Development and Use of Gage Blocks

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Development of Gage Blocks

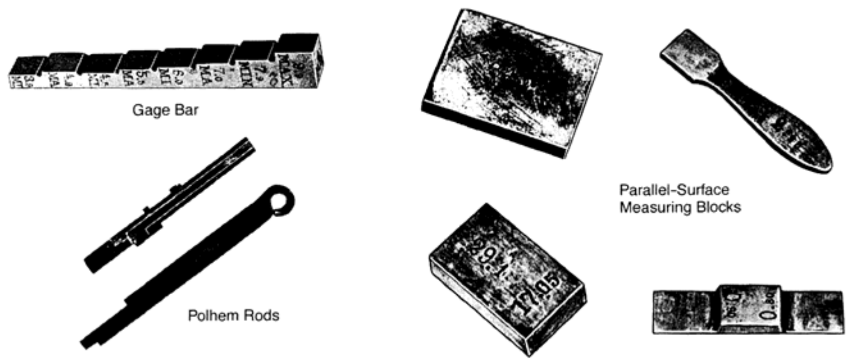


FIGURE 8–1 Long before systemized gage block sets were developed, end standards had shown their value in the dimensional control of manufacturing.

Development of Gage Blocks

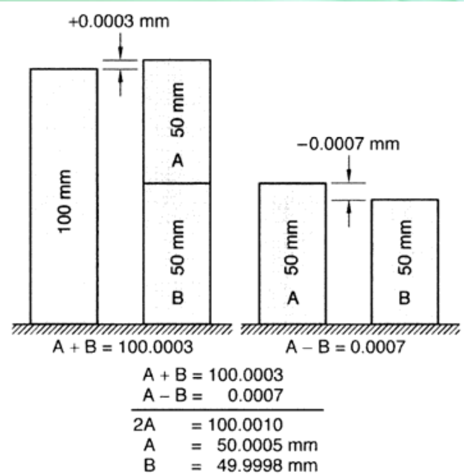


FIGURE 8–2 Starting with one known block, Johansson used simultaneous equations to derive all of the other blocks in the set.

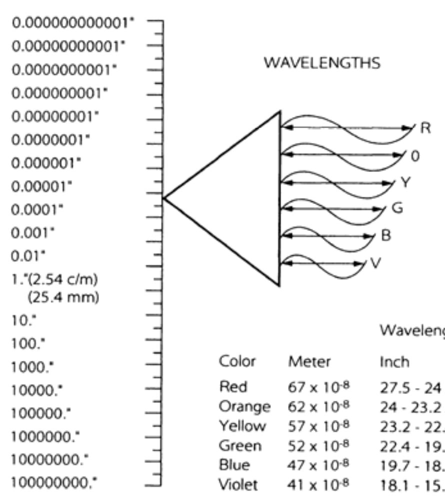
Development of Gage Blocks

COMPARISON OF METRIC AND INCH GAGE BLOCK SETS

1st Series	9 Blocks from	1.001 mm	Inched	0.039439 in.	1st Series	9 blocks from	0.1001 in.
	through	1.009 mm		0.039755 in.		through	0.1009 in.
	Increments of	0.001 mm		0.000039 in.		Increments of	0.0001 in.
2nd Series	49 Blocks from	1.01 mm		0.039794 in.	2nd Series	49 Blocks from	0.101 in.
	through	1.49 mm		0.058661 in.		through	0.149 in.
	Increments of	0.01 mm		0.000394 in.		Increments of	0.001 in.
3rd Series	49 Blocks from	0.50 mm		0.0197 in.	3rd Series	19 Blocks from	0.050 in.
	through	24.50 mm		0.9646 in.		through	0.950 in.
	Increments of	0.50 mm		0.0197 in.		Increments of	0.050 in.
4th Series	4 Blocks from	25.00 mm		0.9842 in.	4th Series	4 Blocks from	1.000 in.
	through	100.00 mm		3.9370 in.		through	4.000 in.
	Increments of	25.25 mm		0.9843 in.		Increments of	1.0000 in.

FIGURE 8–3 Inch sets copied the form but not the intent of Johansson's standard set. Note the sameness of the digits but difference in the actual sizes.

Development of Gage Blocks



Wavelengths

Color	Meter	Inch	Frequency Hz.
Red	67×10^{-8}	$27.5 - 24 \times 10^{-6}$	4.48×10^{-14}
Orange	62×10^{-8}	$24 - 23.2 \times 10^{-6}$	4.83×10^{-14}
Yellow	57×10^{-8}	$23.2 - 22.4 \times 10^{-6}$	5.25×10^{-14}
Green	52×10^{-8}	$22.4 - 19.7 \times 10^{-6}$	5.76×10^{-14}
Blue	47×10^{-8}	$19.7 - 18.1 \times 10^{-6}$	6.39×10^{-14}
Violet	41×10^{-8}	$18.1 - 15.7 \times 10^{-6}$	7.32×10^{-14}

FIGURE 8–4 When Michelson determined that the number of cadmium red wavelengths corresponded to the length of the meter, he simultaneously established light as a basis for length standards.

Development of Gage Blocks

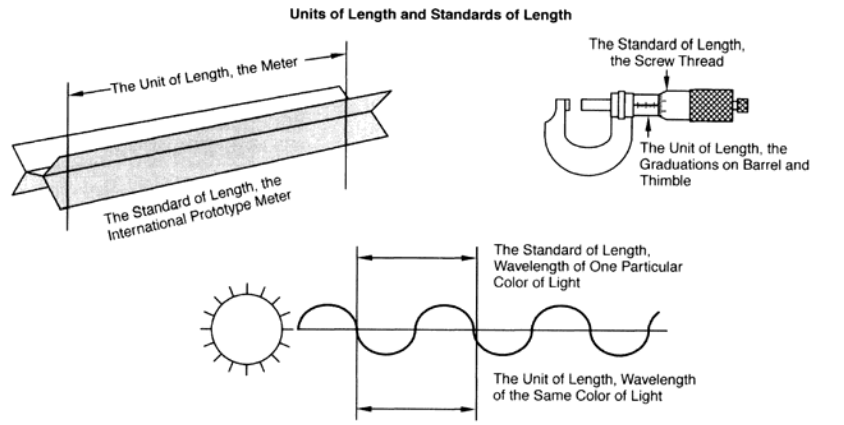


FIGURE 8–5 Only for light does the unit of length and standard of length become one. Therefore, light waves are the standard for both accuracy and precision.

