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Reducing Routine Maintenance Costs of Engine Generator Sets with New Portable Oil Analysis Tools

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What do a hospital, a treatment plant, a police station and a remote mine have in common? They have essential assets requiring uninterruptible power, commonly powered by an engine generator as primary or back up power. Engine generators, often termed "gen sets," combine an electrical generator and an engine. They supply electrical power where normal utility power is not readily available or is unstable. Gen sets are used for temporary power demands and are often mounted on trailers or transportable skids. Portable, handheld oil analysis tools are now widely available and can be used to extend oil drain intervals and reduce routine costs. These tools are getting a boost with the recently amended US EPA NESHAP rules for emergency backup gen sets. The new rules allow condition based oil drain intervals, so asset owners can realize the benefits of oil analysis. This paper outlines the challenges and solutions available to portable/emergency gen set owners who have incurred the cost of time based oil changes.

Why Change Oil?

Engine oil must be changed before it can no longer adequately perform its intended functions within an engine. Oil in RICE (Rotating Internal Combustion Engines) becomes progressively contaminated, and the rate of contamination can vary based on load factor, duty cycle, age, environment and fuel types. Additives deplete to the point the oil and additive combination can no longer satisfactorily protect the engine. It is important to know the type of contaminant in the oil because it provides symptoms of the engine condition and enables a direct remedy to correct the problem.

Figure 1: Typical Generator engine enclosure located adjacent to a customer site (Ref: Jenbacher)

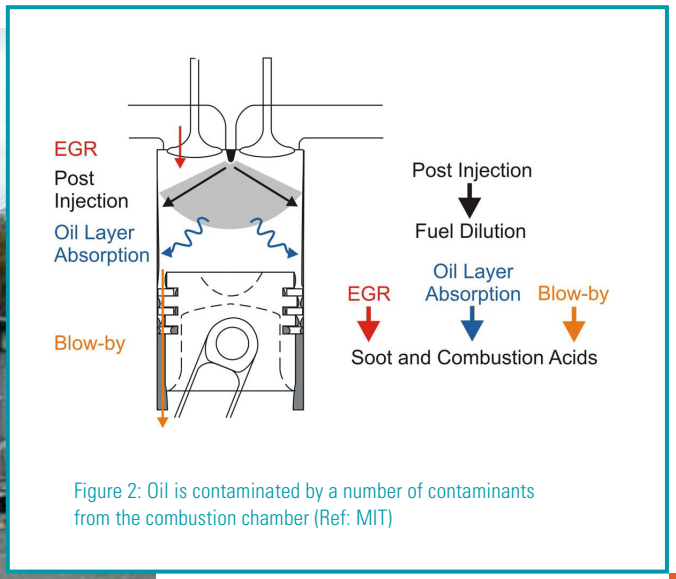

Figure 2: Oil is contaminated by a number of contaminants from the combustion chamber (Ref: MIT)

Top Oil Contaminants

In normal engine operation a wide variety of contaminants are introduced to the lubricating oil. The most common are:

COMBUSTION BY-PRODUCTS These contaminants are exhaust gases (blowby gases) that leak past the piston rings, valve guides and turbocharger seals into the crankcase. The gases contain particles of carbon, water, acids, partially burned fuels, varnish and lacquers. All of these particles contaminate the oil. Sulfur Oxides (Sox) are common gases with sulfurous fuels (diesel, liquid fuel distillates, heavy fuel oil); Nitrous Oxides (NOx) are more pronounced with natural gas (CNG, LNG, Propane) fueled engines. Hydrocarbon Oxidation (HCOx) will be present in varying amounts.

ACIDS, VARNISH, AND SLUDGE As the lubricating oil comes into contact with hot engine components, or when heated oil comes in contact with entrapped air, oxidation and decomposition occur creating contaminants such as acids, varnish, and sludge.

FUEL These contaminants are generally associated with engine malfunction. Fuel dilution, however, can also be caused by excessive engine idling or stop-and-go operation. Fuel dilution of the oil causes a loss in viscosity, resulting in severe wear and possible seizure if left unchecked. Faulty injectors, clogged air filters, and fuel pump failure are also common sources for fuel dilution, though in some cases fuel lines can rupture and contaminate the oil.

WATER Water vapor enters the oil as a byproduct of combustion. Backup generators and low load engines do not allow the oil to get hot enough to boil off the water quickly. Water combined with blowby gases create acids which degrade the oil and corrode the engine surfaces. Ingressed water sourced from the environment or broken cooling lines will cause the oil to degrade rapidly, and in some cases lead to severe wear and engine failure.

COOLANT Glycol based engine coolants are widely used. Cooling system corrosion, head gasket seal rupture or improper cooling line fittings can all lead to coolant mixing with the oil. Glycol is especially corrosive to non-ferrous bearing surfaces. Excessive coolant leads to the telltale sheen or mayonnaise oil emulsion, leading to engine seizure.

