AMP 221 EQUIPMENT QUALIFICATION RE-ASSESSMENT (VERSION 2021)

Programme Description

An equipment qualification programme is established to demonstrate with reasonable assurance that equipment important to safety can perform its safety function(s) before, during and after a design basis event (DBE), such as a loss of coolant accident (LOCA), high energy line break (HELB), main steam line break (MSLB), design extension conditions (DEC) as appropriate [1], seismic events, airplane crash, station blackout, and/or other environments e.g. intense electromagnetic fields, as defined in accordance with applicable national regulatory requirements for equipment qualification. The effects of significant ageing mechanisms are addressed as part of the equipment qualification programme [2-9]. As defined in [25], environmental qualification is a sub-part of equipment qualification.

The equipment qualification programme defines (preparing the master list) and maintains a list of equipment which is hereafter referred to as in-scope equipment. It requires the preparation and maintenance of a qualification file containing the qualified equipment's performance specifications including their safety function(s), the environmental conditions to which the equipment could be subjected during normal operation, postulated DBE(s) and/or DEC(s). The file also establishes auditable links to the associated qualification report(s) [1-6]. The equipment qualification programme contains provisions for ageing that require, in part, consideration of all significant types of ageing degradation (e.g. thermal, radiation, pressure, humidity, chemical effect, submergence, vibration, cyclical ageing, or their synergistic effects) that can affect equipment functional capability [28][29].

It is common practice in some member states (MS) to establish equipment qualification requirements to qualify certain equipment located in mild environments[[1]](#footnote-1) as applicable in line with national regulatory requirements. A qualified life [10] is generally not required for equipment located in a mild environment which has no significant ageing mechanisms and is operated within the limits established by applicable specifications and standards [1]. Qualification for equipment located in mild environments is demonstrated by providing evidence that the equipment meets or exceeds the specified requirements during normal environmental conditions and anticipated operational occurrences as defined in accordance with national regulatory requirements [1, 6, 11, 12].

Some Member States (MS) require the inclusion of life limited mechanical and/or civil structures, systems or components (SSCs) in the equipment qualification programme. Life limiting condition is normally associated with material susceptibility to radiation and/or thermal ageing. Examples of this include, active valve components, containment penetration seals qualified as pressure boundaries, or protective coatings qualified to prevent severe delamination, peeling, or flaking of large portion of the coating system and consequent discharge to the cooling systems. If these SSCs are in-scope a qualification re-assessment may be completed using the guidance contained within this Aging Management Programme (AMP) or by application of a comparable and acceptable methodology in accordance with the national regulatory requirements. The qualification re-assessment usually involves assessments of the environmental effects on the life limiting items such as polymeric/elastomeric seals, gaskets or coatings.

Equipment important to safety, including its interfaces, meets or exceeds the equipment specification requirements. This continued capability is ensured through a programme that includes, but is not limited to, design control, quality control, qualification, installation, maintenance, periodic testing, and surveillance [1]. The focus of this AMP is on activities in the qualification programme dedicated to re-assessment of equipment qualification of SSCs for the intended operating period.

Qualified life, when required, and qualified condition (see definition below) [1] are established during the initial qualification of the in-scope equipment. Qualified life and qualified condition are primarily demonstrated by type testing which may be supplemented by operating experience and analysis [1]. In type testing, the ability of the equipment to perform its safety function is demonstrated as required by preconditioning test sample(s) to the state of degradation expected at the end of the assumed qualified life, followed by simulated DBE(s), DEC(s), and/or other environments as defined in accordance with national regulatory requirements for equipment qualification [1].

The equipment qualification programme establishes activities in order to preserve the qualification of in-service qualified equipment. These activities are implemented to assure the adequacy of the equipment, function and installation under required conditions.

In-scope equipment, as defined above, which are not qualified for the current operating term or intended operating period are reassessed to extend the qualification or replaced or refurbished prior to reaching the ageing limits (qualified life or qualified condition) established in the previous evaluation.

