386(d)	3.2	1.107	0.875	0.749	0.0011	6	L48	125	116	120	112	206	C4	1.5	Nose only extruded
390(d)	3.2	1.107	0.875	0.749	0.0011	20	L48	164	149	146	129	238	C4	5.0	
							Ti-6Al-4V								
437	2.9(e)	0.750	0.663	0.613	0.0012	6	C3-L17	85	79.5	85	77	234	C4	5.0	
438	2.9	0.750	0.663	0.613	0.0012	6	L33 only	103	95	--	--	--	--	--	P_b not achieved
439	2.9	0.750	0.663	0.613	0.0012	6	C3-L33	104	99	--	--	--	--	--	P_b not achieved
485	2.9	0.750	0.663	0.613	0.002	20	C2-L17	84	79	81	78	237	C4	10.0	
506	2.7	0.750	0.663	0.606	0.0008	20	C3-L17	85	75	84	74	212	C4	6.5	
517(f)	1.8	0.663	0.635	0.606	0.0008	20	C3-L17	37	39	--	--	237	--	--	P_b not achieved Tube billet split

(a) Mandrel was 8 inches long.

(b) Billet-end pressure calculated from fluid runout pressure except when billet upsetting occurs; here the maximum fluid pressure is used.

(c) Reextrusion of tubing produced in Trial 351 annealed to 65 BHN.

(d) Reextrusion of tubing produced in Trial 355 and 354 without an intermediate anneal.

(e) For thin-wall tubing, ratio is nominal; ratio varied slightly over tube length because mandrel was tapered.

(f) Reextrusion of tube from Trial 485 without anneal.

pressure itself. This was the case with the Ti-6Al-4V tubing where only a 75,000 psi **fluid pressure** was required to extrude at a ratio of 2.7:1, whereas about 200,000 psi **is** required for solid rounds at the same ratio.

7075-O Aluminum Tubing

Extrusion Ratio

The fluid pressures, at runout, for hydrostatic extrusion of 7075-O Al tubing at various ratios and two tube blank sizes are plotted in Figure 28. The chart also shows (1) billet end-pressures (determined from $P + PA_m/A$) developed at corresponding fluid runout pressures and (2) fluid runout pressure for extrusion of solid rounds of 7075-O Al. It is interesting that the points plotted for billet-end-pressure almost fall on the line representing runout pressure requirements for solid rounds. The fact that the pressure requirements are quite similar for rounds and tubing indicates that the mandrel friction was low for this material under the conditions employed. It is well to point out that with the floating mandrel arrangement, relative motion (and hence friction) between the billet and mandrel only occurs in the billet deformation zone and beyond. In a fixed-mandrel arrangement, friction would occur over the entire length of mandrel, unless it were possible to provide relief on the mandrel.

The advantage of using the floating-mandrel arrangement is seen by the fluid pressure requirements for tubing on the two lower curves in Figure 28. These curves are specifically for the tube blank sizes indicated. The difference in pressure between the fluid pressure curve for tubing and the diverging billet-end-pressure curve, represents the additional end-pressure due to the 3/4-inch-diameter floating mandrel. For a given tube blank size, as extrusion ratio is increased, so does the additional end-pressure simply because of the greater fluid pressures required at the higher ratios.

At a ratio of about 13:1 (Trial 384), the unbalanced pressure was sufficiently high to cause billet upsetting due to the high axial compressive stress, rather than to effect extrusion. Nevertheless, about 4 inches of thin-walled high-quality tubing was produced. The additional end-pressure is estimated to be about 55,000 psi based on the measured difference between the appropriate curves in Figure 28. The yield strength in compression of 7075-O aluminum is approximately 18,000 psi. Because a short length of tube was produced before upsetting occurred, a ratio of 13:1 is believed to be close to the threshold condition where billet upsetting will commence. (For other billet and extrusion dimensions, the critical ratio will be different.) Whereas billet upsetting would not occur with a fixed mandrel arrangement, such as one connected directly to the ram, the pressure requirements would be higher.

Lubrication

Except for two trials, billet Lubricant L17 was applied to the OD and bore of all the 7075-O aluminum tube blanks. Data in Table XXIX indicates that, at extrusion ratios below 4:1, the lubricant worked well and tubing of excellent surface quality was produced. Above this ratio, stick-slip occurred and the finish was good only on the portions of product produced during the slip portions of the stem stroke. In the two trials where lubrication was varied (Trials 388 and 425), neither pressures nor finishes were better than those obtained using L17.