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Equipment Qualification for Nuclear Installations

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DRAFT SAFETY GUIDE

New Safety Guide

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1. INTRODUCTION

BACKGROUND

1.1. This Safety Guide provides recommendations on the establishment and preservation of equipment qualification¹ in nuclear installations, to provide confirmation of the reliable performance of safety functions by such equipment during operational states and accident conditions, to avoid vulnerability due to common cause failure of the equipment.

1.2. Requirements relevant to equipment qualification in nuclear installations are established in the following publications:

- (a) IAEA Safety Standards Series No. SSR-2/1 (Rev. 1), Safety of Nuclear Power Plants: Design [1];
- (b) IAEA Safety Standards Series No. SSR-2/2 (Rev. 1), Safety of Nuclear Power Plants: Commissioning and Operation [2];
- (c) IAEA Safety Standards Series No. SSR-3, Safety of Research Reactors [3];
- (d) IAEA Safety Standards Series No. SSR-4, Safety of Nuclear Fuel Cycle Facilities [4].

1.3. Several other IAEA safety standards also have some relevance to equipment qualification. These include the following:

- (a) IAEA Safety Standards Series No. GSR Part 4 (Rev. 1), Safety Assessment for Facilities and Activities [5];
- (b) IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [6], and supporting Safety Guides, IAEA Safety Standards Series Nos GS-G-3.1, Application of the Management System for Facilities and Activities [7], and GS-G-3.5, The Management System for Nuclear Installations [8];
- (c) IAEA Safety Standards Series No. SSG-30, Safety Classification of Structures, Systems and Components in Nuclear Power Plants [9];
- (d) IAEA Safety Standards Series No. SSG-34, Design of Electrical Power Systems for Nuclear

¹ Equipment qualification refers to the generation and maintenance of evidence to ensure that equipment will operate on demand, under specified service conditions, to meet system performance requirements.

Power Plants [10], SSG-39, Design of Instrumentation and Control Systems for Nuclear Power Plants [11], SSG-37, Instrumentation and Control Systems and Software Important to Safety for Research Reactors [12], SSG-48, Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants [13] and SSG-10, Ageing Management for Research Reactors [14].

1.4. The terms used in this Safety Guide are to be understood as defined and explained in the IAEA Safety Glossary [15]. Definitions for certain terms that are not in the IAEA Safety Glossary but are used in this Safety Guide are provided at the end of this publication.

OBJECTIVE

1.5. The objective of this Safety Guide is to provide recommendations on a structured approach to the establishment and preservation of equipment qualification in nuclear installations to meet the relevant requirements established in SSR-2/1 (Rev. 1) [1], SSR-2/2 (Rev. 1) [2], SSR3 [3] and SSR-4 [4].

1.6. This Safety Guide is intended for use by organizations that have responsibilities for aspects of equipment qualification for nuclear installations. This Safety Guide is also intended for use by regulatory bodies to support their licensing and inspection activities relating to equipment qualification.

SCOPE

1.7. The recommendations in this Safety Guide apply to new nuclear installations, and as far as is reasonably practicable to existing nuclear installations.

1.8. This Safety Guide applies primarily to equipment that performs one or more safety functions, but it may also be applied to items not important to safety, in accordance with national requirements.

1.9. This Safety Guide applies to electrical, instrumentation and controls, active mechanical equipment, and components associated with this equipment (e.g. seals, gaskets, lubricants, cables, connections, mounting/anchoring structures).

1.10. The qualification process for passive mechanical components (e.g. piping and vessels), for which the safety performance is assured by design in accordance with applicable codes, is outside the scope of this Safety Guide.

1.11. This Safety Guide does not specify seismic qualification methods and processes. Recommendations on seismic qualification (for nuclear power plants) are provided in IAEA Safety Standards Series No NS-G-1.6, Seismic Design and Qualification for Nuclear Power Plants [16].

1.12. This Safety Guide also does not specify methods for validation of electromagnetic compatibility. Information and guidance on the validation of electromagnetic compatibility are provided in IEC 61000-4-1 [17].

1.13. This Safety Guide does not provide recommendations on equipment protection against the effects of internal fires and explosions. Recommendations on these topics are provided in IAEA Safety Standards Series No. NS-G-1.7, Protection against Internal Fires and Explosions in the Design of Nuclear Power Plants [18].

1.14. The verification and validation of computer software and firmware are out scope of this Safety Guide; recommendations on these topics are provided in SSG-39 [11] and SSG-37 [12].

STRUCTURE

1.15. Section 2 provides recommendations regarding the concepts and process of equipment qualification. Section 3 provides recommendations on specifying the design inputs needed to support the qualification process. Section 4 provides recommendations on establishing qualification. Section 5 provides recommendations for preserving qualification, and Section 6 provides recommendations on the evaluation of the effectiveness of the equipment qualification programme. Section 7 provides recommendations on the integration of equipment qualification into other safety programmes and processes.

1.16. The Annex provides a list of international nuclear and non-nuclear standards that can be used for equipment qualification, and which have a strong relationship with the major topical areas of this Safety Guide.

2. CONCEPTS AND PROCESS OF EQUIPMENT QUALIFICATION

BASIC CONCEPT OF EQUIPMENT QUALIFICATION

2.1. Requirement 30 of SSR-2/1 (Rev. 1) [2] states:

“A qualification programme for items important to safety shall be implemented to verify that items important to safety at a nuclear power plant are capable of performing their intended functions when necessary, and in the prevailing environmental conditions, throughout their design life, with due account taken of plant conditions during maintenance and testing.”

The same provisions for equipment qualification are established in Requirement 29 of SSR-3 [3] for research reactors, and in Requirement 30 of SSR-4 [4] for nuclear fuel cycle facilities.

2.2. Paragraph 4.48 of SSR-2/2 (Rev. 1) [2] states:

“Appropriate concepts and the scope and process of equipment qualification shall be established, and effective and practicable methods shall be used to upgrade and preserve equipment qualification. A programme to establish, to confirm and to maintain required equipment qualification shall be launched from the initial phases of design, supply and installation of the

equipment. The effectiveness of equipment qualification programmes shall be periodically reviewed.”

2.3. Paragraph 4.49 of SSR-2/2 (Rev. 1) [2] states:

“The scope and details of the equipment qualification process, in terms of the required inspection area(s), method(s) of non-destructive testing, possible defects inspected for and required effectiveness of inspection, shall be documented and submitted to the regulatory body for review and approval. Relevant national and international experience shall be taken into account in accordance with national regulations.”

2.4. Paragraph 5.29 (b) of SSR-2/1 (Rev. 1) [1] states:

“...the features that are designed for use in, or that are capable of preventing or mitigating, events considered in the design extension conditions ... shall be capable of performing in these environmental conditions pertaining to the design extension conditions, including design extension conditions in severe accidents, where appropriate”.

2.5. As indicated in para. 2.1, equipment qualification is required to demonstrate that the equipment will be capable of performing its intended safety function(s) under the range of service conditions specified for the nuclear installation in operational states and in accident conditions. This includes an evaluation of the ability of systems or components to perform these safety functions under the effects caused by specified service conditions during plant states and during external events not excluded by the design of the nuclear installation (e.g. seismic events, electromagnetic phenomena such as arcing, lightning). In contrast, internal fires, explosions, internal flooding, tornadoes and hurricanes are not normally considered in equipment qualification because the design generally protects the equipment from the effects of these events.

2.6. Equipment qualification should consider possible synergistic effects (e.g. simultaneous elevated temperature, humidity and radiation level and dose rates), where such effects could lead to significant ageing effects and degradation mechanisms or adverse equipment performance under accident conditions.

2.7. One of the objectives of equipment qualification should be the prevention of common cause failures arising from the exposure of equipment to the specified service conditions.

2.8. The equipment qualification programme should provide confidence that equipment is designed, manufactured, installed, commissioned, operated, and maintained such that it is capable of performing its intended safety functions, when needed, under the specified service conditions and throughout its qualified life (see para. 2.15), with due account taken of conditions during maintenance and testing.

2.9. Within the context of equipment qualification, the equipment should be considered as an integrated

assembly of one or more interconnected components or subassemblies, each with dedicated functionality and specified interfaces to perform or contribute to one or more safety functions.

2.10. The equipment to be qualified should be an accurate representation of the type or series type of the equipment to be installed.

2.11. The qualified configuration of the equipment should include the equipment itself and the equipment it interfaces with. The qualified configuration should include the final versions of software, firmware, hardware description language, and process, electrical and mechanical interfaces, mounting and equipment orientation.

2.12. Equipment qualification should be considered as an essential programme throughout the whole lifetime of a nuclear installation.

