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Qualification guidelines

Qualification guidelines

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QUALIFICATION Guidelines

Table of Contents

QUALIFICATION Guidelines

1 Purpose

The purpose of this document is to define the guidelines for the qualification of ITER Protection Important Classified (PIC) components in order to demonstrate and document the ability of equipment to perform safety function(s) under applicable service conditions from normal operations to accident conditions and their combinations [1].

2 Scope

The scope of this document is:

- to briefly recall the safety functions of ITER and the safety classification and relevant implications of which qualification is one important aspect
- to define the ITER guidelines to qualify a PIC component in order to warranty the safety function at any time, including at the end of ITER life too and in normal, abnormal and accident conditions when the safety function is necessary to bring and maintain the plant into a safe status.

This document refers as much as possible to existing qualifications programs for other nuclear facilities (e.g. nuclear power plants) in order to adopt standardised equipment that have been used for decades in those facilities. Nevertheless, the specific differences between ITER and these other nuclear facilities have to be reflected also in the qualification programme of the PIC equipment.

3 Definitions

For a complete list of ITER abbreviations see [2]

AH	Additional Heating
ASN	Autorité de Sureté Nucléaire
EMI	Electro-Magnetic Interference
EQ	Equipment Qualification
GP	Group Permanent
ISI	In Service Inspection
NPPs	Nuclear Power Plants
RCC-E	Règles de Conception et de Construction des matériels Electriques des îlots nucléaires
RPrS	Rapport préliminaire de sûreté
SIC	Safety Important Classified
SSC	Structures, Systems and Components

The following definitions of terms are derived from standards relevant to qualification of components in nuclear facilities and are there also applicable to ITER components qualification.

a. Active Components: any component characterized by a change in state, or by mechanical motion, to perform an automatic safety function.

b. Aging: the effects of operational, environmental and system conditions on equipment

during a period of time up to, but not including, seismic and emergency events or the process of simulating these events.

c. Analysis: a process of mathematical or other logical reasoning that leads from stated premises to a conclusion concerning specific capabilities of equipment and its adequacy for a particular application.

d. Age Conditioning: exposure of sample equipment to environmental, operational, and system conditions to simulate these conditions for a period of time; seismic and accidental events are not included.

e. Cliff edge effect : a sudden large variation in plant conditions in response to a small variation in an input

f. Common Mode Failure: multiple failures attributable to a common cause.

g. Components: Items from which the equipment is assembled, e.g., resistors, capacitors, wires, connectors, transistors, tubes, switches, and springs.

h. Event for qualification: the events, enveloping the expected external and internal events taken as reference into the design of structures, systems and components devoted to bring and maintain the plant into a safe status

i. Design Life: the time period during which satisfactory performance can be expected for a specific set of service conditions.

j. Equipment: an assembly of components designed and manufactured to perform specific functions.

k. Equipment Qualification: the generation and maintenance of evidence to ensure that equipment will operate on demand to meet system performance requirements during normal and event (seismic and accidental) conditions.

l. Harsh Environment: an environment, which experiences a significant increase in pressure, temperature, and humidity, or reduction of temperature and pressure because of an accident or is predicted to experience a significant total integrated dose (TID) (e.g. greater than 1-100 Gray depending on the specific electronic or electrical equipment respectively). It is defined as K1 in RCC-E.

m. Margin: the difference between service conditions and the conditions used for equipment qualification.

n. Mild Environment: 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. Any area that is not a harsh environment is a mild environment. It is defined as K2 (inside the containment) and K3 (outside) in RCC-E.

o. Qualified Life: the period of time prior to the start of a seismic and accidental event for which the equipment was demonstrated to meet the design requirements for the specified service conditions.

p. Safe status: a status where the plasma is off, the confinement function is ensured, the temperatures are under control and going down, the radioactive releases are small and reducing with the time.

q. Safety function: the function, identified in the safety analysis, requested to the equipment in order to bring and maintain the plant into a safe status

r. Service Conditions: environmental, loading, power, and signal conditions expected as

QUALIFICATION Guidelines

a result of normal operating requirements and postulated conditions appropriate for the events of the station.

s. Significant Aging Mechanism: an aging mechanism that, under normal service conditions, causes degradation of equipment that progressively and appreciably renders the equipment vulnerable to failure to perform its safety function(s) during the event conditions.

t. Type Tests: tests made on one or more equipment samples to verify the adequacy of the design and manufacturing processes.

4 Qualification Safety objectives

4.1 Introduction

Qualification of components used in the safety demonstration is a key parameter in order to prove that the components will ensure their safety function in all the normal, incidental or accidental situations for which their use is required.

