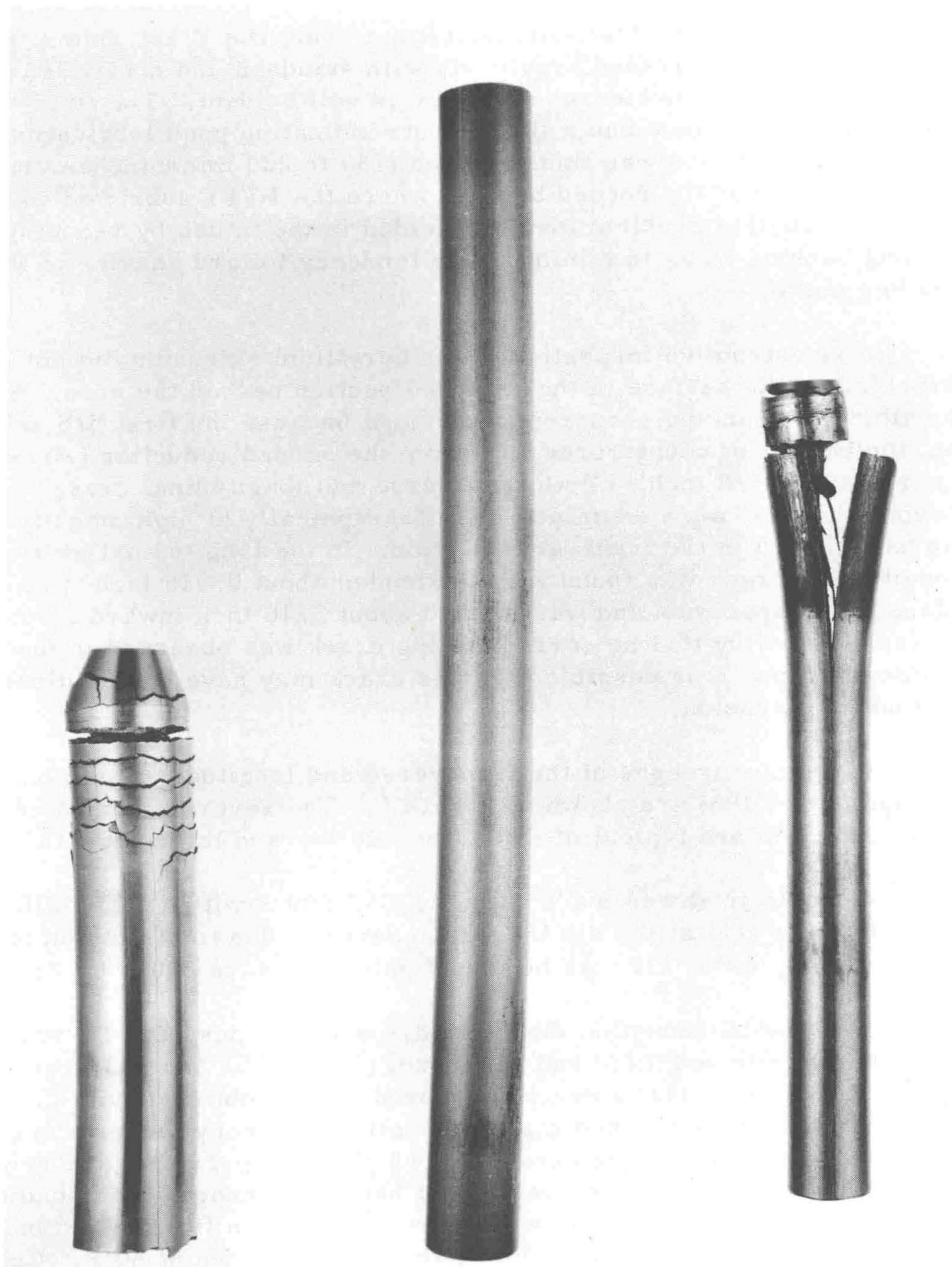

37022

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

FIGURE 4. INFLUENCE OF DOUBLE REDUCTION DIE ON CRACKING OF HYDROSTATIC EXTRUSIONS OF WROUGHT TZM MOLYBDENUM ALLOY

The results obtained with beryllium using Die C are shown in Figure 5 along with other specimens extruded previously with standard and controlled-relief dies. The effectiveness of the double-reduction die is self evident. 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. It is believed that this problem may be avoided in the future by reducing the entry angle to the second bearing so as to minimize the tendency toward shaving of the lubricant and extruding metal.

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). Both transverse and longitudinal cross sections of the extrusion beyond the nose were examined metallographically at high magnification. No cracks were observed in the transverse section. In the longitudinal section, a single hairline longitudinal crack was found which extended about 0.015 inch from the transverse-cut plane of the specimen and was located about 3/16 inch inward from the extruded surface. It was noteworthy that no corresponding crack was observed in the mating longitudinal section. Thus, it is possible that this crack may have been a direct result of sectioning and not of extrusion.

Photomicrographs of the transverse and longitudinal sections of the beryllium extrusion (Trial 495) are shown in Figure 6. The severely elongated grains in the longitudinal section are typical of a heavily cold-worked microstructure.

A single trial was made with Die C at 500 F with a TZM billet (Trial 501). The PTFE O-ring seal at the die leaked, apparently due to distortion of the O-ring at 500 F. Other O-ring materials may be investigated in future 500 F trials.

The double-reduction die with adjacent bearings, Die D, was evaluated at 500 F with stress-relieved TZM and beryllium (Trials 502 and 503, respectively). It is of particular interest that a crack-free product was obtained with the TZM, but the beryllium extrusion was cracked circumferentially in many places along its length. More trials will be necessary to determine whether temperature, the new die design (Die D), or both had an influence on cracking of beryllium under these conditions. The low pressures required for beryllium were particularly significant. Extruding beryllium at 500 F required pressures 1/3 lower than those needed at 80 F. Consequently, much higher extrusion ratios than 4:1 can clearly be obtained at 500 F within the 250,000 psi present capacity of the extrusion tooling.

It appears that the crack-free product of TZM obtained with Die D may have been due to the elevated temperature only and not the design of Die D since a repeat of these extrusion conditions at room temperature with TZM (Trial 505) produced a cracked extrusion. Another trial at 500 F but with the standard die design would confirm whether crack elimination in this case was due to temperature, die design, or both factors.

To date, sound hydrostatic extrusions of beryllium and TZM have been obtained by other workers[8, 9] when the product was extruded into a high fluid pressure environment (fluid-to-fluid extrusion). The extrusion ratios achieved here were in the order of 2:1. The provision of a fluid back pressure requires expensive tooling on the exit side of the