

WF *Wykeham Farrance* *Since 1941*
PIONEERS IN ADVANCED SOIL TESTING



Soil Mechanics Testing Systems

SOIL MECHANICS TESTING SYSTEMS



ESTABLISHED IN 1941

In all sections of civil engineering and particularly in soil mechanics, the engineer during the design stage must ensure that the analysis of soil properties relate directly to the relevant foundation or structure. Using procedures involving extracting, examining and testing representative samples the engineer can compute a model very close to the real situation. In recent years we have seen a significant contribution to experimental analysis resulting from more sophisticated testing procedures, updating of many International Standards and publication of good testing manuals and procedures.

WYKEHAM FARRANCE is one of the longest established manufacturing companies in the world of Geotechnical Testing Systems. It has always been synonymous with high technology and quality. A close working relationship with several premier Universities in Europe ensures a flow of new ideas for development of new testing techniques and systems.

WYKEHAM FARRANCE was originally formed in 1941 by Geoff Wykeham and Geoff Farrance. The original company is now part of the CONTROLS GROUP as the Soil Mechanics Division.

This alliance and synergy, the international network of companies, groups and distributors provide complete customer service and technical advice including planning, installation, training and maintenance for all types of laboratories.

Wykeham

SOIL MECHANICS TESTING SYSTEMS

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SOIL MECHANICS TESTING SYSTEMS

Research and Development Advanced testing from Wykeham Farrance

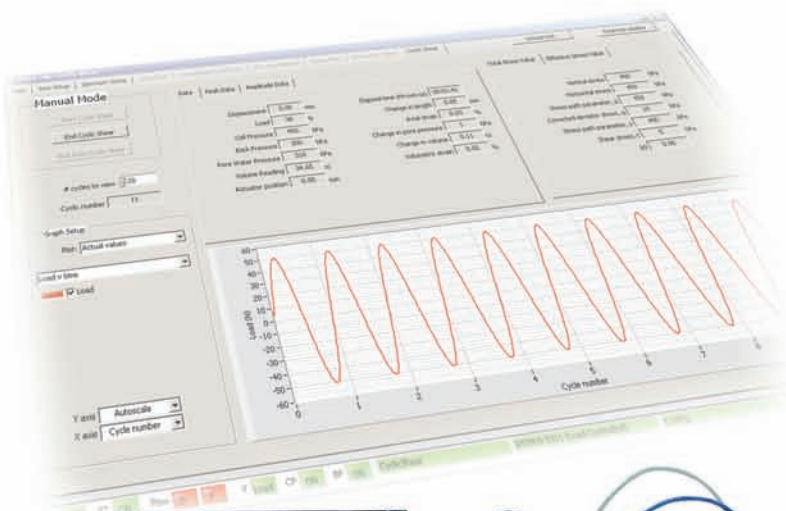
To design foundations, embankments and other soil structures, Geotechnical Engineers require methods of assessing the engineering properties of soils. For over 60 years Wykeham Farrance has been at the forefront of the development of test systems designed to give engineers the information they require.

Some of the more complex phenomena that occur in soils have often been difficult to recreate in the laboratory: seismic activity, vibration, unsaturated condition, control of principal stresses etc. are areas which have proven difficult to replicate, despite their importance being understood.

DYNATRIAX

Cyclic/Stress Path Triaxial System

To investigate the effects of cyclic loading such as earthquakes, ocean waves, traffic, etc.



This was partly due to the lack of test systems capable of reproducing these effects and the complexity of test systems that were developed to carry out such work.

A number of advanced computer/software controlled systems allow the geotechnical engineer to perform the most complex test regimes via a user-friendly software interface.

Farrance

AUTOTRIAX

Automatic stress path triaxial system with hydraulic pressure controllers for pressures up to 3500 kPa

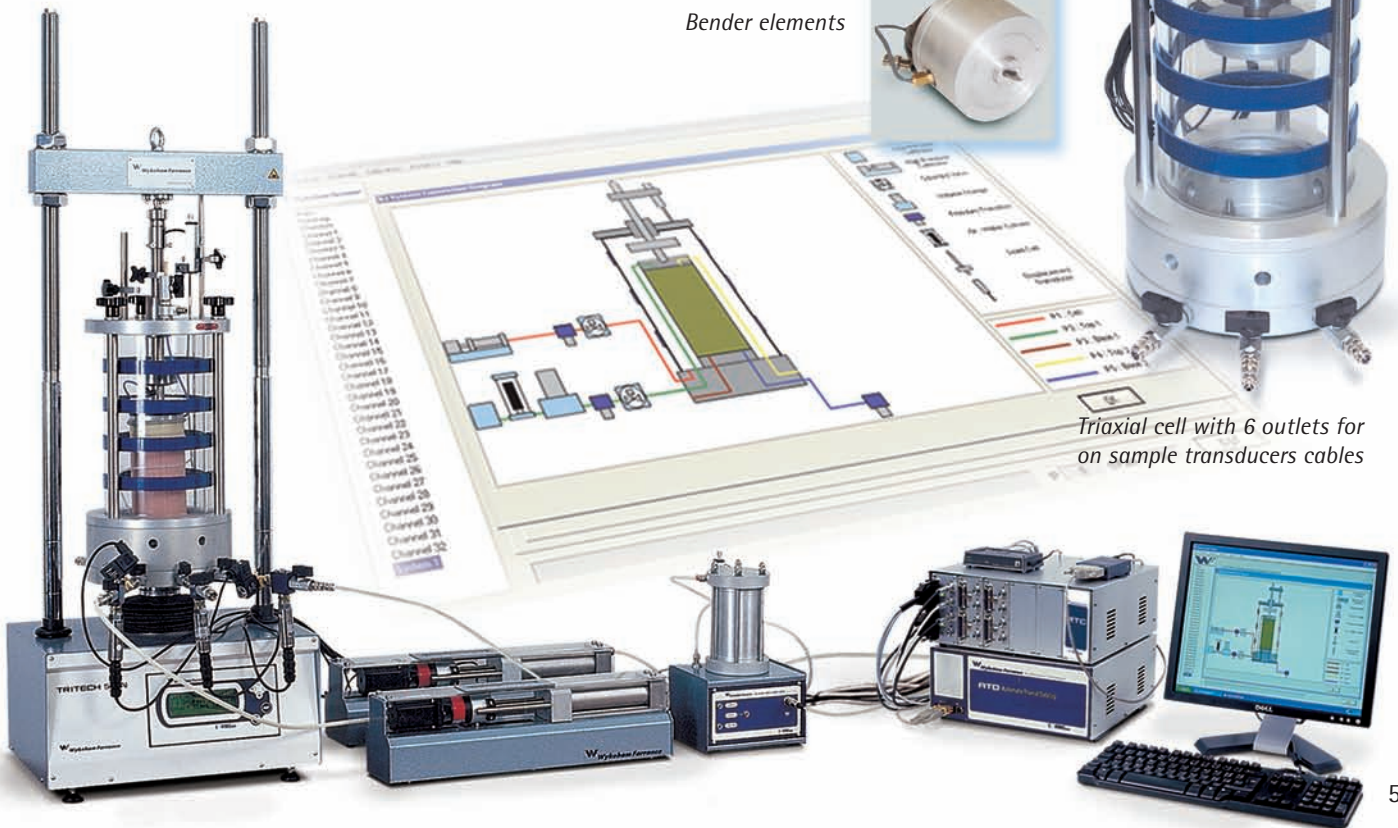
On sample transducers for axial and radial strain



Bender elements



Triaxial cell with 6 outlets for on sample transducers cables



SOIL MECHANICS TESTING SYSTEMS

The International Network. A total “Service” System

The worldwide distribution network is provided by the companies of the **CONTROLS GROUP** which cover the world market.

All of them provide a complete service to the customers including after sales, calibration service and technical-commercial cooperation.

Wykeham

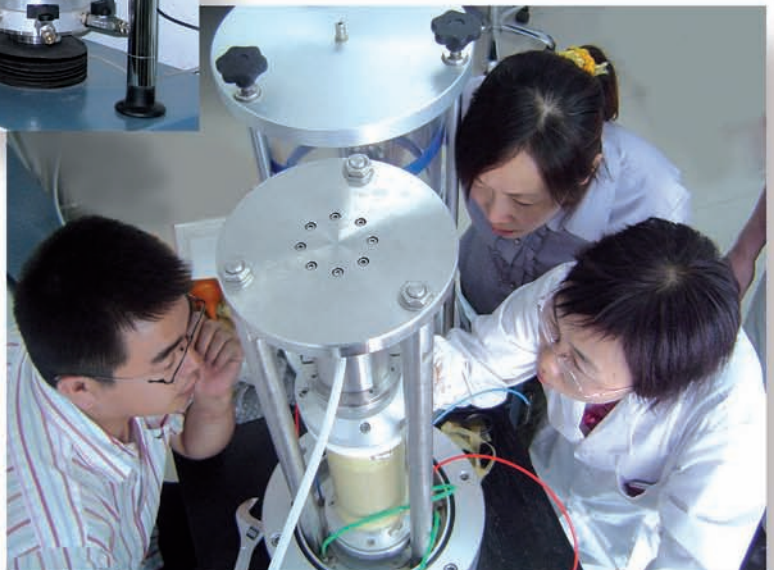
The Service

A group of experienced professionals who are capable of repairing and installing the machines, and also to suggest the best laboratory set up and train laboratory technicians



On-site training

Our team of skilled professionals are available to carry out intensive on-site training



Front loading oedometers

Introduction

This test determines the rate and magnitude of consolidation of a soil specimen restrained laterally and subjected to a number of successive increments of vertical loads. This measure is a requirement of the foundation, road and soils engineer.

FRONT LOADING OEDOMETERS

STANDARDS

BS 1377:5 / ASTM D2435, D3877, D4546 / AASHTO T216 / NF P94 090-1, P94 091 / UNE 103-405, 103-601, 103-602 / CEN-ISO/TS17892-5

26-WF0302

Front loading oedometer

General description and specifications

The oedometer consists of a rigid aluminium alloy frame to avoid any distortion under load. The lever arm assembly is supported in precision self-aligning bearings and has three hanger positions: 9:1, 10:1, and 11:1 ratio.

Max. loading using 11:1 beam ratio:

1848 kg corresponding to 9.061MPa (92.40 kgf/cm²) on 20 cm² specimen (Ø 50.47 mm)

Dimensions: 500x200x750 mm (height less hanger x width x length)

Weight approx.: 21 kg



26-WF0320 – 26-WF0337



- Compact and robust design
- 3 lever arm ratio
- Screw-jack support

Three oedometers 26-WF0302, complete with cell, 30-WF6210 displacement electronic transducer⁽¹⁾ connected to 30-WF6016 GEODATALOG, and 26-WF0312 consolidation bench. (1) As alternative to the standard dial gauges connected to the data acquisition and processing system.

CONSOLIDATION CELLS / FIXED RING AND PERMEABILITY

General description and specifications

The fixed ring models are open to the atmosphere, which permits the saturation of the sample, whereas in the permeability cell model, the sample and the saturating water are sealed from the atmosphere. Complete with reservoir, hose connection, upper and lower porous discs, pressure pad and stainless steel sample cutting collar.

Accessories

- ▶ **26-WF0338/A** Permeability attachment with 50 ml graduated burette. Complete with clamps, stand and rubber hose for connection to the permeability cell. Weight 4 kg
- ▶ **30-WF6401** Dial gauge 10 mm travel x 0.002 mm subdivision, anticlockwise rotation
- ▶ **26-WF0312** Oedometer bench to accept up to 3 oedometers. Supplied complete with locking nuts

note

The oedometer is supplied without dial gauge, (or linear transducers) consolidation cells and weights, which have to be ordered separately. See consolidation cells and accessories next page.



26-WF0338/A fitted to the 26-WF0302 with 26-WF0320

CONSOLIDATION CELLS

Fixed ring ⁽¹⁾ Code	Specimen dia.	Specimen area	Specimen height	Cell dim. dia. x height	Cell weight
26-WF0320	50.47 mm	20 cm ²	20 mm	139x74 mm	1.3 kg
26-WF0321	63.50 mm	31.67 cm ²	20 mm	139x74 mm	1.3 kg
26-WF0325	71.40 mm	40 cm ²	20 mm	139x74 mm	1.3 kg
26-WF0326	75 mm	44.16 cm ²	20 mm	139x74 mm	1.3 kg
26-WF0335	112.80 mm	100 cm ²	25 mm	200x74 mm	3.0 kg

Spare parts for standard and permeability cells

Cell codes	26-WF0320	26-WF0321	26-WF0325	26-WF0326	26-WF0335
	26-WF0322	26-WF0323	26-WF0327	26-WF0328	26-WF0337
Size	20 cm ²	31.67 cm ²	40 cm ²	44.16 cm ²	100 cm ²
Upper porous disc	26-WF0320/4	26-WF0321/4	26-WF0325/4	26-WF0326/4	26-WF0335/4
Lower porous disc	26-WF0325/10	26-WF0326/10	26-WF0325/10	26-WF0326/10	26-WF0335/10
Cutting ring	26-WF0320/3	26-WF0321/3	26-WF0325/3	26-WF0326/3	26-WF0335/3
Accessories					
Calibration disc	26-WF0320/9	26-WF0321/9	26-WF0325/9	26-WF0326/9	26-WF0335/9

(1) Suitable for permeability tests

WEIGHT APPLICATION GUIDE

Cell model	26-WF0320 – 26-WF0322	26-WF0321 – 26-WF0323	26-WF0325 – 26-WF0327	26-WF0326 – 26-WF0328	26-WF0335 – 26-WF0337
Beam ratio ⁽¹⁾	1:10	1:11	1:10	1:9	1:10
Max. pressure	32 kg/cm ² 64 kg/cm ²	20 t/ft ² 40 t/ft ²	16 kg/cm ² 32 kg/cm ²	16 kg/cm ² 32 kg/cm ²	8 kg/cm ² 16 kg/cm ²
Weight set 26-	WF0230/C2 WF0230/C2	WF0230/C2 WF0230/C2	WF0230/C2 WF0230/C2	WF0230/D2 WF0230/D2	WF0230/D2 WF0230/D2
Add. weights 27-	- 8 x WF0275/A	- 8 x WF0275/A	- 8 x WF0275/A	- 8 x WF0277/A	- 8 x WF0277/A
Total weight kg	64 128	64 128	64 128	80 160	80 160

(1) Hanger position on the oedometer lever arm

SLOTTED STEEL WEIGHTS

Code	Weight
27-WF0270/A	0.250 kg
27-WF0271/A	0.500 kg
27-WF0272/A	1 kg
27-WF0273/A	2 kg
27-WF0274/A	4 kg
27-WF0275/A	8 kg
27-WF0276/A	5 kg
27-WF0277/A	10 kg



Slotted steel weights

WEIGHT SETS

26-WF0230/C2 Including	26-WF0230/D2 Including
2x0.250 kg	2x0.250 kg
1x0.500 kg	3x0.500 kg
1x1 kg	1x1 kg
1x2 kg	1x2 kg
1x4 kg	-
7x8 kg	-
-	3x5 kg
-	6x10 kg
Total 64 kg	Total 80 kg

Accessories for data processing

- 30-WF6016 GEODATALOG, 16 channels data acquisition unit. 110–240 V, 50–60 Hz, 1ph. supplied complete with DATACOMM software for PC data acquisition (see description on page 62)
- 30-WF6016/T1 Consolidation Geo-Analysis template BS
- 30-WF6016/T8 Consolidation Geo-Analysis template ASTM

- 30-WF6207 Linear potentiometric transducer, 10 mm travel
- 30-WF6042 Transducer extension cable, 6 m long
- 30-WF6044 Transducer extension cable, 12 m long



GEODATALOG 30-WF6016

Continuous consolidation apparatus

CONTINUOUS CONSOLIDATION APPARATUS

STANDARDS
ASTM D4186

26-WF0360**Continuous consolidation apparatus for CRS* tests**

*CRS = Constant Rate of Strain



26-WF0360 with accessories

Main features

- Designed to perform continuous consolidation tests in conjunction with a traditional compression machine generally used for triaxial tests
- Double chamber cell, so that two different and independent water pressures can be applied
- Pore pressure measured at the base of the specimen with a pressure transducer
- Drainage connected to the top of the specimen for consolidation
- The apparatus requires a pressure system and data acquisition

Advantages

- Continuous monitoring of test parameters (axial load, pore pressure, axial compression) and detailed plotting of the consolidation curve
- Relatively short time to perform the test (less than half the time of a traditional consolidation test, incremental loading type)
- More accurate and reliable evaluation of consolidation and compressibility parameters
- Particularly suitable for cohesive saturated soils.

Specifications

Specimen size: 25.4x63.5 mm (hxdia.)

Max. working pressure: 1000 kPa

Max. piston load: 50 kN

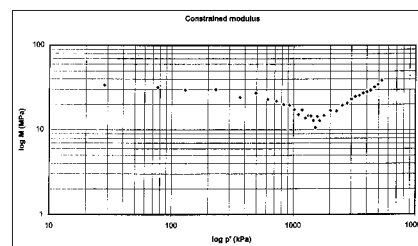
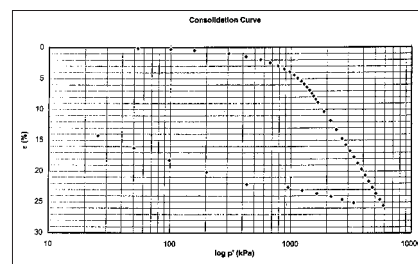
Max. height: 410 mm approx.

Max. length: 240 mm approx.

Weight approx.: 10 kg

Accessories

- ▣ 26-WF0360/1 Cutting ring and accessories for preparation of CRS sample



Some diagrams obtained from the data processing program

Accessories for data processing

- ▣ 30-WF6016 GEODATALOG, 16 channels data acquisition unit. 110-240 V, 50-60 Hz, 1ph. supplied complete with DATACOMM software for PC data acquisition (see description on page 62)
- ▣ 30-WF6016/T6 CRS consolidation testing Geo-Analysis template

CONFIGURATION OF A COMPLETE SYSTEM

Code	Description	Q.ty
26-WF0360	Continuous consolidation apparatus	1
26-WF0360/1	Cutting ring	1
28-WF0490	Nylon tubing 6x4 mm dia.	1
28-WF4330	Triaxial panel two-way	1
28-WF4330/2	Digital pressure gauge for 28-WF4330	1
28-WF4320	Bladder air/water interface	2
28-WF4320/1	Spare bladders for 28-WF4320	1
28-WF4005	Triaxial load frame 50 kN	1
30-WF4459	De-airing block	1
28-WF6301	Pressure transducer 0-20 bar	1
30-WF6207	Linear potentiometric transducer 10 mm travel	1
30-WF0375/T	50 kN capacity strain gauge load cell	1
28-WF4220	De-airing tank, 7 litres capacity	1
28-WF0491/2	Water trap	1
28-WF4225	Valve panel for de-airing tank	1
28-WF2001	Portable vacuum pump	1
28-WF2064	Rubber tube	1
28-WF2015	Laboratory air compressor	1
28-WF0490	Nylon tubing 4 mm bore x 6 O.D.	1
30-WF6016	GEODATALOG, 16 channels data acquisition unit	1
30-WF6016/T6	CRS Geo-Analysis template	1
30-WF6044	Transducers extension cable, 12 m	3

Introduction

The Hydrocon series overcomes the complexity usually associated with hydraulic oedometers and allows more information to be gathered from the soil sample.

Pore water pressure is measured using a pressure transducer and vertical settlement using a linear strain transducer. The chamber consolidation pressure may also be measured with a pressure transducer if required or with a standard pressure gauge.

The coefficient of consolidation may be directly computed from constant gradient tests without the need for curve fitting techniques.

As the Hydrocon is a confined consolidation system, it is possible to measure both pore and back pressure during testing. In addition it is also possible to make accurate permeability measurements.

■ 26-WF0345

Hydrocon hydraulic consolidation device for 100 mm dia. samples

General description

The Hydrocon is supplied complete with three valves, one porous base disc and one top loading porous discs. The cell is manufactured from anodised light alloy and has three support legs for stability.

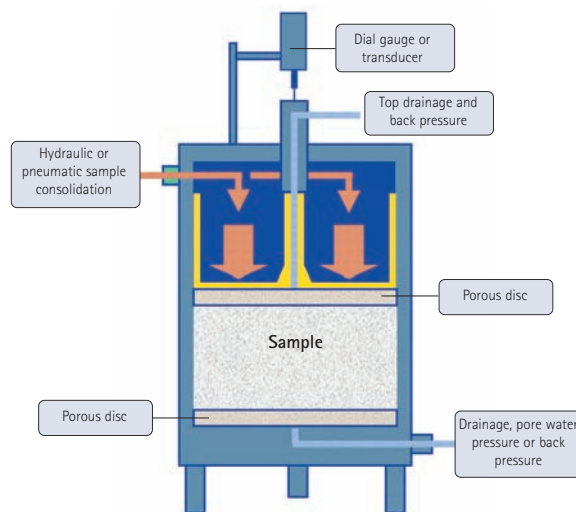
📏 **Overall dimensions** (dxh): 260x450 mm

⚖️ **Weight approx.:** 10 kg



26-WF0345 with transducer

- Hydraulic loading
- Low friction design
- No weights required
- Compact design occupies less space than conventional oedometers
- Possibility of automatic data acquisition
- Incremental or constant rate of loading tests
- Suitable for compacted clay
- Maximum pressure 3500 kPa



28-WF4330

CONFIGURATION OF A COMPLETE SYSTEM

Code	Description	Q.ty
26-WF0345	Hydrocon consolidometer	1
30-WF6401	Dial gauge 10 mm travel x 0.002 mm subdiv.	1
28-WF4400	Double burette volume change apparatus	1
28-WF6300	Pressure transducer 0-10 bar	1
28-WF6310	De-airing block for pressure transducer	1
28-WF4450	Three-channel digital readout system	1
28-WF4330	Triaxial panel two-way for two pressures	1
28-WF4330/2	Digital pressure gauge for 28-WF4330	1
28-WF4320	Bladder air/water interface	2
28-WF4320/1	Spare bladder for 28-WF4320	1
28-WF4191	Nylon tubing 6 mm bore x 8 O.D.	1
28-WF2015	Air compressor 10 bar, 50 litres cap.	1
28-WF2016/2	Air filter/water trap	1
28-WF4220	De-airing tank, 7 litres capacity	1
28-WF4225	Valve panel for de-airing tank	1
28-WF2001	Vacuum pump	1
28-WF2064	Rubber tube	1
28-WF0491/2	Water trap	1

ACE

Introduction

This test determines the rate and magnitude of consolidation of a soil specimen restrained laterally and subject to a number of successive increments of vertical loads. In this automatic model, the incremental loading, in load (stress) or swelling (strain) mode, is fully automatic for a practical and accurate test execution with more reliable test results and time saving.

The ACE unit, the SHEARMATIC Automatic shear testing machine and AUTOTRIAX Automatic triaxial test systems are unique equipment for the complete automation of a CST (Consolidation, Shear, Triaxial) Soil Mechanics laboratory in different configurations.

General description

The ACE, Automatic Consolidation oEdometer, consists of a compact load frame housing two coaxial pneumatic cylinders: the smallest one for low loads and the other for higher loads, with automatic switch off from one to the other. The load is controlled by a high precision pneumatic servo-valve. Two analogue channels: one for the displacement transducer and the other for the load cell with closed loop feedback control. The test end can be programmed either on time or step base. The software controls up to 60 ACE units from PC. The parameters are programmed by the operator. Test results are recorded and displayed in real time. Test data can be processed by the Geo-Analysis template conforming to BS and ASTM Standards. The frame accepts all standard consolidation cells from 50.47 to 112.80mm dia.

PC, consolidation cells, Geo-Analysis templates and test software are not included and must be ordered separately.

■ 26-WF3120

Automatic Computerized Oedometer

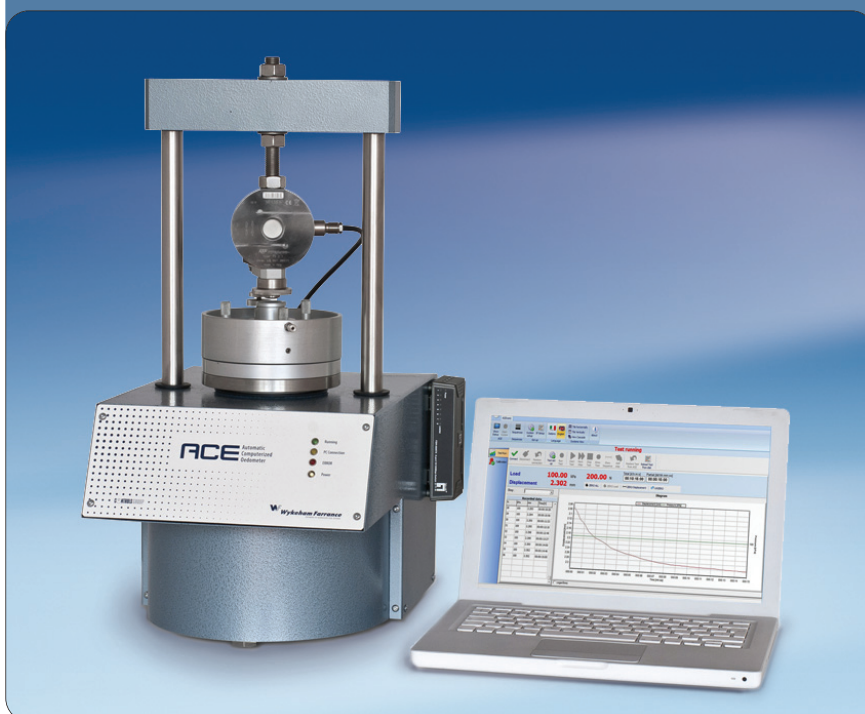
110-240 V, 50-60 Hz, 1 ph.

📄 STANDARDS

ASTM D2435, ASTM D387, ASTM D4546, AASHTO T216, BS 1377:5, NF P94-090-1, NF P94-091, UNE 103-405, UNE 103-601, UNE 103-602, CEN-ISO/TS17862-5.

Main features

- PC controlled automatic test execution
- Incremental consolidation and one-dimensional swell tests
- 24/7 continuous testing for greater throughput and cost saving
- Avoids the negative environmental discrepancies as operator errors, non calibration etc.
- Real time data and graph display
- PC software controlling up to 60 units
- High speed LAN network communication
- Modular expandability



ACE with consolidation cell, PC and Hub-switch

Specifications

Max. vertical load: 15 kN

Displacement transducer: 10 mm travel

Max. air pressure supply: 10 bar. If an air pressure line is not available in the laboratory, our air compressor model 86-D2015, 50 l cap. may be used

Sample dimensions: from 50.47 to 112.8 mm dia. with suitable consolidation cell

Software: controls up to 60 ACE units

Network mode: for the connection to a PC fitted with LAN/Ethernet port of more than one unit (up to 60) it is necessary the use of a LAN/Ethernet hub with the opportune number of ports

Test data accuracy: $\pm 1\%$

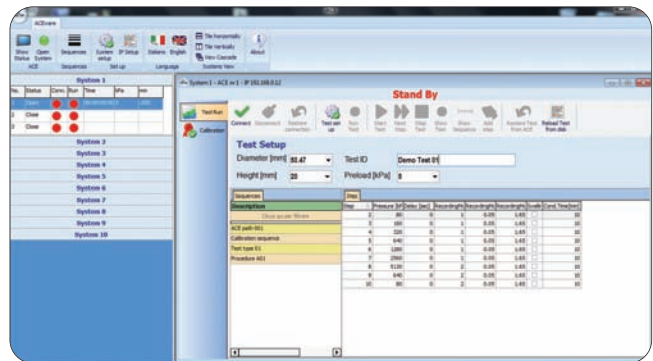
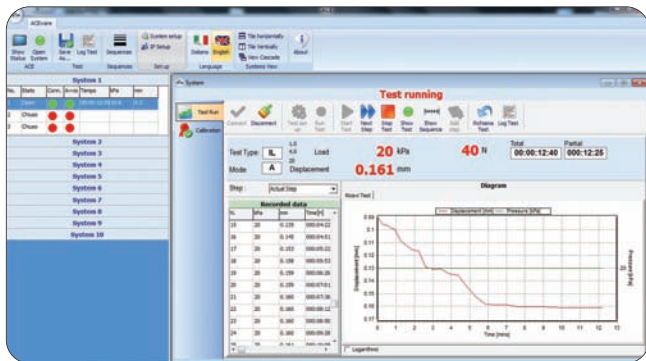
Overall dimensions: 280x300x600 mm

Weight approx.: 25 kg

Software for test execution

26-WF3120/SOF Test software for 26-WF3120, performs automatic consolidation test; compatible with Microsoft Windows® operating system, controls up to 60 ACE units.

26-WF4645 LAN HUB to connect up to 7 units A.C.E or to 6 units in case of multi-hub network to a single PC.



Examples of consolidation diagram and multitask function (up to 60 units)

Test configuration screenshot

ACCESSORIES

CONSOLIDATION CELLS. TO PERFORM EITHER STANDARD OR PERMEABILITY TEST

Code	Specimen Dia. x height mm	Specimen area cm ²	Cell dimension Dia. x height mm	Weight kg
26-WF0320	50.47x20	20	139x74	1.3
26-WF0321	63.50x20	31.67	139x74	1.3
26-WF0325	71.40x20	40	139x74	1.3
26-WF0326	75x20	44.16	139x74	1.3
26-WF0335	112.80x25	100	200x74	3



Consolidation cell

Calibration disks for consolidation cells

26-WF0320/9	Calibration disk for 26-WF0320 cell
26-WF0321/9	Calibration disk for 26-WF0321 cell
26-WF0325/9	Calibration disk for 26-WF0325 cell
26-WF0326/9	Calibration disk for 26-WF0326 cell
26-WF0335/9	Calibration disk for 26-WF0335 cell

Air supply

86-D2015	Laboratory air compressor, 8 bar continuous max. pressure, 50 l cap. 230 V, 50 Hz, 1 ph
86-D2015/Z	Laboratory air compressor, 8 bar continuous max. pressure, 50 l cap. 110 V, 60 Hz, 1 ph

CONSOLIDATION CELLS SPARE PARTS

Cell model/ Size	26-WF0320 20 cm ²	26-WF0321 31.67 cm ²	26-WF0325 40 cm ²	26-WF0326 44.16 cm ²	26-WF0335 100 cm ²
Upper porous disk	26-WF0320/4	26-WF0321/4	26-WF0325/4	26-WF0326/4	26-WF0335/4
Lower porous disk	26-WF0325/10	26-WF0326/10	26-WF0325/10	26-WF0326/10	26-WF0335/10
Cutting ring	26-WF0320/3	26-WF0321/3	26-WF0325/3	26-WF0326/3	26-WF0335/3

Geo-Analysis templates

Test data can be processed by the Geo-Analysis MS-EXCEL® templates 30-WF6016/T1 and 30-WF6016/T8 conforming respectively to BS and ASTM Standards.

