Engineering Metrology
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Lecture – 29
Pressure Measurement (Part 2 of 2)

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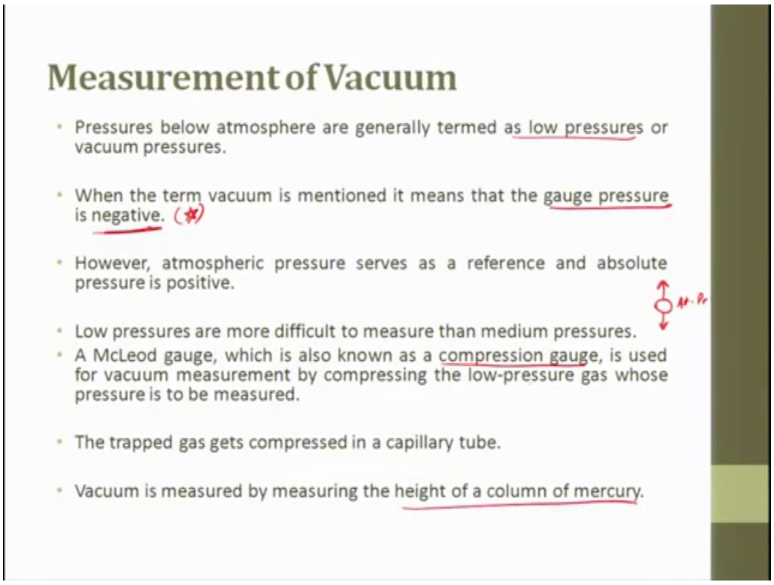

Measurement of vacuum: so, till now we saw atmospheric pressure, total pressure. So now, we have gone into a measurement of vacuum. So, in measurement of vacuum, pressure below atmosphere are generally termed as low pressure or vacuum pressure, below the atmosphere. When the term vacuum is mentioned, it means that that the gauge pressure is negative, this is very important. So, when the gauge pressure is negative it is called as vacuum; however, atmospheric pressure serves as a reference and absolute pressure is positive. Low pressure or more difficult to measure than medium pressure; so, I told you anything which is higher in pressure it is easy, if you want to go this is atmospheric pressure, anything lower than that is always a difficult.

McLeod gauge which is also known as the compression gauge is used for vacuum measurement, by compressing the low pressure gas whose pressure is to be measured.

The trapped gas gets compressed in a capillary tube the vacuum is measured by measuring the height of the column of mercury.

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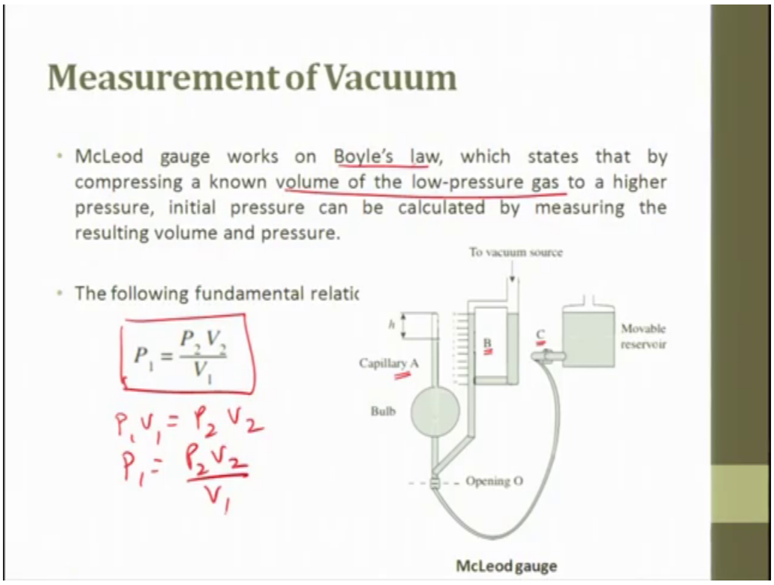

So, this is how the setup looks like. So, you have a bulb. you have a capillary which is attached, then you have a vacuum source, which is attached to here you have graduations, this is capillary A, then you have B, then you have C. C is the moving resorts and here is the opening you have opening O you have vacuum is applied here you try to measure. So, McLeod gauge works on Boyle's, Boyle's law which says that by compressing a known volume compressing a unknown volume, suppose you have a football field with air. So, you compress compressing a known volume of low pressure gas to a higher pressure, compressing a volume of a low pressure gas to higher pressure, initial process can be calculated by measuring the resulting volume and pressure that was Boyle's law.

So, the fundamental relationship is P 1 is equal to so, this is P 1 V 1 equal to P 2 V 2. So, they have considered as P 1 equal to P 2 V 2 by V 1.

