Chemical Process Instrumentation
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Lecture - 01
General Principles and Representation of Instruments

Hello. Welcome to the course on Chemical Process Instrumentation. My name is Debasis Sarkar, I am an Associate Professor in Chemical Engineering Department of IIT Kharagpur. In the title chemical process instrumentation the term instrumentation refers to measuring instruments. So, essentially we will be talking about measuring instruments and we will be talking about those instruments which are used to measure important process variables in chemical process industries. As students of chemical engineering discipline or alloy discipline you know the importance of process variables such as temperature, pressure, flow rate level etcetera.

Let say temperature you know the temperature heavily influences the conversion that you get from a reactor. In case of say fixed bed reactor there is no fixed temperature in the bed there will be a temperature profile, but it is important to know that the temperature cannot exceed the hotspot temperature; that is the hotspot temperature define for that catalytic fixed bed. So, it is important to be able to measure temperatures. Similarly pressure is another important process variable. There are several types of pressures: there are high pressures, there are low pressures, there are intermediate level pressures. High pressures like we have storage tanks at very high pressures, so you should be able to measure those high pressures.

That back home distillation operations which operates at low pressure. So, you should be able to measure low pressures, lower than the atmospheric pressures sometimes we are required to measure extremely low pressures or you call them high vacuum measurement. Similarly there are lots of applications which are intermediate level pressures. So, since there are different types of pressures or ranges of pressures there will there cannot be a single instrument or there cannot be a 2 3 instruments which will serve the purpose of all measurements. So, we will have instruments specific for measurement of high pressure, will have instruments specific for measurements of high vacuum and

will have instruments for measurements of intermediate level pressures similar things will also happen to flow measurements level measurements etcetera.

There are other important chemical process variables such as p h, then will have the say density so on and so far. So, this course is spread over 30 hours, so we will have 60 lectures of 90 minutes and at the end of this course, you will be able to understand the working principles for temperature measuring instrument, pressure measuring instruments, flow measuring instruments, level measuring instruments and so on and so far. We will not be able to cover each and every instrument, but will definitely cover the most commonly used instruments in industries or in laboratories.

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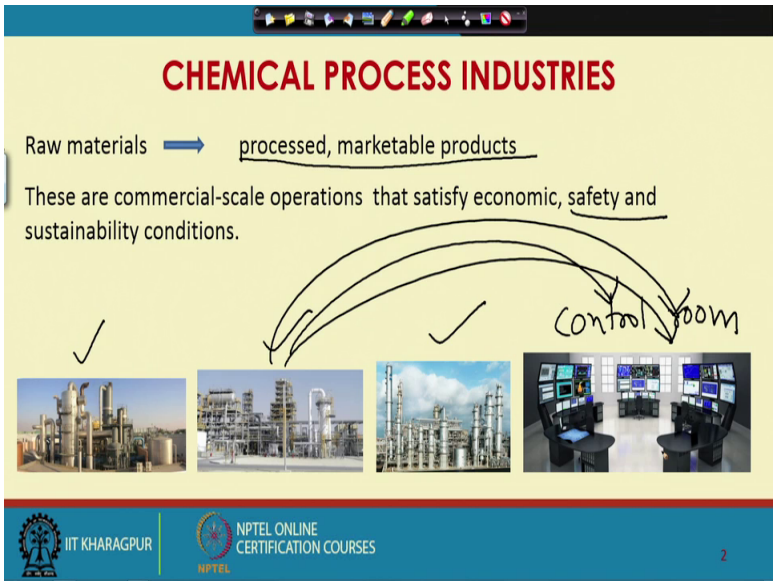

So, what do you mean by chemical process industry? See broadly speaking in a chemical process industry, we convert raw materials into processed marketable products; remember these are large scale operations. So, these are commercial scale operations and these operations must be economic, otherwise not will invest operations will be safe and sustainable. So, these are some typical pictures of various chemical process industries in general there will be series of unit operations, very complex network of chemical reactions and operations.

So, there will be lots and lots of measurements of various chemical process variables, this is a typical photograph of a control room. So, this is here see for this industry if this is the control room for this industry all the process variables not all mostly all will come

to this control room, because each and every operation in this industries has to be monitored. So, that operation is as desired and safe this cannot be done by human being. So, we need instruments to do that for us.

