High-Amplification Comparators

Alessandro Anzalone, Ph.D.

Hillsborough Community College, Brandon Campus

High-Amplification Comparators

Sections:

High-Amplification Comparators

GAGES AND MEASURING EQUIPMENT

1.1.3.1 **Length Standards.** Standards of length and angle from which all measurements of gages are derived.
1.1.3.2 **Master Gages.** Master gages used for checking and setting inspection of manufacturers' gages.
1.1.3.3 **Inspection Gages.** Inspection gages used to inspect products for acceptance.
1.1.3.4 **Manufacturers' Gages.** Manufacturers' gages used for inspection of parts during production.
1.1.3.5 **Nonprecision Measuring Equipment.** Simple tools used to measure by means of line graduations.
1.1.3.6 **Precision Measuring Equipment.** Tools used to measure in thousandths of an inch or finer.
1.1.3.7 **Comparators.** Precision measuring equipment used for comparative measurements between the work and a contact standard such as a gage or gage blocks.
1.1.3.8 **Optical Comparators and Gages.** Optical comparators and gages are those which apply optical methods of magnification exclusively.

FIGURE 10–2 These definitions are condensed from Military Standard, Gage Inspection, MIL-STD-120. They show the distinctions among the classifications of equipment involved in metrology. Note that the high-amplification comparators discussed in this chapter are not independent instruments but require the use of length standards, another one of the classifications.

High-Amplification Comparators

FISHER METROLOGY LTD.

Catalogue No.	Measuring Range	Readings
Metric		
1002 Supramess	± 25 µm	0,5 µm
1003 Millimess	± 50 µm	1 µm
1004 Compramess	± 0.13 mm	5 µm
1010 Zentimess	± 0.25 mm	0.01mm
1050 Dezimes	± 1.5 mm	0.05 mm

High-Amplification Comparators

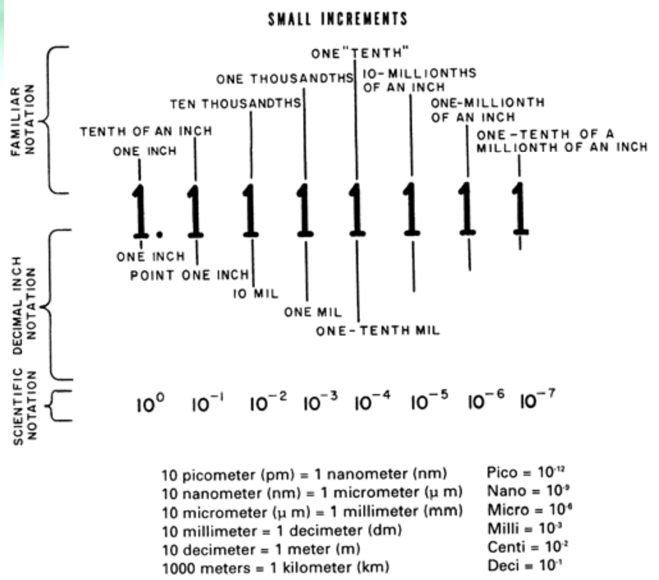


FIGURE 10–3 At high amplification, it is easy to misplace a decimal point.

High-Amplification Comparators

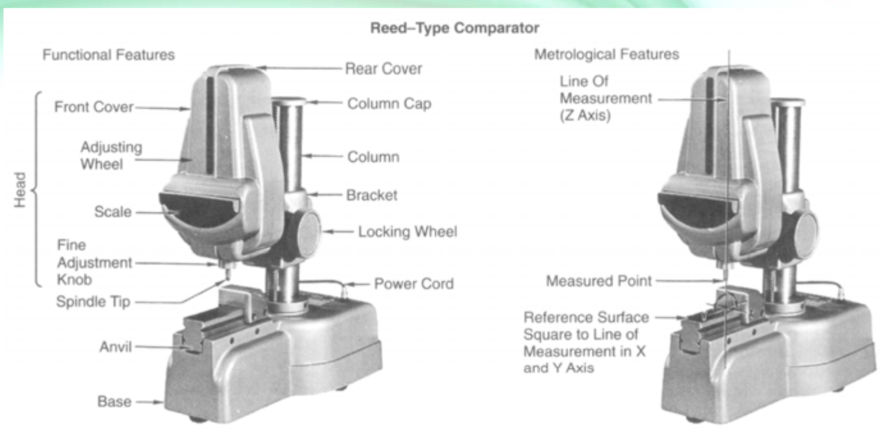


FIGURE 10–6 The metrological features of this reed-type comparator are the same as the other high-amplification mechanical instruments. They are relatively inflexible in configuration compared with the great flexibility of the new electronic instruments. However, there is never any doubt about their geometry. Their adherence to Abbe's law is clear, although it may not be with their electronic counterparts. *(Courtesy of CE Johansson Gage Co.)*

