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17/ENG01/013

CHEMICAL ENGINEERING

CHE 312: PROCESS INSTRUMENTATION

QUESTION ONE:

A. Instrumentation can be defined as the application of instruments, in the form of systems or devices, to accomplish some specific objective in terms of measurement or control, or both. Instrumentation is the variety of measuring instruments to monitor and control a process. It is the art and science of measurement and control of process variables within a production, laboratory, or manufacturing area.

B. Gas chromatography - specifically gas-liquid chromatography - involves a sample being vapourised and injected onto the head of the chromatographic column. The sample is transported through the column by the flow of inert, gaseous mobile phase. The column itself contains a liquid stationary phase which is adsorbed onto the surface of an inert solid.

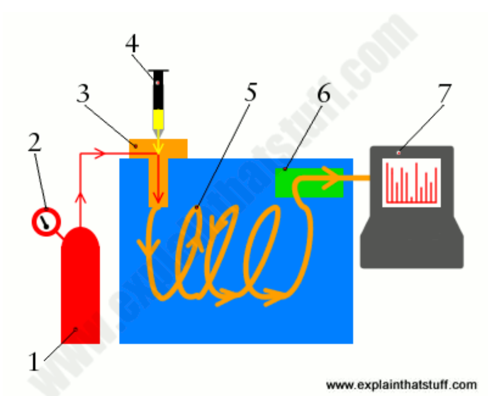
In gas chromatography, the components of a sample are dissolved in a solvent and vaporized in order to separate the analytes by distributing the sample between two phases: a stationary phase and a mobile phase. The mobile phase is a chemically inert gas that serves to carry the molecules of the analyte through the heated column. Gas chromatography is one of the sole forms of chromatography that does not utilize the mobile phase for interacting with the analyte. The stationary phase is either a solid adsorbant, termed gas-solid chromatography (GSC), or a liquid on an inert support, termed gas-liquid chromatography (GLC).

To separate the compounds in gas-liquid chromatography, a solution sample that contains organic compounds of interest is injected into the sample port where it will be vaporized. The vaporized samples that are injected are then carried by an inert gas, which is often used by helium or nitrogen. This inert gas goes through a glass column packed with silica that is coated with a liquid. Materials that are less soluble in the liquid will increase the result faster than the material with greater solubility.

In GLC, the liquid stationary phase is adsorbed onto a solid inert packing or immobilized on the capillary tubing walls. The column is considered packed if the glass or metal column tubing is packed with small spherical inert supports. The liquid phase adsorbs onto the surface of these beads in a thin layer. In a capillary column, the tubing walls are coated with the stationary phase or an adsorbant layer, which is capable of supporting the liquid phase. However, the method of GSC, has limited application in the laboratory and is rarely used due to severe peak tailing and the semi-permanent retention of polar compounds within the column. Therefore, the method of gas-liquid chromatography is simply shortened to gas chromatography and will be referred to as such here.

Typically, **the stationary phase** is a porous solid (e.g., glass, silica, or alumina) that is packed into a glass or metal tube or that constitutes the walls of an open-tube capillary. The mobile phase flows through the packed bed or column. The sample to be separated is injected at the beginning of the column and is transported through the system by the **mobile phase**. In their travel through the column, the different substances distribute themselves according to their relative affinity for the two phases.

How Chromatography works



1. The eluant (carrier gas) is introduced from a gas cylinder outside the machine. It's called the carrier because that's exactly what it does—carry the sample we're studying through the machine. In gas chromatography, the carrier gas is the mobile phase.
2. The rate of flow of the carrier is carefully controlled to give the clearest separation of the components in the sample.
3. The carrier enters the machine through an inlet port/splitter.

4. The sample being measured is injected into the carrier gas using a syringe and instantly vaporizes (turns into gas form).
5. The gases that make up the sample separate out as they move along the column (orange), which contains the stationary phase (typically, it's a thin coating on the inside wall of the column). The column is a very thin (capillary) tube, sometimes as much as 30–60m (100-200ft) long, coiled and entirely contained inside an oven (blue) that keeps it at a high enough temperature to ensure that the sample remains in gas form. The temperature of the oven can be carefully controlled.
6. As the sample separates out and its constituent gases travel along the column at different speeds, a detector senses and records them. Various different detectors can be used, including flame ionization detectors, thermal conductivity detectors, and mass spectrometers (usually separate machines).
7. The data analyzer/recorder attached to the machine draws a chromatogram (chart) with peaks corresponding to the relative amounts of the different chemicals in the sample.

