**Engineering Metrology**

**Prof. J. Ramkumar**
**Department of Mechanical Engineering & Design Programme**
**Indian Institute of Technology, Kanpur**
**Dr. Amandeep Singh Oberoi**
**Department of Industrial & Production Engineering**
**National Institute of Technology, Jalandhar**

**Lecture –3**
**Definitions**

Let us start new lecture on General Concepts and Definitions in Metrology.

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So, in this we will see metrology definition, metrology types then need for inspection and metrology terminologies. This are very important many a times we tried to interchange the terminologies, but it gives you completely different meaning.

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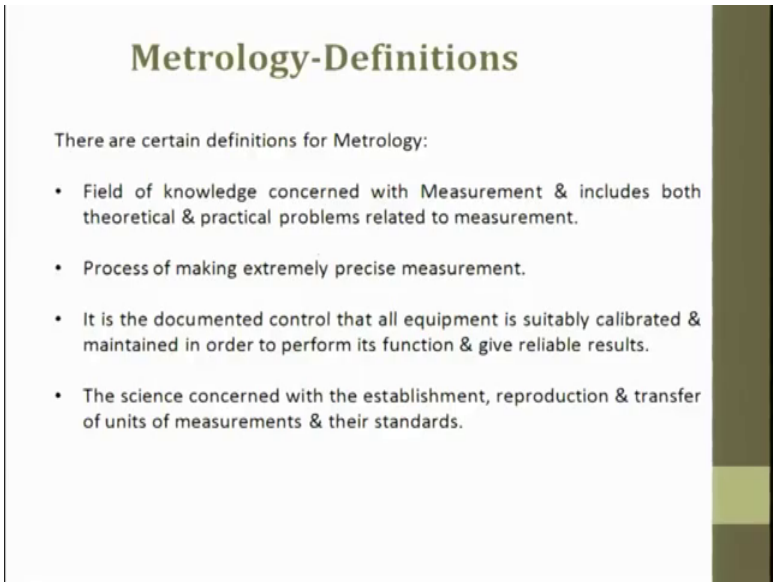


So, there are certain definitions for metrology. It is a field of knowledge concerned with measurements and includes both theoretical and practical problems related to measurement, is one definition of metrology. Process of making extremely precise measurement is also a definition of metrology. It is the documented control that all equipments is suitably calibrated and maintained in order to perform it is function and give reliable results is also the definition for metrology. It is the science concern with the establishment, reproduction and transfer of units of measurements and their standards are another definition for metrology.

So, metrology can be defined by four different ways the science concerned with the establishment, reproduction and transfer of units of measurements and their standards is very popularly accepted.

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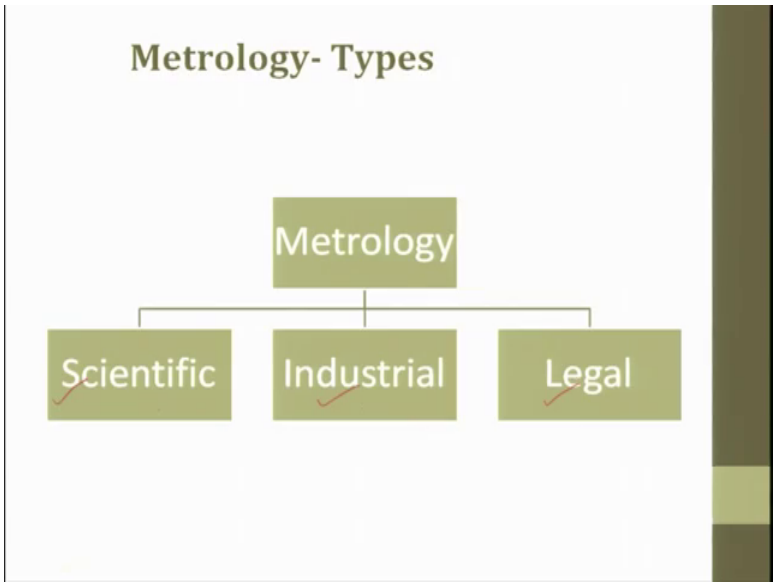


When we talk about metrology there are three different types of metrology. So, the first one is called as scientific metrology, the second one is called as industrial metrology, the third one is called as legal metrology.

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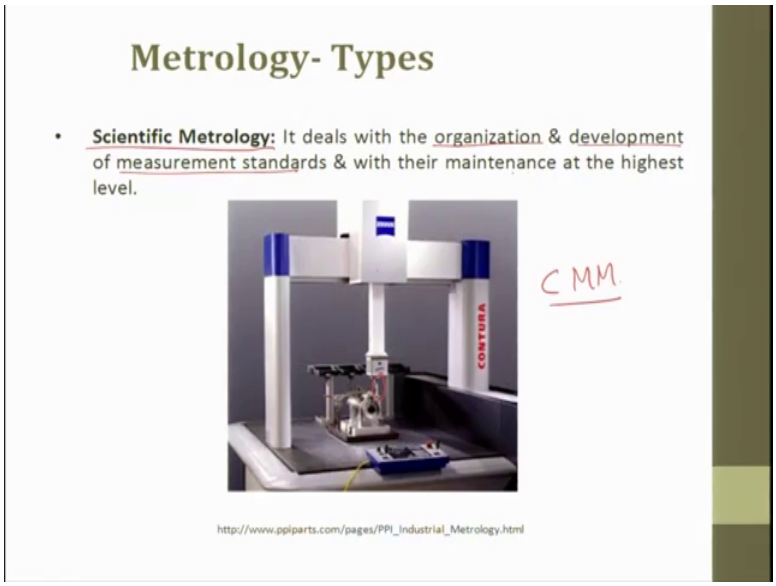


What is scientific metrology? It deals with the organization and development of measurement standards and with their maintenance at the highest level is scientific metrology. This is an example of a coordinate CMM coordinate measuring machine where in which there is pump housing kept there. So, this is a these are two columns in

between you have a bridge. So, in the bridge you have the arm which is resting. So, here is a probe which is used for measuring the pump housing feature details, ok. So, it deals with the organization and development of measurements standards. So, it follows all the standards what is established with their maintenance at the highest level is a scientific metrology.

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When you talk about industrial metrology, it deals with ensuring of the adequate functioning of measuring instruments used in industry as well as in the production and testing processes. For example, here it is already drawing its existing, you look at the component, you try to measure the dimensions or deviations from the component and you try to take the result out of it that is called as industrial metrology, ok. It is necessary to work with quality in the industrial activities.

The difference between this; it deals with the organization and development of measurement standards. So, here we are developing standards with their maintenance at the highest level, but here already preexisting equipment is there using that equipment we are trying to measure and quantify data.

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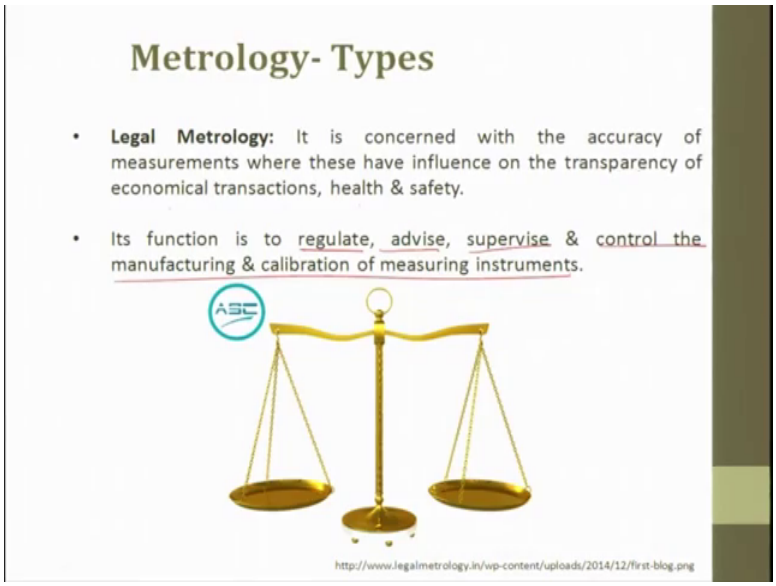


What is legal metrology? It is concerned with the accuracy of measurement where these have influence on the transparency of economical transactions, health and safety.

