IEEE-650 overview

IEEE-650 is the standard that has been used for over twenty years to qualify inverters, battery chargers and ancillary equipment to meet the requirements of IEEE-323 for 1-E equipment. It is specific to mild environments outside of the containment while addressing potential electrical, mechanical and environmental extremes (abnormal conditions) that the equipment could be subject to within the facility over it’s lifetime.

IEEE-650 was developed and is maintained by a group of professional experts, from the designers to industry users, to insure only the highest reliability equipment is installed to protect nuclear facilities around the world. The intention is to verify from design stage through installation that the highest amount of integrity and reliability is build into each system.

For this overview, several figures will be referenced throughout the explanation. For the convenience of the reader, if the figure is referred to multiple times it is placed on a separate page to allow for easy reference.

The purpose of the IEEE-650 standard is to prove that the battery chargers and inverters perform their safety function under specified service conditions.

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

The equipment baseline electrical testing is addressed in IEEE-944 and NEMA-PE-5. The seismic testing requirements are addressed by IEEE-344.

For the following steps in the discussion, Figure 1 should be used as the referenced flowchart.

Step 1

This section 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, their values shall be identified.

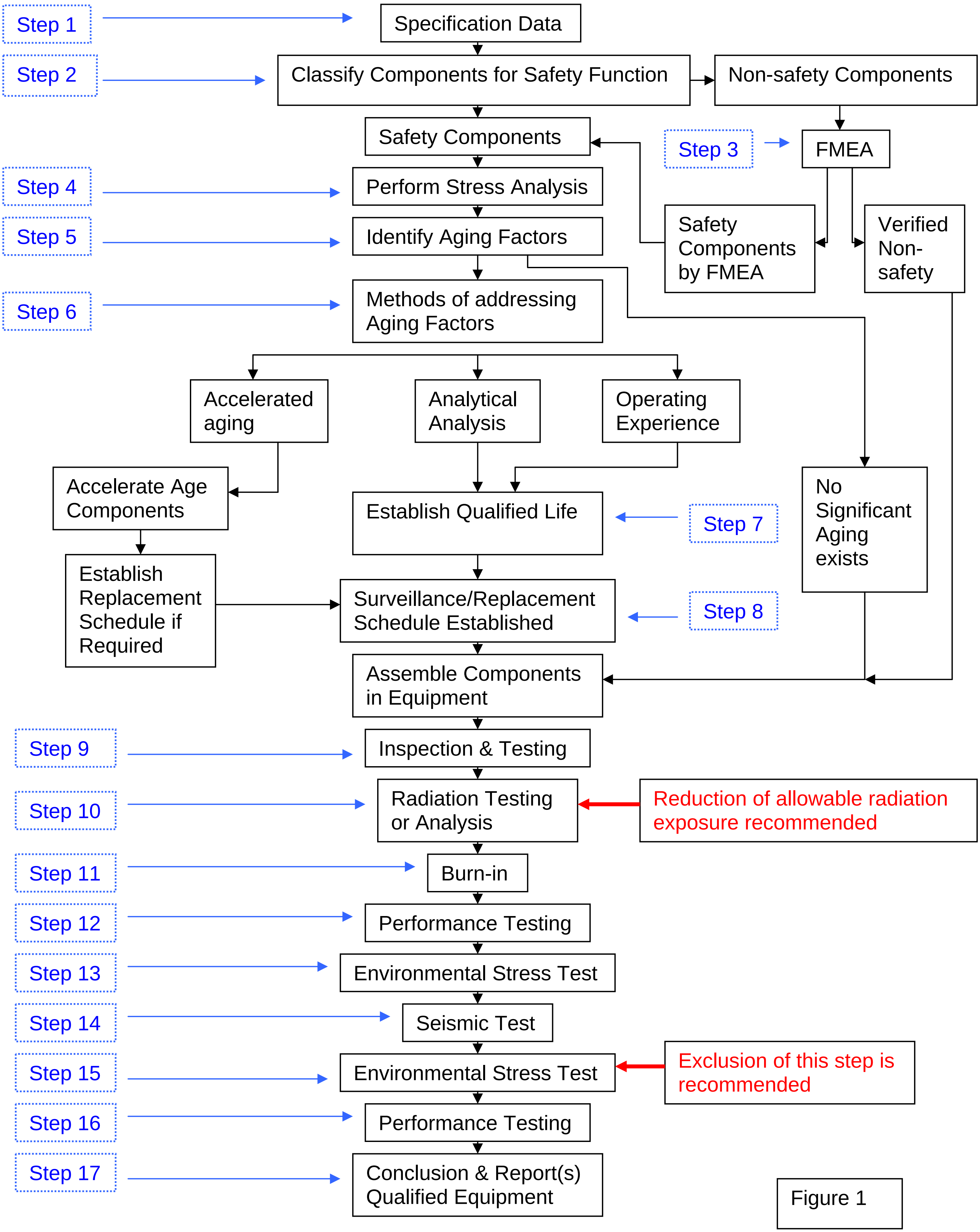
Step 1
Specification Data
Step 2
Classify Components for Safety Function
Non-safety Components
Safety Components
Step 3
FMEA
Step 4
Perform Stress Analysis
Step 5
Identify Aging Factors
Safety Components by FMEA
Verified Non-safety
Step 6
Methods of addressing Aging Factors
Accelerated aging
Analytical Analysis
Operating Experience
Accelerate Age Components
Establish Qualified Life
Step 7
No Significant Aging exists
Establish Replacement Schedule if Required
Surveillance/Replacement Schedule Established
Step 8
Assemble Components in Equipment
Step 9
Inspection & Testing
Step 10
Radiation Testing or Analysis
Reduction of allowable radiation exposure recommended
Step 11
Burn-in
Step 12
Performance Testing
Step 13
Environmental Stress Test
Step 14
Seismic Test
Step 15
Environmental Stress Test
Exclusion of this step is recommended
Step 16
Performance Testing
Step 17
Conclusion & Report(s) Qualified Equipment