30-WF6016/T1 Consolidation template based on MS-EXCEL® conforming to BS 1377:5
30-WF6016/T8 Consolidation template based on MS-EXCEL® conforming to ASTM D2435

Other accessories

Permeability test accessory:

- 28-WF0338/B Permeability attachment with 50 ml graduated burette

Shear testing machines

SHEAR TESTING MACHINES

Introduction

This test covers the determination of the consolidated drained shear strength of a soil material in direct shear. Three different models are available. All accessories are compatible with each model.

■ Model 27-WF2060

DIGISHEAR

Digital control and display of speed.

■ Model 27-WF2160

AUTOSHEAR

Digital control of speed and data acquisition via AUTOMAX control system.

■ Model 27-WF2180

SHEARMATIC

Digital automatic version with pneumatic automatic loading by closed loop system.

All shear box assemblies, dial gauges and transducers are compatible with the above machines.

STANDARD

ASTM D3080 / BS 1377:7 / AASHTO T236 / NF P094 071-1/2 / CEN-ISO/TS7892-10

DIGISHEAR

■ 27-WF2060

DIGISHEAR, direct/residual shear machine, digital control and display of speed. 110-240 V, 50-60 Hz, 1 ph.

General description

This new machine, which is driven by a high resolution stepper motor and worm reduction unit, can accommodate all standard specimens up to 10 cm square and 10 cm dia. The vertical load is directly applied to the specimen through a load frame carrying weights and can be increased using the beam loading device, used to amplify the vertical load on the shear testing machines. It can receive up to 50 kg of weight so that the total load on the specimen can reach 500 N or 5000 N.

Main features

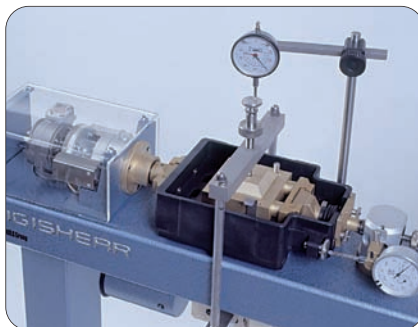
- Reversible stepper motor for residual strength test
- Infinitely variable speed drive from 0.00001 to 4.99999 mm/min
- Compact ergonomic design
- Safety device to prevent overload and overtravel

- RS 232 serial port for remote speed control

The horizontal loading system: loading ram, shear box, load-measuring system are perfectly aligned to avoid distortions with the possibility of mechanical backlash adjustment



DIGISHEAR 27-WF2060 with accessories



Detail of Shear Box housing made of high resistance techno polimeric material

Important note

The machine is supplied without load ring, dial gauges for horizontal and vertical displacement, shear box assembly and weights. All these items have to be ordered separately. See accessories. The machine can also be fitted with electronic measurement system.

Specifications

- Speed range** adjustable from 0.00001 to 4.99999 mm/min (preset via firmware)
- Maximum shear force:** 5000 N
- Maximum vertical load:** 500 N/5000 N using 10:1 lever loading device
- Speed drive ratio:** stepper motor 1/10,000 resolution
- Horizontal travel:** preset via firmware up to 19 mm
- Displacement limits controlled by optical safety switch**
- Digital display:** LCD 4-row by 20 characters. Easy to operate via the membrane keyboard
- Overall dimensions:** 953x387x1180 mm
- Weight approx.:** 120 kg

DIGISHEAR

continued

ACCESSORIES

Shear box assembly (see beside table)

Shear box assemblies for all shear testing machines

DIGISHEAR 27-WF2060,

AUTOSHEAR 27-WF2160,

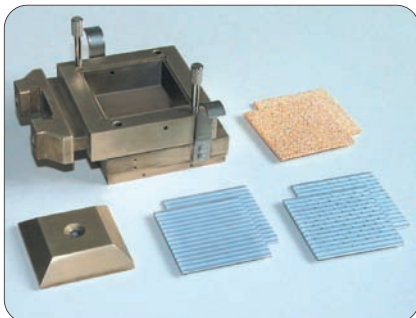
SHEARMATIC 27-WF2180

General description

All shear box assemblies are constructed of brass and are designed to contain water that surrounds the specimen. They consist of a square box with a rigid walled round or square hole complete with adapter loading pad, retaining plate, 2 grids, 2 perforated grids and 2 porous plates.

Code	Size
27-WF0215/B	60 mm sq.
27-WF0216/B	100 mm sq.
27-WF0218/B	60 mm Ø
27-WF0219/B	63.5 mm Ø
27-WF0222/B	100 mm Ø

Weight approx.: 2.5 – 4 kg



Components of the square shear boxes



27-WF1002/ST
Load ring with adapter

LOAD RINGS AND DIAL GAUGES

27-WF1002/ST Load ring 2000 N capacity with adapter

27-WF1003/ST Load ring 5000 N capacity with adapter

30-WF6401 Dial gauge for vertical displacement 10x0.002 mm

30-WF6402 Dial gauge for horizontal displacement 30x0.01 mm with adapter



Extrusion dolly
and sample cutter

Accessories for data processing

27-WF0377/ST Load cell, 5 kN cap., complete with adapters

30-WF6207 Linear potentiometric transducer, 10 mm travel, for vertical deformation, complete with mounting block

30-WF6208 Linear potentiometric transducer, 25 mm travel, for horizontal displacement, complete with mounting block

30-WF6042 Transducer extension cable, 6 m

30-WF6044 Transducer extension cable, 12 m

30-WF6016 GEODATALOG, 16 channels data acquisition unit, 110-240 V, 50-60 Hz, 1 ph. supplied complete with DATACOMM software for PC data acquisition (for more information see page 62)

30-WF6016/T2 Direct and residual shear Geo-Analysis template BS

30-WF6016/T9 Direct and residual shear Geo-Analysis template ASTM

SLOTTED STEEL WEIGHTS AND WEIGHT SETS⁽²⁾ FOR 27-WF2060 AND 27-WF2160 SHEAR TESTING MACHINES

Code	Weight ⁽¹⁾	27-WF0230/C3 set including	27-WF0230/C4 additional set including
27-WF0270/A	0.250 kg	q.ty 2	-
27-WF0271/A	0.500 kg	q.ty 2	-
27-WF0272/A	1 kg	q.ty 2	q.ty 2
27-WF0273/A	2 kg	q.ty 3	q.ty 1
27-WF0274/A	4 kg	q.ty 3	-
27-WF0275/A	8 kg	q.ty 2	-
27-WF0276/A	5 kg	-	-
27-WF0277/A	10 kg	-	q.ty 3
		Tot. 37.5 kg	Tot. 34 kg

(1) The weights can be supplied on request with traceable certificates both in N and/or kg.

(2) The weight sets 27-WF0230/C3 and 27-WF0230/C4 are suitable for all shear boxes to apply the various load step.

SPARE PARTS FOR SHEAR BOX ASSEMBLIES

Part description and code	27-WF0215/B	27-WF0216/B	27-WF0218/B	27-WF0219/B	27-WF0222/B
	60x60 mm	100x100 mm	60 mm dia.	63.5 mm dia.	100 mm dia.
Loading pad	27-WF0215/B2	27-WF0216/B2	27-WF0218/B2	27-WF0219/B2	27-WF0222/B2
Retaining plate	27-WF0215/B3	27-WF0216/B3	27-WF0218/B3	27-WF0219/B3	27-WF0222/B3
Porous plate	27-WF0215/4	27-WF0216/4	27-WF0218/4	27-WF0219/4	27-WF0222/4
Plane grid**	27-WF0215/B5	27-WF0216/B5	27-WF0218/B5	27-WF0219/B5	27-WF0222/B5
Perforated grid**	27-WF0215/B6	27-WF0216/B6	27-WF0218/B6	27-WF0219/B6	27-WF0222/B6
Sample cutter*	27-WF0215/B7	27-WF0216/B7	27-WF0218/B7	27-WF0219/B7	27-WF0222/B7
Extrusion dolly*	27-WF0215/8	27-WF0216/8	27-WF0218/8	27-WF0219/8	27-WF0222/8

* Not supplied with the shear box. They must be ordered separately

** Two pieces are supplied with each shear box

AUTOSHEAR**■ 27-WF2160**

AUTOSHEAR, direct/residual shear machine, digital control of speed and data acquisition via the Automax control system. 110–240 V, 50–60 Hz, 1 ph.

STANDARDS

ASTM D3080 / BS1377:7 / AASHTO T236 / NF P094 071-1/2 / CEN-ISO/TS17892-10

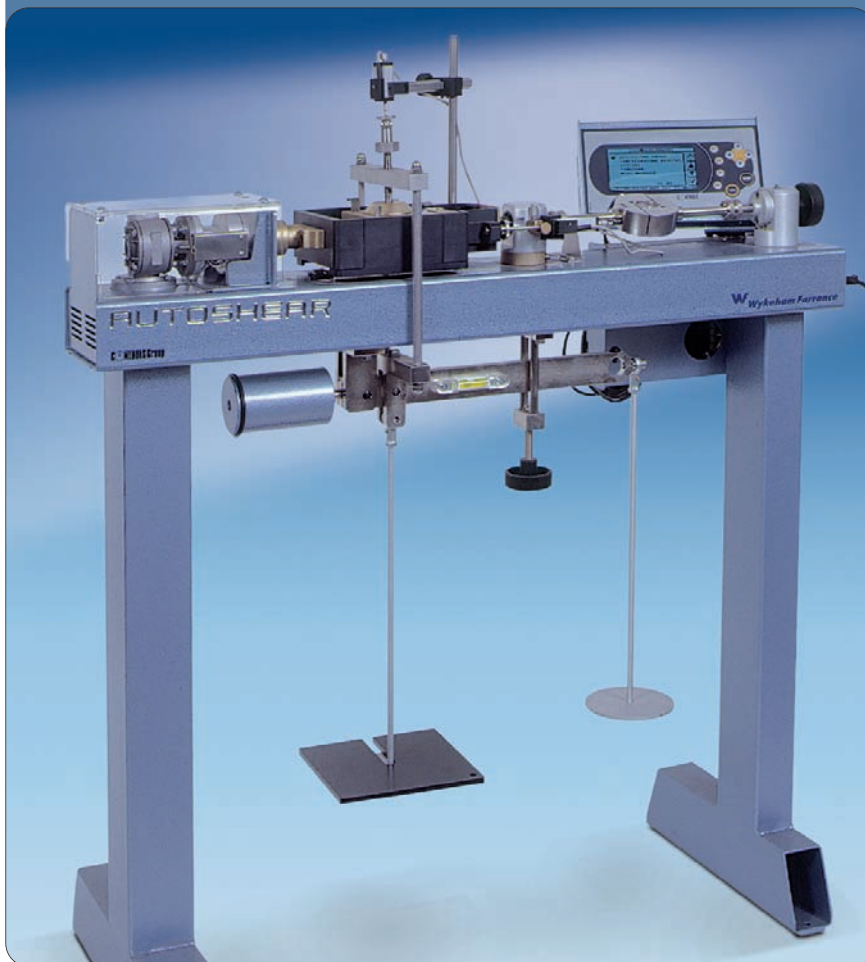
General description

The basic structure of this machine is identical to the standard 27-WF2060 model, except for the electronic part, which is based on our Automax unit, this is a microprocessor system that reads and processes horizontal force and displacement readings, manages the motor and the safety controls through closed loop systems, assuring important features:

- automatic test running
- test speed closed loop control
- large monochromatic graphic display 240x128 pixel to view data recording in real time
- different calibration functions (linear and polynomial)
- language selection
- travel and cycles programmable by 10 button membrane keyboard with 4 interactive specific icons
- continuous monitoring and display of horizontal force, vertical and horizontal displacement
- maximum horizontal displacement (20 mm) is controlled by mechanical and optical safety switch
- different recording modes (linear, exponential (square root), logarithmic, etc.)
- high capacity data memory (up to 1000 lines of data)
- RAM memory with battery back-up with clock/calendar, operating also when the unit is switched off.

Main features

- Microprocessor controlled drive system
- Large 240x120 pixel display
- Test speed, travel and cycles programmable by the keyboard
- Rapid approach and automatic positioning
- Infinitely variable speed drive from 0.00001 to 11.00000 mm/min
- Possibility to set different speed and travel (forward and reverse) in the residual shear tests
- Three analog channels: one for load cell and two for displacement transducers, 130000 point resolution
- Different protocol of data downloading to PC through RS 232 serial port
- Standard load ring and dial gauges also usable for manual recording



AUTOSHEAR 27-WF2160 with accessories

The new design of the horizontal loading system provides straight-rigid alignment of loading ram, shear box, and loading measurement system, to increase the stiffness of transmission of the horizontal force along the shearing plane.

The beam loading device for the application of vertical load (1:10 ratio) and the ASTM balancing frame are included in the machine.

Excellent quality and high resistance techno-polymeric material as been adopted for the carriage of the shear box. It offers excellent resistance to corrosion, wear and tear and it is resistant to all chemical found in a soil specimen. The carriage is light weight and easy to clean.

AUTOSHEAR

continued

Specifications

Speed range: 0.00001 to 11.00000 mm/min

Maximum shear force: 5000 N

Maximum vertical load: 500 N/5000 N using the 10:1 lever loading device

Horizontal travel: preset via firmware up to 19 mm

Cycles: up to 9 (forward and reverse)

Specimen size 60x60 mm, 100x100 mm; 50, 60, 63.5 and 100 mm dia. (lxdxh)

Overall dimensions: 953x387x1180 mm

Weight approx.: 120 kg

Important note

The machine is supplied without load cell, transducers for horizontal and vertical displacement, shear box assembly and weights. All these items have to be ordered separately. See linear transducers accessories.

The machine can also be fitted with mechanical measurement system.

Operating principle

The AUTOMAX microprocessor control system allows the machine to work as an automatic stand-alone unit: the test measurements (force and displacements) are directly displayed and stored in memory according to pre-set recording modes. The PC is only temporary required to download the test data via the RS 232 serial port, once the test is completed. The data can be processed by the Direct Shear Geo-Analysis template 30-WF6016/T2. (See accessories).

Accessories

Shear boxes

See page 13

Slotted steel weights for vertical load

See page 13

Load rings and dial gauges (mechanical measurements)

See page 13

Accessories for data processing

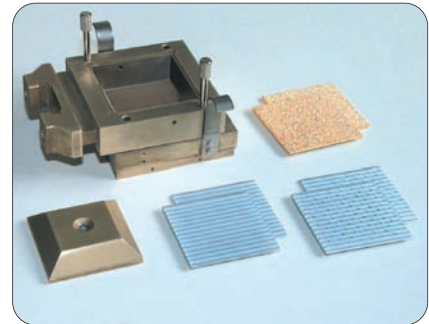
► **27-WF0377/ST** Load cell, 5 kN cap., complete with adapters

► **30-WF6207** Linear potentiometric transducer, 10 mm travel, for vertical deformation, complete with mounting block

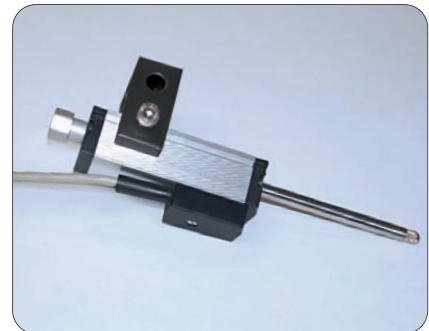
► **30-WF6208** Linear potentiometric transducer, 25 mm travel, for horizontal displacement, complete with mounting block

► **30-WF6016/T2** Direct and residual shear Geo-Analysis template BS

► **30-WF6016/T9** Direct and residual shear Geo-Analysis template ASTM



Components of a square shear box



Displacement transducers 30-WF6207 and 30-WF6208 models



Detail of 27-WF0377/ST, 5 kN load cell

SHEARMATIC

■ 27-WF2180

SHEARMATIC, digital automatic direct/residual shear machine with programmable pneumatic loading
110-240 V, 50-60 Hz, 1 ph.

📄 STANDARDS

ASTM D3080 / CEN-ISO/TS17892-10 /
BS 1377:7 / AASHTO T236 / NF P094 071-1/2

General description

This new microprocessor based advanced model, is a stand-alone machine, driven by a high-resolution stepper motor with epicyclic reduction gear with a reduced backlash. Incorporates a pneumatic closed loop system for the automatic application of the axial pressure by a high performance pressure regulator, with the main advantage of eliminating the manual loading of the dead weights.

Excellent quality and high resistance techno polymeric material has been adopted for the carriage of the shear box.

It offers excellent resistance to corrosion, wear and tear and is resistant to all chemicals found in a soil specimen. The carriage is lightweight and easy to clean.

Electronic

The electronic parts of the SHEARMATIC is based on our "Automax" unit, this is a micro-processor system that reads and processes the force, axial pressure and displacement readings, manages the motor, the pressure valve, the safety systems and the test steps through closed loop systems. It features a front panel in scratchproof poly carbon with a ten key keyboard and a large monochromatic graphic display.

Electronic transducers supplied with the machine

The machine is supplied complete with:

- ±5 kN capacity load cell, bi-directional type (compression and tension), nominal sensitivity 2 mV/V, accuracy ± 0.03%.
- 10 mm displacement transducer, 1 kΩ nominal resistance, ± 0.25% linearity, 0.002 mm repeatability
- 25 mm displacement transducer, same specification as above.
- 1000 kPa pressure transducer, 0.1kPa accuracy, nominal sensitivity 2 mV/V.



SHEARMATIC 27-WF2180 with accessories

Main features

- Automatic pneumatic application of preset consolidation steps (up to 50)
- Automatic management of the test with the possibility to directly continue from consolidation to failure (the operator only needs to remove the clamping screws of the shear box)
- Sets of heavy and bulky dead weights are not required
- A balanced lever arm maintained horizontal is not required
- The vertical force is positively applied to the shear box without any friction
- Straight connection between shear box, drive unit and load cell for the axial transmission of the horizontal force along the shearing plane, instead of the classic "swan neck"
- New high resistance techno-polymeric carriage
- Easy and immediate set up of the test parameters via the large digital graphic display
- Possibility to set different speeds and travel (forward and reverse) in the residual shear tests
- Each single step of axial force can be applied:
 - instantaneously
 - by means of a linear ramp in a preset time interval
- Different and independent data recording mode for consolidation and failure
- Different protocols of data downloading via RS 232 serial port

Specification

- Display:** monochromatic large digital display (240x128 pixel)
- Motor:** high accuracy stepper motor with 1/10.000 resolution
- Test velocity:** infinitely variable from 0.00001 to 11.00000 mm/min (within ± 1%)
- Maximum horizontal force:** 5 kN
- Maximum vertical force:** 8 kN 800 kPa for a specimen 100x100 mm.
- Maximum shear cycles:** 10 (forward and reverse)
- Maximum travel:** 19 mm
- Height of the specimen:** 20 mm
- Maximum air pressure supply:** 10 bar
- Maximum working air pressure:** 8 bar
- 📏 **Overall dimensions:** 973x421x427mm (lxdxh)
- ⚖️ **Weight approx.:** 100 kg

Accessories

Shear box assemblies

See page 13

Air compressor

▶ 28-WF2015

Laboratory air compressor, 10-bar max. pressure, 50 litres cap. 240 V, 50 Hz, 1 ph.

▶ 28-WF2015/Z

Same as above but 110 V, 60 Hz, 1 ph.

Data processing software

▶ 30-WF6016/T2 Direct and residual shear Geo-Analysis template BS

▶ 30-WF6016/T9 Direct and residual shear Geo-Analysis template ASTM

SHEARMATIC

continued

MACHINE SET UP

Automatic test termination:

- After a pre-set horizontal load or displacement
- After a pre-set time of the shear stage (from 1 min to about 7 days)

Safety micro switch:

- Optical for zero and end of travel
- Mechanical for maximum horizontal displacement

Application of vertical loading: pneumatic piston with a high-resolution regulator motor-driven via Automax electronic board in a closed loop with a 10 bar pressure transducer

Input channels:

- One for load transducer load cell with 130,000 points resolution
- Two for potentiometric displacement transducers

3 calibration modes of transducers:

- 1st step linear
- 2nd degree polynomial
- Up to 10 steps linear

Data recording:

- Consolidation stage: vertical pressure and displacement
- Shear stage: horizontal force and displacement; axial pressure and displacement

Recording mode:

- Linear, exponential (square root) and logarithmic
- For pre-set intervals of the recorded data

Maximum recorded data: 2000 lines of data

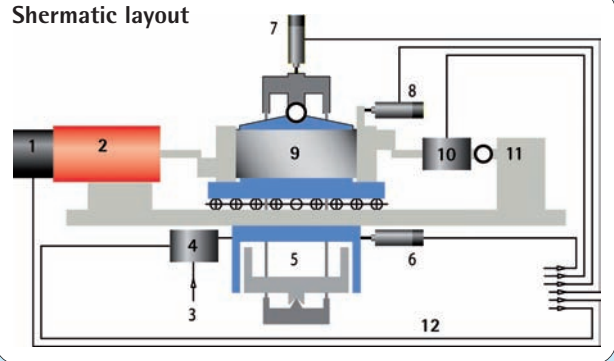
Blocks of memory: up to 25

Communication protocol:

Selectable via RS 232 serial port:

- ASCII for use with Windows Hyper Terminal
- CONTROLS for use with 82-Q0800/TRM
- GEOLAB 2000 for use with 30-T0601/IMP

Shermatic layout



Legend

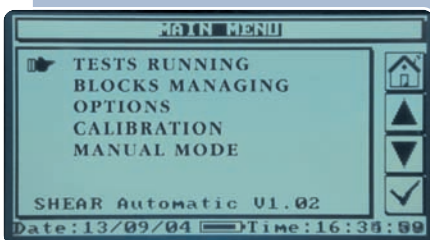
- | | |
|--|--|
| 1 Stepper motor | 6 Vertical load air pressure transducer |
| 2 Horizontal loading assembly | 7 Vertical displacement transducer |
| 3 Compressed air supply | 8 Horizontal displacement transducer |
| 4 Proportional valve to control the vertical load | 9 Shear box |
| 5 Vertical loading assembly | 10 Load cell |
| | 11 Machine frame |
| | 12 Control console |

Example of displays

First page of the main Menu

Selection of main options:

- Start of the test (direct or residual)
- Delete of recorded data and tests
- Options of language clock and data format
- Calibration procedure
- Manual mode for digital display of the transducers (e.g. for calibration control) out of the tests



Set up of the consolidation steps

Each line of this table step is defined by:

- Initial pressure (set point) that is equal to the pressure of the previous step
- Final pressure (target) that will be reached automatically at constant rate
- Pre-set time to pass from initial to final pressure

For example lines No. 3 and 4 of the table on the left means:

- To apply instantaneously (time = 0) the consolidation step from 100 to 300 kPa
- To maintain the pressure of 300 kPa for the time of consolidation (e.g. 500 minutes).

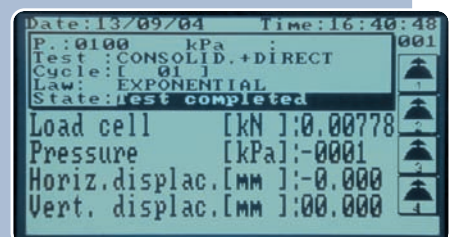
SET. PT	TARGET	TIME	EN
0000	0100	0000	Yes
0100	0100	0300	Yes
0100	0300	0000	Yes
0300	0300	0500	Yes
0300	0050	0000	No
0050	0050	0003	No
0050	0001	0000	No
0001	0350	0030	No
0350	0550	0000	No
0550	0550	0030	No

Confirm Change ?

Direct shear test

Digital display of measurements in real time:

- Horizontal force
- Axial pressure (maintained constant)
- Horizontal displacement
- Vertical displacement



Large digital shear box

SHEARMATIC 300

Introduction

The new digitally controlled large shear box is ideal for testing geo-synthetics and also soils and other materials that contain large particles of up to 20 mm largest dimension.

Sample sizes up to 300 mm can be tested, with various inserts allowing the testing of smaller sample sizes. (See accessories).

■ 27-WF2304

Large digital shear box apparatus, 100 kN cap., with shear box assembly for 300 mm square sample.

110-240 V, 50-60 Hz, 1ph.

📄 STANDARDS

BS 1377:7, ASTM D6243, EN ISO 12957
ASTM D5321 - D3080

General description

The sample is consolidated via a closed loop hydraulic system for the automatic programmable application of the vertical load. The horizontal displacement is driven by an high resolution stepper motor.

The working of the machine is entirely managed by the software of a microprocessor control unit that reads the processes of force, axial pressure and displacement readings, manages the motor, the vertical hydraulic loading system, the safety systems and the test steps through closed loop systems. It features a front panel in scratchproof poly carbon with a ten key keyboard and a large monochromatic graphic display.

By using a larger sample size it is possible to gain a more representative indication of shear strength. The large shear box can be used to obtain the angle of friction between many materials. Particular applications include the construction of earth dams and other embankment work.

The need for such a device has been recognised with its inclusion in BS 1377:7.

The machine includes 100 kN load cell and linear potentiometric transducers 100 and 50 mm travel complete with mounting brackets.



HEARMATIC 300 27-WF2304

Specifications

Maximum sample size: 300 mm sq.

Inserts allow 150 mm size

Shear and vertical force: 100 kN

Speed range: steplessly variable between 0 - 9.99999 mm/min

Maximum travel: 75 mm

Overall dimensions: 1500x760x1400 mm (lxdxh)

Weight approx.: 930 kg

Operating principle

The Automax microprocessor control system allows the machine to work as an automatic stand-alone unit: the test measurements (force and displacements) are directly displayed and stored in memory according to pre-set recording modes. The PC is only temporary required to download the test data via the RS 232 serial port, once the test is completed. The data can be processed by the Direct Shear Geo-Analysis template 30-WF6016/T2. (See accessories).

Main features

- Ideal for testing
Shale – Industrial slag – Brick rubble – Colliery spoils
- Digital control
- Steplessly variable speed control between 0-9.99999 mm/min
- Sample size up to 300 mm
- 100 kN shear and consolidation force
- Suitable for testing geosynthetics
- High performance proportional valve and electronic control of vertical pressure
- Up to 100 steps of consolidation
- Calibration via software of consolidation hydraulic pump with linear function

Accessories

- ▶ **30-WF6016/T2** Direct and residual shear Geo-Analysis template BS
- ▶ **27-WF2304/1** 150 mm sq. sample insert for 300 mm apparatus
- ▶ **30-WF6016/T9** Direct and residual shear Geo-Analysis template ASTM

LABORATORY VANE APPARATUS

STANDARDS

BS 1377:7 / ASTM 4648

27-WF1730

Laboratory vane apparatus

General description

The laboratory vane apparatus is based on an original concept of the Transport and Road Research Laboratory of the United Kingdom. This instrument can be provided with a wide range of vane sizes, although as standard, it is sold with the 12.7 mm square vane and a set of four calibrated springs. A motorizing unit is also available. (See accessories).

 Weight approx.: 11 kg

Accessories for laboratory vane apparatus

- **27-WF1731** Spare standard vane, 12.7 mm x 12.7 mm
- **27-WF1732** Alternative vane of 25.4 mm x 25.4 mm size
- **27-WF1733** Alternative vane of 12.7 mm x 25.4 mm size
- **27-WF1734** Alternative vane of 12.7 mm x 19.0 mm size
- **27-WF1735** Spare set of four calibrated springs
- **27-WF1730/2** Motorizing attachment to convert 27-WF1730 apparatus, including driving belt, pulley set and fixing studs. Testing speed 6 to 12°/min, conforming to BS 1377:7. 240V, 50 Hz, 1 ph
- **27-WF1730/2Y** Motorizing attachment to convert 27-WF1730 apparatus, including driving belt, pulley set and fixing studs. Testing speed 6 to 12°/min, conforming to BS 1377:7. 220V, 60 Hz, 1 ph
- **27-WF1730/3** Motorizing attachment to convert 27-WF1730 apparatus, including driving belt, pulley set and fixing studs. Testing speed 60 to 90°/min, conforming to ASTM D4648. 240V, 50 Hz, 1 ph



27-WF1730 with 27-WF1730/2

- Manual or motorized versions available
- Lightweight, compact and portable, ideal for site or main laboratories
- Convenient and rapid method of determining shear strength of soft soils
- Easy to use, many hundreds in operation today

- **27-WF1730/3Y** Motorizing attachment to convert 27-WF1730 apparatus, including driving belt, pulley set and fixing studs. Testing speed 60 to 90°/min, conforming to ASTM D4648. 220V, 60 Hz, 1 ph
- **27-WF1730/4** Motorizing attachment conforming to ASTM D4648. 110 V, 60 Hz, 1 ph.
- **27-WF1736** Attachment to hold a sample tube of 38 mm or 100 mm dia. Weight approx. 5 kg.

Ring shear apparatus

TORSHEAR

BROMHEAD RING SHEAR APPARATUS

Introduction

The residual shear strength of soils is sometimes also termed the ultimate shear strength. This is the strength of soil when it is sheared to large displacements, for example along the failure plane of a landslide or in a fault zone. A remoulded specimen is used to determine the residual shear properties of the soil. A slip surface is formed in the test specimen as part of the test procedure.

It can also be useful to know what sort of value the residual shear strength of an intact soil can have, because this (when taken in conjunction with the peak shear strength of the same soil) indicates its brittleness or susceptibility to progressive failure. Soils with high brittleness need to be used with caution in engineering works such as embankments (or treated with caution if they cannot be removed, for example in a natural slope).

In the unfortunate event of a slope failure occurring, the general scale of displacement will depend on the magnitude of the brittleness.

