IEEE Standard for Qualification of Class 1E Static Battery Chargers and Inverters for Nuclear Power Generating Stations

IEEE Power Engineering Society

Sponsored by the
Nuclear Power Engineering Committee

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Abstract: Methods for qualifying static battery chargers and inverters for Class 1E installations outside containment in nuclear power generating stations are described. These methods may also be used to qualify similar electronic equipment for use in applications outside containment, where specific standards for such equipment are not available. The qualification methods set forth employ a combination of type testing and analysis, the latter including a justification of methods, theories, and assumptions used. These procedures meet the requirements of IEEE Std 323™-2003.

Keywords: battery charger, inverter, qualification

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

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Introduction

This introduction is not part of IEEE Std 1202-2006, IEEE Standard for Qualification of Class 1E Static Battery Chargers and Inverters for Nuclear Power Generating Stations.

This standard provides the methods of qualifying Class 1E static battery chargers and inverters in accordance with IEEE Std 323-2003. The static battery chargers and inverters discussed in this standard are Class 1E. This document, however, addresses this equipment only as a subsystem in the safety-related electrical system.

The techniques and information contained in this standard may be applied to other similar electronic equipment.

The reliability analysis requirements of IEEE Std 577™-2004 and the methods described in IEEE Std 352™-1987 have been used along with statistical data.

The efforts of the working group on this standard and its annexes will continue for the purpose of updating and disseminating more information regarding qualification techniques. The subjects of aging and the use of surveillance/maintenance techniques to address aging will continue to be investigated and will be among the areas considered by the working group in future revisions of this standard..

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Dennis E. Dellinger, *Chair*
Kenneth Caldwell, *Vice Chair*

Satish K. Aggarwal
Thomas N. Brewington
Nissen M. Burstein
Robert Francis
James F. Gleason
James Parello
John M. Richards
E. Reilly Schum

At the time that it approved this standard, the Subcommittee on Qualification (SC2) had the following membership:

Satish K. Aggarwal, *Chair*
Patrick Gove, *Secretary*

Bohumil Bartonicek
Paul D. Baughman
Anup K. Behera
Steven D. Benson
Brij M. Bharteey
Thomas N. Brewington
Nissen M. Burstein
Steve Casadevall
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Javier A. Chicote
Sun Yeong Choi
Choon-Hoon Chung
James M. Dean
Liviu Nicolae Delcea
Dennis E. Dellinger
Philip DiBenedetto
Michael Doughtery
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Marco Van Uffelen
Laszlo Varga
Carl Weber
John Wheless
John White
Toni Wittamore
Richard T. Wood
Toshio Yamamoto

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George Ballassi
Farouk D. Baxter
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David J. Zaprazny

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Butch Anton
Michael P. Baldwin
Farouk D. Baxter
Robert R. Beavers
Richard T. Bolgeo
Wesley W. Bowers
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IEEE Standard for Qualification of Class 1E Static Battery Chargers and Inverters for Nuclear Power Generating Stations

1. Overview

1.1 Scope

This standard describes methods for qualifying static battery chargers and inverters for Class 1E installations outside containment in nuclear power generating stations. The application of this equipment in the plant's electrical system is not within the scope of this standard as other industry standards, such as IEEE Std 308™-2001 [B3],[1] IEEE Std 603™-1998 [B6] and IEEE Std 946™-2004 [B8], exist for this purpose. In addition, industry standards exist for equipment performance, such as ANSI/NEMA PE 5-2003 [B1] and IEEE Std 944™-1986 [B7]. Performance requirements are not specified in this standard.

1.2 Purpose

The purpose of this standard is to provide specific procedures to meet the requirements of IEEE Std 323™-2003.[2] For the purpose of this standard, battery chargers, inverters, and the associated ancillary equipment must perform their safety function under specified service and environmental conditions.

The demonstration that an installed battery charger or inverter will meet its design specification requires many steps in a program of design, fabrication, quality assurance, qualification, transportation, storage, installation, maintenance, periodic testing, and surveillance. This standard treats only the qualification area of this program. The result of the qualification program may provide a basis for determination of long-term maintenance requirements.

Qualification may be accomplished in several ways: type testing, operating experience, or analysis. These methods may be used individually or in combination. The qualification methods in this standard employ a combination of type testing and analysis. Operating experience is of limited use as a sole means of qualification. Operating experience is, however, of great use as a supplement to testing, as the experience may provide an insight into the change in behavior of materials and components through time under actual service and maintenance conditions. Qualification by analysis shall include a justification of the methods, theories, and assumptions used. In general, battery chargers and inverters are too complex to be qualified

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[1] The numbers in brackets correspond to those of the bibliography in Annex F.

[2] Information on references can be found in Clause 2.

by analysis alone, although analysis is effective in the extrapolation of test data and the determination of the effects of minor design changes to equipment previously tested.

2. Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

EIA 401-73 (Reaff 90), Paper, Paper/Film, Film Dielectric Capacitors for Power Semiconductor Applications.[3]

EIA 454-78 (Reaff 90), Fixed Paper and Film-Paper Dielectric Capacitors with Non-PCB Impregnants for Alternating Current Applications.

IEEE Std 101™-1987, IEEE Guide for the Statistical Analysis of Thermal Life Test Data.[4, 5]

IEEE Std 259™-1999, IEEE Standard Test Procedures for Evaluation of Systems of Insulation for Dry-Type Specialty and General-Purpose Transformers.

IEEE Std 323™-2003, IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations.

IEEE Std 344™-2004, IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Generating Stations.

IEEE Std 383™-2003, IEEE Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations.

IEEE Std 577™-2004, IEEE Standard Requirements for Reliability Analysis in the Design and Operation of Safety Systems for Nuclear Power Generating Stations.

3. Definitions

For the purposes of this document, the following terms and definitions apply. *The Authoritative Dictionary of IEEE Standard Terms* [B2] should be referenced for terms not defined in this clause.

3.1 battery charger: Equipment that converts ac power to dc power and is used to recharge and maintain a station battery in a fully charged condition and to supply power to dc loads during normal operation.

3.2 components: Items from which the equipment is assembled (e.g., resistors, capacitors, wires, connectors, semiconductors, tubes, switches, and electromechanical devices).

3.3 equipment: An assembly of components designed and manufactured to perform specific functions.

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[3] EIA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (http://global.ihs.com/).

[4] IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA (http://standards/ieee.org/).

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3.4 equipment qualification: The generation and maintenance of evidence to ensure that equipment will operate on demand to meet system performance requirements during normal and abnormal service conditions and postulated design basis events.

NOTE—Equipment qualification includes environmental and seismic qualification.[6]

3.5 inverter: Equipment that converts dc power to ac power. It includes auxiliary devices such as transfer switches, alternate source transformers and regulators, input rectifiers (other than battery chargers), and isolation devices (e.g., blocking diodes).

3.6 margin: The difference between service conditions and the conditions used for equipment qualification.

3.7 operating experience: Accumulation of verifiable service data for conditions equivalent to those for which particular equipment is to be qualified.

3.8 qualified life: The period of time, prior to the start of a design basis event, for which the equipment was demonstrated to meet the design requirements for the specified service conditions.

3.9 stressor: An agent or stimulus that stems from fabrication or perservice and service conditions and can produce immediate degradation or aging degradation of a system, structure, or component. (adapted from IEEE Std 1205™-2000 [B9])

NOTE—At the end of the qualified life, the equipment shall be capable of performing the safety function(s) required for the postulated design-basis and post-design-basis events (IEEE Std 323–2003). Class 1E equipment may include components that have significant aging mechanisms. The qualification process will include information on when these aging mechanisms start and any replacement/maintenance interval required.

4. Specifications

4.1 General

This subclause describes the items to be addressed in the owner's specifications for the equipment to be qualified. These items include the equipment identification, the Class 1E performance characteristics, the input power supply, the environmental conditions, and the effect of changes in input power supply and environmental conditions upon the Class 1E performance characteristics. If the equipment specification includes margins, as defined in Clause 3, their values shall be identified.