So, we try to measure certain parts or certain products which are produced and see how legal it is for allowing the product to the market. Its function is to regulate, advise, supervise and control the manufacturing and calibration of measuring instruments is legal metrology. In this course we will be more focus towards scientific as well as industrial metrology only.

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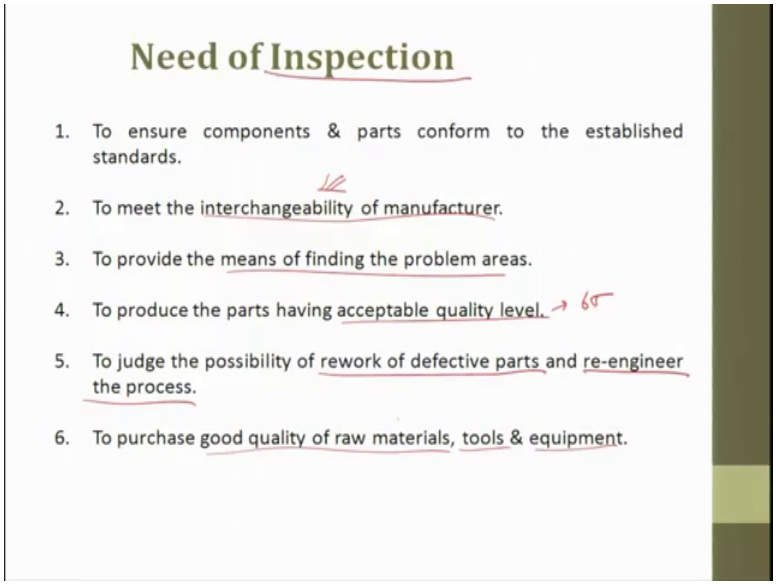

So, there is a word called as inspection. Inspection is very important you have produced a part. So, how do you character how do you evaluate your processes? It is only by measurements, right. When we talk about measurements inspection is a process which is part of measurements process. So, the need for inspection is to ensure components and parts whether they confirm with the established standards. There is a drawing available, there is a part which is produced, all you have to do this measure the part and validate as against the drawing what is their deviation. It to meet the interchangeability of manufacturer; interchangeability is a big concept and interchangeability is a revolutionary concept in interchangeability we can most of the interchangeability concept all under some standards if you want to meet your manufacturer to produce a part and maintain interchangeability concept inspection is very much important.

To produce the means finding a proper problem areas; so, if you start inspecting a part then you can quickly come and say where is the process mistake or in this particular part when it is assembled where can the mistakes happen. To produce the part having acceptable quality levels we always do inspection. For example, people talk about 6 sigma, 12 sigma all those things. So, acceptable quantity level if you want to check we do inspections.

To judge the possibility of rework of defective parts and re-engineering the process we need to do inspection. So, if there is parts generally what happens from a raw material you do value addition, you do machining process produced a part; this part can be accepted, the part can be rejected or the part can be reworked. If you want by some means the part from falls on the rework category you should quickly know how much to rework, what should be rework such that we can make the rework part into acceptable part so, for this we have to do inspection. To purchase good quality raw materials, tools and equipments we need to do inspection. So, these are some of the important points which insist that we have to do inspection.

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Let it be a small product, let it be the pharmaceutical product, let it be the car, let it be rocket you see people try to do different types of inspection. The inspection can be visual, the inspection can be superficial, the inspection can be on the engine, the inspection can be for checking the tires, their alignment all these things are called as inspection.

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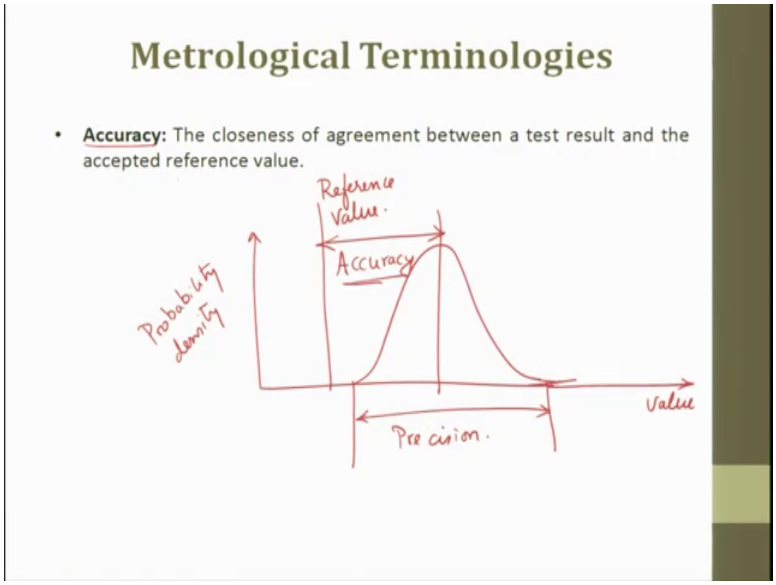


So, let us see some of the metrological terminology. The first thing what we are going to discuss is accuracy. The closeness of agreement between a test result and the accepted

reference values is nothing, but accuracy. If I want to put it on a figure let me draw probability density. From this figure it is very clear that the y axis is probability density, the x axis is value.

So, this is the reference value what you want and this is the value what you have received or achieved. So, this is the value which you have achieved, this is the reference value. The difference between these is called as the accuracy. The variation is called as the precision. So, the closeness of agreement between the test result and the accepted reference value and the accepted reference value is called as accuracy.

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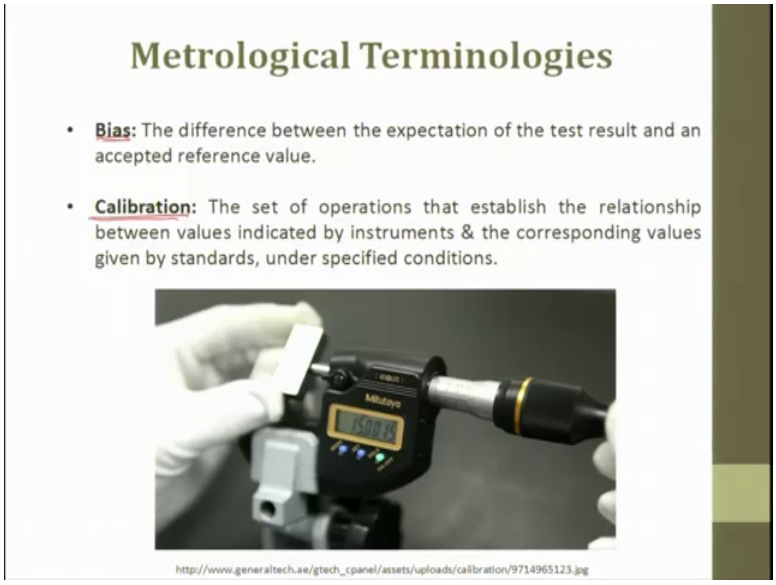


Bias: the difference between the expectation of the test result and an accepted reference value is called as bias. The difference, I repeat, the difference between the expectation of the test result; you accept some test result and an accepted reference value is nothing, but bias.

The next important thing is calibration. Calibration is done at two times; at the beginning and then regularly while running we always try to do calibration. We calibrate it with reference to a standard. So, a set of operation that establish the relationship between values indicated by instruments and corresponding values given by standards under specified condition is nothing but calibration. Calibration is makes your our device whatever is showing as an output and the standard which is available you just compare it and see whether it is whether it is following any trend.