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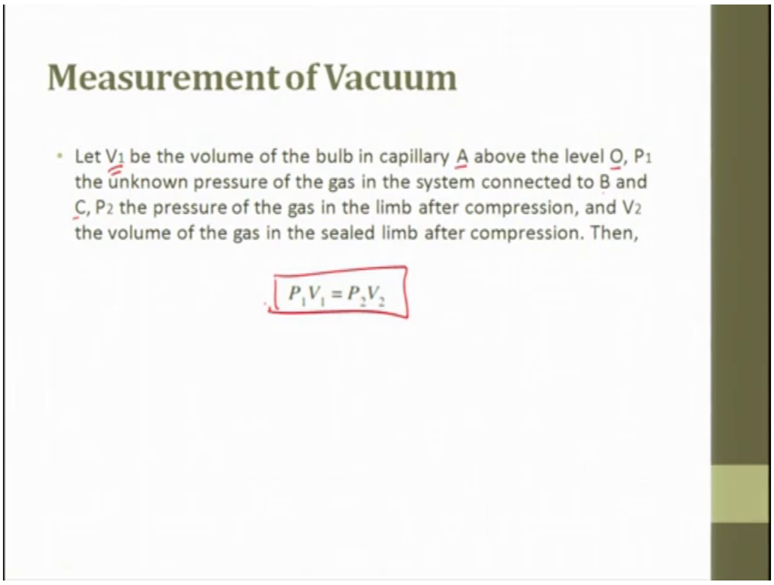

So, if V is the volume of the bulb in capillary A, above the level O P 1 is the unknown pressure of the gas in the system connected to B and C to go back and see connected to D pressure B and C. P 2 is the pressure of the gas in the limb after compression and V 2 is the volume of the gas in the sealed limb after compression, then V 1 V 1 equal to P 2 V 2.

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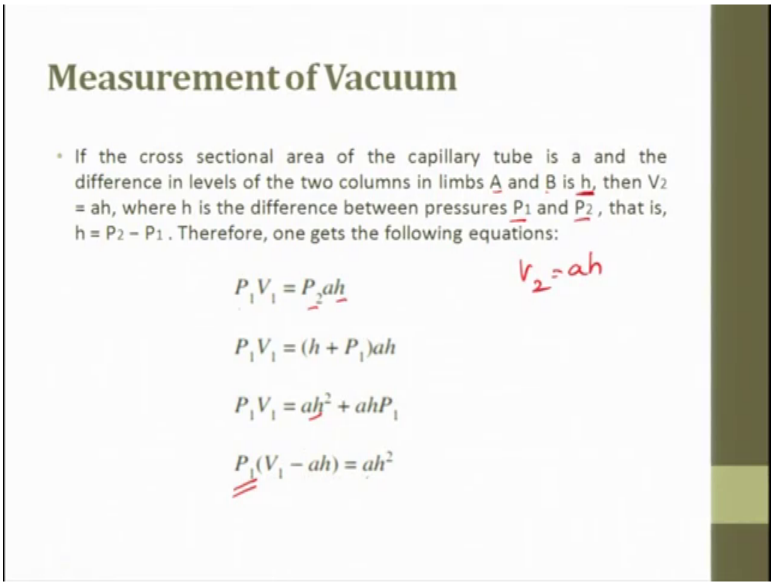

If the cross section area of the capillary tube is a and the difference in the level of the 2 columns in limb B and A and B is heads, then V 2 equal to equal to a into h; h is the difference of P 1 P 2; that is h P 2 minus P 1. Therefore, we can put it back into the equation P 1 V 1 is equals to P 2 which is nothing but V 2. So now, we try to re-alter the equations, we try to make P 1 V 1 equal to heads plus P 1 into. So, we alter the terminologies so, 2 plus P 1. So now, we move this P 1 here; so, P 1 taking common as V 1 minus equal to 2.

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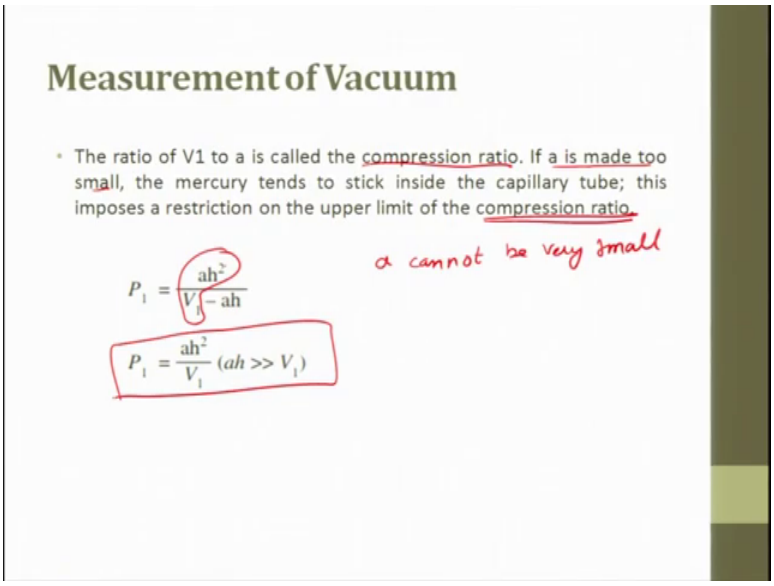

The ratio of V1 to a, is called as a compression ratio v to a, is called as a compression ratio. A is made too small the mercury tends to stick inside the capillary tube; this imposes a restriction on the upper limit of the compression ratio. So a, cannot be cannot be very small. So, if it is very small the system fails. So, P 1 is equal to 2 minus B 1 minus a. So, this terminology comes and we try to remove this greater than V 1. So, with this we can try to measure the vacuum pressure.

