

# Wet Stacking of Generator Sets and How to Avoid It

Information Sheet # 09

## 1.0 Introduction

Most standby generator systems up to five megawatts use the reciprocating internal combustion engine as the power source to drive the generator that produces the electrical power. The engines of choice are either diesel, natural gas or LPG fueled. A large percentage of standby power systems use the diesel engine. Diesel is a convenient independent fuel source and the compression ignition systems of diesel engines have a much higher thermal efficiency than the spark ignition system used by gas engines. However, one factor to be considered when selecting a diesel power source is the potential for "wet stacking."

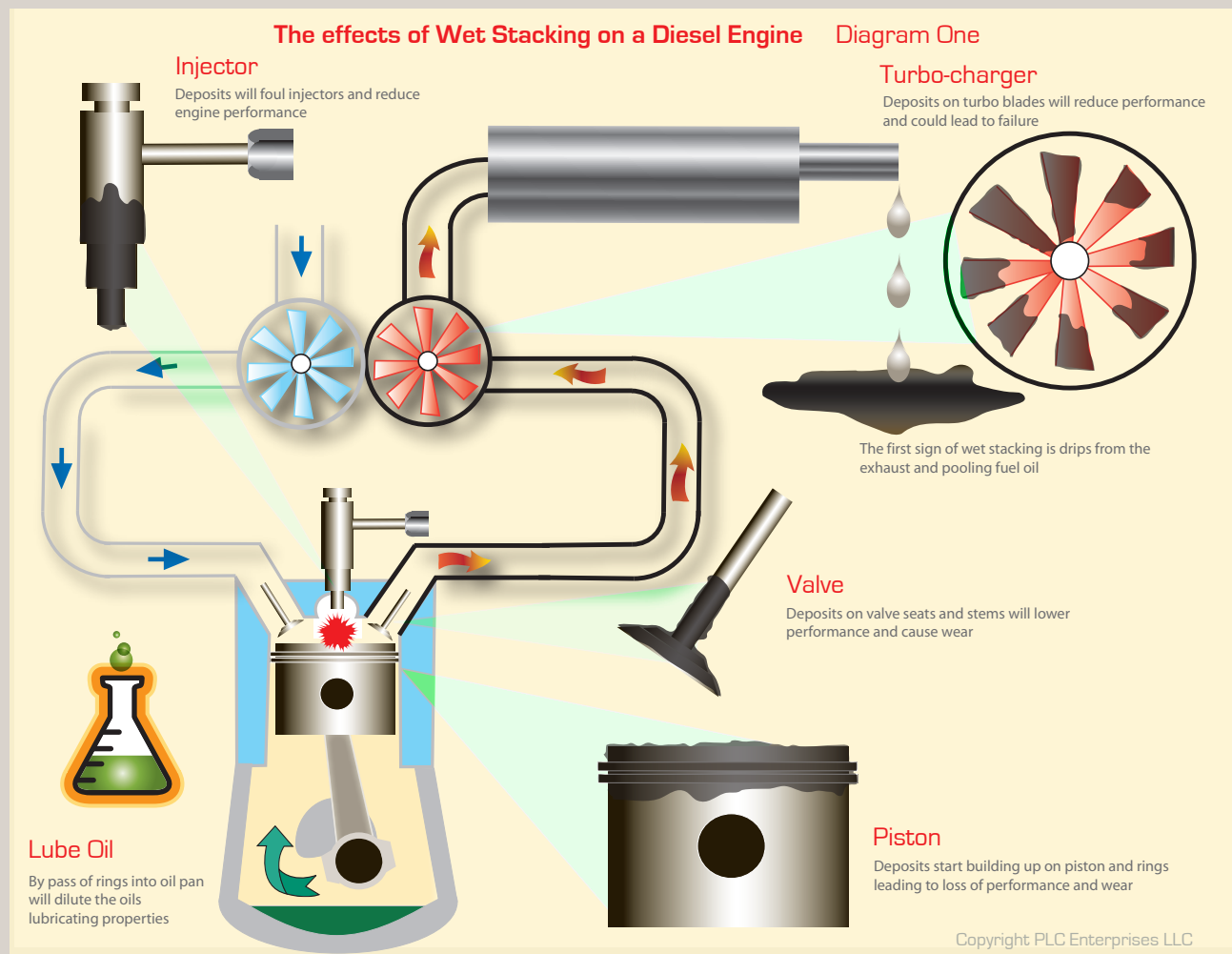
The National Fire Protection Agency (NFPA), in their NFPA 110 Code for Emergency and Standby Power Systems section 6 - 4.2 (1996 edition) refer to wet stacking as a field term indicating the presence of unburned fuel or carbon in the exhaust system. The later 1999 edition suggests a more quantitative method for determining the presence of wet stacking by measuring the exhaust gas temperature, explained later in this information sheet.

This information sheet discusses the causes of wet stacking, its effect on the engine, why it should be avoided and methods for eliminating the condition.

The designer of a generator system must take into account the potential for wet stacking when determining equipment for the system, load calculations and maintenance and service programs. The system designer should consider the following.

## 2.0 Causes of Wet Stacking:

Like all internal combustion engines, to operate at maximum efficiency a diesel engine has to have exactly the right air-to-fuel ratio and be able to sustain its designed operational temperature for a complete burn of fuel. When a diesel engine is operated on light loads, it will not attain its correct operating temperature. When the diesel engine runs below its designed operating temperature for extended periods, unburned fuel is exhausted and noticed as wetness in the exhaust system, hence the phrase wet stacking. (Continued over)



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The installation information provided in this information sheet is informational in nature only, and should not be considered the advice of a properly licensed and qualified electrician or used in place of a detailed review of the applicable National Electric Codes and local codes. Specific questions about how this information may affect any particular situation should be addressed to a licensed and qualified electrician.

