Metrology

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Module-1
Lecture-3
Measurement errors

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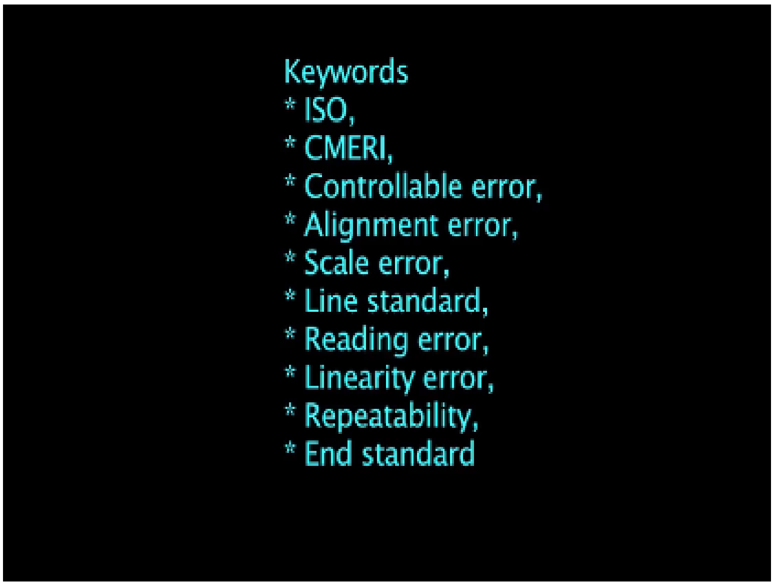

I welcome you all for the current lecture in the module 1. In the last class we started discussion on controllable errors and we completed environmental effects of environmental errors. Now today will have discussion on remaining controllable error.

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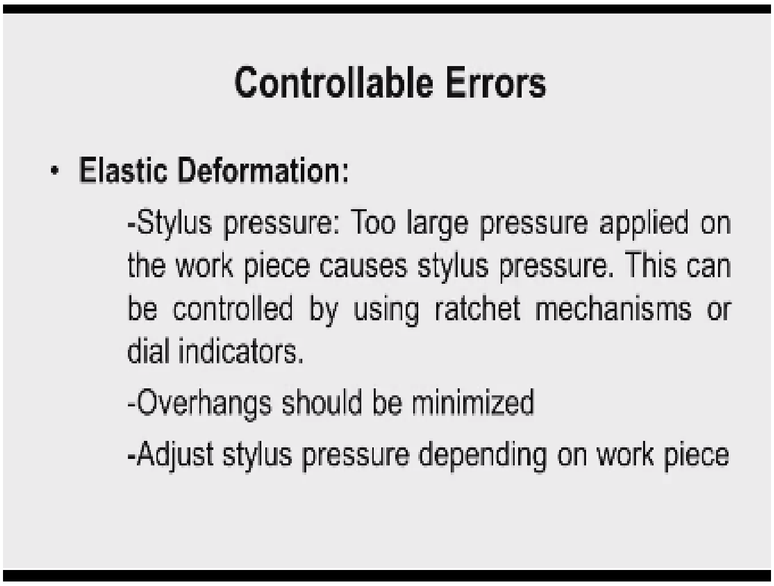

Now we will discuss what is elastic deformation. Now during measurement sometimes what happens operator will apply more pressure on the moving element, so that they are moving jaw will compressors work piece. So due to this what happens the work piece gets damaged and also the measuring instrument store and angle gets damaged. So we will get some error in the measurement, so how this can be eliminated.

Now we should have some sensing device to sense the pressure applied pressure for example ratchet mechanism provided in micrometre or sometimes dial indicators are provided along with instrument to sense the measuring pressure and the overhang setups should be minimised if the part is over hanging, so because of its own weight the measuring instrument made deflect or the setup may deflect leading to some elastic deformation errors. Now we should have some kind of adjustment for applying stylus pressure which I have discussed.

Sometimes what happens they say may be used to measure the different kinds of material like rubber, plastic, and metallic parts. In that case in pressure setting will not be enough. So depending upon the pressure the material that we need to set different settings project settings. So if we have such kind of adjustment in the measuring instrument is always better.

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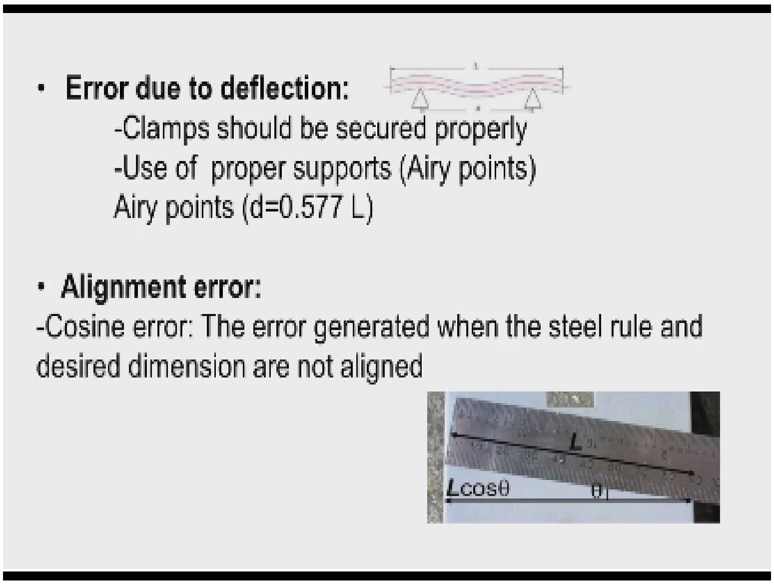

And then due to reflection sometimes they work pieces would be very long and we need to support them using supports. Now in such cases we have to use any points I can see this diagram where in we have a very lengthy work piece, the length of work piece is L and it is supported at two places, 2 supports are there, the distance supports is D. Now when we support the long one piece at a distance of which is known as a d= 0.577times L.

Where L is length of work piece, then even though there is deflection of the work piece, the end faces will be parallel to each other. So that we can I take the measurement by using end faces of the work piece. If we support at any other distance then ends will not be parallel and when we used in faces for the measurement we will be getting some error. So that we can show with the help of a simple diagram and writing a sketch.

Even be used in faces for the measurement I will be getting some here so that we can show with the help of a simple diagram and rating a sketch so we have long work piece like this and then it is supported using 2 supports like this, but the distance is not equal 0.577 times still selling the length of work piece. So in this case we can see that end faces are not parallel. So when we use the end faces for measurement in such a situation then there will be measurement errors due to the deflection of work pieces.

And there is another kind of alignment error ok, this happens when the measuring instrument and desire dimensions are not properly aligned, so this I can understand by using this by studying this diagram we have the work piece of some length which they length of the work piece is to be measured. We have taken a scale for measuring the length. Now scale is not properly aligned with the work pieces.

