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The Application of the B&W Tek i-Spec Visible-NIR Spectrometer to Condition Monitoring of Oils and Lubricants: Example Hydraulic Fluids

John Coates, Coates Consulting LLC, Newtown CT 06470, USA

Summary

Optical spectral measurements have been used for decades for the identification, characterization and quality assessment of oils and lubricants. The most common spectroscopic method, which has been well documented since the 1960s, is infrared spectroscopy, today used in the form of FTIR. In this application note, the role of a new hybrid instrument, covering the range 350nm to 2300nm (visible to the near-infrared) is considered as a complementary tool to FTIR for condition monitoring of fluids outside of the traditional laboratory environment.

This new fiber-optic based system, the ***B&W Tek i-Spec 22***, is packaged as a field deployable test instrument, where lubricant fluids can be monitored in service without removal from the lubrication system. In this application note, examples of fluid condition monitoring are discussed for hydraulic oils, where aging and contamination are measured in situ in less than a minute, and without the requirement of sample collection or the need to return to the laboratory for testing.

Introduction

The term "hydraulics" is all-encompassing and covers a very broad range of applications, including construction and mining equipment, industrial and metal forming, transportation and many more. Each application tends to have its own unique set of parameters and operating conditions. As a result, different hydraulic fluids for different applications typically have very different chemical/physical characteristics that meet the needs of the operating equipment/machinery. Also, regulatory issues can drive the fluid properties; a good example is the class of hydraulic oil environmental ester synthetic (HEES) fluids that are biodegradable, where their use can reduce the incidence of ground/soil contamination.

The chemistry of the lubricant plays an important role in the composition and breakdown regime of an operational hydraulic system and its fluid. Typically the spectral responses of a fluid are in part driven by the fluid chemistry and in part driven by the nature of potential contaminants. The quality and condition of the fluid is critical in terms of maintaining the integrity of the hydraulics system and degradation of the fluid. Aging and/or contamination is an important operational issue, especially if the fluid has to be replaced.

a. ***Traditional mineral oil fluids*** – These mineral oil based fluids (including the HH, HL, HM, HV and HG designated fluids) are the most important and most widely used hydraulic oils. One of the most important properties is viscosity, and the fluids are typically differentiated by a number that represents the viscosity (expressed in cSt at 40°C).

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b. ***Biodegradable ester-based fluids*** – For use in high volumes of hydraulic oils applied to construction equipment where there is a potential for high environmental impact linked to seal failure and leakage; both synthetic polyol esters and vegetable oil based esters are commonly used.

c. ***Automatic transmission fluids (ATF)*** – Although traditionally used in a drive train as a transmission lubricant, an ATF may also be classified as and used as a hydraulic fluid. In the context of this application note, the ATF examples presented (Figure 2C) conform to Dexron II specifications and are distinguished by a characteristic red dye.

d. ***Other fluid types*** – Most hydraulic fluids used for vehicles, construction equipment and heavy industrial applications fall into one of the three types described above. There are other specialist fluids, such as the fire resistant fluids used for certain industrial and aviation applications. These are often required to be non-combustible and an example of such a fluid type involves a blend of water with glycols or polyglycols.

Experimental

While NIR is not a traditional spectral region for the laboratory analysis of lube oils and associated fluids, it is strategically important as a field testing tool. It includes some of the spectral information contained in the mid infrared region, but unlike the mid-infrared (FTIR), the NIR is not typically used for material characterization or identification.

However, the backbone structure of the oil/fluid is represented, as well as indications of certain types of chemical functionality. A good example here is water, which has a characteristic spectrum and can be differentiated from the main hydrocarbon backbone of the main fluid. Taking this into account in a practical system, most fluids probably do not contain water and the presence of water is usually detrimental to operation, leading to corrosion, as well as indicating a potential oil leak.

Water has a strong signature and while its presence may be partially masked by the spectrum of the main fluid, it may be detected and even quantitatively assessed by a differential measurement. In such a differential measurement, the spectral signature is monitored for subtle changes with use and these can be correlated to the presence of contaminants, such as water, or degradation products.

