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# DOE STANDARD

# BACKUP POWER SOURCES FOR DOE FACILITIES

**U.S. Department of Energy**
**Washington, D.C. 20858**

**AREA EDCN**

FOREWORD

1. This Standard is approved for use by the U.S. Department of Energy (DOE). This Standard is not a DOE Order, and its requirements are not automatically invoked at any facilities or on any BACKUP POWER SOURCES. This Standard is intended for use by the operations/field offices or management and operating (M&O) contractors at their discretion. Activities applying this Standard must tailor the requirements to the specific application as discussed in 6.3. This Standard may be invoked by contractual documents, procurement documents, or in the authorization basis for a facility. Unless it is invoked as above, the contractor will not be assessed or inspected against its requirements. This Standard is also suitable for voluntary use by engineers responsible for BACKUP POWER SOURCES at DOE facilities.

2. Acronyms used in this Standard are defined in Section 3 and are therefore not spelled out at their first occurrence. Terms defined in Section 3 are CAPITALIZED in the text.

3. Beneficial comments (recommendations, additions, deletions) and any pertinent data that may improve this document should be sent to: DOE Backup Power Working Group, in care of John Fredlund, DP-45 GTN, U.S. Department of Energy, 19901 Germantown Road, Germantown, MD 20874-1290. The back page of this document may be copied for this purpose.

4. This Standard was prepared in cooperation with and using input from the members of the Backup Power Working Group (BPWG).

The charter of the group is as follows:

The DOE BPWG fosters safe, practical, and effective testing, maintenance, operation, design, and installation of systems and equipment used to provide backup electrical power at DOE facilities. The BPWG provides an open forum on standard practices, safety issues, training, and solutions to problems encountered at DOE facilities. The BPWG promulgates its learning throughout the DOE complex and industry.

To fulfill its charter, the BPWG will:

* Share practical design and operating experience with BACKUP POWER SOURCES by promoting a continuing exchange among DOE contractor personnel, Headquarters (HQ), Operations Offices, and industry.

* Examine existing standards applicable to BACKUP POWER SOURCES and adopt, endorse, or tailor them for DOE applications.

* Identify and apply techniques to achieve and maintain reliability and availability commensurate with mission/safety objectives.

* Promote worker safety, public safety, protection of the environment, and the DOE mission in the application of BACKUP POWER SOURCES.

* Exchange successful and cost-effective management techniques.

* Identify potential means for coordination of training among DOE facilities.

* Discuss graded approaches for conformance with DOE orders.

In the course of meeting this obligation, the BPWG was instrumental in the development and adoption of this Standard. The BPWG provides unique expertise (by virtue of its involvement in the development of this Standard and its responsibilities within the organizations maintaining BACKUP POWER SOURCES) to beneficially impact the reliability of BACKUP POWER SOURCES through promotion and facilitation of the use of this Standard. For information on the BPWG, see http://www.dp.doe.gov/CTG/bpwg/bpwg.htm or contact John Fredlund, DP-45, phone (301) 903-3059.

5. ENGINE GENERATORS, UNINTERRUPTIBLE POWER SUPPLIES, and STATIONARY BATTERIES are used to provide electrical power to equipment upon loss of the normal source when either external (GRID) or internal (plant equipment) failures occur. The need for this backup power ranges from supplying safety class equipment to convenience only. BACKUP POWER SOURCES may be classified under a number of different authorities. Some important aspects of the availability of electrical power are derived from public health and safety, environmental concerns, plant security, costs related to lost production, damage to products or equipment, critical operating considerations, compliance with Occupational Safety and Health Administration (OSHA) requirements, and communications. Reliable performance of the required functions of backup and emergency sources can be ensured through proper engineering, installation, appropriate testing, and maintenance. This can be seen from a University of Dayton Research Institute study of diesel generator failures that resulted in several recommendations to improve diesel generator reliability (see Appendix I).

6. This Standard identifies fundamental criteria, surveillance testing, reporting, and reliability program considerations, which if properly implemented, should improve and maintain capable and reliable backup and emergency power sources. Maintenance programs for BACKUP POWER SOURCES are also required by DOE 4330.4, Maintenance Management Program.

7. In the process of developing this Standard, industry standards (including those of the National Fire Protection Association (NFPA), and the Institute of Electrical and Electronics Engineers (IEEE)) and guidance were reviewed. This Standard incorporates those requirements and guidance from industry standards considered appropriate for backup power system equipment important to worker safety and/or the DOE mission at DOE Hazard Category II facilities. Category I facilities (as defined in DOE STD-1027-92) may place more stringent requirements on design, maintenance and testing commensurate with the safety significance of the power source.

8. This 2000 revision of this standard was unanimously supported by users from several DOE sites. It has been updated and slightly rearranged. Several requirements were softened based on field experiences. Section 4.1 was changed to take advantage of DOE-STD-3024. Sections 5.3.1 and 5.4.1 were reworded to take advantage of DOE-SPEC-3018, DOE-SPEC-3019, and DOE-SPEC-3021.

CONTENTS

1. SCOPE

1.1 Applicability. This Standard establishes fundamental requirements and guidance for BACKUP POWER SOURCES at DOE facilities.

1.2 Purpose. The purpose of this Standard is to document good engineering practices for the installation, testing, and maintenance of BACKUP POWER SOURCES at DOE facilities. The term "BACKUP POWER SOURCES" as used in this Standard covers both "emergency" and "backup" power applications. These sources typically supply loads used to protect health and safety of the public, workers, and the environment; and to reduce the consequences of postulated events involving nuclear, chemical, or other hazards or having an adverse impact on the DOE mission. This Standard applies to design and operating practices for both permanent and temporary installations used while permanent power sources are being serviced. Examples of BACKUP POWER SOURCES covered by this Standard are those which supply power to nuclear safety systems, radiation monitors and alarms, fire protection systems, security systems, data processing equipment, and emergency lighting. The significance of each individual BACKUP POWER SOURCE application should be analyzed to determine the design requirements and classification levels. See 4.1 for more information on the significance of BACKUP POWER SOURCES. This Standard does not provide criteria to establish the need for or level of importance of BACKUP POWER SOURCES.

This Standard is not intended and should not be used as the sole source of information to develop design requirements for specific applications. Other requirements such as those found in DOE Order 420.1, Facility Safety, may apply to BACKUP POWER SOURCES depending on their application. The many appropriate recommended practices presented in this Standard should be implemented to maintain the reliability and availability of BACKUP POWER SOURCES at acceptable levels for both nuclear and non-nuclear safety applications.

1.3 Background. As a result of concerns expressed by former Secretary of Energy James D. Watkins over the number of incidents where BACKUP POWER SOURCES failed to provide electrical power during tests or actual demands, an Augmented Evaluation Team (AET) was formed to evaluate the reliability and availability of BACKUP POWER SOURCES at DOE DP facilities. The AET conducted a series of on-site reviews for the purpose of understanding the design, operation, maintenance, and safety significance of emergency and backup power supplies. The AET found that the quality of programs related to maintenance of backup power systems varied greatly among the sites visited (and often among facilities at the same site), and identified areas where the reliability of emergency and backup power systems should be improved. This Standard was originally developed to provide a vehicle for BACKUP POWER SOURCE reliability improvement to respond to the Secretary's concern and the findings of the AET.

## 2. APPLICABLE DOCUMENTS

Unless otherwise specified by contract, solicitation, or purchase order, the current issue of the following documents form a part of this document to the extent specified herein.

