Power Plant Engineering
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Lecture - 37
Instrumentation of Power Plant

I welcome you all in this course on Power Plant Engineering, today we will discuss about the Instrumentation Power Plant. Instrumentation in a power plant, I mean its integral part of the power plant because without instrumentation power plant cannot work at all. Because we need parameters these parameters, they do control the performance of the power plant and for the safety purpose also we need instrumentation in the power plants.

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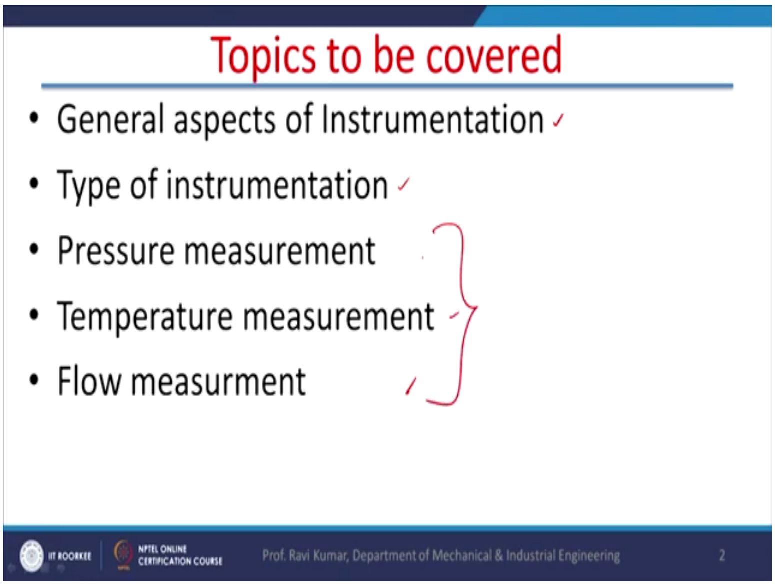

So, today's topic to be covered are general aspects of instrumentation first of all, then type of instrumentations which is which are used in power plants. And mainly we will be discussed pressure measurement, temperature measurement, and the flow measurement.

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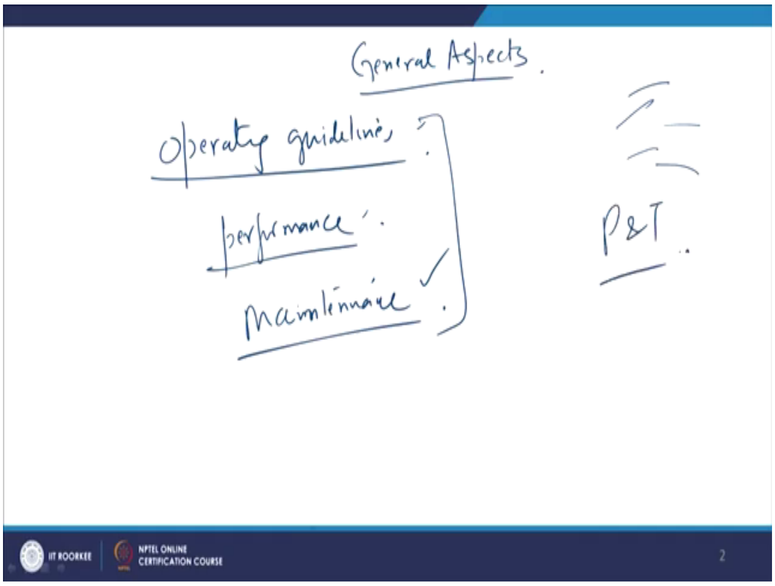

Now, we will start with the general aspects of the instrumentation, so general aspects. First of all if we have instrumentation we can provide operating guidelines to an operator. Because the pressure should vary in this range, current should vary in this range, or humidity it should vary in this range, or exhaust gas analyzers CO 2 should remain in this range, or oxygen should remain in this range.

So, this operating guidelines can be provided to the operator if the plant is properly instrumentation is instrumentated it. Then is performance, to judge the performance we need the values about the performance parameters. So, for that purpose also the instrumentation is required.

Then maintenance for the maintenance of the power plant or a repair guidelines have to be provided to the worker. So, for the maintenance and repair also we need instrumentation in power plant, so there are several reasons. Economical operation of the power plant we need instrumentation right, cost allocation also we need instruments. So, instrumentation is integral part of the power plant, so without instrumentation power plant cannot work. And major suppose you go for the thermal power plant the major thing is pressure in temperature right.

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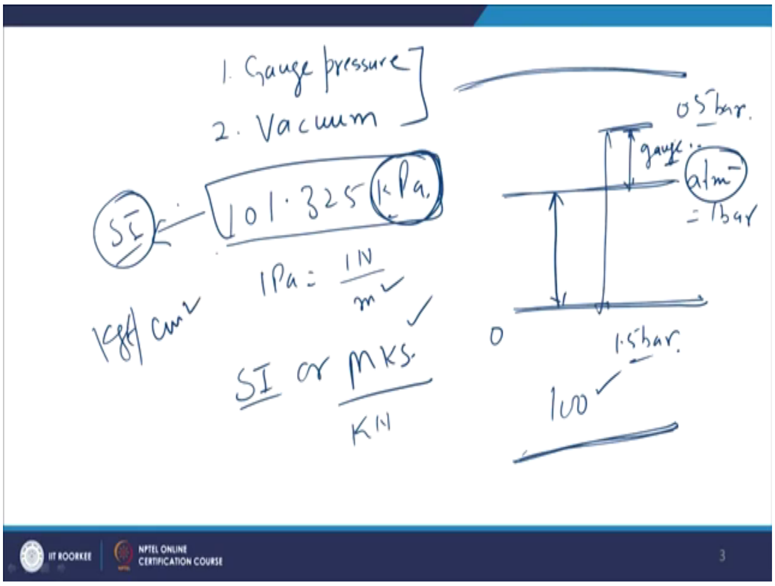

So, there are two things, one is gauge pressure, now second is vacuum. Now, gauge pressure is suppose this is 0 pressures no pressure at all this is determined 0 pressure. And this is your atmospheric pressure, and the gauge pressure is the pressure above atmospheric pressure this is gauge pressure right.

