



TECHNICAL LEVEL

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Version 1.0

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Foreword

The authors hope that after reading this Good Practice Guide, you will better understand the care and use of gauge blocks. The content is written at a simpler technical level than many of the standard textbooks to make it accessible to a wider audience. We are not trying to replace textbooks, operator's manuals, specifications and standards, but rather present an overview of good practice and techniques.

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Chapter 1

Introduction to gauge blocks

- What are gauge blocks?
- What standards are used for gauge blocks?
- Manufacturing and refurbishment of gauge blocks

What are gauge blocks?

Gauge blocks, sometimes called slip gauges, are pieces of wear-resistant material of rectangular cross-section used as references for performing length measurements. Each gauge block has a pair of parallel faces separated by a desired distance, known to a high degree of accuracy. Gauge blocks are most commonly made from steel, tungsten carbide or ceramic. In some cases, chromium carbide gauges are used.

A gauge block set consists of a number of gauge blocks in different sizes, usually specified in millimetres (though some older sets in units of inches may still be in use).

A key document when working with gauge blocks is the specification standard ISO 3650. It defines the **nominal cross section**, or the ideal dimensions, for gauge blocks between 0.5 mm to 10 mm in length to be 30 mm x 9 mm. For larger gauge blocks, the nominal cross section is 35 mm x 9 mm.

Multiple gauge blocks can be combined through a procedure called wringing in order to build a desired length. To learn more about wringing, see page 16.

What are gauge blocks used for?

Gauge blocks are used to calibrate engineering equipment, (e.g. micrometers and Vernier calipers). Higher grade gauge blocks can also be used to calibrate other gauge blocks of the same or lower grade. Finally, gauge blocks can be used with coordinate measuring machines (CMMs) as part of an ISO 10360 CMM reverification test or as a reference artefact when using the substitution method according to ISO 15530-3.

Key definitions

Throughout this guide, we will refer to the terms length and central length in relation to gauge blocks. These terms are defined in ISO 3650 as:

- **Length:** the perpendicular distance between any particular point of the measuring face and the planar surface of an auxiliary plate of the same material and surface texture upon which the other measuring face has been wrung. This means we consider not only the distance between the faces of the gauge block itself, but also the microscopic gap that exists between another gauge block after wringing (in the diagram below, that microscopic distance is not shown and is assumed to be negligible).
- **Central length:** length of a gauge block taken at the centre point of the free measuring face.

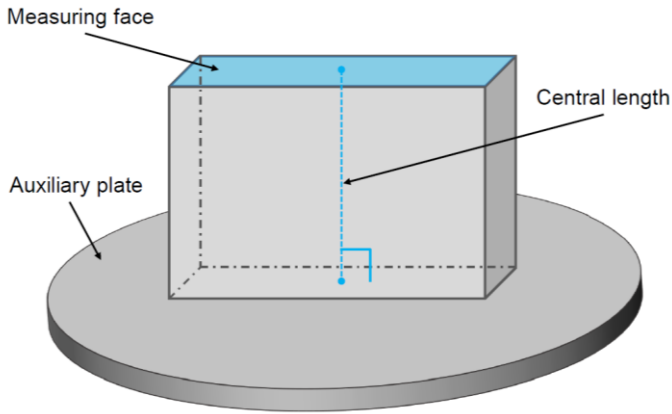


Figure 1. Central length of a gauge block, which is wrung to an auxiliary plate.

What standards are used for gauge blocks?

There are several national and international specification standards that apply to gauge blocks (see Table 1). In several countries, which previously had their own national standards for gauge blocks, these have been superseded by the latest international standard. Each standard gives tolerances for parallelism (or variation in length), central length deviation and face flatness. There are also tolerances on material properties such as hardness and length stability, as well as geometrical features such as squareness of side faces and surface roughness.

Standard type	Standard
International Standards	ISO 3650 : 1998 – metric gauge blocks up to 1000 mm BS EN ISO 3650 : 1999 –metric gauge blocks up to 1000 mm*
American Standards	ASME B89.1.9-2002 – gauge blocks up to 1000 mm and up to 40 inches
British Standards	BS EN ISO 3650 : 1999 –metric gauge blocks up to 1000 mm BS 4311 : 2007 – imperial gauge blocks up to 4 inches BS 4311 part 2 : 2009 – inch gauge block accessories
Japanese Standards	JIS B 7506-2004 –metric gauge blocks up to 1000 mm

Table 1. Overview of standards for gauge blocks. *BS EN standards are international standards that have been adopted as both British Standards and European Norms.

All of the above standards relate to gauge blocks of rectangular cross section (9 mm x 35 mm or 9 mm x 30 mm), but the ASME standard also relates to gauge blocks of square cross section, 24 mm x 24 mm, with an optional central hole, referred to as hole gauges.

There is also a standard which advises manufacturers on how accurate the measuring system should be for calibrating and manufacturing gauge blocks (OIML R30 1981).

What are grades?

Gauge blocks are manufactured to different accuracy levels, or grades, intended for different purposes. Generally the higher quality grades, which are more accurate and more expensive, are used as reference gauges to calibrate gauge blocks of lower quality grade. The most commonly used grades in circulation are as follows:

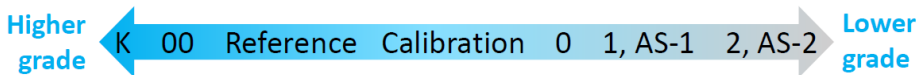


Figure 2. Quality grades of gauge blocks.

