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SUB-CHAPTER 3.6 - QUALIFICATION OF ELECTRICAL AND MECHANICAL EQUIPMENT FOR ACCIDENT CONDITIONS

Preliminary remarks

Sub-chapter 3.6 deals with the qualification of equipment for accident conditions, including severe accidents.

The general principles of qualification (in particular, qualification for normal conditions and for internal and external hazards) are presented in Sub-chapter 3.1.

0. SAFETY REQUIREMENTS

0.1. OBJECTIVES OF QUALIFICATION FOR ACCIDENT CONDITIONS

The fundamental safety objective is to minimise any possible release of radioactive substances. This objective is achieved by implementing necessary technical provisions to meet the following three objectives:

- to maintain the integrity of the pressure boundary of the main primary system,
- to maintain the ability to shutdown the reactor and maintain it in a safe shutdown condition,
- to maintain the ability to prevent accidents or to limit their radiological consequences.

The purpose of qualification is to demonstrate that the equipment can fulfil its required function during accident conditions.

In practice, achievement of this objective is demonstrated by examining the consequences of a limited number of operating conditions:

- design basis operating conditions: PCC-1 to PCC-4 (see Chapter 14),
- operating conditions with multiple failures: RRC-A (see Sub-chapter 16.1),
- severe accident situations: RRC-B (see Sub-chapter 16.2).

Although they are excluded from the conventional list of design basis accidents, breaks equivalent to the double-ended guillotine rupture of a main reactor coolant pipe (2A-LOCA) and to the double-ended guillotine rupture of a steam pipe in the containment (2A-MSLB) are used for the qualification of equipment.

0.2. RELEVANT EQUIPMENT

The equipment requiring qualification is that which is needed to operate so that the systems can fulfil their safety function, i.e. one of the functions required to achieve the fundamental safety objectives described above.

0.3. STRESSES TO BE TAKEN INTO ACCOUNT

The stresses to be taken into account are those resulting from internal and environmental conditions corresponding to the conditions PCC, RRC-A or RRC-B for which the equipment is required to function.

As noted above, stresses due to the 2A-LOCA (in accordance with Technical Guidelines – § C.1.2) and to the 2A-MSLB in the containment are also included in the qualification, despite break preclusion applying to pipes concerned. These faults are evaluated using realistic assumptions.

Depending on their safety role and the conditions for which the equipment is required to operate, qualification requirements are drawn up and incorporated into the equipment design via the technical specifications.

In addition to the operating conditions, the qualification procedure takes account of:

- the effects of ageing, i.e. the cumulative effects of the environmental conditions corresponding to normal operating conditions before the occurrence of the accident conditions taken into account for qualification,
- the effects of seismic stresses for the equipment required to be qualified due to their use in PCC conditions. These effects are taken into account on a case-by-case basis for equipment with a qualification requirement due to its use in RRC-A or RRC-B events (see Sub-chapter 3.2).

0.4. FUNCTIONS TO BE QUALIFIED AND ASSOCIATED REQUIREMENTS

0.4.1. List of functions to be qualified

The list of functions to be qualified is based on:

- 1) analyses of functional requirements conducted on the basis of accident studies (Chapters 14 and 16): PCC-2 to PCC-4, RRC-A, specific studies and RRC-B

For each accident of the PCSR, an analysis of functional requirements is conducted [Ref-1]. This analysis is used to determine all the safety functions required to mitigate the accident and identifies the phase during which the function is needed, i.e.

- period to controlled state of PCCs,
- period to safe state of PCCs,
- period to final state of RRC-As,
- prevention / limitation of releases in RRC-B.

The phase in which the function is needed determines its functional classification.

The RRC-A safety approach differs from the PCC approach in that it needs to be based both on accident studies (the aim being to show that the final RCC-A state has been achieved and is maintained) and on probabilistic safety studies (the aim being to ensure the acceptability of the risk of core meltdown associated with functional sequences involving the same RRC-A provision). Also, in RRC-A accidents, if a system is necessary in order to reach and/or maintain the final RRC-A state or to comply with the probabilistic objectives, the function it achieves must be classified F2 with the requirements that this implies: in particular, qualification to the corresponding accident environmental conditions (normal or degraded conditions depending on the case).

Secondly, cross-disciplinary functional analysis studies for support systems (ventilation, cooling water and electrical sources in particular) are conducted to determine the support functions for each of the safety functions. To carry out these analyses, the main safety functions must first have been identified.

The summary of these functional requirement analyses conducted on each transient is used to draw up the list of classified safety functions with their encompassing classification, from which the functions to be qualified with their corresponding requirements are determined.

- 2) the analysis of requirements relating to post-accident operation: measures necessary to diagnose the state of the plant, or measures necessary for orientation or reorientation between operating strategies.

In particular, the instrumentation necessary to determine the state functions parameters is subject to long-term qualification requirements.

Each safety function identified in the summary of functional requirement analyses is broken down into elementary functions for the equipment located in the buildings whose environmental conditions are affected by the accident.

The elementary functions are the abilities to change state when required. Typically, for a valve, the elementary functions are opening, closing, adjustment, maintaining open and maintaining closed. For a motorised item such as a pump or a fan, the elementary functions are start-up, shutdown, maintaining in operation and maintaining shutdown of equipment. The equipment which has qualification requirements for operation in special conditions (e.g. following rupture of a high-energy pipe, dirty water and active water) are also identified.

0.4.2. Associated requirements

0.4.2.1. Qualification requirement for accident environmental conditions

0.4.2.1.1. Situations to be considered to determine environmental conditions

For each transient analysed (Chapters 14 and 16), the environmental conditions created by the transient in the Reactor Building and/or in other buildings are calculated.

Knowing all the transients in which each safety function is required, the most severe accident environmental conditions for this function and the building affected by these environmental conditions are deduced.

The instrumentation required to diagnose the conditions prevailing during a severe accident is subject to qualification requirements taking account of the environmental conditions it may have suffered before reaching these conditions.

For each elementary function, the enveloping environmental conditions and the total mission time for which it is required, are identified for all safety functions in which it participates. In particular, for equipment whose qualification requirements exclude severe accidents, this enables the range of associated environmental conditions to be determined (see below).

0.4.2.1.2. Qualification requirement for accident environmental conditions, excluding severe accidents

For the functions that must be qualified for accident conditions other than severe accidents (RRC-B), ranges of environmental conditions are defined. They are used to characterise the qualification requirements for accident conditions which the equipment must satisfy.

0.4.2.1.2.1. Zones considered for defining ranges of environmental conditions

The zones to be considered are those:

- in which the environmental conditions may be harsh during an accident
- and where the equipment to be qualified for accident conditions is located.

These zones are:

- the reactor building,
- the safeguard buildings
- the fuel building,
- the main steam valve room and the main feedwater valve room.

No zone is created for the nuclear auxiliaries building. This is because, although environmental conditions in the building may be harsh, the equipment in the building is not required under such circumstances.

The Reactor Building is subdivided into two sub-zones: the zone which is accessible during operation (the service compartment) and the zone with restricted access during operation (the reactor compartment). The dose rates in normal operation differ significantly in the two zones, enabling different ageing irradiations to be considered.

0.4.2.1.2.2. Ranges of environmental conditions in the Reactor Building

0.4.2.1.2.2.1. Accidents in which the equipment function must be ensured

Accidents in which the equipment function must be ensured can be classified into three categories:

- accidents without harsh environmental conditions:

For the equipment required in these accidents, only qualification under normal environmental conditions is necessary. The containment is subdivided into two parts for which the ageing irradiation doses to be used for qualification are different.

The environmental conditions corresponding to these accidents are provided in section 1 within this sub-chapter.

- accidents with harsh environmental conditions in the containment, for which the irradiation is comparable to the ageing irradiation:

Such accidents are main steam line rupture (MSLB) or small or medium Loss of Coolant Accidents (LOCAs). These are accidents without clad failure, or possibly with a low number of clad failures, for which the safety injection (RIS [SIS]) in RRA [RHR] mode (residual heat removal) will be initiated.

For the qualification of equipment which is required to operate in accidents leading to start-up of the RIS [SIS] in RRA [RHR] mode, irradiation corresponding to about 1% of clad failures is very conservatively used. The irradiation values to be used, given in section 1, are low: after 1 year, they are of the same order of magnitude as the 10-year ageing irradiation dose used in the accessible zone.

