Engineering Metrology

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Lecture – 35
Statistics in Metrology, an introduction (Part 1 of 2)

Good morning, welcome back to the course on Engineering Metrology; Dr. Ramkumar has already covered maximum part of this course and we have discussed what is metrology, what is the use of metrology in daily life, use of metrology in manufacturing, in mechanical measurements.

And what we did when we did when we are just going through the previous lectures; we were looking at the various instruments, various kinds of measurements that we obtained from different kinds sources. And we also saw what are the sources of errors and you might have been; now known that the errors of the main thing which we are dealing with. The errors are to reduced at the errors of minimum the readings of very close to the original or the true value.

So, accuracy in precision; so, in this module I will discuss Statistics in Metrology; statistics is an inherent part of metrology nowadays. Because you know the errors can be at both hands; error is one of the technical terms that we have been using till now. So, I am going to talk about statistics here; in statistics the term error is more known as uncertainty. So, what happens when we take measurements; they might be errors because of certain sources, certain this is maybe the instrument is not working well, that is experimenter is not working, well there are systematic error, there are random errors.

And the thing is that we generated data through metrological experiments and when the data is generated some information is to be extracted or obtained from this data; that we have to present finally, this is our final reading or this is our final measurement based on which we need to manufacture.

For that the data that is generated some time is very big; no if not very big let me say if there are 20 observations that we have taken; which has take the average of that. So, 20 observations is just one of these samples that we have taken from. And the overall let me

let me say in a manufacturing concerned that be that might be manufacturing 1000s of components and we have picked one sample in one sample of 20 observation of 20 units out of the 1000 let me say.

So, those 20 units the measurements are taken and that is going to represent the whole population and that is why statistics comes into place.

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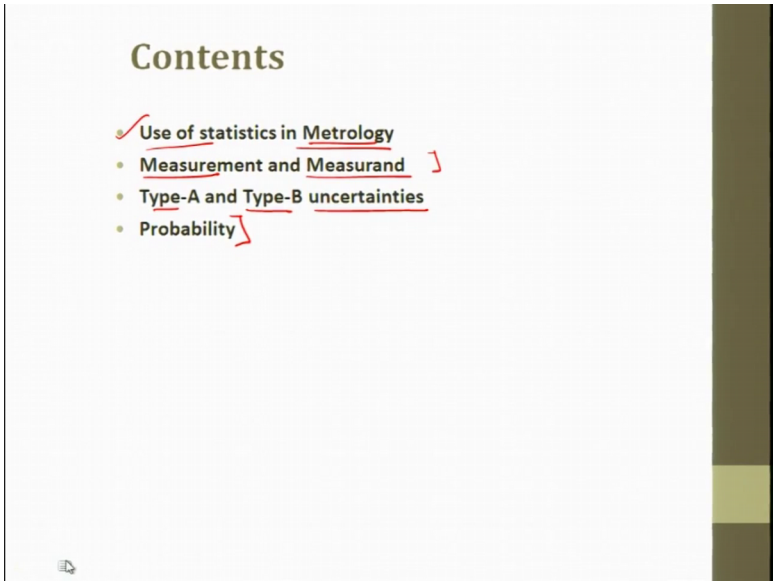

The role of statistics I will go through these contents in the lecture. Use of statistics in metrology that will discuss, then certain definitions like measurement, measured and I also discuss procedure and accuracy, the statistical view point of that, then type A and type B uncertainties.

Uncertainties is equivalents to error that we discussed before, then what is probability? Probability people know what is probability; probabilities are chance of occurrence, but the use of probability there are certain concepts or certain techniques which are devised from the probability. Probability density function cumulative density function probability distributions and how this distributions have used to conduct or to find out that whether the sample represent the whole population or not.

So, these things we will discuss; so, this is just an introductory lecture to certain statistical concepts.

