

Examination Procedure Title Environmental Qualification for Accident Conditions	Document KBE EP-154
	Issue 6
	Date 2022-11-17
	Supersedes 5

1 Scope

The requirements in this examination procedure, when met, will confirm the adequacy of design for electrical equipment with requirements to be in operation during accident and post accident conditions.

The equipment will be exposed for harsh environment as a consequence of Design Basis Events in the area or an adjoining area where the equipment are installed.

Applicable Standards: IEEE 323-1974/1983/2003, IEC/IEEE 60780-323, IEC 60980, IEEE 344, and IEC/IEEE 60980-344.

This document includes additional Swedish requirements on accelerated ageing and DBE tests procedures that are not addressed in applicable standards.

2 Objective

The objective is to verify the product specifications by performing sequential tests as outlined in this examination procedure. This document can also provide guidelines for evaluation of the applicability of already performed tests.

3 Definitions

Analysis

A process of mathematical or other logical reasoning that leads from stated premises to the conclusion concerning specific capabilities of equipment and its adequacy for a particular application (IEEE 323-1974).

Interface

A junction or junctions between equipment of the safety system and other equipment or device (Examples: connection boxes, splices, terminal boards, electrical connections, grommets, gaskets, cables, conduits, enclosures, etc.) (IEEE 323-1974).

LOCA

Loss Of Cooling Accident. A DBE that involves major environmental stresses on equipment located in the reactor containment.

Qualified life

The period of time, prior to the start of a design basis event, for which equipment was demonstrated to meet the design requirements for the specified service conditions (IEEE 323-1983).

4 Method

4.1 General

All tests should be carried out according to standardized tests when applicable. Tests without reference to a standardized test procedure should be performed according to best effort and established engineering practices for nuclear applications.

This examination and test procedure is applicable to type tests (design verification tests) only. The test specimens should be assembled and provided with all protective and mounting devices, cables, connectors and other interfaces, as required for the operation when installed in a system.

After testing, it should be verified that any degradation of the tested equipment is within the required performance range according to the Technical Specification.

The test specimens or any part used for testing is not allowed to be delivered as new equipment or component for replacement or repair.

A seismic event is not assumed to occur in conjunction with a LOCA. Rather, the sequence described previously has been developed as the basis of a conservative qualification, not one indicative of a sequence of expected plant events.

4.2 Test Plan

A detailed test plan shall be written and approved by the Purchaser before any testing will be started. The test plan shall fulfil the test and documentation requirements specified in this examination procedure. The following information shall be included:

- Description of the test specimens including electrical and mechanical interfaces, with references to approved drawings
- The number (quantity) of units to be tested
- Approved Product Performance Specifications. Performance and environmental variables to be monitored and recorded
- Detailed installation drawings, showing how the test specimens should be mounted, connected and be arranged in the test chamber
- Climatic conditions during the pre-test performance verifications
- Radiation ageing data, integrated dose, dose rate and ambient temperature

- Vibration (fatigue) test requirements
- Thermal ageing data, test chamber temperature, test duration, activation energy for parts made of organic materials and the resulting qualified life. The ageing data shall be based on the service conditions to be simulated
- Operational/mechanical ageing data, the number of cycles and loads to be applied to the equipment before the simulated accident test
- Intermediate tests to be performed between each environmental test
- Measuring equipment requirements
- Final tests
- Reasons for proposed changes in the test plan

4.2.1 Acceptance Criteria

Acceptance criteria shall be included in the test plan. It shall be specified and adapted for each type of tested product and application

5 Test Requirements

5.1 Test Set-up

5.1.1 Mounting and connections

Equipment shall be mounted and connected in a manner and position that simulates its expected installation when in actual use. Parameters measured and functions required during test shall be suitable for product type and test set up.

5.1.2 Test Specimens

Minimum three units of each type of equipment together with its required interfaces shall be tested. Other quantities may be agreed upon with the Purchaser.

5.1.3 Test Sequence

The test sequence should be carried out according to 5.2 – 5.5 as specified below. The Purchaser shall approve deviations from the test sequence.

The test sequence should be performed in a conservative order.

5.2 Pre-test

Pre-test performance of the equipment shall be measured and documented. Normal and extreme parameters which are suitable for indicating whether performance is correct shall be recorded in such a way that the pre-test data constitute a basis for performance comparison during and after the tests. The pre-test should comprise at least the following tests and measurements:

- Visual inspection
- Withstand voltage test

- Insulation resistance measurement
- Input/output correlation as applicable to the specific equipment to be tested
- Performance values, electrical/mechanical output limits
- Time limits for changing electrical/mechanical operational states
- Any other significant critical parameter applicable to the specific equipment to be tested
- All pre-tests should be performed at normal operating conditions
- It is recommended that intermediate tests are performed at normal operating conditions between the required test sequences in order to prevent further testing of specimens that may have failed or been degraded outside acceptable limits.