But we can understand I can see in the picture that there is a inclination of theta between the measure dimension and the end of the scale. So because of this we get a length of Yell but actual distance will be Lcos theta. So this is known as cosine error. So this we can eliminate by proper alignment of the measuring tool with the physical dimension that is to be measured.
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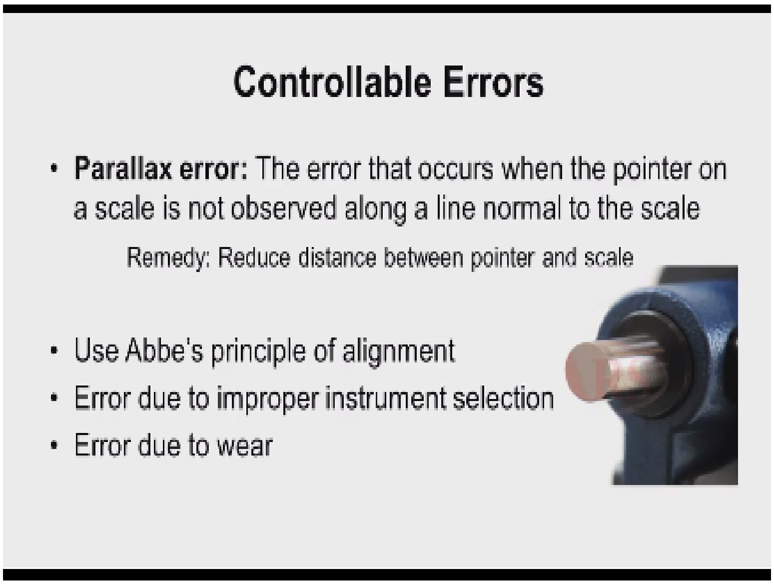

Now under controllable errors we have another error called parallax error. The definition of this be studied when we discussed about metrology terminologies. Now this error occurs when the point on a scale is not observed along a line normal to the scale. Now what is the remedy for this. So we should always try to reduce the distance between the pointer and scale, so this parallax error is minimised.

Now we should always use a base principle of alignment that means the axis of measurement and instrument measurement should be always are collinear. So that the error due to distortions are eliminated and then error due to improper instrument selection. So we can take care example of measurement of a very thin wire of say half millimetre diameter. Now in order to measure this diameter which is approximately 0.5 millimetre diameter.

We should not select a micrometre having the range of 0-25 millimetre. If we select instrument having 0-25 millimetre what happens is we are using the end portion of the range. So the error will be more, so we should always we select the instrument we always use the middle portion of the range. Now if you want to measure 0.5 millimetre diameter wide it is always better we select an instrument having range of may be 0-3 millimeter or 0-5 millimeter if available.

So that the errors are less and then error may occur due to wear also. So due to the continuous usage of measuring instruments the measuring surfaces of the instruments are subjected to wear. For example if we take vernier calliper the faces of measuring jaws are subjected to wear, similarly the angle face and spindle face of the micrometer they are subjected to wear.

Because of this we get some error. Now wherever possible we should try to adjust the instrument.

So that the error is made 0. Otherwise we have to calibrate the instruments and then we should note them at the error, and then we present the measurement result we should account for this measurement error. And many times a measuring instruments are come with the Tungsten carbide coated surfaces. For example in the micrometre angle surface and spindle surface. They are tipped with carbide.

So that the wear is less and the life of the instrument is more. So that we can observe in this picture, this is the spindle. Now we can see the tip of the spindle is at the end of the spindle is tipped with a carbide tip.

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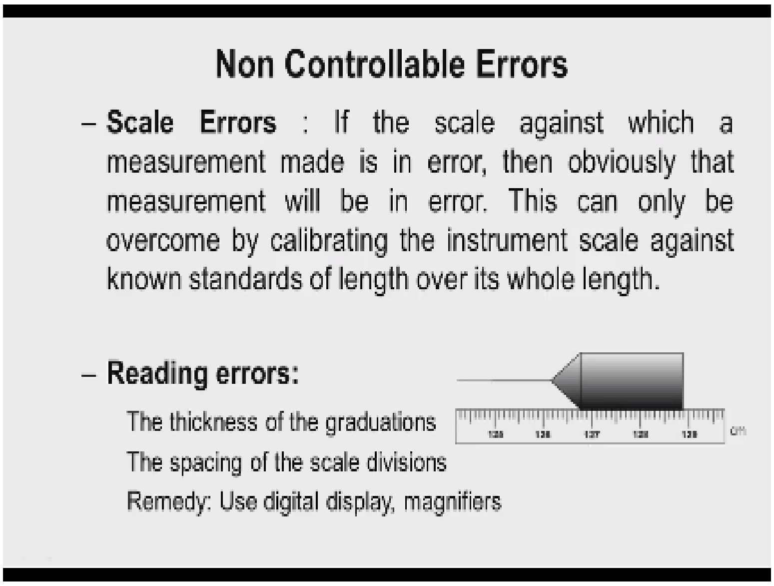

Now let us discuss about non controllable errors. So these are beyond the control of operator and what we need to do is we have to calibrate the instruments and we had a note down what is error and when we present the measurement data we should account for the error. Otherwise we should have we should take a new measuring instrument where in the non controllable errors are very less or another remedy is we should celebrate the instruments.

And then we should use such instruments. Now the first one is scale errors, now when we use some instrument if the scale preparation of the instrument itself is wrong then we always get the wrong reading is known as scale error. This can be eliminated only by calibration of that particular instrument. Now we have another kind of non-controllable error which is known as reading errors. This happens because of thickness of the graduation and line spacing between 2 divisions.

Now we can study this picture wherein we have long component whose length is to be measured. We are using a steel rule, now you can see the end of the work piece is somewhere here now if we read this scale the reading is 128.8, the reading is between 128.8 and 128.9, but it is very close to 128.9. So now what we can what operators will do, he will take a dimension of 128.9 + or – 0.1 cm.

So in this case the 0.1 cm becomes the reading error. Now remedy for this is we should use instruments with digital display or we should use magnifying lens so that we can approximate in a better way. So that reading error or minimised.

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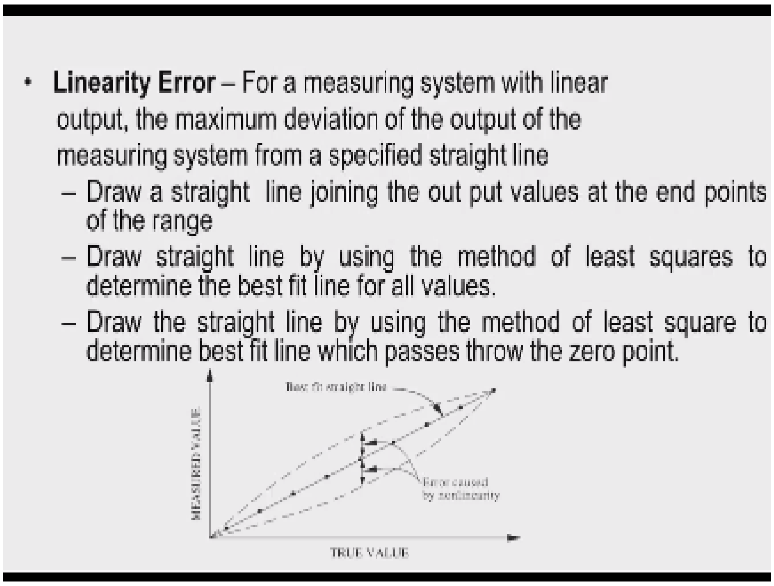

Now we have linearity error ok for measuring system with linear output, the maximum deviation of the output of the measuring instrument from a specified straight line is known as linear. Now we observe this picture x-axis is true value of the physical quantity and y-axis we have measured value and we have a best fit a straight line drawn using the endpoints and that points are lying very close to that.

And now this gap is known as error caused by non linearity. So this best fit line we can always drop by various methods by using the endpoints of the range, also by method of least squares to determine best line for all the values and another method is using a method of least squares to determine best fit line passes through the 0 point. Now for the instrument which is having linearity error we should know what is the amount of linearity error.

