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APPLICATION NOTE

THE SPECTROIL GETS A NEW HEART AND BRAIN

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Synopsis

An effective spectrometric oil analysis program is dependent upon interpretation of the analytical data on wear metals, contaminants and additives as measured by a spectrometer. The Spectroil RDE spectrometer is the world's most recognized system for wear debris analysis of lubricating oils. The Spectroil has been an important part of the US Department of Defense Joint Oil Analysis Program (JOAP) for many years and remains the only approved instrument for that program. Recent enhancements in software and hardware have improved the Spectroil product line, further extending its leadership position as the go-to tool for in-service oil analysis. This paper summarizes the new advances in the Spectroil product line.

Introduction

Wear debris analysis is an important part of any oil analysis program. The Spectroil RDE spectrometer measures trace quantities of elements dissolved or suspended as fine particles in lubricants using the time-tested technology of rotating disc electrode (RDE) atomic emission spectroscopy. The Spectroil RDE spectrometer comes in two configurations. The Spectroil M is a compact, rugged, and transportable system primarily for military applications as specified by the DoD JOAP program (Figure 1). The Spectroil Q100 is a benchtop instrument with a small footprint and is used in commercial applications (Figure 2). Both Spectroil models are easy to use and provide quick, reliable analysis of wear metals, contaminants, and additives in lubricants. The standard commercial calibration program fulfills the requirements of ASTM D6595 Standard Method for Determination of Wear Metals and Contaminants in Used Lubricating Oils or Hydraulic Fluids by Rotating Disc Electrode Atomic Emission Spectrometry and is the default option for commercial customers.1 Other available calibration methods include fuel analysis via ASTM D6728, coolant analysis, and washdown water analysis.[2]



Figure 1. Spectroil M



Figure 2. Spectroil Q100

The Spectroil series has always been a leading tool for lubricant condition monitoring. Recent innovations in the optics and software algorithms have enabled improvements in the performance and reliability of the instrument. The rest of this application note summarizes the new heart (optics) and the new brain (improved software) of the instrument. The optics manufacturing has been brought in-house for total control over the capabilities of the instrument, and the signal processing has been overhauled for improved analytical performance in varied conditions.

Redesigned Optics

The optics of any optical emission spectrometer are the heart of the system and greatly influence the limits of detection, reproducibility, and repeatability. Spectro Scientific, an ISO 9001:2008 company, now manufactures all the Spectroil optics in-house for total control of the product and its capabilities. This improves product quality and core performance of the instrument.

Typical performance of the new Spectroil optics calibrated with the commercial CS-24 program is shown in Tables 1 and 2. The repeatability at 10 ppm far exceeds the specification of ASTM D6595, with most elements demonstrating 2X-6X better repeatability than the reported ASTM D6595 value (Table 1). For example, the repeatability specification for iron at 10 ppm in ASTM D6595 is 1.7 ppm, while a typical repeatability achieved on the Spectroil is 0.4 ppm. This improvement in repeatability is due to the design of the optics, the consistent manufacturing of the optics, and the software used to interpret the results.

An additional benefit of the improved manufacturing, design, and software is seen in the limits of detection (LODs) (10 burns of 0 ppm, 3σ)test results for the commercial program with the new optics and software algorithm (Table 2). Other calibration programs will have different LODs due to the difference in the matrix tested. For example, LODs for the Fuel-Light program with the LD option are typically much lower than the commercial program (Table 3) and meet the GE Specification for Liquid Fuel Requirements for GE Aero Derivative Gas Turbines.

ELEMENT	REPEATABILITY AT 10 PPM (PPM)
Ni	0.3
Cr	
Cu	
V	
Ti	
K	0.4
Fe	
Mo	
Mn	
Al	
Ca	
Na	
Mg	
Si	0.5
Zn	
B	0.6
Pb	

Table 1. Repeatability (typical) of 10 ppm listed by element.

ELEMENT	LOD (PPM)
K	0.03
Ag	0.04
Cu	0.05
Ba	0.06
Ca	0.07
Mg	0.10
Ti	0.12
Cr	0.14
Mn	0.15
B	0.22
Zn	0.25
Fe	0.40
Al	0.46
V	0.50
Ni	0.54
Si	0.57
Mo	0.78
Pb	1.64
Sn	2.01
P	4.28

Table 2. Typical LODs (ppm, 3σ) listed by element for the commercial program.

ELEMENT	LOD (PPM)
V	<0.2
Na+K+Li	<0.2
Pb	<1.0
Ca	<2.0
P	<2.0

Table 3. Selected LODs for Fuel-Light program with the LD option.