In order to assess such changes over the entire measurement region, an extended range spectral measurement, provided by the i-Spec 22 (350nm to 2300nm), is required (Figure 1). The system shown was adapted for the fluid measurements by the use of a commercial dip-style immersion probe (Figure 2A/B), supplied by Spectral Products (Putnam, CT). A transflective tip with a 10mm optical path (5mm physical) was used for all measurements.

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Figure 1: B&W Tek i-Spec 22 Portable Spectrometer

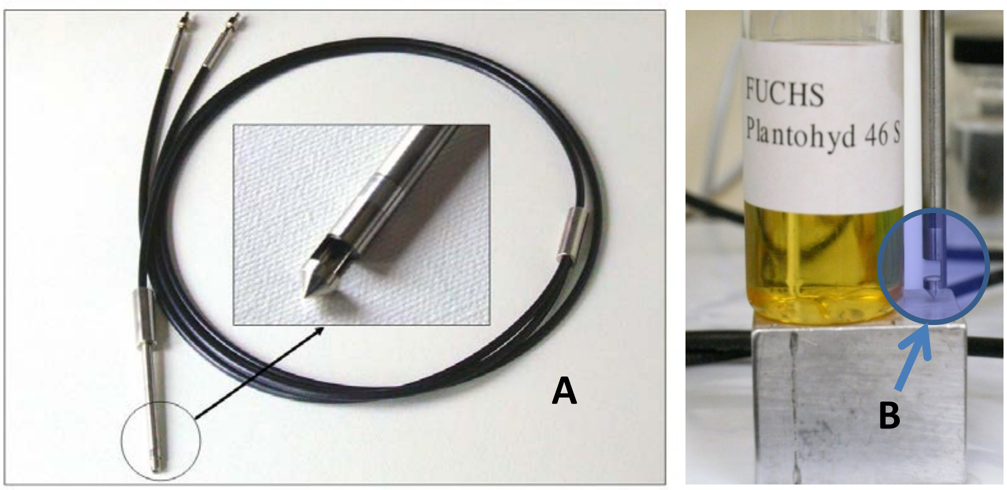

Figure 2: Dip-style Liquid Sampling Probe (A/B)

4. Results

As previously noted, traditional lube oil testing makes use of mid-infrared (FTIR) for basic sample characterization and simple visible spectral assessment of color and clarity. Also, some fluids have a characteristic color associated with their application (such as ATFs). Both color and sample clarity provide a useful means of differentiation and in the case of a used fluid, a change in color can be linked

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to stressing (thermal or oxidative) of the fluid or the presence of a different or incorrect fluid. Clarity, notable haze and opacity, or a loss of clarity is indicative of the presence of particulate matter or dispersed water. Both of these are important indicators for hydraulic fluid condition; an illustrative series of samples is shown below (Figure 3).

Figure 3: An illustrative series of samples showing aging, oxidation and dispersed water

From left to right, the shades range from a pale straw color for the unused fluid to virtually black and opaque in the last sample. The spectral signatures obtained from these samples are consistent with the appearance of this set and the results can be readily interpreted in terms of color linked to oxidation/aging and sample clarity, as well as dispersed water (very hazy) and dispersed insoluble materials (dark/opaque).