Development of Gage Blocks

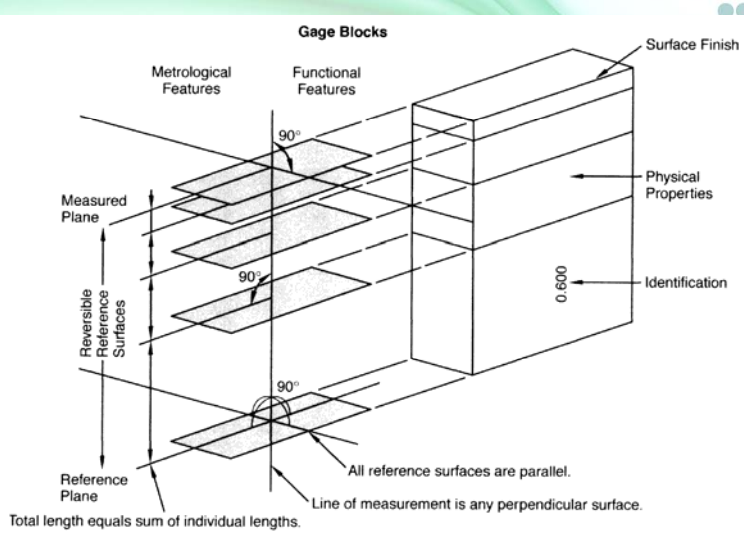


FIGURE 8–6 Both the metrological and the functional features of gage blocks suit them for exacting measurements.

Development of Gage Blocks

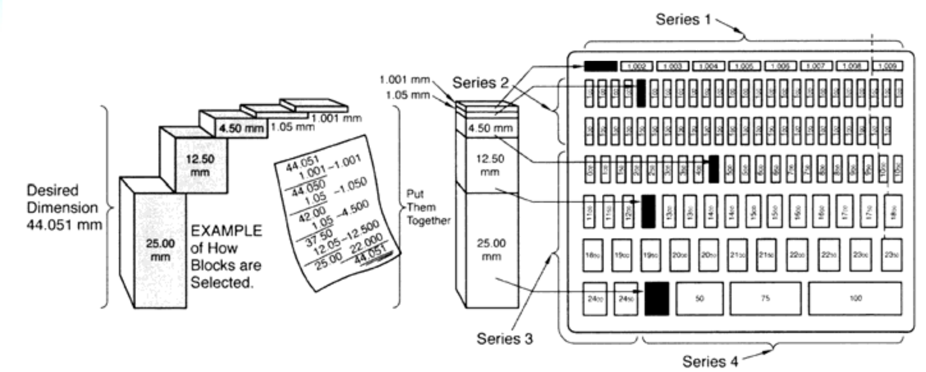
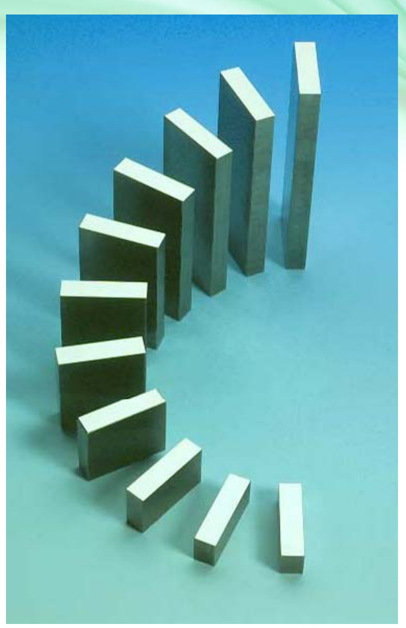


FIGURE 8–7 In Johansson's patent, 11 blocks in 4 series combine to form any dimension from 2 mm to 202 mm in steps of 0.001 mm, a total of 200,000 combinations.

Modern Gage Blocks



Modern Gage Blocks

Modern Gage Blocks

Modern Gage Blocks

Practical, functional **characteristics of gage blocks**:

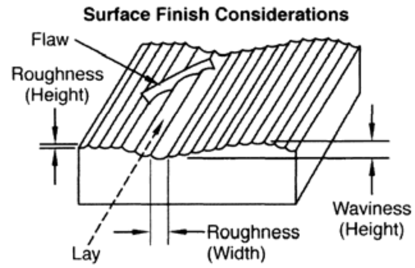
1. They must be made from something that can be accurately sized and finished.
2. They must be stable and not change size of their own accord.
3. They must withstand considerable wear.
4. They must be practical—affordable and wear and corrosion resistant.

Modern Gage Blocks

Macrogeometry and Microgeometry

"Macro" means large, and "micro" means small. **Macrogeometry** generally refers to the **general shape of a part**, and the features can usually be easily measured with instruments like the ones we have discussed. **Microgeometry** refers to the **minute analysis of shape**. We cannot measure to very high precision or accuracy without the following **microgeometric features: flatness, parallelism, straightness, roundness, and surface finish**.
When we use end standards, our length measurements depend on the condition of the contacting surfaces, commonly but inaccurately called the surface finish or surface texture. The proper, completely descriptive term is surface topography.

Modern Gage Blocks



Roughness is finely spaced surface irregularities, in a consistent pattern, produced by machining or processing.

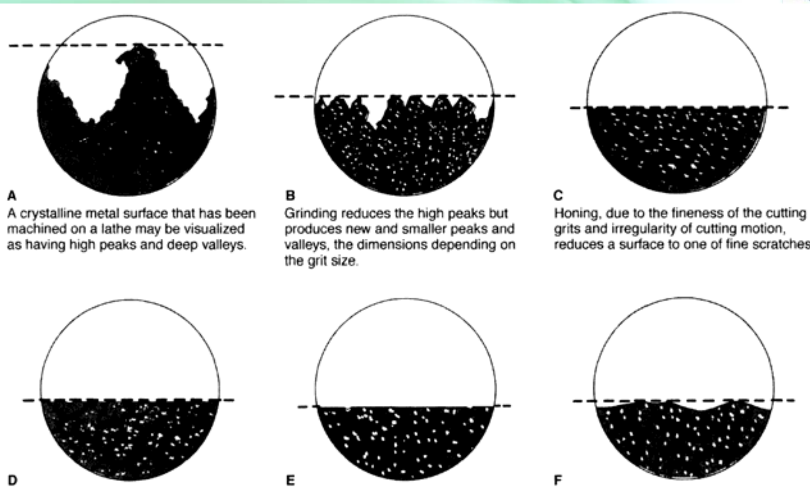
Waviness is an irregular surface condition of greater spacing than roughness. Usually caused by deflections or vibrations, not by the cutting edge.

Flaws are irregularities that do not appear in a consistent pattern.

Lay is the predominant direction of surface pattern.

FIGURE 8–8 These terms are usually used to describe surface conditions.

Modern Gage Blocks



A A crystalline metal surface that has been machined on a lathe may be visualized as having high peaks and deep valleys.

B Grinding reduces the high peaks but produces new and smaller peaks and valleys, the dimensions depending on the grit size.