Grade K, the highest grade, has the smallest tolerances and grade 2, the lowest grade, has the greatest tolerances. Grade K gauge blocks are mainly used to calibrate other gauge blocks via a comparator whereas grade 2 gauge blocks can be found in the workshop for checking various equipment.

The different grades of gauge blocks can be used for calibration or verification on a variety of equipment, such as:

- Coordinate or microcoordinate measuring machine
- Micrometer (see Good Practice Guide No. 40)
- Calliper (see Good Practice Guide No. 40)
- Linear variable differential transformer (LVDT)
- Thread gauge

Some old grades of gauge blocks, manufactured to superseded standards, such as BS 888 or earlier versions of BS 4311, are still in use. These older grades of gauge blocks include:

- Reference
- Calibration
- Inspection
- Workshop
- 3
- 4
- 5

All these different grades can be calibrated by various UKAS accredited calibration laboratories, but the calibration will be performed to the tolerance requirements of standards which are still current.

Manufacturing and refurbishment of gauge blocks

Each grade of gauge block is manufactured to specific tolerances and uncertainties established by the standards. Each grade has a specific tolerance/limit for:

- Central length (deviation from nominal)
- Flatness
- Variation in length or parallelism

Lapping is a special process used on the measuring faces of gauge blocks which creates a smooth surface, to within the appropriate tolerances. During lapping, a gauge block is rubbed or polished by another surface (called a lap or grinding tool) and an abrasive.

Occasionally, if a gauge block is damaged, it can be re-lapped. During re-lapping, the gauge block is polished to remove a small layer of its surface while ensuring the gauge block remains within specification of ISO 3650. This is a specialised process that only qualified manufacturers or shops can perform.

For a list of manufacturers of gauge blocks, see page 30.

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Chapter 2

Care of gauge blocks

- Handling gauge blocks
- Cleaning gauge blocks
- Inspecting gauge blocks
- Storing gauge blocks

Handling gauge blocks

Handling gauge blocks correctly helps keep them in optimal condition. Wearing gloves will help to avoid:

- Corrosion due to oils from your hands
- Thermal expansion due to heat from your hands

Several types of gloves are appropriate, including those made of chamois leather, powder-free latex, rubber and cotton.

Before using a gauge block, check that it is free from any problems that would prevent a good wringing or measurement (we will learn more about wringing in the next chapter). If a gauge block is damaged in any way, this damage could render the gauge block unusable and it will need to be re-lapped or replaced. Damage common to gauge blocks includes:

- Burrs, which are raised spots on the edge of a gauge block and occur when impact pushes the edge of the gauge upwards (usually from dropping or knocking a gauge block). Burrs may hinder wringing and could damage other gauges, the artefact being measured or calibration equipment
- Scratches, even light ones, can damage other gauge blocks and cause incorrect readings when taking measurements
- Rust or corrosion can hinder wringing or contaminate the other gauge blocks in the set
- Chips, where material has been removed by impact but without causing burring (see Figure 3 below)



Figure 3. Chipped measuring face on a gauge block.

Inspecting gauge blocks

Before using a gauge block, it should be inspected for damage that may inhibit wringing or cause further damage to the rest of the gauge block set or other instruments. This section provides guidance on how to inspect your gauge blocks.

Inspection methods

There are three ways to inspect gauge blocks:

1. You can examine gauge blocks by eye. However, this method is unreliable because people have different levels of visual acuity. In addition, reflections from lights on the gauge block surface can interfere with inspection. If you use this method, consider using a magnifying glass to obtain a better view.
2. You may want to inspect a gauge block using an **optical flat**, also called a test plate, which is made of glass and is extremely flat on at least one side. You can wring a gauge block to the optical flat, which uses the interference of light to help determine the flatness of a surface. The optical flat will show changes from a uniform grey colour to small areas of coloured fringes in the case of a deviation from flatness.
3. You may consider using a microscope for very close inspection of the gauge block to identify signs of corrosion or small imperfections. These can be missed if you only inspect the gauge blocks by eye.

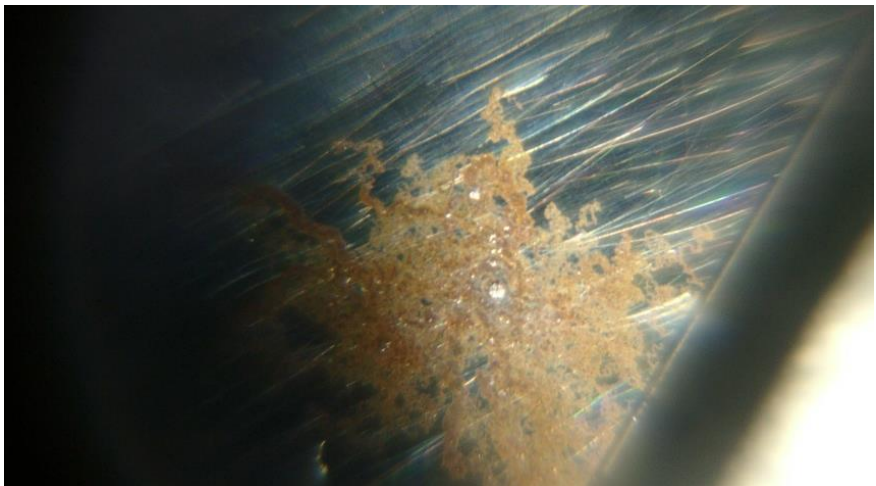


Figure 4. Gauge block with corrosion as seen through a magnifying glass.

