White Paper

Load Bank Testing to Ensure Generator Set Performance

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Diesel Engine Generator sets (gensets), are one of the main components in Emergency Backup Power Systems. Their failure to perform in an Emergency situation could result in catastrophic conditions. The main goal of load bank testing is to uncover potential genset problems in a controlled situation, rather than during an actual power failure. Load bank testing therefore is a critical part of a genset maintenance program.

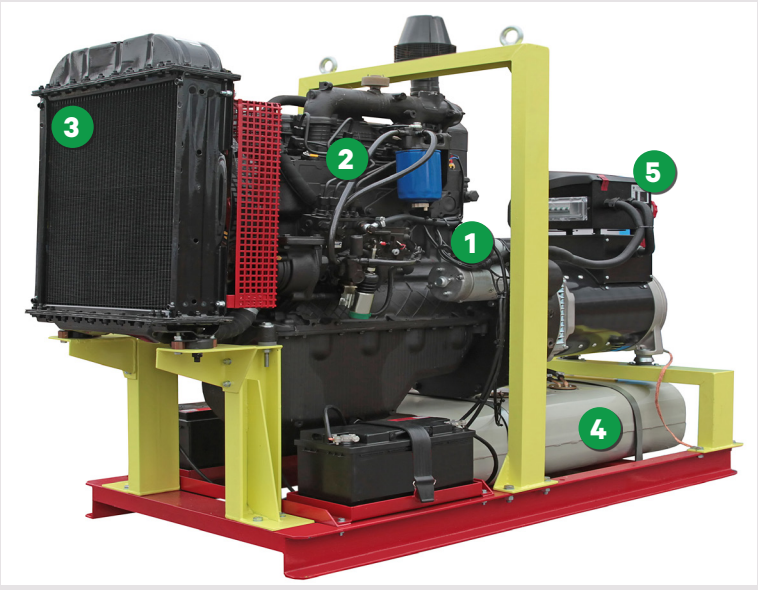
In the case of a standby diesel genset, a load bank test will indicate:

- The engine's ability to provide the required power output (kW)
- Voltage regulator response time
- The alternator's capability to provide required voltage, and frequency stability
- The genset control system under varying conditions of load
- General performance of the whole system, oil and fuel pressure
- A load bank test will also help remove fuel deposits from pistons, engine castings and exhaust
- With data logging software load test results can be recorded and the technician can analyze work that needs to be done

The Case for Load Bank Testing

As detailed below, load bank testing is the best practical means to ensure efficient operation of a genset. Be it just purely resistive or resistive and inductive any load test is far superior then no load testing or using uncontrollable building loads. Load banks can help test and improve the health of generator and its components in the following ways:

1. Voltage Regulator
2. Governor Operation
3. Cooling System
4. Fuel System
5. Control Operation



A typical diesel generator arrangement.

Load Bank Testing to Verify Voltage Regulator Operation

The voltage regulator is a critical component of the genset as it allows the system to recover quickly from large load changes. Only resistive and inductive load bank testing can verify the performance of the genset voltage regulator; the operation of the regulator is not fully assessed in a resistive-only load bank test. When large loads are applied, engine speed drops, before shortly recovering to its steady-state condition. This recovery interval is known as the "transient response." If the regulator(s) are not functioning properly, recovery may not be possible. In some extreme cases, the generator magnetic field will collapse, rendering the generator useless. Testing with a resistive/inductive load bank permits loads to be introduced that have the same characteristics as actual "real world" loads. Automatic transient response tests can be configured by sophisticated load bank control systems to verify voltage regulator operation.

Load Bank Testing to Verify Governor Operation

Governors are devices that monitor, limit and determine engine speed under various conditions. There are three (3) main types of governors: velocity, mechanical and electrical.

- Velocity Governors: Are designed to run on a vacuum, and mount between the carburetor and the intake manifold. These governors limit the maximum RPM of an engine, and as such act as a protective device.
- Mechanical Governors: Will not only limit top speed (as do velocity governors) they will also allow the engine to react while under a sudden load.
- Electronic Governors: Pick up the engine speed from the flywheel ring gear's teeth and control it electronically.