So, at atmospheric pressure the gauge pressure is 0, when the gauge pressure is a suppose atmospheric pressure is 1 bar and gauge is showing 0.5 bar. So, the absolute pressure is 1.5 bar right. Now, third thing is vacuum, when we talk about the vacuum first we should know what is ideal atmospheric pressure? Ideal atmospheric pressure is at 100 meter from mean sea level. Mean sea level is known as the data equal or line of equal energy means sea level.

So, at the mean see level 100 meters from the mean sea level right the atmospheric pressure is sorry at the mean see level the atmospheric at the means see level the atmospheric pressure is the ideal atmospheric pressure one atmospheric pressure. So one atmospheric pressure is 101 sorry 0.325 sorry 325 kilo Pascal, 1 Pascal is 1 Newton per meter square right.

So, this is the atmospheric pressure, this is an SI unit; but if you go to the power plant you will really find gauges and indicators and SI unit. Mostly either they are in SI units or in MKS unit or bigs of SI and MKS also there. Kilo Pascal or kilo Pascal per meter square is the sorry kilo Pascal is the unit which is used in SI system MKS system it is kg force per centimeter square.

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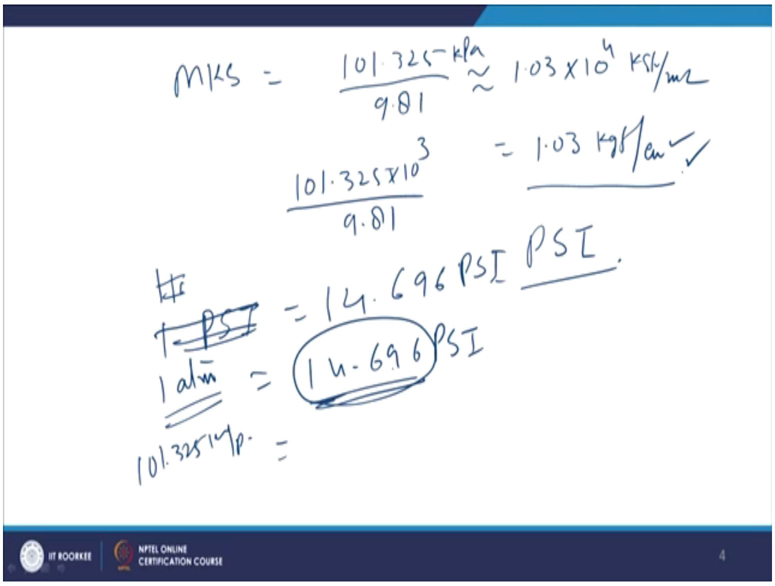

In MKS it is we can always find 0.325 divided by 9.81, it will come around 1.03 something into this is kilo Pascal this is kilo Pascal into 10 to power 4 kilogram force per meter square. And it comes around because it is here it is kilo Pascal 0.1325 will be multiplied by 10 to power 3.

So, it will come around 1.03 kilo gram force per centimeter square, because meter is square is converse, so this is convene to is remember right. Now, pounds per square inch, there is also a unit in SI unit manual the pressure gauges no power plants will find in pounds per square inch.

So, 1 pounds per square inch is equal to 14.696 sorry. Pounds per square inch is 1 atmosphere, 1 atmospheric pressure is equal to 14.696 PSI. So, if this is a multiplying factor, so whatever pressure is there in terms of atmospheric pressure 101.325 kilo Pascal and you just multiply this with this one you will gain the pressure in pounds per square inch.

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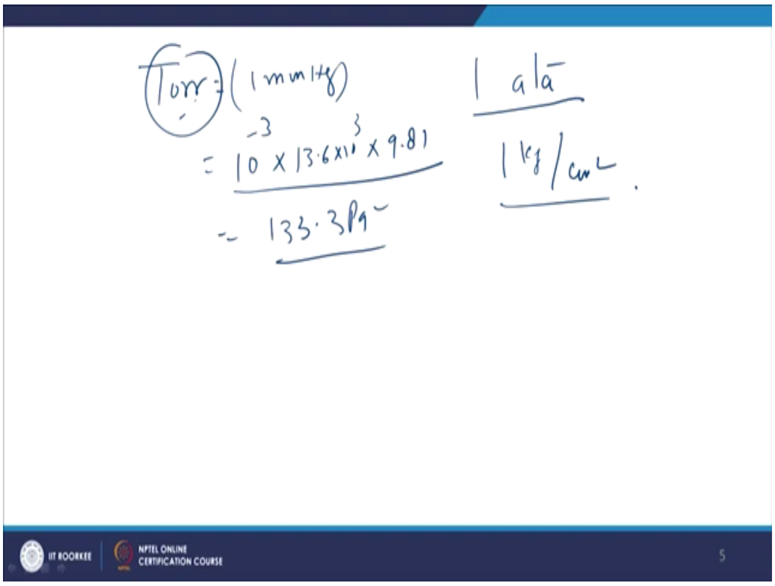

There is a pressure one at now it is now it is not in use 1 ata, 1 ata is 1 kg per centimeter square it is not being used nowadays. And vacuum normally is expressed in terms of torr, torr is pressure equivalent to 1 mm of Hg (Refer Time: 07:15). So, 1 mm of mercury 10 to power minus 3 into rho into 9.81, so it comes around 133.3 Pascal that is one torr pressure. So, this is a normally vacuum is expressed in terms of this torr.

