MENG 436
Metrology & Quality Control
Summer 2020

King Abdulaziz University
Faculty of Engineering
Mechanical Engineering Dept.

MEASUREMENTS BY COMPARISON
Comparators

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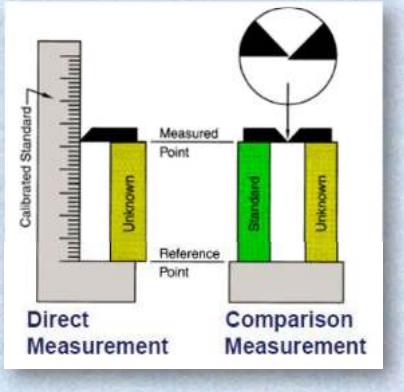
Comparators

- Comparators are precision instruments employed to compare the dimension of a given component with a standard master piece (generally slip gauges).
- It does not measure the actual dimension but indicates how much it differs from the standard master piece.
- Comparators find their applications in all type of production works as they:
  - require very less skill, and
  - reduce the time of inspection.



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Comparators

- In short, Comparator is a device which:
  - Picks up small variations in dimensions (between the standard value and the measured one).
  - Magnifies it.
  - Displays it by using indicating devices.

Comparator Instruments

Name	Alternate Name	Use	Discrimination
Test Indicator	Dial test indicator	Setup in process checking	Not intended for measuring
Dial Indicator	Dial comparator, dial gage	Comparison measurement, alignment and positional measurement	0.01 to 0.002 mm 0.001 to 0.0001 in.
Comparator	Mechanical comparator, electronic comparator, air gages, and many are referred to by trade name	Comparison measurement of precise parts and for gage calibration	0.001 to 0.00002 mm 0.0001 to 0.00001 in.

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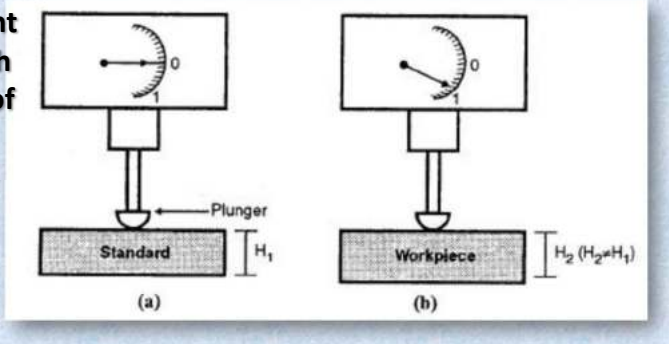
Comparators

- To check the height of the job H_2 , with the standard job of height H_1:



- In (a), the comparator is adjusted to zero (dial) with a standard job.
- Then, in (b), the standard job is replaced by the workpiece to be checked and the dial reading is taken.
- The dial reading is the difference between H_1 and H_2. It has been displayed after magnification, to get the clear variation between the standard and actual job.

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Comparators

Essential Characteristics of a Good Comparator

1. Linear characteristics of scale.
2. High magnifications.
3. Minimum wear of contact points.
4. Free from backlash.
5. Easy to handle.
6. Quick insertion of workpiece and quick in results.
7. Compensate temperature effects.
8. Provision for means to prevent damage during use.

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Classification of Comparators

1. **Mechanical Comparators**
   (Work on gears pinions, linkages, levers, springs, etc.)
   i. Dial indicator (Dial gauge)
   ii. Johansson Mikrokator comparator
   iii. Sigma comparator
2. **Optical Comparators**
   (Using lens, mirrors, light source, etc.)
3. **Pneumatic Comparators**
   (Using high pressure air, valves, back pressure, etc.)
   i. Back-pressure comparator
   ii. Low-velocity pneumatic comparator
4. **Electrical Comparators**
   (Using transformers and galvanometers (Whetstone bridge))
5. **Electronic Comparator**
   (Using transducers, oscillators, amplifiers, demodulators, and meters)