C Honing, due to the fineness of the cutting grits and irregularity of cutting motion, reduces a surface to one of fine scratches.

D Lapping normally leaves a finish of minute scratches. The scratch pitch is finer than that left by a hone.

E Gage block surfaces have a high degree of flatness as well as surface finish. Only occasional extremely shallow scratches are left.

F Buffing produces sufficient heat to bring about "plastic flow" and while aiding reflectability will reduce the quality of surface flatness.

FIGURE 8–9 Comparison of surface finish shows the exacting requirements for gage blocks.

Modern Gage Blocks

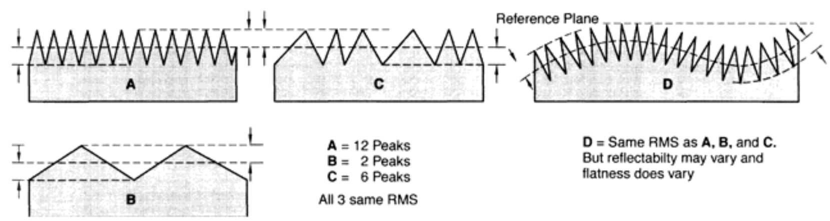


FIGURE 8–10 The top drawings show that an irregular surface or poor surface may have better reflectivity than a good surface finish. The bottom drawing shows the reason for this.

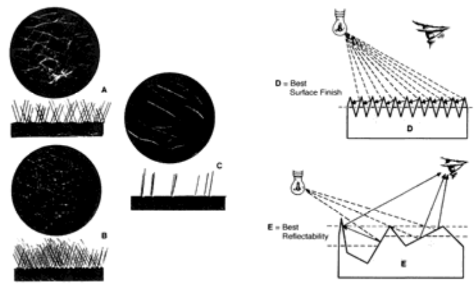


FIGURE 8–11 Surface finish is measured by the height of the crests from the average. These examples show that this does not fully describe the surface.

Modern Gage Blocks

METRIC SYSTEM: TOLERANCE EXPRESSED IN MICRONS (µM = 0.001 MM)

	Calibration Grade K		Grade 00		Grade 0		Grade AS-1		Grade AS-2	
Length of Block (mm)	Tolerance (length) ±	Flatness & Parallelism	Tolerance (length) ±	Flatness & Parallelism	Tolerance (length) ±	Flatness & Parallelism	Tolerance (length) ±	Flatness & Parallelism	Tolerance (length) ±	Flatness & Parallelism
Through 10 mm	0.20	0.05	0.07	0.05	0.12	0.10	0.20	0.16	0.45	0.30
25 mm	0.30	0.05	0.07	0.05	0.14	0.10	0.30	0.16	0.60	0.30
50 mm	0.40	0.06	0.10	0.06	0.20	0.10	0.40	0.18	0.80	0.30
75 mm	0.50	0.06	0.12	0.07	0.25	0.12	0.50	0.18	1.00	0.35
100 mm	0.60	0.07	0.15	0.07	0.30	0.12	0.60	0.20	1.20	0.35
150 mm	0.80	0.08	0.20	0.08	0.40	0.14	0.80	0.20	1.60	0.40
200 mm	1.00	0.09	0.25	0.09	0.50	0.16	1.00	0.25	2.00	0.40
250 mm	1.20	0.10	0.30	0.10	0.60	0.16	1.20	0.25	2.40	0.45

Modern Gage Blocks

English System: Tolerance Expressed in Microinches (µin = 0.000001 in. = 1 Millionth of an Inch)										
	Calibration Grade K		Grade 00		Grade 0		Grade AS-1		Grade AS-2	
Length of Block (inch)	Tolerance (length) ±	Flatness & Parallelism	Tolerance (length) ±	Flatness & Parallelism	Tolerance (length) ±	Flatness & Parallelism	Tolerance (length) ±	Flatness & Parallelism	Tolerance (length) ±	Flatness & Parallelism
Through 0.05"	12	2	4	2	6	4	12	6	24	12
0.4"	10	2	3	2	5	4	8	6	18	12
1"	12	2	3	2	6	4	12	6	24	12
2"	16	2	4	2	8	4	16	6	32	12
3"	20	2	5	3	10	4	20	6	40	14
4"	24	3	6	3	12	5	24	8	48	14
5"	32	3	8	3	16	5	32	8	64	16
6"	32	3	8	3	16	5	32	8	64	16
7"	40	4	10	4	20	6	40	10	80	16
8"	40	4	10	4	20	6	40	10	80	16
10"	48	4	12	4	24	6	48	10	104	18
12"	56	4	14	4	28	7	56	10	112	20
16"	72	5	18	5	36	8	72	12	144	20
20"	88	6	20	6	44	10	88	14	176	24
24"	104	6	25	6	52	10	104	16	200	28
28"	120	7	30	7	60	12	120	18	240	28

Calibration of Gage Blocks

Progressive manufacturers and research laboratories often use gage blocks directly for measurement. To ensure reliability, blocks should be sent to the metrology laboratory for calibration when any of these conditions exist:

1. Visual inspection shows abnormal wear when compared to past calibrations.
2. Wringing becomes difficult.
3. You suspect the reliability of the block(s) when there is an increase in rejects.

Calibration of Gage Blocks

GAGE BLOCK CALIBRATION

What is it?
Verification that the block is within the tolerance specified.

How is it done?
By comparison with master standards of known calibration and know traceability to the national length standards.

When is it done?
1. Periodically, according to a systematic program based on statistical quality control.
2. Not less often than annually for grade AA, quarterly for grade A, and semiannually for grade B.
3. When required by visual inspection, wringability decline, or slipping quality control level.

Who calibrates working sets?
The user's gage department or any of the facilities for calibrating master sets.

Who calibrates master sets?
1. Independent metrology laboratories
2. Manufacturers of gage blocks
3. NIST

What is done with worn blocks?
They are replaced.

What is done with worn sets?
They are regarded for a lower level of precision.

FIGURE 8–14 Considering the critical use of gage blocks, their calibration is of crucial importance.

Gage Block Applications

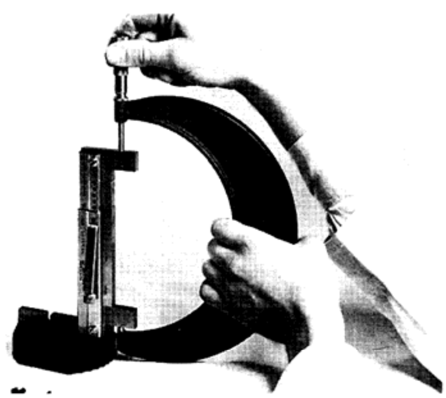


FIGURE 8–15 Gage blocks provide the accepted method for calibration of measurement instruments. When calibrating an instrument, such as a micrometer, ask this question: "Could the measurement be made directly with gage blocks instead of through this middleman?"