Action for damaged gauge blocks

If a gauge block is damaged, it is important to take action to maintain credible measurements. If the edge of a gauge block has a burr, it can usually be repaired with an Arkansas stone, a dense stone used for sharpening metals. This is called **stoning**. When using the stone, ensure it is flat on the gauge block and not at an angle.

If the damage is too significant to be addressed by stoning, the gauge block can be re-lapped by the manufacturer.

If a gauge block's damage cannot be removed by stoning or re-lapping, you will have to replace the gauge block. The new gauge block must be of the same material and grade as the rest of the set. The new gauge block also needs to be calibrated (we will learn more about calibration in the next chapter).

The old gauge block can be reused as an uncalibrated **packing block**, which is a gauge block that is no longer fit for purpose as a length standard but can be used to fill a space in a jig. Damaged gauge blocks should have the corner cut off to clearly show that the gauge block is out of action and should be used as a packing block only.

Cleaning gauge blocks

Proper cleaning procedures, which are outlined below, are another important aspect of gauge block care.

Why should I clean gauge blocks?

Gauge blocks should always be cleaned before and after use to remove dust, fingerprints or anti-rust products.

It is important that gauge blocks are kept clean to prevent corrosion, damage or imperfections that might affect measurement results or effectiveness of wringing (we will learn more about wringing in the next chapter, 'Using Gauge Blocks'). Even a small dust particle can cause trouble.

Cleaning also provides an opportunity to inspect your gauge blocks for scratches or burrs which could then damage other gauge blocks or alter a measurement result.

Cleaning methods

You should clean gauge blocks before and after use, even if they appear clean to the naked eye. A number of different types of lint-free cleaning cloths are suitable, including chamois, microfiber and lint-free tissue. Suitable solvents for cleaning gauge blocks include: isopropanol, ethanol, acetone, or ultrasonic bath solvents. You may also use a canister of compressed air.

There are three main methods of properly cleaning gauge blocks, outlined below in Table 2.

Ultrasonic Bath	Wet Clean	Dry Clean
Place no more than ten gauge blocks in a plastic dish, leaving space between the blocks to avoid damage during the cleaning process. Place the dish in the main water bath with an approved solvent for no more than 5-10 minutes. Remove the gauge blocks and dry them with an approved lint-free cloth.	Dampen a lint-free cloth or tissue with acetone and use this to wipe the gauge block until clean. Once clean, wipe the gauge with a dry microfibre cloth.	Give the gauge block a thorough wipe with an approved lint-free cloth. A number of different types of cleaning cloths are suitable, including: chamois leather, microfiber and lint-free tissue.
Tip: Use this method when the gauge blocks are coated in anti-rust grease.	Tip: Use this method when the gauge block has some residual grease.	Tip: Use this method when the gauge block has been previously cleaned by one of the other methods.

Table 2. *Methods for cleaning gauge blocks.*

Storing gauge blocks

While using gauge blocks, it is recommended to place them in a plastic container that has been lined with anti-corrosion paper. After use, and when the gauge blocks have been cleaned and inspected for burrs, scratches and corrosion, the gauge blocks should be returned to a treated hardwood storage container to keep them in optimal condition and protected from damage or corrosion. It is important that gauge blocks be returned to the correct slots in the hardwood storage box, and each set should have its own box. Storage boxes or containers should not be contaminated with grease or dirt.

Dust and debris

Gauge blocks should be stored in a box to protect them from dust or damage. Lining the storage box with anti-rust paper is a best practice. You may also coat the gauge blocks with a thin layer of protectant (usually petroleum jelly or a commercial brand protectant).

Temperature and humidity

Gauge blocks change length as their temperature changes, and the amount of length change depends on the material they are constructed from.

The **coefficient of thermal expansion**, of a material is its fractional change in length per degree kelvin (or Celsius) of temperature change. It is a set value which can be found inside the gauge block set's case.

- The standard thermal expansion coefficient for steel is $11.5 \times 10^{-6} \text{ K}^{-1}$. According to ISO 3650, this value can vary by 10 %
- For tungsten carbide, the thermal expansion coefficient is $4.23 \times 10^{-6} \text{ K}^{-1}$
- For ceramic, the thermal expansion coefficient is $11.7 \times 10^{-6} \text{ K}^{-1}$

At NPL, gauge blocks are stored and calibrated in a room that is stable at $20 \text{ }^{\circ}\text{C} \pm 0.1 \text{ }^{\circ}\text{C}$ and the humidity is between 45 % RH and 55 % RH.

It is recommend that the gauge blocks are kept in a climate-controlled room of $20 \text{ }^{\circ}\text{C}$ with humidity of about 45 % relative humidity (RH). Corrosion can occur if the temperature and humidity increase too much.

Floor cleanliness

The main room where gauge blocks are stored should have a lightly adhesive floor mat, such as a Takmat, at the doorway to help remove contaminants from shoes. Sweep the floor at least once a week to keep dust levels minimal.

Chapter 3

Using gauge blocks

- Determining which gauge blocks to use
- How to wring gauge blocks
- Protection gauge blocks
- After use

Determining which gauge blocks to use

Occasionally, your required measurement will not correlate directly to the length of a single gauge block. For example, if the size you need is 12.075 mm, there is not a single gauge block with exactly that nominal size. This means a combination of gauge blocks of the same materials will need to be used.

