



DH-Budenberg

**METROLOGICAL
RANGE**



**5000
SERIES**

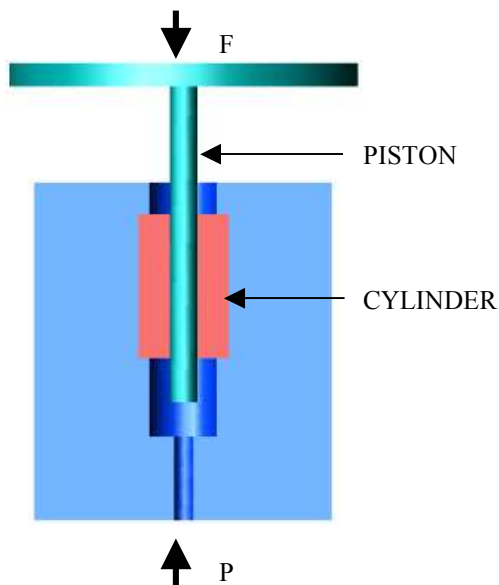
Gas and oil
pressure balances
for gauge and
differential
pressures up to
500 MPa

INTRODUCTION

Type 5000 pressure balances are high accuracy fundamental pressure standards that define the derived unit of pressure directly from the fundamental units of mass, length and time following the formula :

$$P = \frac{F}{A}$$

Where : **P = Pressure (Pa)**
F = Force (N) resulting from mass (kg)
Accelerated by gravity (m/s²)
A = piston-cylinder effective area (m²)



There are three series, in the Type 5000 family which reflect a concerted long term effort to offer the user a broad range of choice in selecting a standard as well suited as possible to current and future requirements.

Type 5000 pressure balances are applicable in a very wide variety of pressure calibration and measurement problems. There are appropriate configurations for use in primary standards laboratories at the highest level offering state of the art specifications as well as for use as production tools on the shop floor. This catalogue is intended to present in detail the full potential of the Type 5000 pressure balances and to allow the configuration of a Type 5000 system that best meets your particular requirements.

DH-B also produces Type 50000, 60000 automated pressure balances and Type DPG digital pressure balances that should be considered before deciding on a Type 5000 standard.

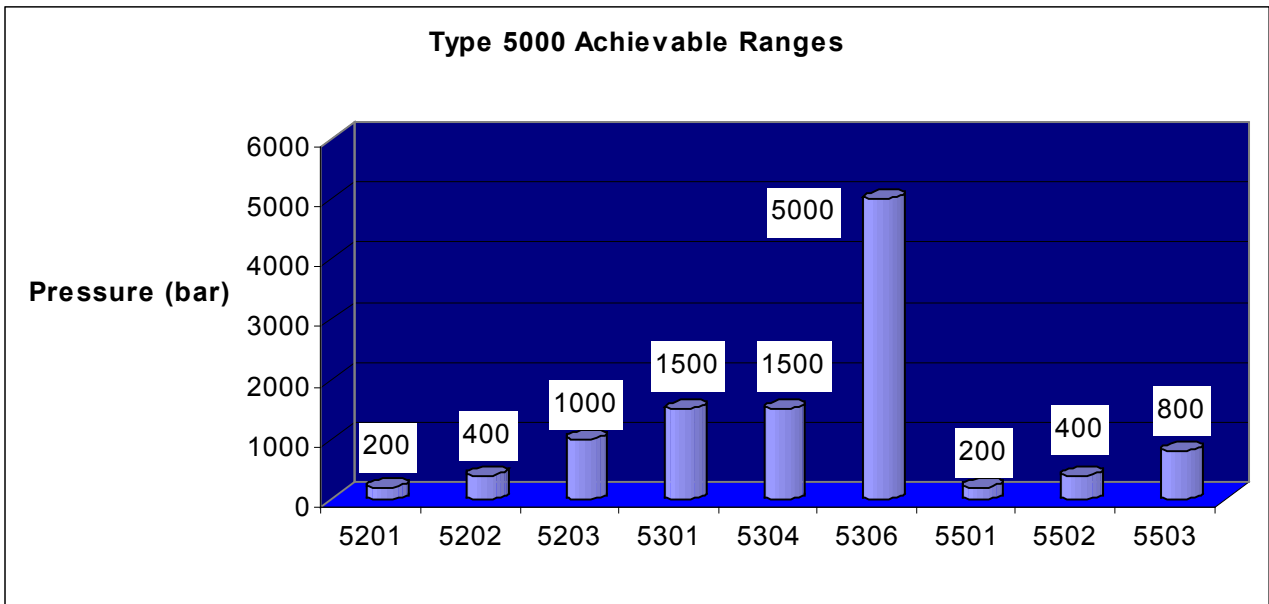
The Type 5000 family is divided into five series, each of which includes several models. Two new series are special application and are not covered in this catalogue. The 5100 Series consists of gas operated pressure balances with very large diameter gas lubricated pistons for low gauge and absolute pressures with accuracy better than $\pm 0.005\%$ and the 5400 Series is a range of water or gas operated pressure balances.