OVERVIEW OF THE EQUIPMENT QUALIFICATION PROCESS

2.13. The equipment qualification process comprises three phases:

- (a) Establishment of appropriate design inputs;
- (b) Establishment of equipment qualification process steps;
- (c) Preservation of the status of qualified equipment.

These three phases and the relationship of activities within each phase are considered in Sections 3, 4 and 5, respectively.

QUALIFIED LIFE

2.14. Qualified life² is the period for which a structure, system or component has been demonstrated, through testing, analysis or experience, to be capable of functioning within acceptance criteria during specific operating conditions while retaining the ability to perform its safety functions in accident conditions for a design basis accident or a design basis earthquake [15].

2.15. A qualified life should be established for all equipment that is subject to significant performance degradation mechanisms that can occur under the range of specified service conditions for operational states.

2.16. The parameters and any modelling of environmental conditions used to establish the qualified life should be specified. Activities such as monitoring the condition of qualified equipment (see paras 5.22 and 5.27) and monitoring environmental conditions (see paras 5.18-5.21) should be performed to determine whether these parameters and specified environmental conditions remain within acceptable

² The term 'qualified life' is not used in all of the Member States. In some Member States, the term 'qualification for the lifetime of the equipment' serves the same purpose of demonstrating the capability of the equipment to perform its intended safety function(s) in accident conditions.

ranges.

2.17. The qualified life may be based upon the performance of the entire equipment assembly or may be dependent on individual components (e.g. gaskets, sealings) within the assembly.

QUALIFICATION METHODS

2.18. Internationally recognized methods for equipment qualification are type testing, analysis, use of operating experience, and a combination of these methods. The Annex provides a list of applicable industry standards, which may be considered when identifying appropriate qualification methods.

PRESERVATION OF EQUIPMENT QUALIFICATION

2.19. The preservation of equipment qualification is needed throughout the lifetime of the nuclear installation (see Section 5).

2.20. Justification should be provided during the reassessment of equipment qualification whenever changes occur that could alter the initial equipment qualification.

QUALITY MANAGEMENT

2.21. Organizations responsible for equipment qualification for nuclear installations are required to develop, implement, assess and continuously improve a management system, which includes quality management, in accordance with the requirements established in GSR Part 2 [6].

2.22. The equipment qualification programme should be subject to a quality assurance programme that includes a variety of elements, such as equipment design control, procurement document control, manufacturing quality control, qualification assessment (e.g. testing, analysis, combined testing and analysis, and experience), storage, installation and commissioning, installation surveillance and maintenance, periodic testing and documentation.

2.23. Equipment qualification activities, including the assessment or reassessment of the status of qualified equipment, should be performed in accordance with approved procedures and controls.

2.24. Data acquisition tools used in equipment qualification should be calibrated against defined criteria and documentation supporting such calibrations should be provided.

2.25. Traceability should be established between the qualification documentation, the conclusions from each qualification test or analysis, and the configuration of the installed equipment, in order to ensure that the installed configuration corresponds to the as-tested configuration.

DOCUMENTATION

2.26. Equipment qualification documentation of a nuclear installation should include the following:

- (a) A list of items important to safety that are subject to equipment qualification. This list should include the intended safety function(s) and the specific location of each item of equipment;
- (b) Criteria for equipment qualification;
- (c) Equipment specifications (see para. 2.27);
- (d) Data and reports from equipment qualification analyses and tests;
- (e) Equipment qualification summary reports (see paras 2.32 and 2.33);
- (f) Instructions for preserving the status of qualified equipment during manufacture, installation, commissioning, operation and maintenance of the equipment.

2.27. The equipment specification should include the following:

- (a) Equipment type, vendor and/or manufacturer, model number (or series type) and dimensions;
- (b) Specific equipment configuration and settings;
- (c) The versions of any firmware, application software and hardware description language to be used;
- (d) The ranges of mechanical and electrical parameters for which the equipment is rated;
- (e) The mechanical, electrical, instrumentation and control interfaces of the equipment;
- (f) Equipment performance capabilities (e.g. accuracy, insulation resistance, cable impedance, response times);
- (g) Operating manual(s), instructions and data sheets, including parts list and maintenance, installation and test procedures;
- (h) Certificates and test documentation with respect to industry standards and quality assurance.

2.28. The equipment qualified configuration should be properly documented, and this documentation should be maintained in an auditable form while the equipment is in service (or in storage awaiting installation).

2.29. The documentation of the equipment qualification should identify individual components that have a qualified life that is shorter than the expected in-service life of the equipment assembly, to allow for their replacement at predetermined intervals consistent with their qualified life.

2.30. Test specifications, test reports and analysis reports should be prepared for each type of qualification (e.g. seismic, environmental and electromagnetic compatibility, functionality testing under specified dynamic loading conditions, ageing and wear through functional cycling).

2.31. All non-conformities and deviations identified during the equipment qualification process

(including during the preservation of equipment qualification) should be analysed, and documented, with conclusions made as to whether any further actions or considerations are necessary.

2.32. A qualification summary report that evaluates the results from each type of qualification tests and/or analyses should be prepared. The qualification summary report should provide the basis for an equipment qualification assessment (also referred to as a 'suitability analysis') which is used to conclude that the equipment is suitably qualified for a specific application in the nuclear installation.

2.33. The qualification summary report should contain appropriate information to serve as a reference for the long term maintenance and procurement processes, in support of the preservation of the status of all qualified equipment included in the report.

TRAINING FOR EQUIPMENT QUALIFICATION

2.34. The personnel involved in equipment qualification activities (including contractors, and personnel involved in the oversight of these activities) should receive suitable training, so that they possess the necessary skills, knowledge and attitudes. This training should be part of the equipment qualification programme.

2.35. A systematic approach to training should be used to design, develop, implement and evaluate the training provided.

2.36. Key training elements for personnel involved in establishing and preserving equipment qualification include the following:

- (a) Training specific to the job, task and procedure;
- (b) Integration of the details of equipment qualification into the hands-on training for maintenance of each equipment type, including criteria to be used when inspecting for degradation;
- (c) A description of roles and responsibilities in relation to equipment qualification.

3. DESIGN INPUTS FOR EQUIPMENT QUALIFICATION

GENERAL

3.1. The design inputs that are necessary for equipment qualification should be established and documented in a specification that includes the following:

- (a) The performance requirements necessary to accomplish the intended safety functions;
- (b) The specified environmental conditions and operating conditions expected during operational states and accident conditions, including for seismic events;

- (c) The safety class (see SSG-30 [9]) assigned to the equipment and the corresponding supplemental classifications (e.g. seismic classification, quality classification);
- (d) The acceptance criteria for equipment qualification.

IDENTIFICATION OF EQUIPMENT PERFORMANCE REQUIREMENTS

3.2. The design requirements for equipment should specify the performance requirements³ necessary to accomplish the intended safety functions under the specified service conditions.

3.3. Equipment needed to perform safety functions in accident conditions should meet the performance requirements throughout the specified mission time.

3.4. Equipment performance requirements should be derived from the design requirements and functional acceptance criteria (e.g. in terms of operational characteristics, measurement accuracy, upper and lower limits of functional physical parameters, response time).

3.5. Equipment performance requirements should be quantified and documented.

IDENTIFICATION OF SERVICE CONDITIONS

3.6. The equipment qualification begins with establishing the range of conditions and events for which the equipment is to be qualified.

3.7. A set of specified service conditions for which qualification is to be established should be determined. This may be performed by identifying boundary conditions that envelop qualification parameters.

3.8. The set of specified service conditions should include operating conditions and environmental conditions associated with all plant states. The operating conditions are generally defined by the service conditions of the systems (e.g. vibration, electromagnetic interference caused by voltage surge), operating conditions (e.g. voltage, current, temperature, pressure, radiation levels), fluid conditions (e.g. differential pressure, temperature, flow, fluid parameters, and chemical content) and environmental conditions in all plant states. The environmental conditions are generally defined by the ambient conditions associated with plant states within the area (zone) of the nuclear installation where the equipment is installed. The localized environmental conditions within these areas, (e.g. temperature and radiation levels) should be considered, where appropriate. Other stressors (e.g. wear, operational cycles, temperature cycles) causing ageing degradation should also be considered.

3.9. The set of specified service conditions should consider the most challenging operational states, accident conditions (with margins), and equipment operating modes (e.g. continually energized or

³ Examples of performance requirements include requirements on accuracy, resolution, range, sample rate and response time.

normally deenergized, loaded or unloaded).

3.10. Differences between the specified service conditions and actual conditions can be addressed through additional considerations (e.g. by establishing exclusion zones to prevent the adverse impact of electromagnetic interference on the performance of the equipment).

