Metrology
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Lecture – 34
Pneumatic Comparators

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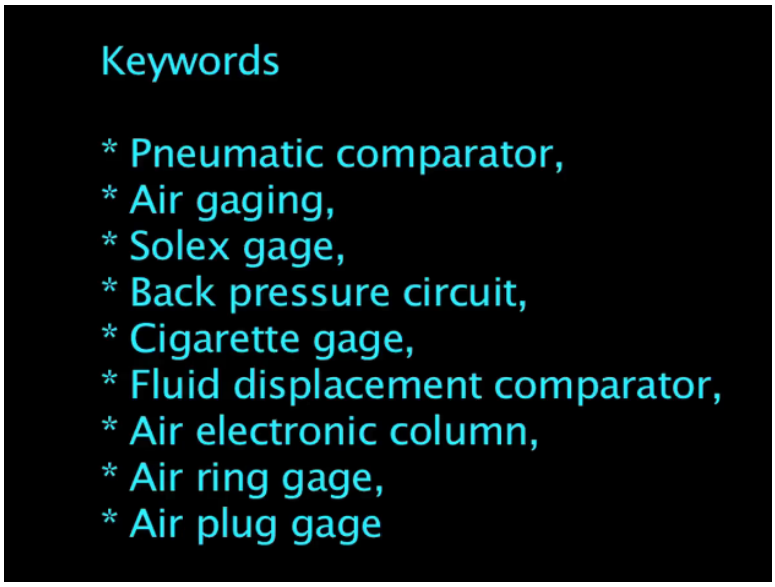

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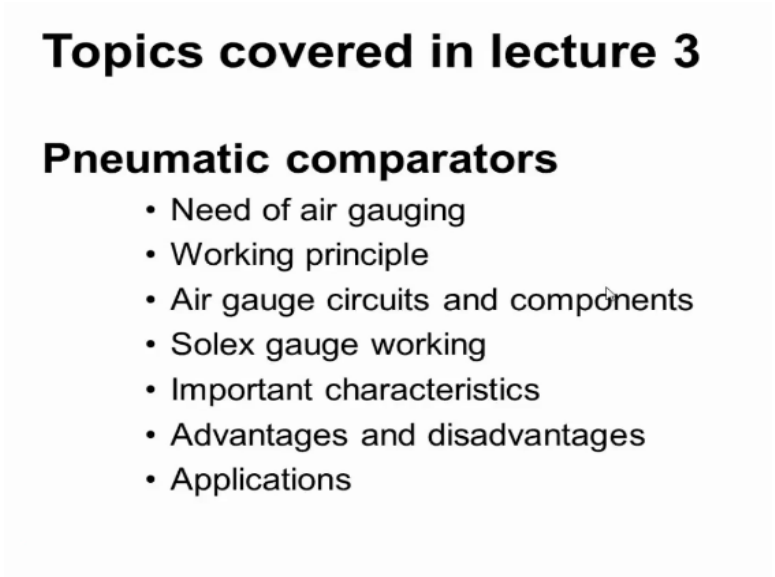

I welcome you all for the lecture number 3, module number 10. In this lecture, we will be discussing about the pneumatic comparators, we will study about the need for pneumatic comparators. There is also known as air gauging equipments, we will also study about the working principle of pneumatic comparators and what are the different kinds of circuits available and what are the various components used in pneumatic comparators.

We will also study about commercially available gauge that is Solex gauge and then we will move on to the important characteristics of pneumatic comparators, then we will discuss about the advantages and disadvantages of pneumatic comparators, finally we will see some application of pneumatic comparators.

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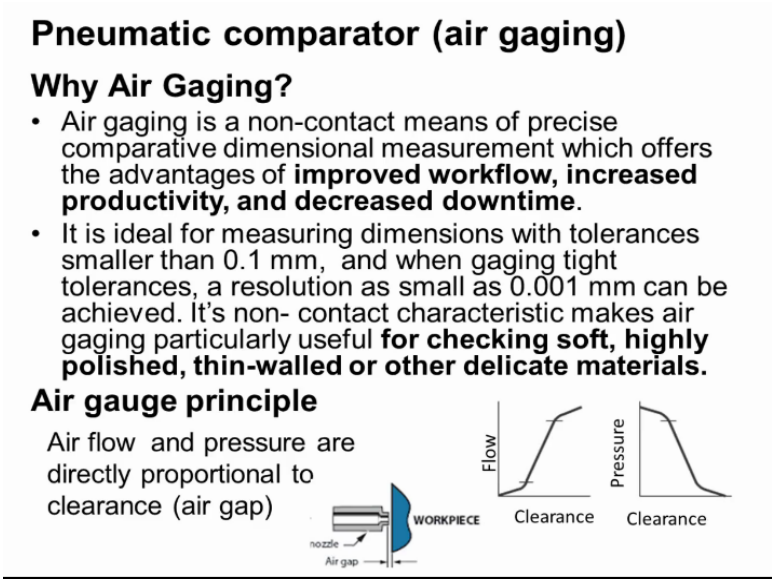

Now let us study why there is need for air gauging circuits or pneumatic comparators, basically they are non-contact type of comparators because of this, they offer the advantages of improved work flow, increased productivity and decreased down time. They are ideal for measuring the dimensions with tolerances smaller than 0.1 mm and when gauging a very tight tolerances, a resolution as small as 0.001 mm can be achieved.

It is non-contact characteristic makes air gauging particularly useful for checking very soft materials, highly polished surfaces, components with highly polished surfaces, the components with very thin walls and other delicate materials. In case of delicate materials and work pieces with highly polished surfaces, we use contacted comparators, then the scratches may appear on work piece, so in that cases, non contact type comparators are designed.

So pneumatic comparators offer that particular benefit of not making any scratch on the work piece surface. Now let us study about air gauge principle, so in this diagram, we can see there is a work piece, this is the surface of the work piece and we have a nozzle, so this is the gap between the nozzle and the work piece. Now when the air gap of the clearance between the

work piece and the nozzle increases, the flow of air through the nozzle increases and when clearance reduces, air gap reduces, the pressure increases.

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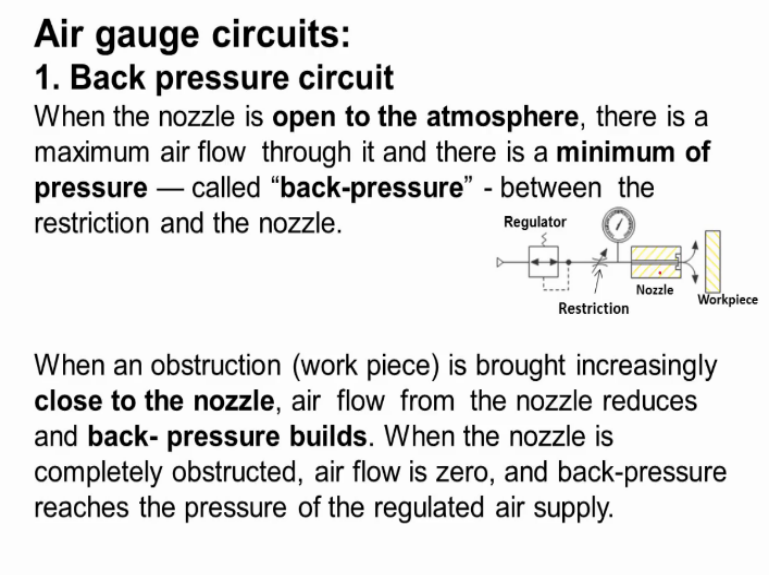

So, this characteristics is used in the pneumatic comparators. Now let us study about the different types of air gauging circuits that are available, first one is the back pressure circuit. We can see in this diagram, this is work piece, this is nozzle and this is the air gap or clearance between the work piece and nozzle and we have the compressed air supply and there is a pressure regulator, so desired pressure is set using this regulator and there is restrictor to restrict the flow of air.

Now when the gap between the nozzle and work piece is high, the airflow is easy. The air escapes easily into the atmosphere and little pressure is developed in the system. Now when the work piece moves towards the work piece, or in other words when the size of this particular size increases that means the air gap reduces, the escapement of air is restricted, so a back pressure is developed in the circuit, which is indicated in this gauge.

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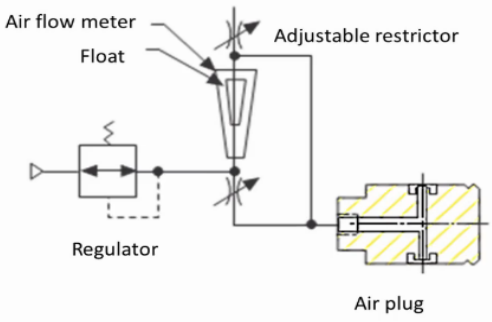
2. Air flow system

Variation in air flow provides an accurate correlation of the distance of the nozzle in the air gage tool to the obstruction (the surface of the work piece being measured).