5500 Series: This is dual pressure balance using air operated liquid lubricated piston-cylinders. The 5500 Series models are specifically intended for differential pressure calibrations at elevated static pressures. Differential pressures start at 10 Pa and static pressures range from 0.5 to 80 MPa. A 5500 model can also be used as a dual range system with two different piston-cylinders mounted simultaneously.

Calibration systems: Using Type 5000 standards and Type 1000 Dividers and Multipliers associated with DH supplied accessories and hardware; virtually any pressure calibration system can be configured and tailored to the user's exact requirements.

5200 Series: This is gas operated pressure balance with liquid lubricated piston-cylinders covering the range of 0.02 to 100 MPa. 5200 Series models are intended for use with any non-corrosive gas as the test medium. Their use is simpler and faster than either gas lubricated pressure balances or the combination of an oil operated standard and separators or interfaces. Liquid lubrication eliminates the operational problems associated with gas operated pistons without compromising metrological performance.

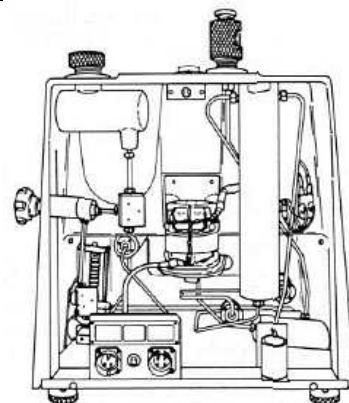
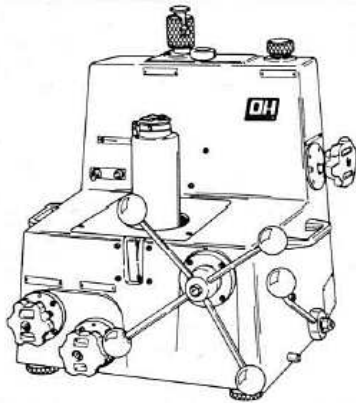
5300 Series: This is oil operated pressure balance covering the range of 0.02 to 500 MPa. 5300 Series models are intended for use with oil as the pressurized medium. Oil operation makes them the fastest and easiest to use pressure balances. The ability to interface oil/air or oil/water using a direct visible level interface makes it possible to calibrate using another medium when necessary. 5300 Series models can drive 1000 Series Dividers and Multipliers making them an excellent starting point in the configuration of an overall pressure calibration system from vacuum to 1000 MPa.



* 5300 Series standard can be coupled with Type 1000 Dividers and Multipliers to cover from less than 1 psi in gas to 150000 in oil.

** Static + Differential Pressure

GENERAL ASSEMBLY



Every detail of Type 5000 pressure balances has been thoroughly studied to assure that their use is practical, safe and reliable over years of operation. Operating components are built-in to a compact, specially designed light alloy housing that protects the operator from pressurized components and provides a rigid and stable base for piston-cylinder mounting and mass loading. Each model is presented as a complete and self-contained instrument that requires minimal bench space and is easily moved.

