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(Revision of
IEEE Std 420-1982™)

420™

IEEE Standard for the Design and Qualification of Class 1E Control Boards, Panels, and Racks Used in Nuclear Power Generating Stations

IEEE Power Engineering Society

Sponsored by the
Nuclear Power Engineering Committee

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IEEE Std 420-2001™
(Revision of ANSI/IEEE Std 420-1982)

IEEE Standard for the Design and Qualification of Class 1E Control Boards, Panels, and Racks Used in Nuclear Power Generating Stations

Sponsor

Nuclear Power Engineering Committee
of the
IEEE Power Engineering Society

Approved 10 October 2001

IEEE-SA Standards Board

Abstract: This standard specifies the design requirements for new and/or modified Class 1E control boards, panels, and racks and establishes the methods to verify that these requirements have been satisfied. Methods for meeting the separation criteria contained in ANSI/IEEE Std 384-1992 are addressed. Qualification is also included to address the overall requirements of ANSI/IEEE Std 323-1983 and ANSI/IEEE Std 344-1987.
Keywords: cabling, control boards, independence, isolation, nuclear, panels, qualification, racks, safety, separation, wiring

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Introduction

(This introduction is not a part of IEEE Std 420-2001, IEEE Standard for the Design and Qualification of Class 1E Control Boards, Panels, and Racks Used in Nuclear Power Generating Stations.)

IEEE Std 420 was originally prepared in 1973 and revised in 1982 by the Power Generation Committee of the IEEE Power Engineering Society. Based on the activities and scope of that Committee and those of the IEEE Nuclear Power Engineering Committee (NPEC), in 1994 the responsibility for the standard was transferred to NPEC, specifically to NPEC Subcommittee 6, Working Group 6.5.

IEEE Std 420-2001 provides the requirements for the design, manufacture, and qualification of Class 1E control boards, panels, and racks. It may also serve for modifications to control boards, panels, and racks installed in existing plants.

This standard is not intended to define the selection, design, or qualification of piping, modules, or other equipment mounted on the Class 1E control boards, panels, or racks. However, it is concerned with the effect that such mounted equipment has on the design and qualification of Class 1E control boards, panels, or racks. The selection, design, and qualification of piping, modules, and other equipment are covered by other standards.

The purpose of this revision, IEEE Std 420-2001, is to address the following:

a) Separation requirements as related to the requirements of ANSI/IEEE Std 384-1992[a]
b) References as listed in ANSI/IEEE Std 420-1982
c) Comments received on ANSI/IEEE Std 420-1982

The separation criteria contained in ANSI/IEEE Std 384-1992 were used in the preparation of this revision, IEEE Std 420-2001. It is the intent of the Working Group that these two documents be consistent. The Working Group received comments regarding the need for specific separation requirements for fiber-optic cabling. Until further guidance is provided, separation requirements for fiber-optic cabling should be in accordance with ANSI/IEEE Std 384-1992.

The qualification of Class 1E control boards, panels, and racks is included in this standard to address the overall requirements of ANSI/IEEE Std 323-1983 and ANSI/IEEE Std 344-1987. The qualification areas covered consist mainly of environmental and seismic requirements that specifically relate to control boards, panels, and racks. Other IEEE standards have been referenced as necessary to provide applicable qualification information, such as aging methodology.

One of the issues discussed by the Working Group was that of commercial grade dedication. After much discussion, it was agreed that there is nothing unique about the commercial grade dedication process as it applies to the design and qualification of control boards, panels, and racks. Therefore, no reference to this process is included in the body of the standard.

