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GOVERNMENT OF INDIA

AERB SAFETY GUIDE

EQUIPMENT QUALIFICATION FOR NUCLEAR POWER PLANTS

ATOMIC ENERGY REGULATORY BOARD

AERB SAFETY GUIDE: AERB/NPP/SG/D-27

EQUIPMENT QUALIFICATION
FOR
NUCLEAR POWER PLANTS

Atomic Energy Regulatory Board,
Mumbai-400094
India
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Price:

Order for this Guide should be addressed to:

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FOREWORD

Activities concerning establishment and utilization of nuclear facilities and use of radioactive sources are to be carried out in India in accordance with the provisions of the Atomic Energy Act 1962 and subsequent amendments. In pursuance of the objective of ensuring safety of members of the public and occupational workers as well as protection of environment, the Atomic Energy Regulatory Board (AERB) has been entrusted with the responsibility of laying down safety requirements and enforcing rules and regulations for such activities. The Board has, therefore, undertaken a programme of developing safety codes, standards, guides and manuals for the purpose. While some of the documents cover aspects such as siting, design, construction, operation, quality assurance and decommissioning of nuclear and radiation facilities, the other documents cover regulatory aspects of these facilities.

Safety codes and standards are formulated on the basis of nationally and internationally accepted safety criteria for design, construction and operation of specific equipment, structures, systems and components of nuclear and radiation facilities. Safety codes establish the objectives and set requirements that shall be fulfilled to provide adequate assurance for safety. Safety guides elaborate various requirements and furnish approaches for their implementation. Safety manuals deal with specific topics and contain detailed scientific and technical information on the subject. These documents are prepared by experts in the relevant fields and are extensively reviewed by advisory committees of the Board before they are published. The documents are revised when necessary, in the light of experience and feedback from users as well as new developments in the field.

AERB safety guide on 'Equipment Qualification for Nuclear Power Plants' provides guidance for the qualification of equipment of Nuclear Power Plants required to function in normal operation and accidents conditions. It covers the aspects related to Equipment Qualification (EQ) such as EQ Concept, process and methods, design inputs for EQ, establishment and preservation of EQ, assessment of effectiveness of EQ programme.

The standards mentioned in the safety guide are acceptable to AERB. Equivalent standards other than those mentioned in the safety guide may also be acceptable if they provide a comparable assurance of safety. Consistent with the accepted practice, 'shall' and 'should' are used to distinguish between a firm requirement and recommendation respectively and 'may' and 'can' are used for desirable options.

The draft guide prepared in-house has been reviewed by experts and vetted by the Advisory Committee on Nuclear and Radiation Safety before issue. In preparing this guide, relevant International Atomic Energy Agency safety standards, and other international publications have been used. Annexures and bibliography are included to provide further information on the subject. AERB acknowledges the efforts of all individuals and organisations who have prepared and reviewed the draft and helped in its finalisation.

(G. Nageswara Rao)
Chairman, AERB

DEFINITIONS

Accident
An unplanned event resulting in (or having the potential to result in) personal injury or damage to equipment which may or may not cause release of unacceptable quantities of radioactive material or toxic/hazardous chemicals.

Accident Conditions
Substantial deviations from operational states, which could lead to release of unacceptable quantities of radioactive materials. They are more severe than anticipated operational occurrences and include design basis accidents as well as beyond design basis accidents.

Normal Operation
Operation of a plant or equipment within specified operational limits and conditions. In case of a nuclear power plant, this includes, start-up, power operation, shutting down, shutdown state, maintenance, testing and refuelling.

Design Basis Accidents (DBAs)
A set of postulated accidents which are analysed to arrive at conservative limits on pressure, temperature and other parameters which are then used to set specifications to be met by plant structures, systems and components, and fission product barriers.

Design Extension Conditions – A[1] (Without Core Damage)
Accident conditions, beyond design basis, in which significant core damage does not occur, though significant fuel[2] degradation is expected but the reactor core geometry that allows for adequate fuel cooling is maintained and reactor core is in long term sub-critical state.

Design Extension Conditions – B[3] (With Core Damage)
Accident conditions, beyond design basis, in which significant core degradation, involving melting of reactor core structures and reactor fuel, is expected.

Inspection
Quality control actions, which by means of examination, observation or measurement, determine the conformance of materials, parts, components, systems, structures as well as processes and procedures with predetermined quality requirements.

Safety Function
A specific purpose that must be accomplished for safety.

Common Cause Failure
The failure of a number of devices or components to perform their functions, as a result of a single specific event or cause.

Common Mode Failure
Failure of two or more structures, systems or components in the same manner or mode due to a single event or cause. It is a type of common cause failure.

Primary Containment
The principal structure of a reactor unit that acts as a pressure retaining barrier, after the fuel cladding and reactor coolant pressure boundary, for controlling the release of radioactive material into the environment.

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[1] 'without Core Damage' to be used for PHWRs and 'without Core melt' to be used for LWRs/FBRs
[2] Fuel stored in fuel pool as well as fuel within reactor core shall be considered
[3] 'with Core Damage' to be used for PHWRs and 'with Core melt' to be used for LWRs/FBRs

It includes containment structure, its access openings, penetrations and other associated components used to effect isolation of the containment atmosphere.

Integrated Leakage Rate Test (Containment)
The leakage test performed on the containment by pressurising the same to particular leakage rate test pressure, and determining the overall integrated leakage rate.