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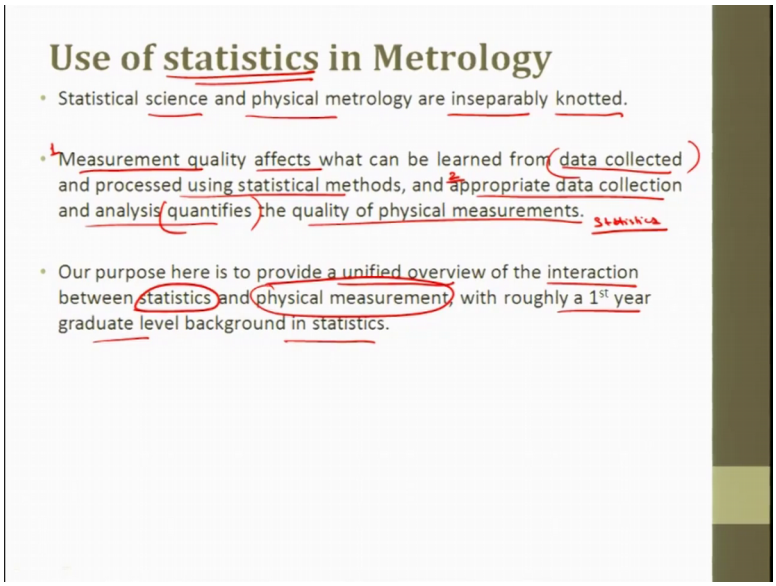

So, statistical science and physical metrology are inseparable knotted; certain necessaries that metrologies have long understood this that statistics cannot be separated from the physical metrology.

Because certain statistical methodology and models are developed which are useful, which has been useful in past. And certain other models are being development in future also which are useful to generate the knowledge from the data that we have obtained from metrological measurements. So, measurement quality affects what can be learnt from the data collected and process using statistical methods.

And appropriate data collection and analysis quantifies the quality of the physical measurements. So, I could say number 1 and number 2; measurement quality if the errors are there in measurements the measurement quality would be low. Measurement quality affects the data the data that is obtained through measurements is not very reliable; I will I will discuss about reliability and validation a, data could be valid or data could be reliable it could be both, it cannot be both; so, data has to be valid and reliable.

So, if the data is sometimes data is not valid, but reliable we will see we will see this in in context of accuracy precision as well in the forthcoming slides here. So, what happens measurement that the metrology affects; what kind of data is collected and appropriate data collection and analysis quantifies; the quality of physical measurements, this is done by the point 2 is done by statistics.

So, a purpose in this course is to provide a unified overview of interaction between statistics and physical measurements with the people who have the prerequisite has people who have completed that is two semester of their engineering or with roughly first year graduate level background in statistics ok. Some background in statistics like or I can discuss that as well that what is mean? What is median? What mode? All those things most of you might be knowing, but I will just give an over view of that as well.

So, in this lecture we are going to discuss the role of statistics in metrology or in measurements. So, satiations notably those who worked in standards organization such as national and industrial laboratories and in quality assurance and statistical organizations, in main sections concerns have contributed to good measurement practice. So, development of statistical methodologies which are useful to quantify the measurement quality and sometime measurements are conducted using some complicated instruments as well.

And they are those instruments are those calibrated properly or not. So, in calibration also statistics play a role a calibration curve has to be plotted that is statistics.

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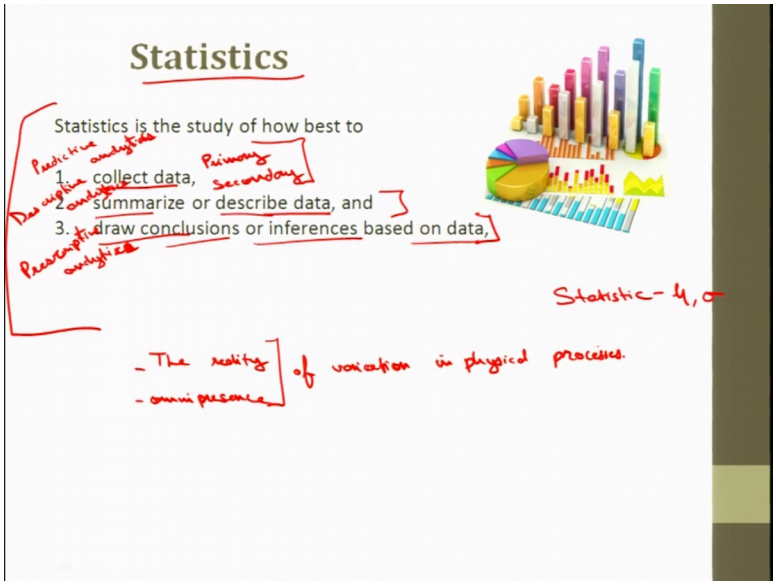

So, what is statistics? Statistics is the study of how best to number 1; collect the data. What is the way to collect data? And; where is the data obtained, is the data obtained from the trans resource what is the data obtained from some handbook.

