The fact that the elastic modulus of the liner, sleeve, and container materials would be less at 500 F than at 80 F, lower estimates of interfacial pressures and prestresses were obtained.

The combined effect of the liner-sleeve and sleeve-container shrink fits caused a hoop prestress of -200,000 psi, at 80 F, on the liner bore. Figure 68 shows that, for this amount of precompression, an internal pressure of 250,000 psi produces a tensile hoop stress on the bore of only 55,900 psi. As shown in Figure 69, a similar internal pressure at 500 F would produce a tensile hoop stress of 89,250 psi at the bore.

In spite of these relatively low hoop stresses, obtained by using the heavy shrink fits, the effective stresses at the bore are extremely severe. For example, the effective shear stress at 500 F, where $\sigma_1 = +89,250$ psi and $\sigma_3 = -250,000$ psi, is approximately 175,500 psi. This means that the uniaxial yield strength of the liner material at 500 F would have to be about 304,000 psi to avoid yielding. Obviously, this is a difficult requirement for most liner materials to meet.

The types of steel ordinarily used for hot-working tools do not have sufficient strength for the application. Some of the high-speed-type tool steels which will develop adequate strength levels are lacking in ductility. Although tungsten carbide has an extremely high compressive strength, the cost of such a large component would be prohibitive.

The compositions of the steels selected for the three parts of the container assembly are given in Table LI. The steel selected for the liner appeared to have the most suitable combination of strength and ductility of materials available in suitable sections. It was less expensive than some of the other materials considered such as tungsten carbide. Both the liner and sleeve were made from steel produced by consumable-electrode vacuum-melting practices. It was expected that this melting process would minimize alloy segregation and inclusion contents. The heat treatments given the components, and the resulting hardnesses, are also given in Table LI.

The components were subjected to ultrasonic inspection at different stages of manufacture. One forging intended for the container ring was scrapped in the rough-machined condition on the basis of the inspection.

The mating surfaces of the components were finished to a surface roughness of 65 μ-in., rms. The inside surface of the liner was ground to a surface finish of 4 μ-in., rms. The smoother surface minimizes the possibility of fluid leaking past the seals at high pressures.

Operational Capabilities Predicted by Theory

Despite the high stresses on the liner and sleeve, stress analyses indicated that the container assembly would meet or closely approach the operational requirements. Table LII presents the results of the stress analyses of greatest interest. The safety factors listed were based on reasonable estimates of the tensile yield strengths and the effective stresses computed by the Hencky-Von Mises relationship. They indicated the container assembly was capable of operating at an internal pressure up to 250,000 psi at room temperature and up to 230,000 psi at 500 F.

TABLE LI. COMPOSITIONS, HEAT TREATMENTS, AND HARDNESSES OF THE COMPONENTS USED FOR CONTAINER I

	Liner AISI M50	Sleeve AISI H11	Container AISI 4340
Composition, percent			
Carbon	0.80	0.41	0.35
Chromium	3.96	5.10	0.97
Molybdenum	4.05	1.23	0.41
Vanadium	1.10	0.50	0.11
Nickel	0.06	--	2.49
Manganese	0.23	0.27	0.70
Silicon	0.20	0.94	0.28
Phosphorus	0.01	0.002	0.012
Sulfur	0.007	0.003	0.011
Cobalt	0.02	--	--
Copper	0.06	--	--
Tungsten	0.03	--	--
Heat Treatment			
Preheat	1500 F for 1-1/2 hours		
Austenitize	2000 F for 1/4 hour	1850 F for 1-1/2 hours	1570 F for 6 hours
Quench	1050 F for 5 min. in salt bath, air cool	Air cool	Oil bath
Temper	1000 F for 6 hours 1000 F for 6 hours	1000 F for 4 hours 1025 F for 4 hours 1025 F for 4 hours	900 F for 12 hours
Hardness			
Rockwell "C"	63	57/58	43