Maintenance
Organised activities covering all preventive and corrective measures, both administrative and technical, to ensure that all structures, systems and components are capable of performing as intended for safe operation of the plant.

Surveillance
All planned activities, viz. monitoring, verifying, checking including in-service inspection, functional testing, calibration and performance testing carried out to ensure compliance with specifications established in a facility.

Loss of Coolant Accident (LOCA)
An accident in which coolant is lost from primary heat transport system at a rate greater than the rate which make-up system can cater to.

Responsible Organisation
Responsible Organisation is an organisation having overall responsibility for siting, design, construction, commissioning, operation and decommissioning of a facility.

Audit
A documented activity performed to determine by investigation, examination and evaluation of objective evidence, the adequacy of, and adherence to applicable codes, standards, specifications, established procedures, instructions, administrative or operational programmes and other applicable documents, and the effectiveness of their implementation.

Review
Documented, comprehensive and systematic evaluation of the fulfilment of requirements, identification of issues, if any.

Quality Assurance (QA)
The function of a management system that provides confidence that specified requirements will be fulfilled.

Quality Control (QC)
Part of quality management intended to verify that structures, systems and components correspond to predetermined requirements.

Documentation
Recorded or pictorial information describing, defining, specifying, reporting or certifying activities, requirements, procedures or results.

Diversity
The presence of two or more redundant systems or components to perform an identified function, where the different systems or components have different attributes so as to reduce the possibility of common cause failure, including common mode failure.

Redundancy
Provision of alternative (identical or diverse) structures, systems and components, so that any single structure, system or component can perform the required function regardless of the state of operation or failure of any other.

SPECIAL DEFINITIONS

(Specific to this guide)

Age conditioning
Exposure of sample equipment to environmental stressors and operational system conditions to simulate their effects on the equipment performance for a specified period of time; design basis events are not included.

Accelerated ageing
A process in which natural ageing effects on equipment is realised in a short period of time by application of elevated amount of stressors representing the plant pre-service (till commissioning) and service conditions.

Equipment
Assembly of components designed and manufactured to perform specific functions (e.g. instruments and equipment like electrical motors, pumps, motorized valves, pneumatic valves, transmitters etc). Equipment includes components such as resistors, capacitors, wires, connectors, transistors, tubes, switches, springs, seals, cables, O-rings etc.

Environmental Qualification
Qualification to demonstrate capability to withstand effects of environmental conditions of temperature, pressure, humidity, contact with chemicals, radiation exposure, meteorological conditions, submergence, ageing mechanisms and other conditions expected during service life of equipment.

Equipment qualification
Generation and maintenance of evidence to ensure that the equipment will operate on demand to meet system performance requirements during normal and harsh service conditions during accident. Equipment qualification includes environmental and seismic qualification.

Equipment qualification process
Set of activities carried out towards the qualification of equipment which is carried out in three phases: design input phase, qualification establishment phase and qualification preserving phase.

Harsh environment
Environmental conditions in Nuclear Power Plant which significantly change as a result of an accident.

Interface
Physical attachments, mounting, auxiliary components, and connectors (electrical and mechanical) to the equipment at the equipment boundary.

Qualified life
Period of time for which performance of equipment is demonstrated to be within acceptance criteria for a specified set of service conditions.

Qualification margin
Difference between the most severe specified service conditions of the plant and the conditions used in qualification to account for normal variations in production of equipment and reasonable errors in defining satisfactory performance.

Sample
Representative equipment or component chosen from a manufacturing lot or batch of similar type for type test qualification.

Service conditions
Environmental and operating conditions expected during normal operation states and accident conditions.

Service life
The time period from which an equipment is put into operation till its removal from service.

Specimen
Individual equipment or component undergoing type test qualification.

Synergistic effect
The effects that result from two or more stresses acting together, as distinguished from the effects of the stresses applied separately.

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1 INTRODUCTION

1.1 General

1.1.1 Nuclear Power Plants (NPPs) are designed, sited, constructed, commissioned and operated in conformity with the applicable nuclear safety standards. The standards ensure an adequate margin of safety so that NPPs are operated without undue radiological risk to the plant personnel or members of the public.

1.1.2 The basic principles employed in the design of systems and equipment are redundancy, diversity, physical separation. Designing and qualifying equipment for operation during the normal, and harsh environmental conditions provides assurance on avoidance of common cause failures due to environmental conditions including that resulting from accidents.

1.1.3 Equipment Qualification is carried out to ensure the capability of the equipment to withstand the stresses of normal operation and harsh environment. Qualification ensures that identified equipment will be capable of performing their intended safety functions in the service conditions expected during normal operation as well as during accidents including seismic events.

1.1.4 This safety guide provides the guidance for establishment and preservation of equipment qualification in an NPP to ensure its safe and continued operation, and for establishing a comprehensive programme for maintaining and overseeing the entire qualification process.

1.2 Objective

1.2.1 The objective of this safety guide is to provide guidance on the establishment and preservation of qualification of safety related electrical, instrumentation & control and active mechanical equipment of NPPs (e.g valves, pumps etc.) that perform safety functions in normal operation conditions and harsh environment expected during accident conditions. This guide covers following aspects:

- Equipment Qualification (EQ) Concept, Process and Methods
- Design inputs for EQ
- Establishment of EQ
- Preservation of EQ
- Assessment of effectiveness of EQ programme
- QA, training & documentation related to EQ.

