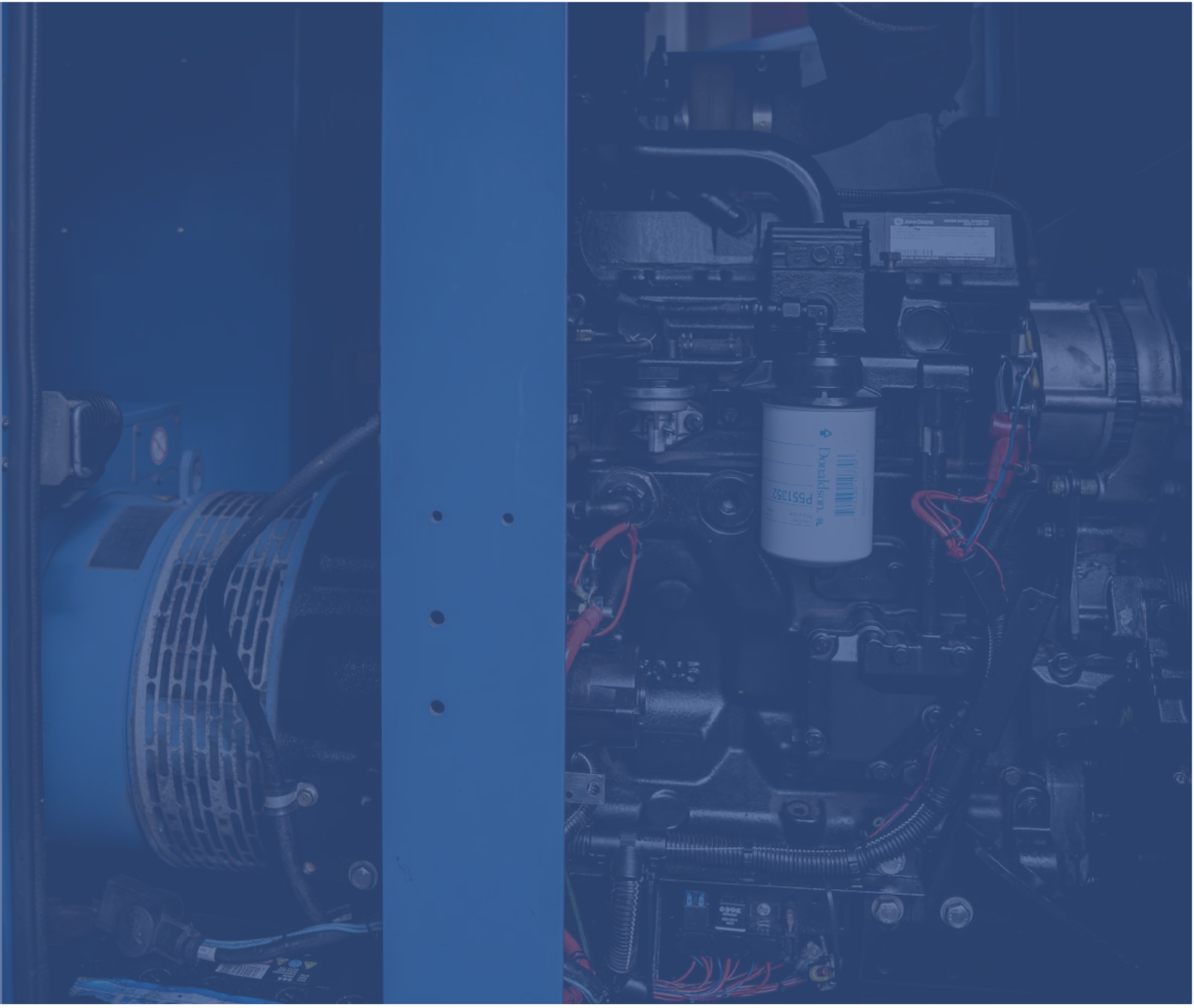

“WET STACKING” AND THE IMPACT ON DIESEL GENERATOR MAINTENANCE

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June 2023

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In this white paper WB Business Consultant Geoff Halliday considers the issue of diesel engine "slobber" or "wet stacking" particularly relating to "light load" or "no load" running for regular maintenance testing of generating sets and their associated exhaust after treatment equipment.