Figure 1

Step 2

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.

Step 3

A failure modes and effects analysis (FMEA) shall be performed on all components presumed to be non-safety 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. This also includes, by way of interfaces, that they do not affect the safety function(s) of other equipment. The non-safety 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.

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.

Note: Complexity of systems along with maintaining dual inventory, QA and maintenance of parts, has dictated that in some systems all components be classified as safety. This eliminates need and cost of dual inventory, procedures and maintenance. The FMEA also assists the maintenance personnel in determining operability for minor issues such as pilot light failure or meter operability.

Step 4

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. Appendix A of IEEE-650 provides background information on this topic, as well as an example of a stress analysis.

Step 5

All safety components within the charger or inverter shall be classified either as 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. Operating experience, testing, and analysis may be utilized in this classification process.

Step 6

Addressing aging of components is covered by three methods, operating experience, analytical analysis and accelerated aging. The use of accelerated aging can be time consuming and expensive thus the data from previous components is used to supplement and verify the methods of operating experience and analytical calculations. For some materials, significant data exists that justify the classification of “no significant aging” as outlined in IEEE-650 and similar documents. Metallic and non-organic materials usually are enveloped in this category.

Step 7

For components and materials that are identified to have aging mechanisms a qualified life is to be established. This allows for the components or materials to be replaced before they degrade to a point where it could effect the operability of the system during and after the DBE event. The qualified life is of a duration shorter that expected life, to encompass margins for adverse operational parameters and increase the confidence levels.

Step 8

For the components that have a qualified life that is less than the qualified life of the system, a surveillance/replacement schedule must be established. This schedule is to include components that have been identified from step seven. In addition, the manufacture may include items, materials and special procedures to encompass operating experiences and good engineering practices.

Step 9

Inspections are to be performed to verify that the system has been manufactured to the appropriate quality assurance standards and guidelines. The testing should include basic functions and dielectric testing to verify proper assembly and design.