So, calibration is done at the beginning when all the assembly is done and now we try to calibrate and put the measuring equipments into action. Next is over a period of time because of wear and tear also calibration is important. Calibration is nothing, but a set of operation that establish the relationship between values indicated by instruments and the corresponding values given by the standard under specific conditions.

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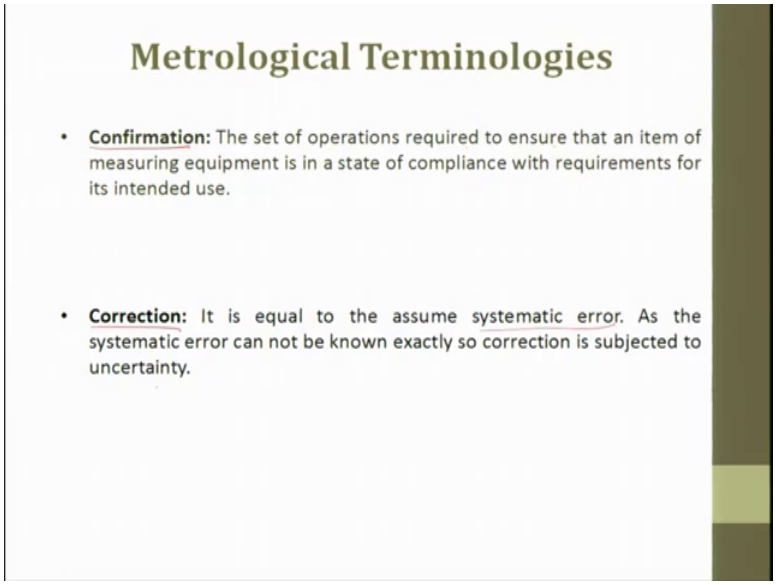


What is confirmation? Confirmation is the set of operation required to ensure that an item of measuring equipment is in a state of compliance with requirements for its intended use, this is confirmation. Confirmation the set of operations required to ensure that an item whatever you produce of measuring equipment is in a state of a compliance which will accept with requirements for its intend use, that is confirmation.

Next is correction. It is equal to the assumed symmetric systematic error. Correction is there is an error now you adjust it accordingly to bring back the system measuring instrument back into action equal to assumed systematic error, we will see what is systematic error in this lecture itself; as this systematic error cannot be known exactly so, correction is subjected to the uncertainty. So, corrections are nothing, but we are regularly trying to we are giving key to the watch and then over a period of time because of the mechanical wear and tear there will be an error for example, initial first day first few years it will be a every 24 hours you do and over a period of time you try to do it for every 20 hours then slowly it will come down.

So, those things variation is from the deviations exact value is called be error and the systematic error is; systematic error is we know what is the reason and the error gradually decreases over a period of time as this systematic error cannot be known exactly so, correction is subjected to uncertainty.

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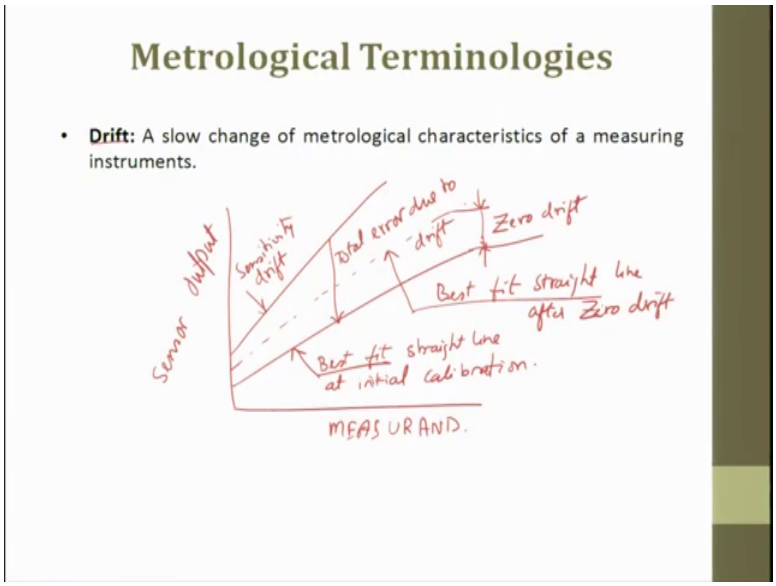


Drift: the English word drift itself very clearly says slow change of metrology logical characteristics of a measuring instruments nothing, but a drift. So, let us so, we will take sensor output and then here it is measurand, and then what is here this is a sensitivity drift, ok. This is the total error due to drift, ok. This is the best fit straight line at initial calibration, then this is the 0 drift, ok. We can see initial and this is at a total error, ok. So, this you can see as and when the measurand it keeps and going over a period of time the sensor output there is always a drift. This was the initial one and this is the final one and you see drift in the center. So, this is called the best fit straight line after zero drift after making a correction, ok.

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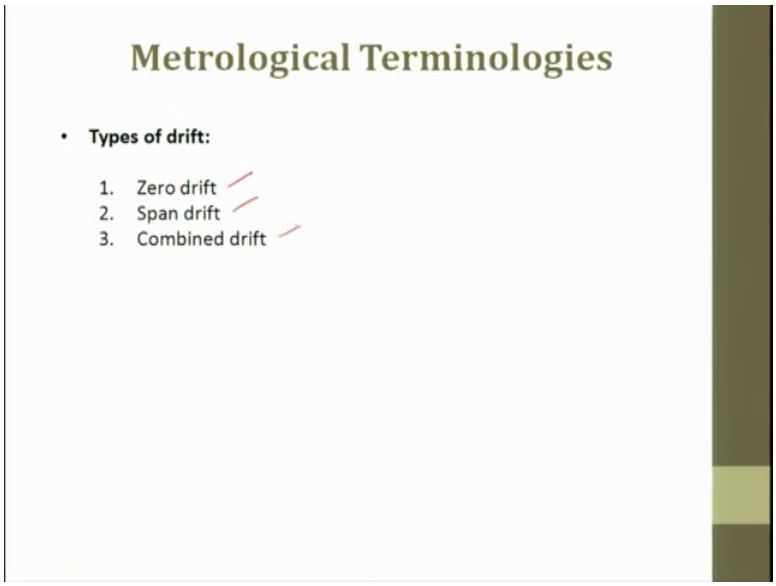


So, these are some of the terminologies, ok. So, you have zero drift, you have span drift, you have combined drift. So, we will see that one after the other.

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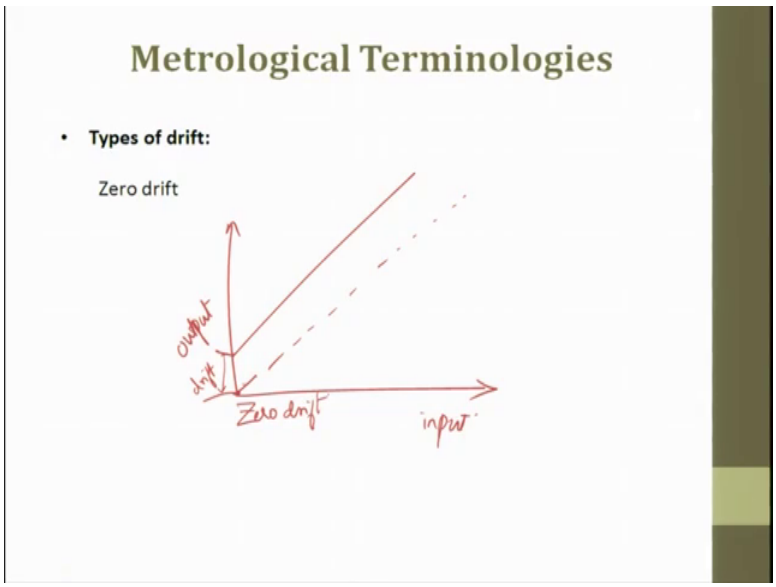


So, what is zero drift? Zero drift means it is output, this is input. So, this is a drift, zero drift ok. So, this is zero drift. So, this is drift which happens when starting point is there and there is a drift which has happened here and almost the slope is almost constant, this is zero drift.

