High-pressure fluids forced out at the stroke of a pump

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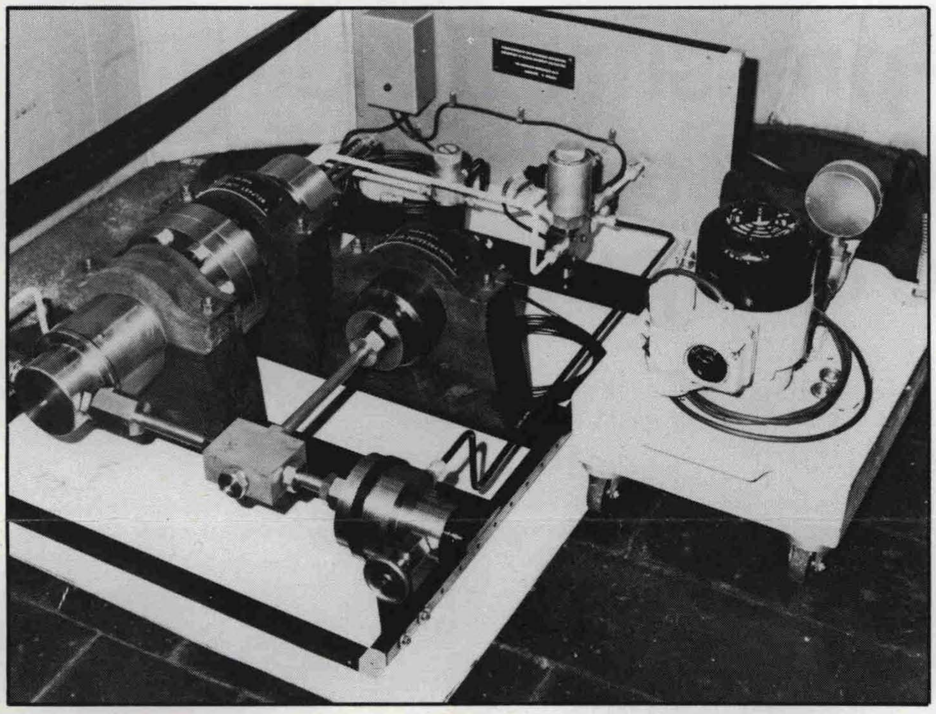
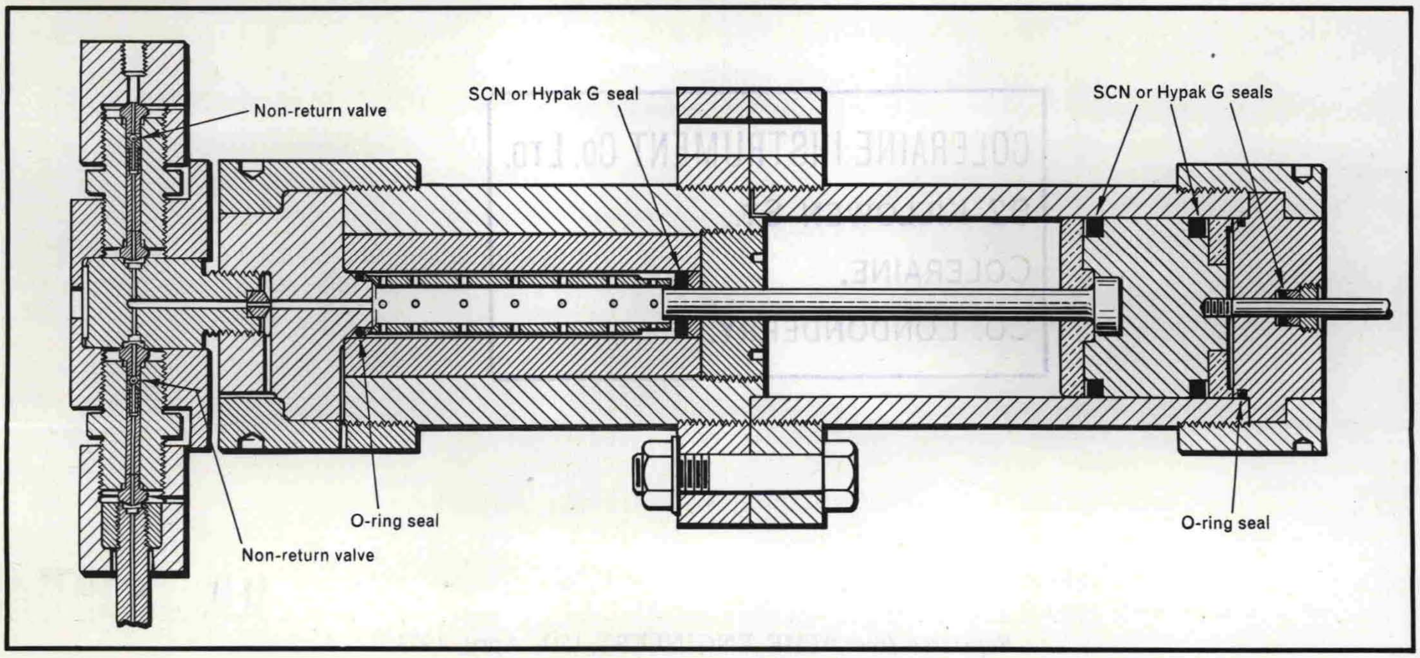
Modern industry is demanding high pressures for testing, extrusion and other purposes. An automatic hydraulic intensifier has been designed to do this