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

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Participants

At the time this revised standard was completed, the Working Group had the following membership:

R. C. Jamison, *Chair*

I. Ahmad	G. L. Doman	T. Wong
S. Avila	J. J. Gyrath	P. L. Yanosy
G. L. Deyoung	P. Katers	M. S. Zar
J. J. Disosway	D. E. Thatcher	

Also, at the time this revised standard was completed, Subcommittee 6 (Safety Related Systems) under the Nuclear Power Engineering Committee had the following membership:

P. L. Yanosy, *Chair*
D. A. Horvath, *Secretary*

W. W. Bowers	B. P. Grim	M. H. Miller
R. Copyak	R. C. Jamison	J. B. Waclo
J. J. Disosway	T. Klein	D. J. Zaprazny
L. E. Erin	A. C. Marinos	

Moreover, at the time this revised standard was completed, the Nuclear Power Engineering Committee had the following membership:

N. P. Smith, *Chair*
J. P. Carter, *Vice Chair*
J. J. Disosway, *Secretary*

S. K. Aggarwal	J. R. Fragola	W. W. Michel
G. Attarian	W. C. Gangloff	G. L. Nicely
V. P. Bacanskas	B. P. Grim	R. D. Parker
F. D. Baxter	R. E. Hall	B. Skoras
B. M. Bharteey	G. K. Henry	J. E. Stoner
W. W. Bowers	D. A. Horvath	P. Szabados
D. F. Brosnan	P. R. Johnson	J. E. Thomas
S. P. Carfagno	S. Kasturi	G. J. Toman
R. C. Carruth	J. T. Keiper	T. J. Voss
J. P. Carter	J. MacDonald	J. B. Waclo
R. L. Copyak	S. Malcolm	R. Weronick
P. Duggan	A. Marion	P. L. Yanosy
S. K. Dureja		D. J. Zaprazny

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The following members of the balloting group voted on this revised standard. Balloters may have voted for approval, disapproval, or abstention:

Satish K. Aggarwal	Edward F. Dowling	Gregory K. Henry
Vincent P. Bacanskas	Richard E. Dulski	James T. Keiper
Michael P. Baldwin	Surinder K. Dureja	John R. Matras
Farouk D. Baxter	Leo G. Egan	John E. Merando, Jr.
Wesley W. Bowers	Julian Forster	Richard B. Miller
Daniel F. Brosnan	Joseph R. Fragola	Burt Nemroff
Nissen M. Burstein	Wilmer C. Gangloff	Neil P. Smith
Salvatore P. Carfagno	Lawrence P. Gradin	James E. Thomas
Robert C. Carruth	John Kenneth Greene	Gary J. Toman
John P. Carter	Britton P. Grim	John B. Waclo
Raymond J. Christensen	Robert E. Hall	G. O. Wilkinson
Robert L. Copyak	Joe T. Hazeltine	David J. Zaprazny
John J. Disosway		Mark S. Zar

When the IEEE-SA Standards Board approved this revised standard on 10 October 2001, it had the following membership:

Donald N. Heirman, *Chair*
James T. Carlo, *Vice Chair*
Judith Gorman, *Secretary*

Satish K. Aggarwal	James H. Gurney	James W. Moore
Mark D. Bowman	Richard J. Holleman	Robert F. Munzner
Gary R. Engmann	Lowell G. Johnson	Ronald C. Petersen
Harold E. Epstein	Robert J. Kennelly	Gerald H. Peterson
H. Landis Floyd	Joseph L. Koepfinger*	John B. Posey
Jay Forster*	Peter H. Lips	Gary S. Robinson
Howard M. Frazier	L. Bruce McClung	Akio Tojo
Ruben D. Garzon	Daleep C. Mohla	Donald W. Zipse

*Member Emeritus

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IEEE Standard for the Design and Qualification of Class 1E Control Boards, Panels, and Racks Used in Nuclear Power Generating Stations

1. Overview

1.1 Scope

This standard applies to the design and qualification of Class 1E control boards, panels, and racks. It does not apply to individual components, modules, and external field-run cables except as they may affect the design and qualification of Class 1E control boards, panels, and racks.

1.2 Purpose

The purpose of this standard is to specify the design requirements for Class 1E control boards, panels, and racks and to establish the methods to verify that these requirements have been satisfied.

2. References

This standard shall be used in conjunction with the following publications. If the following publications are superseded by an approved revision, the revision shall apply.

ANSI/IEEE Std 323-1983 (Reaff 1996), IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations.[1]

ANSI/IEEE Std 338-1987 (Reaff 2000), IEEE Standard Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems.

