From an article **Maintenance 4.0**
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(See 'Lubrication related maintenance program for standby generator sets' by James Wakiru in Lubezine, June 2016, below)

Maintenance 4.0 is the new buzzword for this improved level of condition monitoring, maintenance and asset management.

Twenty years ago, oil analysis was just getting going. STLE had begun work on two new certifications in oil analysis, and everyone was preaching about the ills of **reactive maintenance**—which basically boils down to waiting until something breaks, run out and see how fast you can fix it to eliminate downtime and reduce costs.

Of course, this approach results in downtime or even loss of critical equipment, potential exposure of employees to toxic materials, poor housekeeping or unsafe conditions such as fires and explosions, not to mention delays in supplying those all-important customers, who make it possible to pay the bills. Further these kinds of problems can result in regulatory fines and similar sanctions.

More recently, we began to talk of **predictive maintenance**. This is the idea that through condition monitoring techniques, such as oil analysis, vibration analysis, thermal, etc., we can determine when a machine or machine component is beginning to wear or break down. This then buys a little time to order in replacement parts and to schedule down time to make the needed repairs.

More recently still, we explored the concepts of **proactive maintenance**. Here we introduced the ideas of asset management along with more improved condition-based maintenance techniques. Some of the new ideas were to identify and rate each piece of equipment or component according to the criticality of it to the overall plant operation and assign a dollar amount as a measure of its importance. This provided financial justification for increased condition monitoring of critical equipment, inventorying critical repair or replacement parts and, most important, scheduling maintenance cycles well in advance so key system components receive periodic maintenance to ensure no downtime between cycles.

Now with **Maintenance 4.0**, the emphasis is on risk management maintenance. Some of the characteristics of risk management maintenance involve an even higher level of condition-based maintenance through the use of sensors on critical equipment and through big data analysis to more precisely determine trends and the state of the equipment. Of course, determining the level of risk to the overall operation for each piece of equipment if it fails, and the economic impact if it fails, is taken to a much higher level.

Finally, and this is critical, take proactive steps to eliminate that risk for that equipment or system with the most impact. This could take the form of statistically determining if one brand of bearing lasts longer for a given application and using the longer-lasting bearing regardless of cost. In oil analysis, preferably through use of sensors, monitor not the health of the oil per se but the critical additive system in the oil as it begins to break down. Then the oil can be changed before the machine actually sees degraded oil.

An important part of Maintenance 4.0, implied above, is enhanced asset management. In fact, there is a relatively new standard, ISO 55000, which is an international standard covering management of physical assets.

Initially a publicly available specification (PAS 55) published by the British Standards Institution in 2004, the ISO 55000 series of asset management standards was launched in January 2014. In a recent article, in Noria's Machinery Lubrication, Jim Fitch characterized the standard: "Asset management involves the balancing of costs, opportunities and risks against the desired performance of assets, to achieve the organizational objectives. An asset management system provides a structured approach for the development, coordination and control of activities undertaken on assets by the organization over different life cycle stages and for aligning these activities with its organizational objectives."

Lubrication related maintenance program for standby generator sets

Standby generators are depended on for back-up power systems in very critical situations and locations like airports, hospitals, government buildings, telecommunications industry and other critical installations that require power energy throughout. In standby power applications, diesel generators can start and assume full- rated load in very short time and can operate for many hours between major overhauls. The generator sets should be available without any fault as and when called in to provide power without fail. The critical need for power always comes at a time that simply cannot be predicted. Proactive programs designed to improve the "state of readiness" for your emergency generator will greatly improve the reliability of your backup system. Despite a lot of resources and money spent to improve the generator sets condition and reliability, improper lubrication is still cited as the primary cause of failure of the equipment.

"It is generally accepted in the lubrication community that 60 percent of all mechanical failures are due to inadequate or improper lubrication practices," states Kenneth Bannister in his book Lubrication for Industry. The majority of prime movers for standby power generators are diesel engine due to durability and performance. Maintenance is critical for ensuring that a diesel powered standby generator will start and run when needed.

We look at the place of lubrication in the four maintenance philosophies namely Preventive maintenance, Corrective maintenance, Condition based maintenance and Risk based maintenance.