4.2 Class 1E performance characteristics and safety function

The nuclear plant owner or its representative shall specify the performance characteristics (including the safety function) of the equipment, including, as a minimum, numerical values and durations for normal, abnormal, design basis event (DBE), and post-design-basis event conditions, as indicated in 4.2.1 through 4.2.3. Stressors, as defined in 3.8 and 4.1 of IEEE Std 1205-2000 [B9], shall be addressed in defining the performance characteristics and safety function.

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[6] Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

4.2.1 Class 1E performance characteristics

The following characteristics are suggested conditions, parameters, and performance requirements to be considered in acceptance testing.

a) Input conditions, such as
    1) Voltage
    2) Frequency
    3) Phase
    4) Current (if limiting conditions exist for installed condition)

b) Output requirements, such as
    1) Voltage and voltage regulation
    2) Current (minimum and maximum)
    3) Current limit
    4) Frequency and frequency regulation (inverters only)
    5) Load power factor (inverters only)
    6) Ripple voltage (battery chargers only)
    7) Harmonic distortion (inverters only)

c) Surge withstand capability

d) Reverse dc current flow prevention (chargers only)

e) Characteristics of auxiliary equipment (if used), including
    1) Transfer switches (functional operation, e.g., transfer time, high- and low-voltage actuation, and overcurrent actuation)
    2) Inverter’s input rectifier (same input conditions as battery charger)
    3) Isolating device (blocking and conducting function)
    4) Alternate source transformer and regulator (input conditions and output requirements)

f) Other performance characteristics as required by owner/purchaser specifications

4.2.2 Description of the safety function of Class 1E charger or inverter

The safety function(s) of the equipment (including required operating time) shall be specified for applicable service and DBE conditions expected during its qualified life.

4.2.3 Qualified life objective (where applicable)

The equipment qualified life objective shall be specified along with the set of service conditions under which successful performance must be demonstrated before, during, and after a DBE as applicable.

4.3 Environment

All significant environmental parameters shall be specified in the owner’s specification. The range of environmental conditions shall include, as a minimum, normal and abnormal conditions and durations, as well as DBE and post-DBE conditions.

Where applicable, the equipment specification shall include numerical values for the magnitude and duration of the following service conditions:

a) Minimum and maximum, temperature including profiles if available

b) Minimum and maximum storage temperature

c) Maximum relative humidity (operating and storage)

d) Altitude (static air pressure)

e) Operational vibration

f) Seismic requirements

g) Nuclear radiation type

h) Irradiation (dose rate and total dose)

i) Radio frequency interference (RFI) and/or electromagnetic interference (EMI) levels (i.e., the effects of the charger or inverter on other equipment, or vice versa) as defined in NRC Reg. Guide 1.180-2003 [B11]

4.4 Other conditions

Where applicable, the equipment specifications shall include

a) Any significant rate of change or combinations of specified performance and environmental limits listed in 4.2 and 4.3

b) The expected total number of operating cycles or operating time period for the electromechanical devices (including periodic testing cycles)

c) Unusual atmospheric contamination (dust, oil, fungus, chemical or water spray, etc.)

d) Electrical and mechanical interfaces (input and output connections, mounting, voltages, currents, etc.) between the Class 1E equipment to be qualified and other equipment or devices

e) Dielectric test parameters

5. Qualification

The qualification of Class 1E static battery chargers and inverters shall be established by analysis and test as outlined in this clause. Figure 1 provides a pictorial overview.

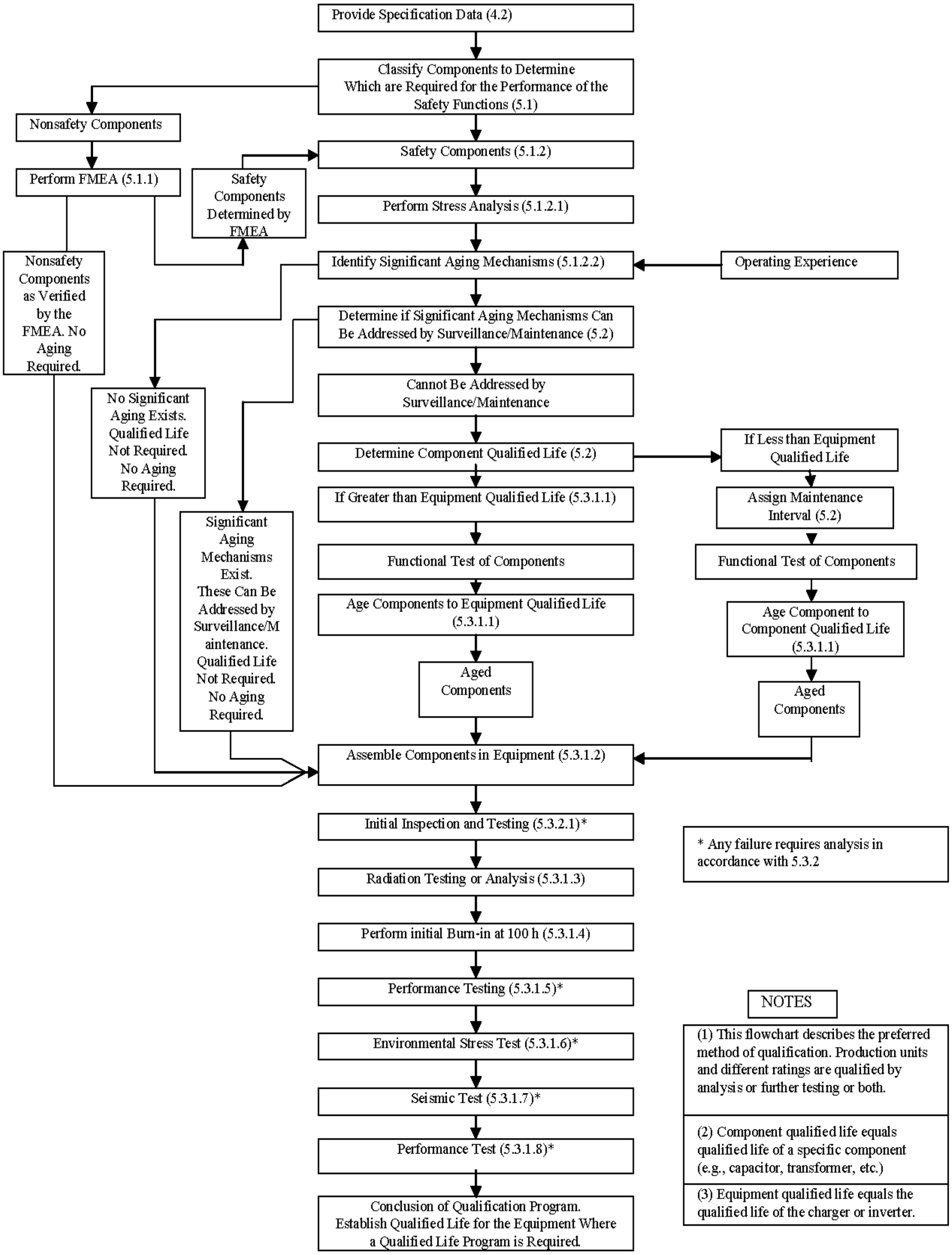

Figure 1—Flowchart for qualification of Class 1E static battery chargers and inverters

5.1 Analytical requirements

An analysis shall be performed on all components within the charger or inverter to determine which components are required for the performance of its safety function and which components are not.

5.1.1 Nonsafety component analysis

A failure modes and effects analysis (FMEA) shall be performed, in accordance with 4.2 of IEEE Std 577-2004,[7] on all components presumed to be nonsafety components. The FMEA shall demonstrate that the failure of these components, as used in the circuit throughout the qualified life of the equipment, does not affect the ability of the charger or inverter to perform its safety function (see 4.2.2) or, by way of interfaces, does not affect the safety functions) of other equipment. The nonsafety components shall be assembled into the sample equipment without additional analysis or testing. Any component whose failure is determined to affect the ability of the charger or inverter to perform its safety function by the FMEA shall be considered a safety component and is addressed in 5.1.2.