So, there will be various instruments hundreds and hundreds of instruments measuring different process variables of interest and will send the information about what they have measured to the control room, the control room will analyze those signals and take appropriate action if necessary.

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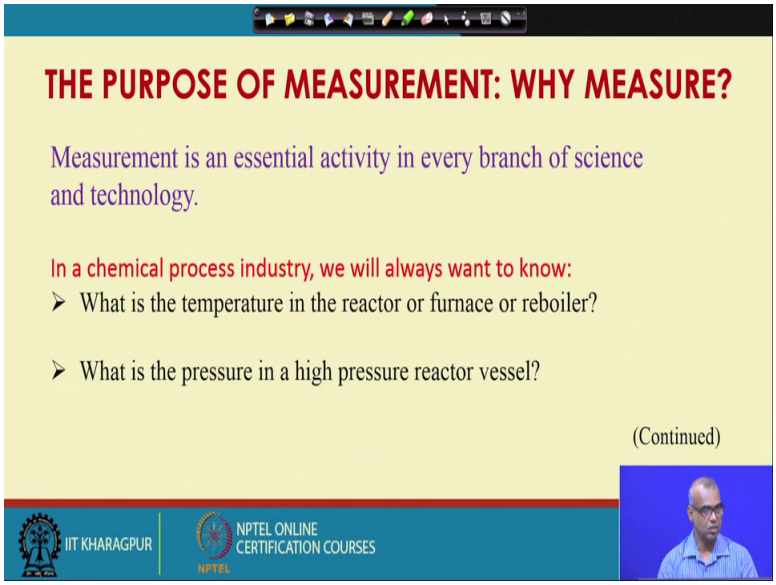

So, what is the purpose of measurement, in other words why should we measure measurement is an essential activity in every branch of science and technology, in a chemical process industry if you work you will see that you are always asking yourself or somebody else is asking you, what is the temperature in the reactor at this time or what is the temperature at the furnace or what is the temperature at the reboiler? What is the pressure in a high pressure reactor vessel? It is important to know because the temp the pressure in the high pressure reactor vessel must not exceed the specified limit, otherwise it we can face a hazardous situation.

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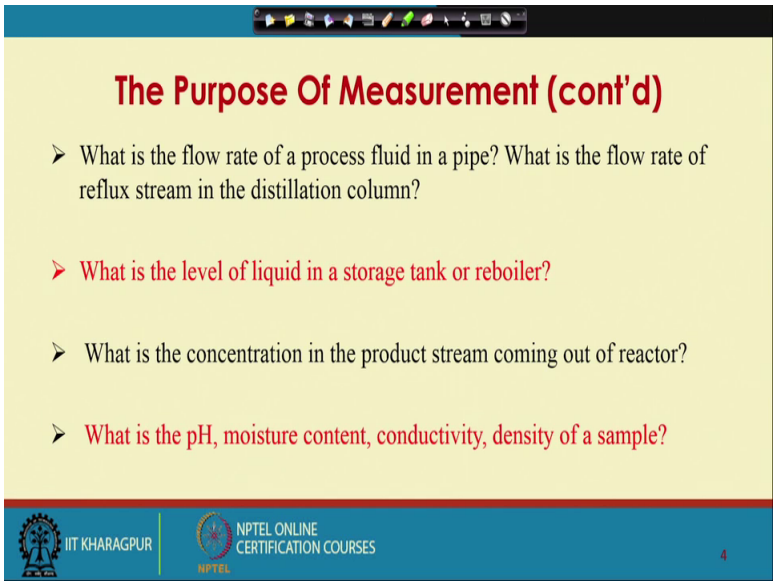

What is the flow rate of a process fluid in a pipe? What is the flow rate of reflux stream in the distillation column? You know distillation column is an extremely important separation process in chemical process industry and using reflux stream we can have a control on the purity of the product that comes from the top of the distillation column. So, it is extremely important to manipulate the flow rate of the reflux stream.

So, to be able to manipulate a flow rate you must be able to measure the flow rate of the reflux stream in a distillation column. So, you need a good flowable flow measuring instrument. Similarly what is the level of liquid in a storage tank or reboiler, it is important to know the level of liquid in storage tank otherwise it can overflow or it can even run dry, if there is drainage from the tank. Similarly for reboiler there has to be a definite level maintain in the reboiler of a distillation column. So, you should know the level of the liquid in the reboiler.