High-Amplification Comparators

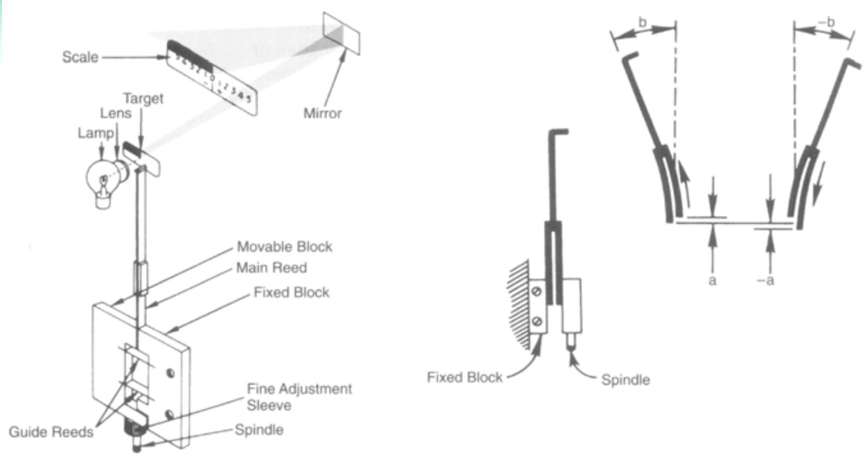


FIGURE 10–7 An actual optical lever is used to amplify the reaction. In the actual instrument, the optical path is longer than is shown here and a prism is used instead of a mirror.

Electronic Measurement

ELECTRONIC MEASUREMENT

Functional Features

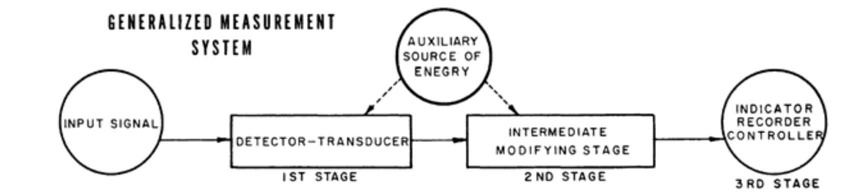
- Rapid operation even at high amplifications.
- Multiple amplification ranges in same instrument.
- Remote operation and multiple input operation.
- Limited self-checking (one scale against another).
- Convenience (most are portable, some entirely self-contained, controls are easy to understand).
- Versatility (large number of measurement situations can be handled with standard components).

Metrological Features

- High sensitivity in all ranges.
- Favorable instrument accuracy compared with other instruments.
- Signals can be combined electronically for added, subtracted, and differential measurements.

FIGURE 10–9 These points are generalities. Any one of them might be sufficient reason to accept or reject an electronic instrument for a particular measurement.

Electronic Measurement



Typical Examples

Instrument	Input Signal	Detector-Transducer	Intermediate Modifying Stage	Loading	Read-out
Test Indicator	Change in Length	Contacting Lever Arm	Lever Arm	Input Signal	Hand on Scale
Dial Indicator	Change in Length	Contacting Spindle & Rack	Gear Train and Pointer Arm	Input Signal	Hand on Scale
Reed-type Comparator	Change in Length	Contacting Spindle and Reed Block	Parallel Reed Mechanism and Optical Lever	Input Signal	Shadow on Scale
Electronic Comparator	Change in Length	Contacting Variable Circuit Element	Electronic Amplifier	Input Signal & Auxiliary Source	Electric Meter
Pneumatic Comparator	Change in Separation	Exit Orifice	Flowmeter	Input Signal & Auxiliary Source	Flowmeter Tube

FIGURE 10–10 All measurement instruments, including those that measure mass and time, as well as length measurement, fall into the generalized system.

Electronic Measurement

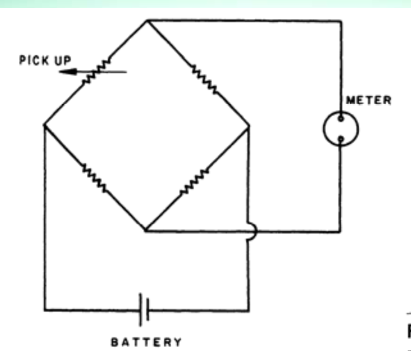


FIGURE 10–11 This simplified bridge circuit is similar t those used in electronic comparators.

