

# **IEEE Standard Periodic Testing of Diesel-Generator Units Applied as Standby Power Supplies in Nuclear Power Generating Stations**

Sponsor

**The Power Generating Committee of the  
IEEE Power Engineering Society**

Approved December 18, 1981

**IEEE Standards Board**

Approved April 2, 1984

**American National Standards Institute**

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## Foreword

(This Foreword is not a part of IEEE Std 749-1983, IEEE Standard Periodic Testing of Diesel-Generator Units Applied as Standby Power Supplies in Nuclear Power Generating Stations.)

This standard is supplementary to ANSI/IEEE 308-1980, IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations, ANSI/IEEE Std 338-1977, IEEE Standard Criteria for the Periodic Testing of Nuclear Power Generating Stations Safety Systems, and IEEE Std 387-1977, IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations.

The IEEE has developed this standard to provide the testing criteria and requirements to demonstrate availability and performance of previously qualified diesel-generator units, including auxiliary equipment, applied as standby power supplies for nuclear power generating stations.

Adherence to these criteria may not suffice for ensuring the public health and safety because it is the integrated performance of all fluid, instrumentation, and electrical systems in the station that establishes the consequences of design basis events. Each licensee has the responsibility to ensure himself and others that this standard, if used, is pertinent to his license and that the integrated performance of his station is adequate.

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# IEEE Standard Periodic Testing of Diesel-Generator Units Applied as Standby Power Supplies in Nuclear Power Generating Stations

## 1. Scope

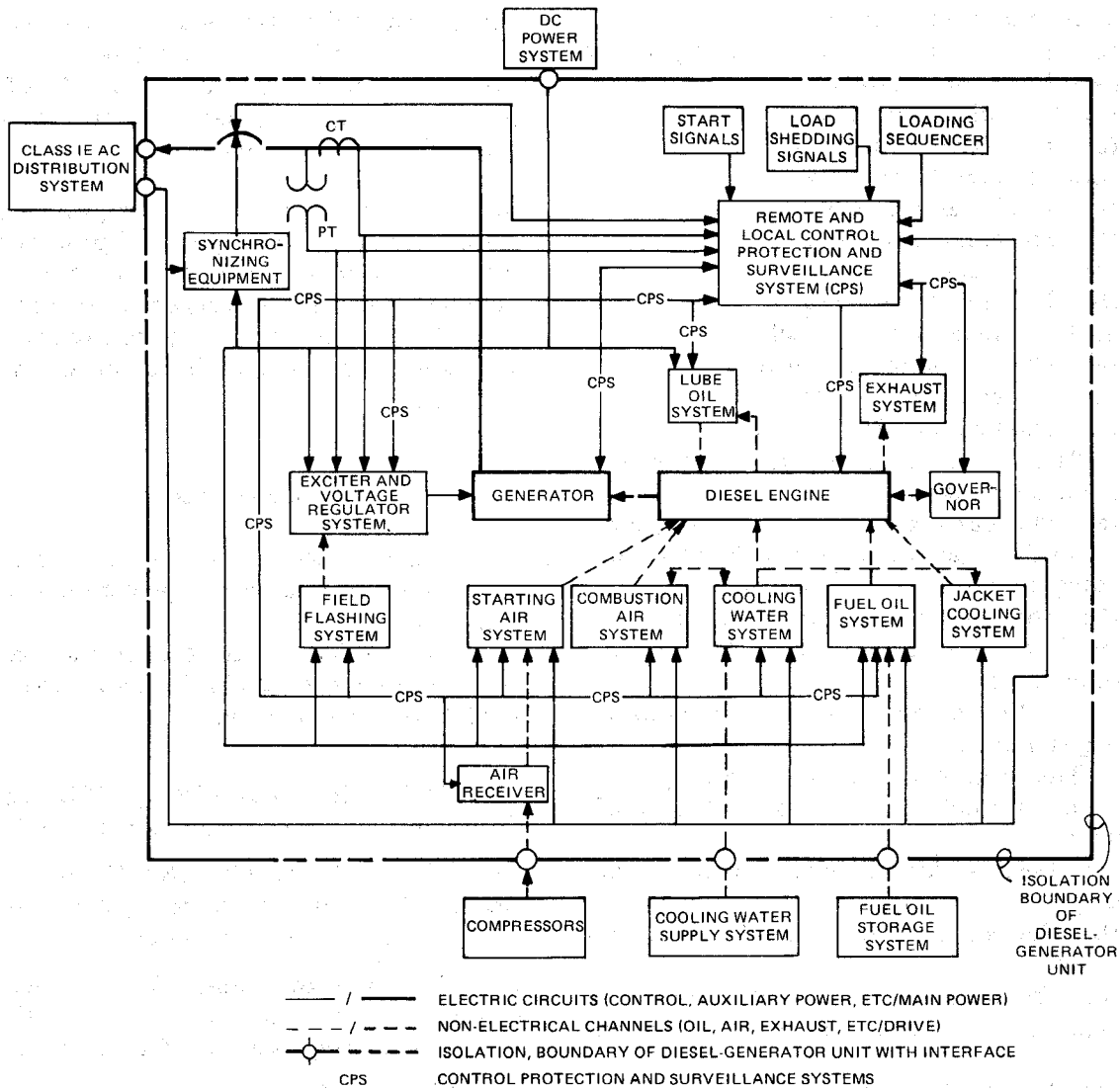
1.1 General. This standard applies to the periodic testing of diesel-generator units applied as standby power supplies in nuclear power generating stations.