C. REASONS FOR MOISTURE MEASUREMENT

In industrial applications, moisture is a contaminant. Either in gas or in liquid form, moisture has the power to dramatically reduce product quality, damage equipment and increase operational costs. Moisture is able to penetrate virtually any surface including metals such as copper, bronze and carbon steel.

As a result, in compressed air and gas applications moisture can render test results useless, cause corrosion in piping and equipment, produce poor product quality, lead to ice formation at low temperatures, generate premature wear and equipment failure, and react with other chemicals and gases to distort industrial processes. It is obvious moisture levels must be monitored and controlled.

1. Moisture Measuring: Power Generation and Distribution

In electric power generation facilities, whether fueled by coal, natural gas, oil or nuclear power, measuring the compressed air dewpoint is an operational requirement for the plant's pneumatic controls and instrumentation.

In certain power plants, another major concern is the measurement of moisture content of hydrogen used to cool an electric power generator. Because hydrogen can be explosive when mixed with air, a dewpoint sensor must be intrinsically safe or explosion proof can be installed at the outlet of a gas dryer or anywhere in the compressed air system to monitor dewpoint.

Again, in this industry, portable hygrometers can be used to spot check gas moisture levels or permanent dewpoint transmitters can be installed for continuous readings.

2. Moisture Measuring: Furnaces/Metal Heat Treating

Failure to properly monitor and control moisture in heat treat furnaces (anodizing, annealing, hardening) risks poor metal quality and potential equipment failure. The presence of metallic particulates and combustion byproducts in these processes requires a sampling system with appropriate filtration to protect the dewpoint sensor and obtain accurate readings.

When a furnace is not pressurized and there is no natural flow of gas to the dewpoint sensor, a vacuum pump is used to draw a sample from the furnace to the dewpoint sensor. A hygrometer can be used to measure dewpoint from the furnace.

3. Moisture Measuring: Pipelines and Natural Gas Production

For oil and natural gas pipelines, water is used to pressure test during initial construction and following any pipeline repairs. After pressure testing, water is purged from the pipeline through hot air drying where moisture is evaporated into vapor and pushed out the pipeline by flowing air. To verify the dryness of the pipeline, two hygrometers are used. One is typically installed at the inlet of the pipe while the other is installed at the outlet. These instruments allow engineers to determine if the pipe is sufficiently dry for the flow of oil or gas.

In natural gas production and transportation, the gas sources are often dirty, corrosive, and laden with moisture. This moisture can corrode the pipes, decrease flow capacity and lead to blockage or equipment damage. Dehydrators with filters are used to both dry the gas and remove contaminants. A permanently installed moisture analyzer can be used to monitor the dehydration process in production plants and a portable (spot check) hygrometer can be used to monitor pipeline dewpoint.

4. Moisture Measuring: Semiconductor Manufacturing

There are two areas where dewpoint measuring is critical to operations in semiconductor manufacturing: Cleanrooms where semiconductor wafers are produced and stored, and in ultra-high purity gases used in the manufacturing process.

To prevent contamination of materials and to eliminate static electricity caused by moisture, optical (chilled mirror) technology is used to measure dewpoint and relative humidity.

METHODS OF MOISTURE MEASUREMENT

1. SPECTROSCOPIC METHOD

The use of spectroscopy in moisture analysis includes infrared, microwave, and nuclear magnetic resonance (NMR) spectroscopy to determine surface and total moisture, respectively. These are indirect methods of measurement can take a long time for determination because of the need to calibrate using multiple samples, and are therefore not much used in industrial moisture analysis.

2. CHEMICAL METHOD

Karl Fischer Titration

The most accurate and specific method for determining the water content of a substance is Karl Fischer (KF) titration. It is based upon the reaction of iodine with sample water, in presence of alcohol solvent, sulfur dioxide, and a base. It uses up the total sample water, including the water of crystallization and surface absorbed water, in the redox reaction.

The reagent titer required until this end point is used is the basis on which the water content is determined. Both volumetric and coulometric variants are available, differing in the size of the sample, the water content measured, the accuracy and the way in which the total water used up is calculated.

Automated KF titration has made this technique convenient and rapid for precise determination of the water in a sample. The volumetric method is more appropriate for higher water content but is slightly more labor intensive. All solids must be dissolved in an appropriate solvent for analysis, and this may be difficult with some solids.

Calcium Carbide Method

The calcium carbide method is cost-effective and uses a combination of materials to react with water. The end product is potentially explosive, and so the method requires great care. Moreover, the total water in the sample does not take part in the reaction and this means that repeated calibration is a necessity.