[1]ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http://www.ansi.org/).

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ANSI/IEEE Std 344-1987 (Reaff 1993), IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations.

ANSI/IEEE Std 383-1974 (Reaff 1992), IEEE Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations.

ANSI/IEEE Std 384-1992 (Reaff 1998), IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits.

ANSI/IEEE Std 518-1982 (Reaff 1996), IEEE Guide for the Installation of Electrical Equipment to Minimize Electrical Noise Inputs to Controllers from External Sources.

ANSI/UL 94-1993, Tests for Flammability of Plastic Materials for Parts in Devices and Appliances.

ASME NQA 1-2001, Quality Assurance Requirements for Nuclear Facilities Applications.[2]

IEEE Std 603-1998, IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations.[3]

IEEE Std 1023-1988 (Reaff 1995), IEEE Guide for Application of Human Factors Engineering to Systems, Equipment, and Facilities of Nuclear Power Generating Stations.

IEEE Std 1050-1996, IEEE Guide for Instrumentation and Control Equipment Grounding in Generating Stations.

3. Definitions

For the purposes of this standard, the following terms and definitions apply. IEEE 100, *The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition [B1],[4] should be referenced for terms not defined in this clause.

3.1 control board: An assembly of panels on which are installed components and modules for monitoring, measuring, and controlling remotely operated systems and equipment. It provides a visual and physical interface between the operator and the systems. A control board is also known as a *control switchboard*, *control panel*, *benchboard*, or *console*.

3.2 panel: A unit of one or more sections of flat material suitable for mounting electrical devices.

3.3 rack: A framework, constructed of rails or steel members, for mounting an assembly of modules for monitoring, measuring, and controlling remotely operated systems.

[2]ASME publications are available from the American Society of Mechanical Engineers, 3 Park Avenue, New York, NY 10016-5990, USA (http://www.asme.org/).
[3]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).
[4]The numbers in brackets correspond to those of the bibliography in Annex A.

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4. Design considerations

4.1 Human factors

The design/layout of the Class 1E control board, panel, or rack shall incorporate human factors engineering principles (see IEEE Std 1023-1988 for further guidance).

4.2 Seismic

4.2.1 General

The structure for a Class 1E control board, panel, or rack shall enable the equipment contained therein to meet its essential performance requirements during and after the postulated design basis earthquake. The Class 1E control board, panel, or rack should be designed to minimize the acceleration levels to which the equipment must be qualified. In minimizing the acceleration levels, consideration shall be given to existing qualification levels of equipment. For further guidance see ANSI/IEEE Std 344-1987.

In designing the control board, panel, or rack, consideration shall be given to the location of the devices mounted upon it or within it. The designer's responsibility is to optimize the effectiveness of the control board, panel, or rack as a suitable structure for mounted devices. The designer should also consider location and availability of component mounting surface areas for future modifications and additions.

4.2.2 Other considerations

Provisions shall be included for mounting the control board, panel, or rack to its supporting structure. The interaction of the plant cable, raceway, and tubing systems entering and/or attached to the control board, panel, or rack shall be considered.

Plug-in equipment, slide-mounted equipment, or devices with access doors shall be provided with mechanical restraints, if needed, to maintain positional integrity.

All non-Class 1E devices within or attached to Class 1E control boards, panels, or racks shall be mounted to preclude degradation of Class 1E equipment or circuits, or both, beyond an acceptable level, as a result of a seismic event.

Where relative motion exists between equipment mounted on or in a control board structure, the maximum range of such motion shall be considered in the physical arrangement and design parameters for wiring and adjacent equipment. Wiring to equipment and termination devices should have sufficient slack or be installed in such a way that relative motion within the control board, panel, or rack does not cause failure.

4.3 Independence

The general requirements for achieving electrical independence of redundant Class 1E equipment and circuits are contained in ANSI/IEEE Std 384-1992.

