Metrology
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Module-1
Lecture-2
Metrology terminologies

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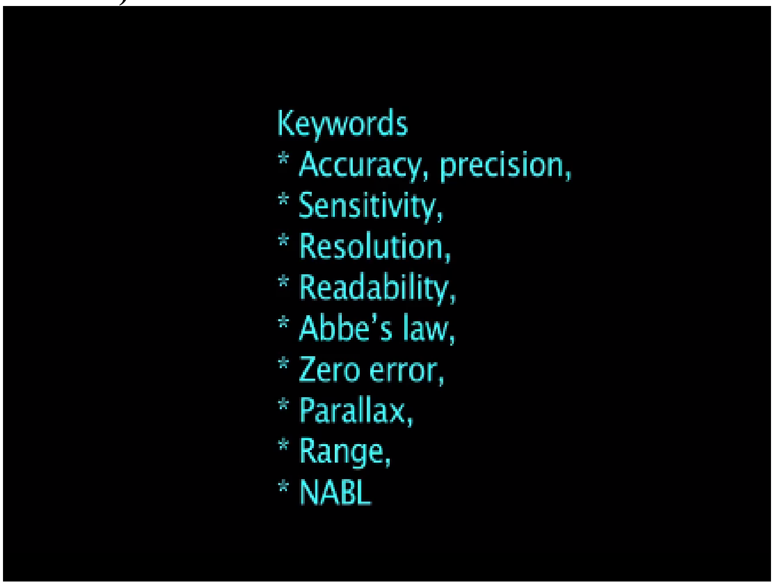

I welcome you all for the second lecture in the series, in the first lecture we started the discussion on basic concepts of metrology. Now will continue with that today we will see about metrology terminologies.

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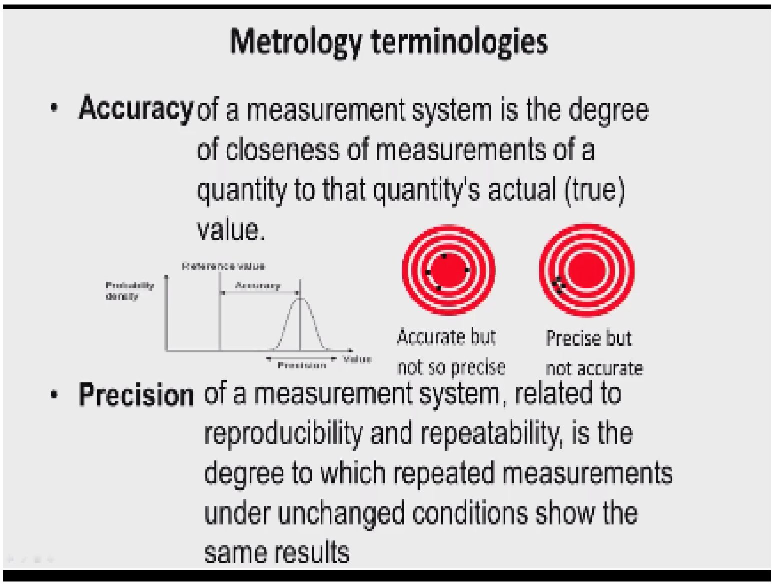

A first one is accuracy of the measurement system, it is the degree of closeness of measurements of a quantity to that quantities actual or true value. So we can understand the term by referring to this figure. We have x-axis, x axis on the x axis we have values measurement measured values and along y-axis we have probability density and all the measurement points are started like this.

Now you can always take calculate the mean of these values, so this line represents mean value of all the measured points and this indicates the reference value or the desired value. Now you can see that there is a gap between reference value and the mean value. If the mean value coincides with the reference value then we say the measurement system is very very accurate. Now we have another set of pictures here.

Now the centre point represents the target value or the desired value and measurement points are scattered around the target value. Now when we calculate the average of these measure it is very close to the target value. So we say they process is very accurate, but the process is not so pretty because of scattering of the measure points. Now in the second picture we can see that all the measure points are very close to each other.

And when we calculate the average to be somewhere here, now there is a gap between the target value and the average value. So we say this process, this measurement system is précised, but not so accurate. Now let us try to understand the position of the measurement system it is related to the reproducibility and repeatability of the process.

It is the degree to which repeated measurements under unchanged conditions show the same results. That we have understood when we study these two pictures. This process is very precise and here the measurement system is not precise.

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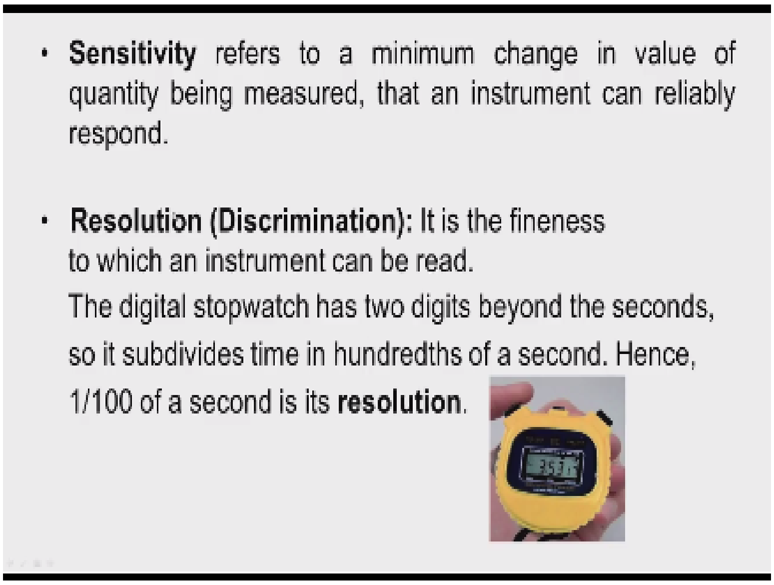

Now the second term is sensitivity of an instrument. This refers to a minimum change in value of quantity being measured that an instrument can respond. If I take an example of a dial indicator when we apply the displacement of point 1 millimeter and if the dial indicator is response to that signal, then we say the sensitivity of the dial indicator is 0.1 millimeter. And we have another term resolution, sometime it is also know as discrimination.

It is the fineness to which an instrument can be read. In the figure you can see the digital stop watch, on behalf of 2 digits beyond the seconds, so it is a subdivides time in to hundrendths of a second. Hence 1/100 of a second is it s resolution of this digital watch.

