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IAEA SAFETY STANDARDS

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Draft H

Step 9

Addressing Member States

Notes:

This is a marked-up revision for comparison, how Member States comments were addressed. Paras that have been moved have been accepted to ensure clarity of the document.

This revision contains the resolution to Member State comments, editorial review performed by the safety guide development team, and IAEA editorial comments.

Resolution of Member States comments required changes in the draft publication that resulted in the following changes:

- Section 3 change the order of subsections;
- Merged and modified paras 4.4-4.23 in Section 3 Identification of service conditions
- Added new paras 3.34-3.38 Service conditions resulting from design extension conditions in severe accident into Section 3 to keep consistency;
- Moved paras 4.24-4.27 on assessment of initial qualification to the end of Section 3.

Equipment Qualification for Nuclear Installations

DS514

DRAFT SAFETY GUIDE

New Safety Guide

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. Equipment qualification in this Safety Guide refers to the generation and maintenance of evidence to ensure that equipment will operate when needed to meet safety functional performance requirements under operational states and accident conditions.

1.2. Equipment qualification is a process of determining whether a system or component is suitable for the intended operational use. It typically includes, for example, seismic qualification, environmental qualification (e.g. environmental conditions resulting from postulated initiating events), validation of mechanical performance characteristics (e.g. mechanical force, torque and response time for valves and pumps), and validation of performance under electromagnetic, radiofrequency interference and electrostatic discharge.

~~1.1.~~1.3. This Safety Guide addresses the establishment ~~, execution~~ and preservation of equipment qualification in nuclear installations, to provide confirmation of the reliable safety functional performance of such equipment during operational states and accident conditions to avoid vulnerability to common cause failure of the equipment.

~~1.2.~~1.4. This Safety Guide is intended for use by entities responsible 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 related to equipment qualification.

~~1.3.~~1.5. This safety guide provides recommendations on the equipment qualification to meet the requirements for the design and operation of nuclear power plants are established in IAEA Safety Standards Series Nos SSR-2/1 (Rev. 1), Safety of Nuclear Power Plants: Design [1], SSR-2/2 (Rev. 1), Safety of Nuclear Power Plants: Commissioning and Operation [2], as well as requirements for other types of nuclear installations are established in IAEA Safety Standards Series Nos SSR-3, Safety of Research Reactors [3], and SSR-4, Safety of Nuclear Fuel Cycle Facilities [4]. Additional requirements relevant to equipment qualification are established in IAEA Safety Standards Series No. GSR Part 4 (Rev. 1), Safety Assessment for Facilities and Activities [5].

~~1.4.~~1.6. Categorization of equipment safety functions is important for defining the scope and selecting the appropriate methodologies to be used for executing equipment qualification. IAEA Safety Standards Series No. SSG-30, Safety Classification of Structures, Systems and Components in Nuclear Power Plants [6] provides recommendations on how to categorize functions and classify systems and components and other items of equipment on the basis of safety function and significance.

~~1.5. IAEA Safety Standards Series No. NS-G-1.6, Seismic Design and Qualification for Nuclear Power Plants [7] provides recommendations on equipment qualification specific to seismic design for nuclear power plants.~~

OBJECTIVE

~~1.6.~~1.7. The objective of this Safety Guide is to provide a structured approach and guidance on the establishment and preservation of equipment qualification in nuclear installations to meet applicable ~~specific~~ safety requirements.

1.8. Several IAEA Safety Standards address equipment qualification. These include IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [8], and its supporting Safety Guides, notably IAEA Safety Standards Series Nos GS-G-3.1, Application of the Management System for Facilities and Activities [9] and GS-G-3.5, The Management System for Nuclear Installations [10]. In addition, recommendations from Specific Safety Guides supporting SSR-2/1 (Rev. 1) [1] and SSR-2/2 (Rev. 1) [2], notably IAEA Safety Standards Series Nos SSG-34, Design of Electrical Power Systems for Nuclear Power Plants [11], SSG-39, Design of Instrumentation and Control Systems for Nuclear Power Plants [12] and SSG-48, Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants [13], are also taken into account in this Safety Guide.

~~1.7.~~1.9. This Safety Guide also provides recommendations on the equipment qualification for nuclear installations other than nuclear power plants to meet specific requirements established in SSR-3 [3] for research reactors, in SSR-4, [4] for nuclear fuel cycle facilities, and in GSR Part 4 (Rev. 1) [5] for all facilities and activities.

~~1.8.~~1.10. Additional guidance on equipment qualification is available from individual States and from international organizations that develop nuclear and industrial codes and standards. This includes publications that provide specific implementation details and methodologies for equipment qualification (see Annex).

SCOPE

~~1.9.~~1.11. This Safety Guide ~~addresses the process for establishing and preserving~~ primarily applies to equipment ~~required to perform safety functions, but also may be used for equipment not important to safety as determined by Member States specific requirements.~~ required to perform safety functions, but it also may be used for equipment not important to safety as determined by Member States specific requirements.

~~1.10.~~1.12. The recommendations of this Safety Guide apply for new and existing nuclear installations.

~~1.11.~~1.13. ~~Equipment within the scope of this~~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 ~~and their anchoring~~).

~~1.12.~~1.14. 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 not included in this Safety Guide, but is covered in Member States codes and standards.

~~1.13.~~1.15. The main topical areas for which this Safety Guide provides recommendations are the following:

(a) Identification of design inputs necessary for equipment qualification;

(b) Qualification methods and practices for establishing and preserving the equipment qualification to provide reliable confirmation that equipment is capable ~~to~~ of performing its safety function for operational states and for accident conditions throughout the lifetime of a nuclear installation;

(c) Integration of qualification processes within the design, manufacturing, installation, commissioning, operation and maintenance programme activities of nuclear installations throughout their lifetime.

~~1.14.~~1.16. This Safety Guide considers integration of qualification aspects ~~of~~with other interfacing programmes and processes, including:

(a) Development and review of the safety analysis report;

(b) Modification processes;

(c) Other processes that affect qualification (e.g. vendor/manufacture~~supply chain~~ quality management, procurement, storage/shelf life, installation, commissioning, operation, maintenance, corrective action programme);

(d) Ageing management and long term operation;

~~(d)~~(e) Operational experience feedback.

~~1.15.~~1.17. This Safety Guide does not specify seismic qualification methods and processes in detail. Recommendations on seismic qualification (for nuclear power plants) are provided in NS-G-1.6 [7]. This Safety Guide also does not specify methods for validation of electromagnetic compatibility. Recommendations regarding validation of electromagnetic compatibility are provided in Ref. [61000, 62003]. Additionally, this Safety Guide does not specify 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 [add ref].

~~1.16.~~1.18. ~~This Safety Guide does not specify software verification and validation methods and processes in detail.~~ Equipment designs may be complex and contain electrical, mechanical and I&C software parts within it (e.g. motor protection relays, digital devices with limited functionality, smart devices). Within the context of qualification, this 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.

~~1.17.~~1.19. In this regard, software and firmware verification and validation should have been performed for equipment performing safety functions. However, the process used to develop equipment containing digital devices with limited functionality should be examined carefully to confirm that such verification and validation methods were deployed during their development. Verification and validation methods are not addressed in this Safety Guide, however recommendations on these topics are provided in SSG-39 [12].

STRUCTURE

~~1.18.~~1.20. Section 2 provides guidance regarding the qualification concepts and process. Section 3 provides recommendations for specifying the design inputs needed to support the qualification process. Section 4 provides recommendations on establishing qualification. Section 5 provides recommendations for preserving qualification. Section 6 provides recommendations on the evaluation of the effectiveness of the equipment qualification programme. Section 7 provides recommendations on programmatic interfaces and integration of qualification within other safety programmes and processes.

~~1.19.~~1.21. The Annex provides a list of international nuclear and industrial standards that can be used for equipment qualification, which have a strong relationship with the major topical areas of this Safety Guide. International nuclear and industrial standards are typically reviewed by their applicable regulatory bodies that specify conditions for their implementation.

2. QUALIFICATION CONCEPTS ~~AND PROCESS~~

BASIC CONCEPT

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.”**

~~2.1.~~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."

~~2.2.~~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."

New 2.3.a. 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".

~~2.3.~~2.4. Qualification should demonstrate that equipment will be capable of performing their intended safety function(s) under the range of service conditions ~~anticipated~~ specified for the nuclear installation in operational states and accident conditions. This includes an evaluation of the suitability of systems or components for performing the safety functions under the effects caused by specified service conditions during plant states and during events not excluded by the design of a nuclear installation (e.g. seismic, electromagnetic phenomena, arcing, lightning). For example, internal fires, explosions, internal flooding, tornadoes or hurricanes are not considered in the qualification since designs generally protect the equipment from these events.

~~2.4.~~2.5. ~~Equipment~~Qualification should consider possible synergistic effects (e.g. simultaneous elevated temperature, humidity and radiation), where such effects could lead to significant ageing degradation mechanisms or for adverse performance under accident conditions.

~~2.5.~~2.6. Establishing an equipment qualification programme is necessary ~~condition~~for the prevention of common cause failures of equipment resulting from exposure to hazards from specified ~~caused by the item not being qualified for the intended function required to perform during anticipated~~ service conditions.

~~2.6.~~2.7. The qualification activities should provide confidence that equipment is designed, manufactured, installed, commissioned, operated, and maintained such that the equipment is capable of performing its required safety functions, when needed in the specified service conditions throughout its qualified life, with due account taken of plant conditions during maintenance and testing.

~~2.7.~~2.8. Within the context of qualification, equipment should be considered as an integrated assembly

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

~~2.8.~~2.9. The equipment to be qualified should be an accurate representation of the type or series type of the equipment to be installed~~representative of the equipment that is to be installed in the nuclear installation and its application~~.

~~2.9.~~2.10. The equipment qualified configuration should include the equipment and its interfaces. The qualified configuration should also include the final versions of software, firmware, hardware description language, and process, electrical and mechanical interfaces and equipment orientation.

~~2.10.~~2.11. Equipment qualification should be considered as an essential programme throughout the whole lifetime of a nuclear installation.

