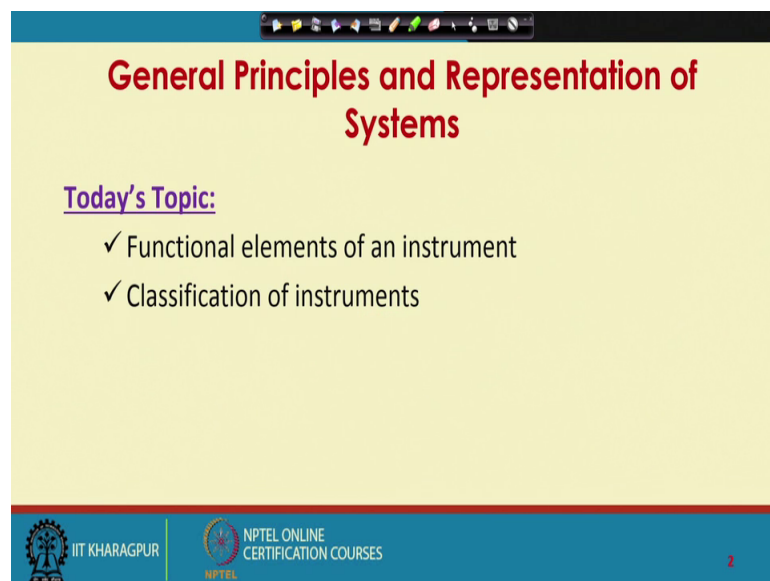**Chemical Process Instrumentation**
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Lecture - 03
General Principles and Representation of Instruments (Contd.)

We have been talking about general principles and representations of instruments for last 2 lectures lets continue with lecture 3.

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So, in this lecture we will introduce an important concept called functional elements of an instrument, we will try to see how this functional elements can be used to break down an instrument and analyze the functions of the inter instrument.

We will also see how to classify various instruments, there are various considerations and depending on these considerations instruments can be classified in various manners. So, we will see some of those ways to classify various instrumentation.

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First let us talk about functional elements of an instrument, all instruments contain various parts that perform specific functions in converting a variable quantity to a corresponding indication, any instrument and its operation can be described in terms of such functional elements. So, the question we ask is how to identify these functional elements, now let us look at these various instruments, this is a ordinary mercury in glass temperature measuring instrument.

This is another temperature measuring instrument which is the thermocouple and this is a pressure measuring instrument and what do you see is pointer and scale and if you take out this dull most likely you will see inside is this which is known as bourdon tube. So, these basically is inside this let us say, now the question you ask here is there are various types of instruments, there are various temperature measuring instruments, there are various pressure measuring instruments, there are various flow level measuring instruments so on and so forth.

Now, if I look at this instruments with the view towards generalization is it possible for us to identify certain elements in the instrument which does similar functions. So, I repeat let us look at these various instruments with a view toward generalization, the question we ask is, is it possible to divide this instruments or break down this instruments into several components and these components do similar functions in while presenting various instruments. So, if I take, if I look at this temperature measuring

instrument and this temperature measuring instrument and this pressure measuring instrument. So, I have 2 temperature measuring instrument and I have one pressure measuring instrument we should look at here in fact.

Now, is there something common is there common elements in these instruments, common in terms of functions they do or they perform not by their look or appearance for example, let us try to understand how we measure temperature using this mercury in glass thermometer, you must have measured temperature of your body using such a thermometer or another mercury in glass thermometer perhaps you have used in your laboratory for measuring temperature of liquid.

Now, what you do is you dip the bulb containing mercury to the medium whose temperature you arr measuring, suppose you are measuring the temperature of some water taken in a glass. So, I put the thermometer bulb into the medium; that means the glass of water, now what happens is the mercury receives thermal energy from the medium undergoes restricted expansion. So, there will be expansion of volume of mercury a pressure will be developed and the mercury will go up in the capillary and will finally, rest at a point and that point will be taken as a measure of temperature from the graduated skill attached to it.

So, what was the first step, there was this bulb in the mercury which first interacted with the medium whose temperature I am measuring, now let us look at the thermocouple, thermocouple is made of 2 junctions. So, it take 2 dissimilar metals and take 2 junctions out of it, 1 junction we call hot junction or measuring junction another junction we call as cold junction or reference junction now if these 2 junctions are kept at 2 different temperatures and e m f will be produced and that e m f is the measure of the temperature difference between these 2 junctions.

