TABLE 1. BILLET LUBRICANTS USED FOR HYDROSTATIC EXTRUSION DURING THIS REPORT PERIOD

Lubricant	Source	Description	Billet Material Traced
L17	Battelle	20 wt% MoS_2 in castor wax	Ti-6Al-4V
L33	Battelle	55 wt% MoS_2 and 6 wt% graphite in sodium silicate	Ti-6Al-4V (400 F trial)
L38	Commercial	PTFE	Be, TZM, Alloy 718, A286
L52	Commercial	Stearyl stearate	7075-0 Al
L53	Commercial and Battelle	20 wt% MoS_2 in stearyl stearate	7075-Al, dispersion-hardened Al

Castor oil was the fluid medium for all the room-temperature trials. In the elevated-temperature trials, silicate ester (SE) was used at 400 F and polyphenyl ether (PPE) at 500 F.

The effectiveness of lubrication systems is judged by their effect on the fluid pressure vs. displacement curve and the extruded-product finish. Figure 1 shows the classifications of the types of curves generally obtained and which were described in detail in Interim Report VIII[6]. For easy reference Figure 1 is placed on a fold-out page at the end of the text.

COLD HYDROSTATIC EXTRUSION OF 7075-0 AND DISPERSION-HARDENED SINTERED ALUMINUM

The experimental data obtained in the hydrostatic extrusion of 7075-0 Al and a dispersion-hardened sintered-aluminum alloy are contained in Table 2.

7075-0 Aluminum Rounds

The compound billet nose, which was described in Interim Report VIII[6], was used at extrusion ratios of 40, 60, and 200:1. This nose design consists of a dual-angle cone having an apex angle of 45 degrees up to a predetermined diameter, A, followed by a reduced angle of 30 degrees. (The standard billet nose is a single-angle cone of 45 degrees.) Above ratios of 20:1 with 7075-0 aluminum the compound angle nose was found to be necessary to aid in achieving thick-film lubrication on breakthrough and thereby prevent stick-slip[6]. Stick-slip always occurred at ratios of 40:1 and above when the standard nose was used.

Lubricant 52 (stearyl stearate) was evaluated at a ratio of 40:1 using the compound billet nose. The aim of this trial (473) was to determine how effective the 20 wt % MoS_2 additive to stearyl stearate (L53) had been in a previously reported trial (Trial 470 in Table 2). A comparison of the results indicates that while the overall pressure levels were a little higher for the plain stearyl stearate, the smooth runout pressures indicated good lubrication and the surface finish of the product was excellent.

The compound billet nose and L52 also provided smooth runout conditions at a ratio of 60:1 (Trial 474), and stem speed of 20 ipm, conditions which have always resulted in stick-slip when the standard nose was used. Here again the product surface finish was excellent and was crack free.

An attempt was made to extrude 7075-0 Al at a ratio of 200:1 (Trial 504). The stem speed was 6 ipm and the billet lubricant was L53. In addition, a compound nose was used on the billet. Seizing between billet and die took place at a fluid pressure of 184,000 psi, when the extruded material leaving the die represented an extrusion ratio of 22:1. At this point, however, the extrusion ratio being attempted at the die entry cone was 150:1 (as measured on the unextruded part of the compound angle nose). The breakdown of lubrication at the billet-die interface which apparently occurred will be investigated further in future trials at these high ratios.

A single trial (Trial 472) was conducted to evaluate the effect of stopping and restarting on pressure requirements during extrusion of a single billet. This was done because, in previous tandem extrusion trials[6], restarting extrusion after stopping to load a tandem billet required unduly high breakthrough pressures and resulted in severe stick-slip, although no P_b peak or stick-slip was encountered initially. It was thought that this might have been partly due to disturbing the first billet in the die while loading the tandem billet. However, Trial 472 shows that, on restarting 10 seconds after stopping, similar high breakthrough pressures and stick-slip were obtained.

This behavior is probably mainly due to lubrication breakdown although the precise mechanism is not clear. One contributing factor may be the temperature increase of the lubrication system (fluid + billet lubricant) developed at the billet-die interface during initial extrusion. Simultaneously, the lubrication system is subjected to the fluid pressure required for extrusion and the viscosity of the system is apparently still sufficient to prevent a high P_b and stick-slip. On depressurization of the fluid, however, the residual temperature at the billet-die interface may still be high enough to effect a sharp viscosity drop and/or an unfavorable chemical change in the lubrication system. Thus, mere repressurization of the fluid may not necessarily renew the same state of lubrication existing during initial extrusion. Other contributing factors may be that:

(1) The change in the surface characteristics of the billet nose may have reduced the contribution of "squeeze" lubrication during re-extrusion.

(2) Sufficient work hardening of the billet nose occurred, in spite of adiabatic heating, that higher pressures were required for re-extrusion.