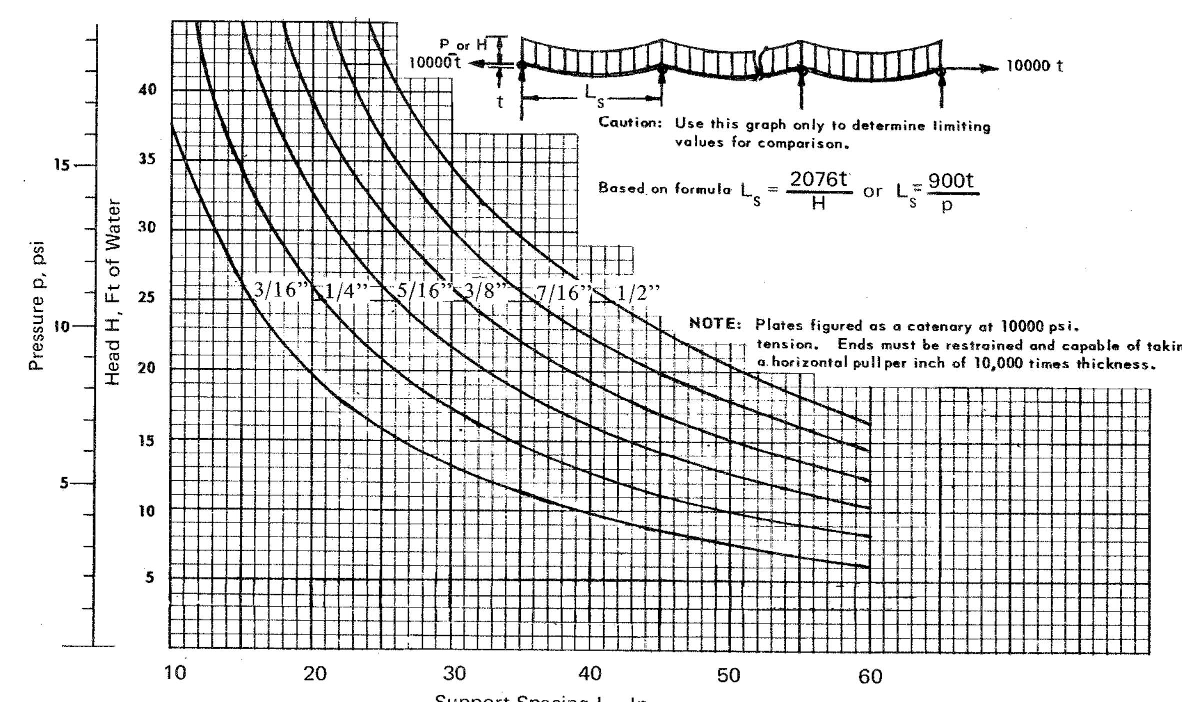

Figure 2. Stiffener Spacing for Flat Plate with Catenary Action.
(Courtesy of Chicago Bridge & Iron Company)