Improving Combustion Turbine Performance with Process Gas Chromatographs

The Natural Gas Turbine Power Plant and Cogeneration Power Plants

The idea of a NO_x zero-emission power plant is much more realistic today then it was even a decade ago. Using innovative new technologies and applying enhanced measurement methods to the power industry, Emerson Process Management is helping power generation companies to reduce emissions and operate their combustion turbines more efficiently.

Emerson offers low-cost, reliable analytical packages for gas turbines and other natural gas combustion processes. Our gas chromatographs provide a reliable, online measurement of natural gas heating value (BTU or CV) for more efficient control of turbine combustion. Unlike other analytical devices, like a calorimeter, the GC does not require additional “clean” air and is capable of providing individual component concentrations and not just calculated indexes.

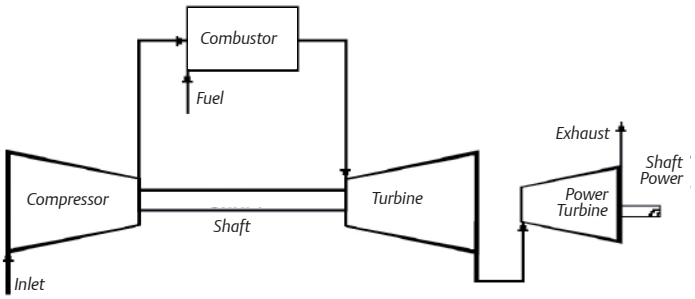
The quality and composition of fuel burned in a gas turbine have a tremendous impact on the life span and maintenance requirements of the turbine. With a gas chromatograph from Emerson, natural-gas-fired turbines can utilize three key gas measurements:

- Gas composition converted to BTU or CV
- Wobbe Index
- Hydrocarbon Dew Point

Measuring Composition

Accurate determination of fuel gas composition allows for optimal adjustments of the air-to-fuel ratio, enabling the combustion turbine to operate at its most cost-effective, efficient point while reducing NOx emissions In the power industry, where emissions are closely regulated, operating cleaner and more efficiently also means a tremendous savings by avoiding potential costly fines.

Figure 1 - Flow Diagram of a Typical Combustion Turbine



Stoichiometric combustion is the ideal combustion condition where fuel is burned completely. Complete combustion is a process burning all the carbon (C) to (CO_2), all the hydrogen (H) to (H_2O) and all the sulfur (S) to (SO_2). Almost all modern turbines require stoichiometric combustion. Any unburned components remaining in the exhaust gas, such as C, H_2, and CO, means the combustion process is incomplete and not stoichiometric.

Not only does the GC provide the individual component concentrations, a process gas chromatograph also provides fuel gas heating values, allowing optimal adjustment of the air-to-fuel ratio. When the chemical mixing proportion is correct (stoichiometric), all fuel and air will be consumed during the combustion process, burning cleanly and enabling the turbine to operate at its most efficient, costeffective point.

In addition, an efficiently operating turbine will help to reduce NO_x emissions. NO_x is a by-product of combustion – the hotter the flame temperature used in the combustion process, the more NO_x the process produces. Reducing NO_x emissions in a power plant can be costly, and is often achieved through the purchase of expensive equipment like low NO_x burners, flue gas recirculation systems, and selective catalytic reduction systems. However, the perfect air-to-fuel combination significantly reduces NO_x emissions, helping to bring power plants into compliance with regulations.

The stoichiometric combustion process can be expressed as:

$[C + H\ (fuel)] + [O_2 + N_2\ (Air)] \longrightarrow (Combustion\ Process) \longrightarrow [CO_2 + H_2O + N_2\ (Heat)]$

where
C = Carbon
H = Hydrogen
O = Oxygen
N = Nitrogen

Measuring Wobbe Index

Turbine damage can be the result from varying flame dynamics caused by variations in the Wobbe index. Most modern turbines can withstand variations of +/- 5 %. The Wobbe Index is calculated from the lower heating value (LHV) in Btu/scf [kJ/Nm3] and the specific gravity (SG).

$$W1 = \frac{LHV}{\sqrt{SG}}$$

The Wobbe Index is an indication of energy flow in the system at equivalent gas pressures and pressure drops. If two unique fuel gas compositions have the same Wobbe Index, the pressure drop in a given fuel system will be identical for both gases.

Different gas compositions can yield the same Wobbe Index, but they may have widely varying hydrocarbon dew points. Minimum engine flameout fuel flows will also vary if the fuel contains high percentages of noncombustible gases. High fuel gas or ambient temperatures can cause problems if the temperature capabilities of elastomeric seals, electrical devices or other system components are exceeded. Low fuel gas or ambient temperatures can cause water and/or heavy hydrocarbon condensation.