So the development of back pressure is used to indicate the dimensional feature in this particular circuit, so another circuit, the airflow is measured, again we have the air plug gauge wherein we have 2 jets. this is the work piece and then this particular dimensions say D is to be checked in pneumatic comparator, now we have the pressure regulator and then there is a air flow meter, for example rotor can be used in such applications.

In the airflow meter, we have float, now when the gap between the plug and the work piece reduces, the airflow is restricted that means airflow reduces, so float level reduces. When this gap increases, airflow will increase and air will escape freely, hence air flow increases with float level increase that will be a scale fixed on the air flow meter, so by knowing the position of the float with respect today skill, we will come to know about the size of the work piece.

(Refer Slide Time: 07:06)

Components of pneumatic comparators

- A **precision air regulator** – to provide consistent air pressure.
- **Tooling** – plugs, rings, or other shapes — which deliver a specific air flow or pressure to the surfaces being checked.
- **An amplifier** – which can be an **air-electronic column**, a **dial-type meter**, or a **flow meter tube**. The amplifier provides visual representation of the size being measured, permitting the user to take readings quickly and accurately

Now let us study what are all the various components used in pneumatic comparators, essentially the comparator requires precision air regulator to provide a constant pressure air supply to the system and then different kinds of tooling are needed like plugs, rings and other shed depending up on the work to be inspected.

These tooling deliver specific airflow or pressure to the surfaces being checked. An amplifier is another essential component used in pneumatic comparator and this amplifier can be a air electronic column or it could be a dialed type meter or it could be a flow meter. The amplifier provides visual representation of the size being measured permitting the user to take readings quickly and accurately.

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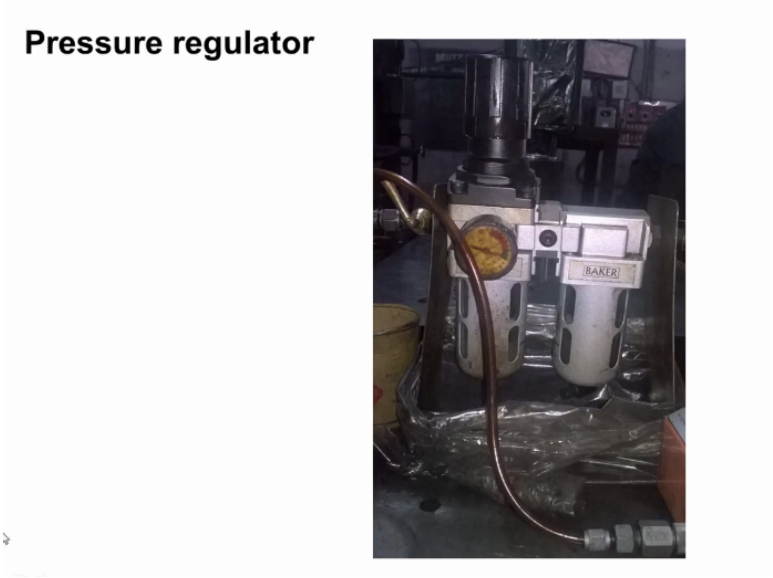

Now in this photograph, we can see a pressure regulator, this is the pressure regulator with filter to clean the air supplied here and this is the knob to adjust the air pressure, and what is the level of the pressure that is available in the system can be noted down by this pressure indicator.

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Setting masters are used to calibrate the comparator depending upon the system 1 or 2 masters usually in the form of discs or rings are used. Masters are typically made from alloy steel or tungsten carbide. We can see here one set of setting masters are used to collaborate the system, one for setting the upper limit of work piece and another for setting the lower limit of work piece.

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This is the close view of setting master, we can see here this is for a particular dimension that is 102.01 mm, this is the desired size of the work piece and this particular setting master used to set the upper limit that is 102.01 + 0.0104 mm, this is the upper limit of work piece and then we have another setting master to set the lower limit of the work piece, so again the basic size is 102.01 mm and this particular setting master used to set the lower limit that is 102.01 - 0.0094 mm, which is the lower limit of the work piece.

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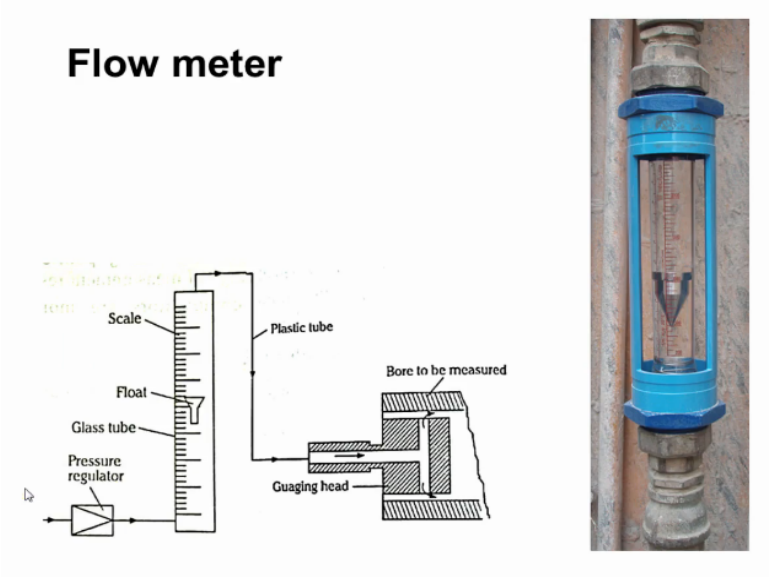

The amplifier or indicators are essentially required, now this photograph shows flow meter, a rotameter, this is a tapered inside surface of flow meter is tapered like this, now this is the shape of the flow meter, inside is the taper and then a scale graduated scale is on the outer surface of the glass tube and then we have float, which will float inside the tapered tube a metallic flow. Now when the gap between the work surface and gauge reduces, airflow reduces and float level will come down.

So, it will indicate that the dimension being checked is small. Now when the gap increases, air flow is more, so the float level increases, which will indicate that the dimension of this particular feature is more, so we can always set 2 limits, upper limit and lower limit using the setting masters, so when the flow crosses the upper limit or lower limit, then the work piece is presumptive.

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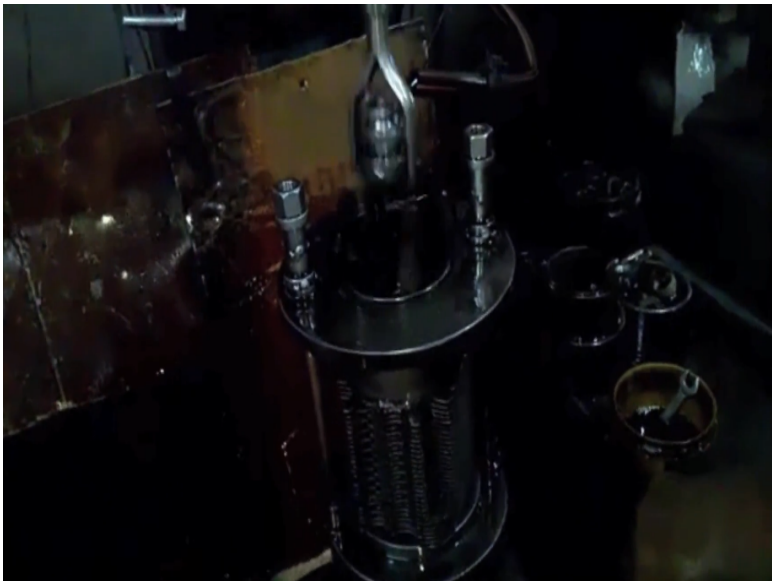

Now let us see the working of air gauge operators, now we are observing the operation, a work piece is clamped ad honing tool is inserted into the bore of the work piece, the honing tool is adjusted. Now the machine is started, the honing tool is reciprocating and rotating, this reciprocating rate and rotation rates can be adjusted depending upon the surface inertia required.

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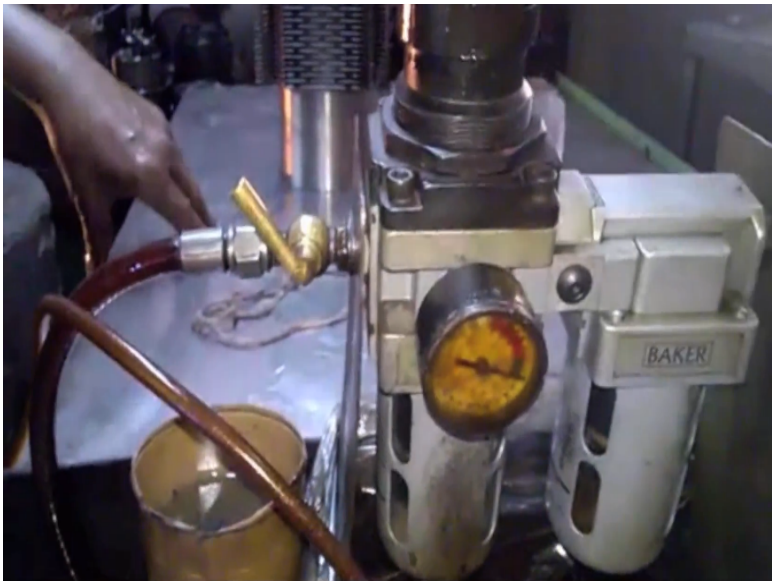

Now the operator is removing the work piece, we can see the coolant flow, lubricant flow, now the coned surface is visually inspected for the finish. Now we are observing the pressure regulator and filter. We can see the pressure indicator using this we can set the working pressure to required pressure like 3 bar, 4 bar or 5 bar. Now, this green area indicates the pressure range in which the air gauge can be used.

