The use of Raman spectroscopy for hydrogen blending of gas turbine fuel feed

Raman technology for gas turbine fuel feed

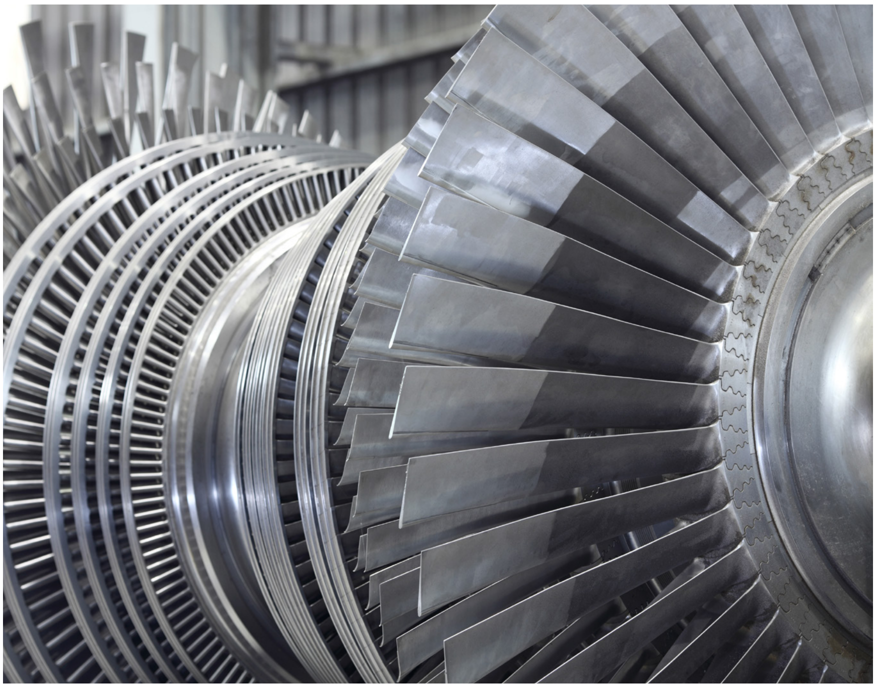
The addition of hydrogen into natural gas used to fuel gas turbines has become a positive trend towards decarbonization. Hydrogen displaces the concentration of methane and other hydrocarbons, resulting in reduced emissions. End-users are turning to gas turbine manufacturers to convert their existing turbine assets to burn hydrogen-rich fuels. Customer demand is for fuels ranging between 5% and 50% H_2, and there are dozens of installed gas turbines running on fuels containing hydrogen today.[1]

The blending of hydrogen is not without complexity. To use a non-traditional fuel in a gas turbine, it is essential to understand the composition to determine the heating value and the Modified Wobbe Index. This information allows the fuel to be matched to the appropriate combustion system and conditions.[2] Gas composition measurement allows the calculation of the hydrocarbon dewpoint, which is critical to avoiding condensate that can result in burner coke up. In addition, hydrogen fuel blends create a higher probability of flashback if the combustion conditions are not adjusted to accommodate the properties of the blended gas.

Gas turbines are frequently shipped with multiple analyzers to perform fuel composition measurement, including gas chromatographs (GCs). However, chromatography is often associated with slow response time. In one study, a 3-hour fuel heating value analysis was conducted at a site that had periodic fuel variation.[3] Analysis was conducted using a GC with a measurement cycle of 180 seconds. Within the survey period, there was a transient event in fuel composition that occurred faster than the capability of the GC to measure. Two complete cycles (6 minutes) passed before the transient was detected, which would pose an increased safety risk for operation of a turbine.