QUALIFICATION ~~PROCESS~~ OVERVIEW

~~2.11.~~2.12. The equipment qualification process comprises three phases:

— Establishment of appropriate design inputs;

— Establishment of qualification process steps;

— Preservation of equipment ~~qualification~~ qualified status.

~~2.12.~~2.13. These three phases of the qualification process and the relationship of activities within each phase are described in Sections 3, 4 and 5 of this Safety Guide.

Qualified life

~~2.13.~~2.14. Qualified life is the period for which equipment 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 reliably perform its safety functions ~~in~~ under accident conditions for a design basis accident or a design basis earthquake.

~~2.14.~~2.15. The qualified life should be established for equipment that is subject to significant performance degradation mechanisms that can occur under the range of specified service conditions for operational states~~(e.g. in-service ageing under service conditions, harsh environment conditions)~~.

2.16. The parameters and any modelling of specified environmental conditions used to establish the qualified life should be specified. Preservation activities, such as equipment condition monitoring and environmental monitoring, should determine whether these parameters and specified environmental conditions remain within acceptable ranges.

~~2.15.~~2.17. The qualified life may be based upon the performance of the entire assembly of equipment or may be dependent on individual components (e.g. gaskets, sealings) within the assembly.

Qualification methods

~~2.16.~~2.18. Internationally recognized methods for qualification are type testing, analysis, use of operating experience or a combination of these methods.

~~2.17.~~2.19. The Annex provides a list of applicable industrial standards which may be considered for identifying appropriate ~~equipment~~ qualification methods. ~~These methods should be supplemented by new knowledge based on previous qualification test results and experiences and/or scientific publications.~~

Preservation of ~~qualified status~~equipment qualification

~~2.18.~~2.20. ~~The qualified status~~Preservation of equipment qualification is required during the lifetime of the nuclear installation.

~~2.19.~~2.21. Equipment functional performance and design requirements specifications should be among the inputs for the assessment of the initial equipment qualification. The equipment specifications should also include vendor/manufacturer processes, procurement, installation and commissioning, replacement intervals, maintenance requirements and interfaces with other programmes for assessment of qualification preservation activities.

~~2.20.~~2.22. The status of equipment qualification may be affected by the following:

— Changes in actual operating and/or environmental conditions from those initially specified;

— Improvements or changes in maintenance practices;

— Modification of systems and substitution of components or subcomponents;

— Modification of equipment design;

— Modifications of the manufacturing process;

— Changes in storage conditions (e.g. time, ambient temperature, packaging);

— Improvements in modelling plant safety analysis;

— Evaluation of ~~Plant~~ plant long term operation;

— ~~Emerging issues or o~~Operating experience.

~~2.21.~~2.23. Justification should be provided during equipment qualification reassessment ~~,~~ whenever changes occur that could alter the initial equipment qualification assessment.

QUALITY ASSURANCE

~~2.22.~~2.24. 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. test, analysis, combined test and analysis and experience), storage, installation and commissioning, plant

surveillance and maintenance, periodic testing and documentation.

~~2.23.~~2.25. Qualification activities, including the ~~review~~ assessment or reassessment of equipment qualified status, should be performed in accordance with approved procedures and controls. It should follow the process that meets the requirements established in GSR Part 2 [8].

~~2.24.~~2.26. Data acquisition tools used during qualification should be calibrated against traceable criteria and documentation supporting such calibrations should be provided.

~~2.25.~~2.27. Traceability should be established ~~between~~ among the qualification documentation, the conclusions from each qualification ~~step~~ test or analysis steps, and the installed equipment configuration that ~~is subject to qualification~~, in order to ensure that the ~~test~~ installed configuration corresponds to the ~~installed~~ as-tested configuration.

DOCUMENTATION

~~2.26.~~2.28. Equipment qualification documentation should include the following items:

— A list of ~~items~~ equipment important to safety that ~~are~~is subject to qualification that includes required equipment safety function and ~~plant~~ specific physical location;

— The qualification requirements specifications;

— Equipment specifications (e.g. identification/configuration of the equipment subject to qualification);

— Qualification analysis and test reports (e.g. qualification analysis and test data);

— Qualification assessment summary report;

— Qualification preservation instructions providing all requirements to preserve the equipment qualified status during installation, commissioning, operation and maintenance of the equipment;

— Manufacturing reference documents outlining all requirements needed to preserve the qualified status during manufacturing of the series equipment.

~~2.27.~~2.29. The equipment specification should include the following items:

— Equipment type, vendor/manufacturer, model number (~~and variants~~or series types of equipment)~~, current manufacturing status~~;

— Specific equipment configuration and settings;

— The versions of firmware and application software, hardware description language to be delivered;

— Dimensions, ranges of rated parameters (mechanical and electrical);

— Mechanical, electrical, instrumentation and control interfaces of the equipment;

— Equipment performance capabilities (e.g. accuracy data, insulation resistance, cable impedance, response times);

— Operating manual, instructions or data sheets, including parts list, maintenance, installation and test procedures;

— Certificates and test documentation with respect to industrial standards.

~~2.28.~~2.30. The equipment qualified configuration should be properly documented and maintained in an auditable form while the equipment is in service or in storage while awaiting installation.

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

~~2.29.~~2.32. Test specifications and test reports should be prepared for each type of qualification (e.g. seismic, environmental, electromagnetic compatibility, functionality testing under specified dynamic loading conditions, ageing and wear through functional cycling).

~~2.30.~~2.33. All non-conformities and deviations identified during the qualification and preservation activities should be analysed, justified and documented, with conclusions made as to whether any further actions or considerations are required ~~to ensure the existing qualified life is not impacted~~.

~~2.31.~~2.34. A qualification summary report evaluating all results from each type of qualification tests and/or analyses should be prepared. The qualification summary report includes the basis for equipment qualification assessment / suitability analysis which is used to conclude that piece of equipment is suitably qualified for a plant specific application.

~~2.32.~~2.35. 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 qualified status of each equipment included in the report.

TRAINING

~~2.33.~~2.36. The personnel involved in qualification activities should be trained to possess adequate skills, knowledge and attitude, and this training should be included in the equipment qualification programme.

~~2.34.~~2.37. A systematic approach to training should be used to design, develop, implement, and evaluate the training provided.

~~2.35.~~2.38. Key training elements for personnel establishing , ~~implementing~~ and preserving qualification include the following:

(a) Training specific to the job, task and procedure;

(b) Integration of qualification details into the hands-on maintenance training for each equipment type (e.g. maintenance personnel training on maintaining electrical equipment or transmitters will cover applicable qualification related details, effective criteria to be used when inspecting for degradation);

(c) A description of related roles, responsibilities and their scope.

~~2.36.~~2.39. The training programme should include an element for oversight of the training of both internal staff and any contractor's personnel involved in qualification activities.

3. DESIGN INPUTS

IDENTIFICATION OF EQUIPMENT PERFORMANCE REQUIREMENTS

3.1. The design requirements for the equipment should address functional performance requirements necessary to accomplish the required safety functions under the specified service conditions.

3.2. Equipment needed to perform safety functions during accident conditions should meet the performance requirements during the specified mission time.

3.3. Performance requirements should be derived from the design requirements and functional acceptance criteria. This typically includes operational characteristics, measurement accuracy, upper and lower limits of functional physical parameters, and/or response time.

3.4. Performance requirements and service conditions should be quantified and documented.

IDENTIFICATION OF SERVICE CONDITIONS

3.5. The equipment qualification ~~programme~~ begins with establishing the range of conditions and events under which the equipment should be qualified.

3.6. A set of specified service conditions for which qualification is to be established should be determined, in order to provide confidence in equipment performance. This may be performed by identifying bounding conditions which influence qualification parameters.

3.7. The set of specified service conditions should include normal operating conditions (e.g. vibration, voltage surge electromagnetic interference), process conditions (e.g. voltage, current, temperature, pressure, radiation), fluid conditions (e.g. differential pressure, temperature, flow, fluid parameters, and chemical content) and environmental conditions in all plant states~~, and during internal events and external events~~.

3.8. The operating conditions are generally defined by the process conditions and ambient service conditions of the systems.

3.9. The environmental conditions are generally defined by the ambient conditions associated with plant states within the areas (zones) of the nuclear installation where the equipment is installed.

Consideration of the localised environment within these areas (zones), (e.g. temperature and radiation hot spots) should be considered, where possible or necessary.

3.10. The set of specified service conditions should ~~bound~~ consider most limiting ~~normal~~ operational states, accident conditions with margin, ~~internal and external events,~~ and equipment operational modes (e.g. continually energized~~,~~ or normally deenergized; loaded or unloaded~~loaded~~), as applicable.

3.11. Differences between these specified service conditions and actual conditions can be addressed through additional qualification of the equipment (e.g. by establishing exclusion zones to prevent adverse impact of electromagnetic or radiofrequency fields on the equipment performance).

3.12. Modelling or simulation of specified service conditions should be used to derive the parameters needed as inputs for the qualification process. The specific methods for conducting this modelling or simulation are outside of the scope of this Safety Guide but can be found in Ref. [SSG-2, Rev.1].

3.13. Qualification processes should provide confidence that safety functions will be accomplished for the set of specified service conditions.

~~Specified s~~Service conditions specified for operational states

3.14. Specified service conditions during operational states should be used to evaluate the suitability of equipment to perform ~~adequately~~reliably.

3.15. Relevant environmental conditions typically include the following:

— Ambient temperature and pressure;
— Humidity/steam;
— Radiation;
— Submergence;
— Boric acid and other applicable chemical leakages;
— Chemicals in the atmosphere (salt mist, oil aerosols);
— Induced vibrations from neighbouring equipment or seismic event;
— Susceptibility to electromagnetic fields;
~~— Seasonal and climatic variations;~~
— .

3.16. Relevant operating conditions typically include the following:

— Power;
— Operating cycles (electrical and mechanical, water hammer);
— Electrical loading parameters (e.g. voltage, frequency, current);
— Mechanical loads (e.g. self-induced flow, self-induced vibration, thrust or torque, displacement);

~~— Seasonal and climatic variations;~~

— Process fluid conditions (e.g. pressure, temperature, chemical composition, flow rate, water hammer);

— Chemical composition;

— Loads and duty cycles;

— Self-heating;

— Submergence;

— Electromagnetic interferences (e.g. electromagnetic and radio frequency interference);

— Power surges.