- accidents with harsh environmental conditions in the containment and significant irradiation (up to 10% of clad failures):

The environmental conditions to which equipment with an operating requirement in this category may be subjected, are given in section 1.

These three types of accident are chosen for two reasons:

- to allocate to a range of environmental conditions to equipment located inside the containment,
- to determine the qualification profile (pressure and temperature, irradiation) that the equipment must meet.

0.4.2.1.2.2.2. Length of time the equipment must fulfil its function in accidents

Three time periods are defined: short-term, medium-term, long-term.

Medium-term / long-term limit

The upper limit of the medium-term is defined as encompassing the time to reach the safe state for PCCs and the time to reach final state for the RRC-As.

PCC accidents:

The safe state, for the PCC accidents leading to degraded environmental conditions in the containment, is:

- either the RIS-BP [LHSIS] in RRA [RHR] mode,
- or the RIS-BP [LHSIS] in hot leg injection mode.

In all accident studies (small, intermediate or large primary breaks, steam line or feed water line rupture), the safe state is reached within 8.5 hours. In addition, the minimum cool down rate prescribed in accident operating procedures is higher than that in French NPPs currently in operation.

2A-LOCA and 2A-MSLB accidents :

These accidents evolve more rapidly than small break accidents; the safe state is therefore reached more quickly.

RRC-A accidents:

The final state for RRC-A accidents leading to degraded environmental conditions in the containment is reached not later than 24 hours after the initiating event.

The medium-term / long-term limit is longer than that for the previous two classes and is fixed at 24 hours.

Short-term / medium-term limit

The short-term / medium-term limit is determined as an upper value for the time until phase-2 containment isolation. At that time, phase-1 containment isolation has normally already been implemented at the same time as the safety injection signal. Phase-2 containment isolation is implemented in one of two ways:

- either automatically, when the containment pressure exceeds a specified value,
- or manually, by the operators, using the operating procedures or at the request of the emergency response team.

There are two types of accidents leading to containment isolation:

- accidents leading to a large rapid release of fluid into the containment, such as large LOCAs, 2A-LOCA, 2A-MSLB. In these accidents the containment pressure rapidly exceeds the containment isolation signal pressure. Isolation occurs rapidly, i.e. well before 1 hour from the start of the accident,
- accidents with a slower containment pressurisation. In these accidents, containment isolation occurs when the containment isolation pressure has been reached. If the containment isolation pressure is not reached, the conditions experienced by the equipment are limited by the pressure achieved and the corresponding saturation temperature. The primary break leading to this limited pressure rise is small and does not result in clad failures. The activity of the primary coolant released into the containment is thus equal to that in normal operation. It is therefore not necessary to consider additional irradiation compared to ageing irradiation.

A two-part qualification profile is defined to cover these two types of situations.

The enveloping pressure and temperature profile bounds all temperatures and pressures that could result from accidents of the first type (the larger breaks).

For accidents of the second type (the smaller breaks), a constant pressure and temperature profile is used: the phase-2 containment isolation pressure (2.5 bar) and corresponding saturation temperature (less than 110°C) for 7 hours. After 7 hours, it is assumed that the operators have isolated the containment.

To simplify qualification, the above profiles are pessimistically consolidated into the following:

- the upper limit for the time from the time of phase-2 containment isolation is taken as the short-term / medium-term limit. This limit is fixed at 12 hours,
- only one thermodynamic profile is associated with this duration: the enveloping thermodynamic profile.

As only the larger breaks lead to an increase of irradiation, the irradiation dose associated with the qualification profile is the dose corresponding to a mission time of 1 hour.

0.4.2.1.2.2.3. Definition of ranges of environmental conditions in the Reactor Building

The ranges of environmental conditions for equipment in the Reactor Building are defined based on the assumptions discussed above for the accidents in which the equipment must fulfil its functions and for the times for which it must do so.

Environmental conditions in the Reactor Building		Length of time equipment must fulfil its requirement		
		Short-term (<12 hours)	Medium-term (<24 hours)	Long-term
P, T	Irradiation			
Normal	Normal	1		
Abnormal	Normal	2	3	4
Abnormal	Abnormal		5	6

0.4.2.1.2.3. Ranges of environmental conditions in the Safeguard Buildings

0.4.2.1.2.3.1. Accidents in which the equipment function must be ensured

Accidents in which the equipment must operate can be classified into three categories:

- accidents not involving harsh environmental conditions in the Safeguard Buildings,
- accidents involving harsh environmental conditions, in terms of temperature and humidity, for which the irradiation is comparable to the ageing irradiation i.e very low or zero (breaks in the RIS [SIS] in RRA [RHR] mode),
- accidents for which irradiation is significant (accidents involving clad failures, for which the active coolant water circulates in the Safeguard Buildings)

The equipment fulfilling safety functions in accidents is qualified with respect to temperature and humidity and irradiation.

0.4.2.1.2.3.2. Length of time the equipment must fulfil its function in accidents

The medium-term / long-term limit is fixed at 24 hours (the same as for the Reactor Building). It encompasses the time to reach the safe state for PCC conditions and the time to reach the final state for the RRC-A conditions.

The short-term / medium-term limit is fixed at:

- 1 hour for accidents with irradiation in the Safeguard Buildings (accidents in which active primary coolant circulates in the RIS [SIS] pipes in the Safeguard Buildings):

The equipment required in the short-term in these accidents is that which operates to isolate the containment (isolation valves outside the containment). The valves are actuated at the same time as the isolation valves inside the containment, i.e. before 1 hour in very harsh containment conditions or 7 hours in less harsh containment conditions (see above in this sub-chapter). The isolation valves only operate after one hour in accidents where there is no clad failure and where the activity in the containment is normal. Thus the isolation valves are not actuated in harsh environmental conditions.

- 5 hours for accidents involving harsh environmental conditions in the Safeguard Buildings (breaks in the RIS [SIS] in RRA [RHR] mode):

In the case of a significant break in the RIS [SIS] in RRA [RHR] mode leading to a rapid and significant increase in temperature in the Safeguard Buildings, the break is isolated automatically after a few minutes (well within 1 hour). A smaller break may be isolated after 1 hour either automatically or manually. Isolation will occur within 5 hours in all break situations where it is necessary, with environmental conditions in the Safeguard Buildings less harsh than in the case of a significant break. The 5 hours is linked to the time required for diagnostic and isolation measures.

0.4.2.1.2.3.3. Definition of ranges of environmental conditions in the Safeguard Buildings (SAB)

The ranges of EPR qualification for equipment in the Safeguard Buildings are defined based on the assumptions discussed above in this sub-chapter, in terms of defining the accidents in which the equipment must fulfil its function and the times during which it must do so.

Environmental conditions in the Safeguard Buildings		Length of time equipment must fulfil its requirement			Corresponding situations
		Short-term	Medium-term (<24 hours)	Long-term	
Temperature Humidity	Irradiation				
Normal	Normal	A_{SAB}			Environmental conditions not harsh
Abnormal	Normal	<1 hour (environmental condition very harsh) or <5 hours (environmental condition slightly harsh) B_{SAB}	C_{SAB}	Not applicable: Environmental condition returned to normal	RIS [SIS] break in RRA [RHR] mode
Normal	Abnormal	<1 hour D_{SAB}	E_{SAB}	F_{SAB}	Circulation of active primary coolant in RIS [SIS]

0.4.2.1.2.4. Ranges of environmental conditions in the Fuel Building (FB)

0.4.2.1.2.4.1. Accidents in which the equipment function must be ensured

Accidents in which the equipment must operate can be classified into three categories:

- accidents not involving harsh environmental conditions in the Fuel Building,
- accidents involving harsh temperature and humidity conditions (accidents leading to a loss of fuel pool cooling),
- accidents involving harsh irradiation conditions (fuel handling accident).

0.4.2.1.2.4.2. Length of time the equipment must fulfil its function in accidents

The medium-term / long-term limit is fixed at 24 hours, (the same as for the Reactor Building). It encompasses the time to reach safe state for the PCC conditions and the time to reach final state for the RRC-A conditions.

For situations involving harsh temperature conditions in the Fuel Building (loss of cooling):

- the temperature increase in the Fuel Building is slow, due to the large mass of water present in the pool. The equipment used in the short-term in this type of accident would, prior to its use, be subjected to slightly harsher conditions than normal. It is therefore not necessary to create a short-term range for this type of accident,

- the equipment required in the medium-term (up to 24 hours) is the same as that required in the long-term, i.e. until cooling in the Fuel Building pool is restored. Thus, the range is the same for both medium and long term.