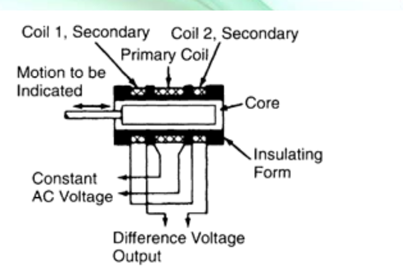


FIGURE 10–12 This is an LVDT. The LVDT gives an output voltage that is proportionally linear to linear changes in core position.

Electronic Measurement

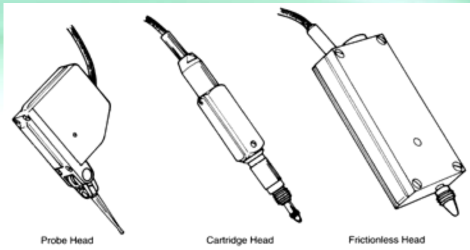
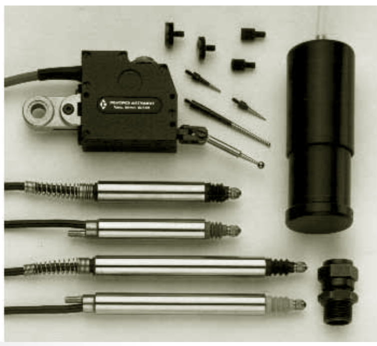


FIGURE 10–13 These are the three most popular configurations for gage heads using LVDT transducers. *(Courtesy of Brown & Sharpe Co.)*



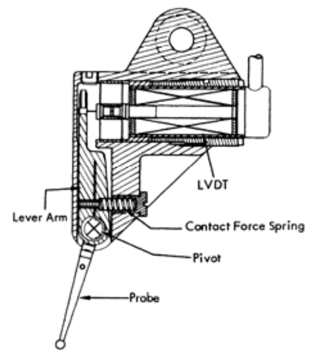


FIGURE 10–15 Probe heads differ considerably but all have similar features. The adjustable probe acts on an LVDT cartridge in a housing for convenient mounting.

Electronic Measurement

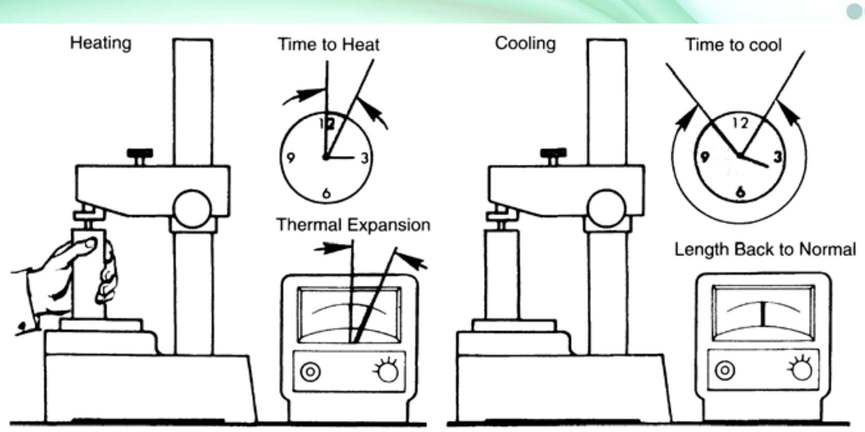


FIGURE 10–33 It takes much longer for a part to cool than to heat.

Electronic Measurement

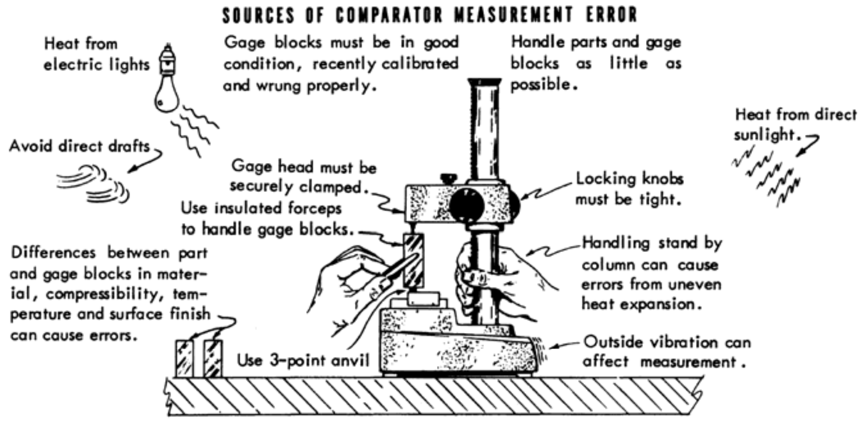


FIGURE 10–34 All sources of potential errors should be consciously investigated whenever a high-precision measurement is made.