No matter what type of governor, all genset engine governors respond to loading by reducing engine speed. The resulting initial voltage drop using 75% load at 0.80 power factor results in a voltage drop that is approximately 25% greater when compared to the equivalent resistive only load application. The engine speed related voltage drop is also similar.

Load Bank Testing to Verify Cooling System Operation

A load test causes the generator to inject additional heat into the cooling air stream, which will highlight any weakness in the cooling system. This additional heat will also stress major cooling system components like radiator, oil cooler and thermostat. The collection of genset heat data from a load bank testing will also help determine the temperature differential (Delta T). This temperature data can be used to verify genset compliance or as another data point for troubleshooting any system air restrictions. Load testing will also verify the operations of cooling system alarms like the engine coolant overheat, and high cooling water temperature alarm.

Load Bank Testing to Verify Fuel System Operation

Modern diesel engines are typically highly turbocharged, and are prone to over fueling and poor combustion at low loads. Unless the engine is run at a load high enough to generate high exhaust temperatures and flow velocities, the deposits will coat engine exhaust surfaces including turbo turbine wheels, exhaust piping, mufflers/silencers, and installed exhaust after treatment systems. Initially this is only a nuisance, however allowed to build up, it will affect engine performance (turbo does not spin up as it should because of debris on the hot wheel), and allowed to go on further will generate a fire hazard by building up combustible debris in the exhaust system.

Wet Stacking: Diesel-driven units are subject to the condition above which is known as “wet stacking”. Wet Stacking occurs from operation under no-load or light-load conditions. Operation in an unloaded condition (such as extended idle time) or continual use at less than the recommended minimum load level causes fuel deposits to collect on the combustion chamber, injector nozzles, piston rings, turbocharger, and exhaust system. The result is diminished engine output capacity. Regular load bank testing burns off accumulated deposits and preserves engine output capability. The amount of minimum load varies per engine manufacturer, but the typical range is 30% to 50% of the kilowatt rating. It is also a proven fact that diesel engines operate more efficiently in the 70% to 80% range of rated kW output.

Load testing will also help identify any potential failures resulting from plugged fuel filters, fuel/injection pump, fuel overheating and cooler operation.

Load Bank Testing to Verify Control Operation

Genset solid-state controls and power supplies are particularly sensitive to transients and can shut down unexpectedly during load changes. Some modern gensets are backed up with a dedicated power source capable of riding through the voltage and frequency transients associated with loading. However, the basic fact remains that a resistive and inductive load test provides the best means to ensure proper generator operation. Many control and electrical issue like circuit breaker trip settings, voltage and frequency adjustments, voltage regulator performance and loose or failed connections can be uncovered during a load test procedure. Resistive and inductive load bank testing provides a best-case simulated real-world condition where voltage-drop, harmonics, and efficiency can be analyzed more effectively. Testing with a resistive-only load bank, a system would not necessarily provide an indication of a power supply or control system condition that would lead to a potential problem during operation.

Resistive vs Resistive Inductive Load Testing

Some load banks contain resistive elements only and therefore cannot provide a true simulation of the loading that the genset will be subjected to in actual service. Most gensets are rated in kW at a specified power factor (for example, 1000 kW at 0.8 PF). These ratings reflect the actual load conditions that the unit will be called upon to satisfy.

A resistive only load test will confirm the engine's ability to provide kW, and the generator's ability to deliver an equivalent (equal) amount of kVA. A resistive only test will not "stress" the generator through actual operating conditions. In reality, only engine performance is validated in a resistive-only test.

With a resistive/Inductive load bank, inductive and resistive are designed to yield a total value of impedance that exposes the engine and generator to the loading that they will experience in actual service. Testing at generator nameplate values requires a resistive/inductive load bank.

The critical differences between testing with a resistive-only load bank and a resistive/inductive load bank are compared in Table 1. A resistive-only load bank can provide adequate testing of the individual prime mover and load sharing (including load add/load shed) controls of a multiple unit facility.