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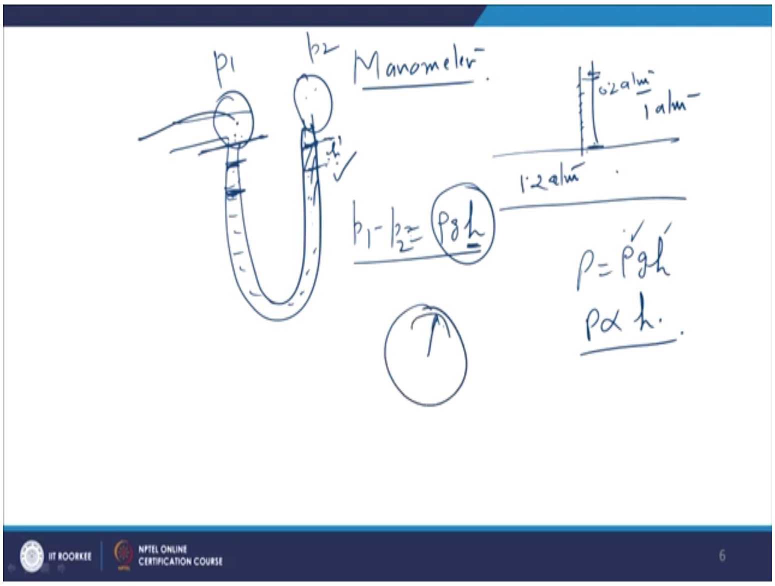

Now, there are several instruments which use which are use for the pressure measurement and the simplest and the most reliable instrument is manometer right. Suppose in a pipe water is flowing in a pipe you fix a tube here. Pressure the pipe is let us say 2 atmospheric pressure, outside is 1 atmospheric right. So, you will get a it is high 2 atmospheric, suppose 1.2 atmospheric pressure. So, outside column you will find equivalent to 0.2 atmospheric pressures. Normally for this column is P is equal to rho gh; rho is the density of the fluid, g is the gravity and h is height. So, this height is directly proportional to the pressure.

So, this can even always make the scale on this and can find out what is the pressure absolute pressure or inside this tube. There are U tube nano meter also they are very popular in pressure measurement, normally they are also used for the differential pressure measurement also. And principle is very simple it is filled with it can be a single fluid or it can be a multiple fluid depending upon the requirement. And when it is connected to the two pipes, suppose this is one pipe, this is another pipe right.

So, if they have certain pressure difference, so pressure difference can also measure with the helpful to U tube nanometer, so this is for example, p 1 this is p 2. So, p 1 minus p 2 is going to be equal to rho gh this is the height. Because, the pressure is high here, so fluid will lift in this limb because it has two limbs or two arms. So, if the pressure here is high this level will be lower than the this level. So, this difference in h will give the difference between pressure between these two pipes, so it is expressed.

So, here also we can easily find the or for absolute pressure of course, this side is suppose expose to atmosphere, this side is exposed to atmosphere in that case also you can make the pressure. So, this is a very reliable and even it is used for the calibration also for the pressure gauges. You can always calibrate the pressure gauges using U tube nanometers their output is quit reliable.

Then diaphragm type of because normally in plants U tube nanometers are not used because their dynamic response is very poor right. And the glass tube it is fragile also nowadays pressure gauges are available dial type of pressure gauges are available.

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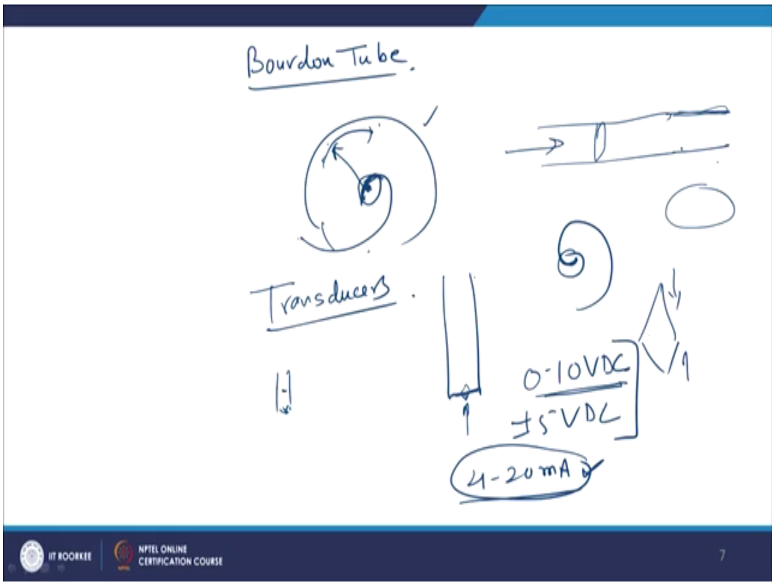

In dial type of pressure gauges there is a tube which is known as Bourdon tube. But, the beauty of the bourdon tube is if you field is the tube of elliptical cross section if you pressurize the fluid inside the tube it will expand. But, the change in the diameter will be negligible in comparison to the expansion tube right.

So, what happens in dial tire pressure gauge the next the another end of the Bourdon tube is fixed here. So, when the tube is pressurized there is a movement here mechanical movement here. And this mechanical movement is captured and is converted to the angular movement of the indicator. So, there is a mechanism here which converts this angular movement, because when the p tube is pressurize it will try to again move in circular direction like this right.

So, this movement is captured with the help of a mechanism and it is reflected on a indicator diagram that is an indicator. And these gauges are I mean is quite cheap and readily available in the market in different ranges. So, these pressure gauges dial type of pressure gauges are very popular another is nowadays pressure transducers are used.

Now, the pressure transducers are electronic devices they are electronic devices right. And there is let us there is a it is active type of transducer active type of transducer means it service requires external energy to activate right. And it has a diaphragm either a stream gauge or a piezoelectric crystal which fits on the diaphragm.

So, when there is a change in the pressure there will be change in the strain in the diaphragm or there will be strain on the diaphragm. Or if there is a piezoelectric crystal there will be certain EMF output, because when the piezoelectric material when it is compressed EMF is generated right.

So, these signals are converted in to the output. And in most of the transducer any transducer you take they have certain range of the output. I mean either it is 0 this is very popular 0 to 10 volt DC, sometimes it is plus minus 5 volt DC also depending upon the manufacturers. Either you can get output in voltages or output is also given in Amperes also 4 to 20 milli Amperes, this is also is very standard output of the transducers.