Now we are observing an indicator, which shows the size variation in terms of microns, so 1 small division is 1 micron. When we insert the plug gauge into the bore of the work piece depending upon the clearance between the work piece surface and dug gauge, the pointer will move and we can note down the reading. Now we can observe the operator is inserting reflect gauge into the bore, he is rotating the work piece or gauge to check for roundness and vertical movement to check the cylindricity of the bore.

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Now we can observe the air plug gauge, air jets through which air escapes, in the opposite direction we have air jets. Now we can see the air connection via the air gauge, the air will flow and it will enter into the air plug gauge. Now holes are provided in the air plug gauge to reduce the rate of the plug gauge. We can set the air gauge, so initial calibration we have to do using the masters.

We can set the limiters, we can observe 2 limiters are there, we can set these limiters to indicate upper limit and lower limit of the both sides, now the plug gauge is being inserted into the work piece. Now operator is rotating the work piece, he is removing the plug gauge. So now we can observe the 2 masters for initial calibration of the air gauge, so this is +0.0104 mm from the desired size and on the lower side -0.0094 mm.

Now, we are observing the indicator removed from air gauge center, we can see the plunger. When the plunger is moved, the pointer rotates, we can see the range 0 to 50 microns on both sides clockwise, as well as anti-clockwise. Now this is the place, where the indicator should

be inserted and operator is inserting the indicator and then using masters, we can set the indicator.

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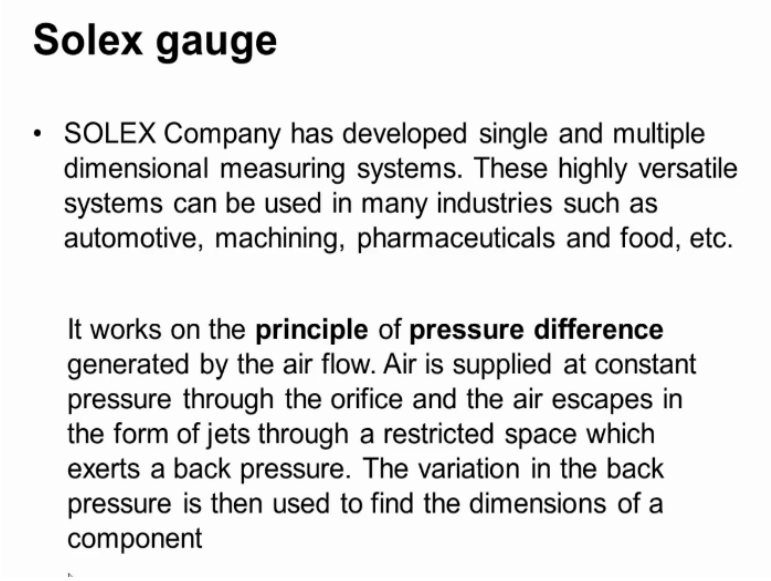

Now let us study a commercially available pneumatic comparator, which is known as Solex gauge produced by Solex company, so this Solex company has developed single and multiple dimensional measuring systems that means a single dimension can be measured at a time or multiple dimensions can be compared simultaneously. These highly versatile systems can be used in many industries such as automotive industry, manufacturing industries, pharmaceuticals and food industries, etc.

They work on the principle of pressure difference generated by the airflow that is back pressure is measured, which will indicate about the size of the work piece. Air is supplied at constant pressure through the orifice and the air escapes in the form of jets through the restricted space, which exerts a back pressure in the system. The variation in the back pressure is then used to find the dimensions of the components.

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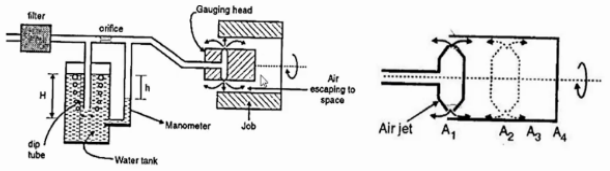
Working of solex gauge

Compressed air is supplied to the system (pressure equal to water head H). Required pressure is maintained by adjusting the **depth of the dip tube** in the water tank.

The excess air escapes in the form of bubbles.

Then the controlled amount of air is passed through the orifice at the **constant pressure**, air is connected to the gauging head.

Due to restricted area, between the gauging head and work piece, at A1 position, the back pressure (h) is developed which is indicated in the manometer tube.



Now let us study how the Solex gauge works, compressed air is supplied to the system, the pressure of the air will be equal to water head History of, we can see here, we have a tank here filled with water to a certain level and this H indicates the air pressure. This value of this pressure can be varied by adjusting the depth of the dip tube in the water tank, so we can adjust the depth and then we can adjust the measured system.

Then, excess air escapes in the form of bubbles, which we can observe here. The controlled amount of air is passed through the office, so we can orifice here and it is connected to the gauging head, the restricted area between the gauging head and work piece, say for example at position A1, the back pressure h is developed because of the restriction here, the back pressure h developed, which indicates the size of the dimensional feature, for example the hole diameter disk.

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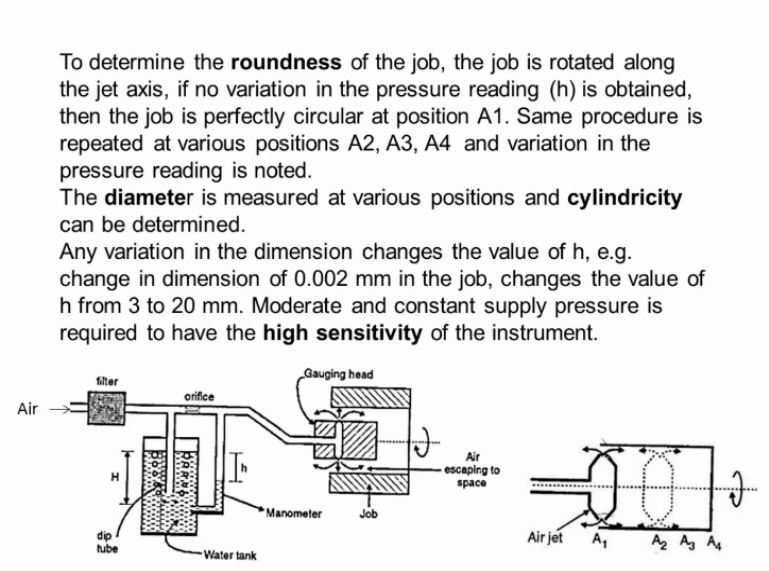

Now you can also determine the roundness of the job and then cylindricity of the job using this system. To determine the roundness of the job, the work piece is rotated along the jet axis, so this is the jet axis and the work piece is rotated. If no variation in pressure reading h, when the job is rotated it indicates that the work piece is perfectly round at this particular position.

So this procedure is repeated at different positions along the length of the hole A2, A3, A4, etc. and then we can note down what is the roundness of different positions of the work piece. Similarly, we can measure the cylindricity of the work pieces. The diameter is measured at various positions A1, A2, A3, A4, etc., which will give the information about the cylindricity.

For example, we have work piece in the axis of the work piece and then we are using 2 gauging head to check the diameter. Now the reading h here and then what is the reading h at this position A1 is noted down, then gauge is moved and then reading is taken at position A2 and then A3 like this at different positions, the reading h is taken.

If there is any variation that will indicate whether the whole work piece is tapered or double tapered like this or the hole is barrel shaped or well mouth shape, so such cylindrical features we can check using this gauges.

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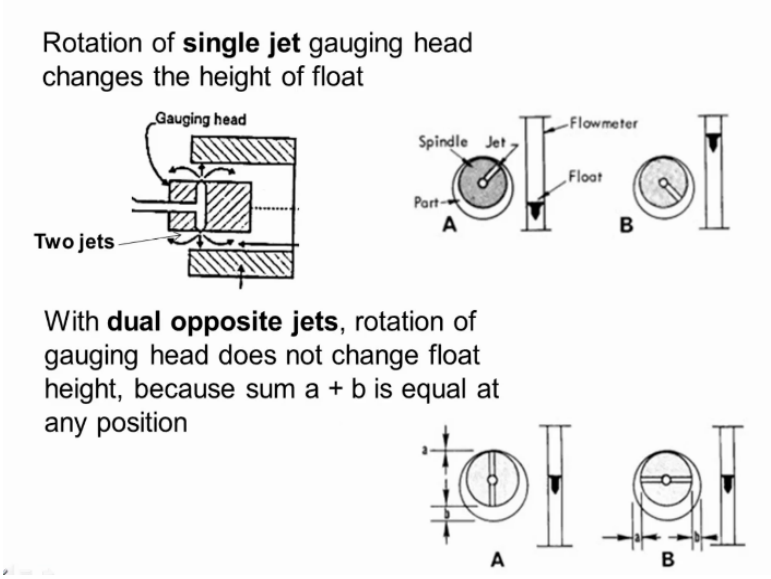

Now let us study why 2 jets are used, we an observe here 2 jets are used in this particular gauging head, what happens if we use a similar jet. Now we can observe here, this is the work piece part being inspected under the gauging head or it is also known as spindle with single jet. Now when the spindle is rotated keeping the jaw fixed, this clearance is varying from angular position to angular position.