The ability to simulate varying inductive loads, which are more realistic, is the most essential benefit for a load bank that provides both kVA (resistive) and kVAR (inductive) loads. Combined resistive and inductive load bank allows testing of the alternator, load sharing, and transient responses because it apply loads that approach those experienced during normal genset operation (see Table 2).

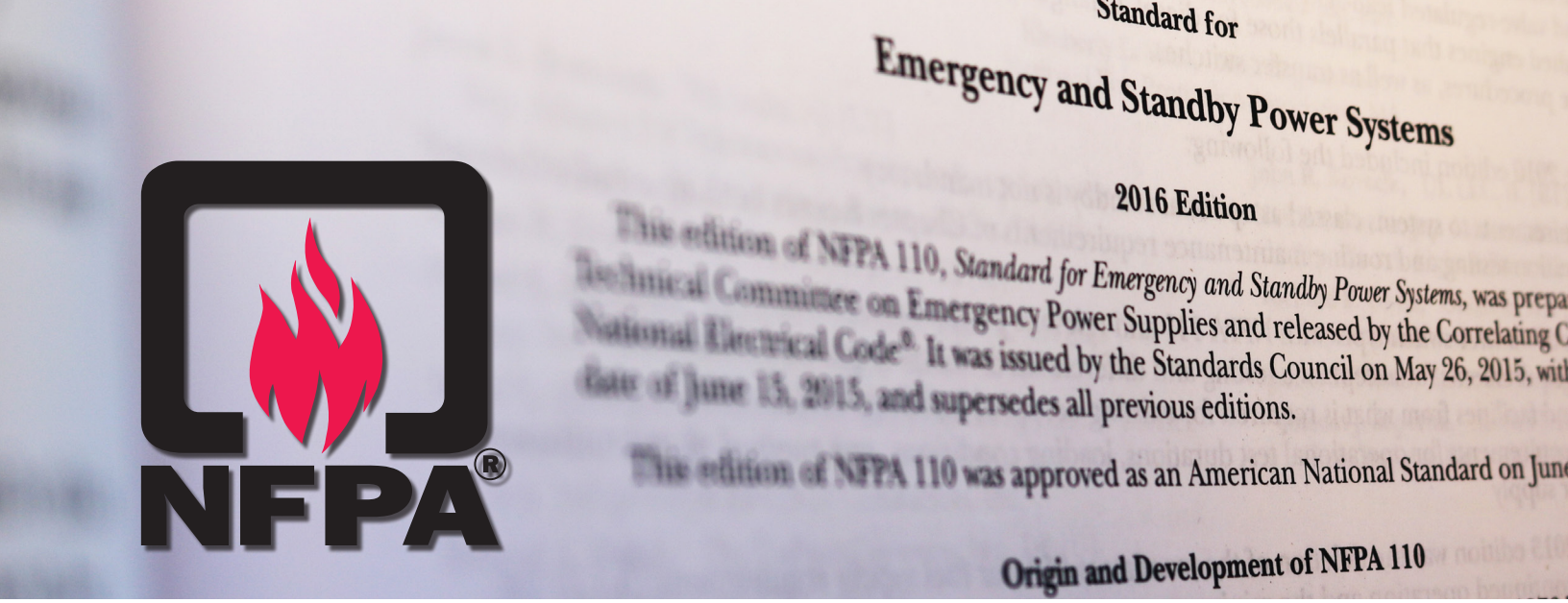
Resistive Only and Resistive/Inductive Load Bank Testing Comparison