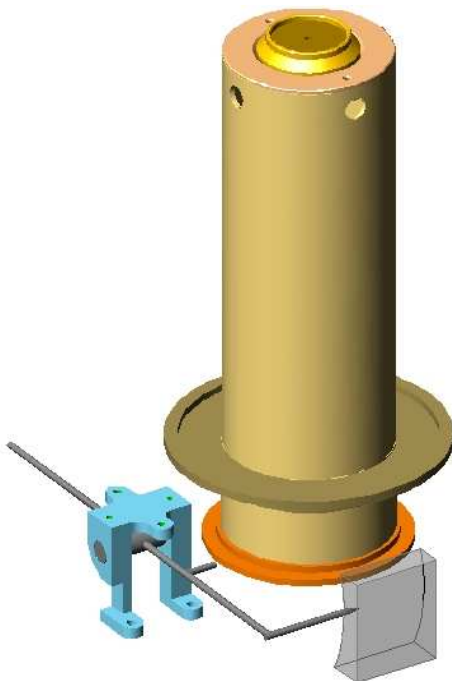
Rather than using off-the-shelf general purpose hard-ware, components such as valves, variable volumes, pumps and reservoirs are designed, manufactured and tested to the stringent requirements of use in a high accuracy pressure standard. Working volumes are kept to an absolute minimum.

Internal tubings are ¼ inch O.D. seamless stainless steel and threaded fittings are used throughout. All tubing connects to a sump in which liquid and solid impurities coming from the system under test drop out and can be purged periodically.

Make and break operations between the standard and the system under test are made by leak free hand tightened quick connectors that use a pressure activated seal. All controls are easily accessible and clearly labelled. The standard's reference level is identified by a label on the front face of the housing. A platinum resistance thermometer is built-in to each mounting post to monitor piston temperature.

Piston displacement and position monitoring:

When the standard is used with the mass carrying bell installed, piston position is monitored and displayed by a pointer fitted onto the end of a lever on a fulcrum. The lever's movement multiplies the indication of the piston's movement by a factor of four. The operator is aware of the precise piston position and movement at all times without having to directly observe mass position relative to a scribed reference point. As an option, electronic monitoring of piston position and displacement is available. Piston position is displayed on a digital meter (with 5 or 25 times multiplication) on the front panel of a separate electronic module which can be placed at a location remote from the standard.

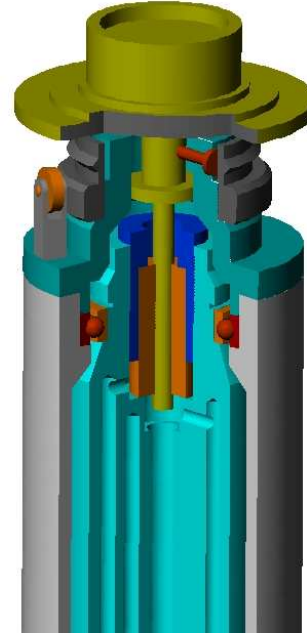


Piston position monitoring

Piston orientation: In order of the force acting on the piston to be properly calculated the piston must be vertical. For this reason, each instrument is provided with a precision bubble level and levelling feet.

Piston rotation: For a piston-cylinder to perform its role effectively, the piston must rotate in the cylinder. Piston rotation is maintained by means of a motor, an oval drive and pulley fitted with a drive pin. Due to the oval drive, the pulley is alternately accelerating and decelerating. The piston only receives an impulse when it has slowed down enough of the drive pin to catch it. The piston is almost always rotating completely freely at the optimum mean speed. The drive motor is a squirrel cage motor that can be left on all times.

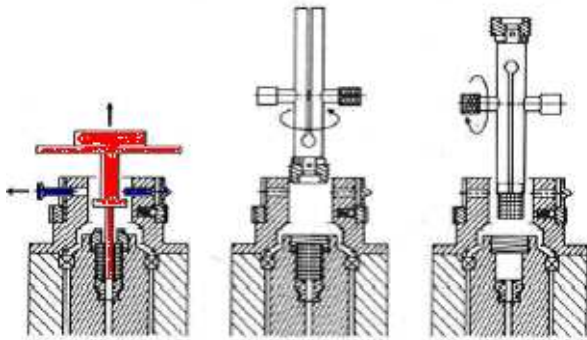
The automatic rotation system is set to rotate the piston in a counter clockwise direction. Piston-cylinder manufacturing techniques result in piston-cylinders upon which the direction of rotation has no significant effect. If rotation by hand is desired the drive pin can easily be removed.



Piston cylinder mounting post

Protecting the piston: In order to avoid risk of interference with the piston's vertical mobility it is imperative that the masses be loaded directly onto the piston. This is accomplished by loading the masses onto a mass loading bell that rests directly on a plate into which the piston is fitted. When the piston is floating the piston and the mass load are completely free and there is no possibility of unintended friction or interference with their free movement. When the piston is at the bottom of its stroke the piston plate rests on the drive pulley and rotates with it. When the piston is at the top of its stroke, the piston plate's movement is arrested by three travel limit pins that are set into the pulley. In either position, even if the motor is on and the piston is rotating, there is no friction point. Maximum mass can be loaded with no pressure applied or maximum pressure can be applied with no mass loaded without risk of damage to the instrument or injury to the operator.