The qualification needs are reminded in the project requirements :

- "*Design verification by qualification testing shall be performed as early as possible and prior to the point when related system, structures, and/or components are installed. [PR1541-R]*"
- *If performance of a related component has not been verified due to application of a new design concept, then the qualification test by model test under conditions that simulate the most adverse design conditions shall be used as the design verification method for the component. Qualification testing to verify the acceptability of a specific design will be conducted in accordance with approved procedures that address, at a minimum:*
    - *Use of adequate instrumentation*
    - *Provisions for test monitoring*
    - *Specification of suitable environmental conditions*
    - *Delineation of test prerequisites, such as calibrated instrumentation, appropriate equipment, trained personnel, and data acquisition equipment*
    - *Demonstration of acceptable performance under conditions that simulate the appropriate adverse design conditions*
    - *Delineation of performance specifications, including acceptable deviations from baseline (or mean) benchmarks.*
- *--- [PR1549-R]*

From a derivation of this project requirements, this guideline outlines the methods for equipment qualification when it is requested to qualify PIC equipment for the applications and the environments to which it may be exposed in providing its safety function.
Qualification is the process of generation and maintenance of evidence to ensure that equipment will operate on demand to meet system performance requirements (safety function) during normal and abnormal service conditions and postulated accidental situations.

The accident is considered to happen conservatively the last day of ITER operation life when the PIC equipment is aged.

The present qualification guideline is focussed on the way to perform a safety function in harsh and/or mild environments for the different types of components: electro-mechanical, electric and electronic equipment as well as for mechanical equipment.

4.2 Situations and environment for qualification

All normal, incidental or accidental situations, and their combinations are able to create loads and stresses on a component ensuring its function. To demonstrate that the safety function is fulfilled, it is needed to demonstrate that the component will continue to operate (*) properly during and after the event.

The events for qualification are:

- Normal conditions (normal conditions include all loads as pressure, temperature, humidity, radiological doses, magnetic field during the expected lifetime of the components) and the relevant aging on each specific component
- Incidental events (cat II),
- Design basis events (categories III and IV),
- Beyond design basis events (cat V) for which their failure can create a cliff edge effect.

In addition, in order to cover stress tests situations, the hard core components [26] that were used and identified in the safety demonstration for obtaining the license (they are called existing situations) have to be verified against stress tests situations [28]. The hard core components that have been implemented or modified after obtaining the license will have to be qualified against stress tests situations [28]. The methodology is identified in [27].

The term *event for qualification* has been generally used instead of the acronyms DBE, DBA, LOCA, LOVA, Loss of He, etc. as well as Seismic event (SL-II) in order to reduce the complexity of the text.

An important concept in equipment qualification is the recognition that significant degradation could be caused by aging mechanisms occurring from the environments during the service life, and therefore PIC electric equipment should be in a state of degradation prior to imposing *event for qualification* simulations.

(*) To be noted that "operate" meaning does not necessarily mean that the component will work in the same conditions than in the nominal conditions, but that he will ensure the function that is required in those conditions. An example could be some fluid systems for which only the maintaining of the integrity is required for specific situations, while their full operation (including the pumping system) would be required for other situations.

The situations that have been studied have been described in the project requirements [1], RPrS [2] and the loads specifications [3].

The knowledge of all normal, incidental or accidental situations in which each safety function is required will allow to provide the full range of environmental conditions for this function and for the affected building and structures. The instrumentation required to diagnose the conditions prevailing during an abnormal event is subject to qualification requirements taking account of the environmental conditions it may have suffered before reaching these conditions.

QUALIFICATION Guidelines

Each function is characterised by a bounding environmental conditions and by an operating time for which they are required.

The environment in which the components have to operate have been summarised in the safety requirement roombook [4].

Degradation with time followed by exposure to environmental extremes of temperature, pressure, humidity, radiation, vibration and, if applicable, magnetic field, low temperatures and submergence resulting from a design basis accident conditions can generate common-cause failures of PIC equipment. For this reason, it is necessary to establish a qualified life for equipment with significant aging mechanisms. The qualified life determination must consider degradation of equipment capability prior to and during service. This qualified condition is the state of degradation for which successful performance during a subsequent *event for qualification* was demonstrated.

Details are reported in the relevant standards and guides [4-10].

Harsh environment in ITER can be found in:

- Most of the tokamak building areas (11)
- Some areas of the Hot Cell and Radwaste (21 and 23) due to high radiation dose rates or and high temperatures

Mild environment in ITER is in the following buildings:

- 11: Tokamak (only in limited areas)
- 21: Hot Cell only in some areas
- 23 Radwaste only in some areas
- 24: PAC
- 14: Tritium
- 74: Diagnostics
- 71, 24: Control building-main control room and emergency control room
- 42, 43, 44, 45, 57, 58: Electrical buildings with PIC equipment
- 75: TF-FDU resistors building
- All the other buildings hosting components not classified PIC

4.3 PIC components qualification objectives

ITER has two main fundamental safety functions: confinement of radioactive inventories and limitation of personnel exposure (radiation protection).

