ETSON

EUROPEAN TECHNICAL SAFETY ORGANISATIONS NETWORK

TECHNICAL SAFETY ASSESSMENT GUIDE

ENVIRONMENTAL QUALIFICATION

ETSON/ 2018-001 September 2018

CONTENTS

LIST OF ABBREVIATIONS

AE	ACTIVATION ENERGY
DBA	DESIGN BASIS ACCIDENT
DEC	DESIGN EXTENSION CONDITION
EQ	ENVIRONMENTAL QUALIFICATION
HELB	HIGH-ENERGY LINE BREAK
LOCA	HIGH-ENERGY LINE BREAK
MSLB	MAIN STEAM LINE BREAK
NPP	NUCLEAR POWER PLANT PIE (POSTULATED INITIATING EVENT)
PQL	PROJECTED QUALIFIED LIFE
QSR	QUALIFICATION SYNTHESIS REPORT
RRS	REQUIRED RESPONSE SPECTRUM
SAR	SAFETY ANALYSIS REPORT
TRS	TEST RESPONSE SPECTRUM
TSO	TECHNICAL SUPPORT ORGANIZATION

1 SCOPE

The goal of this document is to provide guidance for reviewers of TSOs to check the compliance of submitted safety analysis with safety requirements (or safety objectives) related to equipment environmental qualification.

Equipment needed to fulfil safety functions has to be qualified for the conditions in which it is required. Qualification includes both function and reliability, considering environmental conditions which equipment would be exposed to in the plant, including severe accident conditions. The qualification process, especially for new equipment, shall be completed before plant start-up. In some cases, already installed equipment may be used to face up new situations (for example Design Extension Conditions). In such a case, qualification is either demonstrated by verifying that these situations are covered by already performed qualification tests of justification or by performing a new qualification dedicated to these situations. The methodology for the qualification is strictly the same.

This guide deals with Environment Qualification (EQ) in normal, abnormal service conditions, design basis accidents (DBA) and design extension conditions (DEC) including severe accidents. For equipment that needs to be qualified to design extension conditions, specific accident profiles covering these conditions shall be defined.

This guide primarily applies to nuclear power plants (NPPs), but it may be applied to other nuclear facilities, such as research reactors.

The guide does not deal with the means needed to achieve EQ, but with the methods that a safety assessment can use to verify main objectives.

The guide does not cover the actions needed to maintain a qualification status in an operating plant (preservation of qualification). This important topic is well documented in the IAEA report SRS 3 [1].

2 BACKGROUND INFORMATION AND CONCEPTS

Equipment qualification is the generation and preservation of evidence to ensure that the equipment is able to function within its required accuracy and performance requirements in all operational and accidental conditions for which it is required to operate.

Mild environment is an environment that would at no time be significantly more severe than the environment that would occur during normal plant operation, including anticipated operational occurrences. In other cases, environment is said to be **harsh** (for example, environment induced by a loss-of-coolant accident (LOCA), a high-energy line break (HELB) and a main steam line break (MSLB)). The guide provides requirements on EQ in harsh environment. The EQ to mild environment is identical, but does not include the accident conditions tests described in paragraph 2.2.3.

Environmental Qualification (EQ) aims at confirming, as required in [2], that the items important to safety are capable, throughout their design operational lives, of performing their safety functions, while being subject to the conditions prevailing at the time of need:

- environmental conditions (vibrations, including seismic vibrations, temperature, pressure, chemical spray, electromagnetic interference, irradiation, humidity or any likely combination thereof);

- all expected internal stresses (electrical and/or mechanical loadings, temperature, pressure, irradiation…).

The situations taken into account in EQ are normal, abnormal service conditions, Design Basis Accidents (DBA) and Design Extension Conditions (DEC). For DEC, plant specific DEC profiles covering these conditions should be defined. The hypotheses and provisions used to determine DEC profile should be specified in a safety report. They could differ from provisions taken regarding DBA profile.

