Process Control and Instrumentation
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Lecture - 36
General Principles of Measurement Systems (Contd.)

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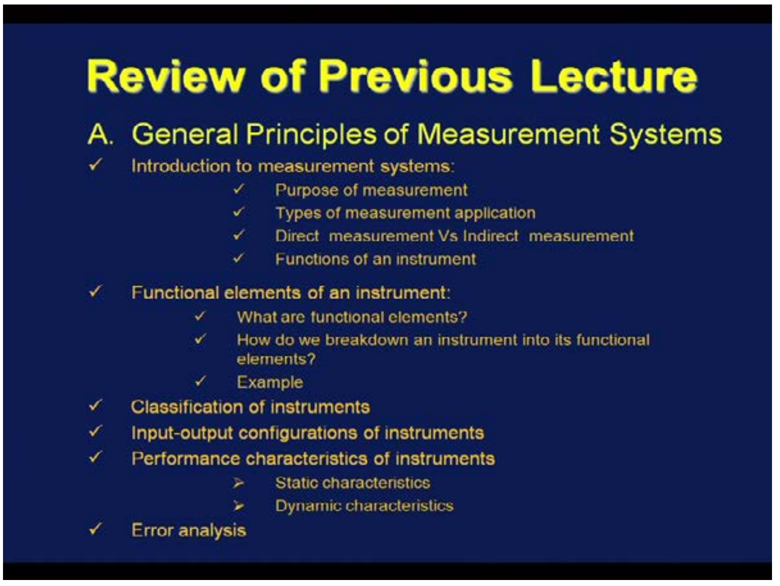

In our previous lecture, we studied our discussion on process instrumentation part of the course, process control and instrumentation. Today, let us start with a brief review of what we learnt in previous lecture. We started with general principles of measurement systems. We gave a very brief introduction to measurement systems, we talked about purpose about measurement, types of measurement applications, direct measurements verses indirect measurement, functions of an instrument. Then we introduced a concept call functional elements of an instrument, we defined what are the functional elements? We also talked about two different schemes, which we can use to break down and instrument into its various functional elements.

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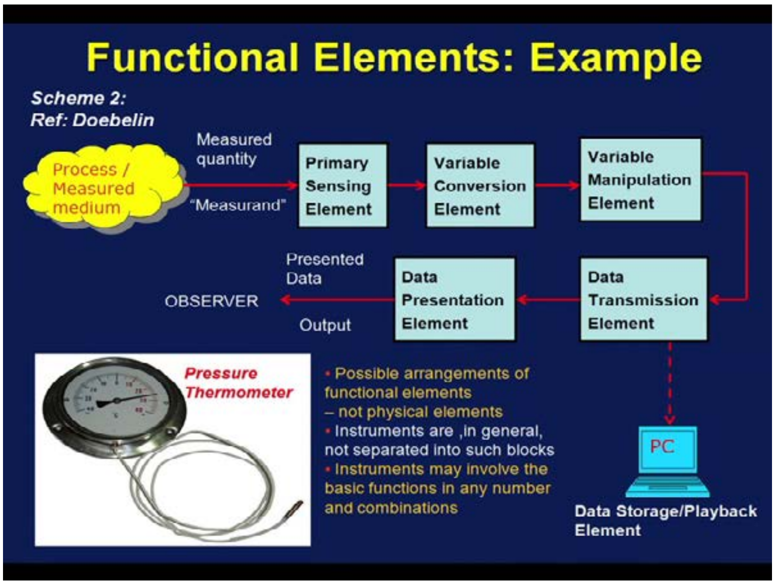

So, today will took an will take an example now to understood better how to break down and instrument to its various functional elements. We talked about this scheme in our previous lecture, this block diagram represents the all possible functional elements that you can expect to see in an instrument, if you want to analyze it.

This is the first this is the process or measuring medium, we call this measuring, the first functional element which is call primary sensing element receives inter interacts with the measuring medium first and receives information about the measured quantity and produces an output, which is somewhere related to the input to the primary sensing element that comes from the measuring medium. Then we are variable conversion element, which when convert the physical nature of the output signal from the primary sensing element, if it is required for the purpose of measurement. So, this output signal can be different from this input signal.

Then if it is necessary to magnify the magnitude of this signal we can have a variable manipulation element next, then if the different parts of the instruments are separated by distance; we need to transmit data from one point two another, so we have a data transmission element which will transmit data from 1.2 another. Then finally, will have an element which will present the data in a recognizable form to the observer so we have a data presentation element.

Before we taken example and breakdown the instrument into is various functional elements, let us stressed on the falling points. These represent a possible arrangement of all the functional elements that is necessary to describe the operation of an instrument. Remember, we are talking about functional elements not physical elements; in this block diagram it is shown that this primary sensing element variable conversion element and all this elements are separated into separate blocks. Instruments are in general not separated into such blocks; instruments may involve the basic functions in any number and any combinations.