And we should consider this by measurement data, the other kind of an uncontrollable hysteresis error. So this is the difference in position between loading and unloading curves, now we can observe this picture wearing they have a loading curve that means the measurement is done in the increasing order and similarly in descending order. Now this difference is known as hysteresis.

Now how do we find whether there is hysteresis error. So when the pointer does not return to 0 weather load has been removed then it indicates that there is some hysteresis error. Now the causes for this hysteresis error are many this may be due to dry friction in the mating parts moving parts because of their properties of elastic elements also error may happen also because of presence of cause of presence of internal stresses in the various components of the instrument.

This can be reduced by proper retreatment of various elements of the instrument and also by proper stabilization of the various components of measuring instrument.

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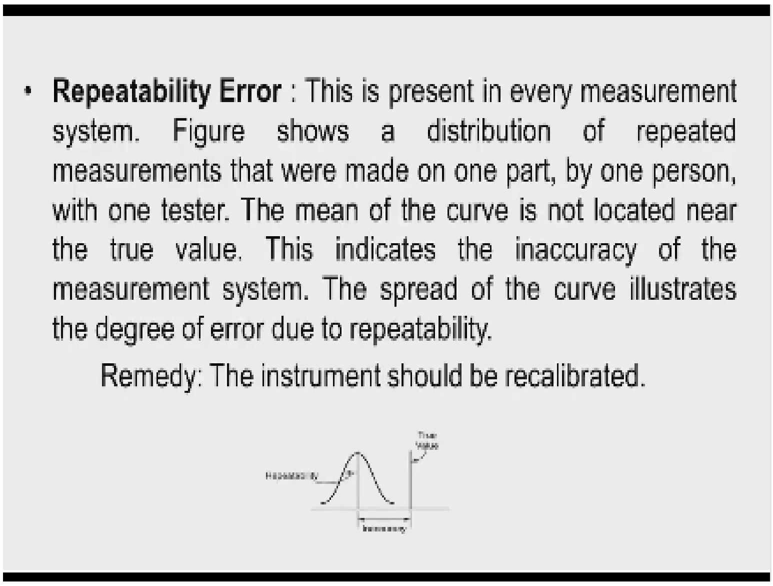

Then repeatability error, so this is present in almost all measuring systems, now the figure shows the distribution of repeated measurement made on one part by one person using one tester. Now we can understand that the different measuring points will fall like this and we can always measure the mean of this ok. And now the gap between the mean line and true value is known as inaccuracy.

And this gap will be known as repeatability error. So this indicates so there is struck in accuracy in the measurement system in spread of the curve illustrate this spread of the curve illustrate the degree of error due to repeatability. So this can be eliminated by proper calibration of the instrument.

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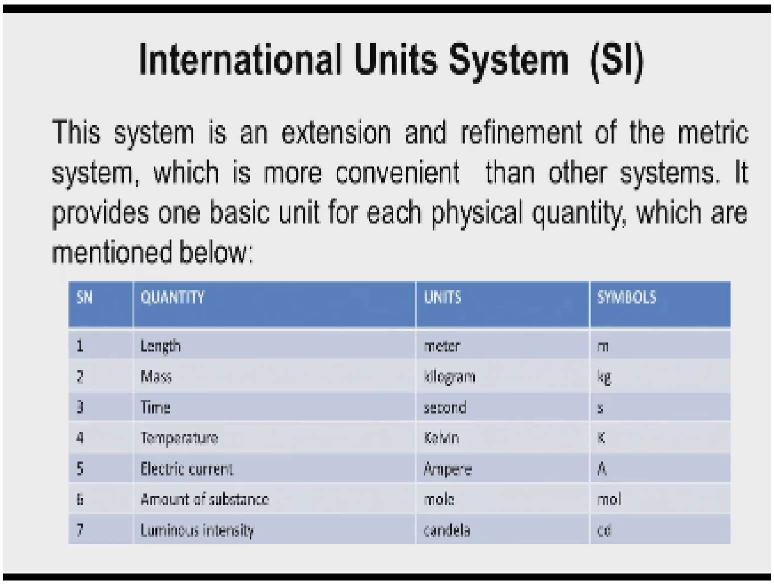

Now let us start the discussion on international unit system. There are many unique systems like imperial system, metric system and this international unit system is an extension and refinement of the metric system which is more convenient to use when compared to other systems.

This provides one basic unit for each physical quantity which are mentioned below. For length the unit is meter and symbol used is m. Similarly for mass the unit is kilogram and symbol is kg. Similarly the seven basic units and all of them have a units sign and symbols as shown here.

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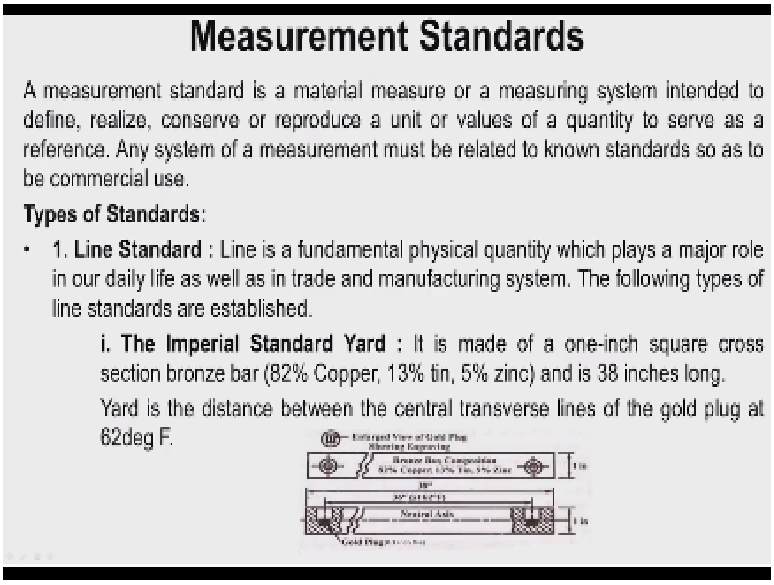

Now coming to the measurement standards. now international organisation for standardization is responsible for establishing the standards and maintaining the standards and they will also responsible for calibrating the other secondary and tertiary standards by comparing those with the primary standards established by international organisation for standardization with the help of its various technical committees.

Now there are different kinds of standards like material standard and wavelength standard. Now under material standards we have line standards and end standard. Now let us learn what is that line standard and end standard. The line is a fundamental physical quantity which plays a major role in our daily life as well as in trade and manufacturing system. The following types of line standards or established.

The first one is imperial standard yard. So this is the material having the 1 inch square cross section and it is made out of branch bar with composition of 82% Copper, 13% tin and 5% zinc and the bar is having certain length. Now 2 gold plug are inserted into the branch bar as shown in the figure on the neutral axis. Now on the gold plug there are 3 lines are engraved.

Now the distance between the centre line of left gold plug to the centre line of right gold plug is taken as one yard. So this is known as imperial standard yard and this is kept at a temperature of 62 degree fahrenheit.

