APPLICATION NOTE

MULTIGAS™ TFS™ GAS MONITOR
GOING BEYOND TRADITIONAL APPROACHES TO TRACE GAS ANALYSIS

PROBLEM

Traditional approaches to trace gas analysis such as gas chromatography and NDIR can be limited by factors like high capital and operational costs, slow response times, and poor analytical specificity. System maintenance and the calibration and support gases associated with some traditional analyzers can represent a significant cost-of-ownership to users, especially those that require analytical data for multiple components from multiple sites within a facility.

BACKGROUND

Infrared (IR) absorption spectroscopy is a direct, first-principles analytical technique that can be used in many environments, ranging from research laboratories to industrial process and quality control. The method is both fast (seconds or sub-second measurement time) and convenient (for gas analyses, it uses simple flow-through sampling configurations that do not require carrier gas or other consumables). Organic, inorganic, organometallic, and polymeric compounds all absorb infrared light and IR absorption data can be obtained from materials in all three states of matter.

Infrared spectroscopy has been used for exhaust gas analysis at scales ranging from laboratory to power plant smokestacks. For example, automotive engine developers have used the IR analysis of exhaust gas concentrations of CO, CO_2, NO_x, and hydrocarbons to optimize engine and catalyst efficiencies [1]. Similarly, power plants can employ IR spectroscopy for the analysis of CO, NO_x, SO_2, CO_2, and H_2O in stack gas to monitor the efficiency of boiler and pollution remediation operations [2]. IR spectroscopy is also very effective for hydrocarbon fuel analyses. MKS Instruments' Precisive® Gas Analyzer provides accurate quantitative analyses for C1-C5 hydrocarbons and is an effective monitor of gas quality and BTU content in natural gas fuels [3].

This Application Note describes the MKS MultiGas™ TFS™ Gas Monitor, an infrared-based analytical tool for continuous on-line monitoring of trace gas impurities, and the results of testing it in ASU (Air Separation Unit) installations that produce bulk oxygen, nitrogen, argon, hydrogen, helium, and other non-IR absorbing bulk gases.

SOLUTION

MKS MultiGas™ TFS™ Gas Monitor

MKS Instruments offers the MultiGas TFS Gas Monitor (Figure 1), a gas analyzer for monitoring trace contaminants in bulk gases that uses a Tunable Filter Spectrometer (TFS™) for the determination of infrared absorption spectral data. Tunable Filter Spectrometry uses a broad-band infrared light source, a tunable wavelength separating element, and a photodetector.

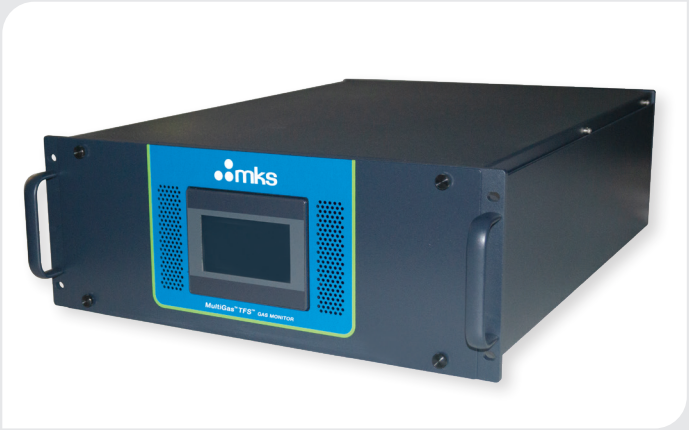

Figure 1 - MultiGas™ TFS™ Gas Monitor

The wavelength separating element produces an infrared probe beam with a nearly singular infrared wavelength, filtering out all other wavelengths. The wavelength separator is designed so that the infrared probe beam is tunable across a wavelength band of between 100 and 300 cm^{-1}. This allows the infrared probe beam to scan a portion of the infrared spectrum sufficiently wide to capture absorption data for individual group frequencies while simultaneously minimizing interferences due to nearby absorptions. This absorbance data can then be used for concentration determination, as noted above.