Electronic Measurement

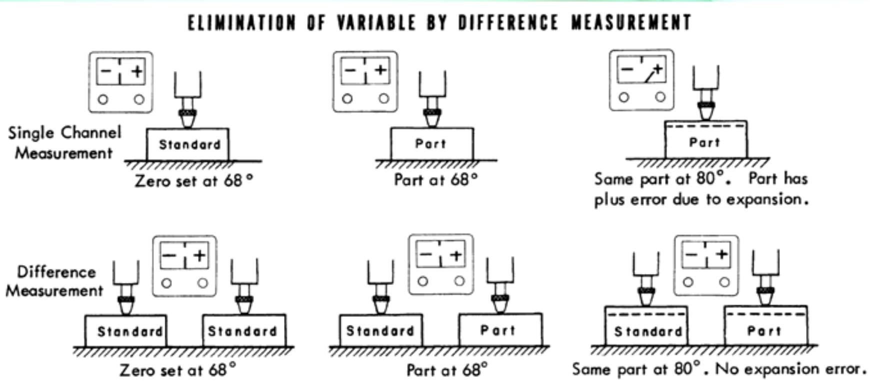


FIGURE 10–36 Thermal expansion provides an example of the elimination of a variable by means of difference measurement.

Applications Unique to Electronic Measurement

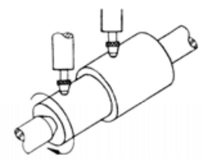


FIGURE 10–37 With the setup shown, only the difference in concentricity is shown on the indicator. If both parts are out of round in the same amount, the reading is not affected.

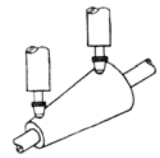


FIGURE 10–38 By placing two gage heads parallel on a tapered part, it is possible to check the degree of taper without regard to its diameter. The taper must be set to a master, of course.

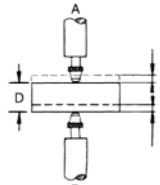


FIGURE 10–39 This is an example of sum measurement using opposing bands.

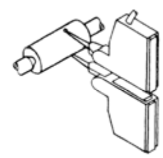


FIGURE 10–40 Sum measurement in this example provides a measurement of the diameter even if the part is not exactly on center.

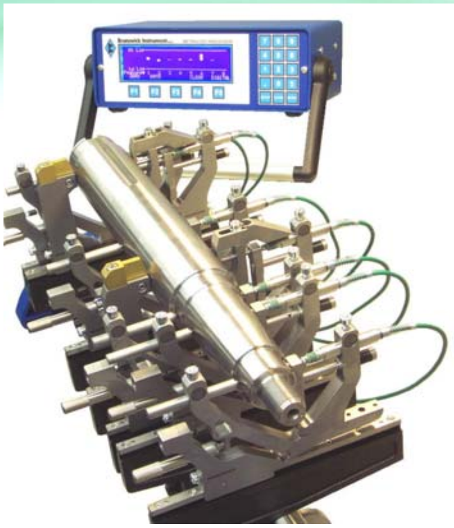
Applications Unique to Electronic Measurement

RELIABILITY CHECKLIST FOR RELIABLE COMPARISON MEASUREMENTS

1. Is there a better way to make the measurement?
2. Can the available instrument divide the tolerance into 10 parts? Is there a record to support this? If not, is lower precision adequate?
3. Are the length standards in calibration i.e., is their accuracy traceable to the National Institute of Standards and Technology (NIST) by up-to-date calibration records?
4. Has the most reliable support been selected? Don't use a height gage if a comparator can be used.
5. Are the instrument, parts, and standards scrupulously clean?
6. Are all parts of the setup locked and secured to eliminate all movement except displacement in the gage head?
7. Has the environment been checked for drafts, direct light, vibration, and other error-causing disturbances?
8. Have the instrument, parts standards, work holders, and reference surfaces (whichever apply) been fully normalized?
9. Has the best scale been selected (electronic instruments only) and are the line values for reading that scale understood?
10. Has the measurement been repeated as a check?
11. If critical, has the measurement been repeated by someone else and the results compared?

