A U-tube manometer is the simplest of the pressure measurement devices. Its name comes from the U-shape formed when the two ends of a flexible tube full of liquid are raised to keep the liquid from coming out the ends. A U-tube manometer is a 'liquid' balance. A spring balance used in the kitchen weighs a load by matching the force produced by the weight of the load with the force produced from the tension of the balance spring. The change in length of the spring is a measure of the load's weight and is shown on a graduated scale by a pointer attached to the spring. Similarly, a U- tube manometer is used to balance the weight of the liquid in one leg of the 'U' against the pressure introduced into the other leg. The difference in height between the two legs of liquid represents the pressure pushing the liquid down one leg and up the other. The height difference is measured on a graduated scale.Pressure in a Column of Liquid or GasInvention of the U-tube manometer allowed the early investigators into fluid mechanics to confirm that pressure was directly related to the sum total of the forces acting on a surface. If you were to stand on the seashore, the pressure on you would be the weight of the air column directly above you. That pressure has been given the name of 'one atmosphere'. If you were to dive to a depth of 10 meters (about 32 feet) there would now be an added pressure on you of the weight of water above plus the weight of the air column. By international agreement (a convention) 'absolute' pressure includes the pressure of the column of air whereas 'gauge' pressure does not. Gauge pressure is the pressure showing on a pressure indicator dial and is one atmosphere less than absolute pressure. The pressure of 1-m depth of water is found from the formula – Pressure = Density x Gravity x Height of liquid column P=ρgh The unit is a Pascal. Gravity has the value of 9.8 m/sec2 at sea level. For simplicity of multiplication the value 10 m/sec2 will be used. The density for water is 1,000 kg per cubic meter at 20 oC. Putting all the know values back into the pressure equation gives – P=ρgh=1000kg/m3 x10m/sec2 x1m = 10,000 Pa = 10 kPa The calculation shows that 1-meter of water is equal to about 10 kPa, which means 30 meters of water produces a pressure of nearly 300 kPa. One atmosphere of air pressure at sea level is 101 kPa. This means the pressure at 30 meters depth below sea level is 300 kPa gauge pressure or about 400 kPa absolute pressure. The same formula can be used to calculate negative, or vacuum, pressures. Figure No. 1 U-tube Manometers with Water and MercuryHow to Use a U-tube Manometer Figure No. 1 shows three manometers open to atmosphere. The left one has the same pressure in both legs and the liquid levels are the same on both sides. The U-tube in the center shows a pressure applied to the left leg of 100 kPa. The water level in the left leg has gone down and the level in the right leg has gone up. The difference in the height of water between the two legs is 10 meters. Since the liquid is water, each meter height represents 10 kPa and a 10 meter high water column represents 100 kPa gauge pressure. The remaining U-tube shows a pressure of 100 kPa as well but this time mercury is used in the tube. The height of mercury is now 750mm. The density of mercury is 13.6 times that of water. Because mercury is so much heavier than water the same pressure raises a correspondingly lower column of liquid. If a manometer were used to measure a vacuum the column of liquid would be drawn up toward the vacuum and the difference in the height of liquid between the two legs would be a measure of the vacuum pressure below atmospheric pressure. Making a U-tube ManometerTo make a U-tube manometer requires a clear plastic tube mounted in the shape of a 'U' onto a board marked with a graduated scale. The pressure to be measured determines the selection of the liquid used in the tube. The U-tube liquid's density and the pressure being measured determine the height of the liquid column and the corresponding height of the backing-board. Mike Sondalini – Maintenance Engineer. If you found this interesting, you may like the ebook Centrifugal Pump Problems & Answers At pressures below 10-4 Torr, direct pressure measurement methods such as capacitance manometers and Pirani gauges no longer work well, and it becomes necessary to use methods that depend on gas density. Pressure is related to gas density by the expression: where P is the pressure, c is a constant, n is the number density of the gas, and T is the temperature. As described above, ionization gauges perform this measurement using free electrons that have been produced by either thermionic emission or plasma generation. The ion current that is collected by the negatively biased collector can be related to pressure once the gauge has been calibrated. The basic gauge equation for ionization gauges is: where Ic is the ion current, k is a constant, n is the number density of residual gas molecules and Ie is the ionizing electron current. Substituting for n and rearranging yields an expression for the pressure: which can be simplified by consolidating constants and defining ionization rate as Ic/Ie: Where K is a gas-dependent constant determined through calibration and I is the ionization rate proportional to molecular density. Bayard-Alpert (B-A) Gauges are hot cathode ionization gauges with effective measurement range between 10-11 and 10-2 Torr. A hot cathode ionization gauge has three electrodes: the cathode or filament, the collector, and the anode grid. Typically, the collector is at ground potential, the anode at 180V and the filament at 30V. Energetic electrons emitted from the cathode are accelerated towards the anode grid, colliding with and ionizing molecules present in the gas phase. The positive ions that are created in the collisions are accelerated towards the collector located along the axis of the anode grid, producing an ion current that is measured by the gauge electrometer. This gauge configuration produces a strict, linear relationship between collector current and pressure. Thus, the collector is negative relative to the filament and the anode and electrons can only go to the anode. The lower limit for measurement is determined by the X-ray limit. In an HCIG, X-rays are emitted when electrons impact the grid. A small fraction of these X-rays impinges on the ion collector, causing electrons to be ejected by the photoelectric effect. The positive ions created by this ejection of electrons is detected as positive ion current, contributing to the pressure reading. The lower measurement limit in the best conventional HCIGs are about 10-11 Torr because of this phenomenon. With good operating protocols and proper calibration, the sensor-to-sensor reproducibility of Bayard-Alpert HCIG readings is typically about 2%. Repeatability of readings is 1-2%, limited mainly by uncontrollable random sensitivity variations. Figure 16. The internal configuration, electron path/ion generation, and physical configuration of a cold cathode ionization gauge. MKS supplies Bayard-Alpert gauges in several different instrument configurations. Traditional B-A gauges such as the nude or glass-enclosed gauges shown in Figure 16 are a stable, economical solution for the measurement of pressure in high and ultrahigh vacuum regimes. Hot cathode gauges have a repeatability of 1-2%. Glass enclosed gauges typically have gauge-to-gauge reproducibility of ±25% (not tested at factory). The nude gauge configuration has a measurement range between the lower X-ray limit (10-11 Torr) and 0.001 Torr; the glass-enclosed B-A gauge has a slightly higher lower measurement limit of