3.17. Test conditions should bound the ~~the~~ most likely ~~specified~~ service conditions for all equipment of the same type. ~~occurring at each individual equipment location.~~ Consideration should be made for cases where temperature/radiation conditions ~~(e.g. variations in air conditioning can~~ may occasionally deviate from specified service conditions (e.g. hot spots)~~change local environmental conditions)~~.

3.18. ~~When equipment is installed inside other devices or behind panels, the local environment may differ from the general area conditions. Self-heating due to the operation of electrical equipment or elevated process temperatures should be identified and considered.~~

3.19. ~~Voltage variations can cause significant differences in the temperature rise due to self-heating for most electrical equipment and therefore should also be considered.~~

3.20. The evaluation of equipment performance for operational states generally involves demonstrating its functional capability when experiencing a combination of service condition extremes.

Electromagnetic interference

3.21. Electromagnetic interference includes radiofrequency interference, electrical surges (e.g. voltage spikes resulting from switching transients, lightning), and electrostatic discharge.

3.22. Electromagnetic interference can affect electrical and instrumentation and control systems and components. Electromagnetic interference qualification addresses the combination of system and component design to minimize the coupling of electromagnetic disturbances to electrical and instrumentation and control components.

3.23. Detailed requirements and acceptance criteria for electromagnetic interference qualification should be determined for safety systems and components in accordance with international standards or alternatively on the basis of individual system requirements. For information regarding such criteria see Annex.

3.24. A site survey of electromagnetic interference should be performed during normal operations and

should include the effects of operating and maintenance activities to verify and establish a basis for qualification criteria.

3.25. Electromagnetic fields can vary in time and in space. Therefore, ~~and~~ periodic measurements of electromagnetic fields should be performed to identify and quantify sources of electromagnetic interference, in order to ensure that the equipment will remain qualified.

Service conditions ~~anticipated~~specified for mild environments

3.26. Qualification for equipment located in mild environment should be achieved by providing the evidence that equipment meets or exceeds the specified requirements, including those of recognized industry associations. When seismic testing is used to qualify equipment located in mild environment, pre-ageing prior to the seismic tests is required only where significant ageing degradation exists.

3.27. The qualification parameters for equipment located in areas in mild environments, can be derived from the performance conditions under all plant states associated with the heating, ventilation, ~~and~~ air conditioning and potential consequences of accidents for those areas. When estimating these parameters, a margin should be included to account for occasional variations or malfunctions of heating, ventilation ~~and~~, air conditioning performance and potential consequences of accidents.

3.28. ~~A qualified life is not required for equipment located in mild environment and which has no significant ageing mechanism and is operated within the limits established by applicable specifications and standards (e.g. in Ref. [14]).~~

Service conditions resulting from postulated accidents

3.29. Harsh environment conditions 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, submergence, or by simultaneous changes in process fluid conditions, chemical composition or mechanical loads.

3.30. The bounding thermodynamic profiles and chemical effects associated with each of the postulated initiating events should be derived from the design basis and the safety analysis of the nuclear installation.

3.31. Service conditions resulting from other postulated events such as earthquake and airplane crash should be addressed by qualification.

3.32. Other postulated initiating events might need to be addressed by qualification if they are more severe than loss of coolant accidents and high energy line breaks conditions.

3.33. Equipment important to safety should be qualified for the mission time of the safety functions corresponding to their performance requirements for the applicable accident conditions.

Service conditions resulting from design extension conditions in severe accident

3.34. Service conditions resulting from design extension conditions in severe accidents should be identified. These include 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; chemical gas exposure; flooding levels), under which the equipment is required to perform its safety functions.

3.35. Characterization of containment thermodynamic profiles should be estimated through simulation using severe accident codes. This may aid in determining not only the environmental conditions associated with the severe accident, but also the necessary accident monitoring instrument ranges (including margins) and mission times. Annex I of Ref. [15] provides examples for calculating containment environmental parameters anticipated during severe accident.

3.36. Representative environmental characteristics for the equipment performance during severe accident conditions should be approximated using modelling for locations directly subjected to severe accident conditions inside the containment, as well as for locations outside the containment.

3.37. 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.

3.38. The mission times for each equipment used for severe accident mitigation or monitoring functions should be derived from the analyses of the various stages of the severe accident. For example, accident monitoring instrumentation is needed to remain functional beyond the achievement of a safe stable state.

IDENTIFICATION OF DESIGN INPUTS FOR QUALIFICATION

~~3.34.~~3.39. The design inputs that are necessary for qualification of equipment important to safety should be established and documented in a specification that includes the following:

— A description of the required safety function;

— Definition of postulated accidents and the corresponding mission time for which each equipment is required to function;

— A description of the specified environmental and operational conditions expected during operational states, accident conditions and ~~external~~ seismic events~~s~~;

— Definition of the safety class of the equipment and the corresponding supplemental classifications e.g. seismic classification or quality classification;

— Definition of acceptance criteria.

~~3.35.~~3.40. Environmental and operational conditions should be defined (e.g. in terms of the following):

— Thermodynamic parameters (characterized by temperature, pressure, humidity);

— Radiation parameters (characterized by radiation energy, type of radiation, ~~fluence,~~ total dose, and dose rate for operational states and accident conditions);

— Induced vibration parameters (characterized by spectra of excitations, response spectra of excitation, response spectra of displacement or acceleration, time history of displacement or acceleration power density spectrum);

— Submergence and flooding;

— Electromagnetic and radiofrequency field parameters for operational states and accident conditions (characterized by frequency range, kind of potential couplings, field strength);

— Fluid condition (characterized chemical composition, fluid level, potential jets, pH-values, temperature, water hammer, flow, differential pressure across valves, radiation, debris);

— Instrumentation and control system parameters (e.g. characterized by response time, accuracy and processing time);

— Electrical system parameters (e.g. characterized by short circuit~~s~~ current, delay of circuit breakers, ranges of system voltages, trip characteristics of protective devices~~motor control centres~~);

— Mechanical system parameters (e.g. characterized by load cycles, required torques and forces, mode of operation – continuous or intermittent, type and size of valve, pump or damper).

ASSESSMENT OF INITIAL QUALIFICATION STATUS

~~3.36.~~3.41. The selection of equipment should 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.

~~3.37.~~3.42. To assess the initial equipment qualifi ed~~cation~~ status, the following information is needed:

— Description of the equipment used to achieve required safety functions;

— Design and performance requirements derived from the safety design of the nuclear installation;

— Qualification criteria;

~~— Regulatory requirements and notifications associated with the item;~~

~~— Description of the items used to achieve required safety functions;~~

~~— Main materials used;~~

~~—~~ Installation, electrical and mechanical interfaces ~~-~~and maintenance requirements ~~for the item;~~

— ~~Clear description of specified service conditions at the specific installation location of the item~~.

~~3.38.~~3.43. The preliminary suitability assessment should consider functional characteristics, resistance to all specified service conditions, and other aspects, such as electrical safety performance, conformity with respective product standards, and requirements for testability and maintainability.

~~3.39.~~3.44. If the preliminary suitability assessment reveals deficiencies between the available documented qualification status and 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 QUALIFICATION

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

— Type tests;

— Analysis;

— Evaluation of operating experience;

— Combined methods

— Assessment of equipment capability for design extension conditions.

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

4.3. The method or combination of methods, ~~theories,~~ analyse~~i~~s and assumptions used for equipment qualification should be justified.

QUALIFICATION BY TYPE TESTING

General

4.4. Qualification by type testing refers to a test or a series of tests demonstrating that the equipment ~~important to safety~~ meets or exceeds the performance requirements with ~~suitable~~ margin under the specified service conditions.

4.5. If it is necessary to test separately for different environmental parameters (e.g. separate tests for radiation effects and for temperature effects), the sequence in which these tests are conducted should be justified as one that ~~conservatively~~ most accurately simulates the degradation due to ageing during service life followed by exposure to the accident conditions. ~~The synergistic effects of multiple parameters, such as application of appropriate radiation dose rates and temperatures, should be taken into account when preparing the test plan.~~

4.6. Qualification results obtained by type testing in accordance with nuclear standards and industrial

product standards should be used to demonstrate that the equipment meets the performance requirements and associated safety functions under ~~anticipated~~specified service conditions. The basis for concluding that the qualification under nuclear industrial product standards ~~is~~ may be ~~acceptable~~acceptable but should be justified and documented.

Test specification

4.7. Type testing should be performed in accordance with a well-defined test specification.

4.8. The test specification is a document derived from equipment qualification programme, covering 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.

4.9. The test specification should include the following:

(a) The ~~item~~ specimen unique identification and description (one-to-one relationship);

(b) Internal dimensions of critical parts that might impact functional performance of the specimen~~item (such as internal clearances and edge radii of valves)~~;

(c) Applicable regulatory or industrial codes and standards;

(d) Description of the test facility to be used (e.g. heating ovens, LOCA chambers, shake tables);

~~(d)~~(e) The quality assurance procedures to be applied;

~~(e)~~(f) Scope of activities covered by the qualification (e.g. seismic, environmental, electromagnetic);

~~(f) Physical description of the item;~~

~~(g) Special requirements based on the test method of qualification;~~

~~(h) The test parameters to be monitored with diagnostic equipment and required accuracy;~~

(g) A description of the required test parameters to be monitored~~,~~ pertinent test acceptance criteria and test data format and analysis;

(h) Requirements for the test assembly, measurement devices, mounting and interfaces;

(i) The need for auxiliary equipment to be included in the test specifications (e.g. test connections, test equipment leads or power supplies);

~~(i)~~(j) R~~the r~~equired ~~diagnostic~~ measurement and test equipment~~,~~ to be used and their required accuracy;

~~(j)~~(k) The need for any witness or hold points among the test steps (e.g. by independent expert organisation, if applicable);

(l) Actions to be taken in the event of deviations and/or failures;

~~(k) Identification of the type of test facility to be used;~~

~~(l)~~(m) Maintenance activities and/or replacements during the tests (e.g. replacement of gaskets after the ageing);

~~(m) Type of documentation to be prepared by the laboratory;~~

~~(n) Requirements for the test assembly, measurement devices, mounting and interfaces;~~

~~(o) The need for auxiliary equipment to be included in the test specifications (e.g. test connections, measurement cables or power supplies);~~

~~(p)~~(n) ~~Actions to be taken in the event of deviations and/or failures~~Type of tests summary documentation to be prepared by the testing facility or the third party organization.