The MultiGas TFS Gas Monitor can perform multi-component trace gas analyses in real-time because it can analyze up to four regions in the infrared spectrum. This means that a single MultiGas™ Monitor can replace up to four separate process analyzers, significantly lowering capital, maintenance, and operational costs. The unit can be configured to provide analytical data for a wide variety of impurities, including CH_4, NMHC (alkanes), CO, CO_2, N_2O, and H_2O. Data on impurity concentrations can be collected with reporting rates up to 1 Hz.

The combination of high optical throughput and the 10-m optical path length of the gas sample cell that is used in the MultiGas TFS Gas Monitor enables high analytical performance over a wide measurement range. The MultiGas Monitor has detection limits that are typically in the low (<50) ppb range with stable analytical results that show very little drift.

Concentration determinations using the MultiGas TFS Gas Monitor also exhibit high linearity over an extended concentration range. The unit is permanently calibrated, requiring no field calibration or fuel gases; this significantly reduces operational costs compared with other analytical options. Table 1 shows a comparison of TFS spectrometry with more traditional analytical methods.

Trace Gas Monitoring in Air Separation Units

Industrial ASUs are employed for on-site production of high-purity bulk gases such as nitrogen, argon, and oxygen in many industries. These gas supplies must maintain impurities typically at ppb levels. Typical impurities that are monitored in ASU bulk gas production units include CO, CO_2, H_2O, N_2O, and hydrocarbons.

	TFS	FTIR	NDIR	Laser Based Sensor	Gas Chromatography	Significance
Specificity	High	High	Low	High	High	Ability to measure target compound in complex real-world mixtures.
Sensitivity	High	High	Medium	High	High	Ability to measure trace components accurately.
Multi-Compound Training	Medium	Multi	Single	Single	Single	Ability to monitor multiple components with one instrument (requirement for most applications).
Response Time	Fast	Fast	Fast	Fast	Slow	Ability to rapidly and accurately respond to changes in gas composition.
Cost-of-Ownership	Low	Medium to High	Low	Low	High	Low cost-of-ownership is a prerequisite for many industrial deployments.