5.3 Ageing

If analysis or past experience indicates that ageing can improve the performance of the equipment during accident conditions, the test specimens shall be divided in two groups:

Group A: Pre-aged test specimens

Group B: Unaged test specimens

The number of test specimens shall be doubled when accident conditions (DBE and Post DBE) test is to be performed for both aged and unaged test specimens

Significant ageing mechanisms should be taken in consideration. Fingerprint on measurable parameters shall be made before LOCA testing. If the fingerprint is a destructive test extra samples needs to be added for the accelerated ageing. Examples on fingerprinting methods are given in IEC/IEEE 62582 standards.

5.3.1 Radiation

The ability of the equipment to withstand ionizing radiation can be demonstrated by analysis or testing, or by analysis and testing combined. Analysis is only acceptable when it can be demonstrated that none of the materials used in the product are subjected to any significant degradation due to ionizing radiation.

Normally, the ability to withstand radiation can be verified by detailed information on all materials used in the unit, and by reference to past tests demonstrating their capabilities. All parts included in the equipment have to be considered, e. g. contact devices, connectors, seals, lubricants, etc.

The ability of the test specimens to withstand radiation should be verified for the accumulated dose and dose rate specified for 'Normal Operation and LOCA Conditions' in the Technical Specification.

The operating and accident radiation dose shall be separated. It can be accepted to perform the radiation simulation for both ageing and LOCA conditions in one integrated test sequence. This shall be approved by the Purchaser.

Ageing simulation (normal operation dose shall be equivalent to TID, Total Integrated Dose, for the qualified life):

- Radiation ageing with duration shorter than 240 hours or a dose rate higher than 5 Gy/h shall be avoided. If higher dose rate are used the results applicability shall be analysed. These requirements are applicable due to that a homogenic ageing is desired, which cannot be guaranteed at high dose rates.

Accident dose:

- The accident dose shall be as stated in the Technical Specification
- The test duration, approximately 10 hours

The test specimens are not required to be in operation during the test.

Cobalt 60 is acceptable as radiation source. Ambient medium shall be air.

5.3.2 Thermal Ageing

The Arrhenius model shall be used for accelerated thermal ageing of the test specimens. The Ageing parameters can be established using the following equation:

$$t_1 = t_2 e^{\Phi/k ((T_2 - T_1)/(T_1 \cdot T_2))}$$

Where:

- t_1 = simulated life
- t_2 = ageing time in test chamber
- T_1 = simulated ambient temperature, K
- T_2 = accelerated ageing temperature, K
- Φ = activation energy, eV (material and temperature specific)
- k = Boltzmann's Constant (8,62 E-5 eV/K)

When different activation energies have to be considered, the most conservative (lowest) value of the materials should be used. If the value of the activation energy is not known, $\Phi = 0,8 \text{ eV}$ should be used.

The acceleration factor is the ratio between simulated life t_1 and accelerated ageing time t_2 .

The acceleration factor shall not be greater than 250. If a higher acceleration factor is being used, the actual estimated simulated life shall be recalculated using the acceleration factor 250. Minimum exposure time t_2 is 1000 hours. The ageing temperature T_2 shall be determined based on the required exposure time t_2 . T_2 should not be chosen greater than required in order to reach the simulated life t_1 . The design temperature for the materials must never be exceeded during the accelerated ageing, even when the acceleration factor is low.

5.3.3 Mechanical Ageing

The test specimens should be operated with the nominal load and the number of operation cycles (start/stop, open/close, activate/deactivate etc.) stated in the Technical Specifications. If no information on required number of operation cycles is given, 1000 operation cycles should be applied.

5.3.4 Fatigue/Vibration Test

The purpose of this test is limited to the simulation of mechanical ageing/degradation due to fatigue induced failure mechanisms.

The unit shall be subjected to a sweep test according to IEC 60068-2-6, Test Fc

Frequency Range:	10 - 150 Hz,
Acceleration, Displacement:	20 m/s ² , 0,15 mm
Cross Over Frequency:	58.1 Hz
Number of sweep cycles in each direction:	5
Sweep rate:	1 octave/minute

The equipment shall be fastened to the vibration table by means of its normal mounting devices. If additional fastening devices are necessary, this shall be specified in the test plan and stated in the test report.

Input and output signals shall be typical of normal operation. Performance tests during the fatigue test are not required.

If, prior to the tests according to this document, the same test specimen is being used for vibration tests according to KBE EP-151 the vibration test does not have to be repeated in this test sequence.

5.4 Design Basis Event Tests

5.4.1 Seismic Test

This test should be individually specified for each application. If no test procedure or test level is stated in the Technical Specification, the test practices according to KBE EP-147 shall apply.

The test unit shall be in operation during the test if required in the Technical Specification. Equipment performance should then be verified during the seismic simulation.

5.4.2 Intermediate Test

A performance test at normal ambient conditions to verify that each test specimen has not suffered any significant degradation due to the ageing simulation and seismic tests

5.4.3 Extreme Operation Test

Equipment for which severity C is specified shall be subjected to a temperature and moisture transient at 90°C / 100 % RH for 8 hours, followed by a recovery time of 8 hours. The rise and fall times for this damp heat cycle should be as short as possible.