Because of this, the float will move up and down, so this will indicate that the diameter is varying from angular position to angular position. Even though, the inside bore is round because of this use of single jet, since the float move up and down, so it will give a false information about the roundness of this bore. Now what happens if we use a double jet in the opposite faces.

So when we rotate the spindle with 2 opposite jets, the sum A+B, this clearance and this clearance or this clearance and this clearance, sum A+B will remain constant at any angular position, so the float remains constant, so when the spindle is rotated, this will not move because the because summation A+B remains constant.

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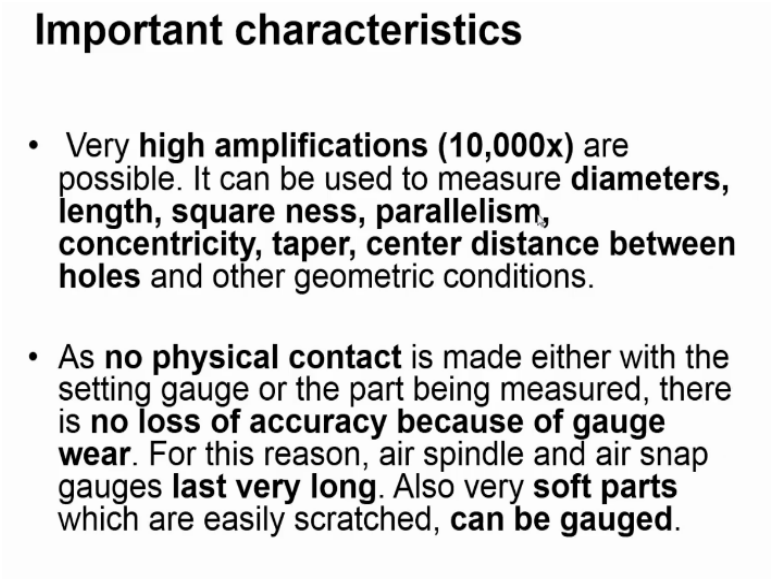

So it will indicate that the hole is round, so this is the advantage of using the dual opposite jets, it will give the correct information about roundness of the bores. Now let us study what are the important characteristics of air gauging. Air gauging operators are available with very high amplifications are amplifications as high as 10,000 times.

It can be used to measure the parameters like diameters, length of the component, square ness, parallelism, concentricity, taper measurement is possible, center distance between 2 holes also can be checked using the air gauging. As there is no physical contact between the gauging head and the work part, the accuracy will not be lost because of the gauge wear.

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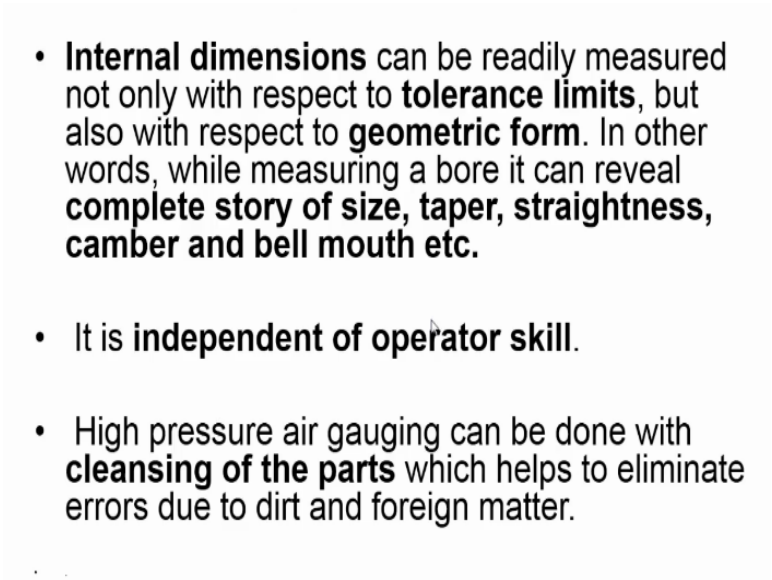

For this reason, air spindle and a snap gauges last very long, also very soft parts can be gauged without any chances of getting scratched. Internal dimensions of the components can

be readily measured, not only with respect to the tolerance limits, but also with respect to the geometric form. Geometric aspect such as tape or straightness, camber, and bell mouth can be easily checked.

These air gauges, they are independent of operator skill. Any unskilled operator can easily use these air gauges for checking the components. High pressure air gauging can be done with cleansing of the parts, which helps to eliminate errors due to the dirt and foreign matter.

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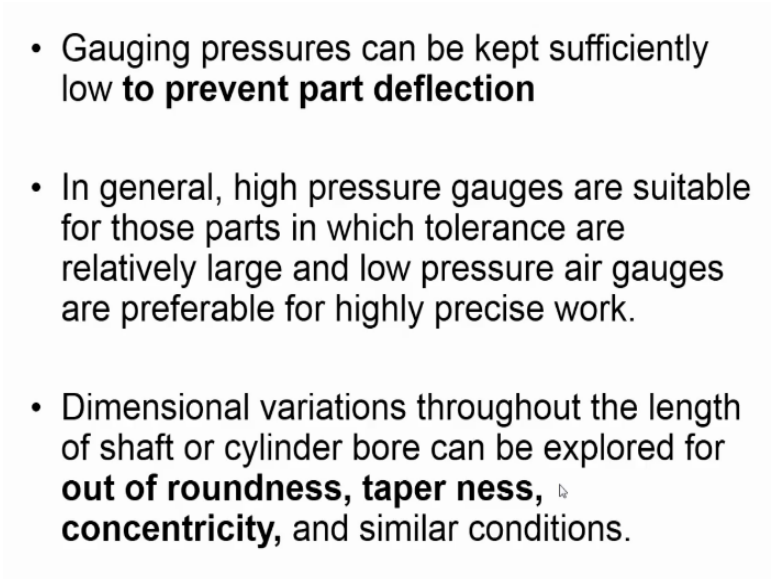

Gauging pressures can be kept sufficiently low as low as some 3 bar or 3 bar to prevent part deflection. In general, high pressure gauges are suitable for those parts in which tolerance are relatively large and low pressure air gauges are preferable for highly precise work. Dimensional variations throughout the length of shaft or cylindrical bore can be explored for out of roundness, taper ness, concentricity and similar other conditions.

That means if we have a cylinder bore like this, we can insert the air gauges into the bore and the bore can be checked throughout ft length for circularity, taper ness, concentricity etc.

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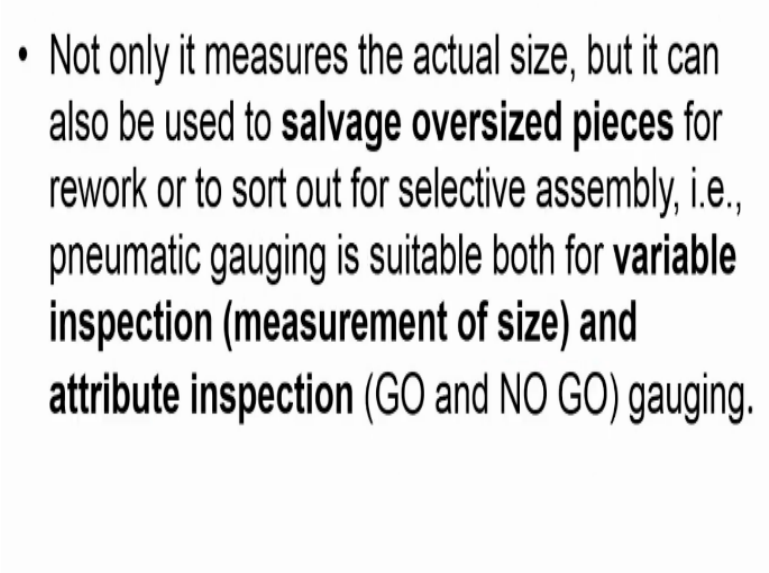

Not only it measures the actual size, but it can also be used for salvage oversized work pieces for rework or to sort out for selective assembly that is pneumatic gauging is very much suitable for variable inspection that is for the measurement of size and also for attribute inspection to segregate the work pieces into acceptable and unacceptable work pieces.