Protection against these factors includes analyzing the variations in the fuel composition, fuel temperature, and ambient temperature so that fine tuning the fuel treatment system and turbine fuel system can be accomplished. A turbine expected to operate with gaseous fuels exhibiting a wide Wobbe Index range will need to be configured differently than one that will only operate with a small variance in Wobbe Index.

An Emerson gas chromatograph provides the safe, reliable data that is required to ensure no damage to expensive rotating equipment results from operating on low- or midrange Wobbe gas.

Measuring Hydrocarbon Dew Point

When heavier hydrocarbons or hydrocarbon liquids are present, movement of flame upstream in the combustion zone could occur, resulting in catastrophic damage to the turbine. A gas analysis alone may not be entirely sufficient for the detection of heavy hydrocarbons, because it may only include the gases, but not the liquids in the stream. Also, it is common practice to lump all hydrocarbons from hexane and heavier into one number. While this is perfectly acceptable for the calculation of the lower heating value as long as the hexane and heavier hydrocarbons constitute a minute fraction of the gas, it will lead to a wrong estimate of the dew point. This is important, because measuring hydrocarbon dew point helps power plants with combustion turbines avoid turbine damage due to flashback.

An Emerson gas chromatograph can provide an accurate hydrocarbon dew point calculation, which indicates when risk increases, and attention is required.

The Emerson Value Proposition

Emerson has a long history of providing process gas chromatographs for the process and natural gas industries Emerson's process gas chromatographs set the standard for online process measurement by supplying analyzers that are both robust and capable of handling tough analytical requirements. Our process gas chromatographs provide precise measurements and analyses, which directly translate to value for our customers. Emerson gas chromatographs can impact your bottom line in a number of ways:

- Installing an Emerson process gas chromatograph provides reliable measurements to help optimize the air to fuel ratio within the combustion process, which allows the turbine to operate at its most efficient point. This, in turn, reduces NO_x emissions, helping power generators comply with environmental regulations
- By providing precise, reliable data, Emerson's process gas chromatographs can eliminate potential turbine damage due to high flame dynamics and variations in the Wobbe Index

- Emerson's process gas chromatographs give early warning of potential catastrophic turbine damage due to high flame dynamics and variations in the Wobbe Index
- Emerson's process gas chromatograph give early warning of potential catastrophic turbine damage due to flashback by providing a reliable hydrocarbon dew point calculation, which indicates when risk increases
- Emerson's process gas chromatograph offer superior analytical capability and felxibility, which translates into better performance than comparable competitive products. Emerson's gas chromatograph include rapid one-minute or two-minute gas composition and Wobbe Index analysis, with pinpoint accuracy that far out-performs calorimeters or Wobbe meters
- With Emerson's process gas chromatograph, extended analysis to C_9^+ and hydrocarbon dew point calculations can be completed in five minutes, without an additional analyzer
- Inherent analytical flexibility of the Emerson process gas chromatograph means that the presence of non-natural gas fluids within the sample stream will not impact the validity of the measurement

Specific Needs

For composition and Wobbe measurement, Emerson's process gas chromatographs are the solutions of choice. They offer two-minute and four-minute cycle times for C_1 through C_6^+ composition and physical property calculations. Energy efficient and designed for field mounting without the need for expensive analyzer shelters or expensive instrument/ bottled air, the Emerson process gas chromatographs are fully compatible with modern Ethernet and Modbus networks and DCS communication.

For turbine applications, Emerson recommends dual-detector process gas chromatographs with HCDP calculations. Dual-detector gas chromatographs are also equipped with the hardware required to measure H2S content, if requested.

Emerson GCs come with easy-to-use and highly regarded gas chromatograph software. This remote access software offers complete control of your process gas chromatographs — either locally or remotely. From within this software, a user can:

- Review and modify analytical settings
- Upload and display multiple chromatograms on the screen for comparison
- Upload and trend any of the measured results
- Export data for use in other third-party applications
- Overlay multiple chromatograms for troubleshooting and calibration
- Check original calibration against last calibration

For process gas chromatographs, Modbus continues to be the preferred choice to connect a process gas chromatograph network to the plant control system. Modbus design avoids the use of central interface cards or computers that can act as a single-point of failure in the Modbus link. Instead, the plant DCS system can communicate directly to each process gas chromatograph to gather the data needed. Furthermore, the register and coil addresses can be easy customized to meet the specific data structure of the DCS. There is also a program built into the workstation software to test the Modbus link to the DCS if troubleshooting is needed.

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