Equipment which has to be qualified is:

- electrical equipment;

- instrumentation and control (I&C) equipment;

- non-static mechanical equipment (requiring a motion to achieve their safety function: valves, pumps…);

- electrical and mechanical (static or non-static) equipment participating to the tightness of the containment barriers in accident conditions;

- hydrogen recombiners.

This guide is best understandable after a familiarization with concepts described in IEC/IEEE 60780_IEEE323 [3] and national standards such as KTA 3504 [4] and KTA 3505 [5], RCC-E [6]…). A selection of the main concepts is nevertheless provided below in order to facilitate the understanding of the next chapters. It discusses some of the issues whose impact has been found in practice to be very significant in the members of ETSON experience.

2.1 Methods of qualification

The overall approach of safety-classified equipment qualification has to be specified by the Licensee; this approach must be applied to equipment inside and outside the reactor building and take into account the accident conditions that might arise due to internal and external events, as well as ageing.

For this approach, the methods of qualification and the standards covering ambient conditions for reference as well as for severe accident situations have to be defined and their representativeness has to be justified (notably for ageing).

Qualification can be obtained by testing one or several samples of this equipment against a sequence of conventional representative tests or by a clear demonstration of the capacity of the equipment to operate under defined conditions, for example by analogy with another equipment (similarity, calculation); a combination of both methods can also be used. Qualification can also be justified by using experience feedback.

Tests of equipment against simulated operational conditions are preferred for the qualification of equipment in harsh environments. Similarity may be accepted when it is possible to show, by engineering judgment, that the behaviour of the equipment will be the same as that of another equipment which was qualified by testing or by operating experience. Operating experience requires that the equipment has successfully experienced loadings as severe as its qualification requirements, thus it is rarely used alone.

2.2 Qualification by test

Tests are generally performed on one or several identical representative samples of the equipment according to the following test sequence. At least one sample shall be submitted to a test sequence including accelerated ageing tests followed by tests covering accident conditions (earthquake included).

2.2.1 TESTS AT THE LIMITS OF OPERATIONAL CONDITIONS

During this phase, the test sample shall be operated to the extreme limits of their utilization field in normal operation (electrical –voltage, frequency, electromagnetic interference, radio frequency interference and environmental - temperature, humidity), according to their performance specification and their localization inside the plant. Their protection against the ingress of dust and water shall be tested [7]. Tests of static overpressure (for example for pressure sensors of the second barrier) are performed during this phase. For practical reasons, radiation tests are performed during radiation ageing.

2.2.2 AGEING

The test sample is preconditioned to place it in a condition representative of its intended service life; in case of success of the tests (see §2.2.4), this period will be named Projected Qualified Life (PQL).

In any case, a determination of the Projected Qualified Life is made whenever components essential to accomplish the safety function of equipment are liable to undergo degradation, like polymers. Semi-conductors and polymers should be considered to be sensitive to both radiation dose rate and heating.

Age conditioning is a process that replicates in a test sample the degradation of equipment over a period of time due to significant ageing mechanisms. This process involves applying simulated in-service stresses, typically thermal, moisture, radiation, cycles of operations inducing wear and vibration at magnitudes or rates more severe than expected in normal operation, but such that they do not cause ageing mechanisms not present in normal operation.

Sequential ageing tests, each of which brings into effect only one of the simulated ageing conditions involved, shall be performed in a conservative sequence which maximizes the ageing effect.

Ageing caused by transport and storage condition shall be taken into consideration by defining ageing test procedures. Some precautions can be defined to limit the stress to which equipment is submitted during transport and storage.

2.2.2.1

Thermal ageing

Two methods are encountered for simulating the thermal ageing. The first one uses the Arrhenius method, which involves testing the equipment at an elevated temperature for a certain length of time depending on the desired PQL and the selected activation energy of equipment. This method requires knowledge of the activation energy of each material constituting the equipment and the possible interactions between them.

The second one is the accelerated temperature ageing using the 10-degrees law rule (reducing the preconditioning time by 50 % for every temperature increase of 10°C). It corresponds to an approximation of Arrhenius law calculated with a rather conservative value of activation energy.

