Fuel and gas properties in an instant

The precise measurement of the Combustion Air Requirement Index (CARI) enables tight combustion control, but what are the user benefits?

Furnace or power plant fuel gases, with variable compositions, pose particular challenges for process engineers who need to achieve optimum efficiency and product yield. As gas composition changes, heating value and burner temperature can also change. So can the amount of air required for combustion. Unless these properties are monitored and compensated for, the furnace or power plant will not be properly controlled, causing significant inefficiency, wastage and even burner damage.

A furnace is normally operated at constant temperature so it would ideally operate under constant process conditions. On an integrated iron and steel works, waste gases from coke oven, blast furnace and steel converters along with natural gas are all used as fuel so gas composition changes as each of these processes change. To maintain a constant temperature, either the gas supply rate needs to be varied or, in a gas mixing station, flow rates of the different gases need to be varied. Also, the air supply rate needs to be varied, since there will be energy wasted if too little or too much air is used. If there is too little, some fuel gas will be unburned and wasted. If too much air is added then heat will be wasted. Excess air can also cause defects on metal surfaces due to oxidation, and poor temperature control can have adverse effects on product quality.

It is therefore vital to provide a comprehensive analysis of the fuel gas, not just measure the major components. Process Mass Spectrometry (MS) is an ideal technique for determining fuel gas properties because of its speed and accuracy.

Fuel gases measurement by Process MS

Process MS is suited to the measurement of fuel gas because the analysis is comprehensive, accurate and fast. The analysis of all the components present in fuel gas (e.g. H_2, CH_4, CO, N_2, O_2, C_2H_4, Ar, C_3H_6, CO_2, C_3H_8, C_4H_{10} and C_6H_6) is completed in less than 30 seconds, with a precision of typically better than 0.1% relative.

An example of such an instrument designed for process measurements is the Thermo Scientific Prima PRO, which is a compact and rugged unit using a scanning magnetic sector MS analyser. This instrument, shown in Figure 1, claims to provide exceptional reproducibility and linearity.

Advantages of magnetic sector Process MS

Magnetic sector analysers offer significantly better precision, accuracy and stability compared with other mass spectrometers. Thermo Scientific manufacture various types of mass spectrometer but more than 30 years' experience shows that the magnetic sector offers the best performance for process gas analysis.

Natural gas
Mixed gas
Process gas streams

Gas composition Calorific value
Wobbe index
Density
CARI

(Available as analog outputs, Modbus or Profibus)

Figure 1: Thermo Scientific Prima PRO magnetic sector MS used for on-line analysis of fuel gases

Measuring fuel properties with Prima PRO

Thermo Scientific's MS can calculate the following fuel properties:-

- Lower heating value
- Higher heating value
- Density
- Specific gravity
- Lower Wobbe index
- Higher Wobbe index
- Air Requirement
- Combustion Air Requirement Index (CARI)

The precision of these measurements is better than 0.1% relative.

Independent fuel gas analysis MS evaluation

The MS was evaluated as a Fuel Gas Quality Measurement System by EffecTech, an independent specialist company providing accredited calibration and testing services to the energy and power industries. The MS was tested in accordance with ISO 10723 for the nine fuel gas components listed in Table 1.

The MS was calibrated using just one mixture. It was then tested with nine reference gases covering the range of compositions shown in Table 1, a range greater than expected through a typical fuel gas metering point.

Component	Calibration Gas	Sample composition	
	(%mol)	Min	Max
Nitrogen	9.000 ± 0.015	0.10	9.94
Carbon Dioxide	5.000 ± 0.015	0.05	2.50
Methane	9.000 ± 0.020	9.84	65.03
Ethane	5.000 ± 0.013	0.50	24.75
Propane	10.000 ± 0.025	0.11	19.74
Ethene	5.000 ± 0.0015	0.099	10.06
Propene	5.000 ± 0.013	0.098	4.91
Hydrogen	43.000 ± 0.070	10.005	69.88
Carbon Monoxide	9.000 ± 0.015	0.098	6.79

Table 1: Calibration gas and reference gas ranges

Each gas was analysed with a 10 second cycle time.

Figure 2 shows the linearity plots generated by EffecTech. They demonstrate significantly better linearity than a TCD fitted to a GC.

