minimum bore pressure, $q_o = 0$,

support pressures, $p_3 = q_3 = 0$.

The support pressure, p_2, on the inner unit was precalculated by an analysis similar to that of Equation (90) to give $(\sigma_\theta)_{max} \approx 0$ at the bore.

The results of computer code MULTIR are

Inner Unit

$p_o = 455,832$, $\Delta_1 = 0.0416$ in.

Outer Unit

$p_o = 202,817$ psi, $\Delta_1 = 0.0772$ in., $\Delta_2 = 0.1220$ in.

The maximum allowable pressure, $p_o = 202,817$ psi, in the outer unit represents a factor of safety of 1.33 over the required pressure of 160,000 psi.

The 6-inch-diameter-bore designs considered would require outside diameters of 40 inches and 76 inches for 325,000 psi and 455,000 psi capacities, respectively. The larger diameter requirement in the second case reflects the conservative shear-strength basis of this design. Containers with 15-inch-diameter bores would require (scaled-up) outside diameters of 100 inches and 190 inches, respectively. Rings of those diameters are considered too large to be practicably manufactured and assembled.

Theoretically, a ring-fluid-ring container can be designed to a maximum pressure capability of $p_{max} \approx 1,000,000$ psi. It would have a multiring inner unit. However, the external-size requirements make such a design impracticable as was the case for the ring-fluid-segment container.

Conclusions and Recommendations

Bore pressures of 450,000 psi corresponding to 10^6 cycles life are found to be theoretically possible in hydrostatic-extrusion containers using the fluid-supported multiring concept. Container designs with 6-inch-diameter bores appear to be practicable to construct. However, outside-diameter requirements of 15-inch-diameter-bore containers appear too large to be practicable at this time.

Theoretical analyses have been based on postulated fatigue behavior of high-strength steels. Experiments to obtain actual fatigue data of high-strength steel cylinders under cyclic pressures up to 450,000 psi is needed before the predictions of theory can be verified. A potential problem in such an experimental fatigue program is foreseen: the fatigue specimens will have to be heavy-walled containers in order to support the high pressures. Therefore, an alternative experimental research program consisting of two steps is recommended:

(1) A preliminary analysis aimed at designing small specimens pressurized and mechanically loaded to simulate the stress condition at the bore of a container, and

(2) Construction and testing of simulated specimens.

XXXI

DESIGN REQUIREMENTS AND LIMITATIONS FOR HIGH-PRESSURE CONTAINERS

As already indicated, the theoretically predicted maximum-pressure capability for the five containers considered in detail in the present study are as follows for 10^4 to 10^5 cycles life:

Container	Maximum Pressure, p, psi
Multiring	300,000
Ring-segment	300,000
Ring-fluid-segment ($p_3/p = 0.3$)	~1,000,000
Pin-segment	210,000
Ring-fluid-ring (multiring inner unit)	~1,000,000

These predictions, based on the fatigue strengths of steels with an ultimate tensile strength of 300,000 psi for the liner and 200,000 psi for the outer cylinders or components, apply to any operating temperature provided these are the strengths at that temperature.

For liners with ultimate tensile strengths much greater than 300,000 psi, the theoretical maximum pressure capability of the various designs may be improved appreciably. This is true if it can be assumed that the higher strength materials would exhibit the same fatigue behavior as that shown in Figure 42 for steels with ultimate tensile strength ranging from 250,000-310,000 psi at room temperature. (Tensile strengths of 410,000 psi have been reported for AISI M50 steel. If the previous assumption is correct, then a multiring or ring-segment container with an M50 liner would have a theoretical maximum pressure capability of 410,000 psi. However, these containers may require that some ductile outer cylinders have ultimate tensile strengths greater than 200,000 psi.)

Possible Manufacturing and Assembling Limitations

It is important to note that the theoretical pressures given in the above tabulation may not be achievable for each design because of practicable design limitations. For example, the outside diameters required for designs having 6- and 15-inch bore diameters and maximum pressures up to 450,000 psi are as follows:

Container	Maximum Pressure, p, psi	Outside Diameter, inches: 6-inch-Bore Design	Outside Diameter, inches: 15-inch-Bore Design
Multiring	300,000	51.0	127.5
Ring-segment	300,000	60.0	150.0
Ring-fluid-segment	450,000	88.0	218.0
Pin-segment	210,000	90.4	180.2
Ring-fluid-ring (Example 2)	450,000	76.0	190.0