MANUFACTURING PROCESSES:
(TA-202)

Metrology and instrumentation

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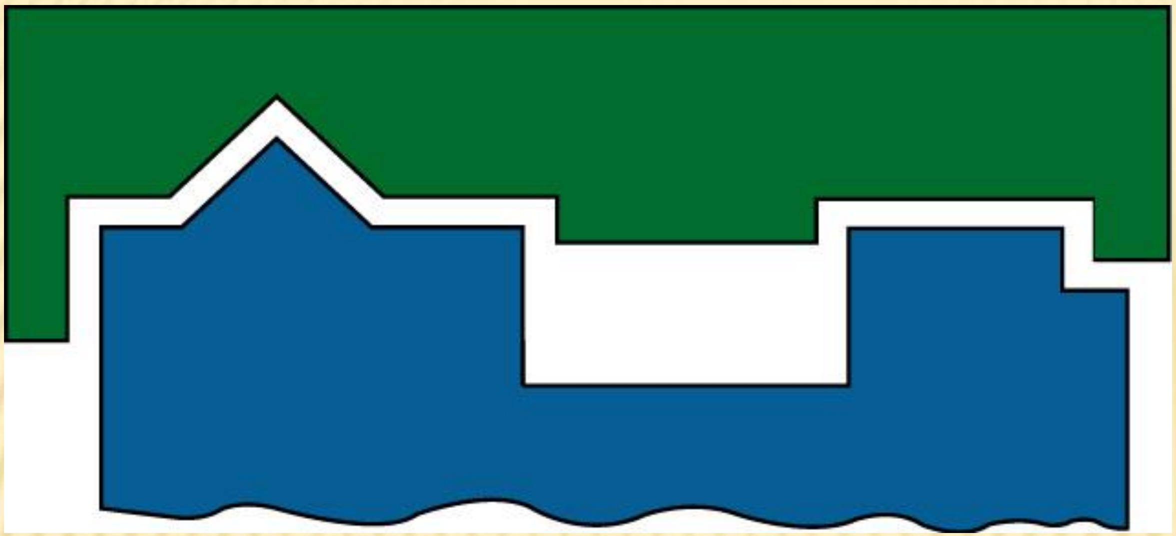
SOURCE: S. KALPAKJIAN BOOK

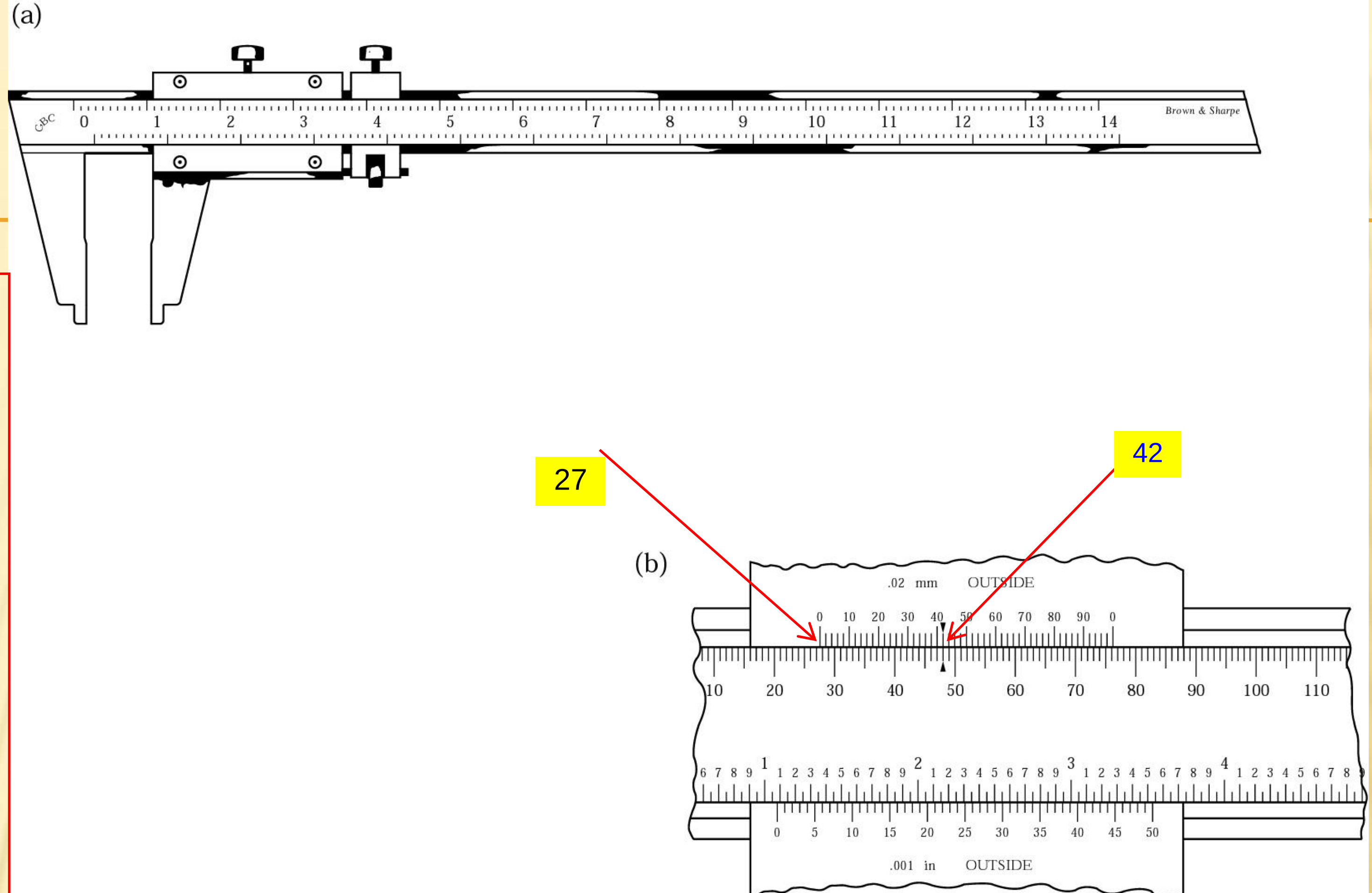
SLIDE-WAY CROSS-SECTION



Cross-section of a machine tool slide-way. The width, depth, angles, and other dimensions must be produced and measured accurately for the machine tool to function as expected.

What is Metrology?
Science of measurement.

CALIPER AND VERNIER



(a) A caliper gage with a vernier.

(b) A Vernier, reading 27.00 + 0.42 = 27.42 mm, (or 1.000 + 0.050 + 0.029 = 1.079 in.)