2.1 Government documents.

2.1.1 DOE standards, handbooks, technical standards lists (TSLs), and specifications.

DOE-STD-1027-92 - Hazard Categorization and Accident Analysis Techniques for Compliance with DOE 5480.23, Nuclear Safety Analysis Reports

DOE-STD-1073-93 - Guide for Operational Configuration Management Program including the Adjunct Program of Design Reconstitution and Material Condition and Aging Management

DOE-STD-3024-98 - Content of System Design Descriptions

DOE-SPEC-3018-96 - Flooded-Type Lead-Acid Storage Batteries

DOE-SPEC-3019-96 - Valve-Regulated Type Lead-Acid Storage Batteries

DOE-SPEC-3021-97 - Uninterruptible Power Supply Systems

DOE-HDBK-1092-98, Electrical Safety

2.1.2 Other Government documents, drawings, and publications.

DOE O 420.1 - Facility Safety

DOE 4330.4 - Maintenance Management Program

DOE 5480.23 - Nuclear Safety Analysis Reports

Federal Specification VV-F-800, Fuel Oil

NRC Publication NUREG/CR 0660 - Enhancement of On-Site Emergency Diesel Generator Reliability

NRC Regulatory Guide 1.160 - Monitoring the Effectiveness of Maintenance at Nuclear Power Plants

NRC Regulatory Guide 1.9 - Selection, Design, Qualification, and Testing of Emergency Diesel Generator Units Used as Class 1E Onsite Electric Power Systems at Nuclear Power Plants

2.2 Non-Government publications.

ANS 59.51 - Fuel Oil Systems for Safety-Related Emergency Diesel Generators

ANSI/IEEE Std 944 - IEEE Recommended Practice for the Application and Testing of Uninterruptible Power Supplies for Power Generating Stations

ASTM D975 - Standard Specification for Diesel Fuel Oils

ASTM D4057 - Standard Method of Sampling Petroleum Products

IEEE Std 387 - Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations

IEEE Std 446 - Emergency and Standby Power Systems for Industrial and Commercial Applications

IEEE Std 450 - Recommended Practice for Maintenance, Testing, and Replacement of Large Lead Storage Batteries for Generating Stations and Substations

IEEE Std 484 - Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications

IEEE Std 485 - Recommended Practice for Sizing Large Lead Storage Batteries for Generating Stations and Substations

IEEE Std 762 - Standard Definitions for Use in Reporting Electric Generating Unit Reliability, Availability and Productivity

IEEE Std 1106 - IEEE Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications

IEEE Std 1115 - Recommended Practice for Sizing Nickel-Cadmium Batteries for Stationary Applications

IEEE Std 1187 - IEEE Recommended Practice for Installation Design and Installation of Valve-Regulated Lead-Acid Storage Batteries for Stationary Applications

IEEE Std 1188 - Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications

NFPA 37 - Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines

NFPA 110 - Standard for Emergency and Standby Power Systems

NFPA 111 - Standard on Stored Electrical Energy Emergency and Standby Power Systems

## 3. DEFINITIONS

All key terms used in this Standard are defined below.

3.1 Acronyms used in this Standard.

a. ac - alternating current

b. AET - Augmented Evaluation Team

c. ANSI - American National Standards Institute

d. ASTM - American Society for Testing & Materials

e. BPWG - Backup Power Working Group

f. C - Centigrade

g. dc - direct current

h. DOE - Department of Energy

i. DP - Defense Programs

j. EG - ENGINE GENERATOR

k. g - grams

l. HQ - Headquarters

m. IEEE - Institute of Electrical & Electronics Engineers

n. kw - kilowatt

o. M&O - management and operating

p. mm - millimeters

q. NCR - Nonconformance Report

r. NRC - Nuclear Regulatory Commission

s. NFPA - National Fire Protection Association

t. OSHA - Occupational Safety and Health Administration

u. RCA - Radiologically Controlled Area

v. RWP - Radiation Work Permit

w. STD/Std - Standard

x. UPS - UNINTERRUPTIBLE POWER SUPPLY

3.2 Backup Power Source. Power source used to supply electrical power when the normal source is unavailable. For simplicity, this Standard uses the term "backup" as an all-encompassing term. "Emergency" is generally used only when the power source is required for nuclear safety or to ensure personnel safety.

3.3 Continuous rating. Maximum continuous power output the EG can maintain in the service environment without necessitating deviation from the manufacturer's recommended scheduled maintenance.

3.4 Design Requirements. As defined by DOE-STD-1073.

3.5 Droop mode. Mode in which the EG speed is governed as a monotonic function of engine load, used when operating in parallel with the GRID to avoid instability problems.

3.6 Engine generator. Independent electrical power supply unit consisting of an internal combustion engine (diesel, gasoline) directly coupled to an electrical generator with associated instrumentation, controls, protective features, and auxiliary systems.

3.7 Equalizing charge. A charge applied to a battery, which is greater than the normal float charge and is used to completely restore the active materials in the cell, bringing the cell FLOAT VOLTAGE and the specific gravity of the individual cells back to "equal" values.

3.8 Float voltage. A continuous voltage supplying a low current from a battery charger applied to a battery in the standby mode to make up for internal losses and maintain the battery in a fully charged state.

3.9 Grid. Offsite and/or onsite interconnected electrical power distribution system.

3.10 Hot restart. Restart of an EG from its continuous duty equilibrium temperature.

3.11 Isochronous mode. Mode of operation of an EG whereby it establishes its own operating speed to maintain the correct frequency over the load range capacity of the EG.

3.12 Load breaker. Breaker that feeds and protects a load, located between the power source bus and the load.

3.13 Output breaker. Breaker located between the BACKUP POWER SOURCE's output terminals and the bus feeding loads, intended to protect the BACKUP POWER SOURCE from various fault conditions and to provide a means to connect and disconnect the source from its load.

3.14 Performance Discharge Test. Test that measures the existing capacity of a battery, to be compared to its rated capacity. The usual units of capacity are ampere-hours.

3.15 Short-time rating. Output rating (typically 110%) of an EG that can be sustained for a specified time in a specified period of operation without necessitating deviation from normal scheduled maintenance (usually 2 hours in 24, per IEEE Std 387).

3.16 Standby conditions. Normal equilibrium status of an EG ready to receive a start signal, either cold start or the conditions maintained by a keep-warm and continuous lubrication system.

3.17 Stationary Battery. A system consisting of a group of battery cells (connected in series, parallel, or combination) normally operated in parallel with a charger(s) and a load.

3.18 Synchronization. Bringing one ac power source of the same nominal frequency as another into the same frequency and phase angle of the other in order to avoid excessive current flow when paralleling two ac sources.

3.19 Uninterruptible power supply. A system intended to provide a continuous source of power, without delay or transients, upon degradation or failure of the normal source of power

## 4. GENERAL REQUIREMENTS

4.1 System Design Description. New BACKUP POWER SOURCE installations shall be described in a system design description according to DOE-STD-3024. Owners of existing BACKUP POWER SOURCE installations should consider preparing a system design description using DOE-STD-3024 as guidance. Consideration should include the safety application of the installation, its importance to DOE's mission, and the potential consequences of failure (for example, excessive costs or delays).

When identifying the system functions of a BACKUP POWER SOURCE, the “System Functions” section of the system design description should address the effects of both normal and BACKUP POWER SOURCE failures, any need for electric power for safe shutdown of the facility, and prevention or mitigation of credible accidents.

The following list gives samples of bases that may be identified in the “Requirements and Bases” section of the system design description.

* Legally required by Local, State and Federal (Codes and Rules).
* Necessary to prevent release of materials (radioactive or toxic) harmful to the public and/or the environment.
* Necessary to protect plant/building occupants from serious injury or health effects.
* Necessary for plant security.
* Necessary to prevent damage to equipment or products (loss of heating, loss of refrigeration, fire.)
* Necessary to minimize lost production.
* Necessary for plant communications.
* Necessary to maintain equipment for restoring normal power.

The following list gives examples of requirements that may be addressed in the “Requirements and Bases” section of the system design description.

* Load lists with load power requirements and load functions;
* Load profile/sequence for various abnormal or accident conditions;
* Method of load transfer or connection to normal offsite power;
* Reliability or availability;
* Protective features; and
* Equipment control and protective setpoints.

4.2 Conflicting Requirements. This Standard does not relieve the contractor from contractual or other mandatory requirements.

4.3 Control of changes. Modifications to system design, installation, or documentation shall be under the auspices of the facility's formal change control program. DOE-STD-1073-93 provides guidance for a facility change control program.

4.4 Ownership. A single specific organization or individual/position should be identified as the "owner" for each BACKUP POWER SOURCE. Typically the "owner" is the one having possession of equipment and control of its operation. The owner shall have the responsibility and authority for ensuring that appropriate maintenance and testing activities are performed to sustain equipment reliability and availability. The owner should be cognizant of all users and of the types and safety classifications of all loads on the power sources. The owner should ensure that all users are apprised of the types and classifications of all other users' loads and the scheduling, problems, and maintenance/repair/testing activities on BACKUP POWER SOURCES. Owners should cooperate with maintenance organizations in scheduling maintenance activities. The owner should get concurrence from the user in the scheduling of all maintenance/repair/testing activities relative to the BACKUP POWER SOURCES on which the user depends.

4.5 User(s). A user is considered to be a specific organization or individual/position that uses or depends on the BACKUP

POWER SOURCE. The owner is often one of the users. Each user should ensure that the owner is aware of the types and safety classification of all the user's loads on the power source.

4.6 Identification plaque. A plaque or other permanent sign should be located at the BACKUP POWER SOURCE identifying the equipment, the owner and the user(s).

4.7 Maintenance requirements. BACKUP POWER SOURCES shall be maintained in accordance with DOE 4330.4, manufacturer's recommendations, and the detailed requirements in Section 5. At least two persons should always be present when working on backup electrical power systems. Refer to DOE-HDBK-1092, federal, state, and local policies for safety practices that may apply.