Redesigned Data Processing

The Spectroil has been made "smarter" with a new peak search algorithm. The results obtained from an instrument are only as good as its data processing capability. The Spectroil is commonly operated in non-ideal laboratory environments where fluctuations in temperature are not uncommon. Variations such as temperature, humidity, and altitude can introduce minor shifts in the location of the analytical peaks of each element on the CCD array. This results in a "drift" of the standardization of the instrument as the peaks shift away from their expected location (Figure 3). In tightly-controlled laboratory settings, doing a profile and standardization check once a day prior to analysis will produce reliable results all day long. However, in the case of the transportable Spectroil M, a variable operating environment historically caused instability in the measured results due to peak drift, forcing some customers to run multiple profiles per day.

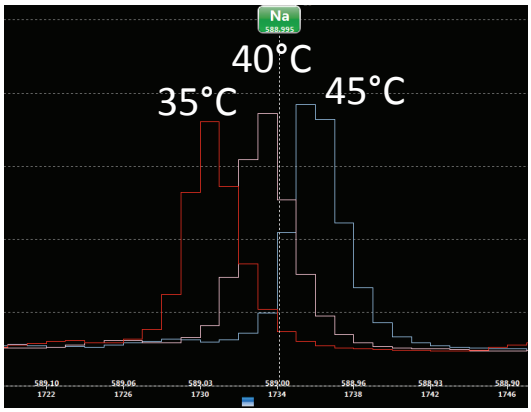


Figure 3. Raw Spectroil data for Na line 588.995 at several operating temperatures.

Compensating for instrument drift is an important step to achieving accurate results. The analytical line is the point in the spectrum where the intensity of the line is measured and is related to the concentration of a given element. An instrument profile adjusts the position of the analytical line, but during a routine measurement the analytical line is static. If a user neglects to perform an instrument profile after the environmental conditions have changed, the accuracy of the results can be affected drastically. To eliminate this problem, a peak searching algorithm was implemented which allows the software to automatically locate the peak position during a measurement, even if it has shifted slightly due to environmental changes.

To demonstrate the power of the new peak searching capability of the Spectroil, a sample was analyzed on the Spectroil under different operating conditions without performing an instrument profile (Figure 4). In Case A, a change in operating temperature (Condition 1 to Condition 2, difference of 4°C) caused the peak to shift about 2 pixels. The resulting intensity reported for this analytical line (without a new profile measurement) changed from 510,000 counts to 160,000 counts with the change in temperature. If the user didn't realize the operating conditions changed and didn't perform an instrument profile to correct for this change, the resulting error could be up to 70%. In Case B, the peak searching algorithm has been implemented and the Spectroil is smart enough to search for the correct peak position before reporting the result. The analytical line aligns with the new position of the peak, as if a new profile measurement had been performed to compensate for the temperature change, and the accuracy of the measurement is retained.