So, let us take an example of pressure thermometer; so this is an instrument used for measurement of temperature. You have a bulk here, then a tube is connected to the bulk and the other end of the tube, goes to a pressure measuring element. What you see from here is just the pointer in the scale; the bulk and the entire tube is field with a liquid call filling liquid.

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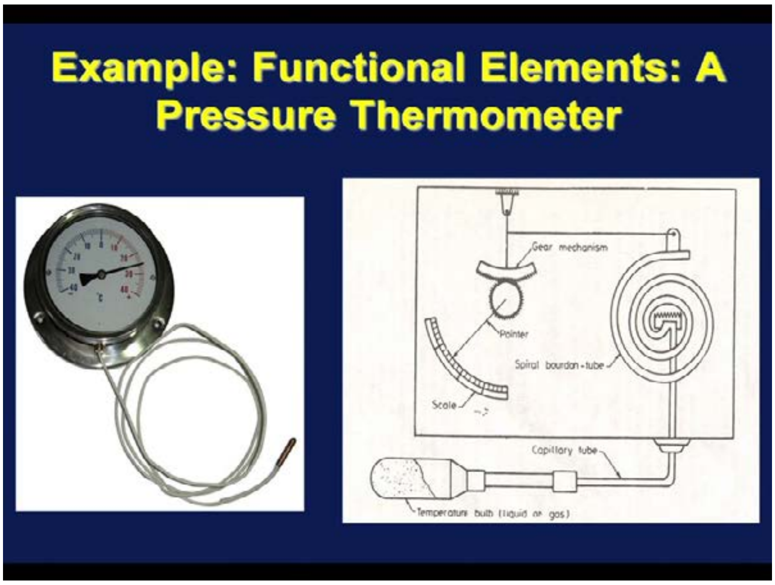

Now let us see, the part which we cannot see this is the pressure thermometer; and this is what it will look like if you get to see what is inside this. You have a bulb here the same bulb the bulb is connected to a tube caplet tube, to other end of the tube. A bourdon tube is attached it may be a spiral bourdon tube or it may be a seaborne tube. Will see what is bourdon tube is in few minutes, then the other end of the bourdon tube or the free end of the bourdon tube is connected to a pointer and scale through some gear and linkage mechanism.

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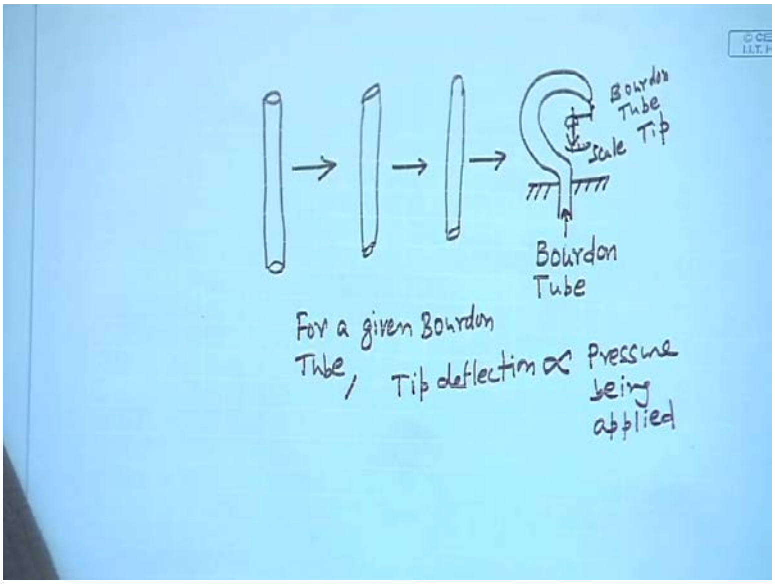

So, before we before we analyze, how this is to met works let us see what a bourdon tube; we take a tube with circular perception. Then pattern the tube to change the cross section of the tube from circular to electrical. And then seal one another tube and finally, then the tube in the form of a c, this is call bourdon tube name the… Now, if I keep this end of the bourdon tube reject fixed and apply the fluid pressure inside the bourdon tube; the tip of the bourdon tube will deflect. This is bourdon tube tip now the tip deflection depends on various factor such as the material of construction of the bourdon tube use a metals with good elastic properties chosen. It depends on the angle through which it is bend it depends on its cross section, but most importantly it depends on the amount of pressure that is being apply inside the bourdon tube.

So, for a given bourdon tube the deflection of the tip can be directly related to the pressure that is being applied inside the bourdon tube. So, for a given bourdon tube the tip deflection proportional to the pressure being applied. So, if through some gear and linkage mechanism; I can attach a pointer and scale the deflection of the pointer over this scale can be directly take an as a measure of the bourdon tube bourdon tube pressure.

So, that is scale can be directly calibrated in terms of pressure units. So, the deflection of the tip of the bourdon tube, which is magnified by this point can be considered as a measure of the pressure.