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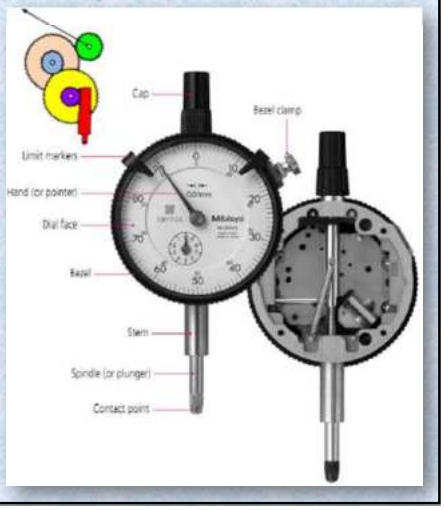
Dial Indicator/Gauge

- One of the most commonly used mechanical comparators.
- The linear movement of the plunger is magnified by means of a gear and pinion train into a rotation of the *pointer* on the dial scale.
- Dial indicators are compact and robust in construction.
- They are portable, easy to handle and can be set very quickly.
- They are used for inspection of small precision machined parts testing alignment, roundness, parallelism of workpieces, etc.



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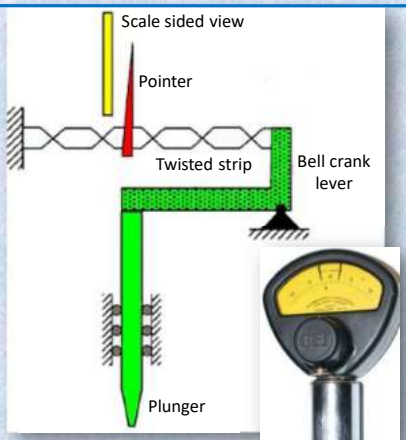
Johansson Mikrokator Comparator

- This comparator uses the simplest and most ingenious method for obtaining the mechanical magnification.
- As the measuring plunger moves, either upwards or downwards, the bell crank lever causes the twisted strip to change its length and thus further twist, or untwist.
- Hence, the pointer at the center of the twisted strip rotates an amount proportional to the change in length of the strip.
- The magnification of the instrument is of order of X 5000.



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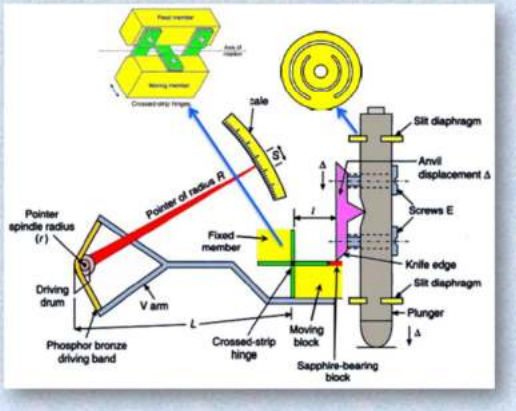
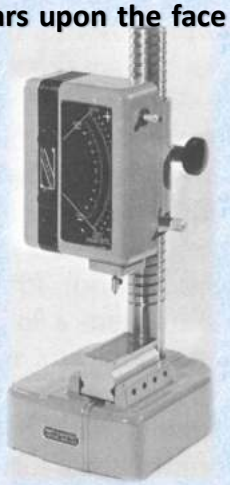
Sigma Comparator

- Sigma comparator provide magnification in 300 to 5000.
- It consists of a plunger mounted on two steel slit diaphragms.
- This provides a frictionless linear movement for the plunger.
- The plunger carries a knife edge, which bears upon the face of the moving block of a cross-strip hinge.





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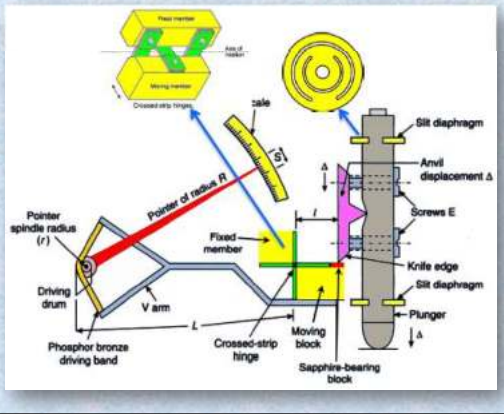
Sigma Comparator

- The cross-strip hinge is formed by pieces of flat steel springs arranged at right angles.
- The moving block carries a flight metal Y-Forked arms.
- A thin phosphor bronze ribbon is fastened to the ends of the forked arms and wrapped around a small drum, mounted on a spindle carrying the pointer.