4.10. The test specifications should outline the service conditions to be simulated, along with the applied margins for each test step. ~~For example, the functional qualification of valves needs to include the pressure, temperature, differential pressure, flow, and other fluid conditions of the valve design.~~

4.11. The test specifications should include the following design and performance requirements:

(a) Test setup;

~~(a)~~(b) Test conditions and margins to be applied;

~~(b)~~(c) The safety function(s) of the equipment to be demonstrated throughout the tests;

~~(c)~~(d) The test sequence(s) and/or the test steps, including the performance characteristics to be tested;

~~(d)~~(e) The acceptance criteria for each test step demonstrating the performance requirements have been achieved (e.g. opening and closing times, response time, accuracy);

~~(e)~~(f) Normal operating condition of the equipment (energized or de-energized);

~~(f)~~(g) Ranges in performance requirements ~~of~~ for each test step, demonstrating the safety function under different plant states (e.g. operational states and design basis accidents);

~~(g)~~(h) Qualification boundaries and interfaces between the items subject to qualification. The interfaces should be defined based on the mechanical and electrical design criteria, as appropriate;

~~(h)~~(i) Data recording and test equipment accuracy~~, diagnostic data for valve operating requirements and valve actuator output~~;

~~(i)~~(j) Applicable mission times;

(k) Specified qualified life;

~~(j)~~(l) Specified qualified conditions, when applicable;

~~(k) The need for taking measurements (e.g. continuous recording, accuracy of the items used to perform recording of data);~~

~~(l)~~(m) Quality assurance requirements.

Test specimens

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

4.13. An evaluation should be performed regarding how many test specimens need to be tested to ensure accurate representation of the performance of the equipment to be tested.

~~4.13.~~4.14. The test specimen description should provide sufficiently detailed information to ensure the unambiguous association of the specimen to the type or type series of the equipment in accordance with the design specification.

~~4.14.~~4.15. The same test specimens should be subject to ageing prior to postulated initiating events testing.

~~4.15.~~4.16. A description of the test setup should provide detailed information to conduct the test and/or test steps. This should include information related to assembling, mounting, and functional testing.

~~4.16.~~4.17. Scale models 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 and it should be proven that the effects of scaling should do not adversely impact the qualification results ~~and the effects of scaling should not adversely impact the qualification results~~.

~~4.17.~~4.18. Test specimens of assemblies may be split into 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.

4.19. 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 measure the possible interactions.

4.20. The electromagnetic interference tests may be performed on a different sample other than the sample that is required to be subjected to operational aging, seismic and design bases events.

~~4.18.~~4.21. The test specimen used during qualification testing should not be considered for use in safety applications following qualification, unless proven that said testing has not adversely affected

its ability to perform safely during its qualified life, nor has any margin been significantly reduced.

Demonstration of safety functions during type tests

~~4.19.~~4.22. Functional tests should be used to demonstrate the ability of equipment to perform the required safety functions over the full range of their specified service conditions.

~~4.20.~~4.23. While the complete qualification process should cover all of the required safety functions, a single functional test may be used to simulate only a portion of the required safety function.

~~4.21.~~4.24. The safety function may also be demonstrated by using indirect tests methods. For example, testing of environmental seal materials (e.g. a gasket compression set) using functional acceptance criteria might apply to this test category.

~~Anticipated~~Specified service conditions under operational states and accident conditions relevant for type testing

~~4.22.~~4.25. The test conditions to be considered for type testing should include parameters associated with ~~anticipated~~specified service conditions. If needed, other parameters (e.g. boric acid or steam spray, salt spray, dust) should also be considered.

~~4.23.~~4.26. ~~Anticipated~~Specified service conditions should be simulated using appropriately justified or accepted methods or models. These methods or models should be explained and justified.

Ageing effect simulation (pre-ageing)

~~4.24.~~4.27. Anticipated ~~Significant~~ significant ageing effects should be simulated during equipment qualification. Ageing of equipment expected during operational states may be simulated by accelerated ageing (e.g. radiation, ~~humidity,~~ thermal) to determine the qualified life of the equipment.

~~4.25.~~4.28. The sequence of equipment ageing should consider sequential, simultaneous, and synergistic effects to simulate the most ~~representative conservative~~ accurate representation state of ageing degradation.

Accelerated thermal ageing

~~4.26.~~4.29. Thermal ageing effects ~~should~~ may be simulated by exposing ~~equipment~~ test specimens ~~samples~~ 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).

~~4.27.~~4.30. The Arrhenius methodology (isothermal ageing at elevated temperature) is considered an acceptable method for performing accelerated thermal ageing. ~~Alternative methods can be used~~.

~~4.28.~~4.31. The higher test temperature used during accelerated thermal ageing should be below the threshold value causing significant different chemical or physical reaction then during normal operating environment~~significant rapid changes in physical and chemical properties of the item~~.

~~4.29.~~4.32. 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, and duration of the test~~, and the specific material that is most sensitive to ageing~~and material sensitivity should be documented and justified when using the Arrhenius method.

Radiation ageing

~~4.30.~~4.33. The total dose that might be received during operational states and accident condition dose should be simulated.

~~4.31.~~4.34. The applied dose rate should be low enough for a realistic accelerated aging~~The applied dose rate should be high enough to cause homogeneous changes and prevent the effects caused by oxidation and gaseous diffusion~~.

~~4.32.~~4.35. Unless otherwise stated (e.g. national requirements), the irradiation ageing simulation should be performed under ambient temperature conditions. Testing at elevated temperatures should be at a temperature representative of the service environment, where required~~Unless otherwise stated (e.g. national requirements), the irradiation ageing simulation should be performed under ambient temperature conditions~~.

Simulation of other stressors

~~4.33.~~4.36. Other stressors (e.g. wear, operational cycles, temperature cycles~~, mechanical~~) causing age-related degradation should be considered.

Non-seismic vibration and mechanical shocks

~~4.34.~~4.37. Non-seismic vibration and shocks, ~~originating from self vibration,~~ vibration from pipes, pumps, running motors or vibration~~s~~ due to ~~as~~ hydrodynamic loading, which produce significant degradation (e.g. fatigue, wear) during normal and abnormal use, should be considered, where applicable.

~~4.35.~~4.38. Such non-seismic vibration should be included in the age conditioning sequence prior to the seismic tests if deemed severe enough to cause mechanical ageing.

Simulation of seismic events

~~4.36.~~4.39. Seismic effects ~~should~~ may be simulated on aged samples, simulating operating conditions to which the ~~sample~~ specimen is subjected to, prior to accident testing~~, if required~~. The plant mechanical load conditions during seismic events and non-seismic events (e.g. hydrodynamic events) applied to any of equipment qualification methods should be developed with consideration of SL-1 earthquake and the plant mechanical loads, as specified in Ref. [7]. This should be also considered in the equipment qualification in both the harsh and mild environment conditions.

4.40. If necessary, test specimens should be energized and subjected to electrical and mechanical loading, with restraints and anchors in a manner that accurately represents the installed configuration.

~~4.37.~~4.41. ~~Details on seismic testing are provided in NS-G-1.6~~Ref. ~~[7].~~

Simulation of ~~postulated initiating event~~ specified service conditions

4.42. Test~~ed equipment~~ specimens should be subjected to environmental conditions resulting from 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. accident radiation, thermodynamic loads appropriate to mission time of the ~~item~~equipment).

~~4.38.~~4.43. The type testing sequence should place the sample in its worst state of deterioration that can occur in service during the qualified life, prior to application of the specified service conditions.

~~4.39.~~4.44. 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, with justification to result in most accurate simulation of applicable aging effects~~The total radiation dose resulting from operational states and postulated initiating events should be applied in either a single exposure or in a series of exposures~~.

~~4.40.~~4.45. 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 the chemical composition for the required mission time.

~~4.41.~~4.46. Tested ~~items~~ specimens should be powered and subjected to loads in a manner that accurately represents the installed configuration.

~~4.42.~~4.47. The successful performance of the safety functions during the simulation of the postulated initiating events for the required mission time should be verified and documented.

Margins for test profiles

~~4.43.~~4.48. Margins should be applied during the qualification process to account for test instrument inaccuracies, production variations and modelling uncertainties.

~~4.44.~~4.49. ~~Qualification by type testing~~Test profiles should include margins that apply to calculated design basis accident profiles. Suitable margins for conducting the qualification type tests are provided in Ref. [14].

~~4.45. Margins are not required to be applied for age conditioning.~~

~~4.46.~~4.50. Qualification type tests should include provisions to verify that an adequate qualification margin exists.

~~4.47.~~4.51. Increasing the number of test cycles (e.g. for wear, operational cycles) may be an acceptable means of adding margins. ~~or the t~~Test durations are acceptable methods of adding margins in testing.

QUALIFICATION BY ANALYSIS

~~4.48.~~4.52. Qualification by analysis that forms part of the evidence of qualification should include a justification of the methods and assumptions used. The validity of the mathematical models used for qualification might be justified on the basis of experimental data, test data or operating experience. A test certificate not detailing the applied test methodology or parameters of the test is not sufficient evidence.

~~4.49.~~4.53. Qualification by analysis may be used to extrapolate existing qualification results to address changes in equipment, material composition, performance requirements, installations, and reassessing qualified life.

~~4.50.~~4.54. Qualification by analysis ~~can~~ may be used to extend the results of 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, different sizes of flow meters). However, qualification by analysis alone ~~might~~ may not be appropriate for certain equipment without supplemental qualification testing to support the qualification.

~~4.51.~~4.55. Qualification by analysis alone is only recommended for analysis of the structural integrity of the equipment and its mounting (not functionality).

~~4.52.~~4.56. Qualification by ~~similarity~~ analysis may be used to demonstrate that an equipment is qualified based on ~~a similar~~ equipment which has been qualified to equivalent or more stringent conditions.

