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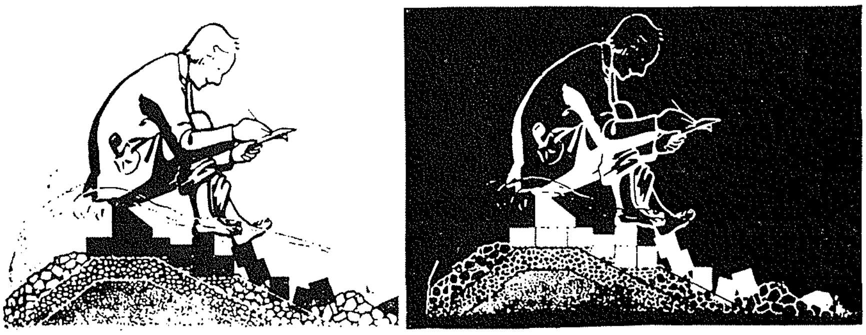

LE COIN DU LABORATOIRE

A PULSATING WATER TUNNEL FOR RESEARCH IN REVERSING FLOW

BY H. R. A. DEDOW *

Introduction

A research facility consisting of a large pulsating water tunnel which permits the study of phenomena in controlled reversing flows has been designed and constructed at the Hydraulics Research Station of the Ministry of Technology at Wallingford, England. The tunnel was required in the first instance to assess at full scale the lift and drag forces acting on a pipeline at the sea bed. Because this investigation was urgently requested by B.P. Trading Ltd., the tunnel had to be designed and constructed in only a few months using materials and techniques available at short notice.

Oscillatory flows with a peak discharge up to 75 ft³/s at a velocity of 6 ft/s can be reproduced in the test section, and a continuous uni-directional flow up to 25 ft³/s at a velocity of 2 ft/s can be superimposed on the pulsating flow. The period of pulsation may be varied, and for the pipeline experiments has been set at 8 s.

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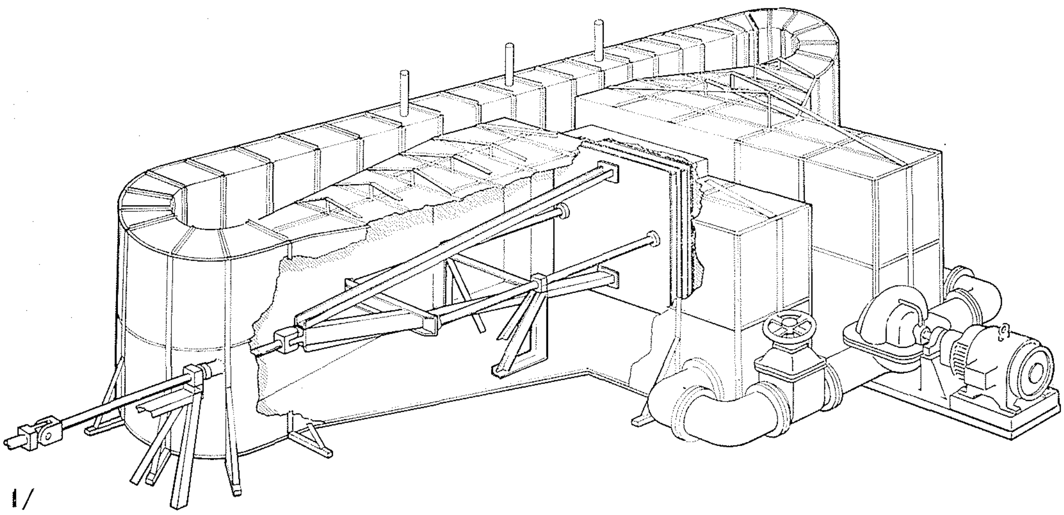
Description of tunnel

The tunnel, which is illustrated by Figures 1, 2 and 3, is constructed from welded steel frames and aluminium alloy cladding in the form of a closed horizontal loop. The dimensions of the straight test section are 20 inches wide by 7,5 ft high by 30 ft long. The mean radius of the bends is 4 ft, and the piston chamber is 6.25 ft high by 6.25 ft wide. The piston has a maximum working stroke of 5 ft which produces a displacement of water in the test section of 15½ ft.