A plant equipment qualification programme may, in accordance with national regulatory requirements, be considered an AMP for the intended operating period. Equipment with an intended qualified life equal to or greater than the duration of the current operating term (e.g. 40 years) is evaluated as TLAA. Ageing evaluations for in-scope equipment that involve elements of the equipment qualification programme are to give due consideration to the guidance in Time Limited Aging Analysis (TLAA) 201 (Equipment Qualification of Electrical and I&C Equipment) [27].

Note: in this AMP, “qualified condition”, “equipment” and “components” have the following meaning:

* Qualified condition:

Condition of equipment, prior to the start of an accident, for which the equipment was demonstrated to meet the design requirements for the specified service conditions. This equipment could include certain post-accident cooling and monitoring systems that are expected to remain operational [1]. This is also called “end of qualified life parameter” or “qualified level of degradation (QLD)” [14].

* Equipment:

Assembly of components designed and manufactured to perform specific functions. Sensors, cables, electrically operated valves, Instrumentation and Control (I&C) cabinet or racks are examples of equipment [1].

* Components:

Parts of the “equipment”. Discrete elements of a system. Examples of components are wires, transistors, integrated circuits, motors, relays, solenoids, pipes, fittings, pumps, tanks and valves [10].

**Reassessment of qualified life**

Current qualified life may be less than the anticipated service life for the intended operating period. In this case, the equipment qualification programme requires reassessing qualified life of equipment, replacement or refurbishment prior to reaching the limit of the current qualified life. The following methods are used for reassess the qualified life [1]. If qualification cannot be extended by the reassessment through these methods, complete replacement of equipment may be required. The reassessment is performed in a timely manner (that is, sufficient time is available to replace, refurbish or requalify the equipment if extension of qualification is unsuccessful).

Method 1: Using conservatism

Evaluation of conservatisms in original assumptions for environmental conditions, failure criteria, and acceleration factors may identify that actual conditions are less severe, and the qualified life may be adjusted accordingly with due consideration of the required margins. Limitation of use of accelerating factors (e.g. time period extrapolation, synergy between effect of temperature and radiation, dose rate effect), verification of ageing models, and proper assessment of environmental conditions are considered [1].

While equipment life limiting condition may be due to thermal, radiation or cyclical ageing, the majority of equipment ageing limits are based on thermal conditions.

The Arrhenius methodology is an acceptable thermal model which may be used for performing a thermal ageing evaluation. The analytical method used for a radiation evaluation is to demonstrate qualification for the total integrated dose (i.e. normal radiation ageing dose for the projected installed life plus accident radiation dose). As an example, for the intended operating period of 60 years, one acceptable method of establishing the 60-year normal radiation dose is to multiply the current operating term (e.g. 40 years) normal radiation dose by 1.5 (the intended period of operation divided by the current operating term, i.e. 60 years/40 years). The result is added to the accident radiation dose to obtain the total integrated dose for the equipment. For cyclic ageing (e.g. thermal loading, mechanical loading), a similar approach may be used. Other models may be justified on a case-by-case basis.

Reducing excess conservatism in the equipment service conditions (for example, temperature, radiation, and cycles) used in the prior ageing evaluation is the primary method used for a reanalysis. For example, temperature data, associated margins, and uncertainties used in an equipment qualification evaluation may be based on anticipated plant design temperatures found to be conservative when compared to actual plant temperature data. This method requires monitoring the specific environmental conditions during normal operation of the plant. Plant temperature data can be obtained in several ways, including monitors used for technical specification compliance, other installed monitors, measurements made by plant operators during rounds, and dedicated monitoring equipment for equipment qualification. A representative number of temperature measurements are conservatively evaluated to establish the temperatures used in an ageing evaluation. Plant temperature data may be used in an ageing evaluation in different ways, such as (a) directly applying the plant temperature data in the evaluation, or (b) using the plant temperature data to demonstrate conservatism when using plant design temperatures for an evaluation.

