Table III. Data Used in Calculating Stress Concentrations for Cylinders of Various Wall Ratios with Side Hole Ratio R_s = 2

Distance from Side Hole, Inches	Hoop Strain[a], Inch/Inch	Longitudinal Stress, Lb./Sq. Inch	Hoop Stress Concn. Factor, K
	R = 4.0 (O.D. = 7.625 Inches)		
0	...	...	2.800[b]
0.05	+0.000367	−93	2.460
0.08	+0.000335	−88	2.230
0.20	+0.000310	−79	2.080
0.28	+0.000296	−74	1.990
0.42	+0.000257	−67	1.700
4.00	+0.000165	+ 3	1.390
	R = 3.0 (O.D. = 5.725 Inches)		
0	...	...	2.750[b]
0.05	+0.000417	−90	2.630
0.08	+0.000388	−85	2.440
0.20	+0.000358	−76	2.260
0.28	+0.000335	−71	2.110
0.42	+0.000285	−64	1.780
4.00	+0.000190	+ 6	1.480
	R = 2.5 (O.D. = 4.77 Inches)		
0	...	...	2.700[b]
0.05	+0.000441	−86	2.560
0.08	+0.000404	−81	2.340
0.20	+0.000377	−72	2.190
0.28	+0.000361	−67	2.120
0.42	+0.000305	−60	1.770
4.00	+0.000198	+10	1.410
	R = 2.0 (O.D. = 3.816 Inches)		
0	...	...	2.620[b]
0.05	+0.000506	−79	2.520
0.08	+0.000450	−74	2.220
0.20	+0.000422	−65	2.100
0.28	+0.000403	−60	2.020
0.42	+0.000338	−53	1.960
4.00	+0.000221	+17	1.340
	R = 1.5 (O.D. = 2.862 Inches)		
0	...	...	2.350[b]
0.05	+0.000636	−56	2.160
0.08	+0.000561	−51	1.900
0.20	+0.000522	−42	1.780
0.28	+0.000494	−37	1.700
0.42	+0.000405	−30	1.390
4.00	+0.000284	+40	1.150

[a] For these cylinders E = 473,000 lb./sq. inch and μ = 0.37.
[b] By extrapolation of K curves to side hole interface.

Table IV. Comparison of Stress-Concentration Factors

Diameter Ratio of Cylinder, R	Side Hole Ratio, R_s	Type of Hole[a]	K Factors: Strain gage	K Factors: Photo-elastic	K Factors: Theory	Deviation, %
1.5	2.0	CCB	2.350		2.35	0
2.0	1.0	CCB	3.020		2.33	−23
2.0	2.0	CCB	2.620		2.37	−10
2.5	2.0	CCB	2.70		2.38	−12
2.5	2.0	CCB	...	2.40	2.38	−1
3.0	2.0	CCB	2.75		2.38	−13
4.0	2.0	CCB	2.80		2.39	−15
2.5	2.0	SLC	...	1.70	...	...
2.5	2.0	SE	...	...	1.46	...
1.5[b]	8.0	SC	...	(1.70) (2.22)	2.50	(+47) (+13)
2.5	2.0	SC	...	2.35	2.40	+ 2
3.0[c]	2.0	SC	...	2.80	2.40	−14

[a] CCB. Circular cross-bore hole;
SC. Single circular hole.
SLC. Slot cross-bore hole.
SE. Single elliptic hole.
[b] From (4).
[c] From (3).

$$\sigma_s' = \frac{p}{R^2 - 1} \tag{23}$$

At the side hole interface this stress is zero and rapidly approaches a constant value in accordance with St. Venant's principle (7). The other stress, σ_{zl}, is determined by considering the zone between the side hole and the end of the cylinder as having a stress distribution expressed by the following equation for the radial direction in a cylinder under internal pressure

$$\sigma_{zl} = \frac{p}{(R_1)^2 - 1}\left(1 - \frac{(b_1)^2}{(r_1)^2}\right) \tag{24}$$

where

R_1 = distance from side hole to end of cylinder divided by side hole radius
b_i = distance from side hole to end of cylinder
r_i = any intermediate distance from side hole to end of cylinder

Analyses of photoelastic data, as well as similar calculations on the cylinder having a side hole ratio R_s = 1.0, supported the calculation of the longitudinal stress as outlined above.

In Figure 8 one of the photoelastically determined K factors is plotted and in Table IV the results of all the tests are recorded and compared with theory; this table also includes data from the literature.

Discussion

In Figure 8 the stress-concentration effects are shown to extend beyond the expected limit of perhaps two side-hole diameters. If this condition is fortuitous, and it may be, on the basis of results of photoelastic tests, the actual factors may be somewhat lower than indicated. There are obvious items associated with the strain gage tests which may have had an undue influence on the results. For example, the cement holding the two cylinder halves together could disturb the uniformity of stresses induced by internal pressure. The presence of strain gages cemented to the bore of the cylinders could disrupt the stresses. Finally, for the large side hole size (R_s = 1.0) the limitations of the plate theory used in the analytical procedure may have been exceeded; bending stresses, if present, were not included in the analysis. In any event, Figure 9, a summary of the data, indicates an important design item—that as the R value of the cylinder increases, K also increases. From Figure 9, the indication is that K decreases as R_s decreases; however, there may be some question about the K values of R_s = 1.0 on the plot. If additional work is undertaken on the problem, K values for R_s = 1.0 should be determined.

The photoelastic test results also require some comment. The method is