The purpose of qualification is to prove that the equipment is suitable for its function subject to the stresses which arise following accidents in which it must function.

The primary objective of qualification is then to demonstrate with reasonable assurance that the PIC equipment for which a qualified life or condition has been established can perform its safety function(s) without experiencing common-cause failures before, during, and after applicable *events for qualification*.

QUALIFICATION Guidelines

The equipment, with its interfaces, must meet or exceed the equipment specification requirements. This continued capability is ensured through a program that includes, but is not limited to, design control, quality control, qualification, installation, maintenance, periodic testing / in service inspection, and surveillance. The focus of this guideline is on qualification, although it affects the other parts of the program.

The pre-ageing phase before the application of an *event for qualification* conditions is required all times for equipment located in a harsh environment.

In a mild environment the dominant *event for qualification* is generally the seismic event, but this would need to be checked for each component.

The pre-ageing phase before the application of *event for qualification* conditions could be avoided if through a detailed analysis it is possible to demonstrate that the specific equipment meet all over ITER life its functional requirements during normal environmental conditions and anticipated operational occurrences (specified in the design/ purchase specifications). In other words it should be demonstrated that the equipment (specific part or material) will not be aged at the end of ITER life. Otherwise the pre-ageing phase is necessary [4].

A maintenance/surveillance program based on vendor's recommendations and on the specific operation in ITER, which may be supplemented with operating experience, should ensure that equipment meets the specified requirements.

4.4 Qualification elements

The essential elements of equipment qualification include the following:

a) Equipment specification including definition of the safety function(s)
b) Acceptance criteria
c) Description of the service conditions, including applicable *events for qualification* and the duration of the accidental conditions [10]
d) Qualification program plan
e) Implementation of the plan
f) Documentation demonstrating successful qualification, including maintenance activities required to maintain qualification. The equipment user is responsible for specifying performance requirements and verifying that the documentation demonstrates that the requirements have been satisfied.

4.5 Qualification documentation

For all equipment, compliance with the requirements is confirmed via a set of documents. These are produced during the qualification process or implemented at the end of the qualification process to ensure sustainability in manufacturing, installation and operation.

The result of a qualification program shall be documented into a qualification report, associated to each PIC equipment, to demonstrate the equipment's ability to perform its safety function(s) during its qualified life and applicable accidental situations. The documentation shall allow verification by personnel of DA, IO and ASN that the equipment is qualified.

EQ files should contain summary information:

- Equipment being qualified: procurement specification (required functions and service conditions included), the model equipment identification file
- Qualification file
  - the general qualification specification for a category of equipment, and the special qualification specification for specific equipment in a given category,
  - qualification procedures,

- relevant MIP, installation, maintenance, inspection and test procedures
- (qualification) test reports, calculation and analysis sheets (dependent on the qualification method used), qualification results, conclusions and limitations,
- the qualification summary note. This gives the qualification of the equipment with or without reservations. If reservations exist, the change request process is triggered,
- replacement activities necessary for qualification and its up-keeping (if any).

Also included are documents to ensure that the qualification is maintained during manufacturing, transportation, installation and operation, such as:

- the sustainability document of qualified equipment,
- the reference file (this document is available from the manufacturer),
- the list of instructions to maintain qualification,
- the reports allocating a supply category to replacement parts.

In general, the equipment qualification report ensures that all the components in the systems fulfilling a classified safety function are qualified for the conditions in which they are required to operate. The report indicates the state of the equipment qualification, by referencing the documents which have enabled qualification to be achieved, and the change files in the event of qualification with reservations.

4.6 Qualification Standards

International Standards on qualification adopted as reference in ITER are reported in the references [4-10]. ITER recommends the following ones as much as possible:

- RCCs, specifically RCCS-E 2012 Vol.B (France) for electrical components,
- IEC 60780 for environmental qualification
- IEC 60980 for seismic qualification.
- NF 64 001 for electrical components submitted to harsh environment without magnetic fields

Other well-known EQ standards are:

- IEEE (United States)
- KTA (Germany)

These standards are tailored to the qualification of NPPs, therefore the application to ITER needs some adaptation to its specific environmental conditions.

Among these, for electrical components, the recommended standard to use as reference is the RCC-E volume B (Qualification) [4].

The RCC-E [4] defines the qualification practices adopted in France for NPPs to be taken as a basic solution.

ITER specific environmental conditions [10] and ITER specific safety functions [2, 3] have to be taken as reference.

Other practices not covered in the RCC-E might be used under the condition that an alternative is considered as proven throughout the nuclear industry and project data is respected. This alternative shall thus conform to the rule drawn up in IEC 60780 [6] in terms of procedures and methods to be used.

A useful reference is also IEEE-323-2003 [7] and analogous KTA standards.

Several other standards are relevant to specific qualification step: seismic, ageing, accident conditions, magnetic field, EMI (see appendix D for the last two qualifications).

