Chemical Process Utilities
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Lecture – 50
Gauges of Pressure Measurement

So, welcome to the new chapter of gauges for pressure measurement under the aegis of chemical process utilities. So, in this particular lecture we are going to discuss about the direct measuring vacuum gauges. After the brief introduction about the topic which we are going to discuss, then we will discuss about the indirect measuring vacuum gauges. Now the Torricelli tubes, this was the sole device capable of measuring the vacuum for almost 350 years from 1644 until around say 1900.

Now it was based on the counter balancing of mercury wall columns, gravitational pull against a pressure differential between the 2 volumes separated by the liquid mercury.

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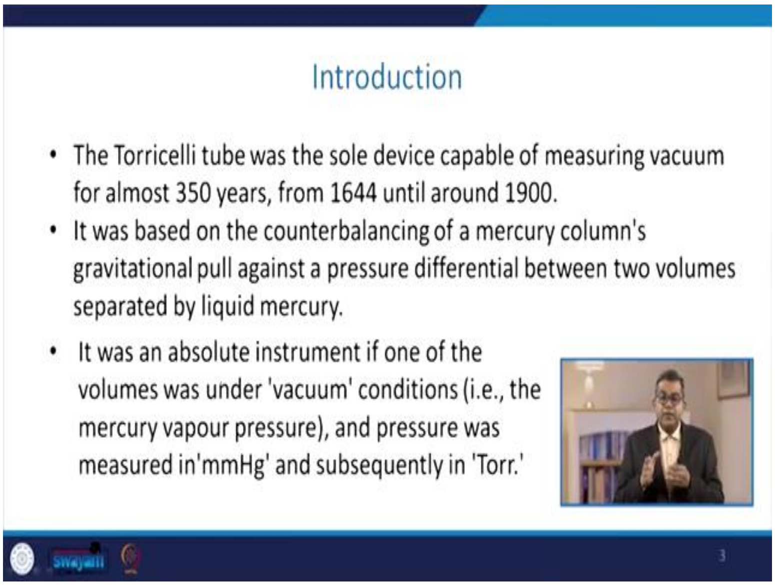

So, it was an absolute instrument, if one of the volumes was under vacuum condition and that is the mercury vapor pressure and the pressure was measured in mm of Hg and subsequently in torr.

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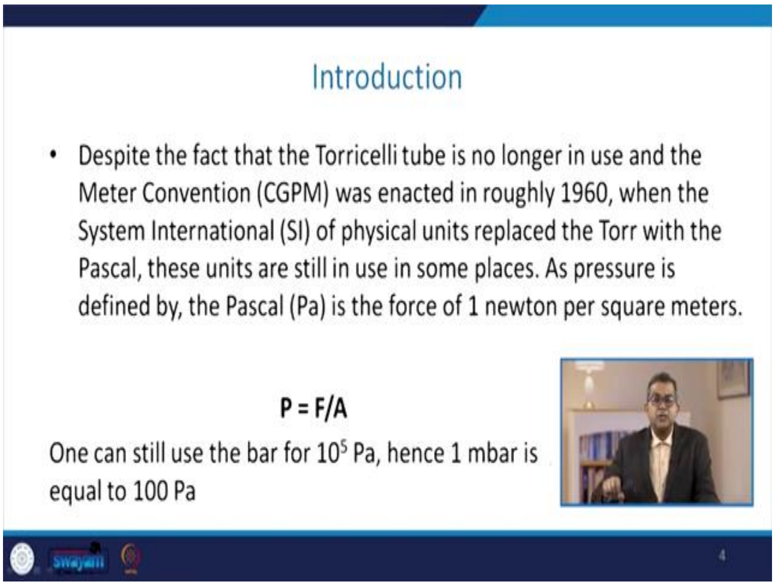

Now, despite the fact that the Torricelli tube is no longer in use, the meter convention, CGPM was enacted in roughly 1960 when the system international or sometimes referred as SI of physical units replace the torr with the pascal. Now these units are still in use in some places, as pressure is defined by the pascal is a force of one Newton per square meter and that is referred as P is equal to F upon A.

$$\mathbf{P = F/A}$$

So, one can still use the bar for 10 to the power 5 pascal, hence 1 millibar is equal to 100 pascal.

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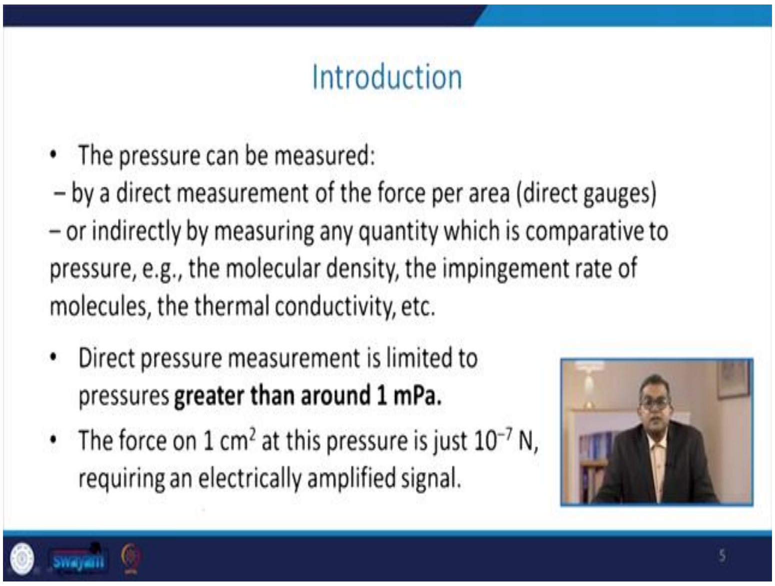

Now the pressure can be measured either by a direct measurement of the force per area. That is the direct gauge or indirectly by measuring any quantity which is comparative to the pressure. That is the molecular density or the infringement rate of the molecules, the thermal conductivity etcetera there are so many ways. Now the direct pressure measurement is limited to the pressures greater than around 1 millipascal.

The force on one square centimeter at this pressure is just 10 to the power −7 Newton requiring an electrically amplified signal.

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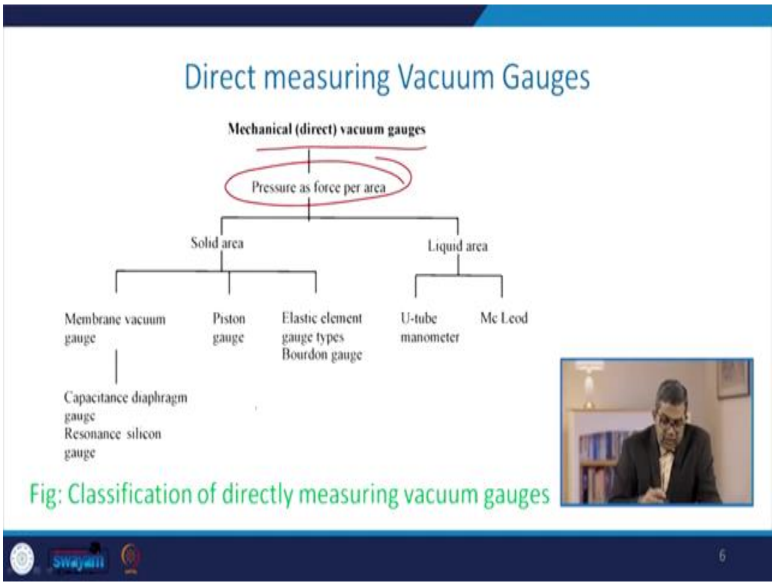

Now here you see the direct measuring vacuum gauges. This mechanical or direct vacuum gauges again the mathematical representation that is pressure as force per area. Again, it can be subdivided into 2 different aspects. When we talk about the classification of directly measuring vacuum gauges, one is the solid area and second one is the liquid area. So, if we take liquid area first into consideration, it can be subdivided into 2 different categories.

One is the U tube manometer and second one is the Mc Leod and if we take the solid area into consideration, it can be in the membrane vacuum gauge. Then the piston gauge and the elastic element gauge type or burden gauges whereas membrane gauges, membrane vacuum gauge is referred as the capacitance diaphragm gauge or resonance silicon gauge.

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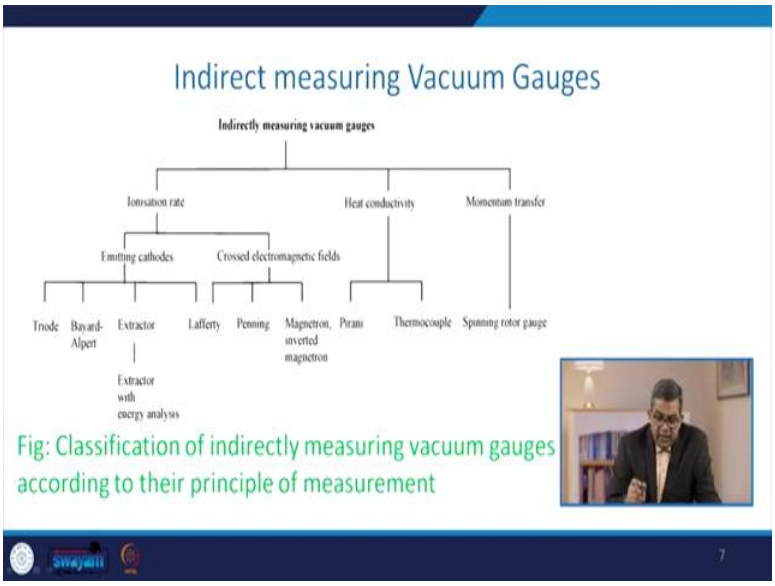

Now, if we talk about the indirect measuring vacuum gauges and if you talk about the classification of these indirectly measuring vacuum gauge. According to their principle of measurement, this can be divided into 3 different categories. One is ionization rate, then heat conductivity and the momentum transfer. Now this heat conductivity is again subdivided into the Pirani gauge and Thermocouple, whereas the momentum transfer is referred to the spinning rotor gauge.

If we talk about the ionization rate, then one is the emitting cathodes another one is the classification is based on the crossed electromagnetic field. Now, if we take the cross magnetic electric field, it can again subdivided into 3 different aspects. One is Lafferty then Penning and the Magnetron inverted magnetron. Now this emitting cathode is subdivided into Triode, Bayard Alpert, Extractor and Extractor is again referred to the extractor with energy analysis.

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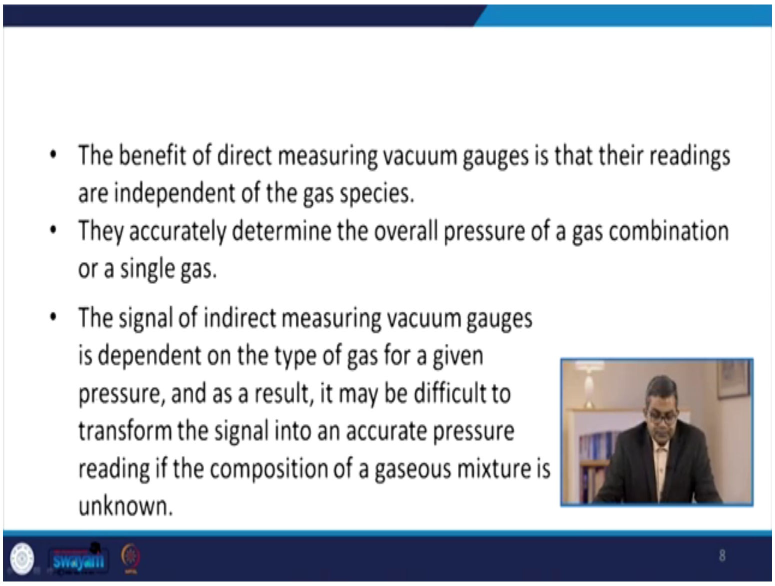

Now the benefit of direct measuring vacuum gauges is that their reading are independent of the gas species. They are accurately determined the overall pressure of a gas combination or a single gas. The signal of indirect measuring vacuum gauges is dependent on the type of the gas for a given pressure and as a result, it may be difficult to transform the signal into an accurate pressure reading if the composition of the gaseous mixture is unknown.

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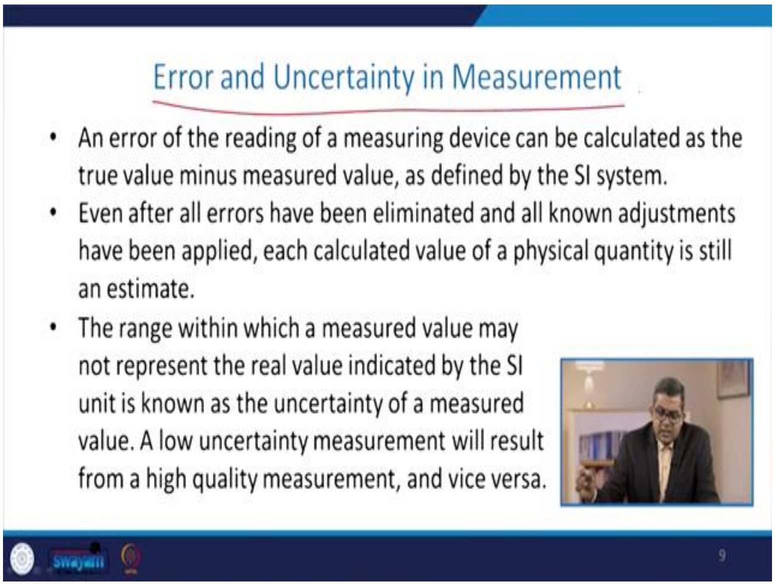

Now there are concept of error and uncertainty in the measurement. Now an error of the reading of amazing device. This can be calculated as the true value minus measured value, as defined by the SI system. Now, even after all, errors have been eliminated and all known adjustments have been applied each calculated value of the physical quantities is still an estimate.

The range within which a measured value may not represent the real value indicated by the SI unit is known as the uncertainty of a measured value. A low uncertainty measurement will result from a high-quality measurement and vice versa.