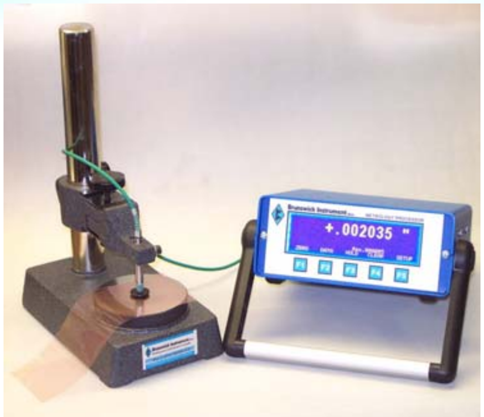
FIGURE 10–41 Temperature considerations have been added to this checklist because of their importance in high-amplification measurement.

High-Amplification Comparators



High-Amplification Comparators

High-Amplification Comparators



High-Amplification Comparators

Metrological Advantages of Multiple Scales

Typical Scale Selections

Scale	Comparator Applications	Height Gage Applications
0.02 mm 0.001 inch	*Production:* appliance parts, agricultural machinery parts, builders' hardware parts, plastic parts, small castings, and small forgings. *Tool and Gage Inspection:* not recommended.	*Plate Inspection:* heavy equipment parts, marine equipment parts, heavy engine parts, forging, and castings. *Tool and Gage Inspection:* assembly jigs and fixtures, patterns and templates. *Setup Measurements:* large planer and boring millwork.
0.01 mm 0.0005 inch	*Production Inspection:* truck and automotive parts, motor shafts, machinery shafts, bushings, bearings (not antifriction), small gears, and precision hardware. *Tool and Gage Inspection:* wide tolerance production gages and small cutting tools.	*Plate Inspection:* machinery and machine tool housings and parts, engine parts, motor, and generator parts. *Tool and Gage Inspection:* machining and inspection jigs and fixtures, precision assembly jigs and fixtures, templates, cams, and large cutting tools. *Setup Measurements:* milling machine and boring millwork, table positioning, and rough surface grinding.
0.002 mm 0.0001 inch	*Production Inspection:* high-production gages and high-speed engine parts, pump parts, small precision gears, and firearm parts. *Tool and Gage Inspection:* production gages and precision cutting tools.	*Plate Inspection:* plastic and injection molds, dies, precision machining and inspection jigs and fixtures, aircraft parts, and large instruments. *Tool and Gage Inspection:* precision machining and grinding. *Setup Measurements:* finish surface grinding, chemical process setup.
0.001 mm 0.00005 inch	*Production Inspection:* instrument and control parts, electronic components, and antifriction bearings. *Tool and Gage Inspection:* close tolerance production gages and master gages.	*Plate Inspection:* precision aircraft and missile parts. *Tool and Gage Inspection:* precision inspection fixtures and instruments. *Setup Measurements:* jig borer, measuring machine, and precision boring machine work.
0.0002 mm 0.00001 inch	*Production Inspection:* high-precision hydraulic and electric parts. *Tool and Gage Inspection:* height accuracy master gages.	*Plate Inspection:* not generally applicable. *Tool and Gage Inspection:* not generally applicable. *Setup Measurements:* not generally applicable.

FIGURE 10–42 There are electrical comparators with a wide range of scales. Most will be between those shown in this table. It is essential to use the best scale in the range of the instrument for each particular situation.

Metrological Advantages of Multiple Scales

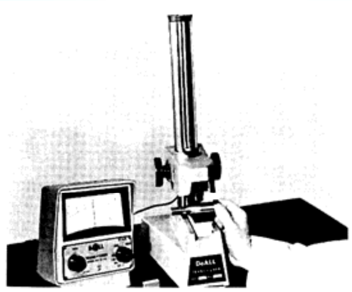


FIGURE 10–43 Comparator applications utilize a stand that provides an accurately flat reference surface square to the gage head.

FIGURE 10–44 Height gage setups use a surface plate or the part itself as a reference surface.