4.7.1 Maintenance records. All repairs, maintenance, and tests for BACKUP POWER SOURCES shall be documented and records maintained.

4.7.2 Coordination. Maintenance organizations should obtain authorization from users prior to conducting maintenance/repair/test activities on BACKUP POWER SOURCES. Scheduling of maintenance activities should be coordinated with owners.

4.7.3 Centralized Maintenance. Sites or facilities should consider whether to establish centralized maintenance of BACKUP POWER SOURCES.

4.8 Testing. BACKUP POWER SOURCES shall be tested in accordance with Section 5. Detailed step-by-step procedures shall be provided for performing testing and surveillance activities. The procedures shall include the appropriate information specified in Section 5. Any test that demonstrates equipment being tested does not meet a DESIGN REQUIREMENT shall constitute a failure. Performance data should be recorded for all tests and actual demands, including tests from standby mode, monthly/weekly testing, loss of normal power simulations, and the like. Performance data should not be recorded for maintenance troubleshooting activities.

# 5. DETAILED REQUIREMENTS

5.1 Requirements applicable to all BACKUP POWER SOURCES. The following requirements are applicable to ENGINE GENERATORS, UNINTERRUPTIBLE POWER SUPPLIES, and STATIONARY BATTERIES:

5.1.1 Internal events. The BACKUP POWER SOURCE shall have the capability to perform its required function over the expected range of environmental and load conditions independent of the normal sources of power. The environmental considerations shall include the effects of anticipated operating conditions and failed plant equipment that may have an adverse impact on the ability of the BACKUP POWER SOURCE to perform its function.

5.1.2 External events. The BACKUP POWER SOURCE, associated distribution systems, and necessary support systems, shall be protected against those events likely to produce a loss of normal power. Examples of such events are hurricanes (high winds), tornadoes, floods, ice storms, lightning, fire, and seismic events. The level of protection should be related to the expected frequency and consequences of total loss of ac power due to the particular event.

5.1.3 OUTPUT BREAKERS. OUTPUT BREAKER protection and LOAD BREAKER protection shall be coordinated in accordance with NFPA 110. A fault on an individual load or circuit should not trip the BACKUP POWER SOURCE'S OUTPUT BREAKER. OUTPUT BREAKERS should have an interrupt rating greater than or equal to the maximum available fault current at its location. OUTPUT BREAKERS should be located such that a fire at the BACKUP POWER SOURCE will not damage the bus feed circuit downstream of the OUTPUT BREAKER. This should prevent a fire at the BACKUP POWER SOURCE from causing the loss of ability to feed loads from the normal source.

5.1.4 Maintenance. A corrective maintenance and preventative maintenance program for the BACKUP POWER SOURCE and its supporting subsystems shall be established in accordance with DOE 4330.4. The program should be based on the inspection activities, intervals, and parts replacement periods recommended by the manufacturer. The program should take into consideration the type of service to which the BACKUP POWER SOURCE is subjected (for example, continuous duty or standby service with the number of expected demands/year). The program inspection and replacement intervals may be adjusted based on documented experience with the particular or similar equipment. The level of detail and rigor applied in a maintenance program should be appropriate to the significance of the BACKUP POWER SOURCE'S failure to function under loss of normal power conditions. This may result in graded requirements for maintenance varying from repair-on-failure to manufacturer-recommended periodic maintenance, or other based on documented experience and failure analysis.

5.1.4.1 Management control. For any maintenance program to be effective, maintenance priority must be established by all management levels. Management objectives and control of maintenance activities shall conform to DOE 4330.4 with particular emphasis as follows:

a. Management shall define the goals, organizational structure, and lines of authority and responsibility for the maintenance program.

b. Management shall assign the responsibility for the development of a program and procedures for the implementation of maintenance, and approve the developed program.

c. Management shall ensure adequate training to qualify maintenance personnel.

d. Management shall identify performance indicators and criteria to be utilized to measure equipment, systems, and personnel effectiveness in maintenance activities. (Additional guidance to be used in formulating performance goals may be found in NRC Regulatory Guide 1.160.)

e. Management shall periodically evaluate the effectiveness of the maintenance program (recommended minimum frequency - 18 months).

5.1.4.2 Qualification of maintenance personnel. DOE 4330.4 provides requirements for qualification and training of maintenance personnel. The required level of qualification of maintenance personnel depends on the level and type of involvement in maintenance activities. Important aspects such as safety practices, failure analysis, inspection, control adjustments, testing, calibration, disassembly, and parts replacement require appropriate training and experience. Training should include specific manufacturer's operating and maintenance manuals and the plant procedures to be followed when performing testing and maintenance as well as specific training on identical or similar equipment to be maintained. When maintenance is provided by an offsite contractor, that contractor's personnel shall have equivalent training and qualification.

5.1.4.3 Maintenance records. Maintenance activities shall be documented and records maintained and utilized. DOE 4330.4 provides requirements for records. Maintenance records provide the performance history of a BACKUP POWER SOURCE and its associated support systems. They are also used to establish parts replacement intervals that will reduce the potential for failure when a loss of normal power occurs. Maintenance records provide essential information for evaluating the effectiveness of the maintenance program. The maintenance records should be comprehensive and well organized to facilitate ready retrieval of information for analysis. The following should be included in the maintenance records as appropriate:

* All inspection and maintenance activities
* Start Reliability (IEEE Std 762 definition)
* All failures, during either testing or operation, or during walkdowns
* Failure analysis and identified cause(s)
* Corrective action(s)
* Out-of-service time
* All part replacements
* Modifications
* Critical or selected operating parameters (for trending)

5.1.4.4 Maintenance Data. A set of operating data should be recorded periodically according to manufacturer's recommendations. The data should be recorded for standard operating conditions. This data is used to determine trends in operating performance as a basis for predictive maintenance actions, and is a ready reference for maintenance and manufacturer personnel in servicing the BACKUP POWER SOURCE.

5.1.5 Testing. The requirements below shall be applied to all testing of BACKUP POWER SOURCES.

5.1.5.1 Test Procedures. Test procedures for BACKUP POWER SOURCES shall include acceptance criteria, review and approval blocks for critical steps, prerequisites, precautions, and other sections to record the information identified in 5.1.5.2. An example of a maintenance/test procedure with associated data sheets is included in Appendix II.

5.1.5.2 Test records. All test activities shall be recorded and records retained. The records should identify the date, time, names of test personnel, type of test procedure conducted, "as found" and "as left" conditions, values of monitored parameters, length of test, unusual conditions, test results (comparison of data to criteria), and description of any failures for each BACKUP POWER SOURCE. Failures shall be defined in terms of the BACKUP POWER SOURCE'S documented requirements. Test, operating, and maintenance logs for all BACKUP POWER SOURCES should be in one comprehensive document or computer data base readily retrievable and available to maintenance and operating organizations responsible for BACKUP POWER SOURCES. Preferably, the document should be kept at the facility or site level. The identity of information (data) related to each BACKUP POWER SOURCE should be preserved.

5.2 EG Requirements. This section covers the EG and those associated systems necessary for its functioning. It does not include the electrical network to which it is attached beyond the generator OUTPUT BREAKER. An EG unit includes the engine, generator, starting system, automatic and manual controls, lubricating oil system, cooling water system (if not self-contained, up to the supply valves), starting energy source (if not dedicated, from the connection points on the unit), fuel supply system, and generator OUTPUT BREAKER (refer to IEEE-387 Std, Figure 1). Other components are necessary for reliability and the continued operation of the EG and are discussed in this Standard. For the purposes of determining an EG unit failure, however, they should be excluded.

Automatic transfer devices are often part of a Backup Power System. Their purpose is to automatically transfer loads between the normal power source and the BACKUP POWER SOURCE upon loss or restoration of the normal power source. Information on transfer device features can be found in NFPA 110 and IEEE Std 446.

NFPA 37 should be used for new EG installations and those portions of existing equipment and installations that are changed or modified. Appendix I provides several recommendations to improve diesel generator reliability that should be considered when modifying existing or developing new designs.

5.2.1 EG capabilities. Consideration of environmental, load, and other design factors at the specific location of the EG shall be in accordance with NFPA 110. The following paragraphs apply when specifying requirements for EGs to ensure their functional performance.

