III. METROLOGY

THERE IS MEASURE IN ALL THINGS.

HORACE
SATIRES, BOOK I, 35 B.C.

Metrology

Metrology is presented in the following major topic areas:

- **Introduction**
- **Common Gages & Instruments**
- **Special Gages**
- **Gage Selection & Use**
- **Surface Plate Tools**
- **Specialized Equipment**

Common Gages & Measuring Instruments is divided into the following subject areas:

- **Variable Gages**
- **Attribute Gages**
- **Transfer Gages**
- **Measurement Scales**

Introduction

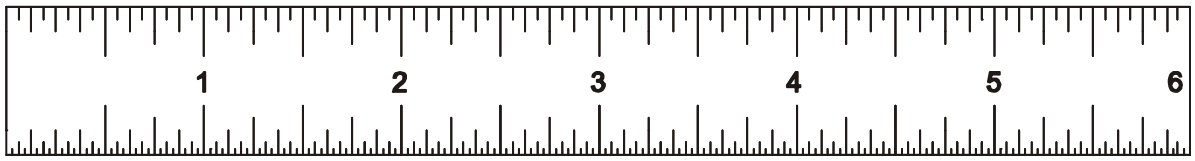
Metrology is the science of measurement. The word metrology derives from two Greek words: matron (meaning measure) and logos (meaning logic). Metrology encompasses the following key elements:

- **The establishment of measurement standards that are both internationally accepted and definable**
- **The use of measuring equipment to correlate the extent that product and process data conforms to specification**
- **The regular calibration of measuring equipment, traceable to established international standards**

Variable Gages

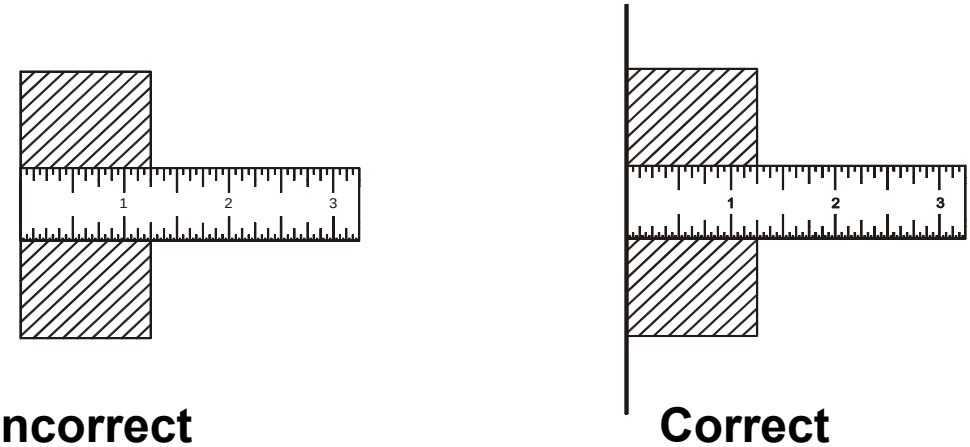
The Steel Rule

Steel rules and tapes are available in different degrees of accuracy and are typically graduated on both edges.



A Typical Steel Rule

The steel rule typically has discriminations of 1/32, 1/64, or 1/100 of an inch. Measurements requiring accuracies of 0.01" or finer should be performed with tools such as a digital caliper.