Gage Block Applications

Gage blocks primarily use the **comparison method** of measurement. In order to take advantage of this method, you need:

1. Knowledge of gage block handling and care
2. The ability to figure gage block combinations
3. The ability to wring blocks reliably
4. An understanding of the principles of comparison measurement

Gage Block Applications

THE PLACE FOR GAGE BLOCK MEASUREMENT

Consider Gage Blocks when:

1. Precision increases
2. Length increases
3. Importance of reliability increases
4. Skill of measurer decreases

The General Rule:

Use gage blocks for every measurement unless adequate reliability can be more economically obtained by another method.

Rules by precision required:

For 0.05 mm or finer, use only high amplification comparison instruments set to gage blocks. Check the working gage block set with a master gage block set (0.002 inch or finer).

For 0.025 to 0.005 mm: (0.001 to 0.0002 in.)

1. Use only high amplification instruments set to gage blocks for all lengths.
2. Over 50 mm, use only comparison instruments set to gage blocks.
3. Under 50 mm, use vernier micrometers checked with gage blocks.

For 0.050 to 0.025 mm: (0.002 to 0.001 in.)

1. Use comparison instruments (such as dial indicators) set to gage blocks for all lengths.
2. Use micrometers to approximately 50 mm. Check with gage blocks.

For 0.125 to 0.050 mm: (0.005 to 0.002 in.)

1. Use comparison instruments (such as dial indicators) set to gage blocks for all lengths.
2. Use micrometer instruments to approximately 125 mm. Check with gage blocks.
3. Use vernier instruments to approximately 125 mm. Check with gage blocks.

For 0.5 to 0.125 mm: (0.015 to 0.005 in.)

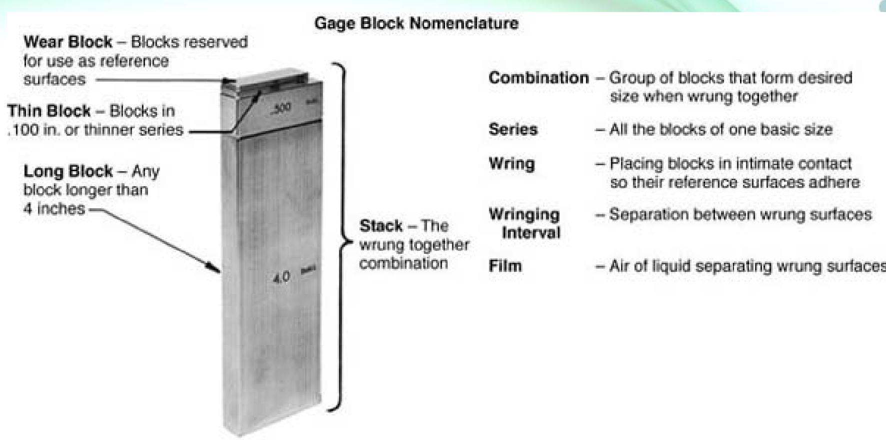
Use micrometers or vernier instruments. Check with gage blocks.

For precision less than 0.5 mm: (0.015 in.)

Gage blocks are rarely preferred.

FIGURE 8–16 Gage blocks are needed at many levels. These rules are based on average measurements, equipment, and skill. Availability of a measuring microscope or an interferometer obviously alters them and they cannot be applied to extremely large or small measurements.

Gage Block Applications



Gage Block Applications

RULES FOR GAGE BLOCK CARE

1. Never attempt to wring or otherwise use gage blocks that have been in contact with chips, dust- or dirt-laden cutting fluids.
2. Before using, clean blocks with a high-grade solvent or commercial gage block cleaner. Wipe dry with a lint-free tissue.
3. Do not allow blocks to remain wrung together for long periods. Separate daily.
4. When not in use, place blocks in a safe place where they will not be damaged, preferably in their case.
5. Before putting blocks away, clean the blocks and cover with a noncorrosive oil or grease or commercial preservative.
6. Be on constant guard for burrs. If anything has been placed on a block or if it does not wring readily, use a conditioning stone immediately.
7. Thoroughly clean the gage block case periodically.

FIGURE 8–18 Obeying these rules will improve reliability, speed measurement, and lower the cost of measurement.

Gage Block Applications

Black Granite Conditioning Stone

Ceramic Conditioning Stone

Gage Block Applications

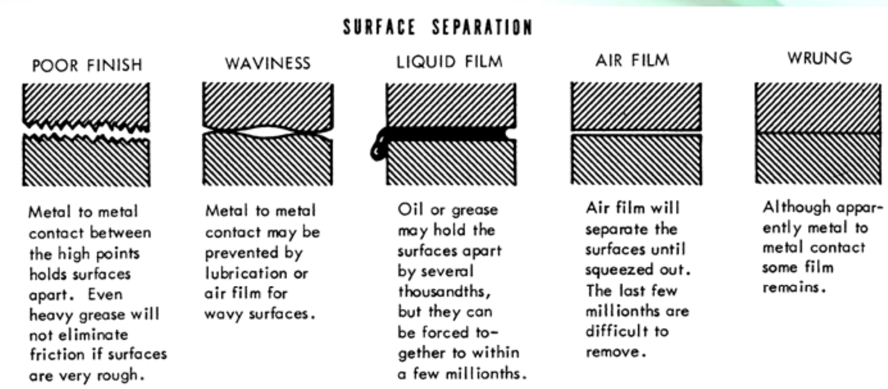


FIGURE 8–21 Air, oil, grease, and surface irregularities hold surfaces apart.

Gage Block Applications

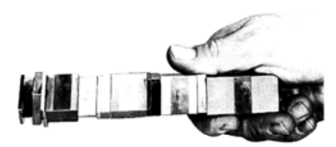


FIGURE 8–20 These blocks show how tenaciously finely finished surfaces will adhere to each other. *(Courtesy of DoAll Company)*

FIGURE 8–22 Three stacks of varying numbers of blocks, all of which total the same length, have been wrung to a toolmaker's flat. Other blocks have been wrung across the three stacks so that the final block supports them all. This shows that the lengths of stacks are self–checking.