The piston is constructed from aluminium alloy channel and plate in the form of a flat box with 6.23 ft sides and 1 ft thick. The internal cavity contains inflated rubber tubes which reduce the submerged weight to zero. Rigidly attached to the piston are two stainless steel guide rods which slide in four guide bearings. A nominal clearance of 0.25 inches exists between the piston and the walls, floor and roof of the piston chamber. This clearance eliminates expensive construction and machining of the chamber and piston, and reduces the required accuracy in alignment of the guide bearings, piston and chamber.

A centrifugal pump with a capacity of 25 ft³/s is connected across the piston chamber, and permits a continuous flow of water to be circulated around the tunnel loop.



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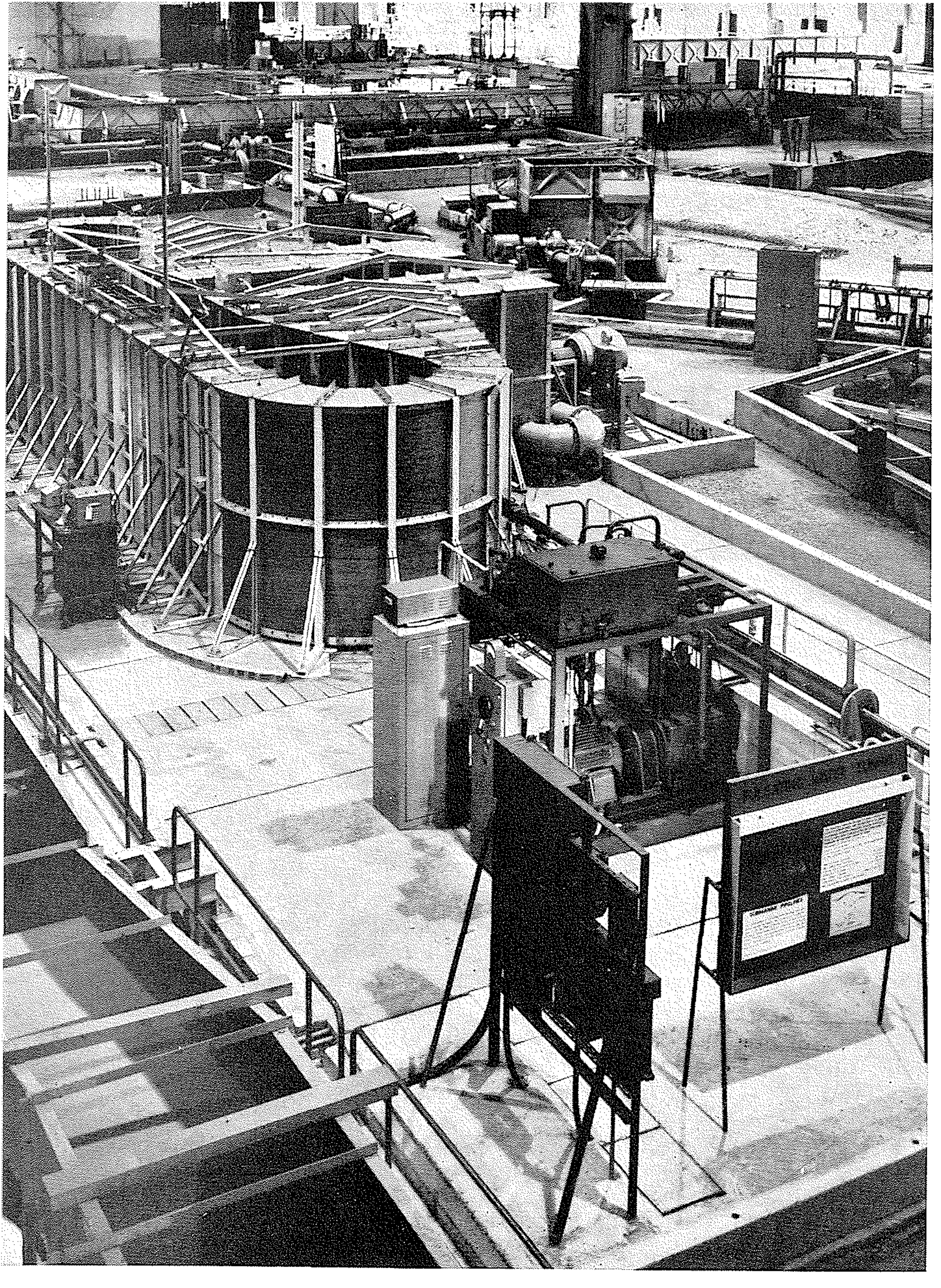
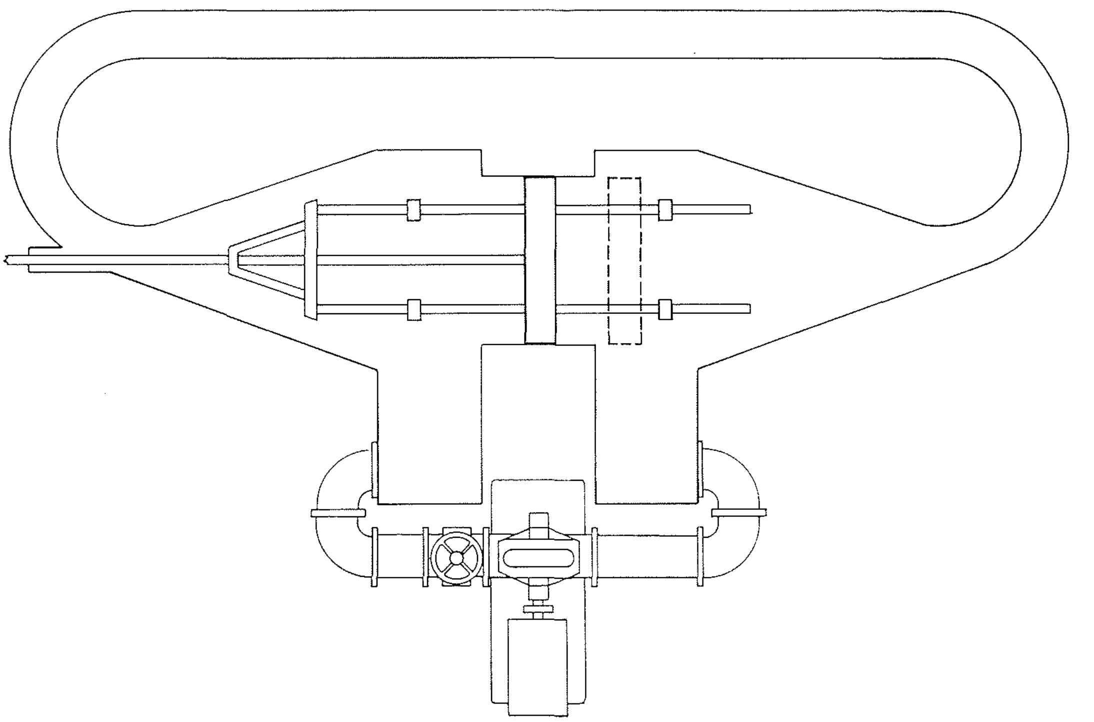
Control equipment