Metrological Advantages of Multiple Scales

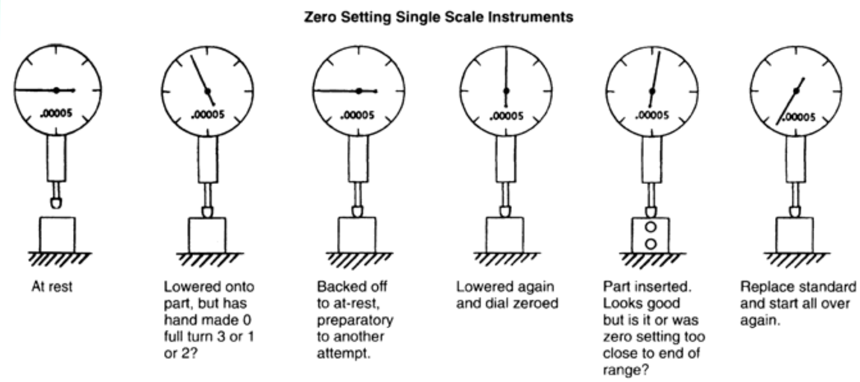


FIGURE 10–45 The problems of zero setting a high-amplification comparator that has only one scale are often even more difficult than this example.

Metrological Advantages of Multiple Scales

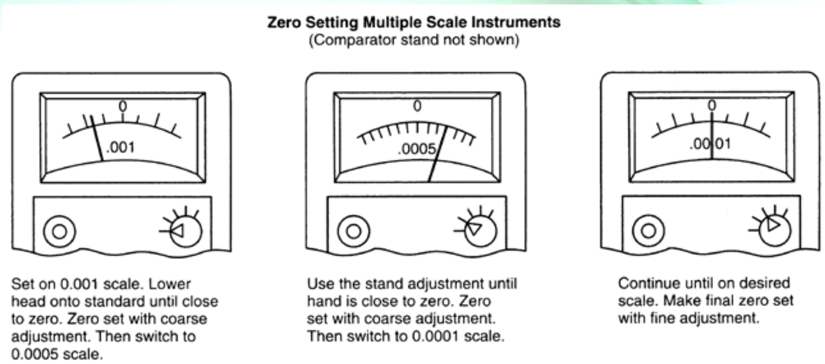


FIGURE 10–46 Multiple-scale selection provides the best amplification for each role in which the instrument is used.

Metrological Advantages of Multiple Scales

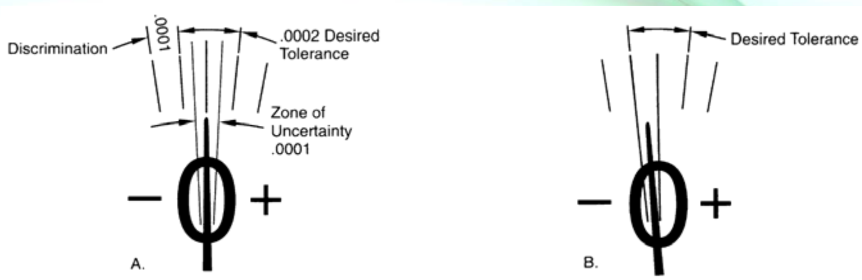


FIGURE 10–47 The dispersion of readings does not cause a problem as long as it is entirely within the tolerance.

Metrological Advantages of Multiple Scales

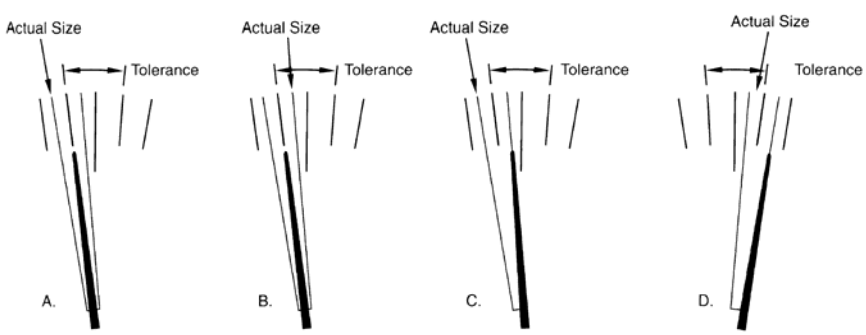


FIGURE 10–48 These examples show that the apparent reading may be very different from the actual size as a result of the instrument uncertainty.

Metrological Advantages of Multiple Scales

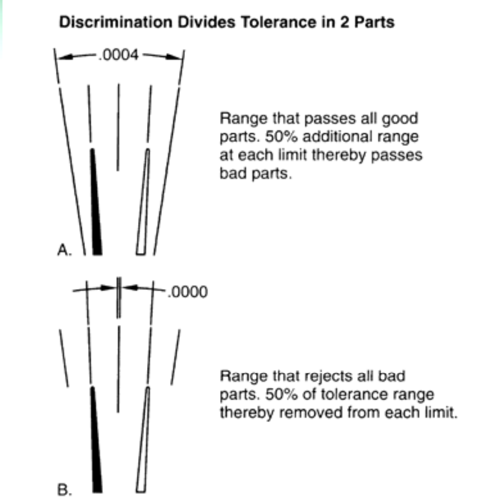


FIGURE 10–49 An allowance must be made for the zones of uncertainty.

