Chemical Process Instrumentation
Prof. Debasis Sarkar
Department of Chemical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 06
Performance Characteristics of Instruments and Data Analysis - I

In week 2 and week 3 we will talk about Performance Characteristics of Instruments and Data Analysis. So, this will be covered in 2 weeks. So, we name it as performance characteristics of instruments and data analysis 1, which would be covered in week 2 and performance characteristics of instruments and data analysis part 2 which will be covered in week 3.

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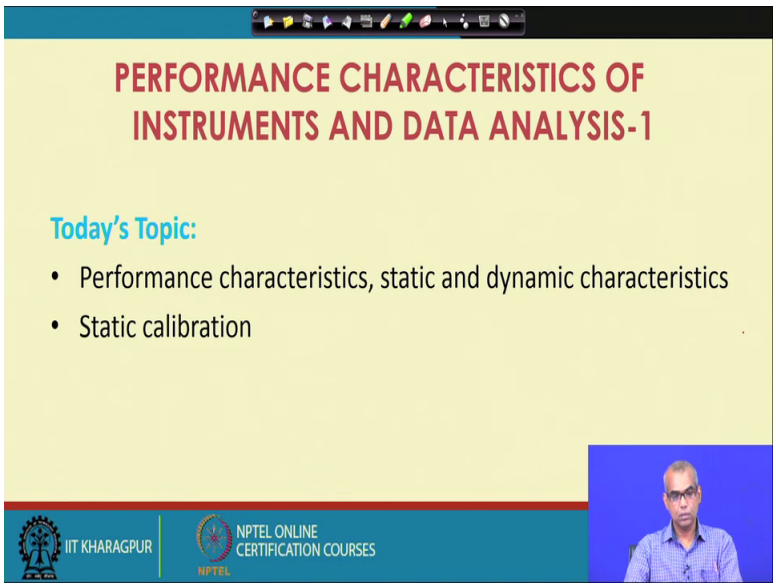

So, what do you mean by performance characteristics?

So, today's topic will be the performance characteristics what are they? Actually there are two types static characteristics and dynamic characteristics. So, we will talk about what are the static characteristics what are the dynamic characteristics will identify them and we will talk about something called static calibration.

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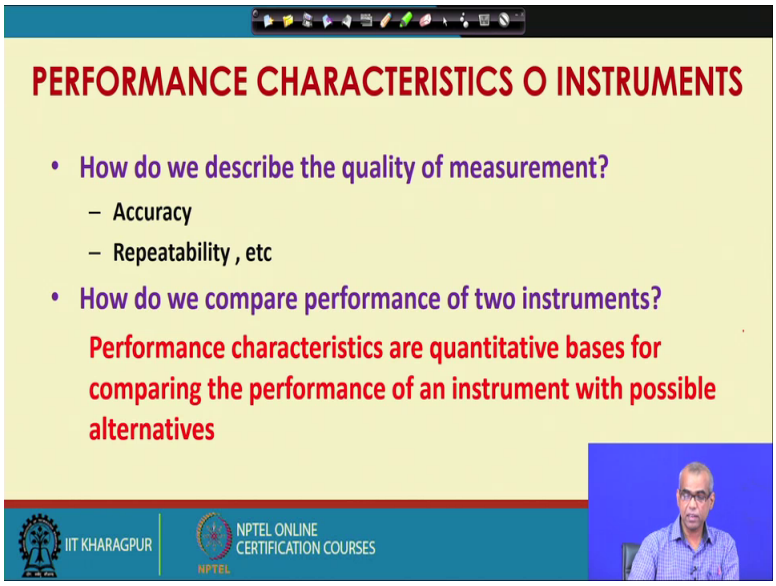

Now, let us try to understand what do you mean by static characteristics of instruments? When we use an instrument to measure some process variables you may ask yourself, how do you describe the quality of measurement or let us say you are measuring say temperature of some process using 2 different instruments and let us say you are doing these things repeatedly.