Now, if one of the reference junction is kept at a constant temperature then the e m f produced becomes the function of temperature at the measuring junction alone. So, to measure temperature by a thermocouple what you do is we bring the medium in contact with the hot junction of the or measuring junction of the thermocouple.

So, thermocouple receives measuring junction of the thermocouple first receives information about the temperature of the medium. So, the mercury in the bulb incase of mercury thermometer and the measuring junction of the thermocouple are essentially

doing similar function. So, they are functional elements, they may look different, but they are doing similar job. So, we call such elements as functional elements similarly there will be a component in a pressure measuring instrument which will first interact with the medium whose pressure and measuring and again that will be the functional elements for the pressure measuring instrument.

So, in all instruments whether it is a temperature measuring instrument or pressure measuring instruments or whatever, there will be a component which will first interact with the medium whose quantity is being measured and that component will be known as primary sensing element, we will talk about bourdon tube more later, but for the time being let us briefly talk about as follows.

So, bourdon tube is basically a metallic tube like this. So, you first take a tube with circular cross section, then flatten the tube to make the cross section electical and then, then seal one end and then bend the tube with electical cross section in the form of a sea. So, this and this seal and this and this free and this and this rigidly hold and when pressure is applied inside this tube this part is same as this. So, this part tries to regain into original circular cross section and while doing, there will be a movement of this teap of the wooden tube. So, this teap deflection is a measure of the pressure.

So, once again I repeat a bourdon tube is as follows you start with a tube with circular cross section then flatten it diametrically. So, that the cross section becomes elliptic, now then you seal one end now bend the tube which has now elliptic cross section in the form of a sea the free end you now hold it tightly and let the pressure be applied inside this bourdon tube, now if we do this that bourdon tube will try to regain its original cross section. So, which is circular cross section while doing so there will be deflection of the teap of the wooden tube and this teap deflection is a measure of the pressure that is been applied into it.

Normally a point, a pointer and scale will be attached to the teak of the bourdon tube using a gear and linkage system. So, that teap reflection can be rate by the movement of the pointer against the scale and that will be a measure of the pressure.

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Functional Elements: A Pressure Thermometer
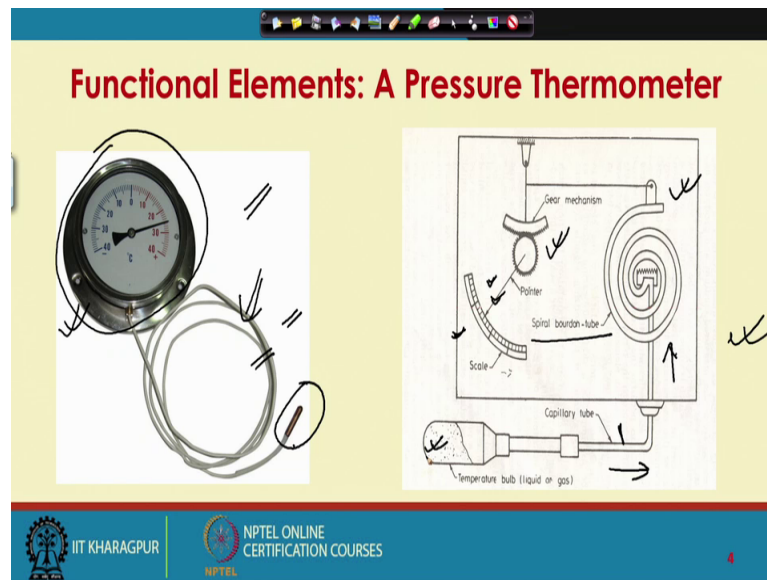
So, now let us take an example, this is an example of pressure thermometer you have a bulb here and then you have this dial here and inside this dial we have either the sea type bourdon tube that we have just talked about or you have a spiral type bourdon tube which is very much similar to this in function which is similar to the sea type bourdon tube.

Now, this is connected by this one end of the spiral bourdon tube which is inside this is connected to this bulb through this tube, now this can be schismatically represented by this. We have this bulb, then we have this tube which is this and then tube is connected to this bourdon tube. Now, with this bourdon tube you have a gear and linkage attached and to that we have this pointer and scale.

