Measurement with Graduated Scales and Scaled Instruments

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Measurement with Graduated Scales and Scaled Instruments

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2. The Role of Error
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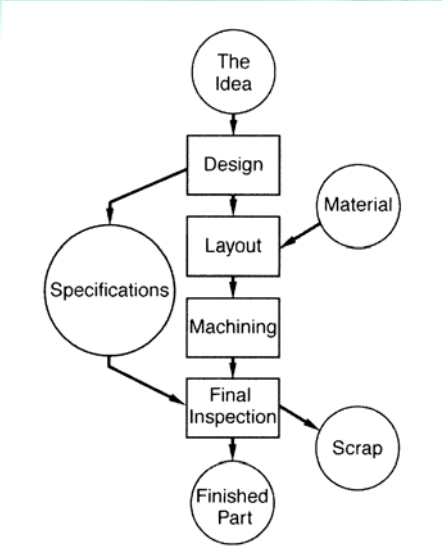
Measurement with Graduated Scales and Scaled Instruments



The Steel Rule

There is a difference between a scale and a rule: a scale is graduated in proportion to a unit of length; a rule is the unit of length, its divisions and its multiples. One unit on a scale may represent one mile in the “real world”; and a scale allows engineers and draftspeople to depict small or large items at a convenient size, not actual size. A 6-inch rule, on the other hand, represents 6 one-inch divisions (multiples of one inch), 12 half-inch divisions, 24 quarter-inch divisions, and so forth. Although they vary in some features, steel rules are all narrow steel strips with one set or more of graduated marks. These marks are referred to as a scale. Steel rules represent lengths from a fraction of an inch to several feet, but the most popular size of rule still seems to be one that you can fit in your pocket.

The Steel Rule

The number of subdivisions of a unit of length on a rule is called its discrimination, and the discrimination of rules is as varied as rules themselves.

When you measure with a rule, you use the interchange method of measurement because you observe both ends of the part feature at the same time. Of course, some people argue that you are using the displacement method because your eye "displaces" from end to end. Whichever method of measurement we are actually using, the rule you are using is the standard for measurement. You also read the measurement directly from the rule, so measuring with a graduated standard or rule is commonly called direct measurement.

The Steel Rule

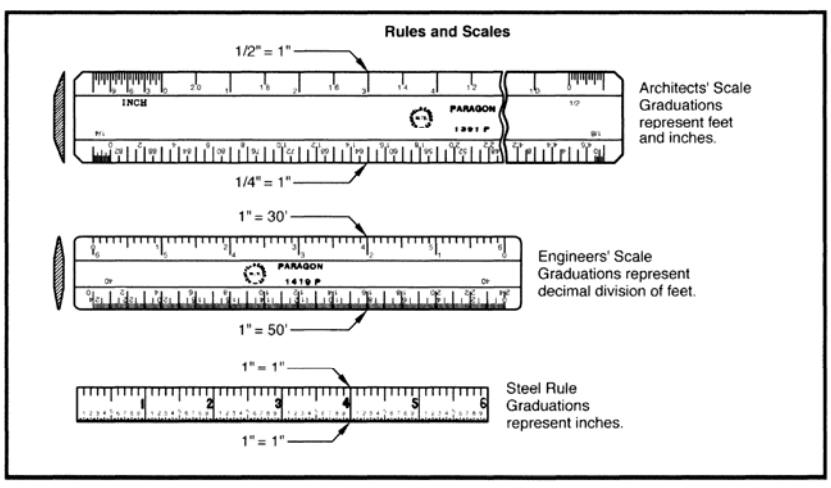


FIGURE 5–4 The architects' scale is read in feet and inches, the engineers' in decimals of feet, but the machinists' steel rule reads directly in units of length. These may be in either SI (metric) units or English and may be in either decimals or fractions and decimals for English.

The Steel Rule

The Steel Rule

You **must** consider three factors when using a steel rule:
Which style of rule will do the best job
Which measurement divisions (scale) should be used
Which method of holding both rule and part allows us to obtain the most precise measurement

The Steel Rule

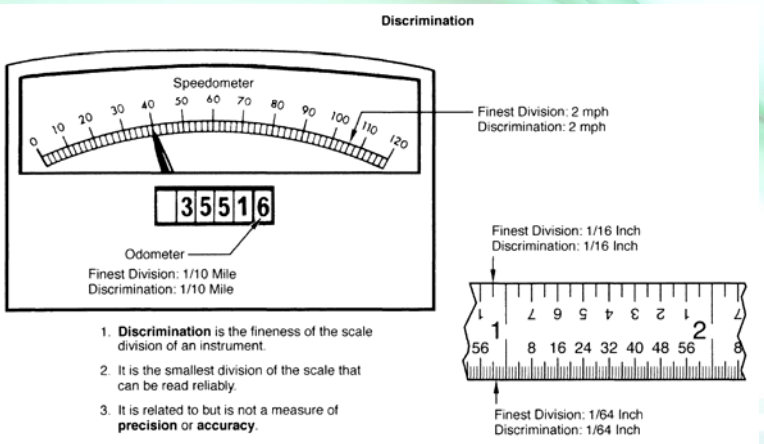


FIGURE 5–5 Anyone who has argued with a police officer knows that the assumed discrimination of the speedometer is not considered proof of its accuracy.