## 1.2 Testing

1.2.1 Inclusions. The following periodic tests are included within the scope of this standard.

- (1) Availability tests
- (2) System operational tests
- (3) Independence verification tests.

Fig 1  
Scope Diagram



**1.2.2 Exclusions.** The following tests are excluded from the scope of this standard.

- (1) Tests to extend the qualified life of the diesel-generator unit and its components
- (2) Reliability tests of the diesel-generator units
- (3) On-site preoperational tests.

**1.3 Equipment, Systems and Subsystems.** The scope diagram presented in Fig 1 illustrates the boundaries of equipment systems and subsystems.

**1.3.1 Inclusions.** The items listed below are included.

- (1) The diesel engine, which includes:
  - (a) The starting air system, excluding compressor units and dryers
  - (b) The fuel oil system, excluding supply to the 7-day storage system
  - (c) The lubricating oil system
  - (d) The cooling water system excluding the cooling water supply system
  - (e) The jacket water system
  - (f) The combustion air system
  - (g) The exhaust system
  - (h) The governor system.
- (2) The generator, which includes:
  - (a) The voltage regulation system
  - (b) The excitation system
  - (c) The field flashing system.
- (3) The ac and dc power distribution system, which includes:
  - (a) The circuits for conveying ac power from the diesel-generator terminals up to and including the main disconnect device
  - (b) The circuits for conveying ac or dc power to the diesel-generator units and associated controls
  - (c) DC power supplies, if dedicated to the diesel-generator unit
- (4) The remote and local control, protection, and surveillance systems (CPS), which include:
  - (a) Devices for automatic and manual starting
  - (b) Devices for load shedding and sequencing
  - (c) The devices for the protection of the diesel-generator unit and its auxiliary equipment
  - (d) The synchronizing equipment

**1.3.2 Exclusion.** The components and systems which support the operation of the diesel-

generator unit and are outside the isolation boundary are excluded from the scope of this standard.

## 2. Purpose

The purpose of this standard is to provide the testing criteria and requirements which result in a periodic demonstration of availability and performance for diesel-generator units after completion of their pre-operational testing.

## 3. Definitions

**engine equilibrium temperature.** The condition at which the jacket water and lube oil temperatures are both within  $\pm 10^{\circ}\text{F}$  ( $5.5^{\circ}\text{C}$ ) of their normal operating temperatures established by the engine manufacturer.

**isolation boundary.** A supporting system, subsystem, or device (valve, control power circuit-breaker, switch, etc) which provides a boundary with the diesel-generator unit. Failures of the device or the supporting system, or subsystem are not considered diesel-generator unit failures.

## 4. References

Applicable portions of the following standards were utilized in the preparation of this standard.

Where conflicts occur between this standard and any reference standards, the provisions set forth herein shall govern.

[1] ANSI/IEEE Std 100-1977, IEEE Standard Dictionary of Electrical and Electronics Terms.

[2] ANSI/IEEE Std 308-1980, IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations.

[3] ANSI/IEEE Std 338-1977, IEEE Standard Criteria for the Periodic Testing of Nuclear Power Generating Station Safety Systems.

[4] IEEE Std 387-1977, IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations.