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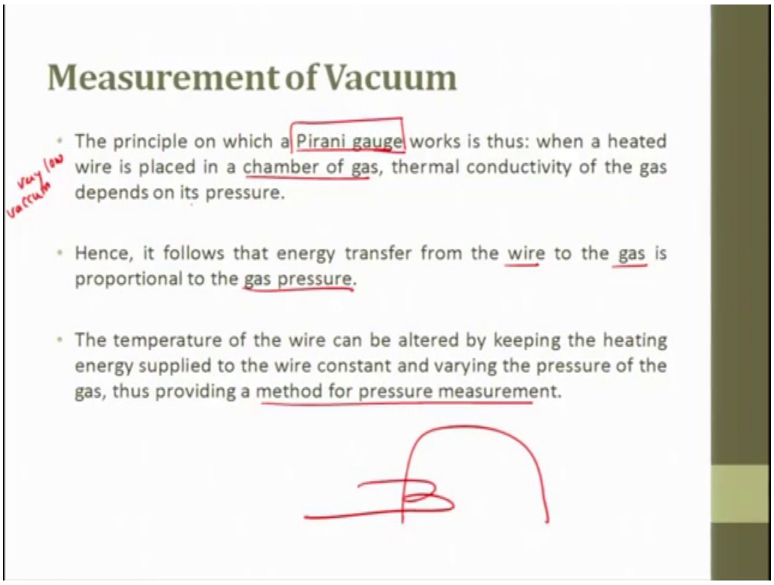

The other one is called as the Pirani gauges. The principle on which a Pirani gauge work is thus when a heated wire is placed in the chamber of gas, thermal conductivity of the gas depends on it is pressure. Very important Pirani gauge is used for very low vacuum and that. So, in the sophisticated instruments we always use Pirani gauge. Pirani gauge when a heated wire is placed in the chamber of gas, the thermal conductivity of the gas depends on it is pressure. Hence, it follows the energy transfer from the wire to gas is proportional to the gas pressure. This is very efficiently used even today. The temperature of the wire can be altered by keeping the heating energy supplied to the wire constant, and varying the pressure of the gas; thus providing the method of pressure measurement. I repeat this is one of a very important gauge which has even now find application; where the working principle is when a heated wire is placed in the chamber, heated wire in a chamber the thermal conductivity of the gas depends on the pressure.

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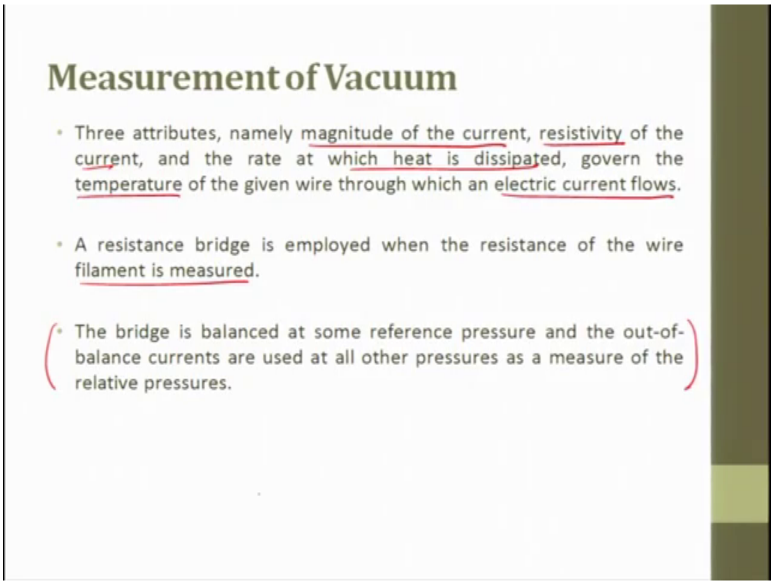

Three attributes, namely magnitude of current resistivity of the current and the rate at which the heat is dissipated governs the temperature for a given wire through the electric current flow. Resistance bridge is employed when the resistance of the 2 filament is measured, the bridge is balanced at some reference pressure, and the out of balance current are used at all the other precious as the measurement of relative pressure. This is also very, very important. The bridge is balanced at some reference pressure, and the out of balance current are used at all other pressure as the measurement of the relative pressures.