Now, how does it work? Inside the tube and the capillary and the bourdon tube is entirely filled with some liquid or gas, the bulb you put into the medium whose temperature you are measuring. So, the liquid inside the bulb receives thermal energy undergoes restricted expansion a pressure is developed that pressure is transmitted through this tube to the bourdon tube.
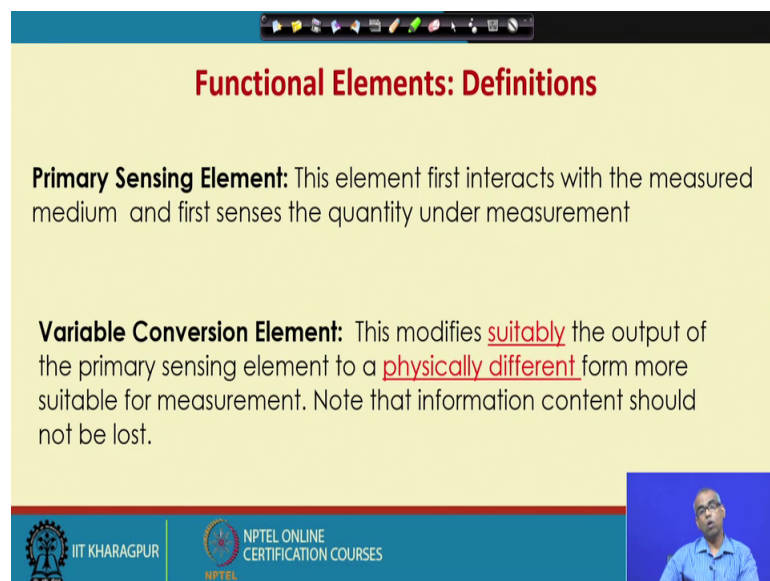
Now, this is same as pressure is being applied to the bourdon tube. So, a pressure is applied to the bourdon tube we know there will be a deflection of the teap. So, this teap will deflect because of the application of the pressure these teap deflection is magnified

by this gear and linkage system and we notice a deflection of the pointer against these scale.

So, deflection of the pointer against this scale is a measure of the pressure that has been developed inside the bourdon tube and that pressure is linked to the temperature to which the bulb has been put to temperature of the medium to which the bulb has been put. So, now, let us try to, now let us try to see whether it is possible to us to breakdown this instrument into several functional elements. So, we just said that there will be a primary sensing element which will first receive information about the quantity being measured, here we are measuring temperature.

So, and we element that first receives information about the temperature is the bulb. So, the bulb is my primary sensing element.

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So, there will be a primary sensing element and this element first interacts with the measured medium and first senses the quantity under measurement.

Now, there will be some output of this primary sensing element here what happens is the bulb is the primary sensing element the bulb receives the thermal energy and then undergoes restricted expansion so pressure is developed. So, it may be necessary to modify the output of the primary sensing element to a physically different form which is more suitable for the part of the measurement.
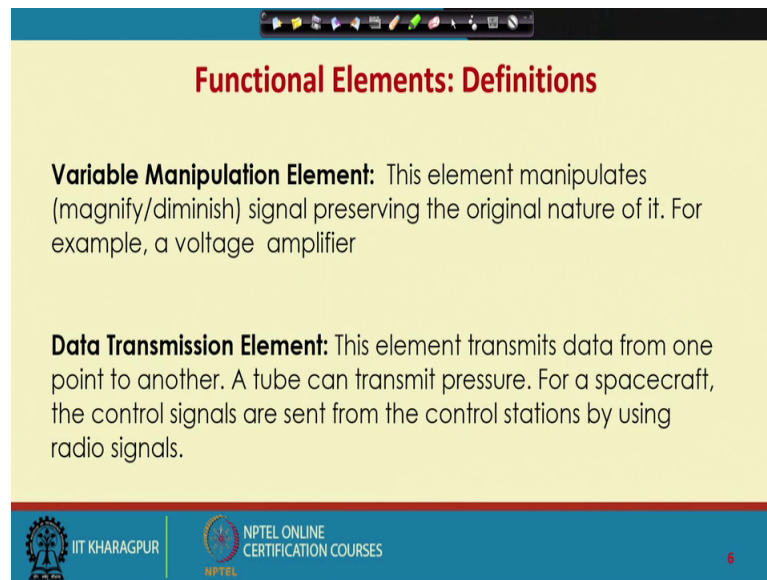
That is the role of a variable conversion element. So, first element is primary sensing element, second is variable conversion element why variable conversion element is necessary because the output of the primary sensing element may be in a form which is not suitable for the purpose of measurement. So, we may have to convert it to a form to a physically different form which is more suitable for the purpose of measurement.