Above: Complete automatic intensifier unit. Below: Cross section of intensifier



There is an increasing demand from industry and research establishments for equipment to operate at up to 1·4 GN/m² (200 000 lbf/in²). Industrially it is of interest in such fields as isostatic compaction of powders and for hydrostatic extrusion presses.

The use of high-velocity jets, produced by pressure differences of this sort of magnitude across an orifice, is being investigated for cutting rock, coal and metals.

High pressures can be used scientifically, for establishing viscosity of lubricants under simulated extreme pressure loading, or for the study of rocks under the pressure found in parts of the earth's mantle.

Extensive knowledge of high-pressure engineering has been gained by the Mechanical Engineering Department of Queen's University, Belfast. Agreement has been reached for this information to be made available to the Coleraine Instrument Company Ltd, 82 Killowen Street, Coleraine, Northern Ireland.

High-pressure fluid. The first fruit of this collaboration is an automatic intensifier system which is essentially simple and relatively cheap. The equipment provides a source of high-pressure fluid for autofrettaging, proof testing, and for development and research.

The essential component of the system is the Belfast intensifier (below) which has been tested exhaustively. Basically it consists of a low-pressure piston which drives a small diameter ram into a high-pressure cylinder.

The intensification ratio, ignoring an allowance for seal friction, is given by the ratio of the area of the low-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/m² (100 000 lbf/in²) 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/m² (200 000 lbf/in²) 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/m² 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. ($\frac{3}{8}$ × $\frac{1}{8}$ in) and 9·5 mm o.d. × 1·6 mm o.d. ($\frac{3}{8}$ × $\frac{1}{16}$ in), of 12% chromium steel with an ultimate tensile strength of about 0·8 GN/m² (50 tonf/in²), and 19·0 mm o.d. × 1·6 mm i.d. ($\frac{3}{4}$ × $\frac{1}{16}$ 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/m² (80 000 lbf/in²) and 0·9 GN/m² (130 000 lbf/in²) respectively. The compound tube is used for 1·4 GN/m² (200 000 lbf/in²).

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/m² (200 000 lbf/in²) and there are cases where it has to withstand pressure in either direction.

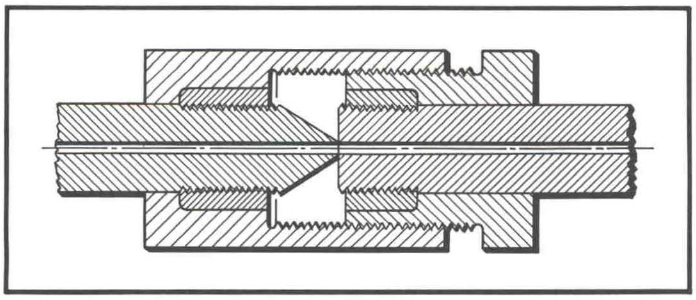
As high-pressure equipment should be housed in a safety enclosure it is desirable for the valve to be remotely controlled.

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.

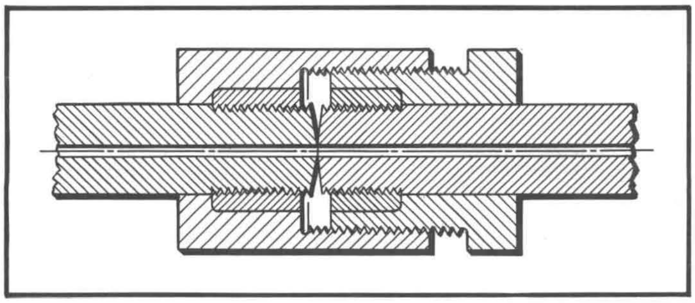
The screw jack can be operated through a long, small-diameter flexible rod or cable. The valve is relatively complicated and consequently expensive, but it operates satisfactorily and can be used like a needle valve to give small adjustments of pressure. A much simpler and cheaper manual spill valve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

