BUDENBERG

An introduction to dead-weight pressure gauge testers

These notes refer only to dead-weight testers for measuring the amount by which a pressure exceeds atmospheric pressure.

Piston/cylinder units

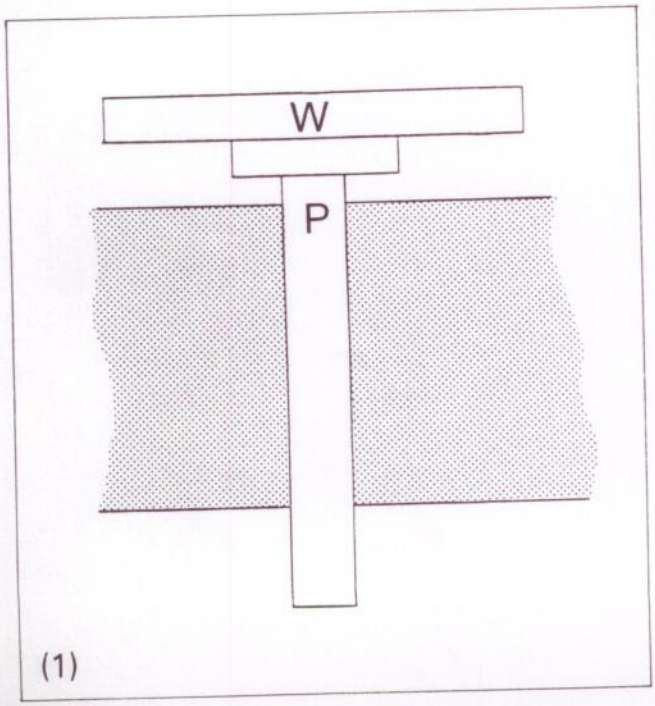
Pressure is defined as force per unit area. Dead-weight pressure testers use these measurements of force and area to produce a pressure to calibrate instruments with great accuracy. The force is derived from weight and the area is that of a piston in a cylinder.

For example, if a piston area $\frac{1}{8}$ in^2 weighing 12·5 pounds is supported by a fluid in a cylinder, the pressure in the fluid is 12·5 divided by $\frac{1}{8}$ = 100 lb/in^2. The piston/cylinder and the weights applied to it are together called a dead-weight balance.

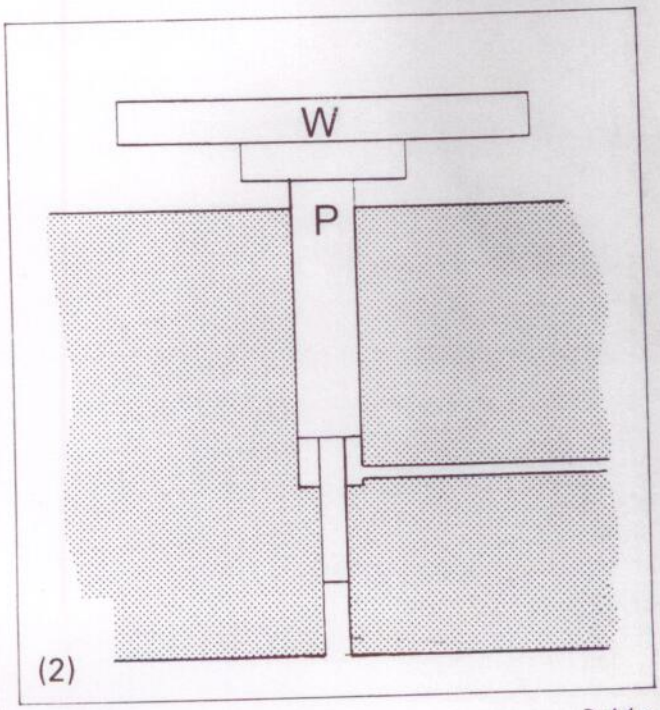
The effective area of the piston/cylinder unit is to the first approximation the average of the areas of the piston and of the cylinder. There is a small gap between the piston and the cylinder so that when the piston rotates in the cylinder the pressure medium forms a bearing eliminating friction and eliminating metallic contact between the two; any viscous forces are circumferential and so do not act in a vertical direction and do not affect the accuracy of the balance. If the gap between the piston and the cylinder is too small the piston will not spin freely at low pressures long enough for a true pressure balance to be attained. If the gap between the piston and the cylinder is too large there will be a leakage between the two and the piston will fall in the cylinder. The piston/cylinder units fitted to Budenberg testers are carefully made so that at low pressure the piston will spin for a reasonable length of time, and at high pressures the piston will remain in its floating position for several minutes.