FEASIBILITY AND BENEFITS OF NO-LOAD TESTING

Many operators and maintainers of standby diesel generator are probably all too familiar with the problem of engine "slobber" or "wet stacking". This problem is typically the result of the generator engine running for long periods at low levels of load, the outcome of which is a build up of unburned fuel in the exhaust system that can lead to reduction in engine performance and if not dealt will in a timely fashion premature failure. This can be caused by a number of reasons not least of which are

- The generator is oversized sized for the power required
- An adequate load is not available during the regular maintenance test running period. Data centre providers frequently have
- Or in a hire application where the generating set 24 / 7 are prime power source and loads are very light for prolonged periods say over a weekend

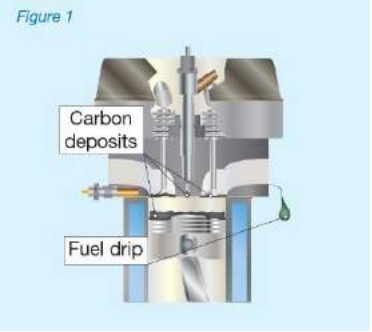
The usual way of overcoming this issue is to connect and external load bank for testing purposes which of course incurs the additional costs and time to connect with resultant higher emissions and extra fuel costs.

WHAT IS WET STACKING

Wet Stacking typically occurs when a generator is run at less than 30% of its nominal capacity for extended periods of time. With this level of load the engine doesn't not achieve or is unable to sustain its optimal operating temperatures needed to fully burn the fuel injected into the engine.
The lack of engine temperature means that the pressure inside the combustion chamber falls below the crankcase pressure and the engine temperature isn't high enough to ensure the piston rings expand enough to seal the space between the pistons and cylinder walls. The result of this is incomplete combustion of the fuel and a propensity for the engine to draw small amounts of lube oil up from the crankcase which becomes visible as white smoke in the exhaust. A build up of lube oil in the combustion area can cause glazing on the cylinder wall. Additionally, there can be a build up of unburnt fuel or soot in the exhaust line which of itself can also be dangerous. Wet stacking

- Fouls the fuel injectors
- Causes excessive valve guide wear
- and can lead to damaged pistons, piston liners, and rings amongst other problems, as depicted in *Figure 1*.

Figure 1



EMISSION CONSIDERATIONS

In addition to the risks of shortening engine life and running higher maintenance costs, operators could also fall foul of tighter emissions regulations due to the discharge, via the exhaust system, of partially burnt lube oil and additional particulates from the unburnt fuel.

THE IMPACT OF NEW EMISSIONS TECHNOLOGY

The introduction of ever more onerous emissions targets, have over recent years, seen the introduction of diesel oxidation catalysts (DOC), diesel particulate filters (DPF) and more recently via the medium combustion plant directive MCPC selective catalytic converters or SCR's. (See Fig 2)

Figure 2

The introduction of these additional elements into the exhaust gas stream further add to the problems of wet stacking elevating its importance as an issue to be dealt with. All of these emission treatment devices only function correctly when they reach their optimal operating temperature / operational temperature range. It is heat generated by full and effective combustion in the engine which generates the necessary heat in the exhaust system. The emissions after treatment devices are also susceptible to becoming clogged by unburnt fuel and soot resulting from wet stacking reducing performance and likely failure to meet the required emissions target set for the installation. (Also see WB white paper….)

WHY IS "WET STACKING" IMPORTANT

It is unlikely that wet stacking will cause engine damage in the short term, but over time it will lead to poor performance, reduced engine life and expose the user to higher maintenance costs. There is then the issues of a build up of unburnt or partially burnt fuel and other carbon deposits in the exhaust / flue system. In extreme cases usually under rapid application of the high exhaust temperatures the exhaust gas stream can combust soot in the system.

WAY TO ADDRESS WET STACKING

The well-trodden path to solving the problems of wet stacking has, for years, been to regularly run the generator(s) at load levels well above the minimum 30% of rated capacity. Depending on the hours run this can be monthly or annually. This has been done to ensure the engine gets to its optimum operating temperature; a temperature at which the piston rings expand appropriately, burn off any cylinder glazing and burn off unused or partially burnt fuel that has built up in the exhaust system. Recent advances in technology are making the need for this costly procedure less demanding.

THE HISTORIC OVERSIZING OF STANDBY GENERATORS

The problem of wet stacking has been with us for many years and occurs in most types of standby generator applications. The main cause of this being down to the oversizing of the generator(s) at project design stage. There are many reasons for this some of which are;-

- Lack of clarity of client load requirements at the design stage
- Client loads never reach those expected
- Energy efficiency improvements over time
- The inclusion of a clause in the specification for "an additional 25% capacity to cover any future business expansion"
- Application related such as the requirement for generator being sized to accommodate locked rotor starting on life safety sets
- Confusion over compatibility between generators and static UPS equipment
- Multi set "rolling" redundancy typical in mission critical / data centre applications

By their very nature of standby generators are installed to protect critical loads of all types be they hospitals, commercial business, or critical infrastructure. In many of these environments there is an acknowledgement that the entirety of the standby system should be regularly tested to ensure it all functions correctly whilst at the same time an operational prerogative not to put fully functioning business systems at risk. In this scenario the idea "off load testing" was born and its practice widely adopted.