For situations involving harsh irradiation conditions in the Fuel Building, a short-term / medium-term limit of 1 hour is used.

In the same manner as for the Safeguard Buildings, this enables the length of time to isolate the containment externally to be covered. Accidents where containment isolation is required in the longer-term have normal irradiation environmental conditions.

0.4.2.1.2.4.3. Definition of ranges of environmental conditions in the Fuel Building

The ranges of EPR qualification for equipment in the Fuel Building are defined based on the assumptions discussed above for accidents in which the equipment must fulfil its function and the times during which it must do so.

Environmental conditions in the Fuel Building		Length of time equipment must fulfil its requirement			Corresponding situations
		Short-term (<1 hour)	Medium-term (<24 hours)	Long-term	
Temperature	Irradiation				
Humidity					
Normal	Normal	A _{FB}			Environmental conditions not harsh
Abnormal	Normal	Not applicable	C _{FB}		Loss of pool cooling
Normal	Abnormal	D _{FB}	E _{FB}	F _{FB}	Fuel handling accident

0.4.2.1.2.5. Ranges of environmental conditions in the main steam valve room and in the main feedwater valve room

0.4.2.1.2.5.1. Accidents in which the equipment must ensure its function

Accidents in which the equipment must operate can be classified into two categories:

- accidents not involving harsh environmental conditions in the feed and steam rooms,
- accidents involving harsh environmental conditions, in terms of pressure, temperature and humidity.

No PCC or RRC-A accidents lead to irradiation in the feed and steam rooms.

0.4.2.1.2.5.2. Length of time the equipment must fulfil its function in accidents

The short-term / medium-term limit is fixed at a bounding value for isolation of breaks in the feed or steam pipes. Isolation occurs rapidly (well within 1 hour) and automatically in the event of a significant break. It occurs later (after several hours) by operator action for smaller leaks.

The medium-term / long-term limit is fixed at 24 hours, after which the environmental conditions have returned to normal.

0.4.2.1.2.5.3. Definition of ranges of environmental conditions in the main steam valve room and in the main feedwater valve room

The ranges of EPR qualification for equipment in the feed and steam rooms are defined based on the assumptions discussed previously in this sub-chapter for the accidents in which the equipment must fulfil its function and for the times during which it must do so.

These ranges are defined as follows:

Environmental conditions in the main steam and feedwater valve rooms.		Length of time equipment must fulfil its requirement		
		Very short-term (<1 hour) in very harsh conditions in the steam/water rooms Or medium-term (<7 hours) in slightly harsh conditions in the steam/water rooms	Medium-term (<24 hours)	Long-term
Temperature	Irradiation			
Humidity				
Normal	Normal	$A_{\text{steam-water}}$		
Abnormal	Normal	$B_{\text{steam-water}}$	$C_{\text{steam-water}}$	Not applicable Temperature returned to normal

0.4.2.1.3. Qualification requirement for harsh environmental conditions for use in Severe Accidents

The qualifications requirements for functions required to operate in severe accidents (RRC-B conditions) are determined on a case by case basis by specific reference to the equipment mission.

0.4.2.2. Seismic qualification requirement

The functions for which the effects of seismic loads should be taken into account are described above in this sub-chapter.

For the functions concerned, the requirement is that seismic induced loads defined in RFS 2001-01 are taken into account in the design, with a sufficient margin to meet the general objective defined in the Technical Guidelines (§ A2.5): "External hazards should not play a significant part in the risk associated with next-generation nuclear units".

0.4.2.3. Qualification requirement for High Energy Pipe Break (HEPB)

High-energy pipe break (HEPB) is a hazard which is taken into account in the EPR design. Installation rules have been defined for this initiating event with the objective of (see Sub-chapter 13.2):

- protecting the equipment or systems required to ensure the safety functions,
- avoiding aggravation of the initial accident.

The consequences of the rupture on the equipment fitted to the ruptured pipe are taken into account in application of these rules.

Generally, the main components affected by the HEPB are the isolation valves, through which the flow is increased and which are may therefore be subject to increased stresses. If safety studies show that these valves must close in the accident sequence being considered, their qualification in terms of HEPB is required. In other cases, they do not need to be qualified since they do not need to operate. Other systems are used to restore the plant to, and maintain it in, the safe state.

0.4.2.4. Qualification requirement for active water with debris

Equipment which must operate in accidents with active water containing debris must be qualified for such operating conditions.

1. DESIGN BASIS

1.1. DESIGN DATA REQUIRED FOR QUALIFICATION

1.1.1. Data for qualification for environmental conditions (pressure, temperature and irradiation)

1.1.1.1. Environmental conditions in the Reactor Building (RB)

1.1.1.1.1. Normal operation

The temperature conditions in the Reactor Building during normal operation are given in Sub-chapter 9.4.

During normal operation the irradiation dose in the accessible zone of the Reactor Building differs from that in the restricted zone.

- Accessible zone during normal operation

Maximum irradiation dose to which equipment may be subjected

During normal operation the accessible zone corresponds to a green radiological zone. Conservatively, for equipment in this zone, the upper threshold value corresponding to the yellow radiological zone is used, i.e. a dose rate of 2 mSv/hr.

During normal operation the maximum irradiation dose to which equipment may be subjected is 0.18 kGy per 10-year period.

Ageing irradiation dose to be used for qualification

The dose rates applied during qualification tests are much higher and applied for shorter times than the dose rates received during plant operation. To take account of this difference, unless there is a justifiable exception, the dose which may be received in operation is multiplied by four to determine the ageing dose to be taken into account for qualification.

The ageing irradiation dose used for qualification of the equipment located in the accessible zone of the Reactor Building is 0.7 kGy per 10-year period.

- Restricted zone during normal operation

Maximum irradiation dose to which equipment may be subjected

The majority of the restricted zone in operation corresponds to an orange radiological zone. For equipment in this zone, the upper threshold corresponding to the orange radiological zone is used, i.e. a dose rate of 100 mSv/hr.

With the exception of some equipment located in the red zone, the maximum irradiation dose to which equipment may be subjected during normal operation is 8.8 kGy per 10-year period.

Ageing irradiation dose to be used for qualification

The dose rates applied during qualification tests are much higher and applied for shorter times than the dose rates received during plant operation. To take account of this difference, unless there is a justifiable exception, the dose which may be received in operation is multiplied by four to determine the ageing dose to be taken into account for qualification.

The ageing irradiation dose used for qualification of the equipment located in the restricted zone of the reactor building is 35 kGy per 10-year period [Ref-1] [Ref-2].

For the few items of equipment to be qualified which may be located in the red zone, an increased ageing irradiation dose is used by convention: 250 kGy [Ref-1] [Ref-2].

To summarise, the following table gives the increased values of the ageing irradiation dose to be taken into account for equipment qualification, according to the zone of installation in the Reactor Building.

AGEING IRRADIATION TO BE USED FOR QUALIFICATION (REACTOR BUILDING)		
(for equipment sensitive to ageing if equipment is not sensitive, ageing irradiation is not taken into account for qualification)		
Equipment environmental condition range	Equipment location	Ageing irradiation (depends on the frequency of replacement of sensitive components)
1 to 6	Accessible zone	0.7 kGy per 10 year period
	Restricted zone	35 kGy per 10 year period
	“Red” zone	250 kGy

1.1.1.1.2. PCC, RRC-A, 2A-LOCA and 2A-MSLB accidents

In accidents, the Reactor Building is assumed to consist of only one zone for determining the pressure, temperature and irradiation values.

1.1.1.1.2.1. Enveloping pressure and temperature profiles

The pressure and temperature profiles used for qualification of equipment in the Reactor Building for all accidents (excluding Severe Accidents), are the following:

Time	Pressure (bar)		Temperature (°C) saturated conditions
	Steam pressure (P_{vap})	Total pressure (P_{tot})	$T_{sat}(P_{vap})$
from 0 to 2 min	5.5	5.5	156
20 mins	4.8	5.5	150
45 mins	3.6	5.0	140
2 hrs	2.7	4.1	130
4 hrs	2.0	3.3	120
10 hrs	1.5	2.8	110
17 hrs	1.0	2.3	100
24 hrs	0.9	2.2	95
96 hrs	0.9	2.2	95
96 hrs + ε	0.4	1.6	73

1.1.1.1.2.2. Enveloping irradiation level

The following tables provide the increased values for the accident dose of γ irradiation and of β irradiation to be taken into account for qualification of equipment, for each range of environmental conditions (the β dose is used if the equipment to be qualified is sensitive and is calculated behind a 1 mm shield of density 1).

