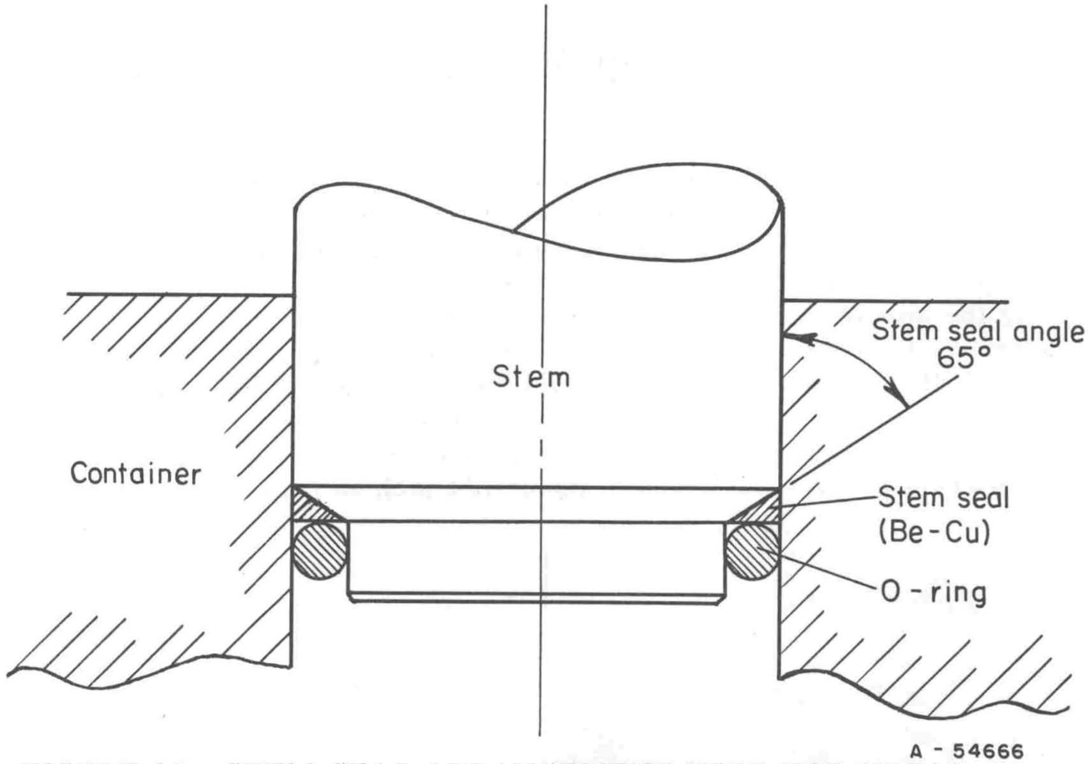

FIGURE 10. STEM-SEAL ARRANGEMENT USED FOR WARM HYDROSTATIC EXTRUSION

In the several trials conducted successfully with a single PTFE O-ring, it was noted that the stem pressure/fluid pressure differences were the lowest of the three combinations. Thus, an increase in stem-seal/container friction occurs with a dual O-ring system. In a single trial, the die seal arrangement shown in Figure 9b was evaluated using a PTFE O-ring. The O-ring expanded on the hot die before the container could be lowered in place, thus preventing sealing. Other O-ring materials however, might be readily used for this application.

Die Design

The die entry-orifice design mainly used in the program was basically as shown in Figure 9. The conical entry was highly polished (in the order of 4 μ-inches, CLA) and was, for most trials, maintained at an included angle of 45 degrees. Other die angles were investigated with 7075-0 aluminum and AISI 4340 steel but, at the extrusion ratios achieved and with the lubricants used, were found to require higher extrusion pressures than those required for the 45-degree design. Data for these trials are given in Section 1.

The standard die material was AISI M50 steel heat treated to R_C 63. In several trials with two dies, the die entry and bearing surfaces were "Flame-Plated"* with a 0.005-inch-thick coat of tungsten carbide containing 15-17 percent cobalt. The base material of the die was AISI M50 heat treated to a hardness of 55 R_C. The purpose of Flame-Plating was to provide a hard (R_C 72), wear-resistant surface which reportedly reduces friction in some applications. Results with these dies reported in Section 1

* Flame-Plate is a proprietary process of the Union Carbide Corporation.

show that the dies had no significant effect on extrusion pressures. Thus, the Flame-Plated die did not appear to reduce friction, but it may be useful for minimizing die wear in a commercial operation.

A further effort was directed toward reducing extrusion pressures by considering the configuration of the entry surface apart from the entry angle itself. The concept that was investigated was the idea of a grooved entry surface. The thought here was that the groove would be occupied by the hydrostatic fluid during extrusion, thereby reducing the amount of billet-die contact area. In this case, the die was "roughened" with a groove to function in a manner similar to a roughened billet which drags fluid in at the die-billet interface. The grooved die evaluated in the program is shown in Figure 11. The groove is about 0.050 inch deep and has a 1/4-inch pitch. The peaks between the grooves are rounded to a 1/8-inch radius. The groove does not intersect the die bearing surface but stops at about 1/4 inch above it.

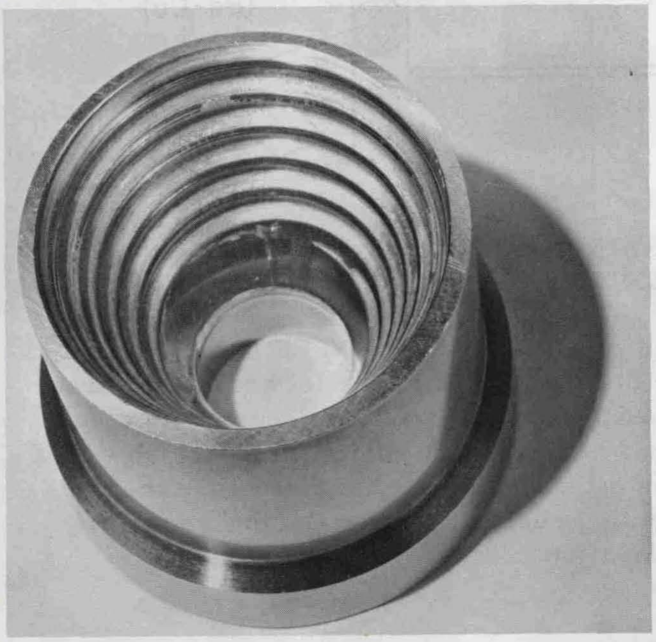

FIGURE 11. DIE DESIGN WITH HELICAL GROOVE IN CONICAL-ENTRY SURFACE

In experiments with the grooved die during extrusion of both AISI 4340 and 7075-0 Al (Trials 284 and 348), the billets were found to have upset into the groove only partially with the steel but completely in the case of the aluminum alloy. This only hindered the extrusion operation because, on continuing extrusion, the billet metal in the grooves tended to shear off rather than flow. This problem might not have occurred if the grooves were much more shallow. At this time, however, it appears that improved lubrication systems and roughening the billet are more effective means of reducing pressures.

On the basis of the results obtained, a die-entry profile of a 45-degree included angle was used as standard for most of the trials with the aim of giving minimum pressure values for all materials. For brittle materials, die design played an important part in obtaining sound products. The evolution of these successful die designs is reported in Section 1. Die design for the extrusion of shapes is described in Section 2.