1.3 Scope

1.3.1 This safety guide provides guidance for the qualification of equipment of NPPs required to function in normal operation conditions and accidents conditions.

1.3.2 The guidance provided is in addition to the qualification requirements for expected environmental conditions during normal operation as per respective design specifications /standards.

1.3.3 This guide provides guidance on measures to be taken for preservation of Equipment Qualification throughout its qualified life or during its extended qualified life.

1.3.4 The concept of application of equipment qualification for handling Design Extension Conditions with core melt is being evolved for various scenarios. The approach towards assessment of equipment capability to function during the environmental conditions resulting from Design Extension Conditions with core melt are briefly covered in this safety guide

1.3.5 Qualification guidance for normal operation condition is available in relevant design guides and standard, including those mentioned in the Bibliography.

1.3.6 This safety guide does not provide guidance on seismic qualification methods and processes. Guidance on seismic qualification is covered in safety guide, ‘Seismic Qualification of Structures, Systems and Components of Pressurized Heavy Water Reactors’, AERB/NPP-PHWR/SG/D-23, 2009.

1.3.7 Qualification of piping, civil structures and other passive components (e.g. vessel) are not in the scope of this guide. Their qualification is achieved by design, construction, inspection, and testing according to applicable standards/codes/guides.

1.3.8 This safety guide does not provide guidance on qualification for Electromagnetic Interference (EMI)/ Electromagnetic Compatibility; and equipment protection against the effects of internal fires and explosions, for which, relevant Codes/ Standards/ Guides should be referred.

2 CONCEPTS & PROCESS OF EQUIPMENT QUALIFICATION PROGRAMME

2.1 Basic concepts for EQ

2.1.1 Equipment qualification deals with the qualification of safety related electrical, instrumentation & control and active mechanical equipment and components associated with the equipment (e.g. junction boxes, seals, gaskets, lubricants, cables, connections) that perform safety functions in normal operation conditions and harsh environment expected during accident conditions.

2.1.2 In general, equipment qualification of civil structures and other passive NPP components such as vessels, tanks, piping and supports is not required as qualification of such structures / systems / equipment / component is achieved directly by design, construction, inspection, and testing according to applicable codes. Their functionality would not get affected by harsh environments due to the postulated accidents. Assessment of their degradation, during service are covered under Ageing Management Programme.

2.1.3 Equipment qualification is required for all equipment along with interfaces which are required to perform safety functions and are likely to be exposed to harsh conditions such as temperature, pressure, radiation, humidity, vibration, chemical spray, sodium aerosol or any likely combination of these during an accident. Protection against submergence, jet impingement, and fire are generally considered during equipment layout at the design stage itself so that equipment qualification is not warranted for such scenarios. If subsequent examination reveals deficiency against any of such conditions, those should be addressed appropriately or the equipment should be qualified accordingly.

2.1.4 Equipment qualification should be established at equipment level. If the components of an equipment are mechanically or electrically interconnected as a functional unit, then the complete functional unit should be qualified. Qualification may also be achieved by properly defining the performance specifications of individual component and qualifying them individually.

2.1.5 Equipment ageing, which has a potential for common cause failure, should also be considered as part of equipment qualification. During installation/ replacement, new equipment/component should be ensured to be capable of adequately performing their intended function under normal & accident conditions. Special emphasis should be given for qualification of equipment that cannot be replaced easily during the designed life of the plant.

2.1.6 Equipment qualification should consider, to the extent possible, synergistic effect also, to determine its effect on the equipment performance.

2.1.7 A programme should be established for the qualification of equipment that are required to operate during and after Design Basis Accident (DBA)/ Design Extension Conditions without Core Melt (DEC-A) to demonstrate their capability for achieving the intended function under the expected environmental conditions.

2.1.8 A programme should also be established for qualification/ assessment of survivability of those equipment that are required to operate during and after Design Extension Conditions with core melt (DEC-B) to confirm/assess their capability for achieving the intended function under the expected environmental conditions. Assessment of equipment survivability should give reasonable assurance that equipment will function in severe accident environment.

2.1.9 Systems and equipment should be identified which are required to fulfill the fundamental safety functions of the reactor during and after DBA/ DEC-A. A consolidated master list, containing details of components/ instruments/ equipment, identified for Equipment Qualification should be prepared.

2.1.10 A separate consolidated list, containing details of components/ instruments/ equipment, identified for Equipment Qualification, required during and after DEC-B should be prepared.

2.1.11 All the identified equipment in the master list should be included in the qualification programme.

2.1.12 Quality Assurance, specialized training and documentation should be essential parts of the EQ programme.

2.1.13 Periodic assessment should be carried out to assess the effectiveness of EQ programme.

2.2 Equipment Qualification Process

2.2.1 The EQ process consists of three main phases i.e. Design Input, Establishing EQ and Preserving EQ. These three phases and sequence of activities involved in each phase is illustrated in figure. 1 below.

