The pressure-to-strength ratio p/σ_1 is plotted in Figure 9. Comparing this figure with Figure 5 for the multi-ring container with $\alpha_r = 0.5$, it is evident that both containers have the same limit $p/\sigma_1 \rightarrow 1$ for large wall ratios. However, $\alpha_r = 0.5$ is possible only if $\alpha_m \leqq 0$ as shown in Figure 3. Actually, $\alpha_m = +0.5$ is likely in the pin-segment container if $\alpha_r = 0.5$ because any interference is expected to be lost in taking up slack between pins and holes. In this case, then, $\alpha_r = 0.5$ would mean only one cycle life whereas $\alpha_r = 0.5$ means 10^4 to 10^5 cycles life in the multi-ring container. If this assembly problem could be eliminated by careful machining and selective fitting of pins, then theoretically, the p/σ_1 ratio of the pin-segment container could be made to approach that of the multi-ring container.

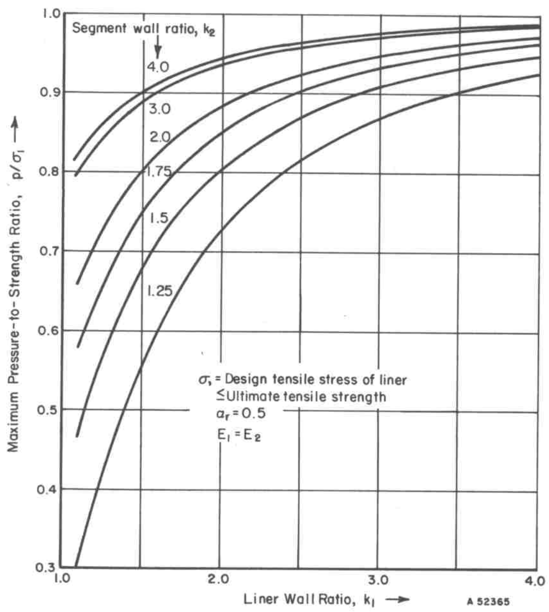

FIGURE 9. MAXIMUM PRESSURE-TO-STRENGTH RATIO, p/σ_1, FOR THE PIN-SEGMENT CONTAINER

Since no prestress has been assumed for the pin-segment container, $\alpha_r = \alpha_m = 0.35$ for 10^4 to 10^5 cycles as shown by Figure 3. For $\alpha_r = 0.35$, it is found that p/σ_1 is limited to 0.7 at best. Therefore, the maximum pressure in the pin-segment container is p = 0.7 (300,000) = 210,000 psi for 10^4 to 10^5 cycles life.

The stresses in the segments have also to be considered. It is found that high stresses develop around the pin holes. Their magnitudes decrease with increasing segment size. The shear stresses in the pins also need to be considered in order to determine the required pin size.

Strip-Wound Container

The strip-wound container uses basically the same principle as the multi-ring container. It has a cylindrical inner cylinder, the liner, under prestress, but the prestress in the liner is provided by wrapping strips or wire under tension onto the liner. It is possible to estimate the pressure-to-strength ratio of the strip-wound vessel if it is assumed that it behaves as a multi-ring container under internal pressure after the strip has been wound on. Referring to Figure 5 we see that the pressure-to-strength ratio p/σ_1 depends only on the over-all wall ratio K and α_r, the semirange stress parameter for the liner material. If K for the strip-wound vessel is taken as the ratio of the outside diameter of the last strip layer to the inner bore diameter, then Figure 5 can be used to estimate its pressure capability. Therefore, it may be concluded that the strip-wound container has a maximum pressure capability equal at best to that of the multi-ring container. However, unknown local stress concentrations and contact conditions between strips may be possible disadvantages in the strip-wound design.

Controlled Fluid-Fill Cylindrical-Layered Container

A controlled fluid-fill container, shown in Figure 10, has been proposed by Berman[16]. All the rings are assumed to be made of the same ductile material and a shear strength criterion applies. Like the ring-segment-fluid container this container also uses the fluid-pressure support principle. The advantage of this design is that residual stress limitations can be overcome by controlling the fluid pressures p_n; i.e., the pressures p_n can be reduced to zero as the bore pressure, p, is reduced to zero. There are no shrink-fits, so there are no residual stresses.

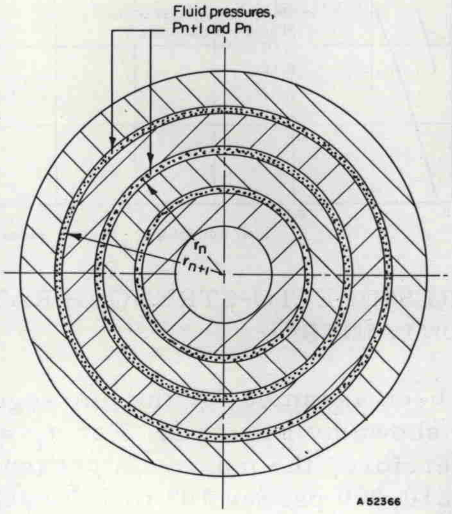

FIGURE 10. CONTROLLED FLUID-FILL CYLINDRICAL-LAYERED CONTAINER (REFERENCE (16)).

Berman's analysis was based upon static strength. A similar analysis at Battelle was based upon fatigue strength. A surprising result was found; Figure 4 applies also to this design – except for the limit curve which does not. Therefore, p/σ can be made as large as desired simply by increasing N. The only problem is that the required N or K may be too large to be practicable. If, for example, σ = 150,000 psi (ultimate strength of a ductile steel), N = 8 and K = 16, then it is found that p = 240,000 psi. Thus, for fatigue applications with bore pressures of 240,000 psi and greater, the controlled-fluid-fill container may become too large to be practicable. Furthermore, eight rings also means there are seven annuli under fluctuating fluid pressures. Design of mechanical apparatus to supply and control all these pressures presents practical difficulties as well.