Engineering Metrology

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Lecture - 1

Introduction

Welcome to this course. And well friends, today we will have our introduction to measurements and metrology. If you see measurements is a very important topic. And today, measurements has become more and more and more complex. Why is it so? Today what has happened, the parts have started shrinking in size; second, the parts have become complex in nature. So, if we have to produce a new part or a product, the first thing what we have to do is after production, we have to measure and validate whatever we have been thinking in our mind or putting it in our paper hasn't been manufactured. So, measurements is a very very important topic. And today, measurements earlier was thought about measurements to be only in contact type. Today, it has gone in to non contact type; that means, to say the tool does not touch the work pierce, but still it is able to measure and tell the values to the engineer or to the practicing engineer or for the manufacturing engineering.

So, measurements has become a very very important topic in today's manufacturing scenario. So, without measurement, the product efficiency or the product iteration or processed iteration cannot happen. So, it is very very important. Metrology is a measurement of science. It is a science of measurement. So, here in which we will try to cover some of the most common measurement techniques and the science which is involved and then later towards the end of the course, we will try to see some of the non contact measurements also.

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So, the content of this lecture is going to be mechanical measurement, then we will talk about need for measurement, then classifications for measurement, then methods of measurement and finally, what are the different levels of measurement.

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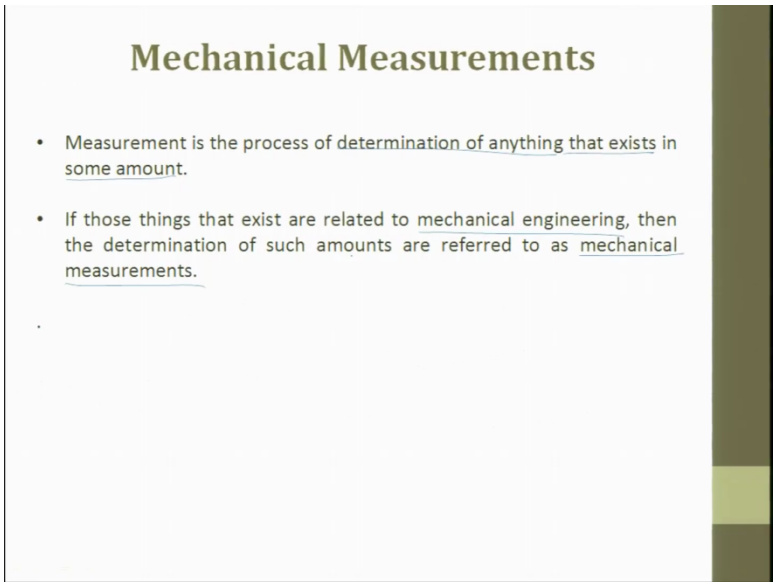

So, measurement is a process of determination of anything that exists in some amount. So, there has to be something existing and when something exists, I would like to determine what is that; for example, it can be in terms of number, it can be in terms of

shape, it can be in terms of size, it can be in terms of finish. So, something measurement is a process of determination of anything that is existing in some amount.

In those things that exists are related to Mechanical Engineering, then the determination of such amounts are referred as mechanical measurements ok. So, we are more focused towards mechanical. So, that is why we are talking about mechanical engineering and mechanical measurements. So, it is a process of determination of anything that exist in some amount, point number 1 and that much exists is related to mechanical engineering, then the determination of such amounts are referred as mechanical measurement.

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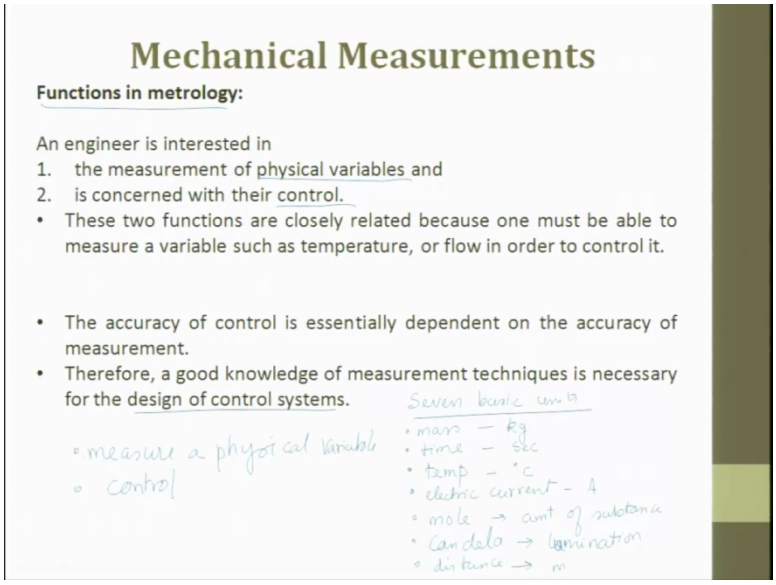

What is the function of measurement? An engineer is interested in the measurement of physical variables and is concerned with the controls also. So, these two are very important. The physical variables can be length, can be mass, can be density, can be power, can be current ok. So, all these things are physical variables.

So, before that let me list down these seven basic units for measurements. So, one is going to be mass, one is going to be time and the other one is going to be temperature ok. These are the basic systems; the other things physical variables can be electric current, it can be mole, it can be in candela; that means to say it is intensity and the last one is going to be distance right. So, mass it is represented in units of kg, time in seconds, temperature in degree Celsius ok, current in Amps, mole is basically the amount of

present of amount of substance which is present ok, candela is for illumination ok, illuminesense or illuminations and distance is in meters.

So, these are the seven basic units. So, whatever we are trying to talk about the physical variables can be a part of a, can be a combination of a, you can have. So, an engineer is always interested to measure the physical variables and is all is concerned with their controls. So, these two functions are closely related because one must be able to measure a variable such as temperature or flow in order to control it. So, these two are the important functions of metrology.

The accuracy of control is essentially dependent on the accuracy of the measurement. So, now, what are we trying to talk about is we are trying to talk about, first you measure a variable and then what you do is this variable has to be controlled. So, that is the second step, you are talking about these two other basic function. If your variable has to be measured, then you should have a measuring device that measures to the highest accuracy and then that data is given to the control, so that the control tries to control the functioning of the object. So, the accuracy of control, the accuracy is of control is directly dependent on the accuracy of physic of the measurement is done by the physical variable. Therefore, a good knowledge of measurement technique is necessary for design of a control.

So, basically what are we trying to talk? We are trying to talk about first measure a physical variable. And next thing, you are trying to control this variable. And why is these two very important today? First is producing and now when we try to automate the process, we are supposed to control the process or the process parameters whatever it is, so that you try to get the best efficient product.