5. Test Requirements

5.1 General Requirements

5.1.1 An overall program designed to maintain the diesel-generator units in a high degree of readiness shall be instituted. The following items shall be included, as a minimum in the overall program:

(1) Routine inspections to ensure that all diesel-generator unit fluid levels and pressures are within design limits

(2) Routine inspections to ensure that all diesel-generator auxiliary equipment is aligned for service

(3) Routine inspections to ensure that all electrical support systems and components are aligned for service

(4) Routine inspections to ensure that all mechanical support systems and components are aligned for service

(5) A routine program to maintain the diesel-generator unit and its auxiliary equipment in accordance with the manufacturer's recommendations

(6) A routine calibration program to calibrate sensors, instruments, timers, and relays

(7) Assurance that fuel in the storage tanks meets manufacturer's specifications and is routinely tested for water, sediment, and biological contamination

Abnormal conditions discovered during the course of this program shall be evaluated to determine if they are valid tests and failures as defined in Section 6.

5.1.2 Test equipment shall not cause a loss of independence between redundant diesel-generator units or between diesel-generator load groups.

5.1.3 Periodic testing of a diesel-generator unit shall not impair the capability of the unit

Table 1  
Test Parameters

| Parameter                                  | Pre-Start | During Test | Post-Test |
|--|-----------|-------------|-----------|
| <b>Pressures:</b>                          |           |             |           |
| Lube oil — engine — inlet                  | x         | x           |           |
| Lube oil — turbo — inlet                   | x         | x           |           |
| Lube oil — engine — filter differential    |           | x           |           |
| Lube oil — turbo — filter differential     |           | x           |           |
| Fuel oil — engine header                   |           | x           |           |
| Fuel oil — filter differential             |           | x           |           |
| Crankcase                                  |           | x           |           |
| Starting air                               | x         |             | x         |
| <b>Temperatures:</b>                       |           |             |           |
| Lube oil — engine — inlet and outlet       | x         | x           |           |
| Jacket water — engine — inlet and outlet   | x         | x           |           |
| Exhaust — each power cylinder              |           | x           |           |
| Exhaust — turbo outlet                     |           | x           |           |
| Exhaust — exhaust manifold (if applicable) |           | x           |           |
| <b>Electrical:</b>                         |           |             |           |
| Frequency                                  |           | x           |           |
| Power                                      |           | x           |           |
| Reactive                                   |           | x           |           |
| Current — generator — all phases           |           | x           |           |
| Voltage — generator — all phases           |           | x           |           |
| Current — field                            |           | x           |           |
| <b>Level:</b>                              |           |             |           |
| Lube oil — engine generator crankcase      | x         |             | x         |
| Lube oil — generator bearing               | x         |             | x         |
| Jacket water — standpipe or expansion tank |           | x           | x         |

NOTE: These parameters are considered the minimum requirements for this standard. Additional parameters may be added for performance measurements.

to supply emergency power in the required time in response to accident signals.

5.1.4 All diesel-generator unit protective trips and alarms should be operative during applicable periodic testing.

5.1.5 Written procedures for testing shall be prepared and utilized.

The procedures shall include the manufacturer's applicable pretest recommendations and shall identify all special arrangements or changes in the normal system configuration required to perform the test. The procedures shall ensure that the system is restored to its normal configuration after completion of the tests.

5.1.6 Communication shall be established between the diesel-generator unit testing location and the main control room, to ensure that the main control-room operators are cognizant of the status of the diesel-generator unit undergoing the test.

5.1.7 During integrated system operational tests, problems may arise with individual components that do not detract from the overall test purpose. These components must be repaired and their interface with the system retested, however, the total integrated test need not be repeated unless necessary due to the critical function of the component involved.

5.1.8 Test procedures that involve starting and stopping the diesel-generator unit shall include the following steps and those steps (included in later subsections) that are pertinent to each specific test:

(1) Observe and record all prestart data listed in Table 1.

(2) Initiate the start signal and measure and record the elapsed time from the start signal to nominal speed.

(3) Confirm that the generator voltage and frequency are maintained within the prescribed limits for the particular circumstances of each test.

(4) Record all *During Test* data listed in Table 1 at the beginning of any load carrying test and at the end of any load carrying test and at 1 h intervals during the test, if applicable.

(5) Observe and record all post-test data listed in Table 1 after completion of the test.

5.1.9 Abnormal conditions discovered during any test shall be evaluated to determine if they

are valid tests and failures as defined in Section 6.

5.2 Specific Requirements. Periodic testing shall consist of Availability, System Operation, and Independence Verification tests.