So, again how will you compare the performance of one instrument against another, there should be some quantitative basis for this performance evaluation. So, when you say that, when you ask yourself that how to describe the quality of measurement, where as you think of whether the result is accurate enough? weather if I repeat the same measurement several times; whether there is repeatability or the agreement among the readings obtain in several trials and how do you compare the performance of 2 instruments, this is what we just discussed.

That if we have 2 different instruments which can be used for the measurement is same process variable, how do I compare the performance of these 2 instruments. So, performance characteristics are quantitative basis for comparing the performance of an instrument with possible alternatives, performance characteristics are quantitative basis for comparing the performance of an instrument with possible alternatives.

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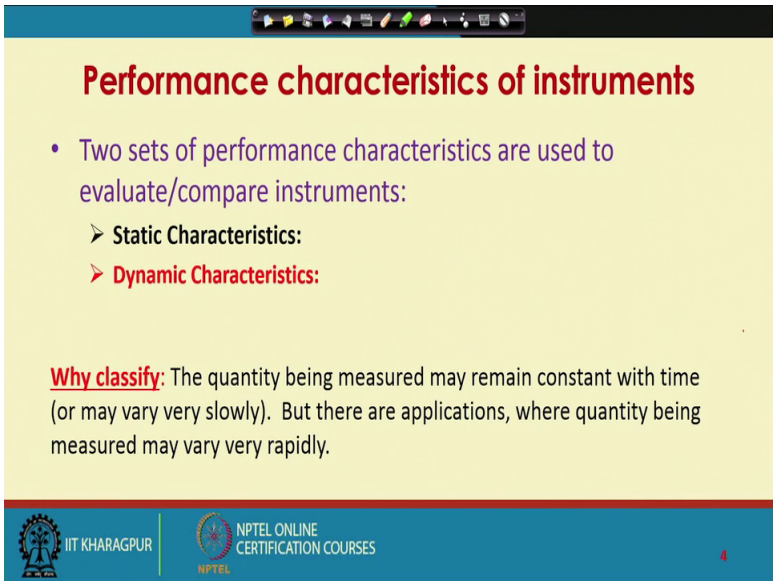

There are 2 sets of performance characteristics and both are used to evaluate the performance of instruments or to compare the performance of instruments, they are known as static characteristics and they are known as dynamic characteristics, static means medium is stationary. So, the quantity you are measuring does not change with time. So, the medium is stationary environment is stationary and dynamic characteristics the word dynamics mean that the quantity, I am going to measure is rapidly varying with time.

So here are 2 sets of characteristics static characteristics intended for static environment, dynamic characteristics intended for dynamic environment, if a medium is varying very slowly with time we can consider this to be static and can concentrate on static characteristics, why do we classify this performance characteristics into these 2 categories static characteristics and dynamic characteristics, because of this reason that the quantity being measured they remain constant with time or may a vary very slowly, but their applications where quantity be measured may vary very rapidly, so it becomes natural to consider a set of characteristics.

For the medium which is remaining stationary or varying very slowly, but when the quantity being measured or the medium is changing very rapidly, it is natural to consider a set of characteristics which is separate from static characteristics. Accordingly we classify them as static characteristics and dynamic characteristics.

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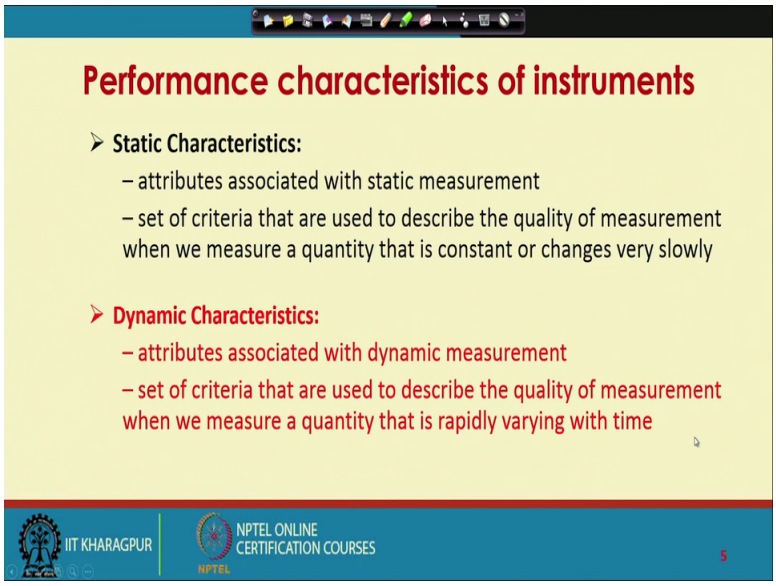