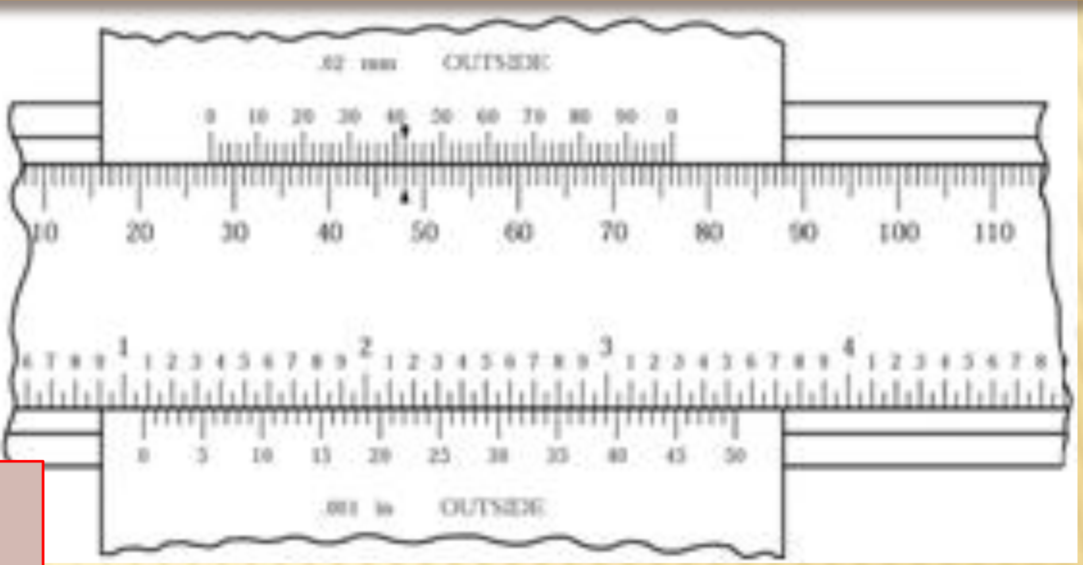
(c) We arrive at the last measurement as follows: First note that the two UPPER scales pertain to the millimeter units. We next note that the 0 (zero) mark on the upper mm scale has passed the 27 (mm) mark on the lower (mm) scale. Thus, we first record a distance of 27.00 mm.

(e) **Finally note that the marks on the two scales coincide at the number 42 (in fact 21 divisionx0.02=0.42). Each of the 50 graduations on the upper scale indicates 0.02 mm. (Given in this case but you should know how to get it). 0.02 is LEAST Count of the Vernier caliper.**

(f) **Thus, the total dimension is 27 mm+ 0.42 mm. = 27.42 mm.**

HOW TO CALCULATE LEAST COUNT?

HOW TO CALCULATE LEAST COUNT OF A VERNIER CALIPER / MICROMETER?



One small division on main scale = 1 mm

No. of divisions on Vernier scale = 50

50 Vernier scale divisions = 49 divisions on main scale (or 49 mm)

Each division on Vernier scale = (49/50) mm

Difference between one main scale division and one Vernier scale division = 1 - (49/50) mm

= (50 - 49)/50

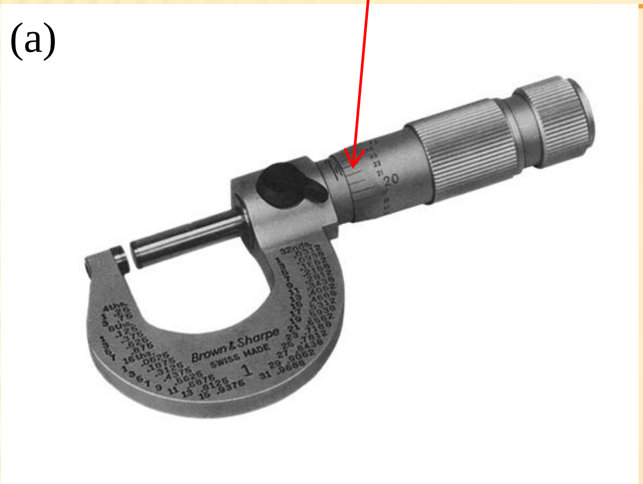
= (1/50) mm

= 0.02 mm

Least Count = 0.02 mm

ANALOG AND DIGITAL MICROMETERS

(a)

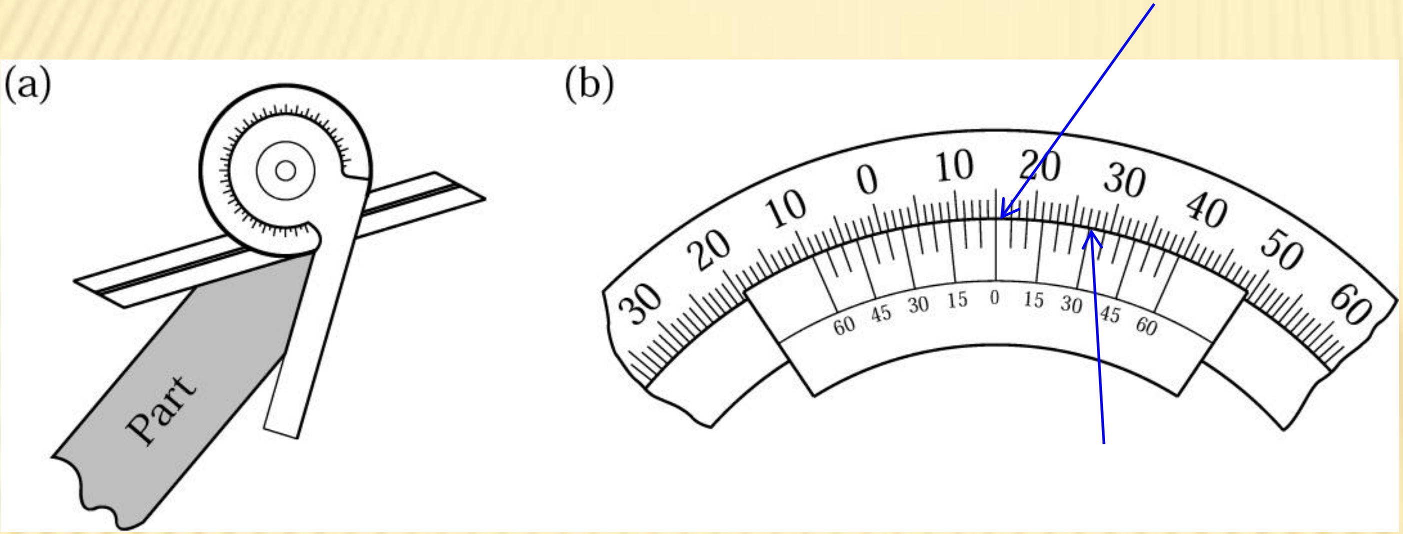


(c)

- (a) A micrometer being used to measure the diameter of round rods.
- (b) Vernier on the sleeve and thimble of a micrometer.
- (c) These dimensions are read in a manner similar to that described Vernier Caliper.

