
بسم الله الرحمن الرحيم

Measurements and Metrology

Fayoum University

Faculty of Engineering
Industrial Engineering Dept.

Lecture (2)

on

Linear Measurements

By

Dr. Emad M. Saad

Industrial Engineering Dept.
Faculty of Engineering
Fayoum University

2015 - 2016

linear Measurements Instruments

The instruments used for linear measurements can be classified as:

1. Direct measuring instruments
2. Indirect measuring instruments

The Direct measuring instruments are of two types:

1. Graduated
2. Non Graduated

The graduated instruments include **rules, vernier calipers, vernier height gauges, vernier depth gauges, micrometers, dial indicators** etc.

The non graduated instruments include **calipers, trammels, telescopic gauges, surface gauges, straight edges, wire gauges, screw pitch gauges, radius gauges, thickness gauges, slip gauges** etc.

They can also be classified as

1. Non precision instruments such as steel rule, calipers etc.,
2. Precision measuring instruments, such as vernier instruments, micrometers, dial gauges etc.

linear Measurements Instruments

Scales

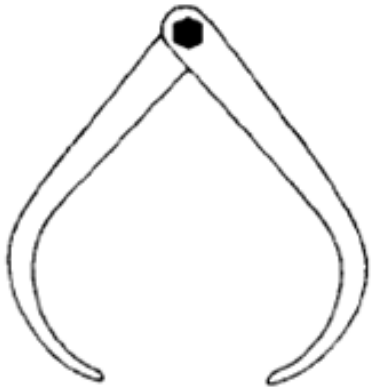
The most common tool for crude measurements is the scale (also known as rules, or rulers). Although plastic, wood and other materials are used for common scales, precision scales use tempered steel alloys, with graduations scribed onto the surface.

Calipers

Caliper is an instrument used for measuring distance between or over surfaces comparing dimensions of work pieces with such standards as plug gauges, graduated rules etc. These instruments are very useful when dealing with hard to reach locations that normal measuring instruments cannot reach. Obviously the added step in the measurement will significantly decrease the accuracy.

linear Measurements Instruments - Calipers

Inside caliper

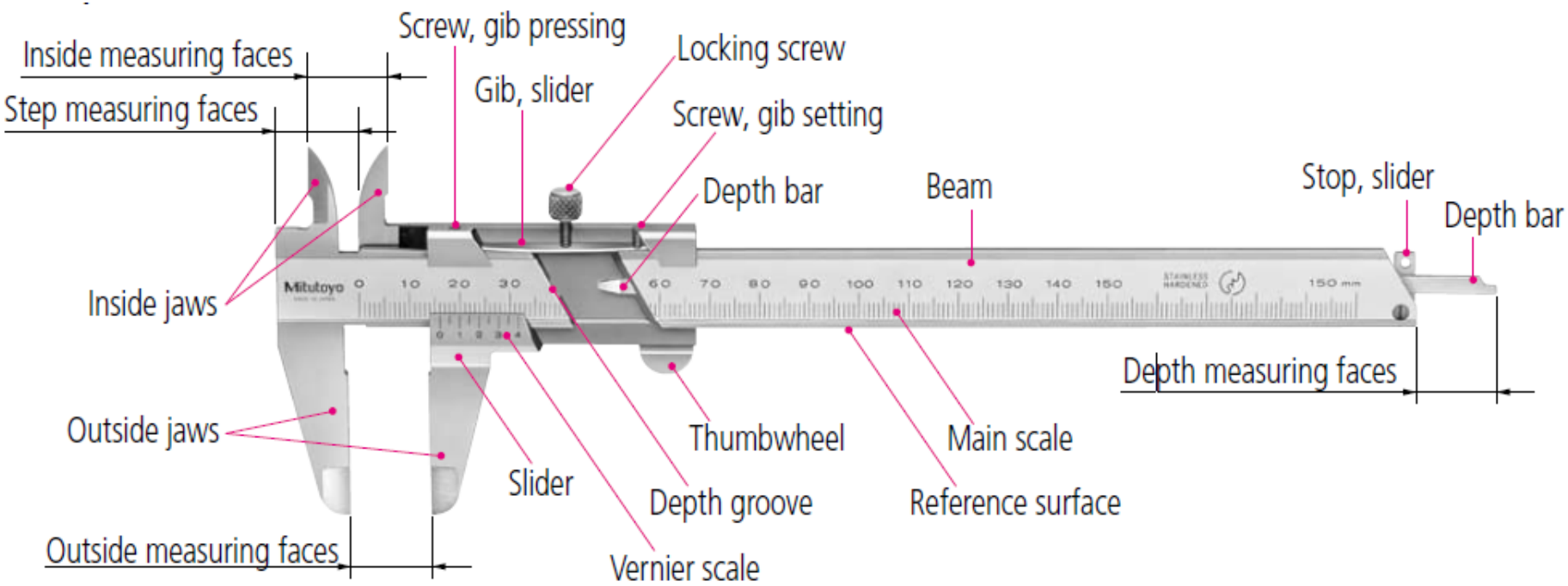


Outside caliper (spring loaded)