Benefits at a glance

- Fast, accurate, non-destructive analysis of gas turbine feed composition
- Ability to protect and optimize gas turbines by delivering data in time for critical operational changes
- Tailored to meet a wide range of fuel compositions
- Low maintenance and OPEX costs - no carrier gases or consumable items



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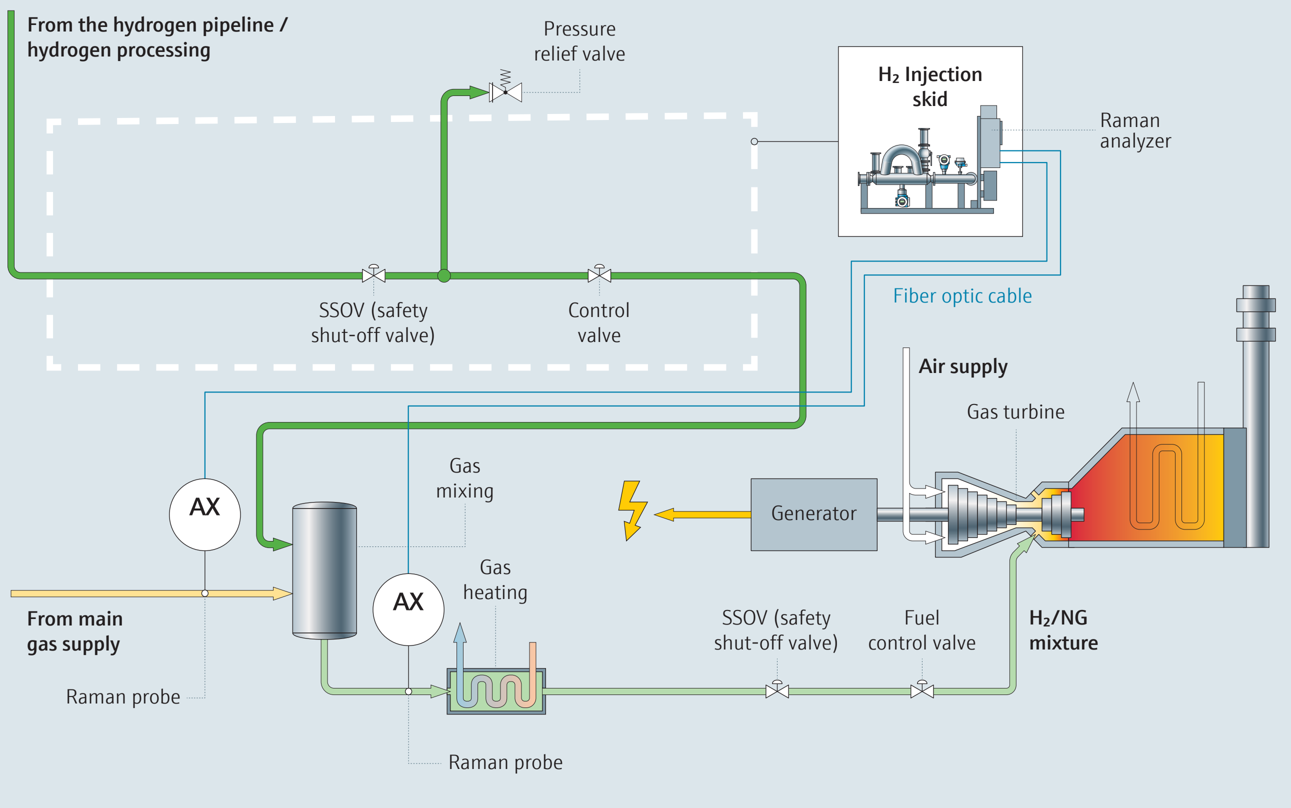
Gas turbine with hydrogen blending



Benefits of Raman spectroscopy

Raman technology offers greatly reduced complexity when compared to other gas analysis methods such as mass spectrometry (MS) and chromatography. Raman probes can be installed at line pressure, thus reducing the need for complicated sample conditioning systems, carrier gases, and columns. The lack of a fancy sample system also decreases speed of response which is highly desirable for measuring changes in the fuel blend and adjusting the gas mixing to maintain safe conditions.

Experimental

Recently, an extended evaluation of a Raman gas-phase analyzer to monitor turbine fuel feed was undertaken at a gas turbine technology laboratory. The owner of this site typically shipped four different analyzer technologies with each turbine, including a calorimeter, a redundant pair of GCs, an oxygen analyzer, and a CO_2 analyzer. The primary goal for this evaluation was to compare MS and Raman spectroscopy for measuring rapid transient events in fuel blending, including H_2 and ethane blended into natural gas. A secondary goal was to determine if a single analyzer could replace the suite of four analyzers in this measurement.