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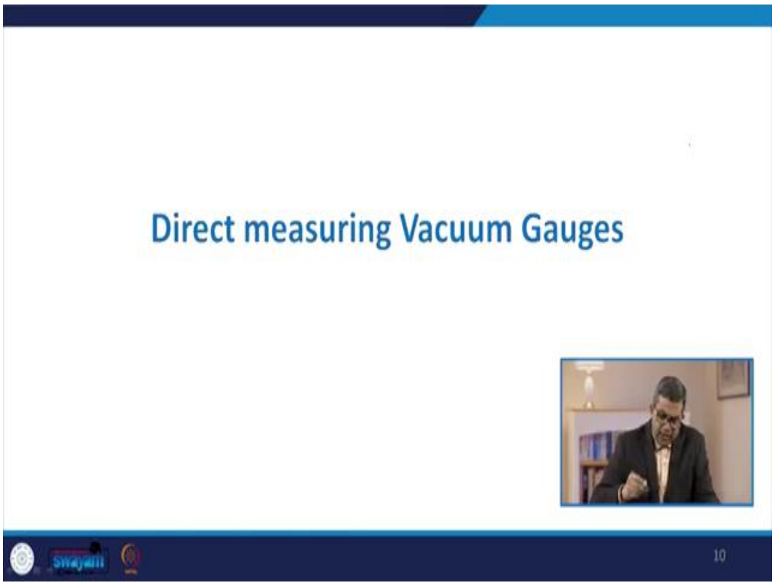

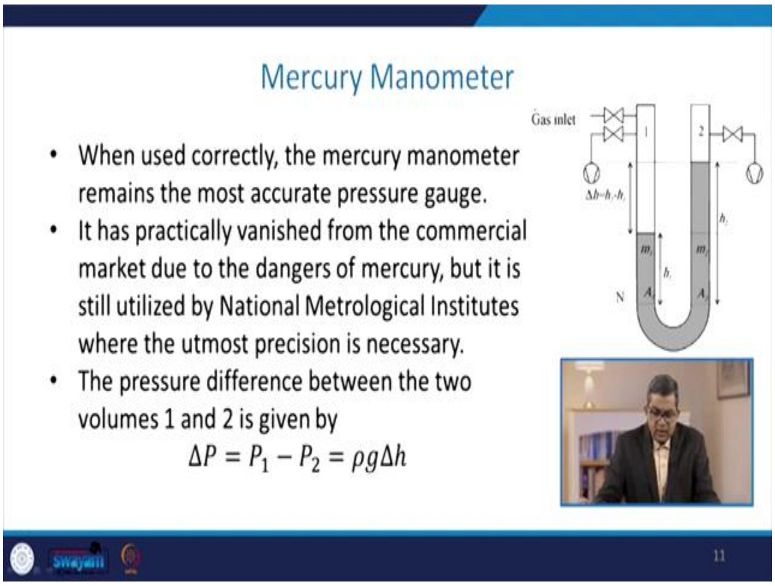

Let us talk about the direct measuring vacuum gauges. Now one is the mercury manometer which is very common in nature. So, when used correctly, the mercury manometer remains the most accurate pressure gauge. Now, it has practically vanished from the commercial market due to the danger of mercury. Because you know that mercury is highly carcinogenic and highly you can say dangerous metal.

Now, but it is still utilized by the national metallurgical institutes where utmost precision is necessary. So, the pressure difference here you see the height differences is. This is the usual mercury manometer and this is the mercury being filled. So, this is the height difference based on the pressure and you, the gas is in it over here. Now that the pressure difference between the 2 volumes, 1 and 2 is given by delta P is equal to P 1 – P 2.

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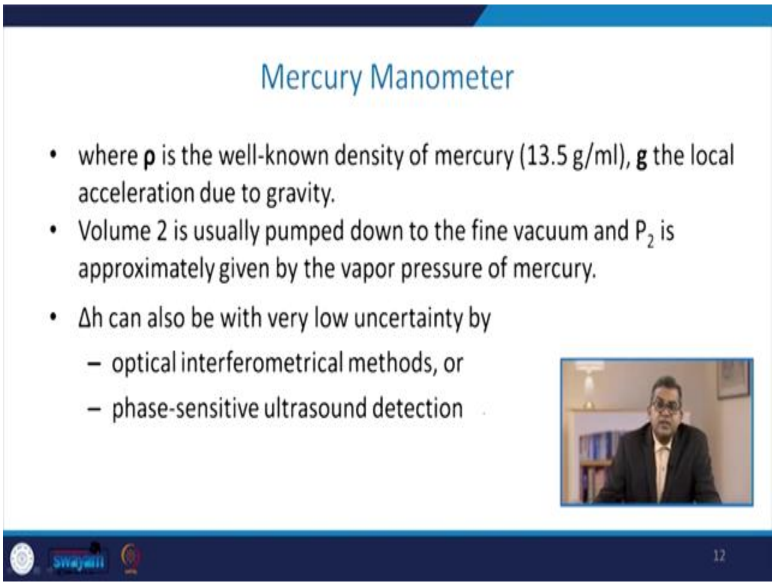
The pressure difference between the two volumes 1 and 2 is given by

$$\Delta P = P_1 - P_2 = \rho g \Delta h$$



And it is equal to rho g into delta H rho is the density of mercury and that is 13.5 gram per ml and g is the local acceleration due to gravity. Now volume 2 this one, the volume 2 is usually pumped down to the 5 in volume and P 2 is approximately given by the vapor pressure of the mercury. Now delta h, this one, the delta h can also be very low uncertainty by optical interferometrical method or the phase sensitive ultrasound detection.

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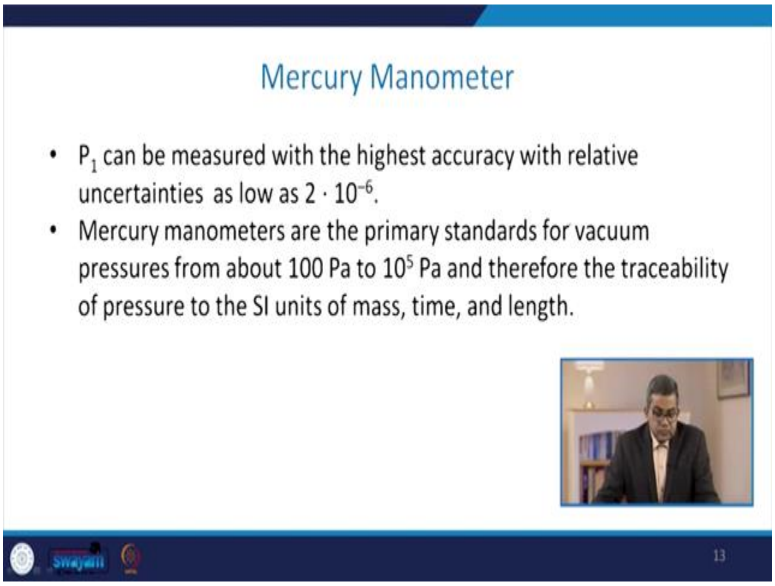

Now the P 1 can be measured with the highest accuracy with the relative uncertainties as low as 2 into 10 to the power −6. Now, mercury manometers: they are primary standards for vacuum, pressure from about say, 100, pascal to 10 to the power 5 pascal and therefore the traceability of pressure to the SI unit of mass time and length.

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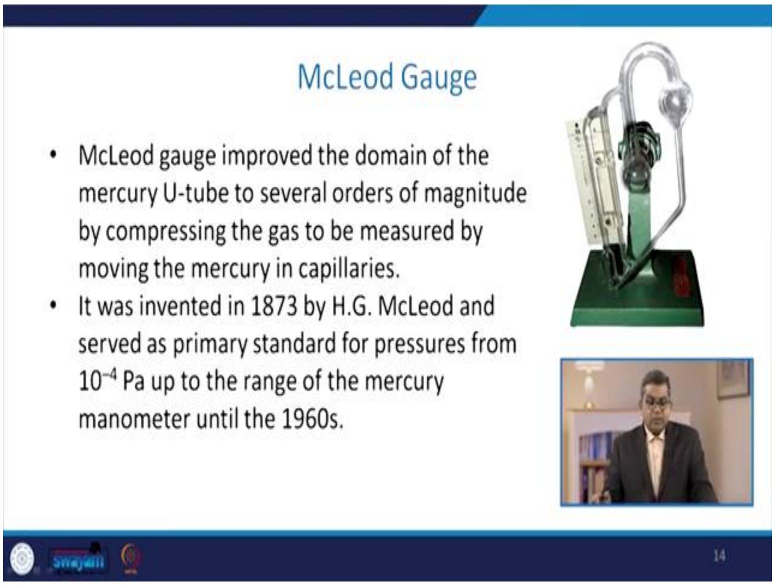

McLeod gauge: McLeod gauge improved the domain of the mercury U-tube manometer for several orders of magnitude by compressing the gas to be measured by moving the mercury in capillaries. It was invented in 1873 by H.G. McLeod and served as primary standard for pressure from 10 to the power minus 4 Pascal up to the range of mercury manometer until the 1960s.

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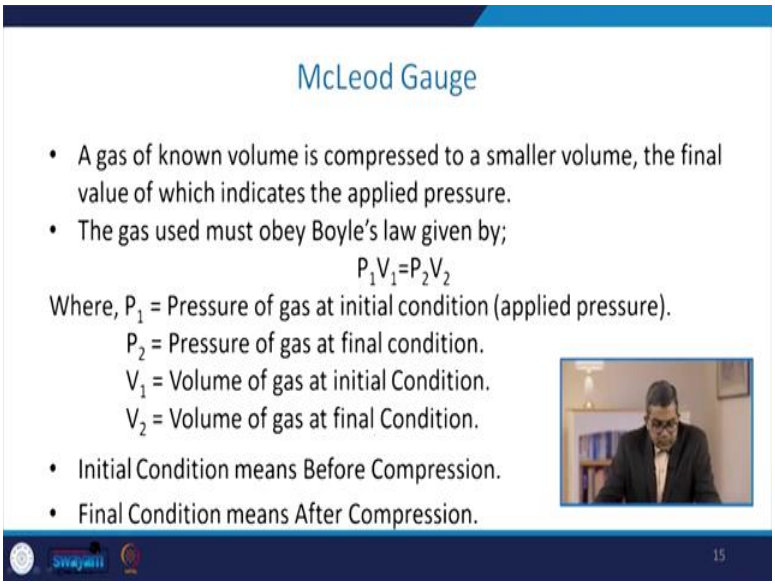

A gas of known volume is compressed to a small volume, the final value of which indicates the applied pressure. The gas used must obey the Boyle's law which is given by P 1 V 1 is equal to P 2 V 2, where P 1 is the pressure of gas at initial condition. P 2 is the pressure of the gas at the final condition. V 1 is the volume of the gas at initial condition and V 2 is the volume of the gas at final condition.

Now initial condition means before compression and final condition means after compression.

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The gas used must obey Boyle's law given by;

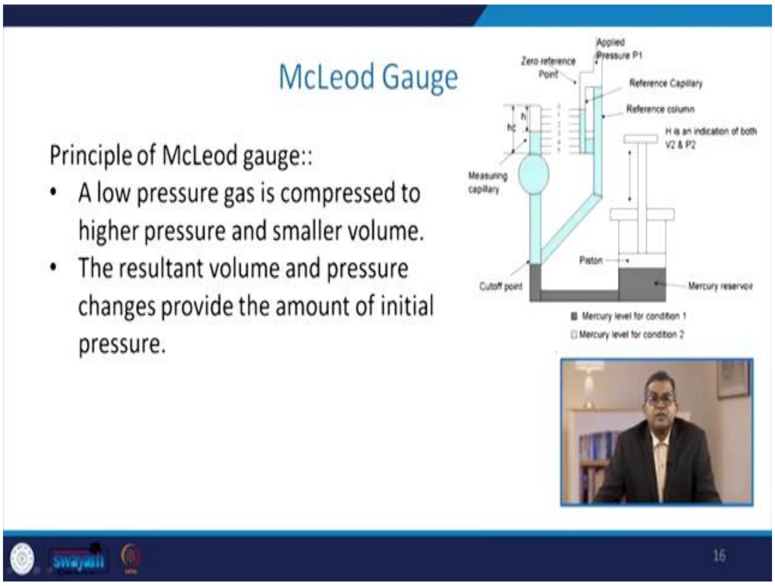
$$P_1V_1=P_2V_2$$

Where, P_1 = Pressure of gas at initial condition (applied pressure).

P_2 = Pressure of gas at final condition.

V_1 = Volume of gas at initial Condition.

V_2 = Volume of gas at final Condition.



Now the principle of McLeod gauge is that a low pressure gas is compressed to high pressure and smaller volume. The resultant volume and the pressure changes provide that amount of initial pressures.

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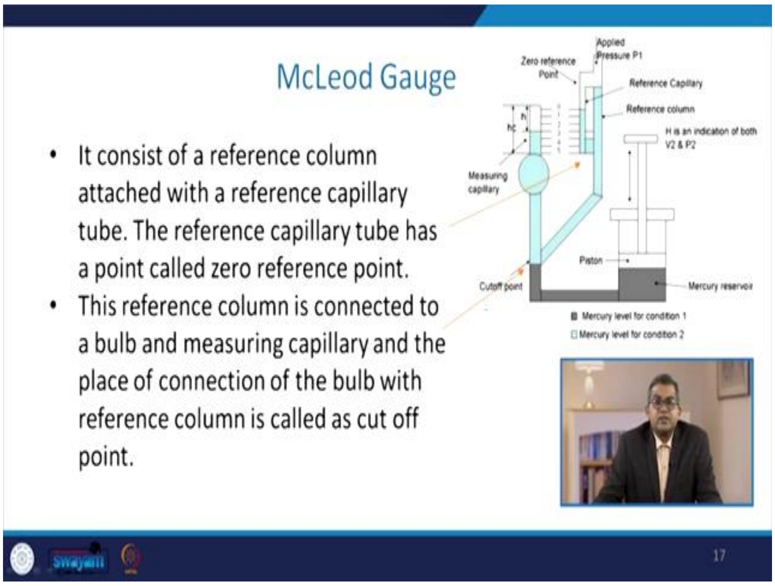

Now it consists of a reference column attached with the reference capillary tube and the reference capillary tube has a point called zero reference point. Now here you see that this is the reference one. Now this reference column is connected to a bulb and measuring capillary and the place of connection of the bulb with the reference column is called as cut off point.

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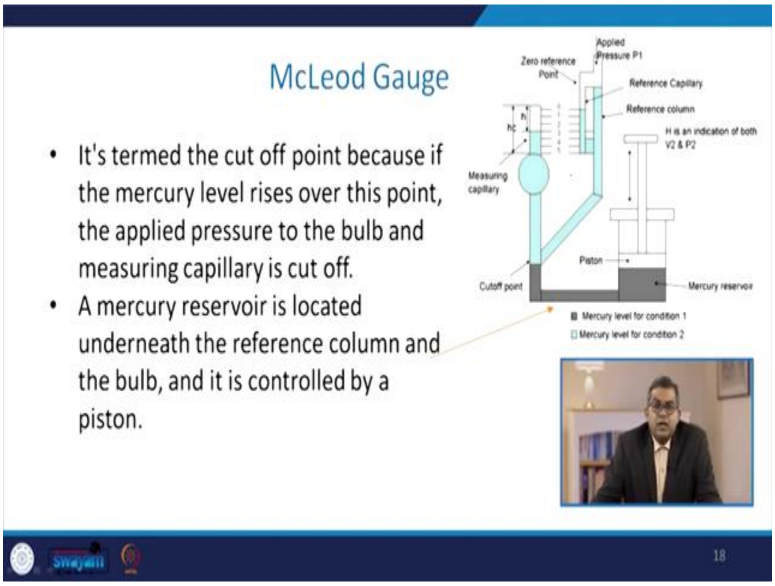

Now it is termed the cut-off point because if the mercury level rises over the point, the applied pressure to the bulb and measuring capillary is cut off. A mercury reservoir is located underneath the reference column and the bulb and is it, is controlled by a piston.