The piston is driven by a power ram whose movement is regulated by a closed loop electronic and hydraulic position-control system. This equipment was designed and constructed to the required



2/ General view of tunnel and control equipment.

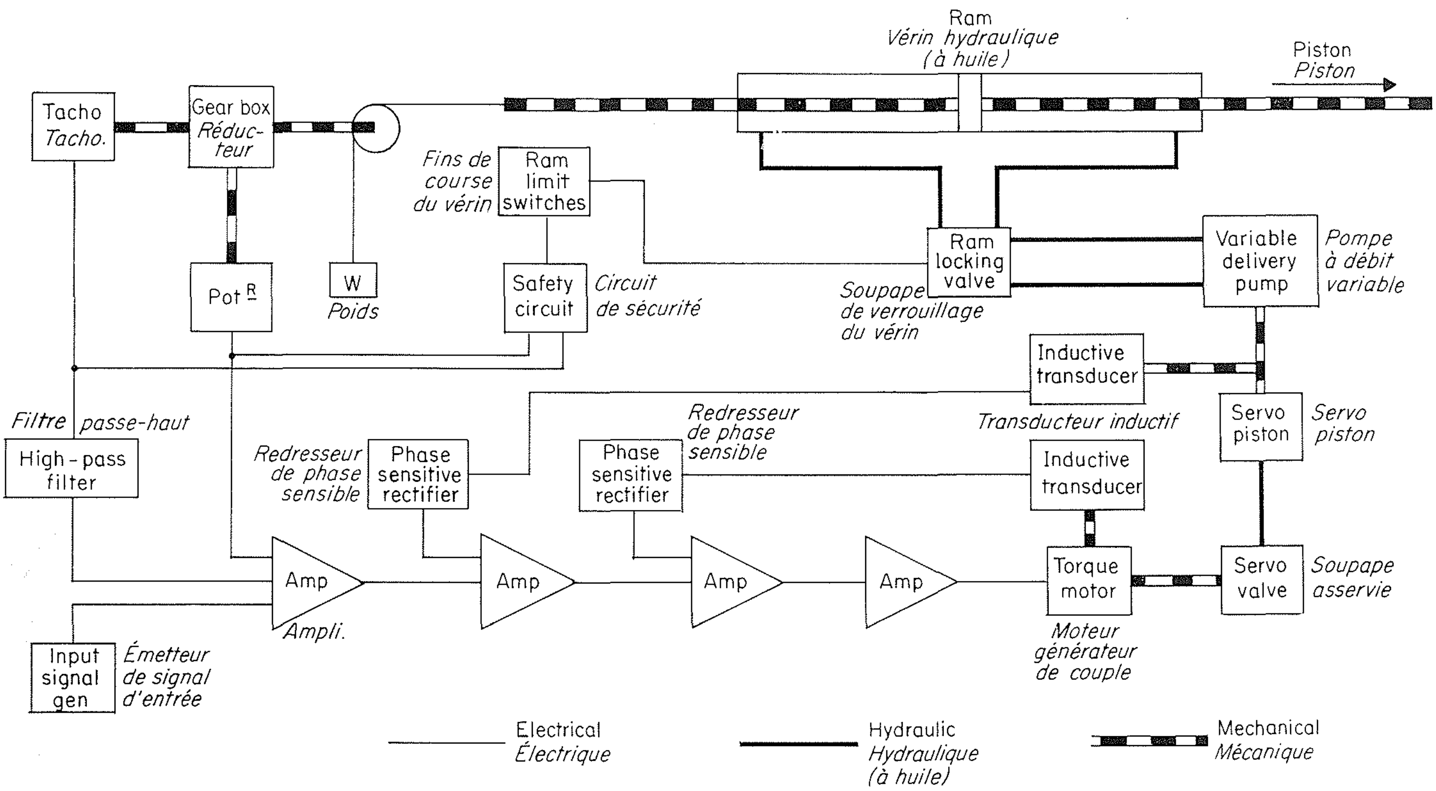
Vue d'ensemble du tunnel et de ses appareils de contrôle et de commande.



