Wet Stacking Prevention Technologies for Cat® 3500 Diesel Generator Sets.

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ABSTRACT

What is wet stacking and what causes it?

What technologies have Caterpillar implemented to help prevent wet stacking?

This paper answers these questions while explaining the cylinder cutout strategies implemented across the Cat® 3500 range.

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INTRODUCTION

Diesel generator sets which are operated at low loads (<30%) for extended periods of time can result in a condition called wet stacking, which is also known as engine exhaust slobber or exhaust manifold slobber. It can be identified by a black, thick liquid egress from joints of the exhaust system (manifold, turbocharger or pipes). This black fluid is typically composed of carbon particles combined with unburnt fuel or lubricating oil giving it the appearance of used lubricating oil. The appearance of this black fluid is not usually an indication of an engine problem but is unsightly. Long periods of underloading however can lead to accelerated wear of components; white paper LEXE0832 "The Impact of Generator Set Underloading" describes this is in more detail and advises on how to manage and prevent this from occurring.

Cat® 3500 diesel engines have implemented various technologies which can help prevent the issue of wet stacking. These technologies include:

- Optimisation of piston assembly design to provide increased oil film scraping.
- Exhaust Seals (ES) i.e. exhaust valve stem seals, used where appropriate to prevent slobber building up inside the exhaust manifold
- Cold Cylinder Cutout (CCC)
- Idle Cylinder Cutout (ICC)
- The latter two technologies are controlled by the engine software and they can be disabled in the software using the Cat Electronic Technician (ET) service tool. They are described in detail below.

COLD CYLINDER CUTOUT (CCC)

CCC technology improves combustion when the engine is cold which should help avoid unburnt fuel entering the exhaust manifold. The intended purpose of the CCC is for the engine control module (ECM) to perform the following functions:

- Reduce the white smoke for cold starting.
- Minimize the duration of advanced timing (cold mode).
- Reduce the use of ether injection (if fitted)

The ECM automatically turns off one electronic unit injector at a time during the following occurrences:

- Cold start-up
- Extended time at low load

The ECM monitors the change of the fuel rack in order to determine if a cylinder is firing. If the cylinder is firing the ECM activates the electronic unit injector. If the cylinder is not firing the electronic unit injector remains deactivated.

In order for the CCC strategy to activate, the engine must have completed the ether injection (if fitted) and be operating within certain ranges of engine load, coolant temperatures and engine speed. Instances of when the CCC deactivates would include a coolant temperature sensor failure or if running a test on the CCC using the Cat ET service tool.

IDLE CYLINDER CUTOUT (ICC)

ICC cuts fuel to multiple injectors in a predetermined sequence rather than just one at a time. The cylinder cutout pattern and timing varies by engine series which is designed to ensure optimum exhaust temperatures are maintained with minimal vibration impact to the engine. The resultant exhaust manifold conditions prevent wet stacking.

Enablement conditions for ICC activation include the engine running at rated speed, where the engine speed is stable and loading is between 0% and a predetermined upper limit which can vary from engine to engine, typically within about 10 – 25% load. Other parameters including coolant temperatures and inlet manifold air temperatures also need to be within predetermined ranges.

If both CCC and ICC are enabled in the software and the operating conditions are met to activate both, then CCC will take priority over ICC as both cannot operate simultaneously. Engine parameters are monitored many times per second. If any parameter deviates from its predetermined range, then either CCC or ICC (which ever strategy is activated) will immediately deactivate.

SUMMARY

Through extensive testing and validation, various combinations of the technologies described above are implemented on Cat 3500 engines to optimise low load running capability whilst protecting the engine.

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