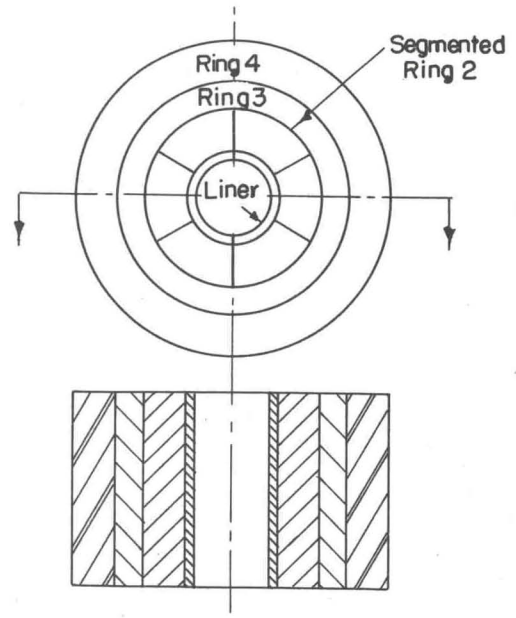
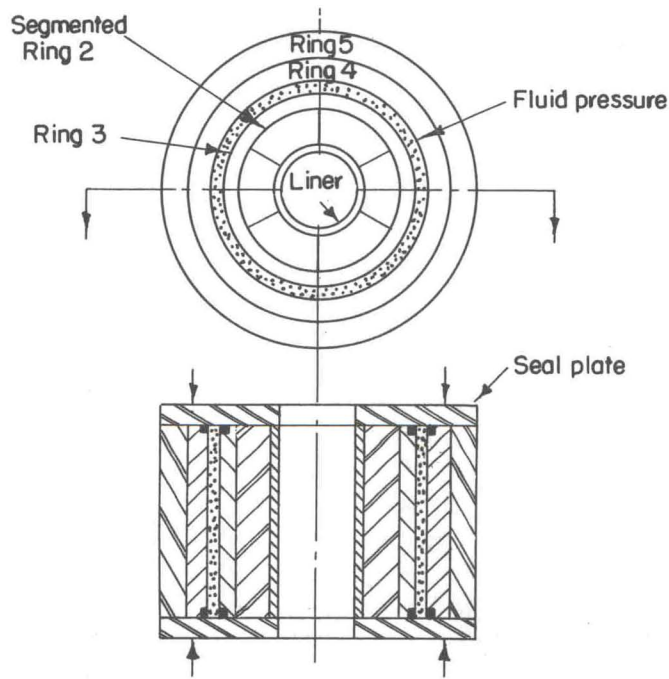


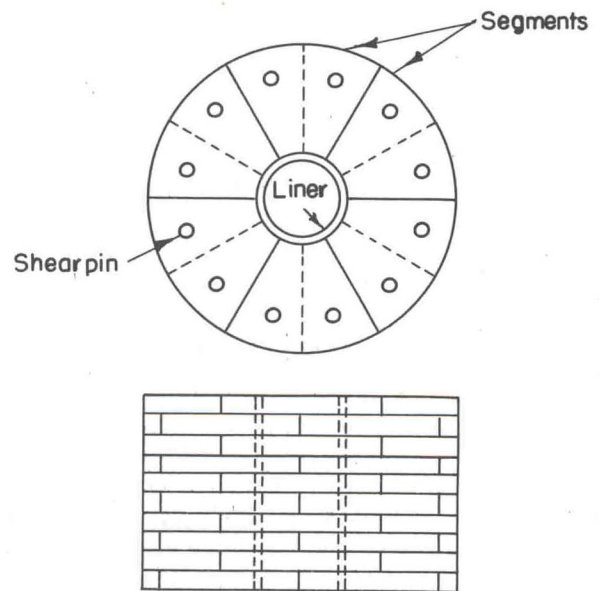
a. Multi-Ring Container



b. Ring-Segment Container



c. Ring-Fluid-Segment Container



d. Pin-Segment Container

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FIGURE 1. SCHEMATIC OF HIGH-PRESSURE-CONTAINER DESIGN CONCEPTS ANALYZED IN THE PRESENT STUDY

The ring-fluid-segment container makes use of the fluid-pressure support principle. This container is essentially constructed of two parts. The inner part is a ring-segment type container with one outer ring, but with a fluid support pressure,  $p_3$ , as shown in Figure 2(c). The outer part is a multi-ring container subject to an internal pressure,  $p_3$ , the support pressure for the inner part. The advantage of this design is that the fluid pressure ( $p_3$ ) provides a compressive hoop stress at the bore which counteracts the tensile hoop stress resulting from the bore pressure,  $p$ . Theoretically,  $p_3$  can be changed in proportion to the change in bore pressure in order to reduce the bore stress over an entire cycle of bore pressure. This variation of  $p_3$  with the bore pressure is assumed in the analysis.

The origin of the ring-fluid-segment concept is not clear. Ballhausen<sup>(5)</sup> patented an approach of this sort in 1963. Another application of the same principle was patented by G. Gerard and J. Brayman<sup>(6)</sup>, also in 1963. A similar design, but with additional features, was reported by F. J. Fuchs<sup>(7)</sup> in 1965.

The pin-segment design is an approach proposed by Zeitlin, Brayman, and Boggio<sup>(8)</sup>. Like the ring-segment container this vessel also uses segments to reduce the pressure that must be carried by the external support. Unlike the ring-segment container, the pin-segment container has segmented disks (thin plates) rather than segmented cylinders. Also, the external supporting members in this case are pins rather than an external ring. The pins carry the reaction to the bore pressure predominantly in shear.

All four containers have one thing in common; the liner is subject to the full bore pressure. The four containers differ in the manner and in the amount they constrain the liner.

### BASIS AND METHOD OF ANALYSIS

In this study the four design concepts for high-pressure containers are evaluated on the basis of a selected strength criterion for the component materials. A high-pressure container for commercial hydrostatic extrusion should, of course, be capable of repeated use without frequent failure. Therefore, it was considered essential that a fatigue strength criterion be used as the basis of evaluation in this study.

Manson and Hirschberg<sup>(9)</sup> have shown that for most materials, failure by low-cycle fatigue (life less than about 1000 cycles) involves almost entirely plastic strain. Above about 1000 cycles life the amount of plastic strain is appreciably smaller and above 100,000 cycles life the plastic strain is negligible. For the relatively high-strength materials, however, the strain is predominately elastic for lifetimes as low as 100 cycles. Because lifetimes greater than 1000 cycles are desirable in commercial applications and since high pressures require use of high-strength materials, the theory of elasticity is used in the analysis.

For the analysis, equations are derived that relate the interface pressures and the radial deformations between components. Elasticity solutions for stresses and deformations are used together with fatigue relations to determine formulas for maximum bore pressures. Stresses due to the bore pressure and shrink-fit assembly only are analyzed; no thermal gradients are assumed present. However, the effect of temperature change