Selecting a Low-Maintenance Sensor for Safety Monitoring of Oxygen and Carbon Monoxide Levels in Industrial Processes and Environments

Summary
For safety, legal, and compliance reasons industrial plants must monitor oxygen (O₂) and carbon monoxide (CO) levels in processes and structures. Traditional technologies for detecting these gases include paramagnetic, nondispersive infrared, electro-chemical cell, and zirconium oxide sensors. Advances in microprocessor technology and spectroscopy have enabled manufacturers to develop in-situ tunable diode lasers (TDLs) that can accurately and quickly measure specific gases, including O₂ and CO, while requiring virtually no maintenance. This paper reviews the operating principals of the most commonly used sensors and outlines why TDLs provide a lower cost alternative that performs as well as or better than the more traditional sensor types.

To Ensure Safety, You Need a Fast, Reliable Way to Continuously Measure O₂ and CO Levels
If you work in an industrial plant, you understand the role continuous gas monitoring plays in ensuring product quality, legal compliance, and personal safety. Worldwide, few if any regulated facilities are allowed to operate without these critical systems.

Many plants are equipped with a combination of in-situ and extractive analyzers, which the operators rely on to ensure automatic and continuous monitoring of gases in exhaust flues, storage silos, and production areas. Monitoring these gases allows plants to optimize process control, product quality, and safety.

For decision makers at most facilities, there is no debate about whether to install monitoring systems. Rather, most discussions involve identifying the most cost effective, reliable, and responsive devices for different production processes.

Rapid, continuous monitoring of combustible and toxic gases such as oxygen (O₂) and carbon monoxide (CO) is important since anomalous concentrations of these colorless, odorless gases quickly can put plant equipment and personnel at risk. For example, a sustained or sudden drop in O₂ levels can be dangerous for workers when they are located in enclosed spaces, while high levels of O₂ or CO can threaten human health and contribute to fires or even explosive conditions.

Traditional Sensors Measuring O₂ and CO
Several types of sensors are capable of monitoring O₂ or CO, including sensors based on paramagnetic, nondispersive infrared, electro-chemical cell, and zirconium oxide technologies. While these sensors traditionally have been used for O₂ or CO monitoring, recent advances in semiconductors have made tunable diode laser (TDL) spectroscopy a more affordable, reliable, and rapid technique for measuring selective molecules. Before we outline why TDLs are superior, let’s review how the traditional sensors operate and some of the issues that make them a less effective choice for measuring of O₂ or CO.

Paramagnetic Sensor for O₂ Monitoring
A paramagnetic sensor operates by exploiting the magnetic behavior of oxygen to capture measurements. The paramagnetic O₂ analyzer creates a focused magnetic field that attracts oxygen. The increase in the pressure or flow of O₂ to a sensor produces an output that is proportional to the O₂ concentration in the sample.
Before a paramagnetic analyzer can calculate a measurement, a sampling system must first condition, filter, and dry the gas. These transport and conditioning steps increase system cost while slowing response times and introducing lags in read time ranging from seconds to minutes.

Extracting and conditioning samples are especially demanding when the flow path or process stream includes chemically reactive or instable constituents. In environments with large amounts of hydrocarbons, capturing accurate O$_2$ measurements with a paramagnetic sensor can be challenging. In many cases, operators are unable to calibrate out or correct interference because hydrocarbon levels and types vary over time. There also is a significant maintenance requirement when a paramagnetic sensor is monitoring streams that require heating or contain particulates, high-boiling components, or inorganic material. Response times for this type of sensor range from seconds to minutes.

**Nondispersive Infrared (NDIR) Sensor for CO Monitoring**
A nondispersive infrared (NDIR) analyzer system is typically installed in an extractive configuration. An NDIR sensor uses spectroscopy to measure levels of a specific target gas. The sensor’s source directs a beam of IR light through a tube of sample gas and toward an IR light detector. CO in the sample absorbs the IR light and passes through an optical filter where it is captured by an IR detector and compared to a reference gas where no energy is being absorbed.

While the optical filter ideally does not allow other wavelengths of light to pass through, it is still subject to cross-contamination from non-target gases in real-world environments.

**Zirconium Oxide Sensor for O$_2$ Monitoring**
A zirconium oxide analyzer system can be installed in an extractive or in-situ configuration. In either case, the zirconium oxide sensor captures data by measuring the signal voltage between the sensor’s two electrodes. The system analyzer then uses this data to calculate values based on the partial pressure of a reference gas.

Because this sensor is a ceramic, it is useful in high-temperature applications. But if soot and other contaminants are allowed to build up on the sensor, response times can increase and, eventually, the sensor may not be able to acquire data. The catalytic coating on the electrodes erodes over time, which means the sensor requires ongoing maintenance or it will eventually stop working. The sensor also is sensitive to combustible gases in the sample path. Inaccuracy will increase if the sensor is exposed to halogens, halogenated hydrocarbons, sulphur-containing compounds, water droplets, dust, mist, and abnormal pressure.

