

### DESIGN FEATURES

Safety and convenience in use involving multiple precautions for safe operation while at the same time minimizing the hassles of high pressure work.

Gas pressure medium ensures an inert and strictly hydrostatic environment.

Three-zone internal furnace ensures minimal heating of the pressure vessel while permitting relatively rapid heating and cooling as well as easy control of the temperature distribution.

Internal transducers permit sensitive measurement of axial load, torque and displacement without correction for piston friction effects being required.

### SPECIFICATIONS

Confining pressure	500 MPa
Temperature	1600 K
Axial Deformation Module	
Maximum displacement	30 mm
Maximum force	100 kN
Displacement resolution	1 $\mu$ m
Force resolution	10 N
Axial strain rates (20 mm specimen length)	$10^2$ to $10^7$ s <sup>-1</sup>
Torsion Module	
Maximum displacement	no limit
Maximum torque	1000 Nm
Displacement resolution	0.001 rad
Torque resolution	0.1 Nm
Shear strain rates (15 mm diameter x 10 mm length)	$10^3$ to $10^7$ s <sup>-1</sup>
Pore Fluid Module	
Maximum volumetric displacement	1900 mm <sup>3</sup>

*Further details available on request*

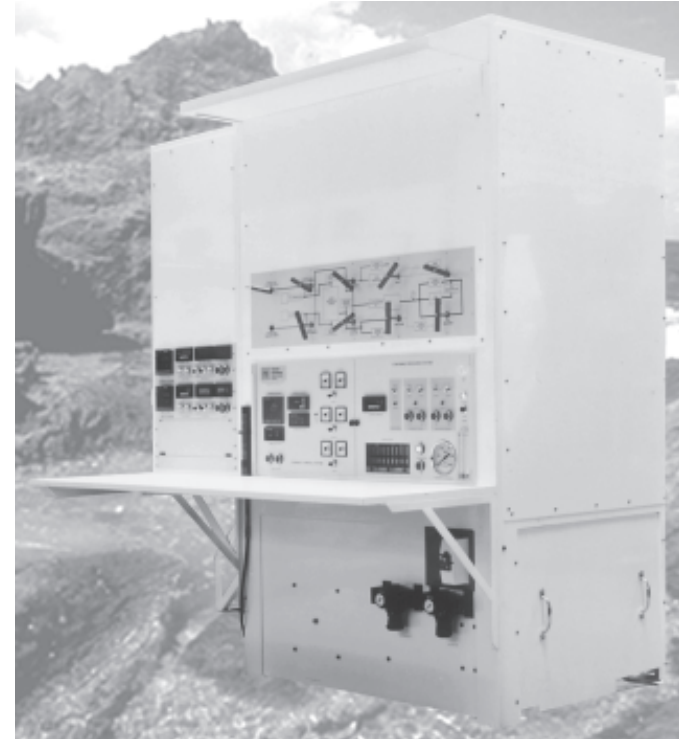
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*Specifications subject to change without notice*

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# PATERSON GAS-MEDIUM HIGH-PRESSURE HIGH-TEMPERATURE TESTING SYSTEM



For Laboratory Studies on Rocks, Ceramics, Metals, Polymers

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# HIGH-PRESSURE HIGH-TEMPERATURE (HPT) TESTING SYSTEM

The Paterson gas-medium apparatus for rock deformation studies at high pressure and high temperature was developed to a high level of sophistication by Professor Mervyn Paterson in the course of thirty years research at the Research School of Research Sciences, Australian National University. The benefit of this knowledge and experience is now available through the commercial production of the Paterson HPT Testing System and many new developments for improved performance and ease of use have been incorporated. The facility provides a basic environment of a confining pressure to 500 MPa and a temperature to at least 1600 K, to which can be added modules for:

- mechanical testing in compression/extension and torsion
- experiments involving pore fluids
- measurement of physical properties
- hot isostatic pressing (HIP) and materials synthesis
- other applications requiring a high-pressure, high-temperature environment.

## BASIC HIGH-PRESSURE HIGH-TEMPERATURE SYSTEM

### HOUSING

The housing serves both as the framework for the complete machine and as its protective shielding. Special attention has been paid to safety through the provision of adequate shielding and door locks, the use of multiwall construction for ear protection, and the minimization of the volume of gas at high pressure. The basic electrical wiring allows for the fitting of the furnace and the connection of the various testing modules at any time, including re-fitting.

### PRESSURE VESSEL AND PUMPING SYSTEM

The duplex steel cylinder, with axis vertical, has a working volume of 65 mm diameter and 360mm length. The outer soft steel safety sleeve incorporates cooling coils. With a solid-ceramic-insulated furnace and internal load cell fitted, the free volume is about 200 ml. The cylinder is tested to 700 MPa and intended for routine use to 500 MPa. Two-stage pumping is provided by a gas booster pump and a 10:1 intensifier. Control facilities enable the pressure to be maintained automatically or programmed as required. Rupture disks are fitted to prevent accidental over-pressuring of the different stages of the pumping system and door interlocks prevent pump-



Pressure vessel and axial loading column

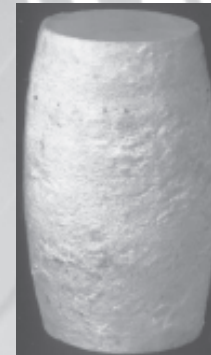
ing to high pressure with the safety doors open. A bubbler system is provided for quick location of any leaks from the O-ring seals in the high-pressure system.