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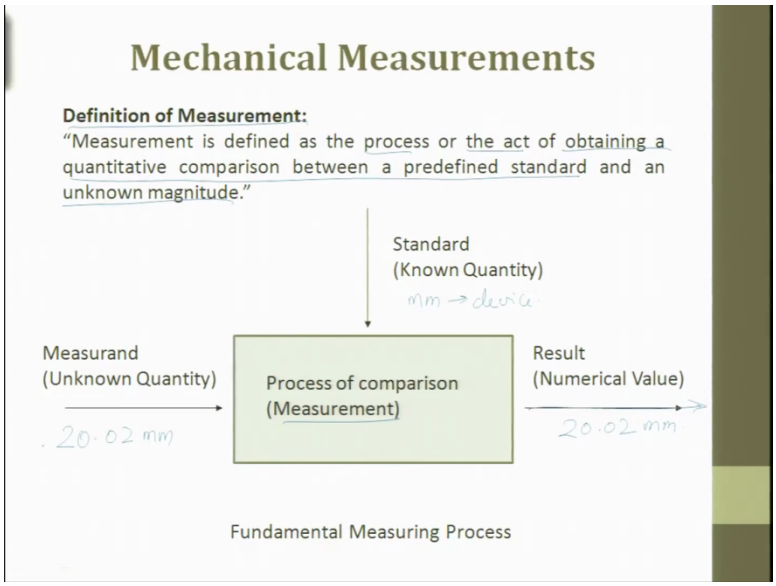

So, if you put it in a schematical diagram, so the definition of measurement is defined as the process or the act of obtaining a quantitative comparison between a predefined standard and unknown magnitude. So, elaborate how clearly the definitions states is quantitative comparison between two variables; comparison always happens between two or many. So, between a predefined standard means to say I have a standard with me, you are giving me an object wherein which I have to measure that physical variable and I do not know what is the magnitude, now, with the known standard I try to measure the unknown magnitude of the variable and try to do the measurement. So, that is the definition for measurement.

If you are put it in a block diagram, you can see the measure and unknown quantity in the input. So, you have standards known quantities and here what you do is the process of measurement happens that is a comparison. So, here you are example, you are making a shaft of a maybe 20.02 millimeter and here you are trying to choose a scale or a vernier or you are trying to take a screw guards which can measure this 20.02. So, here you try to take a millimeter varying standard device and then this device is used to measure the measurand you compare and take the measurement and finally, you try to tell that this result 0.2 millimeter.

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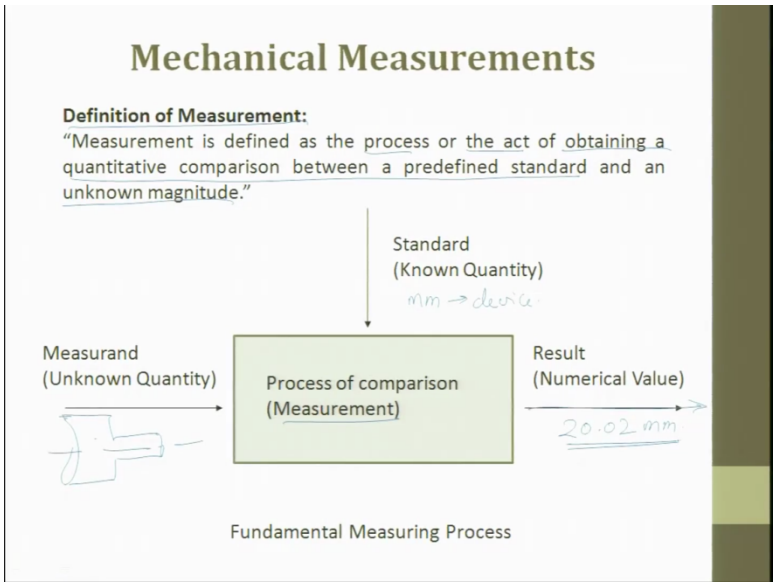

So, initially I will not have this measurement, I will only have the shaft, I will only have a shaft and this shaft is given into the measurement process and it tries to produce the required output, the result magnitude is shown here.

So, this is what is a simple definition for measurement and I repeat now, measurements are very important to understand what we have manufactured whether it is correct or wrong or whether the process what we have followed is good or bad, so such that the efficiency of the product is maintained.

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A typical example; here is a vernier caliper which is used, digital vernier caliper is used to measure the length of may be a shaft or the length of or tool; assuming there are 2 gears which are butted with each other and you have to measure the length such that you have to put a shaft inside it. If you want to measure the height, so the or the length. So, this is a instrument which is used and you can see today when we talk about very high and accuracy and precision work. So, it is better advised to use a glove and it is also advised to have a digital display, so that you can try to see up to here you can see the second accuracy second digit decimal accuracy you can measure and try to read out the results very clearly. So, this is used for internal measurement and this is used for external measurement. So, you have a fixed jar and a moving jar. So, this is a standard, this is a unknown variable, unknown part or product whatever it is it comes here.

So, when it this unknown is come and it is compared with the standard. So, you try to get a measured value. So, this is what I said in the previous class result is the numerical value, you try to see out of this.

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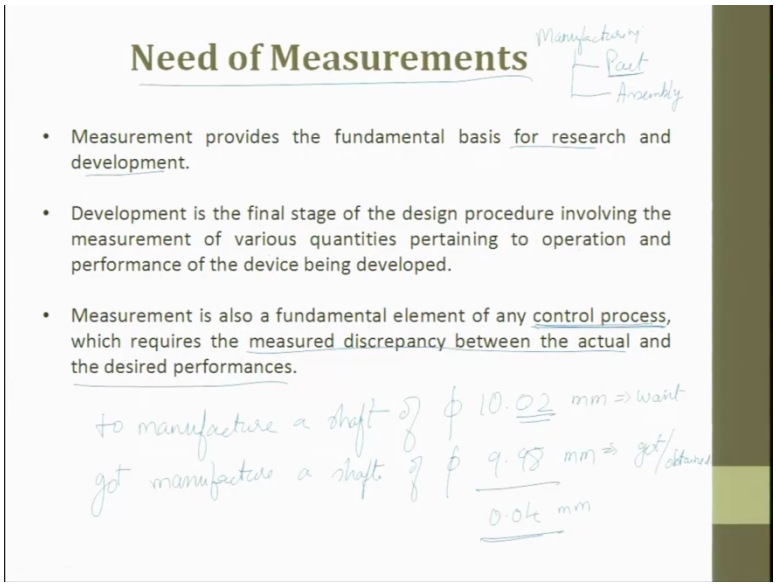

So, the need for measurements the measurement provides the fundamental basic for research and developments I have told you already. The second thing is development is a final stage of the design procedure involving the measurement of various quantities obtaining to operation and performance of the device being developed. So, here it plays a important role, measurement is also a fundamental element of any control process. See if

you want to automate a process, you should have a measurement device which requires the measured discrepancy between the actual and the desired performance.

So, what am trying to tell you is suppose, let us assume I want to manufacture a shaft of diameter 10.02 millimeter. This why is it so important? May be from the assembly point of view, this is very important such that it tries to maintain the efficiency of the entire product see in manufacturing you should understand first there in manufacturing you have two classifications; one is making a part and the other one is assembling the part to make a product. Measurements are used at both, at part stage also we use why is it important because in the next stage, these parts are going to get later and you form an assembly.

So, if you want to have perfect assembly such that your product is working to the best efficiency, you need to have a measuring device to measure the part dimensions and deviations. So, here you need to manufacture a part of this such that you get the best performance and this is to manufacture and what got manufacture, as manufacture a shaft of dia 9.98 millimeter.

Now, you see you want at this; this is one turn this is got or obtained after machining, this is now there is a discrepancy of 0.04 millimeter. As such if you look, it does not look big when you are trying to talk about it in macro scale or in meso scale because it is almost 40 microns right, but when you start working in micro domain, each micron becomes a big change player in terms of performance.

So, here what we are trying to say when a measurement is also a fundamental element of any control process which requires the measured discrepancy between the actual and the desired, this is the desired and this is the actual. So, there is the discrepancy. Now, when I put the next component, I will try to make sure this discrepancy of 0.04 is removed and I get a better control over the process.