QUALIFICATION Guidelines

Several qualification methods may be applicable and acceptable. Postulated initiating events, operational conditions, size and aging are factors which determine the method to be used to assure proper qualification. Each method requires justification in order to assure acceptability.

Equipment is generally qualified by a combination of methods summarised below. Details are reported in the relevant standards [4-10].

5 Qualification programme

5.1 Qualification methods

The methods/procedures given hereinafter are to be considered as a reference. The Suppliers might propose a different programme (subject to IO approval), provided it fulfils the requirements given in the relevant codes and standards.

Qualification can, in principle, be performed:

- By testing,
- By calculation or analysis,
- By operating experience,
- By ongoing qualification
- By mixed methods.

5.1.1 Qualification by testing

This consists of submitting to an equipment strictly representing the equipment installed in the facility, to loads representative of the operating conditions in which it must fulfil its safety function.

The qualification tests are conducted independently of each other and according to a sequence which best represents the operating conditions in which the component shall fulfil its function.

A type test subjects a representative sample of equipment, including interfaces, to a series of tests, simulating the effects of significant aging mechanisms during normal operation.

The same sample is subsequently subjected to *event for qualification* testing that simulates and thereby establishes the tested configuration for installed equipment service, including mounting, orientation, interfaces, conduit sealing, and expected environments.

A successful type test demonstrates that the equipment can perform the intended safety function(s) for the required operating time before, during, and/or following the *event for qualification*, as appropriate. This method shall be preferentially used for equipment submitted to a single loads or to successive loads (successive in time).

5.1.2 Qualification by calculation and analyses

Qualification by analysis and calculations requires a logical assessment or a valid mathematical model of the equipment to be qualified. The bases for analysis typically include physical laws of nature, results of test data, operating experience, and condition indicators. Analysis of data and tests for material properties, equipment rating, and environmental tolerance can be used to demonstrate qualification. However, analysis alone cannot be used to demonstrate qualification for PIC/SIC-1 components.

Qualification by calculation consists of demonstrating that the loads on the component have consequences on the equipment that are acceptable.

This method is notably used when an accident is creating cumulative loads that cannot be represented in a test facility.

For example, an analysis would be performed to demonstrate the adequate qualification of a component submitted to a fire following an earthquake, provided that

- The component would be initially tested for fire conditions,
- The same component would be initially tested for earthquake conditions,
- The fire protection of the component would be calculated as resistant to earthquake conditions.

This method can only be used if:

- the loads have been estimated sufficiently conservatively,
- the calculation models are representative,
- the calculation methods or codes used are valid.

For example, qualification of the valves for pipe whipping events mainly uses analysis, as this can determine the mechanical forces imposed on the valve and the properties of the fluid passing through it.

5.1.3 Qualification by operating experience

Qualification by operating experience consists of deducing the equipment ability to carry out its safety functions, by analysing past history of equipment in industrial operation.

To ensure qualification, operating experience must meet the following conditions:

- the operated equipment must be identical to or sufficiently representative of the equipment to be qualified,
- the operating time must be sufficiently long,
- the service conditions during operation must be at least as harsh as those which will be experienced in the plant,
- the documentation accompanying the operating experience must be sufficiently accurate and detailed to justify the behaviour of the operated equipment.

Performance data from equipment of similar design (e.g. NPPs) that has successfully operated under known service conditions may be used in qualifying other equipment to equal or less severe conditions. Applicability of this data depends on the adequacy of documentation establishing past service conditions, equipment performance, and similarity against the equipment to be qualified and upon which operating experience exists.

A demonstration of required operability during applicable *event for qualification* shall be included in equipment qualification programs based on operating experience, when this qualification is required.

This method can be adopted for extension of the qualified life, for re-assessing the initial qualification considering the feedback from the operating experience (e.g. different rates of ageing factors, etc.).

The standards [4, 5, 6, 7] provide elements where this method can be adopted and how.

Practically, this method is usually used to complete and confirm the behaviour of a component, whose equipment qualification is demonstrated using other methods.

This method is implicitly used for a series production related to a qualified model, when the manufacturer undertake the series production of the equipment in accordance with the qualified model.

QUALIFICATION Guidelines

Conformance with the qualified model shall be maintained and demonstrated throughout the series production period.

As an example, an HEPA filter used widely in all nuclear facilities to maintain the confinement function against radioactive or toxic aerosols is qualified by the manufacturer selling the off-the-shell products but IO shall always be able to prove that the filter has been properly qualified under the environmental conditions, that a certification laboratory has validated the performances and that the operating experience is still valid for all IO operation.

5.1.4 Ongoing qualification, operating experience, extension of qualified life

This method can be adopted for extension of the qualified life, for re-assessing the initial qualification considering the feedback from the operating experience (e.g. different rates of ageing factors, etc.).

The standards provide elements where this method can be adopted and how.