### FURNACE

The internal furnace permits relatively rapid heating and cooling while maintaining the pressure vessel walls close to ambient temperature. The top closure plug of the pressure vessel is fitted with electric feed-throughs for windings and thermocouples. The specimen assembly can be inserted or removed without disturbing the furnace. The standard internal furnace has three molybdenum windings to provide a uniform high temperature zone of 21 mm diameter and 50 mm length. An alternative furnace of 27 mm internal diameter is also available. A Eurotherm self-tuning programming controller permits control from a selected thermocouple, while a separate temperature indicator independently monitors all thermocouples. The current in each winding can be adjusted so as to achieve any desired temperature distribution in the furnace, as monitored with an externally-controlled traversing thermocouple. Current and voltage meters for each winding are fitted.

## AXIAL DEFORMATION MODULE

This module permits mechanical tests to be carried out in both compression and extension under rate, force or displacement control. The bottom closure plug of the pressure vessel is furnished with a pressure-compensated piston for applying the axial load, the magnitude of which is measured with an internal load cell to avoid friction effects. The internal load cell is of a specially-designed type for use at high pressure. The piston displacement is monitored with an internal LVDT and there is access through the bore of the piston for electrical and pore fluid connections. An external load cell is also fitted. The servocontrolled electromechanical actuator of 100 kN capacity is connected to the loading piston. The maximum rate of advance is around 1 mm per second and the minimum around 0.01 mm per hour.

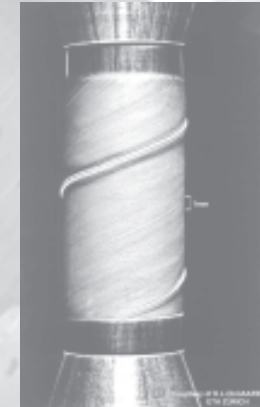


Marble specimen deformed in compression

## TORSION TESTING MODULE

Large shearing strains and shear localization phenomena, which are of great geological interest, can be studied in torsion tests. Also, with the simultaneous application of an axial load, all three principle stresses can be varied independently for fully determining rheological laws. Thus torsion testing, added to the axial deformation facility, greatly extends the range of deformation experimentation. The module consists of an actuator, internal and external torque cells, a rotary displacement transducer, calibrating bars, specimen assembly components, and a control system. Solid specimens of up to 15 mm diameter can be accommodated in the standard furnace. To reduce ambiguities associated with the strain gradient in solid specimens, hollow specimens of 22 mm outside diameter and 16 mm inside diameter can alternatively be used in a special furnace of 27 mm bore. There is no limit to the amount of twist that can be applied, the strain being limited only by the ductility of the specimen jacket, which experience shows can be large.

The servocontrolled electromechanical actuator applies torque to the top of the specimen assembly, while the axial actuator acts on the bottom. The maximum torque is 1000 Nm and the rates of twist can be varied over a range corresponding to strain rates from around  $10^{-3}$  to  $10^{-7}$  s<sup>-1</sup>.



Jacketed marble specimen deformed in torsion

## PORE-FLUID MODULE

The pore-fluid module consists of a volumeter of 2000 mm<sup>3</sup> capacity driven by a servocontrolled electromechanical volumometer. It is suitable for argon or water at pressures up to 500 MPa, and is fitted with pressure and displacement transducers. The volumometer can be operated at constant displacement rate or with pressure or displacement control. It can be used in conjunction with axial or torsion testing, or independently. A downstream pressure transducer is also fitted.

## PHYSICAL PROPERTIES MEASUREMENT AND OTHER APPLICATIONS

The high-pressure, high-temperature facility also lends itself to the measurement of physical properties and to other applications such as hot isostatic pressing (HIP). Electrical connections can be made through the top end of the specimen assembly, and a special bottom closure plug can be provided for an additional eight or more electrical feedthroughs to the bottom end of the specimen assembly. The bottom feedthrough connections are flexibly mounted so that no axial force is generated in the specimen assembly from its compression and thermal expansion. Thus complex measurements such as those of thermal properties, seismic wave speeds, permeability etc are possible. Enquiries regarding specific requirements are welcome.

## ACTUATORS, CONTROLS AND DISPLAYS

Electromechanical actuators are used for each of the testing modules. The actuators can be operated under manual speed control with tachogenerator feedback, or from Eurotherm programmable process controllers with feedback from either force-type or displacement transducers. The alternative of external servocontrol, if desired, is provided for. All parameters are displayed on meters and are available at 10 V level for external use. Arrangements for data-logging, and for any external control, are to be supplied by the user.