Divider caliper

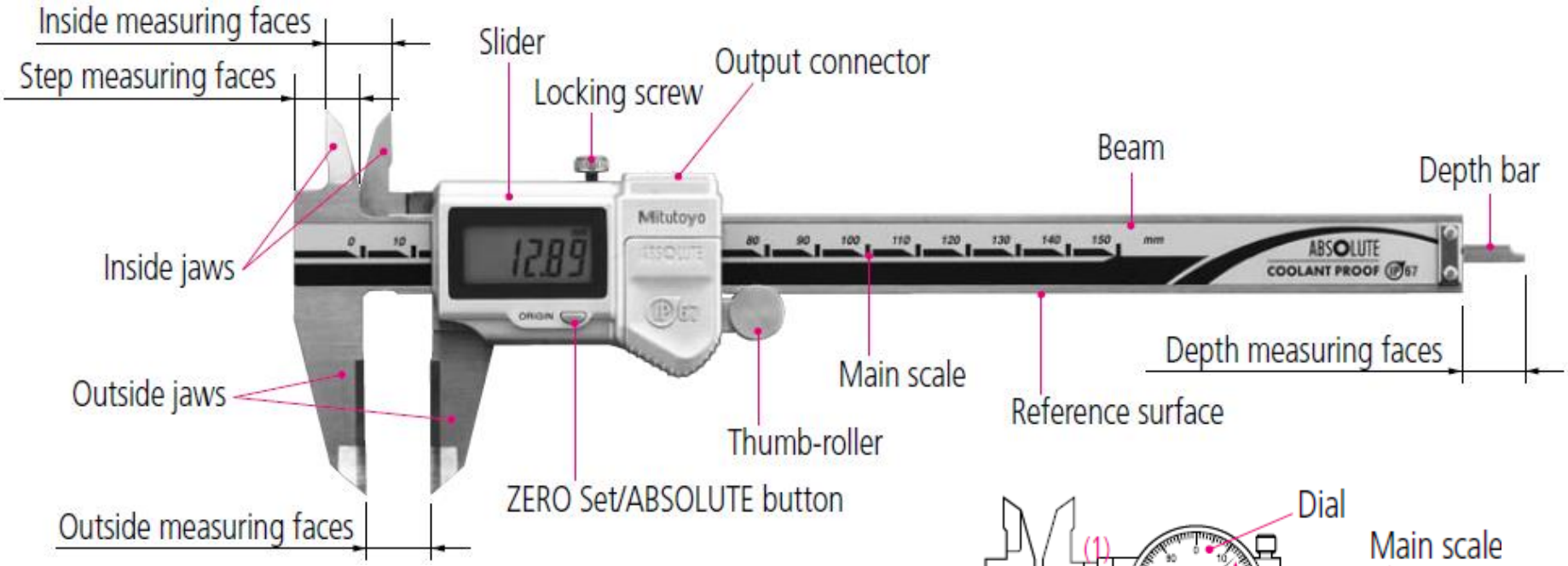
Odd leg calipers

linear Measurements Instruments - Calipers

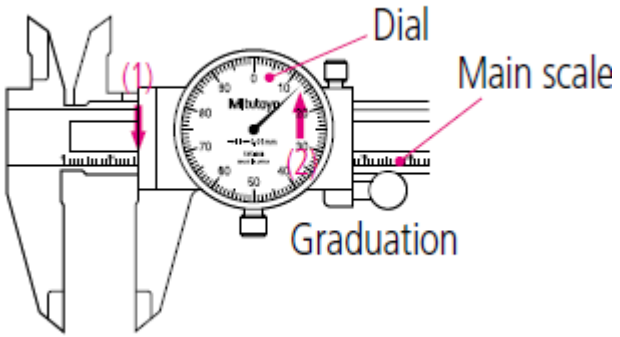


Vernier Caliper

linear Measurements Instruments - Calipers

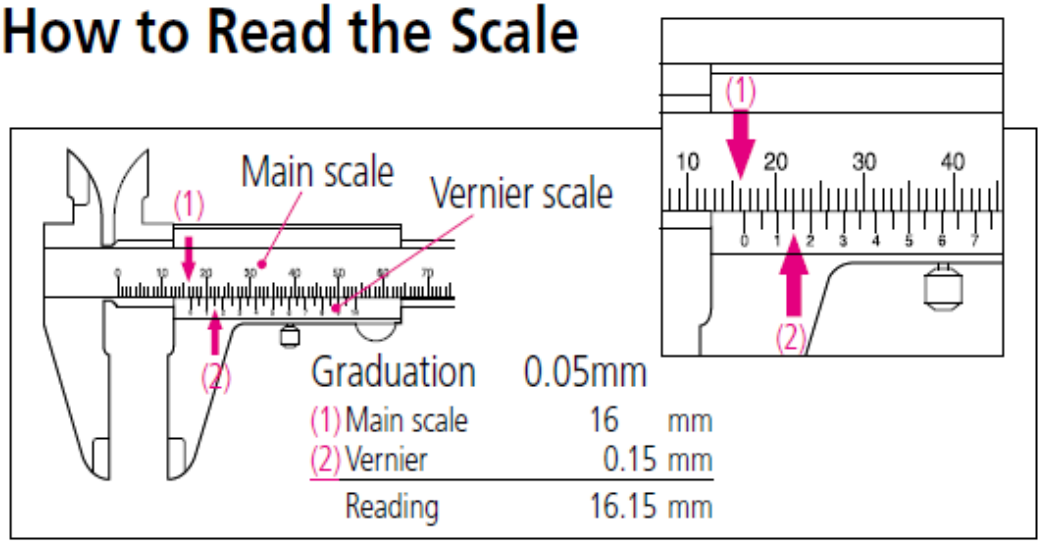


Absolute Digimatic Caliper

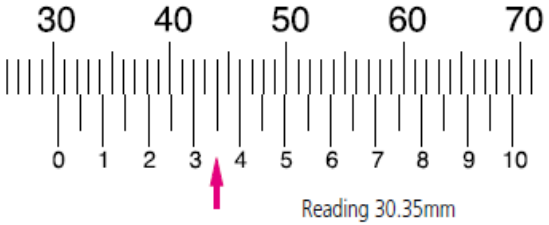


linear Measurements Instruments - Calipers

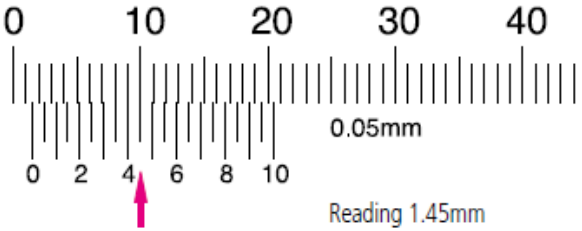
How to Read the Scale

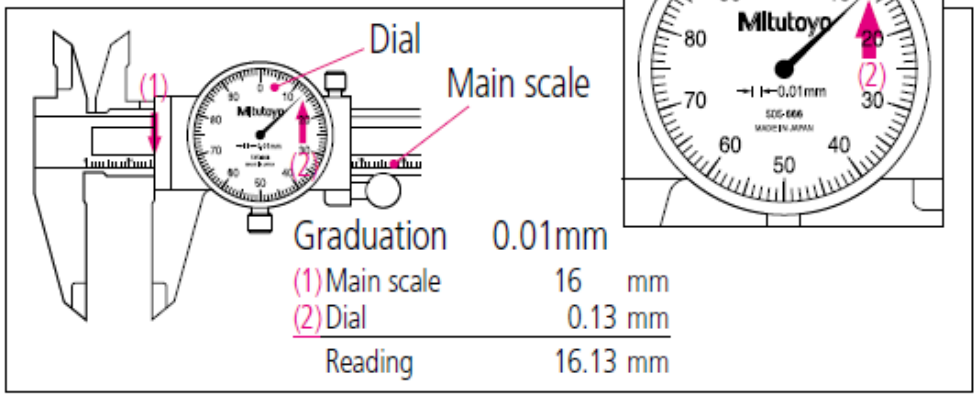


● Long Vernier scale (resolution 0.05mm)