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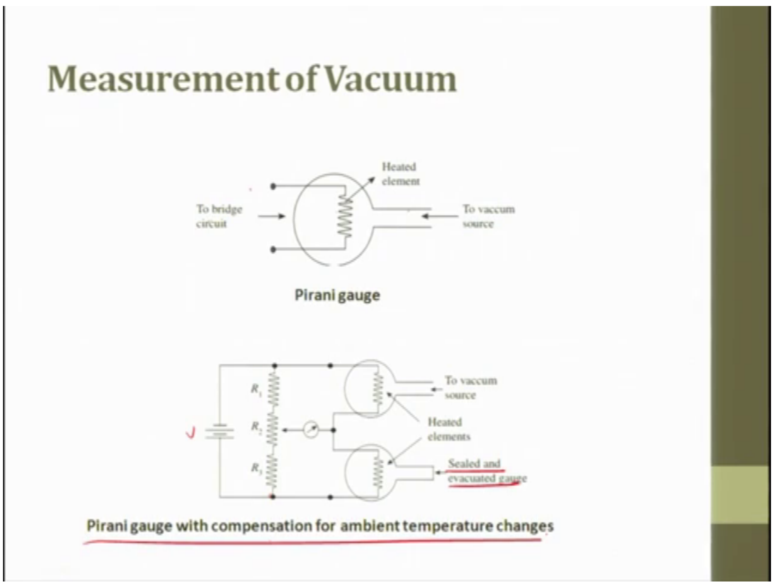

So, this is how a Pirani gauge a vacuum source there, a bridge circuit is there, this is a filament which is heated. So, you apply a constant heat try to measure or you try to change the heat measure the voltage anything is fine. So, Pirani gauge with compensation to ambient temperature, you can see here a vacuum is there. So, here is a heated one the output of the heated one is attached to a voltmeter, and then it is attached to another heated element. So, this gauge is this is the sealed evacuated gauge. So, you have resistance build and this is the applied voltage. So, you see this Pirani gauge with compensation for ambient temperature change.

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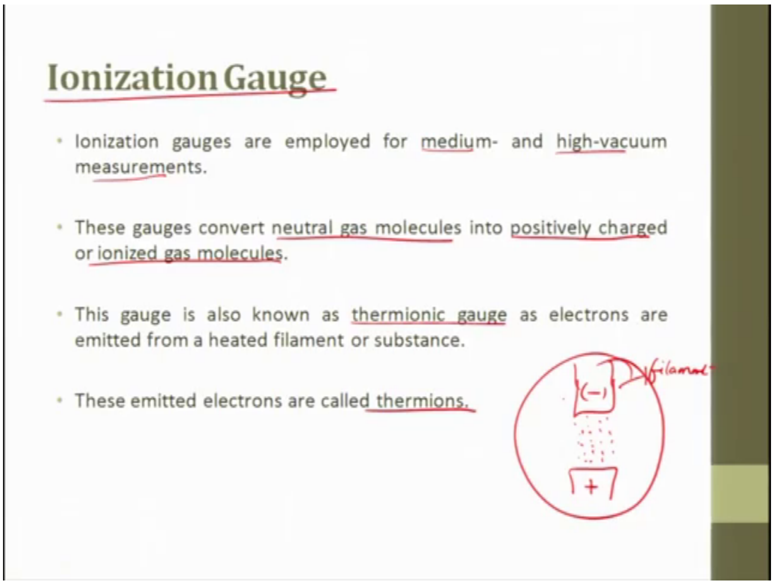

Next is ionization gauge. Ionization gauge are employed for medium and high vacuum measurement these gauges convert neutral gas molecules into positively charged or ionized gas molecules. What is ionization? I take 2 potential may be positive, negative, put it inside a container and keep applying electricity. So, hear what happened the ionization happens ok. So, when the gas converts the neutral gas molecule into positively charged ins gas molecule this is used. The gate is also known as thermionic gauge as electrons are emitted from the heated filament, this is the filament or substance; the emitted electrons are known as thermions thermally emitted ion thermion.

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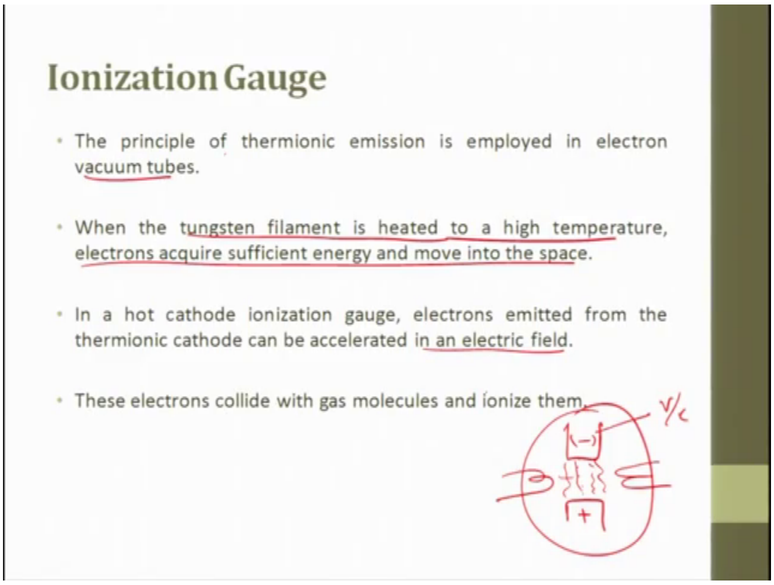

The principle of thermion emission is employed in electronic vacuum tubes; when the tungsten filament is heated at a very high temperature passing very high current, the electrons acquire sufficient energy and moved into the space, the hot cathode ionization gauge the electron emit from the thermionic cathode will be accelerated in an electric field. So, what they are trying to say this is; this is negative, this is positive. So, this is inside a vacuum and you apply lot of voltage, right voltage are current. So, there is ionization happening, this ionization can spread everywhere.