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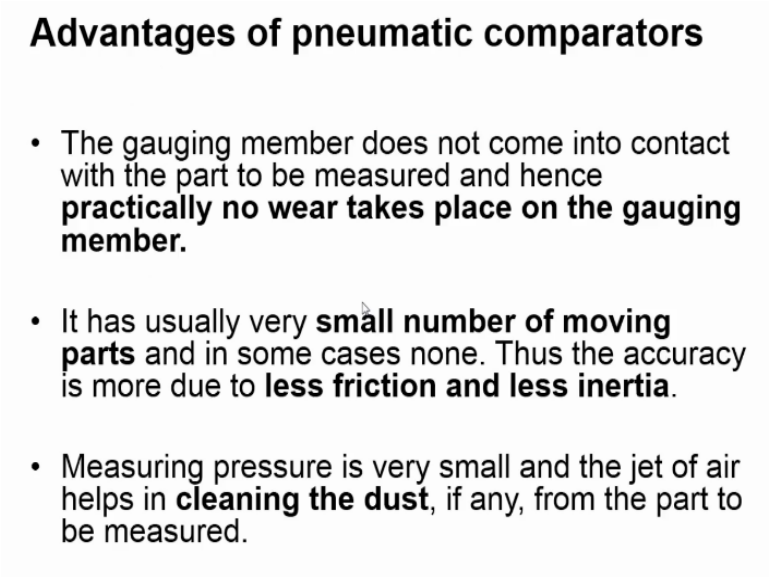

Now let us study what are the advantages of pneumatic comparators. The gauging member does not come in contact with the part to be measured and hence practically., there is no wear of the gauging member, also there are no chances of scratches on the surface of the work piece. It has usually very small number of moving parts, thus the accuracy is more due to less friction and less inertia.

Measuring pressure is very small, it can be as low as some 3 to 4 bar and the jet of air helps for cleaning of the work surfaces. We can also have very high magnification as high as 10,000 times. The indicating instrument can be removed from the measuring unit.

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- It is possible to have very **high magnification** (10,000 x)
- The indicating instrument can be **remote** from the measuring unit.
- It is very suitable device for measuring **diameter** of holes where the diameter is small compared with the length.
- It is possibly the best method for detecting the **ovality** and **taperness** of the circular bores.

These air gauges are very much suitable for measuring diameter of holes, where the diameter is very small compared with the length, for example deep holes like gun barrels can be easily checked with these gauges, it is possibly the best method for detecting the ovality and taper ness of circular bores, so we can check whether there is any taper ness or some bell mouth shape or some barrel shape in the hole, so such things can be easily checked using these air gauges.

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- A row of multiple column amplifiers can be scanned in one glance, **reducing time and fatigue**
- The **amplifier provides visual representation** of the size being measured, permitting the user **to take readings quickly and accurately.**
  - -Back-pressure systems use either columns or dials to display readings
  - -Flow systems use flow meter tubes.
- **Parallel stacking of columns or flow meter tubes** puts all the readouts into the same vertical relationship, making comparisons simpler.

A row of multiple column amplifiers can be scanned in one glance, we can see here many column amplifiers are available and we an observe the multiple readings or multiple features of the work piece at a time, so that the work pieces can be checked at a faster rate that means the checking time or inspection time can be greatly reduced by using multiple gauging. These amplifier, they provides visual representation of the checked feature.

It permits the operator to take readings quickly and accurately, either back pressure system can be used or flow systems, which uses flow meter tubes can be used for visual representation and parallel stacking of columns or flow meter tubes puts all the readouts into the same vertical relationship making comparison very much simpler. For example, multiple dimensions like this can be checked using multiple gauging operators and the relationship can be easily understood by using multiple amplifiers.

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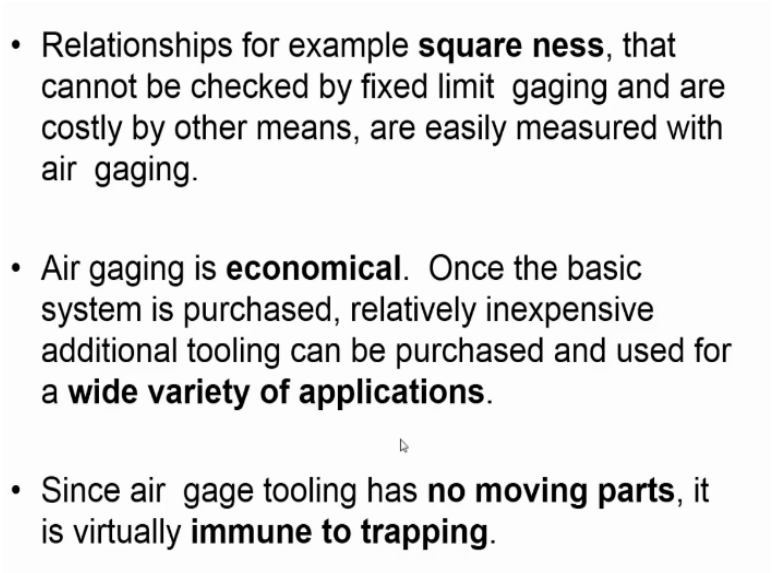

Relationships for example square ness can be easily checked using air gauges. For example, we have a bore like this, whether this bore is perpendicular to the phase such features can be easily checked. air gauging is very much economical. Once the basic system is purchased relatively inexpensive additional tooling such as the gauging heads can be purchased and used for a wide variety of applications.

Since air gauge tooling has less moving parts and most of the cases, no moving parts, it is virtually immune to trapping that means the gauge will not get trapped in the work part.

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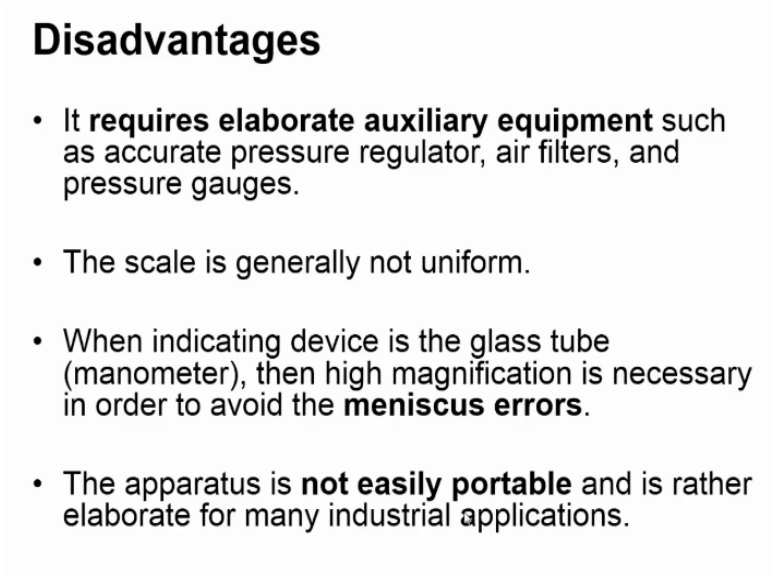

Now let us study what are the disadvantages of air gauging systems. It requires very elaborate auxiliary equipment such as pressure gauges or pressure regulators are required, air filters are needed for filtering the dust particles, so like this it requires elaborate auxiliary equipment. The scale is not generally uniform, when indicating device is the glass tube.

For example a manometer, then very high magnification is necessary in order to avoid the meniscus errors. The apparatus is not easily portable since it is bulky, it should be placed at work place and is rather elaborate for many industrial applications.

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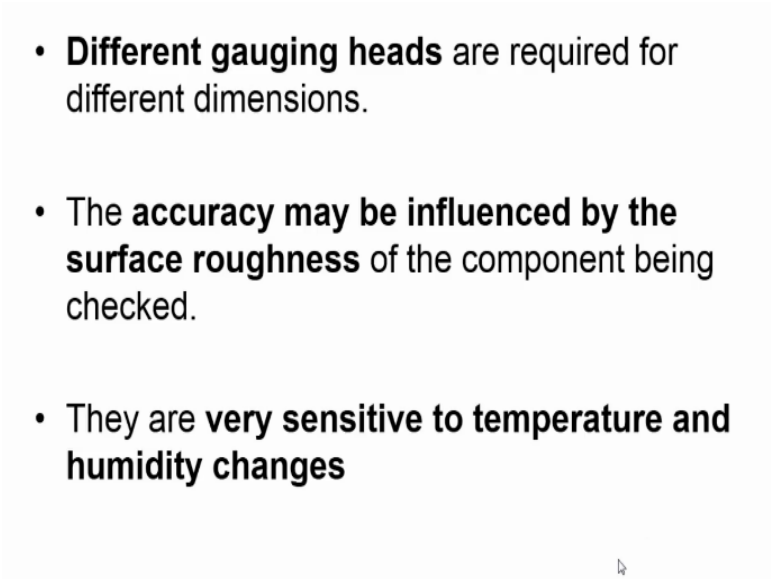

Now different gauging heads were required for different dimension, for example, when the bore size changes, we have to have different set of gauging heads. For example, for 10 mm

bore size, we need 1 gauging head and for 12 mm bore size, we need another gauging head, so like this as the dimension changes, we need to purchase the necessary gauging heads.