1. A digital micrometer with a range of 0-1 in. (0-25 mm) and a resolution of 0.00005 in. (0.001 mm = 1µm).
2. Note how much easier it is to read dimensions on this instrument than on the analog micrometer shown in (a).
3. However, such instruments should be handled carefully.

ANGLE-MEASURING INSTRUMENTS

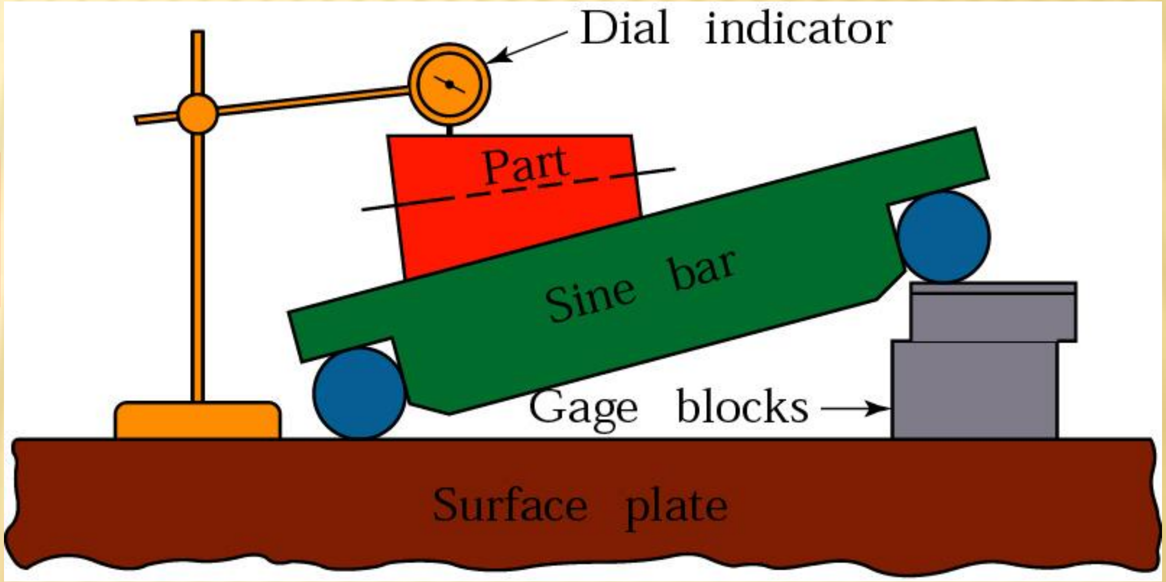


(A) SCHEMATIC ILLUSTRATION OF A BEVEL PROTRACTOR FOR MEASURING ANGLES. (B) VERNIER FOR ANGULAR MEASUREMENT, INDICATING 14° 30´.

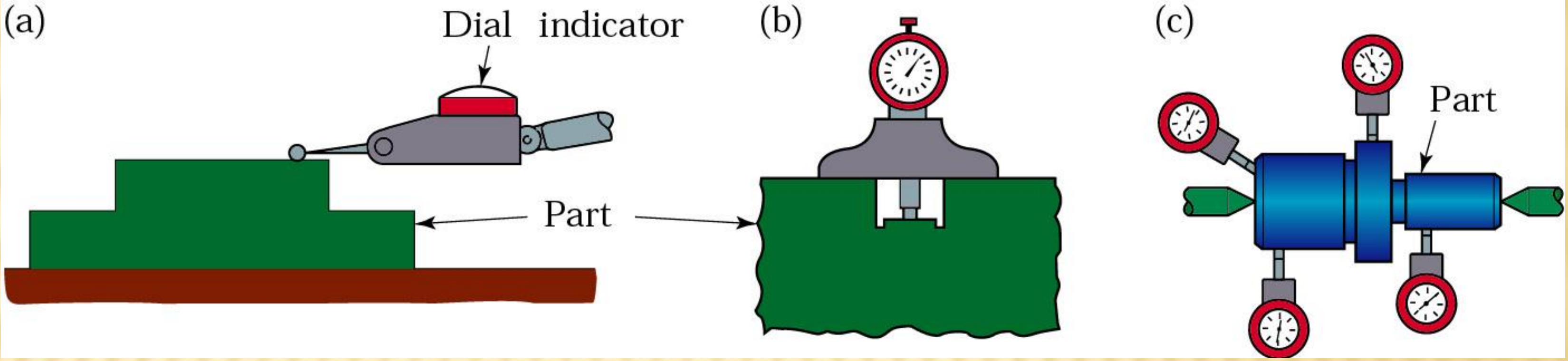
SETUP SHOWING THE USE OF A SINE BAR FOR PRECISION MEASUREMENT OF WORKPIECE ANGLES.

Gage Block Will Give The Height And Center To Center Distance Is Known In Advance.

You Can Find Angle Of Taper Of The Given Block In The Lab.