What is the concentration in the product stream coming out of the reactor, it is important to know the concentration of the product that is coming out of the reactor because there is a basic purpose with which you are carrying out the reaction, and you are carrying out a reaction in a reactor to meet certain conversion. So, by analyzing the concentration of the product stream, you know that whether you are meeting your target or not. So, you should be able to measure concentration, remember concentration measurement is not very easy particularly when it comes to online measurement of the concentration, later

on we will be talking about some concentration measurement in this class. So, what is the pH moisture content conductivity?

Density of a sample, so this a if you summarize you see that the most commonly encountered process variables in a chemical process industries are temperature, pressure, flow rate, liquid level concentration, conductivity, moisture content, pH, density so on and so far. So, in this class we will be talking about some of the important instrumentation that are used to measure these process variables. Since one major objective of measurement is to have a control over the process will also be talking about those instruments whose output can be useful for the purpose of measurement we will be talking more about this soon.

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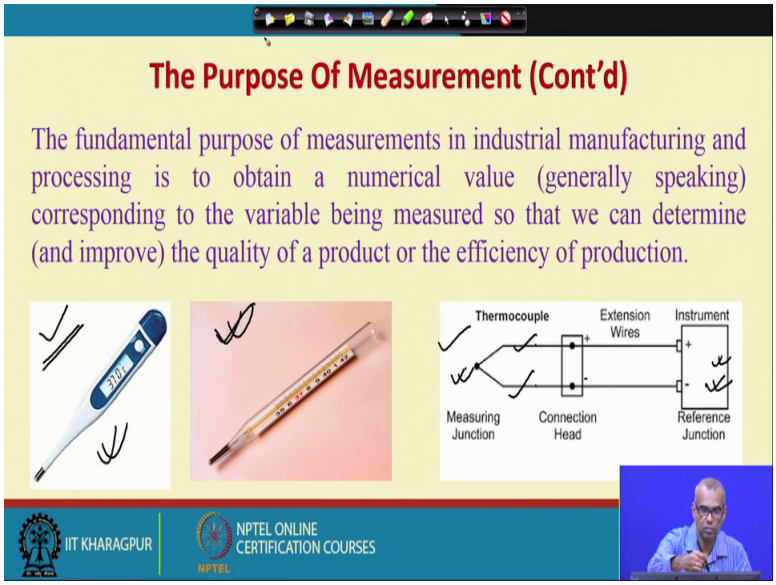

So, to summarize the fundamental purpose of measurement in industrial manufacturing and processing is to obtain a numerical value, generally speaking corresponding to the variable being measured. So, that we can determine and improve the quality of a product or the efficiency of the production. So, the fundamental purpose of a measurement in industrial manufacturing or processing is to obtain a numerical value to the variable that is being measured, see numerical value is always important.

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Let us look at here we have 3 different temperature measuring instrument, this one you are familiar with it is a digital clinical thermometer, this can be used to measure body temperature. This is also a clinical thermometer which can be use to body temperature similar glass ordinary mercury in glass thermometer you must have also seen in your laboratories, this is another temperature measuring instrument which is known as thermocouple.

Now let us look at here, say if I have fever I can say my temp fever is high or my fever is not so high, but instead of saying that if I say that I have temperature 38 degree Celsius or if I have 39 degree Celsius, it will give me a better indication of the degree of fever I have. So, it is important to assign a numerical value to the variable that as I measuring, this 3 figures also show that there are all are temperature measuring instruments, but definitely this 1 or this 1 you will not use to measure say the temperature of a reactor say industrial reactor.

But thermocouple which will talk about in more detail later will be used for measurement of temperature in industrial operations. So, this gives you an in this is a being at digital thermometer gives you an indication in terms of digit directly, say body temperature 37 degree celsius or 38 degree Celsius. Look at here there is a graduated scale attached here and you can read the mercury level from this graduated scale and that is an indication of the temperature, similarly thermocouple works on a principle which is as follows.