This type of Ampere output is normally taken when the distance between the location of the transducers and the data equation system is quite far right. So, there will be no loss in the current, but if you take this type of transducer when the distance is too far then there is a voltage drop will take place, if that case in situ calibration of the transducer has to be done.

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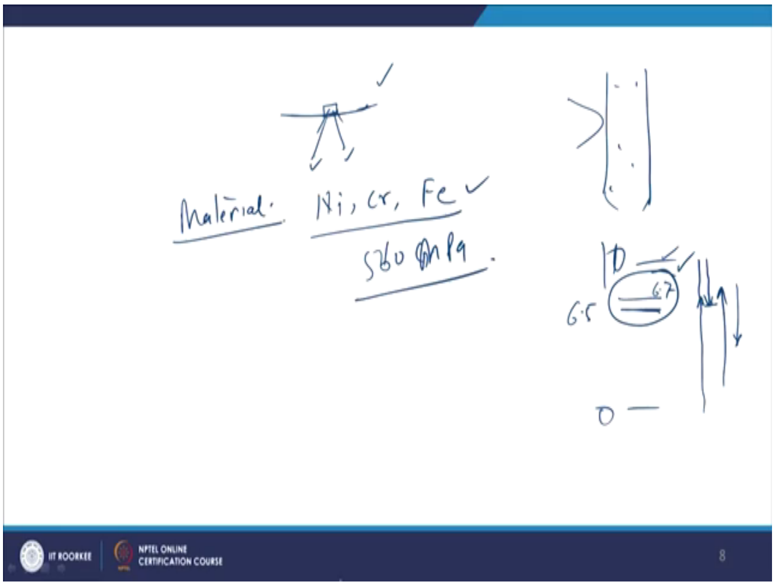

In fact, there are diaphragm type of transducers also right. On a diaphragm there is strain gauge the principle is same. And this strain is captured in electronic type of transducer there is a readymade housing there all arrangements are made. Otherwise the output of this is strain gauge can directly taken on a data equation system and accordingly it can be calibrated first with the help of it pressure gauge and then it can be used in the plant.

Now, material for this type of system is we can go for nickel, chromium, or Fe ferrous. Elastically limit is limited this 560 giga sorry mega Pascal. Beyond this type of diaphragm type of strain gauge does not work, but diaphragm of a strain gauge has certain issues also.

First of all it has hysteresis, hysteresis issue hysteresis is the hysteresis is that the output any of the instrument depends upon the direction of loading. Suppose direction of loading is 0 to 10 right and input is increasing. So, output of the instrument will also increase and you will get a certain leading let us see 6.5.

Now, keep on increasing the input or right when you reduce it reduce input to the instrument you may get for the same input you may get reading around 6.7 right. So, this indication or the reading taken by the display by the instrument it will depend upon the direction of the loading this is known as hysteresis. And in an ideal instrument the hysteresis has to be 0.

Second thing if you take any transducer or this diaphragm type of pressure gauge amplifier is required amplification is required that is why we need always external energy system to activate the transducers of these type of gauges. That is why they are known as active type of devices. And these gauges are susceptible to the shocks and vibrations also. So, a lot of care has to be taken that there are no shock or vibrations at the location where these gauges are fixed.

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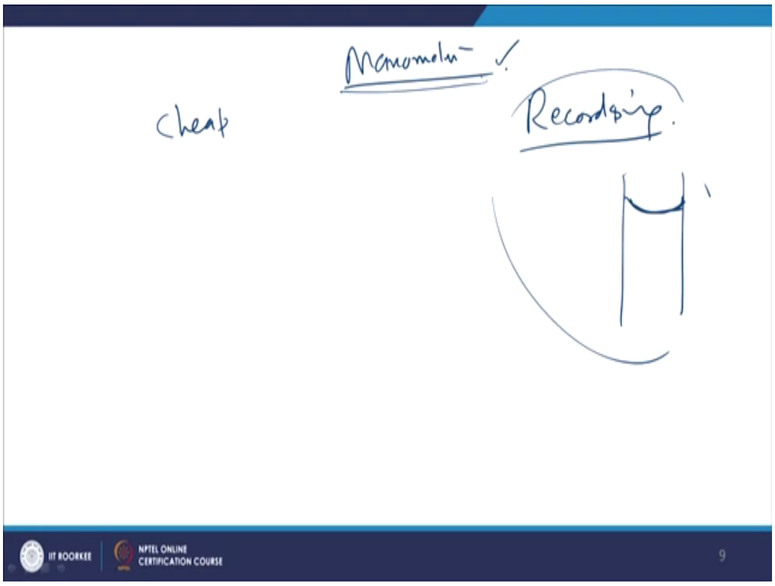

In comparison to that if you look at the nanometer again, nanometers are cheap they are not very costly their accuracy is good right. Maintenance is not required I mean they are relatively cheaper and more reliable, but there other issues with the manometers they cannot take dynamic load. And if you take a the U tube manometer let us say made of glass it is fragile also.

Nanometers are suitable for the low pressure, so the low pressure readings they are quit suitable. But, recording cannot be done in the recording is the main issue nowadays recording; if you cannot record the data then I mean the applications become limited. So, that is why that is the main reason for having mean limited applications of nanometers. Sometimes use two fluids they are not comparatively each other they get mixed upon they react with each other.

So, care has to be taken you take two different type of fluids they are not susceptible with each other if you are using a multi fluid nanometer. Sometimes while taking the reading meniscus is also problem meniscus height is also problem right. And viscosity is also there or capillary effect is also there. So, that all these things are still keeping in all these restrictions in a view nanometer if you want to have accurate measurement of the pressure. Still nanometer is the main device, but nowadays we are going for the electronic type of system.

