is a basis on which to calculate other values. For example, when the side hole is not small or when there are two side holes diametrically opposed, the intensification factors for small single holes are not valid. To account for the size of the side hole, an expression for the longitudinal stress, σ_z, was developed based on the net section of the cylinder cross section supporting the load; this automatically takes into account the effect of changing the side-hole geometry.

Consider Figure 1 and take the pressure length of the side hole as three fourths of the hole length (this was the case in the experimental work). Thus,

$$L = 3/4\,(r_o - r_i) \qquad (16)$$

Now because stress is equal to load divided by area

$$\sigma_z = \frac{\text{force}}{\text{net area}} = \frac{p_o \pi r_o^2}{\pi(r_o^2 - r_i^2) - 2nr_sL} \qquad (17)$$

where $n = 1$ for one side hole and 2 for the case of two diametrically opposite holes. Thus, from Equation 17, for the case of a single side hole (elliptic or circular)

$$\sigma_z = \frac{p_o \pi R^2 R_s}{(R-1)\,[\pi R_s(R+1) - 1.5]} \qquad (18)$$

and for two diametrically opposite side holes

$$\sigma_z = \frac{p_o \pi R^2 R_s}{(R-1)\,[\pi R_s(R+1) - 3.0]} \qquad (19)$$

where R_s = side hole ratio; r_i/r_s for a circular hole and r_i/a for an elliptic hole.

Case of Circular Side Holes. Equation 17 gives an expression for the longitudinal stress as a function of the geometry of the cylinder. To assign the proper stress intensification values to σ_h and σ_z for calculating the K factor for large side hole sizes, reference is made to the recent compilation of data by Peterson (*5*). Pertinent data from Peterson (Figure 6) come from a consideration of two circular holes in a plate subjected to axial loading. These curves show the effect on stress concentration of the proximity of holes; for a cylinder with two side holes diametrically opposed

Table I. Intensification Factors

Side Hole Ratio, R_s	Factor for σ_h, α	Factor for σ_z, γ
10	3	−0.92
9	3	−0.90
8	3	−0.88
7	2.96	−0.86
6	2.95	−0.84
5	2.92	−0.81
4	2.88	−0.77
3	2.82	−0.70
2	2.71	−0.58
1	2.57	−0.33

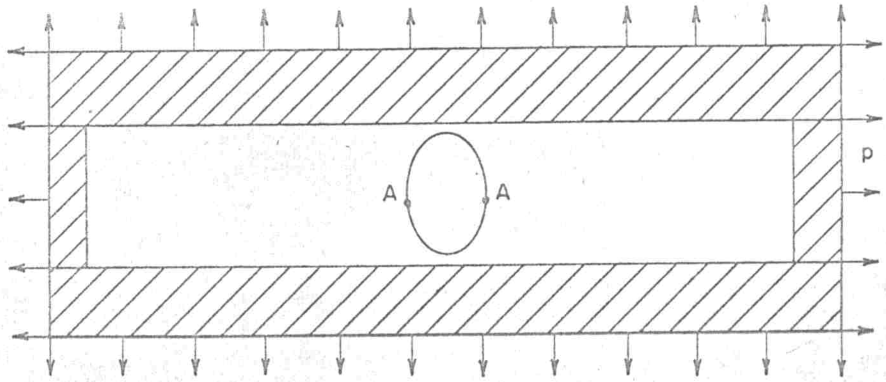

Figure 5. Superposition of Figures 3 and 4

the proximity factor is interpreted as the side hole ratio, r_i/r_s. Curve *A* of Figure 6 is used to arrive at intensification values for the hoop stress at location *A*, Figure 5. σ on the plot represents the hoop stress, σ_h, in the cylinder which is intensified to σ_{max} as shown. Thus, for the case of a circular cross-bore side hole, if R_s is equal to 7, σ_h is intensified by a factor equal to about 2.98.

The intensification factors for σ_z are obtained from curve *B* of Figure 6. For this case σ represents the longitudinal stress, σ_z, in the cylinder with a maximum value, σ_{max}, as shown. This maximum longitudinal stress is positive, but according to plate theory it would induce a negative stress at a location 90° from σ_{max} (the σ_h direction in the cylinder). Thus, as an approximation, if σ_{max} were 3σ, the longitudinal stress would be reflected in the σ_h direction as $-\sigma_z$; if σ_{max} were $1.5\,\sigma$, the longitudinal stress would be reflected as 50% of −1.0 or $-0.5\sigma_z$. Thus, from Figure 6, if the side hole ratio were 7, σ_h would be intensified by a factor equal to about 2.98 and to this would be added the effect of the longitudinal stress, $-0.86\,\sigma_z$. Intensification factors for circular side holes have been listed in Table I for a series of cylinders. With these factors the stress-concentration factor, K, for the hoop stress at the bore–side hole interface can be calculated as follows:

$$K = \frac{\alpha\sigma_h + \gamma\sigma_z}{\sigma_h} \qquad (20)$$

where α and γ are intensification factors determined from Figure 6, σ_h is calculated from Equation 9, and σ_z from Equation 17.

Case of Elliptic Side Holes. In analyzing the case of elliptic side holes the procedure used to determine the effect of circular side holes is applied, except

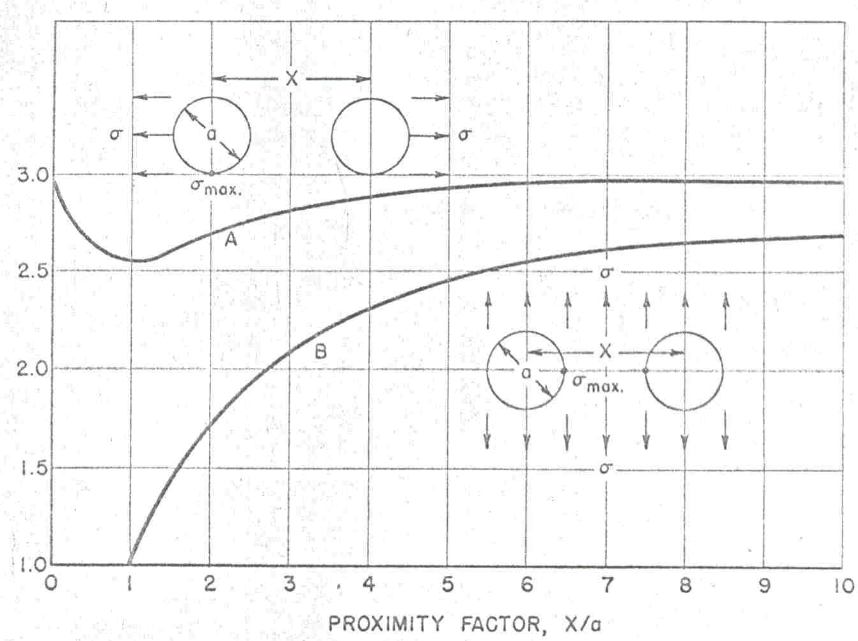

Figure 6. Stress intensification factors