~~EXTRAPOLATION OF QUALIFICATION~~

~~4.53. Extrapolation of the qualification of an item to another size of item or to a different application of the same item should be justified.~~

~~4.54. Extrapolation of a qualified design of a pump or valve should be justified by testing and analysis.~~

QUALIFICATION BY OPERATING EXPERIENCE

~~4.55.~~4.57. ~~Qualification by o~~Operating experience ~~should~~ may be used as supplemental information to demonstrate the reliability of the equipment to perform safety functions. However, ~~Q~~qualification by operating experience alone ~~will~~ is not ~~be appropriate~~sufficient for ~~certain items~~safety systems and should, therefore, be combined with additional qualification testing of the equipment. ~~without additional qualification testing to support the qualification.~~

~~4.56. Qualification by operating experience alone should be limited to items that perform safety functions in mild environments, and when the similarity of the item to previously qualified items can~~

~~be justified.~~

~~4.57. For an item that needs to perform safety functions in a harsh environment, evidence of qualification on the basis of operating experience alone is insufficient because operating experience generally does not include evidence of the capability to withstand the environments associated with design basis accidents. Therefore, operating experience information should at least be combined with limited type testing and with evaluation of the production processes and quality measures applied during manufacturing.~~

4.58. Qualification by operating experience should be based on representative data and technically justifiable conditions. The validity of the operating experience from the manufacturer should be confirmed by a third party, i.e. another operator with the experience, provided for example adequate documentation of the service conditions is available.

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

~~DEMONSTRATION OF PRODUCTION ITEMS~~

~~4.60. The functional performance of production items from a qualified design should be justified.~~

~~4.61. Demonstration of the performance of production pumps and valves from a qualified design should be justified by testing and analysis.~~

COMBINED METHODS

~~4.62.~~4.60. Equipment ~~can~~ may be qualified by a combination of type testing, operating experience, and analysis. For example, where type testing of a complete assembly is not possible, component testing supplemented by analysis could be used. In some ~~cases~~cases, the overall qualification of the equipment, is dependent on the qualification of the most limiting individual component within that equipment.

~~4.63.~~4.61. If ~~individual~~ all components within the equipment are not subject to degradation from the effects of specified service conditions, it ~~is~~ may be possible to demonstrate that the equipment is environmentally qualified through a material analysis.

~~4.64.~~ The specific combination of methods selected will depend upon the system or component under consideration~~. For example, in the qualification of already installed items, operating experience and analysis can compensate for a lack of completely documented verification and validation during engineering and manufacturing~~.

~~4.65.~~4.62. The method or combination of methods used for qualification of the equipment should be justified and documented.

ASSESSMENT OF EQUIPMENT CAPABILITY FOR DESIGN EXTENSION CONDITIONS

4.63. 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".

4.64. Equipment should have the capability, as appropriate, to perform its intended safety functions for the time necessary under severe accident conditions.

4.65. The mission time for each equipment used for mitigation or monitoring functions in a severe accident should be derived from the analyses of the various stages of the severe accident progression. For example, some equipment may be required for the design basis safety function and remain functional throughout design extension conditions.

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

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

4.68. A technical basis that may be considered for assessing the equipment performance capability under severe accident conditions is provided in Ref. [15].

5. PRESERVING 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, procured, stored, installed, commissioned, inspected, operated, maintained and replaced or modified in a manner,

which ensures that the ~~qualified status~~ equipment qualification is maintained for the lifetime of the ~~item and components~~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 qualification implications are appropriately considered whenever changes occur to the plant, equipment, or operating, maintenance, or replacement activities.

5.6. Preservation of qualification is an ongoing process that begins from procurement, and continues through manufacturing, storage, ~~during~~ installation, ~~and~~ commissioning, operation and maintenance of the equipment and continues throughout the ~~service~~ qualified life of the equipment within the nuclear installation.

~~5.6.~~5.7. Preservation includes the need for periodic replacement of component parts (e.g. seals, gaskets, lubricants, filters) which exhibit degradation more readily. Such parts may need to be periodically replaced during required equipment qualification maintenance activities.

~~5.7.~~5.8. Factors that impact the equipment qualification status include changes in design basis, accident analysis, service conditions, operating experience, plant modifications, maintenance, training, procurement activities, storage conditions and material control. All elements of the equipment qualification programme work together and should be evaluated when assessing the qualification status for each equipment requiring qualification.

~~5.8.~~5.9. The qualified life of an 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 equipment qualified life is to be extended, a thorough evaluation supported by adequate basis for the extension should be provided.

~~5.9. If an item important to safety relies on programmable logic or software to perform its required safety actions, the control of access to such software should be protected, and the software should be periodically verified as correct to retain the item's qualified status.~~

5.10. The qualification status of each equipment should be ~~properly documented and~~ maintained and properly documented throughout the lifetime of the installation. The documentation relating to qualification, which is typically part of the equipment qualification programme, includes:

(a) A ~~master~~ list of equipment~~items~~ subject to qualification;

(b) Procurement technical specification;

(c) Manufacturer data in support of qualification;

(d) Installation specification;

(e) Results of environmental monitoring, when relevant;

(f) Results of condition monitoring including visual inspection, when relevant;

~~(e)~~

~~(f)~~(g) The summary report of the qualification;

~~(g)~~(h) Test reports relating to qualification;

(i) Result of maintenance activities, including where sub-components or sealing materials (e.g. seals, gaskets, lubricants) have been replaced and the certificates tracing these replacements and the qualification thereof;

~~(h)~~(j) Non-conformity reports from vendors/manufacturers and operating organizations;

(k) Non-availability of original equipment manufacturer's replacement components (obsolescence), and the acceptability of appropriately qualified substitute replacement components;

(l) Relevant operating experience;

(m) Reports of time limited ageing analyses relating to qualification (e.g. for evaluation for long term operation) or reports of another suitable equivalent analysis;

~~.~~

~~(i)~~(n) Justification that the equipment is suitable for use in each of the functional applications and associated ~~installed environments~~environmental zones.

5.11. Programmatic interfaces should be identified, and procedural control of prescribed activities should be established to provide assurance that activities essential to preserving the qualified ~~status~~ condition of the equipment are correctly performed and properly integrated into plant processes and work practices.

5.12. Operating experience feedback from industry sources (internal and external) should be used for identifying unanticipated ageing mechanisms, or changes in the performance of equipment.

~~5.13. The process of preservation of the qualified status of each item important to safety should be accomplished in an all inclusive manner. All elements of the equipment qualification programme work together and should be evaluated when assessing the qualification status for each item requiring qualification.~~

AGEING EFFECTS AND QUALIFIED LIFE

~~5.14.~~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."

~~5.15.~~5.14. Assessing the actual effects of ageing on the operation of equipment is an essential part of the qualification. This assessment should include a determination of the significance of each ageing effects.

~~5.16.~~5.15. When significant new ageing mechanisms or increases in the effects of previously known ageing mechanisms are identified, the relevant parts of the qualification programme should be re-evaluated to determine whether changes in the qualified life or maintenance of the equipment is needed.

ELEMENTS OF QUALIFICATION PRESERVATION

~~5.17.~~5.16. Factors that can adversely impact the established qualification include:

(a) Deviations from appropriate installation and maintenance practices;

(b) Changes to the design basis or safety analysis;

(c) Changes in regulations and plant licensing activities;

(d) Modifications ~~of~~ to the nuclear installation;

(e) Deviations in service conditions from those accounted for in the 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) New information developed from recent qualification tests or research tests that challenge or modify original assumptions or test or analysis results.

~~5.18.~~5.17. Periodic preventive maintenance, predictive maintenance, equipment calibration, surveillance, testing, condition monitoring, corrective action, failure trending and operating experience reviews are acceptable methods to detect and mitigate unanticipated age-related degradation that was not accounted for when establishing the ~~qualified life of an item~~qualification for equipment important to safety.

~~5.19.~~5.18. Results of processes that identify age-related failures or significant material degradation of qualified equipment should be used to assess the need to revise the qualification related maintenance, surveillance and replacement requirements. These revisions should also be reflected in the applicable qualification support documentation.

~~MEASUREMENT OF~~ ENVIRONMENTAL CONDITIONS MONITORING

~~5.20.~~5.19. A preliminary analysis should be carried out to determine where measurements of environmental conditions should be implemented based on environmental zones, rooms and equipment. This analysis should take in account different factors, such as identification of the stressors acting upon the equipment (e.g. service temperature, radiation, submergence, local vibration, electromagnetic interference, radio frequency interference, toxic chemical exposure) to ~~confirm~~ identify whether environmental conditions ~~are~~ may be more severe than assumed.

~~5.21.~~5.20. Trends in the service conditions should be assessed to determine the impact on the qualified ~~status~~ condition of the equipment~~items~~ and identify corrective actions if required.

~~5.22.~~5.21. Environmental monitoring should be implemented to determine if actual room conditions are similar or identical to the initially estimated room conditions~~The measurement of actual ambient environmental conditions helps to identify worst-case conditions~~.

~~5.23.~~5.22. Environmental monitoring ~~Measurement of the ambient environmental conditions~~ in the nuclear installation under operational states should ensure that:

— The assumptions in the qualification are consistent with the ambient conditions in the installation;

— The design limits of the equipment are not exceeded;

— The initial qualified status remains valid.

~~5.24.~~5.23. Additionally, ambient environmental monitoring ~~should~~ may be used to support the evaluation of remaining qualified life by determining if an equipment is suitable for continued service ~~because it has aged more slowly than expected~~.

~~Environmental monitoring can also lead to a reduction of the equipment qualified life if the measured environment conditions are more adverse than what was originally assumed in the qualification.~~

EQUIPMENT CONDITION MONITORING

~~5.25.~~5.24. Condition monitoring provides information ~~relative~~ regarding~~to~~ the rate of ageing degradation of the qualified equipment. Condition 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 under ~~anticipated~~specified service conditions. Condition monitoring supports execution of activities required for maintaining the equipment in its qualified status.