The data can be of two types here; the data can be primary or secondary. In this course so whatever we have been studying till now who was the primary data; the data that we generate it was the primary data and the third was all collective taking the actual measurements using some instruments and measuring some work spaces and we measured angular, linear, screw thread, gear metrology; we went through all those things that was all primary data.

Primary data; where the data is generated by the experiment that is primary data. sometimes the data is not generated at the first place. However, it is taken from somewhere when we record it previously, the past data that is that we are using the data for instance those are available in the handbooks; those are secondary data.

I can even take it into this contrast that we know the kind of standards the primary standards, secondary standards, tertiary standards and working standards. You know the working standards those we have using in the industry or in our laboratories; those are compared with the tertiary standards or national standards. And those might be compared with the secondary standard or primary standards; so, those kind of data with which the comparison is made is kind of secondary data.

And data that we generate is kind of primary data; when we know that an instrumentation is when you purchase an instrument? You purchase a vernier caliper you know that that the least count is 0.02 mm. And this is the secondary data that the least count is 0.02 mm that is the value that is given, the data that we generate that you actual discount that you find out is the primary data ok.

So, we can detail it further then we will come through actual examples here. So, next step is to summarize or describe the data; to summarize and describe the data we have collected many observations. We have seen that the error that is obtained; error might be linear, might be quadratic very kinds of error forms there are error terms might be there.

So, we need to summarize what kind of data has we generated and the thing is that from the data; information has to be accepted. Summarization means for instance mean, mode, median, standard deviation, variance is kind of summarization of data or is kind of describing the data. So, average would be reference consists; one instance if you are taking some reading using voltmeter and reading has to be 5 volt all the time.

And the reading is actually observing a two value is 5 volt and the reading that we are observing is 5.1, 5.2, 5.3, 4.9, 4.8 so on and average comes out to be 5.1. So, this average data tells that the overall your 0.1 volt forward or 0.14 more than the true value. So, this in the crew describing the data; so, then we draw the conclusions or inference is based on data.

Actually this days a very prominent subject we people are studying is analytics; analytics is dealing with the data, dealing with big data people having so many customers are there, so many products are there; the there are work in progress inventory, there are the various inspection that happens in within factory; during raw material during delivery all those things are so, much of data available in the industry, so, analytics is there.

So, I think I can even divide this three steps include a three major concepts of analytics. So, this is collect data is predictive analytics; predictive analytics is you predict sometimes, sometimes you predict or sometimes you just collapse the data and you just record the data; that is a kind of predictive analytics. Other two parts are descriptive analytics and prescriptive; descriptive analytics is when you describe the data, describe the data you use some statistics some statistic not statistics is the science is the study. Statistic is the variable on which we are working like main is one statistic standard deviation is one statistic; I am using a word statistic here this is nearly represented by mu.

We generally represent sorry standard deviation is represented by sigma. So, we summarize this using descriptive analytics and we draw the conclusion using prescriptive. But prescriptive analytics means we give some prescription, some results, some conclusion that the data that we can generated, we have worked on that, we have v analyzed it, we have try to plot it and we have tried to generate a curve a probability maybe probabilities and stick of that we will discuss.

And we have found that the data is significant or not significant; this might be in new terms for some of you, I will definitely explain what is significant and what is not significant data and for that we will discuss normal distribution curve. So, please bear with me we will discuss this in the next lecture. So, this is all a framework which recognizes the reality and only presence of variation in physical processes.