5.1.2 Safety component analysis

Components designated as safety components are those whose failure affects the ability of the charger or inverter to perform its safety function or, by way of interfaces, affects the safety function of other equipment. They shall be analyzed in accordance with the requirements of this subclause.

5.1.2.1 Operational stress analysis

An essential part of the qualification of this equipment is to verify the integrity of its design. Thus, as part of the qualification process, a stress analysis of the equipment shall be performed to assure that no electrical component is stressed to a point where its aging is accelerated beyond that expected in operation. Should any components be overstressed, a redesign shall be performed to correct this condition. Typical stress levels for voltage and power of 0.5 or less are not considered a contributor to aging. Annex A provides background information on this topic as well as an example of a stress analysis.

5.1.2.2 Component classification

All safety components within the charger or inverter shall be classified as either components for which aging is not a significant failure mechanism or components for which aging is a significant failure mechanism. An aging mechanism is significant if, in the normal and abnormal service environment, it causes degradation during the installed life of the equipment that progressively and appreciably renders the equipment vulnerable to failure to perform its safety function(s) under DBE conditions (see 6.2.1 of IEEE Std 323-2003). Operating experience, testing, and analysis may be used in this classification process.

5.1.2.2.1 Components without significant aging mechanisms

If the components are designed and manufactured with the same techniques used to manufacture the commercial grade equivalent of mil-spec components, and they are applied within their design rating (as determined by the stress analysis in 5.1.2.1) and a radiation environment less than 1.0E + 03 rads, then the aging effect on the components will not be significant during the qualified life of the equipment in which they are installed.

Aging may not be a significant failure mechanism for the components identified with a Phi (Φ) symbol. These components must be designed and manufactured with the same techniques and materials as components that exhibited no difference in performance due to age-related degradation. Component data used to make such a determination must be technically justifiable. Any differences between the specific components used in a charger or inverter and those identified in the publication must be justified.

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[7] For guidance in performing an FMEA, consult IEEE Std 352™-1987 [B4].

NOTE—The symbol Φ as used in this subclause does not refer to activation energy.

The components listed below are reflective of but not limited to:

a) Electronic components*
    1) Discrete semiconductors
    2) Surge suppressors — metal-oxide varistors and silicon type
    3) Resistors
    4) Tantalum dry electrolytic capacitors
    5) Ceramic capacitors
    6) Dry paper and plastic film capacitors
    7) Mica capacitors
    8) Glass capacitors
    9) Integrated microelectronic devices
    10) Hybrid microcircuits
    11) Φ Fuses
    12) Φ Control and instrument transformers and inductors
b) Nonelectronic components.*
    1) Structural, nonwire insulating elements, and connections made of the following materials:
        i) Steel
        ii) Aluminum
        iii) Copper
        iv) Epoxy/fiberglass laminates, NEMA Grade G-10 or G-11 equivalent
        v) Brass
        vi) Ceramic
        vii) Glass-filled diallyl phthalate
    2) Electromechanical components.* Aging is not a significant failure mechanism for certain types of the following electromechanical components in typical Class 1E battery charger or static inverter applications:
        i) Φ Connectors
        ii) Φ Sockets (IC, transistor, relay)
        iii) Φ Terminal blocks made of the following materials:
            — DAP
            — Melamine
            — Nylon
            — Nylon 6.6
            — Glass-filled phenolic
            — General-purpose phenolic

iv) Φ Fuse blocks made of the following materials:
    - Melamine
    - X laminate
    - Glass-filled polyester
    - Phenolic
    - Polycarbonate

v) Φ Meters
vi) Φ Lamp sockets
vii) Φ Electronic time-delay relays
viii) Motors
ix) Circuit breakers (molded case)
x) Φ Relays (general purpose) — normally de-energized
xi) Φ Snap acting switches

*Radiation tolerance levels must be verified by the manufacture/qualifier to envelop the design radiation requirement.

NOTE—Annex A and Annex C furnish guidance for classifying additional components as those for which aging is not a significant failure mechanism.

Justification must be provided to classify components not meeting the above criteria as components without significant aging mechanisms.

5.1.2.2.2 Components with significant aging mechanisms

Unless documentation showing that aging is not a significant failure mechanism can be provided, it shall be assumed that the following components have significant aging mechanisms:

a) Electromechanical components such as relays, fans, contactors, and circuit breakers
b) Insulated wire
c) Power magnetic components
d) Wet electrolytic capacitors
e) Surge suppressors (selenium)
f) AC oil-filled capacitors
g) Organic materials other than the non-aging, electromechanical components listed in item b2) of 5.1.2.2.1
h) Other components or materials not specified above

5.2 Component qualification

Components with significant aging mechanism need not be aged prior to the type test if they can be addressed by periodic inservice surveillance/maintenance. To qualify components with significant aging mechanisms that cannot be addressed by periodic inservice surveillance/maintenance, the component shall be aged to the equipment qualified life objective. If the qualified life of the component is expected to be less than that of the equipment, then the component shall be aged to its qualified life (prior to the type test) based on either operating experience or component-life test data.

The replacement interval for limited-life components that cannot meet the desired equipment qualified life shall be equal to or less than their qualified life. The qualified life of a component may be extended after installation by additional testing, analysis, or operating experience. The specified replacement interval of a component shall be equal to or less than the interval established in the qualification process.

Components with significant aging mechanisms shall be aged in accordance with one or more of the following techniques.

5.2.1 Natural aging

Components may be taken from a field installation that has been operating for the desired period designated as the component qualified life. Documentation shall be provided to demonstrate that the installed service conditions meet or exceed the specified service conditions.

5.2.2 Accelerated aging

Accelerated aging is the process of subjecting a component or equipment to stress conditions at a rate greater than natural aging, in accordance with known measurable physical or chemical laws of degradation. This action renders its physical and electrical properties similar to those it would have at an advanced age operating under expected service conditions. The methodology may include radiation, thermal, and/or wear aging as required. The following methods are recommended for accelerated aging of components where the component has not been exempted (see 5.1.2.2.1 and 5.1.2.2.2).

5.2.2.1 Circuit breakers and electromechanical switches

The predominant age-related failure mode of circuit breakers and switches in typical Class 1E battery charger and static inverter applications is of a mechanical fatigue nature, as induced by switching cycles (Annex D). However, an analysis of the materials employed in this device, in accordance with 5.1.2.2, is also required. Due to the continuous operating mode of this equipment, circuit breakers and control and power switches (and their associated annunciating relays) are cycled only during testing, preventive and corrective maintenance, and plant shutdown periods. A determination of anticipated maximum number of cycles [see item b) of 4.4] during the qualified life shall be made based on the sum of the following:

a) Number of cycles required for all necessary testing prior to plant operation
b) Estimated number of equipment maintenance cycles
c) Number of customer-planned cycles for any purpose (equipment or plant maintenance, etc.)

The breakers and switches shall then be cycled, at their maximum load, for the number of cycles determined above. Coil-insulation systems associated with the breakers and switches shall be aged as described in 5.2.2.3. Lubricants shall also be evaluated to determine whether aging will inhibit operation of the device.

5.2.2.2 Electromechanical relays

The predominant age-related failure modes of electromechanical relays in typical Class 1E battery charger and static inverter applications are, as a result of fatigue, due to operating cycles and failure of the coil insulation system. The operating mode of each relay shall be identified as follows:

a) Normally energized—high-duty cycle (many times per day)

b) Normally energized—low-duty cycle (relay used during maintenance and testing, etc.)

c) Normally de-energized—high-duty cycle

d) Normally de-energized—low-duty cycle

The maximum expected number of operating cycles of each relay shall be determined for the equipment qualified life based on the relay's use in the equipment and the same criteria in 5.2.2.1. All relays shall be cycled under simulated service conditions for the number of cycles determined above. The coil-insulation system shall be aged as described in 5.2.2.3. An analysis of the materials employed in these devices, as described in 5.1.2.2, is also required.