SOOT This contaminant is caused by retarded injection timing and burning fuel mixing with oil on the cylinder liner(s). Excessive soot causes abnormal valve and injector train wear and can overload the emissions control systems leading to air quality fines.

All of these contaminants can be monitored with oil analysis, a technique designed to evaluate the health of the engine through fluid analysis. Before discussing oil analysis, let's review current practices.

Routine Maintenance and Oil Condition

Some of the main operating costs of running and maintaining large engine generators are the material and labor costs associated with changing oil based on a fixed operating time interval. This routine is usually recommended by the engine manufacturer and increasingly by local regulations aimed at curbing emissions (EPA NESHAP rules). Oil changes are recommended based on operating hour or calendar based intervals, regardless if the generator has been running at full load or is idle for most of the time. Until now, this task was non-negotiable, especially if the gen set was under warranty. The US EPA actually mandates oil changes for stationary engines used for emergency backup power.

There are issues with scheduled oil changes that trouble engine owners:

- Good oil gets changed unnecessarily. Not all generators run at the same load amount; therefore, it is likely an oil change is not necessary for particular generators at the recommended change interval. This causes increased operating expense and waste including material, labor, service engineer utilization efficiency as well as recycling cost. If an oil change interval can be extended for even a fraction of the generators, the cost savings can be significant.
- Scheduled oil changes will not solve an ongoing contamination problem. Engine damage due to contamination of the lubricant described earlier can continue, usually increasing in severity.
- Catastrophic failures can still happen and the cost of repair and downtime is not insignificant, even though it might be infrequent.

The Role of Oil Analysis

Forward thinking gen set owners and service providers have recognized these issues for some time, and employ offsite or onsite oil analysis to determine the lubricant and equipment condition. In turn, they can determine if the oil can be extended or if it requires an overhaul.

PARAMETER	CONDEMNING LIMITS
Total Base Number (CI RICE only)	<30% of the TBN of the oil when new
Total Acid Number (SI RICE only)	Increases by more than 3.0 mg of potassium hydroxide per gram from TAN of the oil when new
Viscosity	Changed by more than 20% from the viscosity of the oil when new
% Water Content by Volume	>0.5

Table 1: US EPA NESHAP ZZZZ rule Amendment (Oct 2013) Condemnation limits for in-service oil

The US EPA acknowledged the benefits of condition based changes due to oil analysis. The agency recently amended its regulations for stationary generators in emergency or backup mode to allow for extended changes if oil condition condemnation limits are not exceeded (Fig 2).

The rule is specific that condemned oil must be changed within two days of the engine owner receiving this information. If oil condition is examined at the time of scheduled service, a decision can immediately be made as to whether the oil needs to be changed or if minor repairs are needed. It reduces both operation and maintenance costs, and the engine runs longer. A similar situation can occur in managing an automotive fleet. Time based oil change has been proven to generate waste due to unnecessary oil changes. Though the cost savings are real and the marketplace is starting to support them, the question is why condition based oil changes are not yet a popular practice?

Two good reasons:

1 Investment in a dedicated laboratory is not always practical. In mining operations and large power generation plants, it is common to have central oil analysis labs located onsite to continuously monitor the oil and machine condition of an equipment population. Decisions about oil change and other maintenance activities are made on the recommendation of experienced laboratory data analysts. This is the best industrial practice. However, it is difficult to apply this practice in the case of engine generator fleets because of the large, upfront capital investment as well as the need to hire laboratory technicians and data analysts. Even if a central laboratory is established, the distributed or temporary nature of the gen sets prevents service engineers from making immediate decisions due to the delay in getting results from the central lab. This is the problem with relying on contract labs to perform this work.

2 Previous technologies for onsite oil analysis are insufficient. To implement an effective condition based oil change practice, the tools used to monitor oil condition need to meet the following requirements:

- Easy to use – no need to hire an experienced oil expert.
- Portable – maintenance engineers can carry it from one generator to another.
- Fast – the engineers can use their time on site more efficiently.
- No waste stream and no recycling of hazmat chemicals – minimizes the cost of training on handling, storage, transportation and recycling of chemicals.
- Comprehensive – captures the complete picture of oil condition with minimal chance of false alarms.
- Repeatable and definitive – decisions can be easily made.
- Cost effective – ROI in one or two years.

As you can see, this is not an easy list of requirements. There are many tools on the market that can partially meet these requirements. The tools may be simple and easy to use but not definitive, or they may be accurate and expensive but not easy to use or to deploy in the field.

