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APPLICATION NOTE

ON-SITE TRACE METAL ANALYSIS FOR GAS TURBINES: SPECTROIL MF L/D ON-SITE FUEL ANALYSIS SPECTROMETER

Dan Walsh Director of Product Management | Spectro Scientific

Synopsis

Trace contaminants of alkali metals in liquid fuels can cause corrosion of valuable turbine blades leading to premature breakdown and failure. Spectroil analyzers enable fuel analysis and treatment programs to determine the source of corrosion as early as possible, eliminating the possibility of engine failure and downtime.

Introduction

Gas turbines powered by liquid fuel continue to be a popular solution for power generation. They are particularly attractive in developing nations with plentiful oil reserves. Though most gas turbines are fired with natural gas, almost 13% of the worldwide installed base is powered by fuel oil distillates and crude oil. Trace contaminants of alkali metals in liquid fuels can cause corrosion of valuable turbine blades leading to premature replacement or failure. The Spectroil line of analyzers enables fuel analysis and treatment programs to prevent corrosion and premature failure of valuable turbine components. This applications note explains the problems inherent with liquid fuels and why the Spectroil is the system of choice for turbine manufacturers like General Electric.

Gas turbines for Power Generation

The combustion (gas) turbines being installed in many of today's natural-gas-fueled power plants and ships are complex machines, but they basically involve three main sections:

- **The compressor** draws air into the engine, pressurizes it, and feeds it to the combustion chamber at speeds of hundreds of miles per hour.
- **The combustion system** is typically made up of a ring of fuel injectors that injects a steady stream of fuel into combustion chambers where the fuel mixes with the air. The mixture is burned at temperatures in excess of 2000 degrees F. The combustion produces a high temperature, high pressure gas stream that enters and expands through the turbine section.

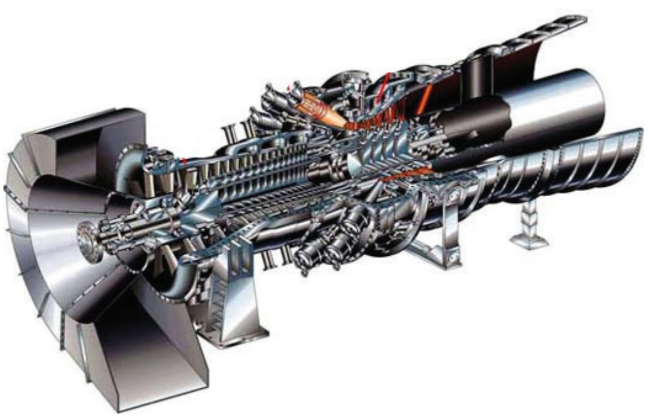

Figure 1: GasTurbine major components

- **The turbine** is an intricate array of alternate stationary and rotating aerofoil blades. As hot combustion gas expands through the turbine, it spins the rotating blades. The rotating blades perform a dual function – they drive the compressor to draw more pressurized air into the combustion section, and they spin a generator to produce electricity.

Land-based gas turbines are of two types: (1) heavy frame engines and (2) aeroderivative engines. Heavy frame engines are characterized by lower pressure ratios (typically below 20) and tend to be physically large. Pressure ratio is the ratio of the compressor discharge pressure and the inlet air pressure. Aeroderivative engines are derived from jet engines, as the name implies, and operate at very high compression ratios (typically in excess of 30). Aeroderivative engines tend to be very compact and are useful where smaller power outputs are needed. They are quite compact and ideal for shipboard power plants, as well as trailer-mounted or skid-based power plants.

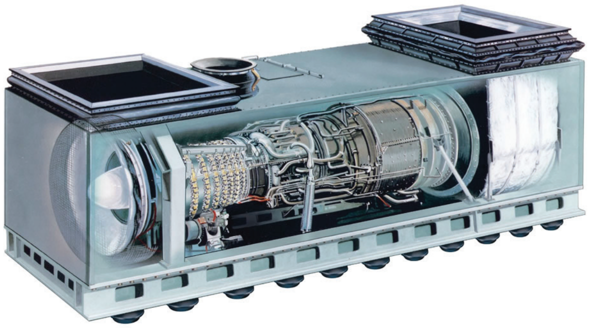

Figure 2: LM 2500 package for marine applications

Challenges of using liquid fuel

Liquid fuel can contain trace elements that can have a detrimental effect on turbine performance. General contamination in liquid fuel is a main reason why maintenance overhauls are almost twice as frequent for liquid fuel turbines as opposed to those powered by natural gas (Figure 3). This contamination can induce corrosion of turbine blades leading to efficiency loss, or in severe cases, blade fracture, unplanned downtime and increased warranty costs.