5.2.1.1 Environmental and load conditions. The EG shall have the capability to perform its required functions over the specified range of conditions during and subsequent to the loss of normal power. These conditions shall have documented operating ranges and performance indicators and shall include the following:

a. Temperature of the EG and necessary auxiliaries including expected ambient extremes and temperature rise due to the EG operation at maximum loading

b. Combustion air quality (range of atmospheric pressure, temperature, humidity, and impurities)

c. Auxiliary equipment extremes and quality (electrical, lubrication, water)

d. Type and quality of fuel

e. Expected operating cycles and hours for the design lifetime (this should include periodic testing, estimated troubleshooting, and loss of power demands)

f. The load profile (the time sequence and duration of load application) including the change in load currents resulting from the extremes of allowable voltage and frequency variations. To the extent practical, the application of loads should be at known time intervals. The loading sequence shall ensure that random loads cannot occur in a manner to overload the EG. "Permissive," as opposed to "demand," start signals shall be evaluated to ensure the loading profile is not compromised and to identify random loading problems. Automatic loading may be limited to the necessary safety or other important loads.

g. Conditions of load transfer needed between the normal source and EG (unloaded bus, automatic SYNCHRONIZATION, manual SYNCHRONIZATION) and including consideration of change between ISOCHRONOUS and DROOP MODE of operation

h. Potential effect of failures or inadvertent actuation of equipment such as water spray from fire protection equipment. Refer to NFPA 110 for additional guidance.

5.2.1.2 Starting and loading. The EG shall be capable of starting, accelerating, and loading within the time required by the demands of the equipment/system being supplied. This requirement is discussed in IEEE Std 387. Voltage and frequency shall be maintained during the loading sequence such that equipment will operate without malfunction. Typically, the frequency should be > 57 Hz and voltage > 75% of nominal. Subsequently, the steady-state operating voltage and frequency to the loads should be within the manufacturer's guaranteed equipment ratings for continuous operation, typically ± 10% and ± 2% respectively. The EG system full load shall be within the CONTINUOUS RATING of the EG. The EG shall have the capability to handle the load power factor during loading and steady-state operation. SHORT-TIME RATING overload specifications shall not be exceeded.

5.2.1.3 Engine cooling. The EG should be provided with a self-contained cooling system. If self-cooling is not available, the EG shall be able to operate without overheating damage or trip for the time required to activate an auxiliary cooling system to ensure EG cooling. Refer to NFPA 110 for additional guidance.

5.2.1.4 HOT RESTART. EGs should have the capability for immediate HOT RESTART upon shutdown at full load temperature conditions (after it has operated at full load for at least 2 hours).

5.2.1.5 EG ratings. Most EGs will have continuous and overload ratings. Typical EGs will have more than one overload rating. These ratings shall accommodate any overload transient that occurs during sequence loading of equipment or a momentary overload that could occur through manual action during testing. The light- and no-load rating shall accommodate the starting and loading sequence. If the EG must be operated under light load longer than manufacturer's specifications, the manufacturer shall be consulted as to what precautions to take to rectify the accumulated detrimental effects of low-load operation and/or how to prevent such detrimental effects. Refer to IEEE 387 for additional guidance regarding light loading.

5.2.1.6 Vibration. Critical speeds associated with excessive vibrational stresses shall not occur within ± 5% of the normal operating speed of the machine. Refer to IEEE Std 387 for additional guidance.

5.2.1.7 Overspeed. The engine overspeed resulting from a SHORT-TIME RATING load rejection shall not cause moving parts to fail nor the engine to trip. The overspeed trip device setting shall protect the unit from damage. Refer to IEEE Std 387 for additional guidance.

5.2.1.8 Automatic operation. If the EG is required to operate separately in DROOP and ISOCHRONOUS MODES, and the voltage regulator is required to accommodate paralleled and nonparalleled operation, the EG controls for each of these control systems should automatically revert to the appropriate mode of operation upon an automatic demand signal. The need for this feature should be assessed based on the significance of unavailability during testing, considering manual action could be taken to place the unit in a condition where it could then respond. There shall be protective features to protect an EG from an overload that may occur during a loss of normal power when the EG is operating in parallel with the GRID.

5.2.1.9 Control. The EG may have automatic and/or manual control capability. Automatic control should include automatic start on a demand signal and automatic adjustment of speed and voltage to a ready-to-load condition. Manual control shall be available to allow operator intervention as needed. To prevent personal injury, an engine start signal shall not override any manual non-operating modes used for repair or maintenance. NFPA 110 and IEEE Std 387 provide additional guidance. Most EG bus designs incorporate an undervoltage relay that will trip and may block closure of the breaker feeding from the normal power source to the EG bus. Features should be incorporated to allow easy restoration of the GRID if the EG fails during a test in which the GRID source is disconnected. Where necessary for equipment protection, especially motor-driven loads with low inertia, controls for breakers and automatic switches should be provided to ensure that neither the ENGINE GENERATOR nor the driven loads can be damaged by out-of-phase transfer between normal and backup sources under both emergency and test conditions.

5.2.1.10 Surveillance features. A surveillance system/program should be provided to monitor the status of the EG for the various modes (operating, test, standby, lockout/maintenance). For important applications (necessary to mitigate/prevent consequences of process accidents) where an EG is unable to perform its design function (when an essential auxiliary/support system is inoperable as well as during maintenance or other lockout conditions), indication of the inoperable status should be provided. Sufficient information should be provided to allow any required remote action to manually start, load/unload, or trip the EG. Where the EG is normally controlled from a remote location, a common trouble alarm may be provided at the remote location for conditions that cannot be rectified from the remote location.

5.2.1.11 Monitored systems. EG systems should be provided with sufficient instrumentation to measure and display the variables indicative of proper operation and to provide alarm signals for abnormal and trip conditions. These systems include the engine, start system (battery or air), generator, exciter or voltage regulator, cooling system, fuel supply system, lubricating system, speed governor, combustion air system, and the EG breaker. Included in the various parameters that may be monitored are: pressure, temperature, flow, level, frequency/speed, current, voltage, power, volt-amperes, power factor, and contact positions.

5.2.1.12 Protective features. Features shall be provided to protect the EG against damage- or failure-inducing events. Such features shall cause immediate shutdown of the EG upon exceeding the trip level. Alarms of a protective trip actuation should be provided at the appropriate location. NFPA 110 provides guidance on equipment safety indications and shutdowns using a graded approach. Protective features should be able to be periodically tested and the trip instrumentation and controls should be periodically calibrated. The capability to block protective trips during an actual emergency condition should be considered. Alternatively, independent indicators with coincident trip logic could be considered. The following is a list of typical equipment safety indications and shutdowns; use may vary with importance and power source application:

* Low lubrication oil pressure
* Engine overspeed
* Generator phase current differential
* Generator overcurrent
* Cooling water pressure
* High engine temperature (typically cooling water temperature downstream of the EG)
* High vibration
* Low turbocharger oil pressure
* High crankcase pressure
* Reverse power (during operation in parallel with GRID or other sources)
* Failure to start after normal cranking time
* Emergency stop

Some protective trip functions should never be bypassed. Trips such as engine overspeed, generator phase current differential, reverse power, and emergency stop should always cause EG shutdown. These trips are indicative of faults or failures that render the EG incapable of supplying its loads, and may cause equipment damage if left unchecked.

5.2.2 Qualification of maintenance personnel for EGs. Specific qualification for EG maintenance personnel should include the following subjects:

a. Diesel and/or gasoline engine fundamentals (as appropriate).

b. Testing and maintenance practices for EGs.

c. Safety precautions for engine-driven generators.

5.2.3 EG testing. EG installations shall accommodate periodic testing during operation of the plant (or process) and during shutdown. When operation of facility processes does not allow such a test, they may be performed on a less frequent basis during planned maintenance or shutdown periods. To the extent practical, the EG system test demands should duplicate actual demands. Simulation of loss of power should exercise the circuits that sense power loss and initiate automatic start, and cause OUTPUT BREAKER closure and transfer device operation. Instrument sensor design and location should permit in-place inspection and calibration. Alarm and status indication of important modes and parameters should be included. Communications should be established between the local test station and the normal operating area to allow test personnel to inform operators of EG test status and condition. Operating data should be recorded at the beginning and end of the test and at regular intervals during the test.

5.2.3.1 Periodic testing during facility operation. EGs for operating facilities shall be periodically tested according to a documented schedule to demonstrate their ability to start and accept required loads. To avoid unnecessary and premature degradation of the EG, manufacturer's recommendations should be followed in regard to prelubrication, acceleration, loading, and unloading. An EG start from normal STANDBY CONDITIONS (fast start test) shall be performed annually or semiannually if not done during the periodic test. Other engine starts should follow manufacturer's recommendations for prelubrication and/or other warmup procedures to minimize mechanical stress and wear. (The use of these slow start tests is more important for larger machines.) The following should be performed at least once per month, unless otherwise specified by the manufacturer or surveillance requirements:

a. Record the as-found conditions, including coolant and lubricant levels, and the identity of the test personnel.

b. Verify that the EG starts and accelerates to operating rpm in (the required value) seconds. Generator voltage and frequency shall be (required value ± 10%) volts and (60 ± 1.2) Hz within (required value) seconds.

c. Verify that the starting system disengages properly (if an indication is provided).

d. Verify that fuel tank levels (fuel storage tank, day tank, and engine tank) are within specifications.

e. Remove accumulated water from fuel tanks and oil/water separator.

f. Verify that the fuel transfer pump system starts and that fuel is being transferred from the storage tank to the day and engine-mounted tank (if present).

g. Verify EG can accept loads up to 90% of the CONTINUOUS RATING and operate for 1 hour (time should consider manufacturer's recommendations). This may be done using normal loads, a load bank, or by synchronizing to the offsite GRID if this capability is available. If a load bank is routinely used, a dedicated connection should be provided. The value of 90% is used to provide margin to avoid inadvertent overloading. If this is not feasible, the test loading conditions provided by NFPA 110 may be substituted.