So, what I do is, I tried to put a magnetic coil around it or an electric field, and make sure that they are focused. These electrons collide with the gas molecules and ionize them.

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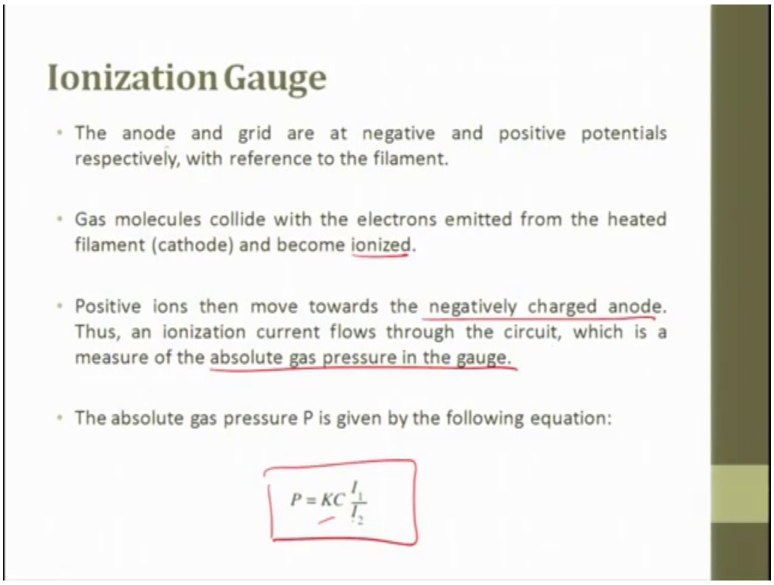

The anode and the grid are at negative and positive potential respectively with reference to the filament. The gas molecules collide with the electron emitted from the heated filament and becomes ionized, the positive ions more towards the negatively charged anode; thus the ionization current flow through the circuit which is measured as absolute gas pressure in the gauge. So, the absolute gas pressure can be defined as KC I 1 by I 2.

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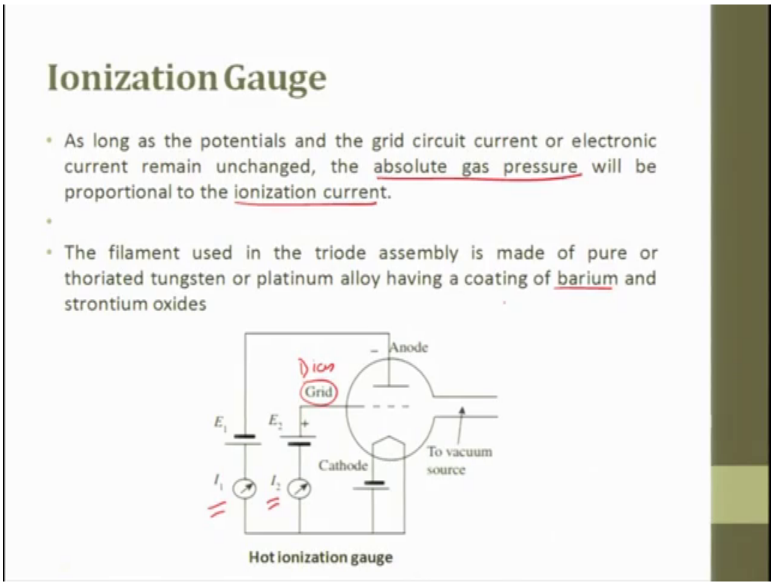

So, this is what is I 1, this is I 2, k is the factor. So, you have an anode you have a cathode here is a grid; which is otherwise called as a bias we apply and here is the vacuum.

As long as the potential and the grid circuit current or the electronic current remains unchanged the absolute gas process will be proportional to the ionization current. The filament used in triode assembly is made of pure or thoriated tungsten or platinum alloy coating of barium and strontium oxide. So, these are the materials which are used for the vacuum measuring gauge.