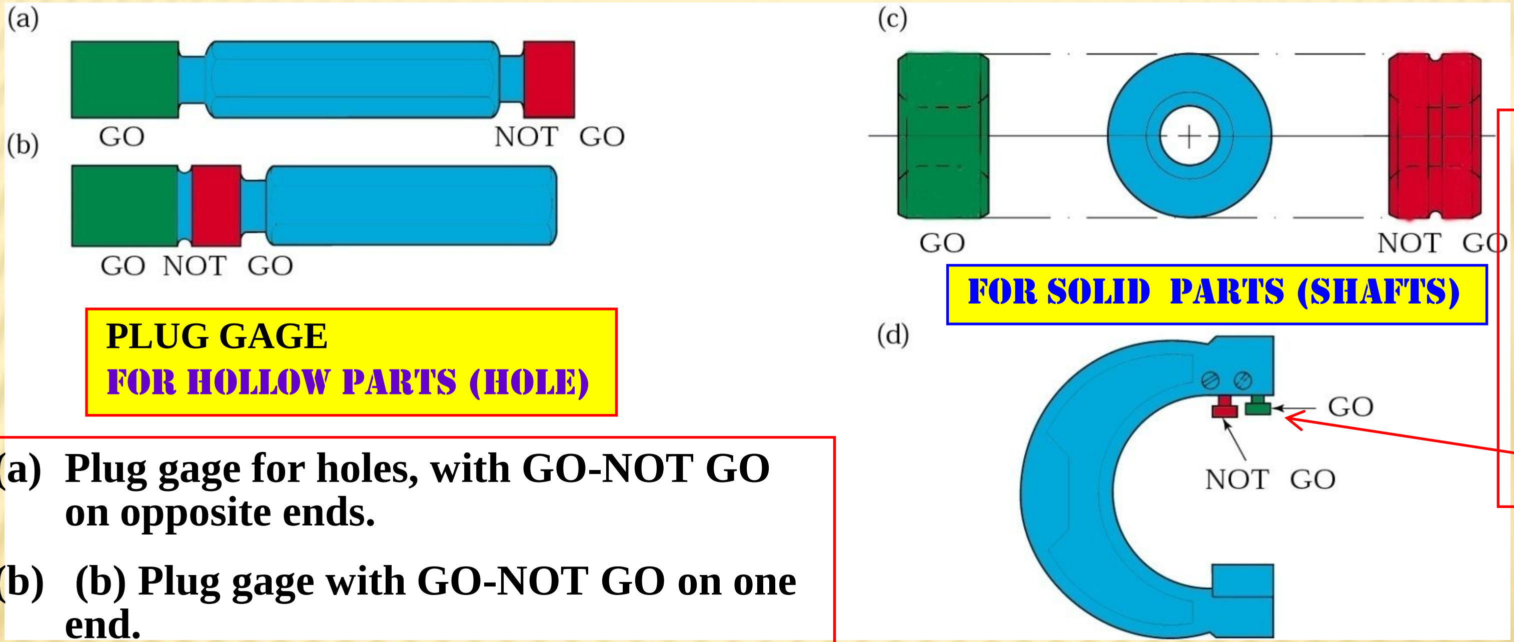
DIAL INDICATORS



Different applications of a Dial Indicator (a) Multi dimensions measurement, (b) Depth Measurement, © Roundness measurement.

GAGES

MASS PRODUCTION: THOUSANDS OF PARTS ARE MEASURED EVERYDAY FOR REJECTION / ACCEPTANCE OF PARTS.
NOT FEASIBLE TO MEASURE DIMENSIONS SAY, (14 +0.03) AND (14-0.03) MM.
USE TWO (GO AND NO GO) GAUGES. INSPECTION BECOMES VERY FAST.



PLUG GAGE
FOR HOLLOW PARTS (HOLE)

FOR SOLID PARTS (SHAFTS)

(a) Plug gage for holes, with GO-NOT GO on opposite ends.

(b) (b) Plug gage with GO-NOT GO on one end.

(c) Plain ring gages for gagin round rods. Note the difference in knurled surfaces to identify the two gages.

(d) Snap gage with adjustable anvils.

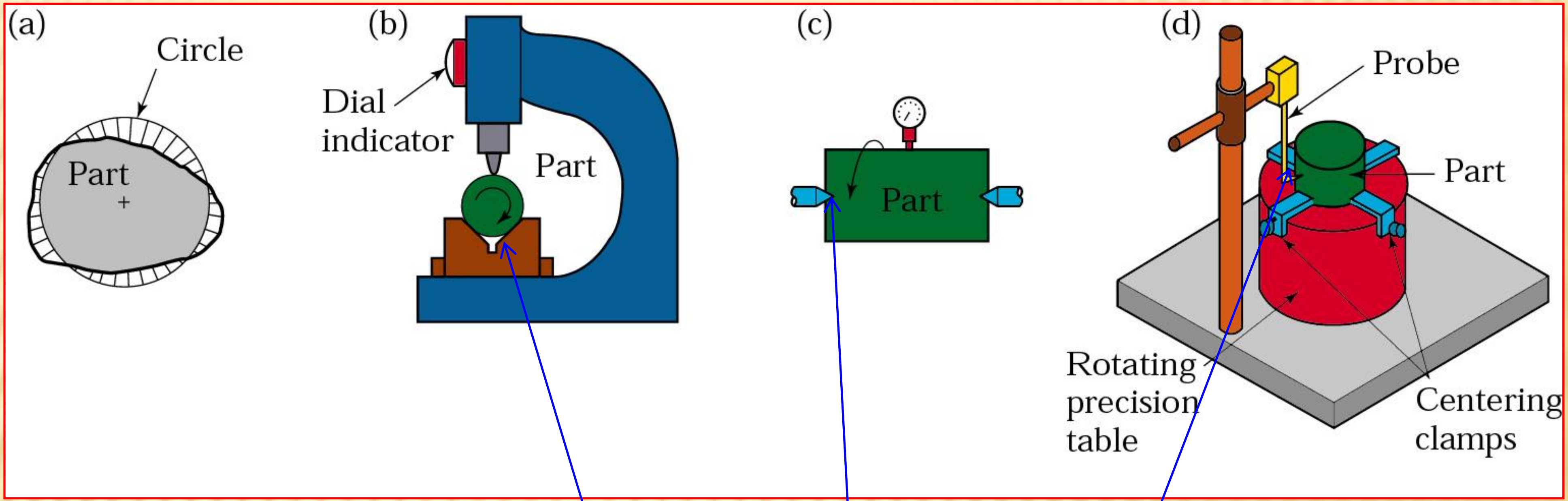
ELECTRONIC GAGES

An electronic gage for measuring bore diameters. The measuring head is equipped with three carbide-tipped steel pins for wear resistance. The LED display reds 29.158 mm. *Courtesy of* TESA SA.

An electronic vertical length mesauring instrument, with a sensitivity of 1 μm.

Courtesy of TESA SA.