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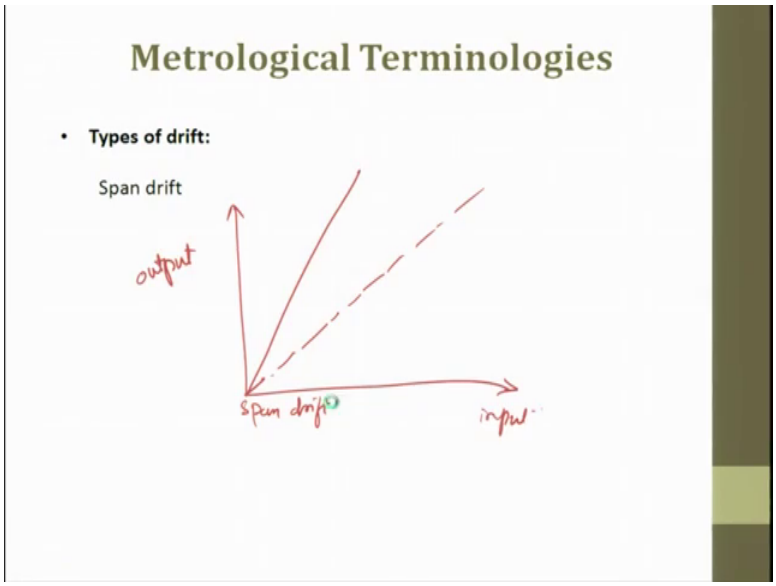


So, next is span drift. So, span drift is nothing, but output, this is input. So, you have this one is the normal thing what you have and this is what is the span drift. So, this is span drift. If you look at it so, if you want this is zero drift, ok.

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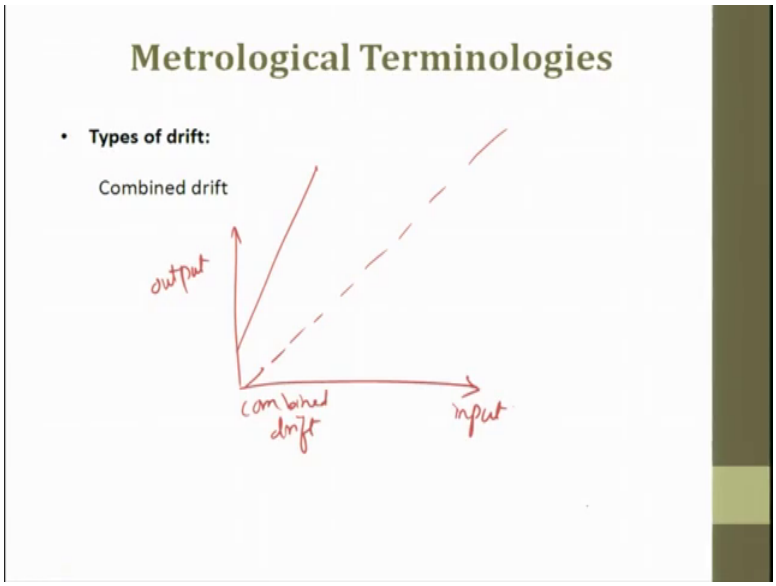


So, the combined drift is nothing, but a combination of these two. So, this is output, any output it can be any variable. This can be any input variable, and this is something like this and this is what is your normally what you get this is called as combined drift.

So, a drift is an offset from the center. So, that is zero drift. So, you will have different types of drift zero drift, span drift or a combination of these two. So, this is a drift which is zero drift, this is a span drift and this is combination drift.

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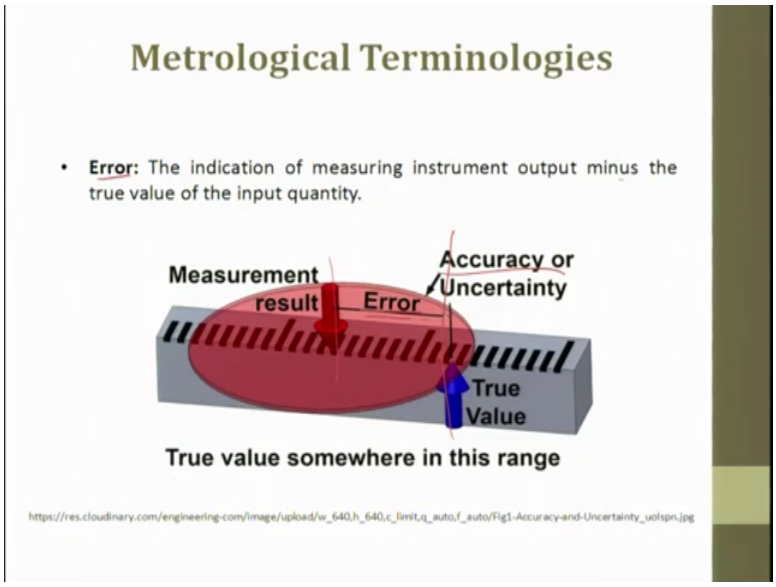


So, when we talk about error, what is a error? The indication of measuring instrument output minus the true value of the input quantity is always the error. So, you look at it here is the so, here is the measurement. So, true value somewhere is in the range. So, here is true value here is the result whatever you get. The difference between these two is nothing, but the error, ok. It is otherwise called as accuracy or uncertainty these are the; this is the true value whatever is there. So, so the indication of a measuring instrument output minus the indication of the measuring instruments output minus the true value. So, this is the error we get a data here this is the true value and here is the error what we get.

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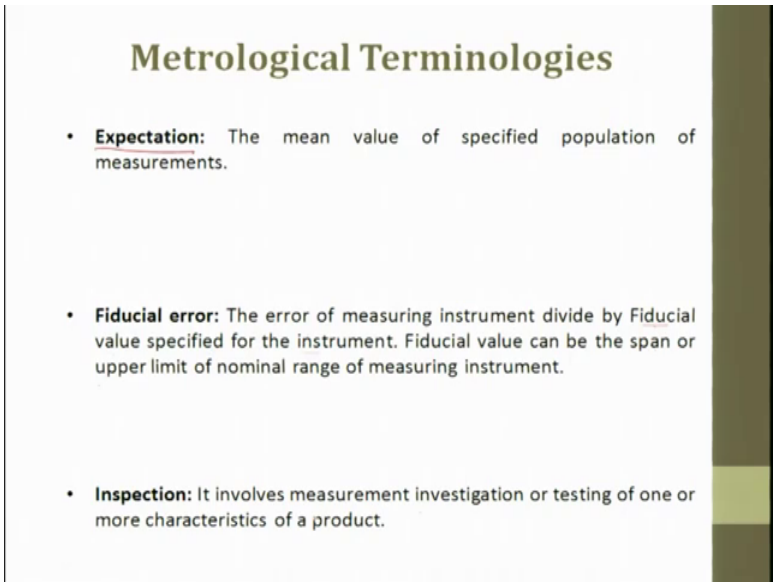


What is expectation? The mean value of specified population of measurements is called as expectation. What is fiducial error? The error of measuring equipment divided by fiducial value specified for the instrument is nothing, but the fiducial error. Fiducial value can be the span or the upper limit of the nominal range of measuring equipment. So, the fiducial error, so, the error of measuring equipment divided by the fiducial value which is specified by the equipment, on the instrument.