~~5.26.~~5.25. Appropriate ~~P~~periodic condition monitoring should be implemented to determine if actual ageing is occurring at a higher rate, which would indicate that possible corrective actions are necessary to ensure qualification is preserved. ~~Periodic condition monitoring should be performed throughout the service life of the items.~~

5.26. Condition monitoring should be used to ~~preserve qualified status~~ detect whether premature degradation is accelerating beyond that which is initially anticipated.

5.27. Condition monitoring should reveal whether~~if~~ any of the following occur:

(a) Service conditions are ~~suspected to be~~ more severe than previously assumed;

(b) Ageing rate deviates from initial assumptions;

~~(b)~~(c) Ageing evaluations contain uncertainties in the initial assumptions;

~~(c)~~(d) Known ageing mechanisms exist, which cannot be fully evaluated or simulated when qualification was established.

5.28. During periodic surveillance, if ~~When~~ unexpected degradation is observed, ~~during periodic surveillance or visual inspection,~~ the ~~impact~~ effect of this ~~degradation~~degradation on the capability of the equipment to perform safety function should be ~~identified and~~ evaluated~~, to ensure reliable operation of items important to safety~~.

5.29. 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.

5.30. Appropriate condition indicators for a given equipment type should be selected to detect changes caused by significant ageing mechanisms~~. For example, gaskets and sealing materials should be monitored for their ability to retain their compression properties~~.

5.31. Condition indicators should be measurable, linked to the functional degradation of the qualified equipment, and should be selected to indicate a consistent observable trend.

5.32. As the qualified equipment approaches the end of its established qualified life, periodic condition monitoring should be implemented to determine if actual ageing is occurring at a slower rate, which would indicate that it is possible to extend the qualified life of the equipment.

5.33. The combination of condition monitoring and measurements of environment conditions should be used to support the re-assessment of qualified life of the equipment. This should ensure that the nuclear installation is being operated within its design basis.

PERIODIC SURVEILLANCE

5.34. Procedures for periodic ~~Surveillance~~ surveillance of qualified equipment ~~activities~~ should ~~be~~

~~performed to~~ ensure that:

(a) Operation and maintenance activities do not compromise the equipment qualified status ~~of the items~~ by changing the qualified in-plant configuration, mounting orientation (horizontal or vertical supports), or electrical, pneumatic or hydraulic interfaces;

(b) Systems and components continue to meet their performance requirements;

(c) Configuration abnormalities are detected, and corrective actions are completed in a timely manner to preserve the equipment qualified status;

~~(c)~~(d) Criteria are included to specify how to identify premature age-related degradation.

MAINTENANCE

5.35. Qualification related maintenance should be performed to preserve the qualified status in accordance with qualification documentation and surveillance procedures. ~~.~~

5.36. ~~Qualification related maintenance should be performed in accordance with the qualification documentation~~accordance with the procedures identified in para. ~~.~~

5.37. To preserve the equipment qualified status, the maintenance programme should address the following:

(a) ~~The control of m~~Maintenance documentation ~~(e.g. maintenance manuals, procedures) to~~ includes qualification requirements and ~~to~~ describes ~~a method~~authorized activities by which qualification is maintained; ~~.~~

(b) The establishment of an appropriate preventive maintenance schedule. Maintenance intervals should be set to ensure the qualified life of the equipment is maintained; ~~.~~

(c) The need for any trending of condition indicators associated with qualified equipment and the detection of any precursors indicating that the equipment is degrading;

(d) Replacement of equipment or components within the equipment assemblies with expired qualified life; ~~.~~

(e) A means to identify to plant personnel that the equipment is qualified; ~~.~~

~~(e)~~(f) ~~Any m~~Maintenance ~~or service~~ necessary to preserve equipment qualified status~~maintain qualificaitonqualification~~.

5.38. Oversight should be performed on all maintenance work on qualified equipment to ensure that qualified replacement parts are used, that the appropriate maintenance procedures are followed and that other qualification preservation ~~criteria~~ requirements are met.

PROTECTIVE BARRIERS

5.39. When protective barriers, enclosures, shields or sealing devices are provided for protecting the equipment from possible environmental effects, the integrity of the barrier should be maintained as part of 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.

~~5.39.~~5.40. ~~When qualification is dependent on the use of barriers, enclosures or shielding which reduce or eliminate environmental stressors, controls should be implemented to ensure that these barriers remain effective and in their proper configuration for the lifetime of the installation~~.

~~5.40.~~5.41. Any protective barriers that can be removed should be clearly identified as being an element of the equipment qualification programme.

~~SUPPLY CHAIN~~VENDOR/MANUFACTURER~~,~~ PROCUREMENT AND ~~WAREHOUSING~~STORRAGE

~~5.41.~~5.42. Qualified equipment and components should be procured in accordance with procurement criteria specified in the applicable qualification report.

~~5.42.~~5.43. Procurement specifications should contain the requirements and specified service conditions for the equipment to be purchased. Replacement ~~purchased~~ equipment should be identical ~~or equivalent~~ to the original qualified ~~item.~~component. If the replacement is not identical, it should be evaluated to determine if the substituted ~~item~~ component is ~~acceptable~~acceptable, and conclusions of the evaluation should be documented.

~~5.43.~~5.44. Qualification documentation ~~(see paras 2.34–2.41)~~ should be updated as necessary to reflect any substitutions that alter the basis for qualification, configuration, maintenance or procurement requirements.

5.45. The acceptance of vendors and/or manufacturers supplying qualified equipment should be in accordance with the national requirements, including ~~for~~ quality assurance requirements. Procurement documentation should explicitly reflect the identification and traceability requirements of the applicable standard.

5.46. The equipment may be procured through a vendor/manufacturer with a quality assurance programme meeting the Member States quality assurance programme requirements, or through a vendor/manufacturer who supplies the equipment using a commercial grade dedication process. In either case, the equipment must be qualified through the approved qualification programme requirements.

~~5.44. Procurement documentation should explicitly reflect the identification and traceability requirements of the applicable standard.~~

~~5.45.~~5.47. Following procurement, ~~Qualified equipment and components~~ qualified equipment should

be ~~procured, be~~ evaluated in a receipt inspection, and stored in a controlled manner to ensure that the qualified status is maintained while the equipment is in storage.

~~5.46.~~5.48. ~~Procurement documentation should contain criteria for addressing the need to demonstrate that the substituted item is acceptable.~~Procurement documentation should reflect the accountability of the vendor and/or manufacturer to demonstrate that the equipment is identical to the original one. The procurement documentation should state that operating organization should be notified when changes to equipment design and manufacturing occur.

~~5.47.~~5.49. Qualified equipment ~~items and components~~ (including subassemblies, spare parts and materials) stocked in the warehouse for future use in qualified applications, should be ~~identified~~ marked as qualified.

~~5.48.~~5.50. Qualified equipment subject to ~~storage~~ shelf life considerations should be controlled to ensure that upon installation, the qualified status of the equipment~~items~~ is maintained. A reliable means should be established to ensure that ~~storage~~ shelf life expiration dates are not exceeded.

REASSESSMENT OF QUALIFICATION

~~5.49.~~5.51. The equipment qualified life should be reassessed throughout the lifetime of the installation to account for changes in the actual service conditions, such as temperature and radiation levels, and development in the knowledge and understanding of degradation mechanisms.

~~5.50.~~5.52. If the equipment qualified life is to be extended, the technical basis should be provided. The technical basis of any conclusions regarding qualified status should be revaluated to support the re-assessment of the initial equipment qualified life to take into account any changes in performance requirements or installation conditions.

~~5.51.~~5.53. The technical basis 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. This includes, for example, new information regarding the appropriate activation energy levels associated with materials of replacement equipment.

~~5.52.~~5.54. Methods such as revaluation of the conservativism used in original assumptions, type testing of naturally aged equipment with additional ageing for qualified life extension, equipment replacement and refurbishment, should be used for reassessing qualified life.

~~5.53.~~5.55. ~~A reduction~~Changes in the stressor intensity (e.g. ~~lower~~ changes in temperature~~,~~ and radiation levels) ~~can~~ may be ~~used~~ evaluated to reassess~~extend~~ the qualified life.~~-~~ Evaluation of data from environmental and condition monitoring programme can be used to reassess equipment qualified life.

~~5.54.~~5.56. ~~The m~~Methods chosen for reassessment of the equipment qualified life should be justified

and documented.

6. EVALUATION OF THE EFFECTIVENESS OF QUALIFICATION PROGRAMME

PURPOSE AND SCOPE

6.1. An assessment of the effectiveness of the qualification programme should be ~~made~~performed. The scope of this assessment typically includes the following:

— Compliance with the governing framework documents;

— Programmatic and technical adequacy of qualification documentation;

— Effectiveness of programmatic interfaces;

— Effectiveness of training related to qualification;

— Reviews of the effectiveness of corrective actions.

— Reviews of maintenance activities related to equipment qualification~~Reviews of maintenance activities related to EQ.~~;

— Audits of vendor/manufacturer quality assurance programme and processes relevant to equipment qualification.~~Audits of vendor CM processes relevant to EQ~~

6.2. The primary responsibility for conducting periodic audits and ongoing surveillance of the equipment qualification programme rests with the operating organization. ~~However~~In some Member States, the regulatory body ~~should, as appropriate,~~ conducts periodic audits of selected equipment qualification programme elements as part of its safety verification activities.

PERIODIC REVIEWS AND AUDITS

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

— Operating organizations;

— ~~Suppliers~~ Vendors/manufacturers of qualified equipment;

— Third party commercial and/or nuclear qualification services;

— Qualification testing facilities (e.g. accredited laboratories).

6.4. The following types of audits of a qualification programme should be performed:

— Audits covering all aspects and activities of a qualification programme, which are usually performed when the programme is first established and as a part of a periodic safety review of the nuclear installation or a licence renewal review;

— Audits covering selected aspects and activities of a qualification programme, which are conducted more frequently and often in response to incidents suggesting possible weaknesses in specific areas;

— Periodic regulatory inspections to ensure that qualification activities are being performed in accordance with Member States regulatory framework for initial licensing and long term operation.

~~6.4.~~6.5. Evaluation of the effectiveness of equipment qualification programme should be an active and ongoing process that provides insights into the following:

(a) Whether ~~the~~ a ~~qualification master~~ 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 required licensing and design basis.