Limits due to used materials and possible acceleration effects shall be identified and taken into account when selecting test parameters for thermal ageing. Acceleration factors shall be chosen with care by considering minimal duration and maximal temperature with respect to material properties. In choosing the test temperature for accelerated ageing, it is not acceptable to exceed the limit temperature defined by the manufacturer, as this could lead to unrealistic ageing or even to direct damage due to increased temperature. For some equipment, where thermal cycling is an important degradation factor, the simulation of such cycling can be required by special specific standards (e.g., for electrical connectors or power cable penetrations).

2.2.2.2

Corrosion tests

These types of tests should be carried out on equipment likely to be located in a damp or corrosive ambient atmosphere.

The most common are:

- damp heat test;
- spraying or immersion test;
- salt mist test.

2.2.2.3

Prolonged operation

To simulate the mechanical fatigue, the wear or possible electrical problems during the equipment life, the test sample shall be submitted to load cycles representative of its operation during its PQL (cycles of opening-closing for valves, operations for relays, motors…). Electrical and mechanical loads on equipment shall be considered. Provision shall be taken regarding the number of cycles of operation expected, their magnitude and their maximal frequency.

2.2.2.4

Mechanical vibration test

If the equipment is likely to be subjected to mechanical vibrations during its service life, in order to verify that the vibrations have no detrimental effect on its integrity or its functional capability, an endurance test should be carried out, submitting the test sample to vibrational cycles by a sweeping in frequency. It should be verified that the (proper) resonance frequencies of the equipment are not modified after the test. An endurance test on resonance frequencies should also be performed if necessary.

Mechanical vibration test shall also take into account mechanical shock to which equipment is submitted (for example in case of depressurization).

2.2.2.5

Radiation ageing

The test sample shall be submitted to an irradiation dose representative of the irradiation it is exposed to during its PQL. The following criteria shall be taken into account by defining test modalities: radiation source, dose rate, oxygen concentration surrounding the specimen, temperature, test duration. Particular care should be taken of the dose rate effect: the degradation caused at very low dose rates in the containment can be more harmful that the degradation caused by the same absorbed dose but obtained at higher dose rates (usually higher by 2 to 4 orders of magnitude) which are used to accelerate the test of irradiation ageing, due to the effects of oxidation and gaseous diffusion. It is always better to apply an irradiation dose higher than the expected dose during the PQL, in order to provide a margin. This point is developed in the Annex. The test should be performed at the upper limit of temperature in operation or slightly more.

2.2.3

ACCIDENT CONDITION TESTS

The aged test sample must be submitted to a sequence that simulates the harsh environment in which it may operate. The order of the sequences of accident tests shall be chosen to be penalizing in terms of damages for the equipment to be tested.

The seismic test is performed first, because it may cause a loss of leak-tightness for some equipment and thus be detrimental to their operation during the thermodynamic and post-accident tests that follow. Note that the mechanical vibration test discussed in § 2.2.2.4 and the seismic test may be done using the same shaking table at the end of the ageing sequence [8]. Since the earthquake might induce small breaks, the seismic and the thermodynamic tests shall be performed sequentially for a conservative qualification.

The accident irradiation test is to be performed at the second step because it can cause mechanical damages on polymeric components (cables, lubricants, greases…) and thus be detrimental to their integrity or operation during the thermodynamic test. However, the accident irradiation may be simulated together with the radiation ageing discussed in § 2.2.2.5, before the seismic test. In this case, the licensee should be aware that there is a risk of failure during the seismic test in an unrepresentative manner [8].

The third and fourth test steps shall be the thermodynamic and the post-accident tests.

For a better understanding of the corresponding acceptable practices, the reader is invited to consult EUR 16246 [9].

2.2.3.1

Earthquake

If seismic qualification is required, the test sample shall be submitted to simulated seismic vibrations corresponding to postulated design earthquake conditions or extreme earthquake conditions (considered within the DEC for hazards). For extreme earthquake conditions, a design extension earthquake is defined for each plant, that provides the basis for the design extension earthquake qualification profile.
The test installation may be monoaxial, biaxial or triaxial. The waves used may be:

- multifrequency waves (time history);
- single frequency waves (sine dwell, sine beat, sine sweep).