What is inspection? As we already saw the instrument involves measurement investigation or testing of one or more characteristic of a product. So, we are now seeing lot of terminologies. So, let me quickly recap what are the terminology we saw. We saw accuracy, you can remember reference value, original value we saw accuracy then we saw bias, then we saw calibration, then confirmation; confirmation is nothing, but the set of operation required to ensure that an item is of the measuring equipment is in a state of compliance with requirements of its intended use, then we saw correction, then we saw drifts. There are three different types of drifts; one is zero drift, span drift and then it is a combination drift we saw. Next one was error. So, we saw the definition for error, then expectation, fiducial error and inspection.

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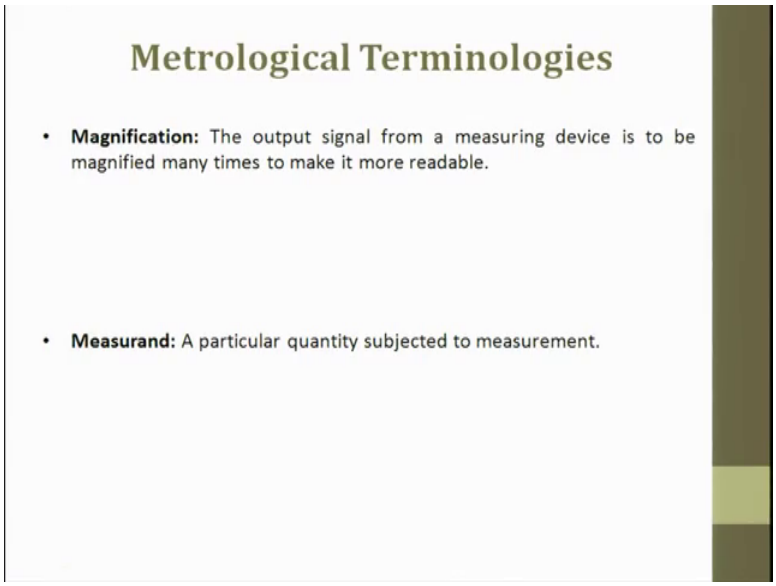


So, further moving on magnification; the output signal from a measuring device is to be magnified many times to make it more readable is magnification and what is measurand? A particular quantity subjected to measurement is called as measurand. So, a particular quantity subjected to measurement is called as voltage, temperature then you have length meter. So, a particular quantity subjected to measurement is called as measurand.

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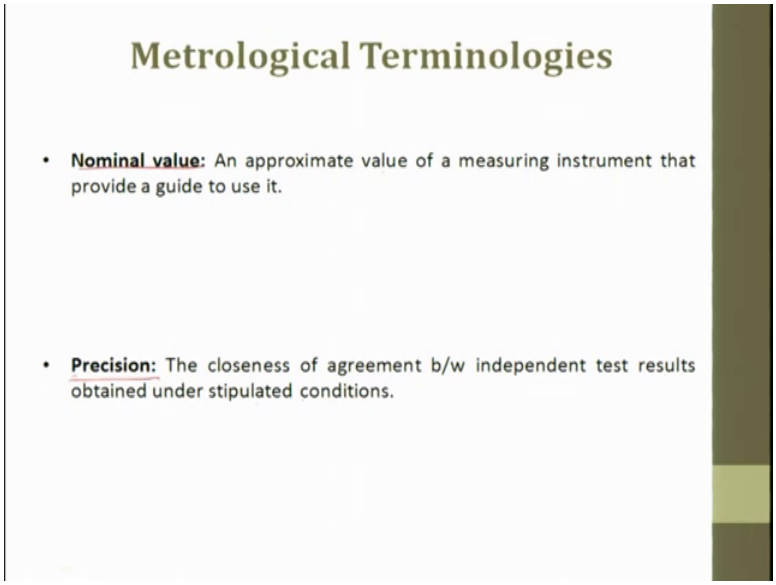


Then, we will see, what is nominal value? The approximate value of a measuring instrument that provides a guide to use it is called as nominal value.

There is a big interchangeability we use between precision and accuracy. What is precision? The closeness of agreement between independent test results obtained under stipulated conditions is nothing, but precision. The closeness of agreement between independent test results obtained under stipulated conditions is nothing, but precision.

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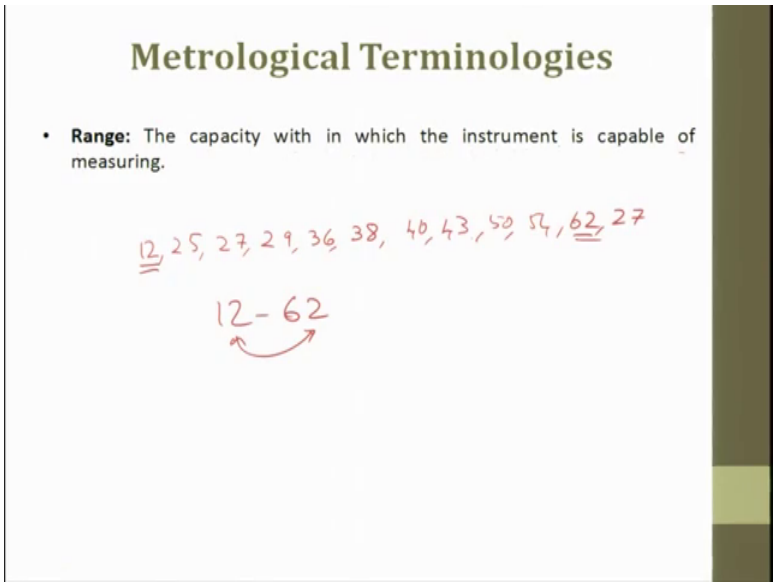


So, what is range? So, range is the capacity within which the instrument is capable of measuring for example, it can be 12, 25, 27, 29, 36 these are some of the values what I get out of measuring device 43 then 50, 54 then 62 then 27.

So, if I see the range, what is the range? Range is nothing, but from the lowest to the highest. It is 12 to 62 is the range which is there in this particular measuring device. So, these are some of the units. It can be voltage, it can be millimeter, whatever it is. So, we are just trying to find out trying to explain out what is the range. The capacity in which the instrument is capable of measuring is called the range.

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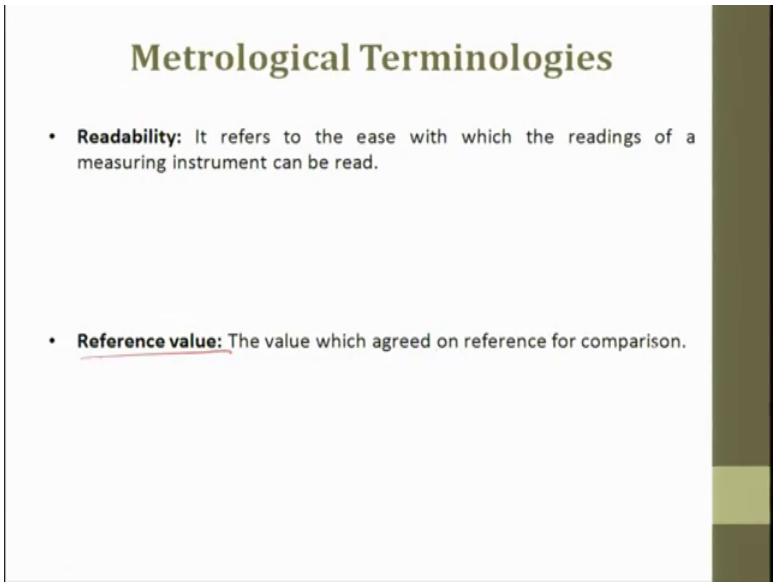


What is readability? Readability it refers to the ease with which the reading of a measuring instrument can be read. The readings for example, if the graduations are too thin or too small then you cannot read it. Readability is also very important.

