Inspection and Quality Control In Manufacturing
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Lecture – 16
Engineering Metrology- Linear Measurement

Hello my friends now we are going to discuss about the engineering metrology that is linear measurements. So, from the title itself we can understand that in this particular lecture we are going to discuss that how we are going to measure. Till now we are talking about the different techniques now suppose you are getting one length or maybe the any width or maybe the any height. So, exactly whatever the instruments we are going to use that that instruments are proper or not.

Or maybe that instruments are capable to measure that particular dimensions exactly or not. So, in this particular lecture we are going to understand all these kind of things that how we can measure the exact dimensions over there. So, generally the metrology if we talk about the definitions soon only it is a one kind of science is measurement of 6 fundamental quantities.

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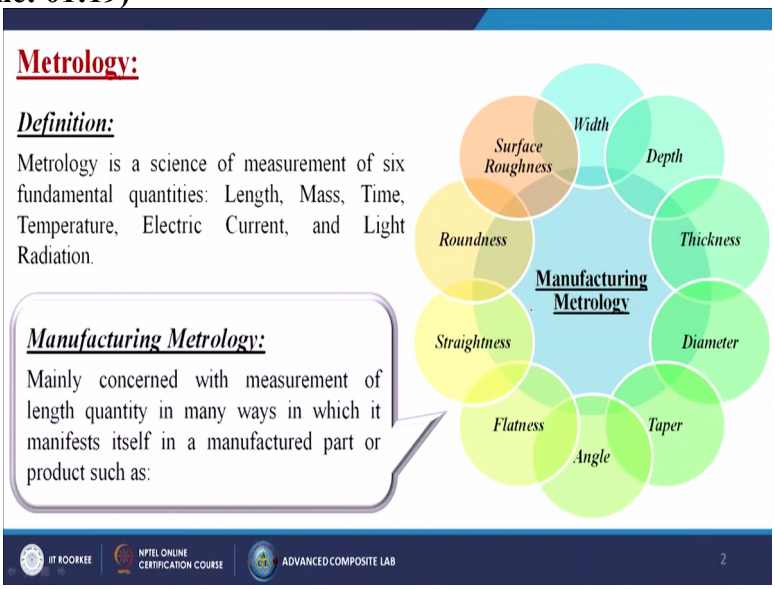

Like length mass, time, temperature, electric current and the light radiation. So, when you are talking about the manufacturing metrology. So, generally it is concerned with measurement of length quantity in many ways in which it manifests itself in a manufactured part or any product such as like width, depth, thickness, diameter, taper, angle, flatness, straightness, roundness and the surface roughness.

Now what is the objective of metrology so generally it will give you the required accuracy in measurement at the minimum cost. So, that means the cost will be reduced time consumption

will be reduced but simultaneously we will get the accurate specific dimensions or may be the information of that particular specimen.

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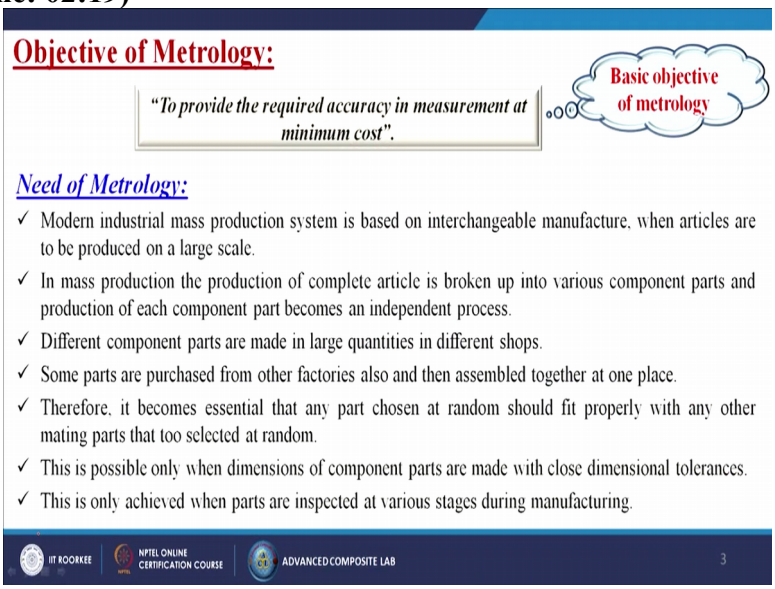

So now if we talk about that need of metrology: So, generally the modern industrial mass production system is based on interchangeable manufacture when articles are to be produced on a large scale. In mass production the production of complete article is broken up into various component parts and production of each component part becomes an independent process. Because when you are talking about any equipment that is consists of about n number of parts.

So, each part we are testing we are measuring and then after that we are doing the assembling. Different component parts are made in large quantities in different shops some parts are purchased from other factories also and then assemble together at one place therefore it becomes essential that any part shows in at random should fit properly with any other meeting parts that to selected at random.

Now this is possible only when dimensions of component parts are made with closed dimensional tolerances this is only achieved when the parts are inspected at various stages during the manufacturing process.

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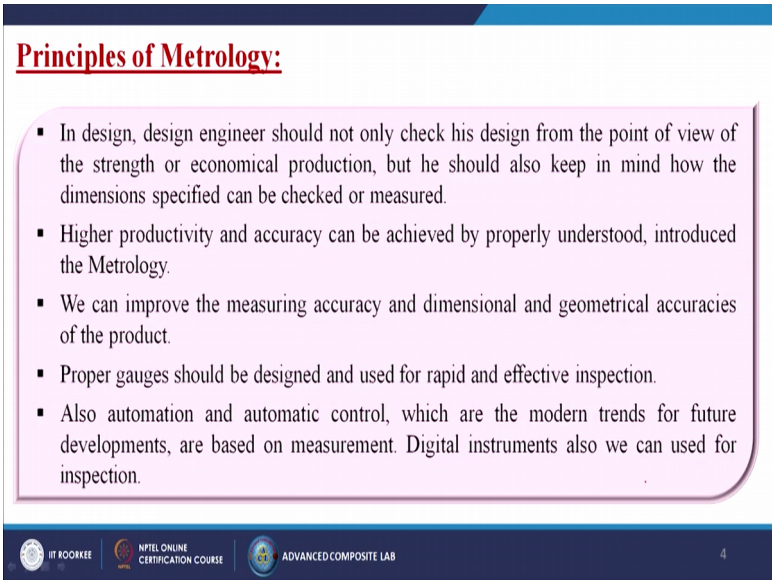

Now what is the principles of metrology? In design, design engineers should not only check his design from the point of view of the strength or economical productions but he should also keep in mind how the dimensions are specified can be checked or measured. So, that means suppose you are going to measure the thickness then how many times you are going to check how you are going to put your instruments so that you can get the accurate dimensions so, that all are the important parameters.

Higher productivity and accuracy can be achieved by properly understood introduced of the metrology system. We can improve the measuring accuracy and dimensional and geometrical accuracies of the product itself. Proper gauges should be designed and used for rapid and effective inspection also automation and automatic control which are the modern trends for future developments are based on measurement digital instruments also we can used for the inspection itself.

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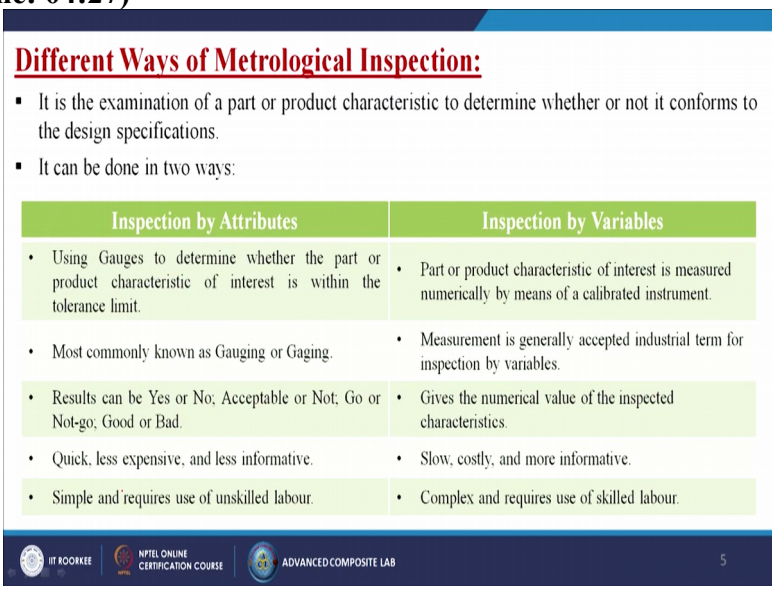

Now there are different ways of meteorological inspections it is the examination of a part or product characteristics to determine whether or not it confirms to the design specifications it can be done in two ways. First one is that inspection by attributes what is that using gauges to determine whether the part or product characteristics of interest is within the tolerance limit or not. Most commonly known as gauging or maybe the gazing only the spelling are the different.

Results can be yes or no acceptable or not go or not go good or bad. Quick less expensive and less infirmative simple and requires use of unskilled labour. Now second one is that inspection by variables part or product characteristics of interest is measured numerically by means of a calibrated instrument. Measurement is generally accept in industrial term for inspection by variables gives the numerical value of the inspected characteristics slow, costly and more informative, complex and requires use of the skilled laborer.