So, let us formally define static characteristics as follows, so these are attributes associated with static measurement. So, static characteristics are set of criteria that are used to describe the quality of measurement when you measure a quantity that is constant or changes very slowly. It is important to note that, it is the measuring measured quantity that remains constant or changes very slowly; so set of criteria static characteristics are set of criteria that are used to describe the quality of measurement, when you measure the quantity that is constant or changes very slowly with time. The quantity that you are measuring either remains constant or changes very slowly, so under such condition or under static environment, the set of characteristics that you use to evaluate the quality of the measurement will be known as static characteristics.

Similarly dynamic characteristics attributes associated with dynamic measurement, so the formal definition will be the set of criteria that are used to describe the quality of measurement, when you measure a quantity that is rapidly varying with time.

So, again note this line, the dynamic characteristics are set of characteristics which we must use to describe the quality of measurement when the quantity being measured is not stationery, the quantity being measured very rapidly with time so this is under dynamic environment. So, static characteristics are set of characteristics which you will use to evaluate the performance of instrument under static environment. So, the quantity being measured does not change with time there and dynamic characteristics are those

characteristics which we must consider to judge the quality of measurement, when the instrument is being used to measure a quantity which rapidly vary with time, so under dynamic environment.

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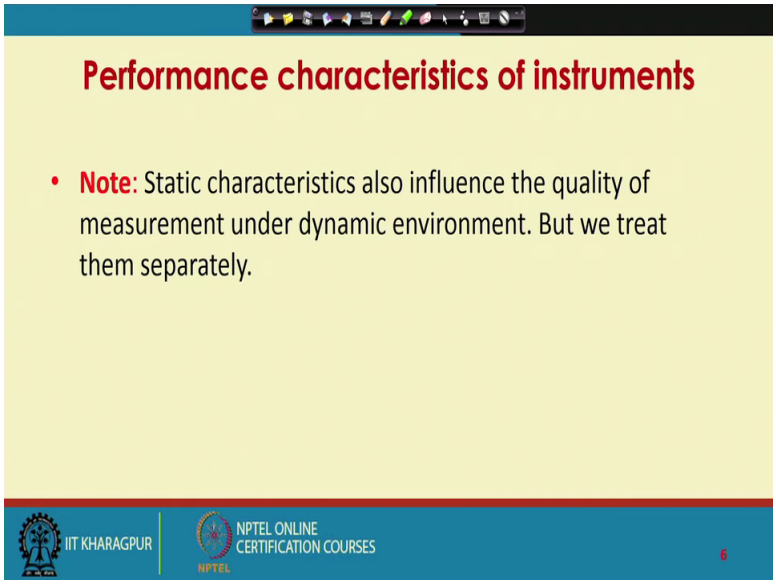

So, the question you can ask now is does static characteristics influence the quality of measurement under dynamic environment, the answer is yes; static characteristics also influence the quality of measurement under dynamic environment, it is not that the static characteristics we will not influence the quality of measurement under dynamic environment, we treat them separately we treat static characteristics and dynamic characteristics separately, but the static characteristics will also influence the quality of measurement under dynamic environment.

So, the both the characteristics are important to evaluate the overall performance of an instrument, but for ease of analysis we treat them separately, dynamic characteristics are easily described by set of differential equations for linear instruments. That means, for instruments which has a linear relationship between input and output these differential equations will be linear differential equations, often times they are ordinary linear differential equations for simples instruments or simple situations.

Now it is not very difficult to solve ordinary linear differential equations for a given input to get output, I am talking about mathematical analysis of an instrument. So, since dynamic characteristics can be analyzed by solution of ordinary linear differential

equations it is analysis is not very difficult, but static characteristics are more non-linear in nature and they also show up as statistical effect.

