It is seen that no significant pressure differences were obtained under any of the above conditions. However, runout extrusion pressures and extrusion surface quality were generally better with either water or castor oil as the fluid medium than with polyethylene glycol. In addition, polyethylene glycol in combination with either L22 or L23 lubricant gave somewhat higher extrusion pressures than did castor oil at an extrusion ratio of 5:1.

A significant aspect of these results is the finding that water performs quite well as a fluid medium at the pressures reached thus far (185,000 psi). Water would certainly be advantageous in a commercial production operation from the standpoint of cost and handling.

Die Angle

Included die angles of 30, 45, 60, and 90 degrees were investigated at an extrusion ratio of 5:1 and a stem speed of 20 ipm with L17 lubricant, and castor oil for the hydrostatic fluid. The extrusion pressures were highest for die angles of 30 and 90 degrees. For a die angle of 60 degrees, the extrusion runout pressure was slightly higher (about 5 per cent) than that obtained for the 45-degree die. Based on available results, it is concluded that an included die angle of 45 degrees approaches the optimum under these extrusion conditions.

Billet Surface Finish

The effect of billet surface finish on extrusion pressure and surface quality was investigated for AISI 4340 at ratios of 4 and 5:1. A comparison was made between standard machined surface finishes (about 60 to 100 microinches, rms) and relatively rough surfaces obtained by grit blasting followed by vapor blasting. The latter step was used to remove superficial grit, and any sharp points and edges caused by the grit. Stem speeds of 20 and 80 ipm were used. Castor oil or water were used as the fluid media and L17 as the billet lubricant.

The extrusion pressures and extruded surface finishes (by visual examination) were found to be about the same for either the machined or grit billet finish. This is an indication that the billet lubricant used was quite effective by itself, and that a rough billet surface finish in this case does not cause any significant pressure reduction.

COLD HYDROSTATIC EXTRUSION OF 7075-0 ALUMINUM ROUNDS

Among the critical process variables investigated thus far with 7075 Al are:

(1) Extrusion ratio
(2) Stem speed
(3) Lubrication
(4) Billet surface finish

The experimental data are given in Table 3. With this material, the effects of these variables are particularly important because of the tendency of the alloy to stick-slip during extrusion. The stick-slip problem stems from momentary breakdown of the billet lubricant. In these extrusion trials, castor oil was used as the fluid, and the billets were lubricated with either L11 or L17.

In spite of the problem of stick-slip, good extrusions at ratios of 20:1, 40:1, and 60:1 were produced at room temperature. Lubricant L17 was found to be very effective in minimizing the tendency toward surface cracking compared to L11. Moreover, of particular significance is the fact that surface cracking was eliminated (based on preliminary inspection) in the 20:1 ratio extrusions by increasing the stem speed from 20 to 80 ipm. Elimination of surface cracks is believed to be associated with the fact that the stem speed of 80 ipm eliminated stick-slip during runout. Cracking tends to occur in the portions of the rod that are suddenly extruded during the "slip" part of stick-slip. These portions are extruded at extremely rapid rates, perhaps in the order of several thousand inches per minute. Exit surface temperatures may become excessive under these conditions and lead to cracking.

This aluminum alloy is known for its tendency to crack during conventional hot extrusion. To prevent cracking, the exit extrusion speeds are kept very low, sometimes as low as 6 to 12 ipm. It has been shown thus far that, with hydrostatic extrusion, sound extrusions can be produced at exit speeds of about 3000 ipm. (This was calculated based on a ratio of 20:1, and a billet speed of 148 ipm produced at the stem speed of 80 ipm.) Obviously, this would be a very significant potential advantage in a production operation.

At ratios of 40:1 and 60:1, the maximum stem speed attempted thus far was 20 ipm. Stick-slip still occurred under these conditions. The effect of extrusion ratio on hydrostatic extrusion pressure is shown in Figure 3. Plots are shown for both breakthrough and runout pressures. The runout pressures are based on the pressure minimums reached after breakthrough. Past experience has shown that such minimums are, in fact, the runout pressures when stick-slip is eliminated. Figure 3 shows the breakthrough pressures to be considerably higher than the runout pressures. An improvement in lubrication to prevent stick-slip would greatly reduce the extrusion pressure requirements, although the fluid breakthrough pressure for extrusion at a ratio of 60:1 with the present lubricant is only 200,000 psi, still substantially below the maximum pressure capability of the present tooling. Extrusion ratios in the order of 100:1 appear to be feasible at present, but even much larger ratios should be possible with better billet lubricants.

A study was made of the effect of billet surface finish on stick-slip and cracking. Machined surfaces varying in roughness from 50 to 500 microinches, rms were investigated in addition to finishes produced by grit blasting followed by vapor blasting. Although the results thus far may not be conclusive, definite trends are evident.

At an extrusion ratio of 20:1, surface finishes in the order of 50 microinches, rms, resulted in the highest stick-slip pressure peaks (beyond the breakthrough pressure point) regardless whether Lubricant L11 (Trial 251) or L17 (Trial 308) was used. Increasing the surface roughness to 300-500 microinch range lowered these stick-slip pressure peaks, but generally did not succeed in preventing them, except in one case (Trial 249). A macroscopic examination of the extrusion butt of Trial 249 is being made to determine whether any special surface finish characteristics may have helped to prevent stick-slip in this case.