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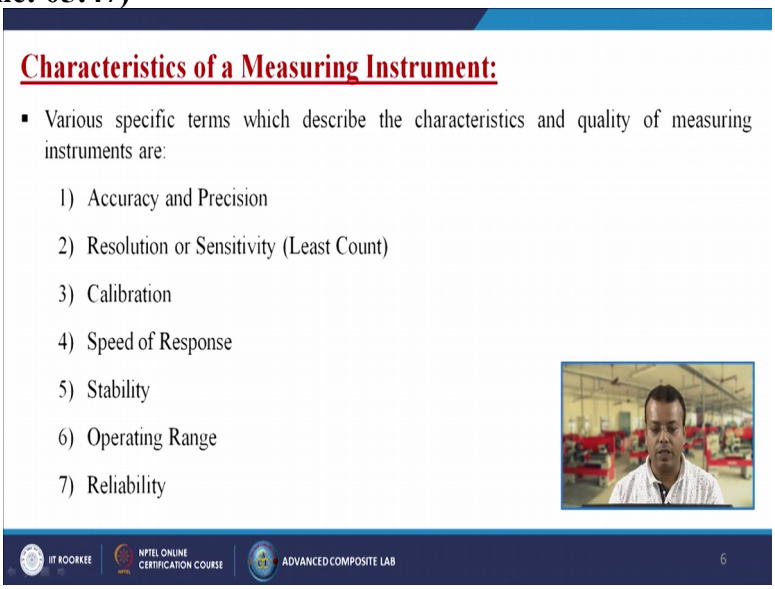

Now what is the characteristics of a measuring instrument? so generally the various specific terms which describe the characteristics and quality of measuring instruments are first one is the accuracy and precision. I will come one by one slowly. Second is called the resolution or sensitivity that means the least count, third one is the calibration, 4th one is the speed of response 5th is the stability, 6th is the operating range and 7th is nothing but the reliability.

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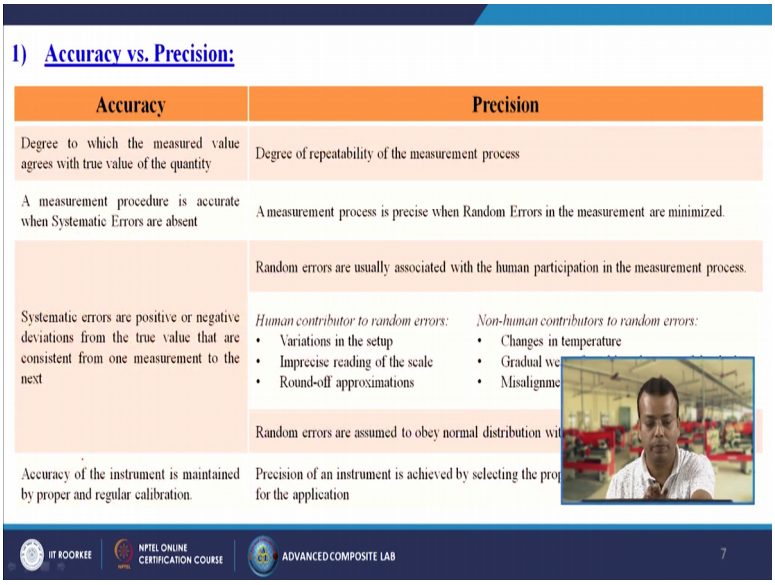

So, first accuracy versus precision okay, so accuracy degree to which the measured value agrees with true value of the quantity. Precision degree of repeatability of the measurement process, accuracy a measurement procedure is accurate when systematic errors are absent. Precision is measurement processes in precise when random errors in the measurement are minimized.

Accuracy is the systematic errors are positive or negative deviations from the true value that are consistent from one measurement to the next. Precision human contributed to random errors like variations in the setup imprecise reading of the scale round of approximations non-human like changing temperature were of the working element of the device, misalignment of working element of the device.

Accuracy of the one instrument is maintained by proper and regular calibrations while precision of an instrument is achieved by selecting the proper and regular calibration technology for the specimen itself. Now from this particular image you can easily understand that what is the difference between the accuracy and precision and what are the similarities.

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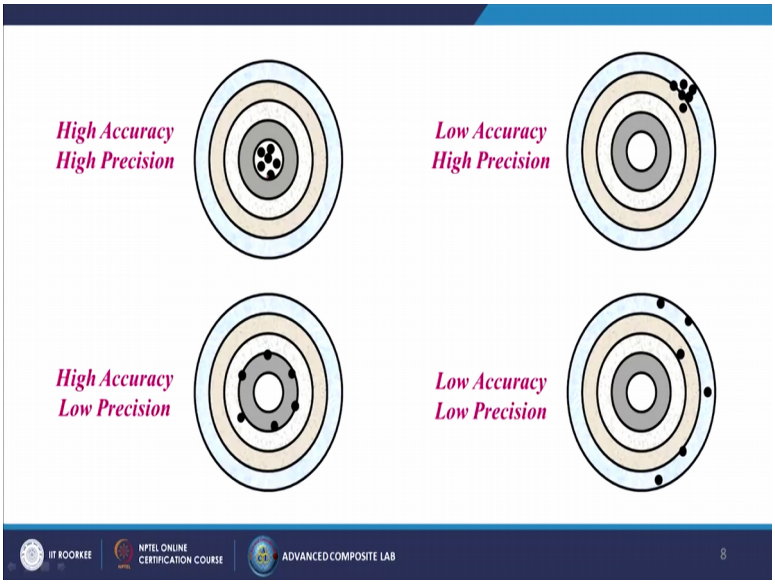

When we are this is a bull's-eye and when we are putting the bullet in a particular area within this circle. So, we are calling it as a high accuracy and a high precision. Then in this particular case also we are not actually putting in the center itself we are putting somewhere else but all the bullets are together. So, in this case it is the low accuracy but the high precision because repeated values are very nearby.

When you are talking about the high accuracy and low precision so in that particular case you can see all our bullets are on to the same line or may be the same path but they are not in to the regular interval or may be in very close proximity and this one is the random so that means it is the low accuracy and the low precision.

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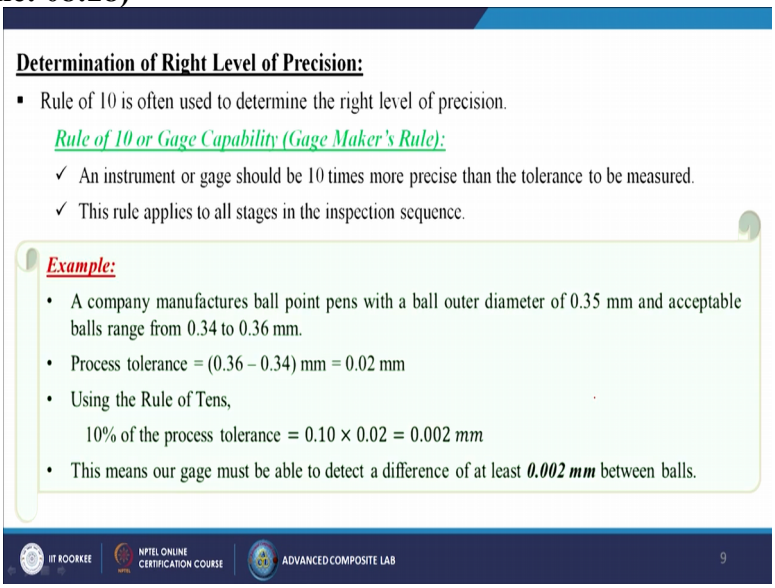

Now determination of the right level of precision rule of 10 is often used to determine the right level of precision. Rule of ten or gauge capability like gauge maker's rule an instrument or gate should be 10 times more precise than the tolerance to be measured the rule applies to

all stages in the inspection sequence. Example a company manufactures ballpoint pins with a ball outer diameter of 0.35 millimeter and acceptable ball ranges from 0.34 to 0.36 millimeter that means that is that tolerance within the tolerance limit.

So, 0.3 pi +-0.01 process tolerance here is the 0.02 millimeter using the rules of 10's that is 10% of the process tolerance that is 0.002 millimeter this means our gauge must be able to detect a difference of at least 0.002 millimeter between the balls itself.

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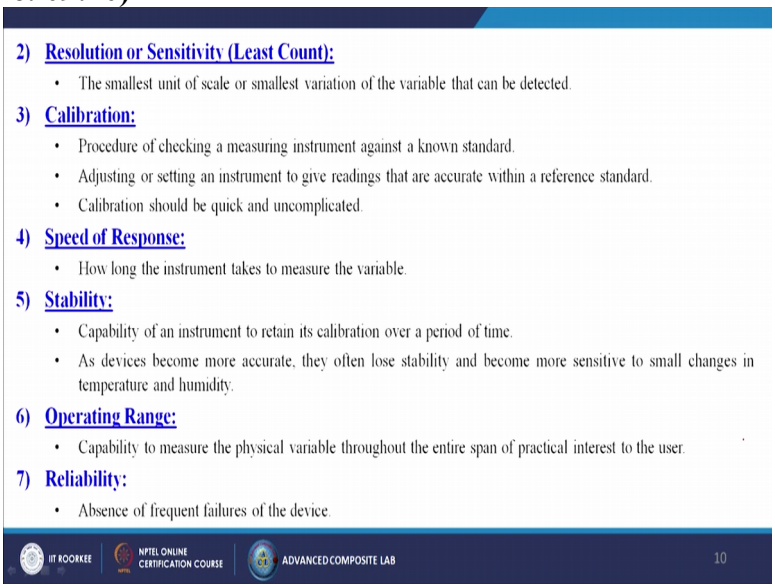

Now come to the resolution or sensitivity or maybe the least count the smallest unit of scale or the smallest variations of the variable that can be detected calibration procedure of checking a measuring instrument against a known standard. So, suppose 1 kg so now every shop when we are going we are measuring our belongings like 1 kg but how to know that whether that is exactly 1 kg or maybe the 950 gram or maybe 1 kg 100 gram.