Piston-cylinder interchangeability : Numerous inter-changeable piston-cylinders are available for each Type 5000 MODEL MAKING MULTIPLE RANGES WITH ONE INSTRUMENT POSSIBLE; In all cases, changing the piston-cylinder requires no major disassembly and the only tool used is a special tool supplied with the standard. The maximum time required to change a piston-cylinder is less than 10 minutes.



Three step range changing

Kn CONVERSION FACTOR

All Type 5000 piston-cylinders and masses are built around a nominal mass to pressure conversion coefficient, K_n . The nominal effective area of each piston-cylinder size is such that, under standard conditions, the piston loaded with 1 kg of mass floats at a whole number pressure value such as 100 psi or 2 MPa. All mass values, including the mass of the piston and of the mass loading bell are adjusted to be a whole number or fraction of the kilogram. The nominal pressure defined by any Type 5000 standard is calculated as $K_n \times$ the mass loaded in kg.

Corrections are applied to K_n to calculate the pressure defined within the accuracy tolerance of the Type 5000 standard used.

The use of K_n and whole number masses in no way affects the traditional pressure equation or the factors that affect a pressure measurement made with a pressure balance. K_n is the basis of a coherent relationship between mass, effective area and pressure throughout the Type 5000 series. It is intended as a tool that reduces operator confusion and errors by simplifying the calculation of mass loads and measured pressures.

PISTON -CYLINDERS



The piston-cylinder is the heart of the pressure balances and the key to its performance. DH's expertise in manufacturing piston-cylinders is the result of over fifty years devoted to perfecting every step of the process. That expertise is widely recognized throughout the world of high accuracy pressure measurement and it is the company's single most valuable asset.

Multiple sizes: There are 13 different type 5000 piston-cylinder sizes ranging from an 11 mm diameter to a 1.6 mm diameter. This range of sizes includes the largest and the smallest

diameters available in a high accuracy pressure balances today. The advantage to the user is in being able to choose, from a very wide selection, the size that best fits his pressure range and other requirements. Small diameters are difficult to

manufacture but provide a high pressure to mass ratio which saves the user from having to manipulate excessive amounts of mass and helps miniaturize the overall system.

Materials and machining: In most cases, both piston and cylinder are made of tungsten carbide which is both extremely hard and wear resistant. Tungsten carbide has a Young's modulus of about 6×10^{11} N/m² and a linear thermal expansivity coefficient of 4.5×10^{-6} /°C. Deformation due to pressure is very low and the effect of temperature is small.

The homogeneity of tungsten carbide permits ultra-precise finishing of the piston-cylinder. Deviation from ideal geometry is generally less than 0.1 micron (4 micro-inches). The radial clearance between piston and cylinder can be controlled very closely and varied from about 0.2

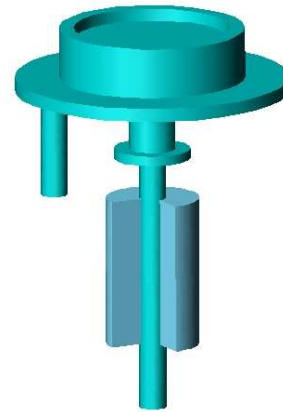


DH-Budenberg

to 1 micron (8 to 40 .micro-inch) depending upon the clearance required to achieve optimum performance. The smaller diameter pistons are also available in a special stainless steel with minimal effect on performance since the most active element is the cylinder, which is always in tungsten carbide.

Operating types: There are three types of Type 5000 piston-cylinders. The largest diameter (lowest range) piston-cylinders are intended for pneumatic operation and use as gas lubrication in the space between the piston-cylinder in the new 5100 Series. Piston-cylinders of Kn=0.1 MPa/kg and above exist in two forms. One is intended for pneumatic operation with liquid lubrication in 5200 and 5500 Series pressures balances. The other is for hydraulic operation in the 5300 Series pressure balances. The piston-cylinders for pneumatic operation with liquid lubrication have a groove set into the inner bore to which liquid is supplied through two radial holes.

All type 5000 piston and plate assemblies are adjusted to a mass of 200 g.