<u>ACCIDENT γ IRRADIATION (Reactor Building)</u> (for equipment sensitive to irradiation if equipment is not sensitive, accident γ irradiation is not taken into account for qualification)		
Equipment environmental condition range	Equipment location	Accident γ Irradiation (kGy)
1	All zones	0
2	All zones	0.3*
3	All zones	0.2
4	All zones	6.8
5	All zones	2.2
6	All zones	68

<u>ACCIDENT β IRRADIATION (Reactor Building)</u> (for equipment sensitive to β irradiation if equipment is not sensitive, accident β irradiation is not taken into account for qualification)		
Equipment environmental condition range	Equipment location	<u>Accident β Irradiation (kGy)</u>
1	All zones	0
2	All zones	1.1*
3	All zones	0.8
4	All zones	8.4
5	All zones	7.9
6	All zones	84

* As indicated above in this sub-chapter, the irradiation dose used for range 2 is that which corresponds to a duration of 1 hour.

1.1.1.1.3. Severe accidents (RRC-B)

1.1.1.1.3.1. Enveloping pressure and temperature profiles

In severe accidents, the pressure in the containment does not exceed 5.5 bar, except for a period of 2 minutes if hydrogen combustion occurs. During this very short period, the pressure remains below 6.5 bar (see Sub-chapter 16.2).

Starting the EVU [CHRS] after 12 hours causes the pressure to fall to 2 bar.

The following pressure profile in the containment is therefore used (all pressures are absolute):

- 5.5 bar for 12 hours
- pressure peak at 6.5 bar maintained for 5 minutes
- linear decrease from 5.5 bar to 2 bar during the next 12 hours
- 2 bar thereafter.

The total duration of the profile to be used is determined on a case-by-case basis for each item of equipment, according to its function. If the mission length is less than 12 hours, the pressure peak at 6.5 bar for 5 minutes is placed at the end of the period at 5.5 bar.

In severe accidents, the temperature in the containment does not exceed 156°C. Starting the EVU [CHRS] after 12 hours causes the temperature to drop to 110°C.

The following temperature profile in the containment is therefore used:

- 156 °C for 12 hours
- linear decrease from 156°C to 110°C during the next 12 hours
- 110°C thereafter.

The duration of the profile used is determined on a case-by-case basis for each item of equipment, according to its function.

Equipment participating in containment leaktightness

Specific qualification conditions are used for equipment ensuring containment leaktightness.

The pressure profile used to qualify this equipment is as follows:

- 6.5 bar for 12 hours
- a linear decrease from 6.5 bar to 2 bar during the next 12 hours
- 2 bar maintained for up to 15 days from the start of the profile.

The temperature profile used to qualify this equipment is as follows:

- 170 °C for 12 hours
- a linear decrease from 170°C to 110°C during the next 12 hours
- 110°C maintained for up to 15 days from the start of the profile.

1.1.1.1.3.2. Irradiation

The irradiation to which the equipment may be subjected is determined for each item of equipment concerned, taking account of its function, its location and its geometry (shielding of components sensitive to irradiation) on a case-by-case basis.

Design provisions are made to reduce the sensitivity to β radiation of equipment required to operate in severe accidents. These provisions consist of:

- avoiding, as far as possible, use of equipment sensitive to irradiation,
- protecting the parts of the equipment most sensitive to β radiation,
- distancing the parts of the equipment most sensitive to irradiation from surfaces where deposits of radioactive isotopes may form during a severe accident.

1.1.1.2. Environmental conditions in the Safeguard Buildings

1.1.1.2.1. Normal operation

The temperature conditions in the Safeguard Buildings during normal operation are given in Sub-chapter 9.4.

During normal operation the Safeguard Buildings contain green and yellow radiological zones, for which the maximum radiation dose is different.

- Safeguard Buildings green zone

Maximum irradiation dose to which equipment may be subjected

During normal operation the maximum dose rate in the green zone is 0.025 mSv/hr. The maximum irradiation dose to which equipment in normal operation may be subjected is $2.2 \cdot 10^{-3}$ kGy per 10-year period.

Ageing irradiation dose to be used for qualification

The dose rates applied during qualification tests are much higher and applied for shorter times than the dose rates received during plant operation. To take account of this difference, unless there is a justifiable exception, the dose which may be received in operation is multiplied by four to determine the ageing dose to be taken into account for qualification.

The ageing irradiation dose to be used for qualification of the equipment located in the green zone of the Safeguard Buildings is $8.8 \cdot 10^{-3}$ kGy per 10-year period.

- Safeguard Buildings yellow zone

Maximum irradiation dose to which equipment may be subjected

During normal operation the maximum dose rate in the yellow zone is 2 mSv/hr. The maximum irradiation dose to which equipment in normal operation may be subjected is 0.18 kGy per 10-year period.

Ageing irradiation dose to be used for qualification

The dose rates applied during qualification tests are much higher and applied for shorter times than the dose rates received during plant operation. To take account of this difference, unless there is a justifiable exception, the dose which may be received in operation is multiplied by four to determine the ageing dose to be taken into account for qualification.

The ageing irradiation dose to be used for qualification of the equipment located in the yellow zone of the Safeguard Buildings is 0.7 kGy per 10-year period.

In summary, the following table gives the increased values of the ageing irradiation dose to be taken into account for equipment qualification, according to the zone in the Safeguard Buildings.

<p style="text-align: center;"><u>AGEING IRRADIATION TO BE USED FOR QUALIFICATION (Safeguard Buildings)</u> (for equipment sensitive to ageing: if equipment is not sensitive, ageing irradiation is not taken into account for qualification)</p>		
Equipment environmental condition range	Equipment location	Ageing irradiation (depends on the frequency of replacement of sensitive components)
A to F	Safeguard Buildings - green zone (< 0.025 mSv/hr)	$8.8 \cdot 10^{-3}$ kGy per 10-year period
	Safeguard Buildings - yellow zone (< 2 mSv/hr)	0.7 kGy per 10-year period

1.1.1.2.2. PCC and RRC-A accidents

1.1.1.2.2.1. Enveloping pressure and temperature profiles

The Safeguard Buildings cannot be pressurised. The accidents which degrade the environmental conditions in the Safeguard Buildings in terms of temperature and humidity are breaks in the RIS [SIS] in RRA [RHR] mode.

Two types of harsh environmental conditions are considered:

- significant breaks in the RIS [SIS] in RRA [RHR] mode, for which the temperature may increase rapidly and automatic isolation of the leak is rapidly required.

In these situations, the temperature may reach a value, of close to 100°C for a duration of less than 1 hour.

- small breaks in the RIS [SIS] in RRA [RHR] mode, not requiring automatic isolation of the break before 1 hour, isolation being initiated later, either automatically, or by operator action.

In these accidents, the temperature does not exceed 70°C before the break is isolated (within 5 hours), and then the temperature decreases.

1.1.1.2.2.2. Enveloping irradiation level

Two phenomena may result in an irradiation dose in the Safeguard Buildings:

- the activity of the water released in the event of a break in the RIS [SIS] in RRA [RHR] mode: the activity of the water released is the normal activity of the primary water,
- the activity due to the circulation of primary water in the event of LOCA (loss of primary coolant accident).

The maximum irradiation to which the equipment is subject (due to water circulating from the bottom of the containment in the RIS [SIS] piping) assumes 10% clad failure.

The irradiation values for a leak in the RIS [SIS] in RRA [RHR] mode assume a clad failure rate of less than 1%.

The following tables provide the increased values for the accident dose of γ irradiation and β irradiation (assumed if the equipment to be qualified is sensitive to irradiation) used for equipment qualification.

Note: The doses indicated do not apply to exterior containment isolation valves, which may be subject to Reactor Building environmental conditions (see above).

They do, however, apply to the valve actuators.