So, the thing is that there is already one standard has been kept in somewhere else and that is the standard one and we are doing the calibration of our weighing scale with respect to that standard one, adjusting or setting an instrument to give readings that are accurate with a within a reference standard. Calibration should be quick and uncomplicated. Now speed of response how long the instrument takes to measure the variables, stability, capability of an instrument to retain its calibration over a period of time.

As devices become more accurate they often lose stability and become more sensitive to small changes in temperature and humidity operating range capability to measure the physical variable throughout the entire span of practical interest to the user, reliability absence of frequent failures of the device.

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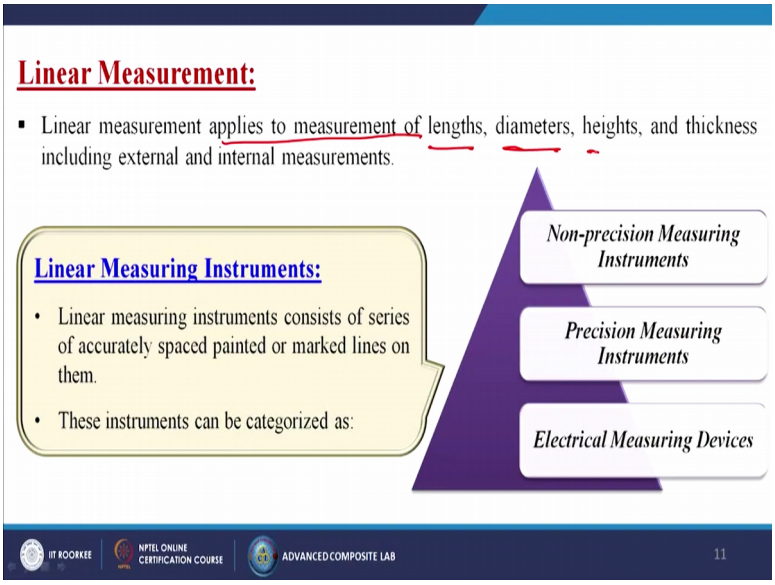

Now come to the linear measurement linear measurement applies to measurement of lengths diameters heights and thickness including external and the internal measurements. So, generally the linear measurement instruments are having of series of accurately spaced painted or mark on them. These instruments can be categorized as non precision measuring instruments precision measuring instruments electrical measuring devices.

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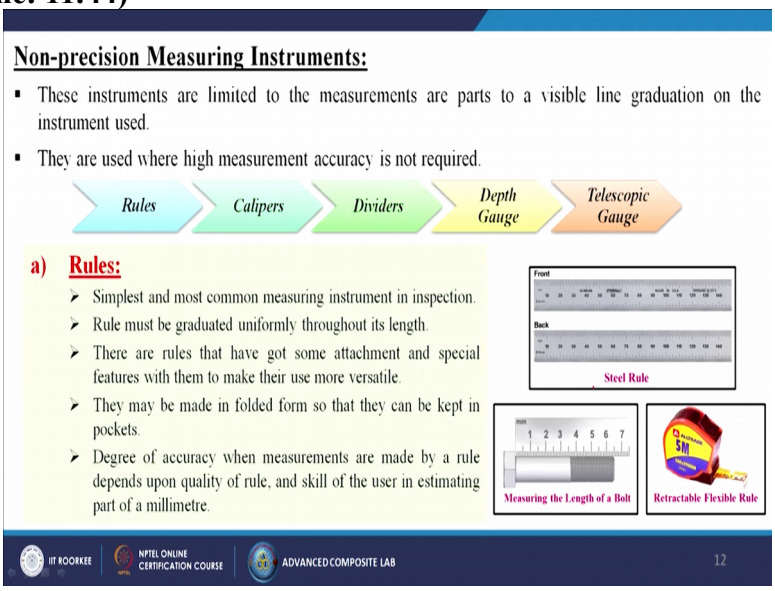

Non precision measuring instruments these instruments are limited to the measurements are parts to a visible line graduations on the instrument used. They are used where high measurement accuracy is not required like rules, calipers, dividers, depth gauges and that telescopic gauge. If we talk about the rules so simple and the most common measuring instrument in inspection rules must be graduated uniformly throughout its length.

So, these all are the examples these are rules that have got some attachment and spatial features with them to make their use more versatile. They must be made in folded firm so that

they can be kept in pockets. Degree of accuracy when measurements are made by a rule depends upon quality of rule and skill of the users in estimating part of a millimeter. So, now our rules should be capable to measure the dimensions within its range.

Here is some kind of retractable flexible rules generally we are using so simple we are taking it out and then if we are removing the pressure then automatically it will go inside.

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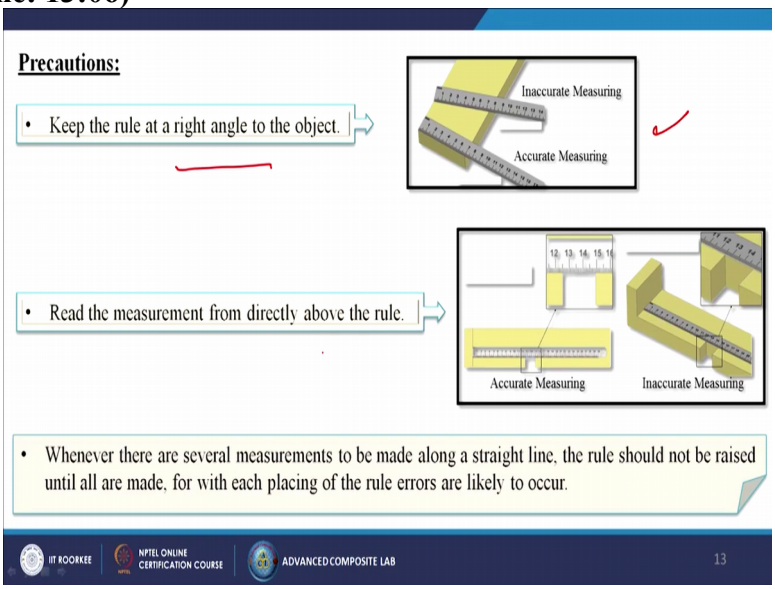

Precautions keep the rule at a right angle to the object read the measurement from directly above the rule itself so simple from the top itself we are going to measure. Wherever there are several measurements to be made along a straight line the rule should not be raised until all are made for with each placing of the rule errors are likely to occur.

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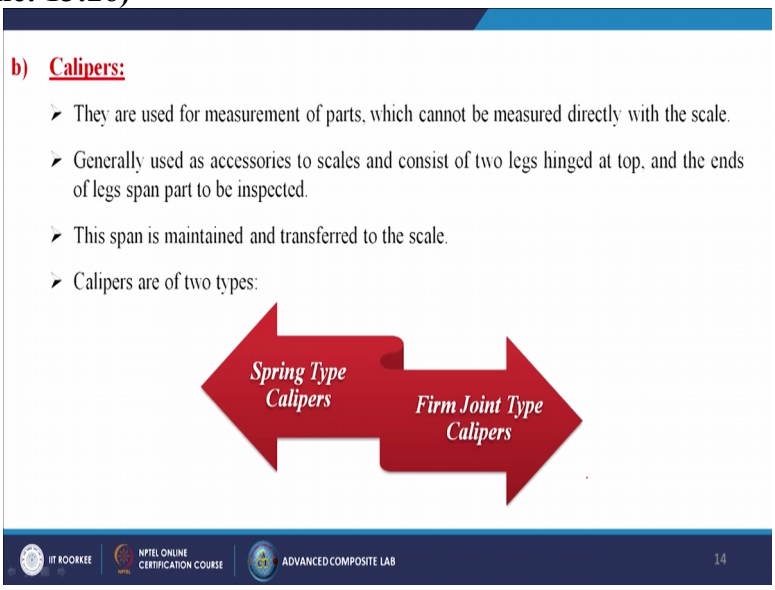

Now come to the calipers they are used for measurement of parts which cannot be measured directly with the scale generally used as accessories two scales and consists of two legs hinged at top and the ends of leg span part to be inspected. This span is maintained and

transferred to the skill calipers are two types that means they are not the direct measuring tool they are the indirect measuring tool. So, one is called the spring type calipers another one is called the farm joint type calipers.