Now let us come to a previous example to analyze how we can breakdown this pressure thermometer into is various functional elements. So, this is the tip of this is the bulb of the pressure thermometer. Next a capillary tube which is connected to a bourdon tube which is not bent in the form of a see, but it is a spiral bourdon tube. The spiral bourdon tube is chosen here because the tip deflection even further increases, if we consider, if we take a spiral take bourdon tube inside instead of a c type bourdon tube.

So, we essentially increase the sensitivity of the bourdon tube by converting it from a c type bourdon tube to a spiral type bourdon tube. Now this entire part of the bulb the capillary tube and the inside of this spiral bourdon tube use field with a liquid called filling liquid. In certain applications it can out we field with gas. Now this bulb is put into the medium, which temperature I want to measure. So, bulb receives thermal energy from the media and the filling liquid inside the bulb expanse. Now due to the strict thermal expansion of the filling liquid of a series build up; and the pressure is transmitted to the bourdon tube through this capillary tube.

Then if the same as applying pressure to a bourdon tube; so the tip of the bourdon tube will deflect, and the deflection will depend on how much of pressure that has been transmitted through this tube to the bourdon tube. So, this tip deflection will cause a movement of this pointer again this scale, which is being magnified by this gear and linkage system. So, let us now try to breakdown the instrument into its various functional blocks.

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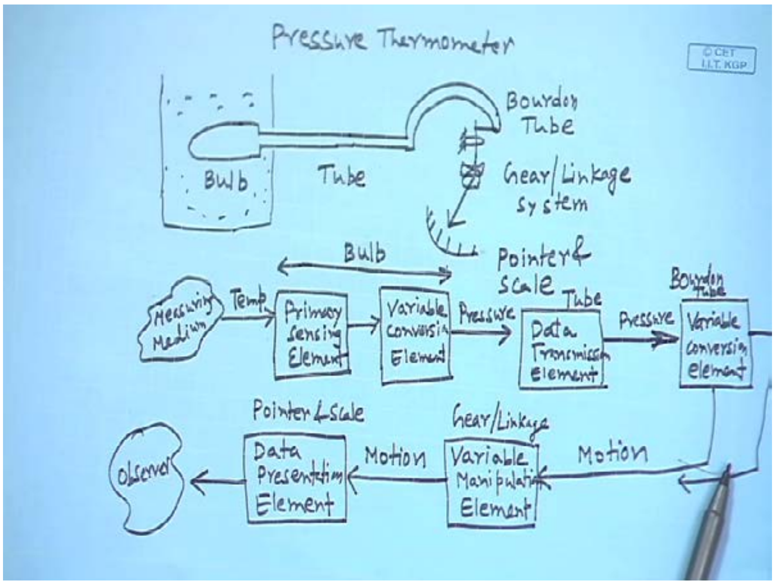

Let us redraw the figure here; you have the bulb of the bourdon tube, bulb of the pressure thermometer. Then the tube and a bourdon tube disconnected for simplicity, let us draw a c type bourdon tube. So, this is bulb, this is the tube or capillary tube, this is the bourdon tube, this is gear and linkage system, this is pointer and scale and this is bulb is put to the medium which temperature I want to measure. So, you can put to a see breathable liquid is temperature we want to measure.

So, you have the measuring medium, which is essentially this; the bulb interacts with the measuring medium and this is information about the temperature. So, the primary sensing element, this is information about temperature first and then what happens due to restrict thermal expansion of the filling liquid. A pressure is develop that also happen inside the bulb. So, the temperature signal is being converted to a pressure signal. So, there is a variable conversion element and both the functions are performed by bulb causes bulb, which first receives information from the measuring medium about the temperature.

And due to restrict thermal expansion of the filling liquid pressure gets developed inside the bulb show and like this signal is no more a temperature signal, but a pressure signal. Then this pressure is transmitted through this capillary tube. So, this tube box as a data transmission element. So, this is tube I am talking about this tube, which is capillary tube which t will have pressure signal here. Then is pressure goes to bourdon tube, which convert, which converts this pressure signal to a displacement or motion signal. **B**ecause when the pressure actions are the bourdon tube the tip of the bourdon tube will reflect. So, the bourdon tube receives pressure as put signal and gives motion or displacement as output signal. So, this is a variable conversion element. So, bourdon tube is variable conversion element.

Now, the output of the bourdon tube is no more a pressure signal, but a displacement or motion signal. This goes to this goes through gear linkage system, which magnifies the reflection. So, gear linkage system works as a variable manipulation element. So, you stellar motion signal, but now has been magnified. Then this signal is presented to the observer by this pointer and scale. So, pointer and scale works as data presentation element.

So, finally, data is presented to observer, you can see here we have a primary sensing element, we have a variable conversion element, we have a data transmission element then again we have a variable conversion element, we have a manipulation element and finally, we have a data presentation element. Let us take another example and again breakdown the instrument into various functional elements. This time let us take a very simple pressure gage.