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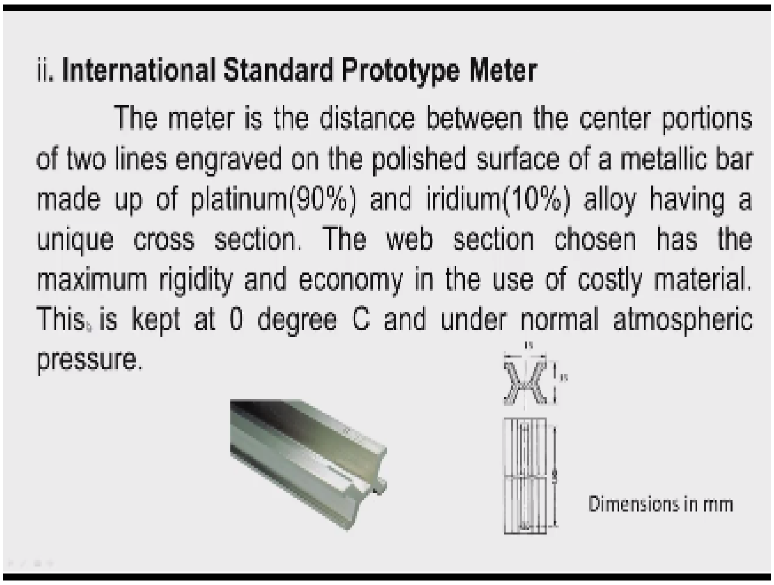

Now there is a kind of line standard known as International standard prototype metre, again this sketch shows special cross-section is used and the length and breadth or 16 millimetre for 16 millimetre and this represents the neutral axis surface, the surface is at Newton acts and two lines are engraved on the surface and the distance between these two lines is taken as 1000 millimetre or 1 metre.

Now what is the material of the bar, it is made out of 90% platinum and 10% iridium and this is kept at 0 degree centigrade and normal atmospheric pressure. Now this is taken as 1 meter and it is used for comparing other measurement standards.

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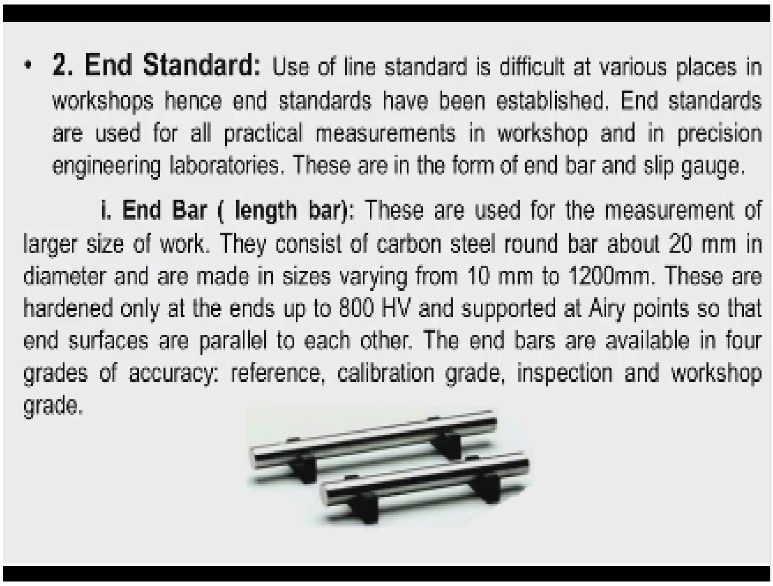

Now the second type of material standard is end standard, that means we have a metallic bar maybe of round shape or square shape and the distance between ends and surfaces of the bar is taken any standard and these are more convenient to use when compared to line standard and these are used in the workshop practical for practical measurements in the workshop and in inspection laboratories.

The examples are the end standard or end bar and slip gauge. So let us try to understand they and bar these are used for measurement of large size of plug. They consist of Carbon Steel round bar about 20 mm in diameter and length is varying from 10 millimetre to 1200 millimetre. They are all done at the end up to 800 hardness and whenever they are supported that supported using airy points.

So that and surfaces will be always parallel. There are available in the different grades like reference great calibration get grid inspection grade and workshop grade, Depending on the usage appropriate grade for selected. For example for measurement in the word shop level they were used for calibration purpose, calibration great stuff and buffer used. These end have threaded ends.

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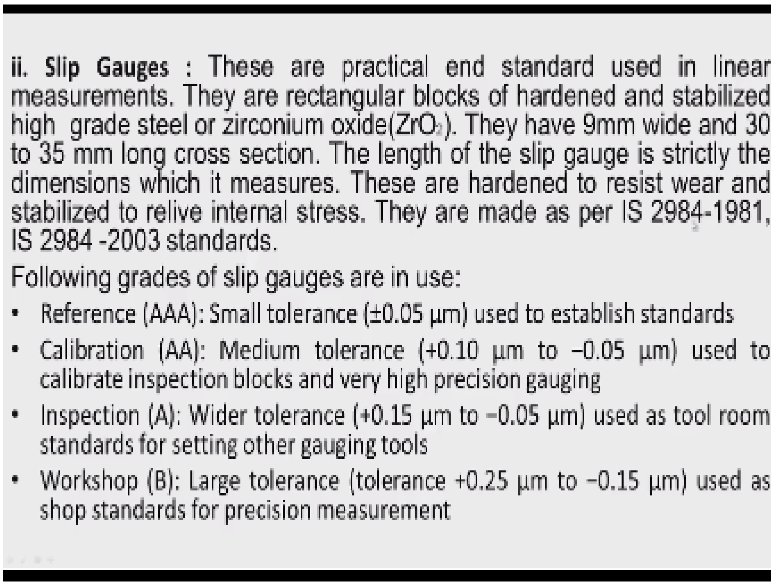

So that the two or more number of and boss can be assembled to have required length. Now second type of end bar or end standard is slip gauge. There nothing but rectangular blocks of hardened and stabilized high grade steel or zirconium oxide. They have 9 millimeter wide and 30-35 millimetre long cross-section. The length of the slip gauge is nothing but the dimension which it measures.

They are hardened to register wear and are stabilized to relieve internal stress stresses. They are made as per IS 2984-1981 and IS 2984-2003 standards for different grades of slip gauges are available like triple AAA grade wherein very close tolerance are maintained like plus or minus 0.05 micrometre. There used to establish standards and use for a reference purposes.

The second category is AA category or calibration A which uses medium tolerance and its length that is less 0.1 micrometre to -0.05 micrometre. There used for calibrating the lower measuring instruments and they can also be used for high precision glazing work and then third grade is A grade or inspection grade varying tolerance is provided on the length of the gauge from 0.15 micrometre to -0.05 micrometre.

That used as tool rule standards for setting other gauging tools. The fourth grade is workshop grade or we say b grade where in the tolerance is wider that is +0.25 microns to -0.15 microns. They are used as shop standards or precision measurement.

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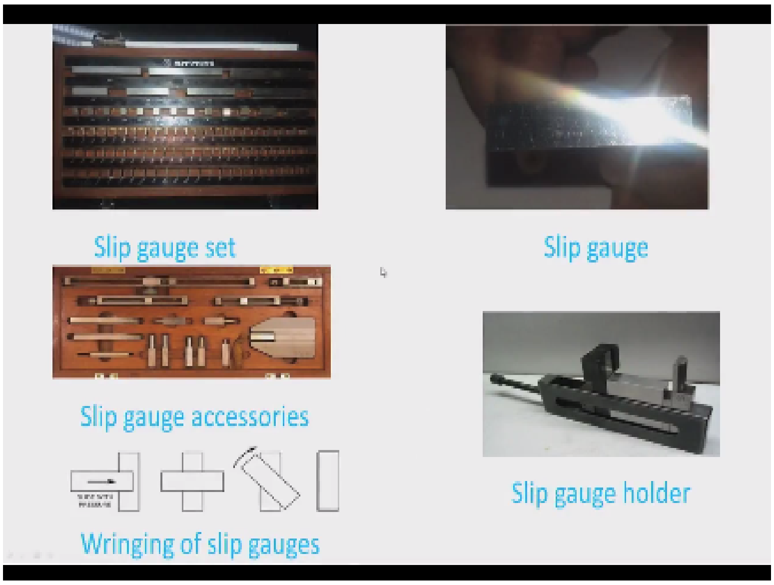

Now we have some photographs here, this shows the slip gauge set varying we have various slip gauges or different lengths and then we can say we finish as a lapping work to be carried out in the measuring surface, so we have very fine finish and very close tolerance can be attained. So this shows the slip gauge accessories varying we can have slip gauge holder and we can see slip gauge holder here.