5.1.5 Combined qualification methods

Combinations of the methods presented above can sometimes be used. These combinations vary according to the equipment under consideration. Equipment may be qualified by combinations of type test, operating experience, and analysis. For example, where type test of a complete assembly is not possible, component testing supplemented by analysis may be used.

In all cases, the equipment dealt with using one of the methods must comply with the corresponding conditions. The combined method must fully demonstrate the capability of the equipment to fulfil its safety function.

5.2 Equipment modifications during construction, transportation, installation or maintenance operations versus qualification up-keeping

Once qualification has been established by testing, analysis or a combined method, it provides documentary proof that sample equipment meets the safety requirements. It is then necessary to ensure that qualification requirements are maintained from equipment manufacturing to component end of life operation.

Each modification to the equipment or to the equipment specification made after the type test or after the beginning of the operating experience reporting period shall be assessed to determine its effect on the equipment qualification. This analysis shall indicate whether or not complete requalification is required. If not, the analysis or the data and the evaluation that demonstrates the effect of the modification on equipment performance shall be added to the original qualification documentation.

<u>During manufacturing</u>

The manufacturing qualification process aims to ensure that:

QUALIFICATION Guidelines

- the supplier is able to produce equipment compliant with the requirements derived for equipment qualification,
- conformity is maintained over time for as long as it is necessary to manufacture mass-produced equipment and replacement parts.

The principal provisions are based on:

- selection of potential product suppliers prior to notification of supply contracts. For a given product, this means choosing the supplier able to meet the needs expressed. It starts with a market survey of the suppliers. For each potential supplier, selection includes an examination of the capabilities of the company and the ability of the product to meet the requirements. This process leads to a contract being signed with the selected supplier,
- creation and maintenance of a reference file by the supplier.. This contractual requirement takes effect prior to the end of the qualification procedure. This file describes the manufacturing procedures used to ensure that the equipment manufactured complies with the qualification requirements and to control developments,
- implementation of a process to manage changes and to examine their effect on the equipment qualification requirements.

<u>During transportation, installation or maintenance situations</u>

The qualification maintenance process during transportation, installation and maintenance activities aims to ensure that qualification of the equipment is maintained and not compromised by inadequate installation:

- during the first installation on site, or for subsequent installations,
- during maintenance activities throughout operation (maintenance, periodic inspections, part replacements).

The principal provisions are based on:

- once the initial qualification is undertaken, issuance of a sustainability document for the qualified equipment. The aim of this document is to indicate to the installation contractor and to the plant operator the instructions arising directly from the qualification process and complements the installation standards and best practices,
- application of transportation procedures that incorporate the qualification requirements.
- application on site of installation procedures and of maintenance instructions that incorporate the qualification requirements.
- preparation of work on site and training of workers must take full account of all equipment qualification requirements.
- control of procurement and storage conditions of equipment and replacement parts, with allocation of a category compliant with their impact on the function qualified.
- analysis of feedback from other facilities using this component, with a detection and analysis process to identify non-conformities with the equipment qualification requirements.
- sustainability of suppliers of goods and services and management of obsolescence.

QUALIFICATION Guidelines

5.3 Specific qualification conditions

For a component submitted to several loads altogether, the components have to be qualified for all loads, but since it is difficult to test a component for all loads altogether in a single facility, then the component shall be qualified for each single loads with a specific margin, provided that it is the SAME component that is exposed subsequently to all the loads.

5.3.1 Ageing

The assessment and simulation of aging effects constitutes an important part of qualification procedures, as it ensures that, when needed, the equipment is "aged" by an accelerated but realistic ageing process before submitting it to type tests and/or accident conditions (e.g. using an Arrhenius law such as the 10C rule).

According to IEC 60780 definition, ageing is a "change with the passage of time of physical, chemical or electrical properties of a component or equipment under design range operating conditions, which may result in degradation of significant performance characteristics".

During the design life of components, it is likely that some of the non-metallic components will require replacement due to aging.

The equipment under qualification needs to be analysed in all its components with respect to ageing factors such as

- Operational requirements foreseen during the life considering the planned maintenance and test (e.g. replacement of part after a certain number of cycles)
- Normal environmental conditions of the specific installation area [10] such as
    - Radiation
    - Temperature, pressure humidity,
    - Vibration
    - Magnetic field and the derivative one
    - EMI
    - Effects from other systems and operational events such as plasma disruptions, reflection of AH power

5.3.2 Accidental conditions

Accidental conditions due to DBE such as

- Seismic event
- Temperature, pressure, humidity
- Fire (when applicable)

To be noted that, differently from NPPs, in ITER the radiation dose rate and integrated dose during accident conditions are not significant [10]. Also chemical spray is not considered/applicable.

The DBA conditions have to be considered once.

Standards provide the details, e.g. for the seismic qualification one SL-II event following 5 SL-I events.