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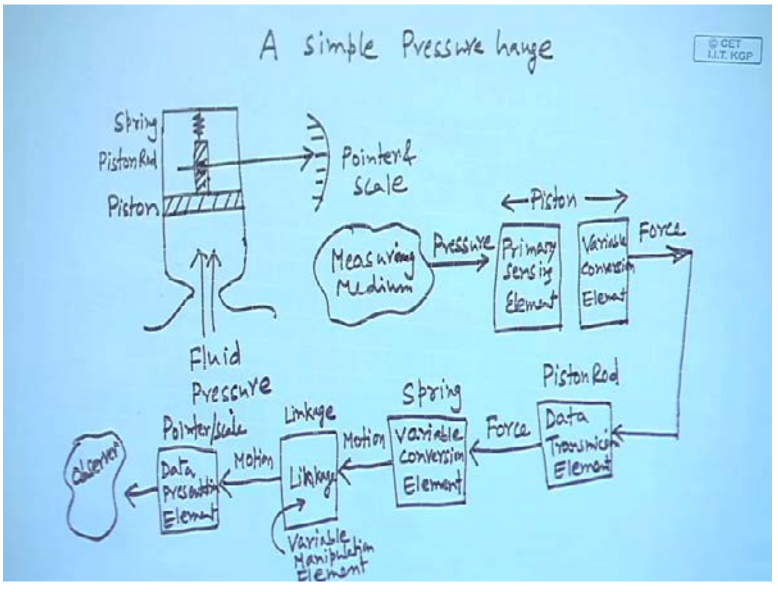

Will take a very simple pressure gage, which measures will pressure of a fluid and the measure pressure is indicated by deflection of the pointer against the scale. Consider a piston here, a piston rod and a spring here and a pointer in scale is attached and let the fluid pressure act only this term surface. So, how does this, the fluid pressure acts on the piston surface. So, force will be developed, that force is transmitted through the to the spring through this piston load.

So, the spring gives displacement or motion as output signal, which can be used to move this pointer against this scale. So, the deflection of the pointer against this scale can be rate as a measure of this fluid pressure. It is a very simple pressure gage; so let us now try to analyze the instrument by breaking down into its various functional elements. So, piston rod which first interacts with the need measuring media receives the information about the fluid pressure, so this is of course the primary sensing element.

So, we have measuring medium, which is fluid pressure here; the piston works as primary sensing element. But the fourth piston also converts this pressure, which is forced by unit area to force. So, piston also axes variable conversion element. So, piston is both a primary sensing element, as well as a variable conversion element. So, the output from the piston is no more a pressure, but a force signal. Now this force is converted, the force is transmitted by the piston rod. So, piston rod works as data transmission element swistle has fourth signal here.

Now this fourth signal is transmitted to the spring, which converse this first signal to a motion signal. So, spring works as variable conversion element. So, you know have a motion signal, this this magnified with the linkage, which is variable manipulation element. You can write it here and put linkage here, so we have a magnified motion; which is presented to observer by data presentation element, which is pointer or scale here. So, data is presented to observer. So, you see it is possible to breakdown and instrument into its various functional elements and the functional elements together will describe how the instrument works.

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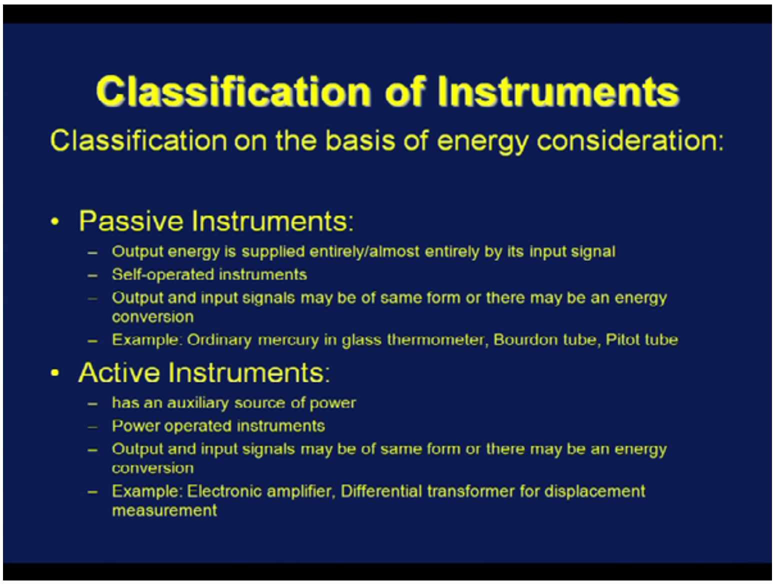

Let's now move on to classification of instruments; the instruments can be classified in various ways. So, depending on the basis of classification that we chose of instruments various instruments can be classified variously. For example, we can classify the instruments on the basis of energy consideration; that means, weather it is self operating instruments or it requires an auxiliary source of power like, weather it is automatic instrument or a manual instrument, weather it is necessary to bring the instrument in intimate contact with the measuring medium or it is not necessary to bring the instrument in close contact with the measuring medium. So, there are various bases classification and now will see some of the ways how we can classify various instruments.