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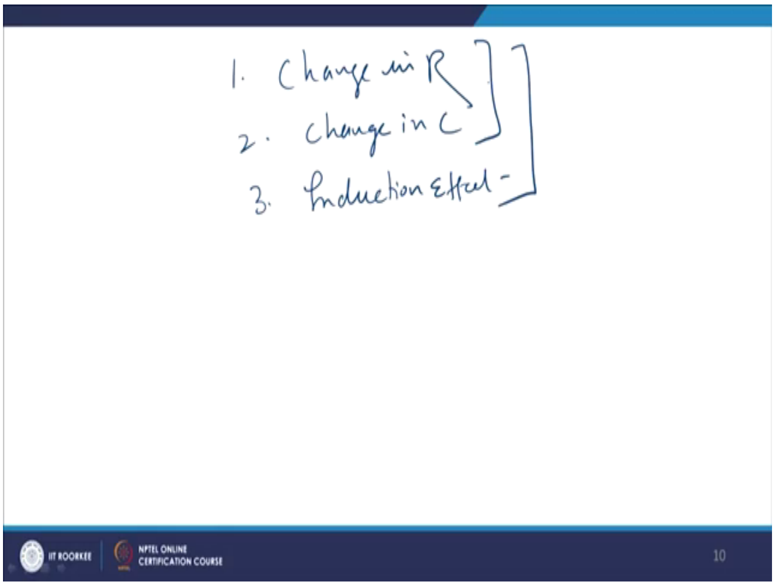

So, electronic type of pressure measurement mainly these devices are dependent on change in resistance right, change in capacitance mainly or some induction effect right. Now, we will; now we will consider this in the case of this happens in the case of pressure measurement and if you go for the temperature and let us talk about the temperature measurement.

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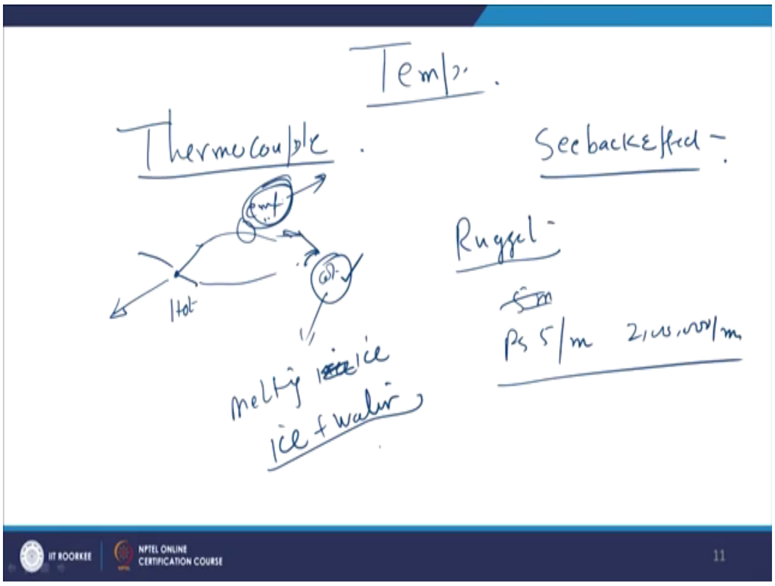

If you go for the temperature measurement these principles are used right. The main device or not device main sensor which is used for a temperature measurement throughout the word is thermocouple for several reasons right. And servo thermocouple works on the see back effect. Now, see back effects is there is junction of two dissimilar materials right. If one junction is hot another is cold and they are connected then EMF will be generated.

Now, this EMF is proportional to the temperature difference not directly proportional it is only proportional right. And if we take cold junction if you fix the cold junction then variation and hot junction will be reflected in variation in EMF. The cold junction is normally fixed as melting ice; means ice plus water and this is pure water or triple distilled water or demineralized water right.

So, the temperature of this is 0 degrees centigrade now this temperature is fixed. Now, hot junction temperature is measured and it is directly related with the EMF of, so, their charts available thermocouple chart. Nowadays, instruments are coming their inbuilt calibration is there they just simply take the EMF and they give display of the hot junction temperature right.

First of all why they are popular? They are popular because first of all they are ragged and they are inexpensive. Completely we cannot say they are inexpensive because the cost of the thermocouple varies from 5 rupees 5 per meter to maybe rupees 200000 per meter. Depending upon the type of the thermocouple and the type of application, but their response is very good they are fast in response. And their response was the thermocouple depends upon the diameter of the thermocouple.

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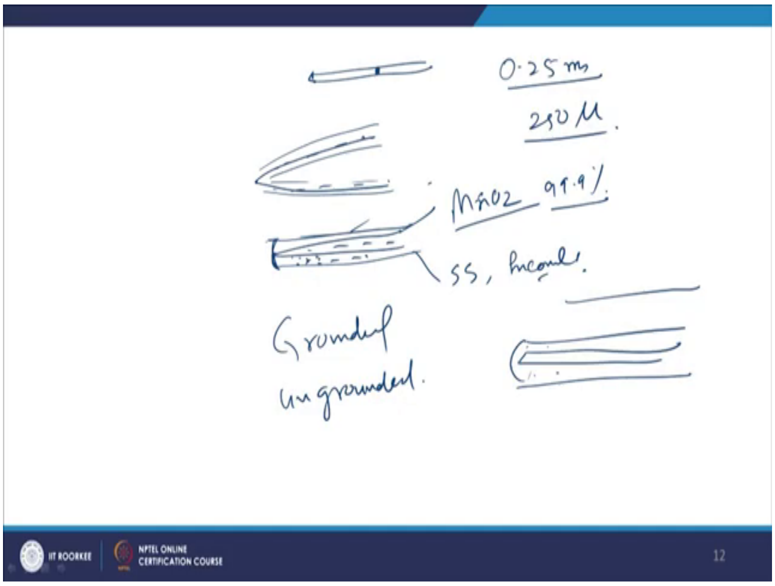

We can have thermocouple or wire up to a diameter of 0.25 mm as well its quite thin 250 micron microns this can be the diameter of the thermocouple sheet. So, because normally there are different types of thermo couples there is thermo couple wire. Than wire often is covered with the sleeve that is not a very costly thermocouple, so that this part of the wire does not come into the contact with the fluid.