#### 5.2.1 Availability Tests

5.2.1.1 These tests demonstrate starting and load acceptance capability. Each diesel-generator unit shall be tested independently from its redundant counterparts. These tests shall be performed at intervals of 31 days or less, as required in 6.2, depending upon the demonstrated performance of each diesel-generator unit, and shall include the following tests:

(1) Demonstrate proper starting of a diesel-generator unit and verify that required voltage and frequency are achieved automatically within prescribed limits and time.

(2) Demonstrate the full load carrying capability (continuous rating) of a diesel-generator unit. The test should be run for a sufficient interval to allow the diesel engine to reach equilibrium temperature and for a minimum of 1 h thereafter. The load test should be conducted immediately after the start test has brought the diesel-generator unit to the prescribed voltage and frequency.

5.2.1.2 The start and load tests shall include the following pertinent steps in addition to the steps listed in 5.1.8.

(1) Manually apply load to the diesel-generator unit at the maximum practical rate until continuous rating is reached.

(2) Run the diesel-generator unit at full load (continuous rating) and record the temperature data specified in Table 1 at reasonable intervals to determine when engine equilibrium temperature is reached.

(3) Run the diesel-generator unit for a minimum of 1 h after the engine equilibrium temperature has been reached.

5.2.2 System Operational Tests. This series of tests demonstrates the ability of the diesel-generator unit to perform its intended function under simulated accident conditions. These tests shall be performed at least once every 18 months and shall include the following tests:

5.2.2.1 Integrated System Test. Demonstrate proper operation during a loss of off-site power and an accident signal. Verify that the emergency buses are de-energized and shed load. Verify that the diesel-generator starts

automatically and attains voltage and frequency within prescribed limits and time. Verify the proper loading sequence and that voltage and frequency are within prescribed limits. This test shall be performed by alternating the sequences given in 5.2.2.1.1 and 5.2.2.1.2 during successive test periods.

**5.2.2.1.1** This test shall include the following pertinent steps in addition to the steps listed in 5.1.8.

Simulate an accident signal and allow the diesel-generator unit to start and achieve nominal rated voltage and speed. Then simulate a loss of off-site power and verify that the emergency bus is de-energized and applicable loads are shed. Verify that the diesel-generator unit re-energizes the emergency bus, the applicable accident loads are properly sequenced, and the voltage and frequency remain within the prescribed limits, and stabilize.

**5.2.2.1.2** This test shall include the following step in addition to the steps listed in 5.1.8.

Simulate a loss of off-site power and verify that the emergency buses de-energize and shed load, that the diesel-generator unit starts and loads, with the voltage and frequency remaining within prescribed limits. Then, simulate an accident signal and verify that the applicable connected loads are shed and the applicable accident loads are sequenced on to the bus. Verify that the voltage and frequency remain within the prescribed limits.

**5.2.2.2 Full Load Test.** Demonstrate full load carrying capability (continuous rating) for at least 8 consecutive hours. If the plant design utilizes a short time rating, then 6 h shall be at the continuous rating of the diesel-generator unit and 2 h at its short time rating. Verify that the prescribed voltage and frequency requirements are maintained and that the auxiliary systems function within their designated limits.

This test shall include the following pertinent steps in addition to the steps listed in 5.1.8:

(1) If necessary, manually synchronize to the off-site power source and load the diesel-generator unit to its full load capability.

(2) Run the diesel-generator unit for at least 8 h after temperature equilibrium is reached. If a short-time rating is a plant design basis, during the first 2 h of the test the diesel-generator unit shall be loaded to its short time rating. For the remaining 6 h of the test, the

diesel-generator unit shall be loaded to its continuous rating.

(3) The test may be terminated or one or more of the other operational tests may be conducted. If the test is terminated, record the post-test data.

**5.2.2.3 Safety Load Rejection Test.** Demonstrate proper operation during the loss of the largest single load. Verify that the voltage and frequency requirements are met.

This test shall include the following pertinent steps in addition to the steps listed in 5.1.8:

(1) With the diesel-generator unit isolated from the system, load the diesel-generator unit with available installed loads. (Not to exceed the diesel-generator unit continuous rating.)

(2) Trip a load equivalent to the largest single accident load.

(3) Verify that the voltage and frequency requirements are met.

**5.2.2.4 Full Load Rejection Test.** Demonstrate proper operation during a complete loss of the continuous rated load (short time rated load, if used in the plant design). Verify that the diesel-generator unit does not trip on overspeed or reach its overspeed setpoint.

This test shall include the following pertinent steps in addition to the steps listed in 5.1.8:

(1) With the diesel-generator carrying its continuous rated load (short time rated load if used in the plant design) disconnect the load.