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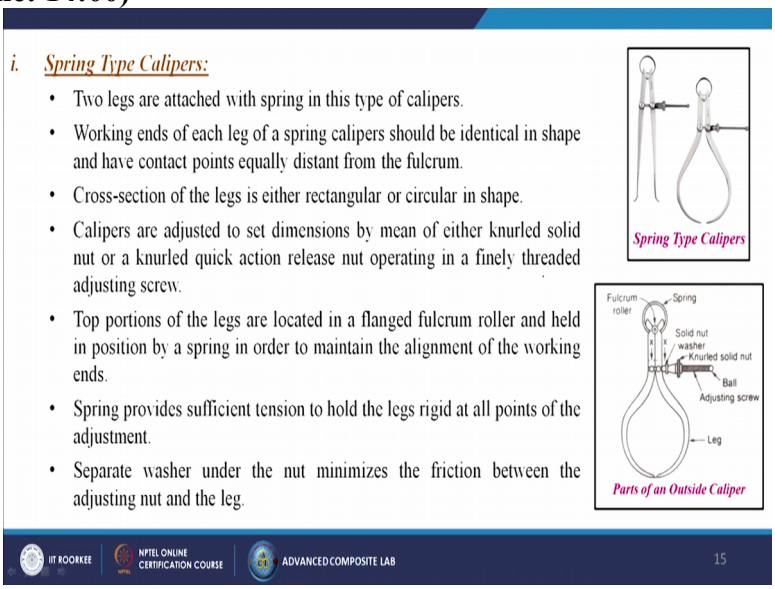

So, what is spring type calipers two legs are attached with springs in this type of calipers so these are the examples so these all are the springs over there and this is the adjustable screw. Working ends of each leg up a spring caliper should be identical in shape and have contact points equally distant from the Fulcrum. Cross-section of the legs is either rectangular or circular in shape. Calipers are adjusted to share dimensions by mean of either knurled, solid nut or a knurled quick action release not operating in a finely threaded adjusting screw.

These all are the thing top portions of the legs are located in a flanged fulcrum roller and held in position by a spring in order to maintain the alignment of the working ends. Spring provides sufficient tension to hold the legs rigid at all points of the adjustment separate washer under the nut minimizes the friction between the adjusting nut and the legs itself. So, from this particular image we can get the whole thing about the spring type calipers.

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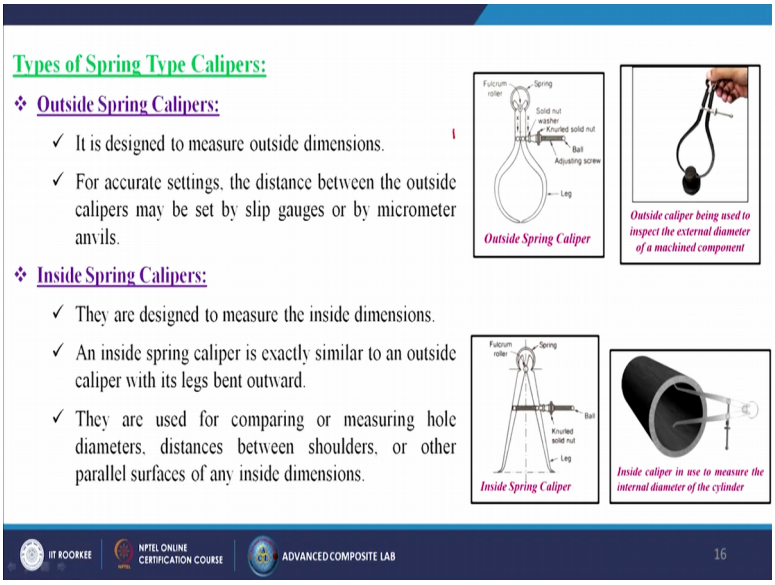

Now types of spring type calipers so there are two types one is called the outside spring calipers so like this way so we are measuring it from the outside itself we cannot measure the inside diameter. It is designed to measure the outside dimensions for accurate settings the distance between the outside calipers may be set by slip edges or by micrometer angles. Now inside spring calipers say suppose we are having the pipe we are going to measure its internal diameter that time we are using this kind of calipers.

They are designed to measure the inside dimensions and inside spring calipers is exactly similar to an outside caliper with its legs bent outward, like this. They are used for comparing or measuring hole diameters distance between shoulders or other surface of any dimensions.

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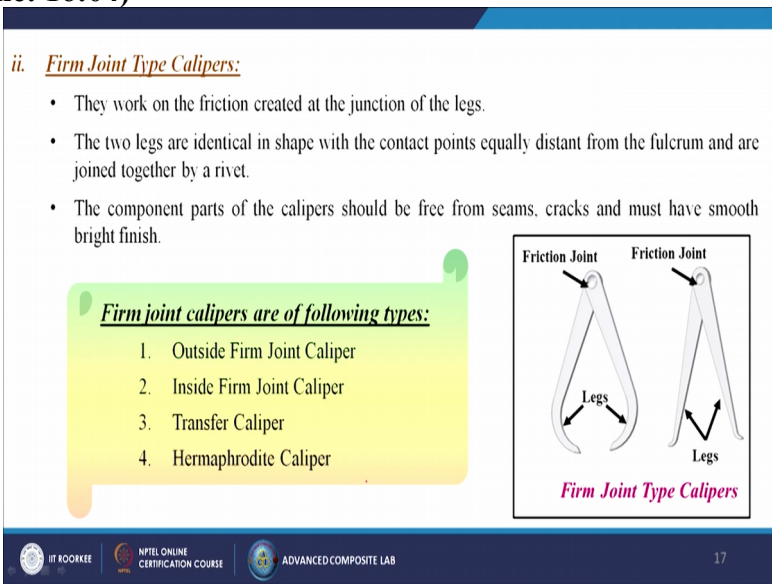

Firm joint type calipers they work on the friction created at the junction of the mix. The two legs are identical in shape with the contact points equally distant from the fulcrum and are joined together by a rivet itself so this is the rivet. The component parts of the caliper should

be free from seams, tracks and must have smooth bright finish. Firm join calipers are of the following types outside firm joint caliper, inside firm joint caliper, transfer caliper and the hermaphrodite caliper.

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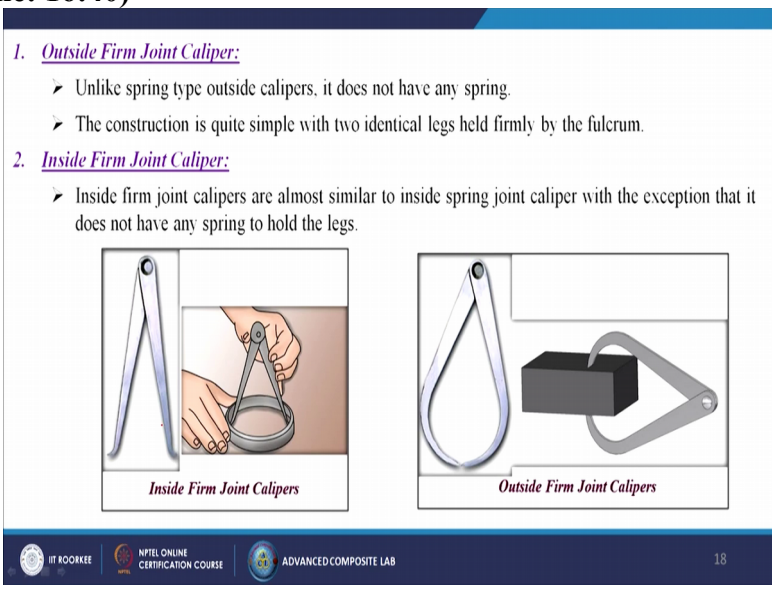

Outside firm joint caliper unlike spring type outside calipers it does not have any spring the construction is quite simple with two identical legs held firmly by the fulcrum. Inside firm joint calipers are most similar to inside spring joint caliper with the exception that it does not have any spring to hold the legs. So, by riveting and two plates there creating the friction in between them and we are measuring it. So, this is the inside one and this is the outside one.

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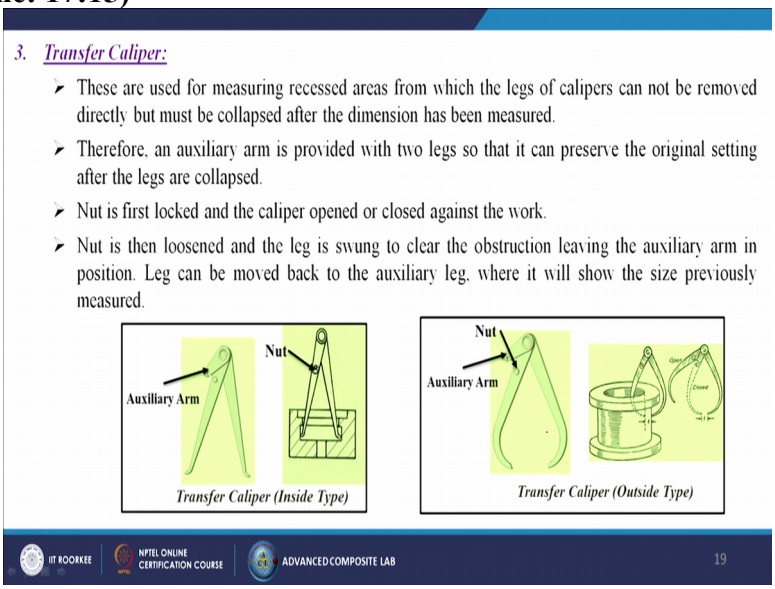

Next one is called the transfer calipers these are used for measuring recessed areas from which the legs of calipers cannot be removed directly but must be collapsed after the dimensions has been measured. Therefore an auxiliary arm is provided with two legs so that it can preserve the original setting after the legs are collapsed. Nut is first locked and the

caliper opened or closed against the work. The nut is then loosened and the leg is swung to clear the obstruction leaving the auxiliary arm in position.