There is a sheeting also there is sheet of the thermocouple, so there is a thermocouple it is covered in a tube. And rest part or this wider spaces is filled with the it is minimally insulated normally is Mno 2 99.9 percent Mno 2. And this thermo a couple is put in the sheet and tip of thermo couple is in contact with the sheet right it can be stainless steel or inconel.

Now, sometimes what happens suppose there is a surface we have charge is flowing surface is charge. So, charge will enter the thermocouple right charge may enter the system also. So, there are two type of thermo couples, grounded and ungrounded. So, this is when it is in contact with this is grounded thermocouple. If I want to make it ungrounded inside the sheet the tip of the thermocouple will no longer remain in the contract, it will be very close to the sheet, but it will not remain in contact with the sheet. So, isolation or thermocouple tip takes place for the sheet.

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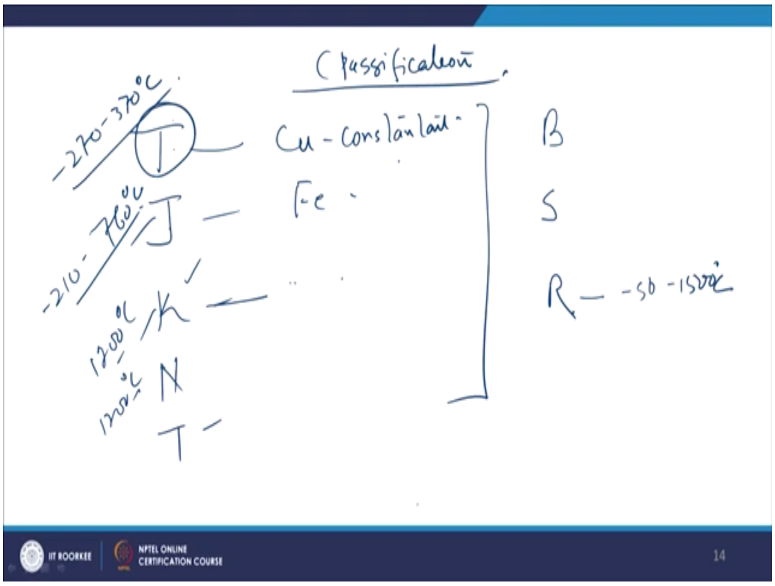

So, this makes the ungrounded thermocouples. Thermocouples are classified, T type thermocouples they are very popular. Copper constant and constant is a copper nickel alloy right. Then T type thermocouples, J type of thermocouples this is iron constant in type of thermocouples. Then their chromel alumel alloy is used for the K type of thermocouples, N type of thermocouples, T type of thermocouples.

Some are upper class thermocouples. They are B type thermocouple, S type thermocouple, R type thermocouple; they have these thermocouple wires there are two similar fires wires, but they are made of different material. So, depending upon the cost of the material the cost of the thermocouple varies right. For example, this K type of thermocouple this chromel alumel alloy is used for this some type of thermocouple.

And they have a temperature range also this T type thermocouples can be used from minus 270 to 370 degree centigrade, up to 400 degree centigrade even we can use this T type of thermocouple. J type of thermocouple can be used let us say minus 210 to around 760 degree centigrade the J type of thermal can thermocouple can be used.

K type thermocouple can go up to 1200 degree centigrade right, N type of thermocouple can also go to 1200 degree centigrade. Now, rare earth this R type of thermocouple it can go from minus 50 to 1500 degree centigrade right. Likewise there is a range for different types of thermocouples.

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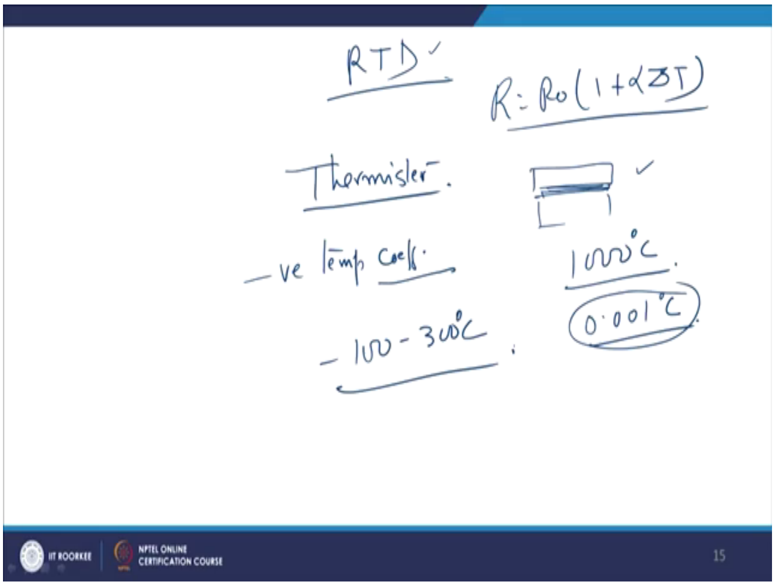

In addition to the thermocouples there other devices which are used which is Resistance Temperature transducers RTD devices. It works on the principle if the resistance of the material varies with the temperature. If you increase the temperature the resistance will change. So, R is equal to R o 1 plus alpha delta T it works on this principle.

So, a thin wafer off tungsten is sandwiched between two plates and current is passed. And with the change in the temperature of this metal or this tungsten the resistance of the we change in the resistance the change in the temperature is determined. So, this is a very I mean good device it can go up to 1000 degrees centigrade, it can measure up to 1000 degree centigrade. And it can measure that the accurate temperature up to 00.1 degrees centigrade as well.

So, if there is a change in temperature has to be measured then RTD is the best device. After that there is a device which is known as thermister. Now, property of the thermister is that it has a negative temperature coefficient. So, if you increase the temperature the resistance will go down, when the resistance will go down more current will pass the temperature will increased. This situation will come the thermister will come will come in the equilibrium in the surroundings right.