The Steel Rule

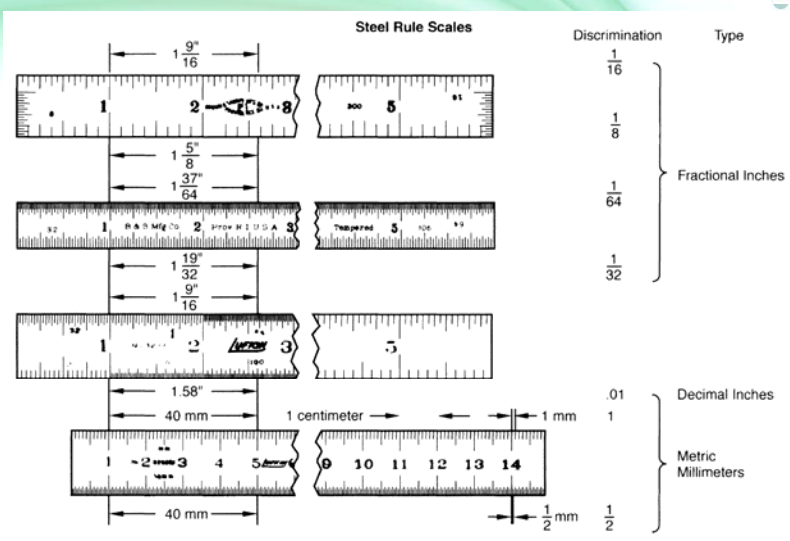


FIGURE 5–6 Many scales are available. The four scales shown above are the most popular in the United States. The decimal-inch is standard in many plants.

The Steel Rule

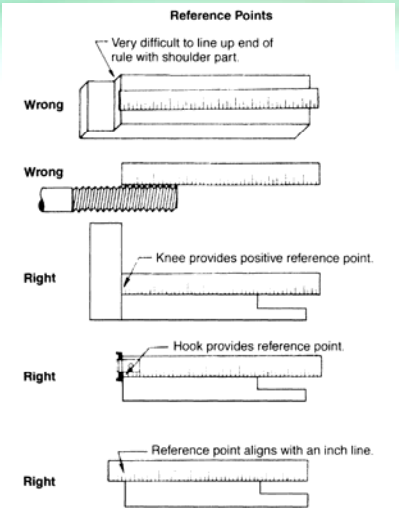


FIGURE 5–7 The right way to use a rule is usually the easiest, fastest, and most reliable.

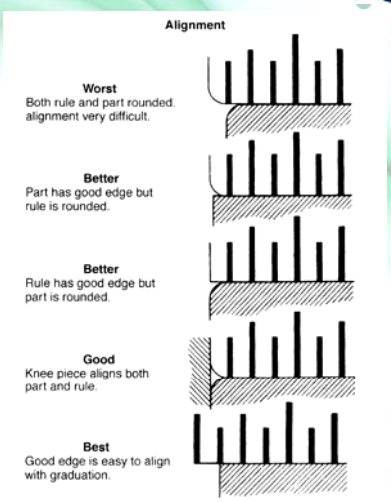


FIGURE 5–8 Use of the end of a rule invites error. Examination with a magnifying glass will usually disclose wear.

The Role of Error

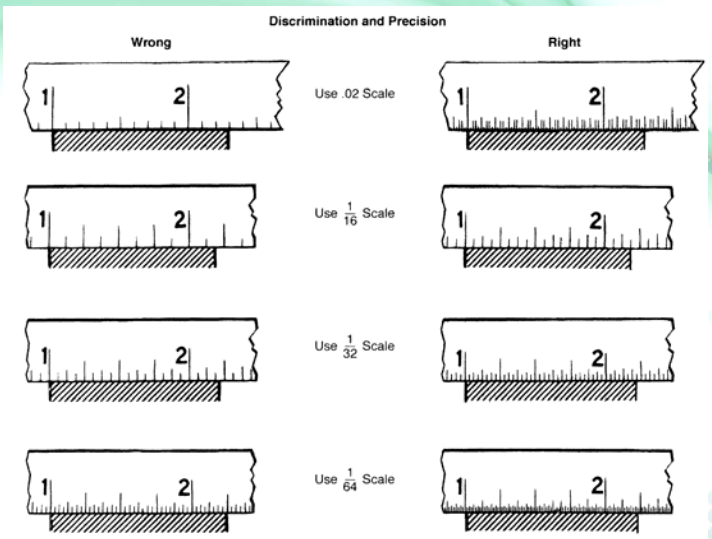


FIGURE 5–10 The only excuse for not using an instrument of the proper discrimination is not having one. Unfortunately, this happens often and carefully considered compromises must be made.