Leg can we move back to the auxiliary leg where it will show the size previously measured so simple the thing is that by this way you can hold the previous data also.

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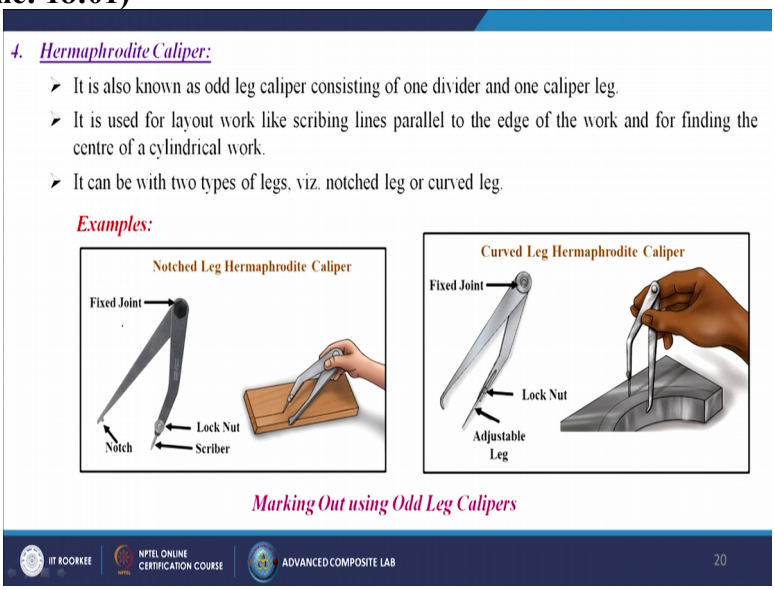

Next is that Hermaphrodite caliper it is also known as odd leg caliper consisting of one divider and one caliper leg. So, here it is used for layout work like scribing lines parallel to the edge of the work and for finding the center of a cylindrical work. It can be with two types of legs one is notched legs or maybe the curved legs. So, like this way we are having this one adjustable leg over there we are having that lock nut and then we are measuring.

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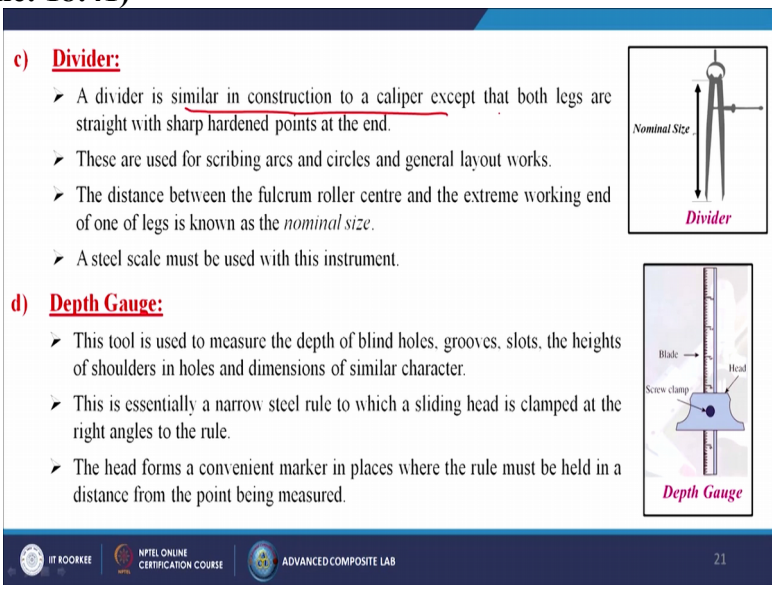

Next come to the divider a divider is similar in construction to a caliper except that both legs are straight with sharp hardened points at the end. These are used for scribing arcs and circles and general layout works. The distance between the fulcrum roller Center and the extreme

working end of one of legs is known as the nominal size. A steel scale must be used with this instrument.

Next come to the depth gauge this tool is used to measure the depth of blind holes, groups, slots, the heights of shoulders in holes and dimensions of the similar character. So, this is the example. So, now we are inserting this one or maybe this side inside the hole itself and now just after getting that one we are measuring what is the distance over there so by this way we are measuring the depth.

This is essentially a narrow steel rule to which a sliding head is clamped at the right angles the head firms a convenient marker in places where the rule must be held in a distance from the point being measured.

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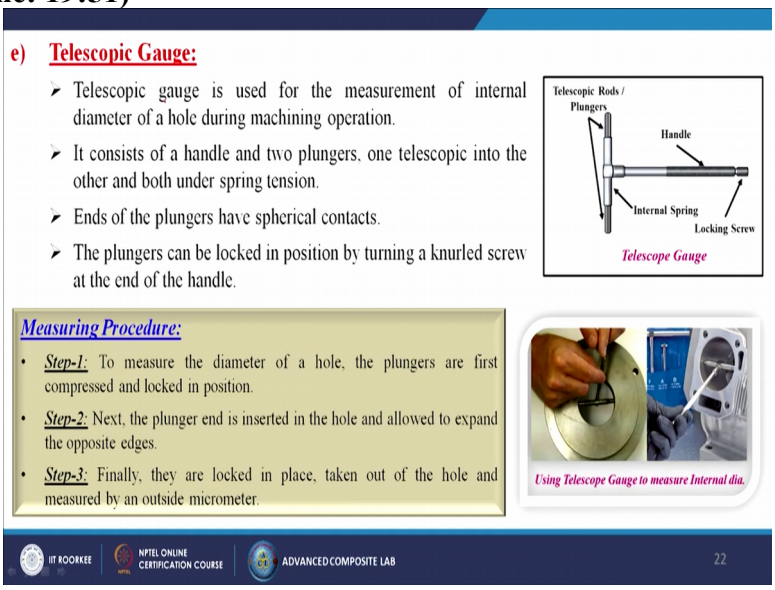

Now come to the telescopic gauge telescopic gauge is used for the measurement of internal diameter of a hole during machining operations. It consists of a handle and two plunger's one telescopic into the other and both under spring tension it looks like this. These all are the telescopic rods so simple these all are the movable parts. So, inside we are putting the spring so by this way we can measure the internal diameter of that particular part.

Ends of the plungers have spherical contacts the plungers can be locked in position by turning an old screw at the end of the handle so this one. So, you can fix the movement of these two plungers. Measuring procedure to measure the diameter of a hole the plungers are first compressed and locked in position. Next the plunger end is inserted in the hole and allowed to expand the opposite edges finally they are locked in place taken out of the hole and measured by an outside micrometer.

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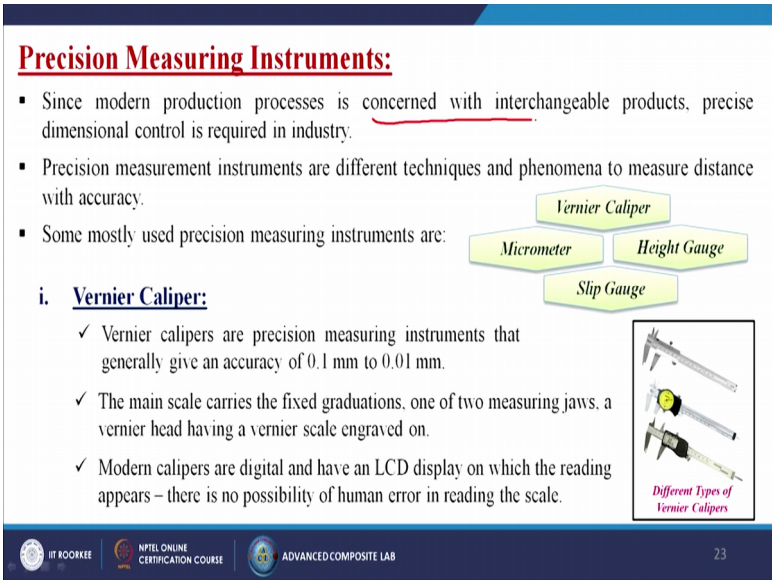

Now precision measuring instruments since modern production process is concerned with the interchangeable products precise dimensional control is required in industry point of view. Precision measurement instruments are different techniques and phenomena to measure distance with accuracy. Some mostly used precision measuring instruments are vernier caliper micrometer height gauge and the slip gauge.

When you are talking about the vernier caliper, vernier calipers are precision of measuring instruments that generally given an accuracy of 0.1 millimeter to 0.01 millimeter. The main scale carries the fixed graduations one of two measuring jaws a vernier head having a vernier scale engraved on. Modern calipers are digital and have an LCD display on which the reading appears there is no possibility of human error in reading the skill. So, directly you are getting the results like calculated display.