Resistive Load Bank Testing kW = kVA at unity power factor	Resistive/Inductive Load Bank Testing Inductive power component
Tests the prime mover (engine) at 100% load	Tests the alternator and voltage regulator at its fully rated (kVA/kVAR) capacity
Tests the full delivery system operation at maximum rating and fuel consumption	Simulates the actual load (kW, kVA, and kVAR) for which the systems are specified and designed
Demonstrates the cooling system operation at the gensets full operating capacity	Simulates transient loads to provide voltage and frequency response characteristics
Allows the exhaust and after-treatment system to reach normal operating temperatures	Simulates and verifies synchronizing, load sharing, and voltage regulation on multiple unit paralleled systems under actual load conditions
Eliminates exhaust wet-stacking by burning off built-up carbon deposits from unburned fuel and oil, and reseats the rings when partial- or low-load conditions are encountered during periodic testing	Allows thermographic/infrared inspection of the electrical systems; identification of potential hot spots; and the condition of cables, terminations and buss work
Evaporates moisture from the engine oil, which reduces wear-causing acid formation	
Identifies deficiencies that can be corrected with proper maintenance and repair before failure, avoiding downtime and additional expenses	

Resistive and Resistive/Inductive Load Bank Comparison

Characteristics	Resistive Load Bank	Resistive/ Inductive Load Bank
Prime Mover Capacity (kW)	Yes	Yes
Prime Mover Controls	Yes	Yes
Alternator Capacity (kVAR)	Limited	Full Load
Alternator Controls	Limited	Yes
Load Sharing Controls	kW only	kW and kVAR
Distribution Buss	Limited	Full Load
Transient Response (Hz)	Yes	Yes
Transient Response (Voltage)	Limited	Yes

Table 1 (above) and Table 2 (left) Resource data for table from "Consulting-Specifying Engineer" (www.csemag.com) 11-12-2013 article.



A Round-Up of Code Requirements

In most cases, emergency power generating systems must comply with a number of different code requirements based on National Fire Protection Association (NFPA) 110, Joint Commission, Environmental Protection Agency (EPA) Tier regulations, and National Electrical Code (NEC) specifications. Here is a rundown of the major industry standards and codes that cover emergency power generation and testing.

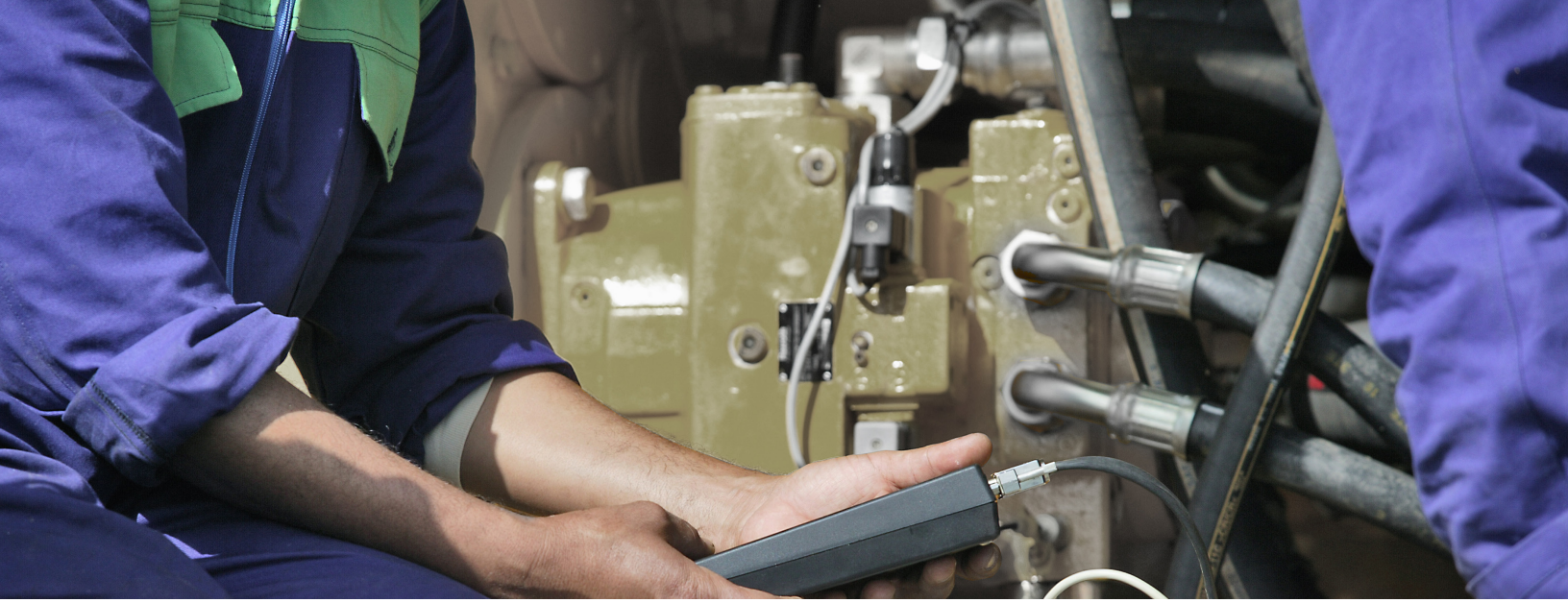
NFPA 110 Emergency Generator Testing Requirements sets safety standards to protect commercial building occupants by making sure generator-powered backup lighting will operate as expected. A monthly test is performed on generators whose failure could result in death or injury. Should a generator fail this monthly test, it should undergo load bank testing for two continuous hours annually, per Section 8.2.4.3. It is not mandatory to use load banks, but most buildings' total load values are below the higher monthly testing requirements. Under the continuous test, the generator should be operated at 25 percent of the nameplate kilowatt rating for 30 minutes, at 50 percent of the kilowatt rating for 30 minutes and at 75 percent of the kilowatt rating for 60 minutes.