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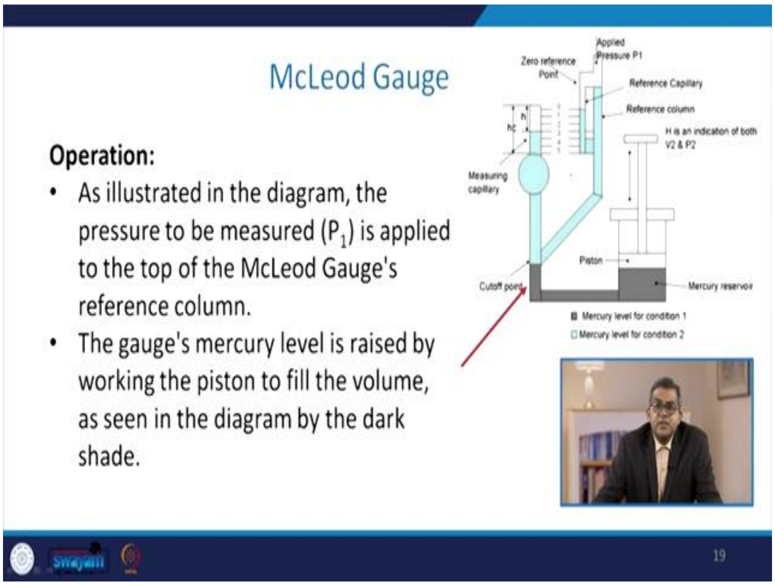

Now here you see, this is the piston. Now let us talk about the operation of this McLeod gauge now. This is very well illustrated in this particular figure. The pressure to be measured P 1 is applied at the top of McLeod gauge. Now here you see, now the gauge gates, mercury level is raised by the working, the pressure to fill the volume, as per the you can see in this particular figure.

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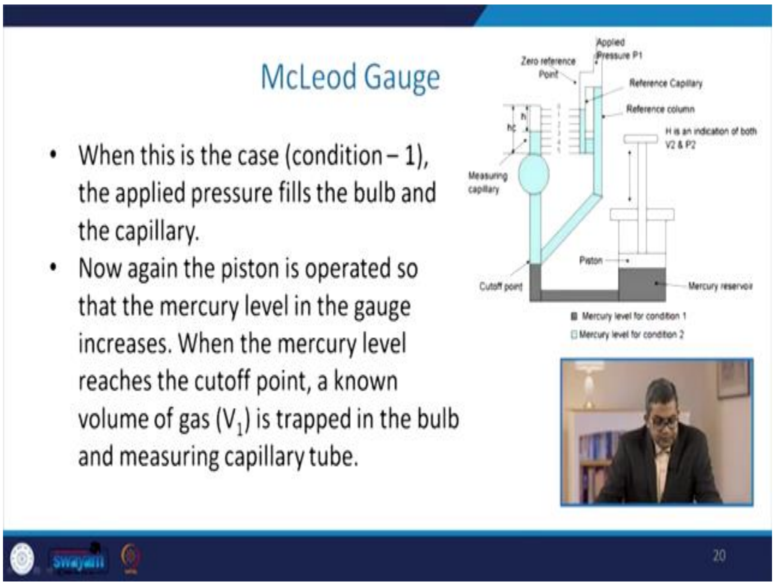

Now, when this is the case, you can refer as a case number one. The applied pressure fills the bulb and the capillary. Now again, the piston is operated so, that the mercury level in the gauge increases when the mercury level reaches the cutoff point known volume of gas. That is sometimes referred as V 1 is trapped in the bulb and measuring the capillary tube.

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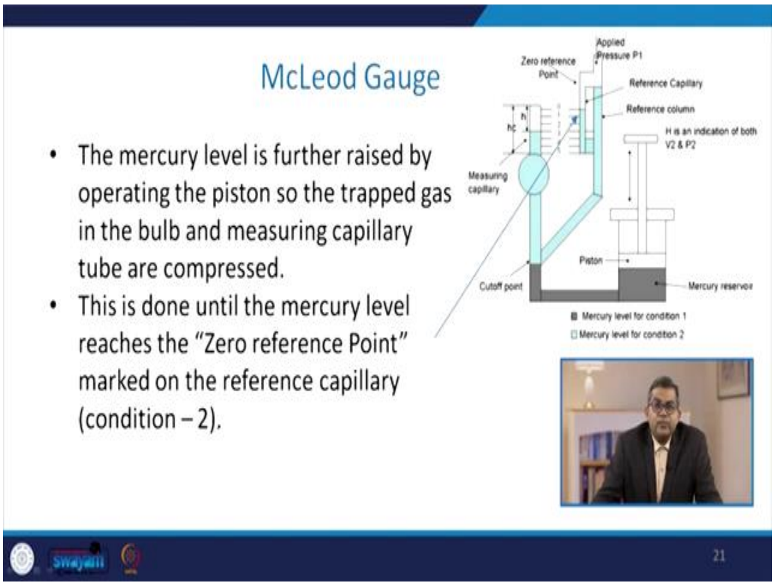

The mercury level is further raised by operating the piston, so, the trapped gas in the bulb and mercury capillary tubes are compressed. Now this is done until the mercury level reaches to the zero-reference point. Now here this is the zero-reference point now, in this condition, the volume of the gas in the measuring capillary tube is read directly by the scale beside it and that is the difference in the height delta h.

Now. This is the h of the measuring capillary and the reference capillary becomes a measure of the volume and the pressure of the final condition of the trapped gas.

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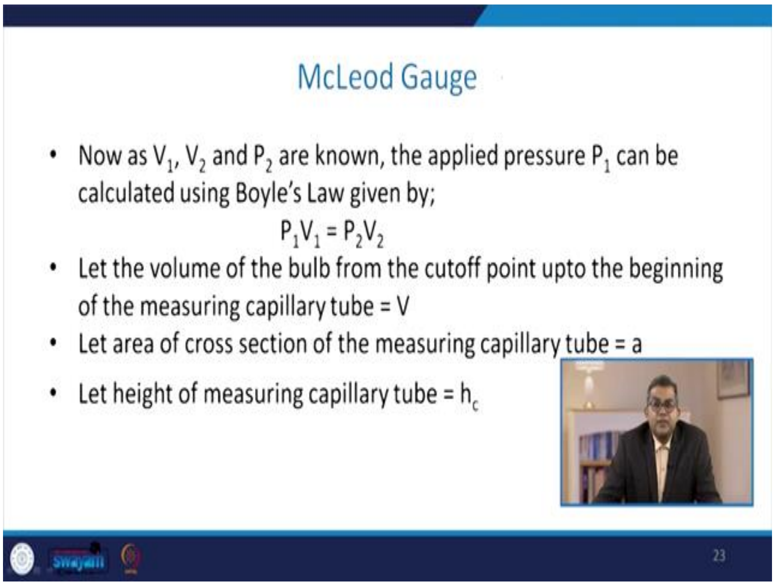

Now as V 1 V 2 and P 2 are known. The applied pressure P 2 can be calculated using the boys law by P 1 V 1 is equal to P 2 V 2. Now let the volume of the bulb from the cut-off point up to the beginning of the measuring capillary tube would be V. Let the area of cross section of the measuring capillarity is a and small a and the let height of the measuring of the capillary tube is h c.

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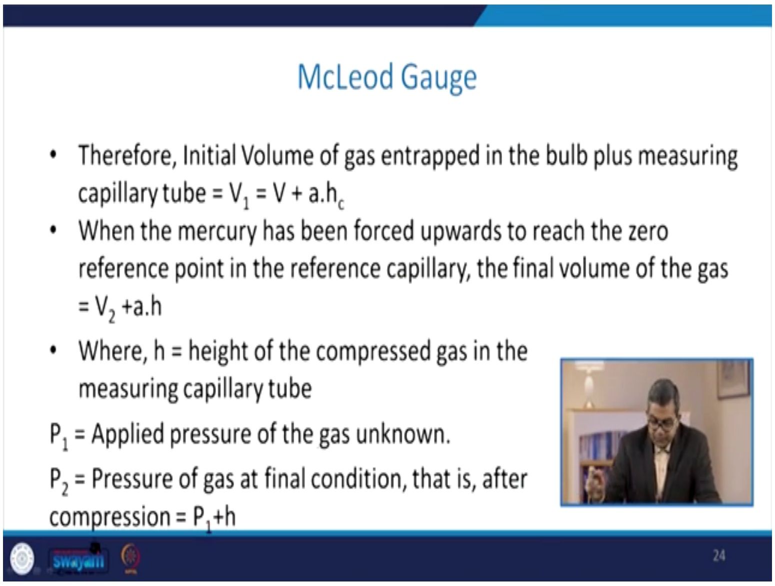
Now as V_1, V_2 and P_2 are known, the applied pressure P_1 can be calculated using Boyle's Law given by;

$$P_1V_1 = P_2V_2$$



Therefore, the initial volume of the gas entrapped in the bulb plus measuring capillary tube is given by V 1 = V + a h c. Now, when the mercury has been forced upward to reach the zero-reference point, the reference capillary, the final volume of the gas would be V 2 + a h. Where h is the height of the compressed gas in the measuring capillary tube P 1 is the applied pressure of the gas.

P 2 is the pressure of the gas in the final condition and that is after the compression and that is equal to P 1 + h.

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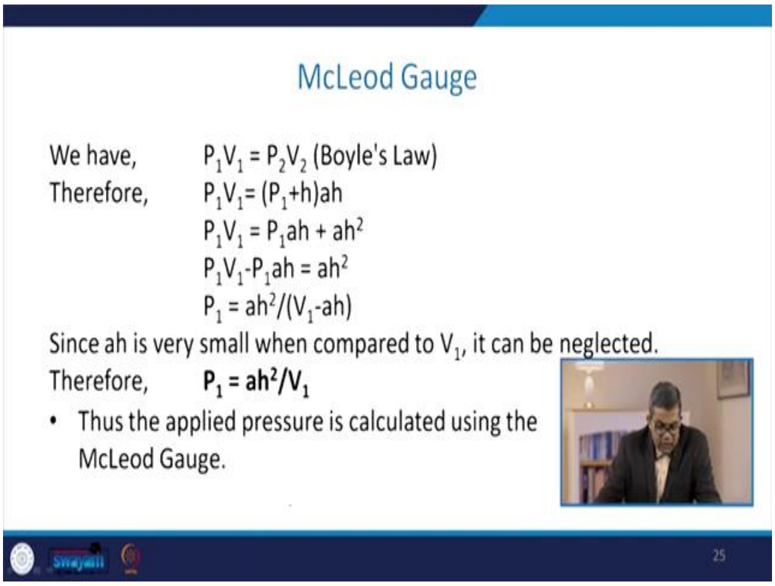
The Initial Volume of gas entrapped in the bulb plus measuring capillary tube = $V_1 = V + a.h_c$

The final volume of the gas = $V_2 + a.h$

Where, h = height of the compressed gas in the measuring capillary tube

P_1 = Applied pressure of the gas unknown.

P_2 = Pressure of gas at final condition, that is, after compression = $P_1 + h$



So, we have Boyle's law with us that is P 1 V 1 = P 2 V 2. Therefore P 1 V 1 = P 1, because we have indicated that this one is equal to P 1 + h into a h. So, P 1 V 1 is equal to P 1, a h + h square or P 1 V 1 − P 1 a h = a h square or P 1 is equal to a h square over V 1 − a h. Since this a h is very small when compared to V 1, it can be neglected. So, therefore, P 1 = a h square over V 1. Therefore, the applied pressure is calculated using the McLeod gage.

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We have, $P_1V_1 = P_2V_2$ **(Boyle's Law)**

Therefore, $P_1V_1= (P_1+h)ah$

$$P_1V_1 = P_1ah + ah^2$$

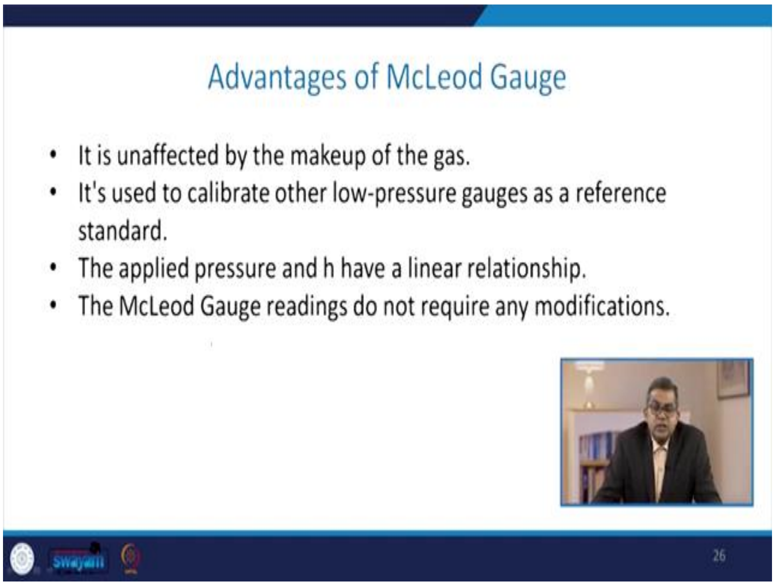
$$P_1V_1-P_1ah = ah^2$$

$$P_1 = ah^2/(V_1-ah)$$

Since ah is very small when compared to V_1**, it can be neglected. Therefore,**

$$P_1 = ah^2/V_1$$

Thus, the applied pressure is calculated using the McLeod Gauge.



Now there are various advantages associated with the McLeod gauge. Now it is unaffected by makeup of the gas it is used to calibrate other low-pressure gauge as a reference is standard. The applied pressure and h have a linear relationship and the McLeod gauge reading do not require any kind of modifications.

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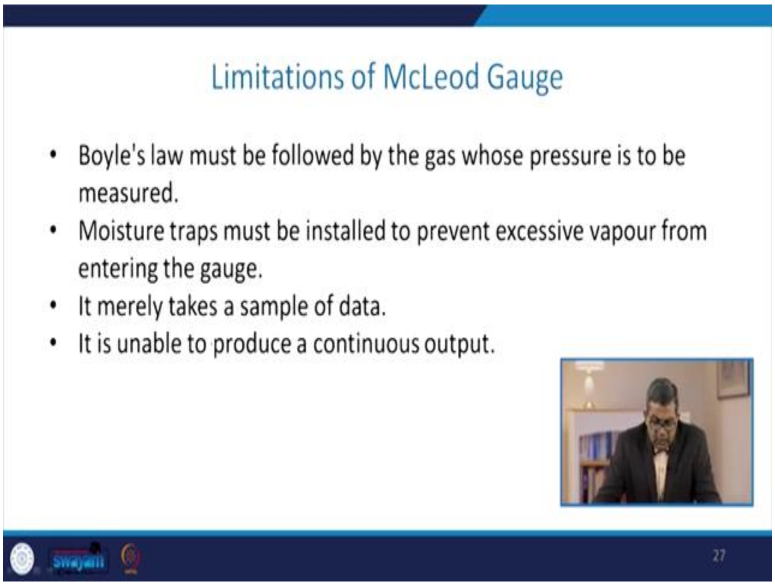

But when we talk about the advantages, then there must be certain disadvantages or a limitation of. So, let us talk about the limitation of McLeod gauge. Now, bias law must be followed by the gas whose pressure is to be measured first thing. Second thing is the moisture traps must be installed to prevent the excessive vapor from entering the gauge and third one is, it merely takes a sample of data and fourth it is unable to produce a continuous output. So, these are the limitations of McLeod gauge.