STANDARDS
BS 1377:7 / ASTM D6467

27-WF2202 TORSHEAR digital ring shear apparatus

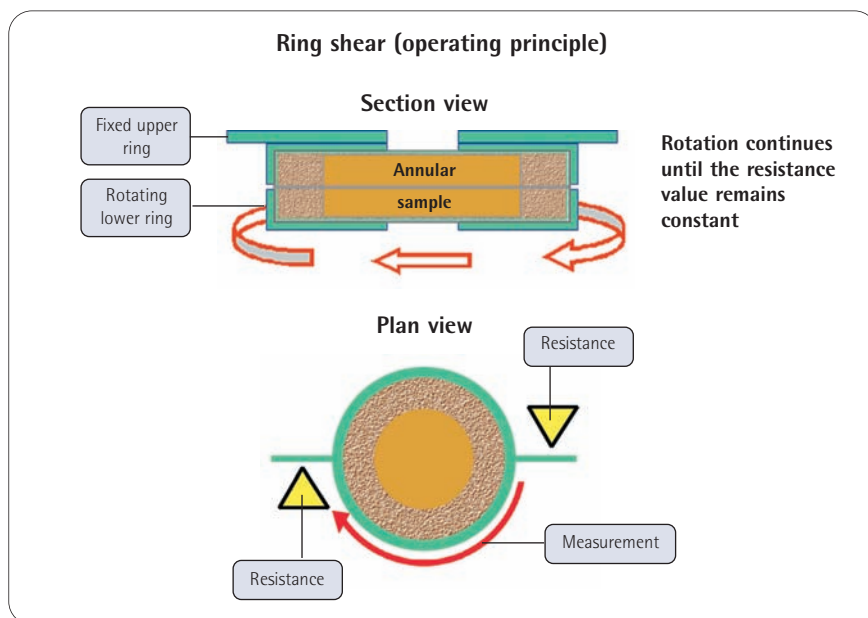
110-240 V, 50-60 Hz, 1 ph.

Main features

- Microprocessor controlled drive system
- Test speed adjustable by the keyboard
- Rapid approach without any limit of rotation
- Infinitely variable speed drive from 0.001 to 180°/min
- Serial port RS 232 for PC remote control
- Dial gauges and load rings (to be ordered separately) are ordinarily used for

- displacement and force measurements. Upgrading version with load cells and displacement transducer for electronic recording with data acquisition system is available (to be ordered separately)
- Waterproof membrane keyboard
- LCD display, 4 lines and 20 characters

TORSHEAR 27-WF2202 with accessories



Torque measured with matched load rings or load transducers
Continuous shear with constant area



TORSHEAR

continued

General description

The TORSHEAR ring shear apparatus tests the residual shear strength of remoulded annular soil samples. The main advantage of this method compared to the direct shear test consists in the continuous shear with a constant area during all the test long. This method allows us to recreate in the laboratory exactly the field conditions, giving very accurate residual shear stress values. The sample is loaded vertically between two porous stones by means of a counter balance 10: 1 ratio lever loading system. A rotation is imparted to the base plate and lower platen by means of a variable speed motor. The settlement of the upper platen during consolidation or shear can be monitored by means of a sensitive dial gauge or linear transducer bearing on the top of the load hanger.

Torque transmitted to the sample is reacted by a pair of matched load measuring proving rings or load cells. Linear transducer and strain gauge load cells can be connected to the GEODATALOG for data acquisition and processing. (see accessories)

Using the waterproof membrane keyboard and the LCD display with 4 rows and 20 characters, it is possible to set the speed in deg/min or mm/min, using also the fast approach for sample positioning. The test can be stopped using the keyboard or setting a limit of rotation or time.

This apparatus is known as *Bromhead Apparatus*. Dr. Bromhead of Kingstone University designed the ring shear apparatus to overcome certain disadvantages of a conventional sherabox. Dial gauge or linear transducers, load rings or cells and weights are not included and have to be ordered separately. (See accessories).

Specifications

Speed range: 0.001 to 180°/min

Maximum shear stress: 500 kPa

Maximum vertical stress: 1000 kPa (lever ratio 10:1)

Specimen dimension: 40 cm² (internal dia. 70 mm, external dia. 100 mm, thickness 5 mm)

Overall dimensions: 770x360x560 mm (lxdxh)

Weight approx.: 60 kg

Accessories (to be ordered separately)

Mechanical measuring system:

➤ **30-WF6401** Dial gauge 10x0.002 mm

➤ **27-WF2202/1** Pair of matched load rings 1 kN capacity

Vertical load:

➤ **27-WF2202/2** Weight set (total 50 kg)

Accessories for data acquisition and processing

➤ **30-WF6207** Linear potentiometric transducer, 10 mm travel with mounting block

➤ **27-WF2202/3** Pair of load cells 1 kN capacity

➤ **30-WF6042** Transducer extension cable, 6 m long (q.ty 3)

➤ **30-WF6016** GEODATALOG, 16 channels data acquisition unit, 110-240 V, 50-60 Hz, 1 ph. supplied complete with DATACOMM software for PC data acquisition (for more information see page 62)

➤ **30-WF6016/T3** Ring shear Geo-Analysis template



30-WF6207 Linear potentiometric transducer, 10 mm travel with mounting block



GEODATALOG 30-WF6016

TRIAXIAL TESTS

STANDARDS

BS 1377-7, 8 / ASTM D2850, D4767 / CEN-ISO/TS 17892-8, 9 / NF P94 070, P94 074

Introduction

To design foundations, embankments and other soil structures, Geotechnical Engineers require methods of assessing the mechanical properties of soils. For over 60 years Wykeam Farrance, now incorporated in the CONTROLS Group, has been at the forefront of the development of test systems designed to give engineers the information they require.

Since the development of the first commercially produced shear box machine in the 1950s, we have been working closely with leading Academics and Universities to produce testing systems that further advance the understanding of soil mechanics.

The experimental investigation used to determine the stress-strain relation is usually carried out with triaxial tests, where undisturbed soil specimen are subjected to different stress levels and drainage conditions to simulate as close as possible the different situations that can occur in the subsoil on site because of the effect of building constructions, excavations, tunnelling, etc.

Our geotechnical division manufactures a large sophisticated state of the art range of triaxial equipment, which is detailed above.

Type of triaxial tests

- Total stress triaxial tests (Section 28)
- Effective stress triaxial tests (Sections 28 and 29)
- Effective stress and stress path triaxial tests (Automatic Triaxial testing) (Section 29)
- Permeability tests (Section 28)
- Unsaturated Triaxial Testing (Section 28)



TRIAXIAL TESTS METHODS

Total stress measurement

Unconsolidated Undrained (UU) tests

With this method the shear strength is measured with respect to total stress. The soil specimen (assumed saturated) is not allowed to consolidate, maintains its original structure and water content, so that its resistance only depends on the level of geostatic stress in the field. Tests are usually carried out on three specimens of the same sample, subjected to different confining pressure. Provided that the soil is fully saturated, the shear strength is the same for each test. The Mohr envelope, plotted with respect to total stress is horizontal and the shear strength is constant and equal to c_u (undrained shear strength).

Effective stress measurement

Consolidated Undrained (CU) tests

With this test method the shear strength is measured in terms of effective stress. At least three specimens are saturated, allowed to consolidate (i.e. to change its structure and water content) at different level of confining pressure before failure. Due to the fact that shear strength increases raising the effective stresses the Coulomb's model can be applied in terms of effective stress:

$$\tau = c' + \sigma'_n \tan \phi'$$

where:

τ = shear resistance

σ'_n = effective normal stress

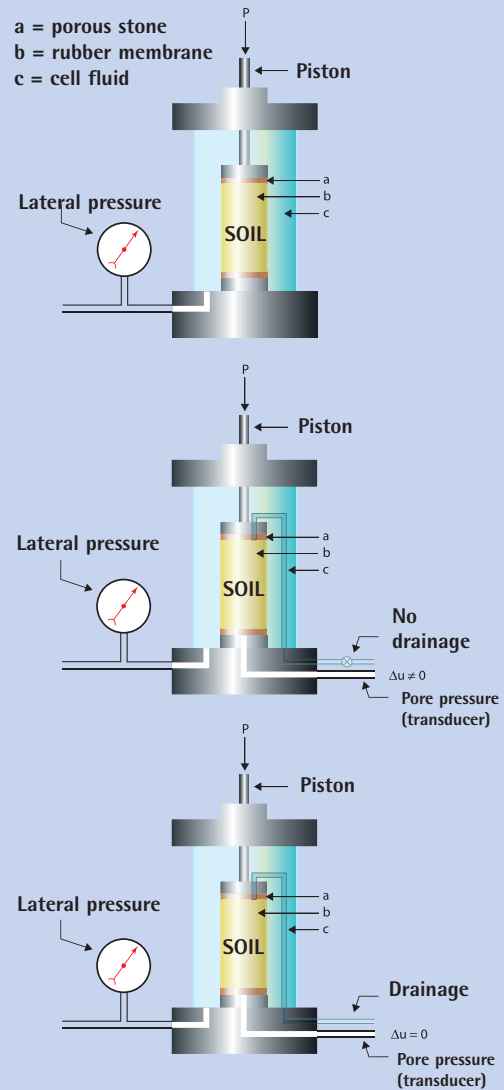
c' , ϕ' = parameters of Mohr envelope in terms of effective stress

During the failure stage the specimen is not allowed to drain and pore pressure is measured, so that the effective stresses are calculated as the difference between the total stress and the pore pressure.

Effective stress measurement

Consolidated Drained (CD) tests

This test method is similar to the "CU" test as the shear strength can be related to the applied level of stress. At least three specimens are allowed to consolidate at different levels of confining pressure. The failure stage is carried out very slowly to prevent the increase of pore pressure inside the specimen, which is allowed to drain. The total and effective stresses are the same. Mohr circles are drawn for effective stresses at failure and the parameters c' and ϕ' are determined from the Mohr envelope.



Type of triaxial tests and basic equipment

This summary table is intended as a guide, to give a general overview of our relevant triaxial equipment, in order that the user can select the system most appropriate to his requirement. Descriptions, details and accessories are included in the Sections and pages here indicated.

Basic Equipment	Effective stress						Stress path	
	Manual		Semi automatic		Fully Automatic		Fully Automatic	
			Automatic - saturation - isotropic consolidation Manual compression		Automatic - saturation - isotropic consolidation - compression		Automatic - saturation - anisotropic / k_0 consolidation - compression / extension	
	(see Section 28)		(see Section 29)		(see Section 29)			
Low press. (1000 kPa)	High press. (3500 kPa)	Low press. (1000 kPa)	High press. (3000 kPa)	Low press. (1000 kPa)	High press. (3000 kPa)	Low press. (1000 kPa)	High press. (3000 kPa)	
28 - WF0401 Standard Triaxial cells	(page 28) (page 30-31)	•	•	•				
28 - WF4005 Standard Triaxial cells	(page 24-25) (page 30-31)	•	•	•		•		
28 - WF4005 Heavy Duty Banded Triaxial cells	(page 24-25) (page 32-33)	•	•	•	•	•		
28 - WF4005 Tri-Cell Plus Triaxial cells	(page 24-25) (page 34)	•	•	•	•	•		•

TRIAXIAL LOAD FRAMES

Two versions available:

TRITECH

Heavy duty load frames, 50 and 100 kN cap.

Particularly suitable for central laboratories and research purposes, with banded triaxial cells up to 2000 or 3500 kPa working pressure.

TRITECH frames can also be fitted with pneumatic actuator to perform, with all the other suitable accessories, dynamic testing. (See page 65).

TRITECH

Triaxial load frames

STANDARDS

BS 1377:8 / ASTM D2850, D4767 /
CEN-150/TS17892-8, 9 / NF P94 070,
P94 074

28-WF4005

TRITECH triaxial load frame 50 kN cap.
110-240 V, 50-60 Hz, 1 ph.

28-WF4010

TRITECH triaxial load frame 100 kN cap.
110-240 V, 50-60 Hz, 1 ph.

General description

The TRITECH range of triaxial load frames has been designed to be also used as part of a computer-controlled triaxial system or as a stand-alone unit. The RS 232 interface enables the TRITECH to be used for automatic stress path tests (see page 48).

The control buttons on the front panel provide fast/slow, up/down and stop commands for platen movement. A waterproof membrane seals the panel and digital display from water and dust.

A rapid approach facility is provided to reduce set-up time. The automatic datum facility returns the TRITECH to previous settings when switched on and micro switches prevent platen over travel.

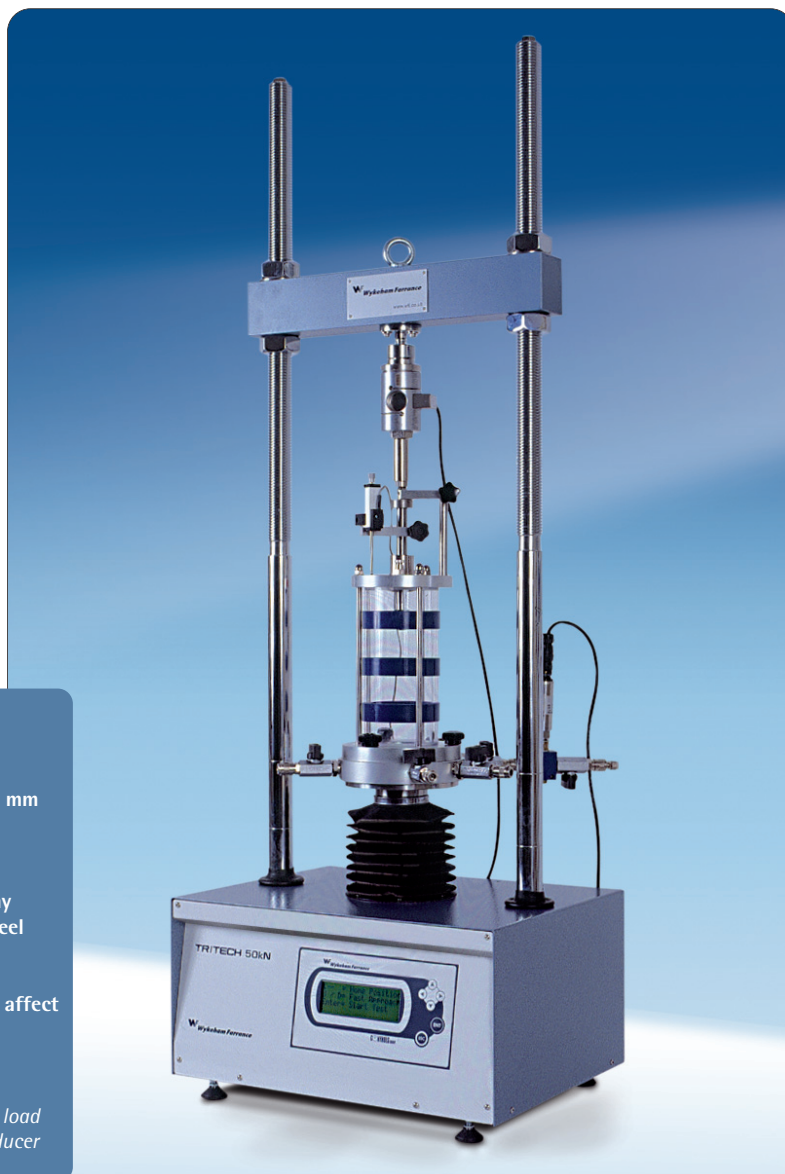
The load frame is of rigid chromed steel twin column construction, for rigidity at high loads. All external parts are either stove enamel painted or chrome plated for corrosion protection. The loading platen is made from stainless steel.

The TRITECH machines are versatile, compact and easy to use bench mounted load frames. They can be used for a variety of test procedures from simple uniaxial to the more sophisticated effective stress triaxial tests, and can also be fitted with pneumatic actuator to perform, with the other suitable apparatus, static/dynamic tests. See page 65. The machines have to be completed with the load measurement system and displacement transducers. (See accessories).

Main features

- RS 232 control interface
- Digital control
- Speed range 0.00001 to 9.99999 mm per minute
- Rapid approach facility
- Audible alarm at limit of travel
- LCD 4-row by 20 character display
- All steel construction, stainless steel platen
- The quality of the design has eliminated all vibrations that can affect the specimen under test

TRITECH 28-WF4005 with triaxial cell, load cell, displacement and pressure transducer



TRITECH

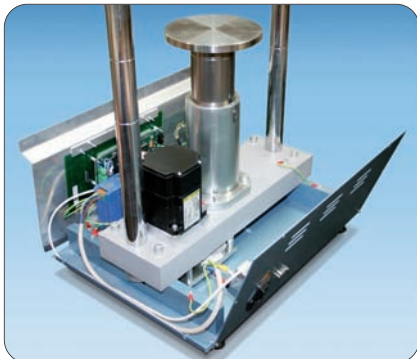
Triaxial load frames. Continued

Technical specifications

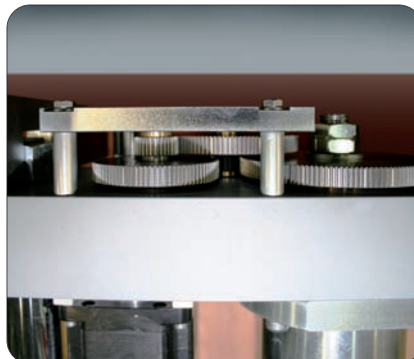
Models	28-WF4005 50 kN cap.	28-WF4010 100 kN cap.
Maximum sample size	105 mm dia.	150 mm dia.
Minimum speed	0.00001 mm per minute	0.00001 mm per minute
Maximum speed	9.99999 mm per minute	9.99999 mm per minute
Maximum force (compression)	50 kN	100 kN
Maximum force (tensile)	5 kN	5 kN
Minimum vertical clearance	335 mm	390 mm
Maximum vertical clearance	1100 mm	1140 mm
Horizontal clearance	364 mm	498 mm
Platen diameter	158 mm	158 mm
Platen travel	100 mm	100 mm
Dimensions (HxWxD)	1460x503x380 mm	1813x586x515 mm
Power (W)	600	680
Weight (kg)	98	195



TRITECH 28-WF4005 with banded triaxial cell 28-WF4050, load ring and dial indicator



Inside view of the machine. The ram is positively guided providing a rigid and linear action



Detail of the gearbox. The system is designed to minimize the vibrations and allow smooth transmission



TRITECH 28-WF4005 fitted with standard triaxial cell 28-WF0410/A load ring and dial indicator

TRITECH

MEASUREMENT ACCESSORIES FOR 28-WF4005 AND 28-WF4010 TRITECH FRAMES

LOAD MEASUREMENT

The machines can be fitted with:

- Standard mechanical load rings (30-WF6450 to 30-WF6452)
- External load cells (30-WF0370/T to 30-WF0376/T) for use with Data Acquisition and processing systems
- Submersible load cells fitted inside the triaxial cells (30-WF6350 to 30-WF6356) for better accuracy as the measurement is not affected by the friction between the ram and the cell collar. For use with Data Acquisition and processing systems

LOAD RINGS

General description

All load rings are supplied ready for direct connection to the adapter supplied with our triaxial load frames and by the simple fixing of a 28-WF1049 connector can be adapted for use with our complete range of triaxial cells.

- 28-WF6450 Load ring 1 kN cap.
- 28-WF6451 Load ring 2 kN cap.
- 28-WF6452 Load ring 5 kN cap.
- 28-WF6453 Load ring 10 kN cap.



Load ring fitted with 28-WF1049 seat

STRAIN GAUGE LOAD CELLS

Used to measure the axial force applied to the specimen in the triaxial cells:

General specifications

Nominal tensivity: 2mV/V

Accuracy: better than 0,1%

Code	Full scale	Thread
28-WF0370/T	3,5 kN	Female M20x1.5
28-WF0373/T	10 kN	Female M20x1.5
28-WF0375/T	50 kN	Female M30x2.0
28-WF0376/T	100 kN	Female M30x2.0

Note. All the load cells are supplied complete for connection to the upper beam of the triaxial frames (all models)



Strain gauge load cells

LOAD MEASUREMENT INSIDE THE TRIAXIAL CELL. SUBMERSIBLE LOAD CELLS

Internal load cells have been designed to work inside the triaxial cell. They have a lower hysteresis and very good linearity together with a substantial over load safety feature.

Specifications

Overload capacity: 200%

Excitation voltage: 10 V DC

Non-linearity: $\pm 0.05\%$ full scale

Hysteresis: 0.05% full scale

Cable length: 2 metres

Diameter: 75 mm

Height excluding ram or stub: 50 mm

⚖️ Weight excluding ram or stub: 850 g



28-WF6352 Submersible load cell fitted with a ram for a triaxial cell

SUBMERSIBLE LOAD CELLS FITTED WITH RAMS AND CORRESPONDENT TRIAXIAL CELL

Model of submersible load cell	Capacity		Model of triaxial cell compatible	Diameter of the ram
	kN	kgf		mm
28-WF6350	1.0	100	28-WF4050	15.5
28-WF6352	5.0	500		
28-WF6354	10.0	1000		
28-WF6351	1.0	100	28-WF4070 28-WF4100 28-WF4150 28-WF4070/P 28-WF4100/P 28-WF4150/P	25.0
28-WF6353	5.0	500		
28-WF6355	10.0	1000		
28-WF6356	25.0	2500		

TRITECH

Accessories. Continued

AXIAL STRAIN MEASUREMENT

Two different types of devices are used:

- Standard mechanical dial indicators (30-WF6402 and 30-WF6403)
- Potentiometric displacement transducers (30-WF6208 and 30-WF6210) with the suitable mounting bracket, for use with data acquisition and processing systems

MECHANICAL DIAL INDICATORS

- 30-WF6402 Dial indicator 30x0.01 mm
- 30-WF6403 Dial indicator 50x0.01 mm

General description

50 mm dia. clockwise rotation. Supplied complete with rear mount for connection to load rings.

Weight approx. 200 g



30-WF6402

POTENTIOMETRIC DISPLACEMENT TRANSDUCERS AND MOUNTING BRACKETS

Input voltage: 10 V DC

Output: from 0 to 10 V DC

Repeatability: better than 0,002 mm

Accuracy: better than 0,002 mm

- 30-WF6208 Axial displacement potentiometric transducer, 25 mm travel
- 30-WF6209 Axial displacement potentiometric transducer, 50 mm travel
- 30-WF6210 Axial displacement potentiometric transducer, 100 mm travel
- 30-WF6220 Mounting bracket for 28-WF4050 triaxial cell, 15.5 mm dia. ram
- 30-WF6221 Mounting bracket for 28-WF4070, 28-WF4100, 28-WF4150, 28-WF4070/P, 28-WF4100/P, 28-WF4150/P triaxial cells, 25 mm dia. ram
- 30-WF1048/T Mounting bracket for 28-WF0410/A, 28-WF0411/A, 28-WF0416/A



30-WF1048/T



30-WF6221



30-WF6209

note

Each displacement transducer must be completed with 30-WF6220 (or 30-WF6221 or 30-WF1048/T) to be connected to the triaxial cell ram.

PRESSURE MEASUREMENT

PRESSURE TRANSDUCERS FOR PORE PRESSURE MEASUREMENT

Input voltage: 10 V DC

Output voltage: 100 mV to full scale

Accuracy: better than 0,1 kPa

Code	Max.
28-WF6300	10 bar
28-WF6301	20 bar
28-WF6302	35 bar

Note. They are connected to the triaxial cell by the de-airing block 28-WF6310 or 28-WF4459

➤ 28-WF6310 De-airing block for pore pressure measurement transducer. It must be connected to the banded triaxial cells

➤ 28-WF4459 De-airing block for pore pressure measurement transducer. It must be connected to the standard triaxial cells



28-WF6300 with 28-WF6310



28-WF6300 with 28-WF4459

DATA ACQUISITION AND PROCESSING

➤ 30-WF6016 GEODATALOG, 16 channels data acquisition unit. 110-240 V, 50-60 Hz, 1ph. supplied complete with DATACOMM software for PC data acquisition (see description on page 56)

➤ 30-WF6042 Transducer extension cable, 6 m long

➤ 30-WF6044 Transducer extension cable, 12 m long

➤ 30-WF6016/T4 Effective stress (CU, CD) Triaxial Testing Geo-Analysis template

➤ 30-WF6016/T5 Undrained (UU) Triaxial Testing Geo-Analysis template



GEODATALOG 30-WF6016

STANDARD TRIAXIAL CELLS FOR SPECIMENS UP TO 100 MM DIA

General description and specifications

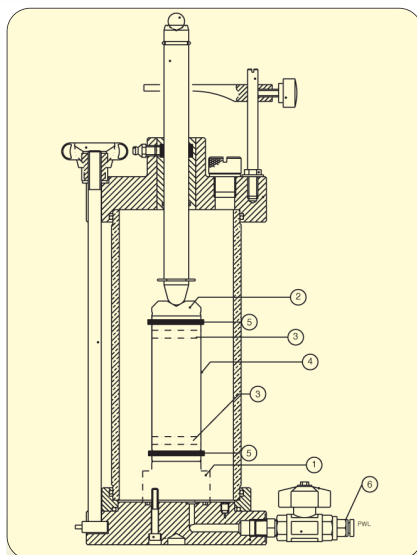
The cell essentially consists of a transparent polycarbonate chamber, which has a piston assembly fitted to the top and a double flange base fitted to the bottom. Three (or six) simple thumbscrews are used to clamp the upper part of the cell to the base, which make assembly and disassembly a very quick and simple operation.

The base of the cell has four inlet points for top drainage/back pressure, cell pressure and bottom drainage/pore water pressure. Two of these are supplied with special no-volume change valves.

Base adapters, plinths, top caps, porous discs, rubber membranes and sealing rings are not included. See accessories.



28-WF0420/9



- 1 Base adapter
- 2 Porous top cap
- 3 Porous disc
- 4 Rubber membrane
- 5 Sealing rings
- 6 No-volume change valve

TRIAXIAL CELLS

Code	28-WF0410/A	28-WF0411/A	28-WF0416/A
Max. specimen size (Ø x h mm)	50x100	70x140	100x200
Max. working pressure(kPa)	1700	1700	1700
Max. piston load (kN)	45	45	45
Max. height (mm)	380	440	515
Diameter (mm)	140	174	200
Weight (kg)	4	7.3	14.3



28-WF0416/A, 28-WF0411/A, 28-WF0410/A

TRIAXIAL CELL ACCESSORIES

Specimen base adapters

Each cell has to be completed with the base adapter corresponding to the specimen size as shown in the following table. All adapters are perforated for bottom drainage/pore

pressure measurement and are supplied complete with a solid disc for use in undrained tests.

Specimen dia. mm	28-WF0410/A Code	28-WF0411/A Code	28-WF0416/A Code
35	28-WF0410/A1	28-WF0411/A1	-
38	28-WF0410/A2	28-WF0411/A2	-
50	28-WF0410/A3	28-WF0411/A3	-
70	-	28-WF0411/A4	28-WF0416/A1
100	-	-	28-WF0416/A2

HAND SAMPLERS

Comprising cutter, wooden dolly and receiver.

Code (complete set)	Size (dia.xh mm)	Spare cutter tube Code	Spare dolly Code
28-WF0420/9	35x70	28-WF0420/91	28-WF0420/92
28-WF04031/G	38x76	28-WF0422/91	28-WF0422/92
28-WF04051/G	50x100	28-WF0425/91	28-WF0425/92
28-WF04071/G	70x140	28-WF0428/91	28-WF0428/92
28-WF04101/G	100x200	28-WF0432/91	28-WF0432/92

TRIAXIAL CELL ACCESSORIES (CONTINUED)

Description	For specimens				
	Ø 35 mm	Ø 38 mm	Ø 50 mm	Ø 70 mm	Ø 100 mm
Base adapters	28-WF0410/A1 ⁽¹⁾	28-WF0410/A2 ⁽¹⁾	28-WF0410/A3 ⁽¹⁾	28-WF0411/A4 ⁽¹⁾	28-WF0416/A2
	28-WF0411/A1	28-WF0411/A2	28-WF0411/A3	28-WF0416/A1	-
	✔ Code	✔ Code	✔ Code	✔ Code	✔ Code
Porous top cap	28-WF0420/A3	28-WF0422/A3	28-WF0425/A3	28-WF0428/A3	28-WF0432/A3
Pair of porous discs	28-WF0420/A4	28-WF4034	28-WF4054	28-WF4074	28-WF4104
Membrane (10pcs)	28-WF0420/A5	28-WF4035	28-WF4055	28-WF4075	28-WF4105
O ring (10pcs)	28-WF0420/7	28-WF4036	28-WF4056	28-WF4076	28-WF4106
Membrane stretcher	28-WF0420/8	28-WF4031/A	28-WF4051/A	28-WF4071/A	28-WF4101/A
O-ring placing tool	28-WF0420/10	28-WF4031/B	28-WF4051/B	28-WF4071/B	28-WF4101/B
Lateral filter drains (50pcs)	28-WF0420/A9	28-WF4031/E	28-WF4051/E	28-WF4071/E	28-WF4101/E
Filter discs (pack pf 100)	-	28-WF4031/F	28-WF4051/F	28-WF4071/F	28-WF4101/F
Split sand former	28-WF0420/A6	28-WF0422/A6	28-WF0425/A6	28-WF0428/A6	28-WF0432/A6
Drainage burette	28-WF0420/11	28-WF0420/11	28-WF0420/11	28-WF0420/11	28-WF0432/11 ⁽²⁾
No-volume change valve ⁽³⁾	28-WF0420/12	28-WF0420/12	28-WF0420/12	28-WF0420/12	28-WF0420/12
Split mould	28-WF0420/13	28-WF0422/13	28-WF0425/13	-	-
Spare parts					
Spare tube and connector for porous top cap	28-WF0420/20	28-WF0420/20	28-WF0420/20	28-WF0428/20	28-WF0432/20

(1) Depending upon cell model (2) 50 ml model (3) Complete with connection for 6 mm dia. plastic hose

Other accessories

- ✔ 28-WF4005/39 Platen adapter to fit standard triaxial cells on Tritech 50 or Tritech 100
- ✔ 86-D0822 Vaseline oil. 1 kg bottle
- ✔ 86-D0845 Water-repellent grease. 1 kg box
- ✔ 28-WF0420/15 Greaser for triaxial cell
- ✔ 28-WF0490/1 Flaring tool
- ✔ 28-WF0490 Nylon tubing 6x4 mm dia., 20 m coil

Legend

- 1 Base adapter.** Used to adapt the triaxial cell for use with the selected sample size. Supplied complete with a plain base cap.
- 2 Porous top cap.** Used to evenly apply the loading over the whole cross sectional area of the sample when drainage to the top of the sample is required. Includes a nylon tube and connector for the base drainage line.
- 3 Porous disc.** Used as a filter ensuring that the passage of water into and out of the sample is evenly spread over the whole cross sectional area. Two required.
- 4 Rubber membrane.** Provides a protective water proof sheath around the sample. Made of rubber latex and supplied in packs of 10.
- 5 Sealing rings.** Used to seal the membrane against the plinth and the top cap at either end of the sample. Supplied in packs of 10.
- 6 Membrane stretcher.** Used to pull open the membrane to allow it to be easily placed over the specimen without any disturbance.
- 7 Filter paper drains.** Used as side drains when specimens have low permeability. They are particularly useful when saturating clays before consolidation and shearing. Pack of 50.
- 8 Split sand former.** A specially designed piece of equipment for use when preparing non-cohesive soils which otherwise could not be mounted in a triaxial cell.
- 9 Drainage burette, 10 ml.** Used to prepare non-cohesive specimens by applying a negative pressure to the base of the specimen and for measuring drainage into and out of the specimen when testing with the specimen open to the atmosphere. Supplied with connections for triaxial cell.
- 10 O-ring placing tool.** To fit the sealing ring with the minimum disturbance to the sample.
- 11 No-volume change valve.** Identical to the two valves supplied with the triaxial cells and used for measuring pore pressure and when fitting the drainage burette.
- 12 Split mould.** Used for trimming the ends of soil specimen.



