die sufficient in length to accommodate the long extrusion. Also, the main pressure chamber is required to contain pressures in excess of those required in fluid-to-air extrusion by the amount of back pressure.

With the double-reduction die a compressive stress is transmitted to a narrow circumferential region of the extrusion only, and the results obtained so far indicate that the small second reduction does not require any appreciable extra fluid pressure over that required for the first reduction. Thus, much of the back pressure in fluid-to-fluid extrusion would appear to be superfluous. The double-reduction die apparently avoids the need for back pressure tooling and the associated higher fluid pressure containment in the main chamber.

Clearly, the results obtained so far are very encouraging and open up new potential applications of the hydrostatic extrusion process. For example, it appears possible that brittle materials may now be extruded into long lengths economically at temperatures previously considered impossible. Unique mechanical properties may well be obtained with these materials. Improvements in lubrication, dimensional tolerances, and contamination control can be expected at low working temperatures. In the case of beryllium, the problem of toxicity can be avoided without difficulty.

HYDROSTATIC EXTRUSION OF SUPERALLOYS ALLOY 718 AND A286

The objective of this series of trials was to determine the extrudability of the superalloys A286 (iron-base) and Alloy 718 (nickel-base). The results obtained are shown on Table 5.

A286 and Alloy 718 billets were received in the solution-treated condition. The initial hardnesses were $<10\ R_C$ and $16\ R_C$, respectively. All billets were lubricated with L 38 (PTFE) and extruded at a stem speed of 20 ipm through standard-profile dies of 45-degree included angle.

The maximum extrusion ratios that were achieved at room temperature within the 250,000 psi pressure capacity of the tooling were:

A286	5:1
Alloy 718	3.3:1

It is particularly noteworthy that all extrusions were free of cracks. Extrusion at 500 F at the same ratios reduced the pressure requirements by about 15 percent.

HYDROSTATIC EXTRUSION AND DRAWING OF BERYLLIUM WIRE

The aim of this portion of the program is to determine the technical feasibility of producing beryllium wire down to a target diameter of 0.001 inch by hydrostatic extrusion-drawing. In this Battelle-developed process, the wire is subjected to hydrostatic fluid pressure on the entry side of the die and controlled draw stress on the exit

TABLE 5. EXPERIMENTAL DATA FOR HYDROSTATIC EXTRUSION OF SUPERALLOYS

Die angle – 45 degrees (included)
Fluid – Castor oil at 80 F
Polyphenyl ether (PPE) at 500 F

Billet surface finish – 60-100 microinches (RMS)
Billet lubricant – L38
Stem speed – 20 ipm

Trial	Extrusion Ratio	Extrusion Temperature, F	Extrusion Pressure: Breakthrough Stem	Breakthrough Fluid	Runout Stem	Runout Fluid	Type of Curve, p 25	Length of Extrusion, inch	Comments
			Superalloy – A-286 (iron-based)						
479	3.3:1	80	198	173	190	165	B-1	13	
480	5:1	80	280	234	258	217	B-1	19	
500	5:1	500	235	--	217	--	B-3	5	Lubrication broke down
			Superalloy – Alloy 718 (nickel-based)						
481	3.3:1	80	273	225	258	217	B-1	15	
484	3.3:1	80	285	238.5	270	226.5	B-1	11	
499	3.3:1	500	245	--	228	--	B-3	3	Lubrication broke down