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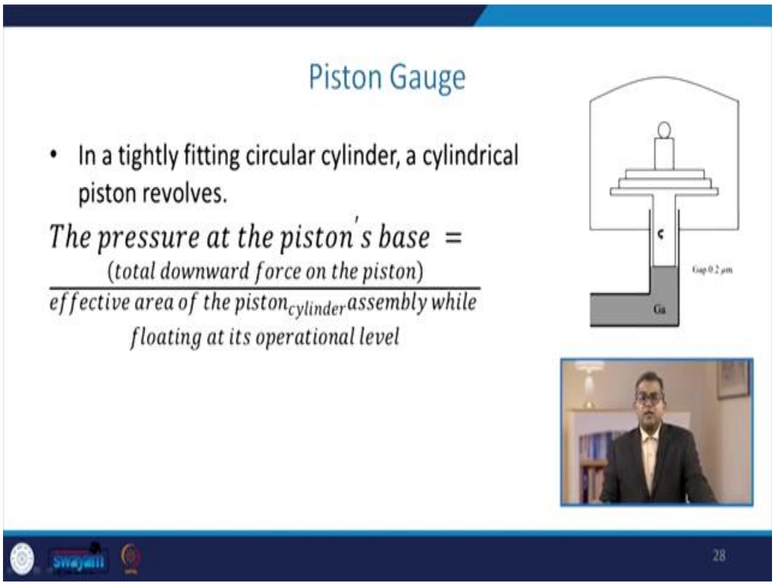

Let us talk about the Piston gauge. Now in in a very tight fitting or in a tightly fitted circular cylinder, a cylinder piston revolves. So, the process, the pressure at the piston base, is equal to the total downward force on the piston over effective area of the piston cylinder assembly, while floating at its operational level.

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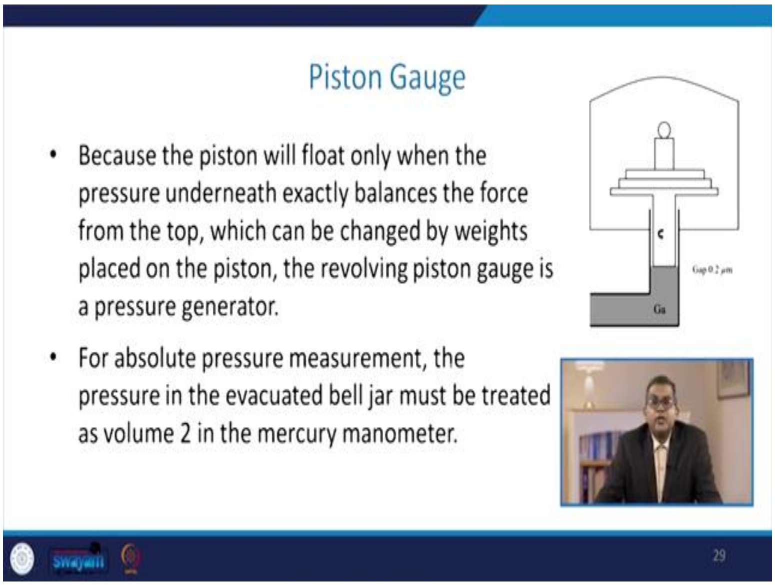
$$\textit{The pressure at the piston's base} = \frac{(\textit{total downward force on the piston})}{\textit{effective area of the piston}_{cylinder}\textit{assembly while floating at its operational level}}$$



Now, because the piston will float only when the pressure underneath exactly balance the force from the top which can be changed by weight placed on the piston. The revolving piston gauge is a pressure generator for absolute pressure measurement. The pressure in the evacuated bell jar must be treated as volume 2 in the mercury manometer.

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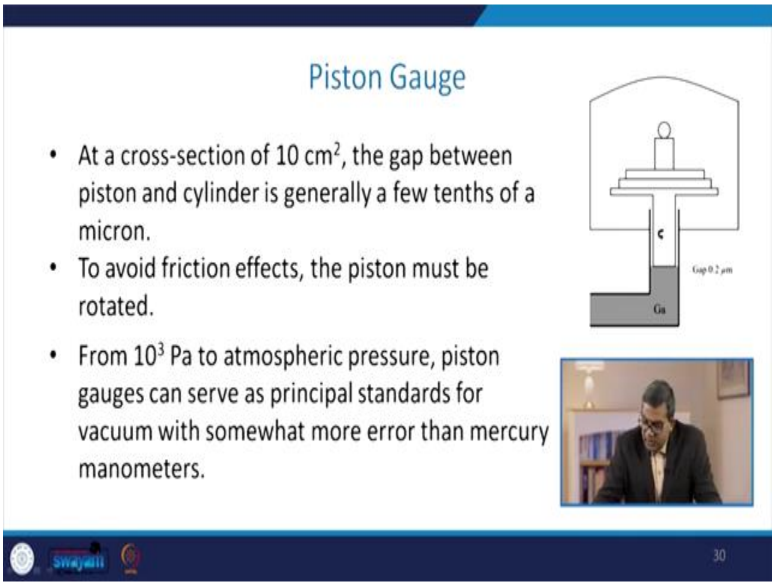

Now at a cross, section of, say, 10 square centimeter. The gap between the piston and cylinder is generally a few tenths of a micron. To avoid the friction effects, the piston must be rotated from 10 to the power 3 pascal to atmospheric pressure. Piston gauges can serve as a principal standard for vacuum, with somewhat more error than mercury manometers.

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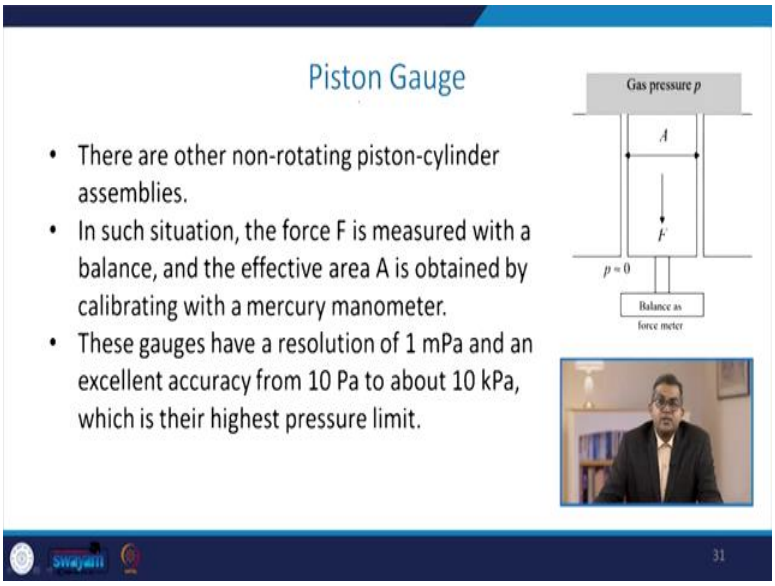

There are other non-rotating piston cylinder assemblies in such situation. The force F is measured, with the balance and the effective area is obtained by calibrating with the mercury manometer. Now these gauges have a resolution of 1 millipascal and an excellent accuracy from 10, pascal to about say, 10 kilo pascal which is their highest pressure limit.

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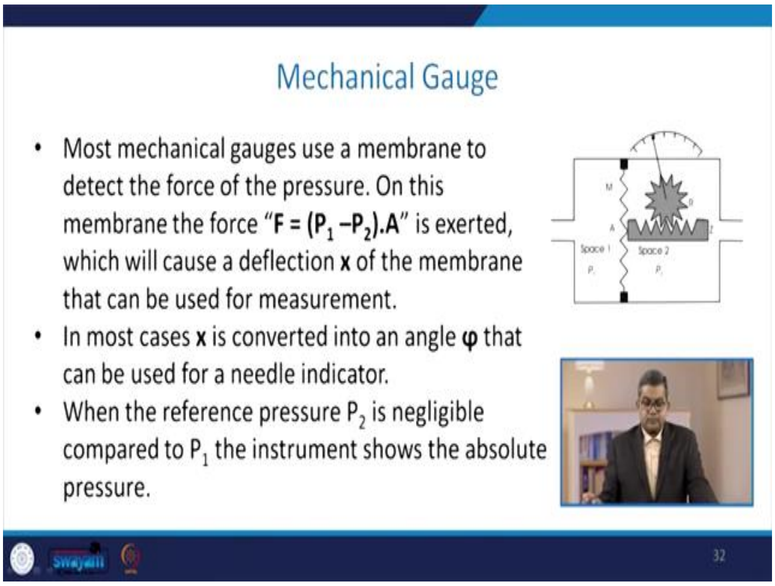

Let us talk about the mechanical gauge. You can see the typical diagram of this mechanical gauge. Now most mechanical gauges, they use membrane to detect the force of the pressure. Now on this membrane, the force F = P 1 – P 2 into A is exerted which will cause a deflection x of the membrane that can be used for measurement. Now in most cases, now this x is converted to an angle chi that can be used for a needle indicator.

Now, when the reference pressure P 2 is negligible compared to P 1, the instrument shows the absolute pressure.

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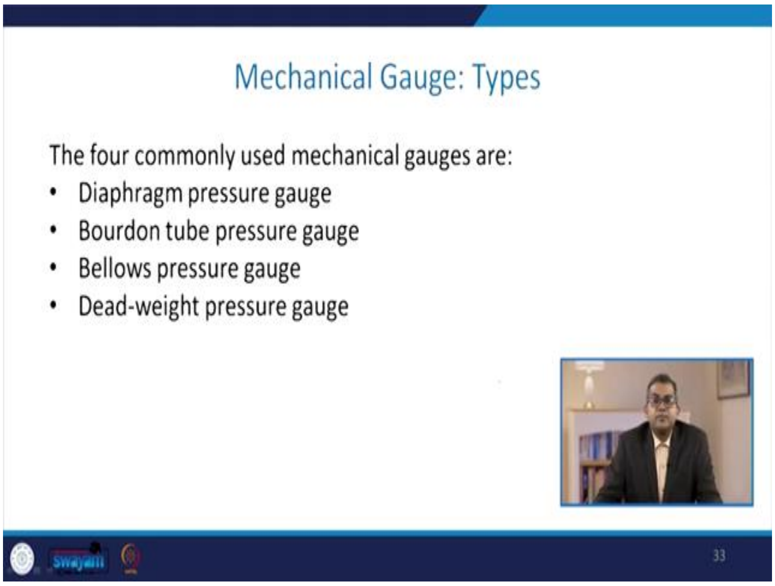
Membrane the force "F = (P_1 –P_2).A" is exerted, which will cause a deflection x of the membrane that can be used for measurement.



Now there are various types of mechanical gauges. There are 4 types which are in popular one is the diaphragm pressure gauge, then burden tube pressure gauge then bellow pressure gauge and then dead weight pressure gauge.

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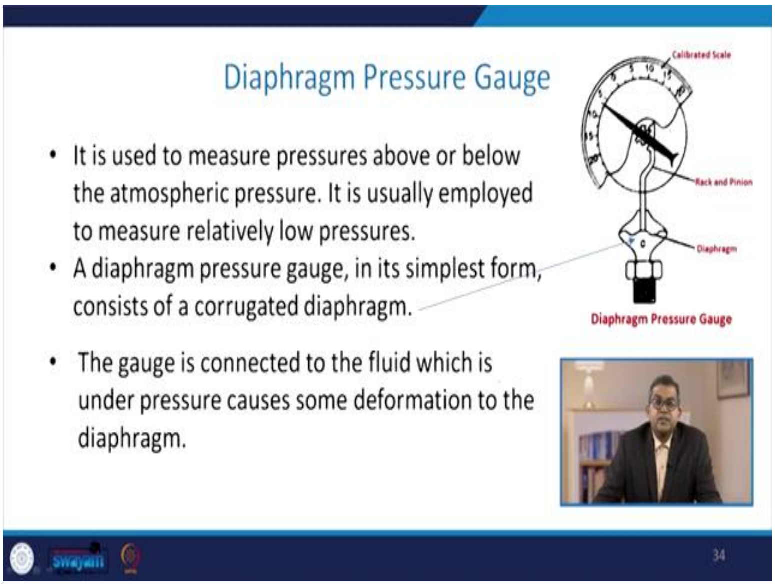

So, let us talk about the diaphragm pressure gauge. Now it is to use to measure the pressures above or below the atmospheric pressure. It is usually employed to measure relatively low pressures. A diaphragm pressure gauge in its simplest form consists of a corrugated diaphragm. Now the gauge is connected to the fluid which is under pressure causes some deformation to the diaphragm.

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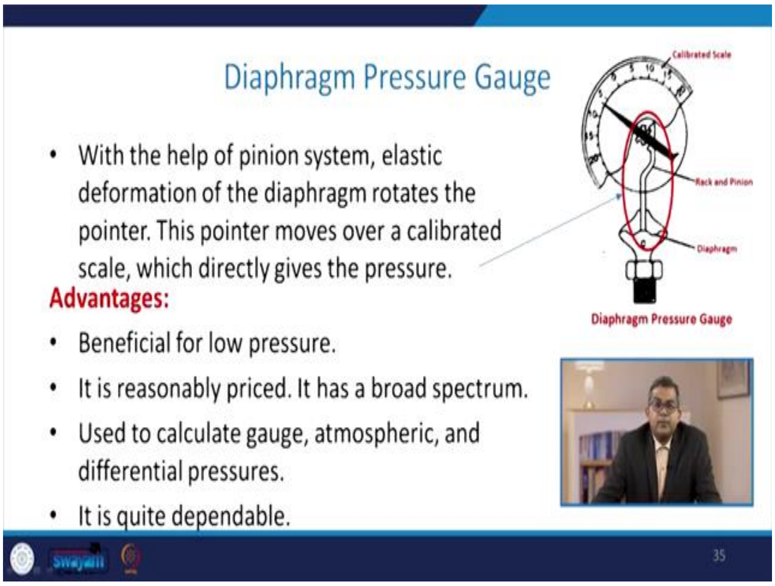

Now, with the help of opinion system, elastic deformation of the diaphragm rotates the pointer and the pointer moves over a calibrated scale which is which directly gives the pressure. There are various advantages attributed to the diaphragm pressure gauge. One is beneficial for low pressure; it is reasonably priced. It has a broad spectrum used to calculate the gauge atmospheric and differential pressures. It is quite dependable.