3. CONDUCTIVITY METHOD

They are very accurate in measuring moisture in very fine uniformly distributed materials. A conductive sensor uses the difference in conductivity from the specific conductivity caused by moisture content, which is measured between two electrodes which are thrust into the material to calculate the moisture content.

4. THERMOGRAVIMETRIC ANALYSIS METHOD

The principle of the thermogravimetric method of moisture content determination is defined as the weight loss of mass that occurs as the material is heated. The sample weight is taken prior to heating and again after reaching a steady-state mass subsequent to drying. Various thermogravimetric methods and technologies can be used for sample drying; for example, the halogen technological thermo-radiation drying method is a universally applicable, highly efficient and practical test procedure for in-process testing. The thermogravimetric drying process has many advantages, notably this type of testing is simple and generally does not require high capital investment.

The measure of moisture content during thermogravimetric analysis defines moisture as the loss of mass of a substance when heated, by the process of water vapourisation. The substance difference is continually calculated and recorded by a precision balance. Sample substance mass is measured before and after the drying process for final moisture determination on percentage basis.

QUESTION TWO

A. It ensures consistency.

Measurements are one of the most important parts in a processing plant. Using the proper process control instrumentation to remodel and rework your internal operations allows your machines to reduce variability and run to the best of their abilities.

2. It improves quality.

Process control systems are central to maintaining product quality. Using proper instrumentation, control systems maintain the proper ratio of ingredients, regulate temperatures and monitor outputs. Without this standard of control, products would vary and quality would be impaired.

With improved quality comes higher levels of safety. Pressure relief valves, for example, can regulate a steam supply. Pressure switches, on the other hand, will stop a pump from overheating. This is crucial, since plant safety is a top priority in any operation.

3. The objective of process control is to keep key process-operating parameters within narrow bounds of the reference value or setpoint. Without adequate and reliable process controls, an unexpected process occurrence cannot be monitored, controlled, and eliminated. Because process variables can and do change, instrumentation
systems measure the variable then control the variable to keep the variable within the given limits.

4. Measurement of process variables are important in controlling a process.
Accurate measurement of process variables is important for the maintenance of accuracy in a process. The value of the process variable is continuously monitored so that control may be exerted.

B.

1. SANITARY APPLICATIONS: The construction of the magnetic flow meter is such that the only wet parts are the liner and electrodes, both of which can be made from materials that can withstand corrosion. In addition, the straight-through (obstruction-less) nature of the design reduces the loss of hydraulic energy across the flow meter (pressure drop) and the potential for abrasion from the flowing liquid. Therefore, magnetic flow meters can measure many corrosive liquids and abrasive slurries. Magnetic flow meter liners and electrodes can be constructed of materials that do not contaminate the liquid. Therefore, these flow meters can be applied when liquid contamination is an issue, such as in sanitary applications.

2. OIL/GAS INDUSTRY: Natural gas and oil flows up the well bore. The water collected along with hydrocarbons during the well's production life is referred to as "produced water". Most of the produced water is the water that had been pumped underground to increase the flow of oil. A separator removes the water from the oil. Usually, the volume of the water is stable throughout the well's life and a challenge for mechanical flowmeters due to abrasive solids. Magnetic flowmeter is designed to meet rigorous oil field production requirements helping lower risk and increase process up-time.

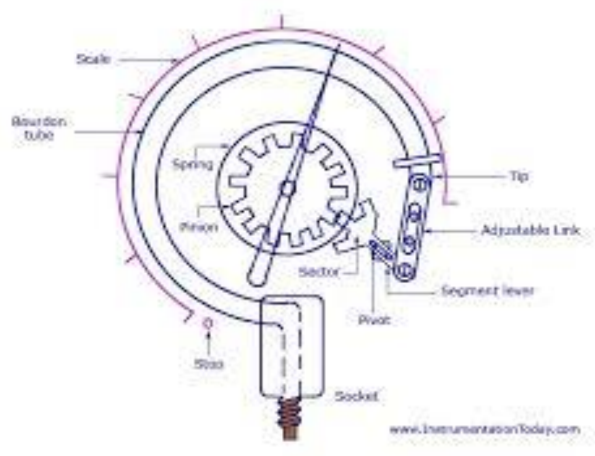
3. Magnetic flowmeters are used in water treatment plants to measure treated and untreated sewage, process water, water and chemicals. Mining and mineral process industry applications include process water and process slurry flows and heavy media flows.

C.