Incorrect **Correct**

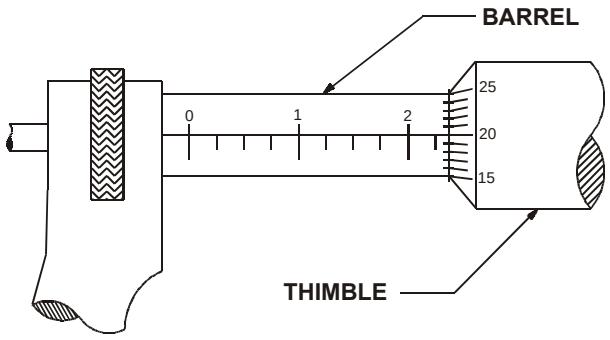
Use of a Flat Surface with a Steel Rule

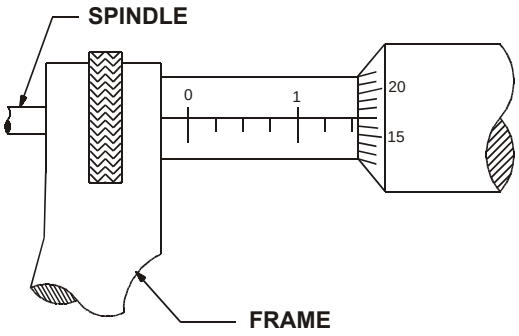
III. METROLOGY
COMMON GAGES / VARIABLE GAGES

II.A.1

Micrometers

Micrometers normally permit a 1" reading span, thus, a 2" micrometer would allow readings from 1" to 2". Most "mics" have an accuracy of 0.001", with the addition of a vernier scale, an accuracy of 0.0001" can be obtained. Digital micrometers can be read to 50 millionths of an inch.





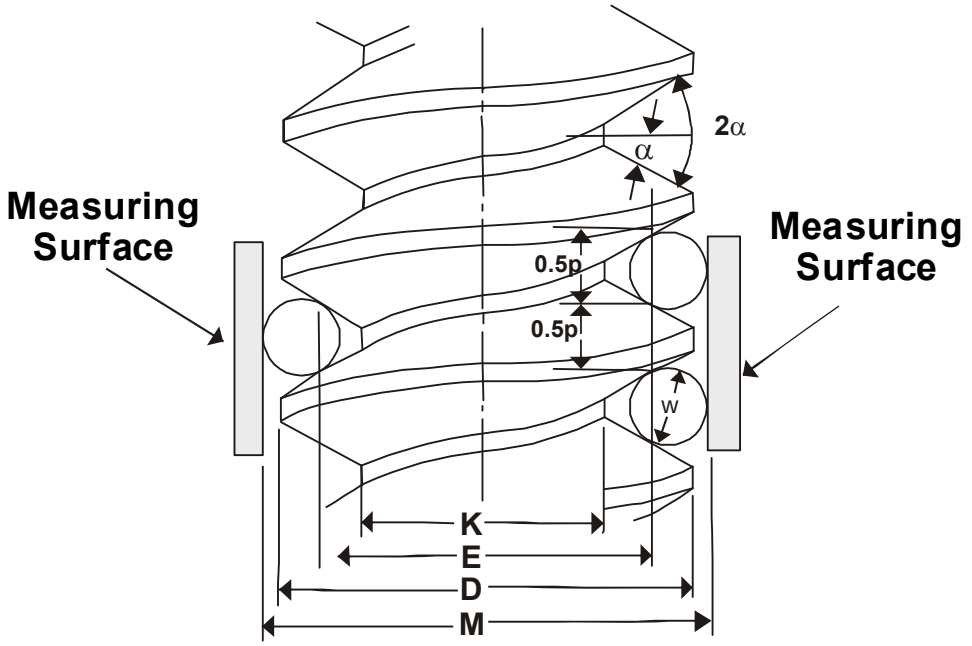
Micrometer set at 0.245"

Micrometer set at 0.167"

0.200"	0.100"
+0.025"	+0.050"
+0.020"	+0.017"
0.245"	+0.167"

Two Micrometer Reading Examples

Three-Wire Method for Pitch Diameter



An Illustration of Three Wire Measurement

The best wire size may be calculated by:

$$w = 0.5p \sec \alpha$$

Where: w = wire diameter
α = 1/2 the included thread angle
p = thread pitch

For a 60° thread:

$$w = 0.57735\ p$$

$$p = \text{the thread pitch} = \frac{1 \text{ inch}}{\text{no. of threads/inch}}$$

Three-Wire Method (Continued)

The formula to calculate the pitch diameter after measurement is:

$$E = M + (0.86603p) - 3W$$

Where: E = pitch diameter
p = thread pitch
M = over the wire measurement
W = wire size used

Example: Assume that M is 0.360", p is 0.050" and W is 0.030". Calculate the pitch diameter.

$$E = M + (0.86603p) - 3W$$
$$E = 0.360 + (0.86603 \times 0.050) - 3(0.030)$$
$$E = 0.360 + 0.0433 - 0.090$$
$$E = 0.3133 \text{ inch}$$

E is the pitch diameter.

Gage Blocks

Carl Johansson of Sweden developed steel gage blocks or "Jo" blocks to an accuracy within a few millionths of an inch. Today gage blocks are used in almost every shop manufacturing a product requiring mechanical inspection. They are used to set a length dimension for a transfer measurement, and for calibration of a number of other tools.

