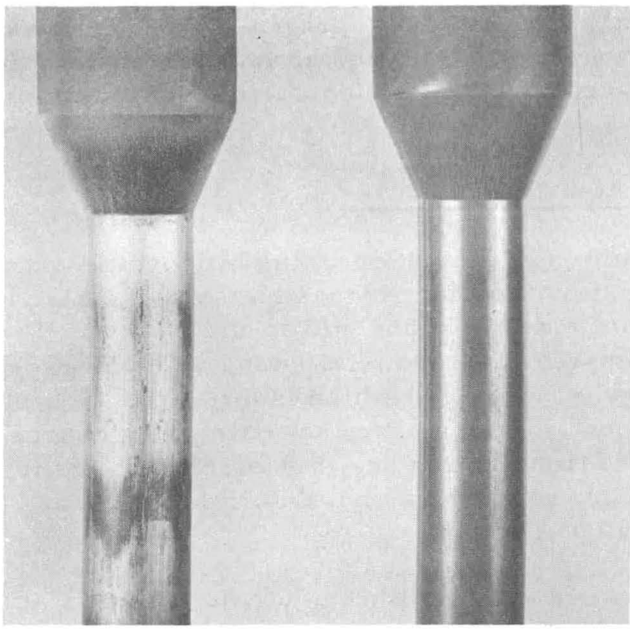

32402

	Trial 375	Trial 368
Lubrication System	(L17 lubricant alone)	(L17 lubricant + C5 anodized coating)
Surface Finish, microinches, rms (transverse)	120-150	20-40

FIGURE 20. COMPARISON OF SURFACE FINISHES ON COLD HYDROSTATIC EXTRUSIONS OF Ti-6Al-4V MADE AT A RATIO OF 3.33:1

Products having good finishes were obtained with both L31 and L38 in conjunction with C5. However, severe lubricant breakdown occurred in both cases during runout resulting in a rapid pressure rise. Lubricants L31 and L33 were evaluated at an extrusion ratio of 4:1 but breakthrough was not achieved in either case. It is worthwhile to point out, however, that L33 was a very effective lubricant in the hydrostatic extrusion of Ti-6Al-4V at 400-500 F even without the C5 coating. This was also true for L38 which, as mentioned above, was not effective at 3.3:1 and at room temperature. Two trials with L31 and C2 coating resulted in smooth runouts after some small initial stick-slip. The surface finish here was badly scored.

In view of the low pressure levels achieved with L31 and L45 on Coating C2, modifications were made to these lubricants in an attempt to improve the surface quality of the product. An addition of 20 wt percent graphite was made to both L31 and L45 which resulted in Lubricants L49 and L50, respectively. With C2 + L49, pressure levels were lowered further by about 6 percent but the surface finish was still poor. With C2 + L50, there was no improvement on the basis of pressure or surface finish, which indicated that the graphite addition to L45 had no apparent effect.

By comparison with coatings C2 and C5, the diffused-nickel-plate coating, C6, which was evaluated with L17 (Trial 367), did not perform satisfactorily. Standard bench tests of the sliding-friction/stick-slip type, however, showed that for commercial-purity titanium, the C6 coating reduced the friction coefficient and minimized stick-slip(14).

Fluids at Room and Elevated Temperatures

The selection of fluids for evaluation in the hydrostatic extrusion of Ti-6Al-4V alloy was guided somewhat by the practices established for AISI 4340. Consequently at 400 and 500 F only silicate ester (SE) and polyphenyl ether (PPE) were evaluated. The fluid used for all the room-temperature trials was, with one exception, castor oil. The exception was a polyphenyl ether (PPE) which in Trial 364 was intended to assist the lubrication of an iodine-containing lubricant by acting as a charge transfer medium to facilitate the formation of titanium iodide, the desired lubricating compound. However, the true effectiveness of this system was not determined because the fluid apparently solidified at about 114,000 psi.

PPE and SE fluids were evaluated in the warm extrusion of Ti-6Al-4V titanium rounds at ratios of 3.3:1 and 4:1 with Lubricant L33. Comparison of the pressure data in Table XX indicates that at 3.3:1 the SE fluid reduces fluid-runout pressures on the order of 7 percent. However, at 4:1 there was no appreciable difference in pressure requirements between the fluids. These are similar to the results obtained with AISI 4340 at ratios of 4:1 and 5:1, respectively. It appears that the SE fluid is more effective than PPE in reducing pressure at the lower pressure levels (about 170,000 psi for the lower ratios) than at the higher levels (about 195,000 psi for the higher ratios). This may be due to some appreciable loss in lubricity resulting from the higher pressures and temperature developed at the billet-die interface during extrusion at the higher ratios.

Billet Lubricants at 400 and 500 F

The results obtained in studies with several billet lubricants at elevated temperatures are given in Table XX. No special billet coatings were applied before lubrication except in Trial 496 where coating C5 was evaluated.

One of the most significant findings was that Lubricant L33 alone (55 wt percent MoS_2 and 6 wt percent graphite in sodium silicate) was effective in completely eliminating stick-slip during both breakthrough and runout at extrusion ratios of 3.3:1 and 4:1 with the SE fluid (Trials 415 and 416) and 3.3:1 with the PPE fluid (Trial 395). Of particular importance is the fact that this was possible without any of the special coatings found essential for hydrostatic extrusion of this alloy at room temperature. The very low breakthrough pressure peaks and excellent surface finishes obtained indicated the complete effectiveness of Lubricant L33. Machining marks carried through from billet to extrusion gave additional evidence of its effectiveness. In Trial 496, the C5 coating was evaluated, together with increasing stem speed and using a compound-nose billet, with the aim of obtaining further improvements. The surface finish obtained was equally as excellent as that in Trial 416. However, the combination of the coating, higher stem speed, and compound-angle nose appeared to have had only a marginal effect on pressure levels.