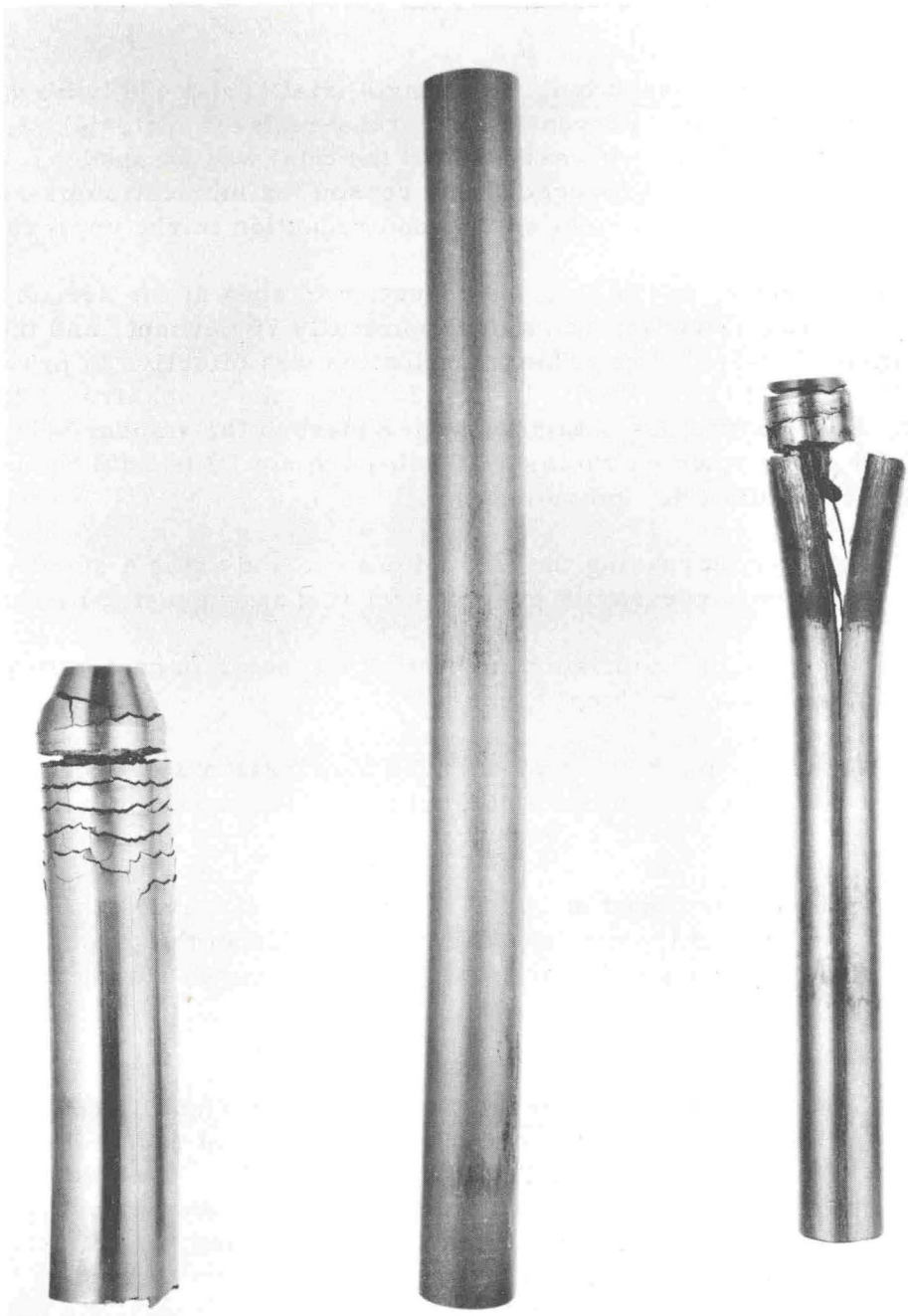

37022

Trial	441	483	443
Extrusion Ratio	2.5:1	4:1	5:1
Billet Lubricant	L17	L38	L17
Die	Standard	Double Reduction(D3)	Standard

FIGURE 23. INFLUENCE OF DOUBLE-REDUCTION DIE ON CRACKING OF HYDROSTATIC EXTRUSIONS OF WROUGHT TZM MOLYBDENUM ALLOY

Double-Reduction Die – Extrusion Ratio 4:1

Size of Second Reduction. In a single trial (Trial 478) with double-reduction Die D2 (second reduction – 3.3 percent), and stress-relieved material, runout pressures rose rapidly due to lubrication breakdown and the trial was stopped. A crack-free, 1-inch length of extrusion was produced. The reason for lubrication breakdown was not clear, but it was believed that a smaller, second reduction might improve runout conditions.

Consequently, in Die D3, the reduction in area at the second bearing was 2.0 percent, the overall reduction remaining nominally 75 percent, and the space between bearings remained at 5/8 inch. This modification was effective in preventing cracks in recrystallized TZM (Trial 483). Figure 23 shows the crack-free TZM extrusion along with two other extrusions obtained earlier through the standard-die. The fact that cracking did not occur when extruding at 4:1 through die D3 but did occur at 5:1 (Trial 443) through the standard die indicates that:

(1) Merely increasing the extrusion ratio and using a standard-die profile may not necessarily prevent cracking as suggested by Pugh[17].

(2) Die design itself is a very important factor in controlling the conditions that cause cracking.

The surface finish of crack-free TZM extrusion was excellent (30 to 45 microinches, rms), even though the PTFE lubricant was apparently scraped off at the second bearing.

Die D3 was also used at 500 F (Trial 501). However, the die seal which was located in the base of the die (see Figure 9b) failed in this experiment. The O-ring material apparently expanded and was probably pinched during the lowering of the container.

The Space Between Bearings. A double-reduction die with no space (H = 1/8) between the bearing of the first reduction and the second reduction, designated Die D4, was evaluated with stress-relieved TZM at 80 and 500 F. The size of the second reduction, 2.2.0 percent, was the same as for Die D3. At 80 F, the extrusion was cracked both circumferentially and longitudinally, but at 500 F a sound, crack-free extrusion was obtained. It appears that the crack-free product obtained here may have been due more to temperature than die design, particularly since TZM exhibits a marked increase in ductility at 500 F. The reduction in area in a room-temperature tensile test on stress-relieved TZM is about 55 percent whereas, at 500 F, the figure is 90 percent[19]. A trial with the standard die at 500 F would determine whether elevated temperature was the sole factor here in controlling cracking.

The Angle at the Second Reduction. Although a crack-free extrusion of TZM was produced with an excellent surface finish through Die D3 (Trial 483), the lubricant (L38) had scraped off at the second bearing. In an attempt to prevent the lubricant from being scraped off and thus possibly reduce the extrusion pressures, Die D3 was modified to Die D5 in which the included entry angle to the second bearing was reduced from 45 to 22 degrees.