The accuracy may be influenced by the surface roughness of the component, which is being checked that means the surface roughness will also affect the reading. They are very sensitive to temperature and humidity changes, so sometimes it becomes necessary to control the working environment, where the air gauges are used.

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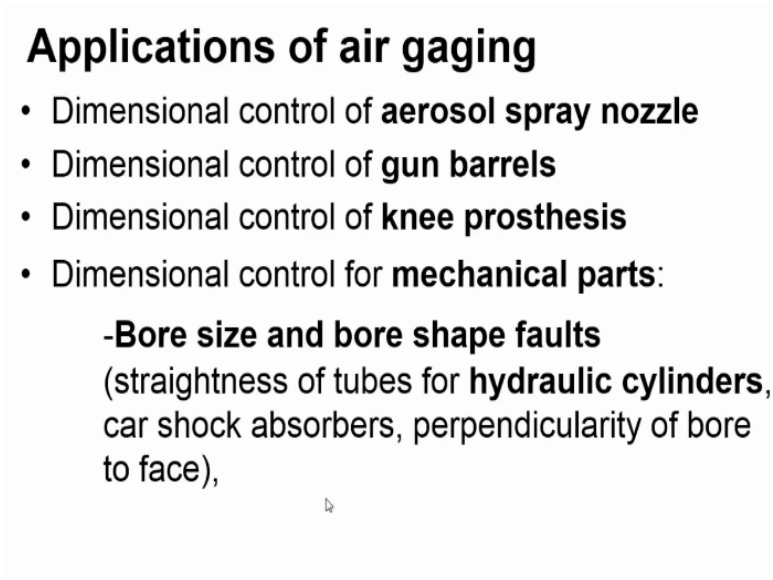

Now let us study what are the various applications of air gauging, these air gauges they are used for dimensional control of aerosol spray nozzle and they are used to control the gun barrels, they are also used to control the dimensions of knee prosthesis. They are very much used for dimensional control of mechanical parts such as bore size and bore shape faults can be detected that means straightness of tubes for hydraulic cylinders.

For example, we have an hydraulic cylinder with a bore, so whether the bore is straight or whether the bore is perpendicular with respect to face or not, such things can be checked. They are used to check the car shock absorbers and perpendicular of bore to face, so such features can be easily checked using air gauges.

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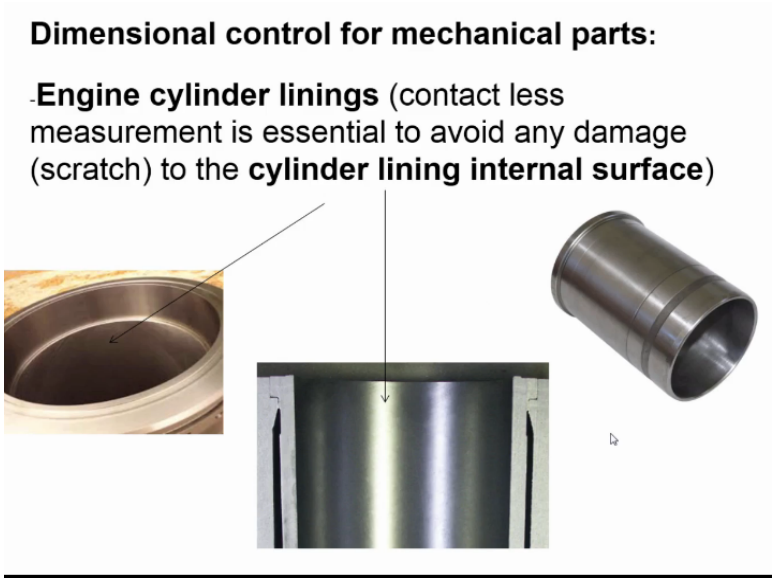

Dimensional control of mechanical parts such as engine cylinder linings can be checked. These engine cylinder internal surfaces, they require very good and fine surface and no scratches should appear on the internal surface of the liners, so in such cases since the air gauge is non-contacted, they are very much used to inspect the lining, cylinder lining of internal surfaces.

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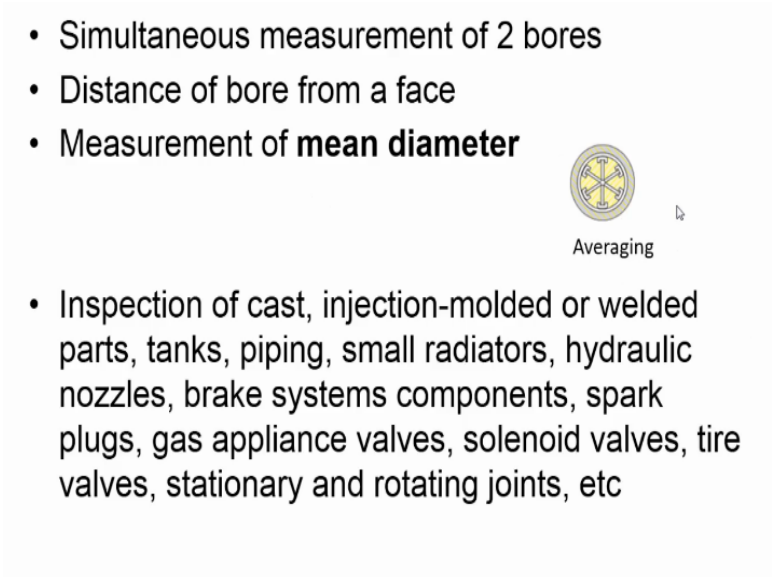

Now it is possible to measure the multiple bores at a time and distance of the bore from face, for example, we have bore and then we have surface here, so what is the distance between this surface and the bore, distance between bore and this face can be checked and it is possible to measure the average diameter by having multiple jets, it is possible to get the average size of the bore and these air gauges.

They are used for inspection of castings, injection molded or welded parts, tanks, pipings, and hydraulic nozzles and brake system components are checked by suing the air gauges. They are also used to check spark plugs, gas appliance valves, solenoid valves, tire valves, stationary and rotating joints etc.

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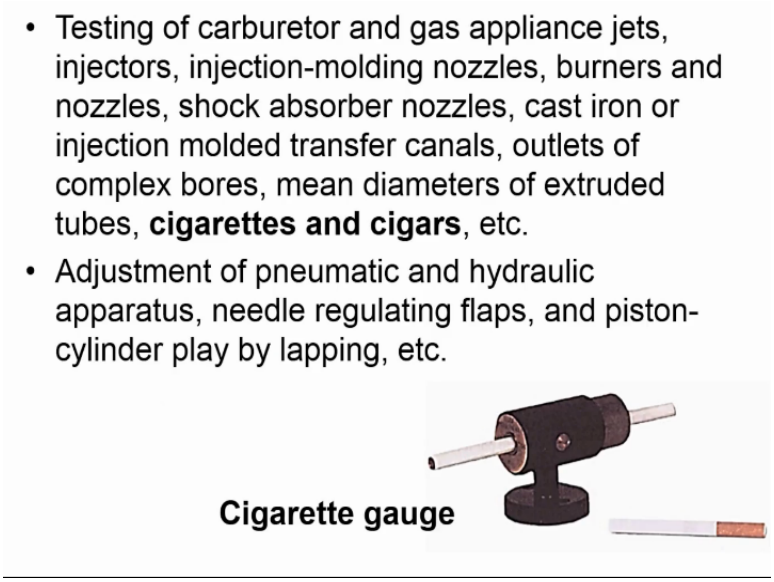

Testing of carburetor and gas appliance jets, injectors, injection molding nozzles are checked by using air gauges. Burners and nozzles are checked, shock absorber nozzles are checked by air gauges, cast iron and injection molded transfer canals, outlets of complex bores are easily checked by air gauging systems and mean diameters of extruded tubes, cigarettes, etc., they are inspected by using air gauges.

Adjustment of pneumatic and hydraulic apparatus, needle regulating flaps and piston cylinder play such things are checked by using air gauges. So in this picture, we can see a cigarette gauge, cigarette is placed here and it is checked for its dimensions.