The Role of Error

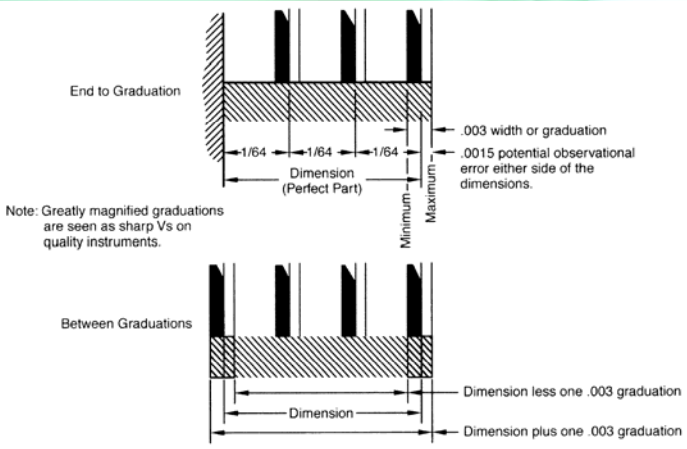


FIGURE 5–11 The maximum observational error that can be caused by the graduation widths is one-half graduation for an end setting, and one graduation for a setting between two graduations. With decimal-inch scales, the margin of safety is greater because 0.02 in. is approximately 28 percent wider than 1/64 in.

The Role of Error

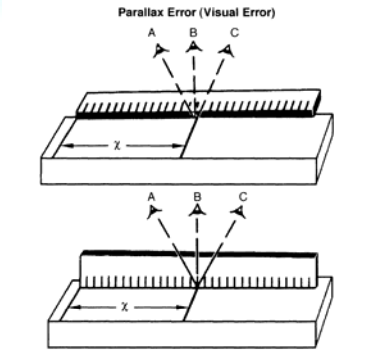


FIGURE 5–12 There are many different types of observational or visual errors. One that must be recognized apart from the other visual errors is parallax error. It is minimized by having the line of measurement of the rule as close as possible to the feature being measured.

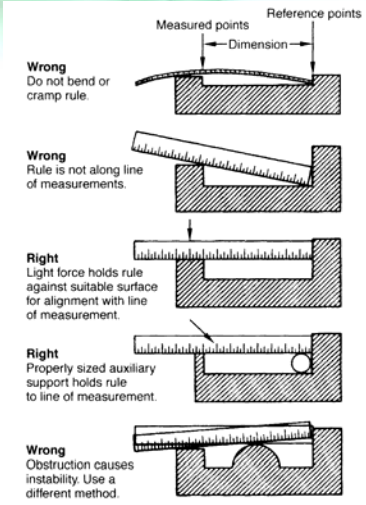


FIGURE 5–13 These potential errors are exaggerated. In practice, they may be much less obvious.

Scaled Instruments

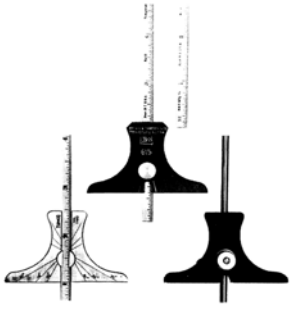


FIGURE 5–16 Types of depth gages. *(Courtesy of Scheerr-Turnico, Inc. and Brown & Sharpe Mfg. Co.)*

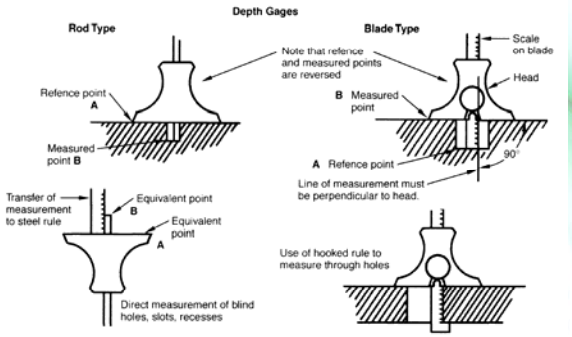


FIGURE 5–17 The depth gage is frequently used to check the progress when machining holes and recesses. When close to the finished size a more precise instrument is substituted.

Scaled Instruments

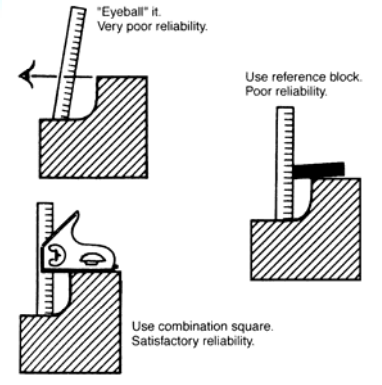


FIGURE 5–18 A combination square improves reliability.

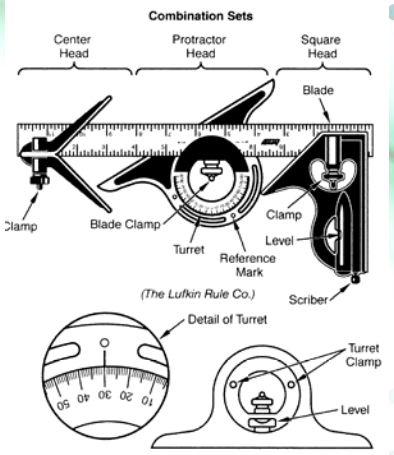


FIGURE 5–19 The steel rule and square head are called a combination square. Adding the center head and protractor head changes the name to combination set.