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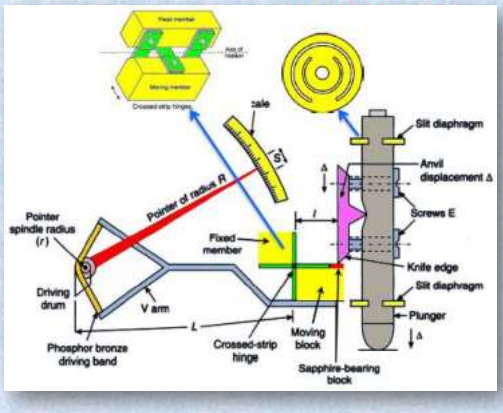
Sigma Comparator

- Any vertical displacement of the measuring plunger, and hence that of the knife edge, makes the moving block of the cross-strip hinge to pivot.
- This causes the rotation of the V-arm.
- The metallic band attached to the arm makes the driving drum and hence the pointer to rotate.

$$Magnification = \frac{L}{l} \times \frac{R}{r}$$



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Mechanical Comparators

Advantages

- Cheaper than all the other types of comparator.
- Does not require any external source of power or air supply.
- Use a linear scale that can be easily understood.
- Are robust, compact and easy to handle.

Disadvantages

- Contains more number of moving parts which increase the friction and reduce the accuracy.
- Slackness in the moving parts reduces accuracy very drastically.
- The moving parts have more inertia which makes the instruments sensitive to vibration.
- The range of the instrument is limited as the pointer moves over a fixed scale.

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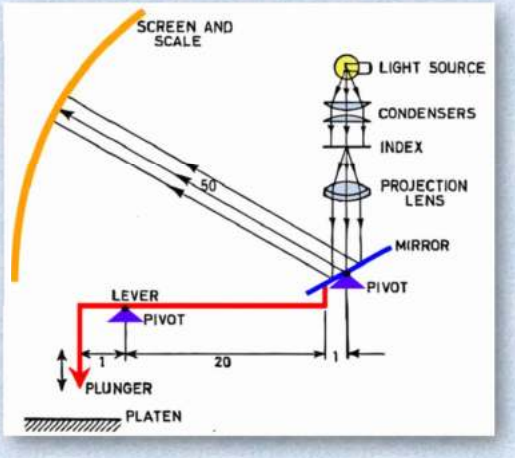
Optical Comparators

- A small displacements of measuring plunger are amplified first by a mechanical system consisting of pivoted levers.
- The amplified mechanical movement is further amplified by an optical system.
- The mechanical system causes a mirror to tilt about an axis and the image of an index is projected on a scale on the inner surface to a glass screen.



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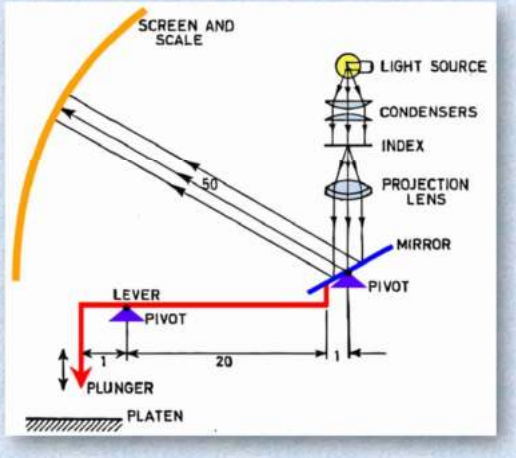
Optical Comparators

- Optical magnification provides high degree of measuring precision due to reduction of moving members and better wear resistance.
- Optical magnification is also free from friction, bending, wear, etc.