The simple form of piston as illustration (1) is used for comparatively low pressures (e.g. Fig. 240, Fig. 380L); at higher pressures smaller diameter pistons are used to reduce the size of the weights, and a simple piston would be liable to accidental damage so the weights are applied to an auxiliary piston mounted above the measuring piston, see illustration (2), as used in Fig. 380D and Fig. 380H testers.

To reduce the weight for low pressures the piston is made hollow in testers such as the Fig. 240L which operate as low as 15 mbar (5" water).



(1)



(2)

The performance of a tester depends largely on the accuracy with which the piston and cylinder are manufactured. These should be straight and round and have a good finish. Most pistons and cylinders are made of hardened and stabilised tool steels. The manufacture of the units is carried out by highly skilled operatives working in temperature controlled conditions using the best equipment available. This accuracy can best be appreciated by realising that a variation of 0.1μm (one ten thousandth of a millimetre) on the effective diameter of a 1/80 in^2 piston/cylinder unit will cause a change of area of 63 parts per million. The pistons and cylinders used on air testers are made of a high chromium steel so that they not effected by corrosion due to moisture in the atmosphere.
All piston/cylinder units are constructed so that if a high pressure is applied the piston does not leave its cylinder, and if the weights are applied without pressure the piston is not in compression.

Testers

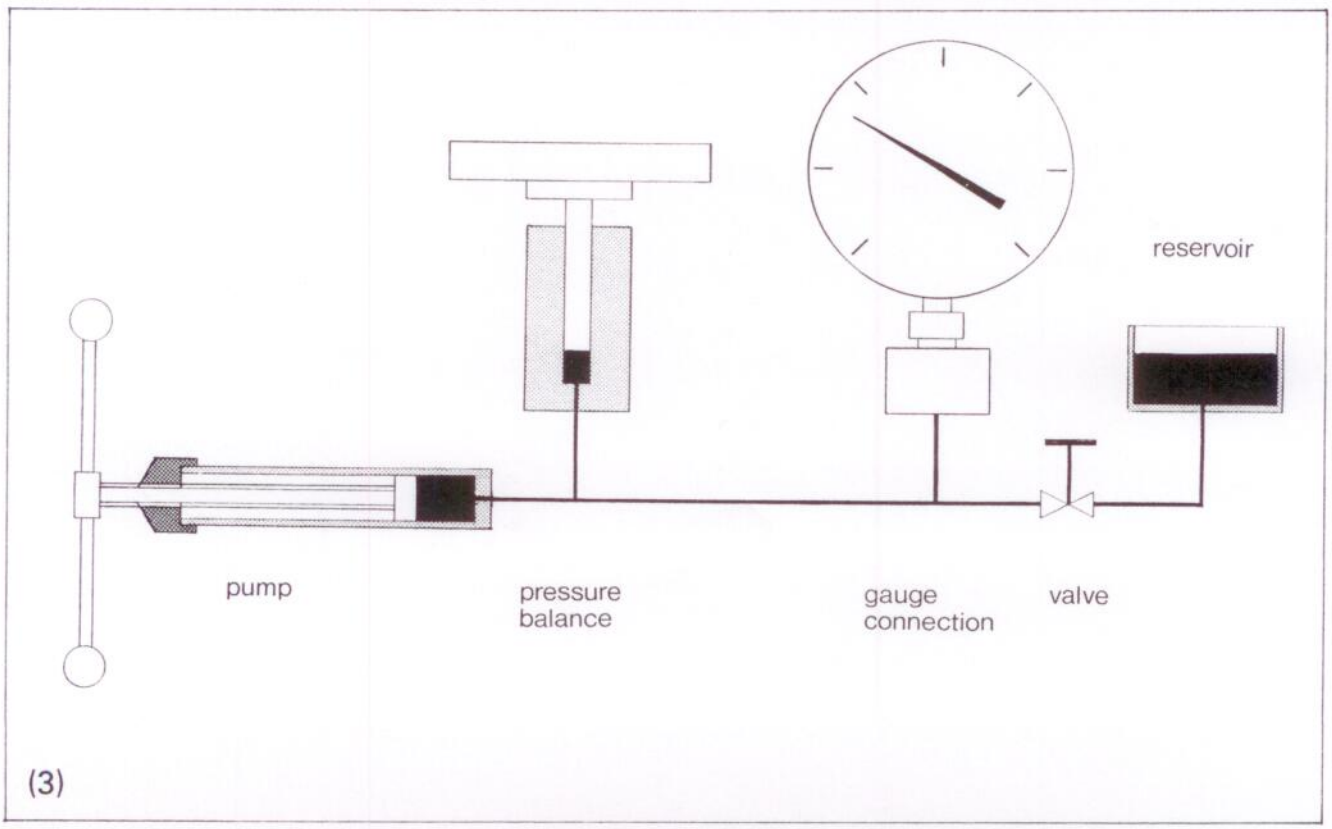
Dead-weight pressure gauge tester comprise dead-weight pressure balance piped to a connection on which a gauge can be screwed; hydraulic testers normally have also a pump and a reservoir as illustrated diagrammatically in illustration (3); pneumatic dead-weight testers such as Fig. 350 have one valve to admit air from an external source to raise the pressure and one to release air to the atmosphere as well as a volume adjuster for fine control. In most Budenberg testers the components are fixed to a base, see illustration (4) and the cover gives a smart, neat appearance to the tester, see illustration (5). Adjustable legs and a spirit level are provided to enable the tester to be levelled so that the piston/cylinder unit is vertical.