Scaled Instruments

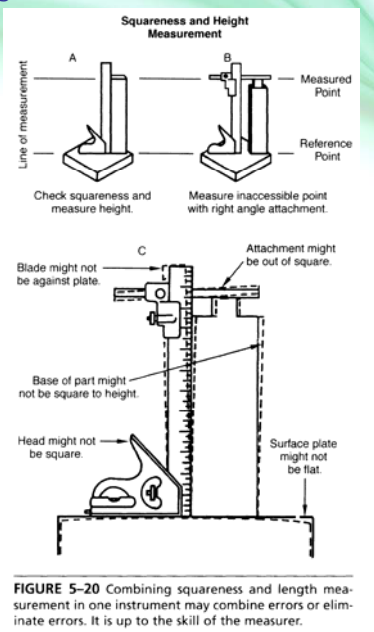


FIGURE 5–20 Combining squareness and length measurement in one instrument may combine errors or eliminate errors. It is up to the skill of the measurer.

Scaled Instruments

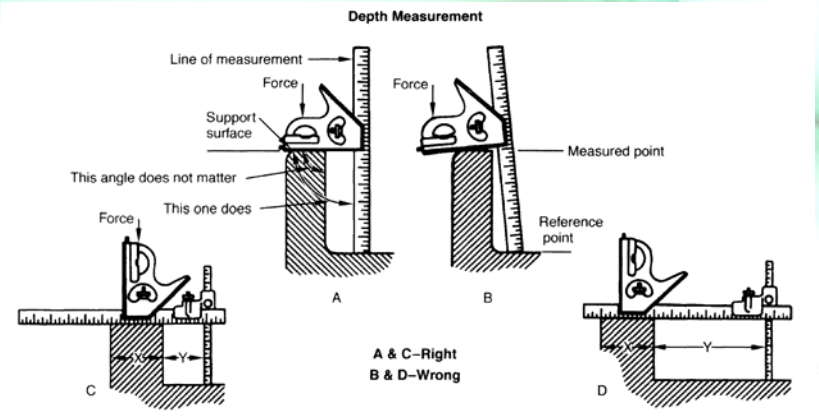


FIGURE 5–21 The combination square can be used like a depth gage. Being larger, it magnifies its range and the errors. Overhang is always a problem.

Scaled Instruments

FIGURE 5–22 The protractor head with sliding blade forms a versatile instrument for the measurement of angles.

Scaled Instruments

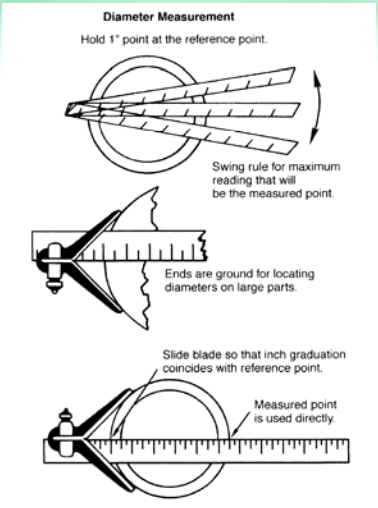


FIGURE 5–23 The center head speeds the measurement of diameters and improves reliability.

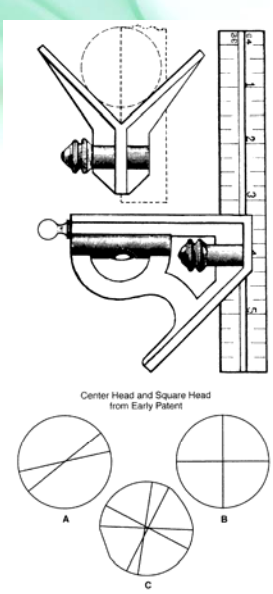


FIGURE 5–24 The center head was considered early in the development of the combination square by L.S. Starrett as the patent drawing shows. In the circles, B would be a more reliable center than A, whereas C is an average for an irregular shaft.

Scaled Instruments

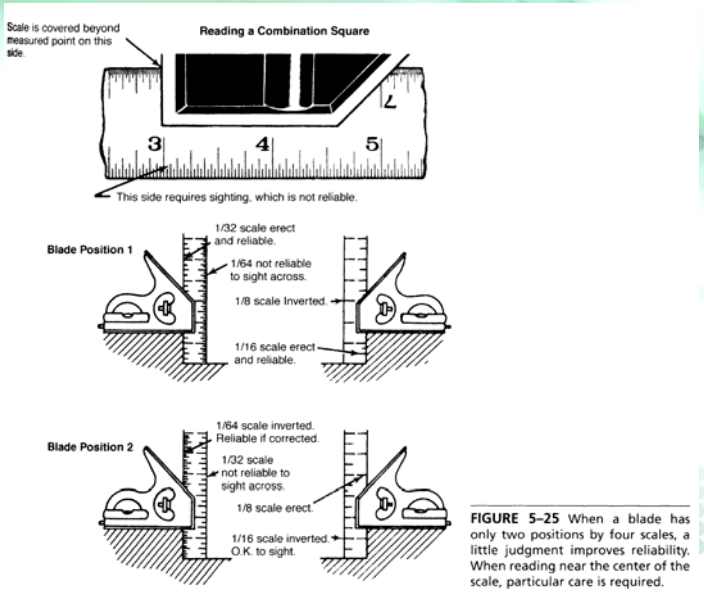


FIGURE 5–25 When a blade has only two positions by four scales, a little judgment improves reliability. When reading near the center of the scale, particular care is required.