(2) Verify that the diesel-generator unit does not trip.

**5.2.2.5 Synchronizing Test.** Demonstrate the ability to synchronize the diesel-generator unit with off-site power while the unit is connected to an emergency load, and transfer this load to the off-site power.

**5.2.2.6 Fuel Supply Transfer Test.** If it is a design requirement, demonstrate that the diesel-generator unit will perform properly when switching from one fuel oil supply system to another.

**5.2.2.7 Isolation Test.** Demonstrate that the capability of the diesel-generator unit to supply emergency power within the required time is not impaired during the availability test.

The following two tests shall be performed alternately during successive test periods and shall include the following pertinent steps in addition to the steps listed in 5.1.8:

(1) During an Availability Test, simulate an accident signal (off-site power still available), and verify that the diesel-generator unit isolates

from the off-site power source, remains running, and the accident loads are properly energized from the off-site power source.

(2) During an Availability Test, simulate a loss of off-site power condition and verify that the emergency bus becomes isolated from the off-site power source, the diesel generator energizes the emergency bus, and the accident loads are properly sequenced.

**5.2.2.8 Protective Trip Test.** Demonstrate the bypassing of all diesel-generator unit protective trips which are required to be bypassed during loss of off-site power concurrent with an accident signal.

Perform this test as part of 5.2.2.2.

**5.2.3 Independence Verification Test.** Subsequent to any modifications where diesel-generator unit independence may have been affected, or every 10 y (during a plant shut-down), whichever is the shorter, a test shall be conducted with redundant units automatically started and loaded simultaneously to identify common mode failures undetected by single diesel-generator unit tests. If a failure results, a common mode failure analysis shall be performed.

## 6. Criteria for Valid Tests and Failures

6.1 Valid tests and failures are based on the following criteria:

6.1.1 All start attempts (automatic, including those from valid signals, or manual) that result in a failure to start, except as noted in 6.1.2, shall be considered valid tests and failures.

6.1.2 Unsuccessful start and load attempts that can definitely be attributed to operating error, to spurious operation of a trip that is bypassed in the emergency operating mode, to malfunction of equipment that is not operative in the emergency operating mode (for example, synchronizing circuitry) or that is not part of the diesel-generator unit as defined in 1.3, shall not be considered valid tests or failures.

6.1.3 Successful starts, including those initiated by valid signals, followed by successful loading (sequential or manual) to at least 50% of continuous rating and continued operation for at least 1 h, shall be considered valid successful tests.

6.1.4 Successful starts that are terminated intentionally without loading, as defined in

6.1.3, shall not be considered valid tests or failures.

6.1.5 Successful starts followed by an unsuccessful loading attempt shall be considered valid tests and failures, except as noted in 6.1.2.

6.1.6 Tests that are terminated intentionally before completion (as defined in 6.1.3) because of an alarmed abnormal condition that would ultimately have resulted in diesel-generator damage or failure shall be considered valid tests and failures.

6.1.7 Tests that are performed in the process of troubleshooting shall not be considered valid tests. Tests that are performed to verify correction of the problem shall be considered valid tests and successes or failures, as appropriate.

6.1.8 Discovery of conditions that would have resulted in the failure of the diesel-generator unit during test or during response to a valid signal shall be considered a valid test and failure.

6.2 The interval for availability testing of a diesel-generator unit shall be no more than 31 days and shall depend on demonstrated performance. If more than one failure has occurred in the last 100 tests due to a component which is not testable independent of the diesel-generator set, the test interval shall be shortened as follows:

| Number of Failures in Last 100 Valid Tests | Test Frequency            |
|--|---------------------------|
| 1 or less                                  | At least once per 31 days |
| 2  | At least once per 14 days |
| 3  | At least once per 7 days  |
| 4 or more                                  | At least once per 3 days  |

However, if repair or replacement is necessary for a component which is independently testable, then satisfactory component performance may be established separately before initiating a full diesel-generator unit test, which would be counted in the above statistics.

Repeated unnecessary rapid starts of the diesel-generator set are ultimately degrading to the engine and should be minimized.

#### 7. Recording Results

All start attempts, including those from valid signals, shall be logged. The log shall describe

each occurrence in sufficient detail to permit independent determination of statistical validity, in accordance with Section 6.

Cumulative records of inspections, maintenance, and test data should be maintained. This data shall be analyzed for trends of critical failure mechanisms, human errors, and common mode failure.

