Component Ring Materials

Consumable-electrode vacuum-melted AISI-M50 tool steel was selected for the liner and Sleeve 1 rings. This tool steel, which had been used in the original liner, was selected over other candidate steels (such as AISI-M1 or M10) because it possessed the most suitable combination of strength and ductility. Each component was hardened to R_C 61 to 63.

Sleeve 2 and the container ring were made of AISI-H11 (R_C 57) and 4340 (R_C 43) steels, respectively.

Operational Capabilities

Safety factors were calculated for internal fluid pressures of 250,000 and 230,000 psi at both room temperature and 500 F. They were also calculated for a fluid pressure of 220,000 psi at 500 F. The results of the calculations are given in Table LIII. It can be seen that the safety factors for the liner and Sleeve 1 are 1.29 and 1.30, respectively, for operation at fluid pressures of 250,000 psi at room temperature. At 500 F, the safety factors fall below the minimum of 1.25. Thus, the fluid pressure must be reduced for 500 F operation to minimize the possibility of low-cycle fatigue. At 230,000 psi, the safety factor for Sleeve 1 is 1.37 but only 1.18 for the liner. In view of this, it is recommended that fluid pressures at 500 F do not exceed about 220,000 psi. At this pressure level, the safety factors are 1.27 for the liner and 1.33 for Sleeve 1.

TABLE LIII. SAFETY FACTORS ESTIMATED FOR LINER, SLEEVE 1 AND SLEEVE 2 OF CONTAINER II FOR VARIOUS OPERATING CONDITIONS

Component	Type of Steel	Tensile Temperature, F	Tensile Yield Strength, psi	Shear Yield Strength[a], psi	Internal Pressure, psi	Effective Stress on Component[b], psi	Safety Factor[c]
Liner	AISI-M50	80	330,000	190,000	250,000	146,250	1.29
(ID)		500	290,000	167,000	250,000	160,500	1.04
		80	330,000	190,000	230,000	137,000	1.48
		500	290,000	167,000	230,000	141,500	1.18
		500	290,000	167,000	220,000	132,250	1.27
Sleeve 1	AISI-M50	80	330,000	190,000	250,000	145,500	1.30
(ID)		500	290,000	167,000	250,000	134,500	1.24
		80	330,000	196,000	230,000	135,000	1.49
		500	290,000	167,000	230,000	128,000	1.31
		500	290,000	167,000	220,000	130,000	1.29
Sleeve 2	AISI-H11	80	240,000	138,500	250,000	95,000	1.46
(ID)		500	215,000	124,000	250,000	83,500	1.48
		500	215,000	124,000	230,000	81,500	1.52

(a) Estimated as being 0.577 of tensile yield strength.

(b) Stress computed by Hencky-Von Mises relationship.

(c) Based on ratio of shear yield strength to effective stress.

It should be noted that the stress analysis of the revised container assembly does not include any supporting contribution from the container component. This assumption was used because it is not known whether the original interference-fit of 0.0025 inch per inch between the container and Sleeve 2 could be maintained while removing and replacing the failed liner. Therefore, the stress analysis assumed that only a metal-to-metal fit existed at this interface and that the container ring was not a load-bearing component. However, if any interference-fit did exist and the container ring did bear a portion of the load, the safety factors of the revised container assembly would be slightly higher than those shown in Table LIII.

Container III

As a result of the liner fatigue failure in Container I, it was considered desirable to have a standby container which would ensure continuity in hydrostatic-extrusion research if further failures occurred. At the same time, construction of such a container presented a unique opportunity to use the up-to-date stress analysis and design for a four-ring unit based on a fatigue-life criterion.

The Design of Container III

It was decided to construct Container III with materials whose fatigue properties were known. On the basis of the data given in Tables XLI, XLII and XLIII, AISI H11 tool steel was considered to be a good candidate material. Calculations showed that a fatigue life of 10^5 - 10^6 cycles could be achieved with AISI H11 within the 250,000 psi pressure limit.

A four-ring container, similar in dimensions to those of Container II, Figure 67, was chosen for analysis. The liner was considered to be of high-strength steel surrounded by lower strength, ductile outer rings. The analysis of residual stresses (prestresses) and the required shrink-fit interferences were programmed for calculation of the Battelle computer. The computer codes developed at Battelle for this container design were:

PROGRAM COMPHS1 - Calculation of maximum pressure-to-strength ratio for container having an ultrahigh-strength liner.

PROGRAM COMPHS2 - Calculation of operating stresses, prestresses at operating temperature, and interferences required for shrink fit assembly.

The hoop and radial components of the design prestresses and operating stresses at room temperature are plotted at their various locations in the assembly in Figure 76. The combined effect of the multiple shrink fits was to cause a compressive hoop stress of 256,000 psi on liner bore. Under an internal fluid pressure of 250,000 psi the figure shows that the design tensile hoop stress produced on the bore is zero.

The high interface and hoop stresses, bore pressures of both zero and 250,000 psi, were considered to be out of the realm of the capabilities of an alloy such as AISI 4340, which was used previously as an outer ring material. Consequently, AISI H11 tool steel in a softer condition than the liner, was chosen for the outer rings. The composition, heat treatment and hardnesses of the H11 steel produced by consumable-