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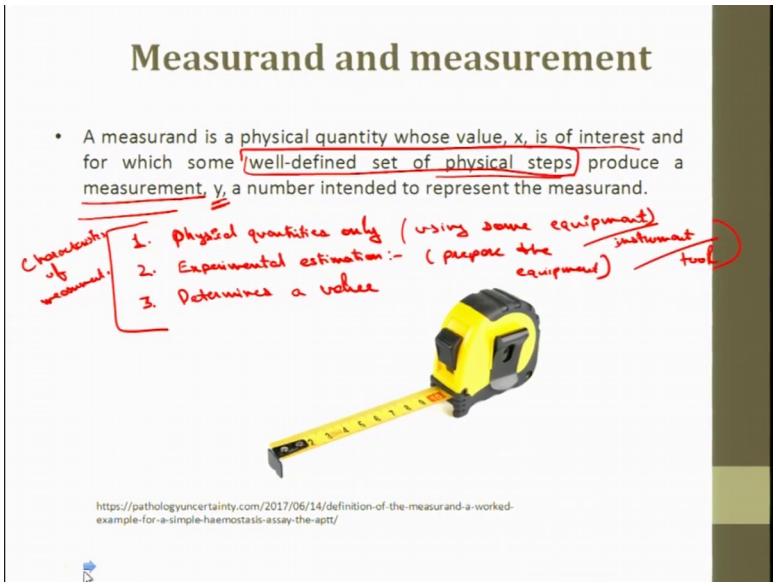

So, next I will have to discuss a few terms measurand and measurement; measurement is the one thing which we have been listening which we have been going through from the very beginning.

So, what is measurand? Measurand is a physical quantity whose value of x is of interest and for which a well defined set of physical steps produce a measurement y, a number that intended to represent a measurand. Measurand is actually the original value which we are trying to find a measurements are the value which through experiments we are obtaining, we are getting the values.

And actually the measurand the measurement has to be equal to the measurand ideally, but is a difference this difference is known as error. So, we need to see what is the behaviour of the error? Is the error linear? Linear means is it is it varying in a linear way; is it continuously increasing or continuously decreasing or is it constant or is it non-linear will see these things. So, measurement is a well defined set of physical step; physical steps that produce some value. So, measurement is the act of experimentally determining physical quantity using specialized equipment. So, it use some I will write such an characteristics of measurements here.

Just to recall; however, we have discussed measurement before; measurement in metrology can be only about the physical quantities; physical quantities only um. However, when we talk about statistics the measurement include sociological,

psychological and many other social and aspects by end. But in metrology we are only interested in the physical quantity; physical quantity means physical quantity not only means the quantity that we can hold, physical quantity might be temperature, might be flow of wind.

So, any quantity that we measure using some specialized equipment that is measurement. So, I will write it using some equipment; so I am using the word equipment here, we can use the word tools or instruments; however, the words tool or instrument or a source sometimes they might be for the interview for the social studies; these are the because we are talking about statistics the tool can be question; they can be telephonic interview the these can also be called as instrument. So, it is better to use what equipment if I use the word instrument as here as well.

The instrument would be the instrument one of the instruments that we have studied before or the tool that we studied before in this course only. So, it is can it is about the physical quantities; so, measurement is the experimental estimation of parameters. So, it is experimental estimation; so it is it always involve experimentation like in laboratory demonstrations that we saw that; we have to first prepare, we have to first tool and a work piece to work piece which is to be measured, the work piece or the measurand that that the value that we need to know and the tool also has to be pair that are ways to handle the tool.

They have specific ways, we have to be careful, we have to be aware of the precautions that we need to use. We have to see that the error that has does not comes those are the experimental error or experimental error Experimental analysis experiment of instance I am the experimenters error or experimental error the experimenter error is if the experimenter for instance I am the experimenter I am not taking the ridics carefully it might be my error.

Experimental errors might be the experiment is not conducted properly; so, because measurement is an experimental estimation as I put here; it is important to prepare the equipment; so, it is an estimation. So, estimation involves the calculation the statistical assessment of product quality indicators and other similar procedures. So, next point is measurement is performed using special technical equipment which may be scales, measuring instruments; this definition general definition of measurement does not

include other determination methods that do not use technical devices when instance sometime the expert assessment is there; an expert can say this is I think this is about 1 feet.

But when we talking about measurements, we are talking about quantitative data mostly we are dealing in quantitative direct it might be qualitative as well; so in that case there has to be some equipment. So, next point here is measurement determines a value; this was actually the basic definition steps to produce a measurement y this value; y has to be determined using measurements.

So, it might be the comparison of a quantity against the unit or scale for that quantity. So, they can be such in criteria; so I would rather put these three major characteristics of measurement.

