WHITE PAPER

Wet Stacking Mitigation Technologies

BY AARON LACROIX
Product Manager, Generac Mobile

Over the last half century, diesel engine technology has steadily advanced with improved efficiency, increased power density and lower emissions. Today, diesel engines provide an ideal combination of power and torque in a relatively compact package. Gasoline engines of similar size cannot match the same power and torque output produced by a diesel engine. As a result, diesel engines are ideal for on- and off-highway machine applications where vast amounts of power and torque are required. Freight hauling, earth moving, agriculture production and power generation all benefit from this technology.

Electric motors also produce large amounts of power and torque for their size with the advantage of not producing any emissions. However, current energy storage technology limits their practical use in these mobile applications to smaller equipment. Therefore, diesel engines will continue to play a vital role powering on- and off-highway equipment.

The last 25 years have seen continued improvements in diesel engine efficiency and significant reductions in emissions with the implementation of regulations in the U.S., Canada, Europe and other countries. The U.S. Environmental Protection Agency (EPA) Tier 4 Final diesel emissions regulations, currently in effect for new diesel engines manufactured for products used in the U.S., have resulted in an emissions reduction of up to 99% compared to unregulated engines from just over two decades ago.

Engine design improvements and exhaust aftertreatment technologies make this emissions reduction possible. Depending on the engine power output, this technology may include an Exhaust Gas Recirculation (EGR) valve; Diesel Oxidation Catalyst (DOC); Selective Catalytic Reduction (SCR) utilizing Diesel Exhaust Fluid (DEF); or Diesel Particulate Filter (PDF). These components along with changes to the diesel engine design itself make the significant emissions reduction possible.

The key to making all these components work together properly is maintaining a hot enough exhaust gas temperature. The higher temperature enables the diesel fuel to burn completely in the cylinder and for the aftertreatment system to function properly. This results in the reduction of nitrous oxides (NOx), carbon monoxide (CO) and particulate matter (PM). Different engine manufacturers have different exhaust gas temperature targets. In general, the temperature needs to be a minimum of about 536°F (280°C).

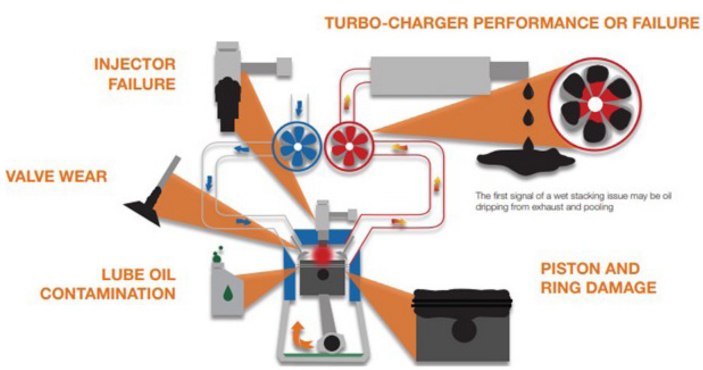
Diesel engines by design operate more efficiently with higher-applied loads. A minimum load of approximately 30% must be applied to raise the exhaust gas to a temperature sufficient for the aftertreatment components to work as intended. The 30% is a rule-of-thumb as the load required will increase as the ambient temperature drops. If an engine cannot raise the exhaust temperature high enough, the diesel fuel does not burn completely. Unburned, liquid diesel fuel is passed into the exhaust system. This can be observed as black smoke coming from the exhaust pipe and oily grime that accumulates in the exhaust stack hence the term ‘wet stacking’. In addition, this oily grime can clog aftertreatment components compromising their function. Eventually, components such as the DPF can become clogged to the point where the engine can no longer run and shuts down. Costly repairs could be required.

Diesel generators that are subject to underloading may require maintenance after use. Buildup in the exhaust system must be cleared to restore the machine to ready operational status and prevent future problems. This is accomplished by running the engine at a high load, typically close to 100, using a load bank for several hours. The heavy load causes the engine to get the exhaust system hot enough to burn off accumulated buildup. The equipment owner ends up bearing the cost of the load bank equipment. The time for the maintenance personnel to setup and apply the load bank and the lost revenue during the time the machine is not able to be used or rented.

Engine manufacturers have developed and refined solutions to avoid wet stack problems. Some earlier approaches to load management with Final Tier 4 engines would interrupt normal engine function for a period of time. This included regeneration (regen) cycles to produce a large amount of heat. The operator could override the cycle, but this would only delay the interruption. Eventually the regen cycle could not be delayed. When the purpose of using a generator is to produce usable electrical power, it becomes difficult to schedule a power interruption.