Table 1 - A comparison of analytical techniques

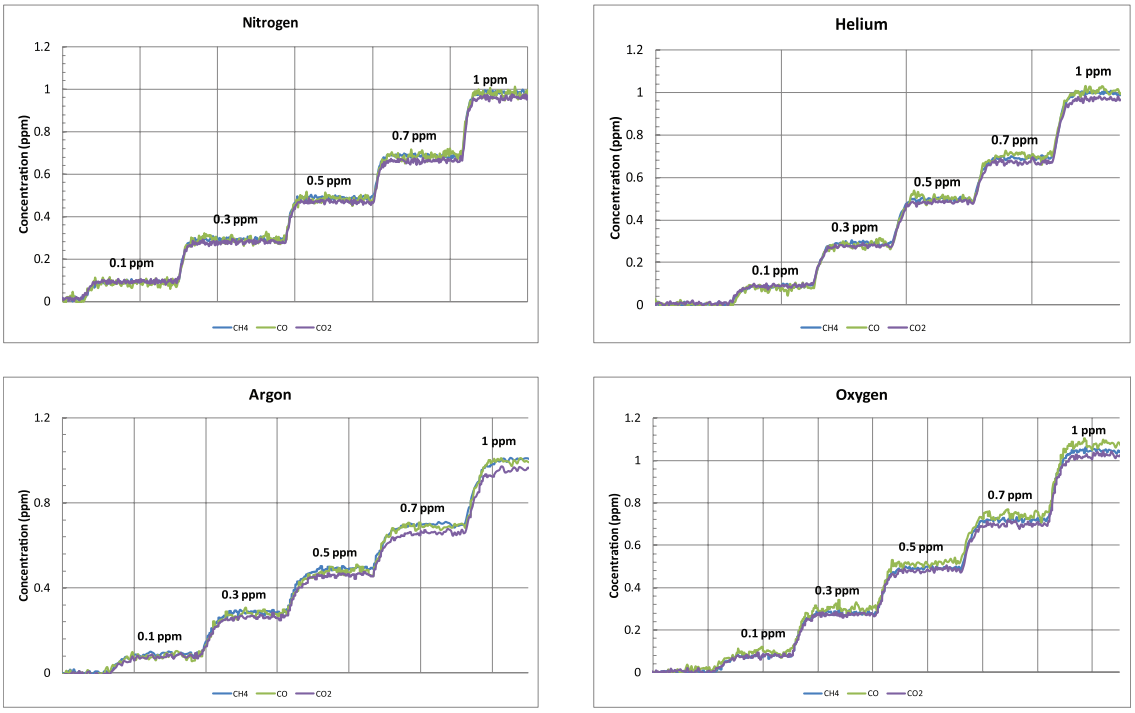

Figure 2 - Impurity determinations and reading stability for MultiGas™ TFS™ Gas Monitor linearity tests

Trace gas monitoring in ASU environments requires an analytical approach that provides continuous on-line monitoring of multiple impurities in real-time with extremely high sensitivity. Simultaneously, the environment in which the analysis is performed demands a relatively rugged analytical tool that requires minimal calibration and maintenance support over long periods of time.

The results of extensive analytical testing show that the all-optical MultiGas TFS Gas Monitor provides exceptional monitoring capability for trace quantities of hydrocarbons, CO, CO_2 and N_2O in the O_2, N_2, Ar, H_2, He, and other non-IR absorbing bulk gas products of an ASU facility. In our test procedure, gas samples were collected at a flow rate of 0.5 SLPM through the gas sample cell maintained at 1 atm pressure. Samples of each bulk gas containing known concentrations of N_2O, CH_4, C_2+, CO, and CO_2 (0.1, 0.3, 0.5, 0.7, and 1.0 ppm) were prepared and used to evaluate the accuracy and linearity of the analytical results. Analytical readings were averaged over 30 seconds.

Figure 2 shows representative analytical results obtained using the MultiGas Monitor while monitoring some typical contaminants in ASU bulk gases. The data demonstrates both the accuracy and stability of the analytical results from the MultiGas Monitor when used in ASU applications. The MultiGas Monitor responds rapidly to changes in the concentration of each of the impurities and the analyses were equally accurate and stable for all impurities tested. The detailed test results for contaminants in bulk nitrogen, displayed in Figure 3, show the high linearity of the analytical results determined using the MultiGas Monitor.