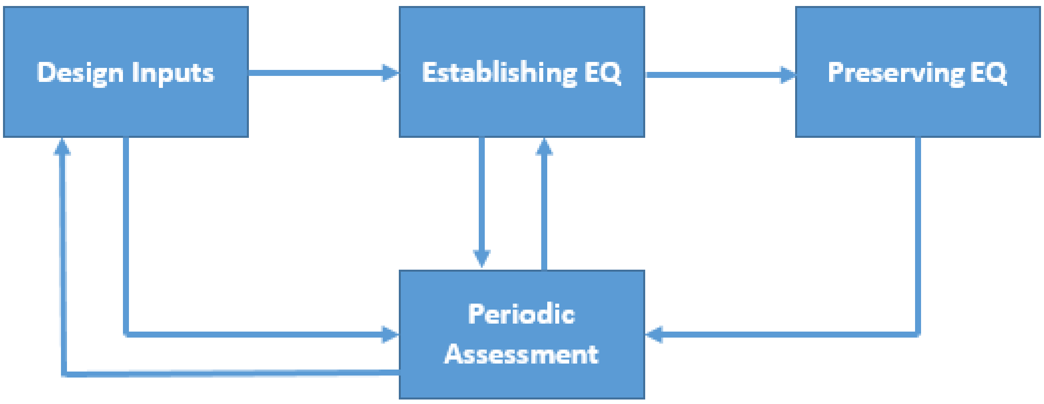

Figure 1: Phases of Equipment Qualification Process

Design Input	**Establishing EQ**	**Preserving EQ**
1. Identification of DBA/ DEC 2. Determination of safety functions and identification of equipment along with mission time 3. Specifying service conditions (normal and accidental) 4. Development of master list of equipment	1. Defining EQ requirements 2. Selection of qualification method 3. Establishing Qualification & documentation 4. Assessment of ageing effects for qualified life 5. Defining installation & maintenance requirements	1. Installation and maintenance control 2. Replacement control 3. Modification control 4. Monitoring of Service condition 5. Analysis of degradation and failures 6. Analysis of experience feedback
#Documentation is an essential part of all the phases		

2.2.2 The overall EQ programme, including the sequence to be followed is depicted in the figure 2 below. Details of various stages of EQ programme are provided in the subsequent sections of this safety guide.

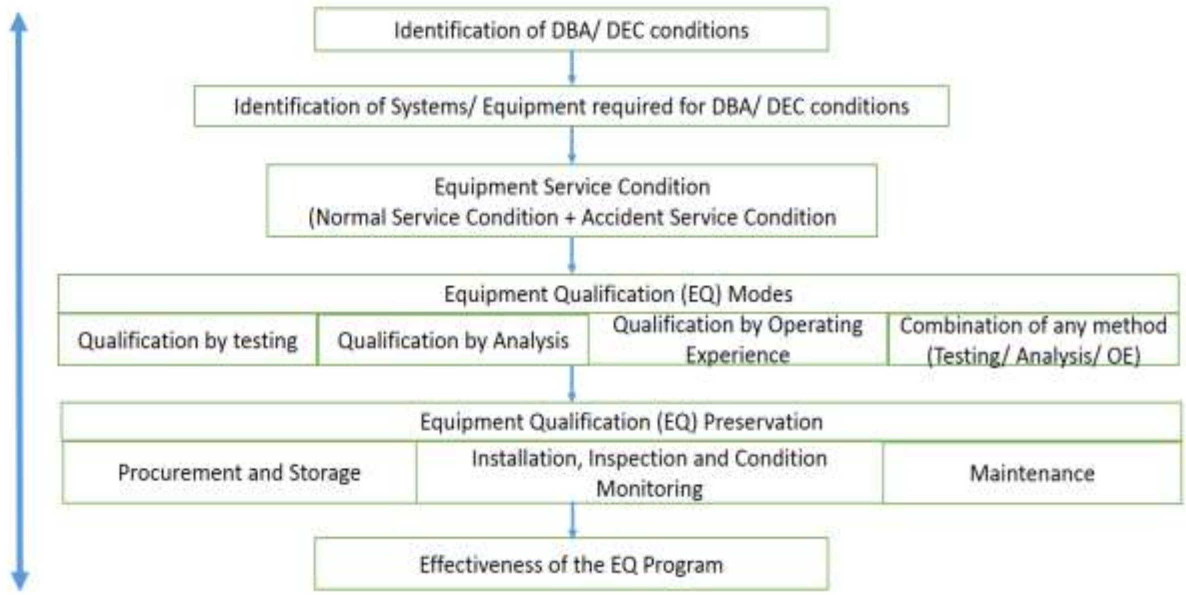

Figure 2: Equipment Qualification Programme

3 DESIGN INPUTS FOR EQUIPMENT QUALIFICATION

3.1 General

3.1.1 Design input phase involves the following activities for establishment of EQ**:**

a) Identification of DBA and DEC governing scenarios/ events

b) Details of specific systems and related equipment which are required to perform safety function in accident conditions'

c) Details of postulated service conditions (normal & accident) under which the equipment has to perform its intended function for its mission time during service life

d) Equipment performance requirements for demonstration / verification in the EQ programme and their acceptance criteria

The above information should be obtained from plant system design documents and safety analysis report.

3.2 Identification of DBA/ DEC governing scenarios

3.2.1 AERB safety guide on 'Design Basis Events for water cooled NPPs', AERB/NPP-WCR/SG/D-5, 2020 provides guidance for identification of DBA/ DEC governing scenarios/ events. The systems and equipment required for handling these events to ensure and maintain fundamental safety functions should be identified along with their mission time. The anticipated service conditions for normal operation and DBA/ DEC should be arrived at based on plant design and safety analysis.