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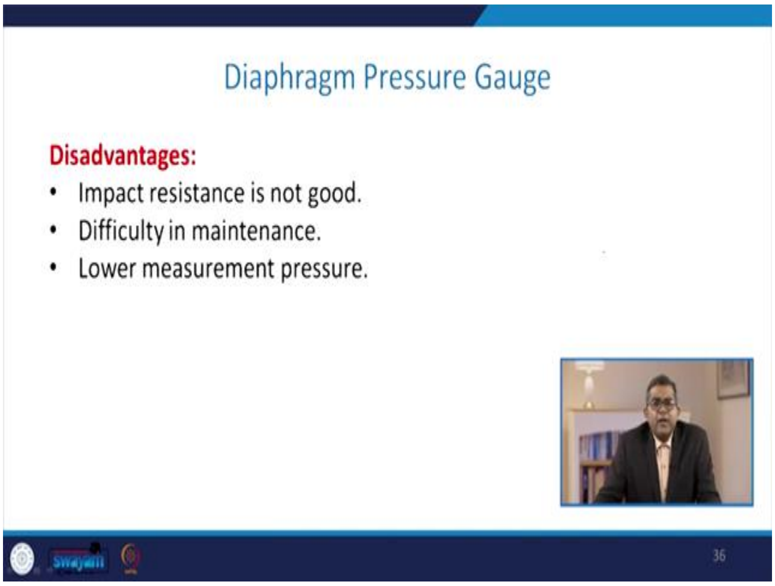

But simultaneously there are so many disadvantages like impact resistance is not good difficulty in maintenance and it has the lower measurement pressure.

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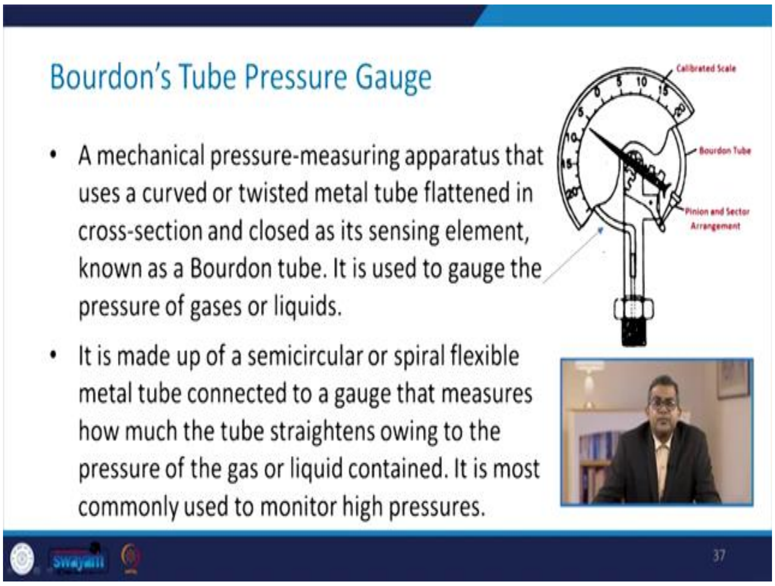

Let us talk about the burden tube pressure gauge. This is a mechanical pressure measuring apparatus and that use a curved or twisted metal tube, flattened in cross section and closed as its sensing element. This is known as the burden tube. It is used to gauge the pressure of a gases or liquid. It is made up of a semi-circular or spiral flexible metal, tube connected to a gauge that measures how much the tube straightens owing the pressure of the gas or liquid contained. It is most commonly used to monitor high pressures.

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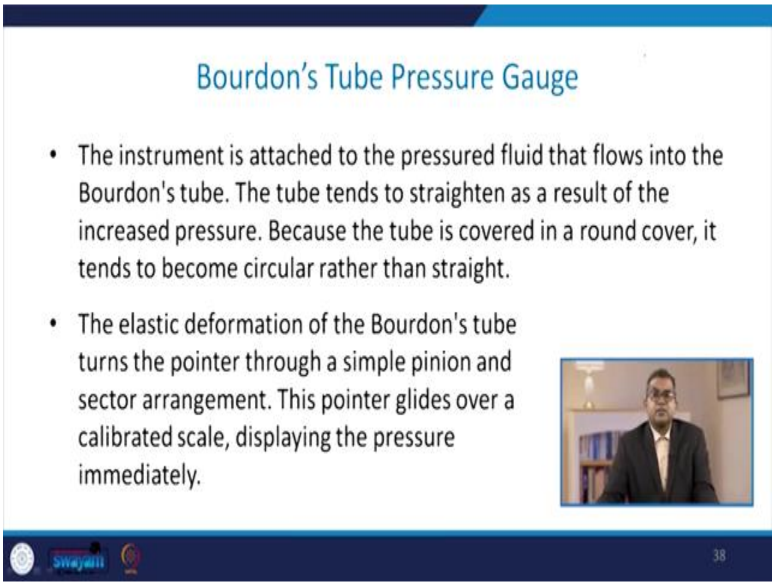

The instrument is attached to the pressurized fluid that flows into the burden tube. The tube tends to straight straighten as a result of the increased pressure because the tube is covered in a round cover. It tends to become circular rather than straight. The elastic deformation of the burdens tube turns the pointer through a simple pinion and the sector arrangement.

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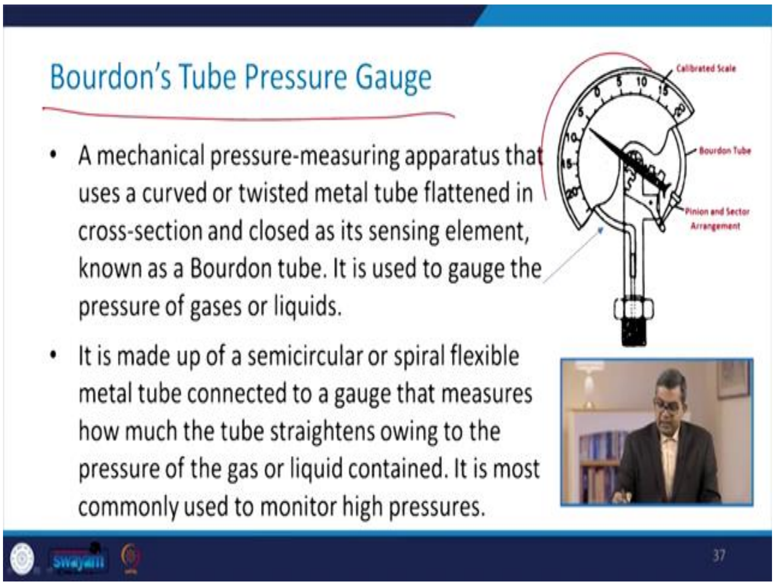

The pointer glides over the calibrated scale like this and displayed the pressure immediately.

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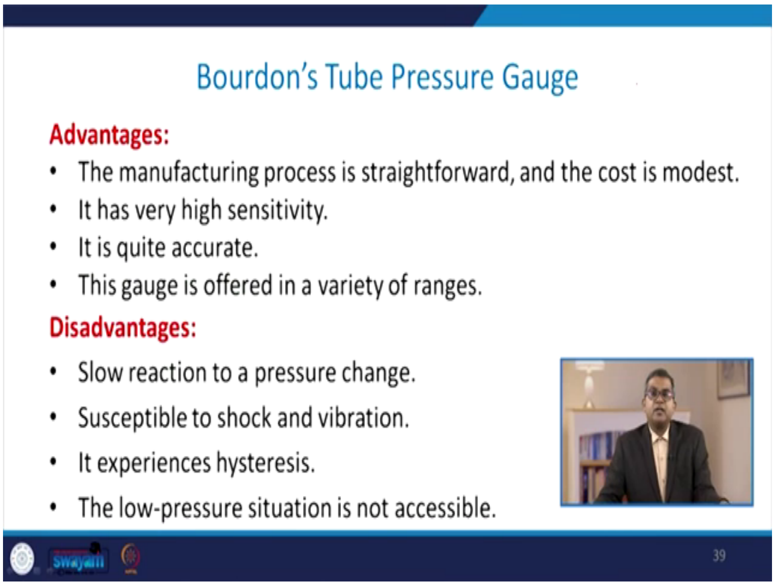

The advantage attributed to the burden tube pressure gauge is that the manufacturing process is straight forward and cost is modest. It has a very high sensitivity. It is quite accurate. This gauge is offered a variety of ranges, but simultaneously there are several disadvantages like slow reaction to pressure changes, it is susceptible to shock and vibration. It experiences hysteresis. The lower pressure situation is not accessible.

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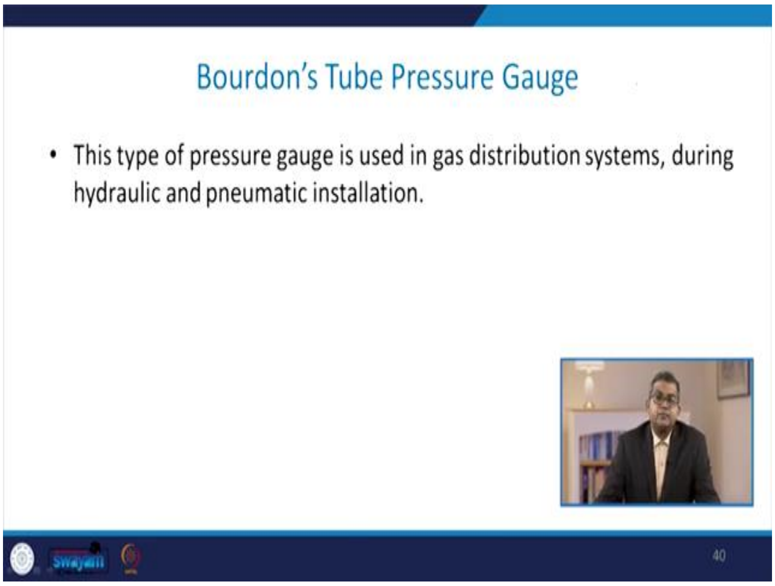

Now this type of pressure gauge is used in the gas distribution system during the hydraulic and pneumatic installation.

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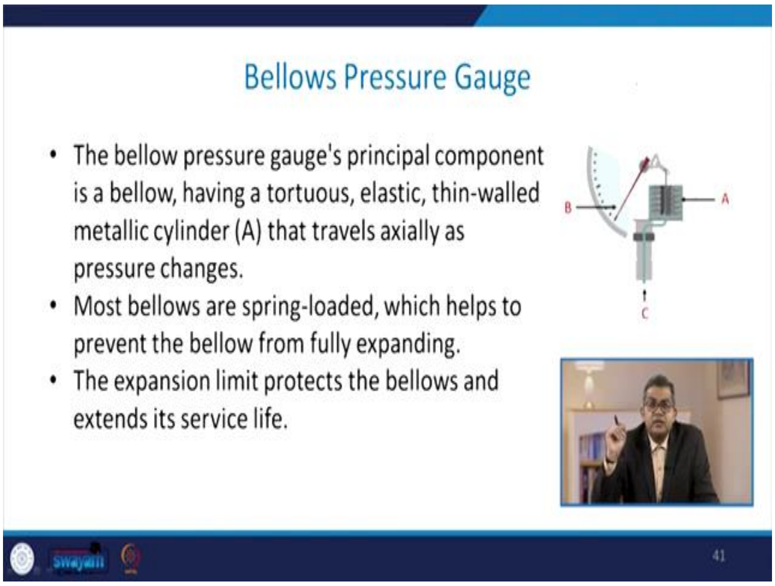

Let us talk about the bellow pressure gauge. The bellow pressure gauge principal component is a bellow this having the tortuous, elastic, thin-walled, metallic cylinder and it travels axially as pressure changes. Most bellows are spring loaded which helps to prevent the bellow from fully expanding and the expansion limit protects the bellows and extend service life.

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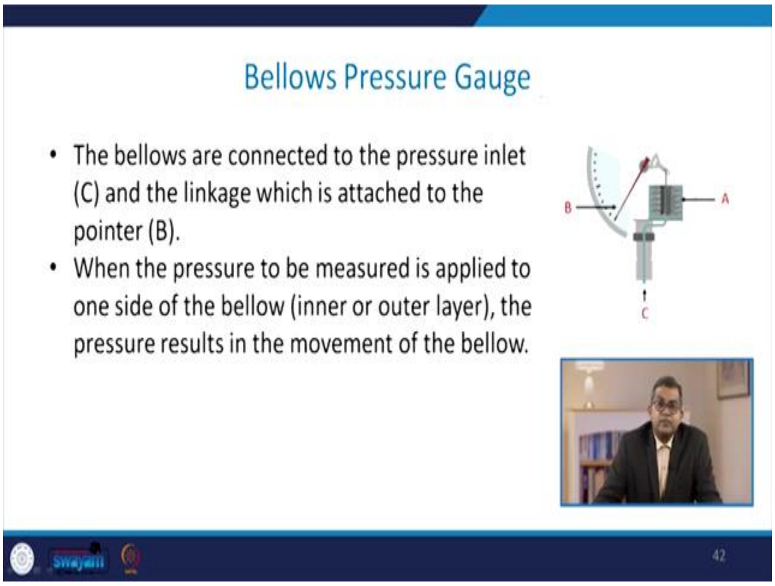

The bellows are connected to the pressure inlet and the linkage which is attached to the pointer B, when the pressure to be measured in is applied to the one side of the bellow inner or outer layer. The pressure results in the movement of the bellow.

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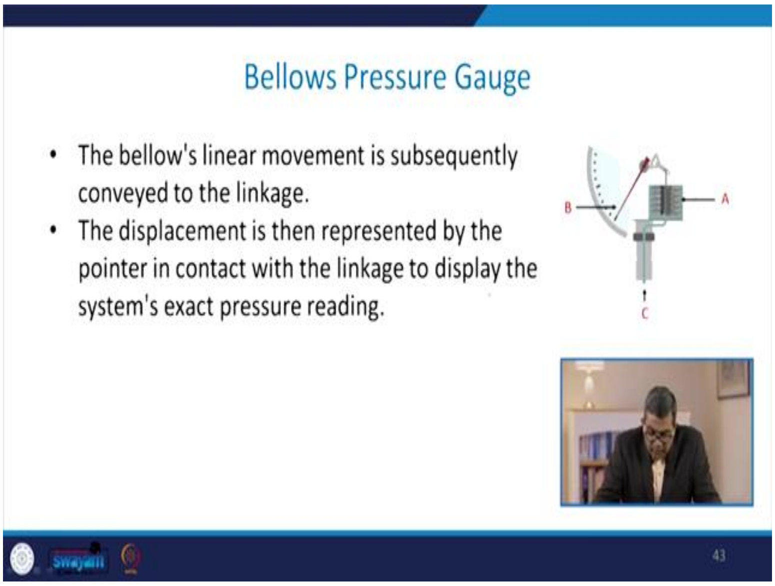

The bellows linear movement is subsequently conveyed to the linkage. The displacement is then represented by the pointer in contact with the linkage to display the system's exact pressure reading.