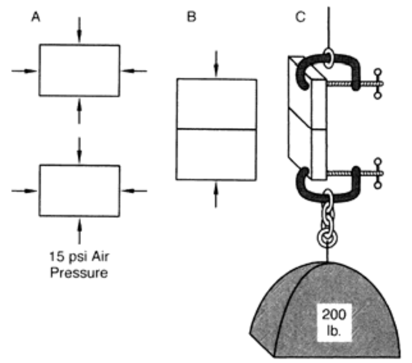


FIGURE 8–23 When the gage blocks are not in contact, as in A, the 15 psi atmospheric pressure acts on all sides and balances. When placed together as in B, the effects on the sides balance but the pressure is now closed off between the blocks. This leaves air pressure on both ends holding the blocks together. But C shows the blocks can resist a 200–pound pull. Based on 15 psi atmospheric pressure and a block area of 0.525 in., the force holding them together would be 7.7 pounds–a far cry from 200 pounds.

Gage Block Applications

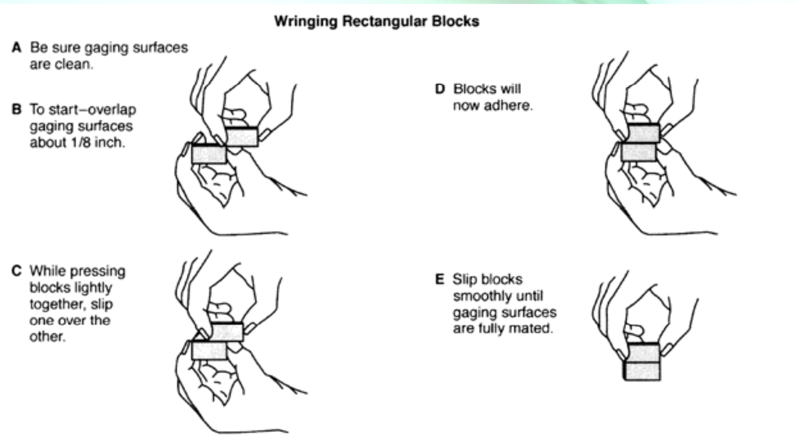


FIGURE 8–24 These steps need to be practiced to develop the feel for wringing.

Gage Block Applications

Wringing Square Blocks

1
Place the blocks together as shown. This minimizes the danger of the corner of one block scratching the other.

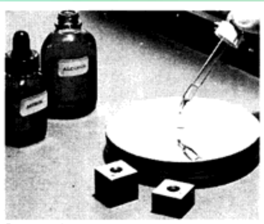
2
Slide the upper block over the lower with a slight circular motion. If they are clean, they will begin to take hold rapidly. Foreign matter can be detected readily and should be removed before it damages either block. Some authorities object to the circular motion.

3
Slide the upper block half out of engagement using light but firm pressure.

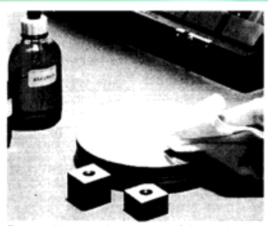
4
Slide the upper block back into full engagement under light pressure, at which point they should be wrung together ready for use. Worn or dirty blocks will not wring.

FIGURE 8–25 Square blocks are wrung in much the same manner as rectangular blocks. *(Courtesy of Pratt & Whitney Co., Inc.)*

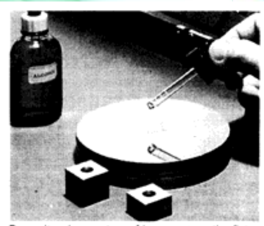
Gage Block Applications



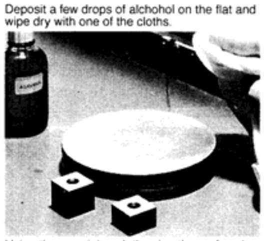
Deposit a few drops of alchohol on the flat and wipe dry with one of the cloths.



Repeat this procedure on one of the gaging surfaces of each block.

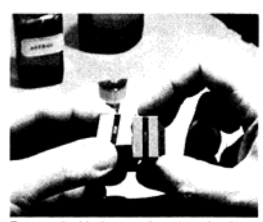


Deposit a drop or two of kerosene on the flat.



Using the remaining cloth, wipe the surface in increasingly larger circles until there is a thin, evenly distributed yellow cast remaining.

Quickly wring the previously cleaned surface of either block to that flat. Using light pressure, slide the block onto the flat. By slight rotation, it should wring firmly.



Remove the block promptly and, again with light pressure, slide it onto the previously cleaned surface of the remaining block. With a circular motion, slide it half out of engagement and back into a mating position.

FIGURE 8–26 This is the method approved by the National Institute of Standards and Technology. Required are two lint-free cotton wipers, pure grain alcohol, filtered kerosene, and a toolmaker's flat. Practice will dictate the slight amount of kerosene required. *(Courtesy of Quality Assurance, Hitchcock Pub. Co.)*

Gage Block Applications

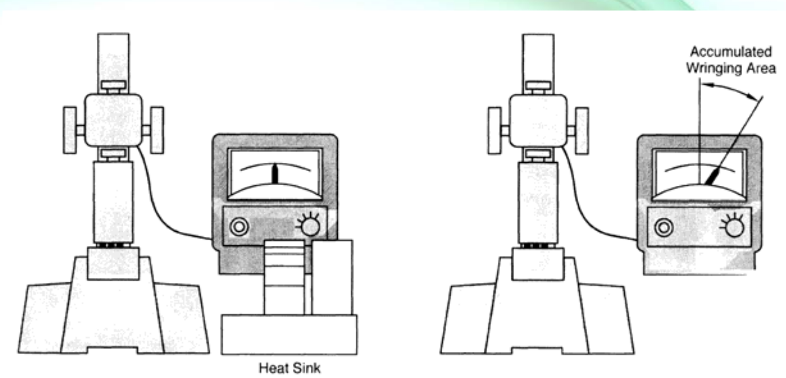


FIGURE 8–27 Patience and a high amplification comparator are all that are needed to test wringing ability. The stack of several wrung blocks is normalized with a single block of the same nominal length. The comparator is zeroed on the single block. That block is replaced with the stack. The plus reading will be your total accumulated wringing interval.

Combining Gage Blocks

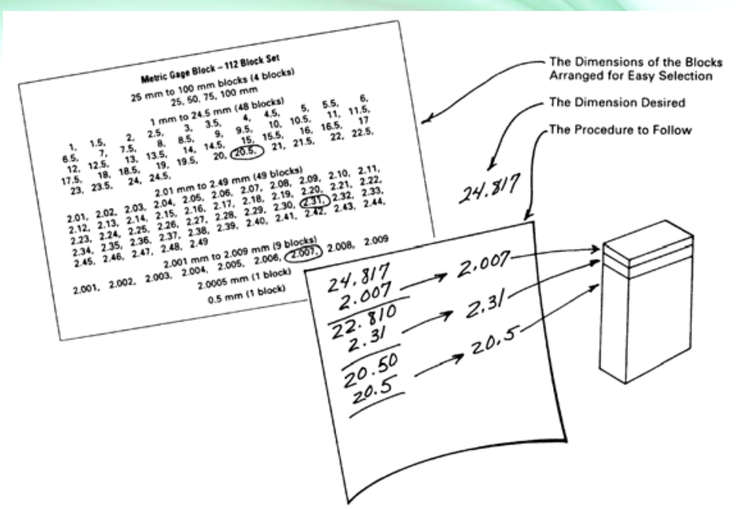


FIGURE 8–28 Elimination of digits from the right selects the blocks required for any combination.