You take 2 dissimilar metals and forms 2 junction, this is one junction and there is one junction here; now if these 2 junctions are kept at 2 different temperatures and EMF is produced within the circuit and this EMF is a measure of the temperature, that EMF can be measured using a millivoltmeter because that EMF is in the range of millivolt. So, from this millivolt, I can correlate the temperature of the medium which is being measured by this so here also this millivoltmeter will give you a number a numerical value to the temperature. So, it is important to obtain a numerical value corresponding to the variable being measured. So, that we can determine the quality of the product on the process and also can improve the quality of the product or efficiency of the process.

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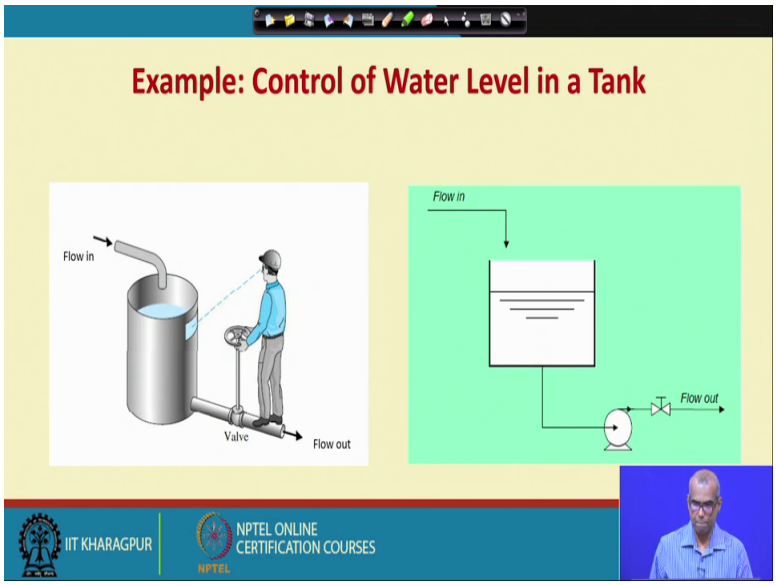

Let us look at a simple example a control of water level in a tank, think of a very simple task you have this tank to which lets say water is flowing in through this and water flows out through this pipe and you have a valve here, now you stand here look at the level of water in the tank and let us say we have decided that you maintain a certain level of water in the tank.

Now you look at the level in the tank if the level is more than the desired level, then we have to open the valve more. So, that more of liquid more of water goes out and the level comes down. Similarly if the level is less than the desired level then less amount of water should go out from this pipe so you have to close the valve. So, by continually by continuously manipulating this valve it will be possible to maintain the level of this water in this tank to the desired level. So, this is schematically presented here.

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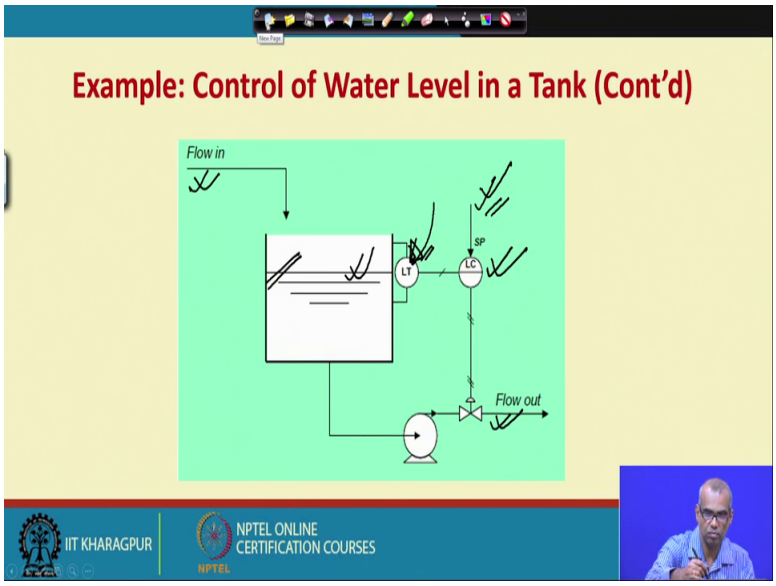

Now, this is how it can be done automatically, instead of manually someone was doing someone is continuously manipulating the con valve a level control can be introduced and the task of controlling the water at a desire level in the tank can be achieved. So, the water comes in flows in through this pipe, look at here there is something called LT this is level transmitter. So, it is essentially is a level measuring instrument. So, please note that to have a control of the water level in the tank, the first thing that we need to know is; what is the level of the water in the tank currently, because if the water in the tank is at the desire level you do not have to do anything.