An exception is the Fig. 239P balance which is a compact portable air dead-weight balance with its own pump, gauge and release valve so that it can be carried around process plant to calibrate DP cells on site at low pressures.

The screw pump on hydraulic testers incorporates roller or ball bearings to take the thrust so that the effort used to raise pressure is low and so that small adjustments can easily be made. In Fig. 380 Series testers a large area ram enables low pressures to be built up rapidly, and a small area ram minimises effort at high pressures giving great sensitivity. In the higher pressures testers such as Fig. 283 the hand pump applies pressure to an intensifier to generate pressures up to 4000 bar.

Weights

The weights applied to the piston of a balance are of prime importance and we take great care to see that the mass of these is within



(3)

specified tolerances and is traceable to British National Standards. We keep a set of weights to NPL tolerances which are periodically themselves checked. These are used for weighing the weights against which our production weights are checked. The production weights are manufactured to give the appropriate force when subject to a gravitational acceleration of 9·80665 m/sec^2 (international standard g) and in air of density 1·2 kg/m^3, applied to a piston of appropriate nominal area.

The weights are manufactured in martensitic stainless steel (known in America as 400 series stainless); under laboratory conditions these maintain their weight to one or two parts per million for many years. We do however on request manufacture weights of austenitic stainless steel (300 series stainless) which is more resistant to corrosion and which has lower magnetic permeability.