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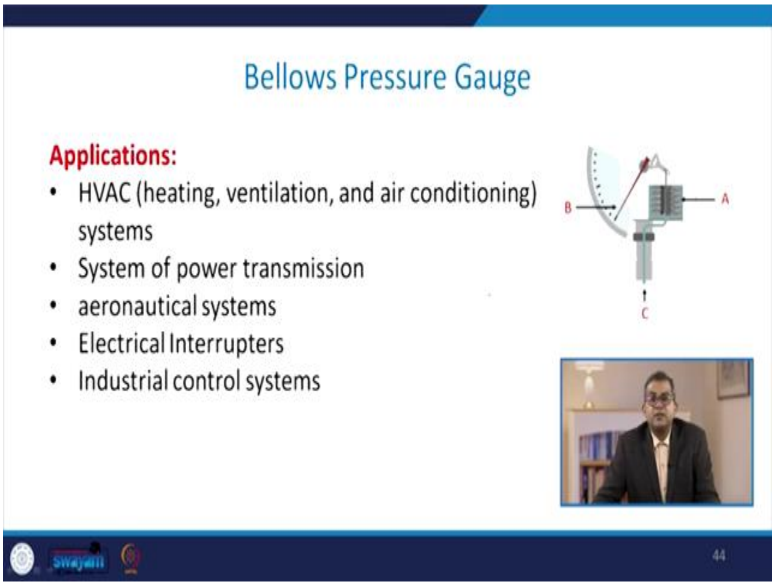

There are various applications associated with this bellow pressure gauge. One is HVAC that is heating, ventilation and air conditioning system, system of power transmission, then aeronautical systems, then electrical interpreters, then industrial control systems.

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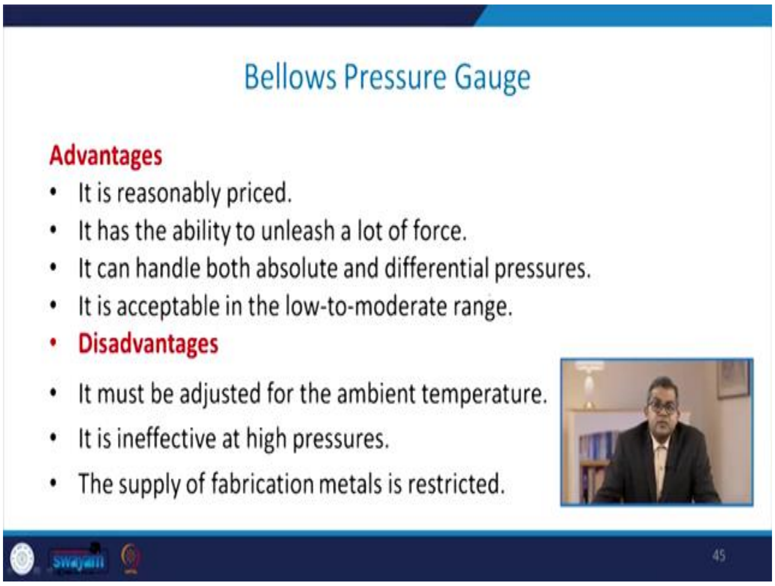

There are various advantages associated with the bellow pressure gauges. One is that it is reasonably priced. Then it has the ability to unleash a lot of forces. It can handle both absolute and differential pressures. It is acceptable in low to moderate range, but simultaneously there are a couple of disadvantages attributed to this bellow pressure gauges. It must be adjusted for the ambient temperature.

That is one of the disadvantages. It is ineffective at high pressures and the supply of fabrication metal is restricted. So, these are the various disadvantages associated with the bellow pressure gauge.

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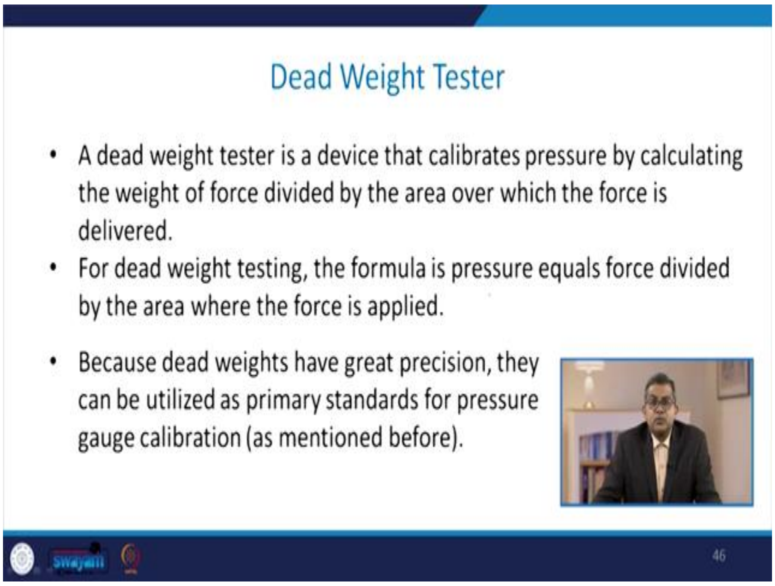

Now let us talk about the dead weight tester. A dead weight tester is a device that calibrates pressure by calculating the weight of a force divided by the area over which the force is delivered. The dead weight testing, the formula is the pressure equals force divided by the area where the force is applied. Because deadweights have a great precision, they can be utilized as primary standards for pressure gauge calibration.

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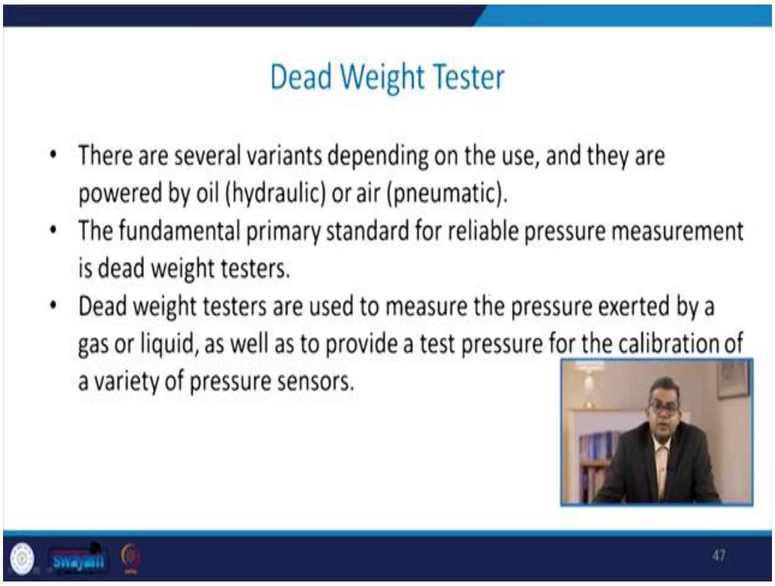

Now there are several variants depending on the use and they are powered by oil that is hydraulic or air that is called pneumatic. The fundamental primary standard for reliable pressure measurement is deadweight tester. Now deadweight testers are used to measure the pressure exerted by gas or liquid, as well as to provide a test procedure for calibration of a variety of pressure sensors.

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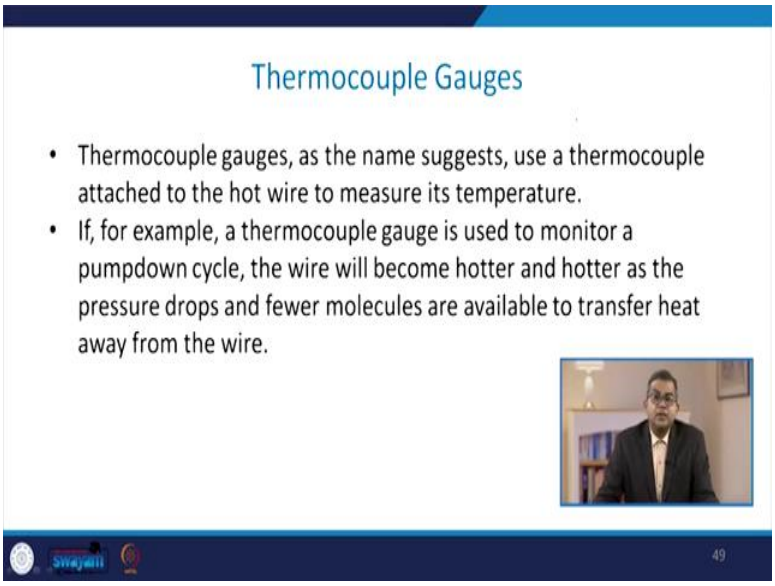

Now let us talk about the indirect measuring vacuum gauges. One is the thermocouple gauges. The thermocouple gauges, as the name you can implies, use the thermocouple attached to the hot wire to measure its temperature. For example, a thermocouple gauge is used to monitor a pump down cycle and the wire will become hotter and hotter, as the pressure drops and fewer molecules are available to transfer heat away from the wire.

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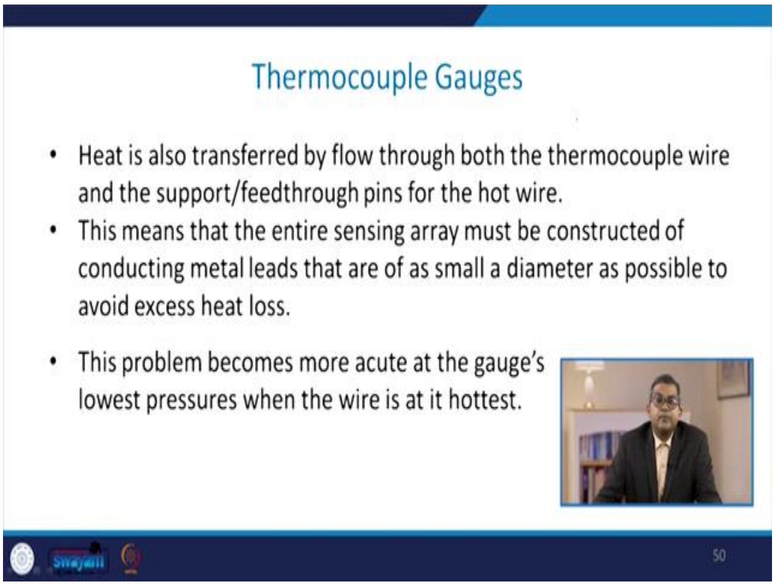

Now heat is also transferred by flow through both the thermocouple wire and the support feed through pins for the hot wire. Now this means that the entire sensing array must be constructed of conducting metal leads that are of as small as diameter as possible to avoid excess heat loss. Now this problem becomes more acute at the gauge's, lowest pressure when the wire is at its hottest level.

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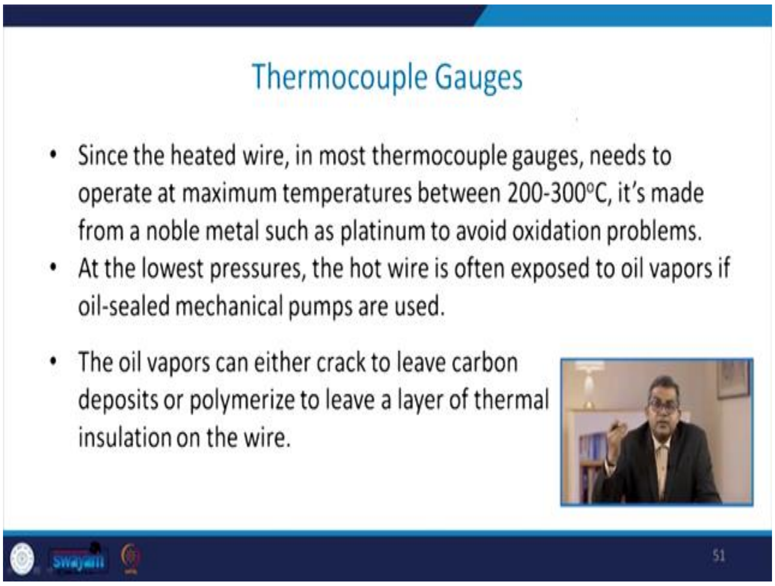

Since the heated wire in most thermocouple gauges needs to operate at maximum temperature between 200 to 300 degree Celsius. It is made from noble metal such as platinum to avoid oxidation problem. At the lowest pressure the hot wire is often exposed to oil vapors. If oil sealed mechanical pumps are used. The oil vapors can either crack to leave carbon deposit or polymerize to leave a layer of thermal insulation on the wire.

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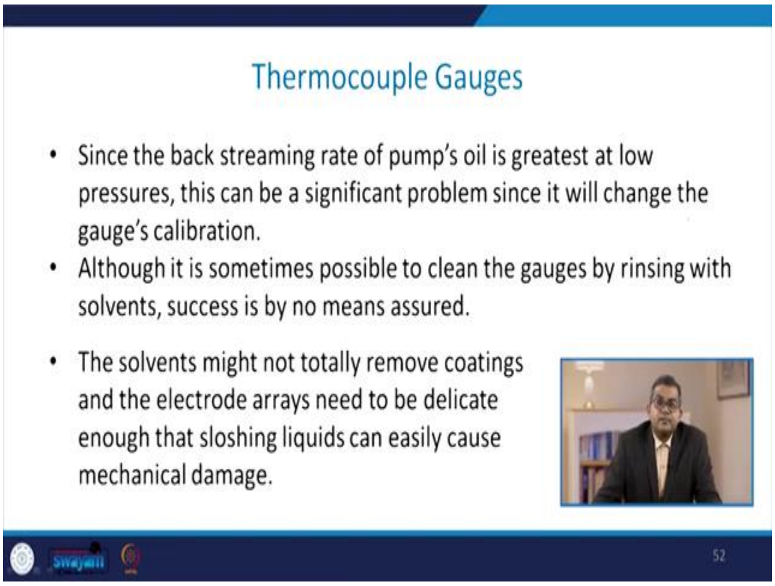

Since the back streaming rate of pumps, oil is greatest at low pressure. This can be significant problem, since it will change to the gauge calibration. Although it is sometimes possible to clean the gauges by rinsing with solvent, success is by no means assured. The solvent might not totally remove coating and electrode array need to be delicate enough, so, that sloshing liquid can easily cause the mechanical damage.

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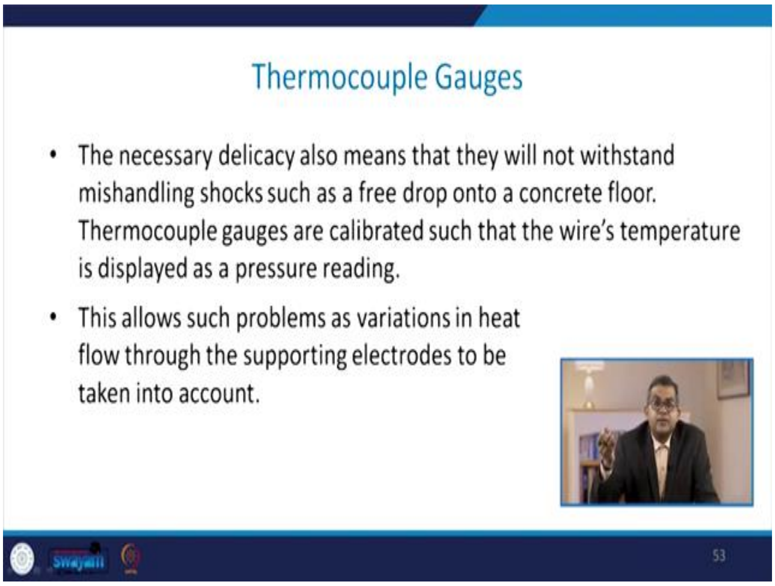

The necessary delicacy also means that they will not withstand mishandling shock, such as a free drop into a concrete floor. Thermocouple gauges are calibrated such that the wires temperature is displayed as a pressure reading. Now this allows such problem as a variation in heat flow through the supporting electrodes to be taken into account.