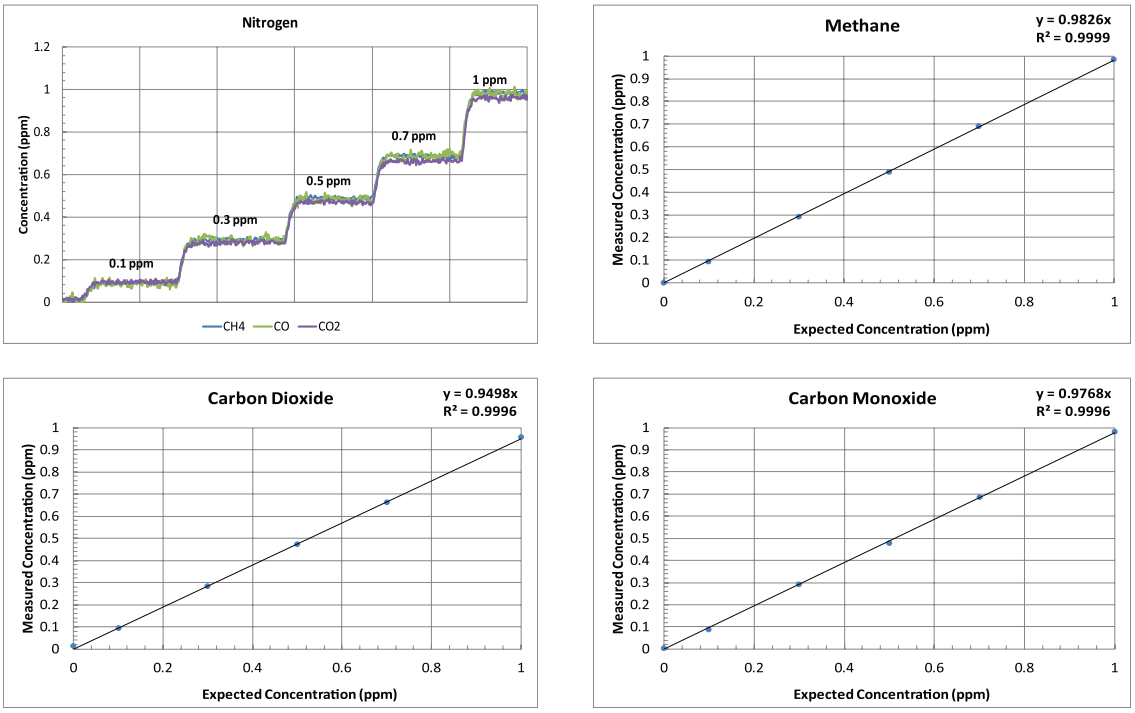

Figure 3 - MultiGas™ TFS™ Gas Monitor analytical linearity results for trace impurities in bulk N_2

Data from these tests was used to determine the lower detection limit (LDL) for each impurity in the different bulk gases. The LDL value was taken to be three times the standard deviation (noise) at zero concentration of each impurity in each bulk gas. The performance results of the MultiGas TFS Gas Monitor for trace gas analysis in ASU bulk gases is summarized in Table 2. Additional tests, not shown here, determined that the MultiGas Monitor exhibited LDL values of 39 ppb and 9 ppb for C_2+ alkanes and N_2O, respectively.

Detection Limits as 3-sigma in N_2				
Configuration	**Dual Filter**		**Single Filter**	
Averaging Time	60 sec	30 sec	60 sec	30 sec
CO_2	20 ppb	30 ppb	7 ppb	10 ppb
CO	20 ppb	30 ppb	15 ppb	20 ppb
N_2O	3.5 ppb	5 ppb	3.5 ppb	5 ppb
CH_4	15 ppb	20 ppb	–	–
C_2+	30 ppb	40 ppb	–	–

Table 2 - Performance results for the MultiGas™ TFS™ Gas Monitor as a trace gas monitor for ASU facilities

CONCLUSION

The MKS MultiGas TFS Gas Monitor is an online, multi-compound, trace gas monitoring system that uses an innovative Tunable Filter Spectroscopy technology to enable continuous and stable analytical measurements that have high selectivity to the trace impurities of interest in a given application. Due to its multi-compound capability, the MultiGas Monitor replaces up to four traditional impurity analyzers.

The MultiGas TFS Gas Monitor has exceptional performance, with low detection limits for most gases (typically low ppb levels) and offers stable, accurate, and highly linear analytical results over a broad range of impurity concentrations (10 ppb to 1000 ppm). The MultiGas Monitor is permanently calibrated so that, once configured, it needs neither calibration gases nor fuel gases, significantly reducing the cost-of-ownership compared with other analytical options. The MultiGas Monitor is an effective, reliable, and low-cost alternative to traditional analyzer technologies, especially for trace gas analyses in environments such as ASU facilities.

References

[1] Y. Ishizawa, M. Matsuishi, Y. Abe, Emori, G. and et al., "Study of Supercharged Gasoline HCCI Combustion by Using Spectroscopic Measurements and FT-IR Exhaust Gas Analysis," SAE Technical Paper 2014-32-0004, 2014.

[2] MKS Instruments Application Note, "Power Plant Emissions and SCR Monitoring with MultiGas™ 2030 Analyzers," MKS Instruments, 2010.

[3] MKS Instruments Applications Note, "Real-Time Fuel Composition Analyzer for Gas-to-Power Control," MKS Instruments, 2015.

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