And we can assemble the different slip gauges by ringing process, we can build required length of the slip gauge and we can put them in the slip gauge holder and this distance can be used as the standard for the measurement purpose.

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Now I am showing a slip gauges set, the different grades of slip gauges re available which we have already discussed and normally or we have 2 types of slips one is normal set and other one is special set, in the normal set starting from 1.001 to 100 millimetre there will be totally 45 pieces.

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In the special set starting from 1.001 to 100 millimetre there will be totally 87 pieces. Now I am showing a special type of slip gauge box varying we can see the slip gauges lengths and they go up to 1.009 in steps of 9001 and then starting from 1.01 to 1.49 up to 1.49 in steps of

0.01 we have 49 pieces and then starting from 0.5 and up to 9.5 we have totally 19 pieces in terms of 0.5 and then starting from 10 and up to 100 millimetre in steps of 10 we have 10 pieces.

And then we have will be having to slip gauges. They are known as wear block and set that missing.

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Now I am showing one slip gauge of 80 millimetre length, this is the distance between two measuring surfaces that means this surface and distance between these two surfaces is 80 millimetre. We can have a look at the measuring surface, so this is the measuring surface, so this surface is finished ground, hardened stabilized and then left will have almost a mirror like finish their flatness of the measuring surface will be fraction affair micrometre.

Prism between these two measuring surface is also very very important and it is maintained between a fraction of a micrometre.

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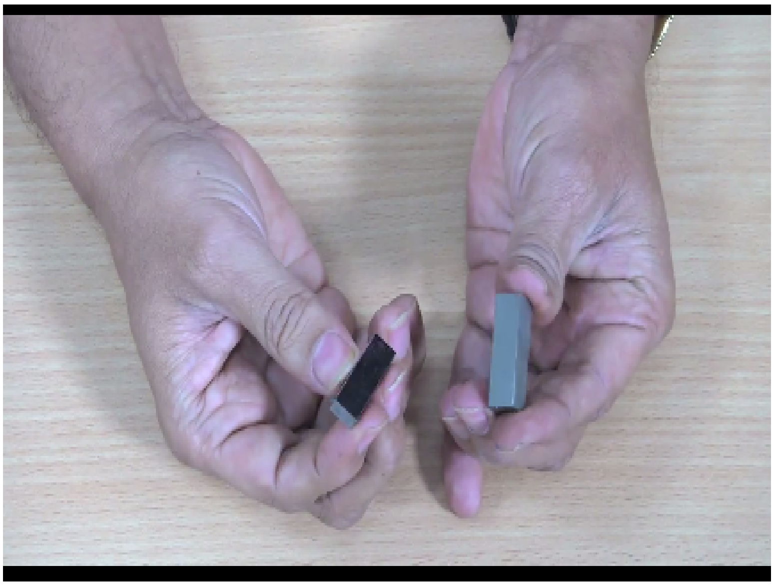

I showed a special type of slip gauge wherein 14 millimeter slip gauge is not available, so we want 14 millimeter lens leakage we have to take to slip gauges and we have to build them, so I have taken 9.5 mm slip gauge and 4.5 millimeter when you can bind them to get 14 millimetre slip gauge. So we have to combine the 2 slip gauges by a process called ringing process.

I will just demonstrate the process that 2 measuring surfaces should be cleaned properly to remove any desk and oil in the year and then we have to keep this to slip gauges like this perpendicular to each other and we have to slowly move one flip case for what other and then we have to rotate like this. Now you can see because the molecule attraction between the two surfaces, there will be adaption of the slip gauges.

Now the distance between this surface and this surface is 14 millimeter, while dismantling the slip gauges we have to repeat the same procedure, we have to rotate the slip gauges like this and then we have to slowly move and then we have to remove it. So this is ringing process. So like this up to 30 decimal place we can build the slip gauges.

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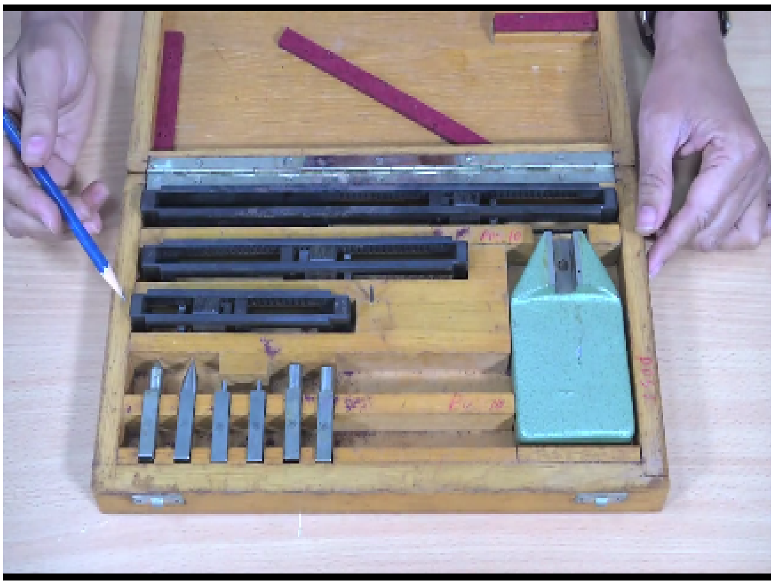

Now I am explaining the slip gauge accessories which are used along with the tickets at this is the slip gauge holder will be having the slip gauge holders in the different ranges for example the first one is having a range of 0 to 50 millimeter, second one is having a range of 0 to 100 millimetre and the third holder is having a range of 100 to 200 millimetre. Now this is the base you can see the bottom surface of the base study centre it is relieved.

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And only here then be contact with a surface plate and we can observe that there is a screw here now these two can be assembled using this screw and credit portion like this so that this assembly can be used as height master. Now how to build the required height, now we have taken 40 mm length slip gauge and these are the measuring jaws. We can observe the measuring surface this is very finally finished lapped surface.