3.11. Modelling and/or simulations of specified service conditions should be used to derive the parameters needed as inputs for the qualification process. Recommendations on conducting such modelling and simulations are provided in IAEA Safety Standards Series No. SSG-2 (Rev. 1), Deterministic Safety Analysis for Nuclear Power Plants [19].

Service conditions specified for operational states

3.12. Relevant environmental conditions for operational states typically include the following:

- Ambient temperature and pressure;
- Humidity and steam;
- Radiation level;
- Submergence;
- Chemical leakages (e.g. boric acid or steam spray);
- Chemicals in the atmosphere (salt mist, oil aerosols and dust);
- Induced vibrations from neighbouring equipment or due to a seismic event;
- SL-1 vibration⁴;
- Electromagnetic fields;

Seasonal and climatic variations should be taken into account when preparing the test plan.

3.13. Relevant operating conditions for operational states typically include the following:

- Power surges;
- Operating cycles (e.g. electrical and mechanical, water hammer);
- Electrical loading parameters (e.g. voltage, frequency, current);
- Mechanical loads (e.g. thrust or torque, displacement, or non-seismic vibration including flow-induced vibration, condensing mode vibration and quenching vibration);
- Process fluid conditions (e.g. pressure, temperature, chemical composition, flow rate, water hammer);

⁴ In general, two levels of seismic vibratory ground motion hazard, SL-1 and SL-2, should be defined as the design basis earthquake for each nuclear installation. This is to ensure the safety of the nuclear installation in the event of a rare earthquake (i.e. SL-2), and to ensure the possibility of continued operation in the event of a less severe, but more probable, earthquake (i.e. SL-1). In some States, SL-2 corresponds to an earthquake level often denoted as the safe shutdown earthquake. In some States, SL-1 corresponds to an earthquake level often denoted as the operating basis earthquake.

- Chemical composition;
- Loads and duty cycles;
- Self-heating;
- Submergence;
- Electromagnetic interference;
- Power surges.

3.14. The test conditions for equipment qualification should, at a minimum, bound the service conditions associated with the mounting location of the equipment. Consideration should be given to cases where the temperature or radiation levels may occasionally deviate from specified service conditions (e.g. hot spots).

3.15. The evaluation of equipment performance for operational states should involve demonstrating its functional capability when experiencing a combination of service condition extremes.

Electromagnetic interference

3.16. Electromagnetic interference, including radiofrequency interference, can be caused by electrical equipment, electrical surges (e.g. voltage spikes resulting from switching transients, lightning), and electrostatic discharges.

3.17. Electromagnetic interference can affect electrical equipment including instrumentation and control systems and components. Equipment qualification for electromagnetic interference should address the combination of the system design and the component design to minimize the coupling of electromagnetic interference between the source and other electrical components.

3.18. Detailed equipment qualification specifications and acceptance criteria for electromagnetic interference should be determined, in accordance with international industry standards or alternatively on the basis of individual system requirements. A bibliography of international standards relating to equipment qualification is provided in the Annex.

3.19. A site survey of sources of electromagnetic interference should be performed during normal operation, and should include monitoring for the effects of operating and maintenance activities to establish and verify the basis for equipment qualification.

3.20. Electromagnetic fields within a specified location within a nuclear installation may change with time due to the operation of equipment or replacement of equipment in the area (zone). Therefore, when changes to electrical inputs or electrical equipment occur within an area (zone), additional site survey measurements of electromagnetic fields should be performed to identify and quantify sources of electromagnetic interference, in order to ensure that the status of qualified equipment will be preserved.

Service conditions specified for equipment located in mild environments

3.21. Equipment qualification for items located in mild environments should be achieved by providing evidence that the equipment meets specified acceptance criteria, including those of recognized industry associations. When seismic testing is used to qualify equipment located in mild environments, pre-ageing (see para.4.23) prior to the seismic tests is necessary only where significant ageing mechanisms exists.

3.22. The equipment qualification parameters for items located in mild environments can be derived from the service conditions associated with the heating, ventilation, air conditioning systems and potential consequences of accidents for those areas. When estimating these equipment qualification parameters, a margin should be included to take into account malfunctions and occasional variations in the performance of the heating, ventilation, air conditioning systems and the potential consequences of accidents for items located in mild environments.

Service conditions specified for harsh environments resulting from design basis accidents

3.23. Harsh environments result from postulated accidents such as loss of coolant accidents, high energy line breaks and main steam line breaks. These conditions are characterized by changes of temperature, pressure, humidity, radiation levels, submergence, vibrations or by simultaneous changes in process fluid conditions, chemical composition or mechanical loads. Other postulated initiating events might need to be considered in the equipment qualification programme if they produce conditions that are more severe than those produced by loss of coolant accidents or high energy line breaks.

3.24. The bounding thermodynamic profiles and chemical effects associated with each postulated initiating event should be derived from the design basis and the safety analysis report for the nuclear installation.

3.25. Service conditions resulting from postulated initiating events such as SL-2 earthquake or airplane crash should be considered in the equipment qualification programme.

3.26. Equipment qualification should take into account the mission time for the equipment under applicable accident conditions.

Service conditions resulting from design extension conditions with core melting

3.27. Service conditions resulting from design extension conditions with core melting should be specified through a consideration of appropriate accident profiles that describe the harsh ambient conditions (e.g. pressure, temperature, humidity, radiation dose and dose rates at various stages of the severe accident, exposure to toxic gases, flooding levels), under which the equipment needs to perform its safety functions.

3.28. The thermodynamic profile of the containment should consider potentially harsh environmental conditions that would exist prior to severe accident occurrence and should be estimated through simulation using severe accident codes. As well as determining the environmental conditions associated with design extension conditions, this approach can help to determine accident monitoring instrumentation ranges (including margins) and mission times. Annex I of Ref. [20] provides examples of calculating environmental parameters for the containment due to severe accidents.

3.29. Representative environmental conditions for equipment performance during design extension conditions with core melting should be estimated using modelling applied to locations inside the containment that are subjected to such conditions, as well as for locations outside the containment. Based on the results of the modelling, test profiles for each of the parameters should be developed to support the assessment of the capability of the equipment to perform reliably.

3.30. The mission time for each item of equipment used for monitoring integrity of fission product barriers or each item of equipment for mitigating the consequences of severe accidents and each item of equipment for monitoring their adequate performance should be derived from analyses of the various stages of the severe accident. This equipment needs to remain functional beyond the achievement of a safe state and should have the reliability that commensurate with the function required to fulfil.

PRELIMINARY SUITABILITY ASSESSMENT

3.31. The selection of equipment should initially be performed by means of a preliminary suitability assessment, showing that the selected equipment is generally capable of meeting the functional and performance requirements while operating within specified service conditions.

3.32. To undertake the preliminary suitability assessment, the following information should be provided:

- (a) A description of the equipment used to perform safety functions;
- (b) The design requirements, service conditions and the performance requirements for the equipment, derived from the safety design of the nuclear installation;
- (c) Criteria for assessing equipment suitability;
- (d) Criteria for installation, for electrical and mechanical interfaces, and for maintenance.

3.33. The preliminary suitability assessment should consider the functional characteristics of the equipment, the expected performance under the specified service conditions, and other aspects, such as electrical safety performance, conformity with product standards, and testing and maintenance criteria.

3.34. If the preliminary suitability assessment reveals deficiencies in terms of meeting the design requirements for given service conditions, supplemental qualification steps are needed. The selection of supplemental qualification steps should be described and justified.

4. ESTABLISHING EQUIPMENT QUALIFICATION

4.1. Equipment qualification should be based on a selection of the following methods:

- (a) Type tests;
- (b) Analysis;
- (c) Evaluation of operating experience;
- (d) Where appropriate, an assessment of equipment capability for design extension conditions;
- (e) A combination of the above methods.

The specific combination of methods selected will depend upon the equipment assembly or component under consideration. For example, in the qualification of pre-existing items⁵, more emphasis might be placed on past operating experience. For items that are not required to operate in accident conditions or after an earthquake, more emphasis might be placed on analysis.

4.2. The method or combination of methods, and the assumptions used for equipment qualification should be justified.

QUALIFICATION BY TYPE TESTING

General

4.3. Qualification by type testing refers to a test or a series of tests on a representative sample of the equipment (including its interfaces) that simulate(s) the effects of significant ageing mechanisms in normal operation. Type testing for equipment qualification is performed with equipment (including any software) functioning in a state representative of its intended use in actual operation.

4.4. If it is necessary to test separately for different environmental parameters (e.g. separate tests for the effects of radiation and of temperature), the sequence in which these tests are conducted should be that which most accurately simulates the worst degree of deterioration due to ageing during service life followed by exposure to accident conditions.