- The test unit shall be in operation during the test. Performance tests shall be conducted during and after the test cycle.
- Recovery should be made at normal operating conditions.

This test can be ignored if the Post LOCA test parameters exceed the requirement in the Technical Specification in such a way that there will be an additional 12 hours of an ambient environment of 90°C / 95 % RH.

5.4.4 LOCA Radiation simulation (when applicable)

If the accident radiation dose was not simulated during the ageing simulation, this shall be performed prior to the LOCA test in the following section.

5.4.5 LOCA Test

The test specimens shall be subjected to the simulated accident environment as defined in the enclosed diagrams. The applicable diagram should be stated in the Technical Specification, otherwise the diagram "BWR/PWR all plants, Inside Containment Generic Accident Conditions" or "All plants, Outside Containment Accident Conditions" can always be applied. The LOCA test comprises the first 96 hours of the accident profile. The Technical Specification defines the required time for the particular equipment's operation in LOCA environment.

Water spray requirements are specified in technical specification.

If the test also should be applicable for PWR applications, the spray water shall consist of a solution containing:

H ₃ BO ₃	1,7 percent by weight
Na ₂ S ₂ O ₃	1,0 percent by weight
NaOH	to get pH 10,5 at 25°C (approx. 0,59 percent by weight)

The solution shall have a flowrate of 6,1 l/min/m². Margins for the ambient conditions should be applied as defined in IEC/IEEE 60780-323.

The test units shall be in operation during the test. Equipment performance shall be monitored for all test specimens during the test.

5.4.6 Post LOCA Test

The LOCA test is followed, if applicable, by the Post LOCA test. The Technical Specification defines the required time for the particular equipment's operation in Post LOCA environment.

The Post LOCA environment is separately specified in enclosed diagram for BWR: "BWR generic, Post LOCA Conditions". This test could be performed by one of two alternative methods,

A or B, as shown in the diagram. Applicable method is specified in the Technical Specification. For PWR, the Post LOCA environment is shown in diagram "PWR, Inside Containment Accident Conditions".

When simulating the Post LOCA conditions, the test time may be reduced by accelerated testing at a correspondingly higher temperature, using a similar approach as for the accelerated ageing simulation.

The test units shall be in operation during the test. Equipment performance shall be monitored for all test specimens during the test.

5.5 Final Examination

After final performance testing, test specimens shall be visually inspected, and other tests applied (e.g. dielectric tests, insulation resistance measurements, leakage rate, etc.), as applicable in order to identify any degradation of the test specimens.

6 Documentation

The test documentation has to comprise the following:

A Product tested

Type and serial numbers
The equipment performance specification
Identification of specific features to be tested

B Test Set-up

A detailed description of the test set-ups, electrical and mechanical interfaces

C Measurement Equipment

Manufacturer, type, accuracy and most recent calibration date

D Test and Inspection Specification

It shall be stated whether the test and inspection was carried out according to this Examination Procedure or to any other specification or procedure that has been agreed upon between Supplier and Purchaser.

E Environmental Conditions

A record of the environmental conditions during each test

F Performance Testing

Description of the performance tests during and after each environmental condition

G Test Results

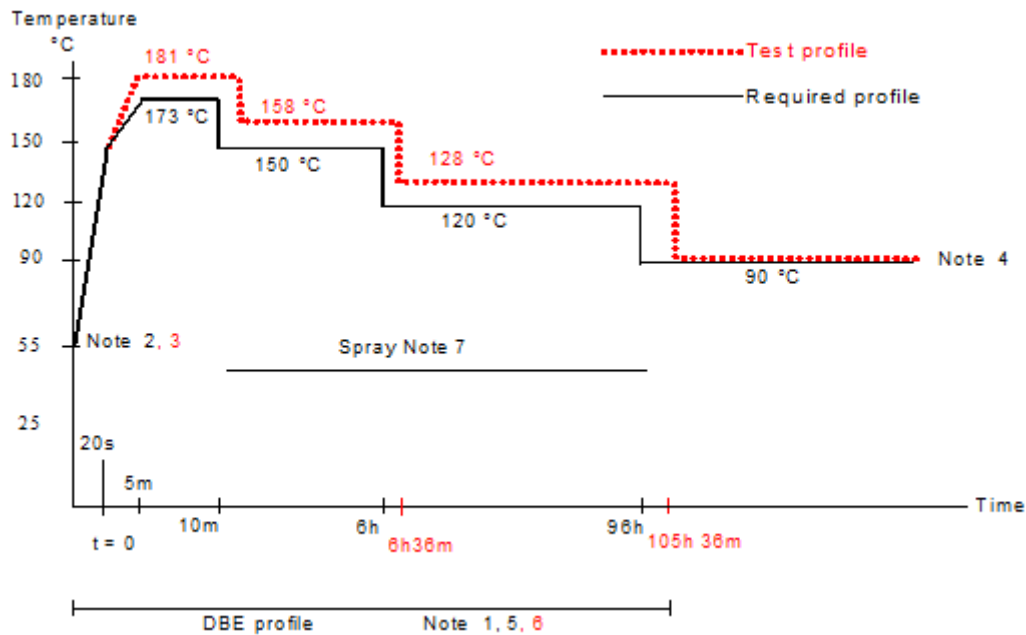
Measured values shall be documented in an auditable form. The documentation has to include a statement whether the product was successfully tested, and that all product specifications and requirements are fulfilled. Any deviation from the Manufacturer's or the Purchaser's specifications shall be stated.