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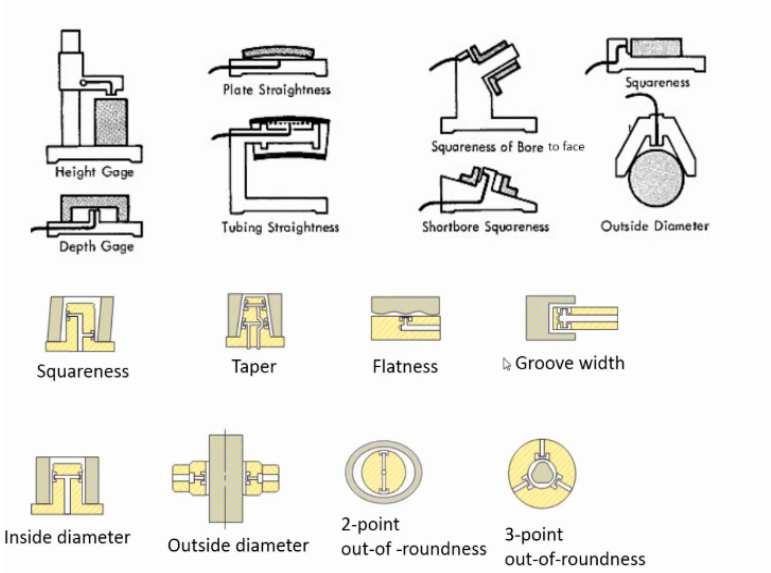

Now we can see some of the applications, what is the height of the component can be easily checked by using air gauges and we can check whether the plate is straight or not, whether there is any curvature in the surface, such things can be checked and here we can see a system where in we can easily check the square ness of bore to face, whether this bore is perpendicular to the face.

It can be checked and the square ness, whether this vertical surface is square with the bottom surface, such things can be checked and then what is the depth of linked hole in the work piece can be easily checked and tubing straightness can be checked by inserting the gauging head into the tube and short bore square ness can be checked, outside diameters can be easily checked.

Square ness of the bore with the face can be checked, taper in the component can be checked, the flatness, screw width, inside diameter, outside diameter such things can be easily checked using air gauges and this shows system where in 2 point out of roundness can be checked and here this 3 point out of roundness can be checked.

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Measuring groove width

Air plug for measuring taper

Master

Two-nozzle air plug, with masters, for measuring inside diameter

Now we can see here, the measurement of groove width, so what is the groove width can be easily checked using air gauges and this is air plug for measuring the taper. We can see the air jets here and the connections, ports for connecting the pressurized air and this shows 2 nozzles air plug, so there will be 2 nozzles in the opposite sides with masters, one master to set upper limit and other master to set the lower limit of the component.

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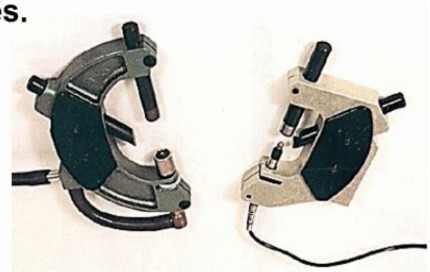
Custom gauges

Plug gauges and a number of air ring gauges can be custom manufactured.

-Taper air-jet ring gauges,

-Multi-diameter air-jet ring gauges, for **simultaneous measurement of several concentric bores.**

5- 300 mm (8models):
5- 38 mm,
32- 68 mm,
62- 98 mm,
92- 12 8mm,
122-158 mm,
155- 204 mm,
200- 250 mm,
250-300 mm



Hand caliper gauges

So this set can be used for measuring the inside diameter in the component. Now custom gauges are available based up on the particular applications, these air gauges are made and we can have plug gauges and also ring gauges, which can be manufactured as per the specifications, so taper air jet ring gauges can be made multi diameter air jet ring gauges can be made for simultaneous measurement of several concentric bores, so we can see here hand caliper gauges, so adjustable hand caliper gauges.

We can keep the work piece here and we can check whether the size is okay or not, so these are adjustable hand caliper gauges. They can be made in different sizes, 5 to 38 mm size, 32 to 68, so like this with different ranges these can be manufactured.

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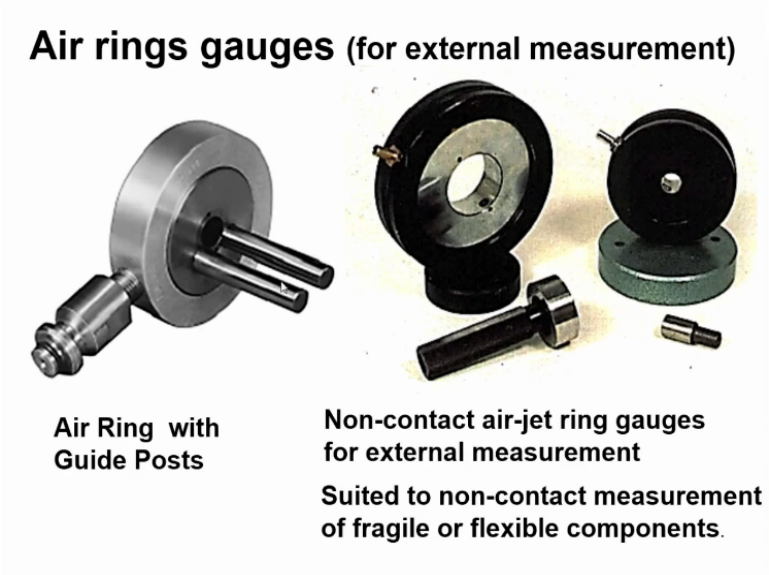

Now we can see air ring gauges for measurement of external diameter, so we can see the pole for connecting the compressed air and we can see the air jets here, so work piece can be inserted and the external size measurement can be easily made. Now this shows air ring with guide post for guiding the gauge.

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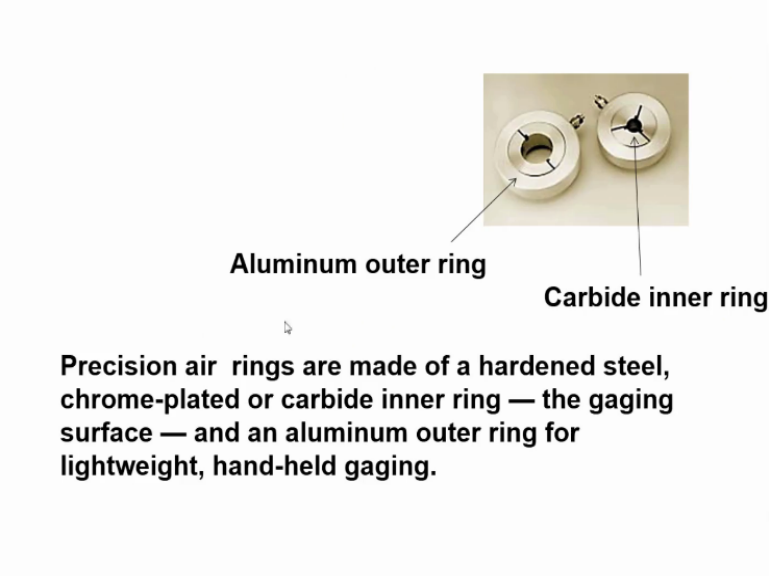

Now here we see a special type of air gauging system where in inside we have 2 portions, one is outside portion, outside ring, which is made out of aluminum outer ring and inside portion

is made out of carbide inner ring, so this outer ring is made by aluminum to reduce the weight of the gauge.

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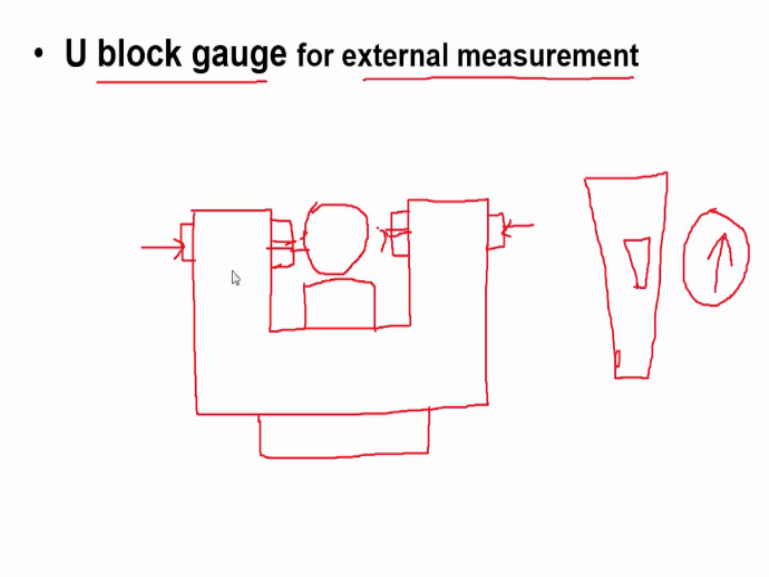

Now for external measurement of the external feature measurement, U block gauges are available, so they will be like this, so this is the body of U block gauge and if the table on which the work piece can be mounted and here we have jets, so we can have jet here, so where air will escape and air connection can be made here.

Here, we can place the work piece depending upon the clearance, we can get the reading from the floor position or if you are using back pressure type, the gauge will indicate what is the size, so this is a U block air gauge for external feature measurement.

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Now we see some air plug gauges for internal measurement here, so these plug gauges, they are inserted into the bore and air escapes here depending upon the clearance, we will get the reading, so the air plug gauges with different sizes are available. We can have air plug gauges in this range 3 to 160 mm, even bigger size gauges are available, we can see a special air plug gauge.