4.5. Equipment qualification results obtained by type testing undertaken in accordance with industry standards should be used to demonstrate that the equipment meets the performance requirements and fulfils the intended safety functions under specified service conditions.

⁵ An item that has been qualified in accordance with an industry standard for a similar application under similar or more severe service conditions.

Test specification for equipment qualification by type testing

4.6. Type testing should be performed in accordance with a well-defined test specification that has been documented as part of the equipment qualification programme. The test specification should address individual tests or test sequences with respect to one or more testing areas (e.g. environmental, seismic, electromagnetic interference) and should provide information on conducting the qualification tests.

4.7. The test specification should include the following:

- (a) A description of the specimen, including a unique means of identification;
- (b) Any dimensions and tolerances that might impact the performance of the specimen;
- (c) Applicable regulatory requirements and industry codes and standards;
- (d) A description of the test facilities to be used (e.g. heating ovens, chambers to test the effects of loss of cooling accidents, shake tables to simulate earthquake motion);
- (e) The quality assurance procedures to be applied;
- (f) The scope of the equipment qualification (e.g. seismic, environmental, electromagnetic);
- (g) A description of the test parameters to be monitored, the test acceptance criteria, the format of test data and the methods to be used for data analysis;
- (h) Specifications for the test assembly, measurement devices and their accuracy, mounting and interfaces;
- (i) The need for auxiliary equipment to be included in the test specifications (e.g. test connections, test equipment leads, power supplies);
- (j) The need for any witnessing (e.g. by independent experts) or hold points during the testing;
- (k) Actions to be taken to correct deviations or failures;
- (l) Maintenance activities and replacements during the tests (e.g. replacement of gaskets after ageing);
- (m) The test documentation to be prepared by the testing facility and/or the independent organizations, as appropriate.

4.8. The test specifications should outline the service conditions to be simulated, along with the applied margins for each test step.

4.9. The test specifications should include the following information:

- (a) The test setup;
- (b) The test conditions and margins to be applied;

- (c) The performance of safety function(s) by the equipment to be demonstrated throughout the tests;
- (d) The test sequence(s) and/or the test steps, including the equipment performance characteristics to be tested;
- (e) The acceptance criteria for each test step (e.g. opening and closing times, response time, accuracy), to demonstrate that the equipment performance requirements have been met;
- (f) The normal operating status of the equipment (e.g. energized or de-energized);
- (g) Ranges in equipment performance requirements for each test step, to demonstrate the satisfactory performance of the safety function(s) for different plant states;
- (h) Boundaries and interfaces between items subject to equipment qualification. The interfaces should be defined based on mechanical and electrical design criteria, as appropriate;
- (i) Data recording and test equipment accuracy;
- (j) Applicable mission times;
- (k) Specified qualified life;
- (l) Special conditions specified for qualified equipment, when applicable;

Test specimens for equipment qualification by type testing

4.10. The test specimens and their assembly and mounting should be accurate representations of the type or series of the equipment to be qualified, in terms of electrical or mechanical attributes, geometrical dimensions, installed configuration and electrical and mechanical interfaces.

4.11. An evaluation should be performed to determine how many test specimens need to be tested to ensure an accurate representation of the performance of the equipment to be qualified.

4.12. The test specimen description should contain sufficiently detailed information to demonstrate that it corresponds to the type or series of equipment in the design specification.

4.13. Test specimens should be subjected to ageing mechanisms prior to being tested for postulated initiating events.

4.14. A description of the test setup should provide detailed information to properly conduct the testing. This should include information on assembling, mounting and functional testing of the equipment to be tested.

4.15. Scale models and a grouping method may be used to simulate the actual configuration of the equipment. Scale models should be representative of the configuration and material properties of the equipment to be qualified. The use of scale models should be justified; in particular, it should be demonstrated that the use of scale models will not adversely impact the results of the equipment

qualification tests. When a grouping method is applied, grouping analysis should be additionally performed to demonstrate the selected item is representative of the group.

4.16. Test specimens for assemblies may consist of individual modules that are tested separately. The interfaces between the modules should be properly identified and comprehensively described, and the individual modules should be tested with overlapping interfaces.

4.17. Individual modules or components may be tested separately, but for certain tests, such as for electromagnetic interference, the tests of the whole assembly (e.g. instrumentation and control cabinet, electrical switchgear) should be performed to fully investigate the possible interactions.

4.18. The electromagnetic interference tests may be performed on a different test specimen to that which is subjected to tests for operational ageing and seismic events and other design basis events.

4.19. The test specimen used during equipment qualification testing should not be considered for use in safety applications following qualification, unless it has been demonstrated that the testing has not adversely affected the ability of the specimen to perform safely during its qualified life, and that any margin has not been significantly reduced.

Demonstration of safety functions during type tests for equipment qualification

4.20. Functional tests should be used to demonstrate the ability of equipment to perform the intended safety functions over the full range of specified service conditions.

4.21. While the complete equipment qualification process should cover all of the intended safety functions, a single functional test may be used to test just one aspect of the ability to perform these functions. For example, a containment penetration has two safety functions; electrical functions and containment pressure boundary functions. These functions may be tested separately.

4.22. The performance of a safety function may also be demonstrated by using indirect test methods, for example, testing of environmental seal materials (e.g. a gasket compression set) using functional acceptance criteria.

Simulation of ageing effects (pre-ageing) in type tests for equipment qualification

4.23. Any anticipated significant ageing mechanisms should be simulated during testing for equipment qualification. The ageing that is expected during operational states may be simulated by accelerated ageing (e.g. thermal, radiation: see paras 4.25–4.30) to determine the qualified life of the equipment.

4.24. The sequence of equipment ageing should consider sequential, simultaneous and synergistic effects, to provide the most accurate simulation of ageing degradation.

Accelerated thermal ageing

4.25. Thermal ageing may be simulated by exposing test specimens to higher temperatures for a

specified duration (accelerated thermal ageing). The rate of accelerated thermal ageing should be documented and justified (e.g. to manage effects of diffusion limited oxidation).

4.26. The Arrhenius ageing model⁶ (isothermal ageing at elevated temperature) is considered an acceptable method for performing accelerated thermal ageing. The elevated test temperature used should be below the threshold value at which significantly different chemical or physical reactions might occur.

4.27. The parameters used during the accelerated ageing process should be documented and justified. For example, the material activation energy, the temperature applied during the tests, the duration of the test, and the material sensitivity should all be documented and justified.

Accelerated radiation ageing

4.28. Simulation of radiation ageing should be limited to gradual permanent changes to material characteristics over time and differentiated from transient changes that might occur because of exposure to radiation.

4.29. The total dose that might be received should be simulated for operational states and accident conditions. The applied dose rate should be equally distributed and low enough to ensure that the accelerated radiation ageing remains realistic.

4.30. Unless otherwise stated (e.g. in national requirements), the simulation of radiation ageing should be performed under ambient temperature conditions. This might include testing at elevated temperatures where these are representative of the service environment.

Non-seismic vibration and mechanical shocks

4.31. Non-seismic vibration and mechanical shocks (including vibration from pipes, pumps, running motors or vibration due to hydrodynamic loading) that produce significant degradation (e.g. fatigue, wear), should be considered, where applicable.

4.32. Non-seismic vibration should be included in the ageing process prior to the seismic tests, if such vibration is considered to be severe enough to cause mechanical ageing.

Simulation of other stressors

4.33. Other stressors (e.g. wear, operational cycles, temperature cycles) causing ageing degradation should be considered for inclusion in the type testing.

⁶ The Arrhenius ageing model is a simplified model characterizing the kinetics of chemical reactions (degradation process), which predicts how the time taken to reach component failure varies with temperature. It assumes that short term thermal ageing at high temperature results in the same degradation as long term ageing at lower temperature.

Simulation of seismic conditions in type testing for equipment qualification

4.34. Seismic effects should be simulated on aged specimens, if necessary, (i.e. specimens that have already been subjected to simulated operating conditions), prior to testing for accident conditions.

4.35. The mechanical load conditions during seismic events (e.g. hydrodynamic events) that are applied to equipment qualification methods should be developed taking into account an SL-2 earthquake and the associated mechanical loads, as specified in NS-G-1.6 [16], ~~IEEE 344-2013 [21] and ASME QME-1-2017 [22]~~. This should be considered in the equipment qualification for both harsh environments and mild environments. [A bibliography of international standards relating to seismic qualification of equipment is provided in the Annex.](#)

4.36. When appropriate, test specimens should be restrained and anchored in a manner that accurately represents the installed configuration and should be energized and subjected to electrical and mechanical loading.

Simulation of specified service conditions in type testing for equipment qualification

4.37. The type testing sequence should place the specimen in its worst state of deterioration that can occur in service during the qualified life, prior to being subjected to a simulation of accident conditions.