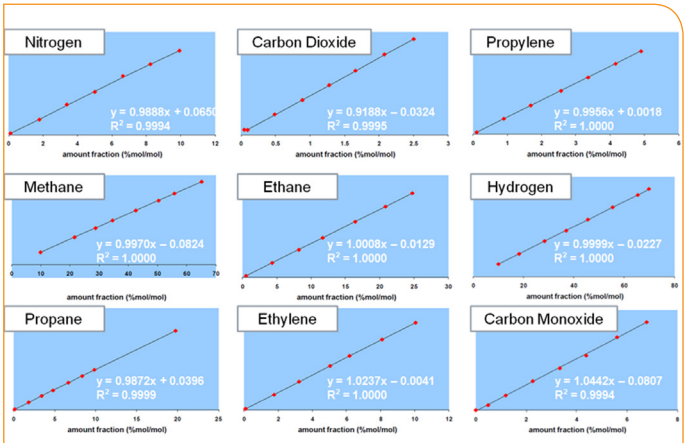

Figure 2: Prima PRO MS linearity data

Analytical flexibility

Prima PRO's software supports an unlimited number of analysis methods, enabling the analysis to be optimised for each individual stream. The most efficient peak measurements and the most appropriate speed versus precision settings, can be selected for each stream depending on process control requirements.

Figure 3 shows example data from test runs on cylinders representing two different types of fuel gas. They show the reproducibility of the calorific value measurements over 24 hours.

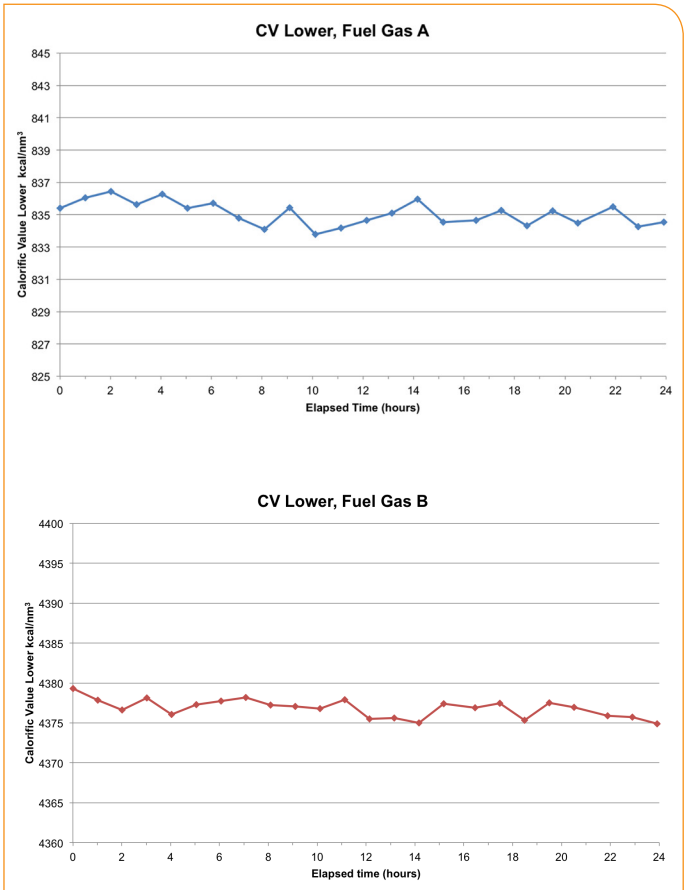

Figure 3: 24-hour calorific value data from two different types of fuel gas

Measured standard deviations are well within Prima PRO's published specifications.

Prima PRO's long-term stability is also excellent. Figure 4 shows a 30-day run without recalibration on a hydrocarbon blend calibration cylinder.

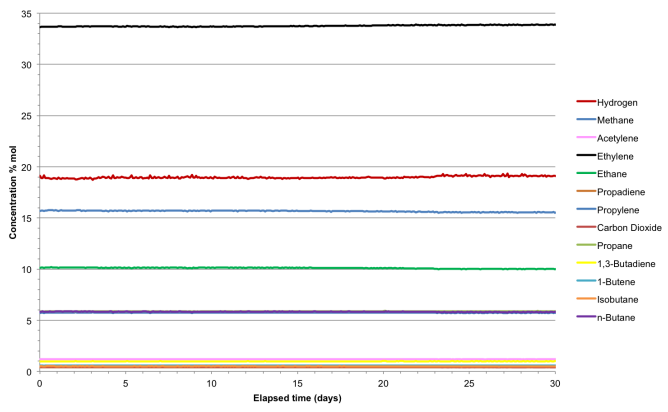

Figure 4: 30-day run with Prima PRO analysing 13-component hydrocarbon blend

Alternatives to MS

There are simpler, lower cost instruments capable of measuring fuel gases properties, but MS measurements claim to be more complete, accurate and quicker. MS precision is typically 10 times better than a calorimeter and response time is at least 10 times faster.

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Calorimeters cannot measure fuel gases of widely varying composition. Unlike GC, MS is flexible – it is easy to modify analytical methods to measure different components, resulting in no problems if sample gases are changed.

Summary

Process MS provides fast, on-line and accurate analysis of fuel gas properties in an integrated iron and steel works. The main benefits of which can include:

- The reduced consumption of fuel gases
- An increase in burner lifetime
- Better furnace temperature control.

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