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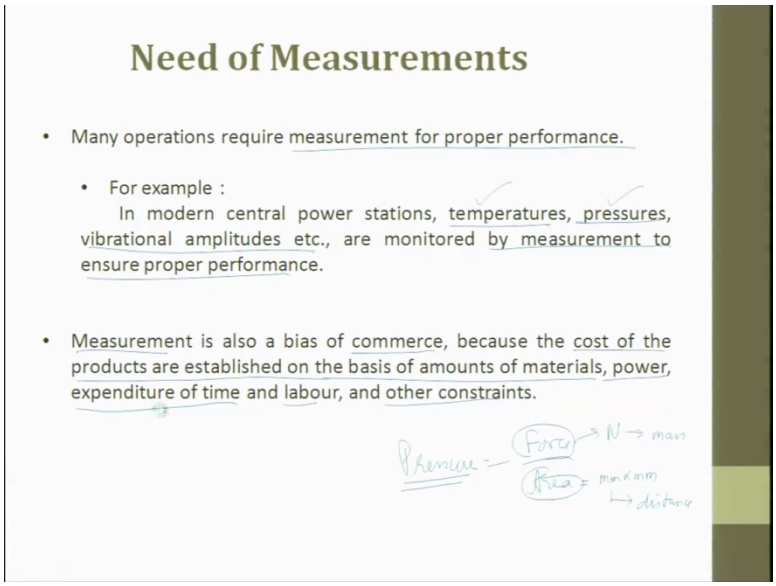

Many operations require measurements for proper performance measurement is done for proper performance. For example, you can have pipe which is leaking. So, why is a pipe leaking? May be the washer which is inside has given away or the assembly at the internal part has given away. So, once that gives it away, so now you are not able to stop the water flow. So, the parts if they are not manufactured to the required dimensions and if you have not assisted when you assemble it, you find a leaking pipe right.

So, the performance of the product has to be evaluated only by measurement and afterwards of course, you can put it on the market or you can put it in the test bed and then measure it, but if you want to do it before then you do a proper measurement. In modern central power station, temperature, pressure, vibration, amplitude, etcetera are monitored by measurement to ensure proper performance.

So, till now we were only talking about variation and dimensions, but now you see I am also trying to say temperature variations, the basic seven variables you see; temperature, pressure. What is pressure? Pressure is nothing but force per unit area, right. So, you can measure the forces, the force in turn can be measured or the force is exposed to Newton and you can measure it from mass. So, you can see, you can link it, the seven variables can be rewritten linked with each other and then you get this area is done in millimeter cross millimeter. This can be in turn link with the distance which I said in the seven basic as meters.

So, you can see all the parameters are now linked and then you can measure this, you can measure this and then you can get this as an output. So, temperature, pressure, vibration, amplitude, etcetera are monitored in the measurement of to ensure proper performance. The measurement is also biased of commerce, because the cost of the product are established on the basis of amount of material, power, expenditure of time, labor and other constraints.

So, measurement if it is done properly, then what we do is we will try to work on type or tolerances. Moment we start working on type or tolerances, the amount of material which is consumed for making the same product can be reduced and the proper field or speeds can be set on machines for the power course down and also the expenditure of time and labor also goes down. So, measurement plays a very very important role.

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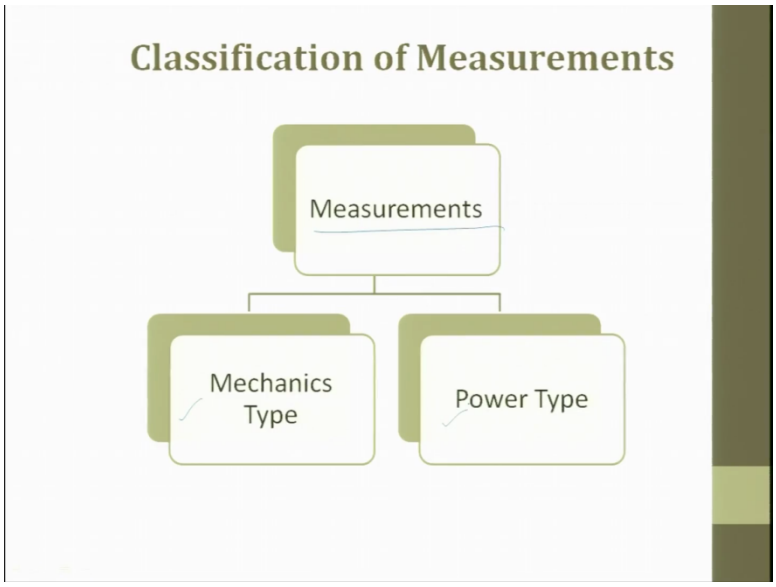

When we talk about classification of measurements, measurements generally can be classified into mechanisms and the next one is by power types.

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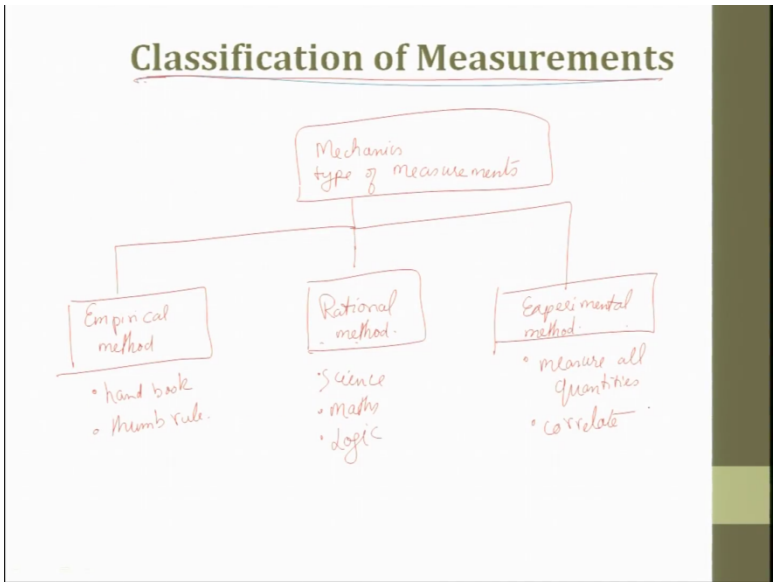

Classification of Measurements, so classifications of measurement, so we will try to take from mechanism, mechanisms type of measurements. So, here it can be by empirical method, the second one can be by rational method, the third one can be by experimental method ok. So, the measurements can classifications of measurements, you have mechanisms type. So, if you go back and see, measurements are classified into mechanism type and power type. We have now further classified, we mechanism type in to empirical method, rational method and experimental method.

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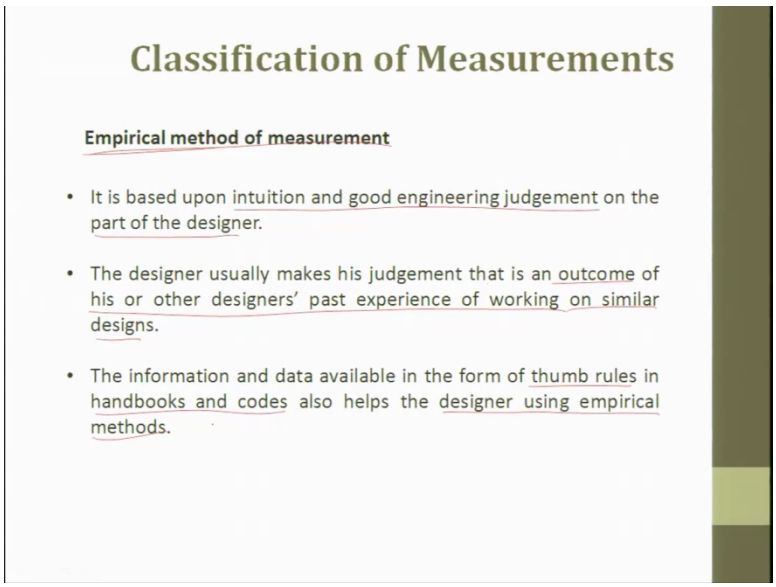

So, what is empirical method of measurements? Empirical means, you do some experiments and then you try to come up with the model. For example, I try to do machining operation in a particular machine at a particular place, then using one type of work piece and then one type of tool which has geometries, I start doing experiments.