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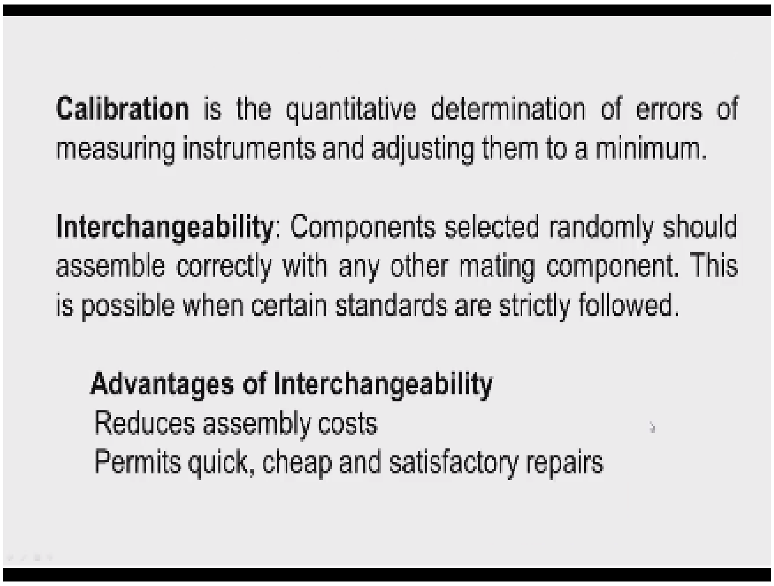

The calibration is the quantitative determination of errors of measuring instruments and adjusting them to a minimum. In the previous discussion we have understood that all the instruments undergo near due to continuous usage, and due to that there will be an error in the instrument. So regular intervals we have to compare the accuracy of these instruments with the equipment available at standard of the plant and then whatever there just be recorded on the instrument.

This process is known as calibration. Now interchangeability, so this is the component selected randomly should assemble correctly with any other mating component. This is possible when certain standard saw strictly followed, due to the mass production all the mating parts that made different places by different operators, when we try to make them by selecting randomly they will make easily without any individual fitting operation.

So this process is known as an interchangeability. This will be possible only when we use standard instruments and standard measuring methods. Now what are the advantages of interchangeability. Now since the mating parts of it easily, the assembly time will be reduced and assembly cost will be reduced. Now since the parts produced in mass there available in the market radially the repair work will be cheaper to be very quick. We need not have to order for the mating point for new for fabrication process.

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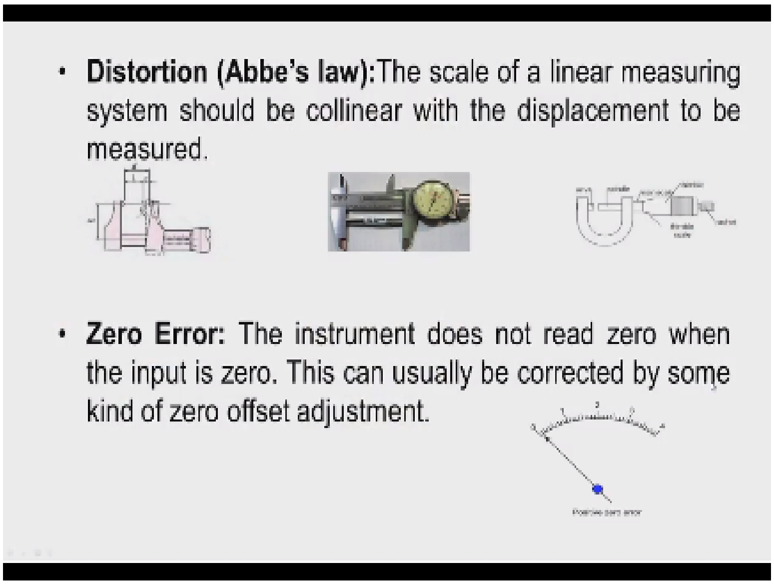

Now distortion is also known as Abbe's law. The scale of a linear measuring system should be collinear with the displacement to be measured. If you take the example of this vernier caliper we can understand that we keep the work piece between angle and spindle. So the axis of the work piece will be here, it is collinear with access the instrument. So in that case the distortion will be minimum.

When we take the example of a Vernier caliper we can see that the work piece is kept between the two jaws and when we apply pressure here there are chances that the jaw may bend like this, introducing another component shown here. So the distortion can be eliminated by designing instrument. So such that the axis of the work piece coincides with instrument.

Now we have another term known as zero error. The instrument does not read 0 when input is 0. So this happens due to the change the dimension of the internal components due to variation with temperature. This can be easily adjusted by adjusting kind of zero offset adjustment provided. Now in this picture we can see that when there is no signal applied the pointer is showing some deflection. So this is known as zero error or zero drift.

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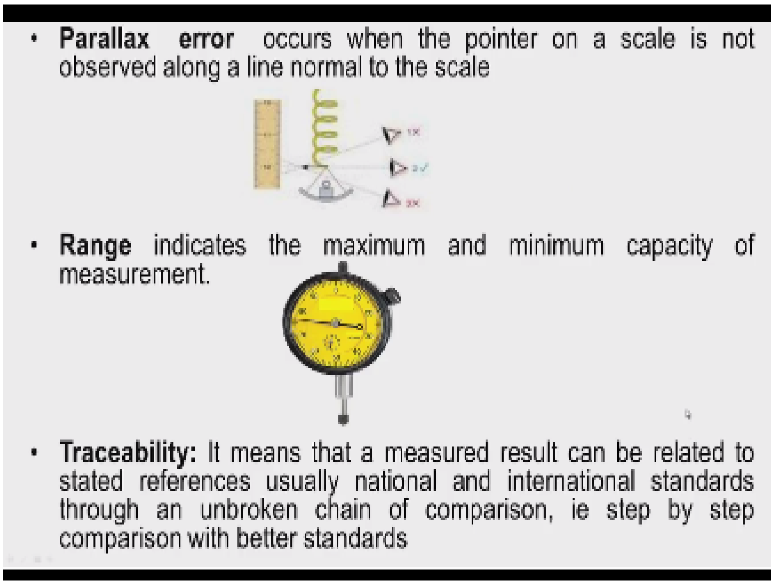

Parallax error this occurs when the pointer in a scale is not observed along a normal a line normal to the scale. Now this can understand with help of this diagram, we have the scale here, and we have pointer here, and the observer is observing the pointer from 3 different positions. This is position number 1, position number 2 and we have position number 3. When the observer observes the scale and pointer from the location 2 is observing the scale normally, then we get the correct real.

When we observes from the location 1 now you may get the reading at this place which is incorrect real. Similarly when the observer observe from location 3 again there will be an error. So this parallax error can be eliminated by reducing the distance between the scale and pointer. Now the range of the instrument in the case the maximum and minimum cap[acity of measurement. What is the maximum physical quantity we can measure, and what is the minimum capacity can be measure the difference gives the range.

We can observe this dial indicator, now for one complete revolution of this pointer the displacement will be 1 millimetre. So now we have in the small dial they have totally 10 graduations are there. So the range of this instrument is 10 millimetre. Now we have the term traceability.

It means that a measured result can be related to stated references usually national and international standards throw an unbroken chain of comparison. That is step by step comparison with better standards. So this step by step comparison with better standards we can understand by studying this flowchart.

