when the extrusion data are being examined. Each family of curves is designated by a letter, and the number following it classifies the typical runout characteristics within each family.

Curves Types A, B, C, and D represent quality of lubrication in decreasing order of effectiveness. These curve types have been numerically classified further according to the following characteristics during runout:

No.	General Runout Characteristics
1	Constant
2	Decreasing
3	Increasing
4	Special

Type A Curves. One of the aims of the experiments in lubrication systems in the current program is to obtain conditions giving a curve of Type A 1 which represents completely effective lubrication throughout the extrusion stroke. Experience has shown that once this type of curve is achieved, for a given material and extrusion ratio other lubrication systems may not lower the value of P_r (runout pressure) markedly and therefore the curve very likely represents near-optimum lubrication conditions. There is no breakthrough pressure (P_b) peak above the runout pressure which suggests that the static friction, μ_s, is about the same as the kinetic friction coefficient, μ_k, developed once the billet starts to move.

The runout characteristics in the other Type A curves may represent partial lubrication breakdown due to pressure-temperature effects at the billet-die interface or changes in flow strength due to adiabatic heating of the billet.

Type B Curves. All the curves in this category are generally characterized by a rounded breakthrough pressure peak (P_b) followed by a smooth runout curve at a lower pressure (P_r). The occurrence of a rounded pressure peak has been attributed to the fact that μ_s is somewhat higher than μ_k(1), but not sufficiently to cause a sharp stick-slip peak. In some cases, the breakthrough pressure peak is sharp, indicating a stick-slip situation at breakthrough only.

Type C Curves. These curves are similar to Type B curves except that one or a few cycles of stick-slip follow the breakthrough pressure peak. Here stick-slip is generally not severe, its amplitude decreasing to give a smooth runout curve.

Stick-slip in hydrostatic extrusion is caused by the energy stored in the fluid at P_b being sufficient to overcome μ_s but much more than necessary for μ_k. Consequently extrusion occurs very rapidly and is accompanied by a sharp drop in pressure(1). The μ_s achieved at the P_r level apparently is not sufficiently greater than μ_k to cause stick-slip of the same magnitude to occur again.

Type D Curves. In these curves stick-slip is generally severe and continues throughout the stroke. Extrusion takes place at extremely rapid rates after each pressurizing stroke. The lower pressure level reached after each "slip" tends to occur at the same level during each cycle of stick-slip. Experimental results have indicated that this level represents fairly well the value of P_r if stick-slip had not occurred.

For this reason, the level is designated as "P_r" to indicate that this is the apparent runout pressure. Often the amplitude of stick-slip (P_b-"P_r") is about 30 percent greater than "P_r".

It is of interest to note that, because of the decreasing stick-slip in curve D2, a smooth runout might eventually be obtained if extrusion were continued further. In curve D3, a constant amplitude of stick-slip is superimposed on an increasing "P_r". As a contrast, however, the amplitude of stick-slip has also been observed to increase over an apparently constant "P_r" value as in Curve D4.

COLD HYDROSTATIC EXTRUSION OF 7075-0 ALUMINUM ALLOY ROUNDS AND T-SECTIONS

In the trials with 7075-0 aluminum alloy, the main points of the study were:

(1) Lubricants and fluids
(2) Special billet nose designs
(3) Tandem extrusion
(4) Extrusion and re-extrusion of T-sections
(5) Extrusion at low ratios
(6) Flame-plated dies.

Extrusion data for trials made to produce 7075-0 aluminum rounds are given in Table 2.

Lubricants and Fluids

A significant advance in lubrication systems for 7075-0 aluminum has been achieved during this report period. It was mentioned in the last interim report(6) that stearyl stearate (L52) was to be modified with additions of MoS_2 and graphite. This was because it showed promise as a base lubricant at a 40 : 1 extrusion ratio.

At a ratio of 20 : 1 and a stem speed of 20 ipm, Lubricant 53 (20 wt % MoS_2 in stearyl stearate) produced exceptionally good results (Trial 454). To illustrate the improvements gained, Figure 3 shows the extrusion pressure-displacement curves obtained with L53 and another good lubricant (L38, PTFE lacquer) in comparison with the curve obtained in Trial 347 with the previous "best" lubricant, L17 (20 wt % MoS_2 in castor wax). Also shown is the further improvement gained when castor oil is replaced by silicate ester (Trial 464). It can be seen that L53 reduced the breakthrough pressure obtained with L17 by 12 percent and completely eliminated stick-slip during runout. L38 was almost equally effective.

Furthermore, silicate ester lowered the runout pressures obtained with castor oil by a further 4000 psi. Billet Lubricant 53 was used in both cases.

Under the same extrusion conditions as those in Figure 3 Lubricant 52 (stearyl stearate) did not show any improvement over L17 while L31 (fluorocarbon telomer)