5.3.3 Electronic Equipment

New digital systems and new advanced analog systems may be sensible to neutron flux also at low level as well as to magnetic field and EMI/ RFI and power surges, if the environments are significant to the equipment being qualified.

ITER policy is to locate these equipment in protected areas as much as possible.

Furthermore, since hardwire instrument and control (I&C) systems are less vulnerable and have the benefit of successful operation under nuclear power plant EMI/RFI and power surge environments, qualification to nuclear flux, to EMI/RFI and power surges might not be necessary in environmental equipment qualification. Relevant references are [4-11]

5.3.4 Mechanical equipment

Electrical equipment is more sensitive than mechanical equipment to accident conditions and related ageing mechanisms.
Mechanical equipment characteristics that contribute to its greater environmental tolerance are:

- Some types of mechanical equipment (e.g. valves and pumps) are designed and exposed to normal process service conditions that are generally more severe than accident environmental conditions.
- Normal operation of mechanical equipment, combined with fabrication, preoperational and periodic tests, demonstrates performance under these normal service conditions.
- Mechanical equipment is principally fabricated of metallic components that are virtually unaffected by radiation and LOCA type environmental conditions.
- Mechanical equipment can remain functional after degradation of certain non-metallic components (e.g. seals, gaskets, packing).
- For pressure boundary components, application of codes and standards demonstrates suitability for normal and accident service conditions.

The specificity of ITER environmental conditions such as Magnetic Field and low temperatures in case of loss of He, has to be considered for the qualification of mechanical equipment.

5.3.5 Seismic qualification

Seismic qualification generally includes both structural integrity and operability/functional capability.
Qualification by analysis restricted to:

- structural integrity (cabinets, fixture points, metallic components)
- simple systems (e.g. check valves)

Qualification by testing

- most frequently used seismic EQ method
- possibility to verify functional requirements
- complex specimens can be tested (limited by the size)
- seismic simulation on vibration/shake tables

5.3.6 Sequence of events for the qualification

Appendix A summarises the process of qualification from input data through the qualification process till the documentation demonstrating the qualification and the relevant conditions, e.g. installation and maintenance, and limitations.

Appendixes B and C report the specific sequence recommended for harsh and mild environments.

Appendix D provides references for magnetic field and EMI qualification.

6 Summary

The qualification is an essential method to assure that the equipment will operate in demand, to meet the system performance requirements.

QUALIFICATION Guidelines

The qualification is important to eliminate several causes of common mode failure of redundant PIC systems.
PIC equipment should be properly qualified to ensure its capability to perform its safety functions under postulated service conditions, including those arising from external events and accidents (such as loss of coolant accidents, high energy line breaks and seismic or other vibration conditions) in a manner consistent with the safety classification [4, 6–8] in order to provide the required safety function.
A qualification procedure should be used to confirm that the equipment is capable of meeting, throughout its service life, the requirements for performing safety functions while subject to the environmental conditions prevailing at the time of need, with account taken of the ageing degradation of the equipment that occurs during service.
PIC classification level, severity of service conditions and equipment type determine appropriate qualification practices and methods.
French and international standards provide reference methods for qualification of PIC equipment in NPPs.
Such standards are applicable and adequate for ITER with the specific peculiarities of ITER in comparison with NPPs outlined in this document.

QUALIFICATION Guidelines

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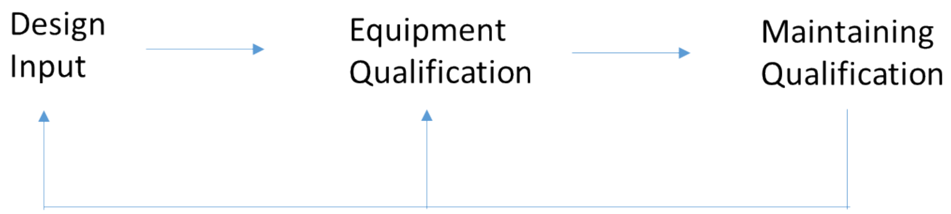
25. Report EUR 16246 EN – A comparison of European practices for the qualification of electrical and I & C equipment important to safety for European LWR power plant
26. Hard core components (PQR228)
27. Stress test detailed methodology (R5389R)
28. Natural external hards for hard core situations

QUALIFICATION Guidelines

Appendix A – Equipment Qualification Process Overview



- Safety functions
- Mission time
- Environmental conditions
- Load and service conditions

- Qualification criteria and requirements
- Qualification methods
- Perform qualification
- Define installation and maintenance procedures, conditions and limitations
- Qualification documentation

- Installation and maintenance control
- Replacements control (if any)
- Modification control
- Service condition monitoring
- Analysis of degradation and failures
- Operating experience feedback
- Training
- Documentation

QUALIFICATION Guidelines

Appendix B - Suggested sequence of tests for qualification in harsh environment (K1 in RCC-E)