Gas operated liquid lubricated piston-cylinder

Oil operated piston-cylinder

TYPE 5000 PISTON-CYLINDER ASSEMBLIES

Kn	Piston Material*	Operating medium	Models in which this size can be used
0.01 Mpa/kg	Tungsten	Gas	5100
0.02 Mpa/kg	Tungsten	Gas	5100
0.1 Mpa/kg	Tungsten	Gas or Oil	5200s, 5301
20 psi/kg	Tungsten	Gas or Oil	5200s, 5301
0.2 MPa/kg	Tungsten	Gas or Oil	5200s, 5301
50 psi/kg	Tungsten	Gas or Oil	5200s, 5301
0.5 MPa/kg	Tungsten	Gas or Oil	All series, all models
100 psi/kg	Tungsten	Gas or Oil	All series, all models
1 MPa/kg	Tungsten	Gas or Oil	All series, all models
200 psi/kg	Tungsten	Gas or Oil	All series, all models
250 psi/kg	Tungsten	Gas or Oil	All series, all models
2 MPa/kg	Tungsten	Gas or Oil	All series, all models
300 psi/kg	Tungsten	Gas or Oil	5300s, 5500s
500 psi/kg	Steel	Oil	5300s
5 MPa/kg	Steel	Oil	5300s

- Cylinder are always made of tungsten carbide.

MASS SETS



100 kg Mass Set

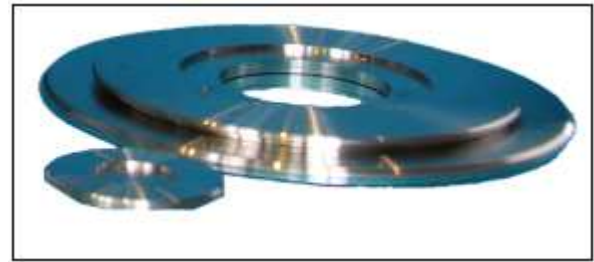
Nine different Type 5000 mass sets are available ranging from 20 kg to 100 kg. Masses are machined out of 304 L non-magnetic stainless steel. All individual masses are whole numbers or fractions of the kilogram and are adjusted to their nominal values within the tolerance of their accuracy class. The different accuracy classes are defined as needed to achieve certain nominal accuracies on pressure. Each mass set is delivered in sturdy and attractive cabinets that are easily transportable.

The kilogram: The unit of mass used is always the kilogram because the kilogram is the SI unit and the national and international standard for mass from which all other mass units are derived. The kilogram also offers the convenience of being based on the decimal system which facilitates mass totalling and data reduction.

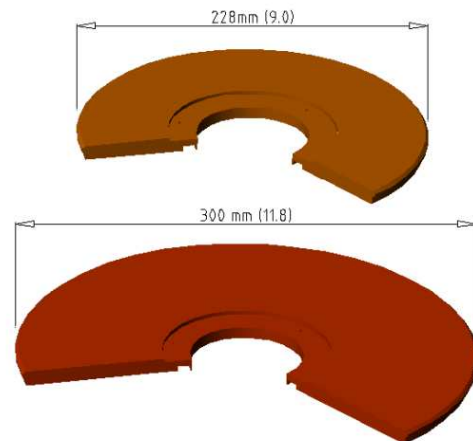
Adjustment and interchangeability: Adjusting each mass to its nominal value within the tolerance of its accuracy class allows complete mass interchangeability within one set as well as among different sets.

Piston-cylinders are not married to specific mass sets and the user need not be concerned with loading masses in prescribed sequences or with complex mass load calculations using different mass values for each mass. Whole number masses are also much easier than odd values to verify and recalibrate. The advantages of adjusted masses are great and their use never significantly compromises the accuracy ultimately achieved on pressure.

Mass set configuration: All mass sets include a number of main masses of either 2 or 5 kg as well as 1 kg and fractions of the kilogram down to 0.01 g. All pistons have a mass of 200 g and all loading bells a mass of 800 g. The minimum load then is 200 g and the piston



loaded with the bell has a mass of 1 kg. A 5, 2, 2, 1 progression of mass values is used making it possible to load any value desired with a resolution of 0.01 g at any point in the range. Each mass is identified with the mass set serial number as well as with an individual number within the set. Mass loading: the 5, 2 and 1 kg masses are discs with a central hole which are loaded onto the mass carrying bell. The smaller masses are loaded onto the piston plate. The majority of the load is therefore below the center of gravity of the piston and the entire load is well centered on the vertical axis of the piston-cylinder.