Sensor. Finally, a pressure sensor is

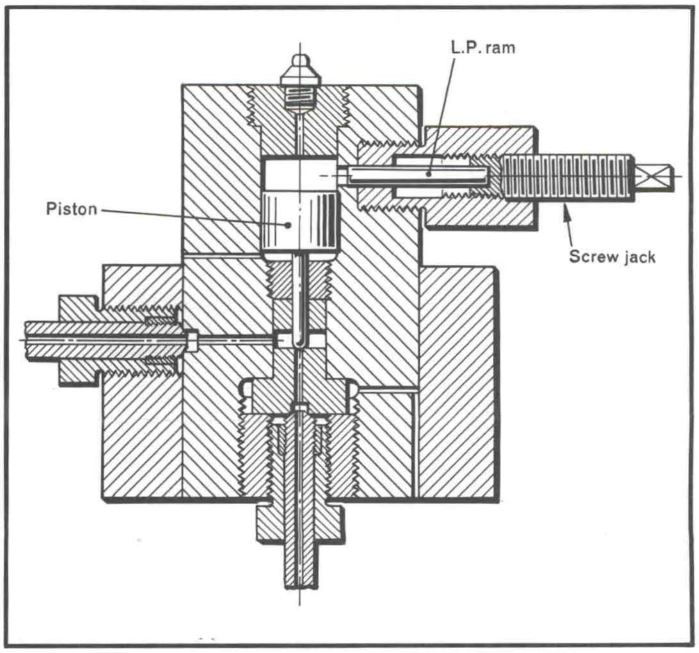
A 60° coned pipe joint



Shallow angle pipe joint



High-pressure valve



required. A manganin sensor, shown below has been developed in which either the manganin coil is exposed to the test fluid, or alternatively it is housed in a flexible bellows subjected to the pressure and contains a fluid which is compatible with the coil and the electrical seals, and which is not electrically conductive.

This sensor can be used with a direct-reading bridge specially developed for the purpose. Alternatively it can be used with a potentiometric indicator/controller, or the output can be presented in a digital form.

The manganin sensor, if calibrated against a deadweight pressure tester, can form a good secondary standard, but there are problems of temperature stability even with the most carefully selected manganin wire. If the pressure is raised or lowered rapidly the gauge could be in error.

However an alternative wire with much better temperature coefficient of resistance change has recently been developed which overcomes this problem, and can be used as a control element. Alternatively a temperature compensated strain gauge transducer has been developed which can also be used for control.

Automatic. The high-pressure components have been built up into an automatic intensifier set. The layout is shown diagrammatically below.

Low pressure oil, at 70 MN/m² (10 000 lbf/in²) is provided by a pumping set such as the Enerpac motorized pump or a Towler Brothers set, which is connected to the intensifier by a flexible high-pressure hose.

The pump delivers through a solenoid-operated valve to the low-pressure end of the intensifier. If the desired or set pressure is not achieved in a single stroke, the tell-tale attached to the intensifier piston operates a microswitch which controls the solenoid operated changeover valve.

This connects the pump to the inlet valve of the high-pressure end of the intensifier, if necessary through a transfer cylinder if the high and low pressure fluids are different. At the same time the low-pressure end of the intensifier is connected through the changeover valve to reservoir. When the intensifier is recharged the tell-tale operates a second microswitch which resets the solenoid operated valve.

Digital pressure indicator/controller with electrical control unit

When the preset pressure has been reached the high pressure sensor switches off the pump motor via the digital controller. Alternatively, control can be achieved by using a low-pressure gauge on the pump, calibrated against the high-pressure output and equipped with electrical contacts to switch off the motor. Yet another alternative is to have a pressure control valve in the low-pressure circuit set to give the desired high pressure.

Safety valve. A safety valve is provided in the low-pressure circuit close to the intensifier in case the inlet ball valve should fail, and also to ensure that the low-pressure pumping set cannot be overloaded. A remote-action or manually-controlled spill valve is provided in the high-pressure system.

The high-pressure connexion to the intensifier set is through a cross piece, and it is possible to bring the connecting tube out of the set in any one of three directions which are at right angles to each other.

It is also possible to use pneumatics to control the intensifier and such a system has, in fact, been designed.

In addition to this intensifier system various items of high pressure equipment such as viscometers, a thick-walled cylinder creep machine, compression tester for rock samples, and a torsion machine have been developed and can be used in conjunction with the intensifier.

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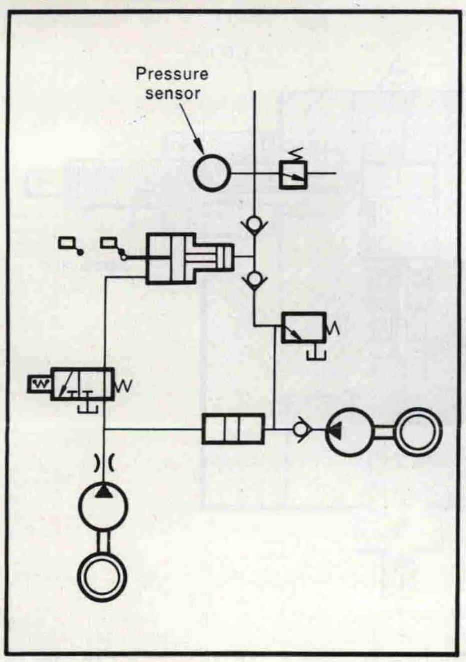
Diagrammatic layout of complete unit



Manganin pressure sensor