5.2.2.3 Magnetic components

The life of magnetic components, as used in chargers and inverters, is determined by the insulation system (see IEEE Std 259-1999). An insulation system, on which thermal evaluation has been performed and correlated temperature versus age data has been established, shall be employed. Magnetic components shall be subjected to accelerated aging to the desired qualified life in accordance with 3.2 of IEEE Std 259-1999.

5.2.2.4 Wire, cable, terminal blocks, and connections

Insulated wire and cable shall be qualified for temperature, humidity, and time required for normal service of this equipment by the methods described in IEEE Std 383-2003. Connectors shall be qualified for temperature, humidity, and time required for normal service of this equipment by the methods described in IEEE Std 572™-1985 [B5]. The basis for qualification shall include pre-aging data to simulate qualified life (such as Arrhenius plots with 95% confidence limits). Wire and cable insulation used in equipment units to be qualified by type testing shall be thermally aged in accordance with this data. Where practical, wire shall be aged in harnesses with connectors and terminal blocks attached, in order to test the integrity of the connection methods employed in the aged condition. When mechanical cycling of connectors can be shown to occur very infrequently, cycling need not be considered as an aging factor for qualification. Each type of connector and terminal block used in the equipment shall be included. Interconnections shall be tested through the thermal and mechanical stresses induced by the burn-in test (see 5.3.1.4), the stress test (see 5.3.1.6), and the seismic test (see 5.3.1.7).

5.2.2.5 DC electrolytic capacitors

Accelerated aging of dc electrolytic capacitors shall be achieved by subjecting the capacitors to rated core temperature and rated working voltage for the rated life or less. The rated life is the life published by the capacitor manufacturer when the capacitor is operated within rated conditions. The acceleration factors are obtained from the capacitor manufacturer's curves that relate the ratio of rated working voltage and core temperature to actual operating working voltage and core temperature.

5.2.2.6 AC oil-filled capacitors

Accelerated aging of ac oil-filled capacitors for sinusoidal voltage applications shall be achieved in accordance with the life data curves in EIA 401-73 and EIA 454-78. Capacitors subject to nonsinusoidal voltage, or other than 60 Hz (e.g., commutating capacitors), shall be aged as described above based on the equivalent 60 Hz sinusoidal voltage.

5.2.2.7 Surge suppressors

The protection of the power and control semiconductors against transient surges across the input and the output of the equipment may be accomplished through the use of surge suppressors, transzorbs, mov's, etc. The rate of aging of surge suppressors is determined primarily by the amount and duration of the applied current. The device passes current only when transient surges are encountered. The surge suppressors shall be aged by subjecting the device to the maximum number of surges anticipated during the qualified life. Unless otherwise required in the equipment specification, the device shall be subjected to 100 surges to simulate the qualified life. The surges shall be equal to or greater than those specified in item c) in 4.2.1.

5.2.2.8 Circuit board assemblies

Circuit boards may consist of devices with significant aging mechanisms and devices without significant aging mechanisms. An analysis shall be performed of all components on the board to determine whether any have significant aging mechanisms. If there are no components with significant aging mechanisms on the circuit board, it does not have to be aged prior to the type test. If there are components with significant aging mechanisms on the board that cannot be addressed by surveillance/maintenance, the component that has the shortest qualified life determines the qualified life of the board. All components with significant aging mechanisms shall be aged to the qualified life of the short-life component in accordance with the aging techniques in this subclause. These components may be aged on or off the circuit board. If aged off the board, care shall be taken to avoid damaging the components during assembly onto the board.

5.2.2.9 Fuses

Fuses in Class 1E battery chargers and inverters are used to protect semiconductors, instrumentation, and power and control circuits. Fuses shall be properly applied in circuits with respect to ampacity, voltage, and temperature. Specifically, an adequate temperature margin shall be provided to preclude an increase in temperature rise at the fuse or fuse holder termination beyond the fuse rating. Documentation may be provided to verify that the fuses are properly applied in the circuits with respect to ampacity, voltage, and temperature, and that adequate temperature margin has been provided to preclude an increase in temperature rise at the fuse or fuse holder termination beyond the fuse rating. If such documentation is provided, there are no age-related common-mode failure mechanisms for the fuses used. If this documentation is not available, this device may be aged by natural or accelerated methods.

5.2.2.10 Organic materials

Arrhenius plots (see IEEE Std 101-1987) may be used to develop accelerated thermal aging techniques for the organic materials to be qualified. If Arrhenius plots and activation energy values do not exist for certain materials, an activation energy of similar material shall be considered. If reference activation energy levels cannot be justified, an activation energy of 0.8 eV should be used as a conservative and technically justifiable value.

5.2.2.11 Motors, pumps, and/or other components

Motors, pumps, and/or other components may consist of materials with significant aging mechanisms. An analysis shall be performed on all materials to determine whether any have significant aging mechanisms. If a component has no materials with significant aging mechanisms, it does not have to be aged prior to the type test. If a component has materials with significant aging mechanisms that cannot be addressed by surveillance/maintenance, the component shall be aged in accordance with the aging techniques in this subclause. The material that has the shortest qualified life determines the qualified life of the component.

5.3 Equipment qualification

Subclause 6.3.1.7 of IEEE Std 323–2003 outlines a sequence in which type testing may be performed. For equipment with components with significant aging mechanisms that cannot be addressed by surveillance/maintenance techniques, this sequence is not followed in this standard, due to the variation in aging rates of the components. Since the equipment is to be assembled of aged components, testing of the sample equipment must come after the components have been aged and the assembly is complete. The type test sequence in this subclause is conservative in that the components are subjected to additional stresses after aging. With the inclusion of the seismic test, this conservatism is sufficient to account for reasonable uncertainties in demonstrating satisfactory performance and normal variations in commercial production, and thus assure that the equipment can perform under the most adverse condition specified.

5.3.1 Type test

The type test sequence shall be conducted as follows.

5.3.1.1 Component aging

Components shall be analyzed and, where required, aged to their respective qualified life or the equipment qualified life, whichever is less, in accordance with 5.2.

5.3.1.2 Component and equipment aging

New (nonaged) and age-conditioned components shall be assembled into a complete piece of equipment in accordance with applicable production procedures. Mechanical inspection, dielectric testing [see item e) of 4.4], and functional testing for normal conditions (see 4.2) shall be performed. When applicable the ability of the equipment to operate within the levels of EMI/RFI specified in item i) of 4.3 shall be demonstrated by analysis, testing, or both to the purchaser specified standard. The equipment that is to undergo the EMI/RFI testing shall be a technically justifiable representative new or aged piece(s) of equipment.

5.3.1.3 Radiation analysis or testing

Since the battery charger or inverter is located in an environment where only low levels (typically less than 1.0E + 03 rads, total integrated dose) of radiation are encountered. Documentation (analysis or testing) shall be provided to demonstrate that the ability of the equipment to perform its required function is unaffected by the radiation dose specified in item g) and item h) of 4.3.

5.3.1.4 Equipment burn-in

The equipment shall be subjected to minimum burn-in of 100 h (50 h at full load, 50 h at minimum specified load) at room ambient temperature. The purchaser may specify variations to the nominal input voltages if deemed appropriate for installed conditions. The burn-in places the equipment into its normal installed condition and is intended to eliminate infant mortality failures.

5.3.1.5 Pre-environmental stress performance test

To establish a reference for the measurement of operating parameters under normal and worst-case conditions and a valid basis for the comparison of test results, the complete equipment shall be subjected to the conditioning process as follows.

Place the equipment in an environmental test chamber that has the capability of being varied in both temperature and humidity over the required service conditions. With the chamber set at an ambient temperature of 25 °C ± 5 °C and prevailing relative humidity, operate the equipment at full load for a period of 2 h and document functional performance data for normal conditions [see item a), item b1), item b2), and item b4) of 4.2.1. This data shall be analyzed for conformance to the Class 1E performance characteristics and used as reference data for the continued tests to follow. Calibration adjustments may be made to the equipment at this time.