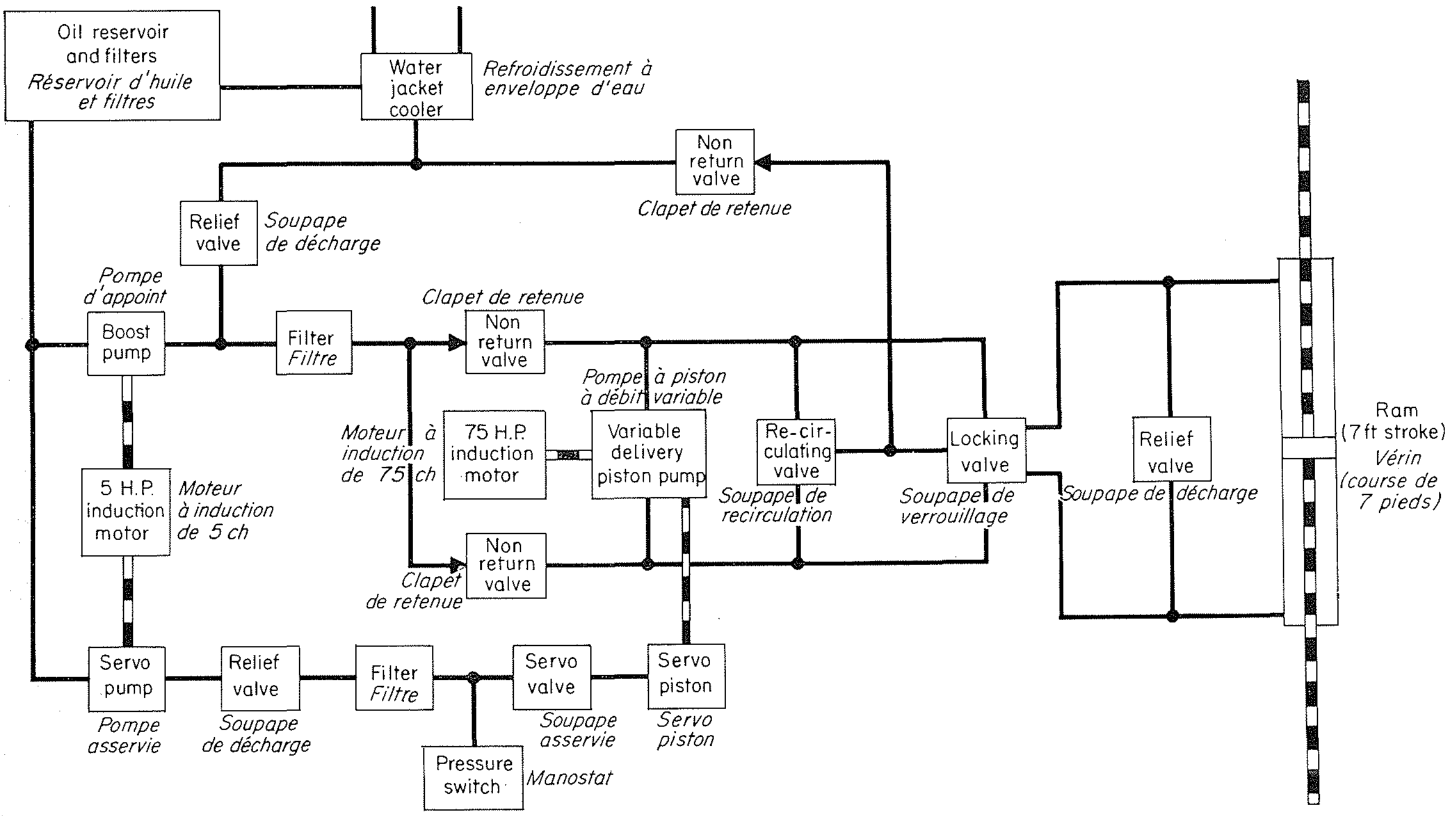
3/ Schematic plan.

Plan schématique.

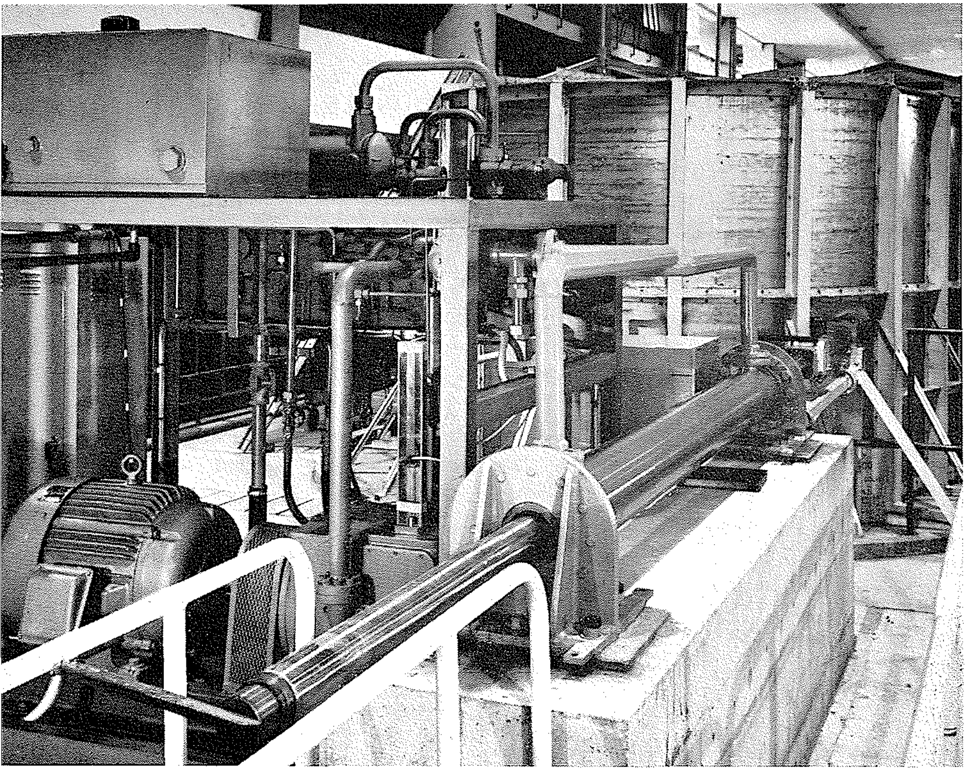
specification by Keelavite Hydraulics Ltd., of Coventry, England, and has functioned very satisfactorily. The basic elements of the control system are shown in Figure 4 and follow the general practice of a power ram system. The tacho-generator feedback through the high-pass filter provides damping of resonances in the main control loop arising from the high inertia of the water in the tunnel. The basic hydraulic circuit is shown in Figure 5 and illustrated by Figure 6.