Some Member States perform a pre-analysis to identify how to implement the most efficient environmental monitoring programme. In this way monitoring may not be performed in a generic and systematic manner. Environment is measured in sensitive spots, there where conditions are envelope for given types of equipment which are used in numerous locations or even in different plants if these are of similar design.

Any changes to material activation energy values as part of a reanalysis can be made on a component/material specific basis provided that sufficient technical justification is defined and documented. Similar methods of reducing excess conservatism in the equipment service conditions used in prior ageing evaluations can be used for other identified ageing stressors.

In-scope equipment ageing evaluations contain sufficient conservatism to account for environmental changes occurring due to plant modifications, seasonal changes and events. A reanalysis demonstrates that adequate conservatism is maintained, consistent with the original analysis, accounting for uncertainties established in the qualification ageing evaluation for the equipment (e.g. diffusion limited oxidation, activation energy, synergistic effects, inverse temperature, and dose rate effects.). Reanalysis that uses initial qualification conservatisms and/or in-service environmental conditions (e.g. actual temperature and radiation conditions) are part of the equipment qualification programme.

In the equipment qualification programme, environmental conditions in normal operation of the plants are monitored with particular emphasis on the identification of adverse localized environments that may impact equipment’s qualification [11, 14-18]. When unexpected adverse localized conditions that affect the environment of a qualified equipment are identified, the affected equipment’s qualification is evaluated, and appropriate corrective actions are taken, which may include changes to the qualification basis and conclusions. A reanalysis demonstrates that adequate conservatism is maintained, consistent with the original analysis, accounting for uncertainties established in the qualification ageing evaluation for the equipment.

Some Member States take measures to mitigate the effects of ambient conditions on the equipment, in order to assure additional conservatism. These measures include modification of the ambient conditions by air conditioning to decrease the ambient temperature and shielding or relocation of the equipment to decrease radiation stemming from a hot spot. Such reductions in exposure to the stressor’s intensity (e.g. lowering temperature, radiation) with proper justification, can be used to extend the qualified life.

Method 2: Type test on aged samples from the plant

This method could include installation of additional qualified equipment in identical service conditions or use qualified equipment aged in the plant. In addition, this method could remove in-service equipment before the end of the qualified life and demonstrate its safety function performance during and after DBE(s) or other environments as defined in accordance with national regulatory requirements for equipment qualification after further artificial ageing to establish additional qualified life [1].

Method 3: Performing type test for longer qualified life

A longer qualified life can be achieved by either performing additional artificial ageing on the test sample from the initial qualification for additional duration or begin ageing on a new sample while the qualified equipment is in service. Equipment safety function is then demonstrated by successfully passing accident condition test [1].

Method 4: Component replacement

Identify age-sensitive components of equipment and replace them with new, identical components or with less sensitive components to extend qualification. Consideration is given to the time required to have the component accessible for the replacement. This method is not used if the disassembly of the equipment can alter its performance in service conditions (including accident conditions) [1].

**Condition monitoring**

Condition monitoring, for condition based qualification purposes, monitors one or more condition indicators to determine whether equipment remains in a qualified condition. Condition indicators are measurable, change monotonically with time and need to correlate with safety function performance under DBE(s) or other environments as defined in accordance with national regulatory requirements for equipment qualification. The trend of the condition indicator is determined during age conditioning of the test specimen for qualification testing to establish data for comparison with observations of the same indicators during service. It is required to establish the condition of the equipment’s condition indicator(s) at the conclusion of age conditioning, prior to testing to accident conditions, which is called “qualified condition”. When condition-based qualification is used, the equipment remains qualified until it reaches a point prior to the end condition that considers margin [1].

Condition monitoring is performed during the whole operating life by adapting periodicity. As the qualified equipment approaches the qualified condition, periodic condition monitoring may be implemented at an increased rate to determine if actual ageing is occurring at a slower rate, and if further qualified service is possible based on the condition monitoring results [1].

Further information on requirements for the condition indicators and methodologies to establish condition-based qualification are provided in [1, 19].