5.3.1.6 Environmental stress test

To demonstrate that the equipment will meet its specified Class 1E performance characteristics under the specified service conditions (as required by IEEE Std 323–2003), refer to Figure 2 and perform the following stress test on the fully loaded equipment, or load condition that generates the maximum heat, in the test chamber:

a) Allow the chamber to increase to the maximum temperature and maximum relative humidity specified in the service conditions (see 4.3). The equipment shall be operated at this level for a period of 8 h, at the end of which functional performance data [see item a), item b1), item b2), and item b4) of 4.2.1] at maximum, nominal, and minimum input voltages, and maximum and minimum loads shall be documented.

b) Allow the chamber to decrease to the minimum temperature specified in the service conditions (see 4.3) and maximum obtainable relative humidity (50% minimum). The equipment shall be operated at this level for a period of 8 h, at the end of which functional performance data [see item a), item b1), item b2), and item b4) of 4.2.1] at maximum, nominal, and minimum input voltages, and maximum and minimum loads shall be documented.

c) A complete cycle, including the transition period, shall last a maximum of 36 h. At the end of the test cycle, the equipment shall be allowed to stabilize at room ambient temperature and humidity, and a final set of functional performance data [see item a), item b1), item b2), and item b4) of 4.2.1] at maximum, nominal, and minimum input voltages, and maximum and minimum loads shall be documented. The above stress test is described in Figure 2.

This test subjects the complete equipment to the worst-case and nominal conditions of temperature, humidity, input voltages, and output loads (input frequency variations have no impact on stressing the equipment).

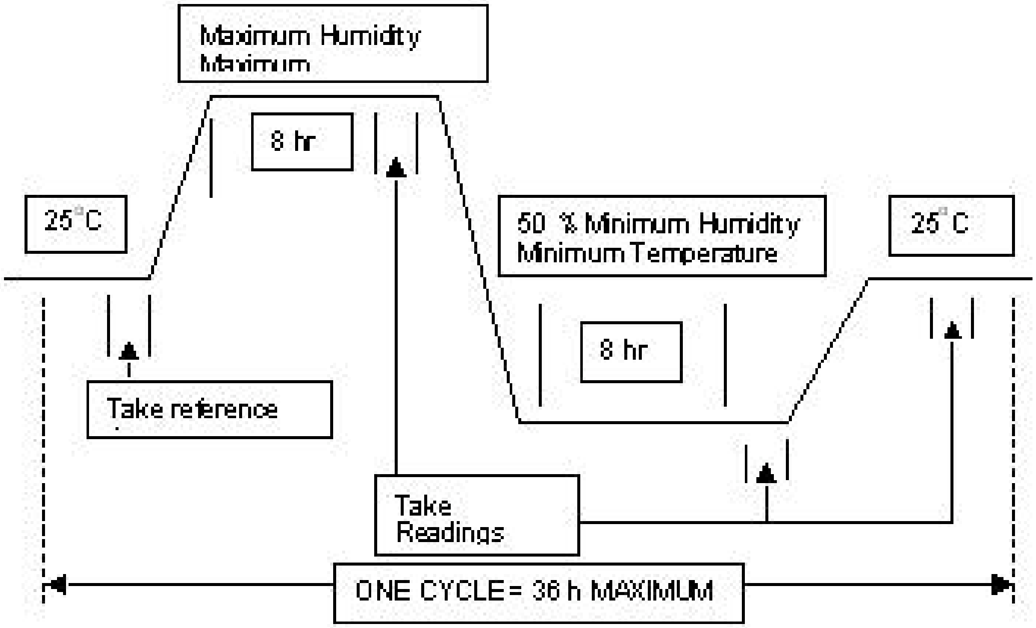

Figure 2—Environmental stress test

5.3.1.7 Seismic test

The ability of the equipment to withstand the operational vibration requirements specified in item e) of 4.3 shall be demonstrated by analysis, testing, or both. The equipment shall therefore be seismically qualified according to IEEE Std 344-2004. The seismic acceleration levels shall include, as a minimum, +10% for margin for the SSE test (see 4.1). If tested, the equipment shall be operated during and after the seismic test at rated output and specified input voltage.

5.3.1.8 Performance test

Upon successful completion of these tests, a functional test shall be performed to meet the Class 1E performance requirements for normal conditions specified in 4.2, and the equipment shall be considered qualified.

5.3.2 Acceptance criteria

Should any failure occur during test steps 5.3.1.2, 5.3.1.3, or 5.3.1.4, the defective component shall be replaced with a component that has been subjected to the same aging as the component that it replaces. In the evaluation of the type test results, any sample equipment is considered to have passed when the equipment meets or exceeds the function required by the equipment specification (see Clause 4).

Any failure occurring during the testing and qualification process shall be analyzed to determine whether it is of random or common cause origin. The failure shall be determined not to be of common cause origin if one of the following criteria is met:

a) Physical examination of the failed component(s) and its interface(s) determines that a random workmanship problem was the cause of failure.

b) Reexamination of the stress analysis determines that the part is properly applied and any components similarly applied in the test sample have had no like failures and the failure is not repeated during subsequent retesting with replacement components.

NOTE—For purposes of this standard, consequential component failures caused by the failure of a single component are not considered to be of common cause origin.

If the above or other methods have not identified the cause of failure, further analysis must be conducted.

If a failure is determined not to be of common cause origin, the equipment shall be repaired with replacement components that have been subjected to the same aging as those that it replaces (see 5.2). If the type test is continued, then it shall commence at the beginning of the specific test during which it failed.

If a failure is determined to be the common cause (either age-related or stress-related), the equipment shall be rejected. Qualification of the equipment may be attained by redesigning, modifying, and retesting as above, or qualifying for less stringent conditions by retesting to lower parameters (e.g., shorter qualified component or equipment life, or lower seismic values).

5.4 Qualification of a product line

It is possible to qualify a product line (that is, chargers or inverters of a similar design of assorted ratings) by using all of the following techniques:

a) Perform a type test on sample equipment in accordance with 5.3.1.

b) Perform a complete analysis of components of the other model ratings, in accordance with 5.1, to demonstrate that no component of the type aged and qualified in the type tests is stressed at a rate higher than that in the qualified model, to the extent that a different aging acceleration would have to be employed. Should the analysis determine that either a different aging acceleration test is necessary or an entirely new generic type of part be employed, the part shall be aged and seismic tested as a component or assembly to a level equivalent to the previous qualification level.

NOTE — Different ratings of the same component family are considered type-qualified if the applied stress does not exceed that in the qualification model.

c) Verify that the service conditions to which the qualified unit was tested are at least as severe as those specified of the unit being qualified.

d) Each model rating shall be seismically qualified by testing or analysis, or both, in accordance with IEEE Std 344-2004, and a determination shall be made that the acceleration of components or assemblies does not exceed that of the qualified model.

5.5 Extension of qualified life

The methods described in 6.3.5 of IEEE Std 323–2003 are applicable for extending the qualified life of Class 1E static chargers and inverters.

6. Documentation

6.1 General

The following documents are required to verify that the Class 1E static battery charger or inverter is qualified for its application, meets the specification requirements of Clause 4, and has its qualified life or periodic surveillance/ maintenance interval established.

6.2 Qualification plan

The qualification plan shall contain a description of the methods and procedures used to qualify a particular Class 1E static charger or inverter for a specific application. The plan shall contain the following:

a) Identification of the equipment to be qualified, including mounting and interface requirements if applicable

b) Qualification procedures applicable to the equipment to be qualified

c) Details on the differences between the equipment to be qualified and equipment that is type tested, and the methods used to justify those differences

d) Description of the acceptance criteria for the equipment to be qualified

e) Description of the safety function of the equipment to be qualified

f) Where applicable, the qualified life objective of the equipment to be qualified

This plan shall be used to ensure consistency between the type-tested equipment and the equipment to be qualified.