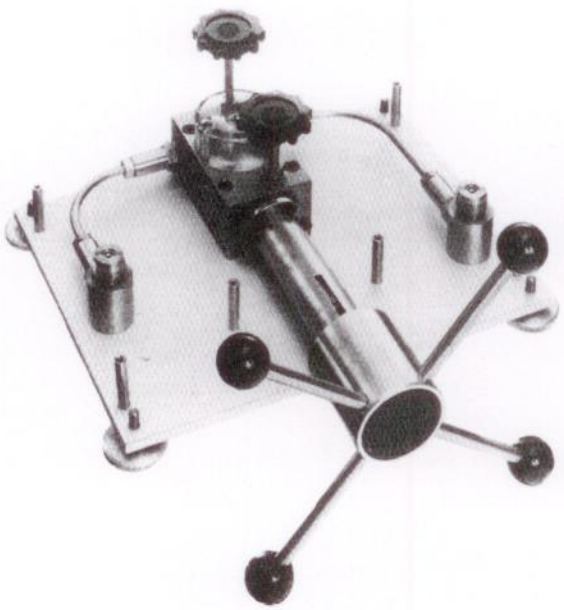
The weights stocked and shown in our catalogue are not made for a particular piston/cylinder unit. They are thus interchangeable. A customer can buy a tester with weights in lb/in^2 and subsequently buy a set of weights in bar. Similarly a set of weights sold with one tester can be used on another tester of the same type and also with a replacement piston/cylinder unit.

Accuracy

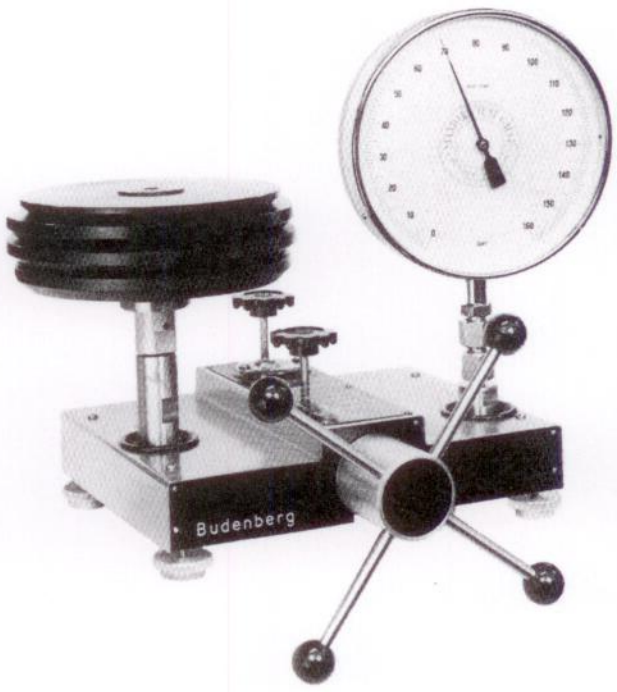
The nominal areas of piston/cylinder units are shown in the catalogue. We keep piston/cylinder units which have been to a national standards laboratory where their areas have been determined by comparison with national standards. These certified units are used to assess the area of the units that are used for calibrating our production units. The areas of two units are compared by connecting them hydraulically (or on gas) under pressure; when they are in balance the area (say A_D) to be determined is found from the known area of a unit (say A_K) knowing the weights applied to each (say W_D and W_K) from the equation

$$\text{Pressure in system} = \frac{W_D}{A_D} = \frac{W_K}{A_K}$$

When calculating accuracies of testers we take into account the effective area of the piston/cylinder unit; this increases with increase of pressure. This distortion effect can be minimised by the use of tungsten carbide which has a high elastic modulus. Tungsten carbide is used in the manufacture of piston/cylinder units for Fig. 368 and Fig. 388 laboratory standard testers and Fig. 380HX testers for pressures up to 1200 bar. For Fig. 283 testers we manufacture the weights so that the weights for equal increments of



(4)



(5)

pressure are greater as the pressure increases up to 4000 bar; these weights must always therefore be applied in the correct sequence. The certificate of accuracy of a tester takes into account the buoyancy of the weights in the air and the buoyancy of the parts of the piston immersed in liquid.

When testing gauges on liquid it is occasionally necessary to take into account heads of liquid since a height difference of 1 cm corresponds to 1 mbar. The datum levels of hydraulic piston/cylinder units are marked with a groove on the outer diameter of the unit. The effect of heads can normally be ignored on air testers.

The certificate of accuracy supplied with testers gives details of the corrections to be made for change of temperature in the unit from 20°C due to expansion of the piston/cylinder unit and also of corrections due to 'g' varying from standard gravity.