<u>ACCIDENT γ IRRADIATION (SAFEGUARD BUILDINGS)</u> (for equipment sensitive to irradiation: if equipment is not sensitive, accident γ irradiation is not taken into account for qualification)		
Equipment environmental condition range	Equipment location	<u>Accident γ Irradiation</u> (kGy)
D	Safeguard Buildings	0.2
E	Safeguard Buildings	1.1
F	Safeguard Buildings	34

<u>ACCIDENT β IRRADIATION (SAFEGUARD BUILDINGS)</u> (for equipment sensitive and subject to β irradiation: if equipment is not sensitive, accident β irradiation is not taken into account for qualification)		
Equipment environmental condition range	Equipment location	<u>Accident β Irradiation</u> (kGy)
D, E	Safeguard Buildings	0.35
F	Safeguard Buildings	5

1.1.1.2.3. Severe accidents (RRC-B)

1.1.1.2.3.1. Enveloping pressure and temperature profiles

A severe accident in the Reactor Building is not combined with an accident in the Safeguard Buildings. The severe accident results in circulation of active water in the Safeguard Buildings, which does not result in a significant increase in environmental temperature.

The pressure and temperature in the Safeguard Buildings remain normal in the event of a severe accident.

1.1.1.2.3.2. Irradiation

The irradiation is due to the circulation of active water from the containment.

The activity of the water from the containment which may circulate in the Safeguard Buildings pipes in a severe accident will be calculated as part of the detailed design phase.

1.1.1.3. Environmental conditions in the Fuel Building

1.1.1.3.1. Normal operation

The temperature conditions in the Fuel Building in normal operation are given in Sub-chapter 9.4 of the PCSR.

During normal operation, the Fuel Building contains both green and yellow radiological zones, for which the maximum doses of irradiation are different.

- Fuel Building green zone

Maximum irradiation dose to which equipment may be subjected

During normal operation the maximum dose rate in the green zone is 0.025 mSv/hr. The maximum irradiation dose to which equipment in normal operation is subjected is $2.2 \cdot 10^{-3}$ kGy per 10-year period.

Ageing irradiation dose to be used for qualification

The dose rates applied during qualification tests are much higher and applied for a shorter period than the dose rates received during normal plant operation. To take account of this difference, unless there is a justifiable exception, the dose which may be received in operation is multiplied by four to determine the ageing dose to be taken into account for qualification.

The ageing irradiation dose to be used for qualification of the equipment located in the green zone of the Fuel Building is $8.8 \cdot 10^{-3}$ kGy per 10-year period.

- Fuel Building yellow zone

Maximum irradiation dose to which equipment may be subjected

During normal operation the maximum dose rate in the yellow zone is 2 mSv/hr. The maximum irradiation dose to which equipment in normal operation may be subjected is 0.18 kGy per 10-year period.

Ageing irradiation dose to be used for qualification

The dose rates applied during qualification tests are much higher and applied for shorter times than the dose rates received during normal plant operation. To take account of this difference, unless there is a justifiable exception, the dose which may be received in operation is multiplied by four to determine the ageing dose to be taken into account for qualification.

The ageing irradiation dose to be used for qualification of the equipment located in the yellow zone of the Fuel Building is 0.7 kGy per 10-year period.

In summary, the following table gives, according to the zone in the Fuel Building, the increased values of the ageing irradiation dose to be taken into account for equipment qualification.

<u>AGEING IRRADIATION TO BE USED FOR QUALIFICATION (FUEL BUILDING)</u>		
(for equipment sensitive to ageing: if equipment is not sensitive, ageing irradiation is not taken into account for qualification)		
Equipment environmental condition range	Equipment location	Ageing irradiation (depends on the frequency of replacement of sensitive components)
A to F	Fuel Building - green zone (< 0.025 mSv/hr)	$8.8 \cdot 10^{-3}$ kGy per 10-year period
	Fuel Building - yellow zone (< 2 mSv/hr)	0.7 kGy per 10-year period

1.1.1.3.2. PCC and RRC-A accidents

1.1.1.3.2.1. Enveloping pressure and temperature profiles

The Fuel Building cannot be pressurised. Accidents leading to harsh temperature and humidity conditions in the Fuel Building involve loss of pool cooling. In these accidents, the temperature increases slowly and does not exceed 100°C before pool cooling is restored; the third PTR [FPCS] train is designed so that, in the event of loss of pool cooling in the Fuel Building, the temperature does not exceed 95°C.

1.1.1.3.2.2. Irradiation

Accidents which may lead to harsh irradiation conditions in the Fuel Building are fuel handling accidents.

Closure of external containment isolation valves in the Fuel Building following an accident in the Reactor Building is required in the short-term. In these circumstances, γ irradiation less than 0.2 kGy and β irradiation less than 0.35 kGy after 1 hour are assumed.

The following tables provide the increased values for the accident dose of γ irradiation and of β irradiation in the water (assumed if the equipment to be qualified is sensitive to irradiation) to be used for qualification of equipment.

Notes:

- The doses indicated do not apply to external containment isolation valves, possibly subject to the Reactor Building environmental conditions (see previously in this sub-chapter). They do, however, apply to the valve actuators.
- The doses indicated do not necessarily apply to the case of equipment required for a fuel handling accident located in air in the Fuel Building hall, which would be sensitive to β radiation. These will be dealt with specifically.

<u>ACCIDENT γ IRRADIATION (FUEL BUILDING)</u> (for equipment sensitive to irradiation: if equipment is not sensitive, accident γ irradiation is not taken into account for qualification)		
Equipment environmental condition range	Equipment location	<u>Accident γ Irradiation</u> (kGy)
D	Fuel Building	0.2 kGy
E	Fuel Building	0.09
F	Fuel Building	10

<u>ACCIDENT β IRRADIATION (FUEL BUILDING)</u> due to transported fluid (for equipment sensitive and subject to β irradiation: if equipment is not sensitive, accident β irradiation is not taken into account for qualification)		
Equipment environmental condition range	Equipment location	<u>Accident β Irradiation</u> (kGy)
D	Fuel Building	0.35 kGy
E	Fuel Building	0.02
F	Fuel Building	1.6

1.1.1.3.3. Severe accidents

Severe accidents are not considered in the Fuel Building. Fuel Building equipment is therefore not qualified for severe accident conditions.

1.1.1.4. Environmental conditions in the main steam valve room and in the main feedwater valve room**1.1.1.4.1. Normal operation**

The temperature conditions in the main steam valve room and in the main feedwater valve room are given in Sub-chapter 9.4 of the PCSR.

There is no irradiation in normal operation.

1.1.1.4.2. PCC and RRC-A accidents**1.1.1.4.2.1. Enveloping pressure and temperature profiles**

The pressure and temperature profile to be used for qualification will be provided as part of the detailed design phase.

1.1.1.4.2.2. Irradiation

Accidents in the main steam valve room and in the main feedwater valve room do not involve irradiation.

1.1.1.4.3. Severe accidents (RRC-B)

Severe accidents do not occur in the steam and feedwater valves rooms. The equipment is therefore not qualified for severe accident conditions.

1.1.2. Data for seismic qualification

The seismic spectra used for qualification are defined in accordance with the methods defined in Sub-chapter 13.1.

For equipment with a seismic qualification requirement, it is possible to use:

- either the enveloping spectra,
- or the corresponding floor response spectra.

1.1.3. Data for high energy pipe break (HEPB) qualification

HEPB qualification data are defined on a case-by-case basis for each high-energy pipe break event considered in the safety case.

1.1.4. Data for qualification against active water with debris

Data for qualification of equipment potentially using water containing debris are as follows:

- the qualification conditions of pumps in terms of dirty water assume a quantity of debris in the water of 500 ppm (1 ppm = 1 gram per metric ton),
- the maximum size of the debris passing through the sump filters is assumed not to exceed 2.5 mm.

Data for the irradiation doses due to water activity are the values indicated previously in this sub-chapter:

- for accidents other than severe accidents,
- for severe accidents.

1.1.5. List of elementary functions to be qualified

The list of functions to be qualified is based on the functional requirements analysis [Ref-1].

1.2. VERIFICATION OF REQUIREMENT COMPLIANCE – QUALIFICATION PROGRAMMES

1.2.1. Qualification methods

Several methods are used in the qualification procedure, as described below.

Qualification methods depend on the type of equipment (electrical, valve, pump etc.), qualification requirements (seismic, inside or outside containment, normal or accident conditions etc.) and the selected suppliers (new or proven technology, availability of experience feedback etc.). The qualification method will be chosen by the supplier.

1.2.1.1. Qualification by testing

This consists of subjecting equipment to loads representative of the operating conditions in which it must fulfil its safety function. The equipment tested must be representative of the equipment installed in the plant.