Evaluation and Technical Basis

1. ***Scope of the ageing management programme based on understanding ageing:***

The focus of this AMP is on activities in the equipment qualification programme dedicated to re-assessment of equipment qualification of in-scope equipment for the intended period of operation. Therefore, this AMP applies to certain equipment that are required to be qualified and whose ageing degradation in service is managed by the traditional qualified life approach or condition-based qualification methodology.

1. ***Preventive actions to minimize and control ageing degradation:***

Actions in reassessment of equipment qualification of equipment that could be viewed as preventive actions may include

(a) performing a preliminary analysis to identify the in-scope equipment’s environmental sensitivity and establishing the equipment service condition tolerance and ageing limits;

(b) monitoring of environmental conditions in normal operation of the plant with particular emphasis on the identification of adverse localized environments that may impact in-scope equipment’s qualified life [11, 14-18] (see Method 1);

(c) mitigation of the ageing effects by modification of the ambient conditions (this can be achieved by air conditioning to decrease the ambient temperature and shielding or relocation of the in-scope equipment to decrease radiation stemming from a hot spot (see Method 1));

(d) identifying age-sensitive components of in-scope equipment and replacing them with less sensitive components (see Method 4); and

(e) identification of in-scope equipment condition indicators to be monitored and qualified condition for the application of condition-based qualification methodology (see “Condition monitoring”).

Adverse localized environments are identified through the use of an integrated approach. This approach may include and is not limited to:

(a) the review of equipment qualification programme radiation levels and temperatures;

(b) recorded information from equipment or plant instrumentation;

(c) as-built and field walk down data (e.g. cable routing data base);

(d) a plant spaces scoping and screening methodology;

(e) plant modifications (e.g. power uprate); and

(f) the review of relevant plant-specific and industry operating experience (OE). This OE includes, but is not limited to:

* Identification of work practices that have the potential to subject in-scope equipment to an adverse localized environment (e.g. influence of maintenance activity that removes thermal insulation and restoration from hot pipes).
* Corrective actions for in-scope equipment involving end-of-installed life, designated life, or qualified life (current operating term).
* Observations from previous walk-downs including visual inspection.
* Environmental monitoring (e.g. long term periodic environmental monitoring of in-scope equipment – temperature or radiation).
* Inspection of accessible in-scope equipment and the evaluation of the equipment’s environment to identify equipment subjected to an adverse localized environment. The ageing impact on accessible in-scope equipment located in an adverse localized environment is evaluated and represents, with reasonable assurance, both accessible and inaccessible in-scope equipment age degradation.

The monitoring and trending frequency may be adjusted based on equipment inspection and test results. A modification to qualification either by reassessment of qualified life or condition-based qualification demonstrates that adequate conservatism is maintained, consistent with the original analysis, accounting for uncertainties established in the equipment’s qualification ageing evaluation.

1. ***Detection of ageing effects:***

Actions in reassessment of qualification of in-scope equipment that could be viewed as detection of ageing effects may include

(a) inspecting and/or testing in-scope equipment periodically,

(b) monitoring equipment condition indicators for the application of condition-based qualification methodology (see “Condition monitoring”).

1. ***Monitoring and trending of ageing effects:***

Actions in reassessment of qualification of in-scope equipment that could be viewed as monitoring and trending of ageing effects may include

(a) monitoring of environmental conditions in normal operation of the plants with particular emphasis on the identification of adverse localized environments that may impact equipment’s qualified life [11, 14-18] (see Method 1);

(b) inspecting and testing in-scope equipment with appropriate techniques, supplemented with walk-downs to look for visible signs of anomalies attributable to ageing;

(c) monitoring and trending of in-scope equipment condition indicators with periodicity for condition-based qualification (see “Condition monitoring”); and

(d) verifying that the plant configuration meets the qualification basis.

A monitoring or trending programme may be used to ensure that the qualified equipment is within the bounds of its qualification basis, or to modify qualified life. Monitoring and trending frequency may be adjusted based on results of equipment inspection and testing.