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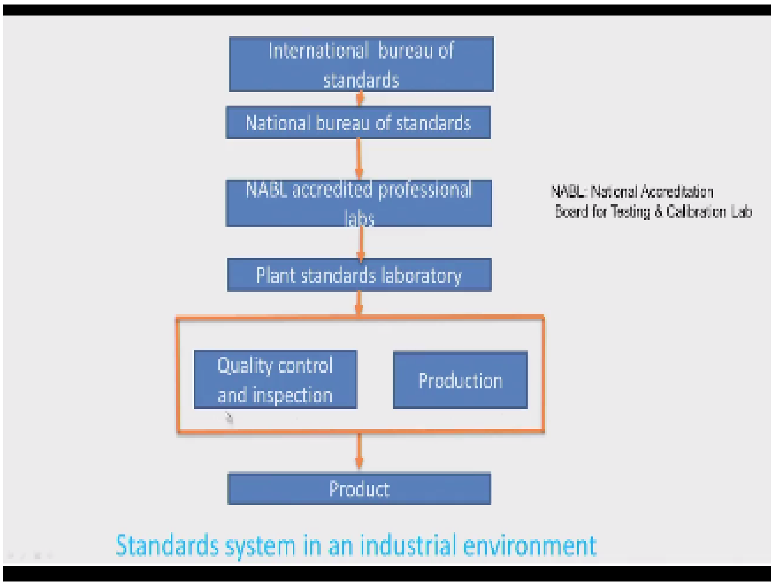

Now this is the manufacturing area where in the production is going on components are produced, assembled and then finally we get the product. During the process of production the quality control department will inspect all the components produced, but due to continuous usage of these instruments the instruments are subjected to be weir and the measurement here we seen.

So to eliminate the measurement here at regular intervals or we need to inspect or we need to compare all the instruments used in the workshop with the plant standards laboratory equipments which are of higher accuracy by comparing the workshop instruments with a plant standards laboratory equipment we can always get the amount of error in the measuring instrument and that can be noted on the instrument.

So while reporting the inspection while preparing the inspection report we should give consideration, we should note down what is the error that is indicated the instrument, then the plant standards laboratory equipment should be compared with the equipment available at NABL accredited professional labs which are of superior quality. So in term accredited professional lab instruments are compare with National Bureau of standards like this.

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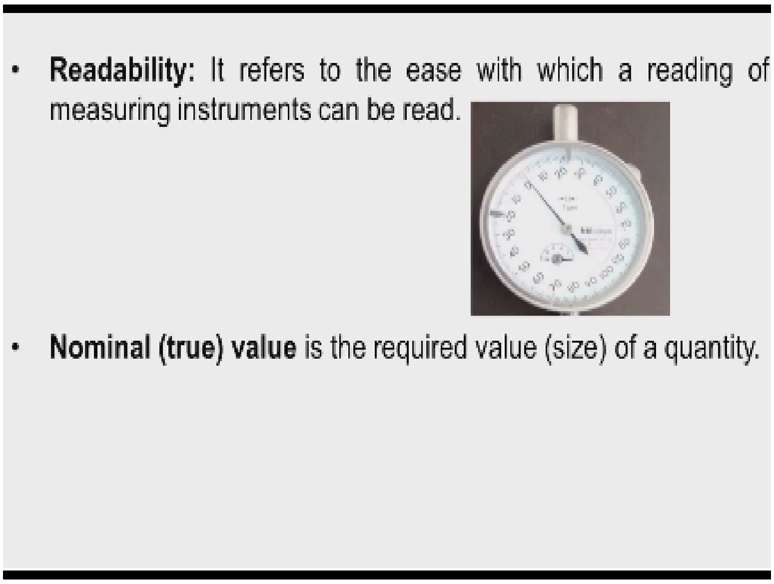

The all the measuring instruments are compared with the higher accuracy instruments in step by step level. Now the term readability it refers to the ease with which the reading of measuring instruments can be taken, that means what is the amount of easiness of reading is readability. Now if you observe this diagram of dial indicator we can see that we have a bigger dial and we have a smaller dial.

We have a bigger pointer and have a small pointer, we can see that this is a reference point 0 and then we have a graduation. So this is tenth graduation in between we have 10 line, so each graduation small graduation indicated 1 micrometer, so now very easily can read this dial indicator, it indicates that readability of this indicator is very good. In some cases if the graduation are very fine then we may have to use magnifying lenses or may have to use microscope for reading the instruments.

Now nominal value or true value is the required value of the quantity, or required say you the quantity for example we have soft the required quantity is 10 millimeter, so 10 millimeter is suggested the design engineer and that is the required value or nominal value of the component.

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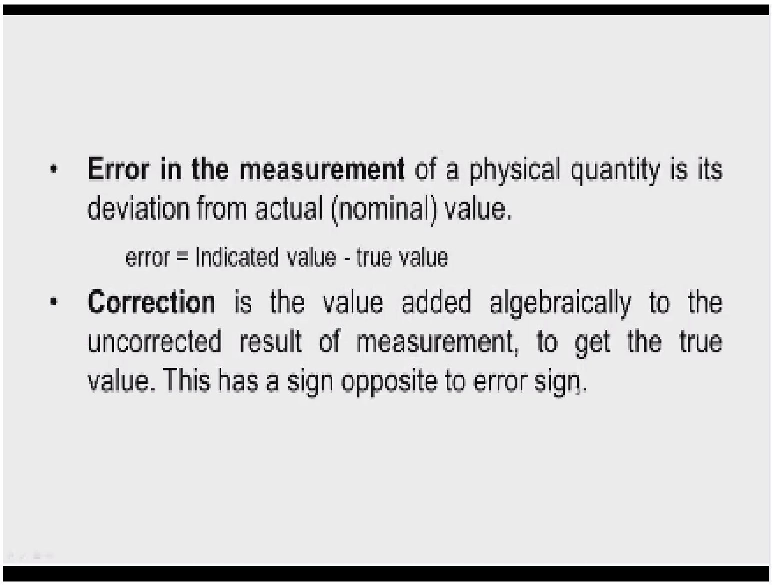

Now let us what is the error in the measurement, error in the measurement of a physical quantity is it is deviation from actual or nominal value. Now if we see this expression error=indicated value that is the measurement given by the instrument and this is the true value of the component, the difference gives the amount of error. For example say the indicated value.

So we are measuring the diameter of a spindle and the micrometre gives a value of 9 millimetre whereas the true value is 10 millimetre. So the difference is -1 millimetre. So this is the error of measurement correction is the value added algebraically to the uncorrected result of measurement to get the true value. This has a sign opposite to the error sign. Again we can take the example of measurement of diameter the spindle.

Now uncorrected result of measurement that is indicated value is 9 millimetre. We need to add the correction factor, so the error is -1 millimetre. So we need to add +1 millimetre to get the true value, that is 10 millimetre. Now we can observe that error is -1 millimeter whereas the correction factor is +one millimeter, so this sign is opposite to the sign of the error.

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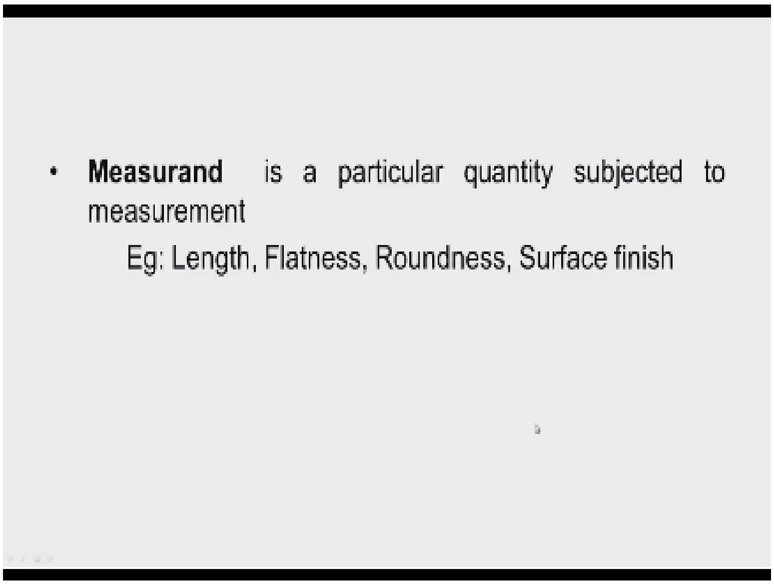

Now data measurement it is a particular quantity subjected to measurement, for example length, flatness, roundness, surface finish etc. These are measured quantities or measurement.