Now if I incorporate the static characteristics into dynamic characteristic; that means, if I incorporate those nonlinearity that are present in static characteristics or statistical effects into the otherwise linear differential equations, that represent dynamic characteristics the overall system will be much more complex to handle. So, for simplicity we treat static characteristics and dynamic character separately. Then instead of making a quantitative superposition we can superimpose qualitatively the effect of static characteristics on to the dynamic characteristics, so that will give me the overall picture.

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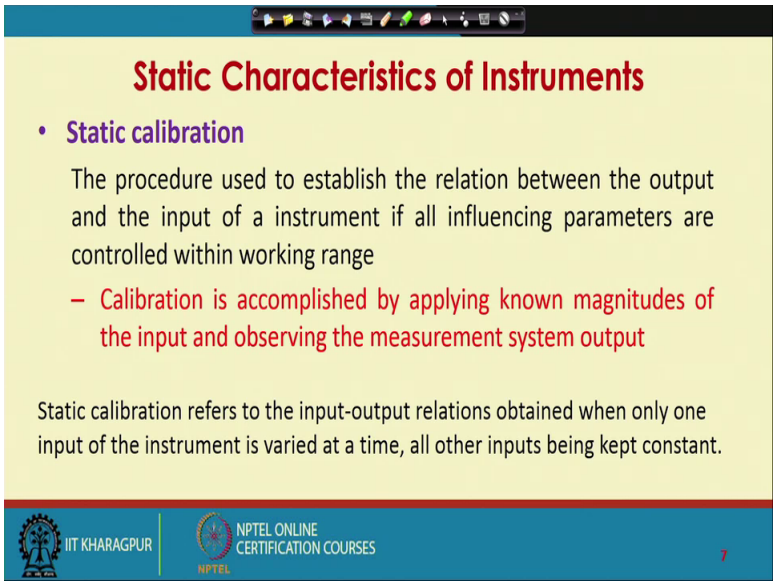

Now, let us talk about something called static calibration. The procedure used to establish the relation between the output and the input of an instrument, if all the influencing parameters are controlled within working range. Basically static calibration is a procedure used to establish the relation between the output and input of an instrument, when all the influencing parameters are controlled within working range. So, by calibration we use to establish a functional relation that exist between input and output and this is done for all the influencing parameters can be controlled within the working range and over these range these calibration will be valid.

So, calibration is accomplished by applying known magnitudes of the input and observing the measurement systems or instruments output. So, we will introduce known

magnitude of the input to the instrument we will observe and record the instruments or measurement systems output and from this known input out. And the instruments output, we can establish the calibration or the functional relationship that exist between input and output; static calibration refers to the input output relations obtained when only 1 input of the instrument is valid at a time all other inputs being kept constant.

So let us define formerly as follows static calibration refers to the input output relations obtained, when only 1 input of the instrument is varied at a time and all other inputs are being kept constant. So, how do I establish this functional relationship or how do I calibrate an instrument? How do I obtain the static calibration?

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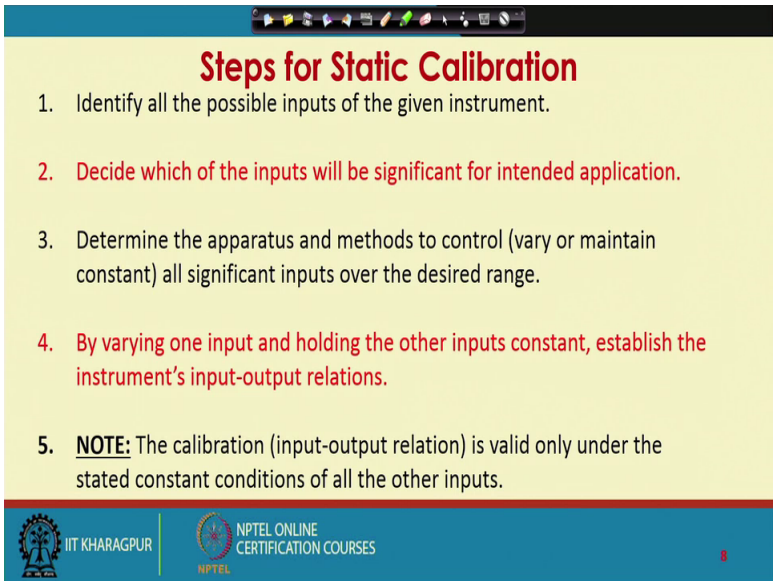

So, let us talk about the steps for static calibration, first for the given instrument let us identify all the possible inputs for the given instrument, whose static calibration we want to establish.