During certain accidents, environmental conditions, operational conditions, or both may be significantly different than those occurring during normal operation and transient conditions.
Significant changes in service conditions create stresses that may result in equipment failures, particularly if the components have experienced in service degradation.
High temperature effects:

- Lower dielectric strength
- Lower insulation resistance
- Change semiconductor device characteristics
- Increase electronic circuit failure rates
- Melt certain thermoplastics
- Produce differential expansion
- Lower mechanical strength
- Increase chemical reaction rates (corrosion)

Low temperature effects:

- Making fragile structures
- Icing liquids challenging PIC function of components

High pressure effects:

- Crush or damage enclosures
- Force external environment into components
- Increase heat transfer under saturated steam conditions

Steam effects:

- Rapid heat transfer under saturated conditions
- Condensate (water) formation on surfaces
- Moisture permeation into polymers
- Swelling of certain polymers (aged)

Radiation - degrades properties of organic materials:

- Decrease elongation and tensile strength
- Brittleness in elastomers and rubbers
- Produces gases, some corrosive (HCl)

Radiation - produces semiconductor property changes (transient and permanent):

- Diodes - increase reverse current
- Bipolar - decrease gain, increase leakage current
- FET - increase junction and leakage currents
- MOS - effects vary, transient

Concurrent conditions (temperature, pressure, steam, radiation):

- Accelerate certain effects
- Produce new effects

This environmental qualification in harsh environment has to consider any ageing effects that result in degradation of PIC equipment failures below the design margins.
In this case recognized EQ methods, most often type testing, are necessary to demonstrate qualification.

QUALIFICATION Guidelines

Table B.1 (taken from RCC-E) provides the general qualification sequence to be followed in a harsh environment (called K1 in RCC-E). A detailed analysis supported by operating experience or/and tests might exclude some tests through an adequate justification.

Phase	Description	Reference
1	Reference tests	B 3200
	Electrical interface characteristic tests (dielectric strength, measurement of insulation resistance)	
	Measurement of functional characteristics	
2	Tests at the limits of operational usage	B 3300
	- relating to the type of equipment	
	- relating to the equipment's installation conditions (pressure and ambient temperature, electromagnetic environment, etc.)	
3	Assessment of behaviour over time	B 3400
	Thermal, mechanical and climatic mechanical tests	
	Prolonged operation test	
	Cumulative radiation during normal operation	B 5200
4	Tests representing constraints due to earthquakes and accident ambient conditions	
4a	Seismic resistance test	B 4200
4b	Cumulative radiation during an accident	B 6221
4b	Test under thermodynamic and chemical conditions	B 6222

Table B.1 - Test procedure phases for category K1 equipment

QUALIFICATION Guidelines

To be noted the difference of ITER environmental conditions in comparison to NPP: equipment located in tokamak building (K1 in RCC-E) requires normally qualification towards Magnetic Field. On the contrary chemical corrosion during and after an accident is not applicable to ITER as well as the radiation dose during an accident are almost negligible in ITER.

QUALIFICATION Guidelines

Appendix C - Suggested sequence of tests for qualification in a mild environment (K2 and K3 in RCC-E)

Environmental conditions in a nuclear plant location which does not significantly change as a result of DBE except for a seismic event.
General practices used to provide for required functionality of equipment in mild environment are:
- conservative design practices
- proven equipment designs
- manufacturing production tests
- pre-operational equipment and system tests
- appropriate QA controls during specification, manufacture, installation, testing, operation

Ageing can be a common-cause failure mechanism if the equipment reaches the wear-out phase.

"Bathtub" failure rate curve often describes failure rate of a component population.

In a mild environment objective is to replace the component population when failure rate information indicates the wear-out stage is occurring.

French standards [4] require environmental qualification programs for mild environment equipment too, through:
- reference tests;
- tests at the limits of operational usage;
- robustness tests and/or assessments of equipment behaviour over time.

Seismic and functional qualification is integrated into a structured equipment qualification program that is similar in principle to the program for harsh environment electrical equipment, but in practice simpler for the absence of few environmental parameters (e.g. the radiation, the accidental conditions but the seismic event).
Table C.1 reports the test qualification procedure phases for equipment in mild environment (K2 / K3 in RCC-E) for a NPP.
In ITER it has to be added the qualification towards magnetic field, on the contrary the radiation should be negligible.