Blade corrosion occurs when the trace metal impurities in liquid fuel cause the formation of low melting point ash deposits. During combustion, these fuel contaminants create ash deposits, such as vanadium pentoxide [V2O5] which has a melting point of 690°C (1274°F). At typical gas turbine operating temperatures, the ash deposits are molten, and thereby accelerate the surface oxidation rate of blades and vanes. Other trace metal impurities, including lead and zinc, also cause high temperature corrosion by similar mechanisms.

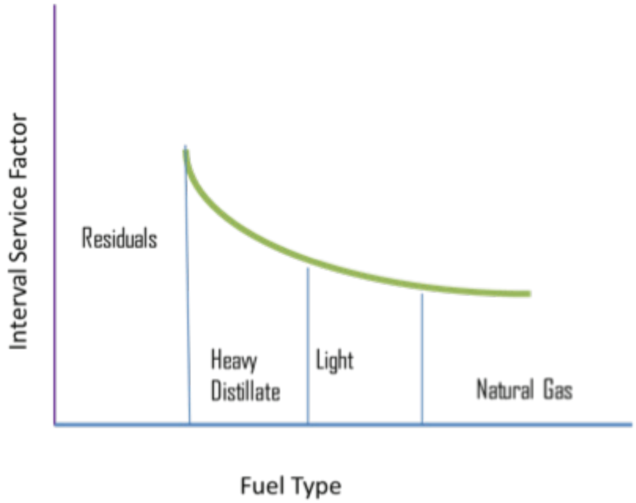

Figure 3: Interval Service Factor as a function of fuel type. Dirty fuels mean more frequent overhauls

Fuels may also contain naturally occurring sodium and potassium salts and refinery and transport sources . Distillate-grade fuels are often contaminated with sodium due to marine transportation. The presence of these alkali metal impurities [Na and K] leads to another type of high temperature corrosion known as sulfidation attack. This mechanism involves the formation of sodium sulfates through reaction with sulfur in the fuel, and results in serious inter-granular pitting of hot section components. In situations where both vanadium and sodium impurities are present, even lower melting point ash deposits can form, further increasing the risk of corrosion.

Figure 4: Severe sulfidation corrosion on turbine blades leads to lost efficiency and blade failure.

Removing Contaminants from Fuel

Sodium and potassium salts are water soluble and can be removed or reduced to acceptable specification limits by on-site treatment processes known as "fuel washing." Fresh water is first mixed with the fuel to dilute and extract the water-soluble impurities. The water is then separated from the fuel using either centrifugal or electrostatic equipment. This type of treatment is normally applied to highly contaminated fuels such as crude oils and residual oils. Distillate-grade fuels are usually not washed at the gas turbine power plant, but are often delivered to the site containing some amount of sodium contamination. Vanadium and other oil-soluble trace metals cannot be removed by fuel washing. Corrosion inhibition must be achieved using magnesium, chromium and/or silicon based additives.

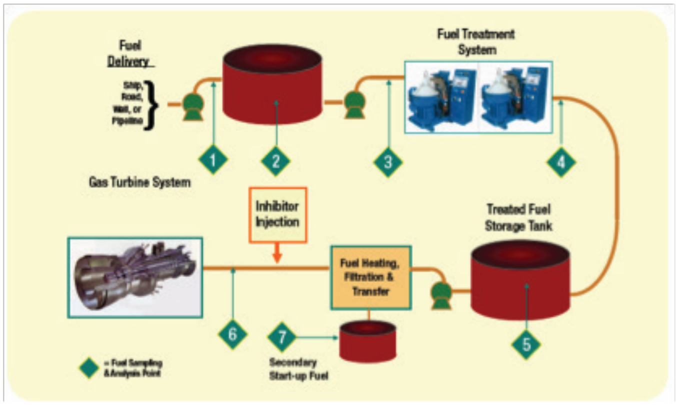

Figure 5: A typical fuel delivery workflow showing where fuel washing equipment is situated, along with common sampling points to ensure contamination control.

Additives containing magnesium [Mg] are used primarily to control vanadic oxidation by modifying ash composition and increasing ash melting point. The proper Mg/V treatment ratio, causes magnesium orthovanadate [3MgO.V2O5] to form instead of Vandium Oxide. Magnesium orthovanadate has a much higher melting point of 1243°C (2269°F). Corrosion is controlled by ensuring that the combustion ash remains in a solid state on gas turbine blades and vanes. The magnesium additive also reacts with sulfur in the fuel, generating magnesium sulfate [MgSO4] as an additional ash component. This compound is water-soluble and can be removed with periodic washing of the hot gas path with water, thereby recovering lost power.

Contamination Limits and Specifications

Turbine manufacturers want to minimize fuel-induced corrosion. Almost all turbine makers have detailed fuel specifications requiring low contamination limits for alkali metals.