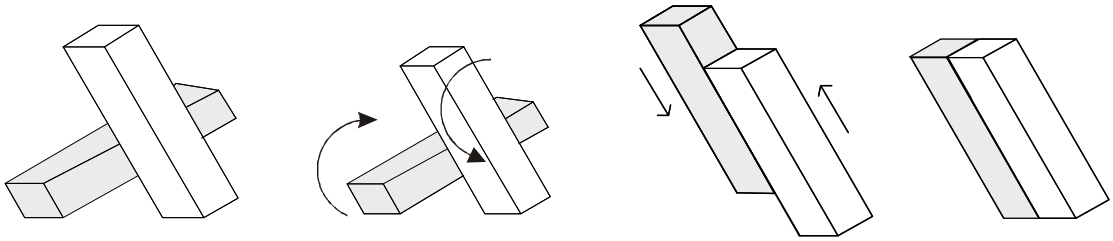
ANSI/ASME B89.1.9, *Gage Blocks*, distinguishes three forms - rectangular, square and round. Gage blocks are made from high carbon or chromium alloyed steel, tungsten carbide, chromium carbide, or fused quartz.

Federal Accuracy Grades		Accuracy In Length
New Designation	Old Designation	
0.5	AAA	± 0.000001
1	AA	± 0.000002
2	A+	+ 0.000004 - 0.000002
3	A & B	+ 0.000008 - 0.000004

Gage Block Grades

Gage Blocks (Continued)

Block stacks are assembled by a wringing process which attaches the blocks by a combination of molecular attraction and the adhesive effect of a very thin oil film. The sequential steps for the wringing of rectangular blocks is shown below. Light pressure is used throughout the process.



Hold Crosswise	Swivel the Pieces	Slip into Position	Finished Stack

Illustration of the Wringing of Gage Blocks

Gage Blocks (Continued)

Gage Block Sets

Typical gage block sets vary from 8 to 81 pieces based upon the needed application. Listed below are the contents of a typical 81 piece set:

Ten-thousands blocks	**(9)**	**0.1001, 0.1002 ... 0.1009**
One-thousands blocks	**(49)**	**0.101, 0.102 ... 0.149**
Fifty-thousands blocks	**(19)**	**0.050, 0.100 ... 0.950**
One inch blocks	**(4)**	**1.000, 2.000, 3.000, 4.000**

Also included in the set, are two wear blocks that are either 0.050" or 0.100" in thickness.

Minimum Stacking

2.5834	**(desired total)**
- 0.1004	**(use 0.1004" block)**
2.483	
- 0.133	**(use 0.133" block)**
2.350	
- 0.350	**(use 0.350" block)**
2.000	**(use 2.000" block)**

Attribute Gages

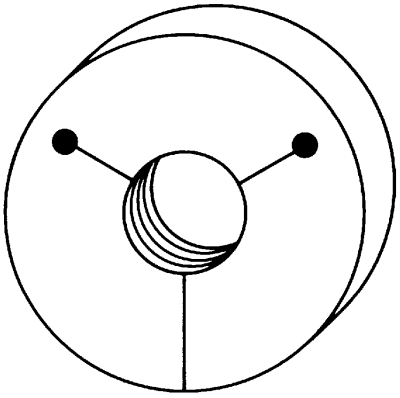
Attribute gages are fixed gages which typically are used to make a go, no-go decision. Attribute data indicates only whether a product is good or bad. Attribute gages are quick and easy to use.

Snap Gages

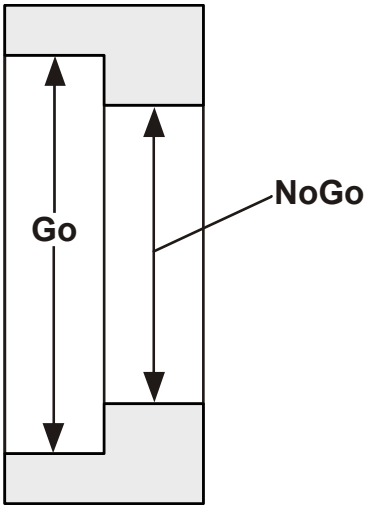
Snap gages are used to check outside dimensions in high volume operations. These gages may have provisions for a small range of adjustments and can be used to make rapid "go, no-go" decisions.