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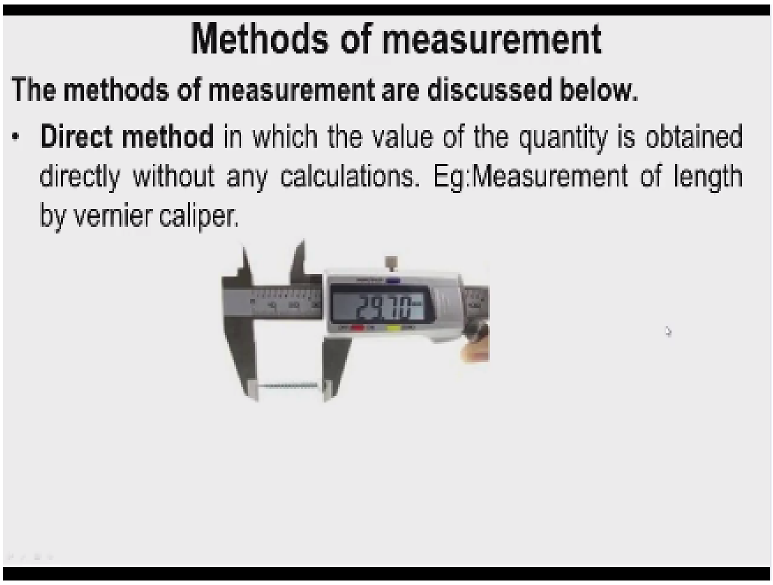

Now the next topic is methods of measurement, different kinds of measurement methods are used and we will discuss a few methods which are relevant to the metrology subject. The first one is direct method. In this method the physical quantity is of time directly without any calculation, example measurement of length by Vernier caliper. You can see that we have the component whose dimension, whose length is to be measured.

We keep the work piece between the moving jaw and measuring jaw and then and then very slowly apply small pressure and then we get the reading in the display. So in this case no calculation is needed, we direct the measuring instrument will directly displayed the measure quantity. So it will be fast direct method measurement will be fast, but there are some disadvantages in this particular case.

If you apply both fresher then the moving jaw may compress the work piece and we may get wrong result. So sense of feel is very important in this case.

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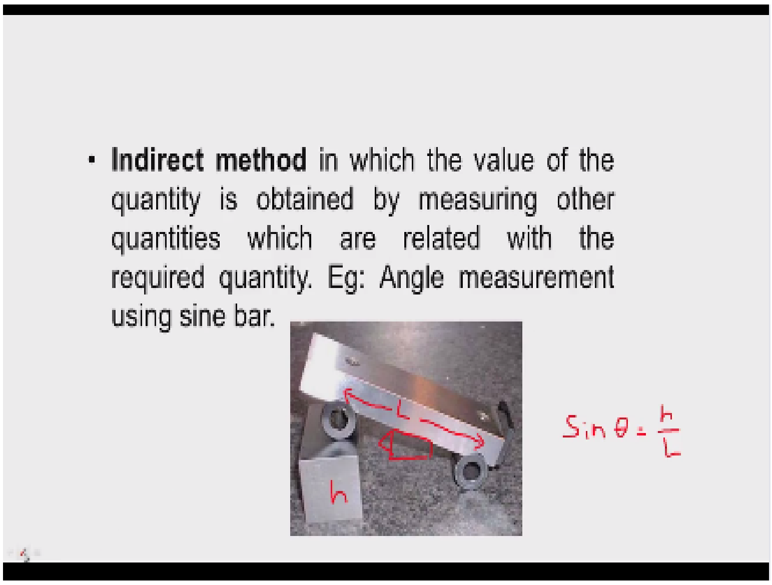

Now second method is indirect method in which the value of the quantity is obtained by measuring other quantities which are related with the required quantity. For example measurement of angle using a sine bar. Now this picture shows the set up for measurement of angle using sine bar, now the component whose taper is to be measure the angle is to be measure should be kept on the datum surface.

So this is the taper component and we need to measure the taper of this component and now we have to select sine bar of appropriate length and then it is placed on a tapered component and now we can see that there is a gap between this roller and a datum we have to fill it using the cages, so this H is the height of the cage and then L is the length of sine bar. So this L is distance between center of this roller and this roller.

The second distance is L, now we can calculate the angle of taper angle the work piece which using this relationship sin teta=h/L. So this is how we calculate the taper angle. So some calculation is involved in indirect method.

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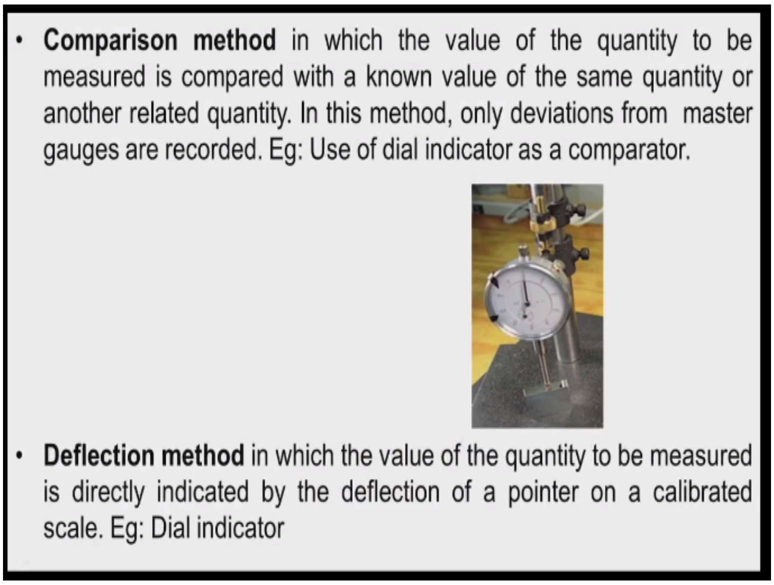

Now the third method is comparison method in which the value of the quantity to be measured is compared with known value of the same quantity or other related quantity. In this method only deviations from master gauges or recorded. For example use of dial indicator as a comparator we can observe this diagram where in we have mounted the dial indicator on the stand, on this column and then we have inserted slip gauge between the datum surface and a spindle to set the desired value.

And then we had to remove the slip gauge and we have to insert the work piece whose height is to be measured. Now when we insert the work piece between datum and spindle the pointer moves and it indicates the deviation of the high with reference to the slip gauge height. Now the fourth method is deflection method in which the value of the quantity to be measured is directly indicated by the deflection of a pointer and calibrated scale.

Again we can take the example of dial indicator, when you insert the work piece between the datum and a plunger the pointer deflects and it gives the displacement.