4.38. Test specimens should be subjected to the environmental conditions that might result from the postulated initiating events specified in the design basis of the nuclear installation. The simulation of such environmental conditions by performing sequential tests is acceptable (e.g. radiation levels and thermodynamic loads during accident conditions, as appropriate to the mission time of the equipment).

4.39. The total radiation dose resulting from operational states and accident conditions may be applied in either a single exposure or in a series of exposures, provided that this results in the most accurate simulation of applicable ageing effects.

4.40. The conditions resulting from postulated initiating events should be defined in terms of the thermodynamic profiles and chemical effects to be simulated. These conditions include, for example, temperature, pressure, humidity, submergence and chemical composition, for the necessary mission time.

4.41. Tested specimens should be energized and subjected to loads in a manner that accurately represents the installed configuration.

4.42. The successful performance of the safety functions during the simulation of the postulated initiating events for the necessary mission time should be verified and documented.

Margins for test profiles in type testing for equipment qualification

4.43. Margins should be applied during the equipment qualification process to take into account test

instrument inaccuracies, production variations and modelling uncertainties. The type tests should include provisions to verify that the type tests for equipment qualification include an adequate margin. Information on suitable margins for conducting type tests on electrical equipment important to safety is provided in IEC/IEEE 60780-323-~~[23]~~[21].

4.44. Increasing test durations is an acceptable means of adding margins in testing. Increasing the number of test cycles (e.g. for wear, operational cycles) may also be an acceptable means of adding margins.

QUALIFICATION BY ANALYSIS

4.45. Qualification by analysis should include a justification of the methods, models and assumptions used. The validity of the mathematical models used for equipment qualification might be justified on the basis of experimental data, test data or operating experience. In the case of using test data, the test certificate should include details of the test methodology and parameters used.

4.46. Qualification by analysis may be used to extrapolate existing equipment qualification results to address changes in equipment, material composition, service conditions, performance requirements, installations, and also for reassessing the qualified life of equipment.

4.47. Qualification by analysis may be used to extend the results of equipment qualification testing to represent an entire family of equipment of the same or similar type, if it can be shown that the tested equipment is representative of other equipment in the same family (e.g. cables, series of motors of the same type, sizes of process instrumentation).

4.48. Qualification by analysis alone is recommended only for analysis of the structural integrity of the equipment and its mounting; it is not recommended for analysing equipment functionality. Exception could be made for oversized equipment, or the limitations of the test facility.

4.49. Qualification by analysis may be used to demonstrate that an item of equipment can be qualified based on the qualification of other equipment to equivalent or more stringent conditions.

QUALIFICATION BY OPERATING EXPERIENCE

4.50. Operating experience may be used ~~as supplementary information~~ to help demonstrate the reliability of equipment to perform safety functions. Qualification for harsh environment by operating experience alone is not sufficient for safety systems and should, therefore, be combined with additional qualification testing of the equipment.

4.51. The validity of any operating experience feedback provided by the manufacturer should be confirmed by a third party, i.e. another organization with relevant experience of the use of the equipment. It should also be ensured that adequate documentation of the service conditions that relate to the operating experience is available.

4.52. The data from operating experience should be based on service conditions and performance requirements that are equivalent to, or more severe than, the equipment to be qualified.

COMBINED METHODS

4.53. Equipment qualification may be achieved through a combination of type testing, analysis and operating experience. For example, where type testing of a complete assembly is not possible, component testing supplemented by analysis could be used. In some cases, the overall equipment qualification is dependent on the qualification of the most limiting individual component within that equipment.

4.54. If not all the components within the equipment are subject to degradation from the effects of specified service conditions, it may be possible to demonstrate that some components can be qualified through a material analysis.

4.55. The specific combination of methods selected will depend upon the system or component under consideration. The combination of methods used for equipment qualification should be justified and documented.

ASSESSMENT OF EQUIPMENT CAPABILITY FOR DESIGN EXTENSION CONDITION WITH CORE MELTING

4.56. Paragraph 5.29 (b) of SSR-2/1 (Rev. 1) [1] states:

“...the features that are designed for use in, or that are capable of preventing or mitigating, events considered in the design extension conditions...shall be capable of performing in the environmental conditions pertaining to the design extension conditions, including design extension conditions in severe accidents, where appropriate”.

4.57. Equipment should have the capability, as appropriate, to perform its intended safety functions for the necessary mission time under severe accidents.

4.58. The mission time for each item of equipment used for mitigation or for monitoring in a severe accident should be derived from the analyses of the various stages of the severe accident. For example, some equipment may be needed to perform a safety function during a design basis accident and also remain functional throughout design extension conditions with core melting.

4.59. The specific functions of the equipment to be accomplished at each stage of a severe accident should be defined. The capability of the equipment to reliably perform those functions under such severe accident conditions should be assessed.

4.60. Type testing may be used as far as reasonably practicable to support the prediction of the behaviour of equipment under simulated severe accident loads.

4.61. A technical basis that may be considered for assessing the capability of equipment to perform under severe accident conditions is provided in Ref. [20].

5. PRESERVATION OF EQUIPMENT QUALIFICATION

GENERAL

5.1. Requirement 13 of SSR-2/2 (Rev. 1) [2] states:

“The operating organization shall ensure that a systematic assessment is carried out to provide reliable confirmation that safety related items are capable of the required performance for all operational states and for accident conditions.”

5.2. Furthermore, paragraph 4.48 of SSR-2/2 (Rev. 1) [2] states:

“A programme to establish, to confirm and to maintain required equipment qualification shall be launched from the initial phases of design, supply and installation of the equipment. The effectiveness of equipment qualification programmes shall be periodically reviewed.”

5.3. To meet the above requirements, qualified equipment should be designed, manufactured, procured, stored, installed, commissioned, inspected, operated, maintained and replaced or modified in a manner that helps to ensure that the equipment qualification is preserved for the lifetime of the installation.

5.4. Requirement 10 of SSR-2/2 (Rev. 1) [2] states:

“The operating organization shall establish and implement a system for plant configuration management to ensure consistency between design requirements, physical configuration and plant documentation.”

5.5. In order to meet the above requirements, configuration management (change control) should provide a systematic process to ensure that the implications of equipment qualification are appropriately considered whenever changes occur to the installation, to equipment, or to operating, maintenance or replacement activities.

5.6. The preservation of equipment qualification includes the need for periodic replacement of component parts (e.g. seals, gaskets, lubricants, filters) that degrade more readily. Such parts may need to be periodically replaced (i.e. not to be reused) during maintenance activities specifically undertaken for equipment qualification purposes.

5.7. Factors that can adversely impact the established equipment qualification include the following:

- (a) Deviations from appropriate installation and maintenance procedures;
- (b) Changes to the design basis or safety analysis;

- (c) Changes in regulatory requirements and in licensing conditions;
- (d) Modifications to the nuclear installation;
- (e) Deviations in service conditions from those assumed in the equipment qualification;
- (f) Feedback on adverse operating and maintenance experiences;
- (g) Unavailability of qualified spare parts;
- (h) Storage conditions of the qualified equipment and spare parts;
- (i) Obsolescence of the equipment or spare parts;
- (j) Recent qualification tests or research results that challenge or modify the original assumptions or test or analysis results.

5.8. All elements of the equipment qualification programme should be evaluated when assessing the status of qualified equipment.

5.9. The qualified life of an item of equipment should be reassessed during its lifetime, taking into account progress in the knowledge and understanding of degradation mechanisms and the actual operating environment of the equipment. If the qualified life is to be extended, a thorough evaluation supported by an adequate basis for the extension should be provided.

5.10. The status of each item of qualified equipment should be preserved and properly documented throughout the lifetime of the installation. Such documentation is part of the equipment qualification programme, and should typically include the following:

- (a) A list of equipment subject to qualification;
- (b) Technical specifications for the procurement of qualified equipment;
- (c) Manufacturer data in support of equipment qualification;
- (d) Specifications for the installation of equipment;
- (e) Results from monitoring the environmental conditions in areas in which equipment is located, where relevant;
- (f) Results from monitoring the condition of equipment, including visual inspections, where relevant;
- (g) Test reports relating to equipment qualification;
- (h) The summary report of the equipment qualification;

- (i) Results of maintenance activities, including where subcomponents or sealing materials (e.g. seals, gaskets, lubricants) have been replaced, and the certificates that establish the traceability of these replacements and of the equipment qualification;
- (j) Non-conformity reports from vendors and manufacturers and operating organizations;
- (k) Records of the non-availability of replacement components from the original equipment manufacturer (obsolescence), and the acceptability of appropriately qualified substitute replacement components (see para. 5.36);
- (l) Reports of relevant operating experience;
- (m) Reports of time limited ageing analyses relating to equipment qualification (e.g. for evaluation for long term operation), or reports of another suitable equivalent analysis;
- (n) Written justification that the equipment is suitable for use in each of the intended functional applications and associated locations within the installation.