MEASURING ROUNDNESS



(A) SCHEMATIC ILLUSTRATION OF "OUT OF ROUNDNESS" (EXAGGERATED). MEASURING ROUNDNESS USING

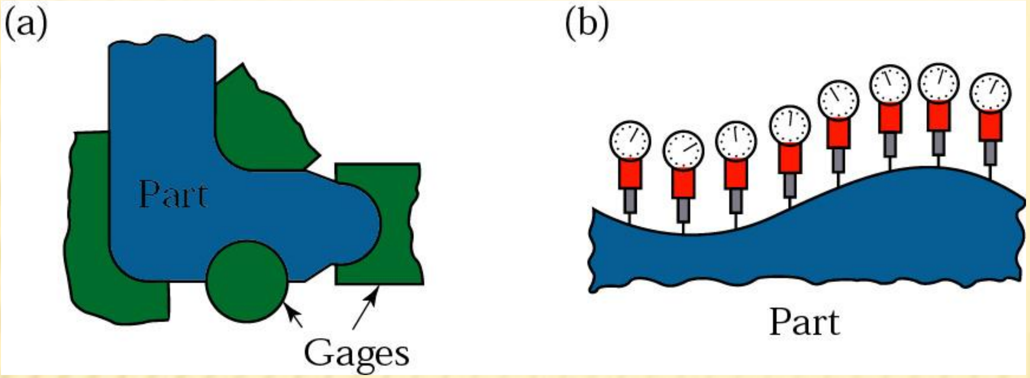
(B) V-BLOCK AND DIAL INDICATOR,

(C) PART SUPPORTED ON CENTERS AND ROTATED, AND

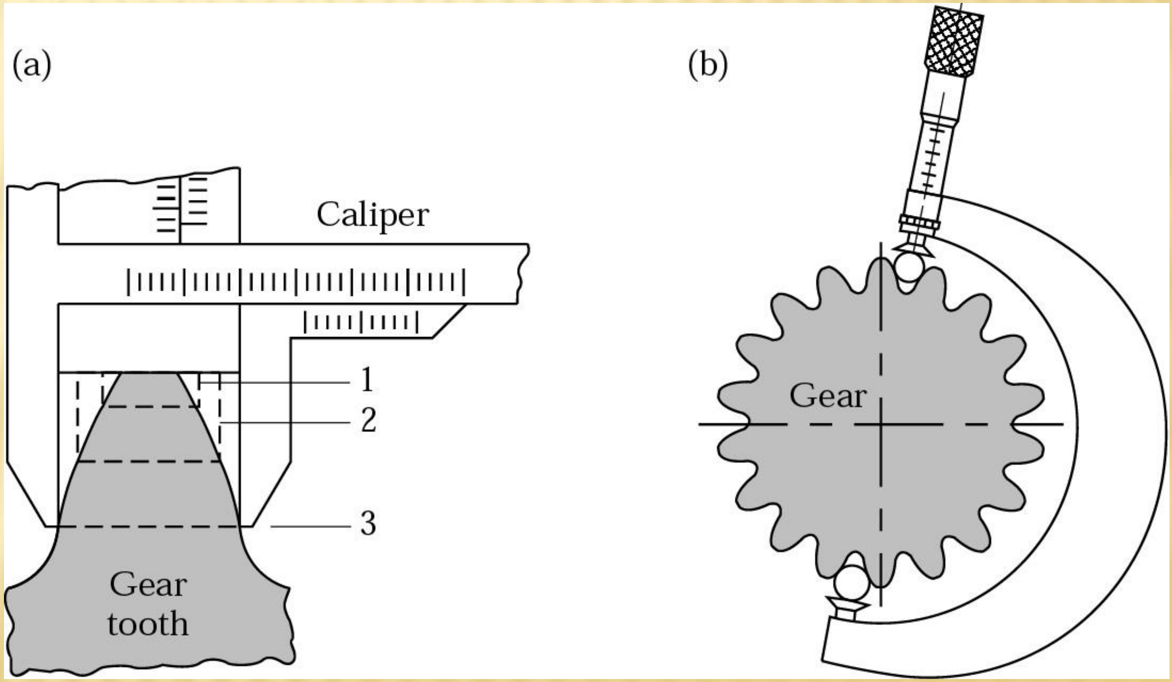
(D) CIRCULAR TRACING, WITH PART BEING ROTATED ON A VERTICAL AXIS.

***(E) SOURCE*: AFTER F. T. FARAGO.**

MEASURING PROFILES



Measuring profiles with (a) radius gages and (b) dial indicators.



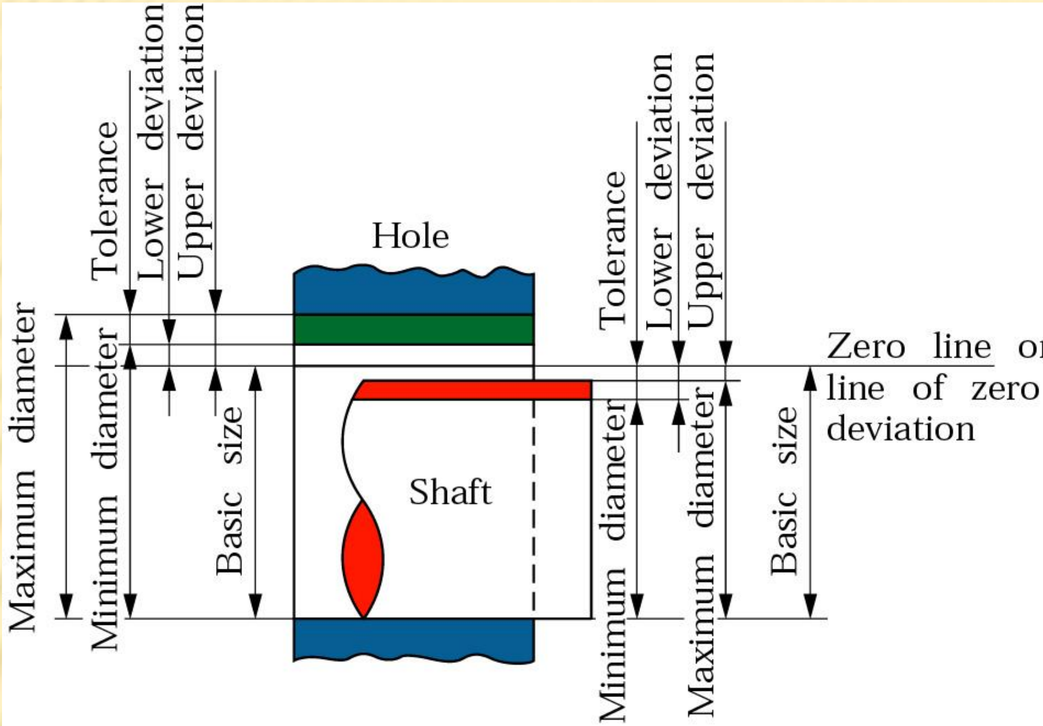
Measuring gear tooth profiles with (a) gear-tooth caliper and (b) Ball and micrometer.

HORIZONTAL-BEAM CONTOUR PROJECTOR

A bench model horizontal-beam contour projector with a 16 in.-diameter screen with 150-W tungsten halogen illumination.

Courtesy of **L. S. Starrett Company, Precision Optical Division**.