So, let us start to the classification of the basis of energy consideration; on the basis of energy consideration we can classify instruments into two categories passive instruments and active instruments. Passive instruments are those whose output energy is supplied entirely almost entirely bits input signal or bit the energy of the input signal. So, you do not need any auxiliary source of power here. These instruments are self operated instruments; it may be noted here, that the output signal and the input signal may be of same form or they are may be an energy conversion.

Some of the examples of passive instruments are ordinary mercury in glass thermometer or clinical thermometer, a bourdon tube, which is use for measurement of pressure or a pitot tube. All this instruments are self operated instruments their own need any power source. The energy required for the act of measurement is supplied entirely by the energy of the input signal it receives.

On the other hand active instruments are those, which an auxiliary source of power. So, there not self operated instruments, but there power operated instruments. Again the output and input signals may be of same form or there may be an energy conversion involved. Examples of active instruments are electronic amplifier differential transformer for displacement measurement, etcetera. So, this qualification is on the basis of weather and instrument requires auxiliary power or not. If the instruments requires auxiliary power for its operation; then instrument will be called an active instrument, if the instrument does not required any auxiliary source of power the instrument will be called a passive instrument.

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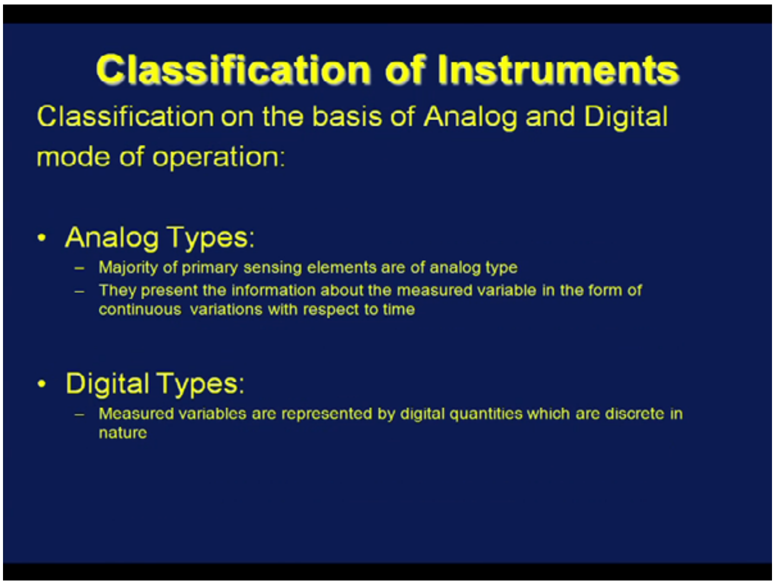

We can also classified the instruments on the basis of analog and digital mode of operation, if the instrument follows analog mode of operation we call the instruments, as analog types of instruments or if the instruments follows digital mode of operation, we call those as digital types instruments. Majority of the primary sensing elements are of analog types. They present the information of about the measure variable in the form of continuous variation with respect to time.

On the other hand digital types of instruments represent the measure variables by discrete quantities or digital quantities, which are discrete in nature. So, this classification is on the basis of whether a particular instrument follows analog mode of operation or digital mode of operation.

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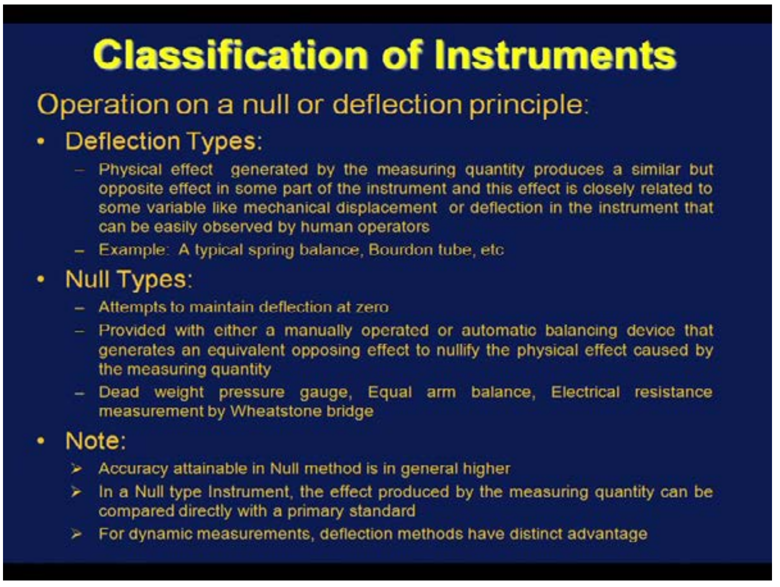

Still another we have classifying instruments is on the basis of operation on a null or deflection principle. Deflection-type instruments the physical effect generated by the measuring quantity produces a similar, but opposite effect in some part of the instrument and this effect is close the related to some variable like mechanical displacement or deflection in the instrument; that can be easily observed by human operators. So, the physical effect in the deflection type of instrument that is generated by the measuring quantity produces a similar, but opposite effect in some part of the instrument and this effect is closely related to some variable like mechanical displacement or deflection in the instrument; that can be easily observed by an human operator. An example can be the typical spring balance or a bourdon tube we are just in bourdon tube. So, let us see the typical spring balance.