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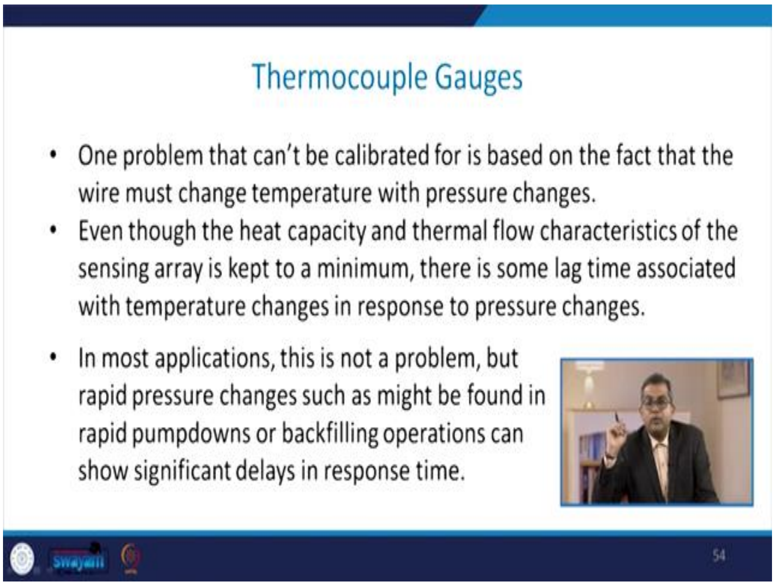

One problem that cannot be calibrated for it is based on the fact that the wire must change the temperature with pressure changes. Even though the heat capacity and the thermal flow characteristics of the sensing areas kept for to a minimum, there is some lag time associated with the temperature changes in response to pressure changes. In most application this is not a problem, but rapid pressure changes such as might be found in rapid pump down or back filling operations can show significant delays in response time.

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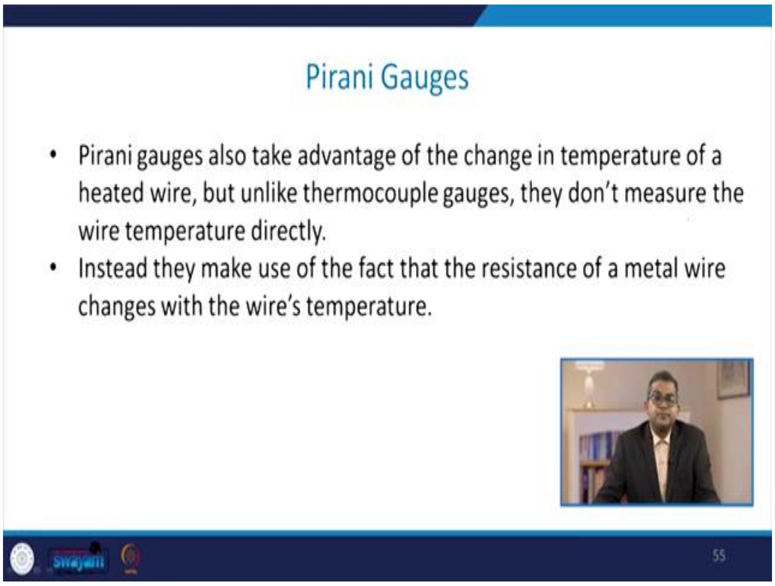

Let us talk about the Pirani gauge. Now Pirani gauge also takes advantage to the change in temperature of a heated wire, but unlike thermocouple gauges, they do not measure the wire temperature directly. Instead, they make use of the fact that the resistance of a metal wire changes with the wire temperature.

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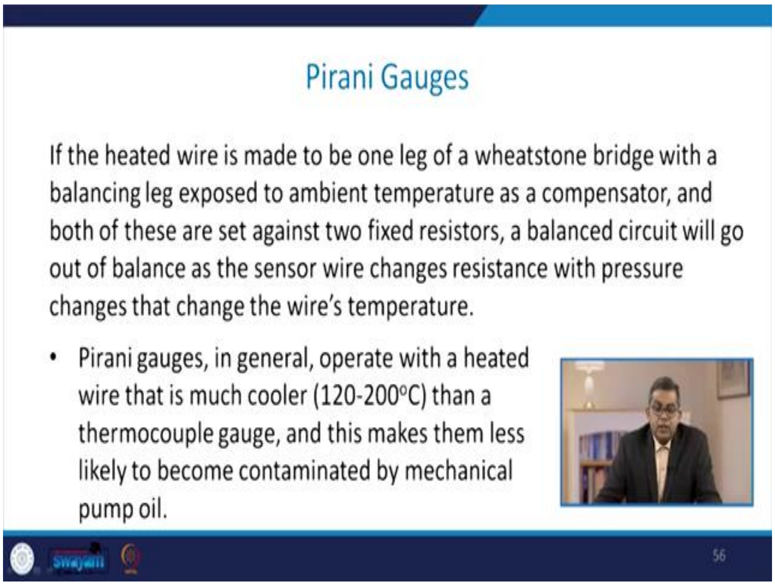

Now, if a heated wire is made to be one of one leg of the Wheatstone bridge with a balancing lag exposed to the ambient temperature as a compensator and both of these are set against 2 fixed resistor, a balanced circuit will go out of the Balance as the sensor wire changes, resistance with the pressure change and that change the wires temperature.

Pirani gauge in general operates with a heated wire and that is much cooler say around 120 to 200 degree Celsius than a thermocouple gauge and this makes them less likely to become contaminated by mechanical pump oil.

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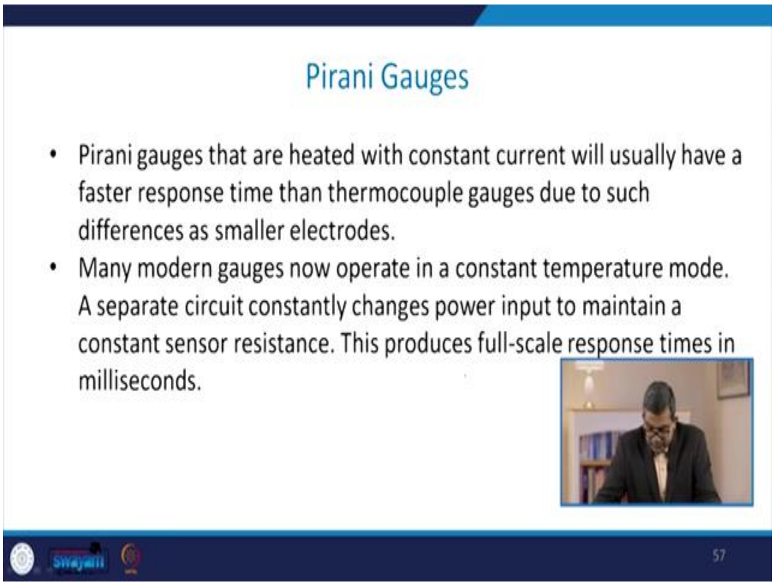

Now, Pirani gauge that are heated with the constant current, will usually have a faster response time than thermocouple gauges due to such difference as smaller electrodes. Many modern gages now operate in constant temperature mode. A separate circuit constantly changes power input to maintain a constant sensor resistance. Now this produces fully scaled response time in millisecond.

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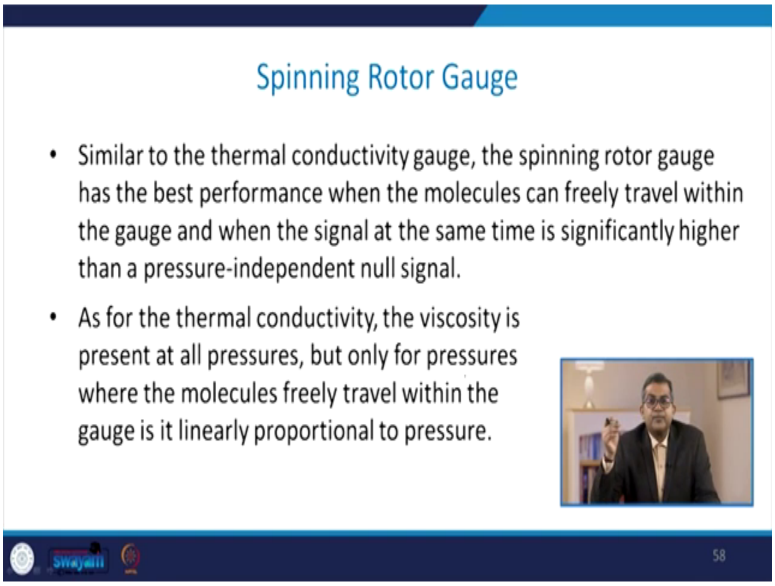

Let us talk about the spinning rotor gauge. Now similar to thermal conductivity gauge, the spinning rotor gauge has the best performance when the molecule can freely travel within the gauge and when the signal at the same time is significantly higher than the pressure independent null sign or signal. Now, as far as the thermal conductivity, the viscosity is present at all pressures, but only for pressure where the molecule freely travels within the gauge is linearly proportional to pressure.

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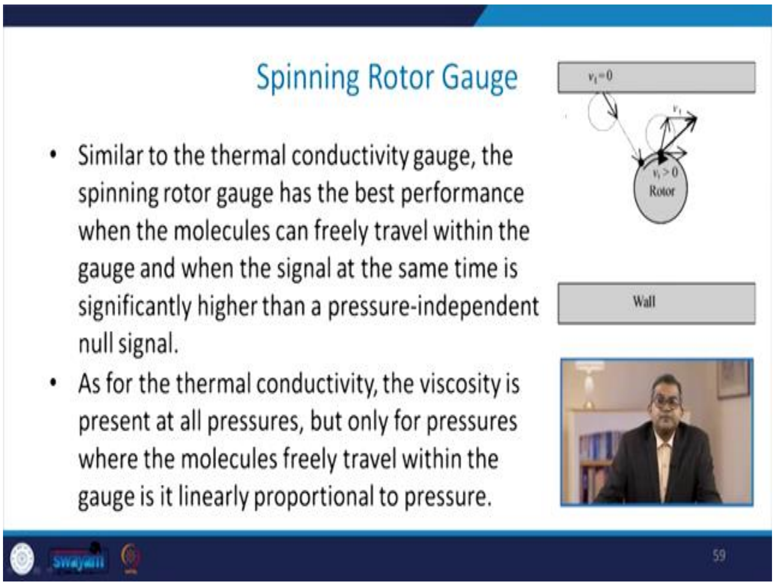

Now similar to the thermal conductivity gauge, the spinning rotor gauge has the best performance when the molecules can freely travel within the gauge and when the signal at the same time is significantly higher than a pressure independent null signal. As far as or as for the thermal conductivity, the viscosity is present at all pressures, but only for pressures where the molecule freely travel within the gauge is linearly proportional to the pressure.

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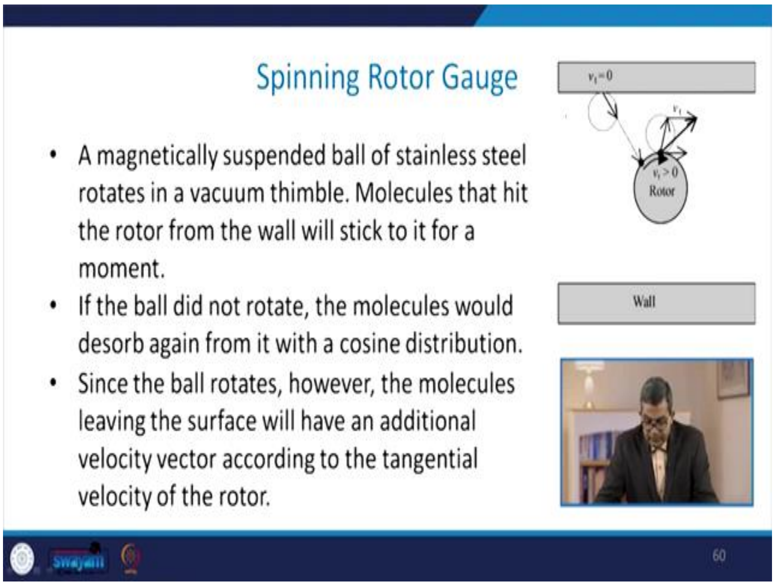

The magnetically suspended ball like this of steel rotates in a vacuum thimble. The molecules that hit the rotor from the wall will stick to it for a moment. Now if the bar did not rotate, the molecules would dissolve again from it with a cosine distribution. Now, since the ball rotates, however, the molecule leaving the surface will have an additional velocity vector according to the tangential velocity of the rotor.

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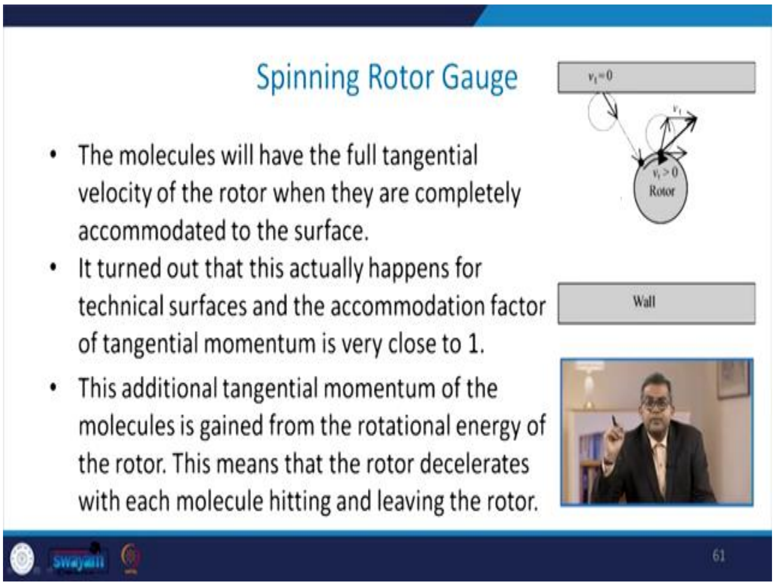

The molecule will have of the full tangential velocity of the rotor when they are completely accommodated to the surface. Now it turned out that this actually happens for technical surfaces and accommodation factor of tangential movement atom is very close to 1. Now this additional tangential momentum of the molecule is gained from the rotational energy of the rotor. Now this means that the rotor decelerates with each molecule hitting and leaving the rotor.