Scaled Instruments

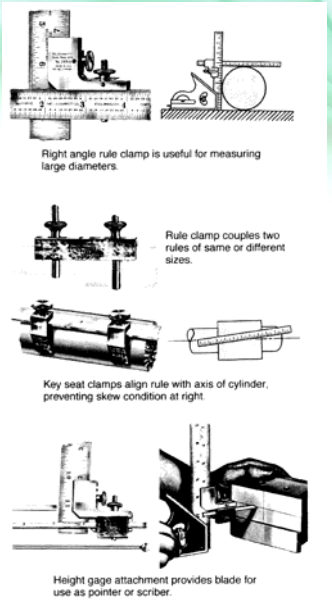


FIGURE 5–26 Use attachments when their added convenience improves reliability more than their added chance for errors decreases it. *(Courtesy of the L.S. Starrett Co.)*

Calipers: The Original Transfer Instruments

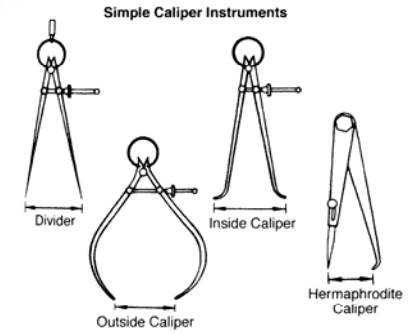


FIGURE 5–28 These are all simple calipers, although the dividers have their own name. They all have ends that are adjustable to transfer a measurement from part to standard, usually a scale.

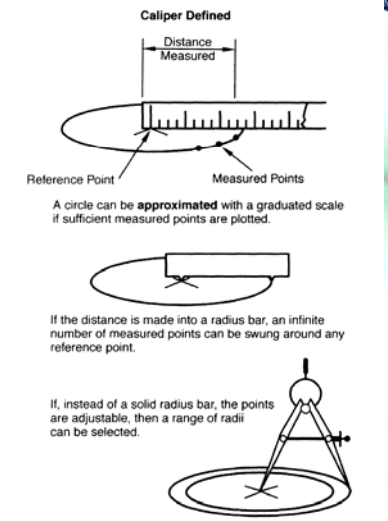


FIGURE 5–29 A caliper is an instrument for mechanically duplicating a measurement. Unless otherwise specified, it is an adjustable instrument. Not all calipers are termed that; dividers are an example.

Calipers: The Original Transfer Instruments

Calipers: The Original Transfer Instruments

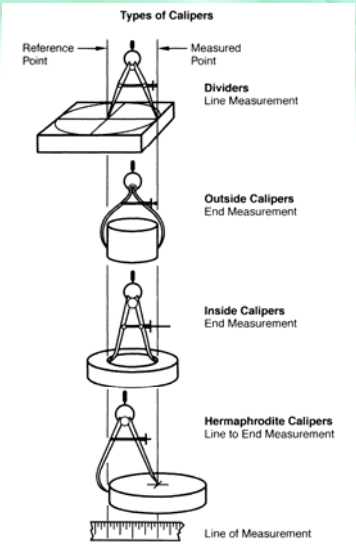


FIGURE 5–30 All caliper instruments transfer measurements. These are the basic types. Other versions bear little resemblance, except in principle of operation.

Calipers: The Original Transfer Instruments

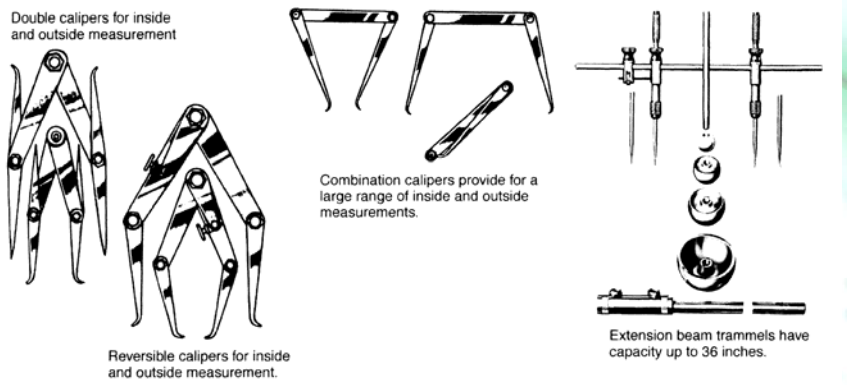


FIGURE 5–31 Many types of calipers have been devised.

Calipers: The Original Transfer Instruments

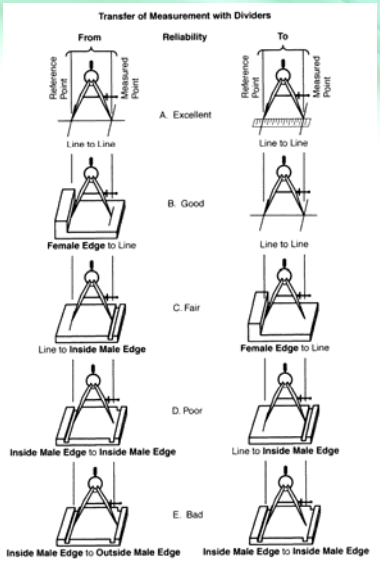


FIGURE 5–33 The important thing to remember in the transfer of measurements is that two, not one, measurements are involved. Each contributes errors.