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4.3.1 Design considerations

Specific guidelines that shall be used in the application of the physical separation criteria in ANSI/IEEE Std 384-1992 to the design of control boards, panels, and racks are as follows:

a) The preferred method for achieving physical separation is to locate redundant Class 1E equipment and circuits on separate control boards, panels, and racks that are physically separated from each other in accordance with the general independence criteria of ANSI/IEEE Std 384-1992. This method is suggested for panels or racks not requiring operator interface, such as termination cabinets.
b) Where operational and human factors considerations dictate, redundant Class 1E equipment or a mixture of Class 1E and non-Class 1E equipment may be located on the same panel, provided that specified separation criteria, established for this purpose in ANSI/IEEE Std 384-1992, are met within the control board.

4.3.2 Circuitry considerations

When redundant Class 1E circuits or a mixture of Class 1E, associated, and non-Class 1E circuits are to be located within the same control board, panel, or rack, the specific separation criteria for control switchboards in ANSI/IEEE Std 384-1992 shall be met.

To facilitate meeting the physical separation criteria, the following factors shall be considered in the design and construction of Class 1E control boards, panels, and racks:

a) Termination areas and cable entrance areas provided for external (field) cables shall be designed and located so that the minimum physical separation requirements of ANSI/IEEE Std 384-1992 for external cables can be maintained at the point of cable entrance into the control board, panel, or rack. Separate cable entrances, wire ducts, and termination areas are a preferred means for meeting these requirements.
b) Equipment and components installed in Class 1E control boards, panels, and racks shall be located to meet the physical separation requirements for Class 1E, associated, and non-Class 1E circuits.
c) Internal wiring shall be routed and supported such that the designed physical separation is maintained throughout the life of the Class 1E control board, panel, or rack.

4.3.3 Acceptable separation distances and barriers

The specific physical separation distances are provided in ANSI/IEEE Std 384-1992. If the minimum allowable separation distance cannot be maintained (and analysis is not used), ANSI/IEEE Std 384-1992 allows the installation of barriers between the equipment and wiring that requires separation. Examples of acceptable barriers for use within Class 1E control boards, panels, and racks are as follows:

a) Metallic conduits that are not in contact with each other
b) A single sheet of fire-retardant material with cable touching only one side of the barrier.

4.3.4 Barrier attachment

When metallic conduit, raceways, or other acceptable barrier material is used, the barrier shall be mechanically secured to the control board, panel, or rack structure by welding, bolting, or other

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suitable means to maintain acceptable separation distance and structural and mechanical integrity. Barriers should not preclude future installation and maintenance of equipment.

4.4 Control of combustibles

a) Flame-retardant materials should be used whenever possible throughout the control board, panel, or rack.
b) Materials used in the control board, panel, or rack are considered flame-retardant if they satisfy the following requirements:
   1) Wiring and cabling: Refer to 4.6 of this standard.
   2) Other nonmetallic materials: Materials used shall be of the classification 94V-0, 94V-1, or 94V-2 when tested in accordance with ANSI/UL 94-1993.
c) Consideration shall be given to treating materials that are not flame-retardant (e.g., chemical change, impregnation, pressure impregnation, and coating).
d) The use of intumescent (fire-protective) paints and coatings shall be considered as an aid in preventing the propagation of fire.
e) Consideration shall be given to avoid the use of materials that release toxic or corrosive gases when burning, or materials that upon melting cause droplets that carry flames.
f) Whenever possible, materials that cannot be considered flame-retardant should be encased in a material that is flame-retardant. If it is not possible to use a flame-retardant material, then the analysis specified in 6.6.2 of ANSI/IEEE Std 384-1992 shall apply for separation.
g) Consideration shall be given to the use of fire-detection devices internal to the control boards, panels, and racks.

4.5 Environmental considerations

4.5.1 Design specifications

Class 1E control boards, panels, and racks shall be designed to withstand the environment that is encountered in both normal and abnormal operations. The designer shall specify, as appropriate, the maximum, normal, and minimum temperature, humidity, radiation, and other service conditions to which the control board, panel, or rack may be subjected. In addition, the potential detrimental effects of other plant features, such as fire suppression system actuation, shall be considered.