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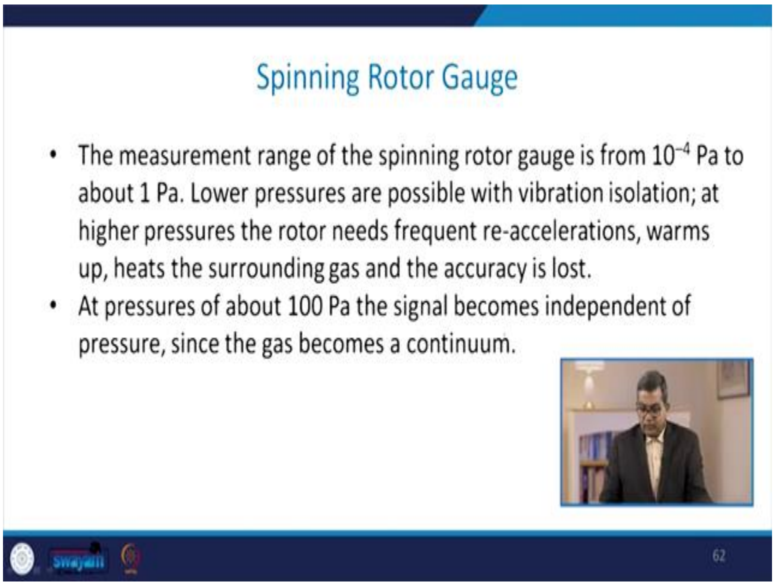

The measurement range of the spinning rotor gauge, is from 10 to the power −4 Pascal to about 1 Pascal lower pressure are possible with the vibration isolation at higher pressure. The rotor needs frequent re-acceleration, warms up heat and surrounding gas and accuracy is lost. At pressure of about say, 100 Pascal, the signal become independent of the pressure. Since the gas becomes continuum.

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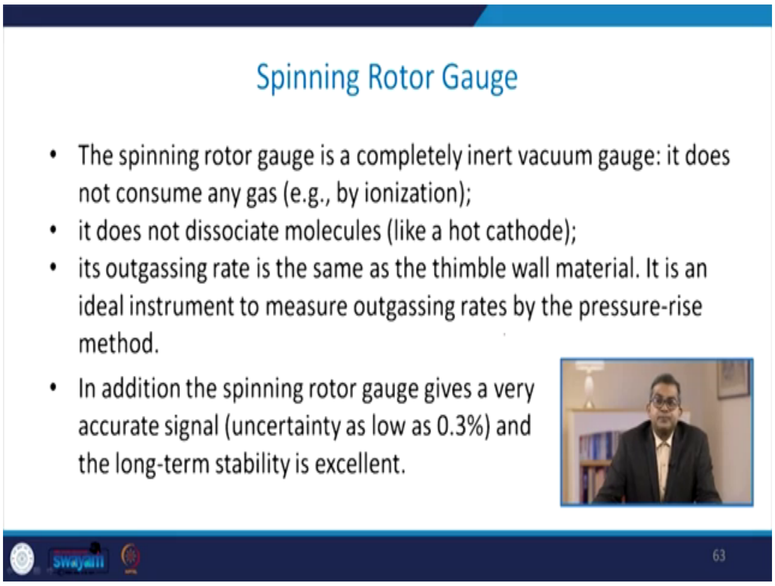

The spinning rotor gauge is a commonly in inert vacuum gauge. It does not consume any gas that is by ionization. It does not dissociate the molecules like hot cathode. It outgassing rate is the same as the thimble wall material. It is an ideal instrument to measure the outgassing rate by the pressure rise method. Now in addition, the spinning rotor gauge gives a very accurate signal and you can say the uncertainty is as low as 0.3% and the long-term stability is excellent.

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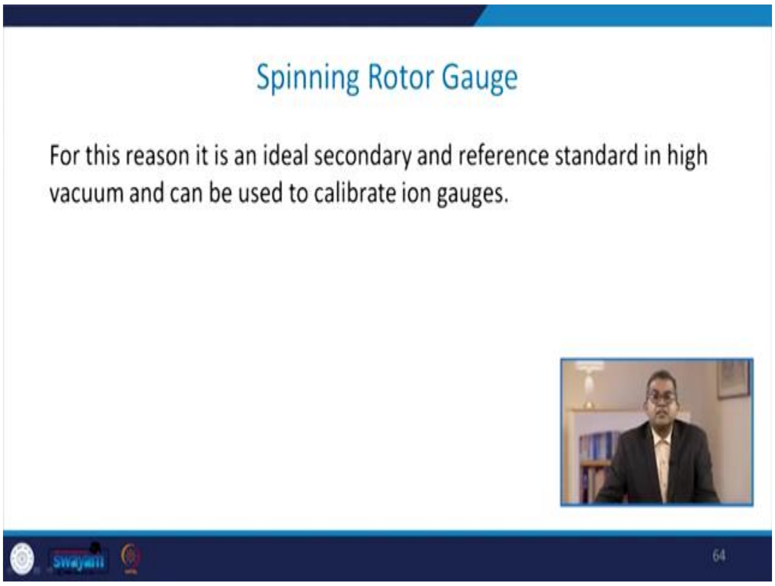

Now, for this reason it is an ideal secondary reference standard in high vacuum and can be used to calibrate ion gauges.

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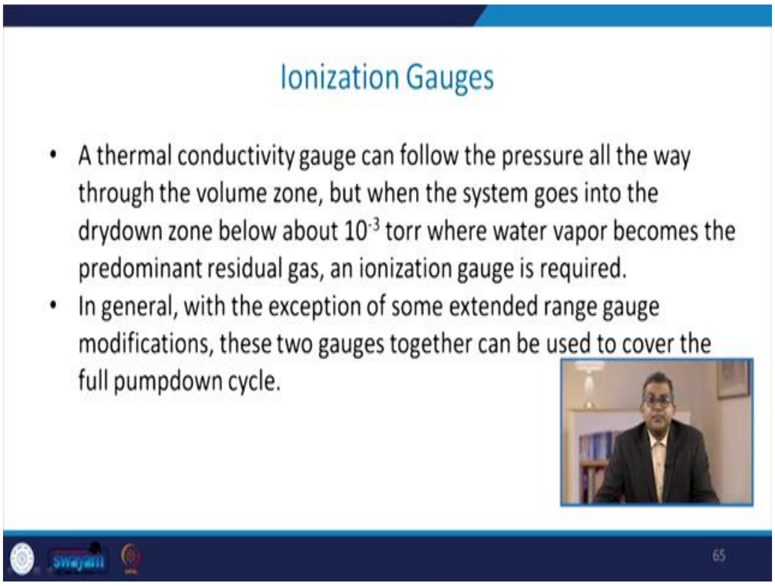

Now ionization gauges, a thermal conductivity gauge, can follow the pressure all the way through the volume zone, but when the system goes into the dry down zone below about 10 to the power −3 torr, where water vapor becomes the predominant residual, gas and ionization gage is required. In general, with the exception of some extended range gauge modification, these 2 gauges together can be used to cover the full pump down cycle.

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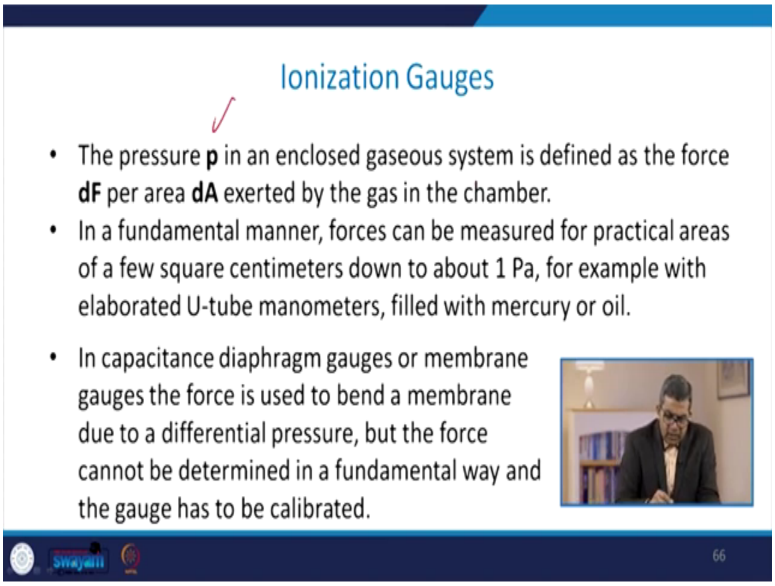

Now the pressure p in an enclosed gaseous system is defined as the force dF per area dA exerted by the gas in the chamber. Now in a fundamental manner forces can be measured for practical areas of a few square centimeter down to about 1 Pascal, for example, with an elaborated u-tube manometer filled with mercury or oil. In capacitance, diaphragm, gauges or membrane gauges the force is used to bend the membrane due to the differential pressure, but the force cannot be determined in a fundamental way and the gauge has to be calibrated.

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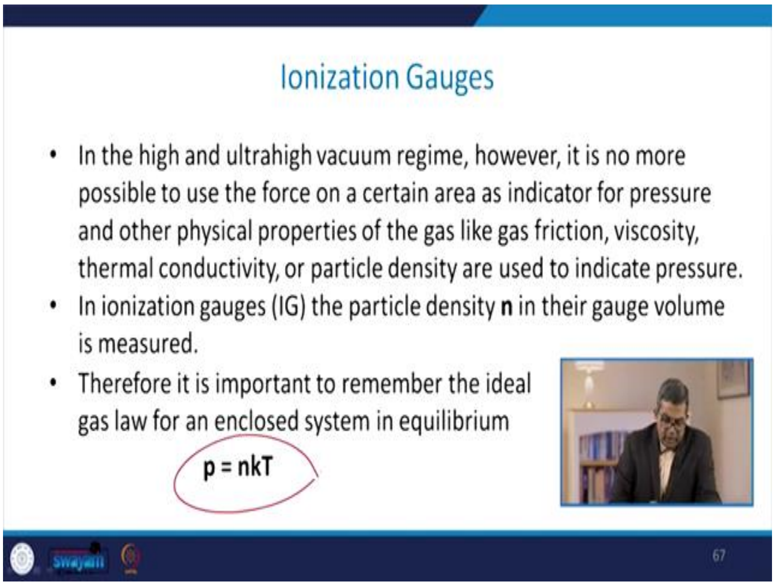

Now in the high and ultrahigh vacuum regime. However, it is no more possible to use the force on a certain area as indicator for the pressure and other physical proportion of the gas like gas friction, viscosity, thermal conductivity or particle density they are used to indicate the pressure. Now in ionization gauges the particle density n in the gauge volume is measured. Therefore, it is important to remember the ideal gas law for enclosed system in equilibrium that is p is equal to n k T.

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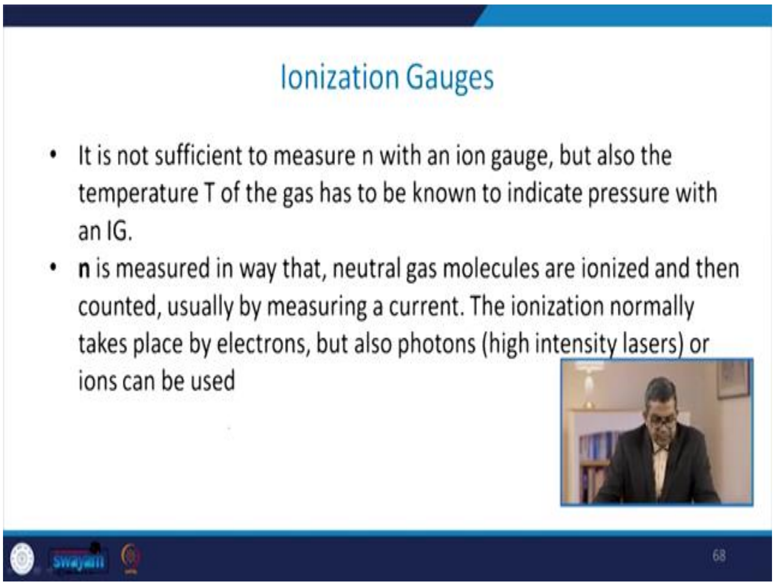

It is not sufficient to measure n with an iron gauge, but also the temperature T of the gas has to be known to indicate pressure with an IG. Now n is measured in a way that the neutral gas molecules are ionized and then counted usually by measuring a current. The ionization normally takes place by electron, but also photon that is a high intensity laser or ions can be used.

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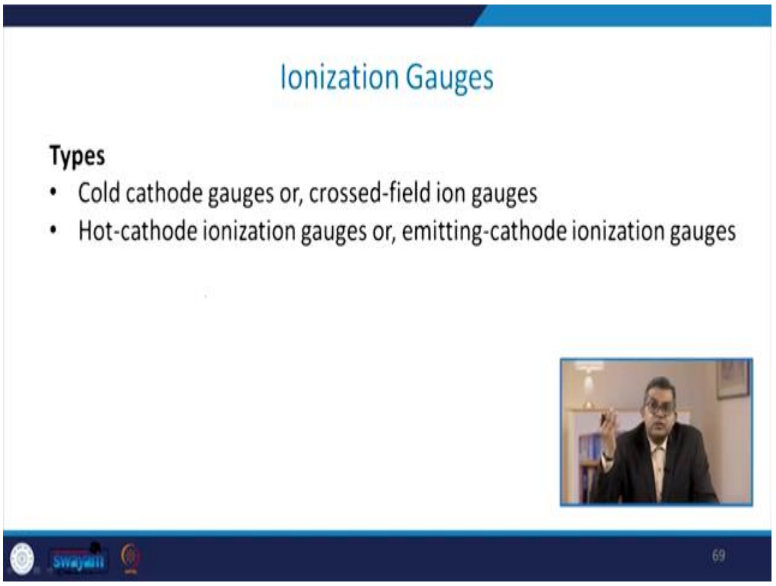

Now there are 2 types of ionization gages, one is the cold, cathode gages or crossed field iron gauges and second one is the hot cathode ionization gauges or emitting cathode ionization gauges. So, in this particular lecture we discussed about the various measuring devices and instrumentation method to for measuring the pressure and other thing which are useful in the chemical process utilities.

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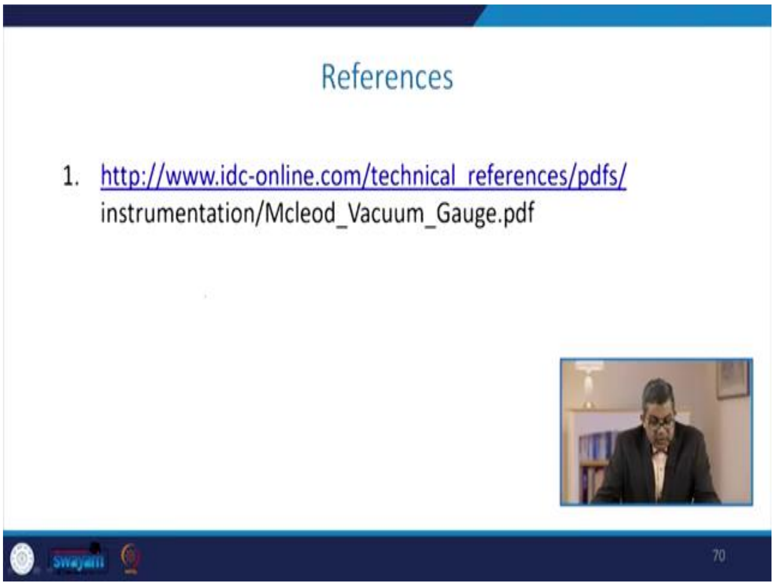

For your convenience, we have enlisted one reference you can go through if you need to have a further information. Thank you very much.