● Standard Vernier scale (resolution 0.05mm)

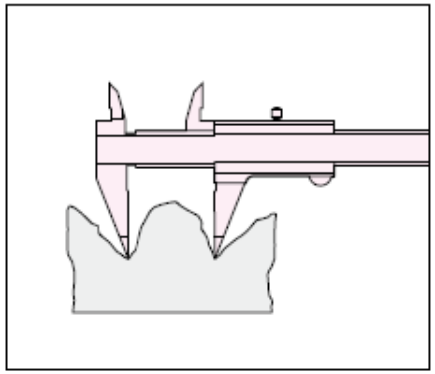




linear Measurements Instruments - Calipers

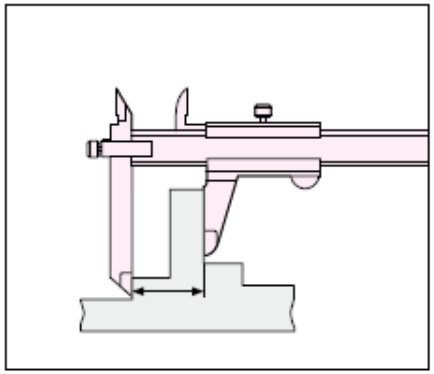
Special Purpose Caliper Applications

Point jaw caliper



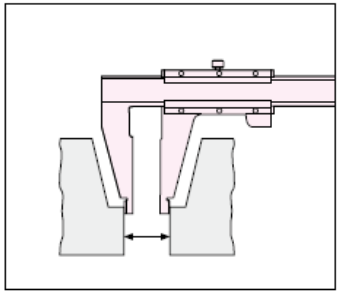
For uneven surface measurement

Offset jaw caliper



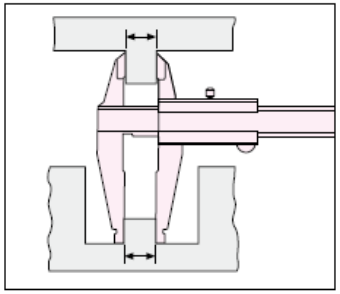
For stepped feature measurement

CM-type caliper



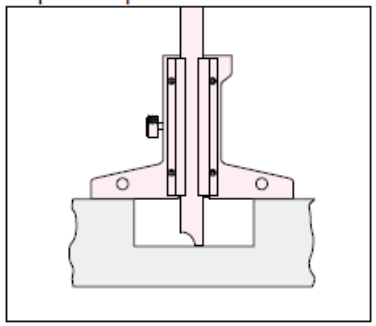
For outside measurement
For measurement of inside bore