Next decide which of the inputs will be significant for intended application. So, first identify all the possible inputs, then decide which of the inputs are more significant; determine the apparatus and methods to control that means vary or maintain constant, all significant inputs over the desired range since the static calibration will require the variation of 1 input, while all other inputs are being kept constant we have to identify an adopt method such that we can vary or keep constants this signifying inputs over a desired range.

So, you have to identify the range and you have to adopt suitable method, so that we can vary or keep constant these significant inputs, by varying 1 input and holding the other inputs constant establish the instruments input output relations. So, now you vary 1 input and hold all other inputs constant and then establish the instruments input and output relations this input output relations can be an equation, it can be a graph which presents the relationship between input and output using a straight line or using a curve will see soon.

So, there are different ways of expressing this calibration, you can either be in terms of graphs you can also in terms of equation, often times they are simple graphs their equations also and also sometimes they presented in the form of a table. So, there are various ways of presenting calibration, but the purpose is same everywhere to establish the functional relationship between input and output, let us note that the calibration got this input output relation that you have obtained is valid only under the state at constant conditions of all the other inputs.

So, the calibration should be used only under the state at constant conditions of all other inputs. So, there will be range over which this calibration will be working.

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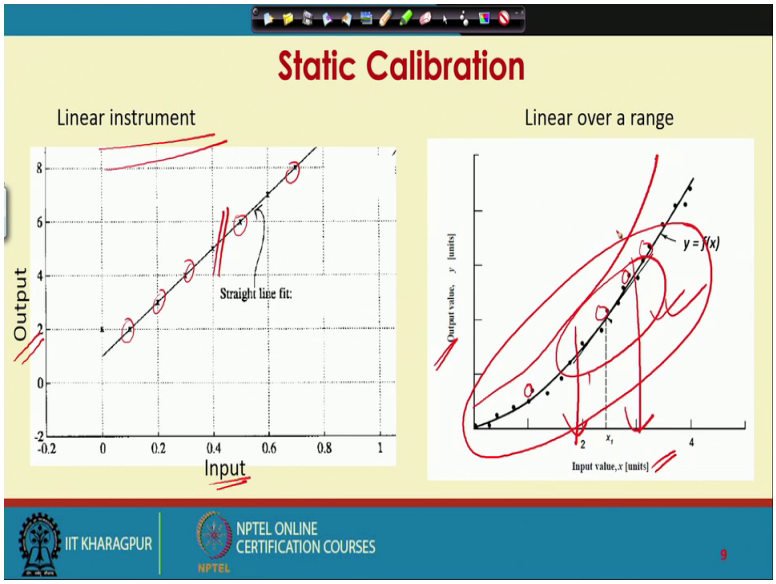

So, let us now look at few examples you have done experiments or you have followed the steps, that we just talked about to obtain the functional relationship between input and output for an instrument let us say and then these are the; let us say the experimental

points and you see that you can draw a nice straight line through most of these experimental points and this is the straight line that has been drawn. So, we say here that linear relationships exist between input and output and we also call the instrument as linear. So, if the functional relationship between input and output is linear, it has distinct advantages because this interpolation and extrapolation becomes extremely easy and reliable.

Let us think of another instrument these filled circles at experimental points and you see that you can not exactly draw a straight line between these input values and output values, but a slightly non-linear curve is fitted. So, the instrument is non-linear to some extent, but if I look at here you see the instrument is kind of linear over the small range, so in this range the instrument behaves like a linear instrument. So, what this range the relationship is linear calibration is linear, but if I talk about these range this instrument is not linear over the entire range.

