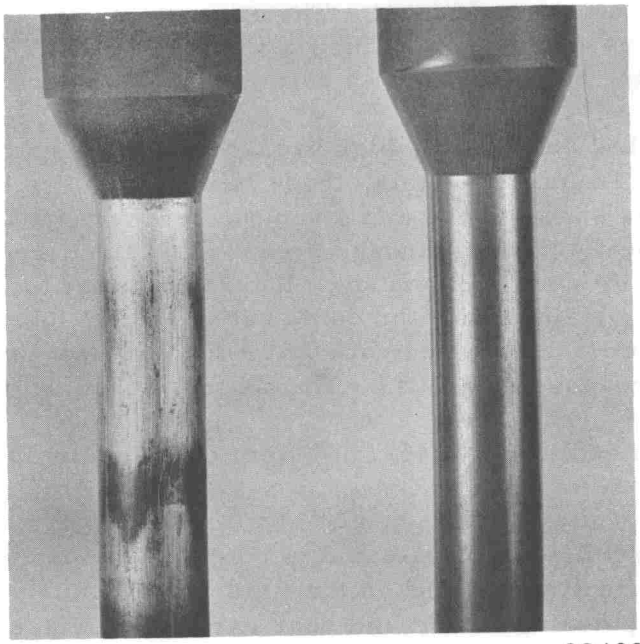

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FIGURE 1. COMPARISON OF SURFACE FINISHES ON COLD HYDROSTATIC EXTRUSIONS OF Ti-6Al-4V MADE AT A RATIO OF 3.33:1

	Trial 375	Trial 368
Lubrication System	(L17 lubricant alone)	(L17 lubricant + C3 anodized coating)
Surface Finish, microinches, rms (transverse)	120 – 150	20 – 40

By comparison, none of the other lubrication systems indicated in Table 4 performed as well as the combination of L17 lubricant and C3 coating. The diffused nickel-plate coating, C4, evaluated in Trial 367 did not perform satisfactorily, although Shapiro and Gisser[6] found this to reduce the friction coefficient and minimize stick-slip for commercial-purity titanium in a sliding friction-stick/slip type of test.

In previous studies[4], the fluoride-phosphate coating, C2, was found to be effective and it was considered worthwhile to evaluate this coating further in conjunction with several promising lubricants listed below:

Lubricant	Description
L31	Fluorocarbon telomer
L45	Low-density polyethylene
L49	20 wt percent graphite in L31
L50	20 wt percent graphite in L45
L34	50 wt percent MoS_2 in castor wax
L35	20 wt percent graphite in castor wax

Two trials were made with L31 lubricant. In one case, moderate stick-slip followed by uniform extrusion occurred during runout. The other trial with L31 gave a uniform runout. Somewhat similar results were obtained with L45 lubricant, although moderate stick-slip occurred during both trials, with uniform runout after the initial stick-slip.

For both L31 and L45 lubricants, high breakthrough pressures occurred at the beginning of extrusion. To minimize this, these lubricants were modified by adding 20 wt percent graphite as shown above and given the new designations L49 and L50. With L49 (Trial 373), the fluid breakthrough pressure was reduced by about 7 percent and the runout pressure by almost 5 percent. It turns out that these pressures are in the same order as those obtained with the combination of L17 lubricant on C3 coating. However, the extruded surface obtained with L49 + C2 was heavily scored whereas an excellent surface was produced using L17 + C3, as mentioned previously.

With L50 (graphite addition to L45), no effect on extrusion pressures was obtained (Trial 370).

The two remaining lubricants evaluated in conjunction with C2 coating (L34 and L35) were relatively ineffective. Although the fluid breakthrough pressure peaks were relatively low, stick-slip during runout and poor extruded surfaces were obtained, indicating lubrication breakdown.

Some of the iodine-containing lubricants evaluated previously(4) showed some promise of reducing stick-slip but were not effective in improving extruded-surface quality or in reducing the wear. The iodine addition was intended to react chemically with the bare billet surface to produce a compound which would offer less frictional resistance than the Ti-6Al-4V alloy itself. It was thought that such lubricants might be improved by adding a solid-film lubricant such as MoS_2 to assist in preventing metal-to-metal contact. In this connection L39 lubricant, which contained 20 wt percent MoS_2 and 20 wt percent iodine in chlorinated terphenyl carrier, was prepared and applied to the as-machined billet surface. In two attempts (Trials 366 and 371), extrusion breakthrough was not achieved although fluid pressures in the order of 240,000 psi were reached.

Another attempt was made with an iodine-containing lubricant, L26, in Trial 364. In this case, the hydrostatic fluid used was a polyphenyl ether which was intended to assist in the lubrication process by acting as a charge-transfer medium to facilitate formation of titanium diiodide, the desired lubricating compound. However, the true effectiveness of this lubrication system was not determined because, at about 114,000 psi, the fluid apparently solidified. The system may be tried again but at elevated temperatures where the fluid would not be as viscous as it was at room temperature.

COLD HYDROSTATIC EXTRUSION OF TUBING

Efforts were continued in the cold hydrostatic extrusion of tubing from both AISI 4340 steel and 7075-0 aluminum. The mandrel tooling arrangement used was similar to that described previously(4) with some modifications. The mandrel taper was increased from 0.001 inch to 0.005 inch over the 8-inch tapered section; also, the lead end of the mandrel was rounded with a 1/8-inch radius. The increase in taper was intended to eliminate the problem of "sticking" which occurred previously during