So, let if you take let machine you have three parameters; speed, feed, depth of cut. I change everything in this and finally, when I complete the relationship and the material remover where is proportional to whatever it is proportional to feed, speed, depth of cut, in and then I have these are the variables. So, for these variables I would try to put either in the power law or in the linear regression problem equation sub magnitude and then you get of the get out with the processed model, ok.

So, what I did was this an empirical method. Empirical method means, when I do the experiment, when the experiment is conducted on this machine during this time of the year and in this lab using this work piece and this tools. So, you see all these things are constraints, but finally, I could understand the process by developing a model and this model is valid only at these conditions. So, it cannot be generalized to a large extent. So, those things are called empirical methods of measurement.

It is based on intuition and good engineering judgment on the path of the designer. The designer usually makes his judgment that is an outcome of his or other designers past experience of work on a similar design, right. The information and data available in the form of thumb rule; how did you get that thumb rule? Thumb rule is by doing these empirical relationships, so right. So, the information and the data available in the form of thumb rules in the hand book and codes helps the designer use the empirical method to make or to manufacture devices for measurement.

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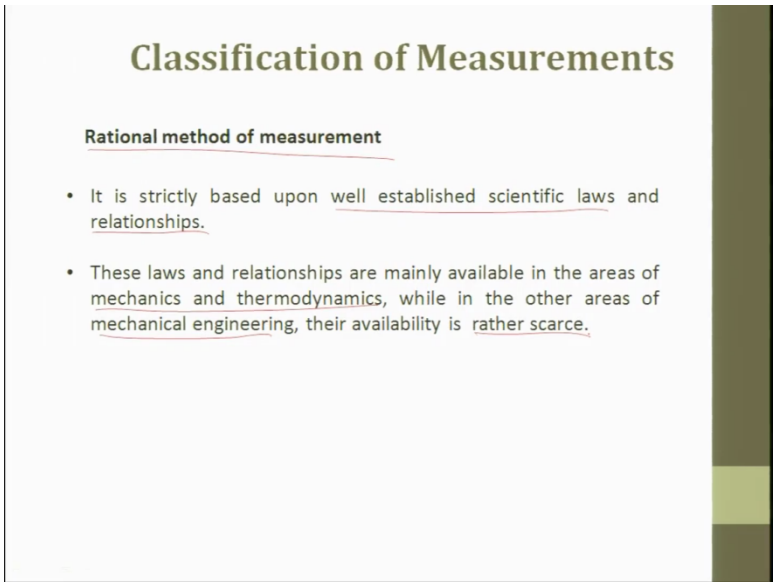

What are rational methods for measurement? So, it is strictly based on well established scientific loss and relationship. These loss and relationship are mainly available in the areas of mechanisms and thermodynamics while in the other areas of Mechanical Engineering, the availability are rather scarce.

So, the first one was more of intuition and you picked up from the handbook or you picked up from some empirical formulas. The next one is completely working on science and mathematics, you do, you generalize the problem and then you come out with a solution. So, that is rational methods of measurement.

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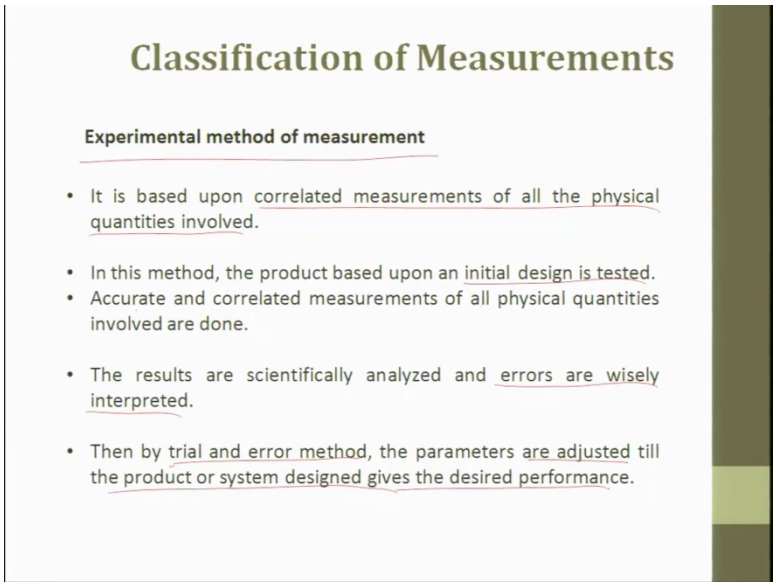

And the last one is Experimental method of measurement. It is based on correlated measurements of all the physical quantities involved. In this method, the product based on initial design is tested, accurate and it is correlated measurements of all physical quantities are involved. For example, you try to take a shaft, you measure the roughness, you try to measure the flatness, you try to measure other parameters then length; all those things you measure and then you measure it accurately and correlate measurement of all these quantities involved are done.

The results are scientifically analyzed and the errors are wisely interpreted. Error means, any deviation from the standard from the basic is called as an error and when you start looking at the error data, you can try to find out many information's. For example, when you try to go to a doctor and if you want to do a measurement for your blood pressure, the general advice is you have to go to the doctor, lie down, take rest or relaxation for 5 to 10 minutes and then start taking measurement.

So then, that measurement is more appropriate than just walking down to the hospital and taking the blood pressure. So, what you get as you walk down and do reading is an error. So, the error can be systematic, the error can be random. For example, in the morning when you try to take a measurement, it can be some 10 percent; in the afternoon, it can be 40 percent; in the evening, it can be 8 percent.

So, variation from the mean ok, so that is called as error, so the results as an scientifically analyzed and errors are wisely interpreted. Then by trial and error method, the parameters are adjusted till the product of the design system design gives the designer performance. So, this measurement is called as experimental method of measurement.

So, we have seen three now; one is empirical, the other one is rational and the experimental one. Rational is based on science and Maths and logic. So, basically it says logic you apply and then you do. So, here we try to take from handbook and thumb rule. But here, what we do is, we physically measure we measure all quantities and we tell measure all quantities and then, we try to talk about we try to and correlate the measurement with all. So, here it is interesting, you measure and then you correlate ok. So, this is experimental method which falls under mechanism type of measurement we do.