But if the water in the tank is not at the desire level whether it is more than the desire level or lower than the desired level, we have to take some corrective action. So, the first thing that you need to know you need to do to take a control action is to know; what is the value of the water level in the tank right now. So, this will be done by a level measuring instrument. So, an instrument takes one of the most important place in the entire control room because, this first receives information about the status of the process whether you need to take any control action or not, so the level transmitter is a level measuring instrument receives the information about the level in the tank and then this sends the signal to a level controller.

The level controller has been fit with the desired set point that is the desired level. So, it compares the level controller compares the desired level and the measured level and

accordingly it either increases the flow rate or decreases the flow rate to maintain the level of the water in the tank at the desired level. So, what we note here is that a measuring instrument takes up very important place in the control room.

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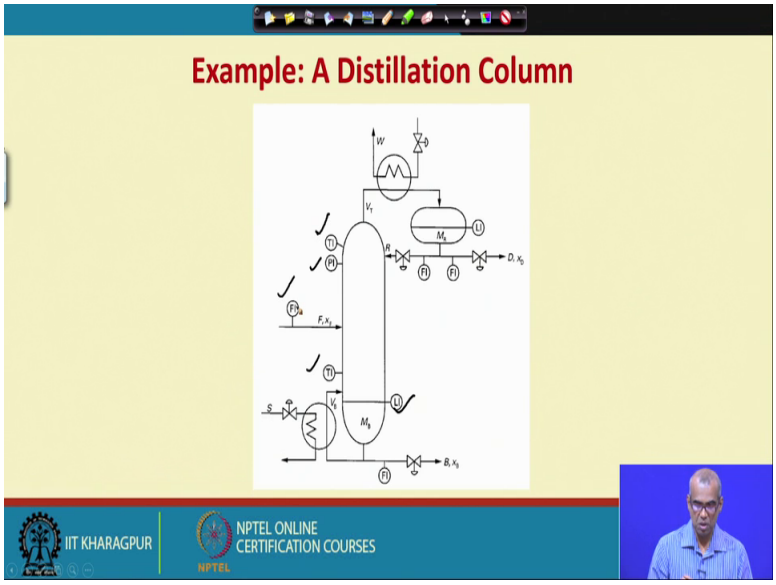

Let us take a look at distillation column. So, distillation column as we just mention that one of the most important separation process in chemical process industry, is a very old and well established process there are many new separation technologies in place that even now distillation column are widely used for separating a liquid mixture, it can separate a binary mixture it can separate a multi component mixture as well.

In the most simplest distillation column you have a feed stream it is containing liquid mixtures, which enters the distillation column somewhere in the middle of the distillation column and you have a reboiler at the bottom of the distillation column and a condenser at the top of the distillation column. So, the feed enters the distillation column it is vaporized, the heat is supplied by the reboiler here. So, the more volatile component of the mixture goes up and the vapor that comes out from the top of the distillation column is richer in more volatile component.

So, using a condenser the vapor is condensed it is collected in a reflux drum, some part of the reflux from the reflux drum is paid back to the distillation column as a reflux team and some part is taken out as product; similarly from the bottom of the distillation column the less volatile component comes out, now look at this distillation column

closely 1 more time all the symbols that you see TI PI FI LI they are all measuring instruments. For example, F I stands for a flow indicating instruments, PI stands for a pressure indicating instrument a TI stands for temperature indicating instrument L I stands for level indicating instrument and so on and so forth.

So, even in the simplest case imagine the number of instruments that will be there in a typical distillation column. The actual number will be much more for an industrial scale operation. The reason I want to show you this is if you look at it carefully, you will see that temperature pressure flow level all in all such instruments are required here, and temperature pressure flow level are the most commonly encountered process variables in chemical process industries. So, at the end of this course you will know more about these instruments.

