

Vacuum Control of Air Sampling Systems: Calibrating Your Gas System for Quality and Safety

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How pressure, which is key to air sampling, can be regulated to ensure that detector calibration is accurate and will provide valid readings

The kids want to go to the beach, but a low-pressure system is approaching. The weatherman advises you to rent a couple of movies because rain is on the way.

Just the way barometric pressure plays an important role in predicting weather patterns, sub-atmospheric pressure impacts the calibration of detectors sampling at standard atmospheric conditions.

Vacuum control is necessary in applications like biomedical analysis, semiconductor processing, ink meniscus control, and instrument calibration to detect impurities such as moisture, oxygen, hydrocarbons, and other constituents, to ensure product quality and workplace safety.

The Mechanics of Air Sampling Systems

Detectors taking air samples require calibration at the same atmospheric conditions. The detector is selected based upon the elements of concern. In the refinery industry, hydrocarbon leak detection is the primary method of ensuring laboratory and building safety. Illustrated in Figure 1 is a typical atmospheric sampling system utilizing catalytic bead sensor technology.

The main advantages of combustible catalytic bead sensor technology is its ruggedness, non-selectivity, and simple calibration [1]. The sensor utilizes an active cell comprised of two platinum wires embedded in

an alumina bead heated to facilitate oxidation of the combustible molecules as illustrated in Figure 2 [2]. As the molecules are oxidized, heat is generated changing the cell's resistance as measured by a Wheatstone bridge circuit. This circuit utilizes three known resistor values to

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determine the unknown resistance received from the catalytic bead detector [3]. The output provides a voltage difference proportional to the amount of combustible gases in the sample.

So now you ask, how did barometric (measurement of atmospheric pressure) pressure and the weather affect the detector accuracy? The weight of the air applies approximately 14.7 lbf (pound-force) that varies with your location. This creates a specific air density in which the subject gas is mixed. When calibrating the detector, a span gas of known concentration is delivered at a rate of 1 to 1 ½ lpm. If the span gas is regulated at a pressure greater than local atmospheric conditions, the gas density will be greater, yielding a false calibration. This would create a condition in which a greater concentration of combustible gas is present as compared to the detector's output therefore under-reporting the level of combustible gas.

The necessary components of the sampling system include span and zero gas standards to provide a NIST-traceable reference for calibration of the detector.

Figure 1 illustrates a two-stage pressure regulator delivering the gas standard between 40-50 psig to the

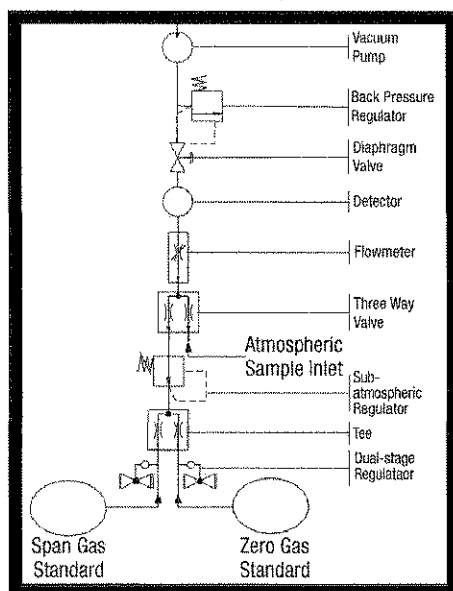


Figure 1. Typical ambient air sampling schematic

inlet of the sub-atmospheric regulator. Figure 3 illustrates the mechanical feature differences of the second stage of the two-stage and sub-atmospheric regulators. Dual-stage regulators reduce pressure in two steps while maintaining consistent outlet pressure. The first step or stage receives cylinder inlet pressure and delivers the gas to the second stage at a preset value typically between 225-400 psig. As the inlet pressure decays, the output of the first stage increases because of less closing force acting upon the seat. This causes the preset value of the first stage to increase by 7-15 psig depending on the size of the seat and closing force of the marginal spring, which represents only a 3-5% change in pressure to the inlet of the second stage of regulation. With stable inlet pressure, the second stage will maintain the set pressure till the cylinder contents drops below the preset value of the first stage. This is the reason a dual-stage regulator is recommended on the span and zero gas standards.