Combining Gage Blocks

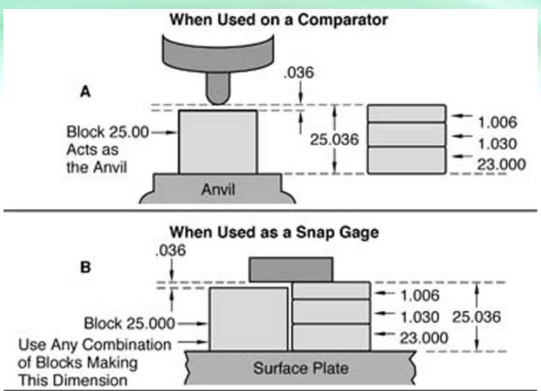
ALTERNATE COMBINATIONS

Finding a second combination choice:

Dimension sought	24.817 mm	Proof
To eliminate the 7, add 1.003 and 1.004	2.007	2.007
Result	22.810	
To eliminate the 1	2.41	2.41
Result	20.4	
To eliminate the 4	2.4	2.4
Result	18.0	
To eliminate the 8	8	8
Result	10	
To eliminate the 10	10	10
Result	0.0	24.817

FIGURE 8–29 Standard block sets provide great versatility in forming combinations.

Combining Gage Blocks



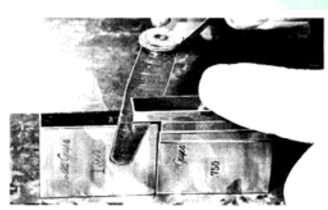


FIGURE 8–31 A feeler gage, which is thinner than any gage block, is calibrated by the difference between two stacks. *(Courtesy of DoAll Company)*

Combining Gage Blocks

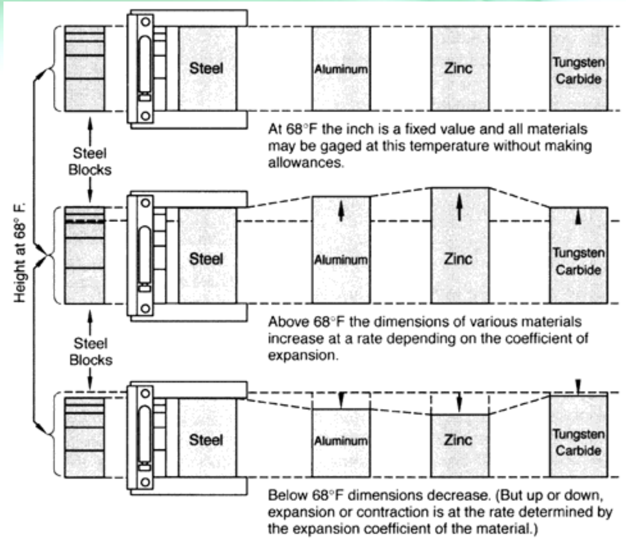
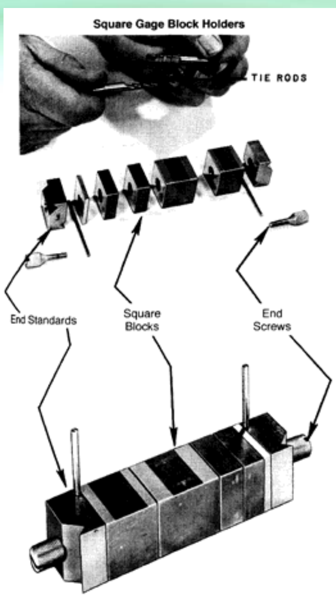


FIGURE 8–34 These exaggerated drawings show the effect of temperature changes on measurement.

Combining Gage Blocks



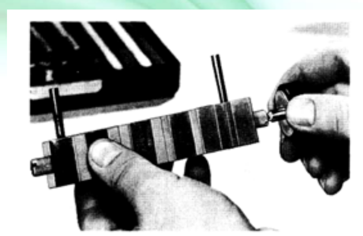


FIGURE 8–36 The torque screwdriver ensures uniform clamping force. *(Courtesy of DoAll Company)*

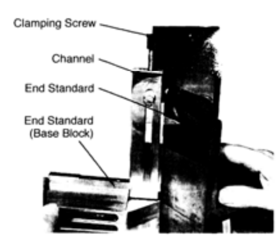


FIGURE 8–37 This basic holder can be used for a wide range of setups by changing the end standards.

Combining Gage Blocks

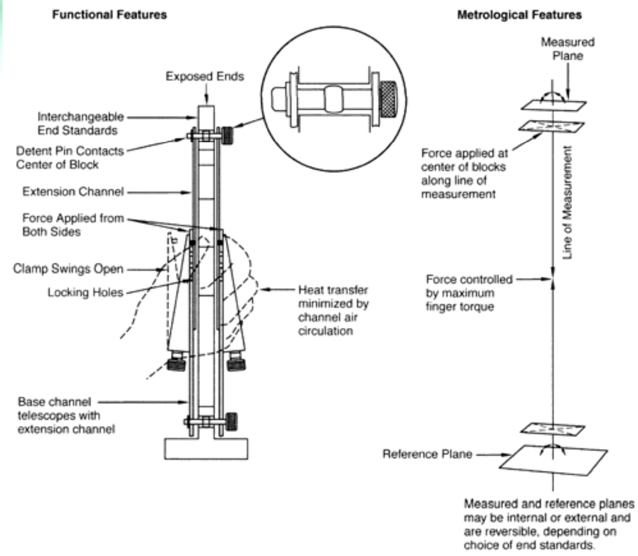
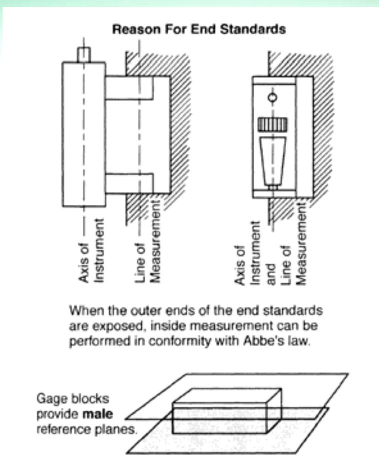
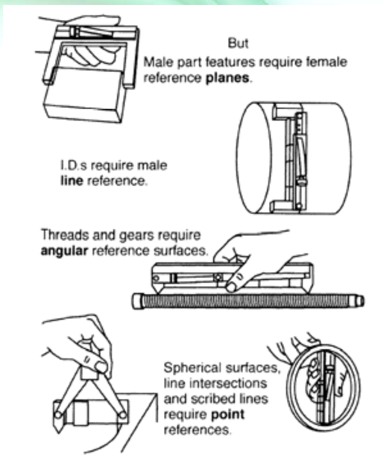