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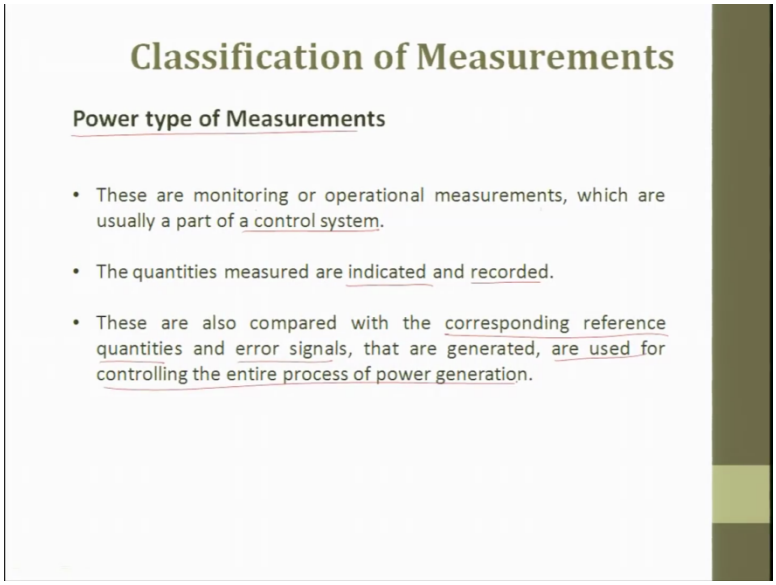

The next classification were the Power type of Measurement. So, here we try to talk about the power which is involved. So, these are monitoring or operational measurements which are usually a part of a control system. So, the quantities measures are indicated and sometimes it is also recorded. So, you have a display to show and suppose you do 20 readings, it shows and also records. These are also compared with the corresponding reference quantities and error signals that are generated are used for controlling the entire process of power generation.

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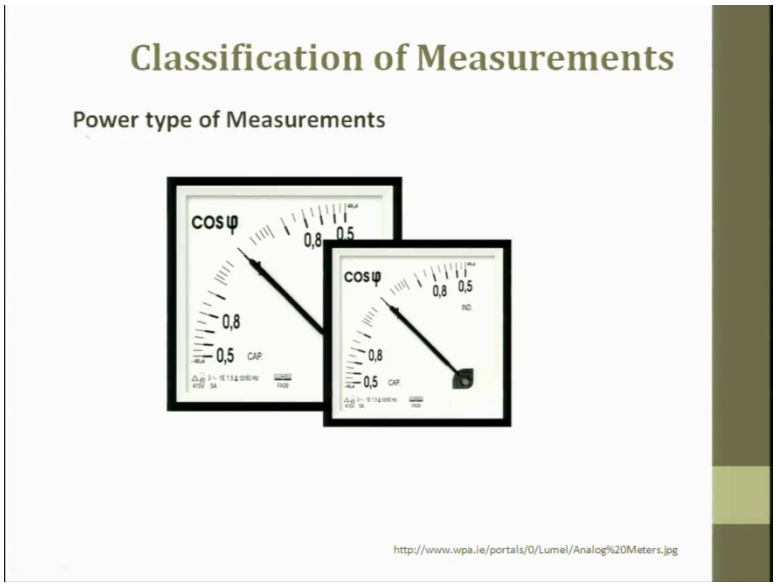

So, this is the power type of measurement. So, the power type of measurement, so you can see these are the devices, wherein which you try to see the needle showing what is the forces phi, the face then it shows in the in the graduation right. It is a device which shows, right.

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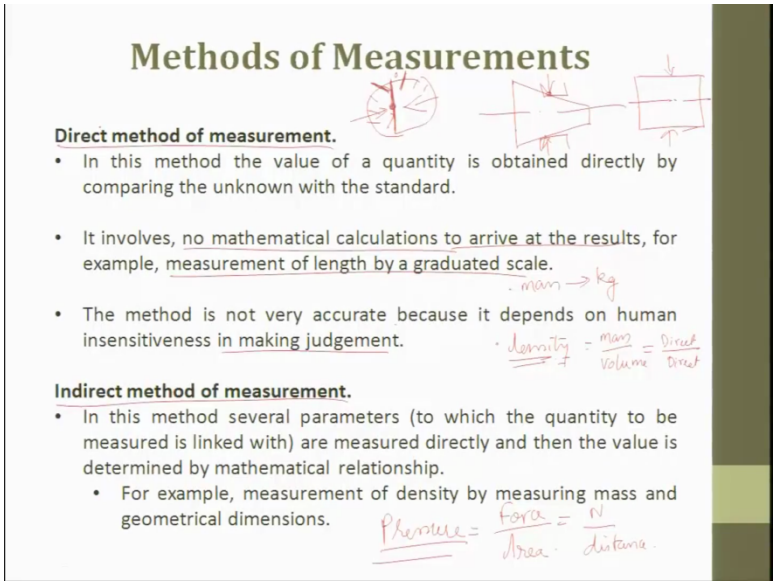

So, when you talk about methods of measurement, there are two types of measurement; one is called as direct measurement, the other one is called as indirect measurement. Direct measurement is you measure a quantity and you quickly compare it with a

standard. For example, I have a vernier caliper, it has graduations, I pick up the vernier caliper, measure the shaft diameter, find out what is the error or find out what is the value.

So, that is direct measurement. What I measure, I get is direct measurement. So, I do not have to change or take a derivation or take a derivative of the value to get a final output. So, that is direct measurement. It involves no mathematical calculation to arrive at the result; for example, measurement of length by a graduated scale ok.

Suppose let us assume, I want to measure mass, I measure by kg, I have a device which can measure. Suppose, if I want to measure density then, it is not a direct measurement density is nothing but mass by volume. So, if I want to measure the volume, I will use a direct measurement, I will then, I will use mass, I will use a direct measurement but when I have to measure density then, I mathematically do some calculations and then come out with some working and then find out the value density. So, this is what I am trying to say direct is mass scale right.

This method the method is not very accurate because it depends on the human insensitive in making the measurement. What am I trying to say is, many a times what we do, if we have a inclined or if we have a tape ward shaft ok, if we have a regular shaft measuring diameter is very easy. If we have a tapered shaft right, how do you measure the diameter? Because at every point there is a change in the diameter.

So, the vernier calipers whatever we use we it has a flat surface. So, if you put a vernier caliper, it will look something like this. So, these two parts might not be exactly align to give the value. So, if at all we try to assure it, then this is called as a error in measurement or in judgment. So, with a tapered work piece, we cannot use the standard permit and then measure it or the other way around is if a in inset of using it exactly at the center, I view this line at an angle.

So, then there is an error in my. Suppose if this is a dial gauge and I have graduations and the dial gauge is indicating some value, I should always see this data, right at the normal. So, if I start going with either from this side or this side, I will either choose this as a value or this as a value rather than 0, right. So, this are these are all depending upon the human insensitive in judgments or error which a human can add to the system. When we talk about indirect measurement, in this method several parameters are measured directly

and then the value is determined by mathematical relationships what I have already told you density. You can also do for pressure.

If you want to find out for pressure, what you do I took force and then I divide it by area, right. I measure force with Newton's and area by distance. Then, I try to calculate this and then finally, what I get is pressure. So, here it is indirect measurement; many a times we use indirect measurements and we many a times we use direct measurements. Direct measurements are generally preferred so that I directly measure and get the value. Or nowadays what has happened, the electronics have become so friendly the indirect mathematical calculations are internally done. So, it exactly displaced the value of the indirect measurement then we try to do a measurement of a shaft. So, it is not direct, it is becomes indirect and get the value.