TOLERANCE CONTROL



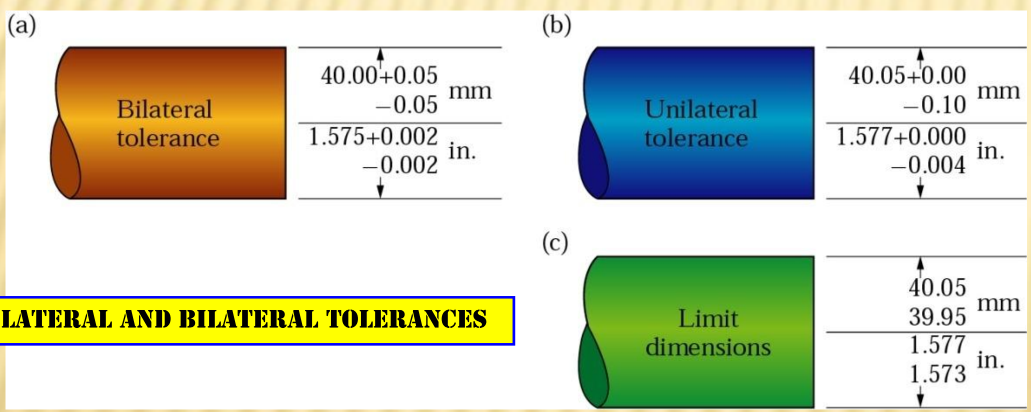
BASIC SIZE, DEVIATION, AND TOLERANCE ON A SHAFT AND A HOLE, ACCORDING TO THE ISO SYSTEM.

BASIC SIZE: The Size With Reference To Which The Limits Of Size Are Fixed.

ZERO LINE: in graphical representation of limits and fits, a straight line to which the deviations are referred.

The zero line is the line of zero deviation and represents the basic size.

When the zero line is drawn horizontally, positive deviations are shown above and negative deviations below.



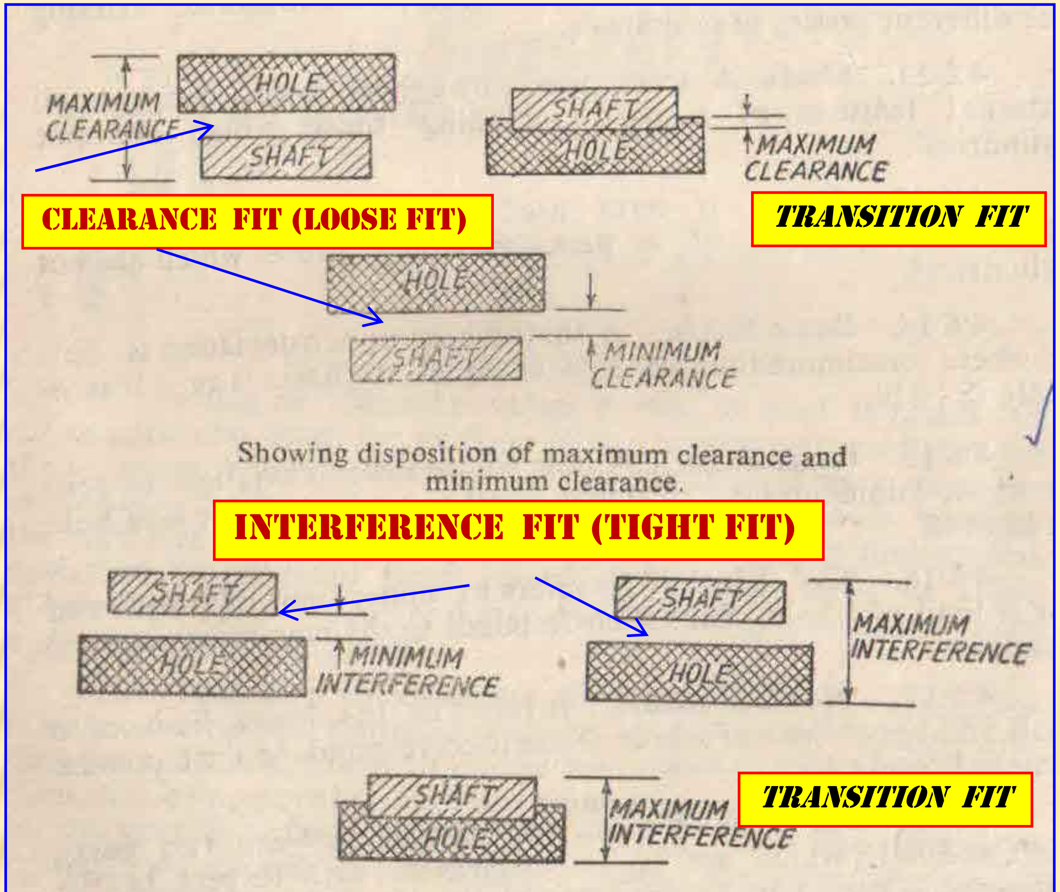
UNILATERAL AND BILATERAL TOLERANCES

DEVIATION: The Algebraic Difference Between A Size (Actual, Maximum Etc.) And The Corresponding Basic Size.

UPPER DEVIATION: The Algebraic Difference Between The Maximum Limit Of Size And The Corresponding Basic Size. It Is A Positive Quantity When The Maximum Limit Of Size Is Greater Than The Basic Size And A Negative Quantity When The Maximum Limit Of Size Is Less Than The Basic Size. It Is Designated By *ES* For A Hole And *es* For A Shaft.

LOWER DEVIATION: THe Algebraic Difference Between The Minimum Limit Of Size And The Corresponding Basic Size. It Is A Positive Quantity When The Minimum Limit Of Size Is Greater Than The Basic Size And A Negative Quantity When The Minimum Limit Of Size Is Less Than The Basic Size. It Is Designated By *EI* For A Hole And *ei* For A Shaft.

Various methods of assigning tolerances on a shaft. *Source*: L. E. Doyle.



Showing disposition of maximum interference and minimum interference

BASIC SIZE OR ZERO LINE, DEVIATION, AND TOLERANCE ON A SHAFT, ACCORDING TO THE ISO SYSTEM.