Today, load management technologies are field proven and widely available to prevent wet stacking without affecting machine function. The technology is automatic and seamless to the operator. Thus, machines with this technology can operate while subject to varying and low (less than ~30%) load conditions. This occurs without machine interruption from a regen cycle and does not require load banking at the end of use. Wet stacking and subsequent costs are avoided.

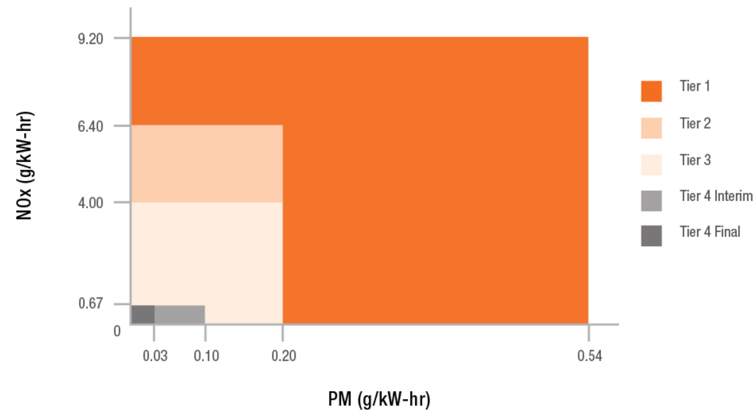
This technology takes three common approaches to achieve higher exhaust gas temperatures. The first is to apply additional load to the engine via its normal operation when it is below the minimum required load (approximately 30%). The second involves more complex engine control strategy. It can involve adjusting fuel injection timing, throttling airflow through the engine or using other auxiliary emissions control devices (AECD) to increase fuel to the engine to raise the exhaust temperature. The third is to heat the exhaust gas directly. This is also described as a regen cycle, but does not affect engine function compared to earlier technology. All of these approaches achieve the objective of ensuring the exhaust gas reaches the required temperature for proper functioning of the Final Tier 4 emissions components thereby preventing wet stacking.



The application of an additional load or electrical load to the engine is the most straightforward approach to mitigating an underloaded diesel engine. No modifications are required to the diesel engine. The controller essentially detects when the exhaust gas temperature is below a defined minimum and applies a supplemental load to the engine.

This load can be applied in different ways. A mechanical device with a clutch/PTO can be engaged to apply a mechanical load directly to the engine. In the case of a generator, another method is to energize a resistive load bank to create an electrical load. This in turn increases the mechanical load on the engine. At the point that the exhaust gas temperature reaches the necessary operating target and operates in a steady state condition for an extended period of time, the mechanical or resistive load would be turned off. The application of either the mechanical load or electrical resistive load does not interrupt or limit power output in the generator application.

DIESEL ENGINE EMISSION TIERS



The adjustment of engine control parameters raises the engine temperature and therefore the exhaust gas temperature. When the exhaust gas temperature is too low due to underloading the engine, the ECU will adjust parameters. Airflow, throttled by the ECU, can be restricted and injection timing adjusted to burn more fuel thereby raising the temperature. Additionally, if the engine is a variable speed engine, the throttle can also be increased to raise the temperature.

Lastly, since the objective is to maintain the exhaust temperature at a defined minimum, the exhaust gas itself can be heated via a regen cycle. Diesel fuel is injected directly into the exhaust system with either post injections or an extra fuel injector downstream of the engine cylinders, but upstream of the emissions aftertreatment components. The fuel is then ignited, quickly raising the temperature of the exhaust gas. The aftertreatment components are heated and kept clean because of this regen process. When an applied load can maintain the required exhaust temperature, the heater will stop. Like the other approaches, the function is automatic and does not affect power output.

Final Tier 4 Final emissions compliant engines will continue to replace earlier diesel engines, with lower tier emissions requirements, as equipment is replaced. Wet stacking will continue to be a valid concern if machines are under-utilized for applications where machines may regularly be underloaded. However, proven technologies are available to prevent this problem. The benefits of load management technology have been demonstrated. It will benefit diesel engine applications that are subject to varying and low load conditions. The equipment owner who does not know the engine loading profile for an application, such as power generation, can be confident that a machine equipped with a load management solution will avoid problems. The benefits include avoiding the time and expense of load banking generators and potential costly repairs to the engine and aftertreatment components. These systems function automatically and are unobservable to the operator. The diesel engine will continue to function reliably regardless of the applied load.

GENERAC® MOBILE

Generac Power Systems, Inc.
S45 W29290 Hwy. 59, Waukesha, WI 53189 | 1-844-ASK-GNRC (1-888-275-4672) | 201904207
GeneracMobileProducts.com