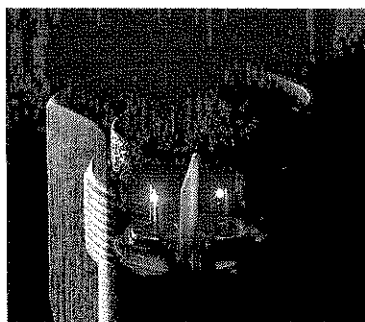


Figure 2. Catalytic Bead Sensor [1]

Other regulator features should include machined instead of tapped threads. Tapped threads require the machine tool to stop at the bottom of the port, leaving a vertical line the entire length of the thread as the tool is reversed out. This is difficult to seal and creates a leak path. Machined threads provide smooth-surface finishes for optimum sealing for pipe-threaded connections. Higher leak-integrity connections are available, such as welded joints, face seals, and compression fittings.

Depending on the design, the manufacturer may include a relief device along the pathway between the two stages. Others may include the relief on the outlet of the second or final stage of regulation.

The major sub-atmospheric design difference is the negative bias spring under the diaphragm pushing up, which requires the combination of inlet pressure and marginal spring force to close the regulator's seat. This enables the system's vacuum pump to create a negative pressure on the regulator's outlet cavity. The negative force will pull down the diaphragm to allow gas flow from the gas standard. The vacuum force combined with the adjustable spring force pushing down on the diaphragm allows the gas standard to be delivered to the detector at atmospheric conditions. Additionally, the sub-atmospheric regulator's convoluted diaphragm design consists of almost twice the surface area, which provides the sensitivity necessary to regulate pressure from 0-30 psig.

The next component is the three-way valve, which enables the operator to change from calibration to sample mode with minimal downtime. The three-way valve also minimizes the number of threaded connections as potential leak sites.

Next in the system is the non-compensated variable-area flowmeter designed to deliver a constant amount of calibration or sample gas to the detector. This design differs from that of a pressure-compensated flowmeter because of the inlet pressure exiting only below the float material. The top of the float material is at atmospheric pressure. A pressure-compensated flowmeter has a valve located on the outlet, which provides equal pressure above and below the float material so the scale can be calibrated at a specific operating pressure.

After the flow meter in the sampling system is the detector and vacuum isolation valve. The appropriate detector is selected depending on the elements or gases of interest. The catalytic bead sensor technology is ideal for anything that can be oxidized like alkanes, amines, and alcohols [3].

Finally, it may be necessary to include a sub-atmospheric back-pressure regulator between the detector and vacuum pump that limits the amount of vacuum applied to the entire sampling system.

In addition to air sampling systems, vacuum control plays a key role in the chemical, pharmaceutical and

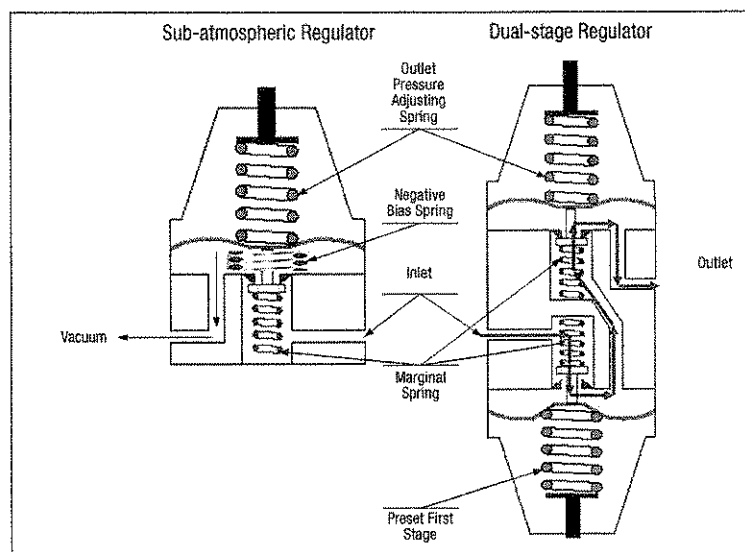


Figure 3. Mechanical differences between dual-stage and sub-atmospheric regulator designs

the refinery industries to ensure product quality and batch verification. Although the detector technology may vary with the application, the principles discussed here apply overall to ensure consistent quality and safety in the workplace.

References

1. Delphian Detection Technology, 220 Pegasus Avenue, Northvale, N.J., U.S.A. <http://www.delphian.com/catalytic.htm>
2. International Sensor Technology, 3 Whitney Irvine, CA., U.S.A. <http://www.intlsensor.com/pdf/catalyticbead.pdf>
3. Detcon Inc. 3200 Research Forest Drive, A-1 • The Woodlands, Texas., U.S.A. <http://www.detcon.com/catalytic01.htm>

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