In any case, the test response spectrum (TRS) shall envelop the required response spectrum (RRS) on the complete test frequency range.

The test should be performed at least on [1-35 Hz] frequency range. Testing of some devices may require a frequency range higher than 35 Hz, up to 100 Hz [10].

Those methods are well documented in IEC 60980 [10] and IEEE 344 [11].

2.2.3.2

Air-plane crash

If an equipment operation is required after an air-plane crash (postulated air-plane crash regarding safety demonstration), it shall be proven that the equipment is not directly impacted and vibrations tests shall be performed to cover vibrations (frequency and amplitude) transmitted by NPP structures, if not bounded by the seismic vibrations.

2.2.3.3

Accident radiation

As regards DBAs, the accident irradiation dose shall cover the dose received during a loss-of-coolant accident (LOCA). The calculation of this dose is dealt within the Annex. If the equipment has to accomplish its safety function during the post-accident period, a post-accident irradiation dose shall be considered.

As regards DECs, including severe accidents, the accident irradiation dose shall be calculated for each equipment to be qualified, taken into account its location and the duration of its mission during the accident.

An estimate of the β dose is necessary when organic materials are directly exposed to contaminated steam or coolant or if their protection is not sufficient.

It is convenient to simulate the effects of a β dose by an identical γ dose. This is conservative, because it covers the effects of the weak penetration of the β rays as well as the γ influence on the non-metallic parts. A less conservative approach could be used in the case of a severe accident with justification.

2.2.3.4

Accident thermodynamic test

This test is intended to verify the behaviour of the equipment when it is submitted to the pressure, temperature, humidity and chemical spraying caused by an accident.

The pressure and temperature test profile shall cover the values calculated for the accidents taken into account in the safety demonstration. A sufficient margin shall exist between the values calculated in the accident simulations and those of the qualification profile, because, if the equipment passes the test, it is not possible to know if it was close to its limits of operation during the test and thus if there exists a potential cliff-edge effect.

Some accidents lead to short-term overheated steam conditions. This overheat need not be simulated if the equipment mass is large enough, because the heat transfer occurs from steam condensating onto the equipment that is therefore at saturated conditions. However, some countries perform tests with superheated steam (e.g. for transmitters located inside the containment).

2.2.3.5

Post-accident test

The post-accident thermodynamic conditions are generally simulated by a humidity and/or flooding (immersion/submergence) test at increased temperature over a few days or weeks, occurring immediately after the thermodynamic test. The temperature of the test can be determined by using the Arrhenius method or by the10-degrees law by taking the same precautions as those given in § 2.2.2.1.

2.2.4
ACCEPTANCE CRITERIA

In general, to succeed in the test sequence, the equipment shall be able to perform each of its functions required for safety demonstration at the end and/or during each test and meet its design requirements. The good performance of these functions shall be checked and acceptance criteria shall be defined in the qualification specification for each sequence of the test. These criteria depend on the type of equipment (e.g. opening/closure for an isolation valve, insulation resistance for a cable…). Note that the separation between electrical channels/circuits is a requirement to be verified for the equipment performing it.

2.3 Preservation of qualification

The Licensee (or its delegate) must present his own assessment on the acceptability of the qualification. All boundary conditions for ensuring success must be documented, in order to be respected during the life of the equipment (procurement, installation, maintenance).

If the demonstrated PQL is shorter than the anticipated life, the equipment is formally inoperable after the PQL. Methods, so called on-going qualification (replacement of the component or of some of its parts by new one(s), tests on operating equipment taken from the plant…) are available to extend the qualified life. They are documented for electrical equipment in IEC/IEEE 60780 [3].

3 REVIEW PROCEDURE

3.1 Acceptance criteria at the safety analysis report level

3.1.1 THE SAFETY FUNCTIONS WHICH CAN BE CHALLENGED BY HARSH ENVIRONMENTS

The environmental qualification shall be assessed [12]. The reviewer should verify (in the safety analysis report (SAR)) that all equipment needed in order to detect, mitigate and monitor DBA and DEC taken into account in the safety demonstration is listed. This requires a comparison with the SAR sections identifying the postulated initiating events (PIEs) and the corresponding safety analyses. All the safety related equipment which is expected to be subject to harsh environment during its lifetime shall be qualified.

