The limitations in some of the designs due to large-diameter outer cylinders may also be partially overcome by using the autofrettage process to provide some additional prestress at the liner bore. The process introduces compressive prestresses by plastic deformation of the bore. This approach could reduce the size and number of outer rings that otherwise would be needed to achieve the total prestress by shrink fitting alone. In fact, the autofrettage process could be used to improve the size efficiency of all the design concepts considered. However, if autofrettaging is employed, then high-strength steels with appreciable amounts of ductility should be selected for the liner because the process requires plastic deformation of the bore.

In addition to the potential problem of cylinder size, the theoretical pressures may not be possible to achieve because excessive interferences may be required for shrink-fit assembly. The maximum interferences required for the designs with the above theoretical pressures are as follows:

Container	Maximum Interference Required, inch/inch
Multi-ring	$\Delta_1/r_1 = 0.0036$
Ring-segment ($k_2 = 1.1$, $\frac{E_2}{E_1} = 3.0$)	$\Delta_{12}/r_1 = 0.0028$
Ring-fluid-segment ($k_2 = 2.0$)	$\Delta_{12}/r_1 = 0.0164$
Pin-segment	None, except for a small amount to take up slack during assembly

For the multi-ring container, the interference required between the liner and cylinder 2 as manufactured is $\Delta_1/r_1 = 0.0036$ in./in. This is a reasonable value and corresponds to a temperature difference of 400 to 500 F for assembly. However, the interference as manufactured is not always the same as the interference as assembled. Suppose that the multi-ring container is assembled ring by ring from the inside out. Each ring expands as it is shrunk on and the assembly interference progressively increases beyond the manufactured interference. Formulas for the assembly interference can also be derived. Derivations are given in Appendix B.

The interference required for the ring-fluid-segment container is $\Delta_{12}/r_1 = 0.0164$ in./in. This interference requirement is severe, if not impossible, especially when one considers assembling not only the liner and cylinder 3, but also a number of segments all at the same time. (Δ_{12} is the interference required between the liner, segments, and cylinder 3. Δ_{12} is also the assembly interference as well as the manufactured interference since the liner, cylinder 3, and the segments must be assembled simultaneously.) The large magnitude for Δ_{12} is primarily due to large radial elastic deformation of the segments under pressure. This is shown as follows: from Equation (22a) it is found that

$$\frac{E_2\,(u_1-u_2)}{r_1 p_1} = 0.69 \text{ for } k_2 = 2 \text{ and } p_2 = p_1/k_2 \quad ,$$

where u_1 and u_2 are the radial displacements of the segment and r_1 and r_2, respectively. From a computer calculation for the ring-fluid-segment container p_1 at pressure ($\sigma_r = -p_1$ at r_1), is found to be $p_1/\sigma_1 = 2.2$. Thus,

$$\frac{E_2 (u_1 - u_2)}{r_1 \sigma_1} = 2.2\ (0.69) = 1.518$$

Hence, $\frac{u_1 - u_2}{r_1} = 0.0152$ in./in.

for $\sigma_1 = 300,000$ psi and $E_2 = 30 \times 10^6$ psi, and it is evident that large interference, $\Delta_{12} = 0.0164$ in./in., is required to overcome large deformation of the segments under pressure. This is a disadvantage for the containers having segments in their designs.

Another potential disadvantage of these designs is the possible problem of gouging the liner with the corners of the segments if the components are assembled by pressing. A further factor that must be considered in the design of segments is bending deformation. This is discussed in Appendix A.

The severe interference requirements imposed by the segments are reduced if the segment size (k_2) is reduced and if a higher modulus material is used for the segments. These effects are shown above for the ring-segment container which has a lower interference requirement; i.e., $\Delta_{12} = 0.0028$ in./in. However, selection of a high modulus material must be done with care, because tensile stresses do develop in the segments as shown in Appendix A and many high modulus materials have low tensile strengths.

Thus, it is seen that some theoretical container designs for high pressure may be impossible to fabricate because of the large outside diameters and interferences required. In order to obtain a more realistic evaluation of the various design concepts, predictions of pressure capability are made for more practicable design requirements, i.e., outside diameters limited to 72 inches and the interferences limited to 0.007 in./in. maximum. These predictions are as follows for 10^4-10^5 cycles life:

Container		Bore Diameter, inches	Outside Diameter, inches	Number of Components, N	Maximum Pressure, p, psi
Multi-ring	($k_1 = 2.0$)	6	51.0	5	300,000
	($k_1 = 1.5$)	15	72.0	7	275,000
Ring-segment	($k_1 = 2.0$)	6	60.0	6	290,000
($k_2 = 1.1$, $E_2/E_1 = 3.0$)	($k_1 = 1.5$)	15	72.0	8	265,000
Ring-fluid-segment	($p_3/p = 0.3$)	6	72.0	10	286,000
($k_1 = 1.5$, $k_2 = 2.0$, $k_3 = 1.25$)	($p_3/p = 0.2$)	15	72.0	5	118,000
Pin-segment		6	72.0	3	195,000
($k_1 = 1.3$, $k_2 = 2.0$)		15	(a)	--	--

(a) OD $\leq$ 72.0 not possible for 10^4-10^5 cycles life and $\alpha_r = \alpha_m = 0.35$ if no prestress is provided.

It is evident that lower maximum pressures are now predicted, particularly for the 15-inch bore designs. The reduction in pressure capability is due only to the restriction in outside diameter for the multi-ring, ring-segment, and pin-segment containers. However, both the outside diameter and interference limitations reduce the predicted pressure for the ring-fluid segment container. The reduction for this container is severe and is caused by three effects. The first is excessive deformation of the segments for