There is a method to ensure you use the minimum number of gauge blocks, by selecting the correct ones from the box. Notice that the designated sizes shown in Figure 4 can be:

- Whole numbers of millimetres (1 mm, 2 mm, etc.)
- Tenths of millimetres (1.1 mm, 1.2 mm, etc.)
- Hundredths of millimetres (1.01 mm, 1.02 mm, etc.)
- Thousandths or ten thousandths of millimetres (1.0025 mm, 1.0050 mm, etc.)



Figure 5. A gauge block set contains gauge blocks of different sizes.

The key is to work from right to left of your desired length. For a measurement of 12.075 mm for example, you should first choose the 1.005 mm gauge block from your set, because there is a 5 at the far right (in the thousands of a millimetre position) in your desired measurement. From there, subtract that amount from your total measurement, which means you have 11.07 mm remaining.

$$\begin{array}{r} 12.075 \text{ mm (total desired measurement)} \\ - 1.005 \text{ mm gauge block} \\ \hline 11.07 \text{ mm (remaining length for measurement)} \end{array}$$

There is a 7 in the far right (or hundredths of a millimetre position) in what remains for our measurement, so we will select the 1.07 mm gauge block. With a simple subtraction, we know we now have 10 mm remaining.

$$\begin{array}{r} 11.07 \text{ mm (remaining length for measurement)} \\ - 1.07 \text{ mm gauge block} \\ \hline 10 \text{ mm (remaining length for measurement)} \end{array}$$

We therefore select the 10 mm gauge block. Now we have the total of our desired measurement, which means it takes three gauge blocks to create our desired length of 12.075 mm as shown below in Figure 6.

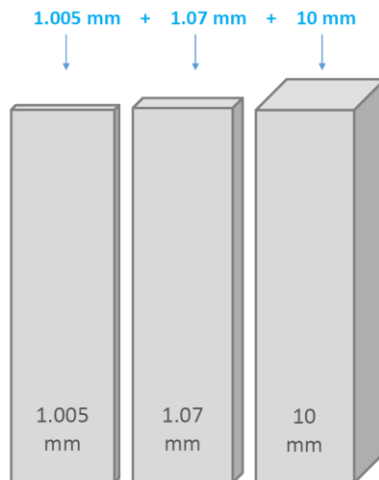


Figure 6. When added together, these gauge blocks equal our desired length.

With a large set of gauge blocks (e.g. a 122-piece set), it is possible to cover the range of sizes from 1.000 mm to 100 mm in 1 μm increments using a combination of no more than four gauge blocks. Now that we know how to select the right gauge blocks, we will learn how to wring them together.

How to wring gauge blocks

Once you've selected the gauge blocks you need, you need to combine them to achieve your desired width. You can stick gauge blocks stick to each other through a process called **wringing**, which is possible because of the phenomenon of molecular attraction between the two lapped surfaces and a thin film of molecules trapped between the surfaces (which is known as the **wringing film**). This wringing film is typically only a few nanometres thick, so it makes a negligible contribution to the overall size of the wrung gauge blocks. Through the process of wringing, gauge blocks can be combined to obtain a desired length.

There are a few ways gauge blocks can be wrung together. Keep in mind that regardless of the method, the gauge blocks must be clean and gloves should be worn.

Wringing: Method one

Hold the faces of two gauge blocks firmly together in a cross shape. Slide the top gauge block up and down along the surface of the bottom gauge block until it no longer moves easily (step 1 in Figure 6). Then, rotate the top gauge block until it is in line with the bottom gauge block (step 2 in Figure 6). This method works well for larger gauge blocks.

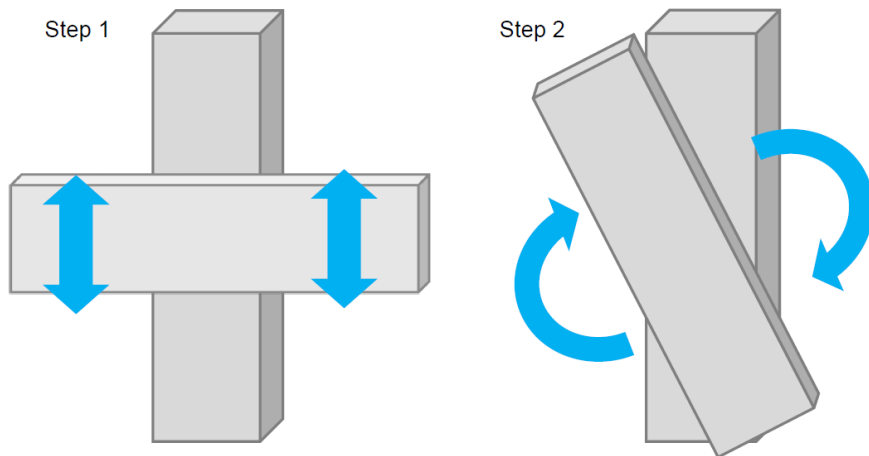


Figure 7. Hold the faces of the gauge blocks in a cross shape, then firmly slide up and down. Then twist the top gauge block into alignment.

Wringing: Method two

Hold the faces of two gauge blocks firmly together in a cross shape. Rotate the top gauge block from side to side (Figure 7) as if you are turning a dial back and forth. When the gauge block no longer rotates easily, rotate the gauge blocks until they line up.