Mass loading

Standard composition and custom sets: The table below details the composition of the standard Type 5000 mass sets not including the piston assembly (200 g) and the bell (800 g). Individual masses can be added to a mass set at any time. If so desired, a unique custom mass set may be composed from standard masses.

Reference mass sets: Reference mass sets made up of solid polished masses of the same shape and materials as Type 5000 masses can be supplied. These are convenient as in house standards for local verification or recalibration of Type 5000 mass sets.

TYPE 5000 MASS SETS

Total Mass	Main Masses	Number of Masses							
		5 kg	4 kg	2 kg	1 kg	0.5 kg	0.2 kg	0.1 kg	50 g to 0.01 g set
20 kg	2 kg	-	-	9	1	1	2	1	1
30 kg	2 kg	-	-	14	1	1	2	1	1
30 kg	5 kg	4	1	2	1	1	2	1	1
40 kg	2 kg	-	-	19	1	1	2	1	1
50 kg	2 kg	-	-	24	1	1	2	1	1
50 kg	5 kg	8	1	2	1	1	2	1	1
60 kg	5 kg	10	1	2	1	1	2	1	1
80 kg	5 kg	14	1	2	1	1	2	1	1
100 kg	5 kg	18	1	2	1	1	2	1	1

CALIBRATION AND TRACEABILITY

Type 5000 pressure balances are delivered with complete calibration report certifying traceability to the French National Standard.

Calibrations of new equipment and periodic recalibrations of existing equipment are performed by our Laboratory accredited by the French Comité Of Accreditation (COFRAC).

The laboratory standards include master piston-cylinders that are regularly submitted to L.N.E. (French National Laboratory) for effective area determination. These master piston-cylinders are an integral part of a chain of piston-cylinders of overlapping ranges that are regularly intercompared amongst themselves.

A similar chain with master standards is maintained in the mass area. Traceability in West Germany to the PTB (Physikalische Technische Bundesanstalt), in the USA to the N.B.S. (National Bureau of Standards) are also maintained and documented.

The recalibration of a Type 5000 standard does not require the return of the complete system. The piston-cylinder can be removed from the standard, packed in its special shipping case, and sent alone or with the mass set. Since the mass set and piston-cylinder are not married they can be recalibrated independently and do not need to be returned together.

METROLOGICAL SPECIFICATIONS

The pressure balance is a primary standard because it defines the derived unit of pressure directly from the fundamental units of mass, length and time. It is the source of accurate pressure values in the measurement system and in most applications it has been selected over other instruments because of this characteristic.

Accuracy definition: The accuracy specification for any DH pressure balance applies to the pressure as defined at the piston's reference level, under appropriate ambient conditions and with the applicable corrections properly applied. Accuracy is defined as the maximum possible deviation between the measured value and the true value as calculated using generally accepted uncertainty analysis and applying the additive technique as opposed to root sum square. Accuracy statements therefore include the uncertainty on the national standards to which they are traceable. Repeatability, the ability to repeat the same value of output for the same value of input under the same conditions over time, is at least ten times better than accuracy.

Accuracy classes: The accuracy with which a Type 5000 pressure balance can define a pressure is a function of the accuracy with which the value of the piston-cylinder's effective area and the masses that are loaded onto it can be

known. To this must be added a number of miscellaneous contribution uncertainties.

Since there are no generally accepted designations to define accuracy on effective area or on pressure, DH uses its own system of two accuracy classes: S2, S. These designations are used as a convenient way to define the uncertainty on piston-cylinder effective area and mass as well as the accuracy that can be achieved on a pressure measurement. The miscellaneous contributing uncertainties are included globally in the uncertainty assigned to piston-cylinder effective area.

The tables below define the S2, S designations and show in what accuracy classes different piston-cylinders are available.

Generally, piston-cylinders and mass sets of the same class are used together to achieve the accuracy on pressure of that class and to maintain a four to one or better ratio between mass uncertainty and effective area uncertainty.

Piston-cylinder and mass accuracy classes can be mixed freely. When this is done, the accuracy with which a pressure can be defined is the sum of the uncertainty on piston-cylinder effective area and the uncertainty on mass.

