TESTOIL
MATERIAL IDENTIFICATION ANALYSIS

Great Lakes Generation

Jack Boilerman
20338 Progress Dr.
Strongsville, OH 44149
216-251-2510

Machine No:	19-1-3105
Fluid Type:	ISO 32 Hydraulic Oil
Machine Type:	Wind Turbine Yaw Brake Hydraulic
Sample Source:	T-2
Analyst:	Monika Malcolm
Report Date:	08/03/2016
Lab Number:	1746507

TESTOIL
MATERIAL IDENTIFICATION ANALYSIS

Background

A sample of yaw brake oil from the system reservoir was received for analysis. It was reported that the brake calipers were leaking and black slimy substance was contaminating the oil. Potential contaminants include brake dust or O-ring seals.

Objective

The goal of the analysis is to identify the black slimy substance via ultracentrifuge and FTIR testing and determine the origin.

Summary of Findings

The primary material contaminating the fluid was identified as a black carbonaceous material (soot). Soot is formed from high temperature events such as elevated operating temperatures or microdieseling. A small amount of silicon was also detected. Silicon is often related to dirt ingression.

Materials Identified

- Soot
- Silicon

Recommendations Based on Findings

Considering this is a hydraulic system, the most likely cause of soot formation is excessive aeration which leads to microdieseling. It is recommended that the source of soot formation is first identified (aeration or elevated operating temperatures). Sources of aeration include damaged pipe unions, loose fittings, pump gasket and seal leaks, low oil level, etc. Aeration can be prevented through system air bleeds, return air diffusers, or the use of a flooded suction pump. Elevated temperatures can be caused by plugged or dirty heat exchangers, low oil levels, or the use of fluids with the incorrect viscosity. In addition, soot can often be removed from a system through the use of very fine filtration.

Analysis

The sample as received was black in color and contained particulates that had settled to the bottom of the bottle. Upon centrifuging the sample black debris did collect at the bottom of the test tube; however, the oil was still black in color.

The customer assumes sole responsibility for the application of and reliance upon results and recommendations reported by TestOil, whose obligation is limited to good faith performance.

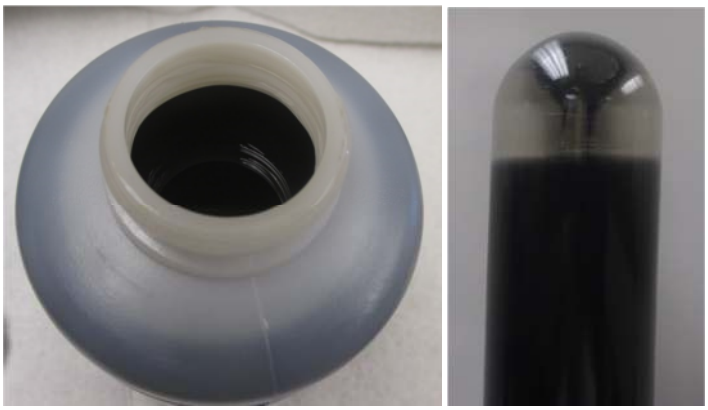

Figure 1. (From left to right) Picture of sample as received, UC result.

The oil as received was then characterized using ICP-AE spectroscopy, viscosity, and FTIR spectroscopy. This initial data suggests that the correct fluid is in use. The ICP data did detect the presence of chromium, sodium, and silicon. These elements are not part of the fluid's formulation.

Element	Concentration (ppm)	Element	Concentration (ppm)
Silver	-	Molybdenum	-
Potassium	-	Sodium	4
Aluminum	-	Nickel	-
Boron	-	Phosphorus	813
Barium	-	Lead	-
Calcium	106	Silicon	6
Chromium	9	Tin	-
Copper	-	Titanium	-
Iron	201	Vanadium	-
Lithium	-	Zinc	251
Magnesium	-		

Table 1. ICP-AES data of sample as received.

	Viscosity at 40°C (cSt)
Sample as Received	33.2
Virgin Fluid	32.9

Table 2. Viscosity data of sample as received and virgin oil.

The customer assumes sole responsibility for the application of and reliance upon results and recommendations reported by TestOil, whose obligation is limited to good faith performance.