6.3 Qualification report

The qualification report shall contain the following:

a) Equipment specifications (see Clause 4).

b) Identification of specific features to be demonstrated by the analysis and testing, including a summary of acceptance criteria met. Specific functions or parameters that may have been excluded from the qualification should also be listed.

c) Qualification plan (see 6.2).

d) Qualification results, which shall include:

    1) Failure modes and effects analysis (FMEA) for nonsafety related components, if applicable (see 5.1.1).

    2) Stress analysis (see 5.1.2.1).

    3) Documentation for classification for component qualification (5.1.2.2).

    4) Identification of any scheduled surveillance/maintenance, periodic testing, and any parts replacement required to maintain qualification.

    5) Test data, aging data (where applicable) for age-sensitive components, accuracy, and instrument calibration for each test described in 5.3.1. A seismic test report or analysis shall be furnished.

    6) Documentation for EMI/RFI analysis or test (see 5.3.1.2).

    7) Documentation for radiation analysis or test (see 5.3.1.3).

    8) Analysis for any failure or anomaly occurring during the qualification type test.

    9) Any shelf-life requirements.

    10) Where applicable, identification of equipment qualified life with a summary of justification for the qualified life.

    11) Where applicable, extension of qualified life data.

6.4 Qualification of product line

The qualification report (see 6.3) may provide a basis for qualifying Class 1E static battery chargers and inverters of various sizes and ratings. Documentation shall be provided that verifies that such analysis is performed in accordance with 5.4.

6.5 Additional documentation requirements

a) *Certificate of compliance*. A certificate of compliance that certifies that the equipment supplied meets the requirements of the owner’s specification is required.

b) *Approval signature and date*. Each of the above documents shall include an approval signature and date.

c) *Qualification report*. The qualification report shall include, in addition, the approval signature of an independent reviewer and date.

Annex A

(informative)

Stress analysis

A.1 Introduction

This annex outlines a stress analysis procedure and provides an example for performing the stress analysis required by 5.1.2.1. Other procedures, if properly justified, may be used.

A.2 Objectives

The primary purpose of the stress analysis, as part of the qualification process, is to ensure that no component is stressed to a point where its aging is accelerated beyond that in expected service conditions. The stress analysis will indicate where redesign is required for any overstressed components. In addition, the stress analysis will provide a database for generic product line qualification, enabling a direct design comparison of other ratings with that originally qualified.

A.3 Definition

stress analysis: An electrical and thermal design analysis of component applications in specific circuits under the specified range of service conditions. Mechanical cycling evaluation shall be performed on applicable components to determine the impact on component life.

A.4 Procedures

A.4.1 Analysis

A part-stress analysis of the components of each charger or inverter to be qualified should be performed in accordance with MIL-HDBK-217F-1995 [B10] (see B.3.2).

a) For stress analysis to be valid, manufacturer’s ratings should never be exceeded.
b) Semiconductors should be analyzed for both thermal and voltage stress.
c) Capacitors should be analyzed for voltage stress.
d) Resistors should be analyzed for thermal stress.
e) Fuses should be analyzed for voltage and thermal stress.

The stress analysis should be performed, assuming an ambient air-inlet temperature of 25 °C, or the maximum, plus the worst-case internal temperature rise for the inverter or charger (normally, 5 °C to 10 °C). Design information should be obtained from the charger or inverter schematic drawings, assembly drawings, list of materials, parts catalogs, and data sheets.

The analysis method described above consists of determining electrical stress, thermal stress, and failure rates of system components based on the proper selection and use of each component and the environment in which the equipment is to be used.

Stress analysis should be performed in accordance with Section 5.1 of MIL-HDBK-217F-1995 [B10] (see B.3.2).

A.4.2 Calculations

In performing the electrical stress analysis, each circuit in the charger or inverter should be analyzed in detail. Equivalent circuits may be used to determine loop currents and node voltages. From these currents and voltages, applied stress can be obtained. All stress calculations should be made in accordance with the methods outlined in MIL-HDBK-217F-1995 [B10] (see B.3.2). Refer to B.3 for the minimum applied stress ratios. The stress ratios are defined as follows:

For semiconductors:

$$\text{stress ratio} = \frac{\text{power applied}}{\text{power rated}}$$

$$\text{stress ratio} = \frac{\text{volts applied}}{\text{volts rated}}$$

For resistors:

$$\text{stress ratio} = \frac{\text{power applied}}{\text{power rated}}$$

For capacitors:

$$\text{stress ratio} = \frac{\text{volts applied}}{\text{volts rated}}$$

Finally, the stress correction factor for each semiconductor device should be determined based on maximum junction temperature T_{max} and operating temperature T_{s}.

$$\text{Stress correction factor (CF)} = \frac{T_{\text{max}} - T_{\text{s}}}{150}$$

Component stress should be calculated assuming that all possible modes of circuit operation may be used continuously. Worst-case operating mode conditions should be used. Since worst case cannot occur for all components simultaneously, the result of the analysis will be conservative.

A.4.3 Stress analysis data

The results of the stress analysis should be tabulated in a form similar to that shown in Table A.1 and Table A.2. These stress analysis data sheets should list all system electrical components by assembly or printed circuit board, or both. Components should be arranged by type and circuit application. Identical components used such that identical maximum stress occurs may be listed together by symbol numbers in the first column, yielding a part quantity. The component MIL style designations are listed along with a brief description, permitting identification. Where MIL designations are not available, the accepted industry type or company source control drawing should be listed. Capacitor values are listed in µF and pF. Resistors values are in Ω, and stress is in mW, unless otherwise noted.

Table A.1—Sample stress analysis data sheet

System: INV 253-1-101				**Assembly: DC–DC Converter Board**				
Reference designation	**Component**	**Value**	**Description or part number**	**Specification**	**Stress**		**Stress ratio**	**Quantity**
CR122	SiDIODE, RECT		1N4004	MILS-19500	1 A	<0.1 A	0.1	1
CR123	RECT		1N4004		1 A	<0.1 A	0.1	
CR124	RECT		1N4004		1 A	<0.1 A	0.1	
CR125	VR		1N5352B		5 W	0.27 W	0.1	
CR126	RECT		1N4004		1 A	0.2 A	0.2	
CR127						0.2 A	0.2	
CR128						0.2 A	0.2	
CR129						<0.1 A	0.1	
CR130	RECT		1N4004		1 A	<0.1 A	0.1	
CR131	VR		1N7534		400 mW	55 mW	0.2	
CR132	SIG		1N914		75 mW	<1.0 mA	0.1	
CR133	RECT		1N4004		1A	<0.1 A		
CR134								
CR135								
CR136								
CR137	RECT		1N4004		1A	<0.1 A	0.1	
CR138	VR		1N5352B		6 W	0.57 W	0.2	
CR139	SiDIODE, VR		1N5352B	1111S-19500	5 W	0.57 W	0.2	1
BRIM	SiDIODE, R BRIDGE		MDA990-3		30 A	1.5 A	0.1	1 × 4
Temperature: 35 °C				Environment: GF				

Table A.2—Sample stress analysis data sheet

System: INV 253-1-101				**Assembly: DC–DC Converter Board**				
Reference designation	**Component**	**Value**	**Description or part number**	**Specification**	**Stress**		**Stress ratio**	**Quantity**
R122	RESISTOR, CC	10 kΩ	RC20	MIL-R-11	500 mW	17 mW	0.1	1
R123	MF	162 kΩ	RN60	MIL-R-10509	125 mW	60 mW	0.5	
R124	MF	13.7 kΩ	RN60	MIL-R-10509	125 mW	7 mW	0.1	
R125	CC	1 kΩ	RN20	MIL-R-11	500 mW	80 mW	0.2	
R126	CC	1 kΩ				3 mW	0.1	
R127		100 kΩ				2 mW	0.1	
R128		2.2 kΩ				90 mW	0.2	
R129		470 kΩ				8 mW	0.1	
R130	CC	10 kΩ	RC20	MIL-R-11	500 mW	20 mW	0.1	
R131	WW	0.68 kΩ	CW5	MIL-R-26	5 mW	0.68 W	0.2	
R132	WW	0.68 kΩ	CW5	MIL-R-26	5 mW	0.68 W	0.2	
R133	WW	0.68 kΩ	CW5	MIL-R-26	5 mW	0.68 W	0.2	
R134	CT	1 kΩ	RC20	MIL-R-11	500 mW	4 mW	0.1	
R135	CC	390 kΩ	RC42	MIL-R-11	2 mW	0.58 mW	0.3	
R136	CC	470 kΩ	RC20	MIL-R-11	500 mW	20 mW	0.1	
R137	RESISTOR, WW	1 kΩ	CW10	MIL-R-26	1 mW	2.5 W	0.3	1
Temperature: 35 °C				Environment: GF				

Annex B

(informative)

Electronic components for which aging is not a failure mechanism

B.1 Introduction

Aging is not a significant failure mechanism for certain electronic components in typical Class 1E static battery charger and inverter applications.