H Date of testing, name of Inspector

I Approval

Documentation have to be checked, approved and signed by the Supplier's Quality Control Supervisor.

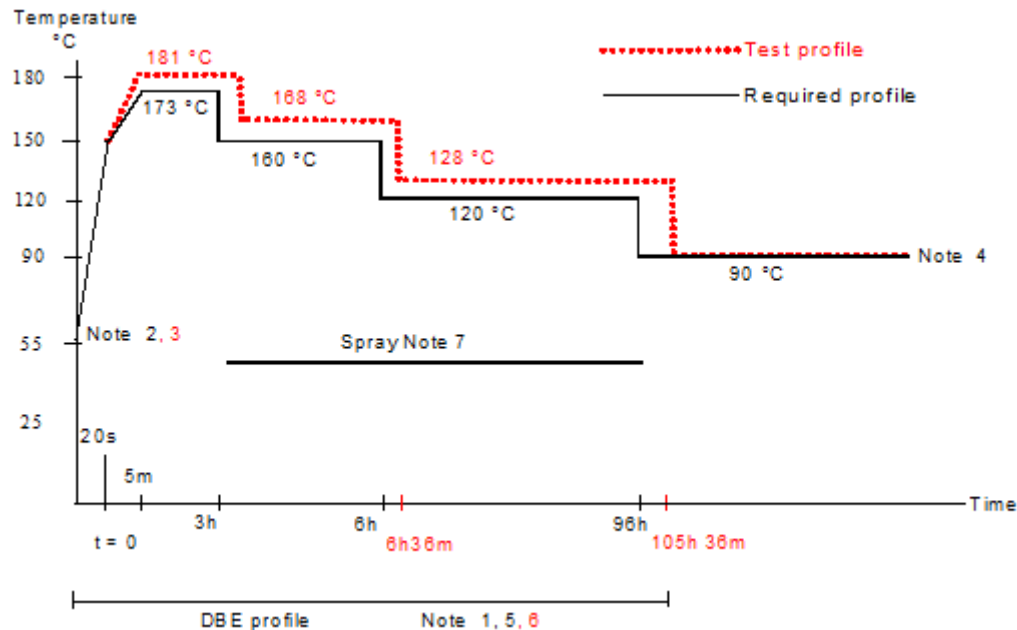
BWR1, Inside Containment Accident Conditions



Note

- 1 Values for temperature and pressure given above shall be achieved or exceeded..
100% RH are valid for required profile and test profile.
Rise and fall times shall be as short as possible.
- 2 Rise time: max 20 s up to 150°C and 5 min up to 173°C. Time t = 0 starts at 173°C.
- 3 Rise time: max 20 s up to 158°C and 5 min up to 181°C. Time t = 0 starts at 181°C.
- 4 Time for Post DBE shall be according to Technical Specification.
- 5 The pressure 0,5 MPa abs shall be kept for at least 6h.
- 6 The pressure 0,55 MPa abs shall be kept for at least 6h 36m.
- 7 Spray is specified in technical specification.

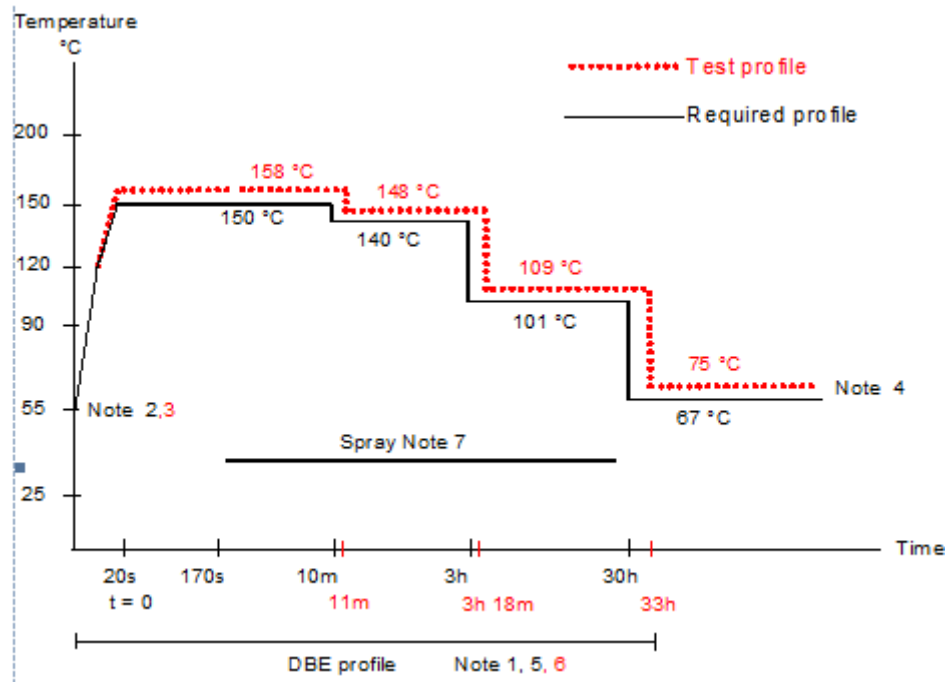
BWR2/BWR Generic, Inside Containment Accident Conditions