Calipers: The Original Transfer Instruments

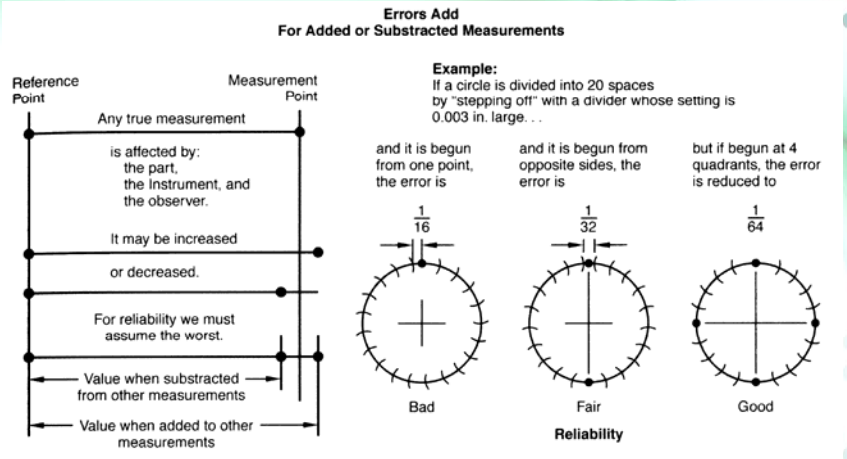


FIGURE 5–34 A group of measurements, each of which begins where the previous one left off, are known as serial measurements. Obviously their errors interact. The accumulation of errors is easily demonstrated by stepping off spaces around a circle of dividers. The results can be startling.

Calipers: The Original Transfer Instruments

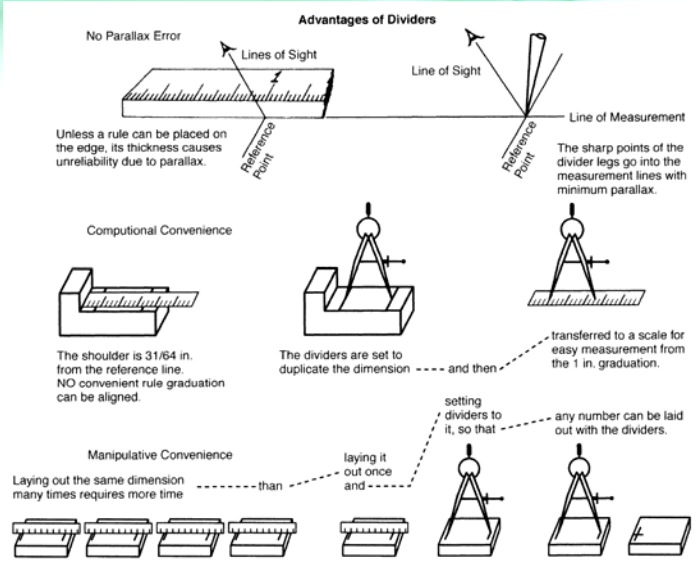


FIGURE 5–35 Properly used, dividers can save time without decreasing reliability.

Calipers: The Original Transfer Instruments

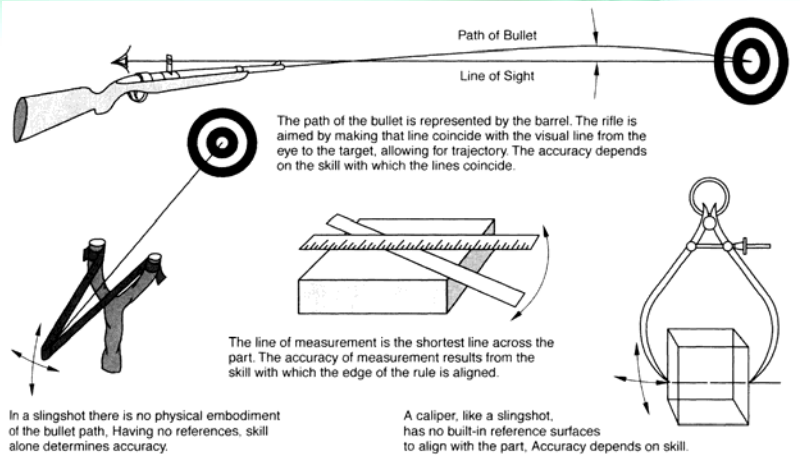


FIGURE 5–36 Calipers have more in common with slingshots than rifles.