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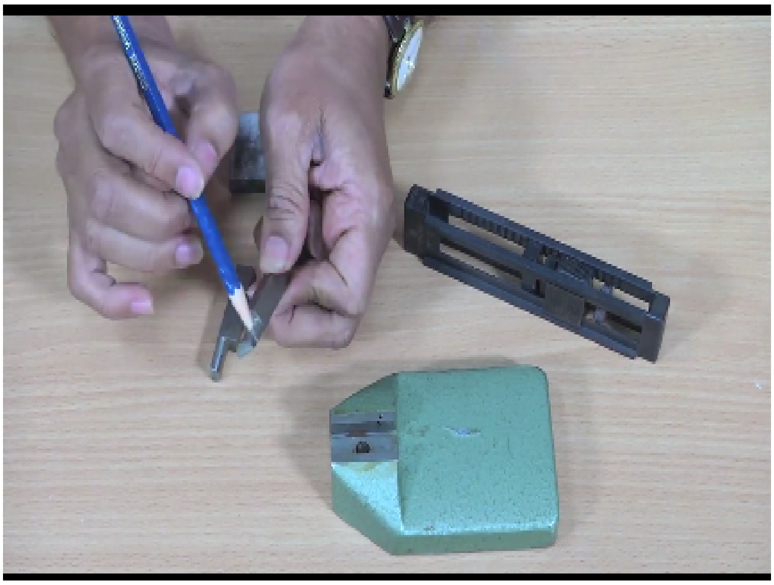

And another side we have a curved surface again this is lapped, so that both inner surface as well as outer surface can be used for measurement purpose. Now I will just show the assembly, so we have to assemble again we have to bring the slip gauge with the measuring jaw, I showed the process of bringing similarly this should ringed and then assembly should be put into the folder.

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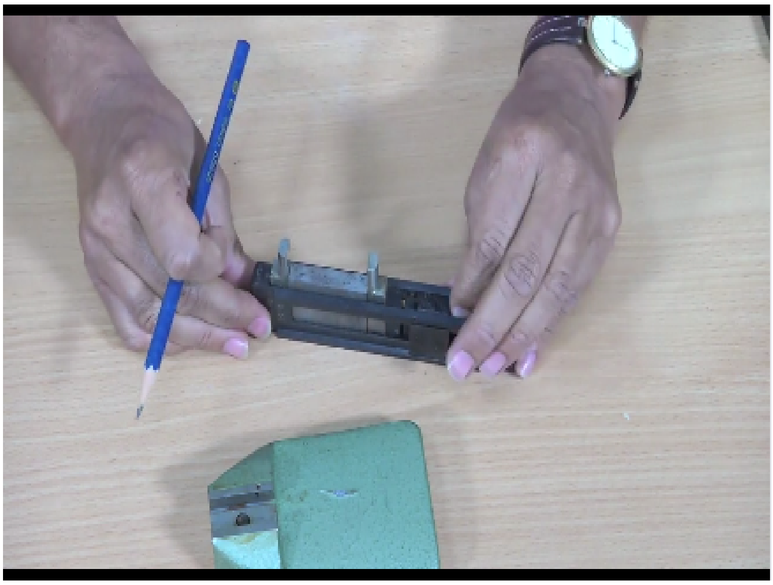

You should be put into the folder like this and then we have to tighten. Now the distance between the surface and this surface is 40 millimetre, now this can be used as standard for measurement process, safe required we can fix this to the base, so now this assembly can be used for both the external measurement that means you can measure external dimensions as well as if I have a component with a bow for this can be used for internal measurement also.

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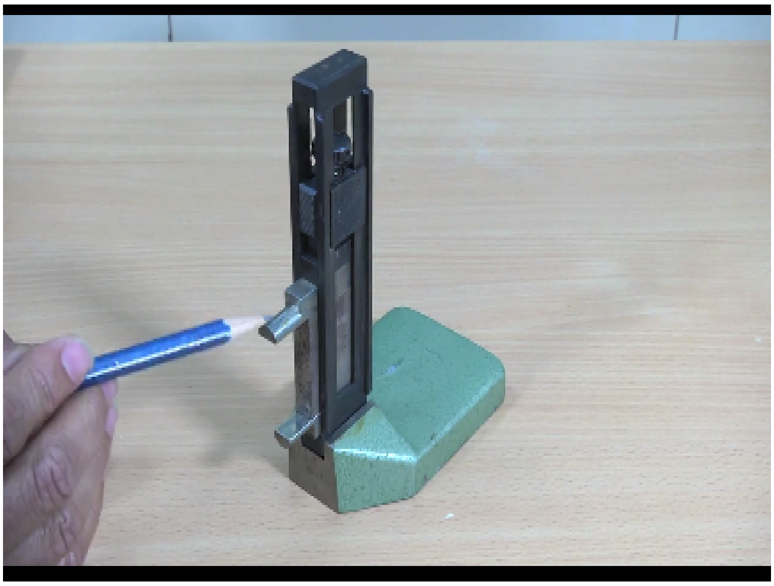

So from here to here it can be used for internal measurement.

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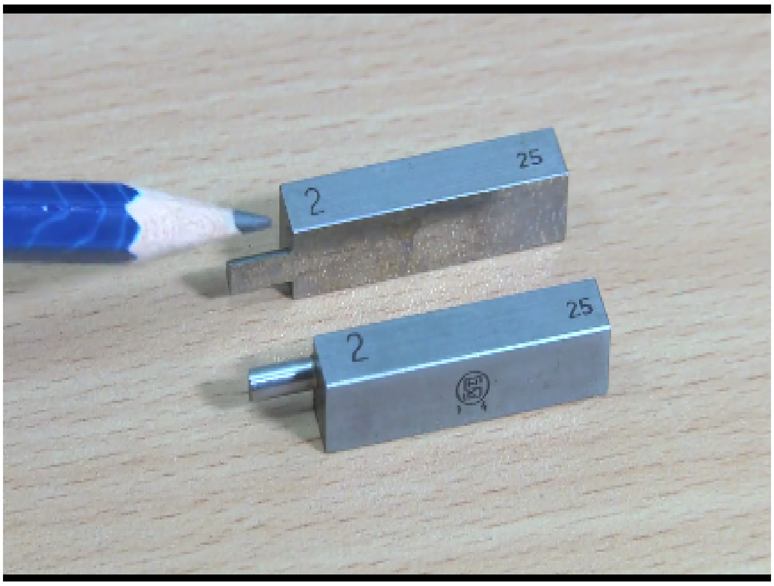

Now this is a pair of measuring jaw with their dimension 2 millimetre, this is the inner surface and outer surface the distance between the inner surface and the extreme point and a curved surface is 2 millimetre. So this can be used for both internal measurement as well as external measurement and then we have a scriber also, so we can use this along with a flip gauge for driving for purpose.

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So we have another kind of jaw which is having a centre point here, this also can be used for driving purpose.

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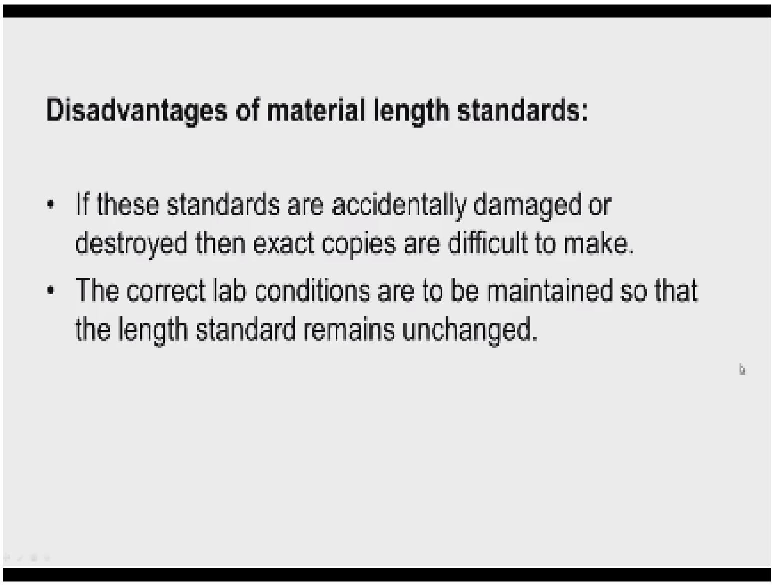

Now what are the disadvantages of material standards, sometimes accidently if these standards are damaged then it becomes difficult to remake them particularly the imperial standard and international prototype metre if they are damaged will be very difficult to reestablish them and then a very accurate lab condition for to be maintained, so that there might be any dimensional changes.