CLEARANCE FIT (LOOSE FIT)

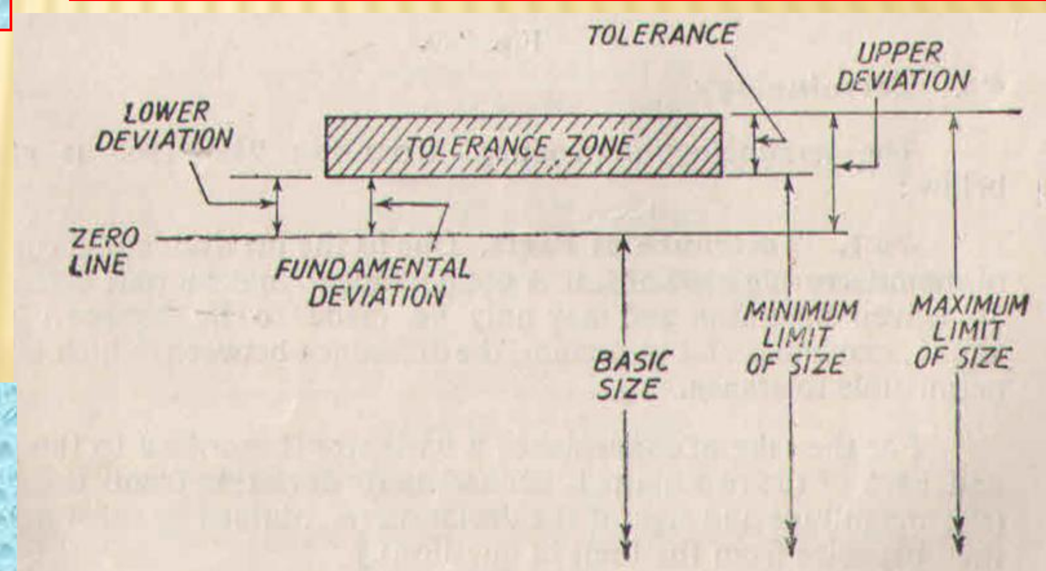
INTERFERENCE FIT (TIGHT FIT)

TRANSITION FIT

LIMITS OF SIZE: The Two Extreme Permissible Sizes Between Which The Actual Size Is Contained.

MINIMUM LIMITS OF SIZE: The Smaller One Of The Two Limits Of Size Is Called The Maximum Limit.

MAXIMUM LIMITS OF SIZE: The Greater Of The Two Is Called The Maximum Limit.



TOLERANCE

Tolerance Is Equal To The Algebraivc Difference Between The Upper And Lower Deviations And Has An Absolute Value **Without Sign**. In The Context Of This Terminology

For Limits And Fits, The Differnce Between The Maximum Limit Of Size And Minimum Linit Of Size Is Called The Tolerance

TRANSITION FIT : IN REAL LIFE THERE IS NOTHING LIKE TRANSITION FIT. IT WILL BE EITHER CLEARANCE FIT OR INTERFERENCE FIT DEPENDING UPON THE FINAL DIMENSIONS OF MALE AND FEMALE PARTS.