Note

- 1 Values for temperature and pressure given above shall be achieved or exceeded. 100% RH are valid for required profile and test profile. Rise and fall times shall be as short as possible.
- 2 Rise time: max 20 s up to 150°C and 5 min up to 173°C. Time t = 0 starts at 173°C.
- 3 Rise time: max 20 s up to 158°C and 5 min up to 181°C. Time t = 0 starts at 181°C.
- 4 Time for Post DBE shall be according to Technical Specification.
- 5 The pressure 0,5 MPa abs shall be kept for at least 6h.
- 6 The pressure 0,55 MPa abs shall be kept for at least 6h 36m
- 7 Spray is specified in technical specification.

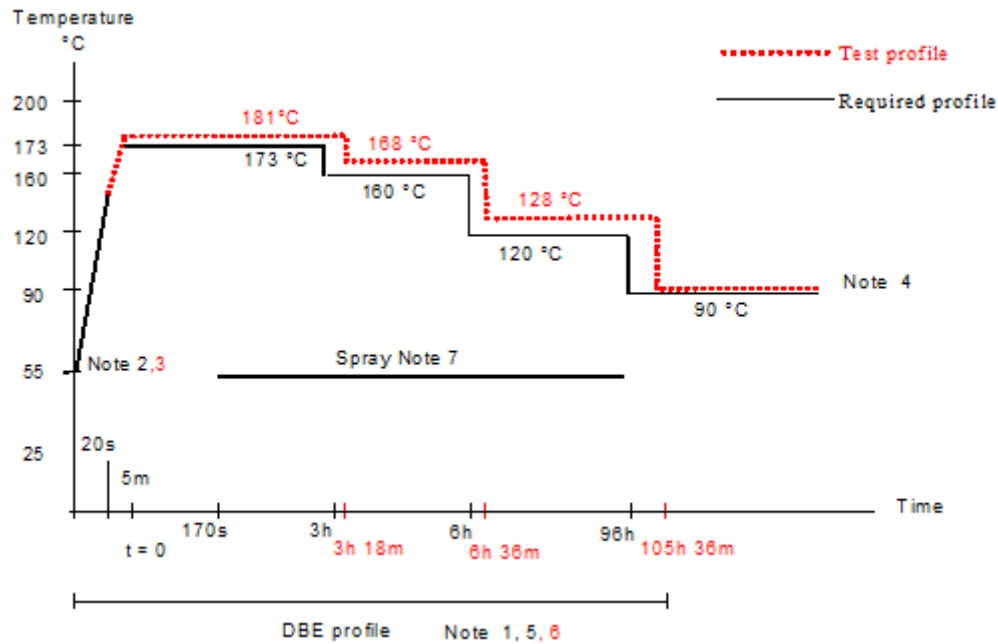
PWR, Inside Containment Accident Condition



Note

- 1 Values for temperature and pressure given above shall be achieved or exceeded. 100% RH are valid for required profile and test profile. Rise and fall times shall be as short as possible.
- 2 Rise time: max 20 s up to 150°C. Time t = 0 starts at 150°C.
- 3 Rise time: max 20 s up to 158°C. Time t = 0 starts at 158°C.
- 4 Time for Post DBE shall be according to Technical Specification.
- 5 The pressure 0,455 MPa abs shall be kept for at least 3h.
- 6 The pressure 0,5 MPa abs shall be kept for at least 3h 18m.
- 7 Spray starts at T=0 + 170s and stops at 30h.