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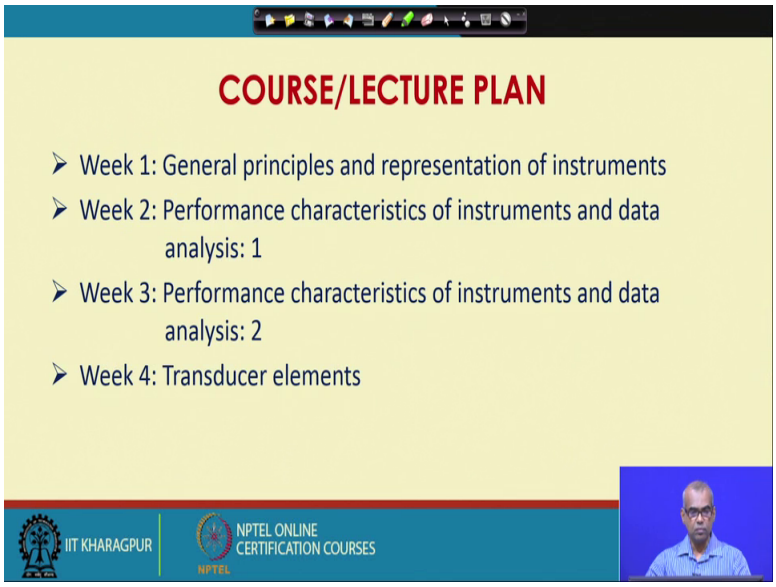

So, let us now talk about the course or lecture plan in the week 1 will talk about general principle and representation of instruments, in week 2 and week 3 we will talk about performance characteristics of instruments and data analysis.

So, will try to understand how to analyze the performance of one instrument over another, and we will also try to learn some basic data analysis procedures in week 2 and week 3. In week 4 will talk about the transducer elements; the transducer elements are those elements which will receive the signal in 1 physical form and send output as in another physical form.

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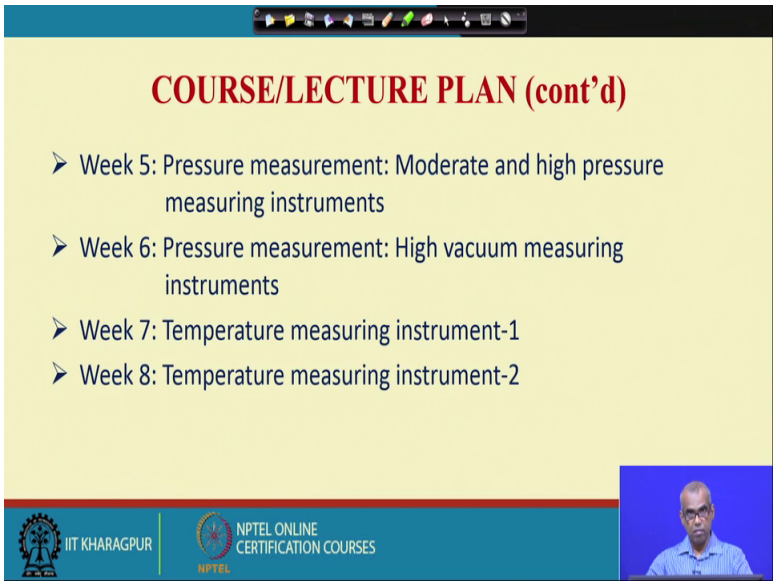

So, we will talk about several important transducer elements in week 4. In week 5 we will talk about pressure measurement. Since we have moderate pressures, we have high pressures; we have very low pressures will talking we will be talking about pressure measurement in week 5 and week 6.

In week 5 we will talk about moderate and high pressure measuring instruments and week 6 will be talking about high vacuum measuring instruments. Similarly we will be talking about temperature measuring instruments in week 7 and week 8.