The qualification tests are conducted independently of one another and according to a sequence which best represents the operating conditions or the stresses applied to the equipment.

1.2.1.2. Qualification by analysis

Qualification by analysis generally differs from qualification by testing because it does not involve specific tests.

1.2.1.2.1. Qualification by calculation

Qualification by calculation consists of demonstrating that the loads experienced by the equipment have consequences for the equipment that are acceptable. 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 HEPB is mainly based on analysis, as this can determine the mechanical forces imposed on the valve and the properties of the fluid passing through it.

1.2.1.2.2. Qualification by operating experience

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

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

- the equipment considered must be identical to, or sufficiently representative of, the equipment to be qualified,
- the operating experience must be over a sufficiently long period,
- 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 equipment.

In practice, this method is rarely used in isolation. It is usually used to complete and confirm the behaviour of a component of a piece of equipment, whose qualification is demonstrated using other methods.

1.2.1.2.3. Qualification by analogy

Qualification by analogy consists of comparing, based on logical rules, the equipment to be qualified with "similar" equipment, already qualified. Three steps are usually necessary to demonstrate qualification by analogy.

These three steps are:

- comparison of equipment design,
- comparison of functional conditions,
- evaluation and justification, for each potential risk of failure, of the equipment design used.

This method of qualification is used mainly for pumps and valves.

1.2.1.2.4. Mixed methods

Combinations of the methods presented above can sometimes be used. These combinations vary according to the equipment under consideration.

In all cases, each part of the mixed method must comply with the conditions corresponding to the selected method. All parts together must fully demonstrate the capability of the equipment to fulfil its safety function.

1.2.2. Applicable qualification programmes

1.2.2.1. General principle

For qualification of equipment, the reference document is the international standard CEI 60780 [Ref-1]. The following three qualification practices, which are compatible with this standard, can be used:

- French practice based on the RCC-E (see Sub-chapter 3.8) and the associated specifications,
- German practice based on KTA [Ref-2] [Ref-3] rules
- American practice based on IEEE [Ref-4] rules

Following a review of qualification practices used in Europe [Ref-5], it has been recognised that all these practices have the same objective, i.e. to demonstrate that equipment operates as expected in the expected environmental conditions and under specified loads. They have all been developed based on similar principles (those found in an agreed document such as CEI 60780) and, for methods involving testing, use the same steps and include identical operating conditions and parameters. However, it is not possible to demonstrate identical equivalence of single tests making up each of the qualification sequences. This variety of solutions for one qualification requirement does not imply a different level of safety. It reflects the different approach of individual test methods and the personal preferences of decision-makers and testers together with the dependency of parameters on design and installation data which may differ from one project to the next.

Each of the above practices is applicable provided the qualification is verified for a requirement that is equal to or more severe than that of the EPR.

The requirement for a given item of equipment is characterised by:

- the environmental conditions in normal operation and the service life for which it is to be qualified,
- the accident environmental conditions for which the equipment must be qualified: temperature, pressure, humidity and irradiation dose,
- the level of the seismic load,
- any high energy pipe break (HEPB) load,
- the properties of any active water.

The possible use of several qualification practices avoids the need for developing new qualification sequences. It also allows the re-use of an existing practice that has been validated and verified, and enables qualification files from previous projects to be re-used.

If a particular specification already validated with one of the permitted qualification practices is not re-used, the provisions of § 5.3 of publication CEI 60780 should be applied to draw up a new specification.

To benefit from an existing practice, it must be applied within the bounds in which its validity has been demonstrated.

Consequently, for a given item of equipment, the qualification sequence chosen should only use one of the practices available. It must be used for all steps in the initial qualification. In other words, the "mixing" of qualification sequences within any qualification sequence is prohibited.

As an example, using RCC-E tests (French practice – see Sub-chapter 3.8) for one part of the qualification process and KTA tests for another, must be considered as a new method. Its use is not authorised (unless a study is made to justify a new sequence). Similarly, it is not permissible to simulate ageing (as equipment pre-conditioning) using RCC-E rules and to conduct accident qualification on the basis of specifications arising from KTA rules.

As a general rule, the original practice should be re-used for any additional qualification. Otherwise, a justification file should be drawn up.

When re-using an existing specification, the validation of a practice and any changes that may have occurred to it must be considered. The following must both be addressed:

- the references of equipment should be provided for which the specification has been recognised as valid as regards the methodology, and which enable it to be considered as common industrial practice, should be provided,
- also, changes to an IEEE or KTA rule subsequent to the revision for which the specification has been validated should be examined.

Verification at the limits of functional use may be carried out on specimens other than the equipment being installed that are subjected to the accident sequence in a laboratory.

For ageing simulation, it is necessary to trace the assumptions made for normal operation.

If available (via a product standard for a given type of equipment for example), a phase of ageing simulation which has been harmonised within the European Community (for preference), or an international CEI or ISO standard should be used.

These provisions, and the methods described previously in this sub-chapter, also apply to the qualification of equipment for severe accidents, with the following clarifications:

- the testing method is recommended if the equipment includes organic materials,
- the specification may differ from that required in PCC conditions (for example, the accuracy specified for a sensor may be lower),
- for equipment with installed radiation shielding, the effectiveness of which has been demonstrated, it is possible:

. either to calculate the environmental dose at the location of the entire equipment and to test the equipment with its protection,

. or to calculate the dose under the radiation shielding and to test the equipment without its shielding.

- when qualification for severe accidents is undertaken in addition to a qualification already undertaken for PCC conditions:

. the lessons learned from the PCC qualification are used to adapt the conditioning prior to the severe accident sequence by retaining the most conservative factors,

. the demonstration of seismic resistance previously acquired should not be made again within the severe accident sequence.

1.2.2.2. Environmental conditions

1.2.2.2.1. Qualification for use in Severe Accidents

As indicated previously in this sub-chapter, ranges of environmental conditions are not used. The functions to be performed by each item of equipment are used as the basis for qualification. For equipment in the Reactor Building, enveloping pressure and temperature profiles are given previously in this sub-chapter. The duration of the profile (P, T) and the irradiation dose to be used are determined specifically for each item of equipment.

1.2.2.2.2. Qualification for use in accidents other than Severe Accidents – standard qualification conditions

The environmental conditions are determined for a given item of equipment, using the following data:

- location (accessible zone of the Reactor Building, restricted zone of the Reactor Building, Safeguard Buildings, Fuel Building, main steam valve room and main feedwater valve room),
- range of environmental conditions,
- any frequency of replacement of components sensitive to ageing,
- any sensitivity to β radiation,
- any qualification requirement for high energy pipe break (HEPB),
- any qualification requirement for dirty and active water

For equipment with a qualification requirement to operate during accidents other than Severe Accidents, the qualification may be carried out using the standard conditions described below.

These standard conditions for environmental qualification do not apply to qualification of equipment required to operate following Severe Accidents.

1.2.2.2.1. Standard temperature and pressure conditions

The location of the equipment and the range of environmental conditions are used to determine the type of standard profile to be used.

1.2.2.2.1.1. Equipment located in the Reactor Building

An enveloping pressure and temperature profile is given previously in this sub-chapter.

This profile envelopes that of the accident thermodynamic phase of RCC-E (see Sub-chapter 3.8), commonly called the K1 thermodynamic profile, during the first day.

Between days 1 and 4, the pressures and temperatures in the enveloping profile exceed those of the K1 profile. This is because, after 1 day, the pressures and temperatures calculated for the LOCA without low head safety injection [LHSI] (RRC-A type accident) exceed this profile.

RCC-E describes, for the French facilities in operation, the applicable conditions for qualification of equipment for accident conditions. These include:

- a test to establish the capability to withstand the accident thermodynamic and chemical conditions, which correspond to the K1 profile in the RCC-E (see Sub-chapter 3.8), with a duration of 96 hours. The first day of this test corresponds to the enveloping profile determined for EPR (see previously in this sub-chapter),
- a test to establish the capability to withstand the post-accident thermodynamic conditions: 10 days at 100°C (see RCC-E for different temperature). This test covers the part of the enveloping profile between 1 and 4 days.

Three standard pressure and temperature profiles, deduced from the RCC-E (see sub-chapter 3.8), are defined in the table below. The ranges of environmental conditions to which they are applicable are indicated.