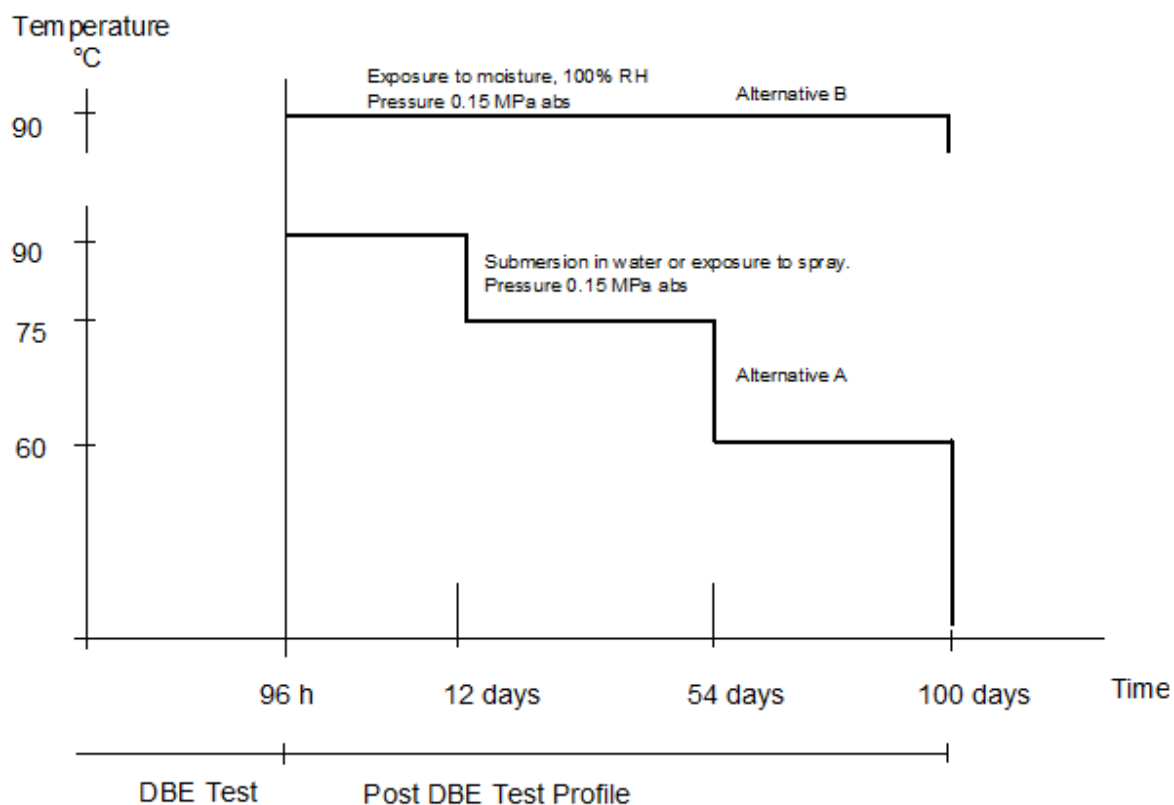
BWR/PWR, all units, Generic, Inside Containment Accident Conditions



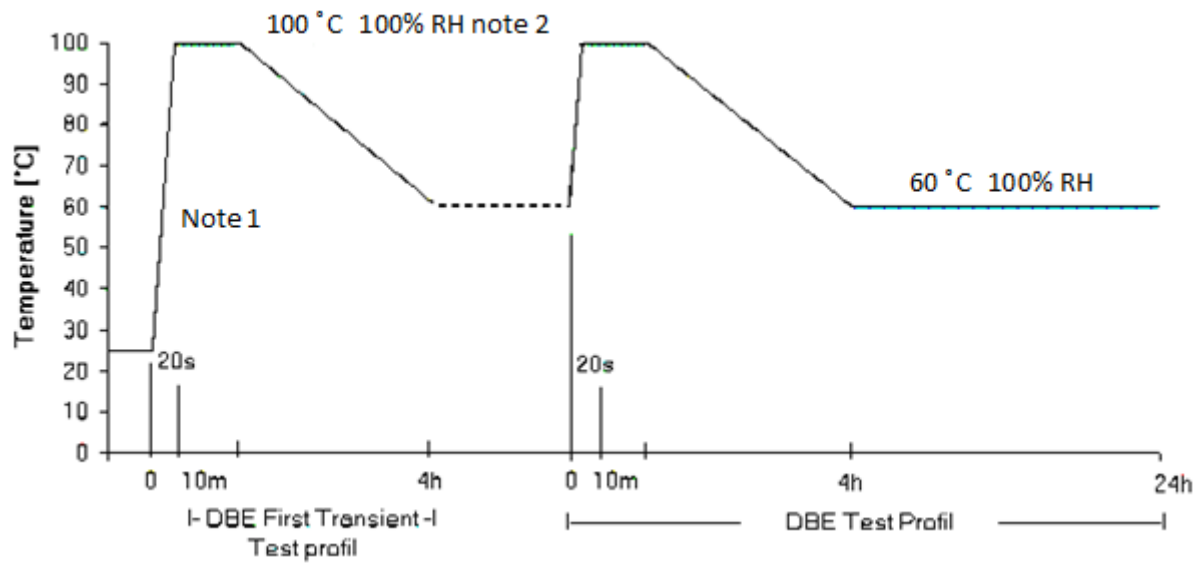
Note

- 1 Values for temperature and pressure given above shall be achieved or exceeded. 100% RH are valid for required profile and test profile. Rise and fall times shall be as short as possible.
- 2 Rise time: max 20 s up to 150°C and 5 min up to 173°C. Time t = 0 starts at 173°C.
- 3 Rise time: max 20 s up to 158°C and 5 min up to 181°C. Time t = 0 starts at 181°C.
- 4 Time for Post DBE shall be according to Technical Specification.
- 5 The pressure 0,5 MPa abs shall be kept for at least 6h.
- 6 The pressure 0,55 MPa abs shall be kept for at least 6h 36m.
- 7 Spray starts at T=0 + 170s and stops at 96 h. The first 30 h is PWR spray and the last 66 h is BWR spray.