ACCURACY CLASS DEFINITIONS

Accuracy class	Accuracy on Pressure*	Repeatability on pressure	Uncertainty on piston-cylinder effective area	Uncertainty on Mass	Comments
S2	± 0.005 %	± 5 PPM	± 0.004 %	± 0.001 % (S2)	Piston-cylinder both in tungsten carbide.
S	± 0.01 %	± 10 PPM	± 0.008 %	± 0.002 % (S)	Piston-cylinder both in tungsten carbide.

* Percent of reading or of Kn of the piston used, whichever is greater.

TYPE 5000 MASS ACCURACY CLASSES

Mass value	DH	
	S2	S
5 kg	50 mg	100 mg
4 kg	40 mg	80 mg
2 kg	20 mg	40 mg
1 kg	10 mg	20 mg
500g	5 mg	10 mg
200 g	2 mg	4 mg
100 g	1 mg	2 mg

TYPE 5000 PISTON-CYLINDER ACCURACY AVAILABILITY

Kn	Piston Dia (mm)	Accuracy class available		Models in which this size can be used
		S2	S	
0.01 MPa/kg	30	•	•	5200s, 5300
0.02 MPa/kg		•	•	5200s, 5300
0.1 MPa/kg	11.2	•	•	5200s, 5300
20 psi/kg	9.5	•	•	5200s, 5300
0.2 MPa/kg	8.0	•	•	5200s, 5300
50 psi/kg	6.0	•	•	5200s, 5300
0.5 MPa/kg	5.0	•	•	All series, all models
100 psi/kg	4.0	•	•	All series, all models
1 MPa/kg	3.5	•	•	All series, all models
200 psi/kg	3.0		•	All series, all models
250 psi/kg	2.7		•	All series, all models
2 MPa/kg	2.5		•	All series, all models
300 psi/kg	2.4		•	5300s, 5500
500 psi/kg	1.9			5300s
5 MPa/kg	1.9			5300s

ACCESSORIES AND SPECIAL SERVICES

DH offers a complete line of accessories and related equipment for use with Type 5000 pressure balances. These include hardware such as pressure interfaces, constant level reservoirs, servo-controlled variable volumes, gas boosters, tubings, fittings, quick-connectors and manifolds. Complete multi-function calibration systems can be configured.

All accessories have been designed and manufactured by DH or carefully selected from

qualified suppliers specifically for use in high quality pressure calibration systems.

DH welcomes the opportunity to address your special requirements and to help ensure that your Type 5000 pressure balance is used to greatest advantage.

SELECTION CRITERIA

Because of the wide range of users and applications that exist, the Type 5000 family of pressure balances intentionally leaves to the user a great degree of latitude in selecting a pressure standard. Extra time taken now to thoroughly consider all of the possibilities will be rewarded over years to come by the satisfaction of working with a tool perfectly adapted to the job at hand.

A complete pressure balance is configured by selecting a base instrument, a mass set and at least one piston-cylinder. Masses and piston-cylinders determine accuracy and can be upgraded, added or changed at any time. The most important decision is the selection of the base instrument(s) keeping in mind that mass sets and in many cases piston-cylinders can be used in more than one base instrument. The general information in the previous pages can direct one towards a particular series and the detail that follows should allow the selection of the most appropriate model or combination of models.

Careful consideration of the following factors will help the decision process:

- What are the most important selection criteria: accuracy, range, pressurized media, convenience of operation, ruggedness, expandability, cost, other ?
- What pressurized medium is preferred in most cases and what other media may be required?
- What are the ranges of the instruments to be calibrated and what range(s) is (are) needed to cover them adequately? What ranges may be required in the future?
- In what environment will the system be operated?
- What are the qualifications of the system operator(s)?
- What accuracy is desired? What accuracy is needed now and may be required in the future?
- Would a Type 50000 automated pressure balance or a Type 20000 digital pressure balance be more suitable in this application?

The DH customer service department is at your complete disposal and will do everything possible to assist you. Please do not hesitate to ask for a visit to your facility, a demonstration or a complete working evaluation.



Calibration Dynamics Ltd
7 Regents Court
South Way
Walworth Industrial Estate
Andover
Hampshire SP10 5NX

TELEPHONE
+44 (0) 1264 339030
FAX
+44 (0) 1264 339040

WEBSITE
<http://www.calibrationdynamics.com>
EMAIL
sales@calibrationdynamics.com