When applied within their design rating, the aging of electronic components occurs at such a low rate that its effect on failure rate is undetectable. Silicon-base semiconductors, for example, never wear out if constructed and used according to specifications. All semiconductors, however, contain manufacturing imperfections (e.g., at the bonding junction) that eventually cause failure. Most devices have only slight imperfections that allow a lengthy service life. About 1% have defects that cause early infant mortality failures. The burn-in requirement is used to eliminate as many of these devices as possible.

B.2 Failure rate history for components

To illustrate the failure rate history of these electronic components, refer to Figure B.1. This bathtub curve has three characteristic sections. The first section reflects a high failure rate due to early failures of weak or defective components. The components are not representative of the longevity of the others and are usually eliminated from use by subjecting the sample to a preliminary period of operation, often referred to as a burn-in period. During this period, the initially high failure rate will continue to decrease until it reaches a value for which it remains relatively constant with respect to time. The burn-in period is of short duration, typically 30 h to 100 h. The second section of the failure-rate time history curve represents the random failure-rate value of the component sample where none of the systematic failure mechanisms are operating, such as early defects or wearout failures. The duration of this section is several thousand times as long as the burn-in period. The third section of the bathtub curve is the beginning of the wearout failure mechanism for the component. Since the desired equipment qualified life falls within the area of the curve in which the electronic component failure rate is constant, the failure rate of a new (burned-in) component is essentially equal to the failure rate of a component aged to the equipment qualified life. That is, the wearout period for electronic components falls beyond the equipment qualified life.

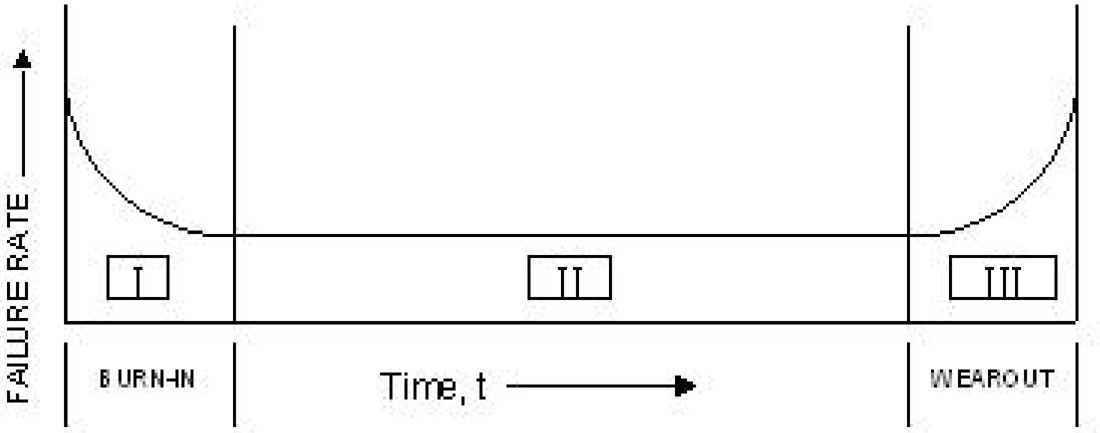

Figure B.1—Failure rate history for components, in percent

Although it is true that extended extremes of temperature and humidity can alter this non-aging characteristic, this annex applies only to applications where the temperature and humidity will remain within the specified service conditions. Thus, aging within the qualified life period is not a significant failure mechanism.

B.3 Bibliography—Electronic components

An extensive bibliography has been assembled to justify the non-aging concept presented here.

NOTE—References that contain specific conclusions that support the non-aging concept are followed by an asterisk.

B.3.1 Non-aging concept for electronic components

EPRI NP-3326, *Correlation Between Aging and Seismic Qualification for Nuclear Plant Electrical Components—Phase 1*, Dec. 1983.*

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B.3.2 Silicon semiconductors

The statements made in the references below are based on actual test data on Mil-Spec as well as on commercial-grade components. This bibliography does not require that Mil-Spec components be used as long as they are components that have been manufactured using the same techniques as those used to manufacture the equivalent Mil-Spec components. For the purpose of this standard, Joint Electron Device Engineering Council (JEDEC)[8] components are considered to be acceptable commercial-grade-equivalent Mil-Spec components.

EIA Recommended Standard RS-313-B, Thermal Resistance Measurements of Conduction Cooled Power Transistors, Oct. 1975.[9]

EPRI NP-3326, *Correlation Between Aging and Seismic Qualification for Nuclear Plant Electrical Components— Phase 1*, Dec. 1983.*

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Table B.1— Resistors—Fixed resistor selection guide

Section	Type	Styles available in standard	Section	Type	Styles available in standard
101	Composition		302	Film, established reliability	RNR50
(MIL-R-11)	(insulated)		(MIL-R-55182)		RNR55
					RNR60
102	Film (high stability)	RN75			RNR65
(MIL-R-10509)					RNR70
103	Film (power type)	RD60	303	Wire-wound (accurate), established reliability	RBR52
(MIL-R-11804)		RD65	(MIL-R-39005)		RBR53
		RD70			RBR54
					RBR55
104	Wire-wound				RBR56
(MIL-R-93)	(accurate)				RBR57
					RBR71
					RBR72
106	Wire-wound (power type)	RW29			
(MIL-R-26)		RW31	304	Wire-wound (power type), established reliability	RWR74
		RW33	(MIL-R-39007)		RWR78
		RW35			RWR80
		RW37			RWR81
		RW38			RWR84
		RW47			RWR89
		RW56			
			305	Film (insulated)	RLR05
107	Film (insulated)		(MIL-R-39017)	established reliability	RLR07
(MIL-R-22684)					RLR20
					RLR32
					RLR42
108	Wire-wound (power type, chassis mount)	RE77			
(MIL-R-18546)		RE80	306	Wire-wound (power type, chassis mount), established reliability	RER40
			(MIL-R-39003)		RER45
					RER50
301	Composition (insulated), established reliability	RCR05			RER55
(MIL-R-39008)		RCR07			RER60
		RCR20			RER65
		RCR32			RER70
		RCR42			RER75

Table B.2— Resistors—Variable resistor selection guide

Section	Type	Styles available in standard
201	Composition	RV4
(MIL-R-94)	(insulated)	RV6
202	Wire-wound (low operating temperature)	RA20
(MIL-R-19)		RA30
203	Wire-wound	RP05
(MIL-R-22)	(power type)	RP06
		RP10
		RP15
		RP20
		RP25
		RP30
204	Wire-wound, precision	RR0900
(MIL-R-12934)		RR1000
		RR1100
		RR1300
		RR1400
		RR2000
		RR2100
		RR3000
205	Wire-wound, semi	RK09
(MIL-R-39002)	precision	
206	Wire-wound (lead screw activated)	RT26
(MIL-R-27208)		
207	Nonwire-wound (lead screw activated)	RJ12
(MIL-R-22097)		RJ22
		RJ24
		RJ26
		RJ50
208	Nonwire-wound	RVC5
(MIL-R-23285)		RVC6
401	Wire-wound (lead screw activated), established reliability	RTR12
(MIL-R-39015)		RTR22
		RTR24
402	Nonwire-wound (lead screw activated), established reliability	RJR12
(MIL-R-39035)		RJR24

B.3.3 Resistors

These resistors meet the non-aging criteria when they are applied within their wattage ratings as in Table B.3.

