TABLE 4. EXPERIMENTAL DATA FOR COLD HYDROSTATIC EXTRUSION OF Ti-6Al-4V ALLOY ROUNDS

Die Angle ----- 45 degrees
Fluid --------- Castor oil
Stem Speed ---------- 6 ipm
Billet Surface Finish ------ 60-100 microinches, rms

Item	Trial	Extrusion Ratio[a]	Billet Lubrication		Extrusion Pressure, 1000 psi				Length of Extrusion, inches	Comments
					Breakthrough		Runout			
			Coating	Lubricant	Stem	Fluid	Stem	Fluid		
1	264	3.33	C2[c]	L17	214.0	200.0	(b)	(b)	5/8	Slight P_b peak; severe stick-slip
	286	3.23	C2[c]	L17	202.0	186.0	209.0	192.0	6-1/2	Slight P_b peak; P_r increased toward end of stroke
	278	3.31	None	L17	244.0	222.0	(b)	(b)	5/8	Slight P_b peak; severe stick-slip
	279	3.23	None	L17	240.0	219.0	(b)	(b)	5/8	Same as above
	291	3.31	None	L17	202.0	188.0	--	--	6-1/2	Slight P_b peak; moderate stick-slip followed by severe stick-slip
2	300	3.19	None	L24	202.0	187.0	216.0	196.0	11	Slight P_b peak; moderate stick-slip followed by uniform P_r
3	296	3.31	None	L25	224.0	210.0	212.0	196.0	11-1/2	High P_b peak; moderate stick-slip followed by uniform P_r
4	290	3.21	None	L26	223.0	203.0	210.0	186.5	11-3/4	High P_b peak; moderate stick-slip followed by moderate stick-slip
5	292	3.21	None	L27	217.0	194.0	219.0	188.5	5-1/2	Slight P_b peak followed by severe stick-slip
6	267	3.33	None	L28	245.0	226.0	(b)	(b)	5/8	Stopped at indicated pressure
	314	3.19	None	L28	249.0	225.5	--	--	0	Billet cocked; die broke
	337	3.33	None	L28	240.0	221.5	--	--	1/8	Stopped at indicated pressure
7	266	3.33	None	L29	240.0	224.0	(b)	(b)	5/8	Slight P_b peak; severe stick-slip
	313	3.19	None	L29	262.0	235.0	--	--	1/8	Stopped at indicated pressure
	338	3.33	None	L29	246.0	222.0	--	--	0	Billet cocked; die broke
8	268	3.33	None	L30	214.0	200.0	(b)	(b)	7/16	Slight P_b peak; severe stick-slip
	304	3.28	None	L30	250.0	223.0	--	--	0	Billet cocked; die broke
	307	3.19	None	L30	228.0	205.0	240.0	204.0	9-1/2	Slight P_b peak; severe stick-slip followed by moderate stick-slip
9	269	3.33	None	L31	240.0	222.0	(b)	(b)	5/8	Slight P_b peak; severe stick-slip
	305	3.19	None	L31	264.0	237.0	--	--	1/8	Stopped at indicated pressure
10	270	3.33	None	L32	226.0	208.0	(b)	(b)	5/8	Slight P_b peak; severe stick-slip

(a) Extrusion ratio initially at 3.33:1 (70 per cent area reduction) but was decreased slightly later when extrusion die orifices were remachined to remove score marks.
(b) Stopped after breakthrough but before runout pressures were obtained.
(c) C2 - Fluoride-phosphate coating.

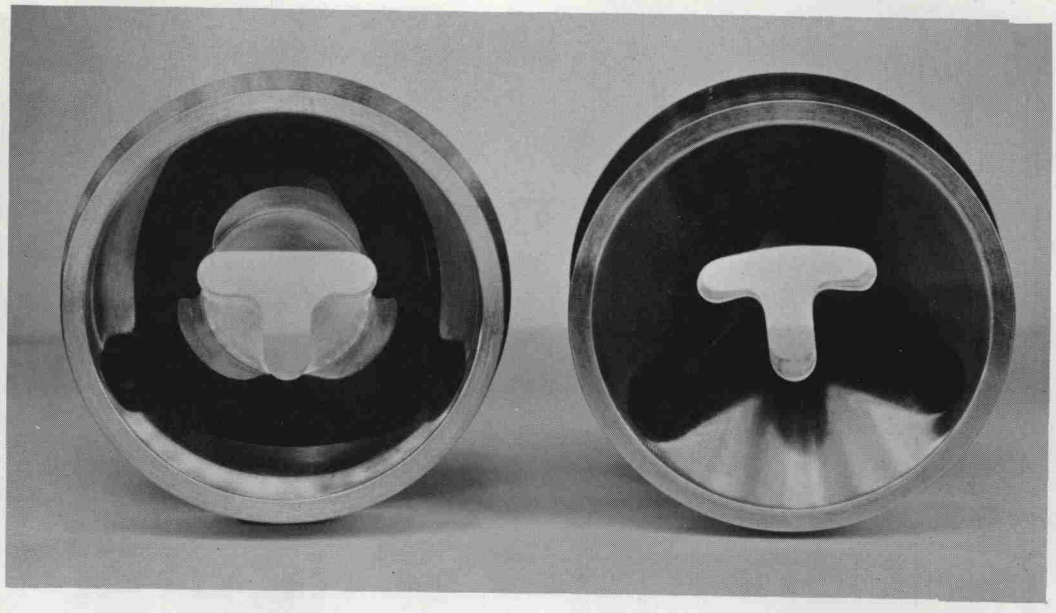

FIGURE 4. DIE CONFIGURATIONS USED FOR EXTRUDING T-SECTIONS

Left: Compound-angle die, 45-degree entry angle leading into a 160-degree angle
Right: Single-angle die with 45-degree entry

The extrusion trials were conducted with AISI 4340 and 7075 Al billets. The experimental data are contained in Table 5. The first trial was made with AISI 4340 at an extrusion ratio of 3:1 with the single-angle T-die. Unfortunately, the billet cocked some time after breakthrough. During the attempt to remove the billet and partial extrusion from the die, the die split into three pieces at the T-corners. At first glance, it appears that the failure was probably due to the high stresses imposed at T-corners by cocking of the billet.

Some worthwhile information was obtained, however, with both die designs. The breakthrough fluid pressure was 210,000 psi (Trial 316) for the single-angle die. However, breakthrough was not reached at 236,000 to 245,000 psi (Trails 341 and 342) for the compound-angle die. Thus, it appears that the pressure penalty for extrusion of AISI 4340 is quite high with the latter die design.

T-sections of excellent surface quality were extruded from 7075 aluminum at a ratio of 7.3:1 with the compound-angle die. (Single-angle die trials will be made in the future for comparison purposes.) Stem speeds of 6, 20, and 80 ipm were investigated. Although this stem speed range did not influence the extrusion pressure requirements, it had a pronounced effect on stick-slip and extruded surface quality. With stem speeds of 6 ipm, extrusion was accompanied by severe stick-slip. At a stem speed of 20 ipm, stick-slip was less severe. Increasing the stem speed to 80 ipm completely eliminated stick-slip and resulted in an extruded surface of very high quality. The T-section extruded at 80 ipm is shown in Figure 5.