CN-type caliper (with knife-edge)



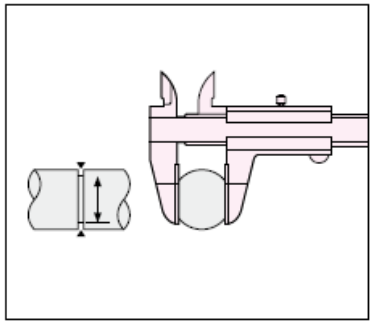
For outside measurement
For stepped feature measurement

Depth caliper



For depth measurement

Blade jaw caliper

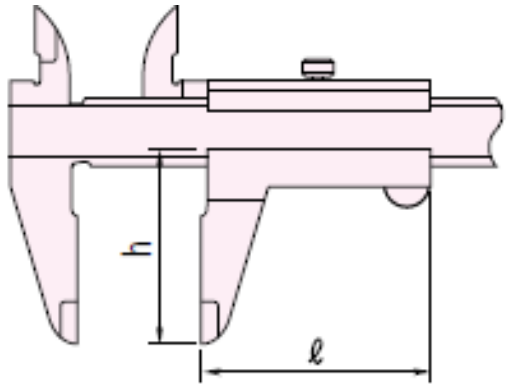


For diameter of narrow groove measurement

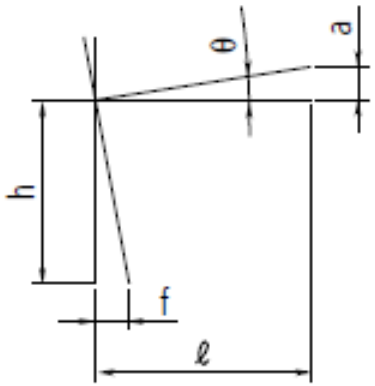
linear Measurements Instruments - Calipers

Moving Jaw Tilt Error

If the moving jaw becomes tilted out of parallel with the fixed jaw, either through excessive force being used on the slider or lack of straightness in the reference edge of the beam, a measurement error will occur as shown in the figure. This error may be substantial due to the fact that a caliper does not conform to Abbe's Principle.



$$f = h\theta = h \cdot a/\ell$$



Example: Assume that the error slope of the jaws due to tilt of the slider is 0.01mm in 50mm and the outside measuring jaws are 40mm deep, then the error (at the jaw tip) is calculated as (40/50)x0.01mm = 0.008mm.
If the guide face is worn then an error may be present even using the correct measuring force.

linear Measurements Instruments - Calipers

Error due to Thermal Expansion

$$L(\alpha \Delta T)$$

L ⟹ The actual length

α ⟹ The linear thermal coefficient of expansion

Example

ERROR DUE TO THERMAL EXPANSION. A 30-m (at 15°C) steel tape is used for surveying work in the summer such that the tape temperature in the sun is 45°C. A measurement indicates 24.567 ± 0.001 m. The linear thermal coefficient of expansion is $11.65 \times 10^{-6}/°C$ at 15°C. Calculate the true distance measurement.

Solution

The indicated tape length would be the true value if the measurement were taken at 15°C. At the elevated temperature the tape has expanded and consequently reads too small a distance. The actual length of the 30-m tape at 45°C is

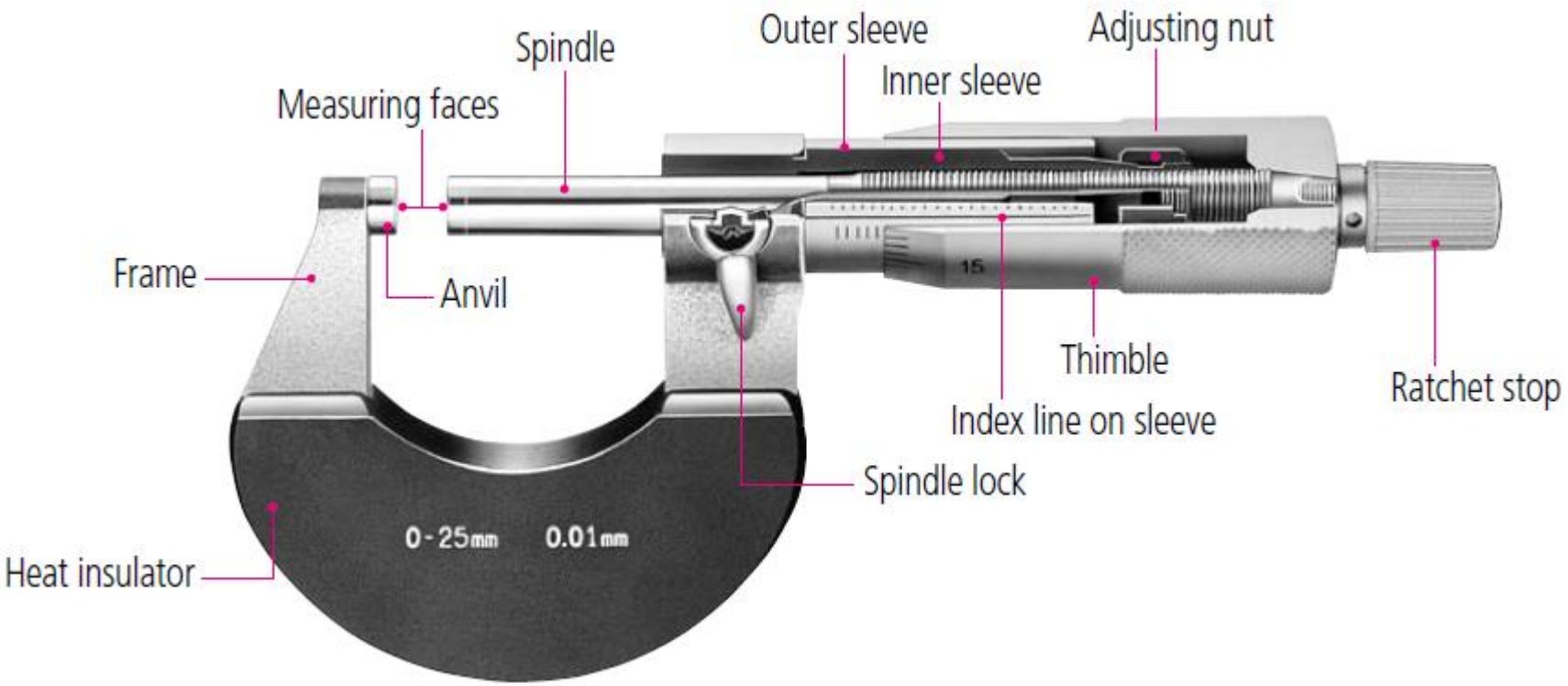
$$L(1 + \alpha \Delta T) = [1 + (11.65 \times 10^{-6})(45 - 15)](30) = 30.010485 \text{ m}$$