1. ***Mitigating ageing effects:***

Actions in qualification reassessment of in-scope equipment that could be viewed as mitigating ageing effects include:

(a) mitigation of the ageing effects by modification of the ambient conditions. This can be achieved by air conditioning to decrease the ambient temperature and shielding or relocation of the in-scope equipment to decrease radiation stemming from a hot spot (see Method 1);

(b) component replacement (also known as partial replacement) (see Method 4); and

(c) complete replacement of equipment.

1. ***Acceptance criteria:***

The acceptance criteria of the equipment qualification programme are that the in-service in-scope equipment is maintained within the bounds of its qualification basis for the intended period of operation. Qualification reassessment of in-scope equipment requires extension of qualification through reassessment of qualified life, condition-based qualification (see “Condition monitoring”), or complete replacement of equipment prior to reaching the qualification limits (qualified life or qualified condition) established in the evaluation.

When monitoring and trending is used to modify the equipment qualified life or qualified condition, plant-specific acceptance criteria are established based on applicable qualification methods in accordance the national regulatory requirements.

1. ***Corrective actions:***

In the equipment qualification programme, if the in-scope equipment is found to be or is projected to be outside the bounds of its qualification basis (e.g. environment, ageing conditions, configuration, etc.)during its intended operating period, corrective actions are implemented in accordance with the plant’s corrective action programme. Actions in qualification reassessment of in-scope equipment that could be viewed as corrective actions include complete replacement of equipment when qualification cannot be extended by the qualification reassessment, or condition-based qualification (see “Condition monitoring”) for the intended period of operation.

When unexpected adverse localized environment or conditions that affect the environment of a qualified equipment is identified, the affected equipment is evaluated and appropriate corrective actions taken, which may include changes to the qualification basis and conclusions. When an emerging industry ageing issue is identified that affects the qualification of equipment, the affected equipment is evaluated, and appropriate corrective actions are taken. These evaluations may require changes to the qualification basis and conclusions. Confirmatory actions, as needed, are implemented as part of the plant corrective action programme, pursuant to national regulatory Quality Assurance (QA) requirements. As discussed in IGALL, the requirements of the national regulatory QA programme are acceptable to address the corrective actions.

1. ***Operating experience feedback and feedback of research and development results:***

This AMP addresses the industry-wide generic experience. Relevant plant-specific operating experience is considered in the development of the plant AMP to ensure the AMP is adequate for the plant. The plant implements a feedback process to periodically evaluate plant and industry-wide operating experience and research and development (R&D) results, and, as necessary, either modifies the plant AMP or takes additional actions (e.g. develop a new plant-specific AMP) to ensure the continued effectiveness of the ageing management.

The equipment qualification programme includes consideration of operating experience to modify the qualification basis and conclusions, including qualified life. Compliance with national regulatory equipment qualification requirements provides reasonable assurance that equipment can perform their intended functions before, during, and after accident conditions considering the effects of in-service ageing.

The programme includes provisions for the continuous review of plant-specific and industry operating experience, including research and development results, such that the impact on the programme is evaluated and any necessary actions or modifications to the programme are performed.

Sources of external operating experience are OECD/NEA (Organisation for Economic Co-operation and Development/Nuclear Energy Agency), INPO (Institute of Nuclear Power Operations), Owner’s Groups, WANO (World Association of Nuclear Operators), IAEA, VGB Database, Nuclear Regulatory Commission (USA) (NRC) generic communications and Equipment Qualification Database (EQDB).