If a tester is to be used only at one place where 'g' varies significantly from the internationally agreed figure we can supply a set of weights specially machined to compensate for the local 'g'. Customer should specify local 'g' to us.

Class A Certificate

The accuracy which is shown in our catalogues allows for:-

(a) Manufacturing limits on the mass of the weights.

(b) Variation of buoyancy of weights in air.

(c) Manufacturing limits on the effective area of the piston unit.

(d) The increase of effective area of the piston unit with rising pressure.

The uncertainties in pressure caused by these sources can be eliminated by:-

A. Marking and weighing each weight and supplying a list of these weights.

B. Allowing for any change of buoyancy of the weights caused by change in ambient temperature or pressure.

C. Assessing the actual effective area of the piston unit.

D. Using the appropriate co-efficient of increase of area with increase of pressure.

We can provide testers with all the above information in a format (Class A Certificate) which enables customers to calculate the actual pressure generated by the tester to an uncertainty which on some models is half the standard accuracy figure. We also provide a pocket calculator programmed to give the actual pressure when the customer has entered the weights applied, temperature, atmospheric pressure and local 'g'. Testers supplied with a Class A Certificate are distinguished by the suffix A to the catalogue Figure Number.

NAMAS

The Budenberg Pressure Standards Laboratory is an accredited laboratory of NAMAS operated by the National Physical Laboratory. For many testers we can issue NAMAS Cerificates of Pressure Calibration. For the customers requiring greater detail we can supply certificates showing the effective area of the piston unit and the masses of the weights.

Ultimate Accuracy

Budenberg piston/cylinder units give reproducibility of a few parts per million and a user who wishes to attain the highest accuracy possible can send a unit direct to his National Standards Laboratory to give a shorter chain of traceability; he can also attach a thermistor to the cylinder to reduce the uncertainty of the temperature correction and he should be familiar with the references below.

Bibliography

(1) *The Pressure Balance. A Practical Guide to its use.* SYLVIA LEWIS and G.N. PEGGS
Published by National Physical Laboratory. (1979)
ISBN 0 950 4496 5 2.

(2) *The Pressure Balance. Theory and Practice.* R.S. DADSON, S.L. LEWIS, G.N. PEGGS.
Published by National Physical Laboratory. (1982)
ISBN 0 11 480048 0.

We recommend (1) to any user who is interested in running a pressure standards laboratory. (2) gives a great deal of theoretical and background information.

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RWP/Graphic Design

OTHER PRESSURE TEST EQUIPMENT

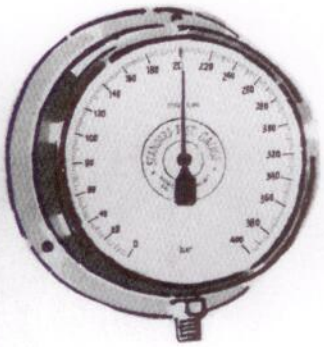
Standard Test Gauges

Accuracy 0.25%

Dial sizes 150, 200, 250mm (6", 8", 10")

Ranges 0-1 to 0-1600 bar (0-15 to 0-25 000 lb/in²)