Calipers: The Original Transfer Instruments

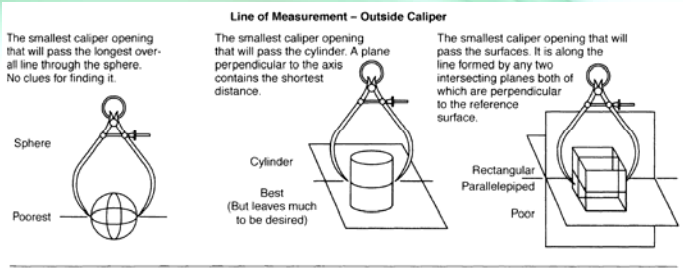


FIGURE 5–37 Seek the smallest caliper opening that will pass the part.

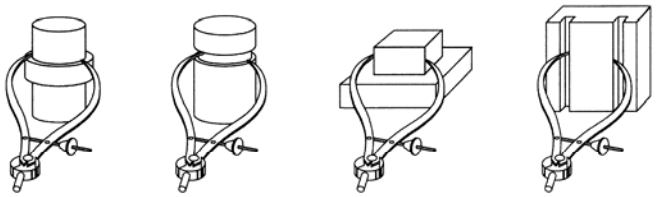


FIGURE 5–38 Greatest reliability is achieved when a shoulder or recess on the part restricts the line of measurement to a plane perpendicular to the part.

Calipers: The Original Transfer Instruments

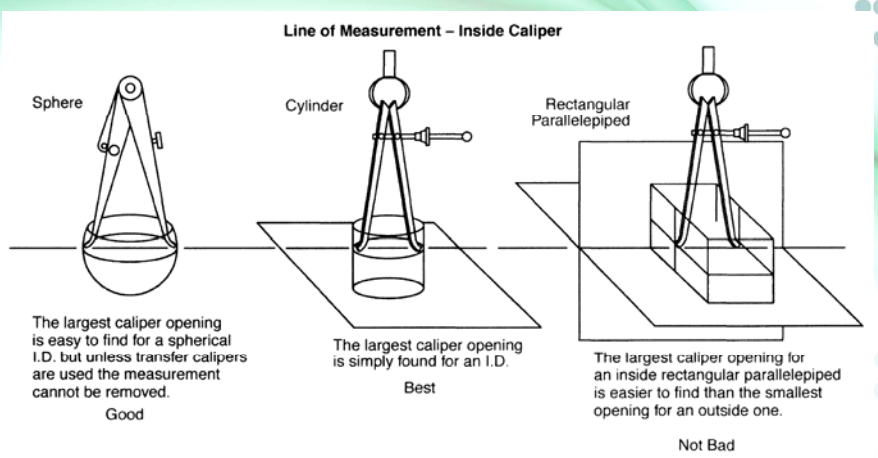
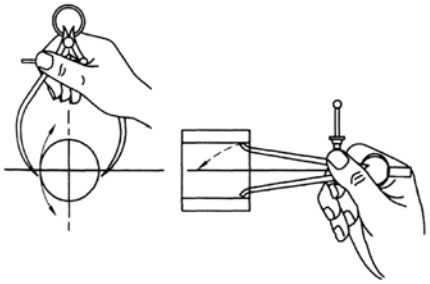


FIGURE 5–39 With calipers, inside measurements are somewhat easier to take than outside.

Calipers: The Original Transfer Instruments



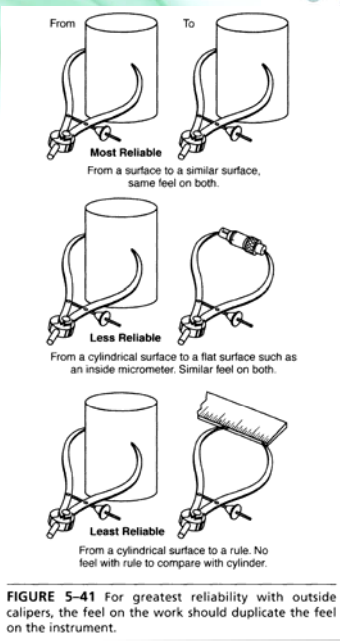
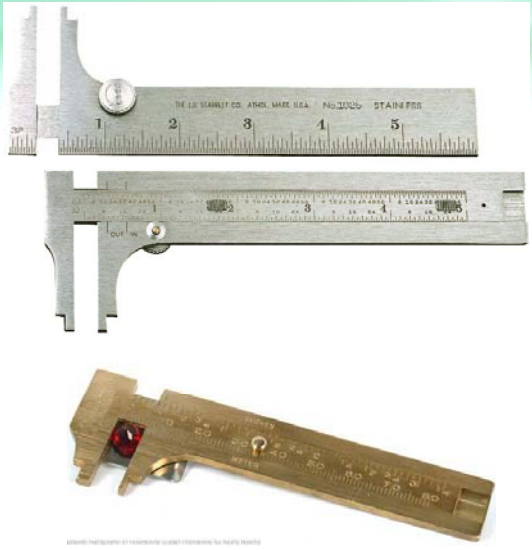
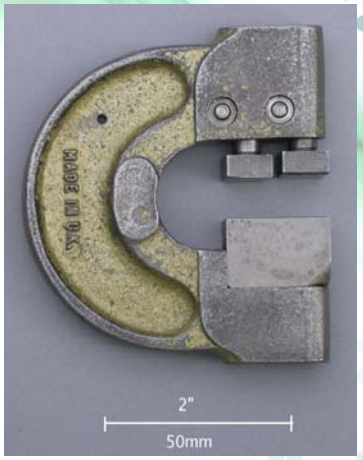


FIGURE 5–41 For greatest reliability with outside calipers, the feel on the work should duplicate the feel on the instrument.