What is reference value? The value which agreed the value which agreed on reference of for comparison is called as reference value. If you go back and see we have already talked about reference value. So, the value which agreed on reference for comparison is nothing, but the reference value.

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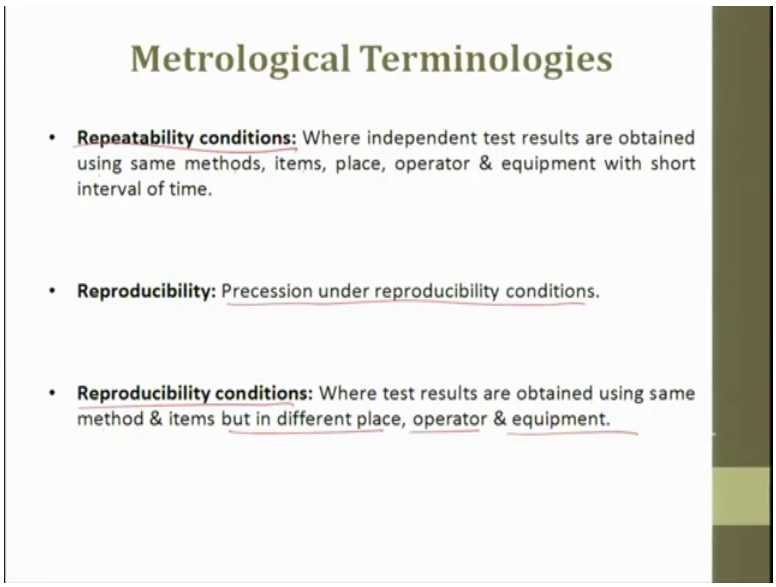

Next repeatability conditions, whenever independent test results are obtained using same methods, items, place, operations and equipment within short interval of time it is a repeatable condition. Repeatability is very important because when you try to measure an object repeatedly 20 times if you get varying results then the repeatability becomes a question mark, ok.

Reproducibility: the precession under reproducibility conditions, this is reproducibility. Reproducibility condition; where the test results are obtained using same method and item, but in different place, operator and equipment. Repeatability conditions where in independent test result obtained using the same method, item, place, operator, equipment within short interval of time repeatability conditions. What is reproducibility conditions; where the test results are obtained using same method and item, but in different place operator and the equipment is reproducibility condition. Please try to understand the difference between repeatability and reproducibility conditions.

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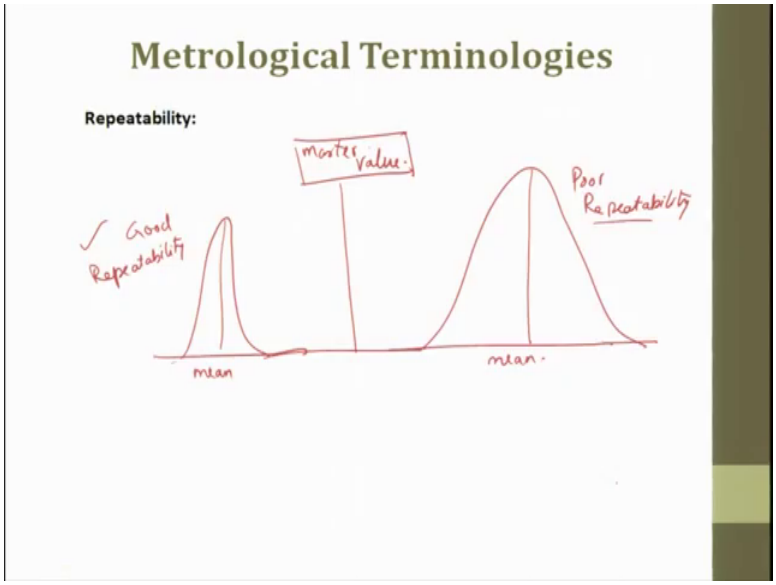


What is repeatability? If I have to plot it I can this is the master value, this one is the you will have mean, this is the mean, this is the mean. So, which of the two conditions are good? This is good. Good repeatability. This is poor repeatability, you see the mean is becoming larger, the mean is at the center the variation is becoming larger and larger and larger. This is poor repeatability. So, that means, to say there is variation for the same machine to produce a shaft, there is a lot of variation in the values in the shaft which is

produced in length in diameter. Here it is almost very precise. So, this one is called good repeatability and this one is called as poor repeatability where you see the huge spread from the mean is there.

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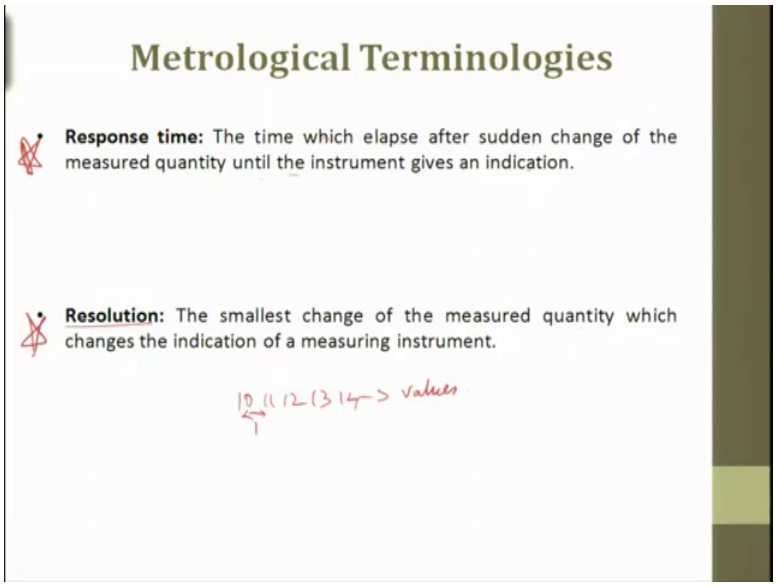


What is response time? The response time, which elapses after sudden change of the measured quantity until the instruments gives an indication so, response time is I give you a command, how quick you respond or you try to send; there is a change in the measuring device or the measurand value if there is a change in and how quickly this change can be responded or this can be recorded. The time which elapses after sudden change of the measured quantity until the instruments gives an indication is nothing, but response time.

What is resolution? The smallest change of measurand quantity which changes the indication of a measuring equipment is or instruments is nothing, but the resolution. The smallest factor for example, if you have data 10, 11, 12, 13, 14 the resolution is 1. The let us assume these are all values; the smallest change of the measured quantity which changes the indication of a measuring equipment is nothing, but resolution.

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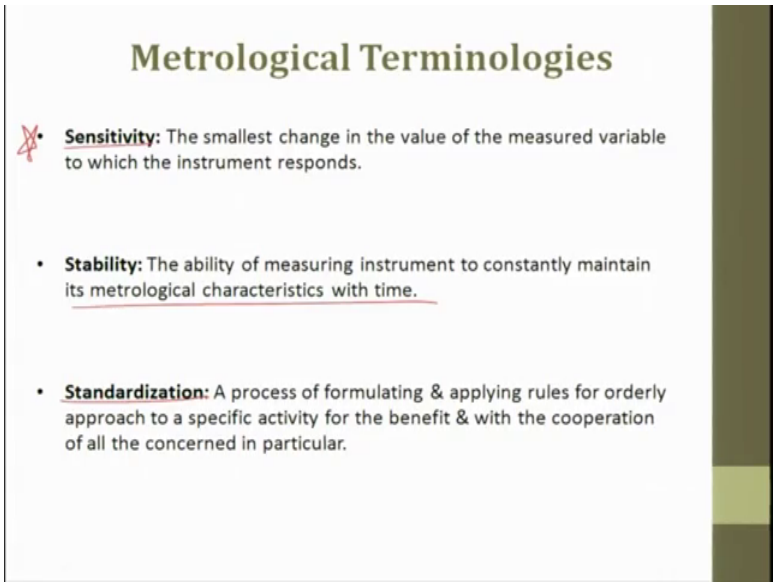


Then, sensitivity is very important. The smallest change in the value of the measured variable to which the instrument can respond is called as sensitivity, very important definition. So, this is also very important respond time, resolution this is also these are all very important.