Described in Catalogue Section 1C

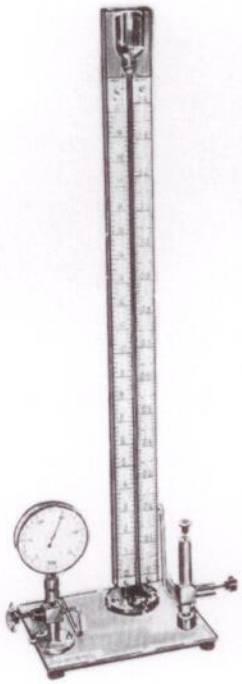


Mercury Column Testers

Ranges 1 bar (30 in. Hg) vacuum
1.4 bar (20 lb/in²) pressure

Self contained, with pump

Described in leaflets, Fig. 1, 1V, 303 and 303V



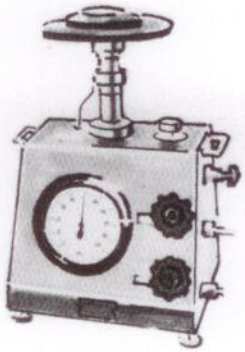
Dead-weight Gauges

To measure pressures accurately

Dead-weight principle

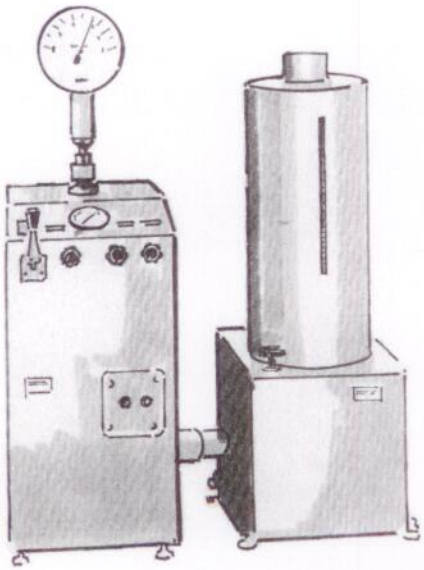
Pressures 1.5 to 600 bar (20 to 8000 lb/in²)

Described in leaflets, Fig. 82, 80L, 80



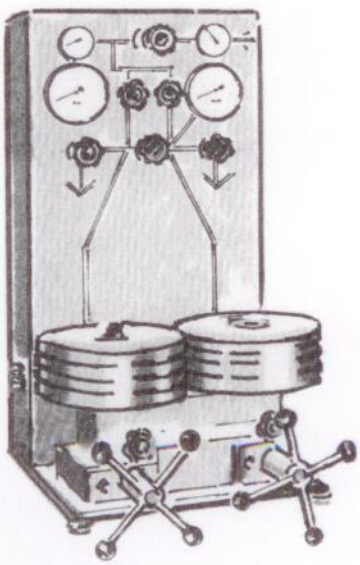
Dead-weight Tester 8000 bar or 100 000 lb/in²

Fig. 284



Differential Dead-weight Tester

Fig. 249T – for calibrating DP cells at high static pressures.