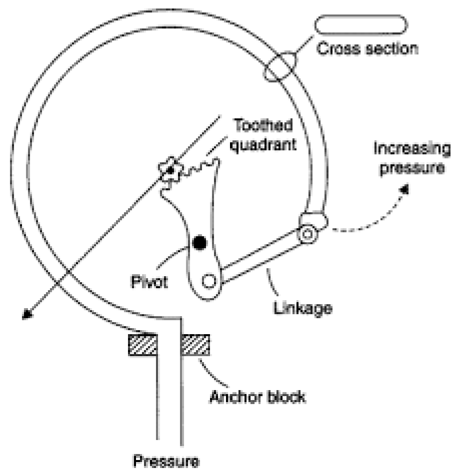
1. BOURDON GAUGE

The Bourdon pressure gauge operates on the principle that, when pressurized, a flattened tube tends to straighten or regain its circular form in cross-section. The Bourdon tube comes in C, helical, and spiral shapes—although most gauges employ the C shape.

When a gauge is pressurized, the Bourdon creates the dial tip travel to enable pressure measurement. The higher the pressure requirement of the application, the stiffer the Bourdon tube needs to be, which means Bourdon wall thickness and diameter are key considerations for enabling the required tip travel to traverse the necessary movement and, thus, facilitate pressure measurement accuracy. A standard gauge for an industrial fluid handling application would generally call for an accuracy range of 3 to 5 percent full scale. A Bourdon test gauge typically provides accuracy of 0.25 to 1.0 percent full scale.



Bourdon Tube Pressure Gauge

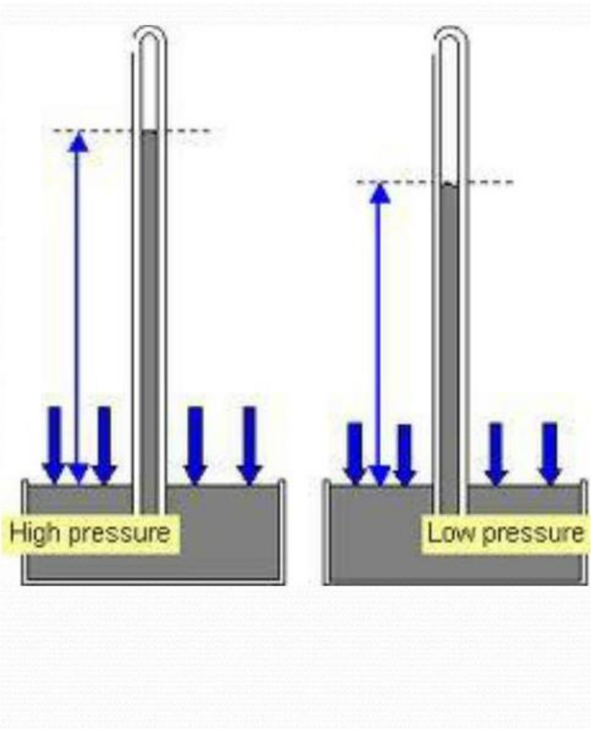


2. MECURY BAROMETER:

That principle can be illustrated as follows: a long glass tube is sealed at one end and then filled with liquid mercury metal. The filled tube is then turned upside down and inserted into a bowl of mercury, called a cistern. When this happens, a small amount of mercury runs out of the tube into the cistern, leaving a vacuum at the top of the tube. Vacuums, by nature, exert very little or no pressure on their surrounding environment.

As atmospheric pressure pushes down on the surface of the mercury in the cistern, that mercury in turn pushes up with an equal pressure on the mercury in the glass tube. The height of the mercury in the tube, therefore, reflects the total pressure exerted by the surrounding atmosphere. Under normal circumstances, the column of mercury in the glass tube stands at a height of about 30 inches (76 centimeters) when measured at sea level.

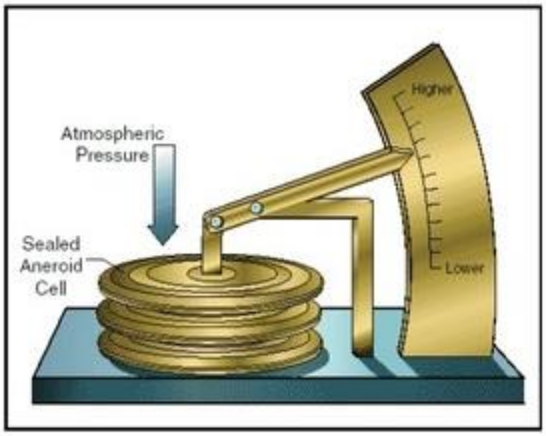
In theory, a barometer could be made of any liquid whatsoever. Mercury is chosen, however, for a number of reasons. It is so dense that the column supported by air pressure is of a usable height.