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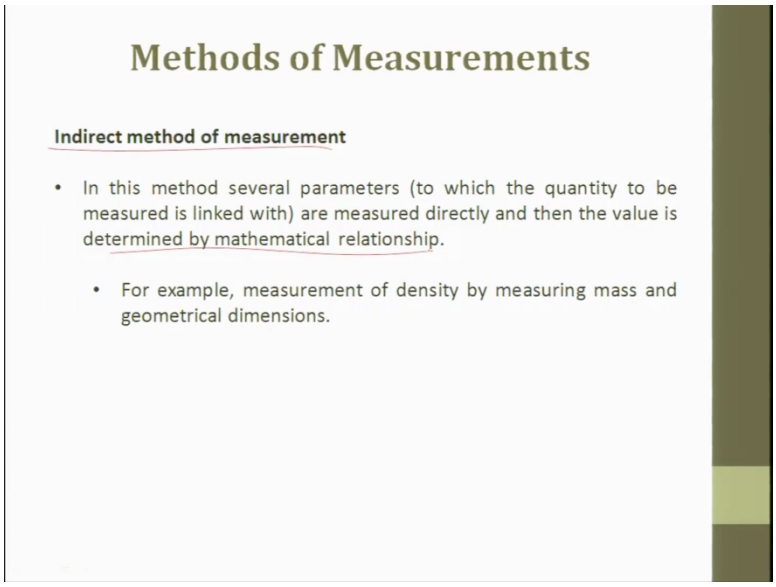

So, in indirect measurements, several parameters are measured directly and then a value is determined by mathematical relationship.

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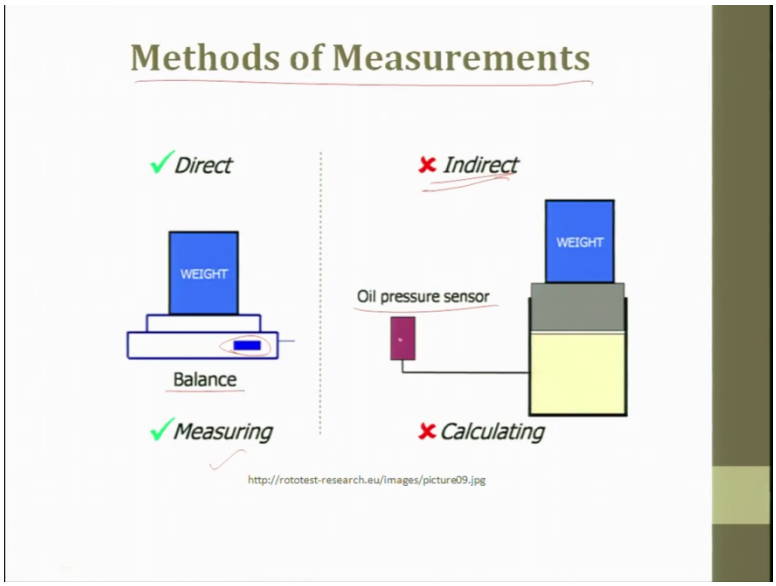

For example, you see the methods of measurement weights. Weight is measured by a balance and it is direct. Suppose for the weight, if I use a sense oil pressure sensor, it has a weight compressor, the oil gets leaked and the pressure increases. If I start doing it this is indirect way of measuring. So, here we put a piece of crystal and the piece of crystal measures the weight displacement and then it quickly tells, this is called as direct measurement and this is called the indirect measurement.

So, I do some calculations and from here now, I will see what is the oil which has got leaked and then try to measure the leak or measure the pressure of the oil and from here I cross correlate to measure the weight.

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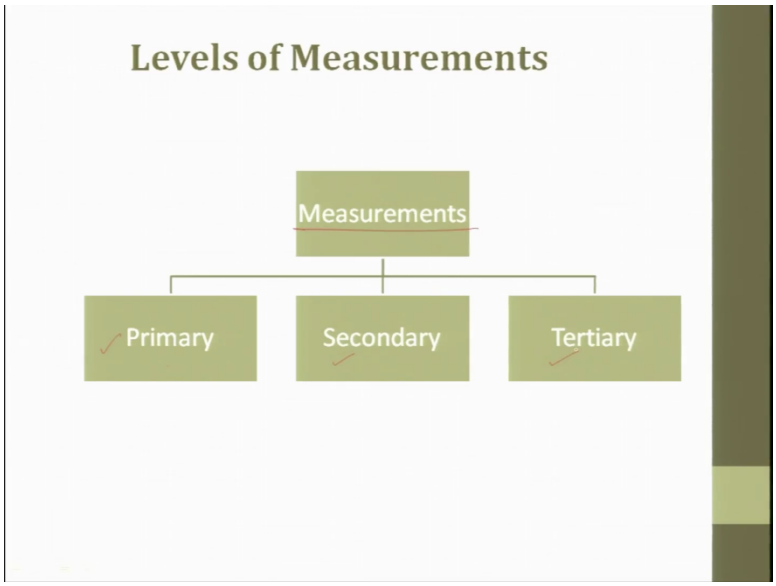

Then we talk about levels of measurements; there are three types of levels; one is called as a primary level, the other one is called as a secondary level and the third one is called as a tertiary level.

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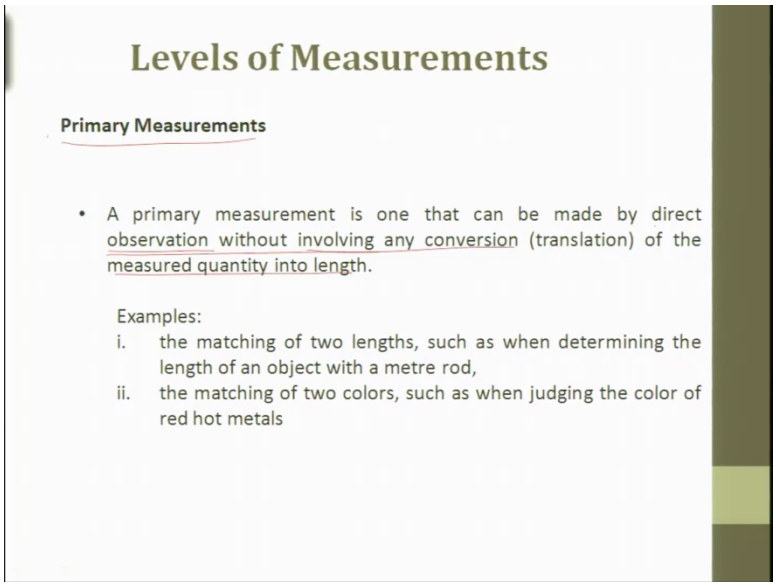

What is primary measurement? Primary measurement is one that can be made by direct observation without involving any conversion of the measured quantity into length. So, the matching of two lengths such as when determining the length of an object with a meter rod; matching two colors such as when judging the color of red hot metal.

So here, primary measurement is one that can be made by direct observation without involving any conversion of measured quantity into length. So, that is called as a primary measurement.