Specifically concerning qualification of cables:

* Recent research programmes developed in Japan [20], OECD/NEA [16] and IAEA [14], on cable environmental qualification and ageing management, describe areas of concern (uncertainties) in the original in-scope cables qualification process, performed in the past (e.g. Institute of electric and electronic Engineers IEEE Std 323-1974 [21]).
* IAEA Nuclear Energy Series Report No. NP-T.3.6, includes detailed information regarding uncertainties and their effects on cable environmental qualification [14]. The uncertainties are related to the following:
* Synergistic effects of sequence applied for the radiation and thermal ageing test.
* Acceleration factors applied in the radiation and thermal ageing tests.
* Oxygen consumption on LOCA chambers effects, during DBE test.
* Dose rate effects.
* Non-conservative or incorrect activation energy values used in Arrhenius thermal ageing calculations.
* Inverse temperature effects (semi crystalline polymers cross-linked polyethylene (XLPE), cross-linked polyolefin (XLPO)).
* The SAND 2013-2388 report results showed the following conclusions of the uncertainties effects [22]:
* There are different degradation mechanisms for cable polymers, in oxidative or inert environments.
* Neither qualification testing nor accelerated ageing studies have satisfactorily addressed inverse temperature effects (XLPE, XLPO).
* While cable performance in oxygen environments may be satisfactory and equipment qualification process margins may exist, these margins cannot be predicted or validated, from existing qualification and ageing studies.
* Regarding condition monitoring techniques IAEA launched a Coordinated Research Project (CRP) on benchmark analysis for CM (Condition Monitoring) techniques of aged low voltage cables based on CM techniques described in [19]. This CRP included 11 chief scientific investigators and 21 observers, representing 17 Member States. The CRP established a benchmarking programme in which 12 types of cable insulation or jacket were aged under thermal and radiation conditions, and tested before and after ageing by various organizations applying different CM techniques, being most of CM techniques applied by at least two different organizations. The results of these tests were then compared to identify the proper condition monitoring techniques for each cable type and to establish recommendations for improvements to these methods [26].

The above considerations are taken into account in any reanalysis for future qualification or life extension activities on in-scope cables, when applicable.

1. ***Quality management:***

Site quality assurance procedures, review and approval processes, and administrative controls are implemented in accordance with the different national regulatory requirements (e.g. Code Federal Regulation (USA) 10 CFR 50, Appendix B [23] and Nuclear Safety Comission (Germany) KTA1401 [24]).