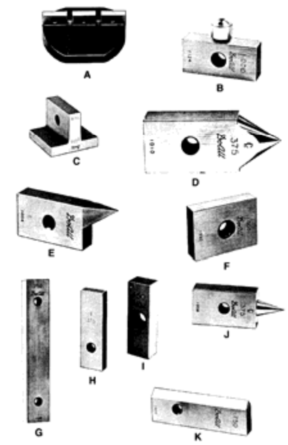
FIGURE 8–38 Gage block holders vary considerably in mechanical construction. The one shown is representative of good design features.

Combining Gage Blocks





Combining Gage Blocks



A Base Block
B Ball End Standard
C Foot Block
D Center Point
E Scriber
F 1" End Standard
G 3" Extension Caliper Bar
H 1" Extension Caliper Bar
I 0.450 End Standard
J Trammel Point
K 1" Extension Knife Edge Caliper Bar

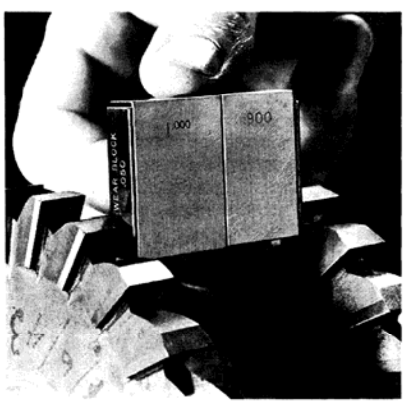
FIGURE 8–40 Design of end standards varies according to the types of gage block holders with which they are used. These types are typical of the references provided by end standards.

PRINCIPAL USES FOR GAGE BLOCKS

1. Calibration of other instruments and lesser standards
2. Setting of comparators and indicator-type instruments
3. Attribute gaging
4. Machine setup and precision assembly
5. Layout

FIGURE 8–41 These are the five principal uses for gage blocks.

Combining Gage Blocks



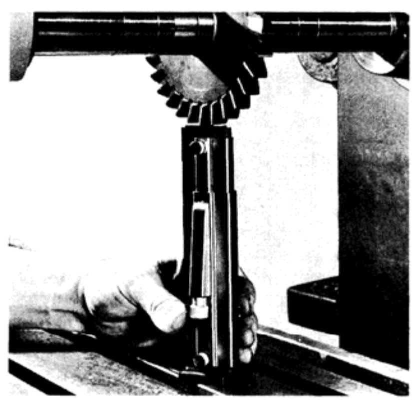


FIGURE 8–42 Sometimes people get upset when they see precision gage blocks being used for setup, such as for these milling machine operations. However, they are highly recommended for fast, accurate setups. The one important caution is that gage blocks are never used in this manner without wear blocks.

Combining Gage Blocks

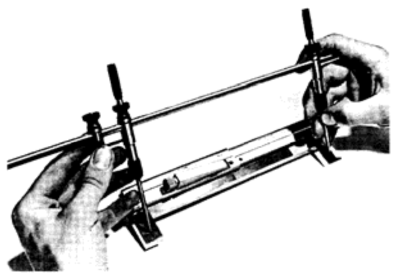


FIGURE 8–43 Trammels and dividers may be set to the scribed lines provided on some end standards, such as the 1-inch extension bar in Figure 8–40.

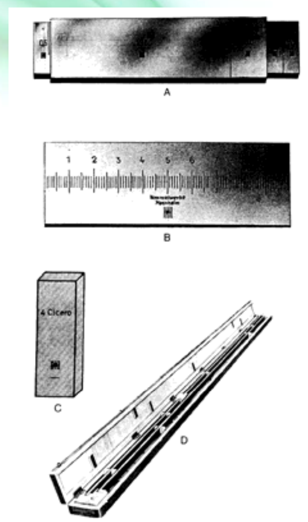


FIGURE 8–44 Many specialized gage blocks are available. A shows blocks with scribed lines for converting end measurement. B is provided with a graduated scale for typographical measurement. B is also for typographical measurement. D shows extremely long blocks. *(Courtesy of Hammelwerke)*

Combining Gage Blocks

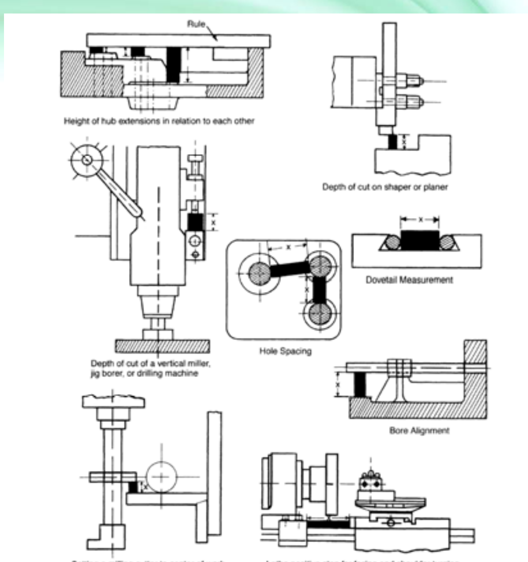
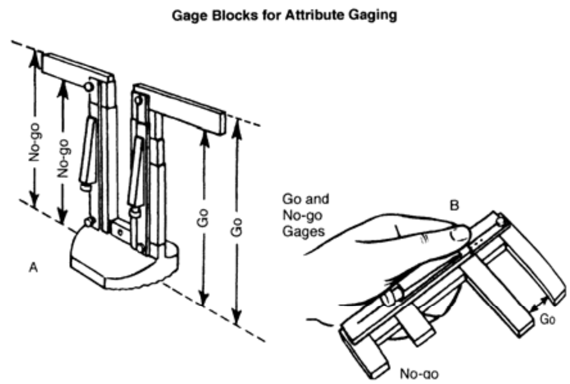


FIGURE 8–45 Direct use of gage blocks to set desired dimensions (x) eliminates errors from transfer of measurement. Gage blocks are widely used with sine bars and sine plates for angle measurements as discussed in Chapter 15.

Combining Gage Blocks

FIGURE 8–46 Gage blocks with end standards and holders are valuable as attribute gages. The most important reason is that they eliminate one or more intermediate steps between the gage and the standards. Another reason is that one set of blocks, end standard, and holders can be made up into thousands of gages, saving tremendous inventory.