5.2.3.2 Diesel fuel tests. A program shall be established for maintaining the quality of fuel. Long-term storage of fuel requires proper selection, proper storage conditions, and monitoring of fuel properties prior to and during storage. ANS 59.51 and ASTM D975 provide guidance for maintaining the quality of fuel for diesel generators. Fuel shall be procured according to the requirements of Federal Specification VV-F-800, ASTM D975, or the diesel manufacturer's specifications if it is more restrictive. The program shall establish criteria for periodic testing and for the disposition of fuel not meeting the appropriate specifications. Procedures for periodic sampling can be found in ASTM D4057. In addition to periodic testing, water should be periodically drained from the fuel tank. The fuel should be kept cool. The tank should be kept full to minimize breathing and reduce exposure to air. These measures will reduce the rate of buildup of condensation water, fungi, bacteria, and oxidation products.

5.2.3.3 Gasoline fuel tests. Gasoline is considerably more reactive than diesel fuel and highly susceptible to deterioration during long-term storage. The best practice is to plan storage capacity and fuel use to avoid prolonged storage. The volatile nature of gasoline dictates that quantities on site be kept to the minimum necessary and all standard precautions be taken to reduce the potential for explosion and fire. The same actions should be taken as with diesel fuel (periodic draining of water condensate from the storage tank; keeping the tank full to reduce fuel exposure to air and minimize moisture intake; and keeping the fuel cool to slow oxidation, fungi, and bacteria rates).

5.2.3.4 Battery surveillance tests. Most EGs used in backup applications at DOE facilities use batteries to provide the initial energy source for the control, start, and field flashing power necessary to bring the unit to operating conditions. A degraded battery may result in failure of the BACKUP POWER SOURCE to perform. Batteries require monitoring, periodic maintenance, and charging to ensure their readiness to perform. Refer to 5.4 for information on maintenance and related activities for ensuring reliable battery operation.

5.2.3.5 Infrequent tests. Infrequent tests are performed on EGs to verify machine capabilities other than start and load that need not be demonstrated on a monthly basis or that cannot be performed during plant operation. Users shall be appropriately notified before performing disruptive tests. The following are typical EG tests that should be performed on an 18-month basis or during plant maintenance periods or shutdown as the plant design and the safety analysis necessitates. The EG test program should be tailored to include the following tests as pertinent to the specific EG application. The testing in b., c., and e. may be accomplished using a load bank, or by synchronizing to the offsite GRID if this capability is available. If a load bank is routinely used, a dedicated connection should be provided.

a. Perform manufacturer's inspection procedures specified for this interval for an EG used in standby service.

b. Verify the capability of the EG to reject a load of greater than or equal to (largest single load) kW while maintaining engine speed less than or equal to nominal speed plus 75% of the difference between nominal speed and the overspeed trip setpoint, or 15% above nominal, whichever is less. The voltage and frequency excursion should not cause damage or misoperation of loads.

c. Verify capability of the EG to reject a load of (90 - 100% of CONTINUOUS RATING) kW without tripping on overspeed.

d. Perform a loss-of-power test that simulates the loss of normal power to the EG buses and:

   1) Verify that the buses that will be powered by the EG deenergize and loads shed, as required.

   2) Verify EG auto-starts and, if required, auto-loads the connected system loads within any required load timing sequence. Verify frequency and voltage are maintained within manufacturer's specifications for connected loads for both transient and steady-state conditions.

   If the EG is manually loaded, perform manual loading as normally done for the specific EG application.

e. Perform an endurance test that will demonstrate that the EG operates (typically for 8 to 24 hours) at 90 - 100% CONTINUOUS RATING and, if installation permits, load power factor. If a short-time rating is provided, it is desirable to test the unit at this load during the 8 to 24-hour period. If the connected load is above the CONTINUOUS RATING but within the SHORT-TIME RATING, the unit should be operated at this load for no longer than the time specified for the short-time rating. The generator voltage and frequency shall be (required value ± 10%) volts and (60 ± 1.2) Hz throughout the duration of the load test. After the test is complete, shut the unit down and within 5 minutes demonstrate the ability of the unit to HOT RESTART and load to 90-100% of its CONTINUOUS RA-

TING for a minimum of 5 minutes. The HOT RESTART test may be performed independently of the endurance and load test provided the EG is at full temperature.

f. Where the system accommodates parallel operation of the EG with the GRID system for the purpose of live bus transfer of loads or for testing, the ability to synchronize and transfer between these sources should be demonstrated. This is unnecessary if done during periodic tests.

g. For systems where the bus undervoltage relay trips the GRID source breaker, the capability to restore the GRID circuit to the EG bus should be demonstrated.

5.2.3.6 Test failure. When recording test results, a failure should be recorded if the EG fails to start, accelerate, reach nominal voltage and frequency, accept the rated load within and for the time required, or otherwise fails to satisfy the specified acceptance criteria. Test success and failure data should be used to determine whether performance (reliability) goals are being met. Refer to IEEE Std 762, NRC Reg. Guide 1.9, and NRC Reg. Guide 1.160 for guidelines.

5.3 UPS system requirements. UPSs are used to supply an uninterrupted source of power to important instrumentation and control systems for loss-of-normal-power conditions. They are also used to provide continuous, quality power for systems sensitive to disturbances occurring in an electrical power distribution system caused by switching, faults, or power transfer. UPS designs include various combinations of rectifier/charger, battery transfer and bypass switches, and an inverter. Rotary UPSs are not covered by this Standard.

5.3.1 UPS capabilities. The specification of requirements for the UPS shall include the sizing (based on the load and duration of the load) of the unit, the type of power required by the load (frequency, voltage), the system configuration (redundancy, transfer features), protective features, limitations of available ac power, limitations of available dc sources, short-circuit capability, required controls, instrumentation, and alarms. Refer to ANSI/IEEE Std 944 and DOE-SPEC-3021 for guidance and criteria for these and other factors to be considered in developing the bases of a UPS system. ANSI/IEEE Std 944 and DOE-SPEC-3021 shall be used to develop the bases and requirements of UPS systems with respect to specification of service conditions (environmental), specification of UPS system requirements, and specification of design test requirements. Environmental conditions exceeding the values in ANSI/IEEE Std 944 should be identified and equipment specifically qualified to these different conditions. Refer to guidance and criteria in NFPA 111 for the development of bases and specifications for transfer devices to be used with UPS designs. DOE-SPEC-3021 should be used to develop and document the specification for new UPS installations.

5.3.2 Maintenance and repair of UPS. The maintenance program should take into consideration the type of service to which the equipment is subjected (duty cycle, chemicals, dust, heat), manufacturer's recommendations, and trending.

5.3.2.1 Qualification of maintenance personnel for UPSs. Specific qualification for UPS systems maintenance personnel should include the following:

a. Fundamentals of electrical and electronic design of UPSs

b. Testing and maintenance practices for UPS systems

c. Safety precautions for UPS systems

5.3.2.2 Routine inspections and servicing of UPS systems. UPS systems should be checked externally daily. The UPS should be checked for evidence of problems by evaluating meter readings and detrimental environmental problems (heat, moisture, chemicals). Less frequent activities such as internal cleaning, filter replacement, checking electrical connections for tightness, and calibration of instruments shall be done according to manufacturer's recommendations or at least every 18 months. This interval may be adjusted according to documented operating experience.