TYPES OF MEASUREMENT AND INSTRUMENTS USED

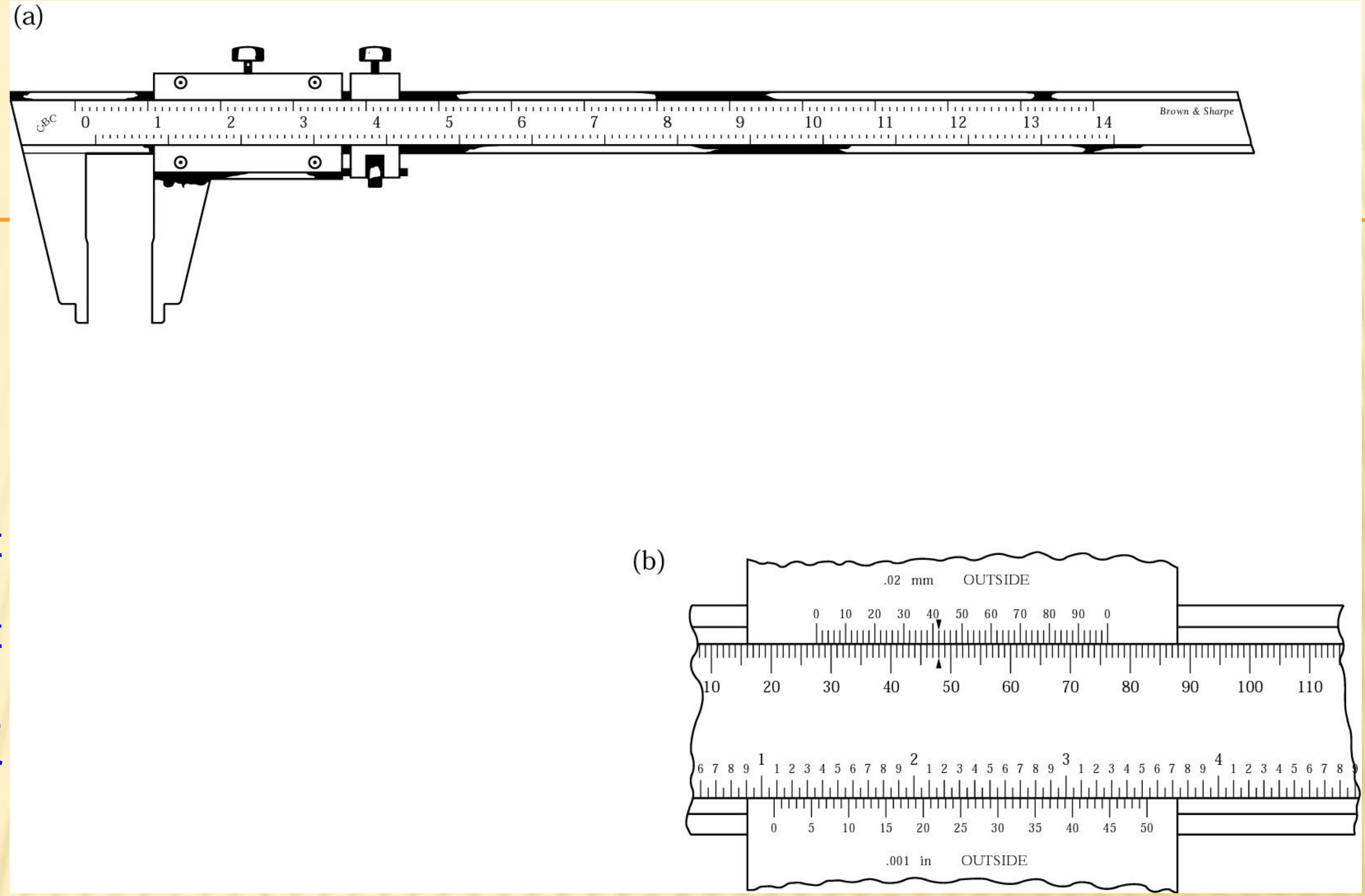
TABLE 35.1

Measurement	Instrument	Sensitivity μm	Sensitivity μin.
Linear	Steel rule	0.5 mm	1/64 in.
	Vernier caliper	25	1000
	Micrometer, with vernier	2.5	100
	Diffraction grating	1	40
Angle	Bevel protractor, with vernier	5 min	
	Sine bar		
Comparative length	Dial indicator	1	40
	Electronic gage	0.1	4
	Gage blocks	0.05	2
Straightness	Autocollimator	2.5	100
	Transit	0.2 mm/m	0.002 in./ft
	Laser beam	2.5	100
Flatness	Interferometry	0.03	1
Roundness	Dial indicator Circular tracing	0.03	1
Profile	Radius or fillet gage		
	Dial indicator	1	40
	Optical comparator	125	5000
	Coordinate measuring machines	0.25	10
GO-NOT GO	Plug gage		
	Ring gage		
	Snap gage		
Microscopes	Toolmaker’s	2.5	100
	Light section	1	40
	Scanning electron	0.001	0.04
	Laser scan	0.1	5

THANK YOU

SUPPLIMENTARY MATERIAL

CALIPER AND VERNIER



(a) A caliper gage with a vernier.

(b) A Vernier, reading 27.00 + 0.42 = 27.42 mm, (or 1.000 + 0.050 + 0.029 = 1.079 in.)

(c) We arrive at the last measurement as follows: First note that the two lowest scales pertain to the inch units. We next note that the 0 (zero) mark on the lower scale has passed the 1-in. mark on the upper scale. Thus, we first record a distance of 1.000 in.

(d) **Next we note that the 0 mark has also passed the first (shorter) mark on the upper scale. Noting that the 1-in. distance on the upper scale is divided into 20 segments, we have passed a distance of 0.050 in (=1/20).**

(e) Finally note that the marks on the two scales coincide at the number 29. Each of the 50 graduations on the lower scale indicates 0.001 in. (Given in this case but you should know how to get it), so we also have 0.029 in (29x0.001).

(f) Thus, the total dimension is 1.000 in. + 0.050 in. + 0.029 in. = 1.079 in.

COORDINATE MEASURING MACHINE

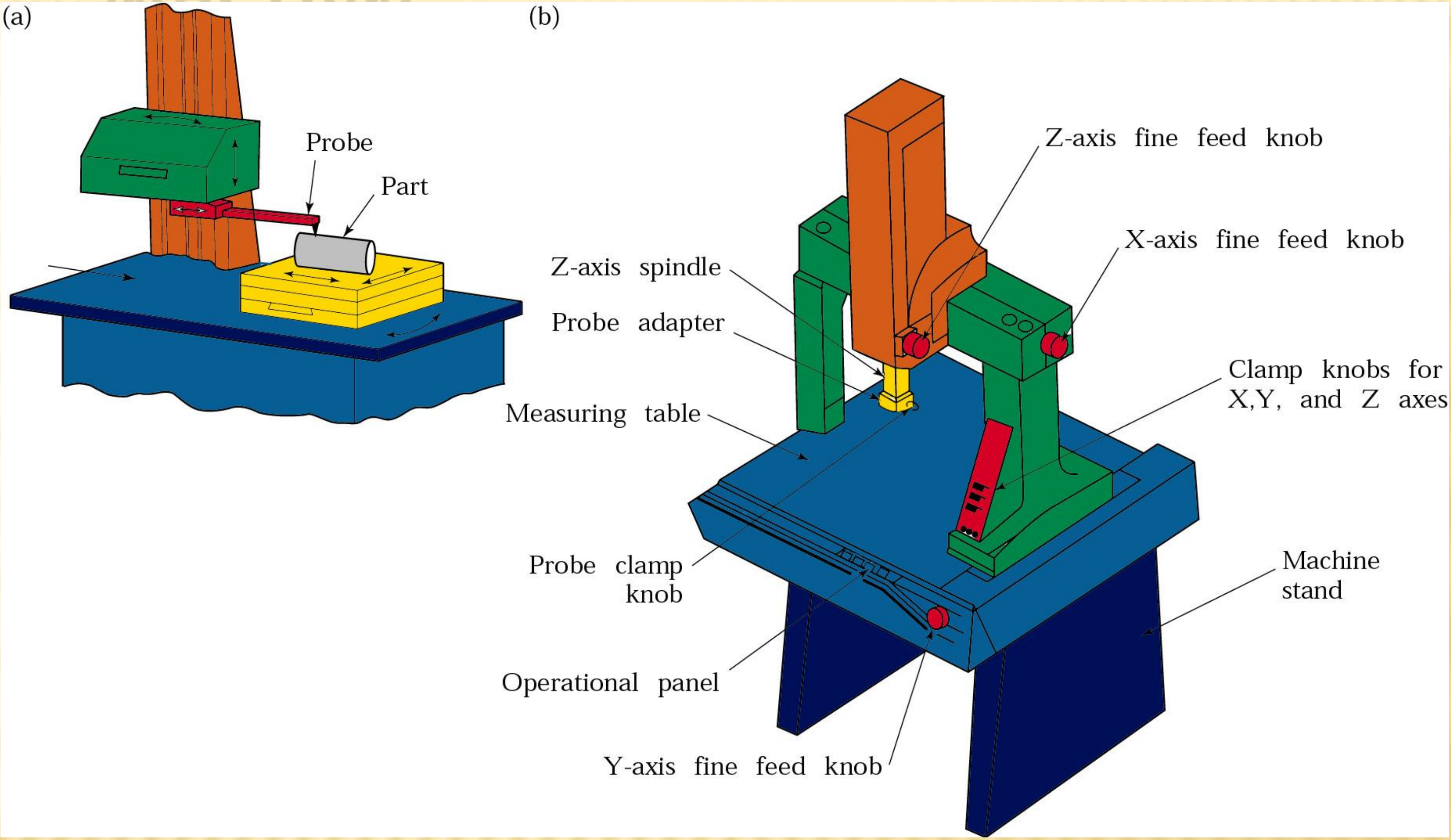


Figure 35.16 (a) Schematic illustration of one type of coordinate measuring machine. (b) Components of another type of coordinate measuring machine. These machines are available in various sizes and levels of automation and with a variety of probes (attached to the probe adapter), and are capable of measuring several features of a part. *Source*: Mitutoyo Corp.

COORDINATE MEASURING MACHINE

Figure 35.17 A coordinate measuring machine. Brown & Sharpe Manufacturing.