BANDED TRIAXIAL CELLS FOR SPECIMENS UP TO 150 MM DIA.

For use with TRITECH 28-WF4005 and 28-WF4010 models only

General specifications

- Light alloy construction, stainless steel ram and O ring seal
- Built-in cell ram clamp
- Includes pillar and anvil for strain dial gauge or transducer
- Five on/off no-volume change valves fitted as standard
- Sample sizes between 38 mm and 150 mm dia.
- Standard length chamber accepts submersible load cells
- Rapid assembly design
- Cells are designed to accommodate a specimen with a high twice its diameter

Important note

The TRI-CELL Plus Triaxial Cells with wire outlets for transducers are shown on page 34

TRIAXIAL CELLS

Code	28-WF4050	28-WF4070	28-WF4100	28-WF4150
Nominal size (Ø mm)	38	70	100	150
Range of specimen size (Ø mm)	38-50	38-70	50-100	100-150
Max. working pressure (kPa)	2000	3400	2000	2000
Max. height (mm)	410	500	564	650
Diameter (mm)*	350	400	440	650
Weight (kg)	7	15	21	40

* Including valves

Conversion sets

The sets listed are used to test smaller sample sizes in the 70 mm, 100 mm and 150 mm triaxial cells. Each set consists of a pedestal, top cap and drainage lead.

■ **28-WF4070/1** Conversion set for testing 38 mm samples in 28-WF4070, 70 mm triaxial cell

■ **28-WF4070/2** Conversion set for testing 50 mm samples in 28-WF4070, 70 mm triaxial cell

■ **28-WF4100/1** Conversion set for testing 50 mm samples in 28-WF4100, 100 mm triaxial cell

■ **28-WF4100/2** Conversion set for testing 70 mm samples in 28-WF4100, 100 mm triaxial cell

■ **28-WF4150/1** Conversion set for testing 100 mm samples in 28-WF4150, 150 mm triaxial cell

Main features

- **Banded cell**
For extra protection when using compressed air systems
- **2000 kPa and 3400 kPa working pressure**
3400 kPa on 28-WF4070 cell
- **Separate cell chamber clamping**
Prevents over stressing chamber. Ensures correct alignment



28-WF4050

28-WF4070

28-WF4100

BANDED TRIAXIAL CELLS FOR SPECIMENS UP TO 150 MM DIA. Continued

BANDED TRIAXIAL CELL ACCESSORIES

Description	For specimens				
	Ø 38mm	Ø 50 mm	Ø 70 mm	Ø 100mm	Ø 150 mm
Cell type	28-WF4050	28-WF4050	28-WF4070	28-WF4100	28-WF4150
Pedestal	28-WF4031	28-WF4051	28-WF4071	28-WF4101	28-WF4151
Top cap ⁽¹⁾	28-WF4032	28-WF4052	28-WF4072	28-WF4102	28-WF4152
Base disc	28-WF4033	28-WF4053	28-WF4073	28-WF4103	28-WF4153
Pair of porous disc	28-WF4034	28-WF4054	28-WF4074	28-WF4104	28-WF4154
Membrane (pack of 10)	28-WF4035	28-WF4055	28-WF4075	28-WF4105	28-WF4155
O ring (pack of 10)	28-WF4036	28-WF4056	28-WF4076	28-WF4106	28-WF4156
Membrane stretcher	28-WF4031/A	28-WF4051/A	28-WF4071/A	28-WF4101/A	28-WF4151/A
O ring placing tool	28-WF4031/B	28-WF4051/B	28-WF4071/B	28-WF4101/B	28-WF4151/B
Three parts split former	28-WF4031/C	28-WF4051/C	28-WF4071/C	28-WF4101/C	28-WF4151/C
Two parts split mould	28-WF4031/D	28-WF4051/D	28-WF4071/D	28-WF4101/D	28-WF4151/D
Lateral filter drains (pack of 50)	28-WF4031/E	28-WF4051/E	28-WF4071/E	28-WF4101/E	28-WF4151/E
Filter discs (pack of 100)	28-WF4031/F	28-WF4051/F	28-WF4071/F	28-WF4101/F	28-WF4151/F
Hand sampler	28-WF4031/G	28-WF4051/G	28-WF4071/G	28-WF4101/G	28-WF4151/G

⁽¹⁾ including drainage leads

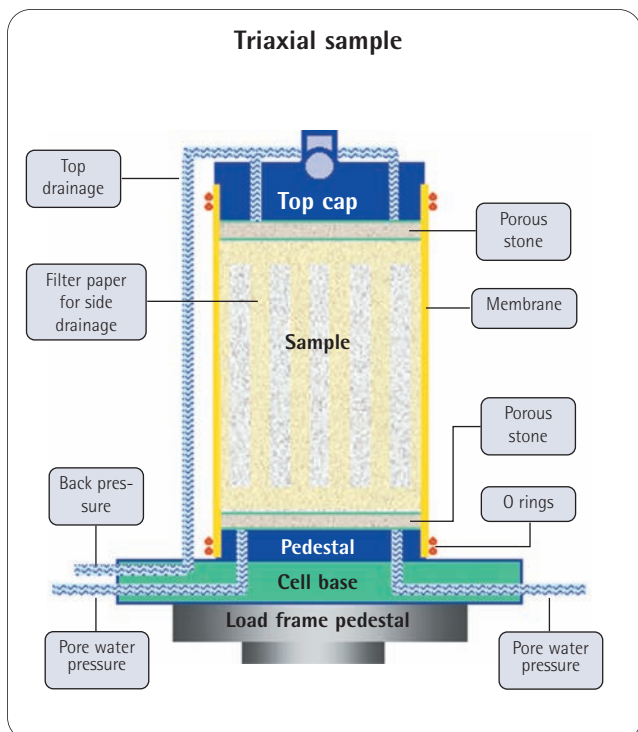
Note. Triaxial cell and accessories for 35mm dia. sample available on request



Triaxial cell accessories



28-WF4051/G



TRI-CELL PLUS, SPECIAL TRIAXIAL CELLS

For use with bender elements and internal electronic transducers

General description

The TRI-CELL Plus cells accept samples of up to 150 mm dia. The design of the cell ensure vertical alignment of the cell ram by clamping the perspex wall separately from the cell top. The cell wall is banded to prevent excessive expansion during the test and to protect against explosive failure when used with compressed air systems.

The TRI-CELL Plus cells include a transducer axis ring with six outlets for on sample transducer cables (i.e. radial and axial transducers, mid height pore water pressure transducers, etc.) or for measurements with bender elements (see page 36). They are also suitable for extension tests.

Space between the cell wall and sample needs to be greater when using on sample transducers. For this reason we recommend using a sample one size down. For this reason conversion pedestal and top cap sets are shown on the tables.

■ 28-WF4070/P

3400 kPa TRI-CELL Plus cell for 70 mm dia. samples with wire outlets for transducers

■ 28-WF4100/P

2000 kPa TRI-CELL Plus cell for 100 mm dia. samples with wire outlets for transducers

■ 28-WF4150/P

2000 kPa TRI-CELL Plus cell for 150 mm dia. samples with wire outlets for transducers

Accessories

- ▶ 28-WF4005/E Extension test accessory for rigid connection to the ram of the banded triaxial cell
- ▶ 28-WF4050/1 Action coupling (3 pieces)



28-WF4070/P

- Transducer axis ring with six outlets for on sample transducer cables
- Suitable for measurements with bender elements
- 3400 kPa max. working pressure (model 28-WF4070/P) and 2000 kPa (models 28-WF4100/P and 28-WF4150/P)

TRI-CELL PLUS ACCESSORIES

Cell type nominal dia.	Sample size	Pedestal	Top cap with 2 drainage leads	Perspex base disc(*)	Conversion set(**)	Top cap vacuum type(***)
28-WF4070/P 70 mm	38 mm	-	-	28-WF4033	28-WF4070/1	28-WF4032/V
	50 mm	-	-	28-WF4053	28-WF4070/2	28-WF4052/V
	70 mm	28-WF4071	28-WF4072	28-WF4073	-	28-WF4072/V
28-WF4100/P 100 mm	50 mm	-	-	28-WF4053	28-WF4100/1	28-WF4052/V
	70 mm	-	-	28-WF4073	28-WF4100/2	28-WF4072/V
	100 mm	28-WF4101	28-WF4102	28-WF4103	-	28-WF4102/V
28-WF4150/P 150 mm	100 mm	-	-	28-WF4103	28-WF4150/1	28-WF4102/V
	150 mm	28-WF4151	28-WF4152	28-WF4153	-	28-WF4152/V

(*) To replace the porous disc when UU tests are carried out (**) Consisting of pedestal, top cap and drainage lead

(***) Required to perform extension tests (where the axial stress applied to the sample is less than cell pressure)

SAMPLE ACCESSORIES

Sample size	Porous disc (pair)	Rubber membrane (pack of 10)	O ring (pack of 10)	Membrane stretcher	O ring placing tool	Three parts split mould	Two parts split former	Lateral filter drains (pack of 50)	Filter discs (pack of 100)	Hand sampler (*)
38 mm	28-WF4034	28-WF4035	28-WF4036	28-WF4031/A	28-WF4031/B	28-WF4031/C	28-WF4031/D	28-WF4031/E	28-WF4031/F	28-WF4031/G
50 mm	28-WF4054	28-WF4055	28-WF4056	28-WF4051/A	28-WF4051/B	28-WF4051/C	28-WF4051/D	28-WF4051/E	28-WF4051/F	28-WF4051/G
70 mm	28-WF4074	28-WF4075	28-WF4076	28-WF4071/A	28-WF4071/B	28-WF4071/C	28-WF4071/D	28-WF4071/E	28-WF4071/F	28-WF4071/G
100 mm	28-WF4104	28-WF4105	28-WF4106	28-WF4101/A	28-WF4101/B	28-WF4101/C	28-WF4101/D	28-WF4101/E	28-WF4101/F	28-WF4101/G
150 mm	28-WF4154	28-WF4155	28-WF4156	28-WF4151/A	28-WF4151/B	28-WF4151/C	-	28-WF4151/E	28-WF4151/F	-

(*) Complete of cutter, wooden dolly and receiver

ON SAMPLE STRAIN TRANSDUCERS

Consist of two axial and one radial transducers. In conventional triaxial testing the determination of axial stiffness is based on external measurements. This method brings errors due to sample bedding effects of the porous stones on either end of the sample and to the loading system and load measuring system.

Furthermore the two ends of the specimen are subjected to restraint, differently from the middle third of the sample, where the strain transducers are mounted and where the realistic deformations occur.

Axial and radial strain transducers give the opportunity to measure with high accuracy the deformations directly on the triaxial test specimen.

These transducers have to be used with TRI-CELL Plus models (see page 34) and with a suitable Data Acquisition system as for example our GEODATALOG shown on page 62.

On sample strain transducers for static testing:

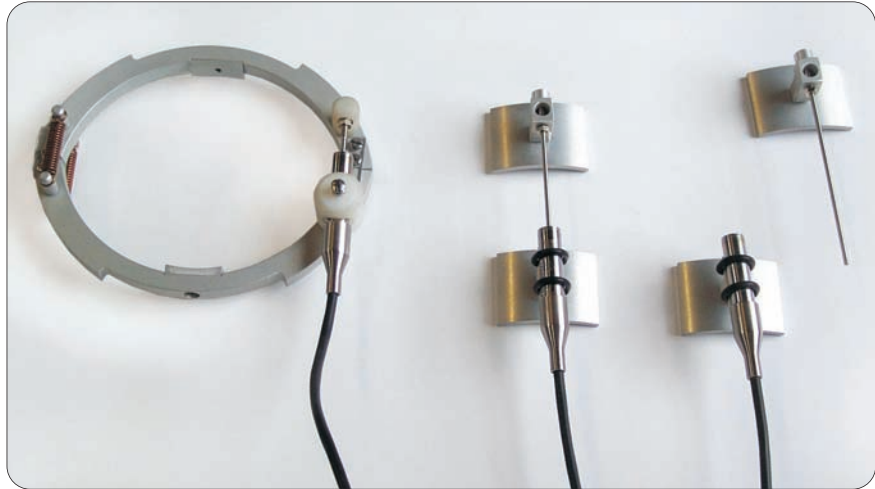
Energise: 10 V DC

Output: ± 250 mV

Linearity: $\pm 0.25\%$

Temp. coefficient: $\pm 0.01\%/FS/deg C$

Resolution: 1 micron



28-WF4109/K

On sample transducers kit for static systems

28-WF4079/K	On sample transducer kit for 70 mm samples with 2 linear and 1 radial transducers, radial belt, axial fixing pads, plus all plugs for use with GEODATALOG*
28-WF4109/K	On sample transducer kit for 100 mm samples with 2 linear and 1 radial transducers, radial belt, axial fixing pads, plus all plugs for use with GEODATALOG*
28-WF4159/K	On sample transducer kit for 150 mm samples with 2 linear and 1 radial transducers, radial belt, axial fixing pads, plus all plugs for use with GEODATALOG*

* See page 62

note

On sample transducers kit for dynamic systems are described on page 74

BENDER ELEMENTS

Applications

Bender elements allow to measure the maximum shear modulus (G_{max}) of a soil sample and from this data to evaluate the stiffness of a soil. G_{max} is generally associated with shear strain levels of about 0.001% and is a key parameter in small strain dynamic analyses, such as those to predict soil behaviour or soil structure interaction during earthquakes, explosion or machine and traffic vibrations.

General description

The piezoceramic bender element is an electro-mechanical transducer, which is capable of converting mechanical energy (movement) either to or from electrical energy. The single bender element consists of two thin piezoceramic plates, which are rigidly bonded together with conducting surfaces between them and on the outsides.

The polarisation of the ceramic material in each plate and the electrical connections are such that when a driving voltage is applied to the element, one plate elongates and the other shortens. The net result is a bending displacement, which is greater in magnitude than the length change in either of the two layers.

On the other hand, when the bender element is forced to bend, one layer will go into tension and the other into compression: this will result in an electrical signal, which can be measured.

In the soil application the bender elements are encapsulated and mounted into inserts, which are fixed into the pedestal and top cap of a triaxial cell. They protrude edge-first into the soil specimen as cantilevered. When excited the bender element bends from side to side pushing the soil in a direction perpendicular to the length of the element and thus having a large coupling factor with the soil. This produces a shear wave, which propagates parallel to the length of the element

into the soil sample. On the other end of the soil sample another bender element is forced to bend and produces an electrical signal that can be measured.

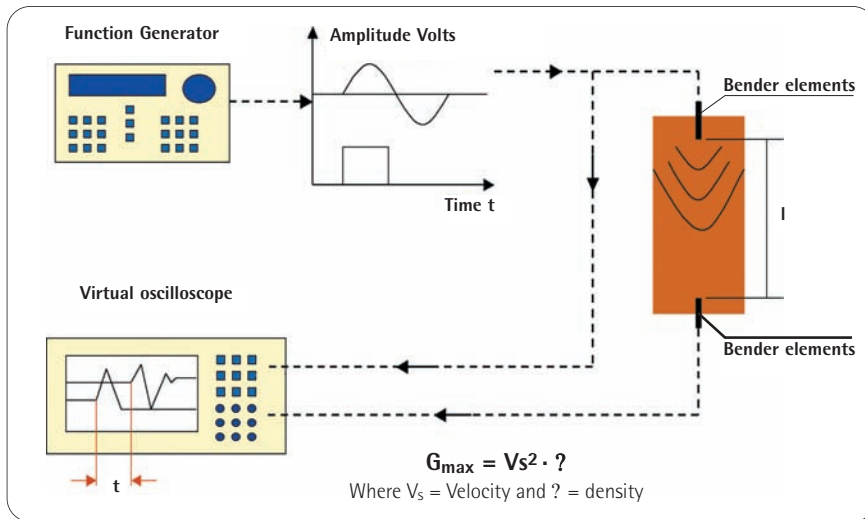
Theory on shear wave propagation in an elastic body tells us that the value of the shear modulus G_{max} of the soil from measurement of shear wave velocity V_s is given by:

$$G_{max} = \rho \cdot (V_s)^2$$

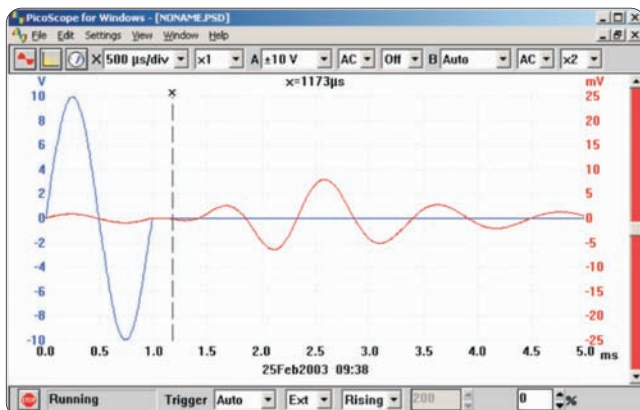
where ρ is the mass density of the soil sample. The system consists of a transmitter, which is energised to produce the shear waves through the soil sample, and the receiver that receive the electrical signal. The travel time of the shear wave from the transmitter to the receiver is determined via a specific software that allows the user to quickly and easily calculate the shear wave velocity.

The complete power and measuring system 28-WF4190 includes:

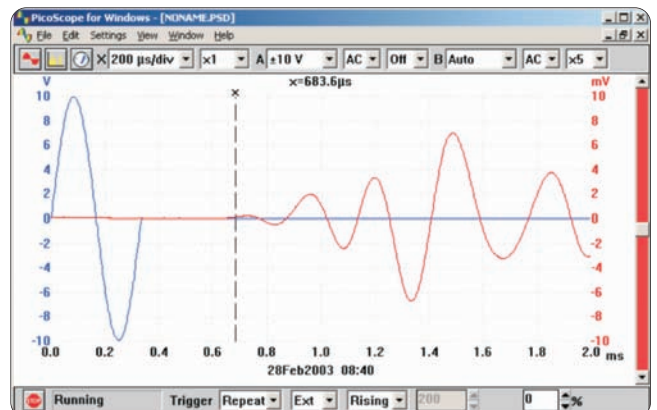
- Waveform generator
- Analog-to-PC interface
- Virtual oscilloscope software
- Connecting cables



Bender elements test results on clay
Frequency set at 1 kHz



Frequency set at 3 kHz



BENDER ELEMENTS

Continued

TRI-CELL Plus model	Sample size	Top cap and base pedestal with bender elements	
		Standard for compression tests only	Vacuum type also for extension tests
28-WF4070/P 70 mm	50 mm 70 mm	28-WF4057/B 28-WF4077/B	28-WF4058/B 28-WF4078/B
28-WF4100/P 100 mm	70 mm 100 mm	28-WF4077/B1 28-WF4107/B	28-WF4078/B1 28-WF4108/B
28-WF4150/P 150 mm	150 mm	28-WF4157/B	28-WF4158/B

Accessories

► 28-WF4190 Power and measuring system

The Bender elements have to be powered by a waveform signal generator. The output signal is converted into digital and transmitted to PC via an interface and processed with the virtual oscilloscope software. The complete system includes waveform generator, analog-to-PC interface, virtual oscilloscope software and connecting cables. PC not included.



Pressure systems

■ 28-WF4300

Hydromatic, Stand Alone pressure controller**Description**

The stand alone Hydromatic pressure controller is a water pressure source and volume change gauge that can generate pressures up to 3500kPa, independently from traditional compressed air source, mercury columns or dead weight devices.

It consists of an hydraulic piston driven by a ball screw and gear box mounted on a ball slide. The system is driven via a stepper motor by Automax microprocessor control system. Automax allows the pressure pump to work as an automatic stand-alone unit that can be easily moved from one triaxial system to another.

The pressure is automatically recharged when piston travel limit is reached.

Stand alone Hydromatic unit includes:

- 3500kPa pressure transducer (used for closed loop control) connected to Automax unit.
- De airing block
- 2 solenoid on/off valves: one connected to pressure controller outlet line, one connected to triaxial cell line (for cell or back pressure)
- 8x6mm tubing for pressure controller and cell connection
- quick couplings for banded triaxial cell and Tri-Cell Plus connections*

Automax unit assures important features:

- Real time reading of pressure
- Fast/slow approach to decrease/increase pressure (through 10 keypad membrane)
- Over travel limits alarm
- Programmable control to ramp and cycles of pressure versus time
- Different calibration modes (linear or polynomial)



28-WF4300

Main features:

- Application of up to 3500kPa pressure for triaxial or permeability tests
- Pressure and volume change measurements recording (displayed in real time)
- Temporary or continuous connection to PC for data downloading with different protocols through RS232
- Possibility to set ramp and cycles of pressure
- Easy connection to any kind of system
- It can be used for AUTOTRIAX system (see sec. 29)
- Different protocol of data downloading to PC via RS232 serial port (either for real time or deferred time downloading)
- Automatic piston recharge
- Ram memory with battery back-up with clock/calendar operating also when the unit is switched off
- Large monochromatic display 240x128 pixel for data recording view in real time

The system can be used for different kind of tests as saturated and unsaturated triaxial or permeability (in triaxial cell or permeability cell, see pages 32 and 44) and can applied to any system.

Specification

Output pressure: up to 3500kPa

Pressure accuracy: +/-0.1% of full scale

Volume accuracy: 0.1 cm³

Resolution: 131.000 divisions

Volumetric capacity: 250 cm³

Data downloading: via RS232

Power supply: 110-240V/50-60Hz/1ph

Overall dimensions: 250x220x150 mm

Weight approx.: 7 kg

* adaptors for standard triaxial cells are available on request.

OIL AND WATER CONSTANT PRESSURE SYSTEM

■ 28-WF4312

Oil and water automatic constant pressure apparatus for pressure up to 3500 kPa. 240 V, 50 Hz, 1 ph.

■ 28-WF4314

Same as above but 110 V, 60 Hz, 1 ph.

■ 28-WF4302

Oil and water automatic constant pressure apparatus for pressure up to 1700 kPa. 240 V, 50 Hz, 1 ph.

■ 28-WF4304

Same as above but 110 V, 60 Hz, 1 ph.

General description and specifications

This apparatus provides an infinitely variable constant pressure using an adjustable spring type dead weight pressure feedback system connected in-line with a pump and an oil/water interchange vessel.

The apparatus comprises: hydraulic pump (motorised); honed piston/spring assembly; cylindrical oil/water interchange vessel; precision gauge; valves; 2 kg of oil.

Pressure range: 0-1700 and 0-3500 kPa

Power: 35 W

Dimensions: 310x300x400 mm

Weight approx.: 16 kg

- Generates and automatically controls the set pressure up to a maximum of 3500 kPa (500 p.s.i.) within $\pm 0.5\%$ of the indicated pressure
- Very stable over long periods
- Required pressure set using precision hand wheel control
- Stepless pressure increments
- No weights nor calibration required

28-WF4302



Accessories

- 28-WF4302/1 High viscosity oil. 5 kg
- 28-WF4191 Nylon tubing 6 mm bore x 8 mm outside dia., 10 m length
- 28-WF4193 Normal action coupling for fitting inlet lines to cell

BLADDER TYPE AIR/WATER PRESSURE SYSTEM

■ 28-WF4320

Bladder air/water pressure cylinder

General description and specifications

For delivery of pressurised water to triaxial cells up to 1000 kPa. The main advantages from using this apparatus are:

- High degree of accuracy
- Extremely simple to operate
- Future expansion of system very easy and relatively low cost
- Bladder enables the use of de-aired water
- Large reservoir to cope with long-term tests and large samples.

This unit acts as a reservoir/interface between compressed air, used as a pressure source, and water used as the pressurising medium in the triaxial cell.

Max. pressure: 1000 kPa

Dimensions: 178 mm dia. x 412 mm height

Weight approx.: 9 kg



28-WF4320

Accessories and spares

- 28-WF4191 Nylon tubing 8x6 mm dia. 10 m coil
- 28-WF0490 Nylon tubing 6x4 mm dia. 20 m coil
- 28-WF4320/1 Spare rubber membrane for 28-WF4320

PRESSURE DISTRIBUTION PANELS

Introduction

The range of water distribution panels have been designed to make them easy to use. They include quick release fittings to allow fast reconnection of water and airlines within the pressure system.

Colour coding of the air and water lines has also been introduced to ensure that the user is able to trace air or water supply throughout the system.

They have to be completed with either a precision Bourdon gauge 200 mm dia. range 0-1100 kPa, 5 kPa div. (see 28-WF4330/1), or with a digital gauge 1 kPa resolution. (see 28-WF4330/2).

Two models available: for two and three pressure lines.

ORDERING INFORMATION

■ 28-WF4330

Triaxial panel, two pressure lines, complete with air regulators, pressure outlets for two pressures.

Dimensions 510x454x184 mm, weight 10 kg

■ 28-WF4331

Triaxial panel, three pressure lines, complete with air regulators, pressure outlets for three pressures.

Dimensions 690x454x184 mm, weight 15 kg

■ 28-WF4330/1

Bourdon pressure gauge 200 mm dia., range 0-1100 kPa, 5 kPa div.

■ 28-WF4330/2

Digital pressure gauge, 1 kPa div.



28-WF4331 with 28-WF4330/2

Spare parts

- 28-WF4330/3 Air pressure regulator, 150 p.s.i., 1000 kPa with fittings for 8 mm OD tube

Water de-airing systems

WATER DE-AIRING SYSTEMS

We propose two different systems, both completed with a de-airing tank 23 (or 7) litres cap.:

- Suitable vacuum pump and water trap to collect condensed water vapour. The water tank has to be fitted at a high level to fill the system by gravity.
- Integrated model incorporating vacuum pump/compressor, and valves. The vacuum pump is used as a little compressor to force de-aired water from the de-airing tank (that can be placed anywhere) to the system (pressure panels, bladders etc.).

■ 28-WF4202

De-airing water apparatus.

240 V, 50-60 Hz, 1 ph.

■ 28-WF4204

De-airing water apparatus.

110 V, 60 Hz, 1 ph.

General description and specifications

This apparatus incorporates a vacuum pump compressor, a water trap and valves. It has to be connected to the de-airing tank. The double function of this unit gives the important advantage of placing the de-airing tank anywhere and quickly filling the de-aired water to the system by a simple valve.

📏 **Dimensions:** 375x240x250 mm approx.

📊 **Weight approx.:** 10 kg



28-WF4202

DE-AIRING TANK

■ 28-WF4220/A

De-airing tank 7 litres cap.

■ 28-WF4221/A

De-airing tank 23 litres cap.General description and specifications

Used in conjunction with a vacuum source this item provides a very efficient and therefore quick means of removing the air from water. The de-airing tank consists of a perspex cylinder fitted with a water spray inlet, an air outlet and a water outlet. A suitable vacuum supply is connected to the air outlet and water is sucked into the cylinder in a fine spray via the water inlet. The vacuum draws the air out of the water. Complete with metal stand.

📊 **Weight approx.:** 3/14 kg

DE-AIRED WATER PANEL

■ 28-WF4225

Valve panel for use with de-airing tankGeneral description

For connection to the vacuum pump and de-airing tank. Includes water tap connection and two de-aired water outlets.

📏 **Dimensions:** 510x200x30 mm

📊 **Weight approx.:** 3 kg

VACUUM PUMPS

■ 28-WF2001

Vacuum pump. 240 V, 50 Hz, 1 ph.

■ 28-WF2001/Z

Same as above but 110 V, 60 Hz, 1 ph.Specifications

Free air displacement: 75 l/min

Ultimate vacuum: 0.1 mbar

Power: 180 W

📏 **Dimensions:** 345x155x215 mm

📊 **Weight approx.:** 12 kg

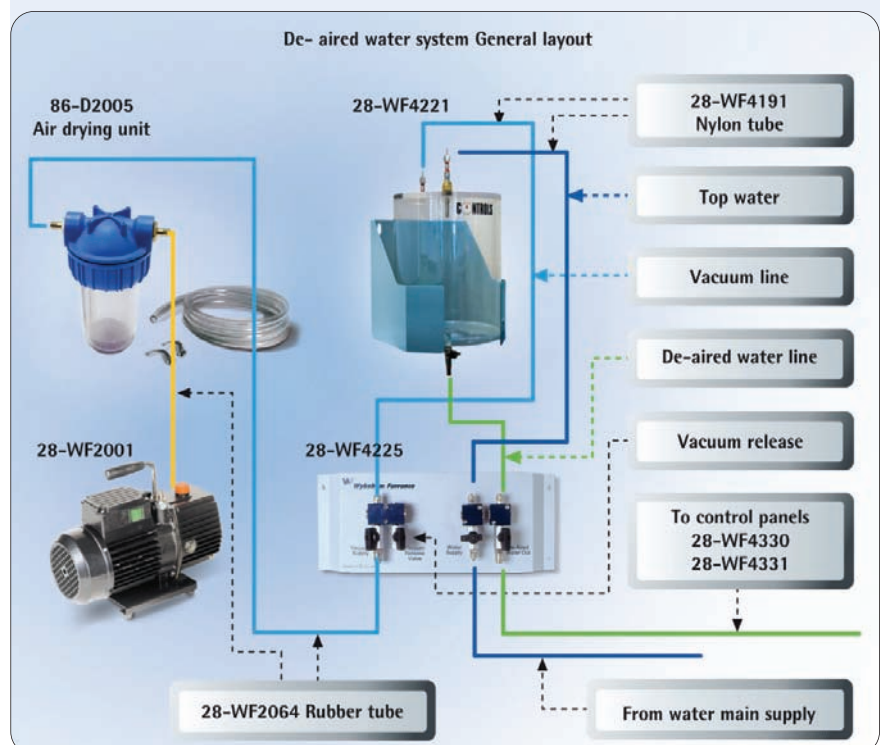
■ 28-WF2064

Rubber tube for vacuum pump

AIR DRYING UNIT

■ 86-D2005

To used with silica gel 86-D0819



VOLUME CHANGE MEASUREMENT


We propose two different models: standard 28-WF4400 and electronic 28-WF4410 suitable for connection to digital display or data acquisition system as for example our model GEODATALOG 30-WF6016 (see page 62).

