Die D5 was evaluated (Trial 514) with stress-relieved TZM and at a stem speed of 20 ipm. During breakthrough the automatic cutout on the press functioned prematurely. The fluid pressure at the point of cut-out was 215,000 psi and a 3 1/2-inch length of crack-free extrusion was produced. The die was also used later and successfully with beryllium.

Effect of Die Design, Extrusion Ratio, and Temperature on Beryllium

Most of the trials with beryllium were conducted at a ratio of 4:1 using the double-reduction dies, but useful information was also gained with controlled-relief dies. All of the data are recorded in Table XXVII.

Controlled-Relief Die

The short controlled-relief die (C1) was evaluated at both room temperature and 500 F (Trials 377 and 417) at a ratio of 2.5:1. In both cases the extrusions cracked badly although they remained in one piece. Fewer cracks occurred on the extrusion made at 500 F as shown in Figure 24. Lubricant L17 appeared to have performed adequately at 80 F. However, Lubricant L31 used at 500 F broke down immediately after the start of runout and severe galling occurred. In spite of galling, the pressure levels at 500 F were 40 percentlower than those obtained at 80 F where the lubrication was good.

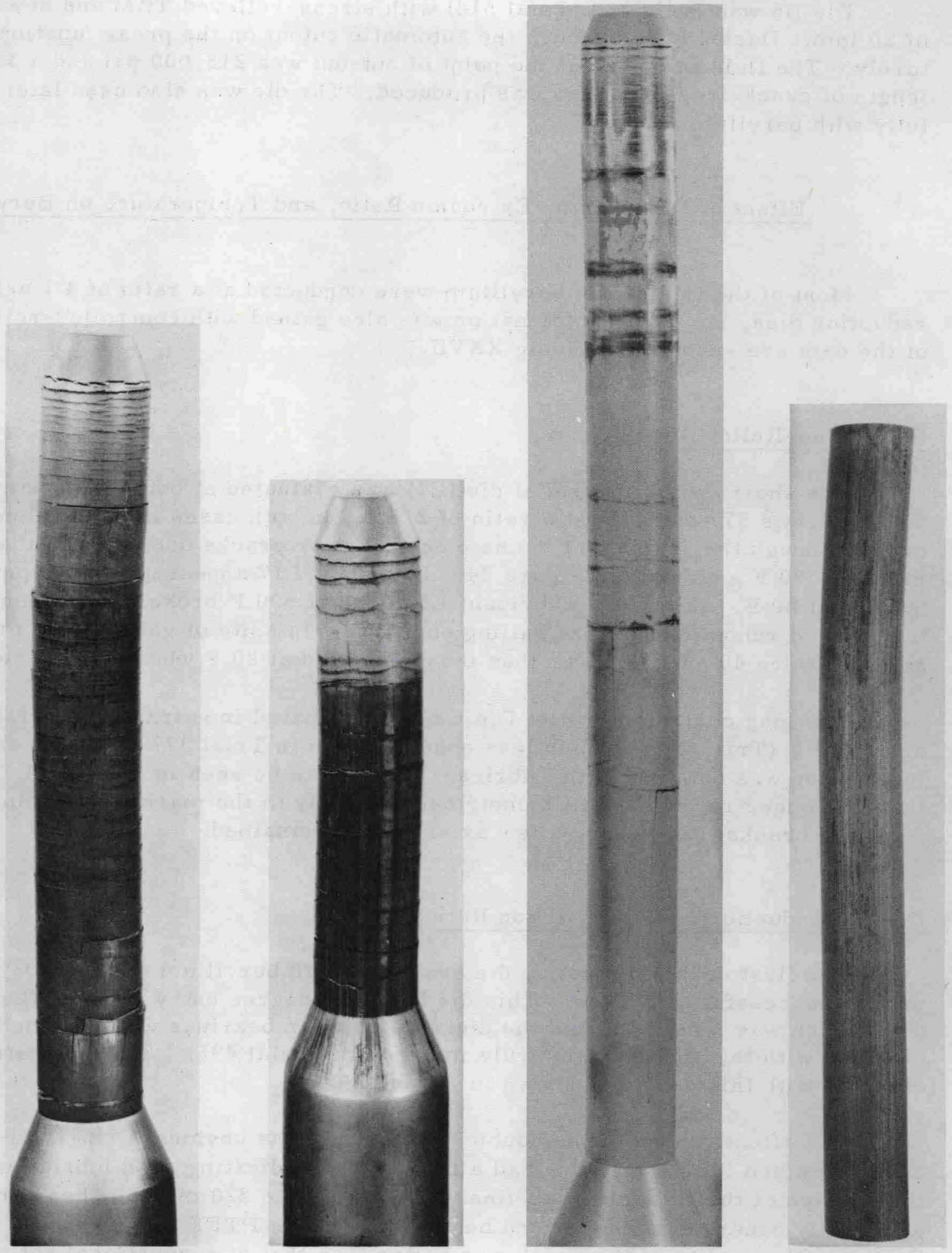
The long controlled-relief Die C2 was evaluated in extrusion at a ratio of 3.3:1 and at 80 F (Trial 461). Much less cracking than in Trial 377 occurred and excellent lubrication was obtained with Lubricant L38 as can be seen in Figure 24. It is believed that the longer relief in Die C2 contributed greatly to the marked reduction in circumferential cracks. However, a few axial cracks remained.

Double-Reduction Die – Extrusion Ratio 4:1

The first double-reduction die evaluated with beryllium was Die D3, which had proved successful with TZM. This die had a 45-degree entry angle to the second reduction (which was 2 percent) and the distance between bearings was 5/8-inch. The results obtained with this design were truly impressive (Trial 495). The crack-free extrusion obtained with this design is shown in Figure 24.

The effectiveness of the double-reduction die is obvious. The fluid-pressure curve obtained in this instance had a flat runout, indicating good lubrication. However, the surface of the extrusion was finely scored (130 to 220 microinches, rms), and this apparently occurred at the second bearing where the PTFE lubricant was scraped off. Even so, the quality of the finish was better than that of conventional hot extrusions. In the conventional hot extrusions of beryllium rod for commercial use, the billet is clad in a steel jacket and requires a billet temperature of 1850-1950 F.

Nondestructive inspection of the beryllium extrusion did not reveal any evidence of cracking on the surface in the extruded section beyond the nose. Severe transverse and longitudinal cracking occurred at the nose because the first 5/8 inch was extruded without the benefit of counterpressure from the second reduction (since the distance between bearings was 5/8 inch). Photomicrographs of the transverse and longitudinal sections



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Trial	377	417	461	495
Extrusion Ratio	2.5:1	2.5:1	3.3:1	4:1
Temperature	80 F	500 F	80 F	80 F
Billet Lubricant	L17	L31	L38	L38
Die	Controlled Relief (C1)	Controlled Relief (C 1)	Controlled Relief (C2)	Double Reduction (D3)

FIGURE 24. INFLUENCE OF DIE DESIGN ON CRACKING IN HYDROSTATIC EXTRUSIONS OF BERYLLIUM