5.11. Interfaces with other programmes (see Section 7) should be identified, and procedural controls should be established to provide assurance that activities essential to preserving the status of qualified equipment are correctly performed and properly integrated into processes and work practices at the installation.

5.12. Operating experience feedback from the installation itself or from other industries should be used for identifying unanticipated ageing mechanisms, or changes in the performance of equipment.

AGEING EFFECTS AND QUALIFIED LIFE

5.13. Paragraph 5.51 of SSR-2/1 (Rev. 1) [1] states:

“The design for a nuclear power plant shall take due account of ageing and wear out effects in all operational states for which a component is credited, including testing, maintenance, maintenance outages, plant states during a postulated initiating event and plant states following a postulated initiating event.”

Similar provisions for ageing and wear out effects are established in Requirement 37 of SSR-3 [3] for research reactors, and in Requirement 32 of SSR-4 [4] for nuclear fuel cycle facilities.

5.14. Paragraph 5.49 of SSR-2/1 (Rev. 1) [1] states:

“The qualification programme for items important to safety shall include the consideration of ageing effects caused by environmental factors (such as conditions of vibration, irradiation, humidity or temperature) over the expected service life of the items important to safety.”

The same provisions for ageing effects are established in para. 6.84 of SSR-3 [3] for research reactors, and in para. 6.115 of SSR-4 [4] for nuclear fuel cycle facilities.

5.15. When new ageing mechanisms or increases in the effects of previously known ageing mechanisms are identified, the relevant parts of the equipment qualification programme should be reviewed to determine whether changes in the qualified life or maintenance of the equipment are needed.

5.16. Periodic preventive maintenance, predictive maintenance, equipment calibration, surveillance, testing, condition monitoring, corrective action, identification of trends in equipment failures, and operating experience reviews are acceptable methods for identifying and mitigating unanticipated ageing degradation that was not accounted for when establishing the original equipment qualification.

5.17. The results of processes that identify ageing-related failures or significant material degradation of qualified equipment should be used to assess the need to revise the maintenance, surveillance and replacement programmes that are related to equipment qualification. These revisions should be reflected in the equipment qualification documentation.

MONITORING OF ENVIRONMENTAL CONDITIONS

5.18. An analysis should be carried out to determine where measurements of environmental conditions should be made based on the zones, rooms and equipment at the installation. This analysis should take into account the stressors acting upon the equipment (e.g. service temperature, radiation, submergence, local vibration, electromagnetic interference, radio frequency interference, toxic chemical exposure), to determine whether the actual environmental conditions are more severe than assumed.

5.19. Trends in the service conditions should be assessed to determine the impact on the condition of qualified equipment and to identify corrective actions, if necessary.

5.20. The monitoring of environmental conditions in the nuclear installation during operation should verify the following:

- (a) The assumptions in the equipment qualification are consistent with the ambient conditions in the part of the installation in which the equipment is installed;
- (b) The design limits of the equipment are not exceeded;
- (c) The status of qualified equipment remains valid.

5.21. Monitoring of environmental conditions may also be used to support the evaluation of remaining qualified life by determining if an item of equipment is suitable for continued service.

MONITORING THE CONDITION OF QUALIFIED EQUIPMENT

5.22. Monitoring the condition of qualified equipment ('condition monitoring') provides information regarding the rate of ageing degradation of qualified equipment. Conditions monitoring includes visual inspection and measurement of parameters that indicate the physical state of the equipment and assess its ability to perform its intended function(s) under specified service conditions. Condition monitoring

supports activities necessary for preserving the status of qualified equipment.

5.23. Appropriate periodic condition monitoring should be implemented to determine whether the actual degradation due to ageing is occurring at a higher rate than expected, which would indicate that corrective actions may be necessary to ensure that the status of qualified equipment is preserved. The results of condition monitoring should also be used to investigate the following:

- (a) Whether service conditions are more severe than previously assumed;
- (b) Whether the initial assumptions on ageing contain uncertainties that were not originally taken into account;
- (c) Whether ageing mechanisms have been identified that were not fully evaluated or simulated when the equipment qualification was established.

5.24. Appropriate condition indicators for a given type of equipment should be selected to help detect changes caused by significant ageing mechanisms. These condition indicators should be measurable, linked to the functional degradation of the qualified equipment, and should be capable of indicating a consistent observable trend.

5.25. Premature failures, degradations or performance anomalies of equipment important to safety should be identified and documented. These deficiencies should be addressed through a corrective action programme.

5.26. As qualified equipment approaches the end of its qualified life, additional periodic monitoring of its condition should be implemented to determine whether actual ageing is occurring at a slower rate than expected, which would indicate that it may be possible to extend the qualified life of the equipment.

5.27. The combination of monitoring environmental conditions and monitoring the condition of equipment should be used to support the re-assessment of the qualified life of equipment.

PERIODIC SURVEILLANCE OF QUALIFIED EQUIPMENT

5.28. Procedures for periodic surveillance of qualified equipment should be implemented to ensure the following:

- (a) That operation and maintenance activities do not compromise the status of qualified equipment by changing the configuration, mounting orientation (horizontal or vertical supports) or electrical, pneumatic or hydraulic interfaces;
- (b) That systems and components continue to meet their performance requirements;
- (c) That abnormalities in the configuration of the equipment are detected, and that corrective actions are completed in a timely manner to preserve the status of qualified equipment;
- (d) That criteria for identifying premature ageing degradation are specified.

5.29. During periodic surveillance, if unexpected degradation is observed, the effect of this degradation on the capability of the equipment to perform safety function should be evaluated.

MAINTENANCE RELATING TO QUALIFIED EQUIPMENT

5.30. Maintenance activities should be performed to preserve the status of qualified equipment, in accordance with the equipment qualification programme and surveillance procedures.

5.31. To preserve the status of qualified equipment, the maintenance programme should include the following:

- (a) Maintenance documentation that describes the maintenance activities necessary to support the preservation of equipment qualification.
- (b) The establishment of an appropriate preventive maintenance schedule. Maintenance intervals should be set to ensure the qualified life of the equipment is preserved.
- (c) The identification of any trends in condition indicators associated with qualified equipment and the detection of any initial indications that the performance of the equipment is degrading.
- (d) The replacement of equipment or components that have exceeded their qualified life.
- (e) A means by which operating personnel can identify that the equipment is qualified.

5.32. All maintenance work on qualified equipment should be subject to appropriate oversight to ensure that qualified replacement parts are used, that appropriate maintenance procedures are followed, and that the status of qualified equipment is preserved.

PROTECTIVE BARRIERS FOR QUALIFIED EQUIPMENT

5.33. Where protective barriers, enclosures, shields or sealing devices are provided for protecting qualified equipment from possible environmental conditions, the integrity of these barriers should be maintained as part of the equipment qualification programme. Controls should be implemented to ensure that these barriers remain effective and in their proper configuration for the lifetime of the installation.

5.34. Any protective barriers that can be removed should be clearly marked as being elements of the equipment qualification programme.

PROCUREMENT AND STORAGE OF QUALIFIED EQUIPMENT

5.35. Qualified equipment and spare parts should be procured in accordance with procurement criteria specified in the applicable equipment qualification summary report. Procurement criteria should contain the specifications and specified service conditions for the equipment to be purchased.

5.36. Replacement equipment should be identical to the original qualified equipment. If the replacement

is not identical, it should be evaluated to determine whether the substituted equipment is acceptable, and the conclusions of this evaluation should be documented. Equipment qualification documentation should be updated, as necessary, to reflect any substitutions that alter the bases for qualification, configuration, maintenance or procurement.

5.37. Requirement 11 of GSR Part 2 [6] states:

“The organization shall put in place arrangements with vendors, contractors and suppliers for specifying, monitoring and managing the supply to it of items, products and services that may influence safety.”

5.38. The arrangements with vendors and manufacturers of qualified equipment should also be in accordance with national requirements, including any quality management requirements. Equipment may also be procured through a vendor or manufacturer who uses a commercial grade dedication process. Whatever the arrangements, the equipment should be qualified in accordance with the equipment qualification programme⁷. ~~(e.g. see Ref. [24]).~~

5.39. Following procurement, qualified equipment should be inspected upon receipt, and stored in a controlled manner to ensure that the status of qualified equipment is preserved.

5.40. Procurement documentation should reflect the responsibility of the vendor and/or the manufacturer to demonstrate that the equipment supplied is identical to that ordered by the operating organization. The procurement documentation should state that the operating organization should be notified when changes to equipment design and manufacturing occur.