Standard profile	Equipment environmental conditions concerned	Description
RB-ST (Short-Term)	Range 2	K1 accident profile limited to 12 hours
RB-MT (Medium-Term)	Ranges 3 and 5	K1 accident profile limited to 24 hours
RB-LT (Long-Term)	Ranges 4 and 6	K1 accident profile (length 96 hours), then 100°C for 10 days

Note: The pressure and temperature profile RB-LT encompasses the RB-MT profile, which encompasses in turn the RB-ST profile. Consequently, it is possible to use the RB-MT profile to qualify equipment in range 2 or to use the RB-LT profile to qualify equipment in ranges 2, 3 or 5.

Equipment qualified according to the K1 profile (accident + post-accident) will meet the qualification requirements for pressure and temperature of equipment located in the EPR Reactor Building.

1.2.2.2.1.2. Equipment located in the Safeguard Buildings

Given the information presented previously in this sub-chapter, two standard pressure and temperature profiles are defined in the table below. The ranges of environmental conditions to which they are applicable are indicated.

Standard profile	Equipment environmental conditions concerned	Description
SAB-ST (Short-Term)	Range B	Profile comprised of 2 parts: - (100°C, 1 bar) for 1 hour - (70°C, 1 bar) for 5 hours Qualification for both parts of the profile is necessary. The same equipment is not necessarily subject to the both parts of the profile
SAB-MT (Medium-Term)	Range C	(100°C, 1 bar) for 1 hour, then (70°C, 1 bar) for 23 hours*

* The rate of change from 100°C to 70°C is not specified.

The profiles SAB-ST and SAB-MT are associated with conditions of humidity close to saturation.

Note: The SAB-MT temperature profile encompasses the SAB-ST profile. Consequently, it is possible to use the SAB-MT profile to qualify equipment in range B.

In accordance with section 0 of this sub-chapter, no long-term temperature profile is defined for the Safeguard Buildings.

1.2.2.2.1.3. Equipment located in the Fuel Building

In accordance with section 0 of this sub-chapter, only one standard temperature profile is defined for the Fuel Building: FB-MT.

This profile covers the medium and long-term, until pool cooling in the Fuel Building is restored.

It is defined as follows:

Standard profile	Equipment environmental conditions concerned	Description
FB-MT. (Medium-Term)	Range C	Rise from 50 °C to 100 °C in 4 hours, then constant at 100 °C until cooling is restored in the Fuel Building pool (100 hours)

This profile is associated with humidity close to saturation and with a pressure of 1 bar.

1.2.2.2.1.4. Equipment located in the main steam and feedwater valve rooms

The standard pressure and temperature conditions will be provided as part of the detailed design phase.

1.2.2.2.2. *Standard qualification irradiation doses*

The standard qualification irradiation doses are derived as discussed in the following two sub-sections. Note that these are not applicable to equipment in the main steam and feedwater valve rooms.

1.2.2.2.2.1. Determination of an increased dose to be used for qualification

An increased irradiation dose for which equipment is qualified is determined as follows:

$$\begin{aligned} & \text{Irradiation for which the equipment must be qualified} \\ & = \\ & \quad \text{Ageing irradiation} \\ & \quad + \\ & \quad \text{Accident } \gamma \text{ Irradiation} \\ & \quad + \\ & \quad \text{Accident } \beta \text{ Irradiation} \\ & \quad \text{(if this affects the equipment)} \end{aligned}$$

The values of ageing irradiation and the values of accident γ and β irradiation to be used are those given in section 1 of this sub-chapter for the Reactor Building, for the Safeguard Buildings and for the Fuel Building.

The values indicated in the tables are used to determine an enveloping irradiation dose for the qualification of a given item of equipment, according to its location, the frequency of replacement of its sensitive components, its range of environmental conditions and any sensitivity to β radiation.

If the dose thus determined creates difficulties in qualifying any equipment, a more detailed analysis is undertaken to justify a lower dose which the item of equipment may experience.

1.2.2.2.2.2. Standard qualification irradiation doses

A limited number of standard qualification doses are used to simplify equipment qualification:

- standard irradiation doses inside the Reactor Building:
50 kGy, 100 kGy, 200 kGy, 300 kGy, 400 kGy,
- standard irradiation doses outside the Reactor Building, (Safeguard Buildings, Fuel Building):
50 Gy, 1 kGy, 10 kGy, 50 kGy.

In practice, the qualification dose used is the first standard dose greater than the dose determined using the method explained above.

Qualification to a higher dose enables the requirement to be met.

The maximum standard dose outside the Reactor Building is used to qualify the equipment located in the yellow zone, subject to environmental condition range F_{SAB} or F_{FB} , that is sensitive to β radiation and whose sensitive components are not replaced during the service life of the plant.

This value should not be used for isolation valves outside the containment. The interior of these valves may come into contact with similar conditions to those inside the containment. These valves are conservatively allocated to the same environmental condition range as their counterparts located inside the containment. This applies to the valves but not to their actuators.

Irradiation is not considered in the main feedwater and steam valve rooms.

1.2.2.2.3. Use of standard qualification conditions

The conditions for qualifying equipment to accident environmental conditions include:

- temperature (and possibly pressure) qualification conditions,
- and/or irradiation qualification conditions.

The following information is required in order to determine the qualification conditions to be used: location of the equipment, range of environmental conditions, frequency of replacement of components sensitive to ageing, any sensitivity to β radiation.

The location and the environmental condition range are used to determine the temperature profile (and pressure profile if the room is pressurised) to be used. There are six possible standard profiles, defined above, (excluding equipment located in the feed and steam rooms, whose pressure and temperature conditions are not currently determined):

RB-ST, RB-MT, RB-LT, SAB-ST, SAB-MT, FB-MT.

For equipment with a qualification requirement in harsh environmental temperature (and pressure) conditions, any qualification to a temperature (and pressure) profile greater than or equal to the standard profile is acceptable. In particular, the K1 pressure and temperature profile in the RCC-E (accident + post-accident), encompasses all the previous standard profiles.

The location, range of environmental conditions, frequency of replacement of components sensitive to ageing and any sensitivity to β radiation are used to determine an increased value for the dose to be used for equipment qualification (see above). Without specific justification, the standard dose to be used for qualification is the next higher value from the following:

- equipment located in the Reactor Building: 50 kGy, 100 kGy, 200 kGy, 300 kGy, 400 kGy,
- equipment located in the Safeguard Buildings and in the Fuel Building: 50 Gy, 1 kGy, 10 kGy, 50 kGy.

For equipment with a qualification requirement in harsh environmental irradiation conditions, any qualification to a dose greater than or equal to the standard dose thus determined, is acceptable.

Sub-chapter 3.6 - Table 1 shows the standard qualification conditions used for equipment in the different ranges of environmental conditions in the Reactor Building in the following cases:

- equipment located in the accessible zone in normal operation,

- equipment located in the restricted zone in normal operation and whose sensitive components are replaced every 10 years,
- equipment located in the restricted zone and whose sensitive components are not replaced.

Sub-chapter 3.6 - Table 2 shows the standard qualification conditions to be used for equipment in the different ranges of environmental conditions in the Safeguard Buildings and Fuel Building.

A given type of equipment may be used in several different locations throughout the plant and/or may be required to operate in different types of accidents. Such equipment is qualified for the most severe conditions in which it is required.

In practice, to qualify a given item of equipment, a profile enveloping the profile required (for example RB-LT for equipment in the Reactor Building) is generally used.

1.2.2.3. Level of seismic load

The spectra to be used are indicated in Sub-chapter 13.1, sections 2.1.5 and 2.1.6 of the PCSR.

1.2.2.4. Qualification to high energy pipe break (HEPB)

As discussed above in this sub-chapter, the corresponding loads are defined on a case-by-case basis, dependent on the rupture to be isolated.

1.2.2.5. Properties of active water with debris

The properties to be used for active water with debris are given in section 1 of this sub-chapter.

1.2.3. Extensions potentially needed during the lifetime of qualified equipment

Initial qualification may take into account an assumption about length of life (qualified life) which is lower than the planned life of the equipment. Then, an extension of qualification based on on-going qualification methods must be achieved, before the installed life exceeds the qualified life.

On-going qualification may use different methods:

- 1) analysis of the conditions of the initial qualification in order to evaluate the potential conservative parameters
- 2) comparison of loadings and environmental conditions (temperature and irradiation) to which operating equipment is effectively subjected with those taken into account during qualification. Using updated values, this comparison may lead to a re-evaluation of the qualified life justified after the initial qualification
- 3) monitoring of the operation parameters of equipment by periodic tests, controls or inspections. These parameters enable detection of an evolution of the equipment which would affect the achievement of the required mission in accident situation or under seismic loading.