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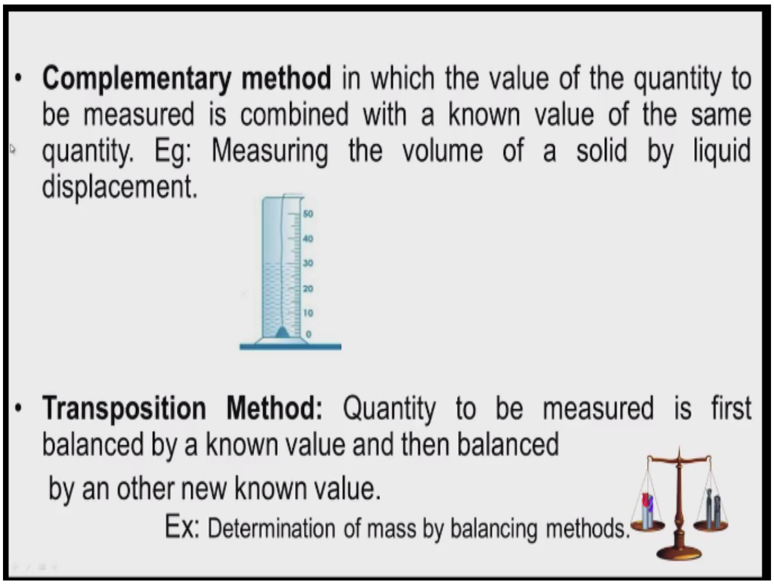

Now the next method is complementary method in which the value of the quantity to be measured is combined with known value of the same quantity. Example measuring the volume of a solid by liquid displacement and now let me explain this complementary method. So initially you have to take a beaker and then we have to fill it with liquid water, now say the water level is 20 units, maybe 20 millimetre cube or 20 centimetre cube.

Now we have a solid use volume is to be measured that we have to insert into this beaker. Now you can see there is a displacement of liquid from 20-30 centimeter cube. So this displacement gives the volume of the solid that is immersed in the liquid. Now transposition method, in this method quantity to be measured is first balanced by a known value and then balance by another known value, so by this method we will come to know about the value of the physical quantity that is to be measured.

So one example is determination of mass by balancing methods. First 4 methods are very important for the metrological point of view. Now let us move to another topic selection of instruments.

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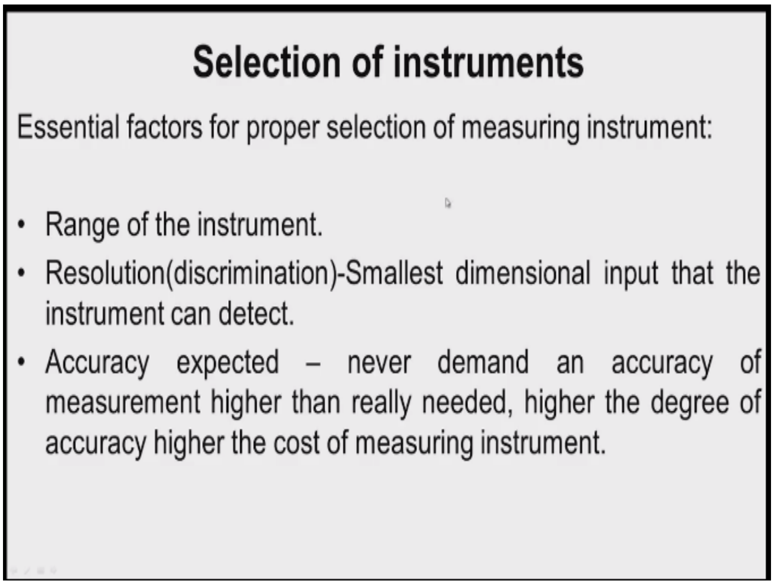

So how to select the instruments, in order to select the instrument we should know what is that we are measuring, what is the environment of measurement and what is the material to be inspected, what are the physical quantities to be measured, so all those things we should study before we select the instrument. Some of the essential factors for proper selection of measuring instrument are listed below.

The range of the instrument, this indicates what is the minimum value we can measure and what is the maximum value that can be measured. If we take example of dial indicator the range of movement of 10 millimetre, then in that case ranger instrument is 0-10 millimeter, then resolution on discrimination smallest dimensional input that the instrument can detect. This depends upon accuracy level what we expect for the measurement process.

If we try to measure the physical quantity to a very accurate level for example length of a spindle, we want to measure up to say 0.001 millimetre then we should select instrument approach accordingly. Then accuracy expected never demand an accuracy of measurement higher than really needed, higher the degree of accuracy, higher the cost of measuring instrument.

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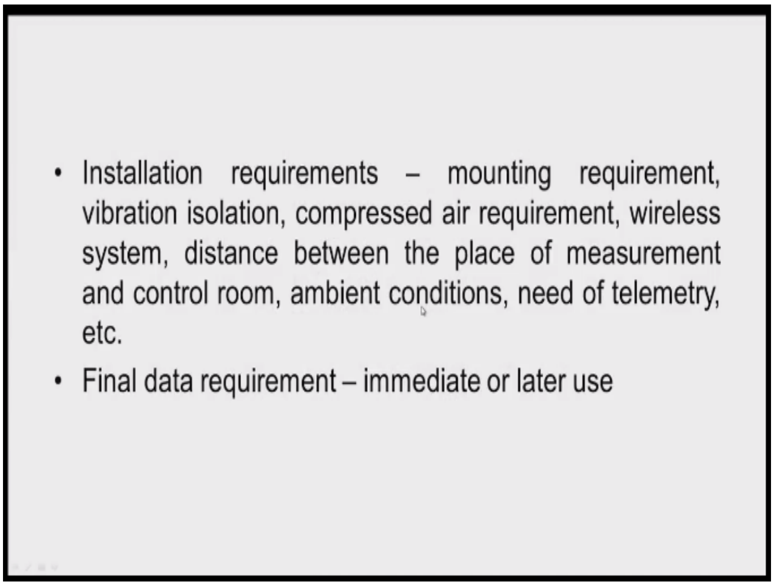

Now what are the installation requirements, sometimes measuring instruments required certain amount of insolation requirements like mounting requirement, how the instrument is to be mounted, weather in a magnetic stand is required or a column is required or vibration isolation system is required or there is any requirement of compressed air, example air gauges.

They require compressor air for their operation, any wireless system is required, what is the distance between the place of measurement and control room, what are the ambient conditions like whether the measurement is required at certain temperature or pleasure and humidity levels or whether we require some measurement to be taken under water or in space like that and what about the need of telemetric.

All these things we should understand and accordingly we should select the instruments. For example if it is necessary to measure underwater measurements then we need to have instruments which are like prof. Final data requirement whether the data is required is immediate or later use, whenever we required data to be read immediately then we should go for instruments having indicators may be mechanical indicators or dial indicators or digital indicator.

So that we can record the measurement result. If it is required if the measurement data is required for later use then we can always store the data and we can use it at a later stage. In that case we need to have data acquisition systems.