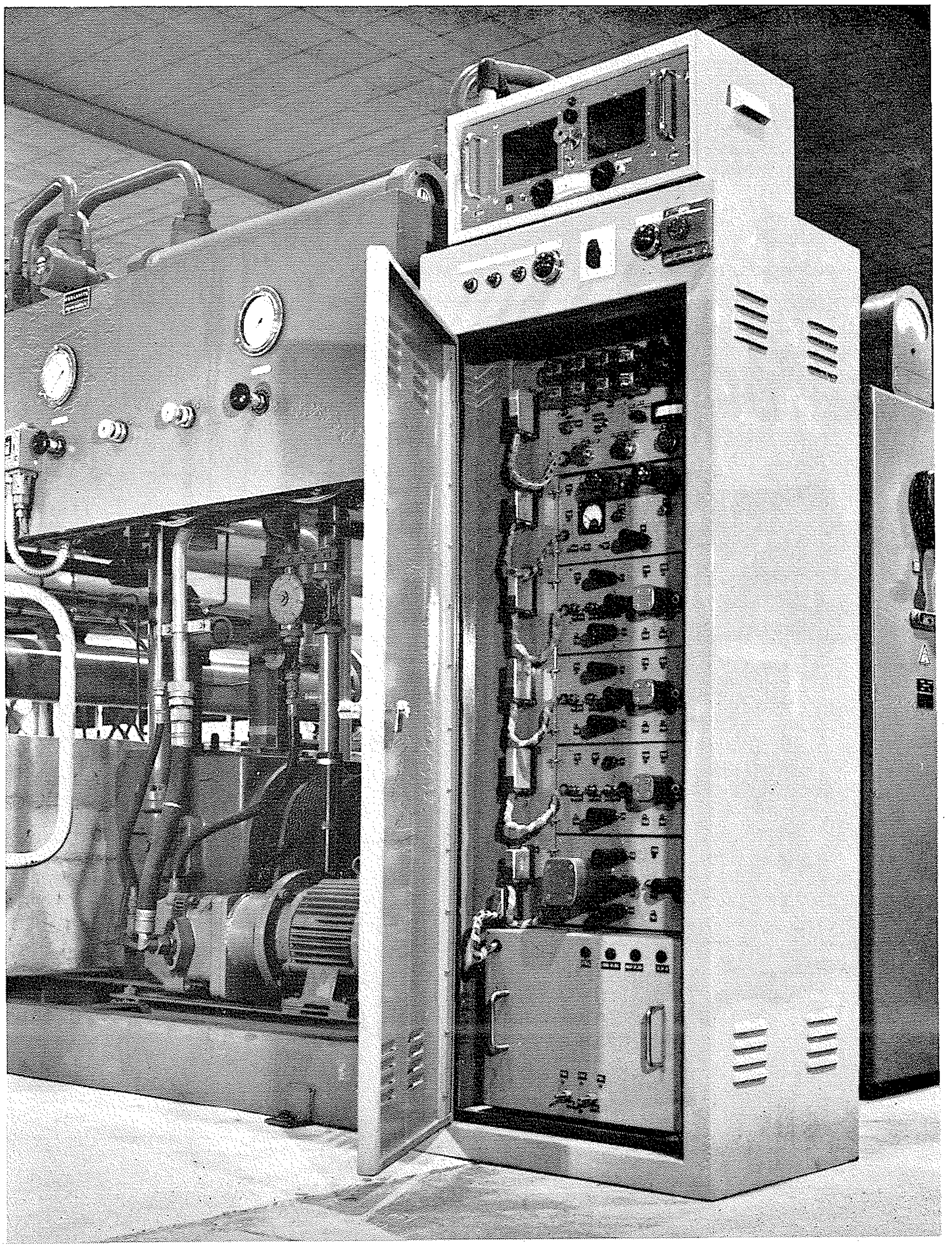
4/ Basic control circuit / *Circuit de commande de base.*



5/ Basic hydraulic circuit / *Circuit hydraulique de base.*



6/ Hydraulic control system.
Ensemble de commande hydraulique.