(c) Whether the original safety, operability and performance assumptions were reasonable and remain valid.

(d) Whether the qualification documentation is available in an auditable and traceable form providing evidence of qualification for each equipment in the equipment qualification master list, including a system for locating required supporting documentation.

(e) Whether the supporting documentation is traceable and includes test and analysis documentation, evaluation of operating experience and information from feedback programmes, procurement documents, production quality assurance, storage, transportation and installation requirements, and surveillance and maintenance requirements.

(f) Whether there is evidence of the following:

(i) The technical basis and assumptions used in modelling of qualified life (e.g. activation ~~z~~energy energy levels, material compositions, assumed actual environmental conditions, and other parameters supporting the qualified life modelling) 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, if required, 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 required to preserve ~~qualification~~ qualified status during the installed lifetime of the equipment are documented in appropriate plant procedures or instructions (e.g. storage and handling of qualified spare parts, installation, surveillance, maintenance and component replacement requirements) and are implemented.

(h) Whether the relevant personnel are appropriately trained and qualified to establish and preserve the qualification of equipment.

(i) Whether the maintenance, testing, surveillance and ~~surveillance programme (including testing,~~ inspection of equipment condition, and measurement of environmental conditions~~)~~ has been established to ensure that the ageing degradation and functional capability of equipment remain acceptable, and a feedback process is in place to address unanticipated degradation identified ~~during surveillance or maintenance~~.

(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 qualification conclusions.

(k) Whether an operating experience programme is in place to collect and review information relevant to the status of qualified equipment. Such information includes nuclear installation operating experience, operating experience from other nuclear installations, significant event reports, ~~supplier~~ vendor or manufacturer feedback, research and development results, and regulatory notices and advisories.

(l) Whether the above elements reflect current design information, including any recent plant and equipment modifications.

(m) Whether there is adequate evidence that programmatic controls (e.g. corrective actions, problem identification, configuration management) are effective.

7. PROGRAMATIC INTERFACES AND INTEGRATION OF QUALIFICATION IN SAFETY PROGRAMMES AND PROCESSES

PROGRAMATIC INTERFACES

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

— Configuration management;

— Operating and industry experience;

— Ageing management and long term operation;

— Surveillance, testing and ~~M~~maintenance;

— Radiation protection;

— Chemistry programme (e.g. chemical effects or damages or equipment deterioration by chemicals);

— Corrective action programme;

— Quality assurance programme audit ~~and self-assessment~~;

— Transportation and packaging;

— Procurement and storage of qualified equipment;

— Training for qualification group personnel.

7.2. Examples of processes that interface with the qualification programme include the following:

— Licensing;

— Operations;

— Outage, planning, and scheduling;

— Maintenance associated with ~~for~~ calibration activitiess and ~~,~~ preventative maintenance;

— Procurement and ~~warehousing~~storage;

— Training;

— Engineering (replacement parts engineering or design engineering);

— Work management for task and work execution planning;

— Ageing management;

— Quality assurance (including vendor/manufacturer surveillance).

7.3. Equipment qualification is an essential programme for a nuclear installation, together with maintenance, in-service inspection and testing, surveillance and ageing management. The coordination of qualification activities between the relevant interfacing units such as maintenance, operations, parts engineering, procurement or design engineering should be ensured.

7.4. Paragraphs 4.23 to 4.31 of SSG-48 [13] provide guidance on how qualification is integrated and reviewed within the framework of the ageing management programme.

SAFETY ANALYSIS REPORT

7.5. Qualification considerations presented in the safety analysis report should include the following:

(a) Information regarding the scope of the equipment~~items~~ and their applications that are subject to qualification;

(b) Information on the location of the qualified equipment;

~~(a)~~(c) Information on mission time of qualified equipment in accidents conditions;

(d) The ~~assumptions~~ bases regarding the ~~choice~~ estimation of process and ambient parameters;

~~(b)~~(e) The bases for defining ~~of~~ environmental zones and ~~anticipated~~specified service conditions;

~~(c)~~(f) The variations of environmental conditions expected in operational states and postulated accident conditions (e.g. vibration, temperature, pressure, electromagnetic interference, radiation levels, humidity);

~~(d)~~ Any unusual environmental conditions that can reasonably be anticipated or arise from specific operational states, such as in periodic testing of the containment leak rate~~;~~

~~(e)~~(g) ~~Principles of qualification of items important to safety~~.

7.6. Changes that affecting the above items ~~to the qualified status of items important to safety~~ should be ~~documented~~ reflected in updates to the safety analysis report.

7.7. Recommendations on the format and content of the safety analysis report are provided in IAEA Safety Standards Series No. GS-G-4.1, Format and Content of the Safety Analysis Report for Nuclear Power Plants [16].

PLANT ~~MODIFICATIONS~~MODIFICATIONS

7.8. The plant modification process should include configuration management provisions to ensure that qualification documentation is updated to reflect all design changes.

7.9. Any plant modification involving qualified equipment should be incorporated into plant controls before the modification is implemented. This includes the following:

(a) All the documentation affected by the plant modification, such as the safety analysis report, operational limits and conditions, drawings, operating and emergency procedures, periodic maintenance and testing procedures and equipment indexes, should have been updated and be available. Documents should not be released for use until the modification has been completed.

(b) The as-built configuration of modified systems ~~should have been verified and the design basis document updated~~is reflected in the plant design basis documentation.

~~(c) Personnel should have been trained on the modifications.~~

~~(d) Records for design, manufacturing, commissioning, quality assurance, testing and installation should have been reviewed for completeness and accuracy.~~

7.10. Modifications that involve only items not important to safety, which might affect the qualified status of items important to safety due to interactions and should therefore also be evaluated for possible impact on affected qualified items. Result of evaluation should be documented.

7.11. Recommendations on controlling activities relating to modifications to nuclear power plants are provided in IAEA Safety Standards Series No. NS-G-2.3, Modifications to Nuclear Power Plants [17].

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Nuclear Power Plants: Design, IAEA Safety Standards Series No. SSR-2/1 (Rev. 1), IAEA, Vienna (2016).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Nuclear Power Plants: Commissioning and Operation, IAEA Safety Standards Series No. SSR-2/2 (Rev. 1), IAEA, Vienna (2016).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Research Reactors, IAEA Safety Standards Series No. SSR-3, IAEA, Vienna (2016).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Nuclear Fuel Cycle Facilities, IAEA Safety Standards Series No. SSR-4, IAEA, Vienna (2017).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment for Facilities and Activities, IAEA Safety Standards Series No. GSR Part 4 (Rev. 1), IAEA, Vienna (2016).

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Classification of Structures, Systems and Components in Nuclear Power Plants, IAEA Safety Standards Series No. SSG-30, IAEA, Vienna (2014).

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Seismic Design and Qualification for Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-1.6, IAEA, Vienna (2003). (A revision of this Safety Guide is in preparation, DS490)

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Leadership and Management for Safety, IAEA Safety Standards Series No. GSR Part 2, IAEA, Vienna (2016).

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, Application of the Management System for Facilities and Activities, IAEA Safety Standards Series No. GS-G-3.1, IAEA, Vienna (2006).

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, The Management System for Nuclear Installations, IAEA Safety Standards Series No. GS-G-3.5, IAEA, Vienna (2009).

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Design of Electrical Power Systems for Nuclear Power Plants, IAEA Safety Standards Series No. SSG-34, IAEA, Vienna (2016).

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, Design of Instrumentation and Control Systems for Nuclear Power Plants, IAEA Safety Standards Series No. SSG-39, IAEA, Vienna (2016).

[13] INTERNATIONAL ATOMIC ENERGY AGENCY: Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants, IAEA Safety Standards Series No. SSG-48, IAEA, Vienna (2018).

[14] INTERNATIONAL ELECTROTECHNICAL COMMISSION, Nuclear Facilities – Electrical Equipment Important to Safety – Qualification, IEC/IEEE 60780-323 std. (Edition 1.0), Geneva, (2016).

[15] INTERNATIONAL ATOMIC ENERGY AGENCY, Assessment of Equipment Capability to Perform Reliably under Severe Accident Conditions, IAEA-TECDOC-1818, IAEA, Vienna (2017).

[16] INTERNATIONAL ATOMIC ENERGY AGENCY, Format and Content of the Safety Analysis Report for Nuclear Power Plants, IAEA Safety Standards Series No. GS-G-4.1, IAEA, Vienna (2004). (A revision of this Safety Guide is in preparation, DS449)

[17] INTERNATIONAL ATOMIC ENERGY AGENCY, Modifications to Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-2.3, IAEA, Vienna (2001). (A revision of this Safety Guide is in preparation, DS497)

ANNEX

BIBLIOGRAPHY OF INTERNATIONAL STANDARDS ~~REALTED~~ RELATED 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. This Safety Guide provides high level recommendations that represent good practice among IAEA Member States. Beyond the recommendations provided by the IAEA, a large body of national and international standards exists that give more detailed recommendations about design methodologies and system characteristics that support compliance with SSR-2/1 (Rev. 1) [A–1]. It is expected that designers, operating organizations and regulatory bodies will take advantage of the information in such design standards.

A–3. Two standards development 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 respond to the common principles underlying the requirements of SSR-2/1 (Rev. 1) [A–1] and the recommendations of this Safety Guide.

A–4. This Annex is intended to explain the relationship between this Safety Guide and the IEC and IEEE standards. Table A–1 lists the IEC and IEEE standards that relate directly the recommendations of this Safety Guide. Table A–1 is not a complete list of either set of design standards, but it identifies the entry points into the sets of IEC and IEEE standards.

A–5. A concerted effort was made to avoid conflicts between the recommendations of 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–6. 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 take the guidance on instrumentation and control systems provided by the IAEA as the source of general recommendations. The IEEE standards focus mostly on items important to safety and, therefore, apply to a smaller set of functions, systems and equipment than this Safety Guide. Nevertheless, the IEEE

standards can be applied to safety related items (items important to safety that are not safety systems) using a graded approach.