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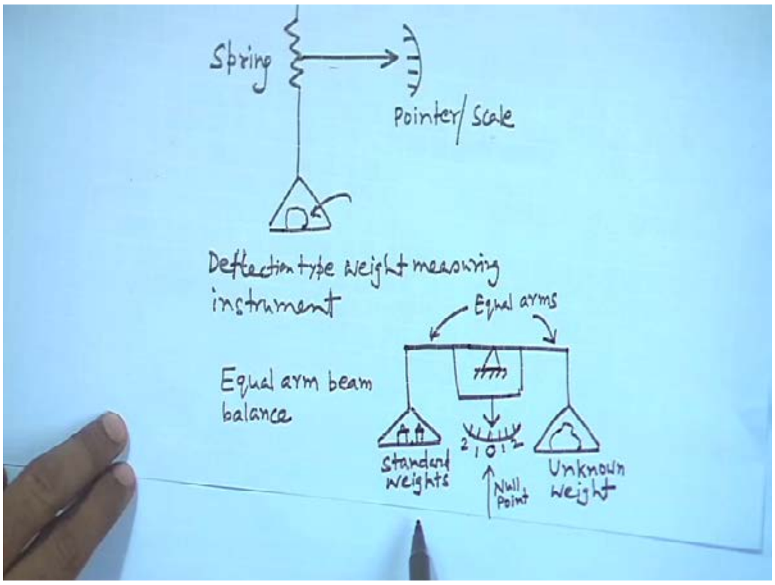

So, this is a deflection type weight measuring instrument; what a simple spring balance weight of the object weight of this object is measured by the deflection of the spring cause by it. So, this is a very simple example of deflection principle the example of bourdon tube we have just seen in our discussion on functional elements Now, null types the null types attempts to mention deflection is zero just provide it with either a manually operated or automatic balancing device; that generates and equivalent opposing effect to nullify the physical effect cause by the measuring quantity. These instruments are provided with either a manually operated or automatic balancing device; that generates an equivalent opposing effect to nullify the physical effect cause by the measuring quantity. Examples are a dead with pressure gage equal arm balance electrical resistance measurement by wheatstone bridge in all this a null point is attend during act of measurement.

Let’s take example of let say an equal arm balance; so we draw the figure of an equal arm balance. We have unknown weight you have standard it. This is the null point; this is equal arms, we call this balance equal arm beam balance. They information about the weight of this unknown object can be measure directly by putting standard weights here and mentioning a null point here.

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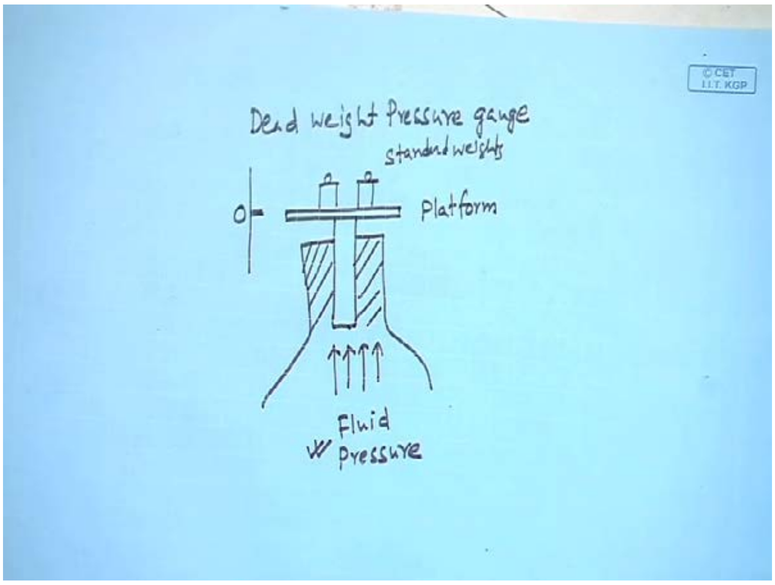

Still another example can be a dead weight pressure gage; let's draw a simple diagram for dead weight pressure gage you. Have a platform, when the fluid force when the fluid pressure acts here, this will try to go which can be counter balance by putting standard weights here. So, by mentioning a null point, we can measure the fluid pressure. It may be noted here; that accuracy attainable in null method is in general higher compared to deflection method. In a null type instrument defect produce by the measuring quantity can be compared directly with a primary standard.

As we have seen in the example of spring balance and equal arm balance in case of equal arm balance, we are measuring the unknown weight by comparing directly with standard weights. But in case of deflection type spring balance, we are comparing the weights again the spring, but spring is not primary standard for weights. So, in general the null methods are superior in terms of accuracy of measurement. However, for dynamic measurements deflection methods have distanced have advantage; because they are faster. However, it is possible to increase the speed of the null method by using automatic balancing devices. So, the advantage of null method is increase accuracy, but disadvantages. It is generally slow because of an type it is manual; however, it can be improved using automatic balancing devices.