3.2.2 Governing events that give rise to harsh environment should be considered for the establishment of service conditions for the concerned equipment as the equipment qualified for a harsher environment would perform the safety functions for less severe events also. This approach should be adopted to decide governing/enveloping event for testing of each equipment.

3.3 Service Conditions

3.3.1 Service conditions are the environmental and operational conditions postulated during normal operation as well as during identified DBA/ DEC. Environmental conditions typically include ambient temperature, pressure, humidity/ steam, radiation, water/ chemical sprays, chemical exposure, fluid submergence and seismic vibration. Operational conditions generally include process related conditions such as load cycling, electrical loading parameters (e.g. voltage, frequency, current), electromagnetic interference (EMI), mechanical loads (e.g. thrust or torque, non-seismic vibrations) and fluid conditions (e.g. pressure, temperature, chemistry, cavitation, flow rate).

3.3.2 Any environmental condition that could be anticipated and that could arise in specific operational states, such as in periodic testing of the containment leak rate, should be considered in the equipment qualification programme.

3.3.3 Environmental service conditions should be derived for a location specific to the equipment based on design and safety analysis.

3.3.4 EQ should be established for service conditions which includes both normal operation conditions and conditions during identified DBA/ DEC as specified in figure 3.

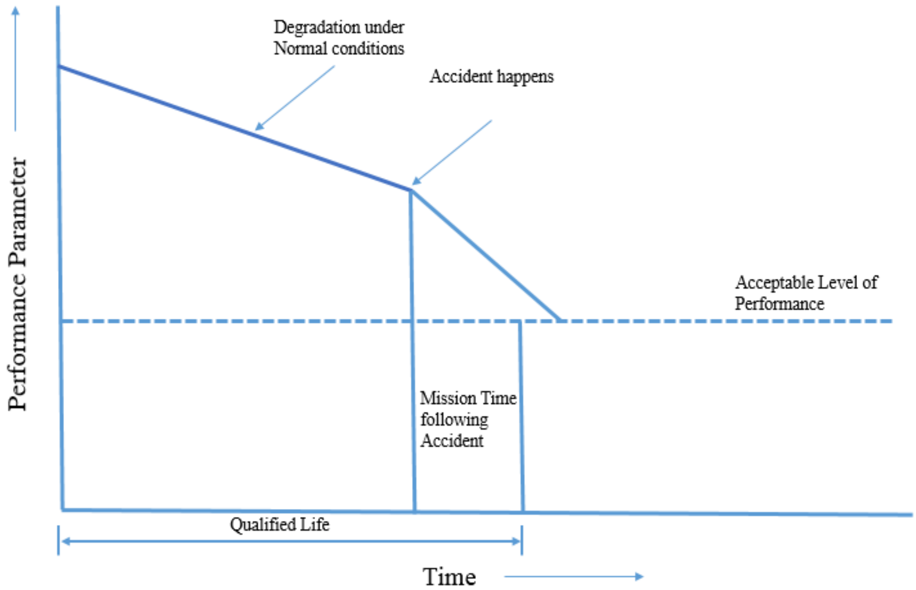

Figure 3: Assumption for qualification of equipment

3.4 Equipment Ageing

3.4.1 Equipment ageing is a potential common cause of failure. It should be evaluated as part of the EQ programme. Equipment which are capable of delivering the function under normal and DBA/ DEC service conditions may not perform as per design intent, after experiencing the potentially degrading effects of prolonged operation and surveillance testing. The contribution of ageing effect to common mode of failures for equipment may be significant during DBA/ DEC, when service conditions become harsher than the normal operation and during periodic testing (e.g. PCILRT-primary containment integrated leak rate test). Equipment which are capable of functioning as per design intent may not perform as expected, due to degrading effects of prolonged operation and surveillance testing, in harsher environment. This may increase its probability of failure while performing under harsher environmental conditions during DBA/ DEC.

3.4.2 EQ should consider ageing effects by simulating the same during tests, evaluating their significance by using analysis or operating experience, identifying ageing related degradation through surveillance and minimizing it through maintenance and periodic replacement of installed equipment or age sensitive parts.

3.5 Criteria for Equipment identification & Selection

3.5.1 Safety related SSCs located inside as well as on the periphery of the reactor building and having exposure to harsh environment and/or radiation, are required to be considered under environmental qualification. These SSCs can be related to civil, mechanical, electrical and instrumentation & control. The aspects to be considered for EQ of SSCs under these are:

Civil

3.5.2 Civil structures are designed as per their functional requirements during normal operation and accident conditions. The specified Limiting conditions with respect to temperature of the civil structures should be maintained by the ventilation system. Relevant safety codes, standards and guides should be referred for the relevant requirements and guidance regarding the same. The health of the civil structures should be periodically assessed and ensured through an ageing management programme.

Mechanical

3.5.3 A qualification program of mechanical equipment should be implemented in cases where the failure of non-metallic components of mechanical equipment can prevent the accomplishment of safety functions. Examples may include, but are not limited to, lubricants, elastomeric components in pneumatic valve actuators, pneumatic amplifiers, gaskets in valves and seals in containment penetrations and airlocks.

Electrical

3.5.4 The electrical equipment which may experience harsher environment should be identified and qualified. Some equipment may see higher loads during accident conditions (e.g. RB coolers/ motors operating in the high pressure environment following LOCA/ MSLB). Such equipment should be considered for qualification for higher electrical loads experienced during postulated accident condition.