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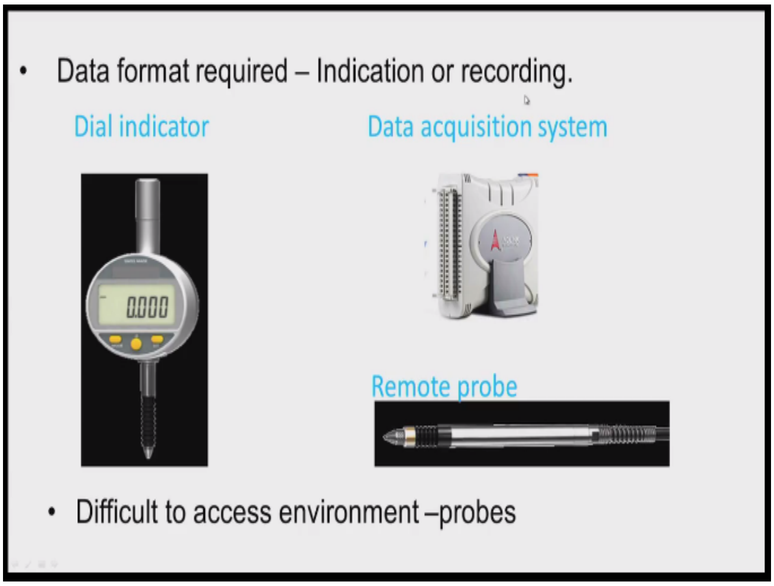

Now what is the data format that is required indication or recording, accordingly better if indication is required we should select the instruments with indications like the dial indicator with digital display and if recording is rich for recording of data is required then get a select data acquisition system having necessary or data acquisition speed, and data acquisition capacity.

And if the measurement has to be taken place at a very difficult to may be where to select the probes, so that it can comfortably measured the difficult to access places, the dimensions.

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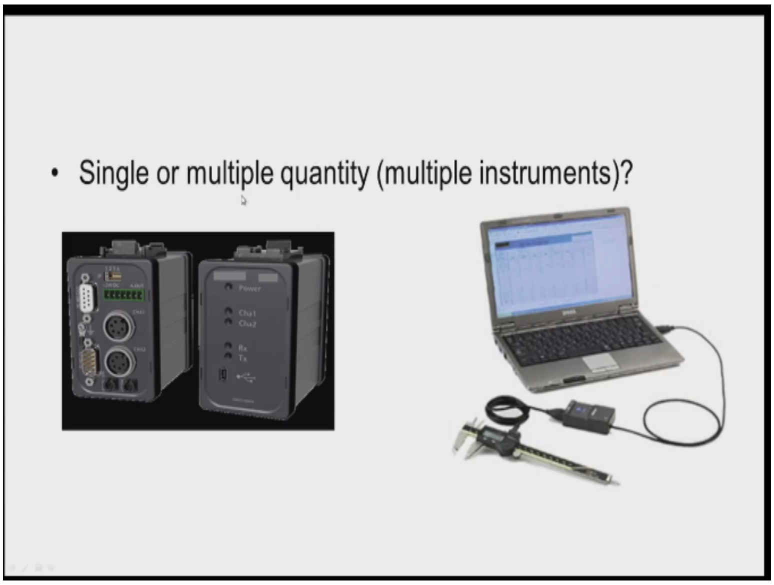

Then whether single or multiple quantity, how many instruments at a time we need to use, if we want 2, 3 or 4 or more than 2 instruments are there which are taking measurements then after data acquisition systems we should select accordingly which are having multiple channels or divisions. Sometimes we may have to dump the data measurement data to the soft ways data management soft ways for getting the statistical characteristics.

So in such case we need to select the measurement which are having the data transmission capability may be in the form of RS32 or PSB holes and then necessary cabling also we should select.

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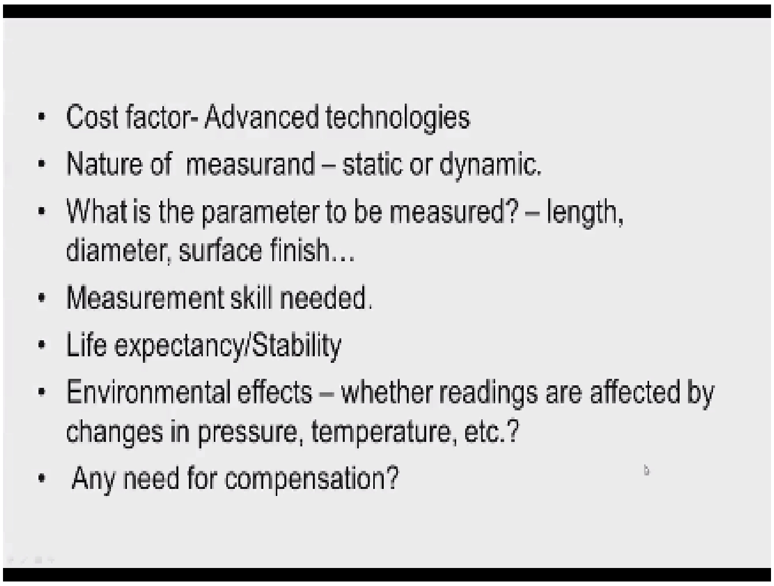

Then cost factor is very very important, suppose we need to have some advanced technologies and coordinate measuring machine or some laser based systems or some automatic measurement systems, non-conduct measurement systems then normally there costly we should see the financial help with the manufacturing plant, whether it can support such advance technologies.

And whether the recovery the economic aspects we have to study and then nature of measuring whether the quantity measured quantity is static or dynamic, whether the signal for the physical quantity is slowly changing or rapidly changing and what is response of the instrument. All those things we need to understand before we select the instrument. Then what is the parameter to be measured.

Whether length is to be measure or diameter is to be measure, surface finishers to be measured, some form of the physical component used to measure taper, angle or the shape of the component like a drum shaped or barrel shaped. So accordingly we should select the dimensional measurement instrument are for measurement instrument or surface finish measurement instrument.

Then what is the skill required, so depending upon that possible measurement skill is needed or any un-skill operator can use, that is also important point before we select the instrument and what is the life expectancy of stability of the instrument. If you want to use for a longer period then we should always go for instruments which have better life expectancy.

And then what are the environmental effects weather reading for affected by the changes in pressure and temperature etc. So environmental compatibility also we need to understand, then any need for compensation for example there is deviation from the temperature, then in that case we should know what is the amount of change in the dimension due to the temperature change.

And we need to compensate for that errors due to changes or we need to calibrate the instruments at that particular temperature where the measurements are taken.