Mechanical amplification
= 20 units
Optical amplification
= 50 x 2 = 100 units
Total amplification
= 20 x 100 = 2000 units



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Optical Comparators

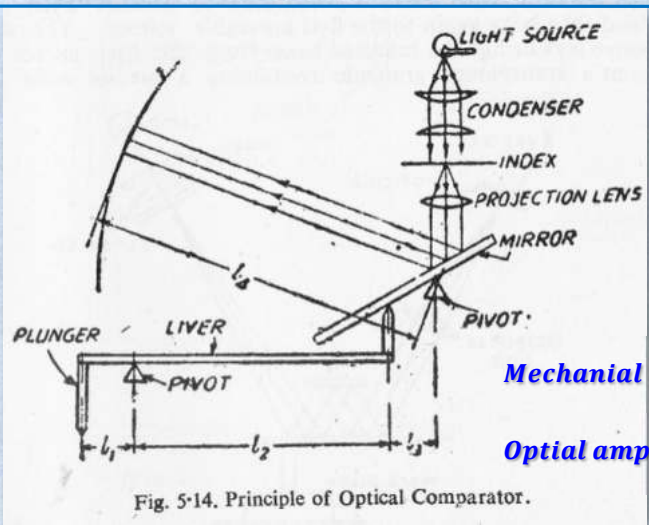

Fig. 5·14. Principle of Optical Comparator.

$$Mechanial\ amplification = \frac{l_2}{l_1}$$

$$Optial\ amplification = \frac{l_4}{l_3} \times 2$$

$$Total\ amplification = 2 \times \frac{l_2}{l_1} \times \frac{l_4}{l_3}$$

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Optical Comparators

Advantages

- They are almost weightless and have less number of moving parts, due to this there is less wear and hence less friction.
- Higher range even at high magnification is possible as the scale moves past the index.
- The scale can be made to move past a datum line and without having any parallax errors.
- They are used to magnify parts of very small size and of complex configuration such as intricate grooves, radii or steps.

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Optical Comparators

Disadvantages

- The accuracy of measurement is limited to 0.001 mm
- They have their own built in illuminating device which tends to heat the instrument.
- Electrical supply is required.
- Eyepiece type instrument may cause strain on the operator.
- Projection type instruments occupy large space and they are expensive.
- When the scale is projected on a screen, then it is essential to take the instrument to a dark room in order to take the readings easily.

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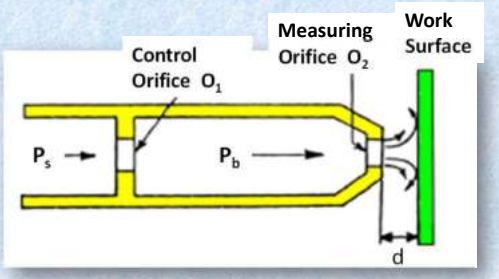
Pneumatic Comparators

1. Back-Pressure Comparator

- Air from a constant pressure source P_s flow to the atmosphere through two orifices O_1 and O_2 in series .
- The relationship between P_s and P_b will depend upon the relative sizes of the two orifices:
- P_b being equal to P_s when O_2 is blocked.
- P_b being less than P_s when O_2 is opened.
- Orifice O_1 is of constant size, but the effective size of O_2 may be varied by the distance d.
- As d varies, pressure P_b changes, and thus provides a measure of distance d.



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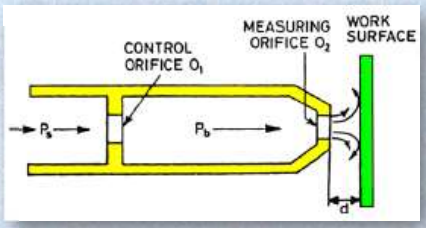
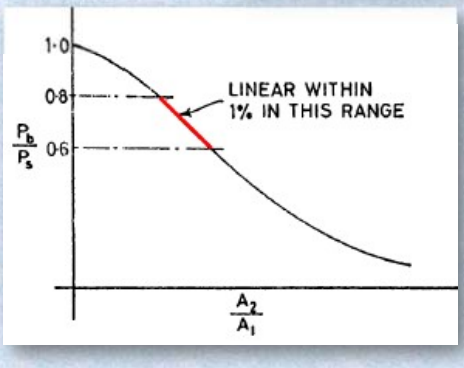
Pneumatic Comparators

1. Back-Pressure Comparator

- If P_b/P_s is plotted against A_2/A_1 a portion of the curve is straight for value of P_b/P_s between 0.6 and 0.8. Where A_1 and A_2 are the areas of orifices O_1 and O_2, respectively.