Instrumentation & Control

3.5.5 I&C equipment identification should include entire chain comprising of sensors, cables, junction boxes, connectors, amplifiers, transmitters, penetrations, seals, O-rings etc. It should be verified that equipment qualification is performed for all the elements in the chain.

3.5.6 Equipment requiring qualification can be identified and grouped based on the following criteria:

a) Equipment required to perform safety function(s) that will experience harsh environment conditions during & post-accident.

b) Equipment which will be required for post-accident monitoring and mitigating functions.

c) Equipment that will experience harsh environment conditions during and post-accident, which are not required to perform the safety function directly, but whose failure could prevent the accomplishment of required safety functions / mitigating functions.

d) The Systems/ Components which are required to perform during severe accident scenario (DEC-B) for monitoring and mitigation functions based on Severe Accident Management Guidelines (SAMG).

3.5.7 Some equipment which are identified based on their functional requirements and included in the EQ master list, need not be selected for environmental qualification by testing. However, such equipment should be qualified through technical justification. These equipment can be categorized as follows:

a) Those performing safety or accident mitigation functions before experiencing harsh environmental conditions and whose subsequent failure would not jeopardize the safety (e.g. Ion Chamber Amplifier for reactor trip which generates trip signal within few seconds of an accident).

b) Those performing accident mitigation functions and having very low radiation exposure but do not experience harsh environment by virtue of their location.

c) Those performing accident mitigation functions and experience harsh environment but their material of construction is either metal or elastomers that are known to withstand harsh environment and elastomers can be replaced with required frequency. Proper justification should be given for all such equipment.

3.5.8 An EQ master list should be prepared for safety related systems which are required to perform safety functions during DBA/ DEC, specifying type of equipment, its function, make and model number, equipment location, location specific environmental condition, mission time etc. A typical format for the master list is given in Appendix - 1. A typical process used for identifying the equipment for EQ is given in Appendix - 2.

4 ESTABLISHING EQUIPMENT QUALIFICATION

4.1 General

4.1.1 Equipment Qualification programme needs to be established to demonstrate that the equipment would perform its intended functions when exposed to the environmental conditions expected during normal operation and the identified DBA/ DEC. EQ is carried out for service conditions viz. humidity, temperature, pressure, radiation field, chemical, other environmental conditions and stresses created due to the DBA /DEC including seismic conditions. Equipment should be qualified for the applicable mission time to conform to the satisfactory functional requirements in the expected service conditions, adopting appropriate test methods and margins.

4.2 Methods of Equipment Qualification

4.2.1 The equipment qualification should be performed based on any one of the following qualification methods:

a) Type testing

b) Analysis

c) Operating experience

d) Any combination of type testing, operating experience, and analysis

Qualification by Type Testing

4.2.2 The representative sample of the equipment, including interfaces, is subjected to a series of tests, simulating the effects of significant ageing mechanisms, expected during normal operation. The aged sample is subjected to testing for simulated conditions of DBAs or DECs and thereby qualifying for the installed configuration of equipment. A successful type test demonstrates that the performance of the equipment meets the requirements of performance specifications including margin under the normal, abnormal and accident conditions, as appropriate.

4.2.3 Details on selection of test sample, test facility, test sequence, margin and acceptance criteria, test results and documentations for type test qualification are given in Section 4.3.

Qualification by Analysis

4.2.4 Qualification by analysis requires a logical assessment or a valid mathematical model to establish that the equipment to be qualified can perform its safety functions when subjected to the specific service conditions. This methodology should be supplemented by test data. The mathematical model used should be validated against experimental data, test data or operating experience.

4.2.5 Qualification by analysis may be used for large size equipment like pump, motorized valves etc. In such cases, the material composition and performance of the equipment should be analyzed, to ensure compliance with the service requirements. However, for such equipment, all the accessories essential to perform the safety function like limit switches etc. should be qualified by testing.

4.2.6 Qualification by analysis can be used to extend the results of an equipment qualified by testing to represent an entire family of equipment of the same or similar type. However, it should be verified that the tested equipment is representative of the same family of equipment (e.g. cables, motorized valves etc.).

4.2.7 Qualification by analysis can also be used for extending the qualified life of the equipment. This method should be supported by justification of the models and assumptions used and documented.

Qualification by Operating Experience

4.2.8 Performance data of equipment that has been successfully operated under known service conditions may be used for qualifying equipment of similar design and make which has to operate under similar or less severe service conditions. Detailed checklist should be prepared to ensure the similarity of the design and the service conditions.

4.2.9 Due to limited availability of operating experience data on performance under accident conditions, qualification by operating experience may be applied for the equipment which has to complete their mission time in the initial stage of the accident condition and prior to exposure to harsh environment conditions.

4.2.10 If the operating experience data are not sufficient to justify qualification of the equipment for the entire qualified life objective including DBA / DEC, it should be substantiated by additional testing of the equipment to ensure qualification under the anticipated environmental conditions determined based on accident analysis.

4.2.11 Operating experience feedback, given by a manufacturer can also be considered for qualification of an equipment. However, this should be supplemented by confirmation of a user. There should be adequate documentation on the service conditions and differences should be evaluated and justified.