4.5.2 Internal temperature considerations

The design shall consider the operating temperature of equipment mounted within the control board, panel, or rack to ensure that its manufacturer's temperature rating will not be exceeded when the control board, panel, or rack is subjected to its maximum ambient temperature. Cooling provisions, such as fans and louvers, may be required. If fans are utilized, consideration should be given to redundancy, power sources, fan failure alarms, and temperature alarms.

4.6 Cable/wire selection

Cable/wire for interconnection of control board, panel, and rack modules and components shall meet, as a minimum, the flame-retardance requirements of ANSI/IEEE Std 383-1974. Consideration shall be given to factors such as current capacity, derating factors, mechanical strength, thermal rating, and insulation characteristics so as to meet the circuit and installation requirements as established by the plant design. For fiber-optic cables, consideration shall also be given to bandwidth, physical protection, and radiation degradation.

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Any insulation that will release toxic or corrosive gases under combustion should not be used. Some examples of insulation that should not be used are untreated polyethylene, polyvinyl chloride (PVC), and nylon.

4.7 Wiring practices

a) Wiring shall meet the following requirements:

   1) Wire bundles shall be supported at intervals not to exceed 45 cm by such devices as clamps, straps, ties, or wire ducts. Uninsulated metallic wire ties should not be used unless needed to maintain the separation requirements of ANSI/IEEE Std 384-1992.
   2) Terminal blocks, plug connectors, and other terminating devices should be arranged in a manner that allows for an orderly arrangement for terminating the field cables. Sufficient space shall be provided to allow for the installation and termination of field cabling and for the maintenance of equipment with consideration given to cable diameter, bend radius, wireway size, and service loops.
   3) Smooth-edged surfaces (e.g., insulated grommets) suitable for the passage of wire and cables shall be installed in any openings provided in barriers. All wiring shall be protected from sharp edges.
   4) Wiring shall be carefully installed to avoid damaging the insulation. Wiring shall be free from abrasions and tool marks. Removal of insulation from the wire shall be performed so that the wire is not cut or nicked.
   5) Wire splices shall be minimized. Where splices are used, they shall be qualified for the application as per ANSI/IEEE Std 323-1983.
   6) Wires forming a hinge cable shall be multistrand, flexible wire, secured on each side of the hinge and formed in a loop to minimize strain, fatigue, and chafing on the edge or door.
   7) Consideration shall be given to the support of field cables upon entrance to control boards, panels, or racks to maintain the separation requirements of ANSI/IEEE Std 384-1992, to prevent cable damage, and to minimize mechanical load transferred to the termination points.

b) Wiring to control board, panel, or rack mounted components, such as switches, indicators, and modules, shall permit removal of the devices for maintenance.
c) Grounding: The control board, panel, or rack shall be connected to the station ground.

4.8 Electromagnetic interference

Consideration shall be given to electromagnetic interference in the design of control boards, panels, and racks. Methods such as grounding, use of low-voltage components, physical separation, shielding of susceptible components, or shielding of the sources of the interference may be employed to minimize the effect of the interference (see ANSI/IEEE Std 518-1982, IEEE Std 603-1998, and IEEE Std 1050-1996 for further guidance).

4.9 Identification

All equipment and wiring should be permanently marked and identified on the interior of Class 1E control boards, panels, or racks. Such identification should be conspicuously placed to minimize the possibility of personnel incorrectly identifying the device. In addition, Class 1E equipment and its

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wiring shall be identified as such, so that personnel may easily confirm its independence from non-Class 1E and redundant Class 1E equipment and wiring.

4.10 Other design considerations

4.10.1 Periodic testing and maintenance

Control boards, panels, and racks shall be designed to facilitate periodic testing of safety systems as required by ANSI/IEEE Std 338-1987. The design should permit inspection and testing of any device without removal of obstructions. Connections for test equipment shall be provided to permit periodic testing without disconnecting permanent wiring or using temporary wiring. Components shall be arranged to permit accessibility for required testing and maintenance. Each device should be removable without disturbing other devices, mounting steel, wireways, or tubing. If special test connections to the device are necessary, it should be possible to add and remove them without removal of the device.