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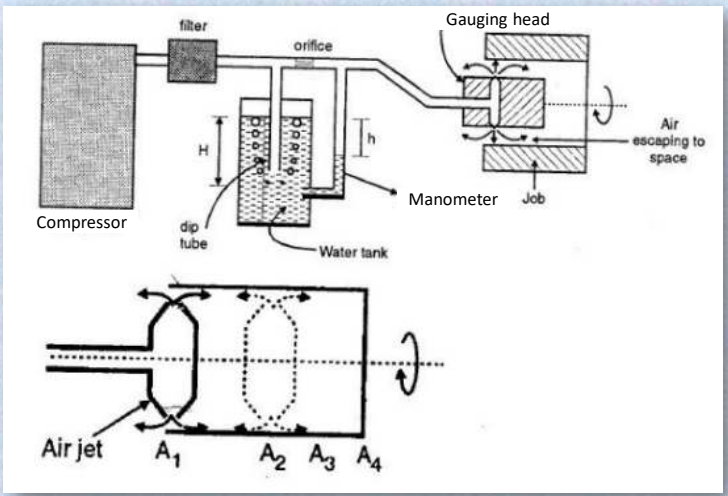
Pneumatic Comparators

1. Back-Pressure Comparator



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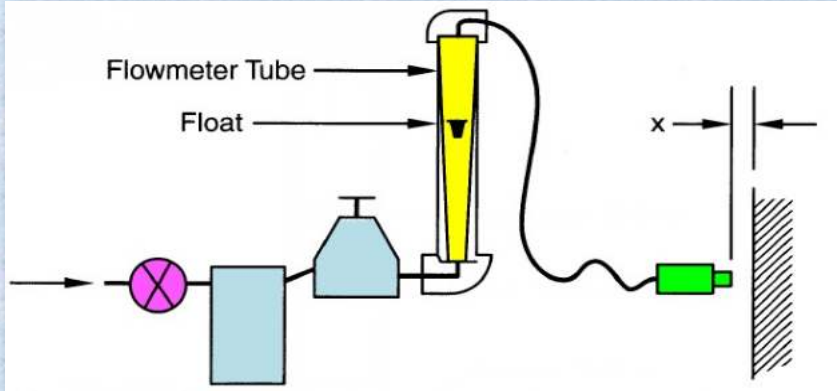
Pneumatic Comparators

2. Flow-Velocity Comparator



Changes in x alter the rate of flow. This is read by the height of a float in a tapered flowmeter tube.

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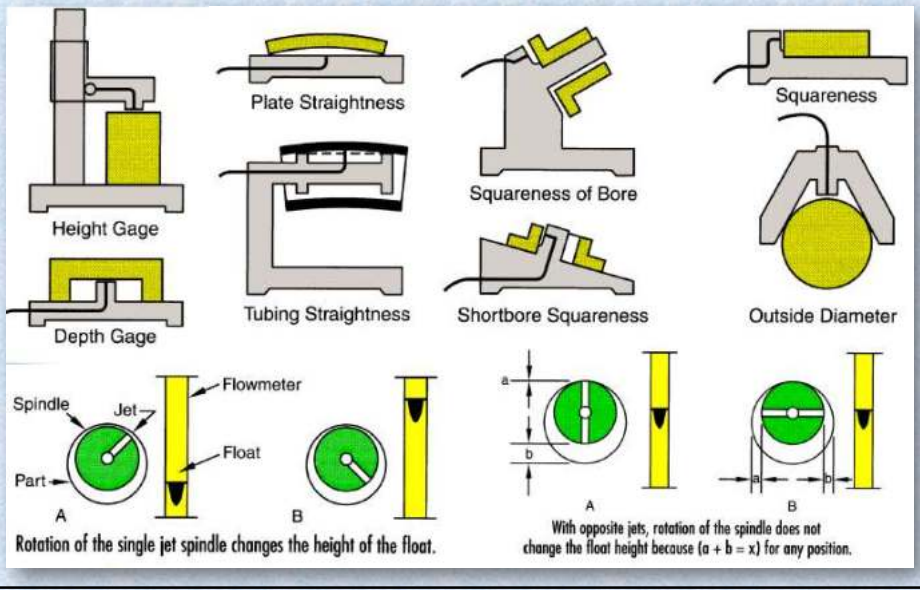
Pneumatic Comparators