QUALIFICATION Guidelines

Phase	Description	Reference
1	Reference tests	B 3200
	Electrical interface characteristic tests (dielectric strength, measurement of insulation resistance)	
	Measurement of functional characteristics	
2	Tests at the limits of operational usage	B 3300
	Relating to the type of equipment	
	Relating to the equipment's installation conditions (pressure and ambient temperature, electromagnetic environment, etc.)	
3	Assessment of behaviour over time	B 3400
	Thermal, mechanical and climatic mechanical tests	
	Prolonged operation test	
4	Tests representing constraints due to earthquakes and downgraded ambient conditions	
4a	Seismic resistance test	B 4200
4b	Test under downgraded ambient conditions if required, with the temperature / humidity for groups B and C in accordance with D 2200	
4b	Test under downgraded ambient conditions with radiation for groups D, E and F in accordance with D 2200	

Table C.1 - Test qualification procedure phases for equipment in mild environment (K2 / K3 in RCC-E)

QUALIFICATION Guidelines

Appendix D - Equipment Qualification to Magnetic Field and to EMI

D1 Qualification versus Magnetic Field

Magnetic field is specific of fusion machines where the need of huge magnetic fields to generate, confine and control the plasma is an essential operational requirement. The plasma and plasma transients generate magnetic field too.

In ITER all the tokamak building areas are immersed in that magnetic field which value decreases with the distance from the torus [11].

In the buildings surrounding the tokamak building with PIC component (e.g. Tritium and Diagnostics buildings) the magnetic field is quite low (~≤10 mT): that value is still important for few sensible equipment [17] that need therefore to be qualified or shielded.

This magnetic field is almost constant or at low frequency, so it can be assimilated to a DC magnetic field, therefore the qualification could be achieved following guidelines and methods similar to those given in IEC 61000-4-8 and DOD-STD-1399/070 [14, 15].

ITER is progressing in the validation of a procedure to be used as reference for that quasi static magnetic field qualification of components whose performance is affected by a static or slowly variable DC magnetic field [16].

A qualification program shall undergo following the general guideline Guidance for EEE in Tokamak Complex (7NPFMA v1.2) [17].

The tests shall be carried out in various modes of operation, such that successful completion of the tests demonstrates that the equipment safety function has not been compromised and the equipment performances are within the design accuracy, as specified in the relevant functional specification.

Also the equipment installation should be chosen in order to minimize the magnetic field.

The methods/procedures given hereinafter for the qualification against the magnetic field are to be considered as a reference. The Suppliers might propose a different programme (subject to IO approval), provided it fulfils the requirements given in the relevant codes and standards.

A DC Magnetic Field Qualification Report should be prepared for each PIC components sensible to that quasi static magnetic field.

D.2 EMI qualification

EMI can be generated in ITER areas where sensible PIC equipment are located by external events (e.g. lightening) and by the functioning of few ITER systems and equipment (e.g. AH) and plasma transients.

The Electrical Design Handbook Part 4 [18] defines the provisions and the reference to protect ITER sensible components from EMI.

A specific ITER guide for equipment qualification test against EMI [19] is under finalisation making reference to IEC 61000-6-2 [20].

Table D.2.1 reports the list of IEC 61000-6-2 tests to be performed in order to qualify PIC equipment to EMI (when applicable).

QUALIFICATION Guidelines

61000-4 section	Immunity test	Equipment concerned	Level	Level Justification	Criteria
2	Electrostatic discharge	All	Immunity - Enclosure port: Contact discharge: level 2 (+/- 4kV) Air discharge: level 3 (+/- 8kV)	ITER_D_4B523E, section 6.2 61000-6-2 Industrial environments	B
3	Radiated, radio frequency, electromagnetic field	All	Immunity - Enclosure port: 80 to 1000 MHz: level 3 (10V/m) 1.4 to 2 GHz: level 2 (3V/m) 2 to 2.7 GHz: level 1 (1V/m)	ITER_D_4B523E, section 6.2 61000-6-2 Industrial environments	A
4	Electrical fast transient/burst	All	Immunity - Signal port: Level 3 (+/-1kV) Immunity - Power port (AC or DC): Level 3 (+/-2kV)	ITER_D_4B523E 61000-6-2 Industrial environments	B
5	Surge	All	Immunity - Signal port: +/-1kV Immunity - Power port (DC): +/-0.5kV Immunity - Power port (AC): Coupling mode line/ground: +/- 2kV Coupling mode line/line: +/- 1kV	ITER_D_4B523E, section 6.2 61000-6-2 Industrial environments	B
6	Immunity to conducted disturbances, induced by radio-frequency	All	Immunity - Signal & Power port: Level 3: 10 V	ITER_D_4B523E, section 6.2 61000-6-2 Industrial environments	A
9	Pulse magnetic field	Only Safety related	Level 4: 30 A/m peak	ITER_D_ 4B523E	A
16	Conducted, common mode disturbances in the frequency range 0 Hz to 150 kHz	All	Level 3: 10V at 0Hz According to level 3 profile from 15Hz to 150kHz	Industrial environments	A
None	Static magnetic field	Equipments in Tokamak complex where magnetic field > 5 mT	6.1 mT x 1,4	ITER_D_98JL4W	A

Table D.2.1 - list of IEC 61000-6-2 tests to qualify ITER PIC equipment to EMI