BWR Generic, Post DBE Conditions



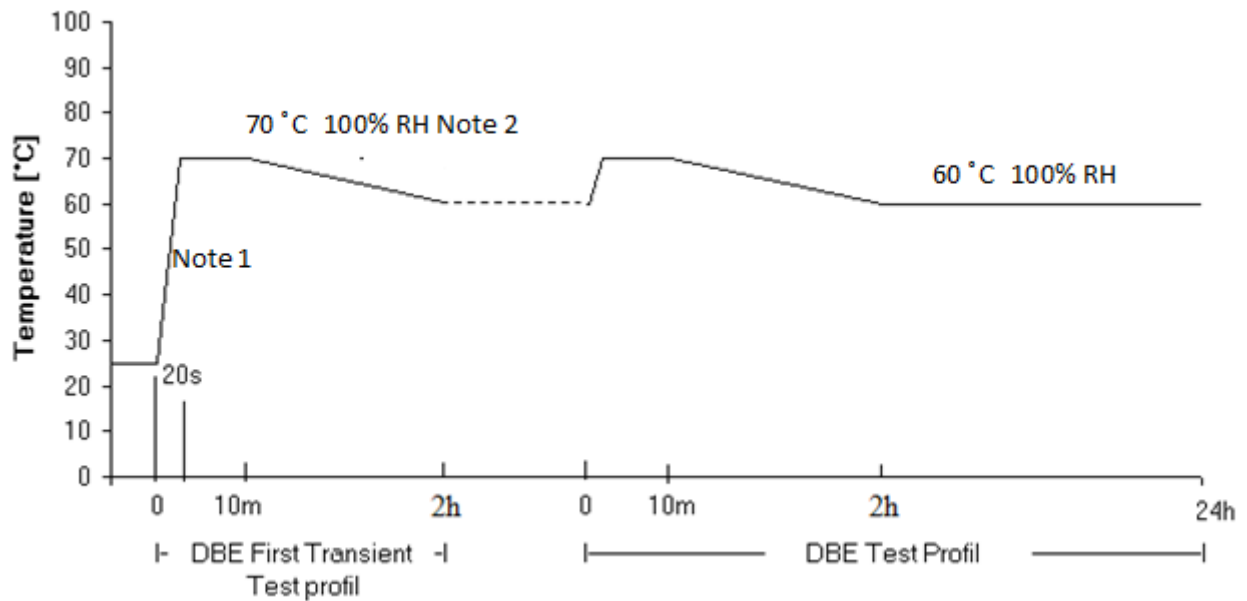
Oskarshamn 3, Outside containment Accident Conditions – Test Profile 1



Note

- 1 Rise times shall be as short as possible for Extreme Operation and DBE First Transient. Maximum values for temperature and pressure given above shall be achieved or exceeded.
- 2 The DBE First Transient may be deleted provided that the temperature is increased by 8°C and that pressure and time values given in the Test Profile diagram above are increased by 10%.

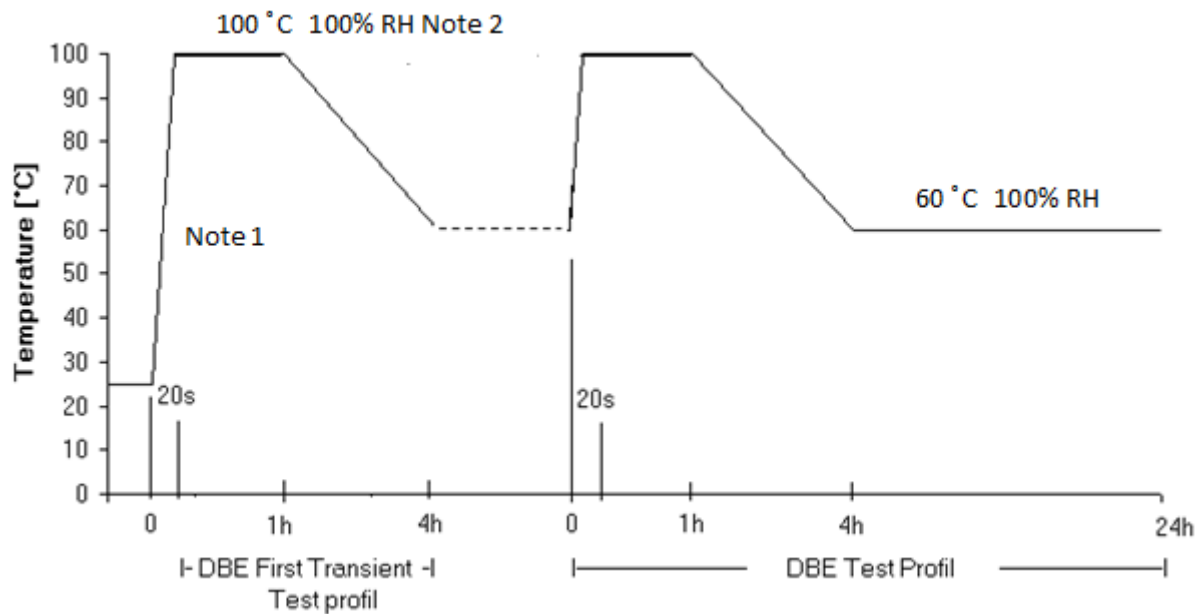
Oskarshamn 3, Outside containment Accident Conditions – Test Profile 2