Calipers: The Original Transfer Instruments



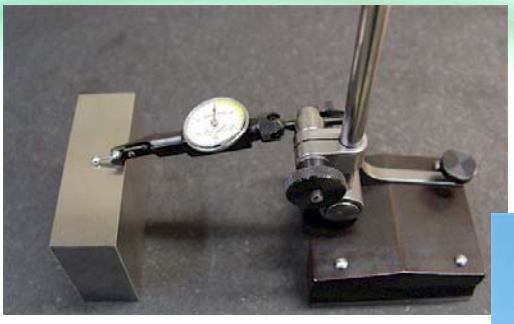


Calipers: The Original Transfer Instruments

SLIDE CALIPER	
Advantages	1. Combines rule, inside, and outside calipers in one instrument. 2. Provides positive contact with reference and measured points. 3. Substitutes line-to-line for line-to-edge readings. 4. Has built-in memory.
Disadvantages	1. No wear adjustment. 2. Subject to misalignment. 3. Limited discrimination. 4. Cannot caliper inside to outside part features.

FIGURE 5–54 Although slide calipers are handy, careful measurement practices must be applied.

Calipers: The Original Transfer Instruments



Calipers: The Original Transfer Instruments

			Metrological Data for Scaled Instruments				Reliability	
Instrument	Type of Measurement	Normal Range	Designated Precision	Discrimination	Sensitivity	Linearity	Practical Tolerance for Skilled Measurement	Practical Manufacturing Tolerance
Depth gage:								
metric	direct	150 mm	0.5 mm	0.5 mm	0.5 mm	0.005/mm	±0.5 mm	±0.5 mm
decimal-inch	direct	6 in.	0.02 in.	0.02 in.	0.02 in.	0.0003/in.	±0.02 in.	±002 in.
fractional-inch	direct	6 in.	1/64 in.	1/64 in.	1/64 in.	0.0003/in.	±1/64 in.	±1/64 in.
Combination sets:								
metric	direct	150 mm	0.5 mm	0.5 mm	0.5 mm	0.005/mm	±0.5 mm	±0.5 mm
decimal-inch	direct	4 in.	0.01 in.	0.01 in.	0.01 in.	0.0003/in.	±0.01 in.	±0.02 in.
fractional-inch	direct	6 in.	1/64 in.	1/64 in.	1/64 in.	0.0003/in.	±1/64 in.	±1.32 in.
Calipers:								
metric	transfer	150 mm	none	none	0.25 mm	none	±0.5 mm	±1 mm
decimal-inch	transfer	3 in.	none	none	0.005 in.	none	±0.02 in.	±0.08 in.
fractional-inch	transfer	3 in.	none	none	0.005 in.	none	±0.02 in.	±0.08 in.
Slide Calipers:								
metric	direct	130 mm	0.5 mm	0.5 mm	0.5 mm	0.005/mm	±0.5 mm	±0.5 mm
decimal-inch	direct	5 in.	0.01 in.	0.01 in.	0.01 in.	0.0003/in.	±0.01 in.	±0.02 in.
fractional-inch	direct	5 in.	1/64 in.	1/64 in.	1/64 in.	0.0003/in.	±1/64 in.	±1.32/in.

FIGURE 5–55 Note that although the caliper instruments have relatively good sensitivity, their reliability is low for a skilled operator and very low for manufacturing applications because two transfers are required for each measurement.

Calipers: The Original Transfer Instruments

Reliability Check List For Scaled Instruments

Inspection of Instrument:	1. Set up periodic system for inspection, depending on use. 2. Inspect contact surfaces with magnifier for wear or abuse. 3. Remove burrs from sliding and contact surfaces. 4. Compare readings against an instrument of higher precision, greater accuracy, and with known calibration. 5. Check all mechanical actions for proper functioning. 6. Clean and lubricate internal parts. 7. Check alignment against square of known calibration.
Use:	1. Never use a measuring instrument for a hand tool (scraper, chip digger, burring tool, mallet, screwdriver or sledge-hammer). 2. Never use beyond intended size range (do not force open). 3. Never use beyond discrimination or recommended precision. 4. Keep contact force to a minimum. 5. Avoid excessive movements causing wear. 6. Clean both part and instrument before using. 7. Substitute mechanical support for hand support whenever possible. 8. Guard against parallax when reading. 9. Have entire setup rigidly supported. 10. Do not overtighten anything.
Care:	1. Lubricate instruments before replacing in case. 2. Keep away from moisture. 3. Do not pile instruments together or with other objects. 4. Do not mark tools in any way that interferes with use. 5. Do not hesitate to throw away a worn or defective tool.

FIGURE 5–56 Some of these suggestions seem self-evident. Carelessness can cause an expensive part to be scrapped or a careful experiment to yield incorrect results.

References

https://littlemachineshop.com/default.php
http://nvl.nist.gov/pub/nistpubs/jres/113/3/V113.N03.A04.pdf
http://its.fvtc.edu/machshop1/Inspection/default.htm