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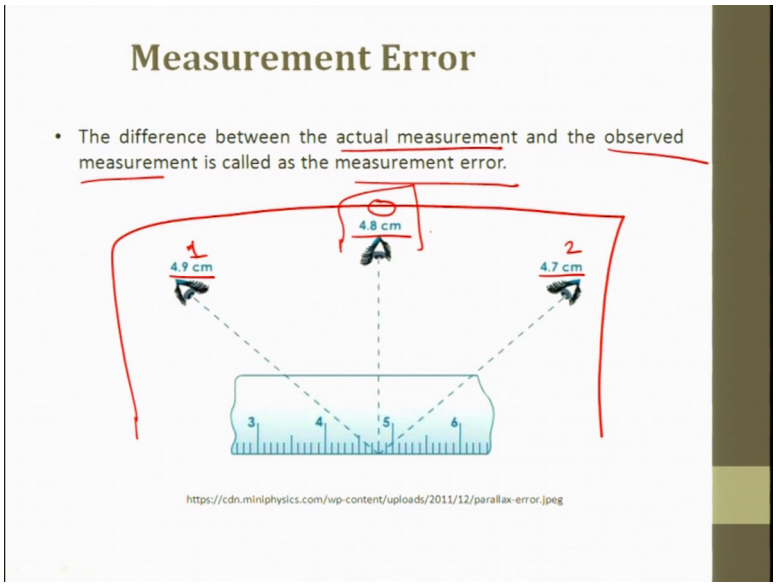

Next is measurement error; measurement error we have discussed it before multiple times, the difference between the actual measurement and the observed measurement is known as measurement error. So, what do you think; what kind of error is this? This is a parallax error; this is the number one if a classified this is the error from the observer this is the observers error. So, the observer is looking from different angles this observer is reading it as 4.9, this is exactly perpendicular to the scale is reading 4.8; which is the actual reading.

So, this is 4.7, 4.8, 4.9; so this is the actual observation at least what is represented by the scale because of the different angles of viewing; angle 1 and angle 2, we are not getting the actual value this is the measurement one of the measurement errors. So, trying to explain the measurement for the; measurement I can classify measurement classification.

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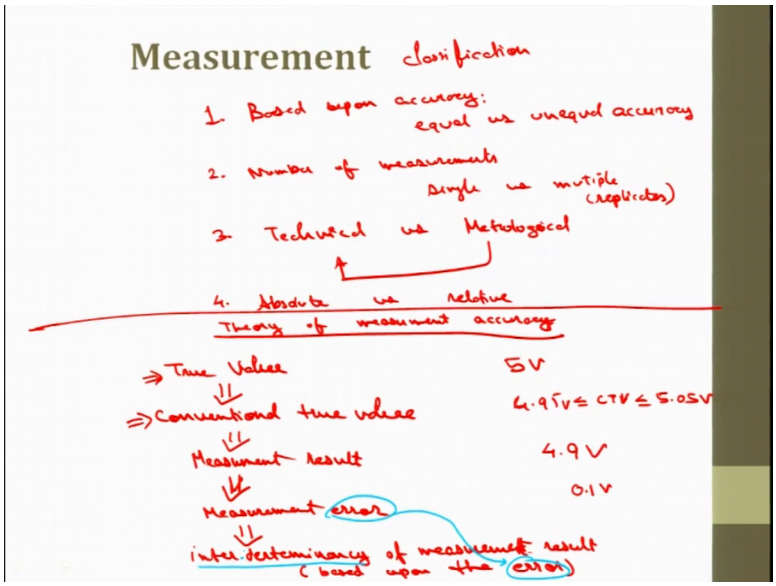

Measurement can be classified based upon the state of accuracy; measurement of equal accuracy or measurement of unequal accuracy based upon accuracy that can be equal versus unequal accuracy.

So, measurement of equal accuracy means a series of measurements of some quantity performed using measuring instrument of identical accuracy under identical conditions. And unequal accuracy would mean the measurement of some quantity which gives different accuracy under different conditions. So, identical accuracy under identical condition; when we are going to measure from this point it has to be all the time because it is the identical way; always if it is at this angle at this angle from the regional it will always give 4.9; this is called measurement of equal accuracy.