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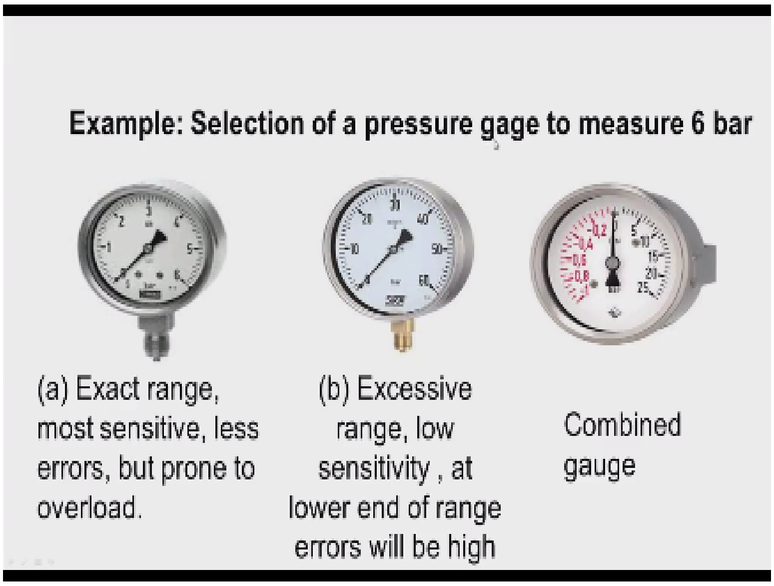

Then let us take an example of selection of a pressure gauge to measure 6 bar. Now if we select a pressure gauge having **6** range of 6 bar then it becomes exact range and will be most sensitive less errors, but prone to overload. If the project increase of beyond 6 but then there were the pressure gauge may be subjected to damage. Then if select 60 bar, if you see if we select the pressure gauge having 0-60 bar range then it becomes excessive range.

Low sensitivity at lower end of the range error will be too high, so if we select a pressure gauge between 0 to 25 bar then it will be alright, sometimes we need to measure both pressure as well as vacuum in that case, case in that case they need to go for combined gauges.

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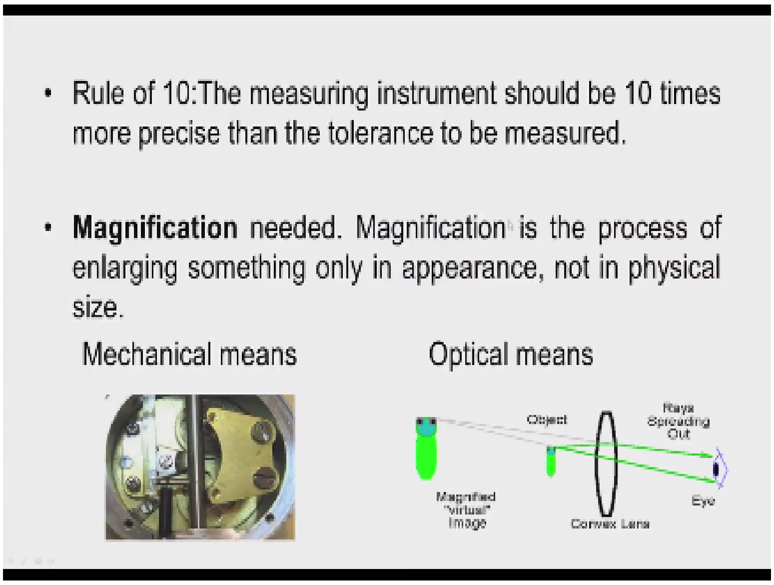

Now there is another important term rule of 10, the measuring instrument should be 10 times more precise than the tolerance to be measured. That means the tolerance level will be complement or say in terms of 0.1, 0.2 millimeter, then we in order to measure such a component we need to select the instrument which are capable of giving 0.1, 0.2 millimeter readings.

So magnification needed, magnification is the process of enlarging something only in appearance, not in physical size. So we need to understand whether any magnification is needed, if the measuring instrument is very simple like steel tool we need not have to use any magnifying systems, but if we need to measure very minute dimensions like the lenses in terms of 0.1 millimeter or 0.2 millimeter.

In that case we need to magnify the quantity physical quantity that is measured, so we can magnify the readings by using mechanical means or optical means. So this picture shows how we can magnify the physical quantity using a mechanical means. We can use rapid and then the gear, so that the physical quantity is amplifier and become comfortably readings.

We can also amplify the signal using optical means, in mechanical means the magnification of 100, 200, 300 possible whereas it use optical means more than 300 magnification is easily achievable.

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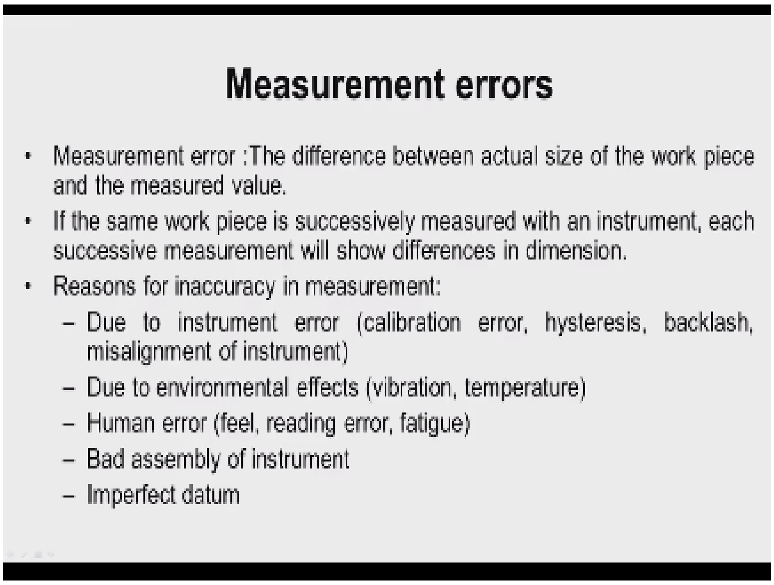

Now let us move to the next topic measurement errors, measurement error is the difference between the actual size of the work piece and the measure value. If the same work piece is successfully measured with an instrument each successive measurement will show differences in dimension, now what are the reasons for this, reasons for in accuracy in measurement are listed below.

The inaccuracy may be due to instrument error that is calibration error or hysteresis, backlash, misalignment the instrument. So these terminologies we will discuss subsequently, then the inaccuracy may be due to environmental effects like vibration or temperature changes. In accuracy maybe also due to human error that means sense of feel or it may be due to reading error like a parallax error or may be due to fatigue of operator.

The error may be due to bad assembly of the instrument that means the measuring instrument is not assembled in a proper way, there are some slackness in the assembly of various components. So due to that also there will clean and then imperfect datum used, it is very essential that the datum we use should be very accurate. So that we get correct feedings, sometimes they datum may be like this it has some errors.

Now we have the work piece like this we accept the work piece in the datum and now we use an instrument to measure the height of this work piece. Now this is spindle, now this is a depth measuring instrument, now if the datum is like the perfect flat then this will be the reading of the instrument. Now there is come here in the datum itself. So we will get an error which will be equal to their size. So it is very essential that we always use good datum surfaces.

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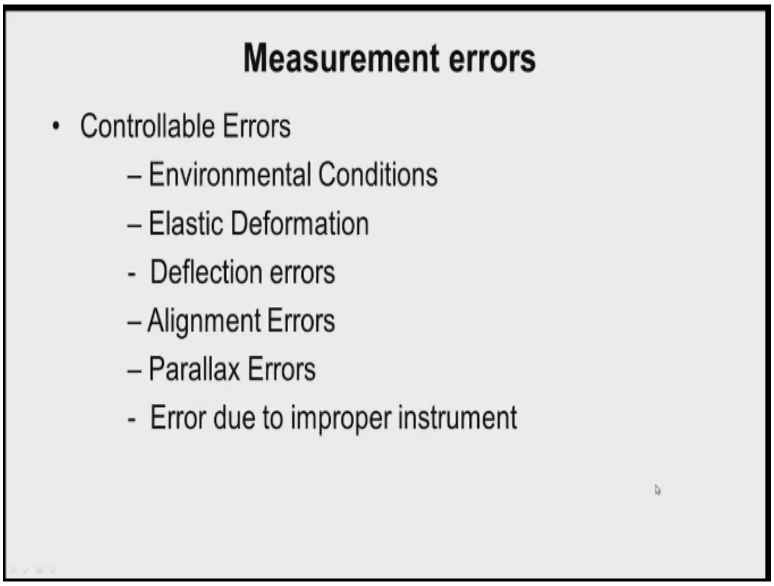

Now the measurement errors can be classified into controllable errors and non-controllable errors, under controllable errors means we can control the amount of these errors by adjusting the working environment. That means under controllable errors errors are due to environmental conditions, errors are due to elastic deformation, deflection errors, alignment errors, parallax errors and error due to improper instrument.