Applications



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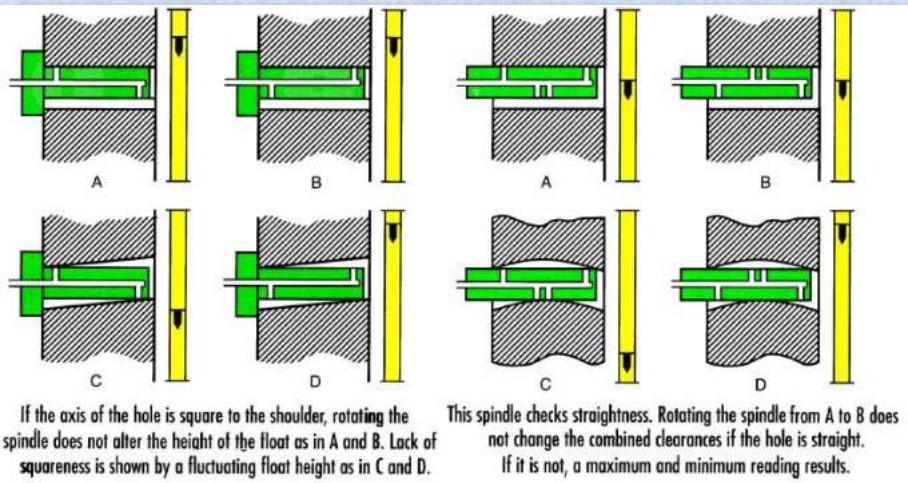
Pneumatic Comparators

Applications



If the axis of the hole is square to the shoulder, rotating the spindle does not alter the height of the float as in A and B. Lack of squareness is shown by a fluctuating float height as in C and D.

This spindle checks straightness. Rotating the spindle from A to B does not change the combined clearances if the hole is straight. If it is not, a maximum and minimum reading results.

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Pneumatic Comparators

Advantages

- The gauging member does not come into contact with the part to be measured and hence no wear takes place.
- Has very small number or no moving parts. Thus, the accuracy is more due to less friction and less inertia.
- High magnification is possible.
- Very small diameter holes can be easily measured even when the length is very large.
- Best instrument for determining the ovality and taperness of the circular bores.

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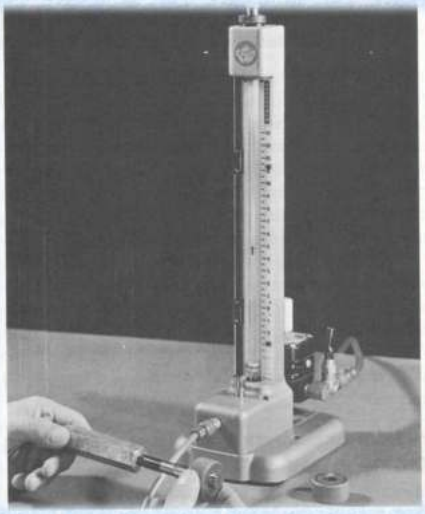
Pneumatic Comparators

Disadvantages

- **Requires elaborate auxiliary equipment** such as accurate pressure regulator.
- Scale has **limited linearity**.
- **Not portable** as it has large auxiliary equipment.
- **Different and special gauging heads** are required for different types of measurement.