Recently Spectro Scientific introduced a comprehensive set of portable oil condition analyzers that provide a complete picture of in-service oil condition. Each tool is battery powered, small in a handheld form, and as accurate as laboratory instruments. Currently, these portable tools are even in use at oil analysis labs.

Each tool uses a small oil sample amount, measured in drops, and does not generate any waste stream. No chemicals are needed to analyze the oil, so no hazmat materials or recycling are needed. Without sample preparation, it only takes a few minutes to analyze oil samples retrieved directly from engines. Results are shown on the analyzer's display and contain alarms so users can make informed decisions immediately. This set of tools all originated from joint development with the US Military for condition based oil changes. The tools are used in the field to reduce costs and improve reliability. Now, maintenance professionals have the power of decision making in the field and are revolutionizing the industry. It makes condition based oil changes both affordable and practical.

Spectro Scientific Portable Oil Condition Combinations

The set of portable oil condition monitoring tools include an infrared spectrometer (FluidScan), a temperature controlled kinematic viscometer and a portable fuel dilution meter. This triple combination paints a complete picture of in-service oil condition including oil degradation, coolant contamination, water contamination, fuel contamination and viscosity. All three tools are battery powered and combined use less than 1 ml of oil. Table 1 highlights the list of in-service oil parameters that can be tested using the combination kits.

GENERATOR ENGINE TYPE	LUBRICANT PARAMETERS
Diesel, Gasoline, Bio-diesel, Propane, Bio-gas, Natural Gas	Oxidation, Nitration, Sulfation, Anti-wear additive, TBN, Water, Glycol contamination, Soot, Fuel dilution, Viscosity

Table 2: Critical engine oil parameters

Portable Oil Condition Analyzers

FluidScan®

FluidScan (Q1000) is a handheld infrared spectrometer.[1,2] It measures oil absorbance spectrum in the mid IR range (2.5 mm-12 mm). Instead of using FTIR technology, which was more widely used in oil analysis laboratories, diffraction grating based optics with detectors were used for better portability and durability. Chemometric calibration was applied on the raw IR spectrum to obtain oil condition information such as Oxidation, Nitration, Sulfation, Anti-wear additive, Total Base Number, Water, Glycol contamination, and Soot.[3,4] The technology was recently granted an ASTM D7889 standard method. FluidScan is widely used in the following scenarios: in laboratories as a titration alternative, in fleet management for mining trucks, in marine vessels, in power generation plants and in industrial plants for oil condition based predictive maintenance. The patented flip top cell uses three drops of oil, takes one minute and does not require any chemicals or solvents to clean. The tool also has an onboard database with asset information and preset alarm limits utilizing a traffic light system. As a result, maintenance engineers can make immediate decisions right after the measurement.

Portable Kinematic Viscometer

The Q3050 portable kinematic viscometer is a battery powered tool that measures oil viscosity at a controlled temperature (40˚C).[5] It can extrapolate viscosity at 100˚C based on a preset viscosity index of a given oil. The patented split cell uses only two drops of oil (60 µL), takes a couple of minutes to test, and does not require any chemicals or solvents to clean. The result is 3% accuracy, enough to make informed maintenance decisions. It is a good companion to FluidScan and is widely used in marine vessel and mining truck settings.

Fuel Dilution Meter

The portable Fuel Dilution Meter (Q6000) is a new member of the oil condition family. The predecessor was the Fuel Dilution Meter (Q600), a stationary analyzer used in analytical labs and on site labs to screen for fuel dilution in engine oil. It was jointly developed with the US Navy and is widely used in mining, railway, and marine environments. The measurement is based on a calibrated response of a Surface Acoustic Wave (SAW) sensor to a fuel vapor aromatic in the sample bottle headspace, which is proportional to the fuel content in the engine oil sample.

The new fuel dilution meter inherited the SAW sensing technique but is smaller, battery operated, and the patent pending sampling system makes it easier to use in the field and requires only 500 µL of used oil.

The three tools complement each other and present a complete set of oil condition information. They all share the same set of characters, which include:

- Small, light, portable and battery operated
- Use small volumes of oil (<1mL combined)
- No need for chemicals or solvent to clean (requirement for onsite analysis)
- Fast (one to two minutes each)
- Accurate (correlates to laboratory results)
- Easy to use (no need for an oil expert)

This set of characteristics is what makes the maintenance professional's life easier. Now it is possible to perform oil analysis at the generator and make immediate and accurate decisions with confidence.

Summary

Advancement in oil analysis technologies makes portable and accurate oil condition monitoring tools available to maintenance professionals. Now, those who manage a fleet of engine generators can easily implement a condition based oil change practice. It lowers operating expenses by reducing unnecessary oil change waste and maintenance costs by preventing catastrophic failures and improving the reliability of the machine. The Spectro Scientific portable fluid condition monitoring combination solution makes these cost benefits a reality.

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