5.3.3 Testing of UPS systems. A UPS in its standby or normal operating mode may not demonstrate many of the various features that may be required to function during emergency conditions such as a loss-of-power or equipment failure. Depending on the design of the UPS system, the following tests should be performed:

a. Light-load Test - Verify inverter voltage & frequency remains within specified limits. Verify proper operation of control switches & meters.

b. SYNCHRONIZATION Test - Measure the rate of change of inverter frequency while a reference frequency is attenuated. Concurrently measure the inverter voltage. (only required when synchronization with alternate source is a design feature)

c. AC Input Failure Test - Disconnect the input power source(s) or shutdown the rectifier on-line to verify that the dc source can indeed instantly sustain the critical loads. Verify inverter voltage & frequency remains within specified limits.

d. AC Input Return Test -Restore the input power source(s) or reactivate the rectifier on-line to verify that the rectifier can instantly sustain the critical loads and re-charge batteries (if used). Verify inverter voltage & frequency remains within specified limits.

e. Transfer Test - (For UPS systems which use a Static Bypass Switch) Cycle the UPS to and from the bypass source, measuring transients, maximum & minimum voltages and transfer times. Simulated failures may be needed.

f. Rated Full-Load Test - Loads (equivalent to the full-rated load) shall be applied to the output of the UPS at the extreme ranges of ac and dc input voltages for rated duration.

g. Output-Voltage Balance Test - Measure inverter phase-to-phase & phase-to-neutral voltages and angles while symmetrical loads are applied. Measure inverter phase-to-phase & phase-to-neutral voltages and angles during the transition from no-load to an imbalanced full load.

h. Harmonic-Components Test - measure harmonic content in the output voltage for rated linear and nonlinear load conditions.

The tests above correspond to tests recommended by ANSI/IEEE Std 944 and should be performed according to manufacturer's recommendations or on at least an 18-month interval. UPS batteries shall be maintained and tested in accordance with 5.4.

5.4 STATIONARY BATTERY system requirements. A STATIONARY BATTERY system is a direct current (dc) standby power system consisting of a group of two or more cells connected together electrically in series or parallel, or combination. A system includes all switchgear and distribution equipment necessary to provide quality voltage and current as required by the connected load. The battery is normally in full float operation where it is connected in parallel with a charger and the load, and where the charger supplies the normal dc load plus any self-discharge or charging current, or both, required by the battery. The battery will supply power to the load upon loss of ac power to the charger, failure of the charger, or when the load exceeds the charger output. STATIONARY BATTERIES are commonly used for standby service in industrial control, electric substation control circuits, UPSs, and communication system service. The following subsections provide requirements and information for STATIONARY BATTERIES, including their maintenance and testing.

5.4.1 Battery system capabilities. The specification of requirements for STATIONARY BATTERIES shall include battery load (load profile), voltage, time period, environment, and installation. DOE-SPEC-3018 or DOE-SPEC-3019 should be used to develop and document the specification for new lead-acid battery installations.

5.4.1.1 Battery sizing. Battery load profiles and sizing shall be developed in accordance with IEEE Std 485 (for lead-acid batteries) or IEEE Std 1115 (for nickel-cadmium batteries). This includes type of load, nature of the load (transient and steady-state values), timing of application of loads, length of time for each load and overall time needed for battery operation. IEEE Std 485 and IEEE Std 1115 provide detailed instructions on how to treat various types of loads and construct a load profile. Other factors involved in assessing proper battery size include: maximum system voltage, minimum acceptable voltage, and battery duty cycle. Cells may be connected in series or series-parallel combinations to arrive at the desired voltage and battery capacity. Refer to IEEE Std 485 or IEEE Std 1115 as appropriate for detailed guidance on assessing cell and battery size (number and capacity of cells), and for information on the treatment of design margin and the various associated factors to assess whether sizing is adequate.

5.4.1.2 Installation. The following factors shall be addressed for an acceptable battery installation: vibration, temperature, ventilation for hydrogen offgassing and heat removal, local heat sources, power source location, mounting rack (support, insulation, and grounding), seismic needs, containment for flooded lead acid batteries, instrumentation, and alarms. Refer to IEEE Std 484 (Vented Lead-Acid), IEEE 1106 (Nickle-Cadmium), or IEEE Std 1187 (Valve-Regulated Lead-Acid) for detailed guidance on battery installation. Refer to IEEE Std 450 (lead-acid), IEEE Std 1106, IEEE 1187, or IEEE 1188 for acceptance testing. Manufacturer's recommendations should be followed, if more limiting, for all batteries.

5.4.2 Battery maintenance, testing, and surveillance. Batteries shall be monitored, periodically maintained, and properly charged to ensure their readiness to perform. Many types of batteries, if allowed to sit without a charger, will internally discharge, often with irreversible cell degradation. For these types of batteries, it is important to maintain proper charging FLOAT VOLTAGE during standby. Due to inherent differences between cells, FLOAT VOLTAGE and specific gravity values will vary from cell to cell over time. If cell FLOAT VOLTAGES and/or specific gravity values are allowed to remain in an unequal condition for extended periods of time, cell sulfation will result. To overcome this problem, periodic EQUALIZING CHARGE must be applied to equalize cell voltages and specific gravities. Manufacturer's recommendations should be followed in regard to EQUALIZING CHARGE. When performing an EQUALIZING CHARGE, care should be taken to assure the charger voltage does not exceed the voltage rating of the loads connected during the equalize charge. Batteries are rated at a temperature of 25 °C. Higher temperatures will improve capacity at high discharge rates but significantly reduce battery life. Lower temperatures have a significant effect in reducing battery capacity. Typical battery types for standby service are lead-acid (calcium, antimony), pure lead (generally a "round cell"), or nickel-cadmium. IEEE Std 1106 provides criteria and guidance for nickel-cadmium batteries similar to that provided in IEEE Std 450 for lead-acid batteries. Manufacturers will provide necessary information on the care, precautions, charging, and treatment of specific batteries including during periods of storage.

5.4.2.1 Routine maintenance and surveillance of lead-acid batteries. Routine inspections and corrective actions for problems found during surveillance and testing shall be in accordance with IEEE Std 450 or IEEE 1188, as applicable. Manufacturers also provide recommended routine maintenance practices that should be considered in the care of batteries. NFPA 110 provides guidance on a graded approach to battery maintenance and surveillance. In addition, TABLE I provides an example of good practices for surveillance and testing of lead-acid cells. Adjustments to (increase or decrease) the intervals in TABLE I should be based on experience and manufacturer's recommendations. Refer to IEEE Std 1106 for maintenance, inspection, and corrective actions for nickel-cadmium batteries.

5.4.2.2 Periodic load tests for batteries. The only real measure of a battery's capacity and capability to provide power to its required load is derived from the performance of two different tests. One of these is called the PERFORMANCE DISCHARGE TEST, and the other is called the Service Test. The PERFORMANCE DISCHARGE TEST indicates the existing capacity of the battery expressed as a percent of the rated capacity. This provides an indication of the remaining useful life of the battery. The Service Test is an as-found test that demonstrates the ability of the battery to carry its required load for the required time period (duty cycle). These two tests are the best indicators of a battery's ability to perform its function. In order to perform the Service Test, the load profile (duty cycle) for the battery must be known. During the performance of these tests, the battery will be unavailable for duty due to significant discharge. These tests should only be performed under conditions when the unavailability of the battery is acceptable, or provisions should be made for an alternate source to be temporarily connected to the loads for the duration of the test and recharging of the battery. Intervals, procedural instructions, and criteria for the Performance and Service Tests for lead-acid batteries shall be in accordance with IEEE Std 450 or IEEE 1188. The schedule and procedures for battery capacity tests for nickel-cadmium batteries shall be in accordance with IEEE Std 1106. Replacement criteria for nickel-cadmium cells shall be in accordance with IEEE Std 1106. Battery replacement criteria for lead-acid cells shall be in accordance with IEEE Std 450.

TABLE I. Typical Lead-Acid Battery/Cell Surveillance and Tests

| Subject (Note 3) | Values (Note 1) | Period |
|---|---|---|
| Battery Terminal Voltage (typical 60 cell battery) | (129-130.2) volts PbSb<br>(130.2-135) volts PbCa | monthly |
| Electrolyte Level | Between fill lines (distilled water only) | monthly |
| Cell Float Voltage (Pilot cell) | (2.15-2.17) volts PbSb<br>(2.17-2.25) volts PbCa | monthly |
| Cell Float Voltage (All cells) | (2.15-2.17) volts PbSb<br>(2.17-2.25) volts PbCa | quarterly |
| Specific Gravity (Pilot cell) | $1.215 \pm 0.010$ | monthly |
| Specific Gravity (All cells) | $1.215 \pm 0.010$ | quarterly |
| Cleanliness and Corrosion Check | (Note 2) | monthly |
| Resistance Measurement Cell to Cell and Terminal Connections | < 20% above the value when new or after cleaning retorquing bolts | yearly |
| Battery Capacity Test (PERFORMANCE DISCHARGE TEST) | $\geq$ 80% of capacity (Note 5) | 5 years |
| Battery Load Test (Service Test) | Design load and duration with adequate voltage | yearly (Note 4) |

Note 1 Values outside these ranges indicate action is necessary to restore the parameter to within the specified values.