Such a true length would be indicated as 30 m. The true reading for the above situation is thus

$$(24.567)[1 + (11.65 \times 10^{-6})(45 - 15)] = 24.576 \text{ m}$$

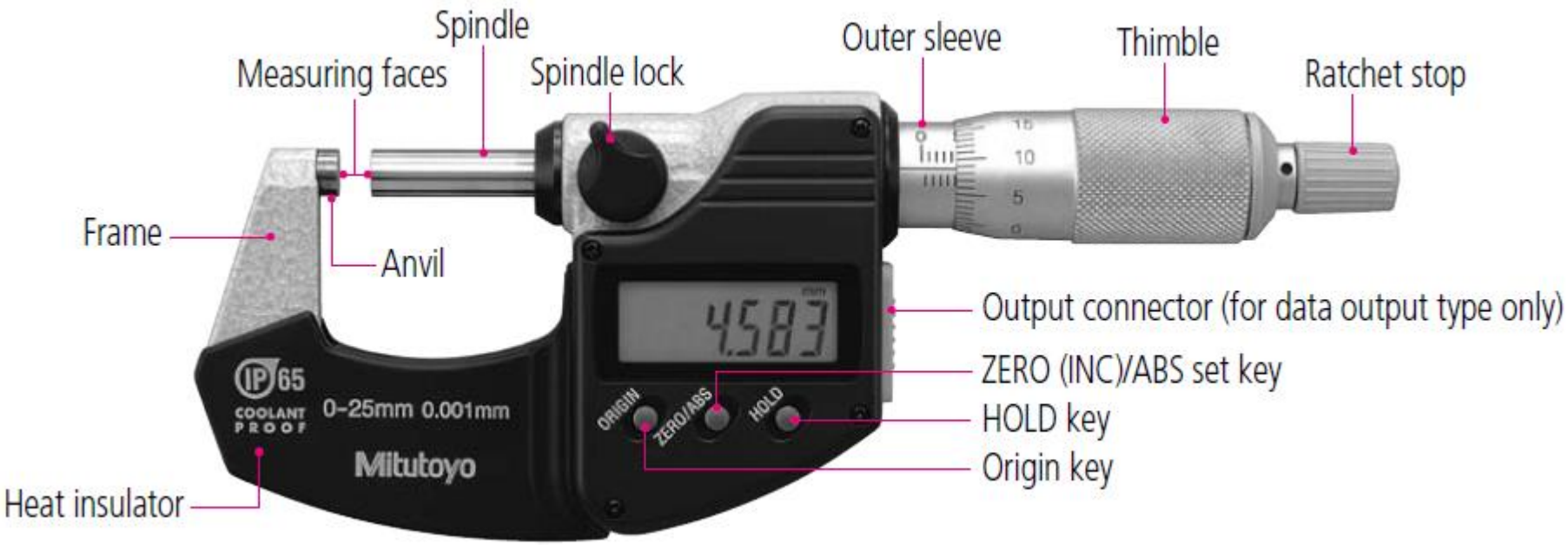
linear Measurements Instruments - Micrometers