Note that information content must not be lost, but we are changing the variable nature because the other form may be more suitable for the purpose of measurement, in this example the bulb is the primary sensing element, but the bulb also converts the temperature signal to a pressure signal because it is within the bulb that the fluid undergoes restricted expansion and the pressure is developed.

So, bulb serves the purpose of both primary sensing element as well as variable conversion element, next we may have something called variable manipulation element. Variable manipulation element what will what it will do is it will not change the physical nature of the signal, but it will either magnify or diminish the strength of the signal, most likely it will be magnify the signal it is like an electric amplifier.

What it does is the signal that is receives will simply be multiplied without changing the physical nature of the signal. So, the difference between variable conversion element and variable manipulation element is the variable conversion element changes the measure of the signal, the variable manipulation element does not change the measure of the signal, it simply changes the magnitude, it simply changes it simply amplifies it or sometime it diminish it as appropriate for the purpose of the measurement an example is the voltage amplifier.

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Then it may be necessary to transmit data from one point to another for example, in the case of pressure thermometer the variable conversion element and the primary sensing element both is played by the bulb.

Then the pressure is developed that pressure signal has to be transmitted to the bourdon tube. So, the element that does this is a tube. So, the tube plays the role of data transmission element. So, the data transmission element transmits data from one point to another in these example the tube transmits the pressure. So, it is a data transmission element, you consider a spacecraft the control signals are sent from the control station by using radio signals.

So, that is the much more complicated data transmission element and this is what I was talking about when I said that the functional elements does similar functions, they may be different in appearance they may be different in the complexity of the operations involved, but ultimately they do similar functions the tube is the data transmission element here and the sending signal from control stations to spacecraft using radio signal is also a data transmission step.

But both are completely different in terms of complexity involved in terms of their appearance and so on and so forth, but in terms of functions they are same. So, both are data transmission element.

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We may have a data storage or data presentation element in the instrument, data presentation element is the part of the instrument which presents data to the experimenter.

See the data will be presented in the form that appeals to any of the sales organs to the experimental, mostly we observe it we view it, but we can see hear it also say a doctors stethoscope, the doctor uses the stethoscope to measure your heartbeat, there it appeals to the audio sense of doctor. The doctor does not see it the doctor hears it, but mostly likely we look at the temperature measuring instrument we look at the temperature indicated by the instrument or look at the pressure indicated by the instrument. So, the data presentation element will present data to the experimentor in a form so that we can understand it.

Data storage element as the name suggests, it can store the data like computer or any unit which has memory it can store data, the data storage usually data presentation element let us drop this part from here and put it data presentation element like this and this element can be named as data storage or data play back element.

So, this stores data for future use which can be play back in futures such as computer and memory device. So, what you learned is that the following functional elements may be present in an instrument, first is primary sensing element which first receives information about the medium whose which has been measured, second variable conversion element

which will convert the output of say primary sensing element to a physicals physically different signal which is more appropriate for the purpose of the measurement. Next we can have a variable manipulation element which will change the amplitude of the signal which will not change the nature of the signal, then we can have a data transmission element which will transmit data from one point to another.

