A materials study is proposed to determine data on the important properties of high-strength materials for high-pressure-container applications.

Based on the design study of the four containers listed above, the ring-fluid-ring design was suggested. This design makes use of the benefits of fluid-support pressure and prestress from shrink fit. It avoids the difficulties associated with the segmented containers. It is shown in this analysis that a ring-fluid-ring container having a bore of 6-inch diameter could withstand a pressure level of 450,000 psi with an outer unit diameter of 60 inches. The fatigue life of this container would be 10^4-10^5 cycles.

Additional details of analysis are included in the appendices of this report. Bending deformations and stresses within segments, and derivations of shrink-fit interferences are some of the items included. Computer programs used for calculations are also briefly described.

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SCOPE OF ANALYSIS

The purpose of this study was to determine the maximum pressure capability of several designs of vessels for containing fluids at the pressures encountered in hydrostatic extrusion and other hydrostatic-forming processes. Containment of bore-fluid pressures up to 450,000 psi at room temperature and at temperatures of 500 F and 1000 F is considered.

The operating cycle of these high-pressure containers consists of application of the pressure needed for extrusion or forming, followed by a decrease in the pressure to zero. To be useful in production, the high-pressure containers must withstand a large number of such operating cycles. Therefore, fatigue strength of component materials must be an important design consideration. However, consideration of fatigue strength appears to be lacking in design analyses heretofore. The general method of design analysis has been to use a safety factor on the yield pressure. As the design pressures have been steadily increased, material limitations have necessitated lower factors of safety, sometimes less than 1:1. Consequently, fatigue failures are being experienced. Because of the extreme operating pressures being considered for hydrostatic extrusion and other forming operations (up to about 450,000 psi), it was essential that the various container-design concepts be analyzed and compared on the basis of a fatigue criterion.

In order to estimate the pressure capability of each container, stress analyses are conducted. Only stresses due to the bore pressure and shrink-fit assembly are analyzed; no thermal gradients are assumed present. However, the effect of temperature change (from operating temperature to room temperature) upon the prestress (residual stresses) is included in the analyses. Excessive residual stresses may result because of differences in thermal expansion of the component parts of each container.

Four types of pressure vessel designs were analyzed in detail. These are:

(1) Multiring container
(2) Ring-segment container
(3) Ring-fluid-segment container
(4) Pin-segment container.

The four concepts for cylindrical containers are shown in Figure 39. A wire-wrapped (strip-wound) vessel and a controlled fluid-fill, cylindrical-layered container also were considered, but only briefly.

As a result of these analyses, a further refinement of the ring-fluid-segment container was conceived in which the segments were replaced by a shrink-ring assembly as shown in Figure 40. An extended analysis of this advanced container design has been completed recently and is described for the first time in this report. A rigorous analysis of the advanced concept together with a more general formulation of fatigue criteria for multiring containers are reported separately at the end of this section.