ANEROID BAROMETER:

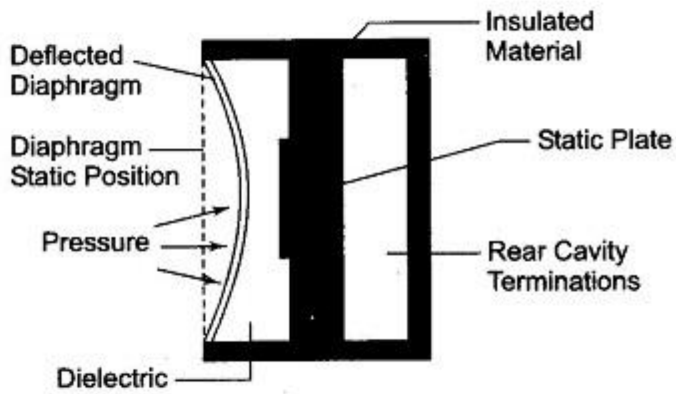
An aneroid barometer is a container that holds a sealed chamber from which some air has been removed, creating a partial vacuum. An elastic disk covering the chamber is connected to a needle or pointer on the surface of the container by a chain, lever, and springs. As atmospheric pressure increases or decreases, the elastic disk contracts or expands, causing the pointer to move accordingly.

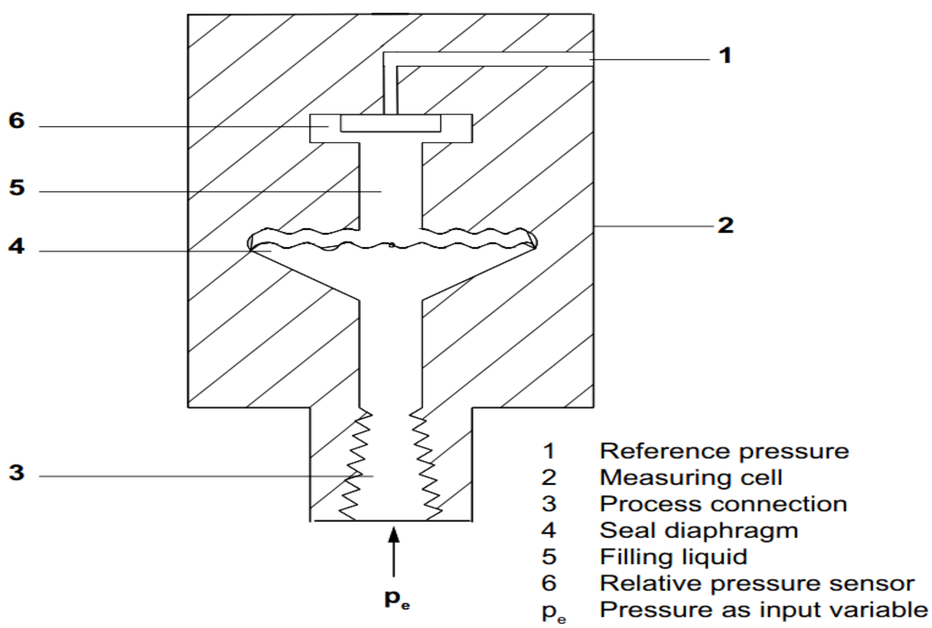
One type of aneroid barometer has a pointer that moves from left to right in a semicircular motion over a dial, reflecting low or high pressure. The simple clocklike aneroid barometer hanging on the wall of many homes operates on this basis. Another type of aneroid barometer has the pointer resting on the side of a rotating cylinder wrapped with graph paper. As the cylinder rotates on its own axis, the pointer makes a tracing on the paper that reflects increases and decreases in pressure. A recording barometer of this design is known as a barograph.



3. PRESSURE SENSORS/TRANSDUCERS : A pressure sensor works by converting pressure into an analogue electrical signal. Pressure transducers have a sensing element of constant area and respond to force applied to this area by fluid pressure. The force applied will deflect the diaphragm inside the pressure transducer. The deflection of the internal diaphragm is measured and converted into an electrical output. This allows the pressure to be monitored by microprocessors, programmable controllers and computers along with similar electronic instruments.

Most Pressure transducers are designed to produce linear output with applied pressure.


Insulated
Material
Deflected
Diaphragm
Diaphragm
Static Position
Static Plate
Pressure
Rear Cavity
Terminations
Dielectric


1
6
5
2
4
3
p_e
1 Reference pressure
2 Measuring cell
3 Process connection
4 Seal diaphragm
5 Filling liquid
6 Relative pressure sensor
p_e Pressure as input variable

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