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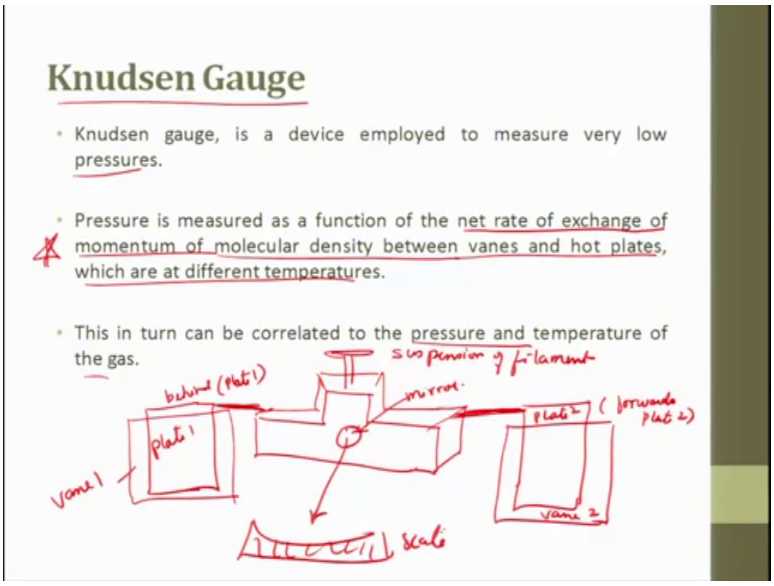

The, another one another gauge is called as Knudsen gauge, it is a device employed to measure very low pressure, the pressure measured is a function of a net rate of exchange of momentum of molecular density between the vane and the hot plate which are at different temperatures. So, this is the principal with which the Knudsen gauge work. The pressure is measured as a function of net rate of change of momentum of molecular density between the vanes of a pump and the hot plate at which are kept at different temperatures. This in turn can correlate the pressure and temperature of the gas ok.

So, let me draw the figure so that you will have a better understanding, this will be the suspension of filament ok. So, here is this is plate 1, this is vane 1 and this is vane 2, plate 2, plate 2, vane 2, the top one, and here I attached plate here and plate here ok. So, the plate 1 is behind this is behind plate 1 is behind, and here plate 2 is forward and vane is behind ok. So, here there is mirror and this in turn has a graduation scale. This is a scale. So, this is how Knudsen gauge works.

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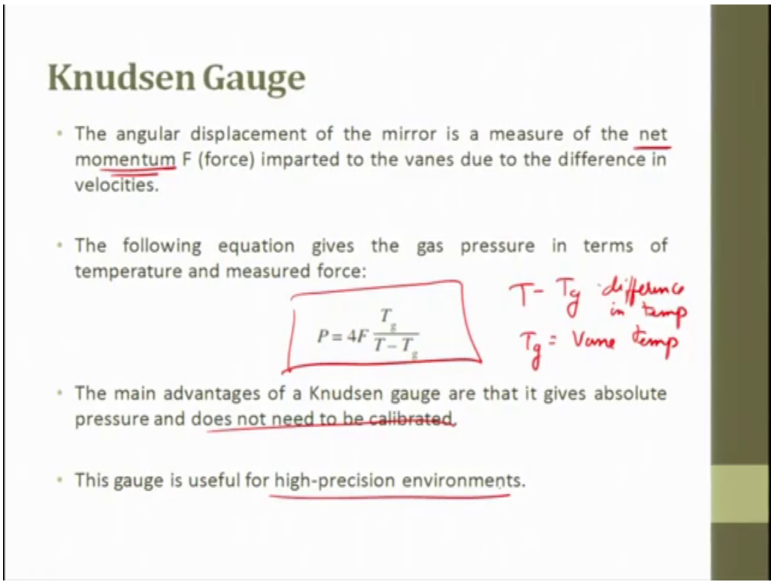

The angular displacement of the mirror is measured of the net momentum force; where is mirror so, this is the mirror, ok. So, mirror is measured of the net momentum F imparted on the vane vanes due to the difference in the velocities. So, the equation for the gas pressure is given as P equal to 4 times F T g by T minus T g. So, T minus T g is the difference in temperature F is the momentum force, net momentum force and P is the pressure change T g; T g is the vane temperature, vane temperature ok.

So, the main advantage of Knudsen gauge are that it gives absolute pressure and does not need any calibration.

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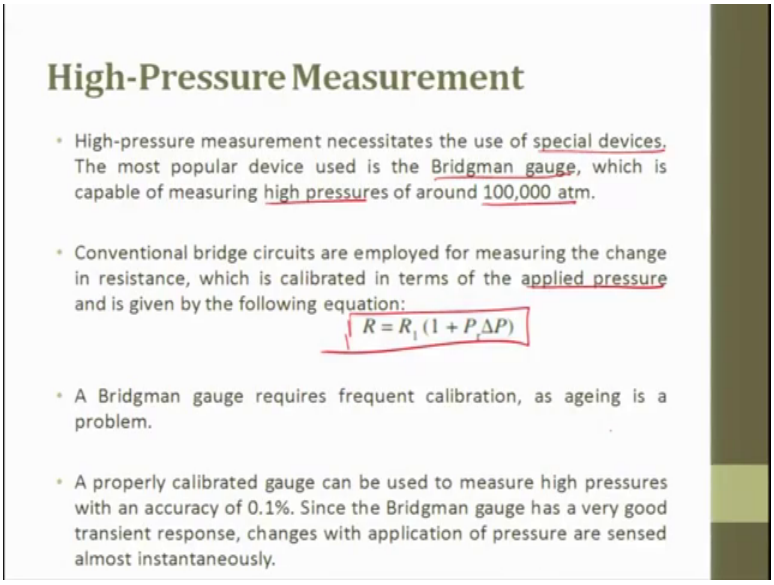

They are very high pressure they are very useful at very high pressure environments, high pressure measurements. High pressure measurements necessitate the use of specific devices. The most popular device used this Bridgman's gauge which can be which can measure high pressure up to 1 lakh atmosphere. The conventional bridge circuit are employed for measuring the change in resistance, which is calibrated in terms of applied pressure which is given by the equation of this; by the Bridgman require frequent calibration as gauging is a problem ok. And in the previous one Knudsen gauge there is no calibration required at all.