7/ Electronic control units.
Groupes de commande électroniques.

Limitation of internal pressures

The mass of the water when referred to the piston is 230 tons. Because the structural design of the tunnel was restricted by material availability, cost and the limited time available for design and construction, it was essential that the basic conception of the tunnel and the hydraulic and electronic control system should include precautions and protective devices to prevent the build up of destructive internal pressures due to excessive acceleration or retardation of the water. Such pressures could be created by failure of the electrical power supply at a time of high velocity, or failure of the electronic or hydraulic servo-control causing the piston to 'run away'.

A relief valve connected across the ports of the power ram limits the oil pressure so that the maximum force available at the ram is restricted to 12.5 tons. Also, the supply of oil to the ram ports passes through a solenoid-operated directional locking valve. When energised, this valve permits the oil to flow from the servo-operated variable delivery pump to the ram in the normal operating manner. When de-energised, the valve isolates the pump from the ram and blocks the pipes connected to the ram ports. These ports, however, remain connected to each other through the pressure limiting relief valve. Thus, failure of the electrical power supply de-energises the locking valve so that the energy stored in the water within the tunnel is dissipated in the relief valve by back-driving the piston and ram, and the water is brought to rest by a retardation force restricted to the same value as the maximum permitted acceleration force during normal operation.

Failure in some part of the servo-system could cause the ram and piston to move out of control, so producing destructive conditions. Such conditions are prevented by four restrictions. The first of these is the relief valve across the ram ports which limits the maximum acceleration force. The second is in the form of a safety circuit connected to the feedback tacho-generator which de-energises the locking valve if the ram velocity exceeds the maximum designed value. Finally, mechanical limit switches de-energise the locking valve if the ram passes outside its normal working stroke, and these switches are backed-up by electronic limit switches in the safety circuit.

Although the various safety devices restrict the maximum acceleration and retardation forces, maximum velocity and maximum stroke of the ram and piston, nevertheless the piston could reach the end of its normal working stroke with maximum velocity and the subsequent retardation to rest involves an appreciable additional travel. It is necessary not only to permit this additional travel, but also to restrict it to a reasonable value. Thus the total possible stroke of the piston and ram is designed to be 7 ft, allowing 1 ft of over-run at each end. To ensure that the piston comes to rest within this over-run it is arranged to pass out of the piston chamber at the end of the normal working stroke of 5 ft, so opening an increasing annulus through which the water passes to circulate around the tunnel.

Use and instrumentation

The first experiments using the tunnel have been concerned with measuring the lift and drag forces on submerged pipelines. Pipes up to 30 inches diameter with various degrees of roughness and bed clearance have been tested. For these experiments the input signal to the control system has been in the form of a sinusoid with a period of 8 seconds and provision for including up to 40 % of second harmonic. The test pipes were suspended from the side walls of the tunnel by internal cantilevers, and the lift and drag forces were measured using strain gauges. Velocity profiles above the pipe and upstream and downstream of the pipe were measured using miniature current meters, and all measurements, including ram position, were recorded simultaneously on a multi-channel ultra-violet recorder.

Acknowledgments

The provision of this research facility was initiated by Mr. R. C. H. Russell, Director of Hydraulics Research, with whose permission these details are published.

Summary of tunnel characteristics

Dimensions of piston.....	6¼ × 6¼ ft (1.9 × 1.9 m)
Maximum stroke of piston.	5 ft (1.524 m)
Dimensions of test section.	1⅔ × 7½ × 30 ft (0.508 × 2.286 × 9.144 m)
Maximum displacement in test section.	15½ ft (4.724 m)
Peak pulsating discharge.	75 ft³/s (2.123 m³/s)
Peak pulsating velocity in test section.	6 ft/s (1.83 m/s)
Maximum steady discharge.	25 ft³/s (0.708 m³/s)
Maximum steady velocity in test section.	2 ft/s (0.61 m/s)
Mass of water referred to piston.	230 tons (233,700 kg)
Maximum acceleration force.	12,5 tons (12,700 kg)