■ 28-WF4400

Double burette volume change apparatus

General description and specifications

The apparatus comprises two measurement tubes, which have a 25 ml burette mounted internally and an acrylic tube externally. The burette tubes are connected directly to a reversing valve system, which is used to reverse the direction of travel of the interface in the measurement tubes without affecting the direction of flow of water to or from the triaxial cell. The unit also includes a by-pass valve system when volume change measurement is not required. Max. working pressure 10 bar. Burettes are calibrated to Class A.

 **Dimensions:** 130x682x87 mm

 **Weight approx.:** 3 kg



28-WF4400

■ 28-WF4410

Automatic volume change apparatus

General description and specifications

When connected with a suitable display or data acquisition system the apparatus provides an electrical signal directly proportional to the volume of water flowing through the unit. The apparatus comprises a piston connected to a 25 mm travel linear transducer and sealed against a precision-machined calibration chamber so that the linear movement of the piston is exactly proportional to the volume of water in the calibration chamber.

The apparatus includes the panel with reversing valve system to measure the water flow in both directions.

For use with the Automatic triaxial systems another version is also available: 29-WF4412 with automatic microelectrovalve for flow inversion by remote control in place of the manual system (see page 53).

Basic capacity: 100 cm³

Transducer input: up to 12 V DC

Accuracy: ± 0.1 ml

 **Dimensions:** 260x280x400 mm (lxdxh)

 **Weight approx.:** 5 kg



28-WF4410

AIR COMPRESSOR AND ACCESSORIES

■ 86-D2015

Laboratory air compressor 10 bar max. pressure, 50 litres cap. 240 V, 50 Hz, 1 ph.

■ 86-D2015/Z

Same as above but 110 V, 60 Hz, 1 ph.


Specifications

Max. pressure: 1000 kPa

Continuous working pressure: 800 kPa

Reservoir capacity: 50 litres

Max. air delivery: 246 l/min

 **Dimensions:** 985x395x820 mm (lwxhxh)

Power: 1500 W

 **Weight approx.:** 62 kg

■ 28-WF2016/2

Air filter/water trap for air compressors



86-D2015



28-WF2016/2

Accessories

► 28-WF4400/1 Red dye hydrocarbon soluble pack for 500 ml

Pore water pressure measurement

PORE WATER PRESSURE MEASUREMENT

Pore pressure can be measured with the electronic readout unit 28-WF4450 battery operated connected to the pressure transducer 28-WF6300 with the de-airing block 28-WF4459 fitted directly to the triaxial cell.

■ **28-WF4450**
3 channels digital readout unit for pore pressure measurement.
Battery operated

General description and specifications

This digital pressure gauge consists of a long-term steady analogic section, and of a 16 bit converter A/D which guarantees 65000 internal divisions.

The unit has internal batteries with 1-year autonomy, which is also guaranteed by the AUTO-POWER-OFF function, which activates if in 30 minutes any measurement change is not detected. It has to be connected to a suitable pressure transducer such as our model 28-WF6300 with the de-airing block 28-WF4459.

The 3-channel version 28-WF4450 is fitted with a multiplexer selector switch.

Specifications

Displays: 4 x 20 characters display

Measuring units (programmable): mbar, bar, MPa, kPa, p.s.i.

Accuracy: $\pm 0.20\%$ full scale

Scanning rate: 50 readings per sec

📏 **Dimensions (lxdxh):** 120x130x75 mm

⚖️ **Weight approx.:** 1 kg



- Programmable in Imperial or metric units
- Battery operated
- Peak function (positive and negative)

28-WF4450 with three 28-WF6300

PRESSURE TRANSDUCERS

■ **28-WF6300**
Pressure transducer, 10 bar

■ **28-WF6301**
Pressure transducer, 20 bar

■ **28-WF6302**
Pressure transducer, 35 bar

■ **28-WF6310**
De-airing block for pressure transducer, for banded triaxial cells

■ **28-WF4459**
De-airing block for pressure transducer, for standard triaxial cells



28-WF6300 with 28-WF4459

Accessories

- ▶ **30-WF6044** 12 m transducer extension cable
- ▶ **30-WF6042** 6 m transducer extension cable



28-WF6300 with 28-WF6310

SPECIMENS CONSOLIDATION

STANDARDS

ASTM D4767-95 / BS 1377: Part 8: 1990 / CEN-ISO/TS17892-9

28-WF0493

Three places consolidation load frame

General description

This apparatus has been designed to reduce the testing time for triaxial tests, where only one compression machine is available. With this equipment it is possible to perform the consolidation stage of three triaxial specimens at the same time for CU and CD tests, where:

- Vertical compression of specimen must be measured
- Anisotropic consolidation has to be performed.

It consists of a steel bench complete with three load frames and centring platens, for all our triaxial cells (28-WF0410/A, 28-WF0411/A, 28-WF0416/A, 28-WF4050, 28-WF4070, 28-WF4100), for triaxial specimens from 35 to 100 mm dia.

The apparatus can also be used for other make of triaxial cells, provided that they are equipped with a centring hole 13 mm dia. x 3 mm deep. Each consolidation frame can be equipped with a beam loading device to reduce the number of dead weights required for anisotropic consolidation (see accessories). Weights can be placed on both the centre hanger and on the lever hanger.

The weights of the loading frames have been reduced to minimum so that a counterbalance of the frame is not required.

Bench dimensions: 1300x585 mm

Overall dimensions (hxdxl):
1300x800x970 mm

Total weight: 145 kg approx.



Detail of the 28-WF0493 10:1 beam loading device



28-WF0493 complete with triaxial cells, dial gauges beam loading device and weights

- To perform simultaneously the anisotropic consolidation stage of three triaxial specimens
- To reduce the testing time where only one triaxial compression machine is available
- For triaxial cells up to 100 mm dia. specimens
- Ergonomic design for better use of space in the laboratory



28-WF0493 Detail of the upper frame with the top knob to adjust and level the position of the beam device conforming to the different triaxial cells. The base plate is also suitable for other makes of triaxial cells provided that they are equipped with a centring hole 13 mm dia. by 3 mm deep

Accessories

Code	Description
Slotted weights	
28-WF0493/1	Set of weights for specimen from 35 to 70 mm dia. Each set, suitable for a single frame complete with beam loading device, consists of the following: No. 4 Slotted steel weight 250 g No. 4 Slotted steel weight 500 g No. 4 Slotted steel weight 1 kg No. 4 Slotted steel weight 2 kg No. 4 Slotted steel weight 4 kg
28-WF0493/2	Additional set of weights for specimen up to 100 mm dia. Each set, suitable for a single frame complete with beam loading device, is used in addition to the other set of weights 28-WF0493/1 for anisotropic consolidation of large size specimens. It consists of the following: No. 4 Slotted steel weight 8 kg
Beam loading device	
28-WF0493/3	Beam loading device 10:1 ratio. Used to amplify the axial load to be applied on the specimens contained in the triaxial cells. The lever is completed with a screw-jack support with handle
Dial gauges and axial transducers	
30-WF6402	Dial gauge 30x0.01 mm
30-WF6403	Dial gauge 50x0.01 mm
30-WF6208	Axial strain transducer 25 mm displacement
30-WF6209	Axial strain transducer 50 mm displacement
28-WF1048/T	Mounting bracket for dial gauges and axial transducers
Holding device	
28-WF0410/A4	Holding lock to maintain the piston of the triaxial cell in contact with the specimen (for use with 28-WF0410/A to 28-WF0416/A cell series only)

PERMEABILITY CELLS

The permeability cells are available either in brass for normal use or in stainless steel for contaminated materials. Top caps and pedestals are available for normal or contaminated materials.

The toxic interface unit is recommended to be fitted between control panel and permeability cells to avoid toxic permeants from entering control panel.

This also prevents contact of air with the permeant, thus no toxic or corrosive vapours can escape into the laboratory.

■ 28-WF0194/A

Cell with brass valves for normal use

■ 28-WF0194/B

Cell with stainless steel valves for use with contaminated soils



28-WF0194/A



28-WF0194/3

TOP CAPS AND BASE PEDESTALS

Code	Application	Sample size
28-WF0194/A1	Normal use	70 mm
28-WF0194/A2	Normal use	100 mm
28-WF0194/B1	Contaminated materials	70 mm
28-WF0194/B2	Contaminated materials	100 mm

Sample accessories

	70 mm	100 mm
Porous discs	28-WF4074	28-WF4104
Membranes	28-WF4075	28-WF4105
O-rings	28-WF4076	28-WF4106
O-ring placing tool	28-WF4071/B	28-WF4101/B
Suction device	28-WF4071/A	28-WF4101/A
Two part split former	28-WF4071/D	28-WF4101/D

ACCESSORIES FOR CONTAMINATED MATERIALS TESTS

Code		Weight approx.
28-WF0194/3	Toxic interface chamber	3 kg

TYPICAL CONFIGURATION OF A SYSTEM FOR PERMEABILITY TEST WITH PERMEABILITY CELLS FOR NORMAL OR CONTAMINATED SOIL SAMPLES

Code	Description	Q.ty
28-WF0194/A	Cell with brass valve	1
28-WF0194/B	Cell for contaminated soils*	1
28-WF0194/A2	Top cap and base pedestal	1
28-WF0194/B2	Top cap and pedestal for contaminated materials*	1
28-WF0194/3	Toxic interface chamber*	2
28-WF4105	Rubber membranes (10 pieces)	1
28-WF4106	Sealing rings (10 pieces)	1
28-WF4101/A	Membrane stretcher	1
28-WF4101/D	Split former	1
28-WF4101/B	O-ring placing tool	1
28-WF6300	Pressure transducer 10 bar	2
28-WF6310	De-airing block	2
28-WF4450	3 channels digital readout unit	1
28-WF4331	Pressure control panel, 3 lines	1
28-WF4330/2	Digital pressure gauge	1
28-WF4400	Double burette volume change	2
28-WF4220/A	De-airing tank 7 litres cap.	1
28-WF4202	De-airing water apparatus	1
28-WF4191	Nylon tubing 6x8 mm dia., 10 m	2
86-D2015	Air compressor, 86 litres	1
28-WF2016/2	Air filter/water trap for air compressor	1
28-WF4320	Bladder air/water cylinder	3

* For contaminated material testing only

DETERMINATION OF PERMEABILITY IN A TRIAXIAL CELL

STANDARDS

ASTM D5084 / BS 1377:6 /
CEN-ISO/TS17892:11

Permeability testing system for water-saturated porous materials

This system has been developed for the laboratory measurement of the hydraulic conductivity (coefficient of permeability) of water-saturated porous materials.

The test is performed using a triaxial cell equipped with 5 no-volume change valves: 2 for upper drainage, 2 for lower drainage, 1 for cell pressure. The cell is connected with three independent pressure system for the cell fluid, the drainage line to the top of the specimen and the drainage line to the base of the specimen.

The complete test system comprises:

- Triaxial cell for 38 or 100 mm specimens
- Pressure control panel, three pressure lines
- Three double burette volume change apparatus
- Bladder type air/water pressure system
- De-aired water system and accessories.

The test can also be performed with 3 triaxial cells.

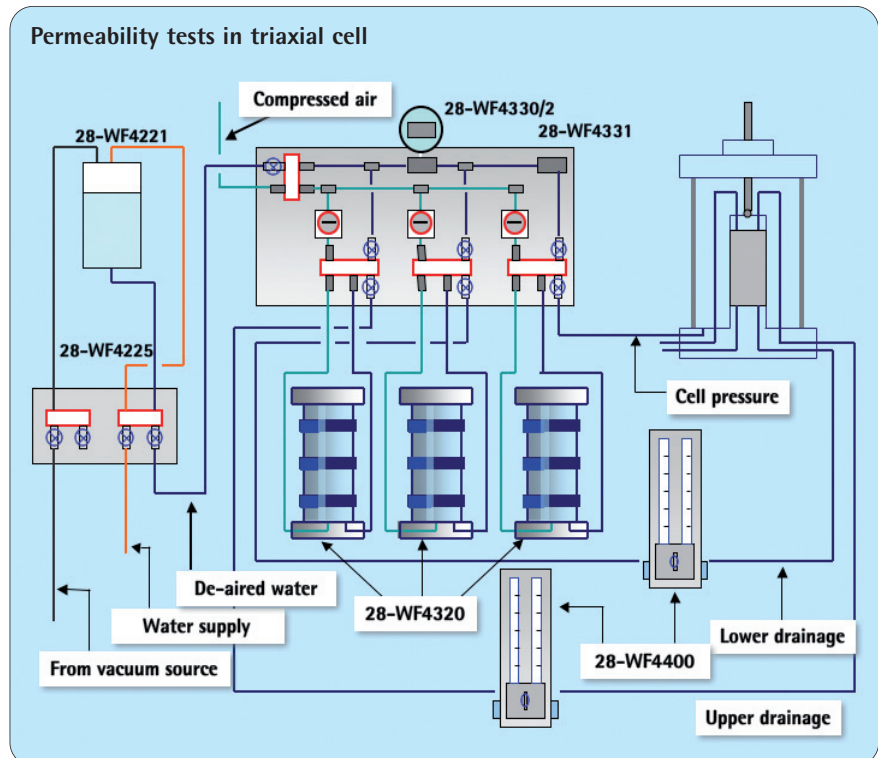
Please refer to the table for a complete list of items.

TYPICAL CONFIGURATION OF A SYSTEM FOR PERMEABILITY TEST ON ONE TRIAXIAL CELL FOR 70 MM DIA. SPECIMENS

Code	Description	Q.ty
28-WF4070	Banded triaxial cell 70 mm dia.	1
28-WF4071	Pedestal	1
28-WF4072	Top cap with drainage leads	1
28-WF4074	Pair of porous disc	1
28-WF4075	Rubber membranes (10 pieces)	1
28-WF4076	O ring (pack of 10)	1
28-WF4071/A	Membrane stretcher	1
28-WF4071/B	O ring placing tool	1
28-WF4071/C	Three parts split mould	1
28-WF4071/D	Two parts split former	1
28-WF4071/F	Filter discs (pack of 100)	1
28-WF4071/G	Hand sampler	1
28-WF6300	Pressure transducer	2
28-WF6310	De-airing block	2
28-WF4450	3 channels digital readout unit	1
28-WF4331	Triaxial panel for three pressure lines	1
28-WF4330/2	Digital pressure gauge	1
28-WF4320	Bladder air/water cylinder	3
28-WF4400	Double burette volume change apparatus	2
28-WF4221	De-airing tank, 23 l cap.	1
28-WF2001	Vacuum pump	1
86-D2005	Air dry unit whit silica gel	1
28-WF2064	Rubber tube	1
28-WF4225	Valve panel for de-airing tank	1
86-D2015	Air compressor	1
28-WF2016/2	Air filter/water trap	1
28-WF0490	Nylon tube 4x6mm, 20 m	2



28-WF4070



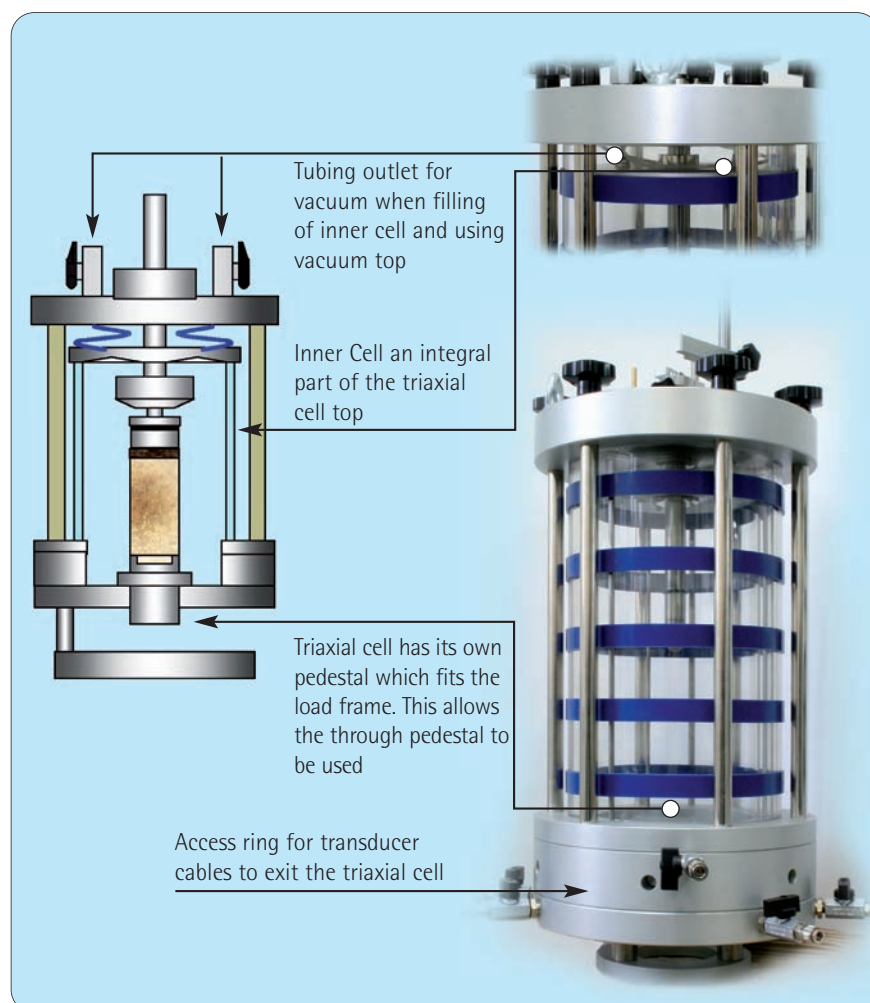
UNSATURATED TESTING

Introduction

Most books and courses in soil mechanics assume that soils are fully saturated, but in most parts of the world soils exist in an unsaturated state. This is particularly true in tropical and arid regions; even in temperate climatic zones, soils above the water table can remain unsaturated. A saturated soil is one where all the voids between the soil particles are filled with water. An unsaturated soil contains both air and water within the soil voids. The presence of surface tension forces at the interface between the air and water within an unsaturated soil allows different pressures to exist in the air and the water. In an unsaturated soil in the field, the pore air pressure is usually at atmospheric pressure and the pore water pressure is lower than the air pressure. Since we normally treat atmospheric pressure as zero pressure, that makes the pore water pressure negative (since it will be less than atmospheric). We call this negative pressure “suction” since, if the soil is put in contact with water at atmospheric pressure, it will suck water into the soil.

The unsaturated layer can extend to great depths, which is governed by environmental conditions. The value of suction is what determines the strength of the unsaturated material. It is when this suction changes that unsaturated soil can behave differently to that expected of a saturated soil, for example collapsible soils, where the change in moisture content can produce a sudden reduction in volume and also have a dramatic effect on the strength of the material. The fundamental difference between the triaxial testing of a soil sample in a saturated condition compared to an unsaturated condition can be summarised as follows:

- The behaviour of a saturated soil is controlled entirely by total stress and pore water pressure (through effective stress). The positive pore water pressures are pushing the particles apart and hence reduce the strength of the soil.
- In an unsaturated soil both air and water fill the voids, and surface tension forces create a negative pore water pressure (or suction). This suction pulls the soil particles together and increases the strength of the soil.



UNSATURATED TESTING

Some examples of application

- **Rainfall induced landslide**

Slopes may stand at steep angles when they are supported by suctions and these impart additional shear strength on the soil. When rain infiltrates the slope, the suctions reduce and the slope falls due to a loss of shear strength.

- **Swelling soils**

The volume change of expansive soils is controlled by the suction changes that take place as a result of water ingress. Swelling causes differential movements in structures, which can cause extensive cracking.

- **Collapsing soils**

Loose clayey soils may be held in a loose stable state by the presence of suction. If water penetrates the soil the suction is reduced and the loose fabric can become unstable. Large volume reduction can take place suddenly and these cause disruption and damage to structures.

Test equipment

An unsaturated triaxial system includes a double triaxial cell with 6 outlets as described in the following paragraph (see page 48 for typical configuration).

TRIAXIAL CELLS FOR UNSATURATED SOILS

Description

In the traditional triaxial systems, where saturated samples are tested, the volume change measurement is a simple monitoring of the water entering or leaving the sample by a volume change transducer.

On the contrary, in the unsaturated systems volume change measurements are complicated by the compressibility of air. If an increase of confining pressure is applied to an unsaturated sample, a movement of water out of the sample will occur but at the same time the size will change due to the compression of the air in the voids.

A correct measurement requires the volume of water leaving the sample and the total volume change of the sample as shown in the sketch. With these two measurements, by difference the volume change due to water being squeezed out of the sample and the volume change due to the compressibility of air can be determined.

A double walled triaxial cell can be the solution: the same pressure inside and outside of the inner cell wall will produce zero expansion

of the inner cell and allow to measure the total volume change from a volume change transducer inserted in the cell pressure line.

The inner wall of the cell above is made from glass: this eliminates the problem of water absorption.

The cell pressure is applied equally to the inside and outside of the glass wall: this eliminates the problem of expansion. The total volume change of the sample can then be measured using a standard volume change transducer.

Models available

- **28-WF4170**

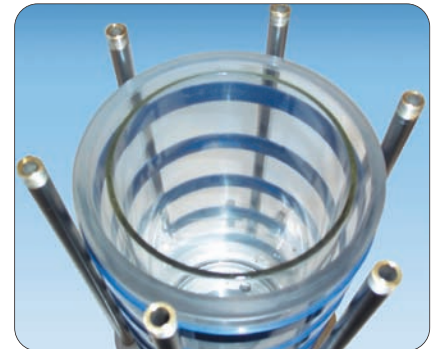
Double triaxial cell for unsaturated tests on 70 mm samples complete with 6 ports

- **28-WF4171**

Double triaxial cell for unsaturated tests on 100 mm samples complete with 6 ports

Accessories for double wall triaxial cells

Each triaxial cell must be completed with the accessories listed in the table here below. In case the axis translation method is used (see next page), the base pedestal with High Air Entry Stone must be adopted.



Detail of the double wall of the 28-WF4170 and 28-WF4171 cells

Main features

- Double cell built into the triaxial cell top:
 - the triaxial cell can be used as a standard triaxial cell
 - perfect alignment between the inner and outer ram bush is assured
- One triaxial ram:
 - both compression and extension tests can be performed
- Unsaturated sample set up exactly the same as a saturated sample
- Cell top placed on the triaxial cell base exactly the same as a standard cell top
- Inner and outer triaxial cell tops filled and emptied at the same time

Accessories	Model of double wall triaxial cell	
	28-WF4170	28-WF4171
Diameter of the sample	70 mm	100 mm
Base pedestal complete with High Air Entry Stone	28-WF4170/1	28-WF4171/1
Top cap for unsaturated cell	28-WF4170/2	28-WF4171/2
Top cap vacuum type	28-WF4170/V	28-WF4171/V

Existing and under development test methods

The test methods on unsaturated soils are still subject of studies, research and testing. The Axis translation method with High Air Entry Stone (H.A.E.S.), which has been developed, will allow water to pass through but not air at various values as specified below.

Other methods are under development using suction transducers as described on page ...

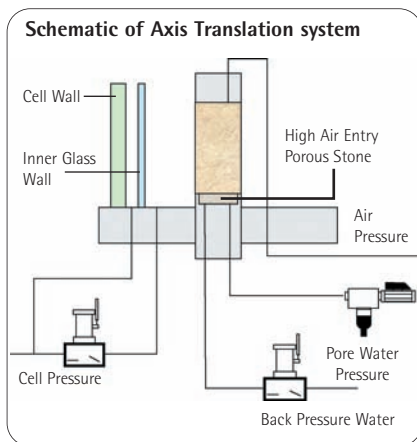
Axis translation method with High Air Entry Stone (H.A.E.S.)

One of the problems when a sample with a high suction is to be tested, is to prevent the sample from sucking the water from the porous stone on the base pedestal and cause cavitation in the triaxial cell pore water measuring system. To prevent this happening the porous disc has been replaced with a high air entry stone, cemented

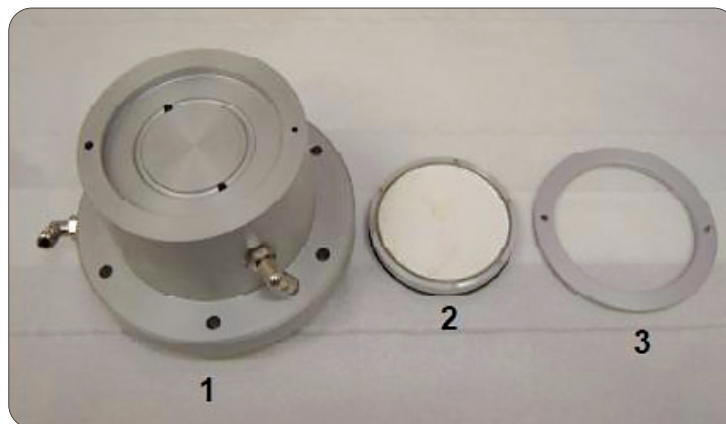
into the base pedestal. The high air entry stone will allow water to pass through but not air, at various values. For example, a 5 bar stone will not allow air under 5 bar pressure to pass through the stone. The stone is cemented into the base pedestal to prevent water passing around the outside of the stone. The saturated stone will then allow the passage of water but not air. This will make it very difficult for the water to be sucked out of the stone; it will stop air entering the stone but it will not stop cavitation under the stone. This requires another modification to our triaxial system. To stop cavitation happening and to enable the suction to be measured, an air pressure is applied to the pore space in the sample. Suction is caused by the surface tension forces providing a difference in pressure between the air and the water pressure. If the air pressure is zero (atmospheric) then the water pressures will be negative. If we increase the air pressure in the pore space, the

Unsaturated Testing (continued)

water pressure will also increase, keeping the difference between the air and water pressures the same. The air pressure is increased until the water pressure becomes positive. The suction is still maintained because the water pressure is still lower than the air pressure. The air pressure is applied via the top cap (in the same way as a water back pressure in a saturated test) at about 200 kPa below the air entry value of the porous stone. This will raise the pressure inside the sample to a positive value and in turn will apply a positive pressure to the porous stone and the pore water pressure transducer.


TYPICAL CONFIGURATION OF A SYSTEM TO PERFORM TRIAXIAL TESTS ON UNSATURATED SAMPLES 70 MM DIA. WITH THE AXIS TRANSLATION METHOD WITH THE DOUBLE WALL CELL 28-WF4171

Code	Description	Q.ty
28-WF4170	Double triaxial cell for specimens up to 70 mm dia.	1
28-WF4170/1	Pedestal for 70 mm including HAES	1
28-WF4170/2	Top cap for 70 mm	1
28-WF4005	Triaxial machine	1
86-D2015	Air compressor	1
28-WF2016/2	Filter for compressor	1
28-WF4220/A	De-airing tank	1
28-WF2001	Vacuum pump	1
28-WF2064	Rubber tube for vacuum	1
86-D2005	Air dry unit with silica gel	1
28-WF4225	Valve panel for de-airing tank	1
28-WF4331	3 ways control panel	1
28-WF4330/2	Digital gauge	1
28-WF4320	Bladders	2
28-WF4191	Nylon tubing 6x8 mm dia., 10 m length	2
28-WF6353	Submersible load cell 5 kN cap.	1
30-WF6208	Displacement transducer 25 mm full scale	1
30-WF6221	Mounting bracket for 25 mm dia. cell ram	1
28-WF6300	Water pore pressure/back pressure (bottom) transducer	1
28-WF6300	Air pressure (top) transducer	1
30-WF6310	De-airing block	2
28-WF4410	Volume change transducer	2
30-WF6016	GEODATALOG, 16 channels data logger	1
30-WF6042	Transducer extension cable, 6 m	6
Options		
28-WF4079/K	70 mm "On sample" transducers	1
30-WF6042	Transducer extension cable, 6 m	3


Components of 28-WF4170/1 or 28-WF4171/1

- 1 - Base pedestal for unsaturated sample (28-WF4170/5 ÷ 28-WF4171/5)
- 2 - High Air Entry Stone (HAES), sealed on aluminium ring (28-WF4170/1B, 28-WF4170/2B, 28-WF4170/5B, 28-WF4170/10B, 28-WF4170/15B)
- 3 - Aluminium compensatium ring for unsaturated tests (28-WF4170/4 ÷ 28-WF4171/4)

AUTOTRIAX

THE BASIC AUTOMATIC TRIAXIAL SYSTEM EXPANDABLE IN SUBSEQUENT MODULAR STEPS FOR:

- **Effective stress** • **Stress path** • **Permeability**
- **Unsaturated tests**

TO CONTROL UP TO THREE INDEPENDENT SYSTEMS

The ability to run and control several triaxial tests automatically from a PC

The advantage of systems expansion in modular steps of components and softwares

The ability, due to the automatic control, to eliminate the negative environmental discrepancies as operator errors, non calibration etc.

Performance of 24 hours 7 days tests without interruption and greater throughput of tests with a considerable cost decrease

The consequent achievement of a test regime that will produce reliable and repeatable results

The possibility to upgrade our or other make existing standard triaxial systems

Effective and Stress Path Triaxial tests

The AUTOTRIAX Automatic Triaxial System not only can perform Effective Stress triaxial tests with all the above advantages but is the unique and indispensable apparatus to perform the **Stress Path** triaxial test.