Standard Outside Micrometer



linear Measurements Instruments - Micrometers

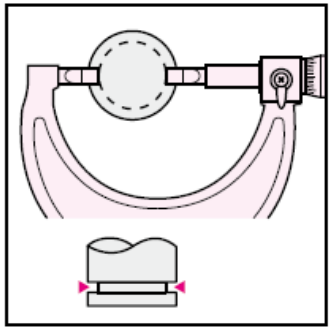
Digimatic Outside Micrometer



linear Measurements Instruments - Micrometers

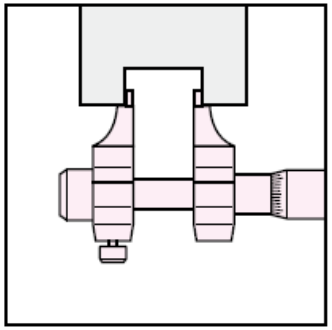
Special Purpose Micrometer Applications

Blade micrometer



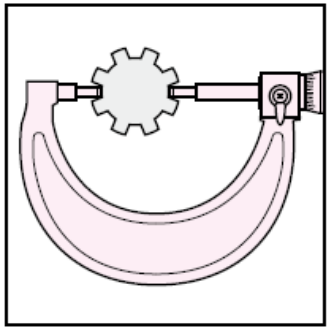
For diameter inside narrow groove measurement

Inside micrometer, caliper type



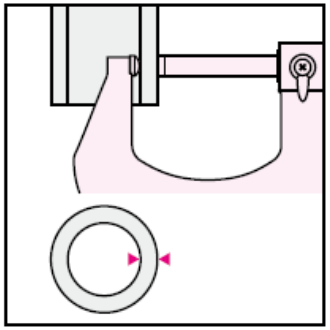
For small internal diameter, and groove width measurement

Spline micrometer



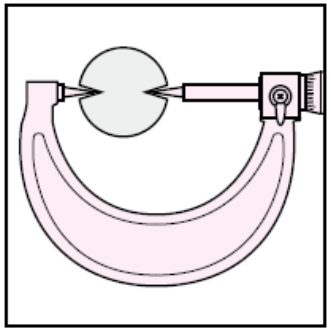
For splined shaft diameter measurement

Tube micrometer



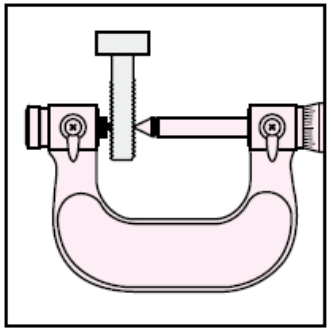
For pipe thickness measurement

Point micrometer



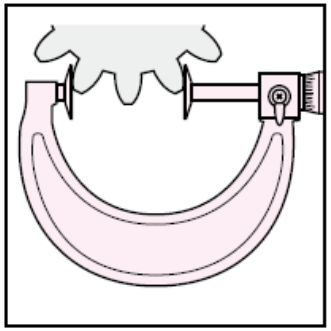
For root diameter measurement

Screw thread micrometer



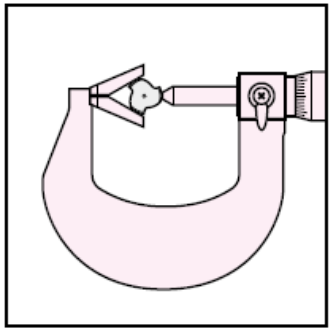
For effective thread diameter measurement

Disc type outside micrometer



For root tangent measurement on spur gears and helical gears

V-anvil micrometer

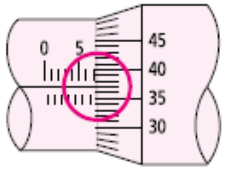


For measurement of 3- or 5-flute cutting tools

linear Measurements Instruments - Micrometers

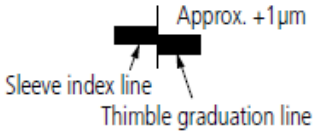
How to Read the Scale

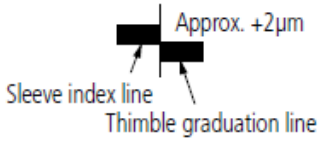
Micrometer with standard scale (graduation: 0.01mm)



Sleeve reading	7. mm
Thimble reading	+ .37mm
Micrometer reading	7.37mm

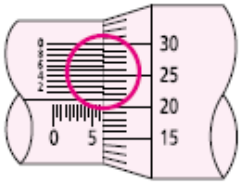
The scale can be read directly to 0.01mm, as shown above, but may also be estimated to 0.001mm when the lines are nearly coincident because the line thickness is 1/5 of the spacing between them.





Micrometer with vernier scale (graduation: 0.001mm)

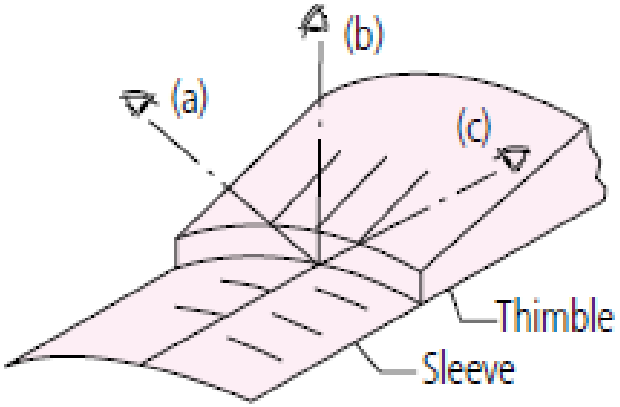
The vernier scale provided above the sleeve index line enables direct readings to be made to within 0.001mm.