4.10.2 Modifications

Addition of components such as switches, indicators, or recorders can be expected over the postulated plant life. When these modifications are made, care shall be taken to ensure that the Class 1E control board, panel, or rack, or the component's qualification is not voided. All of the requirements in this standard for new control boards, panels, or racks shall also be considered when performing modifications.

4.10.3 Specification requirements

Specifications shall include, but are not limited to, the following:

a) Design
b) Fabrication
c) Equipment mounting
d) Wiring
e) Termination equipment
f) Grounding
g) Installation (including anchors and corresponding board attachment points)
h) Testing
i) Seismic loading
j) Separation
k) Packaging and shipping
l) Receiving, handling, and storage
m) Documentation
n) Wiring and component identification
o) Environment and location
p) Flame-retardance
q) Ventilation and cooling
r) Identification nameplates
s) Aging with respect to qualified life as required
t) Qualification
u) Electromagnetic interference/radio frequency interference (EMI/RFI)
v) Human factors

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4.10.4 Quality assurance

Quality assurance requirements shall be in accordance with ASME NQA 1-2001 and shall include:

a) *Test and inspection*. A test shall be conducted to confirm continuity and correctness of all circuits in accordance with wiring instructions. All wiring shall be inspected to verify that good wiring practices, including those identified in 4.7 of this standard, have been applied.
b) *Tools*. All tools shall be of high quality and designed for the intended purpose. Tools requiring calibration shall provide dependable repeatability in proper performance and shall be periodically checked and recalibrated to ensure quality of function during the period of use. Crimping tools shall be of such design that a full crimp must be made before the tools will release (ratchet type).

5. Qualification testing and analysis

5.1 Environmental

Class 1E control boards, panels, and racks located in a harsh or mild environment shall be qualified in accordance with ANSI/IEEE Std 323-1983. They may be qualified by type testing where the physical size permits. The completed qualification may be a composite of individual qualification methods such as type testing, analysis, or combined analysis/testing as defined in ANSI/IEEE Std 323-1983.

A qualification program plan shall be prepared from information provided in the design specifications. This plan should become a part of the documentation package. The plan should describe the equipment to be qualified, the performance and environment to be simulated, and the combination of analyses, operating experience, and type test to be used. Qualification shall include consideration of the heat generated by control board, panel, or rack mounted components. For further guidance see ANSI/IEEE Std 323-1983.

In addition to the requirements of ANSI/IEEE Std 323-1983, specific temperature considerations for Class 1E control boards, panels, and racks located in a mild environment are provided in 5.1.1.

5.1.1 Mild environment temperature considerations

Testing and/or analysis should be utilized to demonstrate that the control board, panel, or rack is adequately designed for its intended environment.

5.1.1.1 Testing

Equipment located in a mild environment should be tested at ambient conditions to demonstrate that the operating temperature of components mounted within the control board, panel, or rack will not exceed the manufacturer's temperature rating, when these temperatures are extrapolated to the maximum external temperature to which the control board, panel, or rack will be subjected.

5.1.1.2 Analysis

Analysis may be used in cases where the control board, panel, or rack contains equipment that does not produce significant amounts of heat or where there is significant airflow relative to the amount of heat produced by the equipment. Analysis of these conditions should apply known thermodynamic principles relative to airflow and heat transfer to verify that the temperature ratings of the components are not exceeded.

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5.2 Seismic considerations

The methods used for performing seismic qualifications are described in ANSI/IEEE Std 344-1987. These methods shall be applied to qualify equipment to meet postulated seismic forces. The qualification shall consider the interaction of the plant cable, raceway, and tubing systems entering and/or attached to the control board, panel, or rack. The equipment shall follow a sequence of qualification as described in ANSI/IEEE Std 323-1983 prior to performing seismic qualification. Two methods identified in ANSI/IEEE Std 344-1987 are discussed in 5.2.1 and 5.2.2 of this standard.

5.2.1 Testing

When control boards, panels, and racks are seismically qualified by testing, the guidance provided in ANSI/IEEE Std 344-1987, Clause 7 shall be used.

