In a single attempt to reduce the 1-3/4-inch-diameter billet to a 1/8-inch-thick T-section at a ratio of 14.3:1 and a stem speed of 6 ipm (Trial 459), breakthrough was not achieved. This was probably due at least in part to lubricant breakdown. As with solid rounds, it is apparent that a limit in extrusion ratio set by the efficiency of the lubrication system exists, and this limit can be extended by further development of improved lubrication systems. Considering only pressure requirements, it is felt that much higher ratios than 7.3:1 are possible within the 250,000 psi pressure capacity of the tooling, provided adequate lubrication can be achieved.

Die Design

The data in Table XXX permit a comparison between the single-angle die and the single-piece compound-angle die (Trials 321 through 383). Without exception, breakthrough pressures for the compound-angle die were in the order of 10 percent lower than those for the single-angle design. The runout pressure requirements, however, were about the same for each die. The reductions in breakthrough pressure were particularly significant since the compound-angle design is less expensive to make and presents fewer machining problems than the single-angle design.

Stem Speed and Billet Surface Finish

In the study of stem speed, it was found that, with both single and compound-angle die designs, a stem speed of 80 ipm eliminated the stick-slip during runout experienced at the lower speeds. Further, the results in Table XXX, coupled with previous observations made with solid round extrusions, suggest that the range of billet-surface finishes evaluated had no appreciable effect on pressure requirements.

Billet Lubrication

Most of the trials were conducted with billet Lubricant L17. However, Trial 488 permitted a comparison of the effects of Lubricant L53 with L17 in the extrusion of a T-section from a round billet. It is believed that the slightly lower breakthrough pressure levels obtained with L53 were due more to improved billet lubrication than to differences in billet finish. The amplitude of stick-slip was reduced markedly with L53.

Extrusion of Re-entrant Channel Section

An attempt to produce the re-entrant channel section shown in Figure 32 from a 1.25-inch-diameter round billet was made in Trial 538. The extrusion ratio attempted was 7.5:1. At a fluid pressure of 40,000 psi, the die insert and support cracked across its weakest section and fluid leaked. It is apparent that this design requires greater support beyond the die than was found adequate for T-section dies.

Re-extrusion of 7075-0 Al T-Sections

T-sections having 1/4-inch-thick legs which were previously made by hydrostatic extrusion from round billets, were successfully re-extruded to T-sections having

1/8-inch- and 1/16-inch-thick legs. These reductions represented extrusion ratios of 2:1 and 4:1 respectively. Details of the trials are given in Table XXX and of the re-extrusion die-designs in Figure 33.

The techniques for preparing the billet nose for re-extrusion were explained in the introduction to this section. Several experiments with sealing compounds resulted in fluid leaks but in two cases, Trials 489 and 507, Wood's alloy permitted sealing and extrusions were obtained. In both trials, stick-slip occurred at breakthrough and on run-out. This was due to the Wood's alloy which, when cast round the billet in situ, melted the billet lubricant.

The breakthrough pressures for the re-extrusion of T-sections were about 10 percent higher than for the extrusion of solid rounds, but this is attributed to lubricant breakdown rather than to a so-called "shape factor". It is of interest, in fact, that the runout pressure obtained in Trial 489 was actually about 17 percent lower than that for solid rounds.

Further experiments in the reduction of 1/4-inch-thick 7075-0 aluminum T-sections using the HYDRAW technique are described later in this section.

AISI 4340 Steel T-Sections

Table XXXI gives data for several trials aimed at producing 1/4-inch-thick T-sections from round billets. In the previous program(1), steel T-sections were produced at an extrusion ratio of 2.5:1 using the single-angle die. In this program, two trials (Nos. 316 and 387) with the single-angle die and two (Nos. 341 and 347) with the single-piece compound-angle die were conducted at an extrusion ratio of 3:1. In both trials with the single-angle die, the die cracked at high pressures, but in Trial 316 breakthrough was not achieved, the pressure required apparently being beyond the capacity of the tooling. In a single trial at a ratio of 2.5:1 (Trial 497), the compound-angle die cracked and leaked fluid at a relatively low pressure before breakthrough was achieved. For this to have occurred at such a low pressure, the die crack may have been initiated in a previous trial but it was not detected.

The data given in Table XXXI for Trial 147, conducted in the previous program(1), indicates that breakthrough pressure for the 2.5:1 ratio and a stem speed of 1 ipm was 214,000 psi. In Trial 316 where the extrusion ratio was 3:1, the breakthrough pressure was 210,000 psi. It is believed that the lower breakthrough pressure obtained at the higher ratio was partially due to the higher stem speed of 6 ipm. However, in both trials stick-slip occurred, and it was particularly severe at the higher ratio. In view of the breakthrough pressure reductions achieved by the compound-angle design with 7075-0 aluminum, a ratio of 3:1 was attempted in two trials with this design (Nos. 341 and 342). However, the pressure requirements again were too high. In view of these results, it may be that Coating C1 (zinc phosphate) applied in Trial 147 to the billet prior to lubrication but not applied in the other trials was an important factor in the successful T-section extrusion. This coating with L17 proved to be marginally more efficient than other systems in the hydrostatic extrusion of AISI 4340 solid rounds, reported in Section 1. It may be that, due to the particular severity of deformation in extruding from a round to a T-section, a coating such as C1 is necessary to provide adequate lubrication. More work would be required to settle this point.