Particularly, the main steam and feedwater isolation valves shall be qualified to the ambient conditions in pressure, temperature, accident spraying and humidity of the main steam and feedwater compartments.

The components of the emergency core cooling and the post-accident containment heat removal lines recirculating primary fluid outside the containment shall be qualified to the internal loadings due to the LOCA (pressure, temperature, radiation, debris generated by the LOCA).

The active or passive components which are part of the second and the third barriers shall be leak-tight in accident situations.

The reviewer should check the completeness of the list of analysed PIEs and of the list of equipment subject to qualification.

3.1.2 THE NORMAL AND ABNORMAL ENVIRONMENTAL CONDITIONS FOR EACH LOCATION

Normal environmental conditions are used to provide data for the ageing tests. The abnormal environmental conditions are used to provide data for the test at the limits of operational conditions.

The reviewer should verify (in the SAR) that the plant buildings and rooms are identified, and that a range of normal and abnormal conditions are defined for each of them. Abnormal conditions means conditions that can be reached for example in case of failures in the ventilation system (extreme temperatures and humidity). In case of fuel leakage, abnormal radiation conditions could also occur.

The radiation conditions should be linked to a set of assumptions relative to the fuel leakage.

The humidity range is also an element influencing the EQ.

3.1.3

HARSH ENVIRONMENTS PARAMETERS

The reviewer should verify that the environmental conditions obtained after the PIEs that release high energy are identified in the SAR for each building of the plant. It must be verified that a margin is included in the qualification profile for pressure and temperature compared to the safety analyses. The qualification profile shall reflect the fast changing environmental conditions in the first minutes of the transients, as well as the long term environmental conditions (conventional value of one year). A logarithmic scale is appropriate for this purpose.

The chemical parameters should be coherent with the solutions proposed for the control of iodine, of steel corrosion, etc.

The radiation dose is addressed in the Annex. It must be verified that a margin is included in the accident radiation dose compared to the safety analyses.

Such information should be available, apart from the containment building, for all rooms where high-energy-line breaks are postulated (main steam and feedwater lines outside the primary containment) or where the environmental conditions can be degraded (spent fuel pool building).

The reviewer should verify the relevance of the approaches to establish the qualification requirements for harsh environmental conditions. The verification and validation of thermal-hydraulic codes used to assess these conditions should be checked.

3.2 Acceptance criteria at the documentation level

It is required to check - at least by sampling - the quality of Qualification Files. It is indeed important to verify that the principles stated in the SAR are applied in practice.

A good practice is to group the pieces of equipment to be qualified into families of components according to their type (motors, sensors…). Each family is covered by a specific EQ qualification programme, which can be documented in a corresponding Qualification File.

Another good practice is to provide a summary of the content of each Qualification File, so called a qualification synthesis report (QSR). This summary should present the specifications of qualification, list the tests and analyses performed to qualify the component or the family of components and their results, list the documents of the qualification file and provide prescriptions for the preservation of the qualification of the equipment during its PQL.

The reviewer should be given access to the complete list of qualification files, including all test protocols. Being technology dependent, such a list is not included in the SAR.

3.2.1

REVIEW PROCEDURE OF A QSR

The reviewer should understand the functional role(s) of the equipment or the equipment family covered by the QSR and its safety role.

The QSR must be available, and checked for completeness. If necessary, access should be asked for the relevant elements of the Qualification File (report of tests and analyses).

It is extremely important that technical acceptance criteria are identified before performance of the tests. Some of them may have to be used in other parts of the safety assessment (example: drifts of instrumentation used in harsh conditions). Other criteria are necessary to ensure the compatibility of different elements of a functional channel/circuit (example: lowest resistance in harsh conditions).

Hereafter are highlighted the major elements expected to be present in those summaries for electrical equipment, and some of the features that a reviewer may want to check. Explanations are given in the next section: This table is an example and its content is not exhaustive.