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- **3. Wavelength Standards:**

Meter is now defined as the length of path travelled by light in vacuum in 1/299792458 second. The light used is iodine helium-neon laser at wave length of 633 nm.

- **Subdivision of Standards:**

Material standards are classified into four basic types:

i. **Primary standards:** This is a material standard which is preserved under very specifically created conditions.

The International Prototype Metre is an example of a primary standard. This should be used only for comparison with secondary standards and cannot be used for direct application.

In order to overcome these difficulties wavelength standards or established. So now metre is defined as the length of path travelled by light in vacuum in 1 upon 299792458 second, so the light used to establish this way and standard is iodine, helium-neon laser at wavelength of 633 nanometre. Now this is not affected by the environmental conditions, so this is more convenient to use that can be established easily.

But there are some subdivision of standard material standards are classified into 4 basic types, the first one is primary standard, this is a material standard which is preserved under a very specifically created conditions like 20 degree Celsius, so one example for this primary standard is international prototype metre, so this cannot be used for direct application that will be always used only for comparison with secondary measurement standards.

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ii. **Secondary standards:** These should be exactly like the primary standards with respect to design, material and length. These are compared with primary standards and deviations if any are recorded. These standards are kept at a number of places for occasional comparison with tertiary standards.

iii. **Tertiary standards :** These are used for reference purposes in laboratories and workshops. They are used for comparison at regular intervals with working standards.

iv. **Working standards :** These are physical standards (gauge blocks for example) that are used for checking measuring instruments used in work shop. These have a traceable relationship to the secondary and primary standards.

Now there are the secondary standards there much like primary standard with respect to design aspect, material aspect and length aspect, these are compared with the primary standards at regular intervals and if there is any deviation it is recorded. These standards are kept at various places in various countries for occasional comparison with the tertiary standards.

Now what are tertiary standards, so these are used for reference purposes in various laboratories and workshops that used for comparison at regular intervals with working standards and now working standard this is a physical standard for example gauge blocks. They are used for checking measuring instruments in the workshop, that means workshop instruments are calibrated by using these working standards.

These are traceable relationship to the secondary and primary standards by step-by-step comparison with higher level standards.

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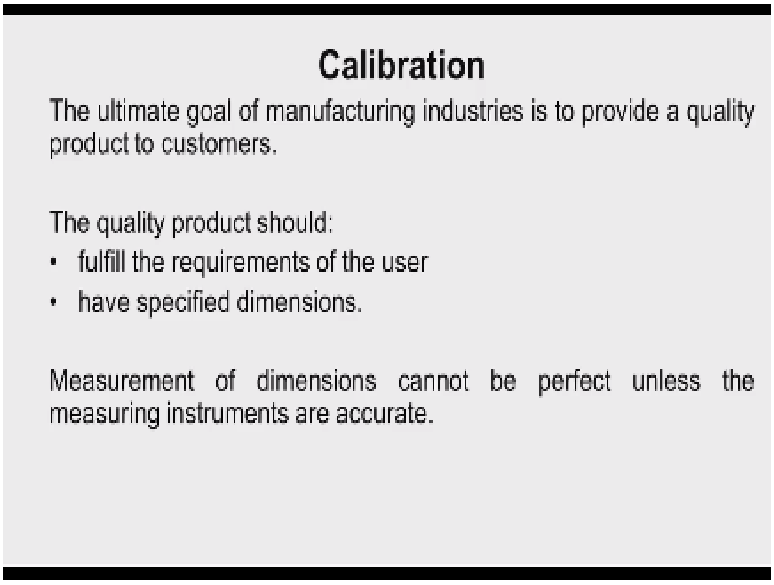

Now let us try to understand the meaning of calibration, any manufacturing industry will have a role of producing very good quality products, they want to supply 0 defect product to the customers so the quality product should fulfill all the requirements of the a customer with respect to functions, with respect to size, with respect to looks economic aspects and they should have specified dimensions as given by the customer.

So in order to establish or have the specified dimensions it is very necessary that measurement is to be carried out and one should have a good and accurate measuring instruments.

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Calibration is a process of comparison of instrument performance with standards of known accuracy. In calibration, the errors of measuring instruments are quantitatively determined, and also minor adjustments are made in the instruments to minimize the error.

To carry out the calibration as per set standards, a number of calibration laboratories at different levels are established as given below:

Now we discussed in the previous classes that due to continuous use all the instruments are subjected to wear and there will be certain amount of error due to wear, so at regular intervals the workshop instruments should be compared with the equipment placed in the standards room of the plant and then the amount of error should be noted down and if possible once you try to eliminate are minimised a error due to wear by making some adjustments.

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a. In-house Calibration Lab (Standards room)
b. Professional Calibration Labs
c. The National Physical Laboratory(NPL)

This process is known as calibration. In order to carry out calibration as per set standards number of calibration laboratory are established at different levels like the in-house calibration lab which is also known as standard room in manufacturing plant and then we have a professional calibration labs established by measurement expert and then they at the higher level at National level they have national physical laboratories.

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a. **In-house Calibration Lab** : This is set up within a company for calibration of in-house instruments. Specialized equipment are kept in this lab to calibrate shop floor equipment. This is also known as standards room.

Functions of standards room:

1. To maintain standard temperature of 20 deg C
2. To calibrate instruments.
3. To check gages, Eg plug gages and gap gages for wear
4. To maintain the expensive and delicate equipment under the carefully controlled conditions of use.

Calibration intervals of different instruments :

Sl. No.	Name of the instruments	Calibration interval in months
1	Vernier caliper, height gauge, micrometer, dial gauge	12
2	Slip gauge, digital dial gauge	36
3	Radius master	24

Now inhouse calibration lab this is set up within a company for celebrating its own the work shop measuring instruments very specialised unsophisticated equipments are placed in the calibration lab and the workshop instruments are occasionally calibration using this sophisticated instruments. Now what are the functions of calibration of standards room and should have a temperature of 20 degree Celsius which is as per international standard.

And they should I calibrate the various instruments at regular intervals or as and when needed and it should check the various inspection gauges plug gauges etc and should also maintained very delicate equipment available in the plant in good condition. Now the recalibration intervals for different instruments are shown here, the Vernier caliper, height gauge, micrometre, dial gauge.

They are normally calibrated every 12 months, once they almost calibrated and similarly slip gauges and dial gauges and once in 3 years and radius masters are calibrated once in 24 months, this is only an example. So like this each instrument will have its own calibration interval.