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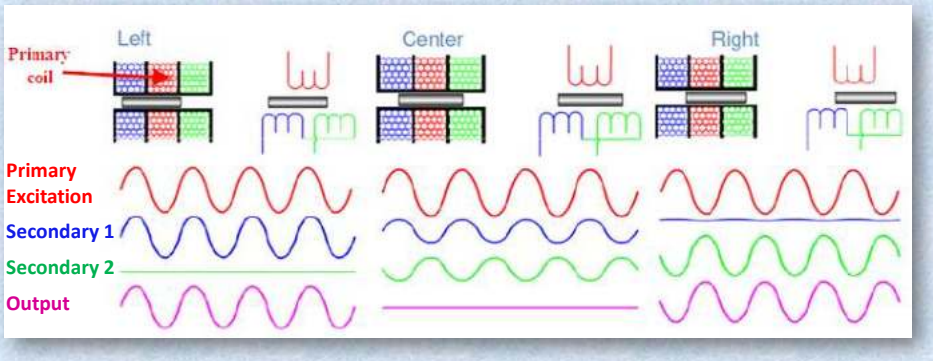
Electrical Comparators

- The **most robust stable** and **reliable electrical comparators** depend upon the operation of **Linear Variable Differential Transformer** (**LVDT**).
- **LVDT** consists of **three coils** symmetrically spaced along an insulated tube.



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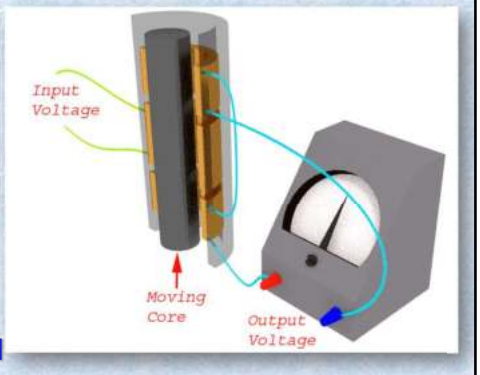
Electrical Comparators

- The central coil is the primary coil. The other two are identical secondary coils which are connected in series in such a way that their outputs oppose each other.
- AC current is induced to the primary coil.
- The movement of the plunger displaces armature from its central position, unbalances the secondary coils, and producing an output voltage.



- The amount of unbalance caused by movement of measuring plunger is amplified and shown on a linear scale.
- Magnifications of the order of x 30,000 are possible.

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Electrical Comparators

Advantages

- Small number of moving parts.
- Have very high magnification and the same instrument may have two or more magnifications. Thus, the same instrument can be used for various ranges.
- Not sensitive to mechanical vibrations.
- Measuring (sensing) unit can be made very small.

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Electrical Comparators

Disadvantages

- Requires external power supply.
- Calibration may be altered due to heating elements used.
- Expensive compared to mechanical comparators.

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Errors in Comparator Measurement

Sources of Error Due to Environment

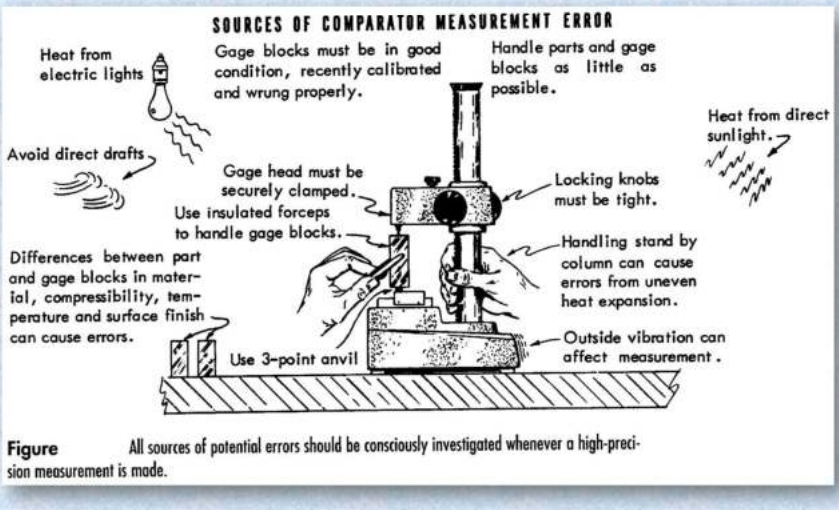

Figure All sources of potential errors should be consciously investigated whenever a high-precision measurement is made.