Item	Expected information (typical)	Critical aspect to be assessed
Material identification	Function, family, model(s)	
Qualification Responsible	Society (not a person)	
Specifications:		
Localisation	Building and Room(s)	
Conditions and service life	Operation request during and/or after an earthquake, and for a specified period after a PIE (DBA, DEC)	
Normal design environnement	Temperature range, humidity, dose or dose rate	
Tests at the limits of operational conditions	■ Limits of voltage, frequency ■ Electromagnetic interference ■ Extreme temperatures in normal operation ■ Humidity ■ Dust ■ Water	
Reference Accident Environment	Envelope P, T, irradiation with post-accident	
Earthquakes	Spectra TRS and RRS	Does the TRS envelop the RRS?
Acceptation criteria:		
Normal or degraded environment	Accuracy	
Accident environment	Accuracy during and after accident	
Seismic	No relay chatter, operation of pumps, valves, transmitters, integrity of pressure components,	

Item	Expected information (typical)	Critical aspect to be assessed
Qualification method:		
Programme type	Sequence on 1 or several samples	
Accelerated thermal ageing	Arrhenius method with justified activation energy (AE), or 10-degrees law	Is the AE enough conservative? Are all heat sources considered for equipment with internal heat generation? The factor of acceleration should be low enough for the test to be representative
Prolonged operation Mechanical fatigue	Number of simulation cycles	Is the number of cycles sufficiently bounding in comparison with the one which is expected during its PQL?
Vibration ageing	Amplitude and frequency of vibrations	Vibration is considered as ageing factor. Vibration induced by hydrodynamic loads (transient) has to be taken into account to define ageing test sequence.
Irradiation ageing	Total dose, dose rate	Total dose including a sufficient margin in comparison with the one which is expected during its PQL? Dose rate for simulation of operation radiation ageing low enough (dose in 2 weeks at least), oxygen concentration…
Earthquake	Monoaxial, biaxial or triaxial testing; multi- and/or single-frequency wave modes	
Accident irradiation test	Total dose, dose rate	Total dose sufficiently conservative in comparison with the one which is expected during the accident?
Accident thermodynamic test	Testing in a pressure vessel	
Post-accident test	Arrhenius method with justified activation energy (AE) or 10-degrees law	The factor of acceleration should be low enough to be representative
Reference qualification file	Precise identification, localisation	
Qualification evaluation	Licensee positive statement, together with related conditions	Are regular replacements of parts needed?

3.2.2
SAMPLE VERIFICATION OF QUALIFICATION FILES

The reviewer should check that qualification summaries are consistent with qualification files. In practice, this can be verified for a sample (e.g. selected at random) of qualification files among the families of equipment to be qualified for harsh environment, in order to compare their content with the summary.

Experience shows that the following issues require particular vigilance for equipment subject to harsh environment qualification:

- was the complete sequence applied to every sample equipment?
- accelerated ageing is needed to define the PQL. A large AE (>1 eV) increases exponentially the apparent PQL (more years for less testing time). If the activation energy is unknown, a value of 0.8 eV is generally considered as conservative for organic materials. The 10-degrees law can also be used in case of lack of information;
- the acceleration depends on the difference between the test temperature and the real temperature. Use of ambient temperature is not acceptable for equipment with internal heat generation (solenoid valve in so-called "fail-safe" applications, running motor, power cable …);
- no critical maintenance should be performed during the test sequence (irradiated parts must remain…);
- how was the behaviour verified? Minimal resistance, absence of excessive loss of contact, drifts, stability… compare with acceptance criteria given in the specification of qualification.

A difficult case is the approval of equipment already qualified according to foreign rules. As those rules can be different, it would be in principle impossible to pronounce the qualification of this equipment without justification. This problem, and suggested resolution approach, has been addressed for electrical and I&C equipment in the work of a group of European experts [3].