The monitoring may take the form of:

- periodic tests on the equipment (for example, accuracy, response time, or an electrical measurement such as insulation resistance)
 - examination of a removed item of equipment, to compare the characteristics of aged and new equipment
- 4) modification of environmental conditions ; protection or moving of the equipment to reduce loadings in service
- 5) extension of the qualification of the equipment : subjecting it to a qualification test based on a longer life. The test may be undertaken :
- on an additional piece of equipment (or sample) installed alongside the required item
 - on an item removed from site, preferably if its reference state and the loadings it has been subjected to are known
 - on a new piece of equipment.
- 6) replacement or renovation of the equipment, totally or partially, as a preventive measure, by similar equipment or other qualified equipment or by components less sensitive to ageing.

1.3. ARRANGEMENTS MADE TO MAINTAIN QUALIFICATION DURING MANUFACTURING AND OPERATION

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 in series-produced equipment manufacturing and operation, all over the lifetime of the plant.

This is the role of qualification maintenance.

1.3.1. Qualification maintenance during manufacturing

The manufacturing qualification maintenance process aims to ensure that:

- the supplier is able to series-produce equipment compliant with the model equipment which has been qualified for accident conditions,
- conformity may be maintained over time for as long as it is necessary to manufacture series-produced equipment and spare parts.

The principal provisions are based on:

- selection of potential 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 suppliers. For each potential supplier, selection includes an aptitude 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 qualified equipment and to control developments,
- implementation of a process to manage changes and to examine their effect on the equipment qualification requirements for accident conditions.

1.3.2. Qualification maintenance during installation and operation

The qualification maintenance process during installation and operation aims to ensure that qualification of the equipment for accident conditions is maintained and not compromised by inadequate installation and maintenance:

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

The principal provisions are based on:

- once the initial qualification is undertaken, issuance of a qualification maintenance 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 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 spare parts, with allocation of a category compliant with their impact on the function qualified,
- analysis of feedback from all plants, with a detection and analysis process of non-conformities with the equipment qualification requirements,
- sustainability of suppliers of goods and services and management of obsolescence.

1.4. DOCUMENTATION ENSURING COMPLIANCE WITH REQUIREMENTS

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 qualification maintenance in manufacturing, installation and operation.

These documents are:

- the model equipment identification file,

- the general qualification specification for a category of equipment, and the special qualification specification for specific equipment in a given category,
- (qualification) test reports, calculation and analysis sheets (dependent on the qualification method used),
- the qualification summary report. This gives the qualification of the equipment with or without reservations. If reservations exist, the change request process is triggered,
- the qualification file. This includes the documents demonstrating qualification (including the summary note).

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

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

In general, the equipment qualification report for accident conditions 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.

SUB-CHAPTER 3.6 - TABLE 1

Examples of correspondences between standard qualification programmes and environmental condition ranges in the Reactor Building

In the following tables, each range is placed in the box corresponding to the minimum standard programme enabling the equipment to be qualified. A qualification programme corresponding to a more onerous (P, T) profile and/or a higher irradiation dose would also be suitable.

Equipment located in the accessible zone of the Reactor Building, independent of the frequency of replacement of sensitive components

and

Equipment located in the restricted zone of the Reactor Building, with a frequency of replacement of sensitive components of 10 years

Profile (P, T) Dose	Normal conditions	RB-ST (Short Term)	RB-MT (Med Term)	RB-LT (Long Term)
50 kGy	Range 1*	Range 2	Range 3 Range 5	Range 4
100 kGy				Range 6 without β^{**}
200 kGy				Range 6 with β

* Range 1 only includes ageing irradiation.

** Direct use of the values in section 1 within this sub-chapter leads to a qualification dose of 103 kGy. Taking account of an availability rate of the order of 90%, which reduces the dose to be used for ageing, the qualification dose is 100 kGy.

Equipment located in the restricted zone of the Reactor Building and whose sensitive components are not replaced (over a period of 60 years)

Profile (P, T) Dose	Normal conditions	RB-ST (Short Term)	RB-MT (Med Term)	RB-LT (Long Term)
200 kGy	Range 1*			
300 kGy		Range 2	Range 3 Range 5	Range 4 Range 6 without β
400 kGy				Range 6 with β

** Direct use of the values in section 1 within this sub-chapter leads to a qualification dose of 210 kGy. For an availability rate of 90 %, the qualification dose is 190 kGy.

SUB-CHAPTER 3.6 - TABLE 2

Examples of correspondences between standard qualification programmes and environmental condition ranges in the Safeguard Buildings or Fuel Building

In the following tables, each range is placed in the box corresponding to the minimum standard programme enabling the equipment to be qualified.

Notes:

- The standard dose indicated includes γ and β radiation due to the fluid transported in the pipes.
- For equipment with a temperature and irradiation (for example C + F) qualification requirement, the standard qualification irradiation to be used is equal to the maximum of the standard qualification irradiations corresponding to the two ranges concerned.
- As indicated in section 0 of this sub-chapter, there is no range B in the Fuel Building.

Equipment located in the green zone, independent of the frequency of replacement of sensitive components

Dose	Profile (T)	Normal conditions	SAB-ST (Short Term)	SAB or FB-MT (Medium Term)
50 Gy		Range A	Range B	Range C
1 kGy		Range D		
10 kGy		Range E		
50 kGy		Range F		

Equipment located in the yellow zone with a frequency of replacement of sensitive components of 10 years

Dose	Profile (T)	Normal conditions	SAB-ST (Short Term)	SAB or FB-MT (Medium Term)
1 kGy		Ranges A, D	Range B	Range C
10 kGy		Range E		
50 kGy		Range F		

Equipment located in the yellow zone whose sensitive components are not replaced

Dose	Profile (T)	Normal conditions	SAB-ST (Short Term)	SAB or FB-MT (Medium Term)
10 kGy		Ranges A, D, E	Range B	Range C
50 kGy		Range F		

SUB-CHAPTER 3.6 – REFERENCES

External references are identified within this sub-chapter by the text [Ref-1], [Ref-2], etc at the appropriate point within the sub-chapter. These references are listed here under the heading of the section or sub-section in which they are quoted.

0. SAFETY REQUIREMENTS

0.4. FUNCTIONS TO BE QUALIFIED AND ASSOCIATED REQUIREMENTS

0.4.1. List of functions to be qualified

[Ref-1] Summary Report on Functional Requirements Analyses per Plant System.
ECEFO100515 Revision D1. EDF. 2006 (E)

1. DESIGN BASIS

1.1. DESIGN DATA REQUIRED FOR QUALIFICATION

1.1.1. Data for qualification for environmental conditions (pressure, temperature and irradiation)

1.1.1.1. Environmental conditions in the Reactor Building (RB)

1.1.1.1.1. Normal operation

[Ref-1] Design and Construction Rules for Electrical Components of Nuclear Islands.
RCC-E. AFCEN, Edition December 2005. (E)

[Ref-2] Cahier des données de projet complétant les exigences du RCC-E déc. 2005 pour EPR.
[Project data book completing the RCC-E December 2005 requirements for EPR.]
ENSEMD050222 Revision C. EDF. 2007

1.1.5. List of elementary functions to be qualified

[Ref-1] EPR - Preliminary list of plant functions to be qualified for accident ambient conditions
ECEFO40759 Revision D1. EDF. 2008 (E)

1.2. VERIFICATION OF REQUIREMENT COMPLIANCE – QUALIFICATION PROGRAMMES

1.2.2. Applicable qualification programmes

1.2.2.1. General principle

[Ref-1] Nuclear power plants – Electrical safety equipment – Qualification. CEI 60780. IEC. 1998 (E) |

[Ref-2] Reactor Protection System and Monitoring Equipment of the Safety System. KTA 3501. TUV. 1985 (E) |

[Ref-3] General Requirements for the Electrical Power Supply of the Safety System in Nuclear Power Plants. KTA 3701. TUV. 1999 (E) |

[Ref-4] IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations. IEEE Standard 323. IEEE. 1983 (E) |

[Ref-5] A comparison of European practices for the qualification of electrical and I & C equipment important to safety for European LWR power plant. EUR 16246 E. Reactor Safety Working Group. 1996 (E) |