TABLE A–1 IEC AND IEEE STANDARDS WITH A DIRECT RELATIONSHIP TO THIS SAFETY GUIDE

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 61000-6-4:2018 [A–8]	Electromagnetic compatibility (EMC) - Part 4-1: Testing and measurement techniques - Overview of immunity tests (IEC 61000-4 series)
IEC/IEEE 60780-323:2016 [A–9]	Nuclear Facilities – Electrical Equipment Important to Safety – Qualification, IEC/IEEE 60780-323 std. (Edition 1.0)
IEEE 308-2012 [A–10]	Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations
IEEE 334-2006 [A–11]	Standard for Qualifying Continuous Duty Class 1E Motors for Nuclear Power Generating Stations
IEEE 344-2013 [A–12]	Standard for Seismic Qualification of Equipment for Nuclear Power Generating Stations
IEEE 382-2006 [A–13]	Standard for Qualification of Safety-Related Actuators for Nuclear Power Generating Stations
IEEE 383-2015 [A–14]	Standard for Qualifying Electric Cables and Splices for Nuclear Facilities
IEEE 420-2013 [A–15]	Standard for the Design and Qualification of Class 1E Control Boards, Panels, and Racks Used in Nuclear Power Generating Stations

IEEE 535-2013 [A–16]	Standard for Qualification of Class 1E Vented Lead Acid Storage Batteries for Nuclear Power Generating Stations
IEEE 572-2006 [A–17]	Standard for Qualification of Class 1E Connection Assemblies for Nuclear Power Generating Stations
IEEE 603-2018 [A–18]	Standard Criteria for Safety Systems for Nuclear Power Generating Stations
IEEE 627-2010 [A–19]	Standard for Qualification of Equipment Used in Nuclear Facilities
IEEE 649-2006 [A–20]	Standard for Qualifying Class 1E Motor Control Centers for Nuclear Power Generating Stations
IEEE 1205-2014	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–21]	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–22]	Qualification of Active Mechanical Equipment Used in Nuclear Facilities

REFERENCES TO THE ANNEX

[A–1] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Nuclear Power Plants: Design, IAEA Safety Standards Series No. SSR-2/1 (Rev. 1), IAEA, Vienna (2016).

[A–2] INTERNATIONAL ELECTROTECHNICAL COMMISSION, Nuclear power plants - Instrumentation Important to Safety - Radiation Detectors - Characteristics and Test Methods, IEC 60515:2007, IEC, Geneva (2007).

[A–3] INTERNATIONAL ELECTROTECHNICAL COMMISSION, Nuclear power plants - Instrumentation Important to Safety, Electrical Penetration Assemblies in Containment Structures, - IEC 60772:2018, IEC, Geneva (2018).

[A–4] INTERNATIONAL ELECTROTECHNICAL COMMISSION, Recommended practices for seismic qualification of electrical equipment of the safety system for nuclear generating stations, IEC 60980:1989, IEC, Geneva (1989).

[A–5] INTERNATIONAL ELECTROTECHNICAL COMMISSION, Nuclear power plants – Instrumentation and control for systems important to safety – General requirements for systems, IEC 61513:2011, IEC, Geneva (2011).

[A–6] INTERNATIONAL ELECTROTECHNICAL COMMISSION, Nuclear power plants - Instrumentation and control important to safety - Requirements for electromagnetic compatibility testing, IEC 62003:2009, IEC, Geneva (2009).

[A–7] INTERNATIONAL ELECTROTECHNICAL COMMISSION, Nuclear power plants - Instrumentation and control systems important to safety - Management of ageing, IEC 62342:2007, IEC, Geneva (2007).

[A–8] INTERNATIONAL ELECTROTECHNICAL COMMISSION, Electromagnetic compatibility (EMC) - Part 4-1: Testing and measurement techniques - Overview of immunity tests (IEC 61000-4 series), IEC 61000-6-4:2018, IEC, Geneva (2018).

[A–9] INTERNATIONAL ELECTROTECHNICAL COMMISSION, Nuclear Facilities – Electrical Equipment Important to Safety – Qualification, IEC/IEEE 60780-323 std. (Edition 1.0), IEC/IEEE 60780-323:2016, IEC, Geneva (2016).

[A–10] INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations, IEEE 308-2012, IEEE, Piscataway, NJ (2012).

[A–11] INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, Standard for Qualifying Continuous Duty Class 1E Motors for Nuclear Power Generating Stations, IEEE 334-2006, IEEE, Piscataway, NJ (2006).

[A–12] INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, Standard for Seismic Qualification of Equipment for Nuclear Power Generating Stations, IEEE 344-2013, IEEE, Piscataway, NJ (2013).

[A–13] INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, Standard for Qualification of Safety-Related Actuators for Nuclear Power Generating Stations, IEEE 382-2006, IEEE, Piscataway, NJ (2006).

[A–14] INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, Standard for Qualifying Electric Cables and Splices for Nuclear Facilities, IEEE 383-2015, IEEE, Piscataway, NJ (2015).

[A–15] INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, Standard for the Design and Qualification of Class 1E Control Boards, Panels, and Racks Used in Nuclear Power Generating Stations, IEEE 420-2013, IEEE, Piscataway, NJ (2013).

[A–16] INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, Standard for Qualification of Class 1E Vented Lead Acid Storage Batteries for Nuclear Power Generating Stations, IEEE 535-2013, IEEE, Piscataway, NJ (2013).

[A–17] INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, Standard for Qualification of Class 1E Connection Assemblies for Nuclear Power Generating Stations, IEEE 572-2006, IEEE, Piscataway, NJ (2006).

[A–18] INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations, IEEE 603-2018, IEEE, Piscataway, NJ (2018).

[A–19] INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, IEEE Standard for Qualification of Equipment Used in Nuclear Facilities, IEEE 627-2010, IEEE, Piscataway, NJ (2010).
[A–20] INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, Standard for Qualifying Class 1E Motor Control Centers for Nuclear Power Generating Stations, IEEE 649-2006, IEEE, Piscataway, NJ (2006).
[A–21] INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, Standard for Qualifying Fiber Optic Cables, Connections, and Optical Fiber Splices for Use in Safety Systems in Nuclear Power Generating Stations, IEEE 1682-2011, Piscataway, NJ (2011).
[A–22] THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, Qualification of Active Mechanical Equipment Used in Nuclear Facilities, ASME QME-1-2017, ASME, Two Park Avenue, NY (2017).

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. Ageing in which the simulation of natural ageing approximates, in a short time, the ageing effects of longer term service conditions. Usually, the accelerated ageing attempts to simulate natural ageing effects by application of stressors representing plant preservice and service conditions, but perhaps different in intensity, duration and manner of application.

ageing mechanism. Specific process that gradually changes 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).

specified service conditions. Physical conditions and stressors which affect the equipment during the service life. This includes process and ambient normal operating conditions, abnormal operating conditions and conditions following a design basis accident and design extension conditions.

Arrhenius ageing model. ~~A simplified mathematical model, characterizing the kinetics of a chemical reaction (degradation process). It indicates a linear relationship between the logarithm of exposure time and the reciprocal of the absolute temperature. Its correct usage is restricted to such a relationship between a reaction rate constant (activation energy) and the thermodynamic temperature.~~ A simplified model characterizing kinetics of chemical reaction (degradation process). The Arrhenius model predicts how component failure time varies with temperature. It assumes that a short-term thermal ageing at high temperature results in the same degradation as long term ageing at lower temperature.

condition monitoring: Refers to activities performed to assess the functional capability of equipment by measuring and tracking suitable condition indicators.

harsh environment. Environmental conditions in a location of nuclear installation which significantly change as a result of a postulated initiating event.

mild environment. Environment that would at no time be significantly more severe than the environment that would occur during operational states.

mission time. Time for which the equipment is required to perform (maintain) its intended function, under conditions of postulated accidents.

pre-existing item. An item that has already been available on the market and has potentially ~~already~~ been qualified in accordance with an industrial or nuclear standard for use in application different from what is required in the nuclear installation.

radiation aging: Radiation Aging should be limited to gradual permanent changes to material characteristics over time and differentiated from transient changes that may occur because of exposure to radiation.

shelf life: The time period between manufacturing and installation during which the equipment may be in storage prior to installation. This time is important because of the potential loss of critical engineering properties.

significant aging mechanism: An aging mechanism that, under normal and abnormal service conditions, causes degradation of equipment that progressively and significantly renders the equipment vulnerable to failure to perform its safety functions during the design basis accident conditions

suitability assessment: A process and procedures used to demonstrate the suitability of an equipment to perform safety functions.

qualification margin. Difference between service conditions and the conditions assumed for qualification.

qualified condition. The worst state of degradation for which successful performance during a subsequent design basis accident was demonstrated.

qualified status. The determination as to whether there is adequate documented evidence that the equipment is qualified.

type testing. A type test subjects a representative sample of equipment, including its interfaces, to a series of tests, simulating the effects of significant ageing mechanisms during normal operation. Equipment qualification testing shall be performed with equipment functioning in a state representative of its intended use in actual operation (including any software).

CONTRIBUTORS TO DRAFTING AND REVIEW

Arita, S.	Hitachi-GE Nuclear Energy Ltd., Japan
Bailey, M.	Sizewell B, Nuclear Generation, United Kingdom
Bravo, J.L.	Tecnatom, Spain
Brossier, H.A.	Electricité de France, France
Duchac, A.	International Atomic Energy Agency
Ge, T.	CNNP, China
Gilbert, L.	Bruce Power Inc., Canada
Gonzalez Nieto, J.J.	Tecnatom, Spain
Kataoka, K.	Nuclear Regulation Authority, Japan
Krivanek, R.	IAEA
Rahn, D.	Nuclear Regulatory Commission, United States of America
Pepper, K.	Office for nuclear regulation, United Kingdom
Placek, V.	UJV Rez, a.s., Czech Republic
Petofi, G.	IAEA
Rovny, K.	Plus Energia s.r.o., Slovakia
Shim, S.	IAEA
Svensson, B.	Ringhals NPP, Sweden
Synak, D.	Slovenske Elektrarne, a.s., Slovakia
Vucetic, J.	Canadian Nuclear Safety Commission, Canada
Waber, P.	Framatome GmbH, Germany