Stability: stability is also very important because suppose when you try to use the voltmeter or when you try to use a ammeter or when you try to take a device and you want to measure it as soon as the there is a change in values, it will start vibrating or it will start fluctuating or it will start running with numbers. So, it will takes some time to find out the stability. So, so ability of measuring instrument to constantly maintain its metrological characteristics within time is called as stability.

Standardization: the process of formulating and applying rules for orderly approach to a scientific activity for the benefit and with the cooperation of all the concerned in particular is nothing, but standardization. Standardization means we make standards and you make sure that your product is to that standard. So, standardization is a process of formulating and applying rules for orderly approach to a specific activity for the benefit and with the cooperation of all the concerned in particular is nothing, but standardization.

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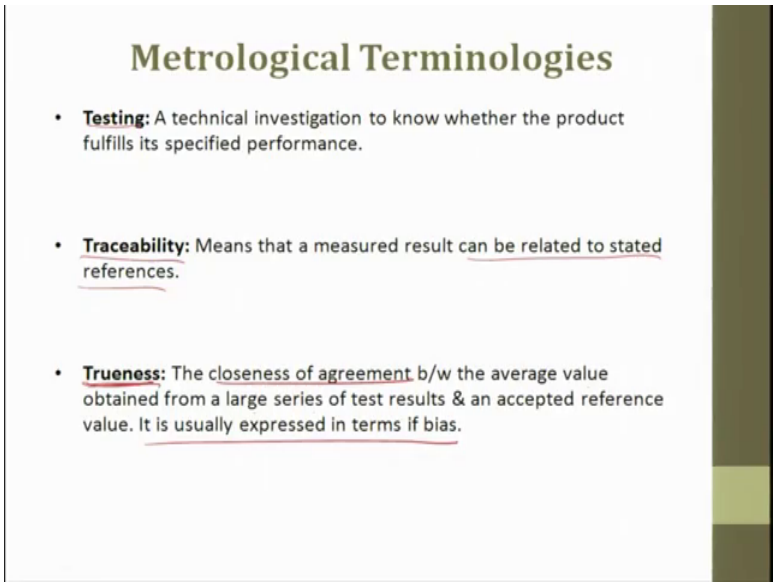


The next one is testing. Testing is nothing but a technical investigation to know whether the product fulfills its specific performance is testing. Then traceability, you have got some data you have to trace it and find out when was it generated and what it mean. So, traceability means that a measured result can be can be related to a reference is nothing, but the traceability.

What is trueness? The closeness of agreement between the average value obtained from a large series of test results and an accepted reference value is nothing, but the trueness it is usually expressed in terms if biased. So, trueness is nothing, but closeness to of agreement between the average values obtained from a large series of test results and an accepted reference value.

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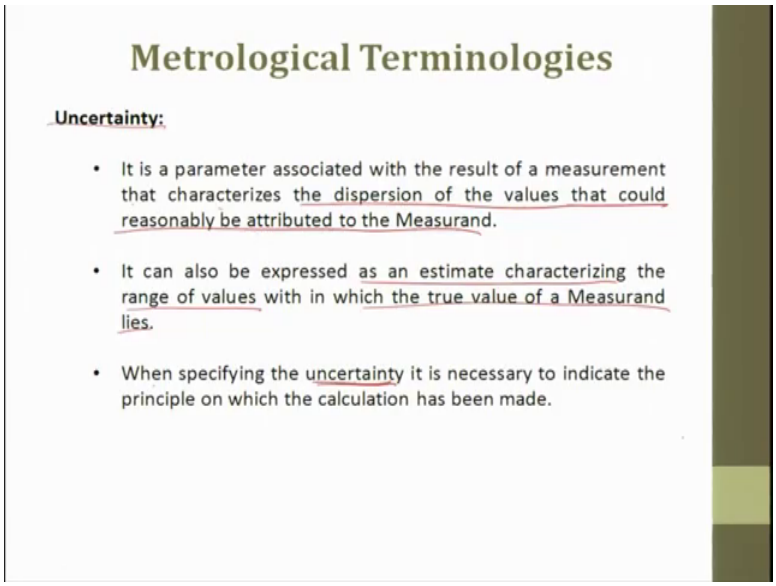


What is uncertainty? It is a parameter associated with the results of a measurement that characterizes the dispersion of values that could reasonably be attributed to the measurand is uncertainty, characterizes dispersion of the values that could reasonably attributed to the measurand is nothing, but uncertainty. It can also be expressed as an estimate characterizing the range of values within which the true values of the measurand lies. Uncertainty, when specifying the uncertainty it is necessary to indicate the principle on which the calculation has been made is uncertainty. When specifying the uncertainty it is necessary to indicate the principle on which the calculation has been made.

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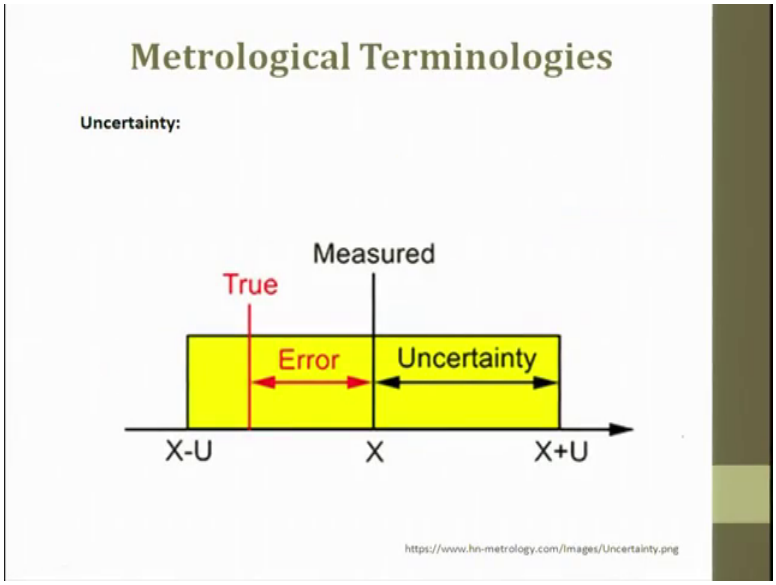

So, this is uncertainty. So, this is the mean, this is mean minus standard deviation, mean plus standard deviation. This is the true value, the difference between the measured mean and the true value is nothing, but the error. Uncertainty means from here your x plus y you have something called as uncertainty. What is uncertainty? Uncertainty is the parameter that is associated with the results of your measurement that characterizes the dispersion of the values that could reasonably be attributed to the measurand, this is uncertainty.