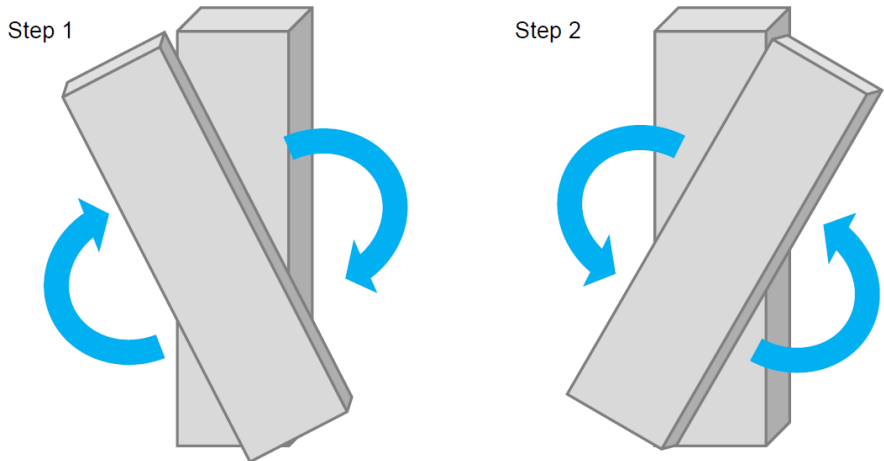


Figure 8. Holding the measuring faces of the gauge blocks together, rotate the top gauge block back and forth. Then, twist the top gauge block into alignment.

Wringing: Method three

Slide the top gauge block straight onto the second gauge block lengthwise onto the bottom gauge block (Figure 8). Slide together firmly, then line up all edges. This method works best with thinner gauge blocks.

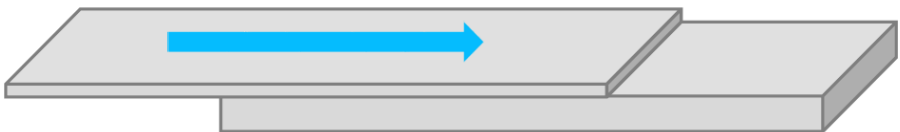


Figure 9. Firmly slide the measuring face of the gauge block onto another.

Wringing fluid

Occasionally, you may have difficulty getting your gauge blocks to wring together correctly. Adding wringing fluid can help.

Wringing fluid is a mixture of liquid paraffin diluted 1:10 in a solvent. To use wringing fluid, add a small amount to the gauge block so that the wringing fluid is spread evenly on the measuring face (and wipe any excess away with a tissue). Try again to wring the gauge blocks together. If they still don't wring, check the gauge blocks under a microscope for any damage that might be interfering with the wringing process.

Wring with care

Gauge blocks can be damaged easily during wringing, so you may need to prepare your work surface to ensure it is very clean. When wringing more than two gauge blocks, lay them on a cloth resting on the work surface in case the stack falls over. Also, wring gauge blocks low above the bare work surface to minimize damage in case you drop them. For this reason, you should also not hold gauge blocks above the open box of gauge blocks, as a dropped gauge block could damage others in the case.

Do not leave the gauge blocks wrung together for more than 24 hours. If you leave gauge blocks wrung together for long periods, they can become very difficult to separate. If you find that you are having difficulty separating your gauge blocks, try gently twisting to loosen the wring or adding some solvent (e.g. ethanol) to the joins.

Protection gauge blocks

Some sets come with **protection gauge blocks**, which are used to protect reference gauge blocks from damage that maybe caused by the artefact being checked by the gauge blocks. Protection gauge blocks are calibrated so they can be used in conjunction with the main gauge block set

Therefore, the size of the protection gauges must be included when adding up the gauges to get the size required for the job at hand.

After use

Remember to properly clean, inspect and store the gauge blocks when you are finished according to the guidance in the previous chapter, 'Care of Gauge Blocks.'

Chapter 4

Calibrating gauge blocks

- Why should gauge blocks be calibrated?
- Calibration classes
- Methods of calibration

Why should gauge blocks be calibrated?

Calibration is a process that determines the length of a gauge block to a given level of uncertainty, and allows comparison with the nominal length. Simply put, calibration determines the accuracy of your gauge blocks. All gauge blocks should be calibrated at regular intervals to ensure measurements are as accurate as possible. New gauge blocks, or those with unknown history, should be calibrated more frequently than gauge blocks with are known to be more stable.

Calibration classes

Calibration of gauge blocks is often advertised as being performed to an accuracy or **uncertainty class**. These classes, which are outlined below in Table 3, describe the calibration process, indicate the likely uncertainty that can be achieved, as well as the relative pricing.

Calibration laboratories list their gauge block calibration services in a matrix format sorted by nominal length and uncertainty class. Uncertainty class A indicates the smallest uncertainty, and the uncertainty levels then increase as far as class D. Some laboratories also include a class E calibration for gauge blocks of particularly low accuracy grade.

Class A	Class B	Class C	Class D
Class A uncertainties apply to the measurement of length by interferometry of grade K standards of length to BS 4311:2007 and BS EN ISO 3650:1999 when they are measured twice, wrung to a platen by each of the two measuring faces in turn, and the mean of these two measurements stated.	Class B uncertainties apply to the measurement of length by interferometry of grade K standards of length to BS 4311:2007 and BS EN ISO 3650:1999 when they are measured once, wrung to a platen by, if not otherwise specified, the left hand (unmarked) measuring face.	Class C uncertainties apply to the measurement of length of gauges by comparison with grade K standards of length of a similar material. Class C uncertainties apply to new and used grade 0, 1 and 2 gauges to BS 4311:2007 and BS EN ISO 3650:1999.	Class D uncertainties represent the best capability for the measurement of length of gauges by comparison with K grade standards of length of a dissimilar material.
Calibration by interferometry		Calibration by comparator	

Table 3. Uncertainty classes of gauge blocks.