And this response is very non-linear type of response, but the response is very good and it can be used for minus a 100 to 300 degrees centigrade temperature measure. And they are bending of the device is which can be used for the temperature measurement. But, mainly these type of devices are used instead of sensors are used in the power plants for temperature measurement.

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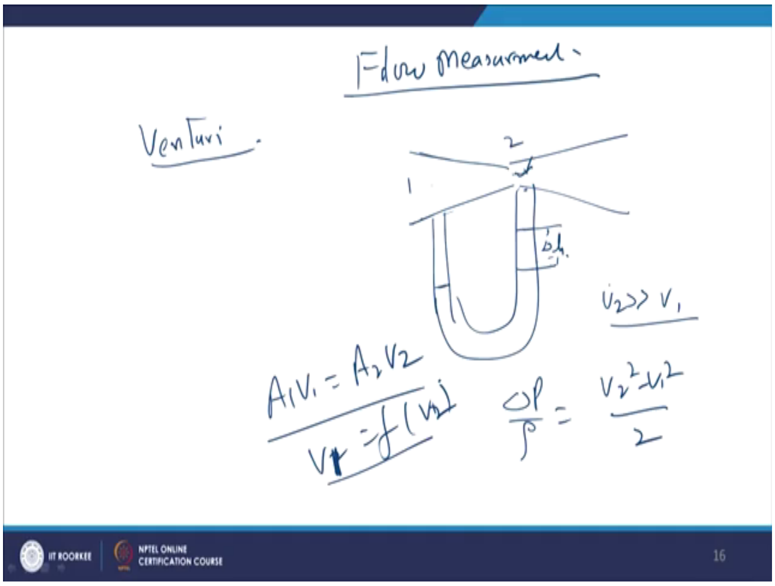

Now, for the flow measurement first is Venturi meter. So, Venturi meter has a converging and diverging passage and it works on the Bernoulli's principle as all of you must have a studied. So, here this is section 1, this is section 2 and here U tube nanometer is used and Venturi type of flow meter. And because either we have the velocity has increased I will not write the equation here, because you both I suppose that you already studied this type of devices in fluid mechanics course.

So, when the fluid the velocities change when is a converging section velocity is reduced sorry velocity is increased at the expense of the pressure. So, we, so the pressure here is low and pressure here is high. So, this pressure difference h, this pressure difference or pressure difference equivalent to this delta h has been converted in to the velocity or velocity change in the velocity.

So, delta P upon rho is equal to V 2 square minus V 1 square by 2 right. So, if V 1 V 2 is 2 very higher very high then V 1 or V 2 V 1 are comparable in that case also we can find the velocity of the fluid which is flowing in the pipe. So, this is because V 1 V 2 can always be related A 1 V 1 is equal to A 2 V 2. So, V 2 can also be taken as a function of V 1 sorry V 1 can also be taken as function of V 2 vice versa. So, that is how we can get the velocity of the fluid.

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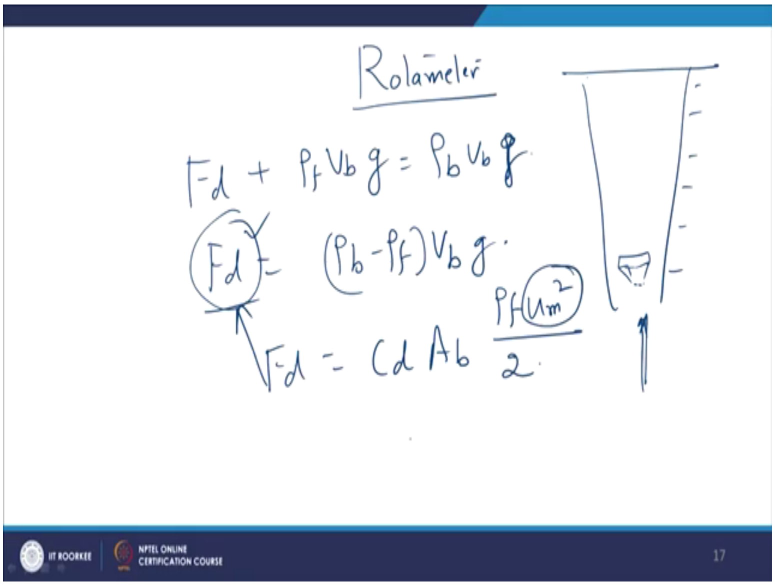

Another most powerful and more widely used is rotameter. Rotameter has a diverging passage any float right. And this float when the velocity of the fluid is increase accordingly this float takes position at different heights in the vertical. It is always vertical rotameter is never horizontal, that is the I mean one of the limitation of the rotameter, it can be installed in a vertical direction only.

Venturi meter can installed in a horizontal and vertical there is no issue, but the issue with the rotameter it can be installed in a vertical direction. And the flow will decide where the (Refer Time: 28:31) will be get balanced and the pressure balanced is drag force plus this is density of the fluid normally it is water density of the fluid and g is equal to.

So, it is it works on the it is (Refer Time: 29:00) to this principle also, so Fd is equal to rho b minus rho f V b into g. Now, drag force is coefficient drag coefficient rho f u m square divided by 2. From here we can calculate the value of Fd and when we are putting this value of Fd here we can always find the velocity being velocity of the fluid.