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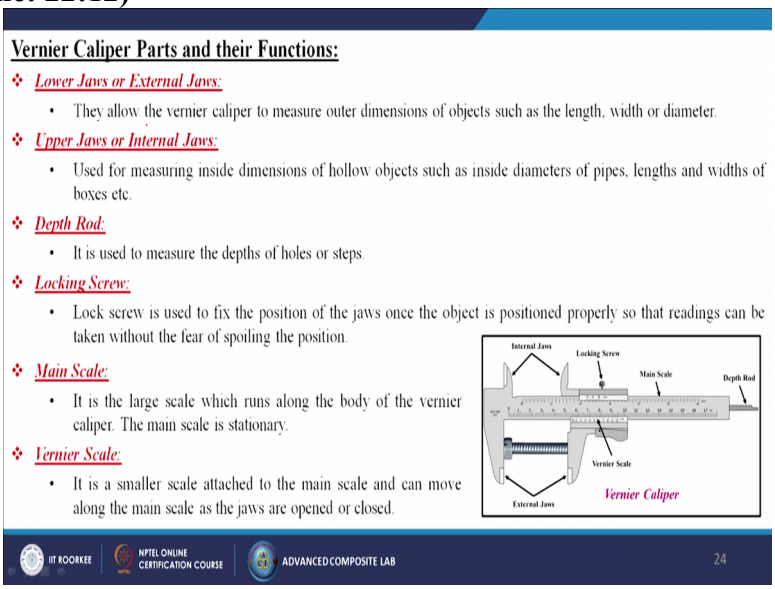

Vernier caliper parts and their functions first is called the lower jaws or may be the external jaws so they allow the vernier caliper to measure outer dimensions of objects such as the length, width or maybe the diameter so this is the external jaws. Upper jaws or may be the internal jaws used for measuring inside dimensions of hollow objects such as inside diameters of pipes lengths and widths of the boxes.

So, this depth rod it is used to measure the depths of holes or maybe the steps so this one. Locking screw lock screw is used to fix the position of the jaws once the object is positioned properly so that the readings can be taken without the fear of spoiling the positions. So, while taking it out so the movement to restrict the movement we are locking the both the legs over there or maybe this one this part.

Main scale it is the large scale which runs along the body of the vernier caliper the main scale is stationary so this one is known as the main scale. Vernier scale it is a smaller scale attached to the main scale and can move along the main scale as the jaws are opened or closed.

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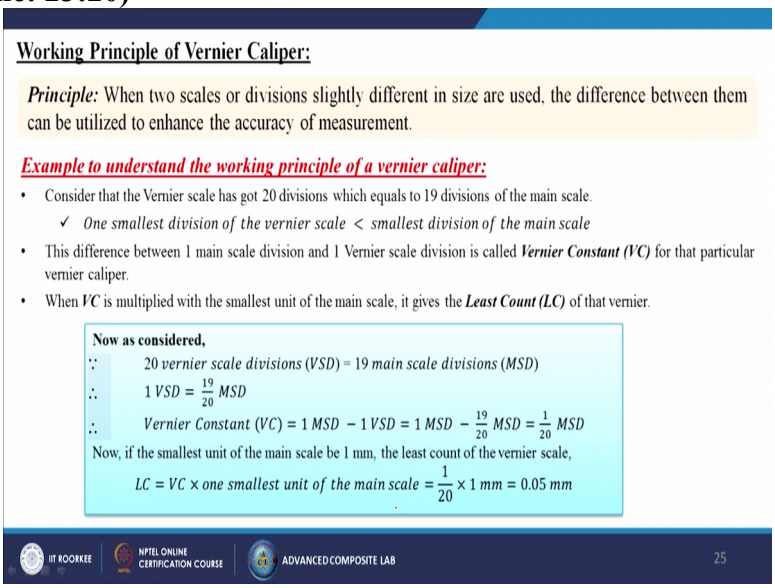

Working principle of vernier caliper principle when two scales or divisions slightly different in size are used the difference between them can be utilized to enhance the accuracy of measurement. Example to understand the working principle of a vernier caliper consider that the vernier scale has got 20 divisions which equals to the 19 divisions of the main scale. One smallest divisions of the vernier scale less the smallest division of the main scale that this difference between one main scale divisions and one vernier scale divisions is called the vernier constant for that particular vernier caliper.

When VC is multiplied with the smallest unit of the main scale it gives the least count of that particular vernier. Now as considered 21 vernier scale divisions is equal to 19 main scale

divisions as I already told. So, one vernier scale divisions is equal to 19 by 20 main scale divisions. Now vernier constant is equal to 1 MSD - 1 VSD, 1 MSD and VSD is this one so you are putting and then after subtracting you are getting 1 by 20 MSD.

Now if the smallest unit of the main scale be 1 millimeter the least count of the vernier scale LC is equal to VC into 1 smallest unit of the main scale that means 1 by 20 into 1 millimeter that is the 0.05 millimeter that is the least count of that vernier caliper.

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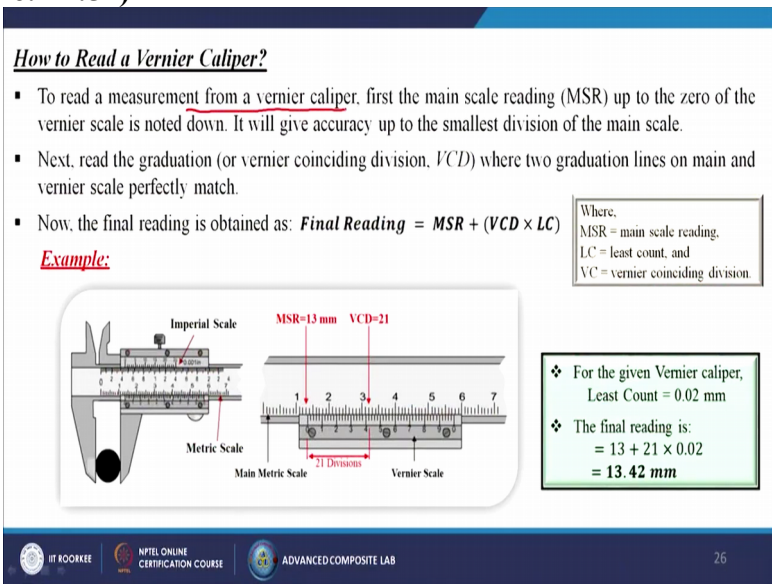

How to read a vernier caliper to read a measure from a vernier caliper first the main scale reading up to the zero of the vernier scale is noted down it will give accuracy up to the smallest divisions of the main scale. Next read the graduations or one year coinciding divisions wear to graduation lines on main and vernier scale perfectly match over there. So, in this particular case you see this is perfectly matching.

Now the final reading is obtained as final reading is equal to MSR + VCD *LC so in this particular case for the given vernier caliper least count is 0.02 millimeter that we have already measured the final reading is what is that 10 11 12 13 so 13 + 21 * 0.02 that is 13.42 millimeter.

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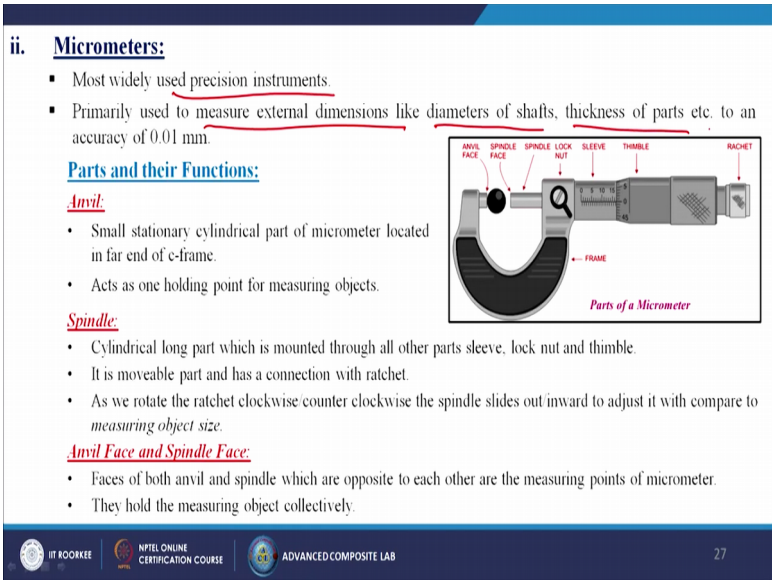

Now come to the micrometers most widely used precision instruments primarily used to measure external dimensions like dimensions of shafts thickness of parts etcetera to an accuracy of 0.01 millimeter. Parts and their functions first one is called the anvil small stationary cylindrical part of micrometer located in far end of a c-frame. So, this is known as the anvil. Listen acts as one holding point for measuring objects and this is the stationary part. Now come to the spindle cylindrical long part which is mounted through all other parts sleeps lock nut and thimble.

It is movable part and has a connection with ratchet as we rotate the ratchet clockwise or maybe the counter clockwise the spindle slides out or maybe the inward to adjust it with compare to measuring the object size. So, now we have to rotate it into the clockwise direction so automatically it will comes closure and if we do the anti-clockwise rotation so it will go into the outward direction.

Anvil face and the spindle face faces of both anvil and spindle which are opposite to each other are the measure points of the micrometer so these points and these points they hold the measuring object collectively.

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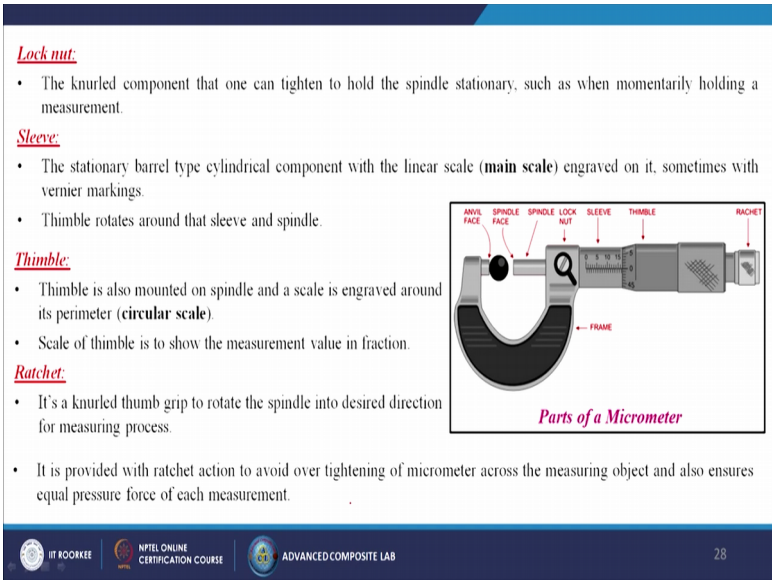

Lock nut: the nut component that one can tighten to hold the spindle stationary. Such as when momentarily holding a measurement itself. So, now in this particular case we are putting the lock nut over there so that movement of this one will be locked. Sleeve the stationary barrel type cylindrical component with the linear scale main scale that is engraved on it sometimes with vernier markings so this is known as the sleeve.