Consider comparing prices of several calibration laboratories which all offer the same class of uncertainty, as well as variations in the achieved uncertainty for each class, to make an informed decision as to which laboratory to choose.

Methods of calibration

Calibration by comparison

Gauge blocks with greater uncertainties (grade 1 and 2) or gauge blocks with poor measuring faces that cannot be measured by interferometry are calibrated by comparison using a gauge block comparator. There are a variety of comparators, some with one probe and some with two probes.

When calibrating, there must be a reference gauge block that is the same size as the test gauge block. The reference gauge block should be calibrated by interferometry, have a nominal value within 1 μm of the length of the gauge block to be calibrated and have a calibration result that is still valid.

The two types of comparator calibrations are called “central length only” and “central length with variation in length”:

- **Central length only calibration** is when a measurement is taken at the centre of the measuring face of the gauge block and at no other area of the gauge block (as seen in Figure 10). This method is preferred when interferometry will also be used as it saves time.
- **Central length with variation in length** is when five measurements are taken at five different points on the gauge block (as seen in Figure 11). These points include a central measurement in addition to the four corners of the gauge block to ensure it is the correct length throughout, not just at the centre. This method is used for lower grade gauges where interferometry will not be used.

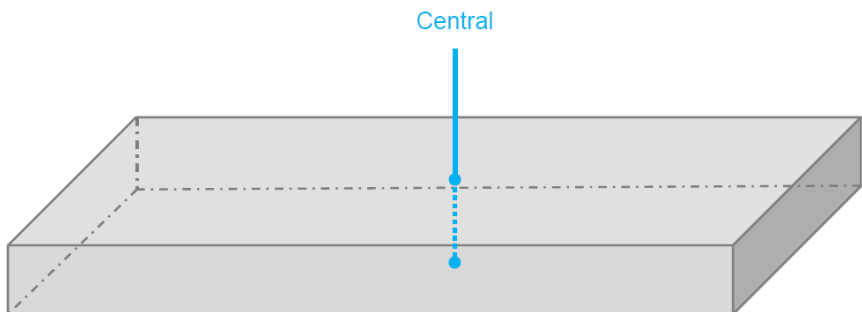


Figure 10. Central length only calibration is taken at the centre of the gauge block.

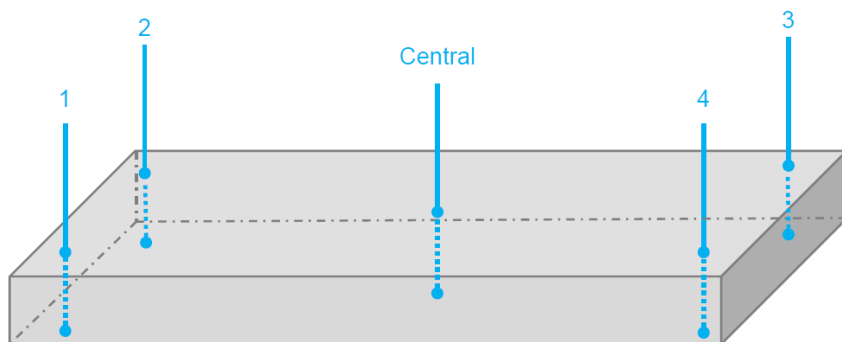


Figure 11. Central length with variation in length calibration includes the four corners of the gauge block, in addition to the central point.

If the reference gauge block is referred to as R and the test gauge block as T, the sequence of measurement for central length and central length with variation in length would follow the pattern as shown below in Figure 12.



Figure 12. Sequence of measurements in gauge block calibration.

Calibration by interferometry

Interferometry is a non-contact technique for measuring gauge blocks. The gauge block length is determined by interfering light reflected from the top surface of the gauge block and from a platen to which the gauge block is wrong with light reflected by a reference mirror. The technique relies on a starting value obtained using a gauge block comparator.

For further details or to register for the NPL gauge block measurement by interferometry course, email us at dimensional_enquiries@npl.co.uk.

Chapter 5

Supplementary information

- Glossary of terms
- Health and safety
- National and international organisations
- National and international standards
- Training courses
- Manufacturers

Glossary of terms

Terms defined below are based on the VIM (International Vocabulary of Basic and General Terms in Metrology) and ISO 3650.

Arkansas stone	A dense stone used for sharpening metals
Burr	Raised spots on the edge of a gauge block, which occur when impact pushes the edge of the gauge upwards
Calibration	The process that establishes a measurement result for a gauge block (such as its central length) by determining the result and its associated uncertainty, by reference to the appropriate measurement standard.
Central length	The gauge block's length at the centre point of the gauge block, measured perpendicularly from the surface to which the gauge block has been wrung.
CMM	A measuring system with the means to move a probing system and capability to determine spatial coordinates on a workpiece surface.
Coefficient of thermal expansion	The fractional change in size of a gauge block per degree temperature change.
Flatness	The zone between two parallel planes within which the gauge block's surface lies.
Gauge block	A rectangular piece of wear-resistant material used as a physical length standard. Also known as slip gauges.
Grade	The accuracy level to which a gauge block has been manufactured.
Interferometry	A non-contact technique for measuring gauge blocks in which light is reflected from the top surface of the gauge block and from a platen to which the gauge block is wrung.
Lapping	A process used on the measuring faces, or wringing faces, of gauge blocks in which a small layer of material is removed from the measuring face of the gauge block.
Length	The distance between one measuring face of the gauge block to the face of whatever the gauge block has been wrung to.