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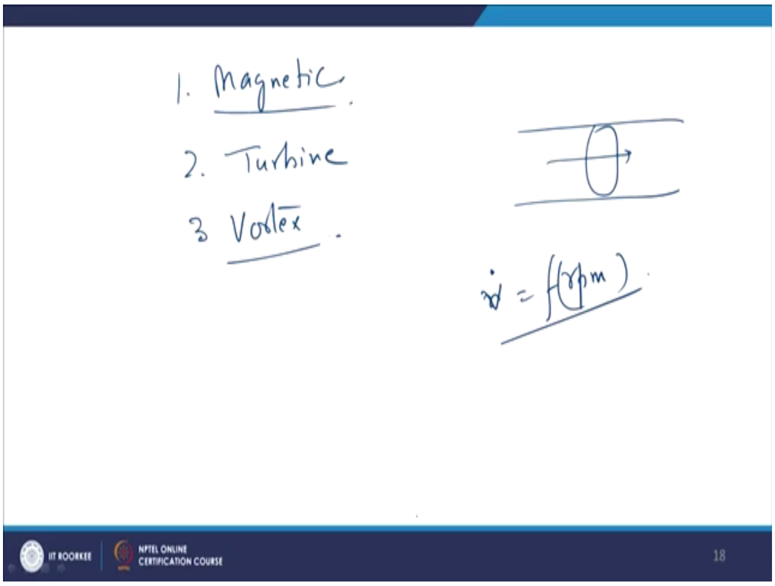

There are other flow meter there are number of flow meter one is magnetic flow meter which works on the electromagnetic induction. And a there is a flow meter which is known as a turbine flow meter. In turbine flow meter is a small turbine is house in a pipe and where the water flows through the turbine starts rotating. So, rpm of the turbine the flow rate volumetric flow rate can be a function of rpm of the turbine right. So, turbine flow rate is there, vortex flow rate is there, vortex flow rate is there if bluff body.

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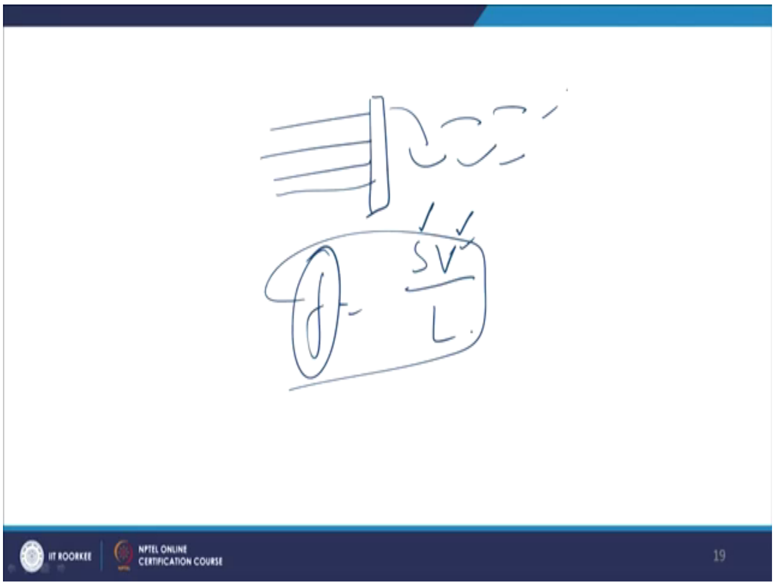

Now, if a bluff there is bluff body, like a cricket bat cricket bat is a bluff body. So, when the fluid flows over the bluff body it is vertexes are formed behind the bluff body. If you are able to capture the frequency of this vertexes it is S V over L right. L is the characteristic length, V is the velocity, S is the stroll Hall lumber and F is the frequency.

If you use this correlation you can these appears to be I mean it appears that this flow meter will not be very accurate. But, practically it has been found for the specially for the low flow rate these flow meters are very effective right.

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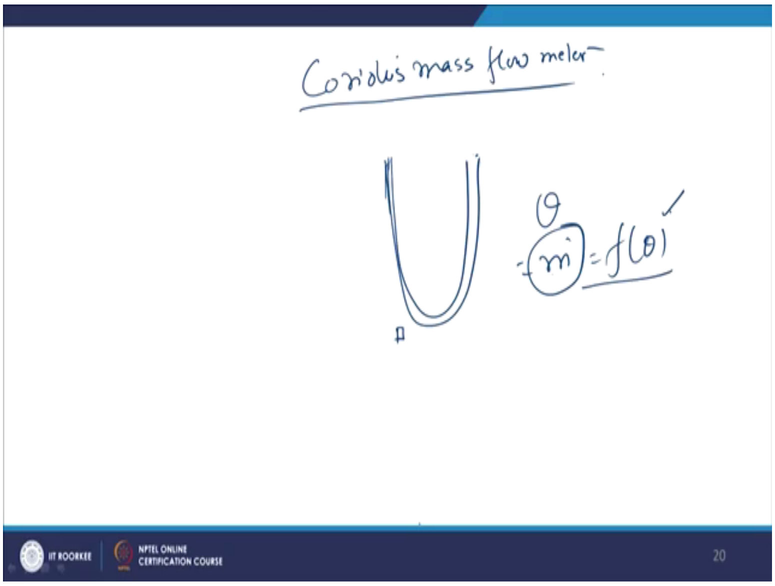

One of another flow meter which is very popular in the industry is Coriolis flow meter, mass flow meter. Because here most of the flow meters they are volumetric discharge flow meter and then volume is volumetric discharge is multiplied by the density and that is how we get the mass flow rate. But, in Coriolis flow meter we directly get the mass flow rate.

And in Coriolis flow meter there is a tube there is a tube and fluid flows in a tube and tube itself vibrate, so due to Coriolis effect the tube gets bent. Suppose there is a tube here this is a tube right and when the flow is taking place inside the tube and the tube is vibrating. Then the both the arms of the tube will twist and angle will be twist an angle and this theta angle. So, mass flow rate is always a function of this angel theta.

So, by putting a proximity sensor here we can find we can always find the value of theta once the value of theta is dawn we can always find the mass flow rate. So, these flow meters are quite popular in the industry and they are quite accurate right. So, these are a few examples I have given you for the instrumentation in power plants.

Otherwise there are the exhaust gas analyzer they are a spectrometer, there are n number of instrument which are used with they cannot be covered in one lecture. So, there are n number of instruments which are used in the power plant. But, the mainly in a power plant flow of the measurement of temperature, pressure, and fluid flow is quite critical right that is all for today.

Thank you very much.