Results and discussion

The Raman analyzer was installed in the gas fuel stream by means of a bypass to a Raman fiber optic probe mounted in a simple 4-way tee interface. Measurements were made at the fuel feed pressure of 350 psia. In contrast, the mass spectrometer required sample transfer lines and sample conditioning prior to the injection port. Measurement of rapid transient events were tracked with both analyzer systems. In one set of tests, H_2 was spiked into natural gas at levels between 25% and 70% over a period of 40 seconds, then stepped back down to 24% over another 40 seconds. Figure 1 depicts how both the Raman and MS analyzers performed during this test. Raman spectroscopic data was updated every 13 seconds and was able to follow the transient event. The mass spectrometer reports data approximately every 2 seconds. Despite having a faster cycle time, the mass spectrometer had a severe lag due to the sample conditioning system.

Figure 2 shows both MS and Raman spectroscopic measurements as ethane is spiked into natural gas during a 1-hour test. The plot includes the results of a proprietary flow algorithm developed by the facility, which was used as a baseline. The Raman analyzer was readily able to follow the transient event of blending ethane into natural gas, with results closer to ‘flow based’ results than the MS. The MS system exhibited an uptime of only 67% during the experiment, whereas the Raman spectroscopy system demonstrated 100% uptime. Similar results were observed during other experiments.

Over an 8-week period of the evaluation, the Raman analyzer did not require recalibration, and it continued to provide fast and accurate results. At the end of the evaluation, feedback indicated that the Raman analyzer was found to be a reliable, accurate, and steady technique for gas turbine fuel feed composition analysis, during both steady-state and transient events. As a result, the Raman process analyzer was approved by the facility and its owner as a suitable GC replacement for turbine fuel feed measurements.

Figure 1: Raman and mass spectrometer analysis of hydrogen spiked into a natural gas stream

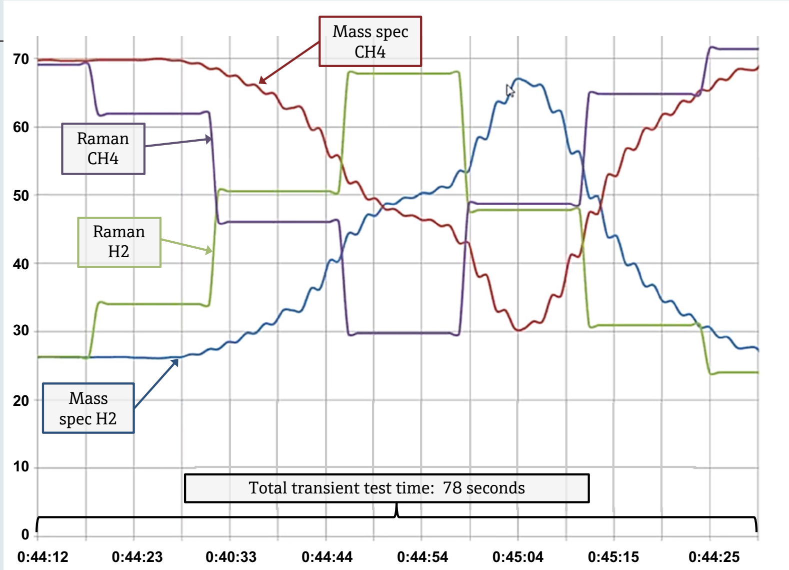
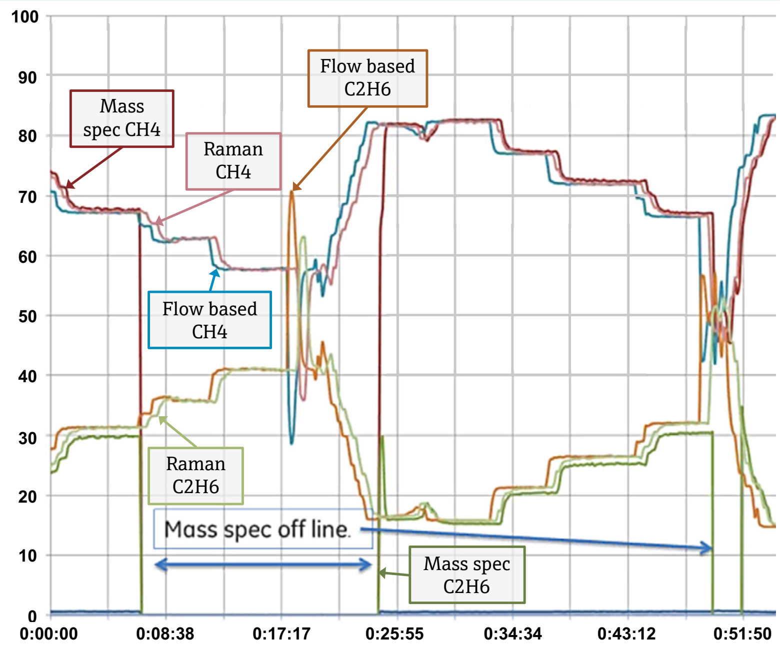