Measuring face	The flat surface of a gauge block from which its length is derived (and its opposite, parallel surface).
Nominal cross section	The ideal dimensions of a gauge block.
Optical flat	A flat plate made of glass which is extremely flat on at least one side. It can, through the process of wringing, be used to determine the flatness of a gauge block face. Sometimes called a test plate.
Packing block	A gauge block no longer fit for purpose as a length standard, but which can still be used as an uncalibrated block to fill a space in a jig.
Protection gauge block	Calibrated gauge blocks that are used to protect reference gauge blocks from damage that maybe caused by the artefact being checked by the gauge blocks
Reference gauge block	A gauge block that has been calibrated by interferometry, and which is suitable as a reference standard for calibrating other gauge blocks by comparison.
Stoning	The process of repairing a burr on a gauge block using an Arkansas stone, held flat on the gauge block and not at an angle.
Test gauge block	A gauge block that is being calibrated.
Uncertainty class	A labelling method that indicates the calibration process, likely uncertainty that can be achieved, and relative pricing of gauge blocks.
Wringing	A technique where the measuring faces of gauge blocks can be stuck together, a phenomenon occurring because of molecular attraction between the two lapped surfaces and a thin film of molecules trapped between the surfaces, to achieve an overall standard at a desired length.
Wringing film	The thin film of molecules trapped between the surfaces of two gauge blocks that have been wrung together.
Wringing fluid	A mixture of liquid paraffin and solvent that helps make wringing easier.

Health and safety

When using gauge blocks, local safety rules should be adhered to and a risk assessment should be completed prior to starting the work. If working at a customer's site, be aware of any evacuation procedures and any extra risks, such as moving vehicles and overhead cranes. Some specific things to look for when carrying out a risk assessment discussed are below.

Mechanical hazards

Many of the length standards mentioned in this guide are relatively heavy. The appropriate lifting techniques and equipment should always be used and safety shoes worn. Operators should wear laboratory coats or overalls for safety reasons and to prevent fibres shed from clothing from falling on items being measured. Machines under direct computer control may move without warning. The operator should stand back from the machine during an automatic run.

Hazards associated with laser illumination

The standards now allow the use of laser interferometers. It goes without saying that any users of laser interferometers should be trained in their safe usage. Some general guidance is given in the box below.

Important safety information

A laser system with a visible output of less than 0.2 mW is considered a Class 1 laser and is not dangerous. A laser with a visible output of between 0.2 mW and 1.0 mW is considered a Class 2 and blinking prevents vision damage. Class 3B refers to power levels above 5.0 mW and can cause eye damage. Class 4 involves powers above 0.5 W and can cause blindness or burns. (For a more detailed description of the classes have a look at BS EN 60825-1 2007.)

Chemical hazards

Chemicals may need to be used for cleaning purposes. Make sure the manufacturer's safety guidance is followed and the relevant personal protective equipment worn. Substances may be covered by the COSHH regulations.

National and international organisations

National Physical Laboratory (NPL)

The National Physical Laboratory (NPL) is the UK's national measurement institute and is a world-leading centre of excellence in developing and applying the most accurate measurement standards, science and technology available. For more than a century NPL has developed and maintained the nation's primary measurement standards. These standards underpin an infrastructure of traceability throughout the UK and the world that ensures accuracy and consistency of measurement.

NPL ensures that cutting edge measurement science and technology have a positive impact in the real world. NPL delivers world-leading measurement solutions that are critical to commercial research and development, and support business success across the UK and the globe.

Good measurement improves productivity and quality; it underpins consumer confidence and trade and is vital to innovation. We undertake research and share our expertise with government, business and society to help enhance economic performance and the quality of life.

NPL's measurements help to save lives, protect the environment, enable citizens to feel safe and secure, as well as supporting international trade and companies to innovation. Support in areas such as the development of advanced medical treatments and environmental monitoring helps secure a better quality of life for all.

NPL employs over 500 scientists, based in South West London, in a laboratory, which is amongst the world's most extensive and sophisticated measurement science buildings.

The Department for Business, Energy and Industrial Strategy (BEIS) owns NPL Management Limited (NPLML) and NPL operates as a public corporation. For further information reach us at 020 8977 3222 or www.npl.co.uk/contact.

National Institute of Standards and Technology (NIST)

NIST is the equivalent of NPL in the United States of America. Founded in 1901, NIST is a non-regulatory federal agency within the U.S. Department of Commerce. NIST's mission is to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.

The NIST web site at www.nist.gov often contains documents relevant to this guide in pdf format.

United Kingdom Accreditation Service (UKAS)

The United Kingdom Accreditation Service is the sole national accreditation body recognised by government to assess, against internationally agreed standards, organisations that provide certification, testing, and inspection and calibration services.

Accreditation by UKAS demonstrates the competence, impartiality and performance capability of these evaluators.

UKAS is a non-profit-distributing private company, limited by guarantee. UKAS is independent of Government but is appointed as the national accreditation body by the Accreditation Regulations 2009 (SI No 3155/2009) and operates under a Memorandum of Understanding with the Government through the Secretary of State for Business, Innovation and Skills.

UKAS accreditation demonstrates the integrity and competence of organisations providing calibration, testing, inspection and certification services.