3.3 Witnessing of tests

A good practice is to witness the critical parts of a test sequence (for example the first hours of the pressure shock). A few reasons to do this are the following:

- it provides a strong assurance of the overall quality: is the laboratory certified? Is the recording equipment well selected?
- it allows a check of acceptability of minor deviations compared to the qualification test procedure;
- it permits a hands-on verification of absence of non-representative configurations (for example a drain open to atmosphere, the absence of pressure difference along a cable);
- it affords unique training for the reviewer, who will see the real behaviour of equipment in accident conditions.

4 DOCUMENTATION OF REVIEW FINDINGS

Ideally, the reviewer should be able to confirm and document that:

- the SAR is complete and accurate regarding equipment qualification;
- a QSR has been written for each family of equipment subjected to harsh environment qualification;
- a sample of complete files has been audited;
- some tests have been witnessed.

5 REFERENCES

- [1] IAEA Safety Report Series n° 3 “Equipment qualification in operational Nuclear Power Plants - Upgrading, preserving and reviewing”, (1998)
- [2] INTERNATIONAL ATOMIC ENERGY AGENCY, “Safety of Nuclear Power Plants: Design”, IAEA Safety Standards Series No. SSR-2/1, IAEA, Vienna (2012)
- [3] IEC/IEEE 60780-323, February 2016 “Nuclear facilities - Electrical equipment important to safety - Qualification”
- [4] KTA 3504 “Electrical Drive Mechanisms of the Safety System in Nuclear Power Plants”, (2006)
- [5] KTA 3505 “Type Testing of Measuring Sensors and Transducers of the Safety-Related Instrumentation and Control System”, (2005)
- [6] RCC-E “Design and construction rules for electrical equipment of PWR nuclear islands”
- [7] ANSI/IEC 60529-2004 “Degrees of Protection Provided by Enclosures (IP Code)”
- [8] EUR 17563 “Guideline for the evaluation of European practices on the harsh environment qualification of electrical and I&C equipment”, (1998)
- [9] EUR 16246 “A comparison of European practices for the qualification of Electrical and I&C equipment important to safety for European LWRs”, (1996)
- [10] IEC 60980 ed1.0 “Recommended practices for seismic qualification of electrical equipment of the safety system for nuclear generating stations (1989-06)”
- [11] IEEE Standard 344 “Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations”, (2004)
- [12] INTERNATIONAL ATOMIC ENERGY AGENCY, “Safety Assessment for Facilities and Activities” GSR Part 4 rev. 1, IAEA, Vienna (2016)

APPENDIX

QUALIFICATION IRRADIATION DOSE

DOSE USED FOR RADIATION AGEING

The tested samples shall be submitted to an irradiation representative of the irradiation they are submitted to during their PQL. Care should be taken of the effect of the absorbed dose rate: the actual absorbed dose rates in the containment can be more harmful that the much higher absorbed dose rates used to accelerate the test of irradiation ageing. The French practice takes this into account by using a dose test equal to 4 times the maximal dose expected in operation during the installed life and using a limited dose rate (1 kGy/h) to take into consideration oxidation and gaseous diffusion effects during the test as well as the dispersion of the fabrication of the tested pieces of equipment.

ACCIDENT IRRADIATION DOSE

The irradiation dose must be the sum of the expected value during the PQL, plus an estimate of the dose caused by the accident, integrated for the duration of the mission of the component or of the equipment to be qualified.

The accident radiation dose raises a special problem because the accident analysis does not provide those figures.

Many countries add conservatism by postulating that the integrated dose possible after the major PIEs is the one following a core melt without vessel breach. While a value of 200 Mrad (2 MGy) has been used in the 60's, it is extremely demanding for organic materials. Some country prefer to make a case by case more realistic dose calculation, considering factors like the time phasing of releases, shielding, etc. An order of magnitude of 650 kGy has been found representative of the accident γ dose in the middle of a PWR large containment in Belgium.

In France, the accident radiation is calculated considering the rupture of 100% of the fuel rods after a large break LOCA. The accident radiation dose is calculated taking into account the area where the component is located (annular area or central area) and the duration of its mission. The resulting dose for a component located in the central area of the containment and used in the long term is 500 kGy.

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