Figure 2: Raman and mass spectrometer analysis of ethane spiked into a natural gas stream



Conclusions

This study demonstrates that Raman analyzers are extremely effective measurement tools for gas turbine fuel feed analysis. Raman spectroscopy is future proof when it comes to upcoming fuels, such as hydrogen.[4] Raman spectroscopic systems offered by Endress+Hauser can be easily tailored to meet the measurement needs of specific fuel feeds. Typically, all that is required to measure a new fuel or blend is to update a software method or model and recalibrate the analyzer on an appropriate calibration gas blend for the new composition. The hardware does not need to be updated or replaced.

References

1. Patel, S., "The POWER interview: GE Unleashing a Hydrogen Gas Power Future", *POWER*, **2019**. https://www. powermag.com/the-power-interview-ge-unleashing-a-hydrogen-gas-power-future/.
2. Goldmeer, J., et al, "Enabling ethane as a primary gas turbine fuel: an economic benefit from the growth of shale gas" *GE GEA32198*, **November 2015.**
3. Goldmeer, J., et al. "Gas Power Systems Fuel Capacity," *The Future of Gas Turbine Technology 8th International Gas Turbine Conference, Brussels, Belgium*. **2016**.
4. Valera-Medina, A., et al, "Ammonia, Methane, and Hydrogen for Gas Turbines", *Energy Procedia*, **75 (2015)** 118-123.

Standard application method

Endress+Hauser has developed a standard method for turbine feed fuel measurement based upon the criteria listed below.

Application data

Target component	Hydrogen 0 to 50% (suitable for smaller concentrations)
Natural gas composition	Pipeline quality natural gas based on table below
Process pressure range	13.8 to 48 bara (200 to 700 psia)
Process temperature range	-20 to 150 °C (-4 to 302 °F)
Measurement response time	Minimum 20 seconds

Natural gas composition prior to hydrogen blending*

Component	Expected range (Mol%)	Measured analyte	Repeatability (Mol%)	LOD (Mol%)
Methane (C_1)	85 to 100%	Yes	0.32%	0.96%
Ethane (C_2)	0 to 7%	Yes	0.13%	0.40%
Propane (C_3)	0 to 2%	Yes	0.08%	0.23%
N-Butane (C_4)	0 to 1% (Sum of N+Iso)	Yes	0.28%	0.85%
Iso-Butane (C_4)	0 to 1% (Sum of N+Iso)	Yes	0.04%	0.12%
N-Pentane (C_5)	0 to 0.2% (Sum of N+Iso+Neo)	Yes	0.12%	0.35%
Iso-Pentane (C_5)	0 to 0.2% (Sum of N+Iso+Neo)	Yes	0.17%	0.51%
Neo-Pentane (C_5)	0 to 0.2% (Sum of N+Iso+Neo)	Yes	0.05%	0.14%
Hexane and other C_6+	0 to 0.2%	No	-	-
Carbon dioxide (CO_2)	0 to 10%	Yes	0.06%	0.19%
Nitrogen and other inerts	0 to 10%	N_2 only	0.15%	0.44%

Hydrogen addition to natural gas*

Component	Expected range (Mol%)	Measured analyte	Repeatability (Mol%)
Hydrogen (H_2)	0 to 50%	Yes	0.06%

*Stream composition must fit within these ranges to use Endress+Hauser's standard method. Applications with different stream composition, temperatures and pressures may use Endress+Hauser's standard method but they must be reviewed by the Endress+Hauser Applications team.

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