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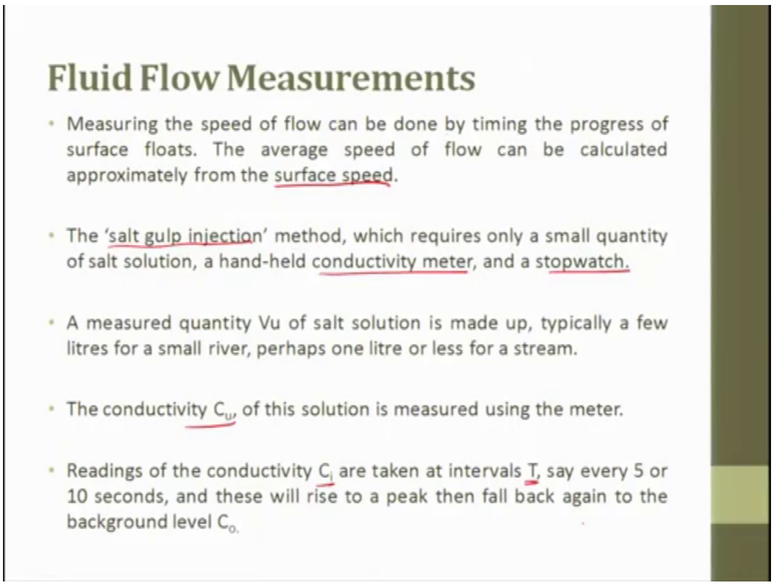

A fluid flow measurement till now what we saw was only air as a media, now we will try to see fluid. Fluid flow measurement measuring the speed of a flow can be done by timing the progress of a surface floats. The average speed of flow can be calculated approximately from the surface speed. For example, if the water is flowing and on top of it you put a small paper, and you time it ok. Now it starts, and then you take for after 100 meter the velocity of the water. So, that is what we are trying to say. The speed of flow can be done by timing the progress of a surface plot. The average speed of flow can be calculated approximately from the surface speed. The salt gulf injection method which requires only a small quantity of salt solution, a hand held conducting meter and the stopwatch we can do it.

So, the measured quantity is V suffix u of salt solution is made up, typically a few letters from a river small river; perhaps, 1 liter or less of stream so, the conductivity is this. So, on the reading conductivity are taken at time interval T say 5 seconds and 10 seconds we try to calculate the a flow.

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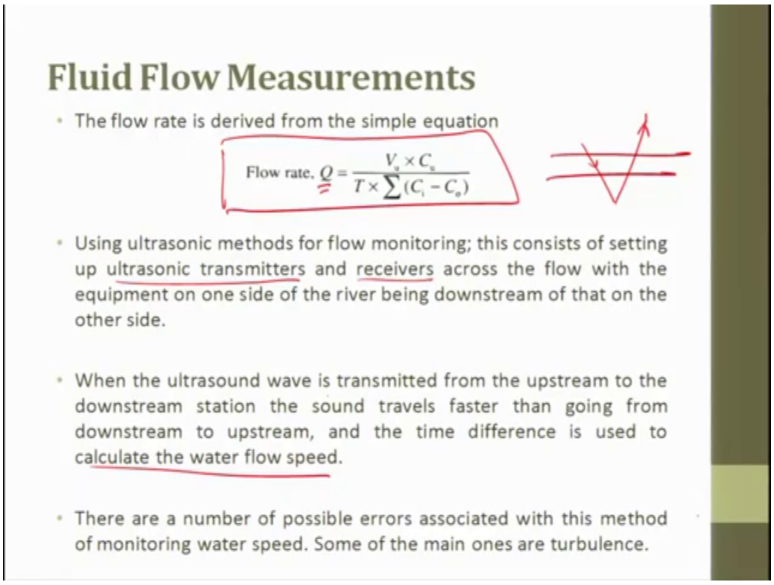

So, the flow can be given by this equation. This is the very simple flow equation, where conductivity of the solution is measured as C u, velocity is V u right, and then C i and C naught, C i is the reading in the conductivity, and C naught is the background level which is there. So, with this we try to calculate Q.

The use of ultrasonic method for flow monitoring this consists of setting up an ultrasonic transducer and a receiver across the flow with the equipment on one side of the river being downstream of that of the other side. So, we see the velocity with which the amplitude travels the velocity with which the sound travels and comes back. So, with the pitch and catch we can try to figure out what is the velocity right, when the sound wave is transmitted from the upstream to the downstream station, the sound wave travels faster than going from downstream to upstream. The time difference is used to calculate the water speed. There are number of possible errors which can happen in this, but still people do it for a ballpark figure.