So we have split type air plug gauge, so where in the weight of the plug gauge can be reduced, accuracy between 25 to 200 micrometer is possible in such air plug gauges.

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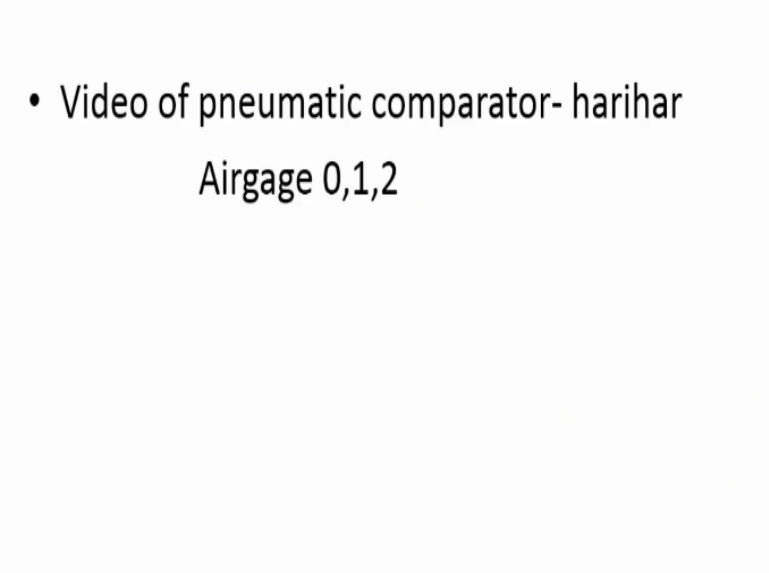

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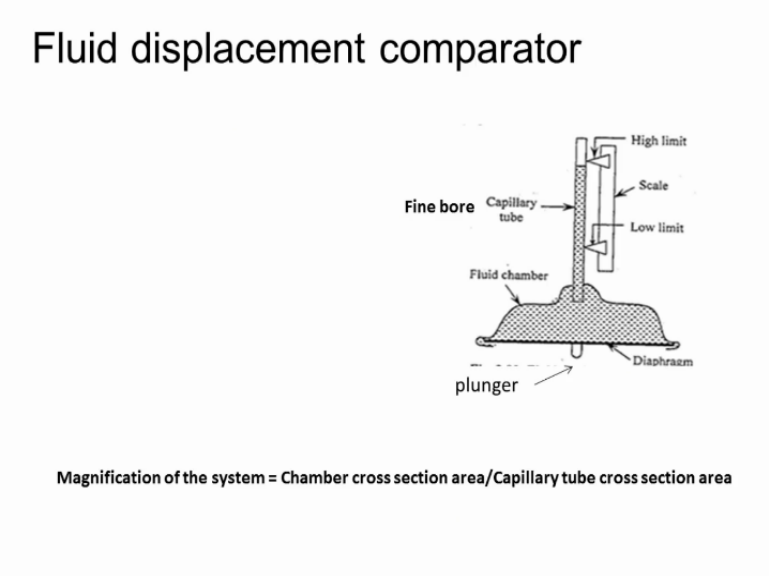

Now let us study about another type of comparator, which is known as fluid displacement comparator, so we can see the construction of fluid displacement comparator in this diagram.

There is a chamber in which low viscosity liquid is filled, one end of the chamber is having a diaphragm to which a plunger is fixed, at the other end of the fluid chamber, we have fine bore capillary tube.

When the diaphragm deflects, the liquid rises in the capillary tube and there is a scale to note down the level of liquid in the capillary tube. We can also have 2 pointers to indicate upper limit of the work piece and lower limit of the work piece. Now during usage of fluid displacement comparator, what we have to do is we have to insert the work piece between the table and the plunger.

Depending upon actual size of the work piece whether it is greater than the desired size or lower than the desired size, this plunger will move up and down accordingly, the liquid level in the capillary tube will rise or fall. Now if the work piece size is equal to the desired size, then the level of the liquid in the capillary tube will be in the middle position to indicate that is the desired position that means the deviation of the work piece from the desired size is 0.

Now, when the size of the work piece is smaller than the desired size, then the plunger will move down and the level of liquid in the capillary tube will move down. If the size of work piece is greater than the desired size, then the liquid level in the capillary tube will move up. If the liquid level in the capillary tube is beyond the upper limit or lower than the lower limit, then the work piece is rejected.

Now the magnification of such a system is chamber cross sectional area divided by capillary tube cross sectional area. By adjusting these values, we can construct a fluid displacement comparator of the desired magnification.

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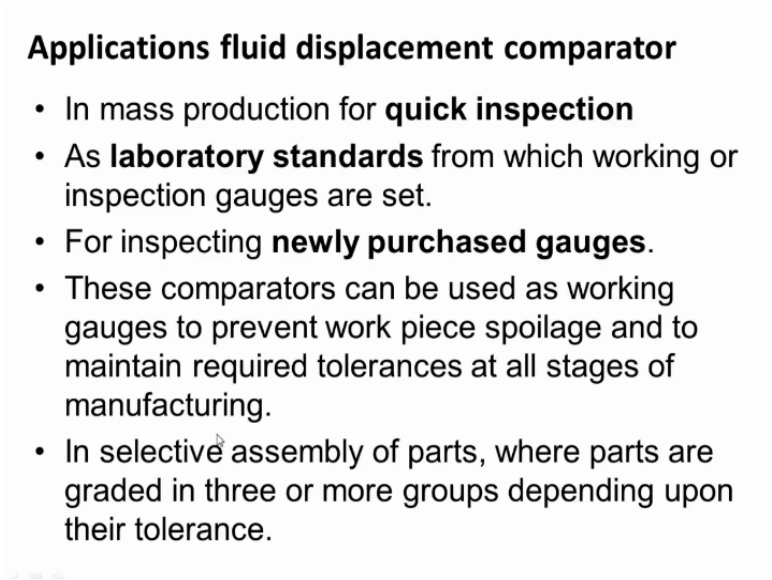

Now let us study what are the various applications of fluid displacement comparator, these comparators are used in mass production for quick inspection. The operators will insert the work pieces between plunger and table and then they will just observe what is the level of liquid in the capillary tube and then they take the decision whether the work piece is acceptable or not.

It can be used as a laboratory standard from which working gauges or inspection gauges can be set. These fluid displacement comparators are used for inspecting newly purchased gauges. They can also be used as working gauges to prevent work piece spoilage during the manufacturing all the work pieces, to maintain the required tolerances on the work pieces.

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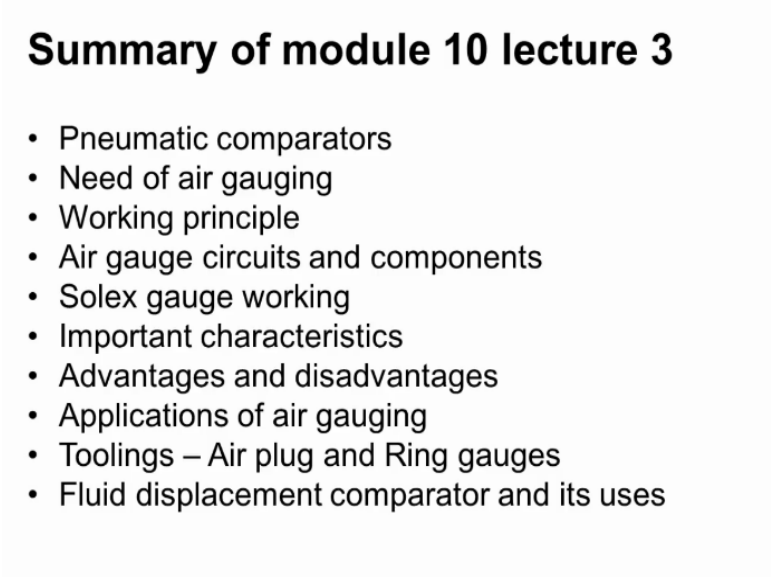

These can be used in selective assembly of parts, where parts are graded in 3 or more groups depending upon their tolerance. Now let us conclude the module 10, lecture 3. In this lecture, we discussed about the different aspects of pneumatic comparators, we discussed about the need of air gauging systems and working principle or air gauging systems, we also discussed about the different circuits used in air gauges, such as back pressure circuit or the free flow circuit.

We also discussed about the various components used in air gauging systems such as amplifiers and then different types of gauges, different type of amplifier system, and we also discussed about commercially available Solex gauge system. We discussed about the various important characteristics of air gauging systems, what are the advantage and disadvantages of the air gauging systems.

We also discussed about the various applications of air gauging systems and different fields like manufacturing field and how they can be used to check prosthetic tooling also discussed like air plug and ring gauges, we also saw about the fluid displacement comparator and what are the uses of fluid displacement comparator, so with this we will conclude module 10, lecture 3. Thank you.