Further information on UKAS can be found at www.ukas.com.

National and international standards

British Standards Institution (BSI)

BSI started in 1901 as a committee of engineers determined to standardise the number and type of steel sections in order to make British manufacturers more efficient and competitive. The BSI Group is now the oldest and arguably the most prestigious national standards body in the world and is among the world's leading commodity and product testing organisations. Visit www.bsi-group.com for more information.

International Organisation for Standardization (ISO)

The International Organization for Standardization (ISO) is a worldwide federation of national standards bodies from some 140 countries.

The mission of ISO is to promote the development of standardisation and related activities in the world with a view to facilitating the international exchange of goods and services, and to developing cooperation in the spheres of intellectual, scientific, technological and economic activity.

ISO's work results in international agreements that are published as International Standards. Further information on ISO can be found at: www.iso.ch

The key standard for the purposes of this guide is ISO 3650:1998 Geometrical Product Specifications (GPS) – Length standards – Gauge blocks.

NPL Training Courses

NPL offers a variety of metrology training courses related to this Good Practice Guide. If you would like further instruction, consider the following:

Dimensional Measurement: Level 1 – Measurement User

This is a three-day training course introducing dimensional metrology, the importance of good measurement practice and the right measurement behaviours. To learn more, visit <http://www.npl.co.uk/training>.

Dimensional Measurement: Level 2 – Measurement Applier

This is a four-day training course providing a good basic understanding of measurement principles gained through the Level 1 training course. To learn more, visit <http://www.npl.co.uk/training>.

Dimensional Measurement – eLearning course

This online course introduces dimensional metrology, improves measurement behaviours and supports good measurement practice. In addition, it explores the relevance of Dimensional Measurement to all stages of the engineering process. To learn more, visit <http://www.npl.co.uk/training>.

Gauge Block Measurement by Interferometry

This course is a 2-3 day course (depending on attendee experience) which takes place within the NPL gauge block laboratories. The course is a mixture of theory (lectures) and practical laboratory sessions covering the key aspects of how to calibrate gauge blocks by interferometry. The course is suitable for both novices and those more familiar with gauge block measurement, seeking refresher training (the course is tailored based on requirements). During the course, attendees will be guided through practical calibration of gauge blocks using NPL equipment, starting with initial inspection, and progressing through mechanical comparison, interferometry and result calculation. Derivation/study of relevant uncertainty budgets is included to complete the knowledge required to obtain traceable measurements. Full printed course notes are provided.

To enquire about this course, contact dimensional_enquiries@npl.co.uk.

Manufacturers

The following is a list of manufacturers providing products or services relevant to this guide. The appearance of a manufacturer in this list is not an endorsement of its products or services. The list contains those companies known to the authors and may not be complete.

Manufacturer description	Address
Alan Browne Gauges provide a broad range of services including gauge block production, calibration and precision flat lapping (http://www.alanbrowne.co.uk)	Alan Browne Blackdown Mill Kenilworth Road Leamington Spa Warwickshire CV32 6QT
Broomfield specialises solely in the development, manufacture and calibration of tungsten carbide gauge blocks (http://www.broomfieldgauges.com)	Broomfield Carbide Gauges Ltd. Brigg Mills 3 The Cobbles Meltham Holmfirth HD9 5QQ
Hexagon Manufacturing Intelligence manufactures gauge blocks and calibration equipment under the brand name TESA Technology (http://www.tesatechnology.com)	Hexagon Metrology (also Tesa and Cary products) Metrology House Halesfield 13 Telford Shropshire TF7 4PL
JK Metrology & Quality Services supply and service metrology equipment including gauge blocks (http://www.jkmetrology.com)	JK Metrology & Quality Services Unit 11 Holman Road Liskeard Business Park Liskeard Cornwall PL14 3UT
Kolb & Baumann GmbH & Co. KG (http://www.koba.de) are manufacturers of gauge blocks, and related accessories	Kolb & Baumann GmbH & Co. KG Fabrik für Präzisions-Messzeuge Daimlerstraße 24 DE-63741 Aschaffenburg

Mahr are manufacturers of gauge blocks based in Germany with several distributors throughout Europe (http://www.mahr.com)	Mahr U.K. Plc Metrology Division 19 Drakes Mews Crownhill Milton Keynes MK8 0ER
Mitutoyo also produces gauge blocks, related equipment and accessories (http://www.mitutoyo.co.uk)	Mitutoyo (UK) Ltd Heathcote Way Heathcote Industrial Estate Warwick Warwickshire CV34 6TE
Opus Metrology produce a variety of different gauge blocks and offers a flat lapping service for gauge block interferometer platens (http://www.opus.co.uk)	Opus Metrology 15 Maylan Rd Corby Northamptonshire NN17 4DR
Webber Gage Division is a well-known American manufacturer of gauge blocks in both rectangular and square (hoke) shape (http://www.starrett-webber.com)	Webber Gage Division 24500 Detroit Road Cleveland, Ohio 44145 USA

Care and Use of Gauge Blocks

Good Practice Guide No. 149

Gauge blocks are the most popular and widespread material length standards used throughout industry. Although they are relatively robust, obtaining the best accuracy from gauge blocks requires proper handling. Written for those new to using gauge blocks, or for more experienced users who would like to refresh their knowledge, this guide outlines some of the best practices for handling, inspecting, cleaning, and storing gauge blocks. Readers will also learn how to determine which gauge blocks to use, how to wring them and some basics of gauge block calibration.



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ISSN: 1368–6550

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