Any testing sequence applied shall include exploratory resonance search and multiaxis, multifrequency testing, which exposes the control boards, panels, or racks to the required response spectra (RRS), operational base earthquake (OBE), and the safe shutdown earthquake (SSE).

5.2.1.1 Control board, panel, or rack mounted devices

During the control board, panel, or rack seismic tests, the accelerations at the device-mounting locations shall be determined for device qualification.

5.2.1.2 Installation of control board, panel, or rack

Two methods are commonly used for installing the control board, panel, or rack: bolting or welding to embedded steel. When using either of these methods, a dynamically equivalent support shall be used when conducting the seismic test of the contro1 board, panel, or rack.

5.2.1.3 Device functionality

Class 1E devices mounted on the control board, panel, or rack during the seismic test shall be checked to ensure that the effects of the seismic test will not prevent them from adequately performing their design function.

Non-Class 1E modules or equipment mounted on the same structural frame as Class 1E modules or equipment shall maintain structural integrity such that their failure could not adversely affect the operation of Class 1E modules or equipment.

Should a malfunction be experienced during any test conducted, the effects of the malfunction on the equipment shall be determined. Documentation of the solution taken to eliminate those malfunctions (which may include retesting) shall be provided in the final test report.

5.2.2 Combined analysis/testing

ANSI/IEEE Std 344-1987, Clause 8 shall be used when performing seismic qualification by the combined analysis/testing methods. The information described in 5.2.1, related to testing, shall be considered in any testing conducted. Analysis is generally used for control boards, panels, or racks that are large and/or complex and cannot be tested as a single unit. In-situ testing is generally used to verify the analytical model. Where analysis of like equipment is performed, the mass, mass distribution, mounting, and shape are to be similar.

If a computer model is used to predict response to a seismic force input for control boards, panels, or racks that are similar in shape and size, the computer model should be verified by test. Results obtained from the computer model shall closely approximate any result that would be attained if the

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control board, panel, or rack was tested. When conducting analysis supplemented by testing in situ, the same criteria shall apply.

Assumptions used in an analysis shall be documented and the basis for the assumptions delineated.

5.3 Modifications

5.3.1 Effects of modifications on seismic qualification

The effects of adding or deleting equipment or performing structural modifications on the control boards, panels, or racks shall be determined for the overall seismic qualification. This shall be done in accordance with the requirements of ANSI/IEEE Std 344-1987. Alternatively, the control board, panel, or rack may be initially qualified with sufficient margin in weight loading to encompass most expected modifications. In this case, analysis will be satisfactory to demonstrate that the change in weight loading required by the modification is within the envelope of tested conditions.

When a modification is made that significantly affects the mass or changes the structure of the control board, panel, or rack, requalification is required.

When the modification performed is not significant when considered with respect to the mass of the control board structure, testing may be bypassed and simple analysis or engineering judgment may be used. An example is the addition or deletion of a switch that is relatively insignificant when considered relative to the mass of the entire control board, panel, or rack.

5.3.2 Effects of modifications on other qualifications

Any modification performed on control boards, panels, or racks shall be evaluated in the following areas and an appropriate analysis performed and supplemented by testing if required:

a) Changes in heat load caused by the modification and the way that such change affects other components within the control board, panel, or rack. Heat loading shall be determined from two standpoints: spot or area increases that may affect closely spaced components and the effect that the modification has on the overall heat load of the particular control board, panel, or rack.
b) Equipment qualification status with respect to ANSI/IEEE Std 323-1983.

6. Documentation

6.1 General

Overall auditable qualification documents shall exist that provide assurance that each control board, panel, and rack will reliably operate under specified performance characteristics and environmental parameters. This documentation shall be maintained for the life of the equipment. In cases where modules and equipment are to be qualified individually, documentation for the control board, panel, and rack qualifications and documentation for the component/module qualification shall be compatible.

6.2 Detailed documentation requirements

Documentation indicating compliance with quality assurance aspects of the specification shall be provided. Qualification documentation shall be consistent with the requirements detailed in ANSI/IEEE Std 323-1983, Clause 8.

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Annex A

(informative)

Bibliography

[B1] IEEE 100, *The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition.

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