Step 10

The radiation testing or analysis is required to verify that the components and materials used will withstand the potential of radiation exposure that the system may be subject to under a DBE event. Significant data is available to typically verify this by analysis. Note: Radiation can be an aging factor and, depending on condition, may not be a replaceable item. Radiation analysis is typically performed in conjunction with addressing aging factors.

Step 11

The equipment is subjected to minimum burn-in of 100 h (50 h at full load, 50 h at minimum specified load) at room ambient temperature. The burn-in places the equipment into its normal installed condition and is intended to eliminate infant mortality failures. The placement of the burn-in in the testing cycle is sometimes placed after the initial performance test to insure that a component change due to a performance factor is incorporated.

Step 12

Performance testing at a minimum should encompass the production test requirements IEEE-944, NEMA-PE5, etc. Additional testing may be specified by the purchaser or deemed necessary by the manufacture to insure that all the operational parameters are verified. Typical tests include Line and load regulation tests, alarm circuit verification, harmonics etc.

Step 13

In order to demonstrate that the equipment will meet its specified Class 1E performance characteristics under the specified service conditions, a stress test shall be performed. This test, referenced by IEEE-323, is characterized in Fig 2 (below). The environmental stress test subjects the fully loaded equipment in the test chamber to the potential extremes it may be subject to before and/or after the DBE event. This complete event must be complete in 36 hrs. maximum.

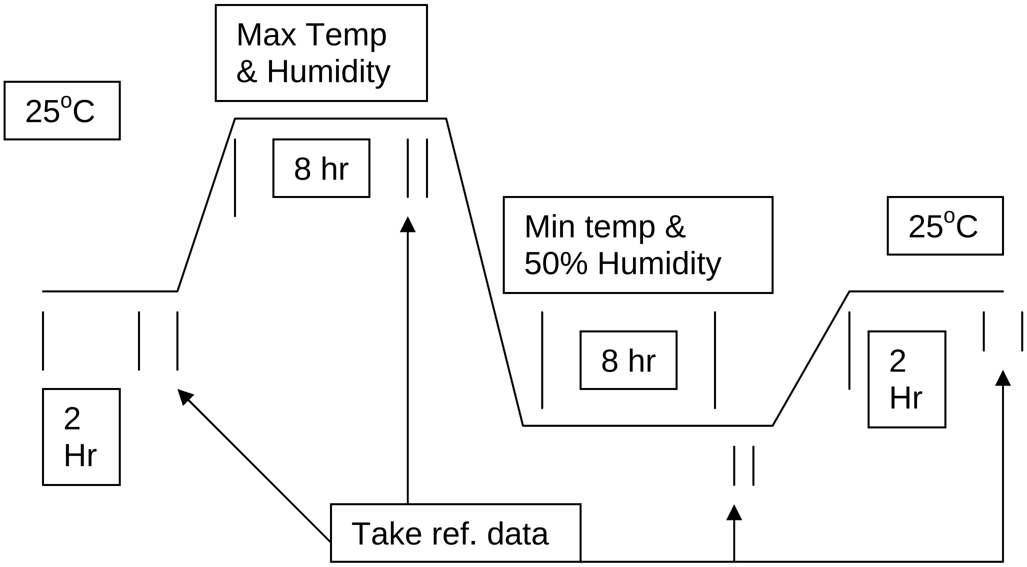

Figure 2

Step 14

The ability of the equipment to withstand the operational vibration requirements shall be demonstrated by analysis, testing, or both. The equipment shall therefore be seismically qualified according to IEEE Std 344-1987. The seismic acceleration levels shall include, as a minimum, +10% for margin if not already incorporated into the required response spectra. If tested, the equipment shall be operated during and after the seismic test at rated output and specified input voltage.

Step 15

This step is a repeat of step 13 to verify that the equipment can function as intended following a seismic event and at extreme environment conditions.

Step 16

This is a series of electrical performace tests to verify that the equipment functions as intended under all line and load conditions. In generat a majority of the tests performed is step 12 (excluding burn-in) may be performed.

Step 17

While not an actual portion of the qualification this step compiles all the data, test reports and certification to prove that the equipment is qualified to the imposed requirements.