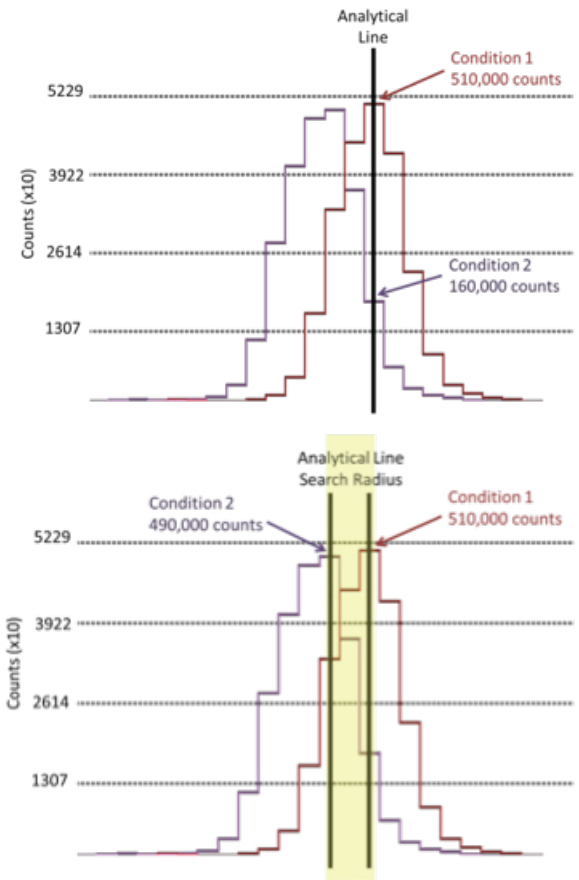
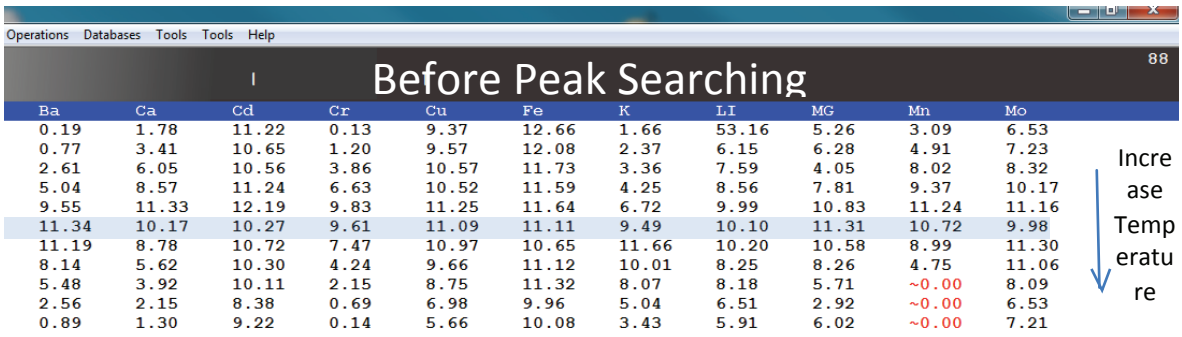
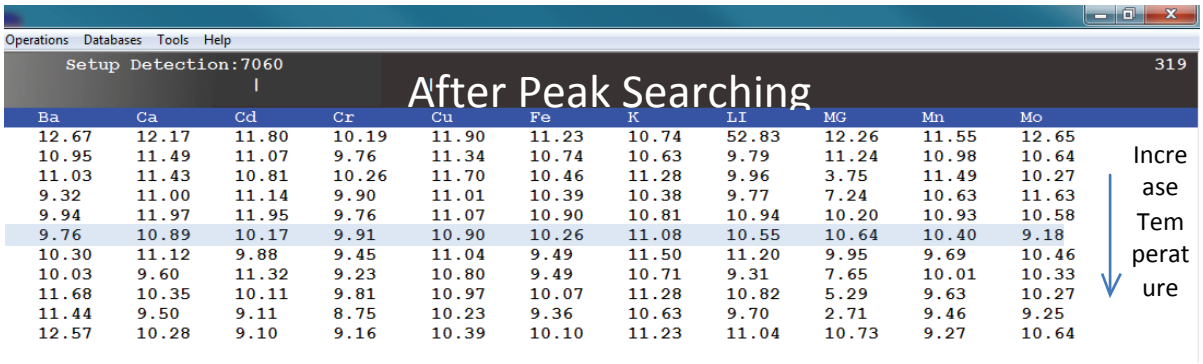


Figure 4. Demonstration of how peak searching compensates for instrument drift. A) Without the peak search algorithm enabled, the analytical line is static and the reported sample concentration may vary up to 70% (intensity = 510,000 counts vs. 160,000 counts) with temperature. B) With the peak search algorithm, the detected signal intensity is much more stable regardless of the operating condition of the instrument.

The benefit of the new peak searching algorithm is clearly seen in Figure 5. Measurement of a 10 ppm CS-24 standard was performed at different optic temperatures, from 35°C to 45°C, with burns performed every 1°C. Without the peak searching capability, a difference of even a couple of degrees severely impaired the accuracy of the result for the 10 ppm standard. With the new peak searching algorithm enabled, the results throughout the entire temperature range are significantly more stable. Temperature is the most common variable in the operating environment and was used to examine the peak drift due to operating conditions but a similar effect could be seen with other changes in the ambient conditions such as humidity or altitude. It is clear that the peak searching capability is a powerful tool to help the user obtain the most reliable results.





Conclusion

The Spectroil M and Q100 have been improved due to changes in the manufacturing and data processing methods. Bringing the manufacturing of the heart of the system, the optics, in house allows Spectro Scientific to improve the quality and flexibility of the platform for future innovations and developments in RDE technology. The new peak searching capability in the signal processing has made the instrument smarter and more adaptable to changing operating conditions without any action required from the user.

References

1 ASTM D6595 Standard Method for Determination of Wear Metals and Contaminants in Used Lubricating Oils or Hydraulic Fluids by Rotating Disc Electrode Atomic Emission Spectrometry.

2. ASTM D6728 Standard Test Method for Determination of Contaminants in Gas Turbine and Diesel Engine Fuel by Rotating Disc Electrode Atomic Emission Spectrometry.

3. Liquid Fuel Requirements for GE Aero Derivative Gas Turbines. GE Aviation GE Energy, MID-TD-0000-2, February 2010, Pages 1-7

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