Preventive Maintenance
Maintenance carried out at predetermined intervals or according to prescribed criteria, aimed at reducing the failure risk or performance degradation of the equipment. The maintenance cycles are planned according to the need to take the device out of service. The incidence of operating faults is reduced.

Preventive maintenance for diesel engine generators plays a critical role in maximizing the reliability of these standby systems. Because of the durability of diesel engines, most maintenance is preventive in nature and consists of the following operations:

- General inspection
- Lubrication service
- Cooling system service
- Fuel system service
- Servicing and testing starting batteries
- Regular engine exercise

It is generally a good idea to establish and adhere to a schedule of maintenance

/service based on the specific power application and the severity of the environment. While determining the type of lubrication schedule and lubricant to use, it is important to analyse the environment the generator set will be subjected to.

For example locations with extreme temperatures will determine the specifications of the lubricant to use being mono-grade or multi-grade, remote locations that are not easily accessed, a high performance lubricant like synthetic could be used to increase the service interval. If the generator set will be used frequently or subjected to extreme operating conditions, the recommended service intervals should be shortened accordingly.

Corrective Maintenance
Maintenance is carried out following detection of an anomaly and aimed at restoring normal operating conditions. This approach is based on the firm belief that the costs sustained for downtime and repair in case of fault are lower than the investment required for a maintenance program. This strategy may be cost-effective until catastrophic faults occur. This is a failure based maintenance strategy which works in odd times. It is applied to equipment with low level of criticality and whose faults are not a problem , economically or technically. This philosophy is rarely implemented while dealing with generator sets due to the criticality of the generator sets. Despite lack of implementation, it is always performed in order to restore the failed equipment to return to full working condition and also it provides another advantage as it may uncover problems not otherwise detected.

Risk based maintenance
Maintenance carried out by integrating analysis, measurement and periodic test activities to standard preventive maintenance. The aim is to perform the asset condition and risk assessment and define the appropriate maintenance program. Maintenance based on the equipment performance monitoring and the control of the corrective actions taken as a result. It’s common to treat every piece of equipment within a power plant or generator set equally when it comes to maintenance. A better way is to use a risk-based approach that classifies each piece of equipment in terms of its impact on output.

Oil analysis and other predictive techniques like vibration analysis can be used effectively while conducting failure mode identification and root cause analysis. Various aspects of the generator set operating conditions that have the potential of rendering the generator set inoperable can be identified using this program. Oxidation of the lubricant which can be a identified and a failure mode can be due to an increase in TAN(Total Acid Number) can be traced to high temperature being caused by either cooling problem or lack of ventilation for the generator set. Lower value of TBN (Total Base Number) in the oils could be subjected to risk based analysis and one could identify the causes like use of high sulphur diesel, use of inferior lubricant with low base number or increase in acidity inside the engine. After identification of the probable failure mode causes, a corrective action is taken and a long term maintenance strategy laid down to mitigate the failure mode recurrence.

Condition based maintenance
Maintenance is carried out when certain indicators give the signalling that the equipment is deteriorating and the failure probability is increasing.

This strategy, in the long term, allows reducing drastically the costs associated

with maintenance, thereby minimizing the occurrence of serious faults and optimizing the available economic resources management.

Condition monitoring by carrying out oil analysis of lubricants in the generator sets can help improve availability and reliability of the generator set in a great way. Oil analysis examines lubricants properties, contaminants and various kinds of wear debris to determine machine health in terms of which areas have wear challenges. Use of oil analysis and interpreting the various aspects, can help correlate machine issues well in advance. One can compare it to a blood test on the human body which would correlate the issues in the body.

Oil analysis can also be used to check and set up the lubricants drain nterval which have far reaching benefits in terms of cost savings and environmental management. One of the benefits of oil analysis is that it detects problems in both the fluid and the machine. It can also detect some defects earlier than other technologies. Oil analysis is often referred to as the first line of defence as far as predictive technologies are concerned.

It clearly goes that lubricants and Lubrication is a critical and vital aspect in the maintenance of generation sets. Lubrication cuts across the four maintenance philosophies as addressed above. There is no clear strategy that can be adopted for the lubrication related maintenance of generator sets but a blend of different respective philosophies as analysed and dictated by the conditions would ideally be sufficient.