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OIL TESTERS

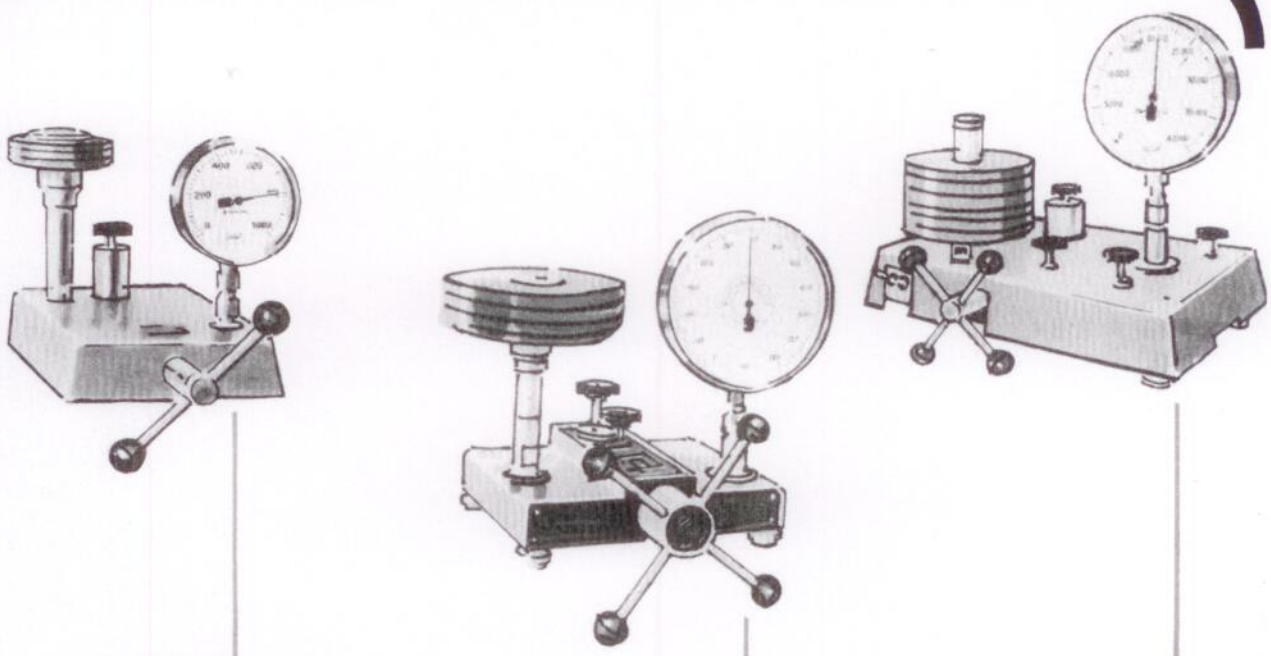

Figure number	279	278	380L	380M	380D	380H	283
bar	40	70	120	300	600	1200	4000
kPa	4000	7000	12 000	30 000	60 000	120 000	400 MPa
lb/in^2	600	1000	1600	4000	8000	16 000	60 000
kg/cm^2	40	70	120	300	600	1200	4000
Piston area	1/16 in^2	1/8 & 1/80 in^2	1/16 in^2	1/40 in^2	1/8 & 1/80 in^2	1/8 & 1/160 in^2	1/200 in^2
Size mm	290 x 355	290 × 355	400 × 310	400 × 310	400 × 310	400 × 310	630 × 400
Standard accuracy	0.05%	0.05%	0.04%	0.04%	0.03%	0.05%	0.05%
Class A accuracy	0.008%	—	0.008%	0.01%	0.01%	0.012%	0.04%

For detailed information contact –

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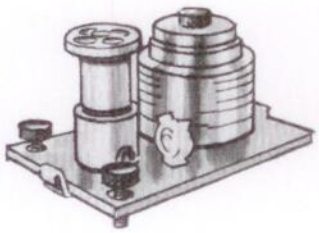
ON DEAD-WEIGHT PRESSURE TESTERS

AIR TESTERS



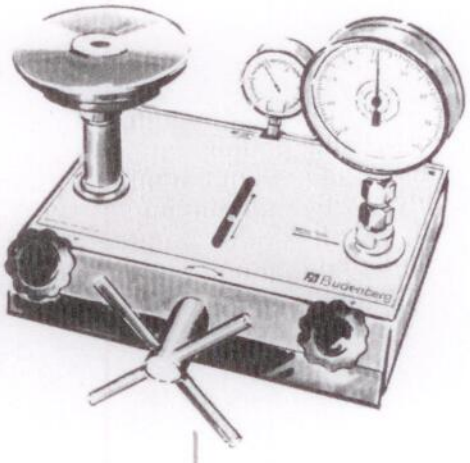


Figure number	**239P**	**351**	**352**	**354**	**356**	**358** oil lubricated
bar	1	1	7	25	70	120
kPa	100	100	700	2500	7000	12 000
lb/in^2	400 in. water	400 in. water	100	400	1000	1600
kg/cm^2	10 000 mm water	10 000 mm water	7	25	—	120
Piston area	$\frac{1}{2}$ in^2	$\frac{1}{2}$ in^2	$\frac{1}{2}$ in^2	$\frac{1}{8}$ in^2	$\frac{1}{16}$ in^2	$\frac{1}{16}$ in^2
Size mm	280 × 166	400 × 320	400 × 320	400 × 320	400 × 320	400 × 320
Standard accuracy	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Class A accuracy	0.01%	0.01%	0.008%	0.01%	0.011%	0.009%

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designed and made in Britain

BUDENBERG

Pressure standards for the world

Wide ranges – 15mbar to 8000 bar, 5 inches water to 100 000 lb/in^2
High accuracy – certified – Interchangeable components
Portable models
Hydraulic or pneumatic – Laboratory or workshop
Ergonomic design