We can we will we may have a data storage or data playback element and we will have a data presentation element.
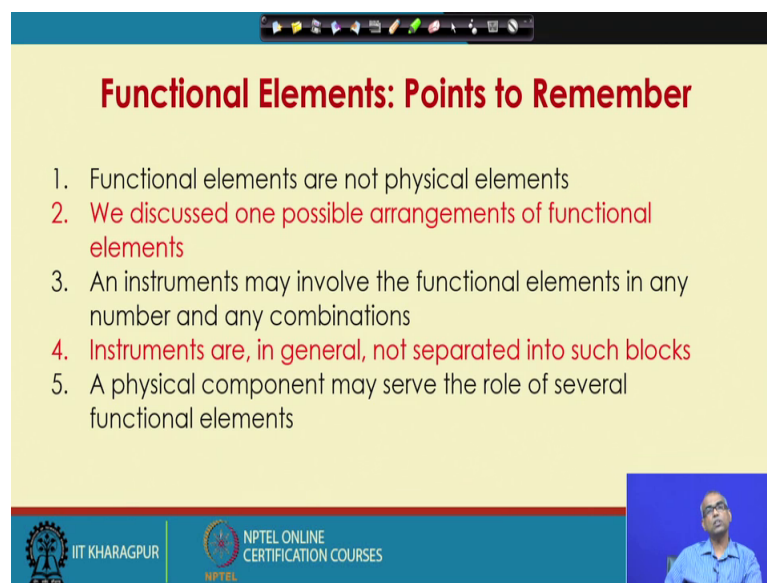
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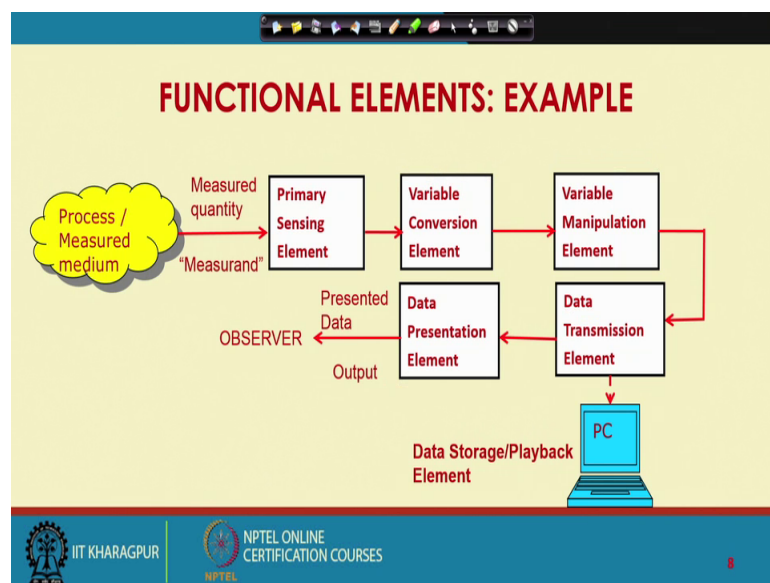
So, let us try to put these functional elements into a sequence, so that the job of the instrument or the function of the instrument can be explained. So, this is the process or the measure medium. So, some quantity about this process or measure medium I am interested to measure. So, primary sensing element first receives information from the measure medium the measured quantity is also known as measure and the output of the primary sensing element may go to variable conversion element the output of the variable conversion element may go to variable manipulation element for changing the amplitude of the signal.

The output of the variable manipulation element can go to data transmission element so that the data is transmitted from one point to another from data transmission element it can go to data presentation element or from the data transmission element the data can go

to a storage or playback device, the data transmission element presents data to the observer.

So, this is this may be a logical sequence of the functional elements of an instrument, but in except what sequence these functional elements will be present will depend on the particular instrument we have be we are talking about, but if you understand the role of these functional elements you will be able to analyze the function of any instrument in terms of these functional elements.

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Some points to remember about these functional elements functional elements are not physical elements they are functional elements we discussed one possible arrangement of functional elements. So, the exact sequence will depend on the particular instrument we are talking about, an instrument may involve the functional elements in any number and any combinations like there may be 2 variable conversion element in an instrument, there may be 2 variable manipulation element or there may be one manipulation element or there may be none it depends on the particular instrument that we are talking about.

Instruments are in general not separated into such blocks it is for our convenience we are separating the functions of instrument in such blocks of functional elements, a physical component may serve the role of several functional elements. Though we have seen this in case of pressure thermometer the bulb serves the role of primary sensing element as well as variable conversion element.

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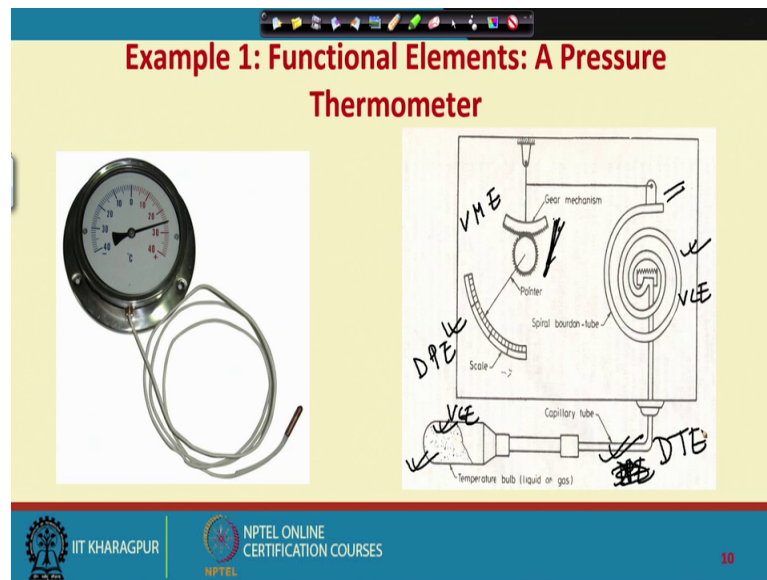
So, let us try to identify the functional elements of the pressure thermometer that we have talked about.