Metrological Advantages of Multiple Scales

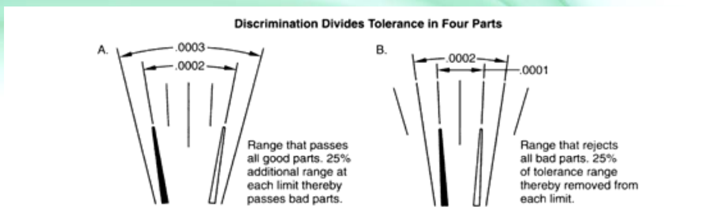


FIGURE 10–50 The higher discrimination reduces the lost range for good parts and the additional range for bad parts.

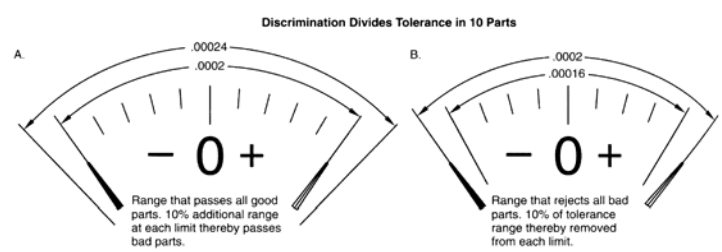


FIGURE 10–51 When the instrument has sufficient discrimination to divide the tolerance into 10 parts, only 10% of range gives trouble at each limit.

Metrological Advantages of Multiple Scales

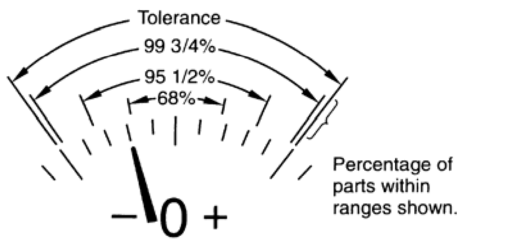


FIGURE 10–52 In a typical manufacturing operation, most of the parts will be grouped close to an average size. The purpose of quality control is to ensure that the average is close to the basic desired size.

Metrological Advantages of Multiple Scales

The Ten–to–One Rule

Rule:
The instrument* must be capable of dividing the tolerance into 10 parts.

The Purpose:
To eliminate 99% of the instrumentation errors of previous steps in a measurement.

When Applied:
To every step in the measurement sequence until the limit of the available instrumentation is reached.

The Results:
Fewer bad parts accepted and good parts rejected.

* Instrument includes standards.

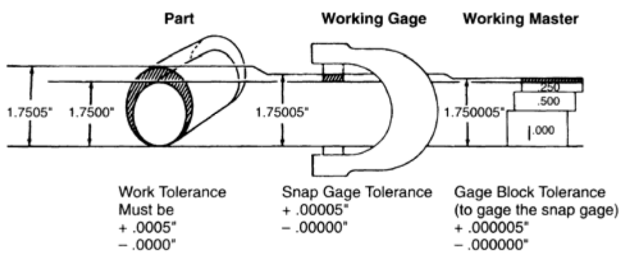


FIGURE 10–53 This is a pragmatic rule, not a law. It is based on practical results. Often, practical considerations force us to deviate from it.

Metrological Advantages of Multiple Scales

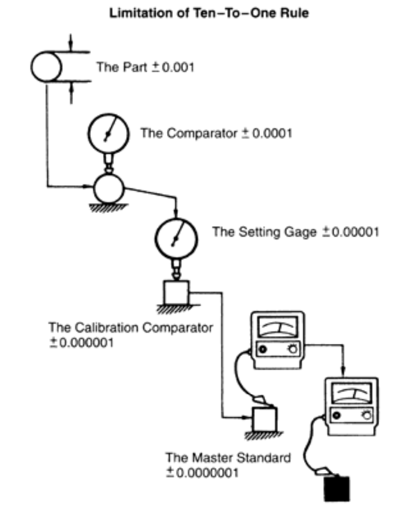
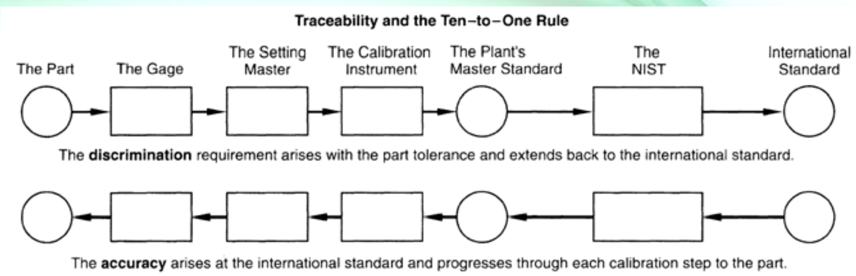


FIGURE 10–54 The demands of the ten-to-one rule quickly exceed present measuring instrumentation. The National Institute of Standards and Technology is currently investigating 1/10 millionth measurements and finer.