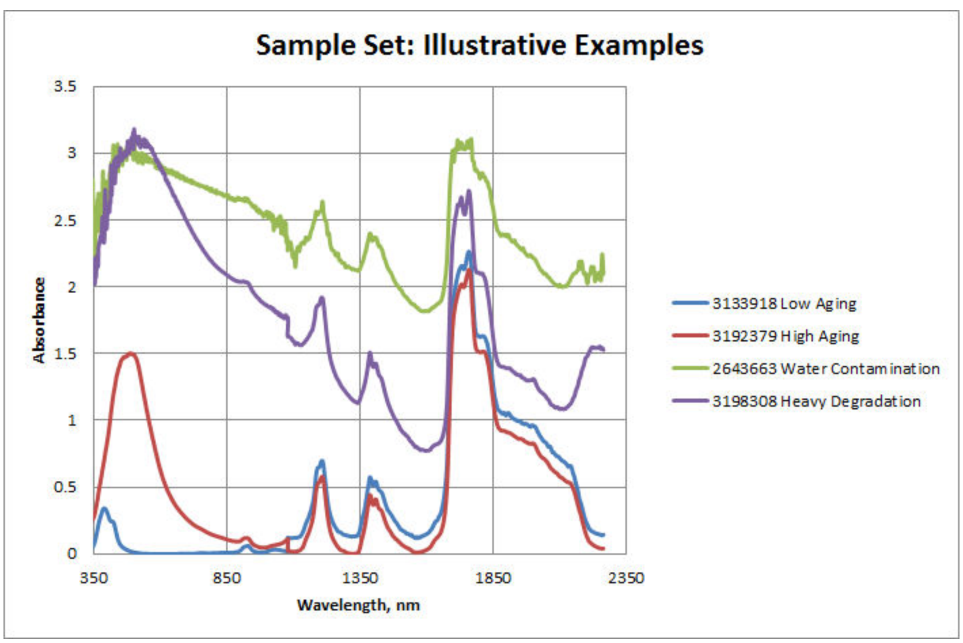

Figure 4: Spectral signatures from illustrative set of samples

Additional sets of spectral data linked to color (aging) and clarity are provided in Figures 5 to 8:

Figure 5: Spectral data that illustrates the aging process, where there is a progressive increase in absorption between 350nm and 550nm, notably for the peak between 400nm and 450nm.

Figure 6: Similar to the series in Figure 5, but higher levels of fluid degradation is noted by the peaks at an absorbance of 1.3 and above.

Figure 7: Samples with low to medium levels (in the 100ppm to 1000ppm) of water contamination.

Figure 8: Water contamination at levels from 1000ppm to % levels where some free water may be seen visibly in the sample; note increasing background in the spectral data, finishing up as near total absorption with values 2.5 and above.

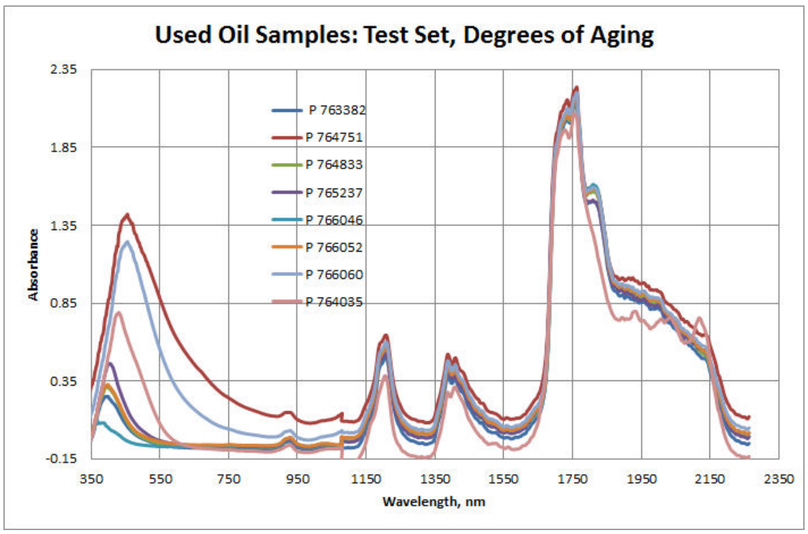

Figure 5: Used hydraulic oils: progressive aging/oxidation of fluids

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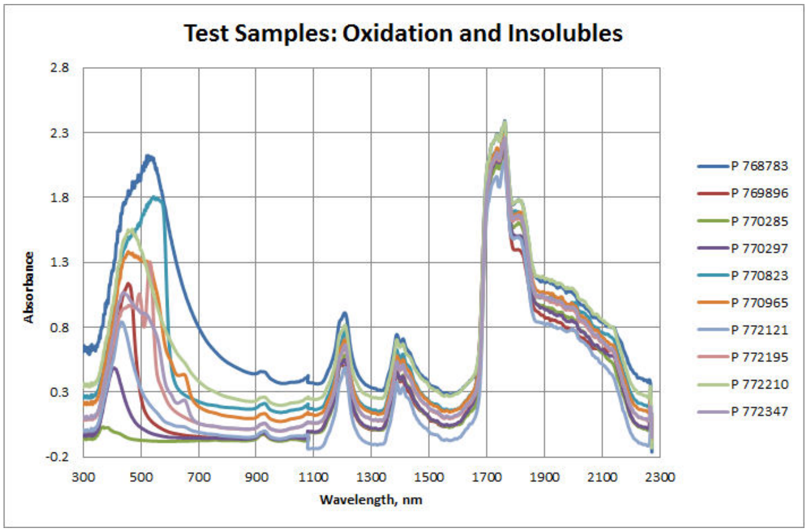