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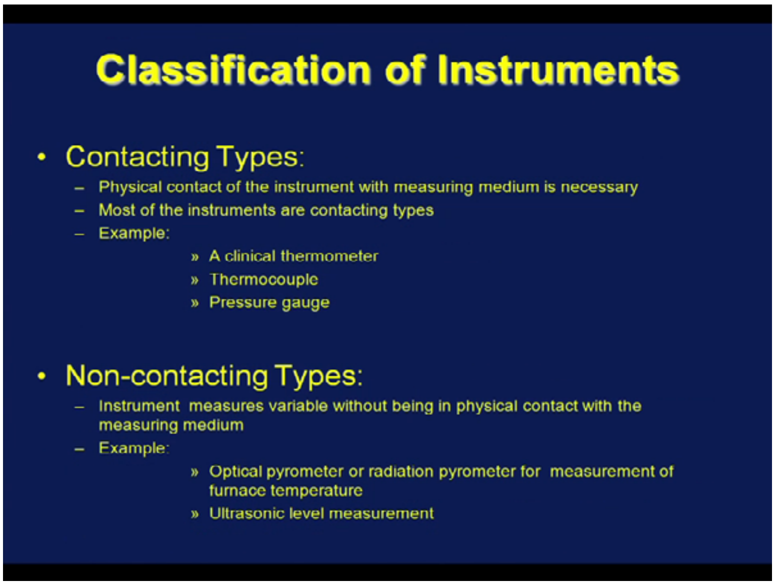

The next classification is based on whether the instrument is contacting type or non contacting type. As the name suggest the instrument as contacting type, when it is necessary to bring the instrument in direct contact with the measuring medium. For example clinical thermometer, the ordinary clinical thermometer you put in your mouth wait for some time how much time, you wait usually depends on the time constant of the instrument. And finally, you get the reading directly of the scale let us to the clinical thermometer.

It is necessary for the purpose of measurement that you bring the thermometer in direct contract with the measuring medium. So, this is contacting type most of the instruments are contacting type; other examples can be a thermocouple a pressure gage and so on. So, fore while non-contacting types you do not have to bring the instrument in direct contact with the measuring medium. So, the instrument can measure the variable without being in physical contact with the measuring medium.

For example an optical pyrometer or radiation pyrometer measures the temperature of the furnace; but you do not have to bring the pyrometer in direct contact with the furnace. It is inconvenient to that to do that as well, will see later how this instrument to work we need to talk about temperature measurement in detail. But this is an instrument which is of non-contacting type. Similarly ultrasonic level measurement, which makes use of the speed of the ultra sound, to get an indication of the level of ugly quick is also non-contacting type.

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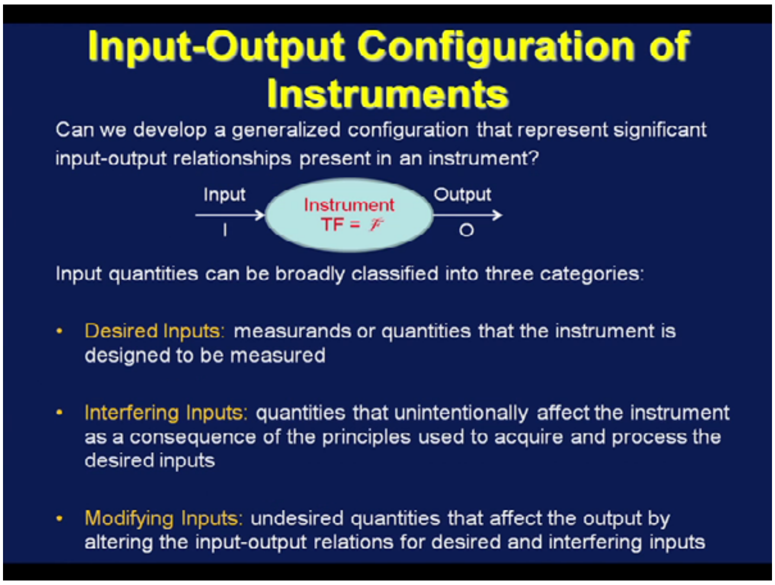

Let us now move on to input output configuration of instruments; we are asking here can you develop a generalized configuration, which represent significant input output relationships present in an instruments. Let us consider this general model of an instrument an instrument receives input signal from the measuring medium and gives us and output signal, which is related to this input signal.

So, you can consider that there is a transfer function here, which acts on this input signal and gives as output signal. Now let us try to see, what are the various types of instruments that effect this instrument any particular instrument. The input quantities can be broadly classified into three categories, desired input, interfering inputs and modifying inputs. Desired inputs measuring and quantities that the instrument is designed to be measure; so the instrument has been designed to be sensitive two desired inputs only; interfering inputs are those quantity is that unintentionally affect, the instrument, as a consequence of the principles use to acquire and process the desired inputs.