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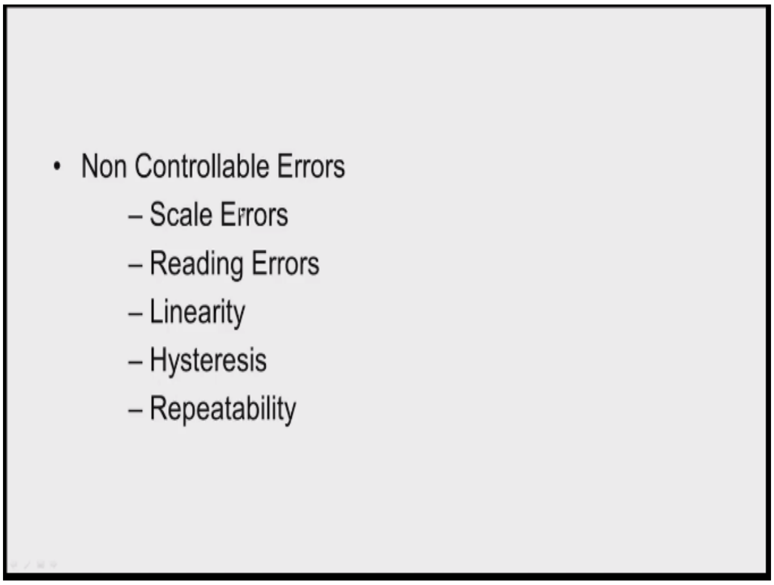

Now under non controllable errors these are these cannot be controlled but we can always measure what is the amount of error and then we can while repairing the inspection reports we have to account for these non controllable error you should know and accordingly we should represent the inspection reports.

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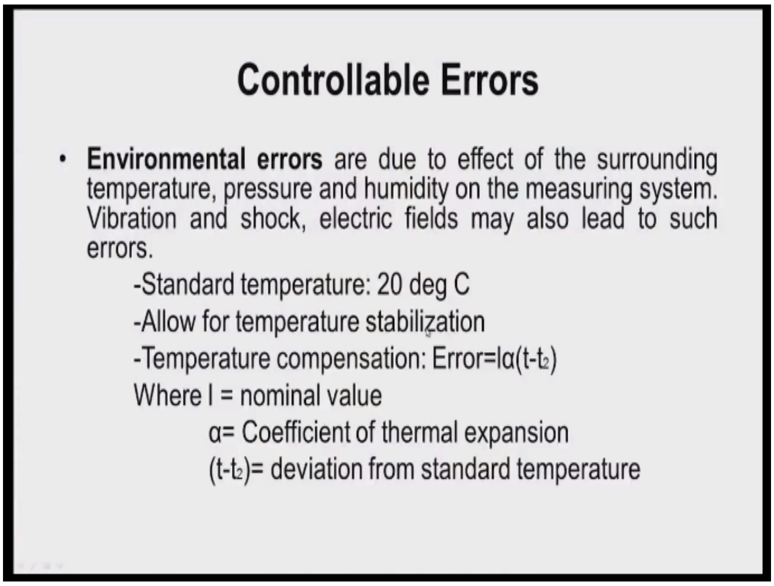

Now under controllable errors the first one is environmental errors, these are due to the effect of surrounding temperature variation the surrounding temperature, pressure and humidity or may be due to vibration and shock electric fields ok. Now we need to understand that when we conduct the measurement process we have to maintain a standard room temperature of 20 degree Celsius which is internationally accepted.

When we keep the work piece for measurement or when we take the work pieces for measurement we have to keep the work pieces at this temperature and we have to allow for temperature stabilization then only we should go for measurement then if the temperature is deviated from the standard temperature say 22 degree and 23 degree then we need to compensate for that variation in the temperature.

So that compensation we can calculate using this relationship error=ltimes alpha times t-t2 where l is nominal value and then alpha is coefficient of thermal expansion of the material and t-t2 is deviation from standard temperature, if t is 20 degree and t2 is 22 degree then deviation is 2 degree, using this relationship we can always calculate the error due to environmental factors and we have taken for their when we give the measurement results.

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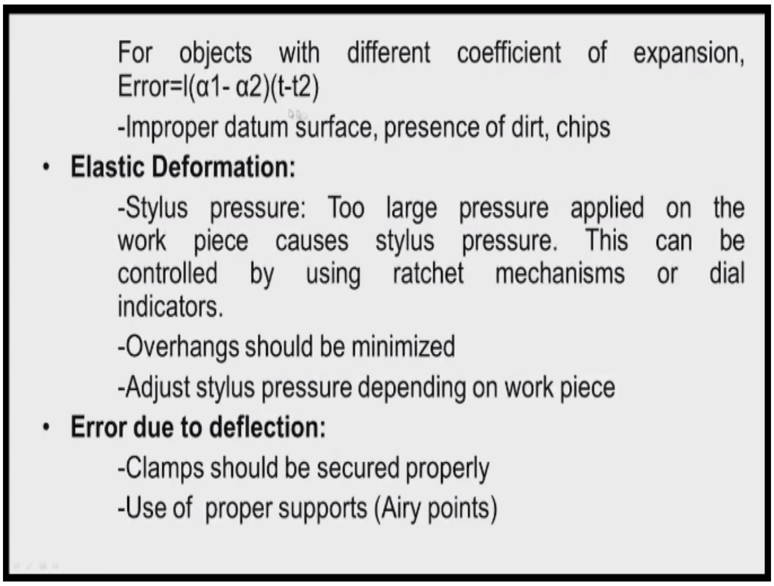

Now if you have two different kinds of material then the error can be calculated using this relationship, ltimes alpha-alpha2 times2-t-t2 where alpha 1 is coefficient of thermal expansion of the first material and alpha2 is coefficient expansion for second material. So measurement error maybe also due to improper datum surface which we discussed already and maybe there is presence of dirt and presence of chips.

Due to this also the measurement error may creep thin, that mean we need to clean the datum surface properly, so that there is no dirt or chip, so this we can understand there is simple diagram say there is a dust particle or dirt particle, and then if we use place the instrument like this then this much error will be introduced. So if we clean the datum surface and then we should go for measurement process.

Now we are coming to the end of second lecture, so in this lecture we discuss about various metrological terminologies and what are the different methods of measurements. We also discuss about selection of instrument based up on the parameters have to be checked and then we start the discussion on measurement errors. In the next lecture we will continue this discussion on measurement errors, thank you.