5.41. Qualified equipment (including subassemblies, spare parts and materials) in storage should be marked as qualified.

5.42. The storage of qualified equipment with a defined shelf life⁸ should be controlled to ensure that, upon installation, the status of qualified equipment is preserved. In particular, a reliable means should be established to ensure that shelf life expiration dates are not exceeded.

REASSESSMENT OF THE QUALIFIED LIFE OF EQUIPMENT

5.43. The qualified life of equipment should be reassessed throughout the lifetime of the installation to take into account changes in the actual service conditions, such as temperature and radiation levels, and development in the knowledge and understanding of degradation mechanisms.

5.44. If the qualified life of equipment is to be extended, the technical basis for this should be provided.

⁷ For example, [Nuclear Power Plant Equipment Qualification Reference Manual](#). ~~(e.g. see Ref. [24])~~Ref. [22].

⁸ The ‘shelf life’ is the maximum time period between manufacturing and installation during which the equipment may be in storage prior to installation, i.e. so as to avoid the potential loss of important engineering properties.

In addition, any conclusions regarding the status of qualified equipment should be re-evaluated to take into account any changes in performance requirements or installation conditions.

5.45. The technical basis for extending the qualified life of equipment should be evaluated to determine whether any changes in documented material composition and parameters, or in assumed environmental conditions, load cycles and other parameters, are needed to support this evaluation.

5.46. Methods such as reevaluation of the conservatism of assumptions made in the original equipment qualification, type testing of naturally aged equipment with additional ageing to support the extension of the qualified life, and equipment replacement and refurbishment, should be used for reassessing qualified life.

5.47. Changes in the stressor intensity (e.g. changes in temperature and radiation levels) may also be evaluated to reassess the qualified life. Consequently, evaluation of data from monitoring environmental conditions and the condition of equipment can be used to reassess equipment qualified life.

5.48. Methods chosen for reassessment of the qualified life of equipment should be justified and documented.

6. EVALUATION OF THE EFFECTIVENESS OF THE EQUIPMENT QUALIFICATION PROGRAMME

6.1. An assessment of the effectiveness of the equipment qualification programme should be performed. This assessment typically includes reviews of the following:

- (a) Compliance with the governmental, legal and regulatory framework for safety;
- (b) The adequacy of qualification documentation in terms of programme implementation and technical accuracy;
- (c) The effectiveness of interfaces with other programmes;
- (d) The effectiveness of training relevant to equipment qualification;
- (e) The effectiveness of corrective actions;
- (f) Maintenance activities relevant to equipment qualification;
- (g) Audits of vendor and manufacturer quality management programmes and processes relevant to equipment qualification.

6.2. The primary responsibility for conducting periodic audits and ongoing surveillance of the equipment qualification programme rests with the operating organization. In some States, the regulatory

body conducts periodic audits of selected elements of the equipment qualification programme as part of its safety verification activities.

6.3. The assessment of the effectiveness of the equipment qualification programme should include the evaluation of activities performed by the following organizations:

- (a) The operating organization;
- (b) Vendors and manufacturers of qualified equipment;
- (c) Third party providers of equipment qualification services;
- (d) Equipment qualification testing facilities (e.g. accredited laboratories).

6.4. The following types of audit of the equipment qualification programme should be performed:

- (a) Audits covering all aspects and activities of the equipment qualification programme. These audits are usually performed when the programme is first established and as a part of a periodic safety review of the nuclear installation or a review for licence renewal.
- (b) Audits covering selected aspects and activities of the equipment qualification programme. These audits are conducted more frequently and often in response to incidents suggesting possible weaknesses in specific areas.
- (c) Audits covering vendor and manufacturer quality management programmes and processes relevant to equipment qualification;
- (d) Periodic regulatory inspections to ensure that equipment qualification activities are being performed in accordance with the national regulatory framework for initial licensing and long term operation of the installation.

6.5. The assessment of the effectiveness of equipment qualification programme should be an active and ongoing process that considers the following:

- (a) Whether a list of equipment subject to qualification is available and up to date.
- (b) Whether the methods and criteria used in the equipment qualification programme reflect licensing conditions and the design basis.
- (c) Whether the original assumptions regarding the safety, operability and performance of equipment were reasonable and remain valid.
- (d) Whether the equipment qualification documentation is available in an auditable and traceable form, provides evidence of qualification for each item of equipment in the equipment qualification list, and includes a system for locating supporting documentation.
- (e) Whether the supporting documentation is traceable and includes the following:

- (i) Test and analysis documentation;
 - (ii) Evaluation of operating experience and information from feedback programmes;
 - (iii) Procurement documents;
 - (iv) Quality assurance data from manufacturing of qualified equipment;
 - (v) Criteria for storage, transport and installation of qualified equipment;
 - (vi) Criteria for surveillance and maintenance of qualified equipment.
- (f) Whether there is sufficient evidence of the following:
- (i) The technical basis and assumptions used in modelling of qualified life (e.g. activation energy levels, material compositions, assumed environmental conditions and other parameters) remain valid;
 - (ii) The installed equipment matches the qualified equipment;
 - (iii) The equipment is installed correctly (e.g. mounting, connections and conduit seals comply with the qualified configuration documentation, actuators and hydraulic or pneumatic lines are connected and arranged in accordance with design requirements);
 - (iv) The equipment and any protective barriers are appropriately maintained;
 - (v) Corrective actions are identified and performed in timely manner;
 - (vi) Personnel are capable of identifying characteristics of ageing degradation effects.
- (g) Whether the measures necessary to preserve the status of qualified equipment during the service life of equipment are documented in appropriate procedures or instructions (e.g. for storage and handling of qualified spare parts, and for installation, surveillance, maintenance and component replacement) and are implemented.
- (h) Whether the relevant personnel have appropriate qualifications and training to establish and preserve equipment qualification.
- (i) Whether maintenance and testing of qualified equipment, surveillance and inspection of equipment conditions, and monitoring of environmental conditions have been established to ensure that the ageing degradation and functional capability of qualified equipment remain acceptable, and whether a feedback process is in place to address any unanticipated degradation that has been identified.
- (j) Whether a programme is in place to analyse premature degradation or failures of qualified equipment, and to implement appropriate corrective actions, including revisions of conclusions on the status of qualified equipment.

- (k) Whether an operating experience programme is in place to collect and review information relevant to the status of qualified equipment. Such information includes operating experience from the nuclear installation and from other installations, reports of significant events, feedback from vendors or manufacturers, research and development results, and guidance from the regulatory body.
- (l) Whether the equipment qualification programme reflects the as-built design of the installation, including any recent modifications.
- (m) Whether there is adequate evidence that controls implemented within the equipment qualification programme (e.g. corrective actions, configuration management) are effective.

7. INTEGRATION OF EQUIPMENT QUALIFICATION INTO SAFETY PROGRAMMES AND PROCESSES

INTERFACES BETWEEN THE EQUIPMENT QUALIFICATION PROGRAMME AND OTHER PROGRAMMES

7.1. The equipment qualification programme should have clearly defined interfaces with other programmes and processes and activities should be coordinated to ensure the status of qualified equipment is preserved. These other programmes and processes include the following:

- (a) Licensing;
- (b) Operations, including work and task planning;
- (c) Quality management programme (including the supply chain);
- (d) Configuration management;
- (e) Operating experience feedback;
- (f) Ageing management⁹ and long term operation;
- (g) Surveillance, testing and maintenance;
- (h) Radiation protection;
- (i) Chemistry programme;
- (j) The corrective action programme;
- ~~(k) The quality management programme (including the supply chain);~~
- (+)(k) Packaging and transport of equipment;

⁹ Paragraphs 4.23–4.31 of SSG-48 [13] and para. 7.8 of SSG-10 [14] provide recommendations on how equipment qualification is integrated and reviewed within the framework of the ageing management programme.

- ~~(m)~~(l) Procurement and storage of equipment;
- ~~(n)~~(m) Training of personnel;
- ~~(o)~~(n) Outage planning, and scheduling (where appropriate);
- ~~(p)~~(o) Engineering (replacement parts engineering and design engineering).