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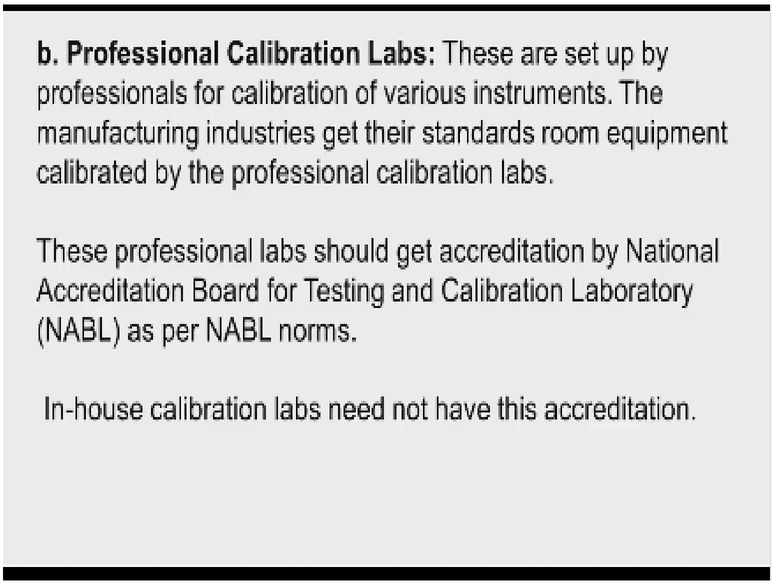

Now higher level compared to standards room is professional calibration labs, a very experienced people and measurement experts they established this calibration labs and their own the calibration lab , they maintain a very good quality accurate and precise measuring instruments sophisticated instruments in the a professional calibration lab and these are used to calibrate the equipment of the manufacturing plants.

And these professional labs should get accredited by national accreditation board for testing and calibration lab as per enable norms, in house calibration lab not have accreditation.

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Examples of NABL accredited Labs in India are the central manufacturing technology Institute situated at Bengaluru fluid control Research Institute established at Palakkad and then the central mechanical engineering research institute at Durgapur. So these are some of the NABL accredited labs in India.

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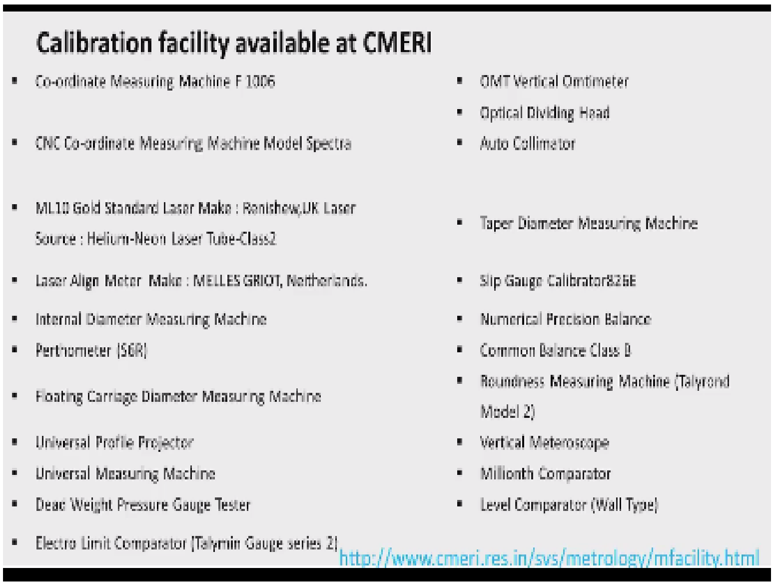

Now let us see what are the calibration facilities available at mechanical engineering research institute, they have calibration facility like co-ordinate measuring machine CNC co-ordinate measuring machine ML10 gold standard laser and then laser alignment meter, internal diameter measuring machines pathometers universal profile projector like this they have different kinds of facilities for calibration purpose.

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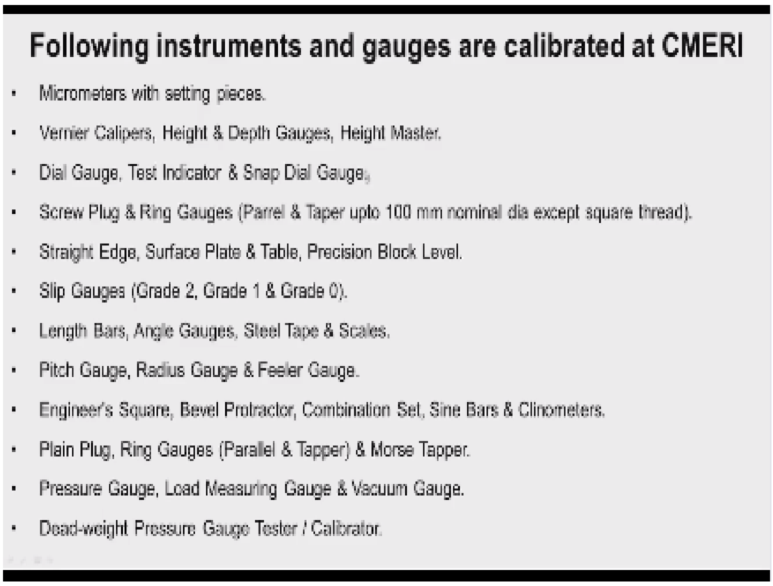

And following the types of instruments and gauges can be calibrated at mechanical engineering research institute instruments like micrometre with setting pieces Vernier caliper, height cages, depth gauges and height masters, dial gauges are different kind, straight edge, or slip gauges, all these types of instruments can be calibrated by using the facility available at chemical engineering research institute.

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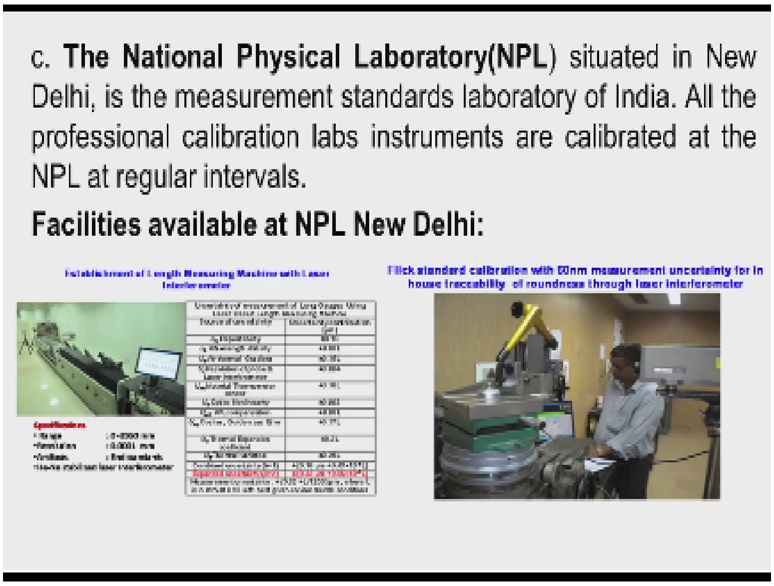

Now at the highest level in India we have the National Physical Laboratory is situated in New Delhi. So this is the measurement standards laboratory of India, all the professional calibration lab instruments are calibrated at NPL at regular intervals and they get in AVL certification. Now some of the facilities available at NPL are shown here they have the length measuring machine with laser interferometer they have flick standard calibration with 60 nanometre measurement uncertainty for inhouse traceability of roundness through laser interferometer.

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And they have 1000 millimetre length measuring machine Gigo interferometer for flatness measurement and then 3D co-ordinate measuring machine and then they also have gauge block interferometer apart from this they have other sophisticated instruments for the purpose of calibration. Now in this session we discussed about the various kinds of error measurement errors.

And then we also studied about international unit system and various the measurement standards like line standard and standard and wavelength standard and what are the levels of standards like the primary standard, secondary standard, tertiary standard and workshop level standards and then we try to understand what is the meaning of calibration.

And how it is carried out and what are the various NABL accredited labs in available in India and what facilities they have for calibration purpose, so this things we understood in this lecture now we will stop the lecture, thank you.