TABLE XXV. MECHANICAL PROPERTIES OF SINTERED-ALUMINUM PRODUCT AS WORKED BY COLD HYDROSTATIC EXTRUSION AND HOT CONVENTIONAL EXTRUSION

Test Temperature - 840 F

Extrusion Process	Extrusion Ratio	Strength, psi		Elongation, percent
		Yield, 0.2 Percent Offset	Ultimate Tensile	
Hydrostatic (cold)	10.0	6,800	7,400	0.45
Hydrostatic (cold)	20.0	7,050	7,550	0.39
Conventional (hot)	28.4	11,225	12,335	1.1

It is apparent that cold working of the dispersion-hardened SAP by hydrostatic extrusion did not develop as high a strength level as did conventional hot extrusion. The lower strength and ductility obtained possibly may have been associated with some micro-cracking or fluid penetration of the billet surface during hydrostatic extrusion of this material. Alternatively, the higher temperatures and ratios used in the conventional extrusion process may well have further consolidated the powder compact in addition to possibly improving intermolecular bonding.

XIII

HYDROSTATIC EXTRUSION OF BRITTLE MATERIALS

The aim of this series of trials was to establish the production capabilities of the hydrostatic extrusion of brittle materials. Two materials were selected which were known to behave in a brittle manner when subjected to cold work. These were:

(1) Wrought TZM molybdenum alloy (both the stress-relieved and recrystallized conditions)

(2) Beryllium (powder-metallurgy origin).

Tables XXVI and XXVII give the experimental data obtained in the developments leading up to and including the cold hydrostatic extrusion of crack-free products of both materials. This achievement was accomplished by use of a novel die design which eliminated the need for fluid back pressure. These developments, especially in the case of beryllium, are truly significant and represent a major breakthrough in the deformation of brittle materials. Furthermore, in the hydrostatic extrusion of beryllium at 500 F, the data in Table XXVI indicate that sizeable extrusion ratios, up to 8:1, are possible within the present capacity of 225,000 psi at that temperature level.

Both TZM and beryllium displayed similar tendencies towards cracking. The cracks typically exhibited by these materials are circumferential ("rattle-snake" or "fir-tree" type) and longitudinal cracks. Historically, crack-free extrusions of both these materials were generally obtainable only when the product was hydrostatically extruded into a chamber producing a fluid back-pressure(17, 18): this technique is sometimes referred to as differential-pressure hydrostatic extrusion or fluid-to-fluid extrusion. An alternative method involving only die design was investigated in this program with the aim of eliminating the complexity and limitations of a second high-pressure fluid container.

Extrusion Ratio

The data in Tables XXVI and XXVII are plotted in Figure 21 to show the relationship between extrusion ratio and extrusion pressure at 80 and 500 F. The figure gives fluid pressures for the results obtained at 80 F but at 500 F, stem pressures are plotted. (The fluid pressure gage was out of action at this time. Fluid pressures at 500 F would be at least a few percent lower than the stem pressures plotted.) Beryllium and stress-relieved TZM apparently require similar pressures at 80 F. At 500 F, beryllium requires about 20 percent less and TZM (SR) about 7 percent less pressure than that at 80 F.

Extrapolation of the curve at 80 F indicates that both beryllium and TZM can be extruded at ratios of about 30:1 by a fluid pressure of 450,000 psi. The estimated ratio achievable at 500 F for beryllium within that pressure capacity is approximately 50:1.

It is of interest to compare the data reported by Pugh in his review papers on hydrostatic extrusion(2). All the results he quoted indicated that beryllium required much higher pressures than those shown in Figure 21. The lowest of these pressures