Figure 6: Used hydraulic oils: fluid degradation – oxidation and insolubles

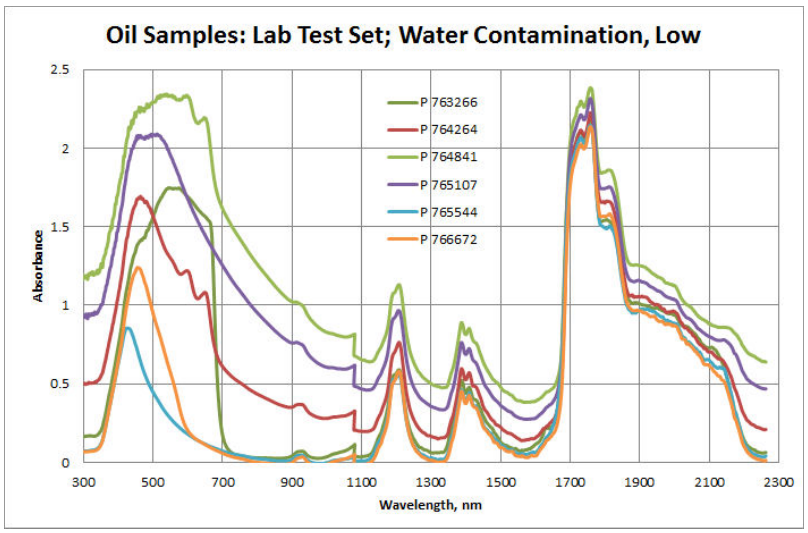

Figure 7: Used hydraulic oils: water contamination, low levels

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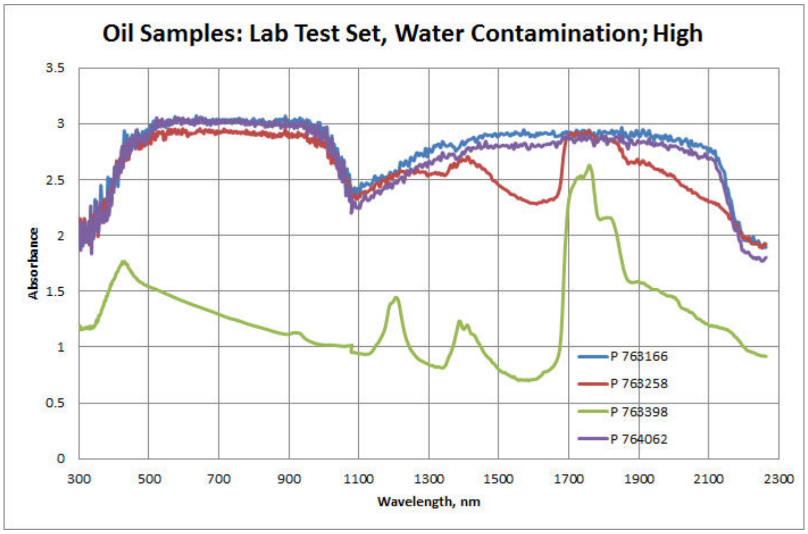

Figure 8: Used hydraulic oils: water contamination, high levels

Discussion

This application note describes a new spectrometer system that can be used as a maintenance tool for determining the integrity of the hydraulics used on heavy equipment. The system provides a rapid and easy to use diagnostic tool for determining fluid quality as an indicator for equipment condition and the need for maintenance. The ability to do such measurements in the field, without returning samples to the laboratory, saves both time and money. The system is portable and easy-to-use with a liquid insertion probe and can be programmed to provide diagnostic information without the need for a trained operator.

Acknowledgement

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19 Shea Way, Newark, DE 19713, USA • Tel: +1 (302) 368-7824 • Fax: +1 (302) 368-7830 • Web: www.bwtek.com

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