Note 2 Battery cleaning should be done with baking soda and water with clear water rinse--no other cleaning materials shall be used.

Note 3 All manufacturer's safety precautions should be observed when working on batteries.

Note 4 Not required where battery is for engine generator only and not other loads. The periodic monthly start of the engine generator is a load test. Load tests should be done in as-found condition.

Note 5 Battery capacity (performance discharge) test is used as a battery age indicator. Initially, battery should be fully charged, temperature near 25 °C, and terminals clean. See IEEE Std 450 for times the battery capacity test should be performed.

## 6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. This Standard is not a DOE Order, and its requirements are not automatically invoked at any facilities or on any BACKUP POWER SOURCES. This Standard is intended for use by the operations/field offices or M&O contractors as desired. It may be invoked by contractual documents, procurement documents, or in the authorization basis for a facility. Unless it is invoked as above, the contractor cannot be assessed or inspected against its requirements. This Standard is also suitable for voluntary use by engineers responsible for BACKUP POWER SOURCES at DOE facilities.

6.2 Revision status. A specific revision of this Standard should only be invoked and used when required by contractual considerations. In all other cases, the most current revision should be assumed to be used.

6.3 Tailoring guidance. For applications that are not related to nuclear safety, use of this Standard should be tailored based on the relative importance of the power source to safety of the public, the environment, operating personnel, and the facility. Procurement documents invoking this Standard should tailor the requirements contained herein to suit the particular procurement. Contractual or authorization basis documents invoking this document must specify assessment or inspection criteria appropriate to the application.

6.4 Subject term (key word) listing. The following listing of subject terms (keywords) is provided so that this document may be found during retrieval searches.

Backup power
Emergency power
Diesel generator
ENGINE GENERATOR
UNINTERRUPTIBLE POWER SUPPLY
STATIONARY BATTERIES

# APPENDIX I

## Considerations to Improve Diesel Generator Reliability

NRC publication NUREG/CR 0660, Enhancement of On-Site Emergency Diesel Generator Reliability, was developed from a comprehensive study of diesel generator problems and installations. The document made a number of recommendations to improve diesel generator reliability. The following were selected for consideration by DOE facilities:

1. Provide refrigerated air dryers between the air compressor and air storage tank to reduce detrimental effects of entrained moisture causing rust and pipe scale that result in damage to air start motors.

2. Diesel generator room air quality is often poor; this can be overcome by providing dust-tight covers for relays and contactors or by providing filters for static inverters to protect field flashing contacts. Room ventilation should be taken from about 6 m above the ground to reduce intake of local dust.

3. Provide training for those personnel operating and maintaining specific diesel generators.

4. Provide prelubrication for all engine starts (except true auto-start) for 3 - 5 minutes (longer per manufacturer's recommendation) to reduce potential for engine bearing wear.

5. Provide an electric fuel pump that starts upon engine auto-start signal and shuts off when engine is up to speed.

6. Mount instruments and controls in a separate floor-mounted panel independent of the EG (minimizes vibration effects on instruments and controls).

APPENDIX II

EXAMPLE PROCEDURE

FLOODED LEAD-ACID BATTERY (IDENTIFICATION NO. _______) MONTHLY MAINTENANCE

Date/Time Started: _____________ / _____:______ a.m./p.m.

This procedure is authorized by Work Request No. ___________ .

Battery Location: ____________________

Battery Identification No. ____________________

PURPOSE

The purpose of this procedure is to provide instructions for performing monthly maintenance and checks on the XXX volt lead acid (battery identification).

FREQUENCY

Monthly, except when the quarterly or annual maintenance is performed.

REFERENCES

* Site Safety Manual
* IEEE Std 450, IEEE Recommended Practice for Maintenance, Testing, and Replacement of Large Lead Storage Batteries for Generating Stations and Substations.
* Battery manufacturer _______________(manual)
* Technical Standard - (Plant Standards)
* Technical Specification - (Identification Number)
* Specific Battery Equalizing Charge Procedure

GENERAL LIMITATIONS AND PRECAUTIONS

"WARNING! Failure to complete this procedure correctly in its entirety and within the frequency specified may result in operation outside the requirements of the Technical Standards or, ultimately, the Technical Specifications."

1) A Nonconformance Report (NCR) is required for any nonconforming equipment or test failure that has been identified during the performance of this procedure, unless the corrective actions are authorized by this procedure.

2) Electrical Supervision shall be notified of any abnormal condition discovered while performing this procedure.

3) Readings shall be taken under normal float conditions. Specific gravity readings are not meaningful during charge or following the addition of water.

INFORMATION

1) The battery consists of XX cells of the lead-calcium type, Battery Model XXXXXXXXXXXXXXX. Battery terminal voltage is XXX Vdc (nominal) and specific gravity is 1.215 (nominal) at 25 °C. Charging float voltage is XXX-XXX Vdc.

2) Pilot cell selection shall be directed by Electrical Supervision at least annually, or as often as deemed necessary by the periodic review of cell data, to ensure that the selected pilot cell(s) are representative of the overall battery condition.

TOOLS/INSTRUMENTS/MATERIALS

* Voltmeter with an accuracy range of better than ± .008 Vdc.
  Instrument I.D. # ___________ Calibration Expiration Date _________
* Hydrometer. Range: 1.180 - 1.310
  Instrument I.D. # ___________ Calibration Expiration Date _________
* Glass thermometer. Range: 0 - 65 °C
  Instrument I.D. # ___________ Calibration Expiration Date _________
* Density Meter, minimum accuracy .0025 specific gravity
  Instrument I.D. # ___________ Calibration Expiration Date _________
* Electrolyte level gauge/ruler
* Acid neutralizing agent (120 g bicarbonate of soda to 1 liter of clean water)
* Clean rags or paper towels
* No-Ox-Id grease
* Brush, stiff plastic bristles
* Distilled water

AUTHORIZATION

An authorized Work Request is required.

SAFETY PRECAUTIONS

1) Follow applicable Site and Area Safety Rules for work on batteries.
2) Obtain an approved Work Clearance Permit per Site Safety Manual before initiating any work on batteries.
3) The use of personal protection articles such as acid-resistant gloves, apron, face shield, and goggles is required.
4) Electrolyte is highly corrosive and extreme care is required during handling.
5) Use only non-conductive/insulated/non-sparking tools in the battery room.
6) Do not smoke or use open flames, do not cause arcing in the vicinity of the battery.
7) All metallic objects such as jewelry (rings, bracelets, necklaces) must be removed before working on batteries.
8) Neutralize static buildup just before working on battery by having personnel contact nearest effectively grounded surface.
9) Ensure entrance and exit from the battery area is unobstructed.
10) Verify availability of currently inspected and operable (portable or stationary) water facilities for rinsing eyes and skin in case of acid spill.
11) A Radiation Work Permit (RWP) is required for all work in a Radiologically Controlled Area (RCA).

12) For safety reasons, a person shall not work alone. At least two persons (Two Man Rule) must always be present when working on electrical power systems.

PROCEDURE

A. PREPARATION

CHECK

1) Read the following PROCESS SIGNIFICANCE statement:
Statement of battery function and significance .... ____

2) Check to ensure that this is the latest approved revision of this procedure. ____

3) Confirm each Instrument has a current calibration sticker and record the information in the Instrument/Tool Report (No.______) attached to this procedure and in the TOOLS/INSTRUMENTS/ MATERIALS Section of this procedure. ____

4) Obtain an authorized Work Request (No.______) and record the number on Page 1 and Data Sheet 1 of this procedure. ____

5) Obtain an approved Work Clearance Permit (No.______) per Site Safety Manual. ____

6) Confirm that the Battery Room ventilation system is operating. ____

7) Confirm with Operations that the battery has been on normal float voltage (XXX-XXX Vdc) for at least 72 hours since the conclusion of the last equalization charge and subsequent return to float voltage. If not on float charge, notify (Operations and Electrical) supervision. ____

Section A completed by ____________________ / ______________________________
(signature) (print name)

Date/Time Completed ________________ / ________ : ________ a.m./p.m.

B. INSPECTION AND CLEANING

1) Check the battery cells for cracks and leakage of electrolyte. ____

2) If cell cracks and leakage of electrolyte are found, note the location in the Comments section of Data Sheet 1, complete an NCR, and notify Electrical Supervision promptly. ____

3) Check the intercell and terminal connections for corrosion. ____

4) If any cell connections are corroded:

   a) Neutralize the corrosion with a neutralizing agent. ____

   b) Remove corrosion with stiff plastic bristled brush and clean rags. ____

   c) Note the location in the Comments section of the Data Sheet 1. ____

NOTE: Use water only as a cleaning agent; do not use hydrocarbon-type cleaning agents or strong alkaline cleaning agents that may cause containers and covers to crack or craze.