PROPERTY	LIMIT	TEST METHOD
Ash, %, maximum	0.01	ASTM D482 (IP 4) or ISO 6245
Sulfur, %, maximum	1.0	ASTM D129, (IP 336) D4294 (IP 61), D1552, D2622, D1266, D7039, D5453, or ISO 8754
Vanadium, ppm, maximum	0.2	ASTM D3605, D7111, D6728, or ISO 6891 (V only)
Sodium, Potassium and Lithium, ppm, maximum	0.2	ASTM D3605, D7111, D6728
Lead, ppm, maximum	1.0	ASTM D3605, D7111, D6728
Calcium, ppm, maximum	2.0	ASTM D3605, D7111, D6728
Phosporus, ppm, maximum	2.0	ASTM D4951
Hydrogen content, %, maximum	12.7	ASTM D1018, D3701 (IP 338), or D5291
Demuisification, minutes, maximum	20.0	D1401 and Note 3 therein, or D2711 (if viscosity > 90 cSt)
Particulates, mg/gal, maximum	10.0	ASTM D2276 (IP 216), D5452, or D6217
Water and Sediment, volume %, maximum	0.10	ASTM D2709, D1796, D6304, or ISO 3734
Flash Point, ˚F, maximum	200˚F (93.3˚C)	ASTM D93 (IP 34), D56, D3194, D3828, D3941(IP 170), or ISO 2719
Copper corrosion, maximum	No. 1	ASTM D130 (IP 154), D1838, ISO 2160, or ISO 6251
Asphaltenes, %, maximum	None Detectable	ASTM D6560, or IP 143
Viscosity, cst	6 to 12	ASTM D445

Figure 6: Excerpt from GE Fuel Specifications for Aero Derivative Turbines

Methods for measuring alkali metals, such as atomic absorption spectroscopy and flame atomic absorption spectroscopy, have been used for single element analysis in laboratories for many years. These techniques do have low limits of detection necessary for this application, but they suffer from being time consuming, and unreliable, particularly when there is water present in the fuel. The preferred on-site method for power plants and shipboard applications is the ASTM D 6728 method, which measures contaminants such as Vanadium, Lead, Calcium, Phosphorus, Sodium, Lithium and Potassium.

	SPECTROIL RDE-AES ASTM D6728	GFAA ASTM D3605	ICP ASTM D7111
Instrument LOD necessary to meet specification	Yes	Yes	Yes
Simultaneous analysis of all elements	Yes	No	Yes
Operation stability in non-laboratory environment	Yes	No	No
Ability to analyze other fluids including oils, wash down water, glycols without preparation/dillution	Yes	No	No
Simple to operate with predefined fuel profiles built in	Yes	No	No
Continuously available for analyses (Certfiable results immediately)	Yes	Yes	No
Ability to easily analyze large particles	Yes	No	No

Figure 7: Comparison of Analytical techniques showing why ASTM D6728 is preferred

An Ideal Solution: Spectroil MFW L/D

The need for a quick, rugged on-site system to detect contaminant metals has been recognized for a long time. GE Power Systems' recommends that turbine owners invest in a spectrometer that is able to detect the elements of interest for both analysis and quality control.

The Spectroil MFW L/D (Low Detection) has a fuel calibration program specifically designed to meet the GE Power Systems recommendation. This calibration program includes a standard specifically developed to contain 3 ppm of the metals of interest. The alkali element list and typical Levels of Detection (LOD) are outlined in Figure 9..

Figure 8: Spectroil MF L/D is also ruggedized to meet shipboard environments and operate in power plant sites.

Spectro Scientific worked with GE and others over many years to develop the proof of concept and to ensure that the Spectroil MF instrument has the sensitivity required for this task. GE turbine Customers can ask for specification 386A7601 or 91-475534 which details requirements for the liquid alkali measurement system. A very helpful resource which details the comparison of methods for field labs is discussed in GE Whitepaper: "Measurement of Alkali Metals in Gas Turbine Fuels," 9/02. The low limits of detection for alkali metals, combined with ease of use and ruggedness, make this the instrument of choice for fuel contamination control.

ELEMENT	MFW/Q100 L/D PROGRAM	LOD (IEC) PPM
Sodium	0-100	0.002
Lithium	0-100	0.001
Potassium	0-100	0.03
NA+K+Li Combined LOD: 0.033ppm IEC: inter element correction		

Figure 9: Typical Spectroil M elements and LOD for Fuel analysis

Summary

The Spectroil MF L/D is designed to meet the needs of gas turbine fuel analysis for alkali metals. The special low detection calibration program and standards enable the analyzer to meet the fuel specification. In addition, the RDE method makes the analyzer east to use as well as fast and reliable.

Spectro Scientific has delivered several units to power plants and marine customers globally with the low detection program. The L/D package is available on both the Q100 and the Spectroil series of spectrometers. For more details, please visit our website at www.spectrosci.com.

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Spectro Scientific | One Executive Drive, Suite 101, Chelmsford, MA 01824-2563 | 978-431-1120
sales@spectrosci.com | sales@spectroinc.com An ISO 9001:2008 company