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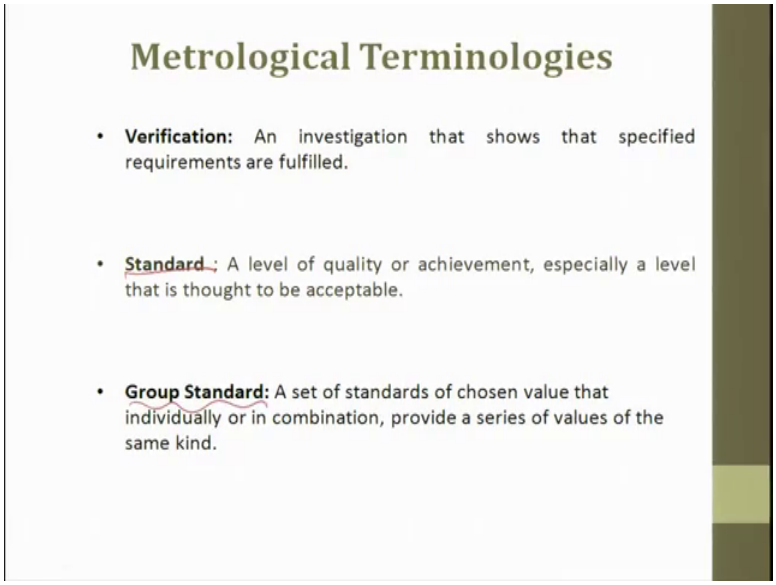


Verification: an investigation that shows that specific requirements are fulfilled is nothing but verification. Standard is a level of quality or achievement, especially a level that is throughout to be accepted is standard. Group standard: a set of standards of chosen values that individual are in combination provides a series of values of the same kind is called as group standards.

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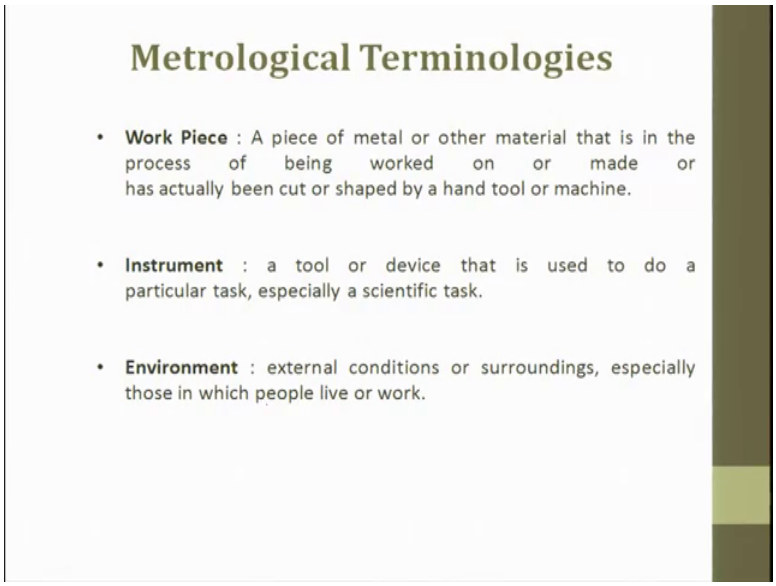


Work piece is known. Instrument is a tool or a device that is used to do a particular task is called instrument. Environment: external conditions or surroundings especially those in which the people live or work is called as environment. So, this is also very important.

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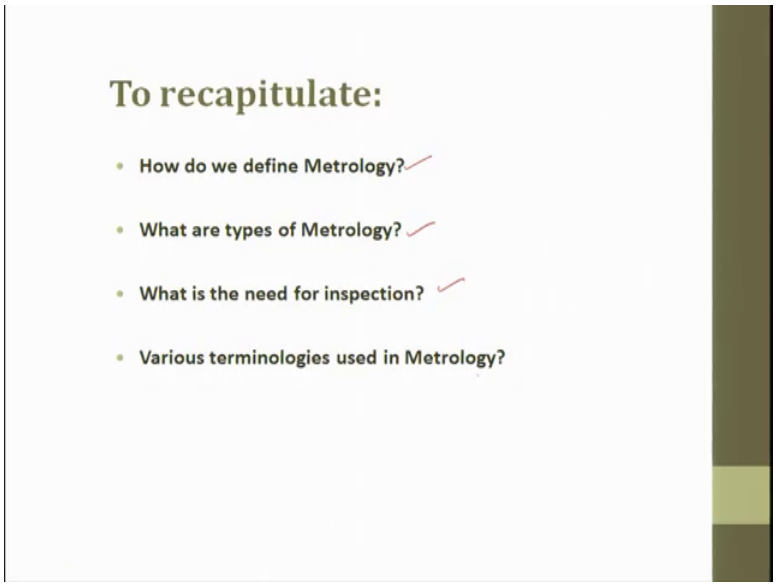


So, to recapitulate in this chapter we saw different definitions for metrology. We saw different types of metrology, what are they? They are scientific, industrial, and legal. What is the need for inspection, yes, we saw and we saw various terminologies in metrology which is very important various terminologies we saw, ok.

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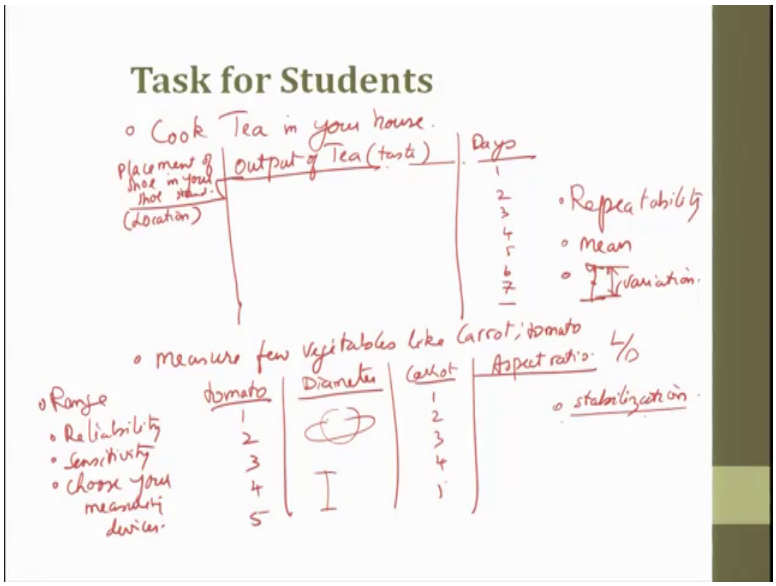


So the task to students; let us see two tasks; one is I want you to cook tea in your house, ok. So, what I want is every day the output of the tea output of tea is nothing but the taste. You are supposed to measure the output of that of the tea means to say in terms of taste for varying days may be 1 2 3 4 5 6 7 for 7 days you try to do and 7 days I also want you to do exercise and see how do you place placement of shoe in your shoe stand; that means, to say location, we are talking about location, which location do you place your shoes everyday for 7 days you have to see measure or try to have some variable some data how you can a measure the location of your placement. So, you I want you to do it for 7 days. So, what is the reason of doing this is you will try to see how repeatable is your; repeatability of your process. You will never get a mean you will always try to get a mean with a variation. So, this is the variation, ok.

Next thing I would like you to measure few vegetables like carrot, tomato. Try to take tomato may be 1 2 3 4 and 5 try to measure the diameter and see what is the variation and in terms of carrot try to take carrot may be 1 2 3 4 5 try to measure their aspect ratio. Aspect ratio means it is length by diameter. So, measure it and then you start reporting it. When you do this two things you will try to see that repeatability and then you will also see how reliable is your data reliability. Repeatability, reliability and then what is then sensitivity of your measuring device and then how sensitivity and the geometry is complex how do you choose your measuring device and those of you who are not having a Vernier caliper will the easiest way of measuring diameters try to take the tomato try to

take a rope or twine, just bind it around slip it off and then try to measure length. So, you have length and then from here you can try to find out the diameter.

So, you can do this and try to understand. So, when you do this two exercise for yourself you will try to realize if at all I have to choose a instrument for measuring, how will I choose then whatever data I get is that data going to be constant or is it going to be varying. Then you will also understand the concept of so, the value falls within with range then you will also have to realize one more information what we studied is the steps stabilization, ok. Some devices I first time I measure I will not be able to understand I do from two three times understand the process and then I try to figure out how stable is the process.

So, if you go through this I these two examples many of the definitions what we discussed in this lecture you will be able to appreciate that necessity and their significance.

Thank you very much.