5) Clean the battery and rack:

   a) Remove electrolyte spillage with clean rags and a neutralizing agent. ____

   b) Remove dirt from cells and rack using clean cloths dampened with clean water. ____

6) If protective grease was removed from intercell and terminal connections during cleaning, apply a light coat of No-Ox-Id grease to the affected terminal.

Section A completed by ____________________/____________________________
(signature) (print name)

Date/Time Completed _______________/_______:_______ a.m./p.m.

C. BATTERY AND CHARGER CHECK

NOTE: Data from applicable Step(s) in this section shall be recorded on Data Sheet 1.

1) Check and record Battery Charger voltage (as found) and current meter readings from the dc distribution panel meters. ____

2) Take and record the Battery Room ambient temperature.

Acceptance Criteria: Temperature recorded correctly.
(15 °C to 35 °C) ____

3) Check and record the battery (as found) terminal voltage, using a digital voltmeter and reading at the battery terminals. ____

CAUTION: Do not allow charger output to exceed XX amps.

4) If battery terminal voltage is outside the XXX to XXX volt range, adjust the charger to obtain XXX to XXX volts and record the battery terminal voltage (as left).

Acceptance Criteria: Adjustment made and readings (as left) correctly recorded. (XXX-XXX Vdc) ____

5) Check and record the charger (As Left) voltage and current meter readings from the dc distribution panel.

Acceptance Criteria: Readings recorded correctly.
(XXX-XXX- Vdc) (≤ X amps) ____

NOTE: A table providing manufacturer's correction factors for determining corrected specific gravity (corrected for temperature and level) should be provided with procedure.

6) Take and record the following Pilot cell parameters:

- Pilot cell number
- Hydrometer reading (HYD)
- Pilot cell temperature (TEMP) and temperature correction factor
- Electrolyte level (LEVEL) and level correction factor
- Pilot cell voltage (VOLTS). ____

Completed by ____________________/____________________ Date________
(signature) (print name)

7) Inspector shall verify that the values obtained are correct and that acceptance criteria are met in Steps C.1 through C.6.

Verified by ____________________/____________________ Date________
(signature) (print name)

8) Correct the hydrometer reading for level and temperature and enter on Data Sheet 1 as specific gravity. ____

9) Measure and record the electrolyte level (as found) for each cell. Read from the bottom of the electrolyte High Level line.
Above line: Add; Below line: Subtract.

Completed by __________________/__________________ Date_______
(signature) (print name)

10) Inspector shall verify the values obtained in Steps C.8 and C.9.

Verified by ____________________/____________________ Date_______
(signature) (print name)

11) If any cell's electrolyte level is below the Low level mark, add distilled water to those cells to the High level mark, and place on equalize charge per Battery Equalize Procedure immediately after completion of this procedure. ____

12) Measure and record the electrolyte level (as left) for each cell. Read from the bottom of the electrolyte High Level line.
Above line: Add; Below line: Subtract.

Completed by __________________/__________________ Date_______
(signature) (print name)

13) Inspector shall verify that the Acceptance Criterion in Step C.12 was met.

Verified by ____________________/____________________ Date_______
(signature) (print name)

Section C completed by ____________________/_____________________________
(signature) (print name)

Date/Time Completed _______________/_______:_______ a.m./p.m.

D. RETURN TO CUSTODIAN

1) Clean work area and remove tools and special equipment. ____

2) List the number here of each Nonconformance Report (NCR) prepared for any nonconforming condition identified during the performance of this work:

_______________________________________________

3) Notify Operations Shift Supervisor that this procedure is complete. ____

Section D completed by ____________________/______________________________
(signature) (print name)

Date/Time Completed ________________/________:_______ a.m./p.m.

DATA SHEET 1

Work Request No. ____________________ Battery No. __________________

C.1) Meter readings: _____ volts _____ amps, as found

C.2) Battery Room temperature _____°C (15 °C to 35 °C)

C.3) Battery terminal voltage _____ V, as found

C.4) Battery terminal voltage _____ V (XXX-XXX V), as left

C.5) Meter readings _____ volts (XXX-XXX Vdc) ____ amps (≤ X amps), as left

C.6) & C.7) Pilot Cell data:

| CELL NO. | HYD | TEMP.(°C)/ TEMP.CORR. FACTOR | LVL. (mm)/ LVL. CORR. FACTOR | SPECIFIC GRAVITY (1.215) | VOLT (2.13 - 2.38) |
|---|---|---|---|---|---|
| | | / | / | | |

COMMENTS:

_______________________________________________________________

_______________________________________________________________

_______________________________________________________________

_______________________________________________________________

_______________________________________________________________

_______________________________________________________________

_______________________________________________________________

_______________________________________________________________

_______________________________________________________________

_______________________________________________________________

DATA SHEET 1 (Continued)

Work Request No. ____________________ Battery No. __________________

| CELL No. | ELECTROLYTE LEVEL AS FOUND | AS LEFT |
|---|---|---|
| 1 | ________ | ________ |
| 2 | ________ | ________ |
| 3 | ________ | ________ |
| 4 | ________ | ________ |
| 5 | ________ | ________ |
| 6 | ________ | ________ |
| 7 | ________ | ________ |
| 8 | ________ | ________ |
| 9 | ________ | ________ |
| 10 | ________ | ________ |
| 11 | ________ | ________ |
| 12 | ________ | ________ |
| 13 | ________ | ________ |
| 14 | ________ | ________ |
| 15 | ________ | ________ |
| 16 | ________ | ________ |
| 17 | ________ | ________ |
| 18 | ________ | ________ |
| 19 | ________ | ________ |
| 20 | ________ | ________ |
| 21 | ________ | ________ |
| 22 | ________ | ________ |
| 23 | ________ | ________ |
| 24 | ________ | ________ |
| 25 | ________ | ________ |
| 26 | ________ | ________ |
| 27 | ________ | ________ |
| 28 | ________ | ________ |
| 29 | ________ | ________ |
| 30 | ________ | ________ |

| CELL No. | ELECTROLYTE LEVEL AS FOUND | AS LEFT |
|---|---|---|
| 31 | ________ | ________ |
| 32 | ________ | ________ |
| 33 | ________ | ________ |
| 34 | ________ | ________ |
| 35 | ________ | ________ |
| 36 | ________ | ________ |
| 37 | ________ | ________ |
| 38 | ________ | ________ |
| 39 | ________ | ________ |
| 40 | ________ | ________ |
| 41 | ________ | ________ |
| 42 | ________ | ________ |
| 43 | ________ | ________ |
| 44 | ________ | ________ |
| 45 | ________ | ________ |
| 46 | ________ | ________ |
| 47 | ________ | ________ |
| 48 | ________ | ________ |
| 49 | ________ | ________ |
| 50 | ________ | ________ |
| 51 | ________ | ________ |
| 52 | ________ | ________ |
| 53 | ________ | ________ |
| 54 | ________ | ________ |
| 55 | ________ | ________ |
| 56 | ________ | ________ |
| 57 | ________ | ________ |
| 58 | ________ | ________ |

Completed by ______________________ / ______________________ Date____________
(signature) (print name)

INTENTIONALLY BLANK

CONCLUDING MATERIAL

**Review Activity** (Original Revision)**:**

| DOE | Field Offices |
| --- | --- |
| DP | AL |
| EE | CH |
| EH | ID |
| EM | NV |
| ER | OR |
| FE | RL |
| FM | SF |
| HR | SR |
| NE | Fernald |
| NN | Golden |
| PO | |
| RW | |

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**Preparing Activity:**

DOE-DP-45

**Project Number:**

EDCN-0002

DOE F 1300.3
(01-94)

U.S. DEPARTMENT OF ENERGY

# DOCUMENT IMPROVEMENT PROPOSAL

*(Instructions on Reverse)*

OMB Control No.
1910-0900
OMB Burden Disclosure
Statement on Reverse

| 1. Document Number | 2. Document Title |
|---|---|
| | |

3a. Name of Submitting Organization

3b. Address *(Street, City, Zip Code)*

4. Type of Organization *(Mark one)*

- ☐ Vendor
- ☐ User
- ☐ Manufacturer
- ☐ Other (Specify: ____________________ )

5. Problem Areas (Attach extra sheets as needed.)

a. Paragraph Number and Wording

b. Recommended Wording

c. Reason/Rationale for Recommendation

6. Remarks

| 7a. Name of Submitter *(Last, First, MI)* | 7b. Work Telephone Number *(Include Area Code)* |
|---|---|
| 7c. Mailing Address *(Street, City, State, Zip Code)* | 8. Date of Submission |

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