So, the instruments becomes unintentionally sensitive to interfering inputs; so while an intent to measure desired inputs and instruments has been design to be sensitive to desired input only. The instruments becomes unintentionally sensitive; to some other inputs and we call those inputs as interfering inputs, and finally, modifying inputs. Modifying inputs are those undesired quantities, that affect the by altering the input-output relations for desired and interfering inputs, if we consider this as desire input and there is a terms of function, which works on the desired input and gives gives us output.

Now, modifying inputs will tend to change this transfer functions; in other words modifying inputs affect the modifying output affect the relationship that exist between input and output. And in this in this block diagram, we are saying this transfer function relates this modifying input and output. So, modifying input will tend to change this transfer function. if we have to speak mathematically.

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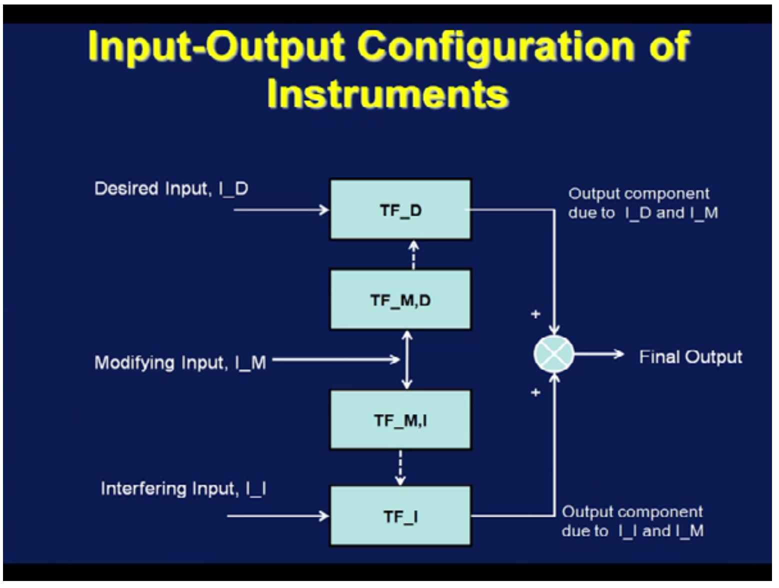

So, we can have a generalized input-output configuration of instruments like this, we have desired inputs, modifying inputs and interfering inputs. We have a transfer function corresponding to desired inputs. So, this transfer function works on this desired input and gives as output component due to desired input. We have an interfering input and there is transfer function corresponding to interfering input with gives us an output component due to interfering input. But modifying input, will tend to change the relationship that exist between desired input and the output as well as interfering input and output.

So, we have a transfer function corresponding to modifying input, corresponding input modifying input verse desire input interactions and the modifying input interfering input interactions. So finally, we have the component for the output that is due to desire input or modifying input you also have a component due to interfering input and modifying input, when these two signals are edit together we have the final output.

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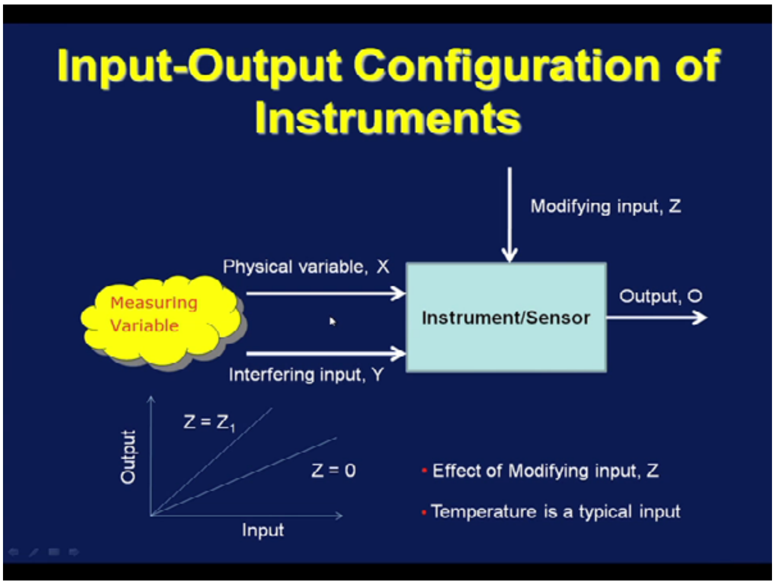

We can also explain this in terms of a simpler block diagram as follow, we have measuring variables; this goes to the input instrument or sensor. So, this is the desired input, it also receives interfering input as input signal and also modifying input as in input signal, and finally gives us the output. As understanding you that modifying input will tend to modifying will tend to relationship between to this input, and these two inputs, it can explain graphically like this.

Suppose this is input-output relationship when there is no interfering input, sorry, when there is no modifying input. In presence of modifying input this presence you can be shifted like this. So, will stop here for the day and in our next class will see more on interfering input, desire input, and modifying input. What corrective measures, we can take, so the our instrument you sensitive to only desired inputs. In other words how can we cancel out the effect of interfering input and modifying input.