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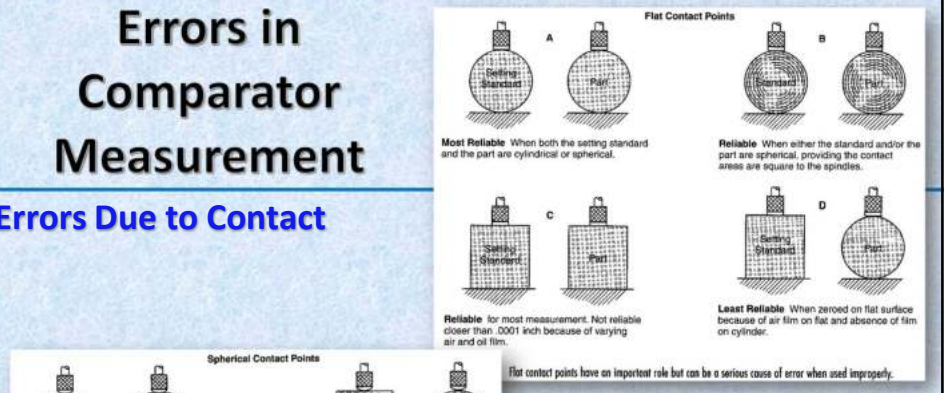
Errors in Comparator Measurement

Errors Due to Contact



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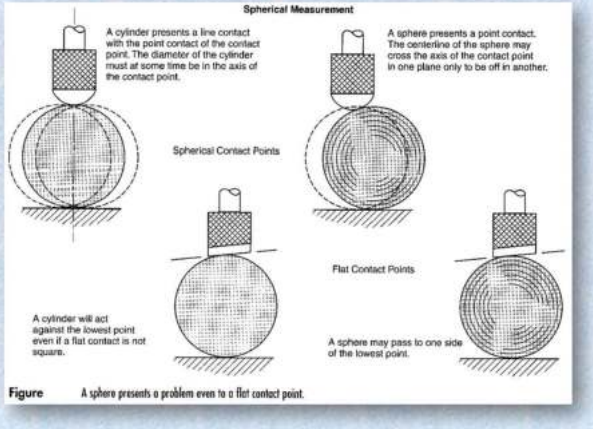
Errors in Comparator Measurement

Errors Due to Contact



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Errors in Comparator Measurement

Errors Due to Misalignment

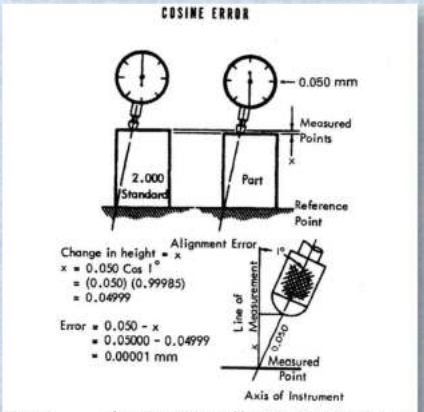

Figure The cosine error caused by 1° applies only to the travel of the indicator and figures out to an error in length of only 10 μin. Note that the same misalignment with a vernier height gage creates an error based on the full length and would be 300 μin.

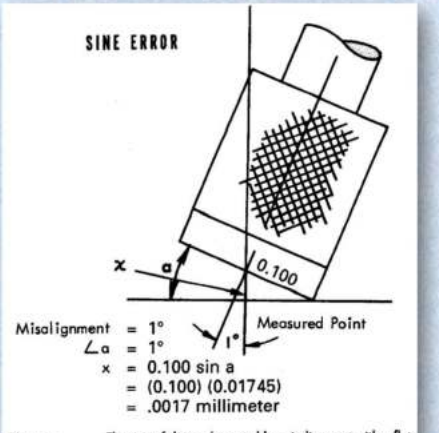

Figure The sine of the angle caused by misalignment with a flat contact is a much more serious cause for error than the cosine error. **Note:** A misaligned micrometer or snap gage would have this error at each contact surface.

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Best Wishes . . .

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