Table B.3—Maximum applied stress ratios

Type	Applied stress in percent of rated Watts
Carbon	50%
Film	50%
Wire-wound	60%

NOTE 1—The above stress values in B.2 were obtained from MIL-Std-199B-1974.

NOTE 2—Various grades of resistors, from Mil-Spec to commercial grade, are available for use in Class 1E charger/inverter applications. The non-aging criteria apply to the resistors in Table B.1 as long as they are used within their wattage ratings as stated above and manufactured with techniques used to manufacture the equivalent Mil-Spec resistors.

NOTE 3—Mil-Spec resistors are not required by this standard.

"Flameproof Resistors—Select Them Carefully or You May Get Burned," *Electronic Products Magazine,* Aug. 15, 1983.

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B.3.4 Tantalum dry electrolytic capacitors

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B.3.5 Capacitors (ceramic, paper, plastic film, mica, glass)

With the exception of oil-filled type paper or plastic film capacitors, the non-aging criteria applies, provided the capacitors are manufactured using the same techniques used in manufacturing the equivalent Mil-Spec components listed in Table B.2. For additional information, see Mil-Std-198D-1976.

NOTE—This standard does not require the use of Mil-Spec components.

EPRI NP-3326, *Correlation Between Aging and Seismic Qualification for Nuclear Plant Electrical Components—Phase 1*, Dec. 1983.*

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B.3.6 Integrated microelectronic devices and hybrid microcircuits

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Table B.4—Capacitors

Dielectric	Applicable specification
Glass	
Fixed	MIL-C-23269 (ER)
Variable 1	MIL-C-14409
Mica	MIL-C-10950
Button style	MIL-C-5
General purpose	MIL-C-39001 (ER)
Electrolytic	
Tantalum (solid)	MIL-C-39003 (ER)
Tantalum (solid) chip	MIL-C-55365 (ER)
Paper	
Wax-impregnated	MIL-C-12889
Metallized	MIL-C-39022 (ER)
Paper-Plastic	
Polycarbonate	MIL-C-19978 (ER)
Paper & polyethylene	
Terephthalate	MIL-C-19978 (ER)
Plastic or metallized plastic	MIL-C-55514 (ER)
Polyethylene terephthalate	MIL-C-19978 (ER)
Ceramic	MIL-C-11015
Fixed, general purpose	MIL-C-39014 (ER)
Temp compensating	MIL-C-20 (ER)
Variable	MIL-C-81
Fixed, chip	MIL-C-55681 (ER)
Gas or vacuum	
Fixed	MIL-C-23183
Variable	MIL-C-23183

Annex C

(informative)

Nonelectronic components for which aging is not a failure mechanism

C.1 General

Aging is not a failure mechanism for certain nonelectronic components used as structural, nonwire insulating elements, and connections (in typical Class 1E charger/inverter applications) that are processed using approved methods. The quality assurance procedures required for nuclear safety applications by ASME NQA-1-1986 (see C.2.1) and 10-CFR-50 (see C.2.1) provide for stringent controls of such processes as welding, soldering and crimping, and assembly and finishing. One purpose of these controls is to assure that no degradation of structural integrity occurs to mechanical parts, fasteners, and the like. In addition, IEEE Std 344-2004 specifically requires that equipment that is to be qualified be subjected to requirements that simulate the effects of structural-related aging on the equipment. The following components do not have a significant age-related failure mechanism when used in Class 1E static battery chargers and inverters:

a) Aluminum
b) Brass
c) Ceramic
d) Copper
e) Steel

C.2 Bibliography—Nonmetallic, nonelectronic components

An extensive bibliography has been assembled to justify that certain nonmetallic components, as used in typical Class 1E charger/inverter applications, do not have age-related failure mechanisms within a service life of 40 years.

NOTE—References that contain specific conclusions that support the non-aging concept are followed by an asterisk.

C.2.1 Epoxy fiberglass grade G-10 and G-11 or equivalent (not exposed to bright light for prolonged periods)

ASME NQA-1-1986, Quality Assurance Requirements for Nuclear Facilities.[11]

EPRI NP-3326, *Correlation Between Aging and Seismic Qualification for Nuclear Plant Electrical Components—Phase 1*, Dec. 1983.*

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C.2.2 Glass-filled diallyl phthalate

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EPRI NP-2129, *Report of Radiation Effects on Organic Materials in Nuclear Plants*.

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RADC-TR-73-400, Reliability Study of Polyimide/Glass Multilayer Boards (Final technical report, Mar. 1972–Jun. 1973), AD-777 194/2.

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[12] RADC documents are available from Customer Services Staff, NTIS—US Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161, USA.

RADC-TR-74-88, Infrared Testing of Multilayer Boards (Final report, Sep. 1973–Jan. 1974), AD-780 550/0.

RADC-TR-75-22, Nonelectronic Reliability Notebook (Final report), AD-A005 657/2.

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10-CFR-Title 15, Regulations Relating to Foreign Trade, Appendix B, 869-011-000-48-7.[13]

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Annex D

(informative)

Discussion of failure mechanisms in electromechanical devices

The predominant cause of failure of electromechanical devices used in chargers and inverters is cycle-induced fatigue. This applies to relays, switches (including contactors), and circuit breakers when applied properly in the design in terms of electrical stress. This statement applies to electromechanical devices using approved materials of the types described in Annex C or other qualified components. Thus, an analysis, in accordance with 5.1.2, of the materials employed in the devices is required.

Some concern has been voiced about relays and other devices that, after being kept in the same state (energized or de-energized) for a period of years, are called on to act, only to be found frozen into position. This may not apply to chargers and inverters for the following reasons:

a) Routine plant maintenance of batteries to which the chargers and inverters are connected may require that the equipment be turned on and off, as well as disconnected, one or two times a year. This action would cycle all devices in question.

b) Maintenance replacements of limited-life items may occur every few years, again cycling these devices.

These electromechanical devices have typically been endurance tested by the device manufacturer for tens and hundreds of thousands of operations. As applied in battery chargers and inverters, these devices will typically be subjected to only a few hundred operations over their expected qualified life. The actual operating duty is therefore only a small fraction of the tested life of the device, and thus, it provides a very high design margin.

As a result of the above, cycling these electromechanical devices to the total number of anticipated cycles during the qualified life period under equivalent stress (load) conditions, along with the final temperature-humidity seismic testing of the equipment itself, will provide a reasonable simulation of expected condition at the end of the qualified life period.

Annex E

(informative)

Cycling of connectors

In Class 1E battery chargers and static inverters, wire and cable harnesses, and their associated connectors and terminal blocks, are fixed objects after they have passed final inspection and acceptance by the customer. Connector disconnect and reconnect may occur on a very low duty cycle basis. This can be demonstrated by performing mean time between failure (MTBF) calculations on the associated circuit board assemblies to determine their replacement interval. There is no planned maintenance requirement for operation of the connectors or terminal blocks. Thus, cycling of these devices, as employed in this equipment, is not an age-related failure mechanism. For more information, refer to IEEE Std 572-1985 [B5].[14]

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[14] See Footnote 3.

Annex F

(informative)

Bibliography

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[B4] IEEE Std 352-1987, IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Safety Systems.

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[B9] IEEE Std 1205-2000, IEEE Guide for Assessing, Monitoring and Mitigating Aging Effects on Class 1E Equipment Used in Nuclear Power Generating Stations.

[B10] MIL-HDBK-217F-1995, Reliability Prediction Of Electronic Equipment.[17]

[B11] NRC Reg. Guide 1.180-2003, Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems.[18]

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