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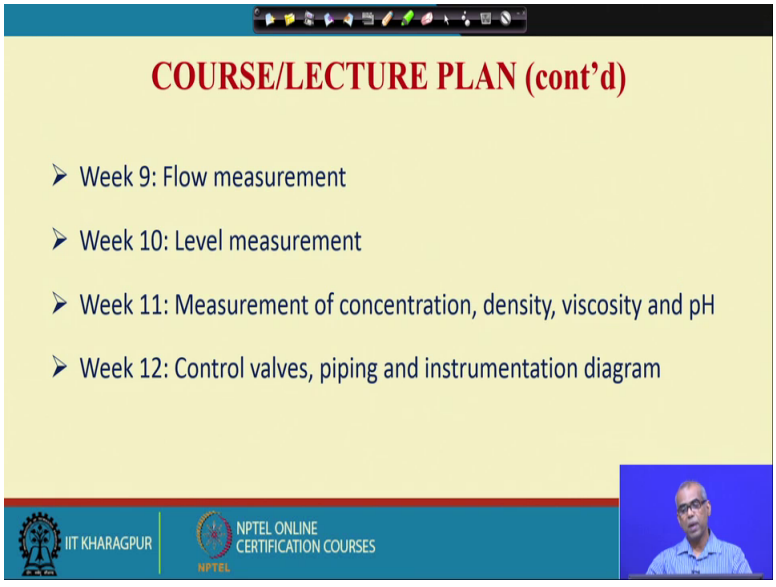

Week 9 we will be talking about various flow measuring instruments that are available, and you should be familiar with. Week 10 will be talking about various level measuring instruments. In week 11 we will talk about concentration measurement, density measurement, viscosity measurement and pH measurement. And finally, in week twelve we will talk about control valves and piping and instrumentation diagram pipe and instrumentation diagram is something like a process diagram with all the instruments that are used are indicated in that diagram. So, at this end of this course you should be able to analyze a piping and instrumentation diagram as well.

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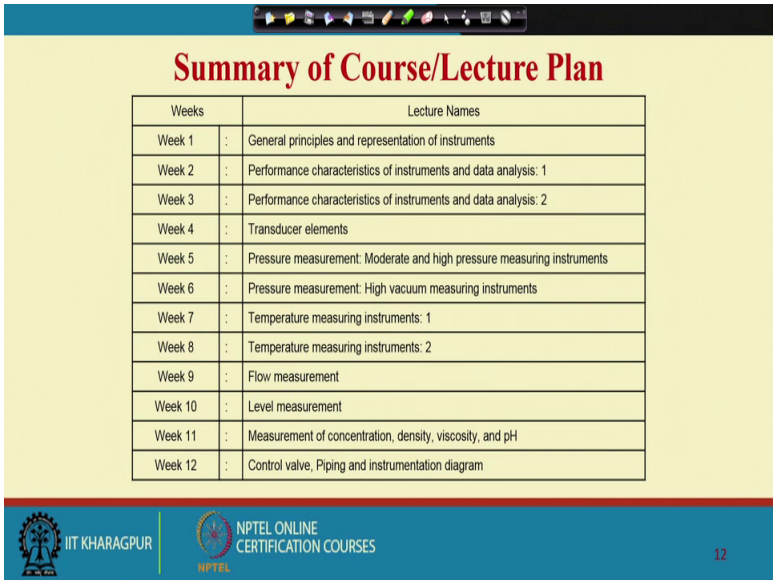

So, this is the summary of the course plan that we just discussed.

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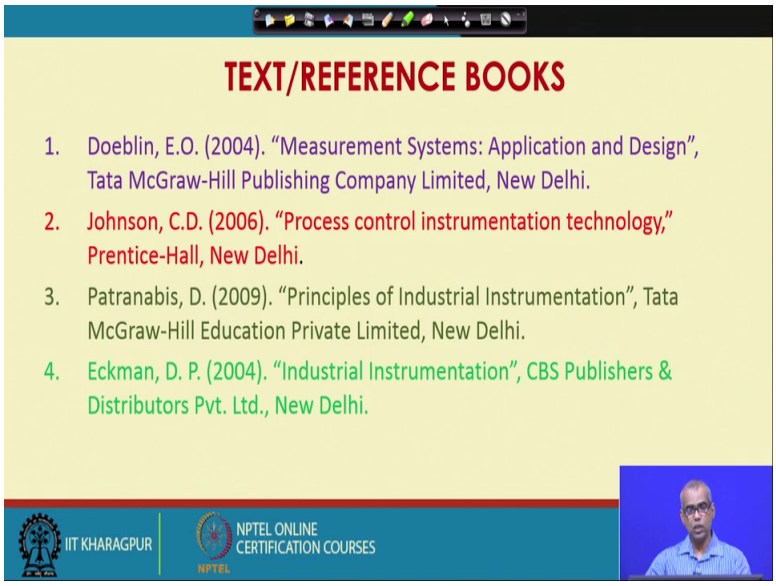

These are the textbooks Doeblin is a very good book measurement systems applications and design you can also look at Johnson process control instrumentation technology patranabis is another good book principles of industrial instrumentation, Eckman is another good book industrial instrumentation.