Thimble rotates around that sleeve and spindle so this is known as the thimble so this is rotating on top of this one. Thimble is also mounted on spindle and a scale is engraved around its perimeter means circular scale so this one. We are talking about this scale. Scale of thimble is to show the measurement value in fraction. Next come to the ratchet it is a non thumb grip to rotate the spindle into desired directions for measuring the process so this one is the case it is provided with ratchet actions to avoid over-tightening of micrometer across the measuring object otherwise it will hurt your specimen. And also ensures equal pressure force of each measurement.

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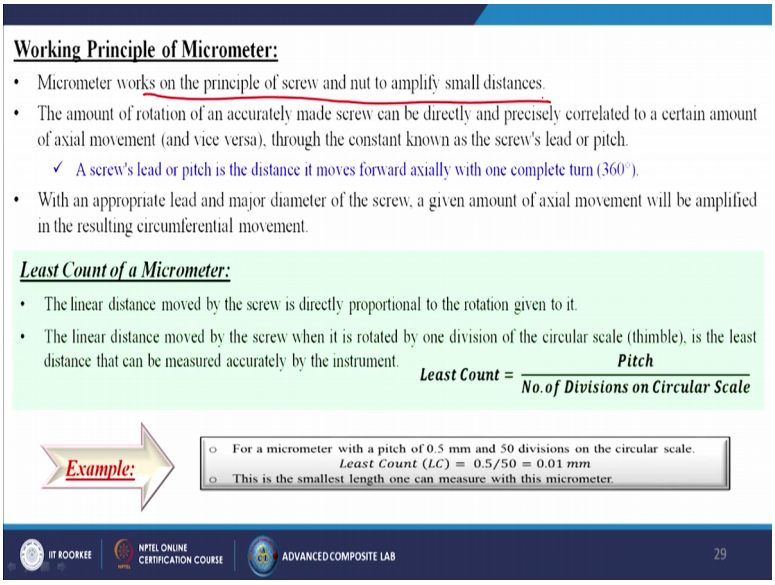

Now working principle of the micrometer: Micrometer works on the principle of screw and not to amplify the small distances the amount of rotation of an accurately made screw can be directly and precisely correlated to a certain amount of axial movement and vice versa through the constant known as the screw lead or may be the pitch. Screw lead or peach is the distance it moves forward axially with one complete turn that is 360 degree rotation.

With an appropriate lead and major diameter of the screw a given amount of axial movement will be amplified in the resulting circumferential movement. Least count of a micrometer the linear distance moved by the screw is directly proportional to the rotation given to it the linear distance moved by the screw when it is rotated by one division of the circular

Scale thimble is the least distance that can be measured accurately by the instrument so what is the least count pitch by number of divisions on circular scale. Example for a micrometer with a pitch of 0.5 millimeter and 50 divisions on the circular scale least count is 0.5 into 50 that is 0.01 millimeter this is the smallest length one can measure with this micrometer so if you are having any parts which is like 0.001 millimeter then that time it is not possible because it can go up to minimum 0.01millimeter.

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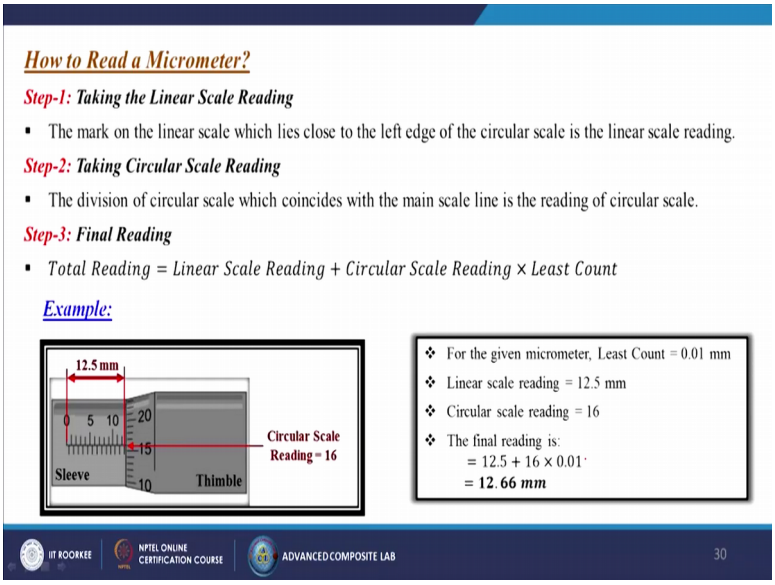

How to read a micrometer taking the linear scale reading the mark on the linear scale which lies close to the left edge of the circular scale is the linear scale reading so here 12.5 millimeter. Taking circular scale reading the division of circular scale which coincides with the main scale lines in the reading of circular scale so this one. Circular scale reading is 16 over here that is matching with the main scale.

Final reading total reading linear scale reading plus circular scale reading into least count so in this case least count is 0.01 millimeter linear scale reading 12.5 millimeter circular scale rating is 16 so the final reading is 12.5 + 16 * 0.01 that is nothing but that 12.66 millimeter.

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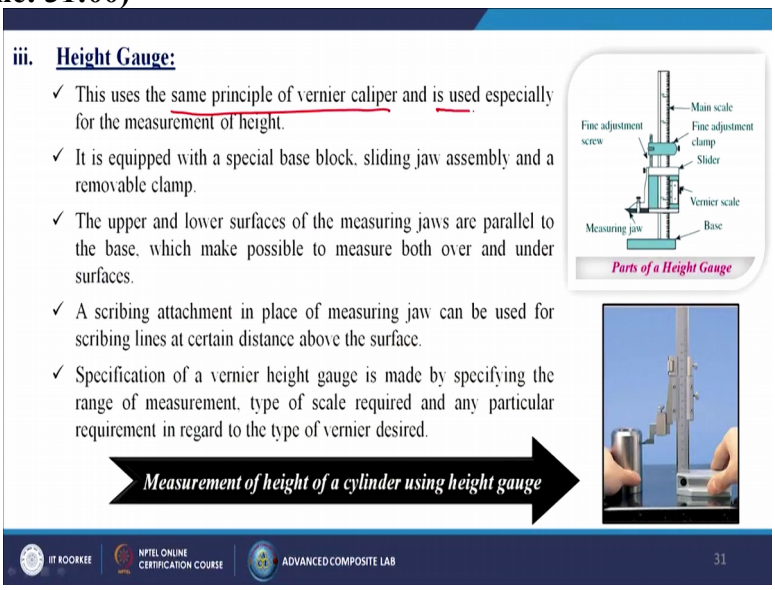

Now come to the height gauge this uses the same principle of vernier caliper and used especially for the measurement of height it is equipped with a special base block sliding jaw assembly and a removable clamp. The upper and lower surfaces of the measuring jaws are parallel to the base which make possible to measure both over and under surfaces. Ascribing

attachment in place of measuring jaw can be used for scribing lines at certain distance above the surface itself.

Specification of a vernier height gauge is made by specifying the range of measurement type of scale required and any particular requirement in regard to the type of vernier desired. So, you see here we are having a base plate that means what your sample and your gauge should be properly fixed on a parallel surface or maybe the smooth surface. Measurement of height of a cylindrical using this height gauge. Now we are moving this one upward or maybe the downward directions and we are measuring the height of this particular specimen.

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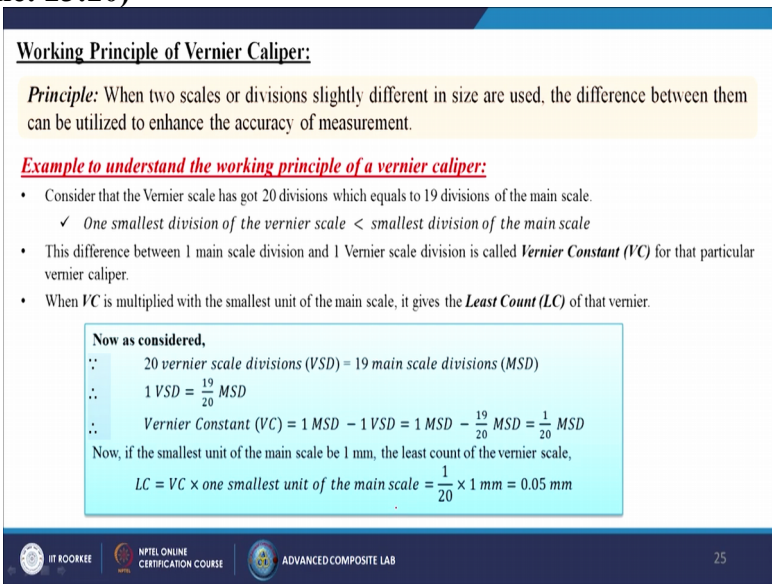

Next one is called the slip gauges or maybe the gauge block slip gauges also known as gauge blocks gauge blocks only the spelling are different Johansson gauges or maybe the Jo blocks are a system for producing the precision lengths. The individual gauge block is a metal or ceramic block that has been precision ground and lapped to a specific thickness. Gauge blocks come in sets of blocks with a range of standard lengths.