Note

- 1 Rise times shall be as short as possible for Extreme Operation and DBE First Transient. Maximum values for temperature and pressure given above shall be achieved or exceeded.
- 2 The DBE First Transient may be deleted provided that the temperature is increased by 8 °C and that pressure and time values given in the Test Profile diagram above are increased by 10%.

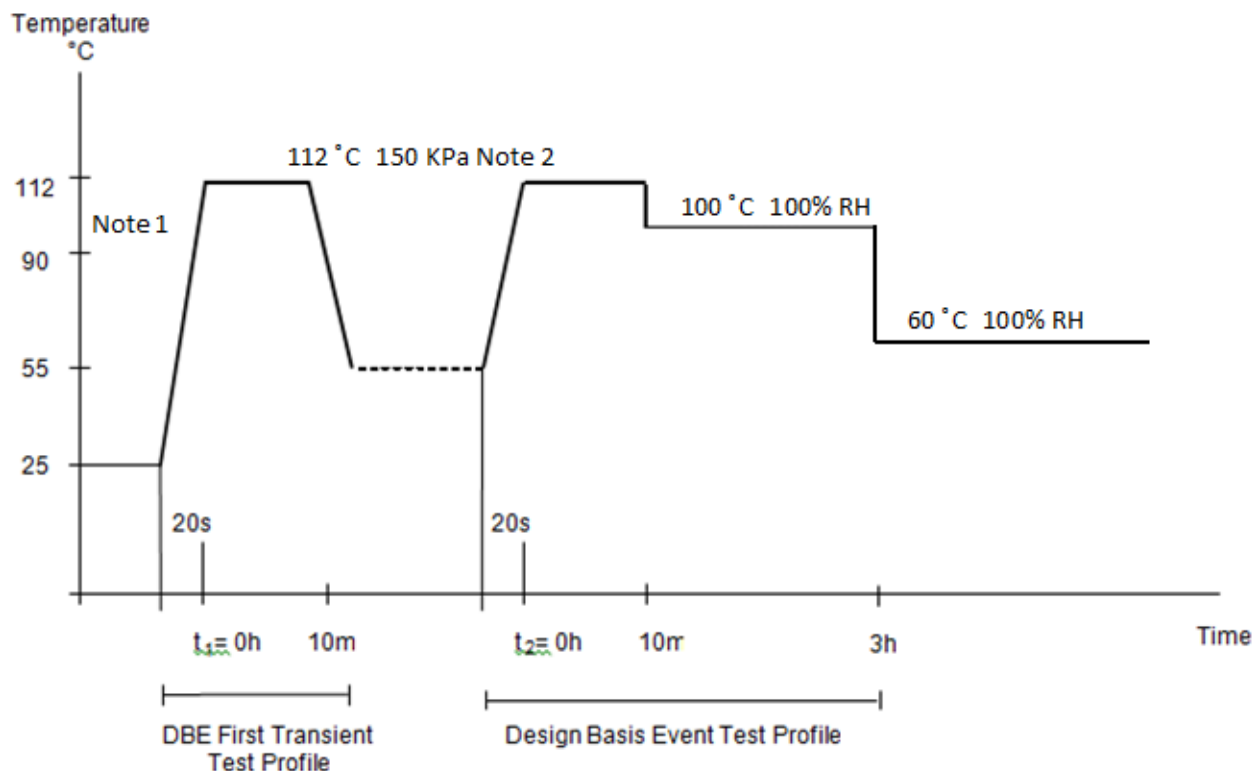
Oskarshamn 3, Ringhals 3-4, Outside containment Accident Conditions – Test Profile 3



Note

- 1 Rise times shall be as short as possible for Extreme Operation and DBE First Transient. Maximum values for temperature and pressure given above shall be achieved or exceeded.
- 2 The DBE First Transient may be deleted provided that the temperature is increased by 8°C and that pressure and time values given in the Test Profile diagram above are increased by 10%.

All plants, Outside Containment Accident Conditions Test Profile 4



Note

- 1 Rise times shall be as short as possible for Extreme Operation and DBE First Transient. Maximum values for temperature and pressure given above shall be achieved or exceeded.
- 2 The DBE First Transient may be deleted provided that the temperature is increased by 8°C and that pressure and time values given in the Test Profile diagram above are increased by 10%.