So, any of these books will do.

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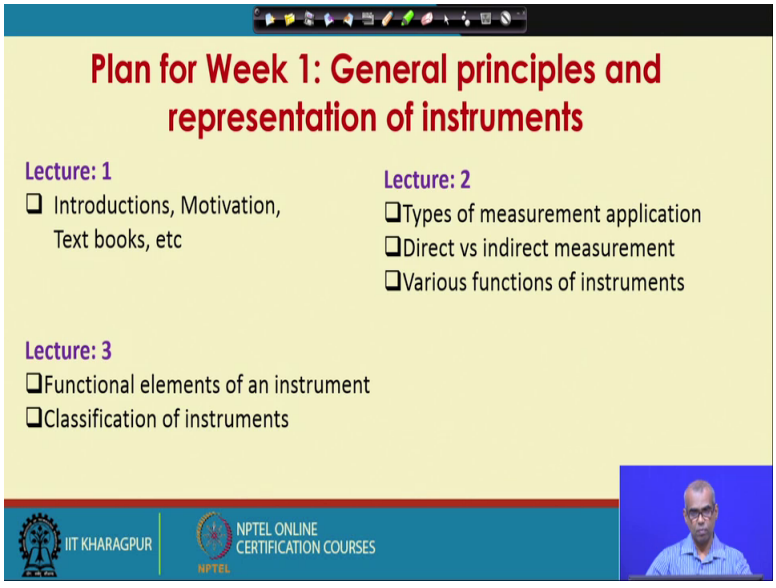

So, now the quickly plan for this week 1 the lecture 1 the current lecture we essentially talked about some introduction motivation course plan, text books etcetera. In lecture 2

will talk will be talking about types of measurement applications, direct measurement versus indirect measurement and various functions of instruments. Lecture 3 will be talking about an important concept known as functional elements and will also be talking about how to classify various instruments.

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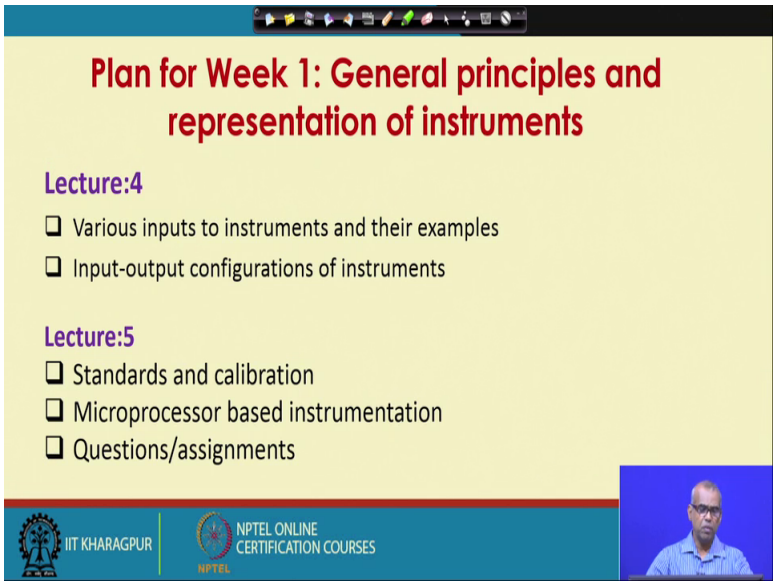

Lecture 4: we will be talking about various inputs to the instruments and their examples, such as desired inputs interfering inputs, modifying inputs etcetera. And we will also be talking about input output configurations of instruments, what are the influence of interfering input when the instrument is actually want to measure the desired input. Such issues will be talking about in lecture 4. And finally in lecture 5 we will be talking about standards and calibrations; briefly will catch up on microprocessor based instrumentation, and there will be questions and assignments for this week.

So, I will stop this lecture here, and we will continue in the next lecture.

Thank you.