Ring Gages

Ring gages are used to check external cylindrical dimensions, and may also be used to check tapered, straight, or threaded dimensions. A pair of ring gages inserted in a holder as "go", "no-go" gages. A groove is often cut in the outer surface of the "no-go" gage to provide distinction.



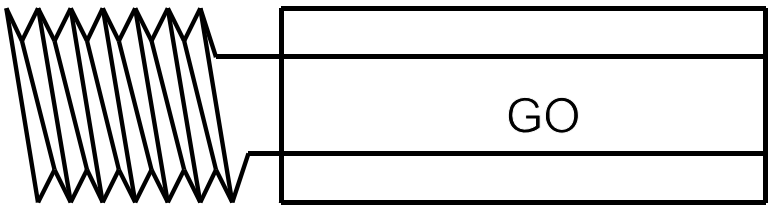
A No-go Thread Ring Gage



Progressive Ring Gage

Plug Gages

Plug gages are generally "go, no-go" gages, and are used to check internal dimensions. The "go, no-go" set is usually held in a hexagonal holder. The "no-go" plug is generally made shorter.



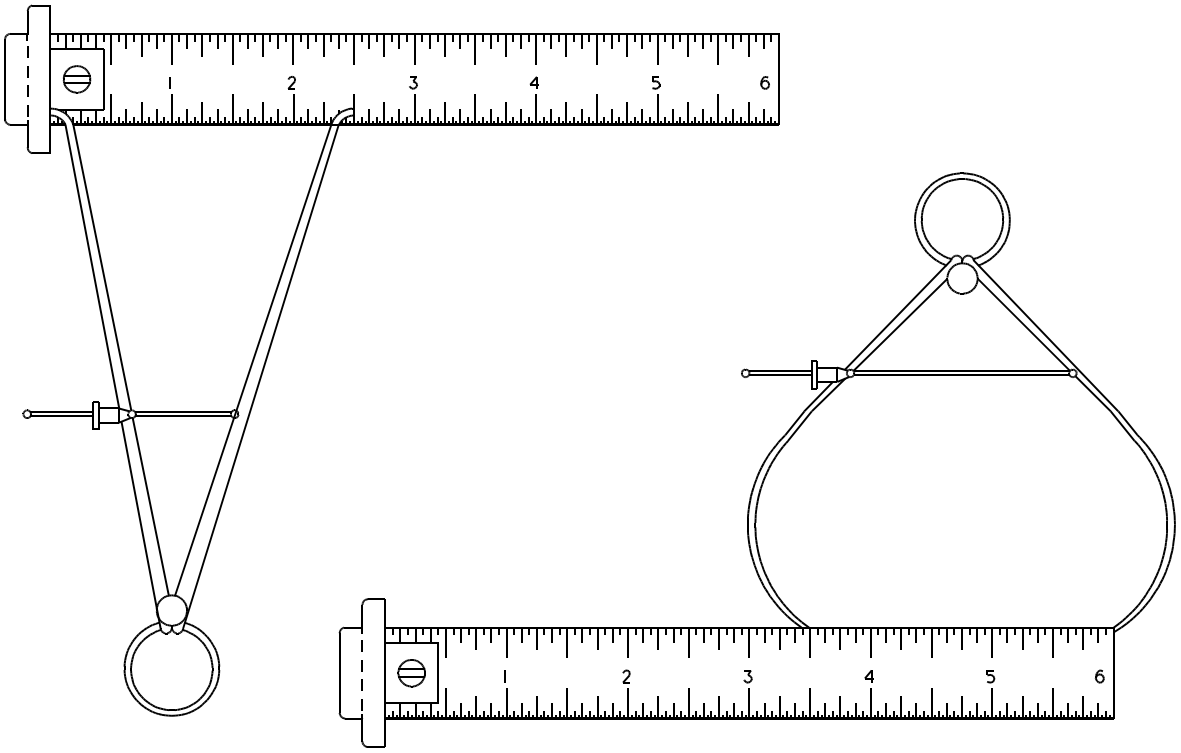
A Thread Plug Gage

III. METROLOGY
COMMON GAGES / TRANSFER GAGES

II.A.3

Spring Calipers

A spring caliper measurement is typically transferred to a steel rule by holding the rule vertically on a flat surface. The caliper ends are placed against the rule for the final readings.



Inside Calipers **Outside Calipers**

Spring Caliper Applications