Metrological Advantages of Multiple Scales



Traceability is the procedure for determining that none of the connecting links between the part and NIST has been severed. It is required by law on government contracts and by sound economics for all other measurements.

MIL-1-45208a Inspection System Requirements, MIL–Q–9858A Quality Control Requirements, and MIL-C-45662A Calibration System Requirements are the applicable standards.

FIGURE 10–55 The ten-to-one rule deals with the precision of the measuring instruments but carried to its limit it reaches the international standard. By definition, this is the ultimate existing accuracy. If any link along the way is broken, the accuracy is lost; hence the need for traceability.

Metrological Advantages of Multiple Scales

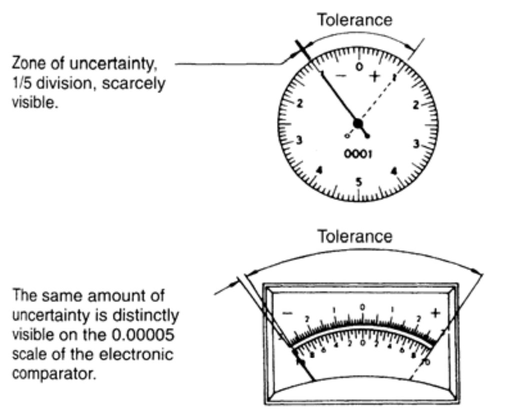


FIGURE 10–56 Both of these instruments fulfill the requirements of the ten-to-one rule. The electronic gage provides readings in the uncertainty zone of the dial indicator.

Metrological Advantages of Multiple Scales

METROLOGICAL DATA FOR HIGH-AMPLIFICATION COMPARATORS — **RELIABILITY**

Instrument	Type of Measurement	Normal Range	Designated Precision	Discrimination	Sensitivity	Linearity	Practical Tolerance for Skilled Measurement	Practical Manufacturing Tolerance
Mechanical (5000 X) Comparison	Metric English	0.025 mm 0.001 in.	0.0006 mm 0.000025 in.	0.0006 mm 0.000025 in.	0.00025 mm 0.00001 in.	2% 2%	± 0.0005 mm ± 0.00002 in.	±0.006 mm ±0.00025 in.
Electronic 0.0001 Scale Comparison	Metric English	± 0.06 mm ± 0.0024 in.	0.0025 mm 0.0001 in.	0.0025 mm 0.0001 in.	0.0013 mm 0.00005 in.	2% 2%	± 0.0013 mm ± 0.00005 in.	± 0.0025 ±0.0001 in.
0.00005 Scale Comparison	Metric English	±0.004 mm ± 0.0016 in.	0.0013 mm 0.00005 in.	0.0013 mm 0.00005 in.	0.0005 mm 0.00002 in.	2% 2%	±0.0010 mm ± 0.00004 in.	± 0.013 mm ±0.0005 in.
0.00001 Scale Comparison	Metric English	±0.0061 mm ± 0.00024 in.	0.00025 mm 0.00001 in.	0.00025 mm 0.00001 in.	0.0013 mm 0.00005 in.	2% 2%	± 0.00020 mm ± 0.000008 in.	± 0.00025 mm ± 0.00001 in.

FIGURE 10–57 At very high amplifications, the many variables to measurement accuracy are even more important than the inherent capability of the instrument itself; hence these conservative data.

High-Amplification Comparators

References

http://www.mountainmetrology.com/images/big_calibrator.jpg
http://www.fishermet.com/p_mahr_2.html
http://www.mahr.com/images/products/Metrology/millimess/systems/mechanical_comparators/1003/millimess--1003-pic--320x240.jpg
http://telc.tanta.edu.eg/hosting/pro5/containt/L3.htm
http://www.brunswickinstrument.com
http://news.thomasnet.com/fullstory/815754

High-Amplification Comparators

Alessandro Anzalone, Ph.D.

Hillsborough Community College, Brandon Campus