When all of the above elements come together and are combined with a range other application driven needs it is clear to see how a significant number of installations across the UK are running lightly loaded generators for many hours each, eventually leading to issues with wet stacking.

In terms of the design phase though it should be noted that when generator manufacturers, generator dealers and specifying engineers work more closely together, specifically at the design stage, can largely resolved these issues. Generator dealers with a wide range of application knowledge that also have access to today's much improved generator sizing tools generator sizing tools can provide more accurate solutions. The wet stacking problems present in the market today caused by oversizing should be a lesser concern in the future confining the problem to more of an issue associated with monthly or quarterly off load testing.

LOAD BANK TESTING

The easiest way to avoid wet stacking during monthly exercise is to run the generator at the manufacturer's recommended minimum load level (this will vary from engine to engine and manufacturer to manufacturer). Many of today's infrastructure operators do not wish to "risk" operational integrity by transferring the building load onto the generator at critical times. With many operations today being true 24/7 operations time to undertake key preventive maintenance works is at an absolute premium, ensuring any generator testing is either off load or with a load bank. It is often the case that load bank testing is undertaken annually. In many operational environments such as in a data centre for example monthly load testing might be mandatory.

The use of a load-bank artificially boosts the amount of load available to be placed on the generator itself, ideally ensuring that the engine reaches optimal temperature enabling it to burn any accumulated build up. Most generator operators recommend that load-bank testing be done at least annually for a minimum of 30 minutes runtime. Of course, needs will vary depending on overall hours run in the period; your generator maintainer will be happy to advise on this.

In addition to running time, the operator or maintenance company will need to consider the time it takes to setup the load bank. For a typical large hospital or data centre facility using between five and ten

generators, that can add up to a significant time commitment by operations personnel, not to mention fuel consumption.

LATEST DIESEL ENGINE TECHNOLOGY

The push and pull of market forces, government legislation and a growing environmental awareness within the populations in general has seen, over recent years, significant changes to the modern diesel engine. Modern engine designs now incorporate a number of new technologies that enhance operating efficiency such as

- More precision engineering in cylinder blocks and heads which enable a reduction the gaps between pistons and rings that previously allowed lube oil from the sump to transit so easily into the combustion chamber or "blow-by" which is when unburnt fuel escapes the cylinder
- The introduction of high pressure common rail systems which allows better atomisation of fuel into the cylinder
- More sophisticated engine management systems with "fuel mapping" when combined with high pressure common rail systems can facilitate multiple fuel injections per cycle. This allows near real time management of the combustion process enabling it to be better tailored to the requirements of emissions and/or those all-important cylinder temperatures
- The addition of charge air cooling allows more low temperature air to be delivered to the cylinder facilitating more complete combustion of the fuel permits fuel

With the much finer tolerance now being achieved in the newer piston and piston ring assemblies over those of older engines blow-by has been significantly reduced engine now burn fuel far more efficiently mitigating some of the conditions that lead to wet stacking.

A combination of

- The use of higher cylinder pressures which increase cylinder temperature at lower loads
- The addition of common rail systems and fuel mapping
- Improved ring designs which better contain combustion gases and enable a shaped charge to be created

See *Figure 3*

When all of these elements come together in one package this enables the engine to run at much lower load levels when being testing on a regular basis. This combination of changes potentially permits generators to be safely run at loads as little as 30% of the rated capacity or higher as little as once per year to maintain optimal performance and stay within emissions guidelines.

REVISITING LOAD BANK TESTING AND MAINTENANCE PROCEEDURES

Many infrastructure operators / maintenance organisations, where budgets permit, still undertake generator maintenance in the time-honoured way by conducting load bank testing in accordance with maintenance procedures drawn up many years ago and that have never been revisited. These procedures then, may not embrace many of the technological improvements that have been made and that can now simplify and reduce the monthly/ quarterly/ annual procedure.

Many hours of testing and extensive field experience with generators such as the KOHLER KD Series suggests that "no load" monthly exercise is allowable, providing the generator is load bank-tested annually, which is standard practice for many operators particularly in the data centre and healthcare sectors.