Sometimes at different accuracies or at sorry at different conditions the measurement values have different accuracies. So, the method used for reduction of measurement of equilateral as an and measurement of unequal accuracy are slightly different. Thus prior to reducing a series of measurement a check needs to be performed to determine whether or not measurement are of equal accuracy. So, this is generally used using the f test or

goodness of fit test, cascade test that we might discuss. So, in terms of number of measurements the measurements can also be classified; so, it is single versus multiple.

Single measurement is a measurement that is performed only ones; multiple measurement is a measurement of the same quantity in which the result is obtained from several single measurements in a succession; so, physical replicates. So the various ways to classify measurement another way maybe the measurement based upon the technical measurement and metrological measurement.

So, the technical measurements are intended to plane information under properties of physical objects, processes and phenomena in the surrounding world. And metrological measurements or the measurements which we are studying in this course and that ensure metrological traceability and require accuracy of technical measurements. So, another base is relative or absolute the certain ways.

We can say technical versus metrological; actually metrological measurement supports the technical measurement, it is the see that if or the technical measurements repeatable or not reproducible or not. So, then is absolute we have discussed this absolute versus relative; this you know the absolute in absolute measurement we have an exact 0 and in relative measurement the ratio of some quantity is taken; so, there various other ways.

Next we can discuss something here about how the theory of measurement is devised theory of measurement or it can better put it here theory of measurement accuracy. So, what we have originally? We have a true value; true value is the one; that is desired that we need to be close to or between need to equal to if possible. So, true value is the value those are the standards which are maybe primary standard or maybe secondary standards, but the conventional the true value that we have in the working; in the actual industrial environment or in the in the actual laboratory environment, we have some true value; some value that is not exactly true value, but that is acceptable; so, that is the conventional true value based on which actually we are not working on this.

We are not actually working using true value, we working using an instrument that can give us or that can measure the closest up to the conventional true value. So, then we have based upon the conventional true value; we have if I use some equipment here or some instrument here or some tool here to measure something, I will get a measurement result. So, what we have obtained? We have obtained a result like I said a voltmeter that

was the true value was actually 5; conventional true value could be if I take up to two places of decimal conventional true value may be 5 point 5.05; 5.05 or 4.5; this is the acceptable infinitesimal value.

4.9 5 to 5.05 volts two will I could say here is 5 volt, this is 4.9 5 less than equal to conventional true value less than or equal to 5.05 volt and volt. Then measurement result; measurement result is something that we have to let me say the value we have got here is 4.9. This measurement result; however, I worked on this thing this measurement results as two things now; it has the value original value the true value plus error. So, from here we will get the error here error I can say is 0.1 volt; this is deference from 5; 5 volt.

So, this here we get the measurement error; now we need to work on the measurement errors, we need to see that the errors that we are getting that we are getting here are these error high enough So, that we can reject the measurement that we have taken. You can say that the measurement or the instrument is not working properly or there is some error on the part of experimental, observer, instrument because of which the, we are going to reject the overall experimentation that we have done or is it significant or we can accept that as well based on certain criteria.

So, what we do? Here we use certain statistical tools or statistical methods to find the inter determinacy of measurement result. So, this is based upon the error; the error that we have obtained here that we have obtained here is used here based upon this error, used here to find the interdeterminancy. This was just an introduction to what statistics can do, so what way are the statistic statistical theory can be applied to obtain some information out of the data that we have obtained from the experimentation.

I will just take a break here; in the next part of the same lecture I will discuss this concept further. So, this first lecture would be just a introduction, in the second part of lecture, in the second lecture on statistics will discuss about uncertainties, we will discuss about the parameter of the statistics which are used in determining the various in this interdeterminancy of measurement result.

And we will discuss about probability distributions and how the probability distributions can be used. Not only this, this will be the first section of our statistical concepts in metrology; in the second session we will also discussed this sampling; what is the sample number that is to be taken send then quality control. So, what is the way or when we can

say that the quality is within control or what is the way to control the quality; quality assurance; quality assurance is that how the quality assure quality control procedures are implemented; how well are they implemented?

So, we will discuss all these things and acceptance sampling as well we will discuss these things. So, let us meet in the next part of this lecture

Thank you.