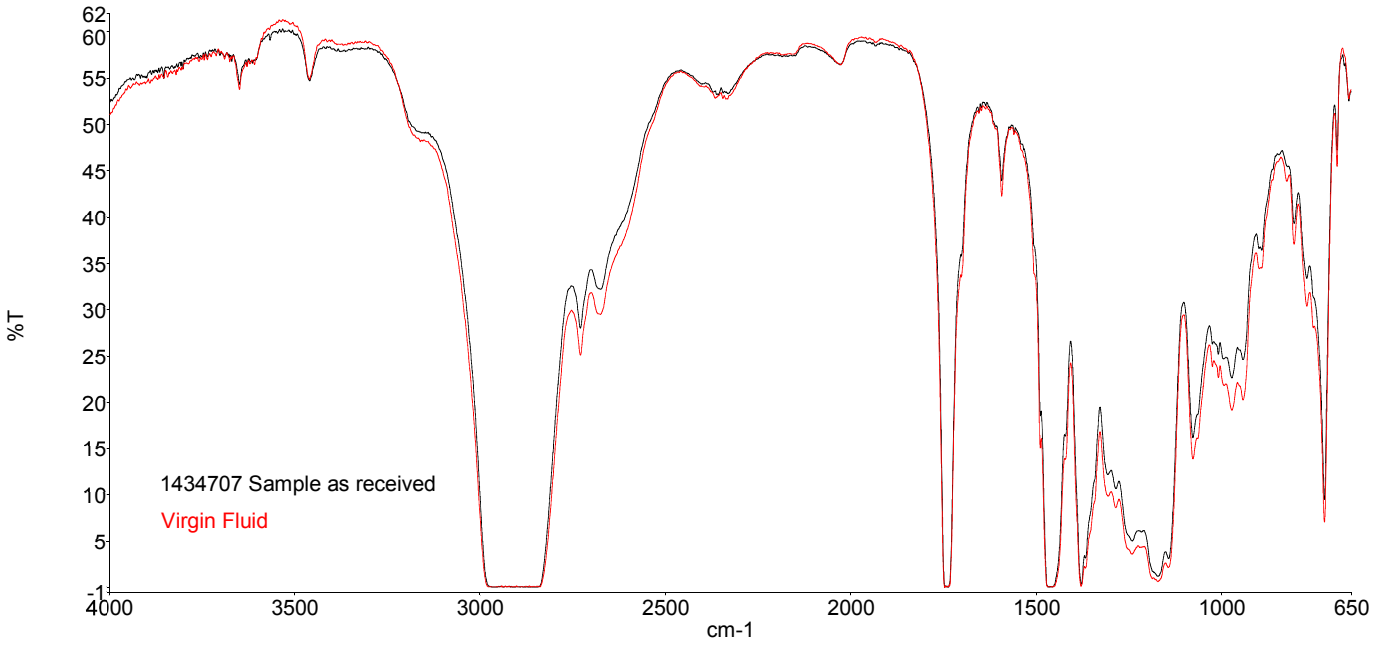

Figure 2. FTIR spectra comparing the sample as received to virgin oil.

The lubricant was first washed with a hydrocarbon based solvent in order to extract the contaminating material. The insoluble material was then washed with a polar organic solvent. The material was not soluble in the polar organic solvent indicating it was inorganic in nature.

Figure 3. (From left to right) Picture of hydrocarbon soluble fraction, inorganic fraction.

The customer assumes sole responsibility for the application of and reliance upon results and recommendations reported by TestOil, whose obligation is limited to good faith performance.

The hydrocarbon soluble fraction was characterized using FTIR spectroscopy. The chemistry in this fraction was identical to a reference of the fluid indicating again that the correct fluid is in use. This data is expected in the hydrocarbon soluble fraction.