In fact this test is performed to allow the engineering to replicate the changes in stress conditions soil sample subjected to compression and extension both in loading and unloading status. In few words, that soil, due for example to excavation, or construction or natural events, can produce the changes of magnitude of the principal stresses (major and minor).

This test can only be accurately and reliably performed with a servocontrolled closed loop system.

Permeability tests in triaxial cell

The permeability test can be automatically performed with the AUTOTRIAX system using the appropriate accessories. For more information see page 56.

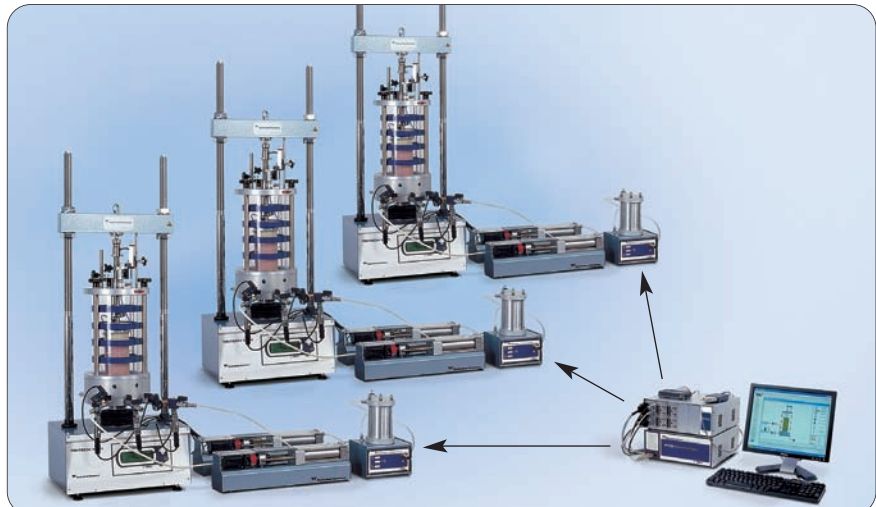
Unsaturated soil testing

The unsaturated soil testing can be automatically performed with the AUTOTRIAX system using the appropriate accessories. For more information see page 56.

Typical AUTOTRIAX system configuration for effective stress or stress path testing



Three systems can be run simultaneously from one PC, data logger and control box



AUTOTRIAX Continued**AUTOTRIAX SYSTEM DESCRIPTION**

The system consists essentially of the following components:

Triaxial compression frame

A suitable machine is our model 28-WF4005 or 28-WF4010, 50 or 100 kN cap.

Triaxial Cell with vacuum top cap

A suitable models are our Tri-Cell Plus 28-WF4070/P to 28-WF4150/P equipped with vacuum top cap.

Control Unit

The **RTC, Real time control box**, 29-WF4530 with 29-WF4537 expansions modules, are the brain of the AUTOTRIAX. Provide the automatic control and drive of up to three triaxial systems.

Data acquisition unit

The **ATD, Automatic Triaxial Datalog**, 29-WF4616 and 29-WF4616/UP1 Expansion, provides the automatic data acquisition and broadcasts all transducers measurements on the high speed communications network to the RTC Real Time Control box

Test Softwares

These softwares are the interface between the operator and the AUTOTRIAX System to manage automatically all test stages.

Various Software packages are available depending on the test to be performed: 29-WF4616/S1 to 29-4616/S6. See page 55-56

Pressure Systems

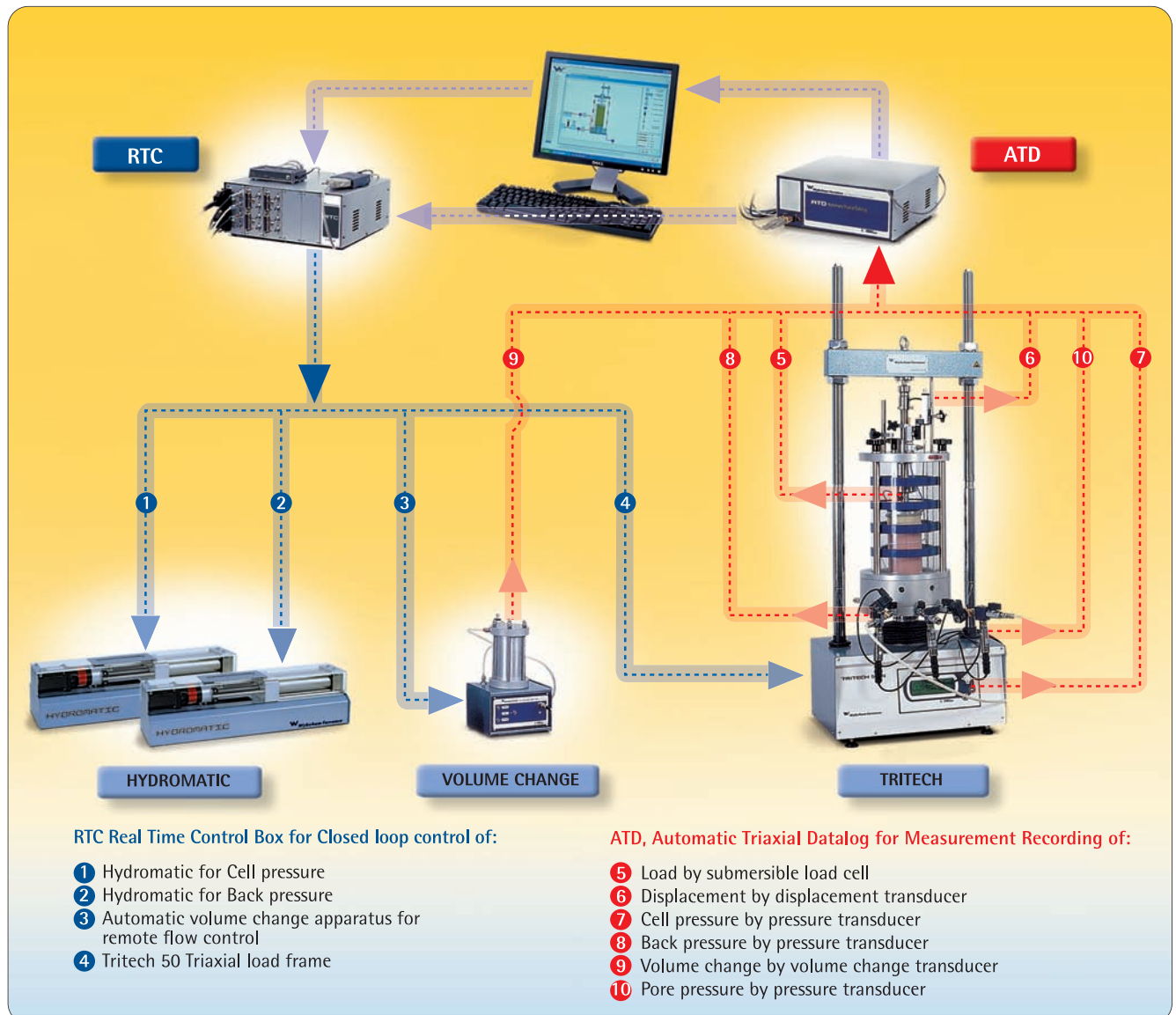
Two models available depending on the maximum pressure to be applied:

- **Hydromatic** servo-controlled hydraulic actuator 29-WF4502 for pressures up to 3500 kPa
- **Servoflow** electro-pneumatic servo-valve 29-WF4511 and 29-WF4512 expansion, for pressures up to 1000 kPa

The Close/Open Microelectrovalves 29-WF4515 are accessories for the pressurelines.

All the above components are fully described in the following pages.

Flow diagram of the AUTOTRIAX system



RTC Real Time Control box

RTC AUTOMATIC TRIAXIAL TEST CONTROLLERS

Description

The base RTC (Real Time Control) system is made up a chassis fitted with one module. This will control one fully automated triaxial test system. The RTC chassis can be fully expanded by installing two additional modules to allow control of three fully automated triaxial test systems. One RTC module can control:

- two pressure lines up to 3500 kPa
- two ON/OFF valves for drainage lines
- the speed of the Triaxial load frame
- the flow direction of the automatic volume change

The base RTC system comes with RTC software which manages the transducers calibration and the setup of up to three systems. The calibration data can be exported to the supplied calibration spreadsheet template to print calibration certificates.

The RTC module, ATD data logger and computer running the software modules are all connected together by a high speed communications and control network which allows simultaneous communication between the RTC modules, ATD data logger and computer. When the RTC module receives a command from the test software, (e.g. a pressure increase, closing the pressure line to the triaxial cell, changing the triaxial load frame speed or changing the automatic volume change device flow direction), the commands are then applied to the triaxial system by a closed loop control system using feedback from the ATD data logger. The RTC module then runs independently of the test software maintaining all the current parameters until new commands are sent from the test software.

Important note

Upgrading existing standard triaxial systems:
The advantage of the RTC system is that existing manual triaxial compression frames can be used as part of a semi-automated system. When you require the full automation you will need to upgrade to a Trittech triaxial load frame 29-WF4005 and/or vacuum cap assembly

29-WF4530

RTC Base System

110-240 V, 50-60 H2, 1ph.

Base unit used to control one automatic triaxial system.

Specifications

Hardware:

- Closed loop control system firmware with:
- 2 x pressure control outputs
- 2 x open and close valve control outputs
- 2 x automatic volume change device flow control outputs
- 1x RS-232 port for triaxial load frame
- 1 x network Ethernet port

Dimensions: 320x270x140mm (lxdxh)

Weight: 3 kg approx.

Software:

- RTC module management software
- System setups
- Channel management
- Transducer calibration
 - From 2 to 10 calibration points
 - Linear or polynomial best fit equations
 - Export calibration data to a spreadsheet template for printing certificates

note

MS excel is required to run the supplied calibration certificate spreadsheet templates

29-WF4531

RTC expansion module for two pressure outputs

This module added to the base system 29-WF4530 or to the 29-WF4537 controls two

more pressure outputs and the relevant accessories to measure the volume change. The base system RTC can accept up to three 29-WF4531 modules to be used for permeability or unsaturated tests.

Specifications

Same as module 29-WF4530 previously described except for the RS232 and Ethernet ports which are not available

29-WF4537

RTC extension module

This module added to the base system controls another fully automated triaxial test system. A maximum of two RTC expansion modules can be installed for a 3 triaxial system control.

Specifications

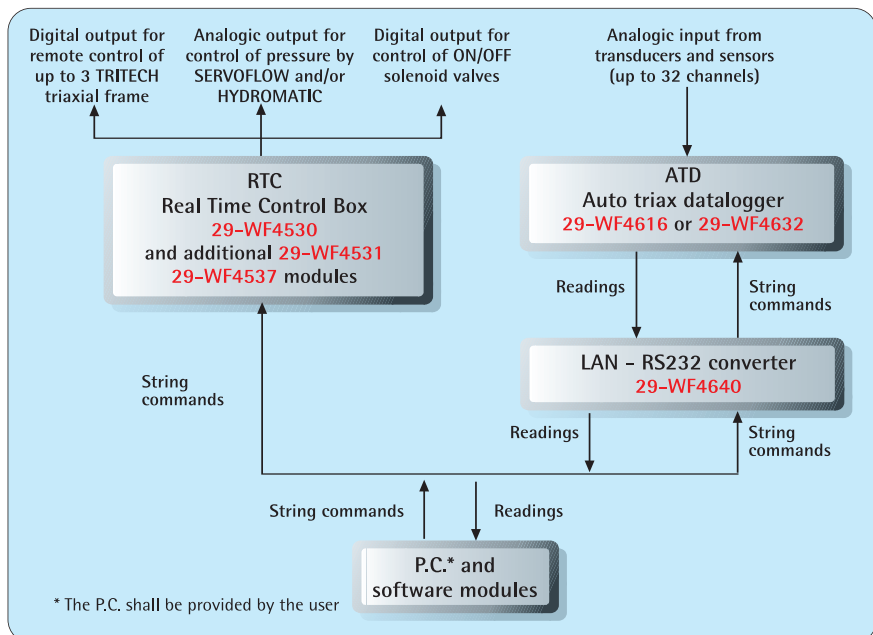
Same as model 29-WF4530



Insertion of 29-WF4531 and 29-WF4537 in a 29-WF4530 RTC base system

note

29-WF4537 RTC modules must be factory installed



Automatic Triaxial System.
Pressure systems/Volume change transducer

SERVOFLOW

PNEUMATIC PRESSURE CONTROLLER FOR PRESSURES UP TO 1000 kPa

Description

The SERVOFLOW pneumatic pressure controller consists of an electro-pneumatic control valve that reduces the supply air pressure to a regulated output air pressure which is directly proportional to an electrical input signal received from the RTC module. Each SERVOFLOW has an integral safety valve.

■ 29-WF4511 SERVOFLOW one pressure line

Chassis fitted with one SERVOFLOW which allows control of one pressure line.

Specifications

Supply pressure: up to 1000 kPa
Output pressure: up to 1000 kPa
Air consumption: 0.1cu.m/hr
Electrical connection: 25 pin D type
📏 Dimensions: 255x210x140 (lxdxh)
⚖️ Weight: 2kg

■ 29-WF4513 SERVOFLOW two pressure lines

Chassis fitted with one SERVOFLOW which allows control of two pressure lines.

Specifications

Supply pressure: up to 1000 kPa
Output pressure: up to 1000 kPa
Air consumption: 0.1 m³/h

note

The 29-WF4513 SERVOFLOW two pressure lines



HYDROMATIC

HYDRAULIC PRESSURE CONTROLLER FOR PRESSURES UP TO 3500 kPa

Description

The HYDROMATIC pressure controller consists of a hydraulic piston driven by a ball screw and gear box mounted on a ball slide. The system is driven via a stepper motor controlled by the RTC module closed loop control system. The apparatus has a clear Perspex cover allowing moving parts to be viewed.

HYDROMATIC 29-WF4502



PRESSURE LINE OPEN AND CLOSE VALVE

Description

This two way solenoid valve is positioned on the triaxial cell to open and close the pressure line to the cell. This is powered and controlled by the RTC module.

■ 29-WF4515 Two way open and close valve

Specifications

Power supply: 24Vdc from the RTC module
Solenoid operating speed: <10ms
⚖️ Weight: 0.2kg

AUTOMATIC VOLUME CHANGE FOR REMOTE FLOW CONTROL

Description

This is a standard automatic volume change transducer with integral solenoid valves to allow automatic control of the flow direction and by-pass functions. The automatic volume change controller is powered and controlled directly from the RTC module which enables continuous volume change to be measured during a test. The volume change can be used in pneumatic or hydraulic

■ 29-WF4502 HYDROMATIC Servo controlled hydraulic actuator with pressure adjustable to 3500 kPa

Specifications

Supply pressure: none required
Output pressure: up to 3500 kPa
Pressure accuracy: +/-0.1% of full scale
Electrical connection: 25pin D type
Power supply: 110-240V, 50/60 Hz, 1ph
📏 Dimensions: 60x138x163mm (lxdxh)
⚖️ Weight: 5 kg

systems. LED indicators on the front panel show the by pass and flow direction status.

■ 29-WF4412 Automatic volume change transducer with automatic flow inversion for remote control

Specifications

Capacity: 100cc
Accuracy: 0.1cc
Max operating pressure: 2000 kPa
Power supply: 24Vdc from RTC module
Solenoid operating speed: <10ms
📏 Dimensions: 260x280x400mm (lxdxh)
⚖️ Weight: 9 Kg

29-WF4412



ATD Automatic Triaxial Datalog**Introduction**

The ATD (Automatic Triaxial Datalog) comes in two versions of 16 or 32 channels. It provides automatic data acquisition for the automatic triaxial system. The ATD broadcasts all transducer values on the high speed communications network to the RTC modules and computer running the testing software modules for the automatic test control, data logging and processing. The offset and gain values during the transducer calibration are adjustable for each channel and saved in firmware.

It is compatible with all transducers required for effective stress and stress path triaxial testing such as pressure, displacement, load and volume change.

■ 29-WF4616

ATD 16 channel data acquisition for automatic triaxial system

■ 29-WF4616/UP1

ATD module to expanded 29-WF4616 from 16 to 32 acquisition channels for automatic triaxial systems. It shall be factory installed.

General specification**Hardware**

Number of channels: 16 (29-WF4616) or 32 (29-WF4616+29-WF4616/UP1)

Sensors outputs:

- V_{ex} adjustable up to 10V DC (common to all channels)
- compatible with 3 and 4 wires sensors single and double ended

Sensors inputs:

- from -10V to +10V including the following sensors:
 - any amplified sensor with DC output;
 - potentiometric transducers;
 - wheatstone bridge transducers with mV/V DC output (load cells, pressure transducers, linear transducers, and equivalent)
- sensors impedance from 100 Ohm to 10 kOhm

Real resolution: $\pm 32\ 000$ divisions

Sampling rate: adjustable up to 10 samples/sec per channel

Data storage capacity: 8 Mbytes

Communication ports: RS232 and USB for data download to PC with software included

Power supply: 110-230V ; 50-60Hz ; 1F

On-board firmware

Suitable for remote management of the logger with AUTOGEOLAB software modules (see separate description on page 53).

Minimum PC Specifications:

- Processor speed 500 MHz minimum
- Hard disk 200 MByte minimum
- RAM 512 Mbyte
- CD - ROM
- 1 serial port RS232 or USB with adapter
- USB-RS232 or Ethernet card with adapter
- Ethernet-RS232
- Windows® 2000 Professional or XP
- Monitor minimum resolution 800x600 pixel
- MS Excel® suggested
- A4 printer

Dimensions: 320x270x140mm (lxdxh)

Weight: 2,5 kg approx.



Picture of ATD front panel



Picture of ATD rear panel

note

The 29-WF4616/UP1 16 channel expansion module must be factory installed.

Interface and interconnection accessories

- **29-WF4640** LAN-RS232 converter to connect the ATD to the high speed communications and control network
- **29-WF4645** 8 port LAN* HUB box. Used to connect the ATD, RTC modules and a PC to the high speed communication and control network

* LAN = Local Area Network

AUTOGEO LAB SOFTWARE MODULES FOR THE AUTOMATIC TRIAXIAL SYSTEM

Introduction

These software modules are used in conjunction with the RTC chassis, RTC modules and ATD all connected using the high speed communications and control network. They allow the full automation of triaxial tests including effective stress and stress path testing using different testing standards such as BS1377, ASTM and EN. From the start to the end of the triaxial test the software modules have total control of the triaxial frame, the adjustment of pressure to the triaxial cell, the opening and closing of pressure lines to the triaxial cell, and the measurement of continuous volume change to perform automatically the different stages required.

The software modules have an export function to automatically transfer test data into a spreadsheet template.

The software modules come with a standard processing spreadsheet template which can be fully customised.

The following software testing modules are available:

■ 29-WF4616/S1 Effective Stress software to BS 1377:8

Automatically performs the test depending on reference standard:
BS 1377:8

- Saturation with full automatic control
- Isotropic consolidation stage with volume change measurement
- Consolidated undrained triaxial compression with measurement of pore pressure
- Consolidated drained triaxial compression with measurement of volume change
- Non standard shearing of the specimen in extension (undrained or drained)
- Export test data to a spreadsheet template for processing and plotting

■ 29-WF4616/S2 Stress Path software

Automatically performs the different stages of a stress path triaxial test.

- Saturation stage
automatic or manual
- Consolidation stage:
Isotropic
Anisotropic
 k_0 with axial or radial stress control
(k_0 control can use either radial belt measured sample volume change methods)
- User defined target stress parameters (p , q , s and t)
- Monotonic shear stage in compression or extension
- Export test data to a spreadsheet template for processing and plotting

■ 29-WF4616/S4 Effective Stress software to ASTM D4764

Automatically performs the test depending on reference standard:
ASTM D4764

- Saturation with full automatic control
- Isotropic consolidation stage with volume change measurement
- Consolidated undrained triaxial compression with measurement of pore pressure
- Consolidated drained triaxial compression with measurement of volume change
- Non standard shearing of the specimen in extension (undrained or drained)
- Export test data to a spreadsheet template for processing and plotting
- Multi stage test

■ 29-WF4616/S5

Unsaturated soil triaxial test software

Automatically performs the test stages using the axis traslation method:

- Simultaneous and independent control of air pressure, pore water pressure and axial stress
- Performance of various test stages: saturation, consolidation and shear
- Test data recording of each stage



■ 29-WF4616/S6

Permeability triaxial test software to BS 1377:6

Automatically performs permeability test in triaxial cell conforming BS 1377:6, part 6.3:

- Automatic control of saturation stage
- Isotropic consolidation stage with pore pressure and volume change measurements
- Automatic procedure to generate hydraulic gradient through the sample and constant head water flow
- Export test data to a spreadsheet template for processing and plotting.



**AUTOTRIAX - CONFIGURAZIONE TIPICA
OF TRIAXIAL SYSTEMS**

Expansion from 1 to 3 systems for
different tests at different pressure
levels typical configuration

The following tables represent a practical
guide for typical configurations limited to
the parts required for the automation

TABLE A - PNEUMATIC SYSTEM WITH CELL PRESSURE UP TO 1000 kPa AND BACK PRESSURE UP TO 1000 kPa

Codice	Descrizione	Effective Stress Number of systems			Stress path Number of systems		
		1	2	3	1	2	3
29-WF4530	RTC chassis and RTC module	1	1	1	1	1	1
29-WF4531	RTC expansion module	-	-	-	-	-	-
29-WF4537	RTC module	-	1	2	-	1	2
29-WF4511	SERVOFLOW base system	1	2	3	1	2	3
29-WF4512	SERVOFLOW expansion	1	2	3	1	2	3
28-WF4320	Air/Water Bladder	2	4	6	2	4	6
28-WF4005	Tritech 50	1	2	3	1	2	3
29-WF4515	Two way Open and Close valve	2	4	6	2	4	6
29-WF4412 (*)	Automatic volume change	1	2	3	1	2	3
29-WF4616	ATD 16 channels	1	1	1	1	1	1
29-WF4616/UP1	16 channels expansion module	-	-	1	-	-	1
29-WF4645	LAN - HUB	1	1	1	1	1	1
29-WF4640	LAN - RS232 1 converter	1	1	1	1	1	1
29-WF4616/S1	Effective stress software module	1	1	1	-	-	-
29-WF4616/S2	Stress path software module	-	-	-	1	1	1
29-WF4616/S4	Effective stress software for Automatic Triaxial ASTM	1	1	1	-	-	-
29-WF4616/S5	Unsaturation test software	-	-	-	-	-	-
29-WF4616/S6	Permeability test software BS	-	-	-	-	-	-

TABLE B - HYDRAULIC SYSTEM WITH CELL PRESSURE UP TO 3000 kPa AND BACK PRESSURE UP TO 3000 kPa

29-WF4530	RTC chassis and RTC module	1	1	1	1	1	1
29-WF4531	RTC expansion module	-	-	-	-	-	-
29-WF4537	RTC module	-	1	2	-	1	2
29-WF4502	HYDROMATIC pressure system	2	4	6	2	4	6
29-WF4511	SERVOFLOW base system	-	-	-	-	-	-
28-WF4005	Tritech 50	1	2	3	1	2	3
29-WF4515	Two way Open and Close valve	2	4	6	2	4	6
29-WF4412 (*)	Automatic volume change	1	2	3	1	2	3
29-WF4616	ATD 16 channels	1	1	1	1	1	1
29-WF4616/UP1	16 channels expansion module	-	-	1	-	-	1
29-WF4645	LAN - HUB	1	1	1	1	1	1
29-WF4640	LAN - RS232 1 converter	1	1	1	1	1	1
29-WF4616/S1	Effective stress software module	1	1	1	-	-	-
29-WF4616/S2	Stress path software module	-	-	-	1	1	1
29-WF4616/S4	Effective stress software for Automatic Triaxial ASTM	1	1	1	-	-	-
29-WF4616/S5	Unsaturation test software	-	-	-	-	-	-
29-WF4616/S6	Permeability test software BS	-	-	-	-	-	-

TABLE C - HYDRAULIC/PNEUMATIC SYSTEM WITH CELL PRESSURE UP TO 3000 kPa AND BACK PRESSURE UP TO 1000 kPa

29-WF4530	RTC chassis and RTC module	1	1	1	1	1	1
29-WF4531	RTC expansion module	-	-	-	-	-	-
29-WF4537	RTC module	-	1	2	-	1	2
29-WF4502	HYDROMATIC pressure system	1	2	3	1	2	3
29-WF4511	SERVOFLOW base system	1	2	3	1	2	3
29-WF4512	SERVOFLOW expansion	-	-	-	-	-	-
28-WF4320	Air/Water Bladder	1	2	3	1	2	3
28-WF4005	Tritech 50	1	2	3	1	2	3
29-WF4515	Two way Open and Close valve	2	4	6	2	4	6
29-WF4412 (*)	Automatic volume change	1	2	3	1	2	3
29-WF4616	ATD 16 channels	1	1	1	1	1	1
29-WF4616/UP1	16 channels expansion module	-	-	1	-	-	1
29-WF4645	LAN - HUB	1	1	1	1	1	1
29-WF4640	LAN - RS232 1 converter	1	1	1	1	1	1
29-WF4616/S1	Effective stress software module	1	1	1	-	-	-
29-WF4616/S2	Stress path software module	-	-	-	1	1	1
29-WF4616/S4	Effective stress software for Automatic Triaxial ASTM	1	1	1	-	-	-
29-WF4616/S5	Unsaturation test software	-	-	-	-	-	-
29-WF4616/S6	Permeability test software BS	-	-	-	-	-	-

(*) In the cell pressure and back pressure lines, where the volume change apparatus 29-WF4412 is connected, the pressure has to be limited to up to 2000 kPa.

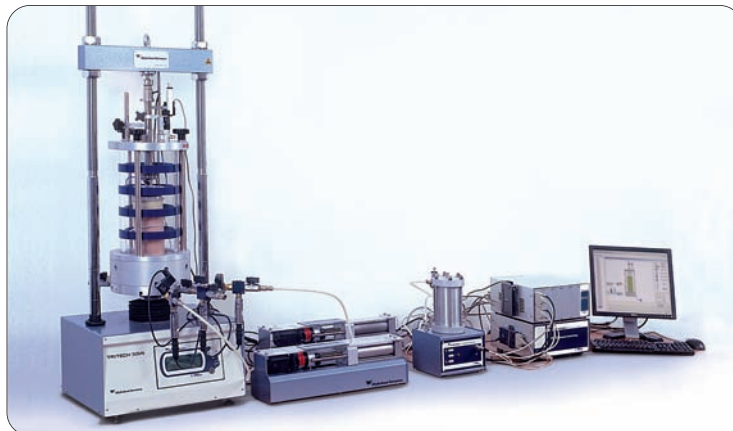
(**) The unsaturated triaxial testing can be performed with 1000 kPa maximum air pressure.

Permeability			Unsaturated		
Number of systems			Number of systems (**)		
1	2	3	1	2	3
1	1	1	1	1	1
1	2	3	1	2	3
-	1	2	-	1	2
2	4	6	2	4	6
1	2	3	1	2	3
3	6	9	2	4	6
-	-	-	1	2	3
3	6	9	3	6	9
2	4	6	2	4	6
1	1	1	1	1	1
-	-	1	-	1	1
1	1	1	1	1	1
1	1	1	1	1	1
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	1	1	1
1	1	1	-	-	-

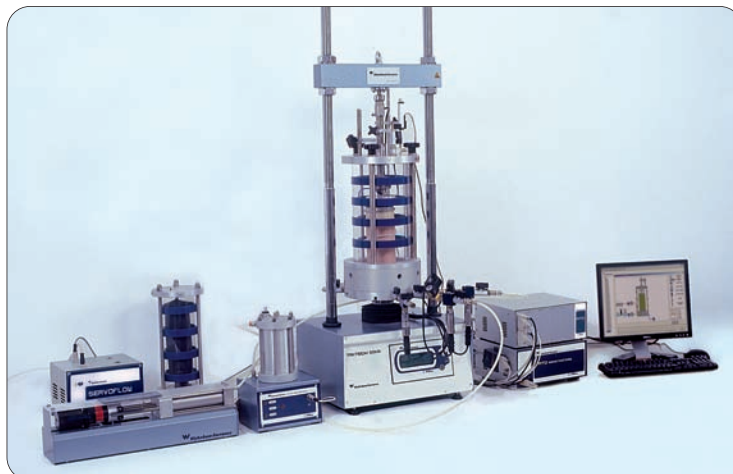
Three possible Automatic Triaxial configuration for effective stress test



1	1	1	1	1	1
1	2	3	1	2	3
-	1	2	-	1	2
3	6	9	2	4	6
-	-	-	1	2	3
-	-	-	1	2	3
3	6	9	3	6	9
2	4	6	2	4	6
1	1	1	1	1	1
-	-	1	-	1	1
1	1	1	1	1	1
1	1	1	1	1	1
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	1	1	1
1	1	1	-	-	-



1	1	1	1	1	1
1	2	3	1	2	3
-	1	2	-	1	2
1	2	3	2	4	6
1	2	3	1	2	3
1	2	3	-	-	-
2	4	6	1	2	3
-	-	-	1	2	3
3	6	9	3	6	9
2	4	6	2	4	6
1	1	1	1	1	1
-	-	1	-	1	1
1	1	1	1	1	1
1	1	1	1	1	1
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	1	1	1
1	1	1	-	-	-

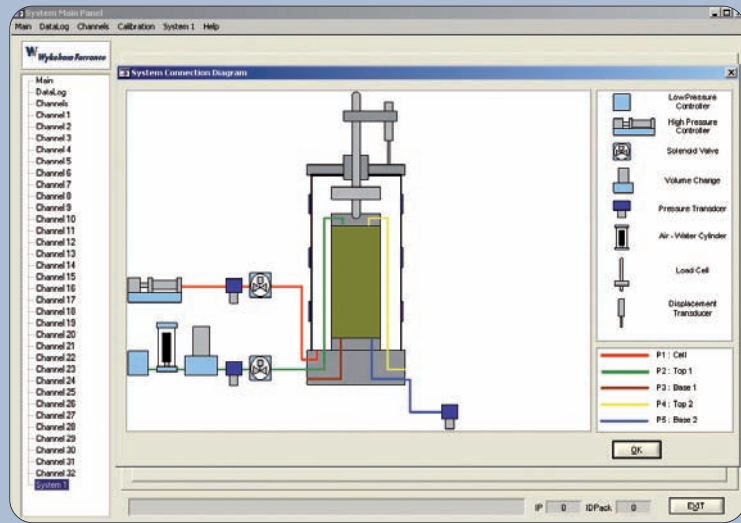


29 Automatic Triaxial Testing

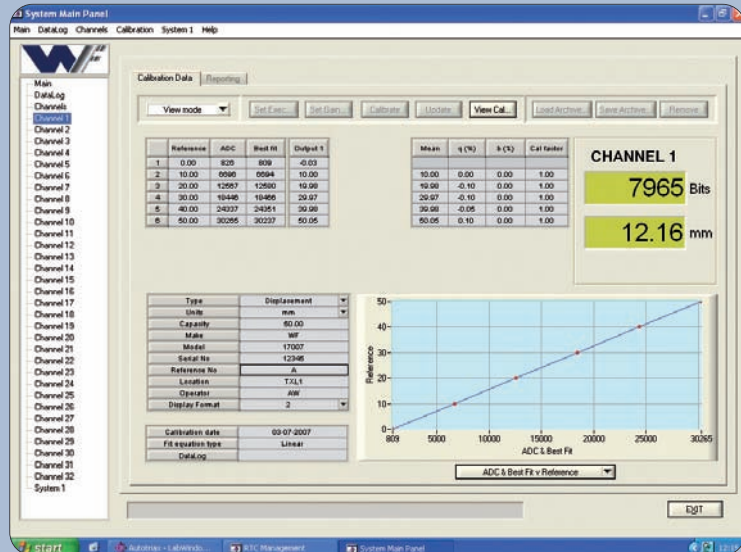
Automatic Triaxial System/Automatic data acquisition and processing

SOFTWARE AUTOTRIAX EXAMPLE OF SCREEN SHOT

Stress path software screen



Transducer calibration



Effective stress set up

Axial	Label	Assign Transducer	Channel No.	Location	Lower Limit	Upper Limit	Connect to	Slot
Displacement	Displacement	Select	1	AXIAL	0	50		
Lead	Lead	Select	2	AXIAL	+1000	2000		
Pressure 1	Cell	Select	7	CELL	0	3000	P1	1
Pressure 2	Back	Select	5	TOP 1	0	2000	P2	1
Pressure 3	Pressure	Select	3	BASE 2	1000	3000	P5	1

Test Type: Effective Stress

SUBMERSIBLE LOAD CELLS

Internal load cells have been designed to work inside the triaxial cells. They have a lower hysteresis and very good linearity together with a substantial over load safety feature. The submersible load cells are fitted complete with rams to suit TRI-CELL Plus triaxial cells.