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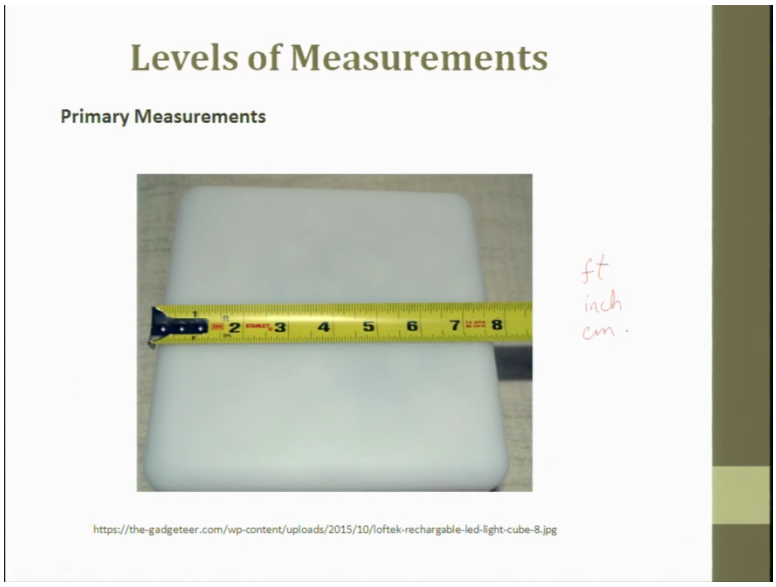

For example, I try to take a block, I try to take a measuring scale, measure it, what data I get is direct. So, if you go back to the definition, a primary measurement is one that can be made by direct observation because there is a scale, in the scale I have graduations without involving any conversions then I do not convert anything of the measured quantity into length right. So, you see here one is in feet, the other one is in inches.

So, whatever I measure, I can refer it either to feet units or I can even write to talk about in inches or sometimes if you have inches and centimeter. So, I can use it and do it.

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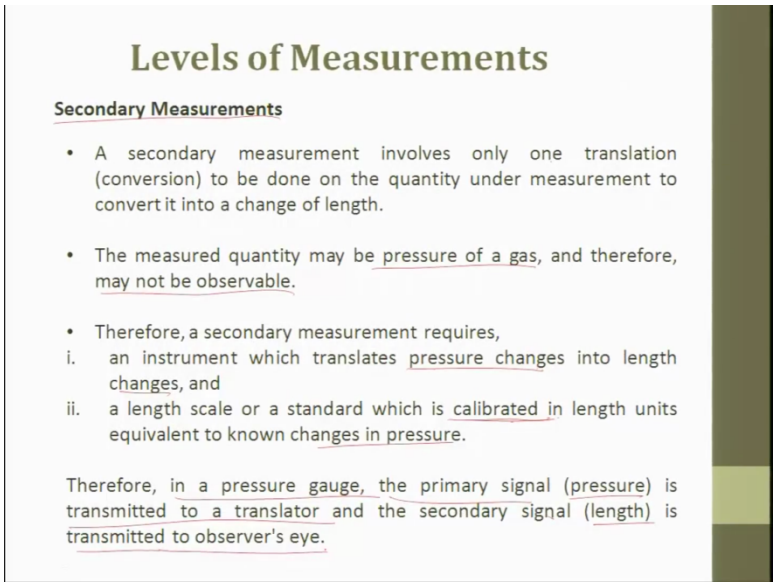

What is secondary measurement? Secondary measurement involves only one translation to be done on the quantity under measurement to convert into a change of length. The measured quantity may be pressure of a gas and therefore, may not be observable. Therefore, a secondary measurement requires an instrument which translates pressure change into length change. A length scale or a standard which is calibrated in length units equivalent to know the change in pressure. So, here what we do? We measure the pressure change into a length change; one parameter is getting converted into other parameter. So, and then from there, we start measuring this one.

So, here there is an important terminology which is called as calibration which comes into existence. So, I measure a known parameter, then I measure a unknown parameter and then I try to plot it, understand the relationship and then use that relationship in measurement. So, here an instrument which translates pressure change into length change, the length scale or a standard which is calibrated in length units equivalent to known as a change in pressure. Therefore, in pressure gauge, the primary signal pressure is transmitted to a translator and the secondary signal length is transmitted to an observer's eye. So, here it is a secondary measurement.

Secondary measurement in involves only one transmission to be done on the quantity under measurement to convert into a change of length.

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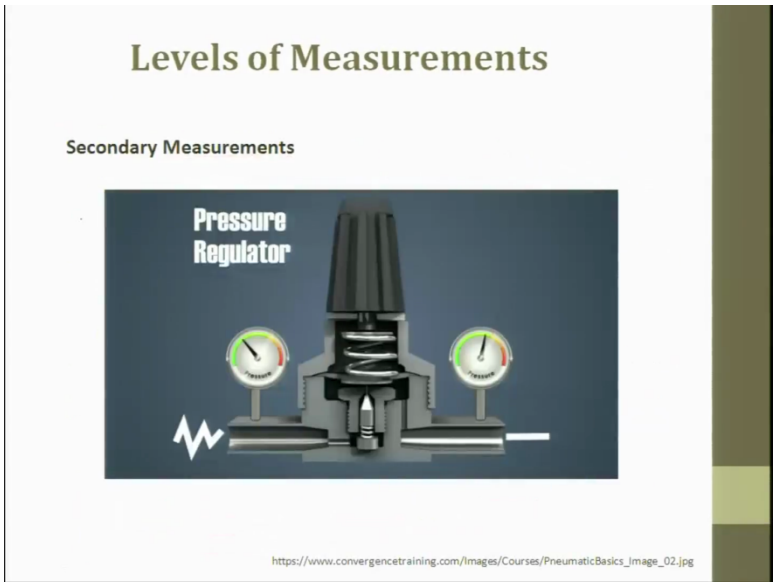

So, this is a pressure regulator. So, there is of fluid which is flowing. So, here what we do is this knob we operate to change the pressure. So, here is a pressure gauge which measures and tells you. So, this is the in and this is the out ok, this is the out. So, we do all this changes. So, this change is change in length here ok, change in pressure.

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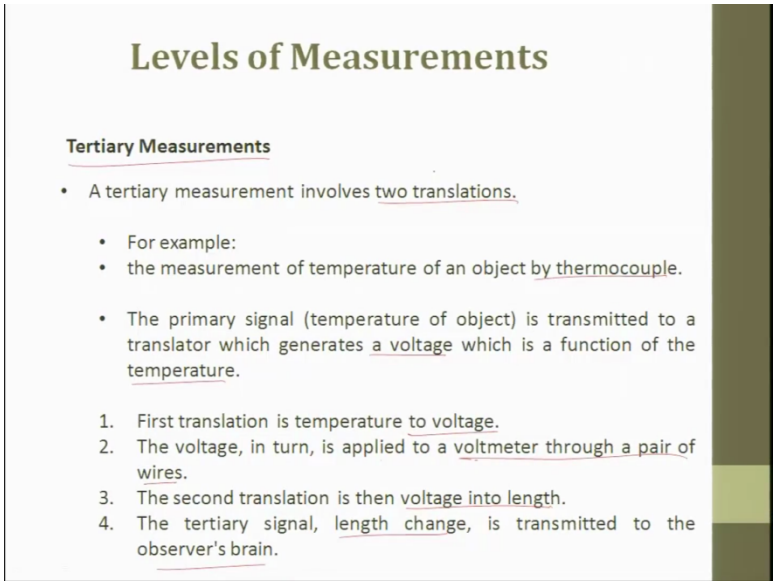

The tertiary measurement, the ternary measurement involves two translations. Secondary is one translation, here it is two translations. The measurement of temperature of a object

by thermocouple, the primary signal is transmitted to a translator which generates a voltage which is a function of temperature.

So, the first translation, the first translation is temperature to voltage. The voltage in turn is applied to a voltmeter through a pair of wires, the second translation is then voltage into length, the third translation is length change is transmitted to observer's brain. So, here there will be two translations from this; so primary means, directly you take the data, secondary means, one translation; ternary means, you do two translations to get the measurement.