Qualification by Combined methods

4.2.12 Equipment can be qualified by combination of type test, operating experience, and analysis. For example, where type test of a complete assembly is not possible, component testing supplemented by analysis may be used. If material for some components of the equipment is not susceptible to degradation from the effects of specified service conditions, those components can be qualified through a material analysis and others by type test or operating experience. The combination of methods used for equipment qualification should be justified and documented.

4.3 Details of Qualification by Type Testing

4.3.1 For qualification by type testing, a representative sample of the equipment along with its interfaces are subjected to a series of tests, simulating the effect of significant ageing stressors to which it would be exposed during normal service. Further, the same specimen is tested for DBA/DEC by simulating the effect of radiation, temperature and pressure, chemicals and shake table test for seismic qualification. Type testing for equipment qualification is performed with equipment functioning in a state representative of its intended use in actual operation including software controlled functions. Qualification by type testing establishes that the equipment meets the performance requirements and the intended safety functions will be performed under the specified service conditions.

Test Sequence

4.3.2 The sequence of these tests should be designed in such a way that the worst state of degradation due to ageing stressors during service life followed by exposure to the accident conditions are simulated most accurately or conservatively.

4.3.3 Before commencing the type test, equipment should be tested for its functional and performance requirements as per design specification. All the readings should be recorded so that baseline data are available for further comparison and review.

4.3.4 The preferred test sequence to demonstrate equipment qualification is given below:

a) Initial Inspection

b) Baseline Function Test

c) Radiation Ageing*

d) Accelerated Thermal Ageing*

e) Seismic Testing#

f) Accident Simulation Test#

g) Final Inspection

*Sequence can be interchanged for ageing where such change is not expected to have any impact

A seismic event is not assumed to occur in conjunction with Design Basis Accident such as LOCA. However, in test sequence, if seismic qualification is carried out as first test, then accident simulation test is performed as governing sequence. This sequence can be interchanged, as long as it ensures a higher degree of conservatism.

Test Specifications

4.3.5 Type test should be carried out following a well-defined and documented test specification. The test specification should include the following:

a) Basis for selection of sample and description with unique identification

b) Determination of the required number of test specimens to ensure accurate representation based on evaluation

c) The test specimens and their assembly and mounting should be identical to the type or series of the equipment to be qualified and similar to the installed configuration. (For example, Junction Box testing along with cable connectors and identical mounting)

d) Any dimension and tolerance that might impact the performance of the specimen

e) The service conditions to be simulated for qualified life and specified mission time along with margin during accident

f) The normal operating status of the equipment (e.g. energized or de-energized, simulation of process input conditions) and functional performance monitoring requirements during and after the test

g) For large sized equipment (example Pump, Cable Penetration Assembly etc.) which are difficult to be tested in test facilities, scale down models can be used for environmental qualification. Scale down models should be representative of the configuration and material properties of the equipment to be qualified. It should be justified that the use of scale down models will not adversely impact the results of the equipment qualification tests in comparison with the actual equipment testing.

h) The electromagnetic interference tests can be performed on a test specimen different than that of the one which is subjected to tests for operational ageing, seismic events and other DBA/ DEC.

i) Fire survival test on cables for specified rating should be performed on the same test specimen which has undergone all the other environmental tests, if such item is required to perform during post-accident conditions (e.g. fire survival cable for post-accident monitoring).

j) Procedure should be prepared for correcting deviations or failures observed during test

k) Witness/ Hold points (by an independent expert) during the test

Test Facility/Setup

4.3.6 Test facility should have provision for simulating the required test conditions. Following should be considered for the test facility:

a) A description of the test facilities/ setup to be used (e.g. accelerated thermal ageing oven, radiation ageing setup, LOCA/MSLB test chamber, and shake tables to simulate earthquake motion)

b) Specifications for the test assembly, mounting and interfaces

c) Details of measurement devices and their accuracy

Acceptance Criteria

4.3.7 Following acceptance criteria should be ensured during and after the test:

a) The performance of safety function(s) by the equipment should be demonstrated throughout the test, as far as practically achievable.

b) Test acceptance criteria (e.g. opening and closing time, response time, status change of contact, accuracy etc.), should be specified before starting the test. Details of test parameters that should be monitored and recorded. It should be verified with the test acceptance criteria.

c) After each test, baseline function test should be carried out, and then subsequent tests should be continued without any adjustment/ modification in test specimen. Type testing for equipment qualification should be performed with equipment (including any software and its interfaces) functioning in a state which is representing its actual operation. In case, if any adjustment or modification is required, it should be done only after proper justification to ensure that there is no loss of conservatism in test results.

d) After completion of each sequential test, equipment should be examined for any visible damage/ deformation, moisture ingress etc. and observations should be recorded

e) The test documentation should include details of test specifications, results, and qualified life along with boundary conditions/ limitations

f) Test specimen used during equipment qualification testing should not be used in the plant for safety applications

g) The quality assurance procedures should be followed throughout the type test qualification

Test Margins

4.3.8 In equipment qualification process, adequate margins on the accident simulation test conditions should be applied to take care of the inaccuracies in the test instruments, normal variations in commercial production and modelling uncertainties.