Model	Full range	Dia. of ram
28-WF6351	1 kN	25 mm
28-WF6353	5 kN	25 mm
28-WF6355	10 kN	25 mm
28-WF6356	25 kN	25 mm

Technical specifications

Overload capacity: 200%
Rate output: 2 mV/V
Excitation voltage: 10 V DC
Non-linearity: $\pm 0.05\%$ full scale
Hysteresis: 0.05% full scale
Deflection at full load: 0.05 mm
Maximum side force without effect: 50% full scale
Compensated temperature range: 0 to 50°C
Thermal zero and sensitivity shift: $\leq 0.02\%$ full scale/°C max.
Cable length: 2 metres
Diameter: 75 mm
Height (excluding ram): 50 mm
Weight (excluding ram): 850 g



28-WF6353

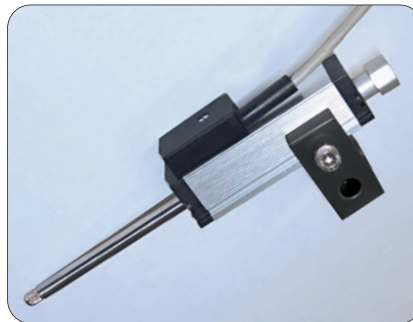
DISPLACEMENT TRANSDUCERS

Used for measurement of axial deformation of triaxial samples, they are placed outside the triaxial cell.

30-WF6208
Axial displacement potentiometric transducer, 25 mm travel, complete with mounting block

30-WF6209
Axial displacement potentiometric transducer, 50 mm travel, complete with mounting block

30-WF6210
Axial displacement potentiometric transducer, 100 mm travel, complete with mounting block



30-WF6208

Accessories

30-WF6221 Mounting bracket for displacement transducer, to be connected to triaxial cell ram (25 mm dia.)

note

Each displacement transducer must be completed with mounting bracket 30-WF6221



30-WF6221

Transducers for Automatic Triaxial System

PRESSURE TRANSDUCERS

Three units are required for measurement of cell pressure, back pressure, pore pressure (water or air).

■ **28-WF6300**

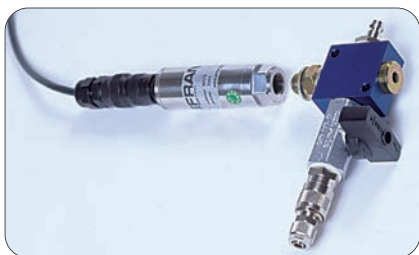
Pressure transducer, 1000 kPa

■ **28-WF6301**

Pressure transducer, 2000 kPa

■ **28-WF6302**

Pressure transducer, 3500 kPa



28-WF6300 with 28-WF6310

Accessories

- **28-WF6310** De-airing block for pressure transducer, to be completed with ON/OFF valve 29-WF4515. To be connected to the triaxial cell

AUTOMATIC VOLUME CHANGE TRANSDUCER■ **29-WF4412**

Automatic volume change apparatus, maximum capacity 100 cm³, complete with microelectrovalve for flow inversion by remote control



29-WF4412

General description and specifications

The apparatus provides an electrical signal directly proportional to the volume of water flowing through the unit. The apparatus comprises: a piston connected to a linear transducer and sealed against a precision-machined calibration chamber so that the linear movement of the piston is exactly proportional to the volume of water in the calibration chamber.

The apparatus includes the panel with reversing valve system to measure the water flow in both directions and microvalves for flow inversion by remote control.

Specifications

Accuracy: ± 0.1 ml

Power supply: ≤ 12 V CC

Cable length: 2 metres

Connector: Lumberg type, 6 pins male

Basic capacity: 100 cm³

Maximum working pressure: 2000 kPa

📏 Dimensions: 260x280x400 mm

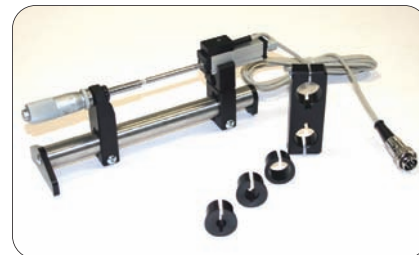
⚖️ Weight approx.: 9 kg

Accessories**Calibration device for linear transducers**

- **30-WF0652** Calibration device for linear transducers. It consists of a stainless steel frame with two holders: one for the transducer and the other for the micrometer gauge head. The holder can receive transducers having nominal diameter of 8, 12, 19, 22 mm or 18 mm square. Traceable calibration certificate available upon request.

Max. travel: 25 mm

Resolution: 0.01 mm



30-WF0652 with 30-WF6208

29-WF4412

AUTOMATIC CONSOLIDATION, SHEAR AND TRIAXIAL TESTING SYSTEM

Automatic Consolidation, Shear and Triaxial testing system

The real automation of a Soil Mechanics laboratory is not limited to a modernization of the testing equipment only but is a contribution to cost saving. The possibility of performing 24 hours 7 days tests without interruptions is a great value.

The ACE Automatic Computerized Oedometer together with the SHEARMATIC Shear Testing Machine and AUTOTRIAX Triaxial Testing System is our proposal for your automated laboratory. For detailed information visit our web site or get in touch with our technical-commercial dept.

ACE, automatic oedometer

- PC controlled automatic test execution
- Real time data and graph display
- PC software controlling up to 60 units
- High speed LAN network communication
- Modular expandability



SHEARMATIC, Automatic Shear Testing Machine

- Automatic pneumatic application of pre-set consolidation steps (up to 50)
- Automatic test management from consolidation to failure: the operator is only requested to remove the clamping screws of the shear box
- High resistance techno-polymeric carriage
- Easy and immediate set up of the test parameters via the large digital graphic display
- Possibility to set different speeds and travel (forward and reverse) in the residual shear tests
- Each single step of axial force can be applied instantaneously or by means of a linear ramp in a pre-set time interval
- Different and independent data recording for consolidation and failure



AUTOTRIAX, Automatic Triaxial System for Effective stress, Stress path, Permeability, Unsaturated tests

- More than 30 possible configurations to suit your requirements
- Control up to three independent systems
- System is expandable in modular steps
- With the opportune accessory system performs also stress-path test and advanced examination on unsaturated soil



GEODATALOG

Introduction

The main advantage of GEODATALOG is to record and monitor in real time whichever measurement involved in a general test carried on in a soil mechanics laboratory. The different transducers can be set up and grouped so that a single test can involve as many measurements as required: all these transducers will record data at the same time with a specific recording mode.

GEODATALOG is particularly suitable for research laboratories and universities where non standard tests are performed.

General description

This datalogger which is proposed in two versions: 16 or 32 channels capacity (30-WF6016 and 30-WF6032), provides automatic data recording in the non-automatic systems.

The GEODATALOG is directly connected to PC. Data are automatically stored in memory and downloaded to PC in real time for immediate monitoring of the different tests in progress at the same time.

It is compatible with a complete range of transducers for the various test requirement. A general purpose basic software DATA-COMM is included for calibration, data recording and monitoring in real time of the transducers involved in the tests in progress (see 30-WF6016/S).

Proper templates have been developed for data analysis, processing and printout of test certificates according to the most important international standards (ASTM, BS, EN). (See 30-WF6016/T1 to 30-WF6016/T7).

■ **30-WF6016**
GEODATALOG, 16 channels Data acquisition system for geotechnical tests. 110-240 V, 50-60 Hz, 1 ph.

■ **30-WF6032**
GEODATALOG, 32 channels Data acquisition system for geotechnical tests. 110-240 V, 50-60 Hz, 1 ph.

Specifications

Hardware

Number of channels: 16 (30-WF6016) or 32 (30-WF6032).

With 64 channels expansion kit model 30-WF6032/NET and DATA-COMM software included it is possible to connect to a single PC 2 logger units extending number of channels to 64.

Sensors outputs:

- V_{ex} adjustable up to 10V DC (common to all channels)
- compatible with 3 and 4 wires sensors single and double ended

Sensors inputs:

- from -10V to +10V including the following sensors:
- any amplified sensor with DC output;
 - potentiometric transducers;
 - wheatstone bridge transducers with mV/V DC output (load cells, pressure transducers, linear transducers, and equivalent)
- sensors impedance from 100 Ohm to 10 kOhm

Real resolution: $\pm 32\ 000$ divisions

Sampling rate: adjustable up to 10 samples/sec per channel

Data storage capacity: 8 Mbytes

Communication ports: RS232 and USB for data download to PC with software included

On-board firmware

Suitable for remote management of the logger with DATA-COMM software (included).

DATA-COMM Communication software for data download and data filing

Digital calibration of channels with linear, polynomial and multi-coefficient calibration mode. Recording modes: controlled by time and/or readings with linear, exponential and polynomial modes.

Graphical and numerical displaying of readings.

Report generation

Data export as HTML, XLS and TXT. Selection of the language including a custom language which can be input by the user. Requires Microsoft Windows XP® or superior Microsoft operating system.

If used with 2 logger units connected to a single PC with extension kit model 30-WF6032/NET can manage up to 64 channels.

Minimum PC Specifications:

- Processor speed 500 MHz minimum
- Hard disk 200 MByte minimum
- RAM 512 Mbyte
- CD - ROM

- 1 serial port RS232 or USB with adapter USB-RS232 or Ethernet card with adapter Ethernet-RS232
- Windows® 2000 Professional or XP
- Monitor minimum resolution 800x600 pixel
- MS Excel® suggested
- A4 printer

📏 **Dimensions:** 320x270x140mm (lxdxh)

⚖️ **Weight:** 2,5 kg approx.

Accessories

- **30-WF6042** Transducer extension cable, 6 m length
- **30-WF6044** Transducer extension cable, 12 m length
- **30-WF6032/NET** Extension kit for management of up to 64 channels (to be used only with GEODATALOG)

MS Excel® Geo-Analysis Templates

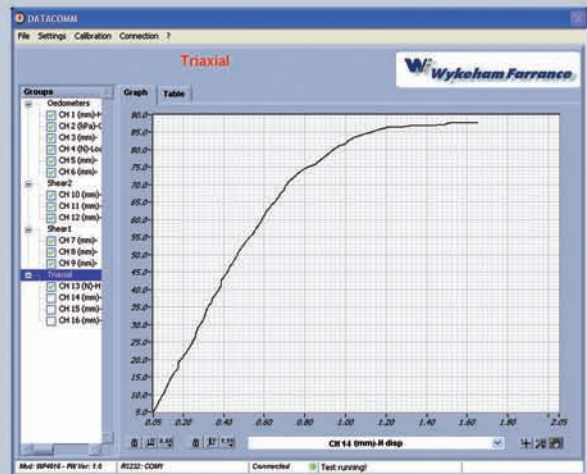
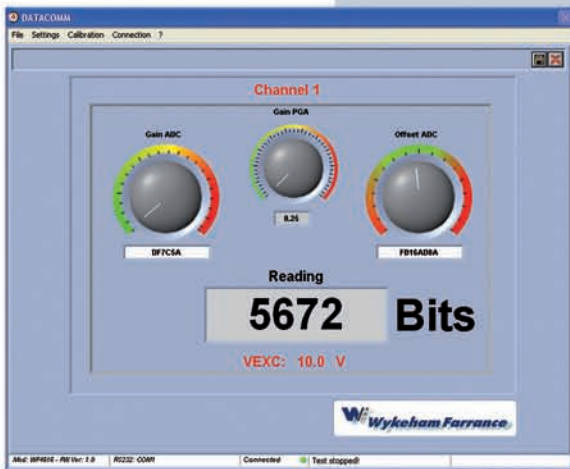
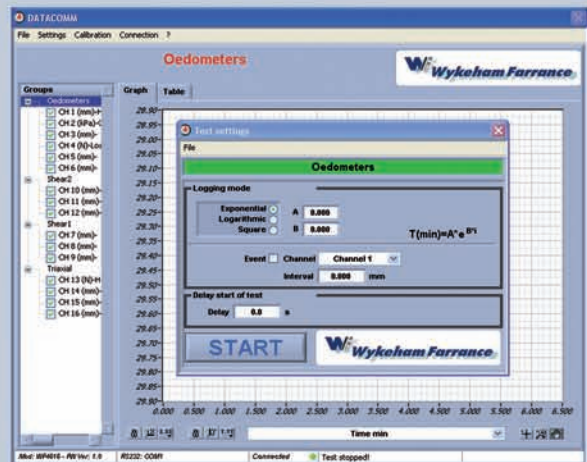
- **30-WF6016/T1** Consolidation Geo-Analysis Template conforming to BS 1377:5
- **30-WF6016/T2** Direct and residual Shear Geo-Analysis Template conforming to BS 1377:7
- **30-WF6016/T3** Ring Shear Geo-Analysis Template conforming to BS 1377:7
- **30-WF6016/T4** Effective Stress (CU-CD) Triaxial Testing Geo-Analysis Template conforming to BS 1377:8
- **30-WF6016/T5** Undrained (UU) Triaxial Testing Geo-Analysis Template conforming to BS 1377:7
- **30-WF6016/T6** CRS type consolidation Geo-Analysis Template conforming to ASTM D4186
- **30-WF6016/T7** CBR Geo-Analysis Template conforming to BS 1377:4
- **30-WF6016/T8** Consolidation Geo-Analysis Template conforming to ASTM
- **30-WF6016/T9** Direct and residual Shear Geo-Analysis Template conforming to ASTM D3080
- **30-WF6016/T10** Undrained (UU) Triaxial Testing Geo-Analysis Template conforming to ASTM D2850
- **30-WF6016/T11** Effective Stress (CU) Triaxial Testing Geo-Analysis Template conforming to ASTM D4767

DATACOMM

DATACOMM SOFTWARE
SOME EXAMPLES OF SCREENSHOT



Front panel of GEODATALOG 30-WF6032



Electronic transducers

ELECTRONIC TRANSDUCERS

For use with the GEODATALOG 30-WF6016, 30-WF6032, and DATALOG 30-T0601/A series.

The beside table summarises the type and application of the various transducers, which are afterwards described.

DISPLACEMENT POTENTIOMETRIC TRANSDUCERS

■ **30-WF6207 Linear potentiometric transducer**, 10 mm travel, with 6-pin Lumberg connector complete with mounting block

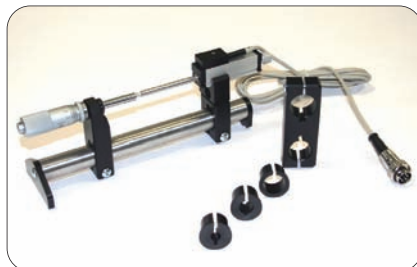
■ **30-WF6208 Linear potentiometric transducer**, 25 mm travel, with 6-pin Lumberg connector complete with mounting block

■ **30-WF6209 Linear potentiometric transducer**, 50 mm travel, with 6-pin Lumberg connector complete with mounting block

■ **30-WF6210 Linear potentiometric transducer**, 100 mm travel, with 6-pin Lumberg connector complete with mounting block



30-WF6208



30-WF0652 with 30-WF6208

Codes	Description	Measure	Application
30-WF6207 to 30-WF6210	Displacement potentiometric transducers	Linear displacement	Consolidation Shear testing Triaxial
27-WF0377/ST	Strain gauge load cell	Force	Shear testing
28-WF0370/T 28-WF0373/T 28-WF0375/T	Strain gauge load cells	Force	Triaxial
28-WF6351 to 28-WF6356	Submersible load cells	Force	Triaxial with triaxial cells 28-WF4050 to 28-WF4150 and Tri-Cell Plus 28-WF4070/P to 28-WF4150/P
28-WF6300 28-WF6301 28-WF6302	Pressure transducers	Pressure	Triaxial Continuous consolidation
28-WF4410	Automatic volume change apparatus	Volume	Triaxial
28-WF4079/K to 28-WF4159/K	On sample strain transducers	Axial and radial deformation	Triaxial with Tri-cell Plus 28-WF4070/P to 28-WF4150/P

Specifications

Input voltage: 10 V DC

Output: from 0 to input voltage

Repeatability and accuracy: better than 0.002 mm

Accessories

► **28-WF6220** Mounting bracket for displacement transducers to fit 15.5 mm dia. triaxial cell ram

► **28-WF6221** Mounting bracket for displacement transducers to fit 25 mm dia. triaxial cell ram

► **28-WF1048/T** Mounting bracket for displacement transducer to fit standard triaxial cell ram

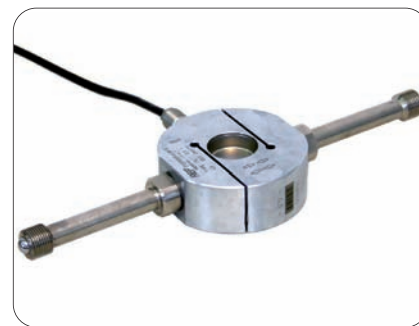
► **30-WF0652**
Calibration device for linear transducers

It consists of a stainless steel frame with two holders: one for the transducer and the other for the micrometer gauge head. The holder can receive transducers having nominal diameter of 8, 12, 19, 22 mm or 18 mm square. Traceable calibration certificate available upon request

STRAIN GAUGE LOAD CELL

For shear testing machines 27-WF2060 and 27-WF2160

■ **27-WF0377/ST** Load cell 5 kN cap. complete with adapters



27-WF0377/ST



30-WF6220

Specifications

Nominal sensitivity: 2 mV/V

Accuracy: better than 0.1%

ELECTRONIC TRANSDUCERS

Continued

For use with the GEODATALOG 30-WF6016, 30-WF6032, and DATALOG 30-T0601/A series.

STRAIN GAUGE LOAD CELLS FOR TRIAXIAL FRAMES

- **28-WF0370/T** Load cell 3,5 kN cap.
- **28-WF0373/T** Load cell 10 kN cap.
- **28-WF0375/T** Load cell 50 kN cap.
- **28-WF0376/T** Load cell 100 kN cap.



28-WF0370/T, 28-WF0375/T

Specifications

- Nominal sensitivity:** 2 mV/V
- Accuracy:** better than 0.1%
- Connecting thread:**
 - Female M20x1.5 (2.5 and 10 kN models)
 - Female M30x2 (50 and 100 kN model)

SUBMERSIBLE LOAD CELLS

Internal load cells have been designed to work inside the triaxial cell. They have a low hysteresis and very good linearity together with a substantial over load safety feature.



28-WF6352

PRESSURE TRANSDUCERS

Used for measurement of cell pressure, back pressure, pore pressure (water or air).

- **28-WF6300**
Pressure transducer, 1000 kPa
- **28-WF6301**
Pressure transducer, 2000 kPa
- **28-WF6302**
Pressure transducer, 3500 kPa

Specifications

- Input voltage:** 0-10 V DC
- Output:** 100 mV full scale
- Accuracy:** better than 0.1 kPa



28-WF6300 with 28-WF4459



28-WF6300 with 28-WF6310

Accessories

- ▶ **28-WF6310** De-airing block for pressure transducer. To be connected to banded triaxial cells
- ▶ **28-WF4459** De-airing block for pressure transducer. To be connected to standard triaxial cells

Technical specifications

- Overload capacity:** 200%
- Excitation voltage:** 10 V DC
- Non-linearity:** ± 0.05% full scale
- Hysteresis:** 0.05% full scale

- Cable length:** 2 metres
- Diameter:** 75 mm
- Height excluding ram or stub:** 50 mm
- Weight excluding ram or stub:** 850 g

SUBMERSIBLE LOAD CELLS FITTED WITH RAMS AND CORRESPONDENT TRIAXIAL CELL

Model of submersible load cell	Capacity		Model of triaxial cell compatible	Diameter of the ram
	kN	kgf		mm
28-WF6350	1.0	100	28-WF4050	15.5
28-WF6352	5.0	500		
28-WF6354	10.0	1000		
28-WF6351	1.0	100	28-WF4070 28-WF4100 28-WF4150 28-WF4070/P 28-WF4100/P 28-WF4150/P	25.0
28-WF6353	5.0	500		
28-WF6355	10.0	1000		
28-WF6356	25.0	2500		

ELECTRONIC TRANSDUCERS

Continued

VOLUME CHANGE TRANSDUCER

■ 28-WF4410

Automatic volume change apparatus

General description and specifications

When connected with a suitable display or data acquisition system the apparatus provides an electrical signal directly proportional to the volume of water flowing through the unit. The apparatus comprises of a piston connected to a linear transducer 25 mm travel and sealed against a precision-machined calibration chamber so that the linear movement of the piston is exactly proportional to the volume of water in the calibration chamber.

The apparatus includes the panel with reversing valve system to measure the water flow in both directions.

Basic capacity: 100 cm³

Transducer input: up to 12 V DC

Accuracy: ± 0.1 ml

Dimensions: 260x280x400 mm (lxdxh)

Weight approx.: 9 kg



28-WF4410

ON SAMPLE STRAIN TRANSDUCERS

On sample transducers consist of radial and axial strain belts. In conventional triaxial testing the determination of axial stiffness is based on external measurements. This method brings errors due to sample bedding effects of the porous stones on either end of the sample and to the loading system and load measuring system.

Furthermore the two ends of the specimen are subjected to restraint, differently from the middle third of the sample, where the strain transducers are mounted and where the realistic deformations occur.

Axial and radial strain transducers give the

opportunity to measure with high accuracy the deformations directly on the triaxial test specimen.

These transducers have to be used with TRI-CELL Plus triaxial cells models (see page 34) and with a suitable Data Acquisition system as for example our GEODATALOG 30-WF6016 or 30-WF6032.

On sample strain transducers for static testing:

Energise: 10 V DC

Output: ± 250 mV

Linearity: ± 0.25%

Temp. coefficient: ± 0.01%/FS/deg C

Resolution: 1 micron

On sample transducers kit for static testing

28-WF4079/K On sample transducer kit for 70 mm samples with 2 linear and 1 radial transducers plus all plugs for use with GEODATALOG*

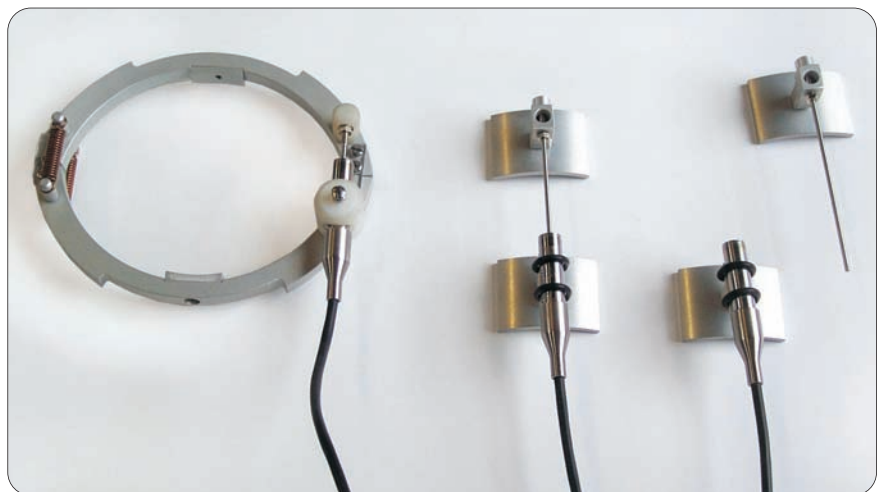
28-WF4109/K On sample transducer kit for 100 mm samples with 2 linear and 1 radial transducers plus all plugs for use with GEODATALOG*

28-WF4159/K On sample transducer kit for 150 mm samples with 2 linear and 1 radial transducers plus all plugs for use with GEODATALOG*

* See page 62

note

On sample transducers kit for dynamic testing are described on page 71



Introduction

We know that all of our structures are subject to vibration, shock and cyclic loading. The effect on our foundation design has usually been determined by testing with a 1 Hz sinusoidal wave shape but from the graph below it can be seen that each application will have its own unique wave shape and frequency.

The Cyclic Stress Path system can replicate these unique applications in the laboratory test.

WF7000 SERIES 50/100 KN STATIC/DYNAMIC TRIAXIAL SYSTEMS

STANDARDS

ASTM D2850, D4767, D3999, D5311 /
BS 1377:Part 7, Part 8:1990

Applications

To reproduce in the laboratory the same vibration, shock and cyclic forces to the soil sample, to give engineers a better understanding of how a soil material behaves under these unique situations.

Construction

The preservation of archaeological sediments and artefacts during construction. To establish the effects of past stress regimes on archaeological remains as seen in their contemporary, in-situ context.

To maximise site stability and integrity, thereby enhancing the future preservation of archaeological remains. Laboratory studies will simulate past loading regimes as a consequence of the historic accumulation of debris and sediment and future loading based on a range of construction scenario.

Liquefaction

Liquefaction is a phenomenon that occurs in saturated soils, in which the space between individual particles is completely filled with water. This water exerts a pressure on the soil particles that influences how tightly the particles themselves are pressed together. Prior to an earthquake, the water pressure is relatively low. However, earthquake shaking can cause the water pressure to increase to the point where the soil particles can readily move with respect to each other. During the last three decades progress has been made in theoretical and experimental aspects of research concerning phenomenon of liquefaction.

The phenomena and problems associated with liquefaction concern saturated cohesionless soils, even if they contain considerable amount of fines. In recent years particular attention has been focused on sloping ground conditions, which although do not require earthquake loading, might result in flow failure associated with catastrophic consequences.

Offshore

To investigate the wave effect on offshore, structures, waterside buildings, harbours and pipelines. Wave effect and pipeline vibrations can be recreated.

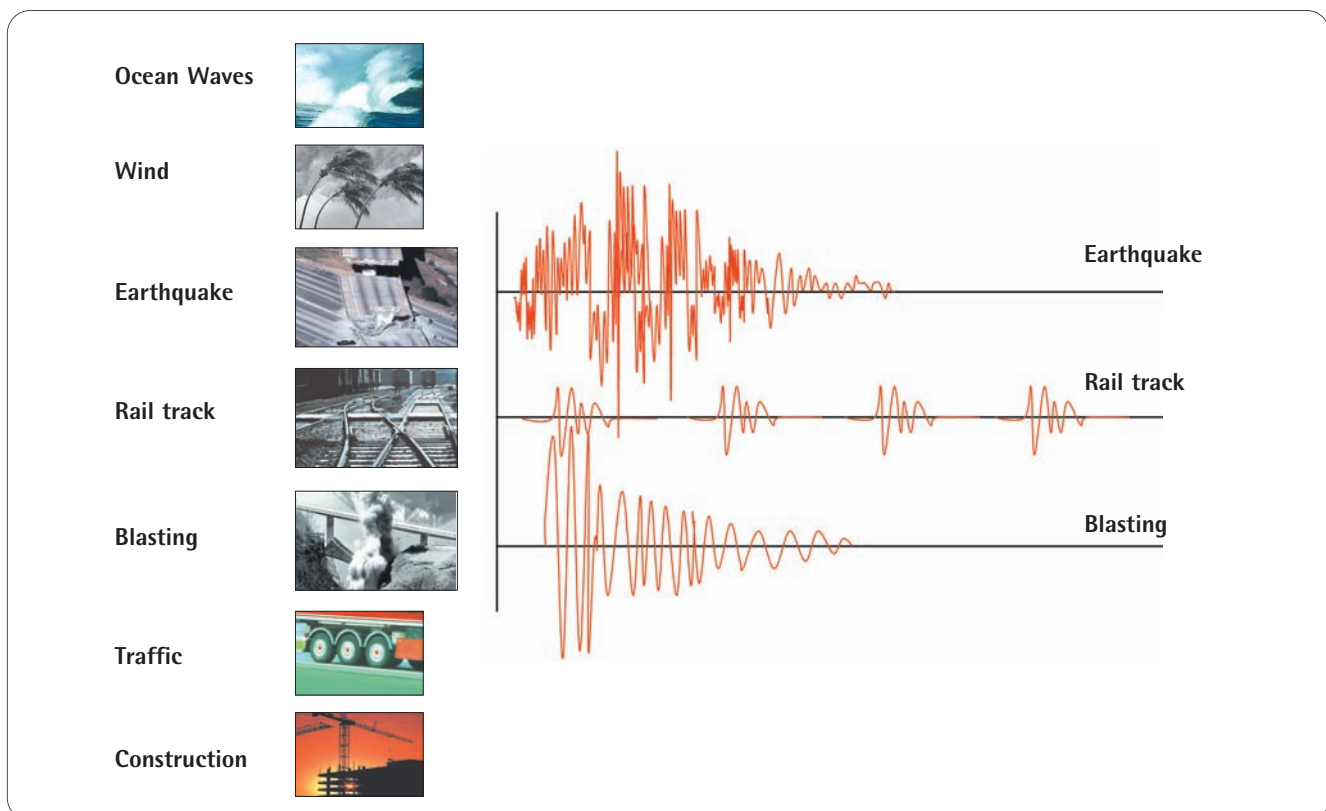
Blasting

What effect does blasting have on structures in the areas surrounding the quarry or site? What effect does blasting have on the foundations of these structures? The blasting signature can be used for testing the foundation material.