SWITCH TO ANNUAL LOAD TESTING

The financial and environmental savings available when switching from monthly to annual loaded testing are quite compelling. By way of an example, a KD4000 / 3120kW set running at full load for 30 minutes each month will burn approx. 4,400l of diesel fuel per year.

If the same testing regime is used but with monthly no load tests and an annual full load test, approx. 1,160l less fuel per year is consumed and total pollutant emissions are reduced by 82% (on a pounds per year basis). See *Figures 4 & 5*.

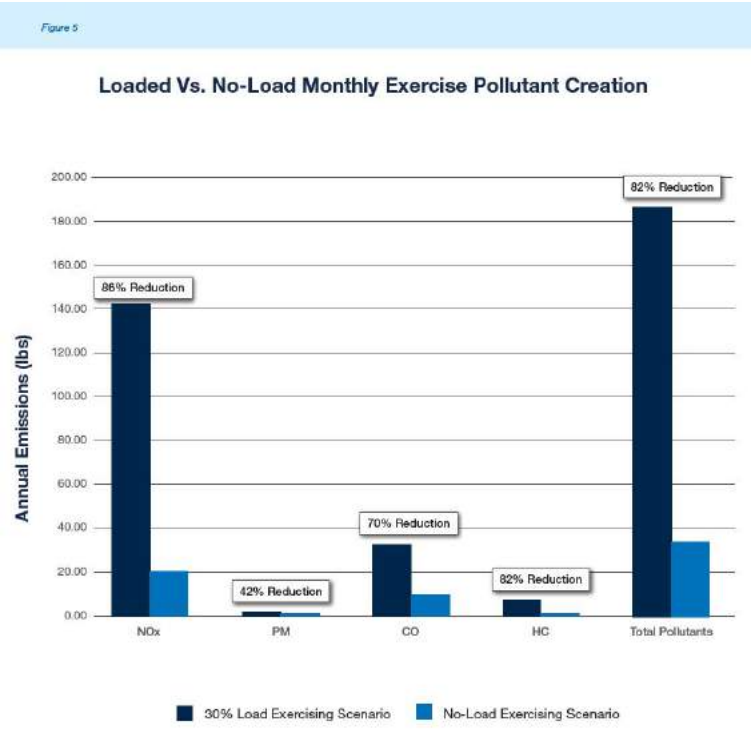
Consumption data shown here in US Gallons and generator running at 1800RPM

There are also the onsite savings too such as reduced load bank and associated labour costs.

BEFORE REVISITING MAINTENANCE SCHEDULES

In the UK the Medium Combustion Plant Directive (MCPD) became UK law in December 2017 (Directive (EU) 2015/2193) and covers diesel engines with ratings between 1 and 50MWth requiring them to meet a level at or below 190mg of NOx /Nm3 plus levels of other emissions too. These "medium sized engines" represent an important source of emissions such as Nitrous Oxide (NOx) and dust (Particulate Matter). The directive seeks to regulate the emissions of them with the aim of reducing the production of these substances known to be harmful to human health. The devolved government of these Isles also carry additional responsibilities for environmental protect as do local and large city authorities and it is these local bodies which typically mandate site specific/ local air emissions levels and permitting of the site or facility. These local decisions, depending on the site, can dictate or influence the testing requirements/regimes adopted especially when using aftertreatment devices. Always check with WB Power Services Ltd.

Figure 5



Before changing any maintenance procedures, please consult with your dealer, service provider, or the manufacturer. Depending upon the types of exhaust aftertreatments that are fitted to the set, service schedules and capacities may well differ. For example, low-temperature operations in the presence of a SCR emissions control system may run the risk of oxidising stored hydrocarbons and damaging the SCR catalyst particularly when exhaust temperatures are later raised through load testing or full system operation.

The author fully acknowledges the major contribution made in the production of this paper by KOHLER and in particular Brad Meissner who currently works as a product manager with responsibility for >700 kW diesel generators at Kohler Co in the USA.

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Geoff Halliday started his career as an apprentice working for Square D (later part of Schneider) before moving into the critical power sector where he has now worked for over 40 years, splitting that time equally between both the UPS and standby diesel generation sectors.

During this period Geoff has held several roles ranging from Customer Service Engineer, Project Manager, Technical Director, Sales Director through to Managing Director.

The Critical Power market exposes the individual to a wide and diverse range of market sectors ranging Health Care, Life Science, Water Treatment, Banking and Finance, Military, Manufacturing, Process Control through to Data Centres of all sizes. Drawing on his management skills, product knowledge and vast application experience amassed throughout his career Geoff now enjoys sharing his knowledge with others.