So, may often times we try to make use of those properties or principles which will give me a linear relationship between an input and output. In other words the principles of measurements will be chosen such that I can obtain a linear instrument that may not be possible always, but if it is done you will get a linear instrument you will get a linear calibration and interpolation and extrapolation will be much easier.

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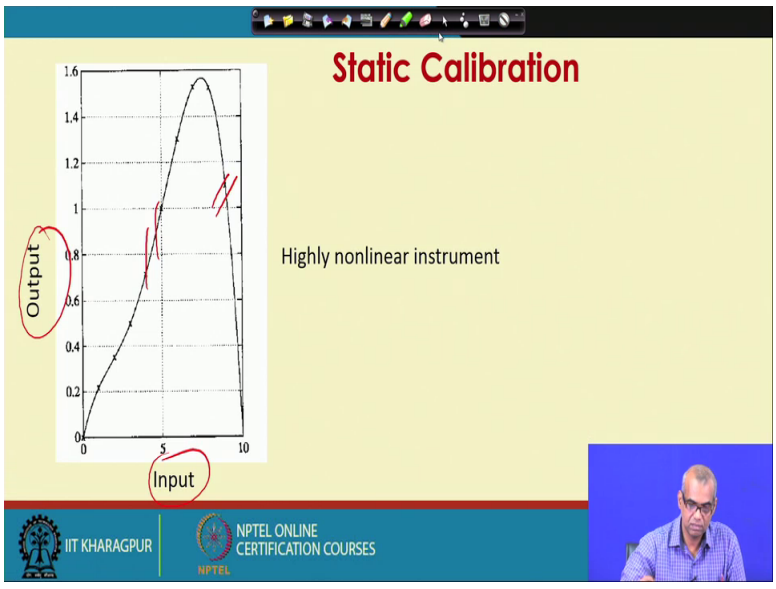

If you look at here so this is the relationship between input and output which is extremely non-linear in nature. So, this is a highly non-linear instrument, so extrapolation and interpolation is not very simple here compare to linear instruments.

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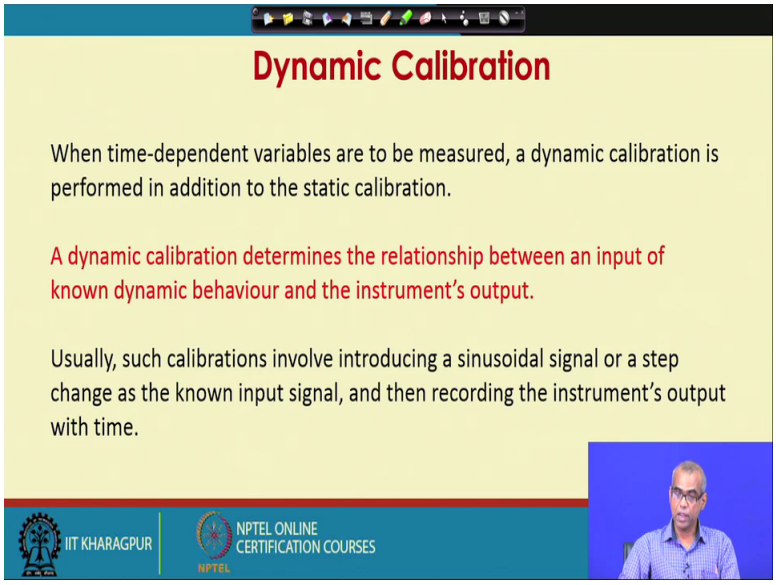

Similar to static calibration we also have a dynamic calibration. When time dependent variables are to be measured, a dynamic calibration is performed in addition to the static calibration. A dynamic calibration determines the relationship between an input of known dynamic behavior and the instruments output. So, dynamic calibration determines the relationship between an input of known dynamic behavior and the instruments output.

Usually, dynamic calibrations involve introducing a sinusoidal signal or a state change as the known input signal and then recording the instruments output with time. So, dynamic calibrations will require you to introduce either a sinusoidal input or a state change and then we record the instruments output with respect to time. So, there are both static calibration and dynamic calibration.

We will stop here, for this lecture 6 and we will continue for lecture 7 in the next class.