**Electrochemical Gas Cell Sensor for CO and O$_2$ Monitoring**
An electrochemical gas cell analyzer system can be installed in an extractive or in-situ configuration. The sensor normally contains two to four electrodes and an electrolyte for creating a reaction.

While this type of sensor can be very sensitive, cell life is limited and requires regular maintenance. Cross-sensitivity can cause the sensor to over-read O$_2$ levels and under-read CO levels. The anode electrode oxidizes over time and must be replaced when depleted. Changes in the anode also means the sensor has to be recalibrated to remain accurate. In addition, the cell is sensitive to large pressure pulses and changes in temperature and the molecular weight of the background gas, although manufacturers can address some of these issues during system design. Sample streams that include solvents and acidic gases can render the sensor inoperable.

**Advantages of the TDL Sensor**
Commercial analyzers with tunable diode laser spectroscopy (TDL) sensors have been available for more than 25 years. Operators are installing these sensors in in-situ because the technology offers a reliable method of measuring O$_2$ and CO concentrations under a variety of conditions while minimizing maintenance costs and, offering faster response times than traditional sensors.

A typical industrial TDL analyzer consists of a central unit and several pairs of cross-duct sensors in a transmitter and receiver configuration. The central unit is connected to the sensors by fiber optic cable. This configuration allows the operator to locate the analyzer away from hostile environments without compromising response time. These TDL systems measure levels in real time and with very little interferences.

The TDL sensor determines gas levels by beaming a specific wavelength laser light across or along a straight run of pipe to a receiving unit. This method, which relies on Beer’s Law, is very precise and subject to minimal cross interference from other components in the process stream.

The TDL sensor has no moving parts, which helps to ensure a very long service life. And it is intrinsically safe for Class 1, Division 1 installations. The TDL analyzer does not require a separate sampling system, which reduces initial capital costs. Maintenance is minimal with purging of soot and dust from the transmitter and receiver windows as the only requirement. Calibration of an in-situ sensor is simple using a calibration cell filled with a reference gas. In some cases, the in-situ sensor has to be removed and mounted on an extractive flow path and validated and calibrated using a reference standard.

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Typical Monitoring Scenarios Where TDL Sensors Are Ideal
When a new monitoring technology is introduced, decision makers must decide if it is better for a required task than existing solutions in terms of performance, maintainability, ease of installation, and operational costs. TDL-equipped analyzers such as the Siemens SITRANS SL and LDS 6 product families provide advantages in each of these areas for monitoring O₂ or CO gases.

Siemens has designed both devices to measure target gases directly in a stack, duct, or process stream without sample handling or conditioning. While Siemens TDLs have many applications, they have proven to be a popular choice for monitoring flue gases, flare stacks, and coal silos.

In Flue Gas and Flare Stacks
Many industrial operations produce exhaust gases that contain dust, fly ash (unburned constituents), fumes (including fine elemental particles such as cadmium, sulfur, and lead), and coal tar mist. To meet regulatory requirements, a plant operator can use an electrostatic precipitator (ESP) to remove these contaminants from the process flue gas.

With an ESP, it is important to monitor upstream gases to prevent high concentrations of CO that might cause an explosion and place people and equipment at risk. In this type of scenario, Siemens recommends installing an in-situ TDL such as the LDS 6 Laser Gas Analyzer, which is ideal for capturing accurate data and enabling a real-time safety control circuit. Some plants rely on flare systems (continuous and/or emergency) to safely dispose of waste combustibles from oil wells, refineries, and other chemical or petrochemical processes. Air infiltration into the flare stack can cause a destructive detonation, which is why operators are careful to monitor O₂ levels in the flare-drum.

In Coal Silos
Coal silos are widely used in mining and as intermediate storage containers at cement factories, power plants, and steel mills. Under the right conditions, coal dust in these enclosed spaces can spontaneously ignite. Because the conditions leading up to a partial ignition are hard to anticipate, most operators monitor the coal silo atmosphere to look for early signs of fire, such as an increase in the level of CO within the silo headspace.

As with flare stacks, a Siemens LDS 6 Laser Gas Analyzer provides a fast, accurate way to detect fire and elevated levels of CO that might endanger workers. Dynamic load compensation enables the TDL to determine the correct CO concentration values even with high levels of dust in the light path.

CO gas is odorless, toxic, and explosive at levels above 12 percent by volume of air. With low-maintenance TDL sensors located strategically throughout a facility, plant operators can evacuate employees and take fire suppression measures before the event becomes unmanageable. Because the sensor delivers the concentration values and there are no extractive gas paths, the response time for a reading is very short.

Conclusion
The marketplace provides plant operators with several technologies for in-situ monitoring of CO and O₂ gas concentrations. Among these devices, analyzers equipped with tunable diode laser (TDL) sensors represent a unique approach with significant advantages. TDL monitoring improves the safety of plants while delivering consistent reliability, incredibly fast measurement speeds, and ongoing cost savings.

To Learn More
Siemens Process Industries and Drives Division can help you select the most reliable and cost effective technology for each monitoring situation. Call (713-939-7400) or email (ProcessAnalyticsSales.industry@siemens.com) to be put in touch with your nearest Siemens representative.