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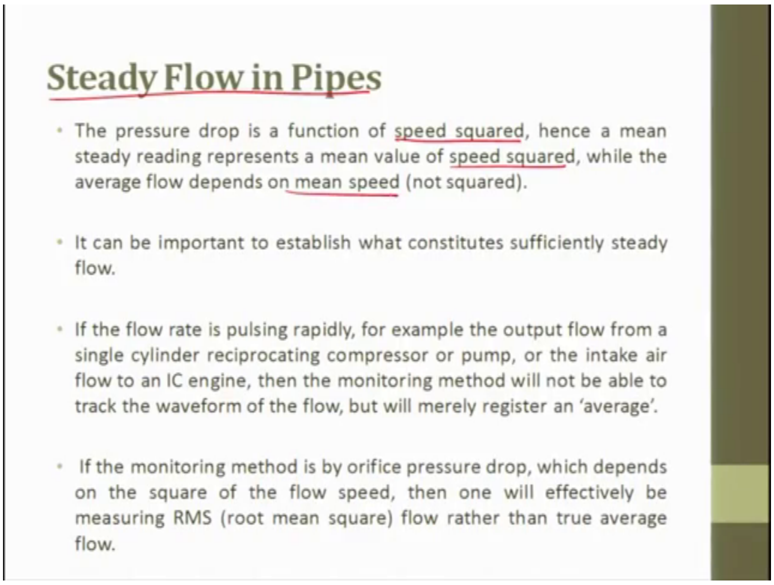

Steady flow in a pipe this is the very common experiments where fluid mechanics people do. The pressure drop is the function of speed squared; hence, a mean steady reading represents a mean value of the speed squared while the average flow depends on the mean speed not squared.

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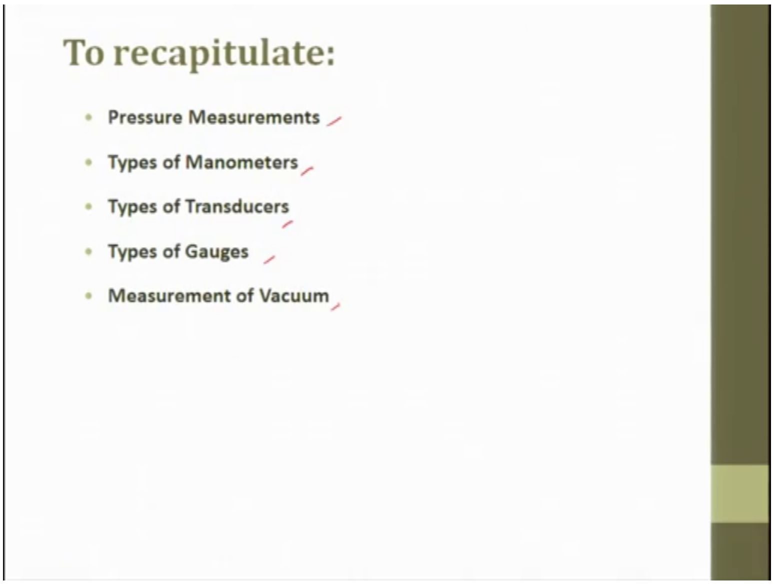

So, to recapitulate what we saw in this particular lecture is pressure measurement type of manometer, type of transducers types of gauge and measurement of vacuum. There is a flow measurement also there, but we are restricting ourselves up to vacuum.

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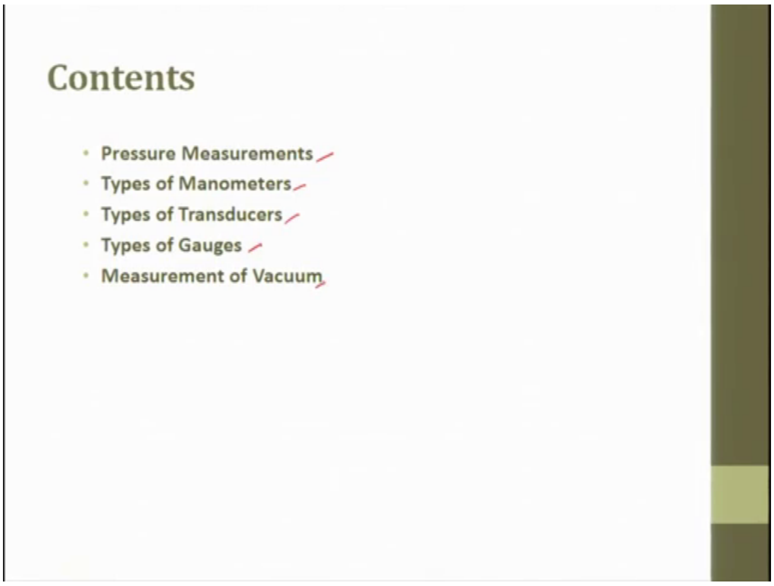

The content of this picture is going to be pressure measurement, type of manometers, different types of transducers, type of gauges and measurement of vacuum.

Thank you.