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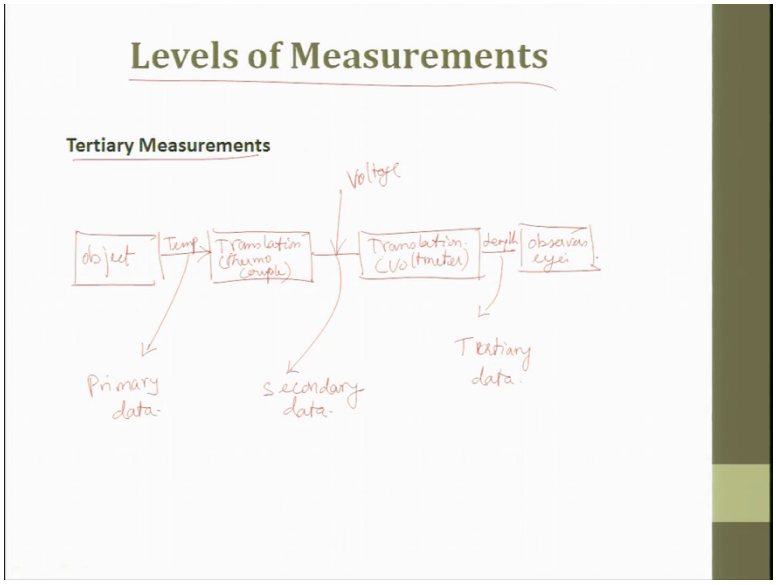

So, here in ternary measurement, we will have an object, then this will be a translation, then you will have translation and then you will have output or observers eye. So, here you will measure the temperature which is nothing but the primary data ok. So, here you will try to you will try to measure the translation is thermocouple, this is a secondary data, secondary signal of data and then translation here will be voltmeter and the last one here will be the ternary data and then will try to get it here.

So, here you will have voltage, here temperature, here voltage and you had a length ok. So, these are the different levels of measurement. So, an object then you will have a primary data where temperature is measured, thermocouple is used, then what we do is this thermocouple data is converted into a voltage data. So, that is nothing but again a

translation happens and then finally, what you get is the length data which a observer looks through his eyes.

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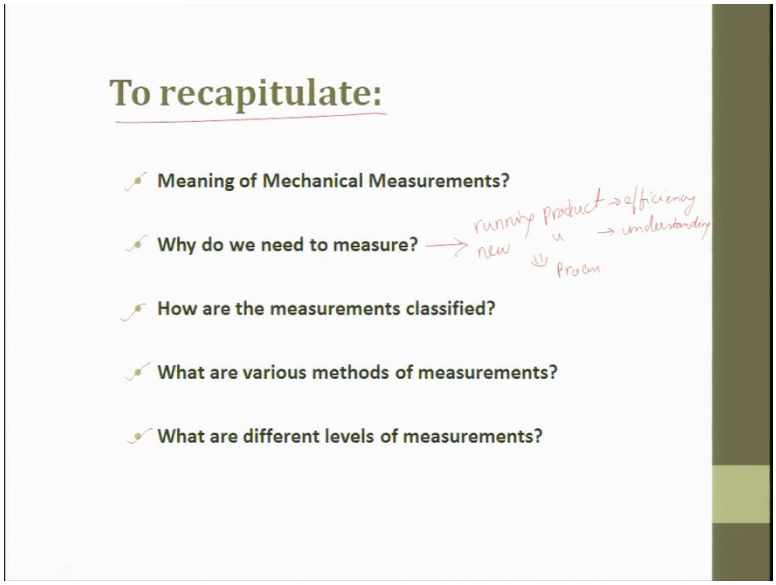

So, to recapitulate, so what have we seen in this chapter? We have seen the meaning for mechanical measurement and then we have seen what is the need for measurement. So, need for measurement I very clearly said if you have a running product, you have to improve the efficiency of the product and product efficiency; if you want to do a new product, then their understanding and then if; so, these two are there. So, then new product you would always try to do understand what is a variation and then, this variation you will lead to choosing process properly. So, for the entire process selection also measurements is very important, then we classified measurements, then there are various methods of measurement we saw and finally, we saw the levels of measurement wherein which we saw primary, secondary and tertiary where the data is changed and then you convert it to get the original value, you try to get the data, you try to get the final data which is readable by the customer.

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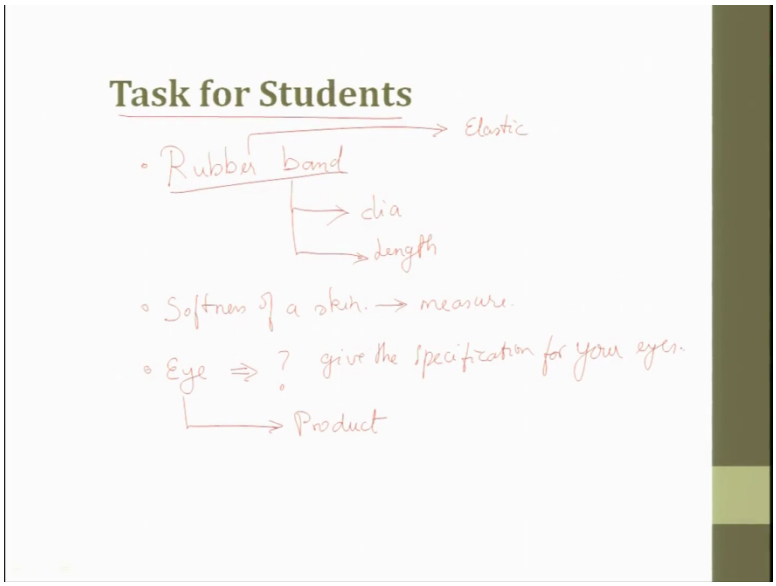

So, what is the task for the student? So, the task for the student is I want you to take a rubber band, any rubber band and for this rubber band I want you to measure the diameter and if there is the length, if at all there is a length, so please measure the length also for the same. So, you should understand I will also give you the problem constraints, constrain is rubber band; rubber band is elastic in nature. So, the challenge given to you is you should try to measure a rubber band, when you try to put it in a scale or when you try to hold it in your hand is going to stretch.

So, if it stretches then whatever instrument we use for measuring is not going to be correct. So, now, you think how will you do it? Second thing is I want you to also try to understand how do we quantify softness of your skin? Softness of a skin, how do we measure? This is very important because softness is one parameter where directly you do not have any units. So, softness is something like get relate to scale. So, what is soft for me is not soft for my wife or it is not soft for my son and when you see all these diaper advertisements which is coming TV, they say it is very soft. So, now, what is the measure for the soft?

So, you have understood measurements. I have told you different types of measurement what are they? So, please try to think about what how do we measure softness of a skin? And the last assignment is if I want to measure your eye, right, how will I do it? So, take eye as a product right, stand in front of a mirror, stand in front of a mirror, you see your

eyes. Now I want to measure your eye or let me tell you please give the specification for your eyes. So, now look at it students I have given you all challenging problems statements. So with this problem statements, if you are able to think and look forward for various devices ok, I am not asking to look at very high and all look at something which with which you can measure. So, the first one the challenges it is an elastic material. So, moment you touch, it is going to shrink; the moment you pull, it is going to expand. Next one is going to be the softness of a skin ok. So, softness of a skin is something which currently you do not have any units to measure, then how do people measure? Almost all your advertisements which come on screens talk about softness, the last one with which you see the world. Now I want you to give a specification for that product or a part eye ok,. With this we try to see will try to understand what is measurement? How complex is measurement? And later down the course, you will enjoy because we will see many devices which are used to for measurement.

Thank you very much.