SAFETY ANALYSIS REPORT

7.2. Recommendations on the format and content of the safety analysis report are provided in IAEA Safety Standards Series Nos SSG-61, Format and Content of the Safety Analysis Report for Nuclear Power Plants ~~[25]~~[23] and SSG-20, Safety Assessment for Research Reactors and Preparation of the Safety Analysis Report ~~[26]~~[24]. With regard to equipment qualification, the safety analysis report should include the following:

- (a) Information regarding the safety functions of the equipment that is subject to equipment qualification;
- (b) Information on the location of qualified equipment;
- (c) Information on the mission time(s) of qualified equipment in accident conditions;
- (d) The bases for determining specified service conditions;
- (e) The bases for defining areas within the installation with different environmental conditions;
- (f) The variations in environmental conditions expected in operational states and accident conditions (e.g. vibration, temperature, pressure, electromagnetic interference, radiation levels, humidity);
- (g) Any unusual environmental conditions that can reasonably be anticipated or arise from specific activities, such as in periodic testing of the containment leak rate;
- (h) Information on approaches to qualification of a particular type of equipment, the qualification program, the documents in which qualification results are given, and conclusions about qualification.

Any changes that affect the above items should be reflected in updates to the safety analysis report.

MODIFICATIONS TO NUCLEAR INSTALLATIONS

7.3. The process for making modifications to the installation should ensure that equipment qualification documentation is updated to reflect any design changes.

7.4. Any modification involving qualified equipment should be carefully planned before the modification is implemented. This includes ensuring the following:

- (a) All documentation affected by the modification, such as the safety analysis report, operational limits and conditions, drawings, operating procedures and emergency procedures, periodic

maintenance and testing procedures and equipment indexes, has been updated and is available. Documents should not be released for use until the modification has been completed.

(b) The as-built configuration of modified systems is reflected in the design basis documentation.

7.5. Modifications that only involve items not important to safety, but which might affect items important to safety should also be evaluated for the possible impact on qualified equipment. The results of evaluation should be documented.

7.6. Further recommendations on controlling modifications to nuclear installations are provided in IAEA Safety Standards Series Nos NS-G-2.3, Modifications to Nuclear Power Plants ~~[27]~~[\[25\]](#) and SSG-24, Safety in the Utilization and Modification of Research Reactors ~~[28]~~[\[26\]](#).

DRAFT

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ANNEX

BIBLIOGRAPHY OF INTERNATIONAL STANDARDS RELATING TO EQUIPMENT QUALIFICATION

A–1. Requirement 9 of IAEA Safety Standards Series No. SSR-2/1 (Rev. 1), Safety of Nuclear Power Plants: Design [A–1] states:

“Items important to safety for a nuclear power plant shall be designed in accordance with the relevant national and international codes and standards.”

A–2. A large number of national and international standards exist that establish detailed criteria, methods, processes and practices on design methodologies and system characteristics that support compliance with the requirements established in SSR-2/1 (Rev. 1) [A–1]. It is expected that designers, operating organizations and regulatory bodies will take advantage of such design standards.

A–3. Two organizations are responsible for most of the internationally used standards for instrumentation and control systems in nuclear installations: the International Electrotechnical Commission (IEC) Subcommittee 45A and the Institute of Electrical and Electronic Engineers (IEEE) Nuclear Power Engineering Committee. Each organization has developed a number of design standards that support the common principles underlying the requirements established in SSR-2/1 (Rev. 1) [A–1] and the recommendations provided in this Safety Guide.

A–4. A concerted effort was made to avoid conflicts between the recommendations provided in this Safety Guide and the standards of IEEE and IEC. Members of both the IEC and the IEEE standards committees participated in the development of this Safety Guide and both standards organizations reviewed drafts to help identify and eliminate conflicts.

A–5. There are important differences between the IEC and the IEEE standards. IEC standards take the IAEA Safety Requirements publications and Safety Guides as fundamental inputs for their development. As a result, the IEC standards deal with items important to safety and use IAEA recommendations and guidance on instrumentation and control systems as a basis. In contrast, the IEEE standards focus mostly on items important to safety. The IEEE standards can be applied to safety related items (i.e. items important to safety that are not safety systems) using a graded approach.

A–6. Table A–1 lists the IEC and IEEE standards that relate directly the recommendations provided in this Safety Guide. Table A–1 is not intended to provide a complete list, but it identifies the entry points into the sets of IEC and IEEE standards. Table A–1 also contains a relevant standard issued by the American Society of Mechanical Engineers.

TABLE A-1 INTERNATIONAL STANDARDS RELATING TO EQUIPMENT QUALIFICATION

IEC 60515:2007 [A-2]	Nuclear power plants - Instrumentation important to safety - Radiation detectors - Characteristics and test methods
IEC 60772:2018 [A-3]	Nuclear power plants - Instrumentation systems important to safety - Electrical penetration assemblies in containment structures.
IEC 60980:1989 [A-4]	Recommended practices for seismic qualification of electrical equipment of the safety system for nuclear generating stations
IEC 61513:2011 [A-5]	Nuclear power plants – Instrumentation and control important to safety – General requirements for systems
IEC 62003:2009 [A-6]	Nuclear power plants - Instrumentation and control important to safety - Requirements for electromagnetic compatibility testing
IEC 62342:2007 [A-7]	Nuclear power plants - Instrumentation and control systems important to safety - Management of ageing
IEC 61000-4-1:2016 [A-8]	Electromagnetic compatibility (EMC) - Part 4-1: Testing and measurement techniques - Overview of the IEC 61000-4 series
IEC 61000-6-1:2016 [A-9]	Electromagnetic compatibility (EMC) - Part 6-1: Generic standards - Immunity standard for residential, commercial and light-industrial environments
IEC/IEEE 60780-323:2016 [A- 910]	Nuclear Facilities – Electrical equipment important to safety – Qualification
IEEE 308-2020 [A- 1011]	IEEE Approved Draft Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations
IEEE 334-2006 [A- 1112]	IEEE Standard for Qualifying Continuous Duty Class 1E Motors for Nuclear Power Generating Stations
IEEE 344-2013 [A- 1213]	IEEE Standard for Seismic Qualification of Equipment for Nuclear Power Generating Stations
IEEE 382-2019 [A- 1314]	IEEE Standard for Qualification of Safety-Related Actuators for Nuclear Power Generating Stations and Other Nuclear Facilities
IEEE 383-2015 [A- 1415]	IEEE Standard for Qualifying Electric Cables and Splices for Nuclear Facilities
IEEE 420-2013 [A- 156]	IEEE Standard for the Design and Qualification of Class 1E Control Boards, Panels, and Racks Used in Nuclear Power Generating Stations

IEEE 535-2013 [A- 1617]	IEEE Standard for Qualification of Class 1E Vented Lead Acid Storage Batteries for Nuclear Power Generating Stations
IEEE 572-2019 [A- 1718]	IEEE Standard for Qualification of Class 1E Connection Assemblies for Nuclear Power Generating Stations and Other Nuclear Facilities
IEEE 603-2018 [A- 1819]	IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations
IEEE 627-2019 [A- 1920]	IEEE Standard for Qualification of Equipment Used in Nuclear Facilities
IEEE 649-2006 [A- 2021]	IEEE Standard for Qualifying Class 1E Motor Control Centers for Nuclear Power Generating Stations
IEEE 1205-2014 [A- 2122]	IEEE Guide for Assessing, Monitoring, and Mitigating Aging Effects on Electrical Equipment Used in Nuclear Power Generating Stations and Other Nuclear Facilities.
IEEE 1682-2011 [A- 2223]	IEEE Standard for Qualifying Fiber Optic Cables, Connections, and Optical Fiber Splices for Use in Safety Systems in Nuclear Power Generating Stations
ASME QME-1-2017 [A- 2324]	Qualification of Active Mechanical Equipment Used in Nuclear Facilities

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DEFINITIONS

The following definitions are specific to this publication and are not provided in the IAEA Safety Glossary: Terminology Used in Nuclear Safety and Radiation Protection (2018 Edition)

accelerated ageing. A method of equipment testing in which the ageing associated with longer term service conditions is simulated in a short time.

- ① Usually, the accelerated ageing attempts to simulate natural ageing effects by application of stressors representing pre-service and service conditions, but with differences in intensity, duration and the manner of application.

ageing mechanism. A process that gradually changes the characteristics of a structure, system or component with time or use (e.g. curing, wear, fatigue, creep, erosion, microbiological fouling, corrosion, embrittlement or chemical decomposition).

condition monitoring. Activities performed to assess the functional capability of equipment by measuring and tracking the condition of the equipment.

harsh environment. Environmental conditions that are significantly more severe than the conditions anticipated for operational states.

mild environment. Environmental conditions that would at no time be significantly more severe than the conditions anticipated for operational states.

mission time. The length of time for which equipment is intended to perform its intended function under accident conditions.

significant ageing mechanism. An ageing mechanism that, under normal and abnormal service conditions, causes degradation of equipment that makes the equipment vulnerable to failure to perform its safety functions in accident conditions.

specified service conditions. Physical conditions and stressors to which the equipment is subjected to during its service life.

- ① This includes normal operating conditions, process conditions, abnormal operating conditions and conditions during and following a design basis accident or in design extension conditions.

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