References

1. IEC/IEEE, “Nuclear facilities - Electrical equipment important to safety – Qualification”, IEC/IEEE 60780-323:2016, 2016.
2. UNITED STATES NUCLEAR REGULATORY COMMISSION, “10 CFR 50.49, Environmental Qualification of Electrical Equipment Important to Safety for Nuclear Power Plants”, Office of the Federal Register, National Archives and Records Administration, Latest edition.
3. INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Nuclear Power Plants: Design, IAEA Safety Standards Series No. SSR-2/1 (Rev. 1), IAEA, Vienna (2016).
4. 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).
5. INTERNATIONAL ATOMIC ENERGY AGENCY, “Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants”, Specific Safety Guide No. SSG-48, IAEA, Vienna, 2018.
6. INTERNATIONAL ATOMIC ENERGY AGENCY, “Equipment Qualification in Operational Nuclear Power Plants: Upgrading, Preserving, and Reviewing”, Safety Report Series No.3, IAEA, Vienna, 1998.
7. French Association for design, construction and in-service inspection rules for nuclear island components (AFCEN), “RCC-E: Design and construction rules for electrical equipment of nuclear islands – January 2016 Edition”, 2016.
8. KERNTECHNISCHER AUSSCHUSS, “Ageing Management in Nuclear Power Plants”, KTA 1403, Germany, November 2010.
9. KERNTECHNISCHER AUSSCHUSS, “Ensuring the Loss-of-Coolant-Accident Resistance of Electrotechnical Components and of Components in the Instrumentation and Controls of Operating Nuclear Power Plants” KTA 3706, Germany, June 2000.
10. INTERNATIONAL ATOMIC ENERGY AGENCY, “IAEA Safety Glossary Terminology Used in Nuclear Safety and Radiation Protection 2018 Edition”, IAEA, Vienna, 2018.
11. UNITED STATES NUCLEAR REGULATORY COMMISSION, “Environmental Qualification of Electric Equipment”, NUREG 2191 Vol. 2 Chapter X. E1, USNRC, July 2017.
12. KERNTECHNISCHER AUSSCHUSS, “Type Testing of Measuring Sensors and Transducers of the Instrumentation and Control System Important to Safety”, KTA 3505 Germany, November 2015.
13. UNITED STATES NUCLEAR REGULATORY COMMISSION, “Environmental Qualification (EQ) of Electric Components”, NUREG 1801 Rev. 2 Chapter X. E1, USNRC, December 2010.
14. INTERNATIONAL ATOMIC ENERGY AGENCY, “Assessing and Managing Cable Ageing in Nuclear Power Plants”, IAEA Nuclear Energy Series No. NP-T.3.6, IAEA, Vienna, 2012.
15. INTERNATIONAL ATOMIC ENERGY AGENCY, “Assessment and management of ageing of major nuclear power plant components important to safety: In-containment instrumentation and control cables”, IAEA-TECDOC-1188 Volume I, pp.35-39, IAEA, Vienna, 2000.
16. NUCLEAR ENERGY AGENCY, “Technical Basis for Commendable Practices on Ageing Management - SCC and Cable Ageing Project (SCAP) Final Report”, NEA/CSNI/R(2010)15, pp.77-84, April 2011.
17. UNITED STATES NUCLEAR REGULATORY COMMISSION, Regulatory Guide 1.211, Qualification of Safety-Related Cables and Field Splices for Nuclear Power Plants, US NRC, April 2009.
18. NUCLEAR and INDUSTRIAL SAFETY AGENCY, Environmental Monitoring for Safety-related Cables in Primary Containment Vessels of Nuclear Power Plants (in Japanese), NISA-167b-07-1, October 2007.
19. IEC/IEEE, “Nuclear power plants – Instrumentation and control important to safety Electrical equipment condition monitoring methods”, IEC/IEEE 62582.
20. JAPAN NUCLEAR ENERGY SAFETY ORGANIZATION, “The Final Report of the Project of “Assessment of Cable Aging for Nuclear Power Plants”, JNES-SS-0903, July 2009.
21. IEEE, “IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations”, IEEE Std 323-1974, 1974.
22. SANDIA NATIONAL LABORATORIES, “Nuclear Power Plant Cable Materials: Review of Qualification and Currently Available Ageing Data for Margin Assessments in Cable Performance”, SAND 2013-2388, 2013.
23. UNITED STATES NUCLEAR REGULATORY COMMISSION, “10 CFR Part 50, Appendix B, Quality Assurance Criteria for Nuclear Power Plants”, Office of the Federal Register, National Archives and Records Administration, USNRC, Latest edition.
24. KERNTECHNISCHER AUSSCHUSS, “General Requirements for the Quality Assurance, KTA1401, Germany, November 2017.
25. INTERNATIONAL ATOMIC ENERGY AGENCY Equipment Qualification for Nuclear Installations, Draft IAEA Safety Standards Series No. DS514, IAEA, Vienna
26. INTERNATIONAL ATOMIC ENERGY AGENCY, “Benchmark analysis for condition monitoring test techniques of aged low voltage cables in nuclear power plants”, IAEA-TECDOC 1825, IAEA, Vienna, 2017
27. INTERNATIONAL ATOMIC ENERGY AGENCY, “Ageing Management for Nuclear Power Plants: International Generic Ageing Lessons Learned (IGALL)”, IAEA SRS No.82 (Rev.1), IAEA, Vienna, 2020
28. ELECTRIC POWER RESEARCH INSTITUTE, “Plant Support Engineering: Nuclear Power Plant Equipment Qualification Reference Manual”, Revision 1. EPRI, Palo Alto, CA: 2010. 1021067
29. ELECTRIC POWER RESEARCH INSTITUTE Long Term Operations: Subsequent License Renewal Electrical Handbook. EPRI, Palo Alto, CA: 2018. 3002010401

1. Environments that would at no time be significantly more severe than the environment that would occur during normal plant operation, including anticipated operational occurrences) [↑](#footnote-ref-1)