First is bulb is primary sensing element, it receives thermal energy undergoes restricted expansion of a service developed. So, temperature signal gets converted to pressure signal. So, it is also variable conversion element. So, bulb is both primary sensing element as well as variable conversion element, then comes the capillary tube it transmits the pressure from bulb to the bourdon tube. So, the capillary tube is data transmission element.

Bourdon tubes receive pressurized signal and gives output of the teap as it gives output as the deflection of the teap. So, bourdon tube changes the measure of the signal input was pressure output is deflection of the teap or a motion. So, a pressure signal is that converted to a motion signal by the bourdon tube. So, the bourdon tube is variable conversion element, now this teap deflection which is normally not great small deflection is magnified by this gear and linkage mechanism.

So, this gear and linkage is variable manipulation element. So, motion is input to the gear and linkage mechanism output is also motion because output is the deflection of the pointer against this scale. So, gear and mechanis so, gear and linkage mechanism is variable manipulation element the pointer and the scale presents data by reflection of the pointer against the scale. So, this is data presentation element

So, variable conversion element, data presentation element again variable conversion element, variable manipulation element and data presentation element sorry this is data transmission element tube is data, data transmission element.

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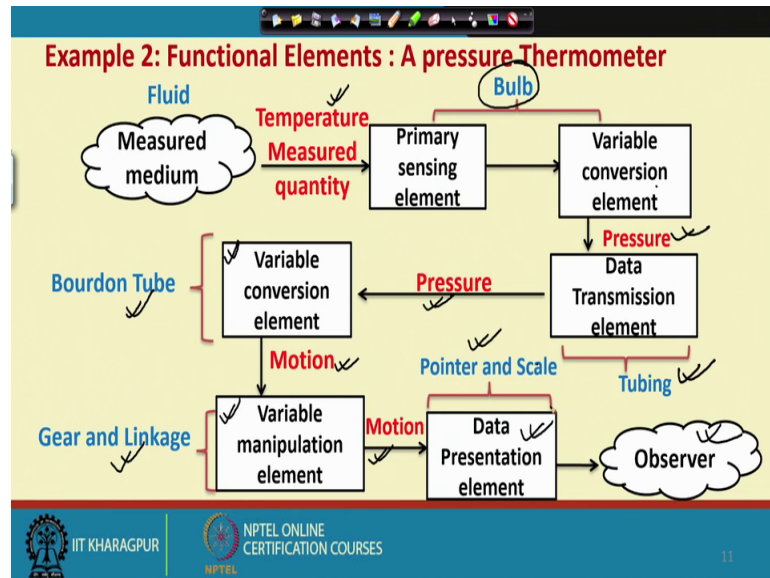
See if I just put this things into blocks it will look like this. So, we are measuring the temperature of this fluid. So, fluid is my measure medium, temperature is measured quantity or measure and primary sensing element variable conversion element both are bulb. So, to bulb temperature undergoes as input and what comes out from bulb is a pressure because it plays the role of variable conversion element as well. So, the pressure is convert pressure is transmitted by the tube. So, data transmission element is tube.

Then pressure is transmitted to the bourdon tube bourdon tube receives pressure as input and gives teap deflection as output which is a motion signal. So, bourdon tube plays the role of variable conversion element, then gear and linkage receives this motion as input gives you motion as output, but magnify. So, gear and linkage serves the role of variable manipulation element the output of the gear and linkage goes to pointer and scale which presents data to the observer. So, pointer and scale serves the role of data presentation element.

These way if you understand the role of various functional elements in an instrument you should be able to analyze any instrument in terms of its functional elements. In the next class we will take another example and try to breakdown the instrument in terms of

various functional elements that are present in the instrument. Remember these are functional elements not physical element and there is no unique or there is no fixed sequence of the presence of these functional elements, the sequence in which these functional elements will appear will depend on the particular instrument we have to analyze the instrument and then you will be able to find out the sequence of the functional elements that explains the function of the instrument as a whole.

Thank you.