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### 3.0 Engine Effect

When unburned fuel is exhausted out of the combustion chamber, it starts to build up in the exhaust side of the engine, resulting in fouled injectors and a buildup of carbon on the exhaust valves, turbo charger and exhaust.

Excessive deposits can result in a loss of engine performance as gases bypass valve seatings, exhaust buildup produces back pressure, and deposits on the turbo blades reduces turbo efficiency.

Permanent damage will not be incurred over short periods, but over longer periods, deposits will scar and erode key engine surfaces. (Diagram One) Also, when engines run below the designed operational temperature, the piston rings do not expand sufficiently to adequately seal the space between the pistons and the cylinder walls. This results in unburned fuel and gases escaping into the oil pan and diluting the lubricating properties of the oil, leading to premature engine wear.

### 3.0 Why To Avoid Wet Stacking

In addition to the adverse engine effect, the designer and user of a system have to consider:

- **Expense** - Excessive wet stacking will shorten engine life by many years and before planned replacement.
- **Pollution** - Many urban areas restrict the level of smoke emissions wet stacking produces.
- **Power** - Even before an engine is damaged, deposits will reduce maximum power. A prematurely worn engine will have a lower maximum power than it was designed to develop.
- **Maintenance** - An engine experiencing wet stacking will require considerable more maintenance than an engine that is adequately loaded.

### 4.0 NFPA Guidelines

Wet stacking is a recognized condition with organizations that write codes for standby generator set systems, such as the National Fire Protection Association (NFPA) which has issued several guide lines for controlling the effects.

The NFPA guidelines in Level 1 and 2 applications require exercising the unit at least monthly for 30 minutes under either of two methods:

1. Under operating temperature conditions and not less than 30 percent of the EPS name plate kW rating, or
2. Loading to maintain the minimum exhaust gas temperature as recommended by the manufacturer. (See NFPA 8.4.2.) Exhaust gas temperature specifications are available from the manufacturer of the unit.

### 5.0 Additional Conditions

The Joint Commission on Accreditation of Health Care Organizations (JCAHO), the organization that accredits health care institutions, has taken this testing to a level beyond the NFPA. They require testing of 12 times per year with testing intervals between 20-40 days. Testing generators for at least 30 minutes under a dynamic load of 30% or greater of the name plate rating.

Systems that do not meet the 30% load capacity have three options.

1. Increase the load to meet or exceed 30% of the name plate rating,
2. Maintain the minimum exhaust temperature as recommended by the engine manufacturer, or
3. Undertake load bank testing for a total of 2 hours continuous loading as follows: a) Load at 25% of name plate for 30 minutes b) 50% for 30 minutes c) 75% for 60 minutes.

JCAHO also recommends that all automatic transfer switches (ATS) are tested 12 times per year at 20 and 40 day intervals. The provider of the power system through planned maintenance programs can undertake load testing when testing the ATS.

### 6.0 Solutions to wet stacking:

The obvious solution is to always run the generator set with an electrical load that reaches the designed operational temperature of the diesel, or approximately 75% of full load. Built-up fuel deposits and carbon can be removed by running the diesel engine at the required operational temperature for several hours if wet stacking has not yet reached the level where carbon buildup can only be removed by a major engine overhaul. The following load bank solutions should prevent a reoccurrence of wet stacking.

#### Automatic auxiliary loading:

When the generator set is the only source of power and the connected load for periods is very light a auxiliary load bank. The auxiliary automatically switches on when it detects the facility load is too low to adequately load the generator. When the facility load increases the load bank will switch off.

#### Facility manual load bank:

Operated as described for the automatic load bank, but a manually operated system for use with light loads and when the larger load is also manually initiated. The load bank can also be used for load testing a system primarily used for standby power.

**Portable load bank:** The distributor for the diesel generator set is often the best qualified to undertake the maintenance of the system. Today it is very common for the owner of a standby generator system to outsource complete maintenance of the system and have a planned maintenance (PM) contract with a full service generator-set supplier.

During a regularly scheduled planned maintenance call, the distributor will bring in a portable load bank to run the generator at a load that maintains the designed operational temperature. Portable load banks range from a few 10kW thru 2MW units mounted on large trailers as pictured.

### 5.0 Note regarding - Joint Commission of Accreditation for Hospital Organizations (JCAHO)

We feel it of interest to note that many hospitals are now being accredited by the Joint Commission. This organization addresses emergency management of hospitals (such as occurs with loss of utility power, water, etc). They provide standards covering: provisioning of care, treatment and services, patients rights and responsibilities in hospitals, and this includes a reliable EPSS in most cases. There has to be a written emergency plan in place with clearly defined responsibilities and assignment of adequate staff, including multiple back-up personnel.

All such persons must be trained and their attendance should be taken into account by the EPSS supplier when arranging such courses. The EPSS maintenance requirements must conform to NFPA 110 for testing purposes, but in addition, calls for monthly testing of generator and automatic transfer switches.

More details can be found on JCAHO web site:

[www.jointcommission.org](http://www.jointcommission.org)

### Typical Portable Load Bank Shown to Left