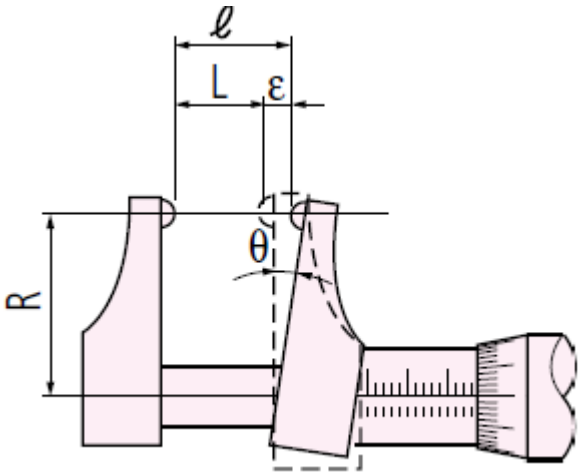


Sleeve reading	6. mm
Thimble reading	.21mm
Reading from the vernier scale marking and thimble graduation line	.003mm
Micrometer reading	6.213mm

Potential Reading Error Due to Parallax

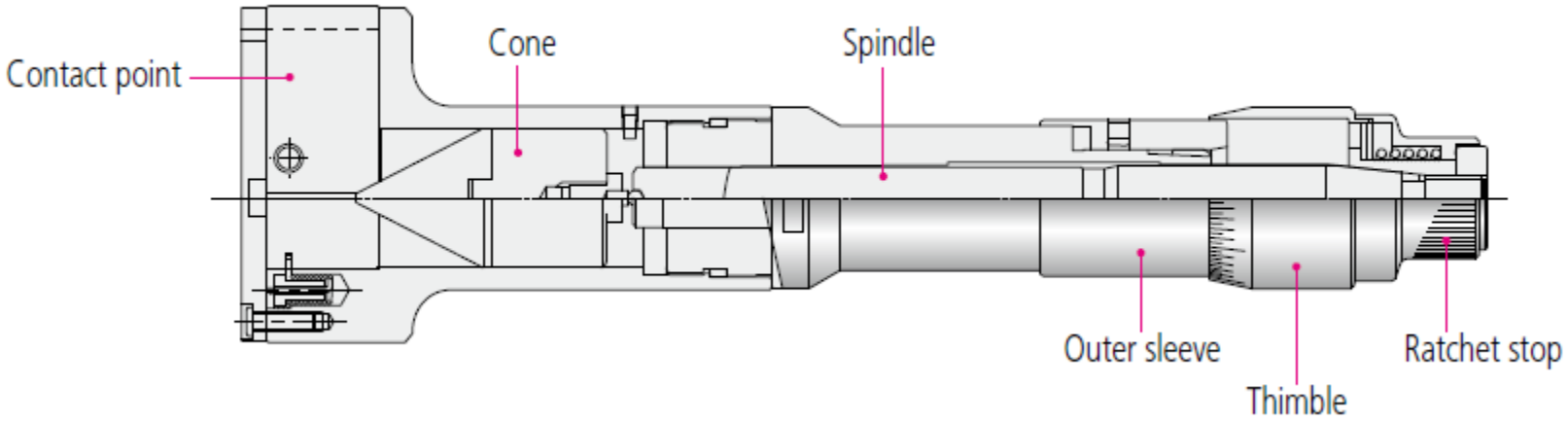
When a scale and its index line do not lie in the same plane it is possible to make a reading error due to parallax, as shown below. The viewing directions (a) and (c) will produce this error, whereas the correct reading is that seen from direction (b).





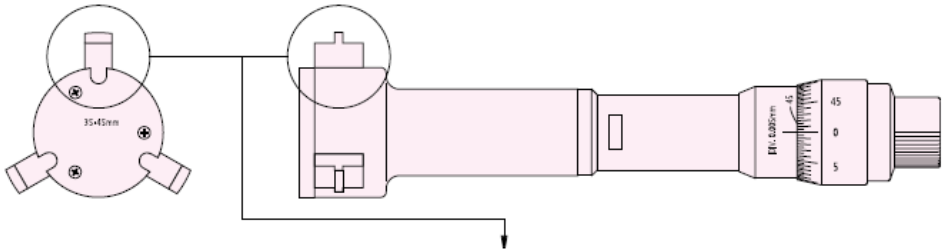
linear Measurements Instruments - Micrometers