Rail track

What effect does vibrations have on buildings close to railway track? Trains are becoming faster creating vibrations of greater frequency, which are transmitted into the surrounding ground. Cyclic tests on the track subbase can be performed.

Causes of Vibration or Cyclic Loading



DYNATRIAX

The dynamic triaxial system developed using the latest technologies and decades of WF experience in the dynamic soil testing field, ideal for commercial and research laboratories.

FLEXIBILITY

- Three axis closed loop control for axial load or displacement, cell and back pressure
- Operating frequency up to 10 Hz
- Two dynamic load/displacement options:
 - Up to ± 25 mm (± 5 kN actuator)
 - Up to ± 15 mm (± 14 kN actuator)
- Two load frame options: 50 and 100 kN
- Capability to perform static (effective stress and stress path), dynamic and unsaturated soil triaxial tests
- Available upgrade for bender element testing, local strain and mid height pore pressure measurement

MODULARITY

- Test setup by unique programmable multi-stage test procedure: during the test run, access to all controls to expand and modify the stages according to the response of the soil specimen
- Designed to easily integrate existing static systems

RELIABILITY

- Standard and user defined wave shapes also derived from in situ measurements (from violent earthquake to sedate ocean waves)
- Complete test automation of all test stages using an high sensitivity closed loop P.I.D. feedback (up to 10 kHz)
- Automatic compensation of cell/back pressure during dynamic stage
- Transducers calibration and verification management by the software
- Manual and automatic emergency air shut off function

DYNATRIAX

Continued

COMPONENTS AND SPECIFICATIONS

The **DYNATRIAX** is a computer controlled servo-pneumatic system designed to perform the static and dynamic stages of a triaxial test.

The system manages three closed loop axis:

1. Vertical load/displacement
 - up to ± 25 mm (± 5 kN actuator)
 - up to ± 15 mm (± 14 kN actuator)
2. Cell pressure up to 1000 kPa
3. Back pressure up to 1000 kPa

The base system includes:

Tritech 50 or Tritech 100 load machines

The TRITECH digital loading machine is a microprocessor controlled drive system, specifically designed to perform both static or dynamic tests.

- Static load capacity: 50 kN or 100 kN
- Static vertical displacement up to 100 mm (machine travel)

Actuator

The double acting pneumatic actuator is digitally controlled and includes an integrated LVDT displacement transducer to control the position and the movement of the piston during the test.

- Dynamic load capacity: ± 5 kN or ± 14 kN
- Dynamic vertical displacement with travel up to ± 25 mm or ± 15 mm
- Operating frequency up to 10 Hz (depending on test conditions)

Dynatriax includes PC and software that provides the control of all test stages in automatic mode.

The air reservoir is provided with two servo valves for cell and back pressure control.

On/off valve.

The pneumatic actuator applies the vertical cyclic load/displacement according to the set wave shape.

Servo valve for the vertical load control

The actuator locking system allows the user to easily skip from dynamic to static testing taking advantages of the load frame's maximum capacity.

Submersible load cell is used for accurate measurement, not affected by the friction of the ram and the cell pressure.

PC software controlled automatic volume change apparatus.



CDC - Compact Dynamic Controller with manual emergency shut-off switch. It is provided with 16 channels 16 bit ADC.

Tritech50 load frame fitted with ± 5 kN actuator and TRI-CELL Plus triaxial cell.

Min. air supply: 800 kPa - Max. servovalve frequency: 70 Hz.

Data Acquisition, process & control system

The **CDC - Compact Dynamic Controller** is a compact self contained unit that manages the three closed loop axis (vertical load/displacement, cell and back pressure) with a control loop rate of 10 kHz. It provides the automatic control of the system and drives the servovalve units of the three axis

and two on/off valves, one connected to the drainage line and one connected to the air main supply of the triaxial cell.

The CDC communicates with the PC through an Ethernet communication link (100 Mbit/s). The controller has sixteen transducer input channels using 16 bit ADC.

Max. servovalves frequency: 70 Hz.



Continued

SOFTWARE

Multitasking, user-friendly Windows-based software is pre-installed on the computer provided with the system. The software provides control of the following utilities and stages of a cyclic triaxial test:

Saturation

- Cell pressure increments with B value check
- Back pressure increments with volume change measurement
- Cell and back pressure ramp

Consolidation

- Isotropic consolidation with continuous volume change measurement

K_0 Consolidation

Vertical displacement loading with sample diameter control using either:

- Direct measurement by radial belt with on-sample transducer -
- Measurement of sample volume change and height

Stress path

- Horizontal and Vertical Stress
- s , t (average stress and shear stress)
- p , q (mean normal stress and deviator stress)
- Vertical stress using strain control

Monotonic Shear

- Strain controlled static shear stage, drained or undrained
- Loading in compression or extension, using the vertical actuator or the Tritech

Any or all of the above stages can be performed in 'automatic mode' where the test parameters are entered at the start of the test or stage and the software takes control of managing the stages using predefined criteria.

Cyclic loading

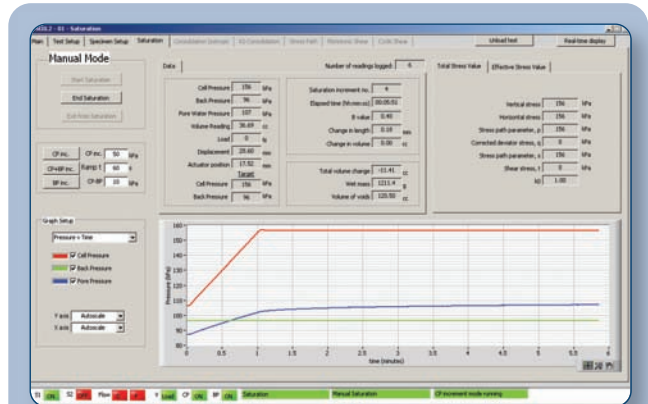
- ASTM D 5311 Load Controlled Cyclic Strength
- ASTM D 3999 Load Controlled Modulus & Damping
- ASTM D 3999 Displacement Controlled Modulus & Damping
- Non Standard (single or multi cycle test)
- User defined or imported Waveshape

Transducer limits

- An air shut-off valve can be programmed to be activated using user defined channel limits.

Calibration

- Digital calibration using linear fit, polynomial fit or linearization.
- Transducer verification option

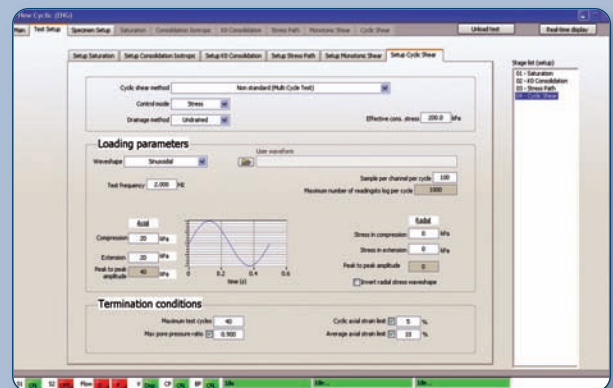


Saturation

This stage follows the incremental saturation as per BS 1377-1990 but is flexible and allows other methods to be used. The software will let you apply cell and back pressure increments with B value displayed in the cell pressure stage.

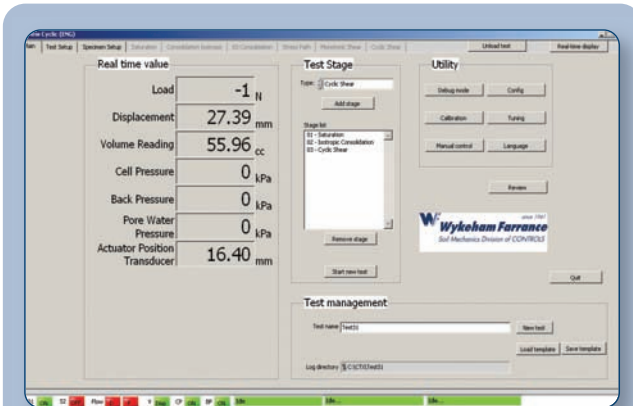
Graph displays

- Cell pressure against time
- Pore pressure against time
- Back pressure against time
- Volume change against time

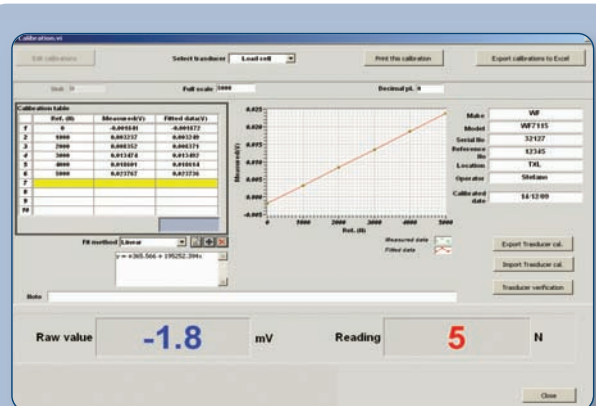


Selection of the cyclic stage and set up of the relevant parameters:

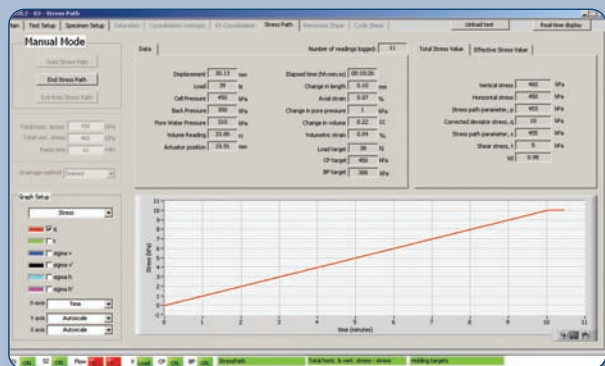
- Test method: ASTM D5311, D3999, non standard
- Waveshape: sinusoidal, triangle, square, user defined
- Frequency
- Peak to peak amplitude
- Type of control (stress, strain, force, displacement)
- Failure conditions: e.g. number of cycles, pore pressure ratio, strain limit



Set up of the different stages of the test
Saturation; isotropic consolidation; K_0 consolidation; Stress path; Cyclic shear; Monotonic shear.

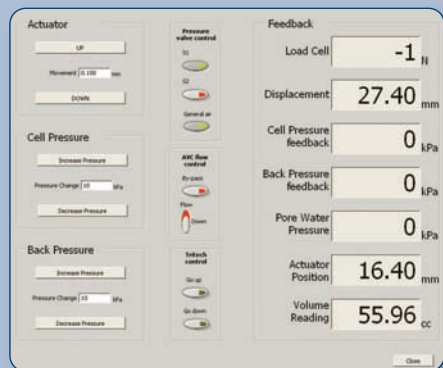


Transducer calibration
Transducers can be allocated and calibrated from the library in the test configuration.

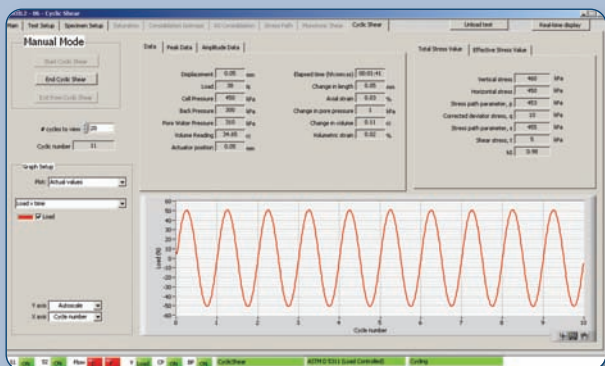


Stress path
This stage allows axial and radial stresses to be increased and decreased in incremental stages.

Available graphs
All transducer calculated; stresses and strains; stress path.



Manual control procedure
The operator can manually manage the actuator, cell pressure, back pressure, volume change, electrovalves and, at the same time, monitor the transducer readings.



Cyclic stress controlled
The cyclic stage applies the specified cyclic loading to the specimen. This screen shows all the varying values during the cyclic stage.

Available graphs
Real time transducers peak compression/extension and amplitude values.



Cyclic shear
Young's modulus and shear modulus are monitored during the cyclic stage against the number of cycles.

DYNATRIAX

Continued

■ 31-WF7005

Dynatriax, dynamic triaxial basic system, ± 5 kN cyclic, on a 50 kN load machine. 110-240 V, 50-60 Hz, 1 ph.

■ 31-WF7006

Dynatriax, dynamic triaxial basic system, ± 14 kN cyclic, on a 50 kN load machine. 110-240 V, 50-60 Hz, 1 ph.

■ 31-WF7010

Dynatriax, dynamic triaxial basic system, ± 5 kN cyclic, on a 100 kN load machine. 110-240 V, 50-60 Hz, 1 ph.

■ 31-WF7015

Dynatriax, dynamic triaxial basic system, ± 14 kN cyclic, on a 100 kN load machine. 110-240 V, 50-60 Hz, 1 ph.

■ 31-WF7000/UNS

Upgrading package for unsaturated soil testing.

The package includes the additional servo-valve for air pressure control and the software to automatically perform the test stages using the axis translation method:

- Simultaneous and independent control of air pressure, pore water pressure and axial stress
 - Performance of consolidation, saturation soil water curve and shear stages
 - Test data recording for each stage
- Triaxial cell and test accessories must be ordered separately.

■ 31-WF7000/RES

Upgrading software package for resilient modulus determination according to AASHTO T307.

ACCESSORIES

Triaxial cells (Tri-Cell Plus models)

The Tri-Cell Plus cells include outlets for on sample transducer cables or for bender elements. They are also suitable for extension tests and can be equipped with submersible load cells.

▼ 28-WF4070/P

3400 kPa Tri-Cell Plus cell for 70 mm dia. samples.

▼ 28-WF4100/P

2000 kPa Tri-Cell Plus cell for 100 mm dia. samples.

▼ 28-WF4150/P

2000 kPa Tri-Cell Plus cell for 150 mm dia. samples.

Double triaxial cells for unsaturated tests

▼ 28-WF4170

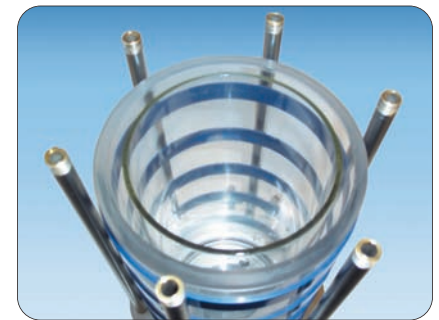
Double triaxial cell for unsaturated tests on 70mm samples complete with 6 ports.

▼ 28-WF4171

Double triaxial cell for unsaturated tests on 100mm samples complete with 6 ports.



28-WF4100/P



Detail of the double wall of 28-WF4170 and 28-WF4171

TRI-CELL PLUS ACCESSORIES

Cell type nominal dia.	Maximum working pressure	Sample	Pedestal	Top cap with 2 drainage leads	Perspex base disc ⁽¹⁾	Coverion set ⁽²⁾	Top cap vacuum type ⁽³⁾
28-WF4070/P 70 mm	3400 kPa	38 mm	-	-	28-WF4033	28-WF4070/1	28-WF4032/V
		50 mm	-	-	28-WF4053	28-WF4070/2	28-WF4052/V
		70 mm	28-WF4071	28-WF4072	28-WF4073	-	28-WF4072/V
28-WF4100/P 100 mm	2000 kPa	50 mm	-	-	28-WF4053	28-WF4100/1	28-WF4052/V
		70 mm	-	-	28-WF4073	28-WF4100/2	28-WF4072/V
		100 mm	28-WF4101	28-WF4102	28-WF4103	-	28-WF4102/V
28-WF4150/P 150 mm	2000 kPa	100 mm	-	-	28-WF4103	28-WF4150/2	28-WF4102/V
		150 mm	28-WF4151	28-WF4152	28-WF4153	-	28-WF4152/V
28-WF4170 70 mm	2000 kPa	70 mm	28-WF4170/1 ⁽⁴⁾	28-WF4170/2	28-WF4073	-	28-WF4170/V
28-WF4171 100 mm	2000 kPa	100 mm	28-WF4171/1 ⁽⁴⁾	28-4171/2	28-WF4103	-	28-WF4171/V

(1) Only for UU tests - (2) Consisting of pedestal, top cap and drainage leads - (3) Required to perform extension test - (4) It includes 2 bar high air entry stone. Also 1, 5, 10, 15 bar stones capacity are available

NOTE: further samples accessories are available on request

SAMPLE ACCESSORIES

Sample size	Porous disc (pair)	Rubber membrane (pack of 10)	O ring (pack of 10)	Membrane stretcher	O ring placing tool	Two part split mould with vacuum attachment	Two part split former	Lateral filter drains (pack of 50)	Filter discs (pack of 100)	Hand sampler
38 mm	28-WF4034	28-WF4035	28-WF4036	28-WF4031/A	28-WF4031/B	28-WF4031/H	28-WF4031/D	28-WF4031/E	28-WF4031/F	28-WF4031/G
50 mm	28-WF4054	28-WF4055	28-WF4056	28-WF4051/A	28-WF4051/B	28-WF4051/H	28-WF4051/D	28-WF4051/E	28-WF4051/F	28-WF4051/G
70 mm	28-WF4074	28-WF4075	28-WF4076	28-WF4071/A	28-WF4071/B	28-WF4071/H	28-WF4071/D	28-WF4071/E	28-WF4071/F	28-WF4071/G
100 mm	28-WF4104	28-WF4105	28-WF4106	28-WF4101/A	28-WF4101/B	28-WF4101/H	28-WF4101/D	28-WF4101/E	28-WF4101/F	28-WF4101/G
150 mm	28-WF4154	28-WF4155	28-WF4156	28-WF4151/A	28-WF4151/B	28-WF4151/H	-	28-WF4151/E	28-WF4151/F	-

Submersible load cells

Designed to work inside the triaxial cell. The load measurement is highly accurate as it is not affected by the friction of the ram in the triaxial cell bush and cell pressure and by cell pressure.

▼ **31-WF7117**

Submersible load cell, 5 kN cap.

▼ **31-WF7118**

Submersible load cell, 10 kN cap.

▼ **31-WF7119**

Submersible load cell, 25 kN cap.

Common Specifications

Overload capacity: 200%

Excitation voltage: 10 VDC

Hysteresis: 0.05% full scale



31-WF7117

Water distribution panel

▼ **31-WF4335**

Water distribution panel, two pressure lines, complete with digital pressure gauge and hand pump.



31-WF4335

Bladder Air/Water pressure cylinder

▼ **28-WF4320**

Bladder air/water pressure cylinder for pressures up to 1000 kPa.



28-WF4320

Air compressor

▼ **86-D2015/A**

Air compressor, 10 bar max. pressure, 200 l capacity. Power: 5.5kW, 400 V, 50 Hz, 3 ph.

Transducers

▼ **31-WF7121**

LVDT linear transducer, ±25 mm travel, (0,2% FSO accuracy).

▼ **28-WF6300**

Pressure transducer, 10 bar max.

▼ **28-WF6310**

De-airing block for pore pressure transducer.



28-WF6300 with 28-WF6310

▼ **29-WF4412**

Automatic volume change device with remote controlled flow inversion. 100 cc capacity, 0.1 cc accuracy, 2000 kPa max. operating pressure.



29-WF4412

▼ **28-WF4079/K**

On sample transducer kit for 70 mm sample (with 2 linear and 1 radial transducers).

▼ **28-WF4109/K**

On sample transducer kit for 100 mm sample.

▼ **28-WF4159/K**

On sample transducer kit for 150 mm sample.



RESONANT COLUMN

RESONANT COLUMN (RC)/TORSIONAL SIMPLE SHEAR (TSS) TESTING SYSTEM

■ 31-WF8500

For the determination of:

RC test

- shear wave velocity
- secant shear modulus G
- damping ratio D
- ratio from free-vibrations

TSS test

- secant shear modulus from stress-strain response
- damping ratio from hysteresis loops

Automatic calculation of:

- Resonant Frequency
- Shear wave velocity
- Shear modulus
- Shear strain
- Damping ratio from half power band width
- Damping ratio from free vibration decay

Reference Standard:

ASTM D4015-2000



31-WF8500

MAIN FEATURES

- Combined Resonant Column / Torsional Simple Shear device
- Automatic detection of fundamental frequency
- RC: damping ratio from half power bandwidth and from free vibration data
- TSS: damping ratio from hysteresis loops
- Internal floating frame for large angular and axial deformation
- Confining pressure up to 1 MPa
- Suitable for 50 mm dia. specimen (or 70 mm on request)
- Integrated signal generator and oscilloscope

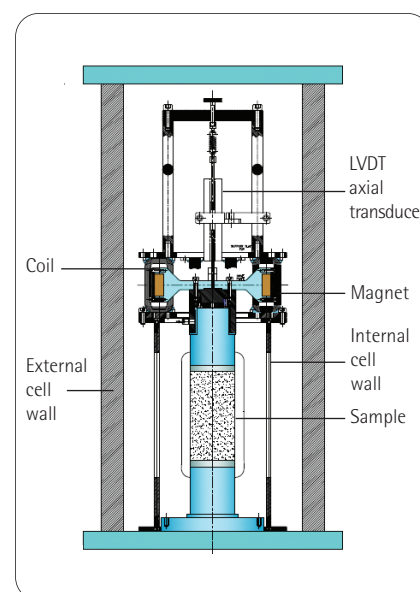
OPERATING PRINCIPLE

RESONANT COLUMN combines the features of both resonant column and torsional shear into a single unit including the current driven motor to apply torsional load to sample, a series of transducers with signal conditioning, a cell and back pressure electro-pneumatic control system and a data logger.

In the Resonant Column test a cylindrical soil specimen is restrained at the bottom and dynamically excited at the top. The torsional force at the top is generated using an electrical motor constituted by eight drive coils encircling four magnets attached to a drive plate. The generated frequency is up to 250 Hz. The fundamental mode of vibration is found from the maximum amplitude of motion; from the resonant frequency, shear wave velocity

and shear wave modulus are calculated using elasticity theory. The corresponding shear strain is evaluated from the motion amplitude. Material damping can be determined from the half power bandwidth or from a free-vibration decay curve, which is generated by shutting off the driving power.

In the Torsional Simple Shear test the soil specimen is deformed cyclically at a low frequency (a maximum of 10 Hz), continuously monitoring torque and deformation. From the torque-deformation curves, a relationship between average shear stress and average shear strain is obtained, which in turn provides the shear modulus and the damping ratio.



RESONANT COLUMN

(continued)

TEST STAGES

Saturation stage

During saturation stage a small amount of cell and back pressures are applied in steps, with a consequent dissolution of the air contained in the intergranular spaces. A control system generate the cell and back pressures using air/water interfaces. Cell, back and pore pressures are measured by pressure transducers 1000kPa cap, 0.1 kPa accuracy. Volume change is measured using high sensitivity differential pressure transducer.

Consolidation stage

The sample is subjected to the same back pressure used during the last saturation step while the cell pressure depends on the effective stress required in the next steps. When pore water pressure and volume changes are completely dissipated the consolidation stage ends.

During this stage the axial strain is measured using a LVDT transducer ± 12.5 mm travel, 0,2% class.

RC and TSS tests are usually performed in undrained conditions, closing the drainage channels and measuring changes in the pore water pressure.

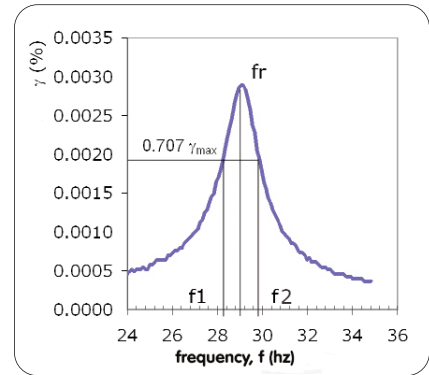
Resonant Column test (RC)

A signal generator supplies a sinusoidal voltage to the driving amplifier and a proportional current to the coils attached to the cell body. The magnetic field in the coils interacts with the magnets attached to the driving plate, that in turn conveys a torsional oscillation to the top of the specimen. As the frequency of the input signal varies, the dynamic response of the specimen results in a varying motion amplitude. The amplitude is captured either by an accelerometer attached to the driving plate and by proximity displacement transducers measuring the relative movement of the driving plate relative to the coils.

The frequency that maximizes the motion of the top of the specimen is associated to the first-mode resonance and is found applying an input signal with a frequency sweep.

uated from the resonant frequency. The damping ratio can be evaluated either from the complete frequency response of the soil specimen ("half power band width"), or from a free-vibration decay curve that is generated by shutting off the driving power.

At a given consolidation effective stress, RC tests are repeated several times, increasing progressively the amplitude of the input voltage, thus obtaining the secant shear modulus and the damping ratio corresponding to increasing shear strain values.



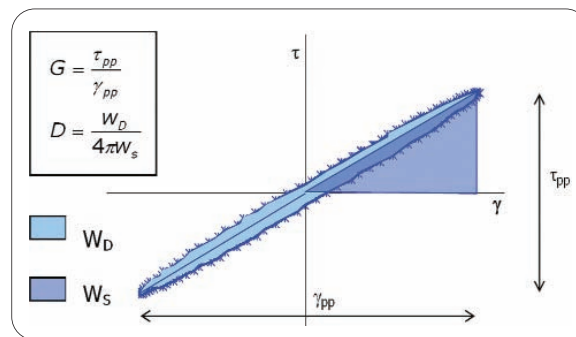
RC: Resonant Column test

Torsional Simple Shear test (TSS)

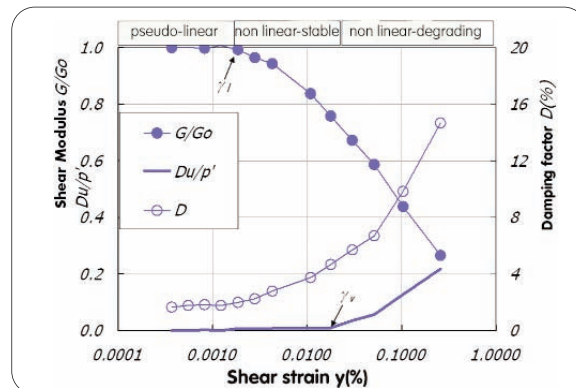
A sinusoidal current is applied to the coils in a quasi-static condition and the motion of the top of the specimen is monitored using the proximity displacement transducers. The input current (proportional to the shear stress) and the corresponding torsional rotation (proportional to the shear strain) are simultaneously recorded. The shear modulus of the soil is determined from the average

slope of the stress-strain loops, while material damping is related to the area of the hysteresis loop.

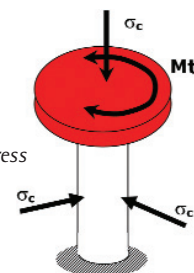
At a given consolidation effective stress, TSS tests are repeated several times, increasing progressively the amplitude of the input voltage, thus obtaining the secant shear modulus and the damping ratio corresponding to increasing values of the shear strain.



TSS: Determination of the shear modulus and damping factor



TSS : Strain level and mechanical behavior of the soil sample in simple cyclic shear condition



TSS: Schematic stress representation

RESONANT COLUMN

(continued)

GENERAL SPECIFICATIONS

Includes items:

- aluminium cell with stainless steel columns and acrylic transparent cylinder with 170 mm int. dia. x 200 mm ext. dia., including channels for bottom drainage;
- test accessories for 50 mm (or 70 mm) dia. specimens;
- internal floating frame for assembling the electrical motor that applies the torsional loads; this motor has four NeFeB 10 x 25 x 40 mm magnets and eight coils.
- main control box including:
 - power supply
 - current amplifier
 - 8 channels signal conditioning unit
 - USB data acquisition and signal generation board
 - two electro-pneumatic converters for cell & back pressure
- sensor kit containing:
 - axial LVDT transducer
 - automatic volume change apparatus with flow inversion
 - three Pressure transducers
 - two Eddy current displacement sensors (with miniaturised driving system)
- PC and software

Maximum torque: 1 Nm

Maximum angular deformation: 10°

Maximum Cell and back pressure: 1 MPa.

Excitation frequency

- Dynamic (RC) 1-300 Hz
- Cyclic (TS) from 0 to 50 Hz maximum

Optional sensor:

- MEMS accelerometer

Optional calibration Kit:

- N² calibration bars kit + N² calibration weights



31-WF8500 system. Controls panel.



31-WF8500 system. Detail of the electrical motor.

RESONANT COLUMN

Code	Description	Q.ty
31-WF8500	RESONANT COLUMN combined resonant column/torsional shear device for the automatic determination of damping ratio from half power bandwidth and free vibration decay method.	1
28-WF2016/A	Air Compressor 10 bar 145 psi maximum working pressure, Output 10.2 cfm, 100 L receiver. 230 V/50 Hz/1 ph	1
28-WF2016/2	Water Trap for Air/Water assembly	1
28-WF4221/A	De airing tank, 23 lt capacity	1
28-WF2001	Portable vacuum pump. 220-240 V/50-60 Hz/1 Ph	1
28-WF2064	Rubber tube dia 6,5 x 12,5 mm, 2 m long for vacuum	1
28-WF0491/2	Water trap	1
28-WF4225	Valve panel for use with de-airing tank	1

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