In use the blocks are stacked to make up a desired length also used for the verification and graduation of measuring apparatus and for direct measurement of linear dimensions of industrial components simple we are having some standard depth gauge. So, simple suppose I want to measure the distance in between these two simple I am inserting the depth gauges over there and that if it is touching both the sides that means that is the height of that particular area.

Uses of slip gauge setting up a comparator to a specific dimension direct precise measurement purpose to inspect the vernier caliper micrometers and some other linear

measuring instruments. Conjunction with sine but to measure the angle of workpiece used to check the distance between the parallel faces.

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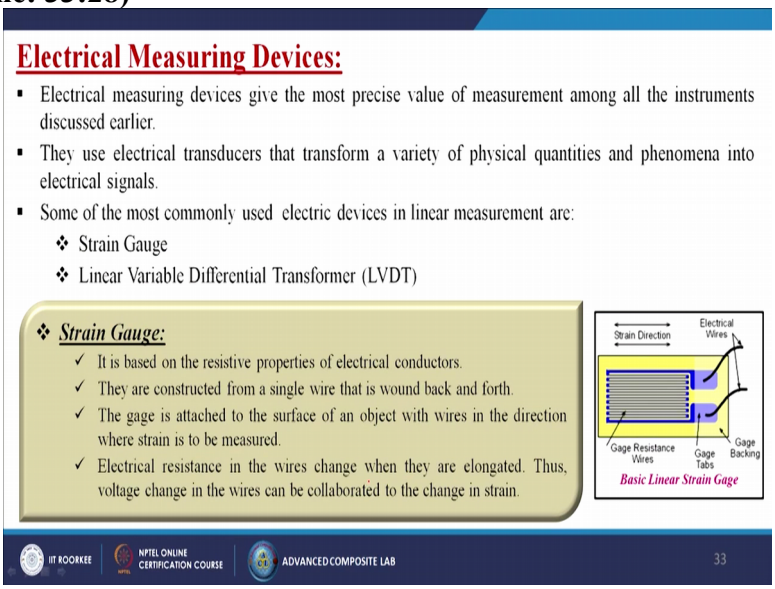

Now come to the electrical measuring devices electrical measuring devices give the most precise value of measurement among all the instruments discussed earlier. They use electrical transducers that transform a variety of physical quantities and phenomena into electrical signal. Some of the most commonly used electrical devices in linear measurements are strain gauge and another one is called the linear variable differential transformer in short generally we are calling it as a LVDT.

Strain gauge it is based on the resistive properties of electrical conductors they are constructed from a single word that is wounded back and forth the gauge is attached to the surface of an object with words in the direction where strain is to be measured. Electrical resistance in the words change when they are elongated does voltage changes in the words can be collaborated to the change in strain. So, here the simple thing this is the arrangements.

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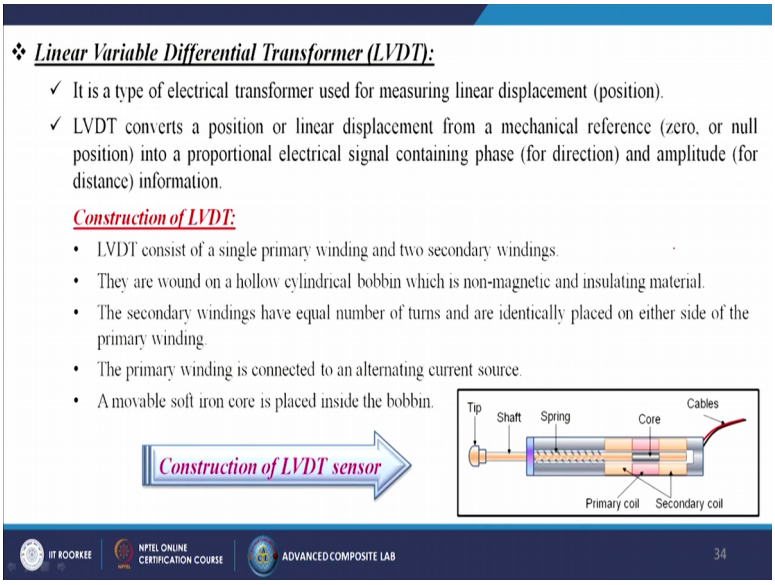

Now if we are talking about the LVDT it is a type of electrical transformer used for measuring linear displacement like position. LVDT converts a position or linear displacement from mechanical references like zero on null position into a proportional electrical signal contacting phase for direction and amplitude for distance information. Construction of the LVDT consists of a single primary winding and two secondary windings over there.

So, here you can see this is the primary coil and this is the two secondary coils are there they are owned on a hollow cylindrical bobbin which is non-magnetic and insulating material. The secondary windings have equal number of turns and are identically placed on either side of the primary winding. The primary winding is connected to an alternating current source a movable soft iron core is placed inside the bobbin itself this is the construction of the LVDT.

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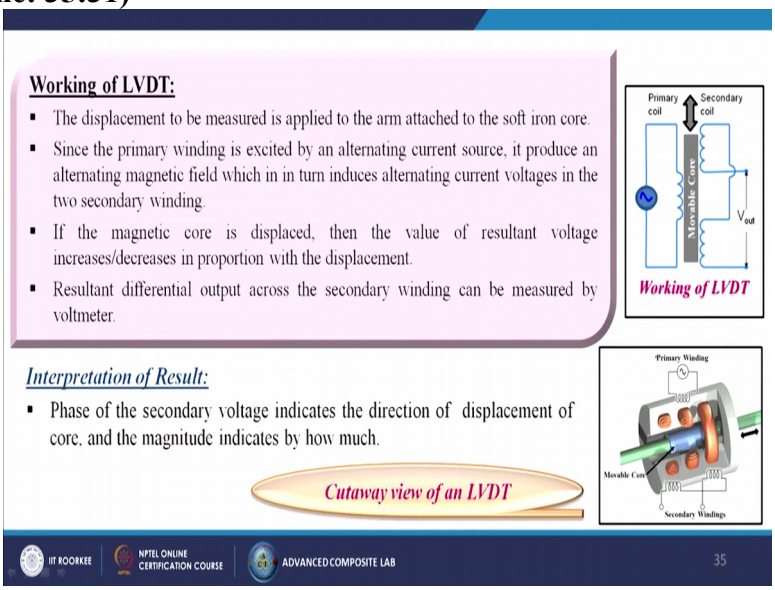

Now working with LVDT the displacement to be measured is applied to the arm attached to the soft iron core since the primary winding is excited by an alternating current source it

produces an alternating magnetic field which in turn induced alternating current voltages in the two secondary windings. If the magnetic core is displaced then the value of resultant voltage increases or decreases in proportion with the displacement itself resultant differential output across the secondary windings can be measured by the voltmeter itself.

So, now this is the case so primary windings we are having we are having the secondary windings too and then we are having that moveable core over there. Interpretation of reason phase of the secondary voltage indicates the direction of displacement of core and the magnitude indicates by how much quantity this is the cutaway view of an LVDT.

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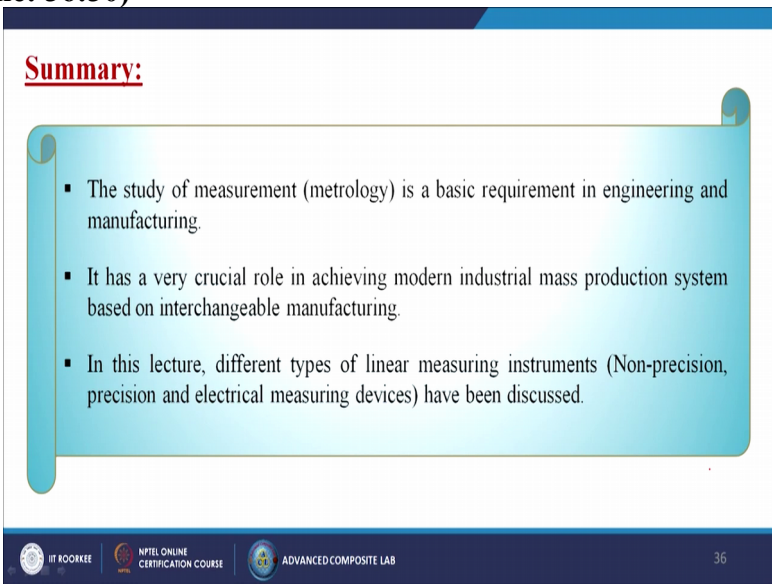

Now we have come to the last slide of this particular lecture so in summary we can say the study of measurement generally it is known as the metrology is a basic requirement in the engineering and in the manufacturing point of view. It has a very crucial role in achieving the modern industrial mass production system based on the interchangeable manufacturing process. In this particular lecture we have discussed about the different types of linear measuring instruments like non precision, precision electronic, measuring devices some contacts some non-contact mode have been discussed, thank you.