Combining Gage Blocks

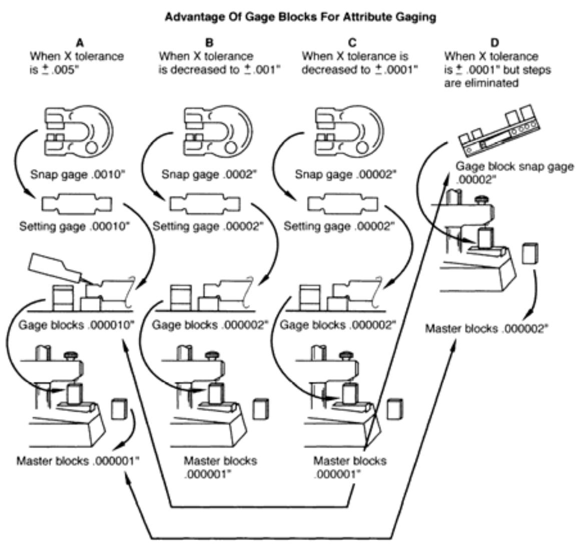


FIGURE 8–47 In example D, a tolerance, 1/50th as large as the one in example A, is being controlled with double the final margin of safety. This is achieved by the direct use of gage blocks for attribute gaging.

Combining Gage Blocks

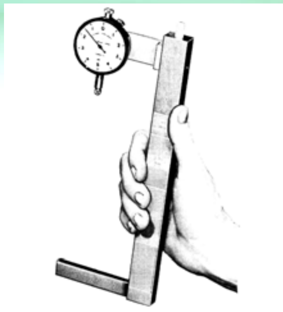


FIGURE 8–48 This could well be a demonstration of the effect of heat upon gage block length, but it is not. It is an example of the precalibrated indicator.

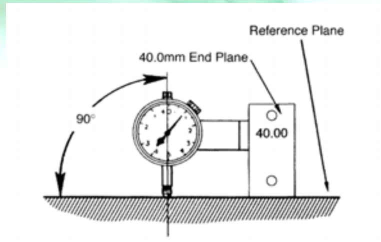


FIGURE 8–49 For precalibrated indicator measurement, an end standard is needed that will hold a transducer at a right angle to a reference plane and at a suitable distance from that plane to permit zeroing.

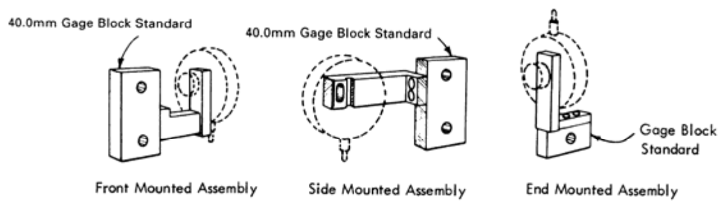


FIGURE 8–50 If mechanical indicators are used, both right– and left–hand side mounted brackets are required. This is simplified for remote reading of electronic and pneumatic instruments.

Combining Gage Blocks

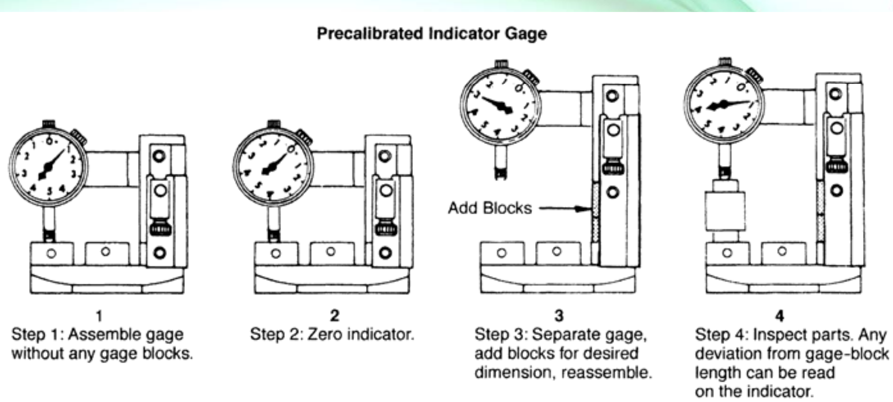


FIGURE 8–51 These four simple steps provide a nearly limitless range of gages with microinch accuracy, even though their precision is in thousandths of an inch.

Combining Gage Blocks

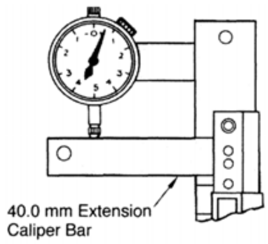


FIGURE 8–52 An extension bar is inserted to recalibrate the gage.

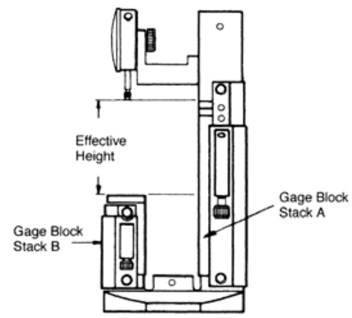


FIGURE 8–53 The use of standard holders and end standards gives great versatility to the precalibrated indicator technique. The effective height in this example is the length difference between stacks A and B. Therefore, this method can be used for dimensions that are ordinarily too small for gage block methods.

Combining Gage Blocks

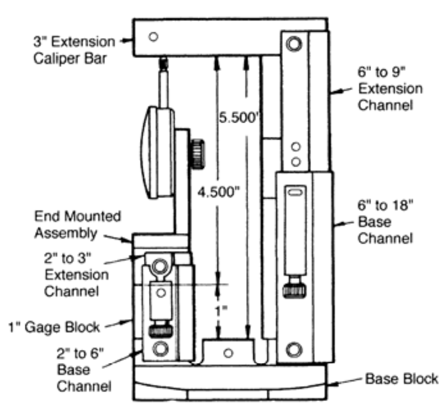


FIGURE 8–54 The precalibrated indicator technique can also be used for inside measurement, as shown in this example. It is being zeroed in the illustration. Following that, gage blocks will be inserted in one or both stacks to create the desired dimension. The extra step, of course, somewhat reduces the reliability.

FIGURE 8–55 Although very unusual, this setup shows the versatility of the precalibrated gage. In this case, it is set up for internal measurement. For ultraprecise work using electronic instruments instead of dial comparators, the effect of gravity may have to be considered. A stack of gage blocks is approximately one-millionth of an inch shorter for each 10 inches when in the vertical position than when in the horizontal position.

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http://www.qualitydigest.com/_qd.video_player.php?category=115&video=7256