NEC 700 Emergency Systems are legally required to receive an operating permit as determined by the local code enforcement authority. This electrical code requirement is essentially a people-oriented lifeline, ensuring that lighting and controls for occupant life safety loads take priority over other building loads. Should the main electrical power supply fail, backup emergency power for life safety systems must be available within 10 seconds.

NEC 701 Legally Required Standby Systems are the next priority, after NEC 700. NEC 701 requires standby power to be available in 60 seconds or less after a power loss to certain legally required standby systems. Basically, NEC 700 is designed for people who are exiting the building, while NEC 701 responds to the needs of firefighters and other personnel responding to the emergency.

NEC 702 Optional Standby Systems apply to situations where standby generators are optional. In these cases, the systems may be put in place to protect economic loss or business interruptions. For instance, data centers may lose millions of dollars from lost power.

NEC 708 Critical Operations Power Systems (COPS) came into being through the U.S. Department of Homeland Security after 9-11, Hurricanes Katrina and Rita, and other disasters. This code requires a commissioning plan for on-site backup generation, baseline testing, and periodic witness testing, as well as a documented preventive maintenance program, written records of testing, and the way for testing all critical power systems during maximum anticipated load conditions.



Joint Commission requirements encourage hospitals, health centers, and nursing homes to go beyond local, state, and national electrical codes, thereby ensuring that emergency power systems provide patient safety and prevent loss of life. Periodic testing is required for all healthcare facilities, preferably under higher loads than the 30 percent minimum. At least once every three years, all healthcare facilities are required to exercise the power system under the facility's actual load and full emergency conditions for at least four hours.
In 2014, the Joint Commission announced changes to monthly generator load testing, permitting it to be done anytime during the month, rather than the previous requirement of no less than 20 days and no more than 40 days from the previous monthly load test.

EPA Tier Level regulations apply to emissions from modern diesel generators, when operated at loads of more than 50 percent. Using load banks allows for simultaneously testing multiple units, thereby reducing the time required to perform and document mandatory testing to ensure the electronic engine and emissions controls are operating at the manufacturer's recommended load levels and temperatures.

ISO 8528 applies to test methods and criteria for measuring the alternating current of generation sets that are driven by reciprocating internal combustion engines in load bank testing. In part 6 of the standard, three performance classes, Grade 1, Grade 2 and Grade 3 are defined, along with their associated performance criteria. A fourth class, Grade 4, also is available but applies to customized performance criteria determined by the supplier and the customer. Grade 2 is the normal grade specified.

Summary

With emergency generator sets becoming more mandated and commonplace, proper load bank testing becomes much more important. Selecting the proper type of load bank, be it either 100% resistive or combined resistive and inductive is critical for performance testing and troubleshooting of the genset.

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