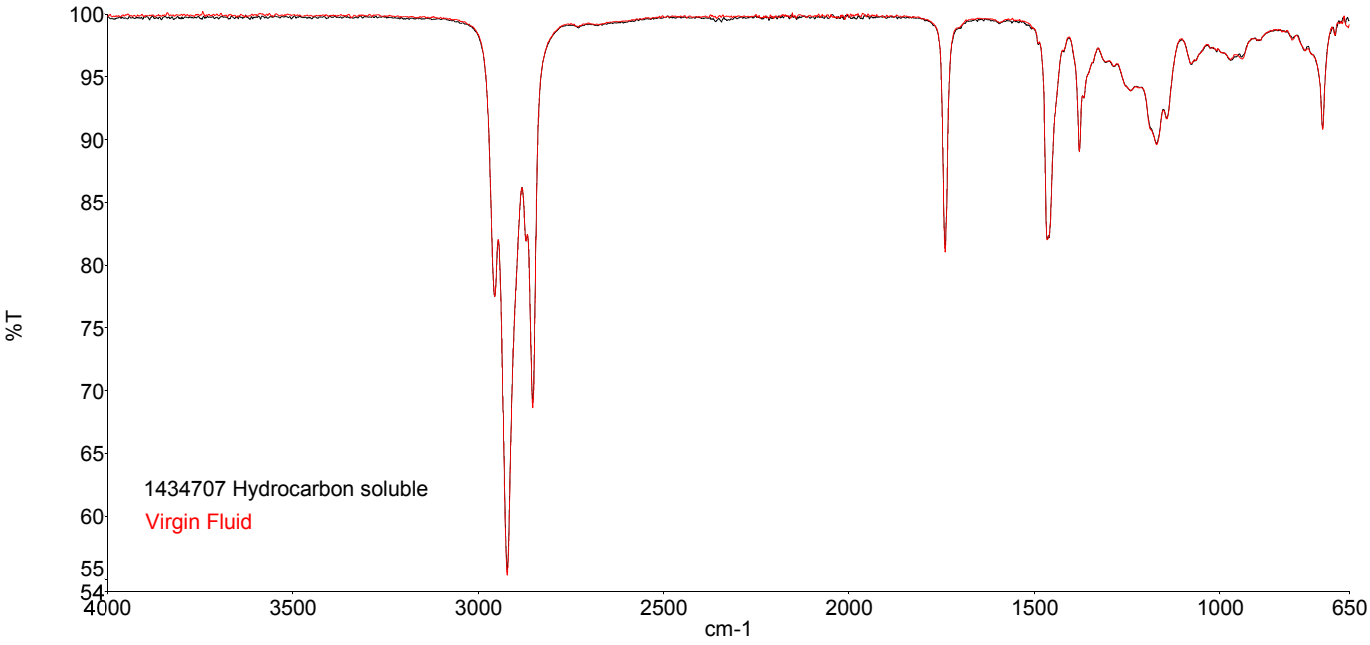

Figure 4. FTIR spectra comparing hydrocarbon soluble fraction to a reference fluid.

The customer assumes sole responsibility for the application of and reliance upon results and recommendations reported by TestOil, whose obligation is limited to good faith performance.

The inorganic fraction was also characterized using FTIR spectroscopy. The contaminating material was identified as primarily black carbon due to the spectrum's depressed baseline at 4000 cm^{-1} and the downward slope across the x-axis. Noise in the baseline from the black carbonaceous material obscures regions of the spectrum making it difficult to identify other chemistry that may be present. However, the peak at 925 cm^{-1} is most likely associated with silicate which typically originates from dirt ingression. The black carbonaceous material is most likely soot. Soot is a common contaminant in hydraulic fluids that is less than one micron in size.

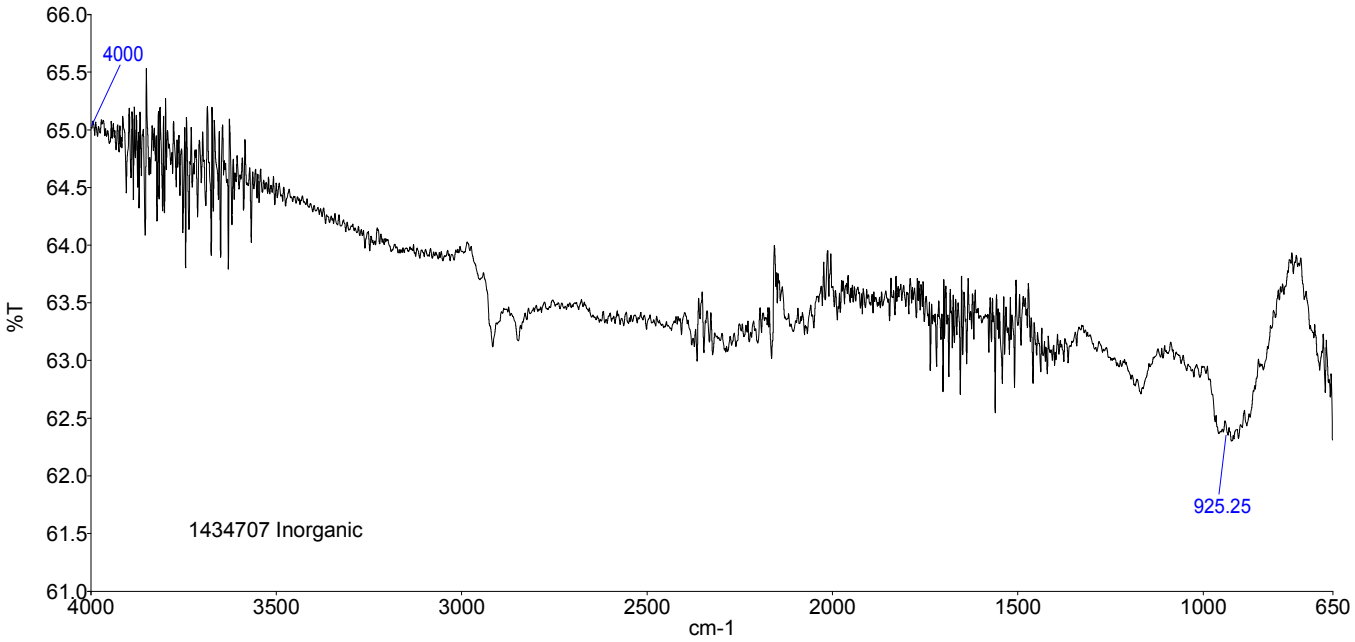

Figure 5. FTIR spectrum of inorganic fraction.

Please refer to the Summary of Findings section located at the beginning of the report for a conclusion of the results. Analysis completed by Monika Malcolm. For questions please e-mail mmalcolm@testoil.com.

The customer assumes sole responsibility for the application of and reliance upon results and recommendations reported by TestOil, whose obligation is limited to good faith performance.