Internal Micrometers

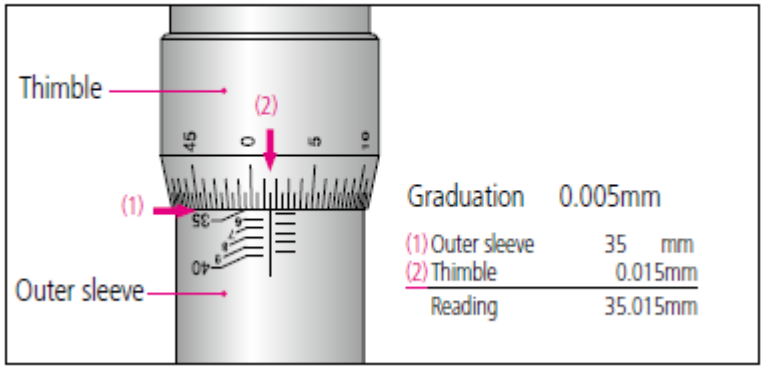


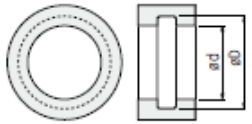
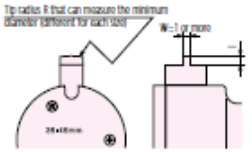
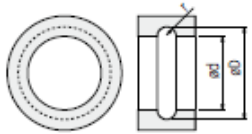
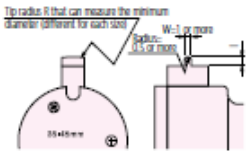
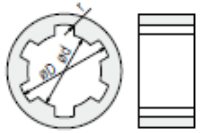
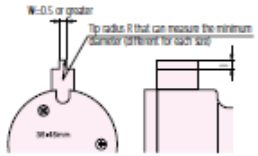
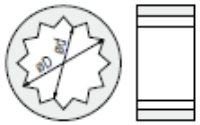
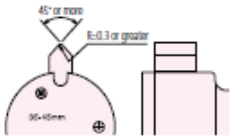
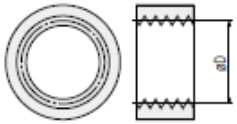
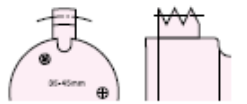
linear Measurements Instruments - Micrometers

Internal Micrometers



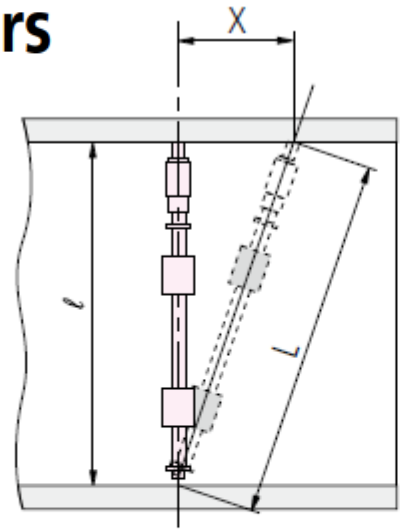
How to Read the Scale



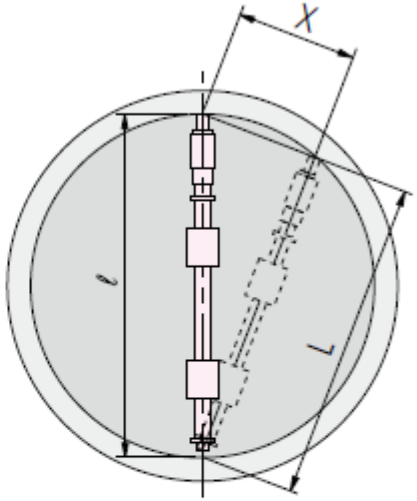
Type of feature	Workpiece profile (example)	Contact point tip profile (example)
Square groove		
Round groove		
Spline		
Serration		
Threaded hole		

Internal Micrometers

Misalignment Errors



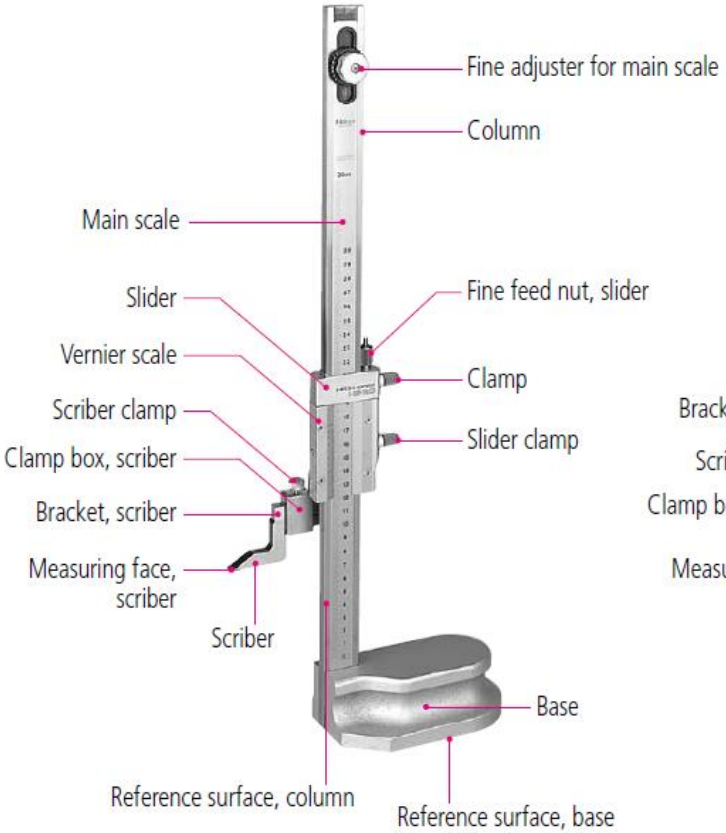
ℓ: Inside diameter to be measured
L: Length measured with axial offset X
X: Offset in axial direction
△ℓ: Error in measurement
△ℓ: $L-\ell=\sqrt{\ell^2+X^2}-\ell$



ℓ: Inside diameter to be measured
L: Length measured with radial offset X
X: Offset in radial direction
△ℓ: Error in measurement
△ℓ: $L-\ell=\sqrt{\ell^2-X^2}-\ell$

linear Measurements Instruments – Height Gages

Vernier Height Gage



Mechanical Digit Height Gage