

## HIGH-PRESSURE METAL FORMING

will press the punch downward into the blank. For difficult materials a back pressure can also be employed much as is done in fluid extrusion work.

To provide a measure of quality, some of the shells made by the new process were sectioned, as shown in Figure 11, and micrographs were made to check the grain structure and hardness of the drawn material. In the case of copper it was found that shells made with a 4 to 1 blank-to-shell-diameter ratio possessed a hardness of Rockwell B-75 in the drawn walls. This temper is equivalent to that of extremely hard-drawn copper wire; however, the parts have retained considerable toughness.

### TUBE FLANGING

In many cases it is desirable to fabricate heavy flanges on the ends of thin-walled tubing. Conventionally this operation is performed by either soldering or welding a specially constructed plate onto either end of the tubing. If, however, it is necessary to maintain the inside dimensions of the tubing within close tolerances, heat distortion during the flanging process makes it necessary subsequently to re-size the tube opening. The re-sizing operation is particularly necessary in the case of copper microwave transmission lines, which are manu-

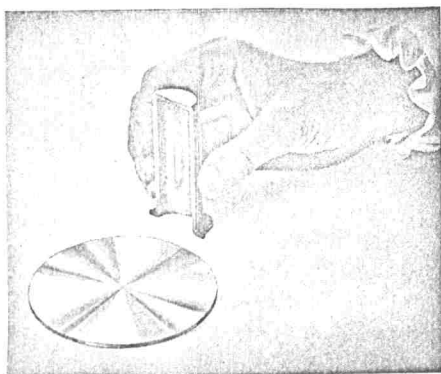


Figure 11. Section of a shell drawn under high pressure. (Shown with original blank.)

factured at Western Electric in considerable quantities in various sizes ranging from about 1 to 3 inches in diameter.

With this type of product in mind a high-pressure process was developed to perform the flanging operation. In principle the new process is the reverse of high-pressure deep drawing. Since no heat distortion takes place during the process, subsequent re-sizing of the tubing is unnecessary.

The first successful method for forming flanges with high pressure is diagrammed in Figure 12. In this process the tubing to be flanged is supported on a mandrel and placed within a high-pressure chamber filled with fluid. As a hydraulic ram pushes the mandrel farther into the chamber, a step on the mandrel pressurizes the fluid, which in turn forces the end of the tubing to start moving through an extrusion die opening at the end of the chamber. On the other side of this opening a back-up die is located in close proximity to the face of the extrusion die. Between the two dies just enough space is provided to permit the lip of the tube to flair outward into a flange limited ultimately by a retainer ring. The back-up die, which is supported by a hydraulic cylinder, requires about 100,000 psi contact pressure from the flange material before the die will back off and so allow the thickness of the flange to increase. This resistance provides the high hydrostatic pressure required to raise the flange material into a state of higher ductility and thus make possible the flow of tubing metal into the flange.

This technique proved highly successful, and a number of small flanges of aluminum tubing were made with the apparatus described. This apparatus, however, possessed two serious disadvantages that limited its application. First, since some of the parts to be made ranged up to 12 feet in length, loading and unloading the apparatus posed a difficult problem. Second, if flanges were to be placed on both ends of a piece of tubing—as is normally the case—the extrusion die would have to be split to allow removal. With such a split die it

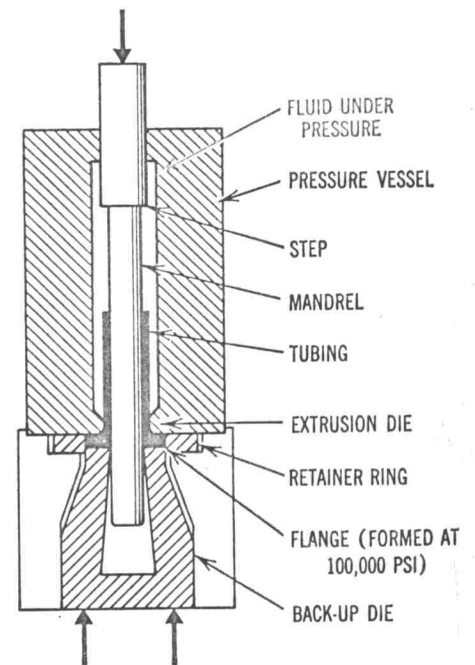


Figure 12. Early method for forming a flange under high pressure.

would have been very difficult to seal the chamber against fluid leaks at pressures up to 300,000 psi.

In view of these considerations the apparatus has finally evolved into that shown in Figure 13. In place of the fluid previously used to contain the tube a Teflon jacket now surrounds the part. The back portion of the jacket is made thin so that friction prevents the jacket from transmitting high back pressure along the tube; as a result the tube can project out of the device into the open without giving rise to the problem of "pinch off". In operation, the pressure in the Teflon jacket is raised to a high level—

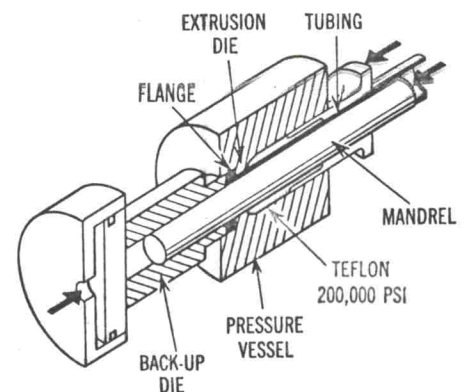


Figure 13. Present method for forming a flange under high pressure.