pressure piston to the area of the high-pressure one. In many applications it is necessary to use more than one stroke of the intensifier to attain working pressure, so inlet and outlet ball valves are fitted.

There are several problems involved in the design of such an intensifier, perhaps the most important being the problem of fatigue strength of the high-pressure system, head and tee piece. With a relatively simple cylinder construction it may be possible to achieve an infinite fatigue life for repeated pressures of 0·7 GN/m^2 (100 000 lbf/in^2) but not for significantly higher pressures.

More complex designs involving dynamic support have been proposed but no fatigue data have been established yet to demonstrate if the expected improvement in fatigue is realized.

In the present design a finite life is accepted but the materials of construction for the inner component of the cylinder, the head and the tee piece have been selected after exhaustive tests. Electroslag-refined or vacuum remelted steel is used; these materials give a high yield strength with an acceptable fracture strength.

Long life. The inner component of the cylinder is a press fit in a lower strength but high fracture strength outer component which contains the inner one when it fails.

The tee-piece is of very simple and cheap design for ready replacement, but surprisingly its fatigue life appears to be as high as for the main cylinder, despite the stress concentration at the junction between the axial hole and the cross bore. Fatigue tests at 1·4 GN/m^2 (200 000 lbf/in^2) have established fatigue life of 2 500 cycles, and current work may well increase this figure significantly.

Another problem is the high-pressure ram seal, which is fixed, with the ram sliding through it. Several high-pressure fluids have been used in the system and the seal has to be compatible with all of them. Brake fluid, a good lubricant with a very high freezing pressure, has been used, but it is a good electrical conductor and this may be a disadvantage in some applications.

Alternatively Plexol 201 oil—Rohm and Haas Inc or Lennig Chemicals Co in Britain—can be used. For these fluids an SCN ring (Ronald Trist & Co) or a Hypak G seal (James Walker & Co) have given satisfactory life. Chamfered anti-extrusion rings must be used and in general Hydurax (Langley Alloys) has proved satisfactory, though at 1·4 GN/m^2 beryllium copper may be preferable.

Pipe fittings and high-pressure tubing have been tested under cyclic pressure and to failure under steadily increasing pressure. Three sizes of tube have been standardized: 9·5 mm o.d. × 3·2 mm i.d. ($\frac{3}{8} \times \frac{1}{8}$ in) and 9·5 mm o.d. × 1·6 mm o.d. ($\frac{3}{8} \times \frac{1}{16}$ in), of 12% chromium steel with an ultimate tensile strength of about 0·8 GN/m^2 (50 tonf/in^2), and 19·0 mm o.d. × 1·6 mm i.d. ($\frac{3}{4} \times \frac{1}{16}$ in) compound tube, with a stainless steel core and an alloy steel sheath.

The first two tubes are sufficiently ductile to be bent, which usefully reduces the number of fittings needed, and are suitable for 0·6 GN/m^2 (80 000 lbf/in^2) and 0·9 GN/m^2 (130 000 lbf/in^2) respectively. The compound tube is used for 1·4 GN/m^2 (200 000 lbf/in^2).

Jointing. Up to the present joints have been made either by coning the tube or inserting a coned nipple or cone ring as shown below. However, experience and testing have shown that it is much better to use a much larger angle; indeed, if it were not for problems of alignment and tube-end preparation, perfectly flat surfaces normal to the tube axis would appear to be best. A typical connector with an angle only a few degrees from flat is shown below left.

It is necessary to have a valve capable of operating at 1·4 GN/m^2 (200 000 lbf/in^2) and there are cases where it has to withstand pressure in either direction.

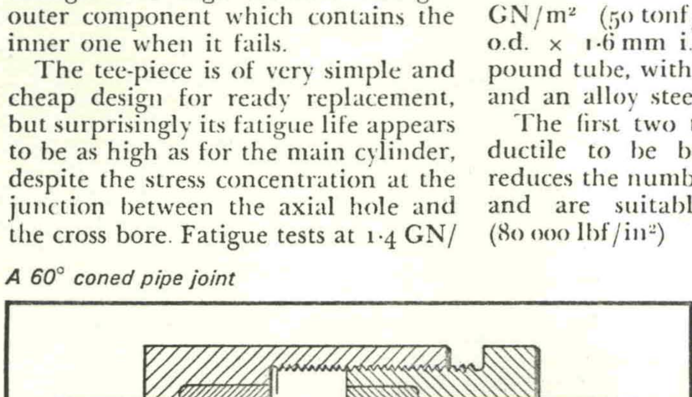
As high-pressure equipment should be housed in a safety enclosure it is desirable for the valve to be remotely controlled.

The valve as designed is shown below right. It will be seen that the valve spindle is actuated by a piston which is itself actuated by fluid pressure. This pressure can be generated hydraulically by a remote pump, or pneumatically, but as shown it is produced by a screw jack, which forces a small piston into the oil-filled space.

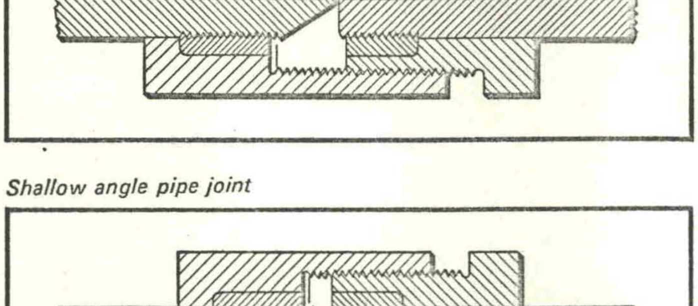
The screw jack can be operated through a long, small-diameter flexible rod or cable. The valve is relatively complicated and consequently expensive, but it operates satisfactorily and can be used like a needle valve to give small adjustments of pressure. A much simpler and cheaper manual spill valve is also available.

Sensor. Finally, a pressure sensor is

A 60° coned pipe joint



Shallow angle pipe joint



High-pressure valve