4.3.9 The following margins are considered in service conditions for DBA/ DEC-A:

a) Peak temperature: +10% of peak transient temperature to a maximum of +8 ºC

b) Peak pressure: +10% of peak transient gauge pressure

c) Radiation: +10% (on total integrated accident dose)

d) Equipment operating time (Mission Time): +10% of the period of time the equipment is required to operate following the start of the design basis event. The minimum time considered for qualification should be at least 5 minutes even if the equipment mission time is lesser, else it should be justified.

e) Seismic vibration: +10% added to the acceleration requirements at the mounting point of the equipment

f) Power supply voltage: + 10 % but not to exceed equipment design limit

g) Line frequency: ±5% of rated value

4.3.10 Margins are not applied for the age conditioning of the equipment.

4.3.11 Margins can be positive or negative to increase the severity of the test. For example, generally, it is necessary to use higher temperatures, while in the case of equipment supply voltage, higher or lower values that causes the most degradation should be chosen. Based on factors such as product design control, test sample size, and test measurement accuracy, lesser values may be considered.

4.3.12 Figure: 4 illustrates example of a test profile, including margin in design basis event/ design extension conditions (without core melt) for equipment qualification.

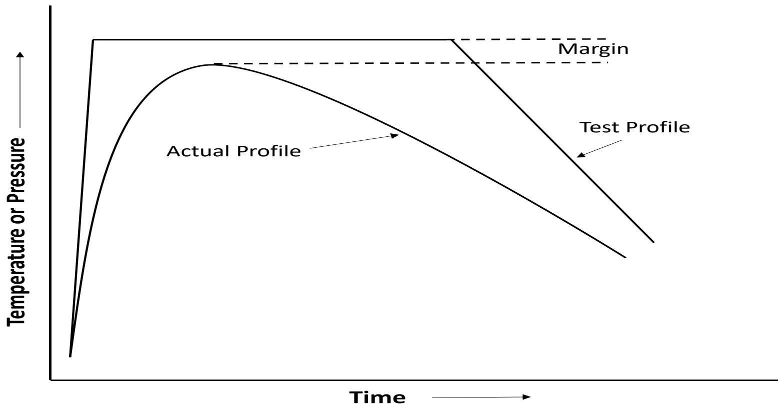

Figure 4: Example of test profile enveloping actual profile with margin

Accelerated Radiation Ageing

4.3.13 Simulation of radiation ageing should be limited to gradual permanent changes to material characteristics over time and differentiated from transient changes that might occur because of exposure to radiation

4.3.14 Radiation ageing tests should be simulated to represent the operational and accident dose that would be experienced by the equipment. The application of the simulation dose rate should be low enough to ensure the accelerated ageing remains realistic or conservative

4.3.15 Equipment should be exposed to a total integrated dose equal to the ∑ [life time dose + 1.1 x accident dose] for DBA or DEC-A]

4.3.16 The total integrated radiation dose for operational states as well as accident conditions can be applied in either a single exposure or in a series of exposures

Accelerated Thermal Ageing

4.3.17 In order to simulate the deterioration due to temperature during service life of an equipment, the test sample is subjected to high temperature for specified duration (accelerated thermal ageing). Temperature for accelerated thermal ageing test and duration is derived using Arrhenius methodology (Arrhenius methodology, used in predicting material ageing is given as reference in Appendix-3). The elevated test temperature used should be below the threshold value at which significantly different chemical or physical reactions might occur based on data given by the manufacturer.

4.3.18 The material activation energy, temperature applied during the tests, duration of the test, and the material sensitivity should be documented and justified. In cases where activation energy value is not known, appropriate test should be carried out to determine the value (thermal ageing test is carried out at two temperature conditions to determine the activation energy value). Generally in the absence of activation energy value, 10^0 C thumb rule (equivalent to activation energy =0.68 eV) is followed with a justification for the conservatism, where in, increase of 10^0 C temperature during accelerated thermal ageing, results into equivalent thermal ageing in half of the actual ageing time.

4.3.19 After accelerated thermal ageing test, residual life can be estimated using Arrhenius method.

4.3.20 All functional/ performance parameters should be checked and recorded after the thermal ageing test.

Accident Simulation Test

4.3.21 Accident simulation test should be carried out on the same test specimen which has undergone radiation ageing and thermal ageing test, to demonstrate the capability of the equipment to function when subjected to pressure, temperature and humidity effects which are associated with the environment conditions of DBA and DEC-A.

4.3.22 The test profile should be simulated encompassing the thermodynamic profiles, obtained by analysis along with adequate margins. The effect of chemical environment on equipment during the event can either be simulated or analysed based on the material of construction of the equipment/ accessories and the chemicals involved. Tests should be done for the mission time of the equipment for the expected environment.

4.3.23 The test specimen should be mounted in the test chamber along with interfaces to replicate the plant installation configuration. The specimen should be kept energized and subjected to simulated loads/ inputs in a manner to generate output that represents the equipment function in the plant. Functional performance of the equipment during the simulated events for the mission time should be verified and documented.

Seismic Test

4.3.24 Seismic testing demonstrates ability of the equipment to perform its safety function while subjected to seismic conditions. After successful completion of radiation ageing and thermal ageing, the same test specimen should be subjected to seismic test, using shake table for sinusoidal acceleration (site specific value) in all the three orthogonal axes for site specific frequency range. During test, the test specimen should be mounted/ fixed in a manner that accurately represents the installed configuration. Test specimen should be kept energized and its output should be monitored to evaluate its function and performance as per specifications with electrical and mechanical loading expected during operation.

4.3.25 Guidance provided in AERB Safety Guide on ‘Seismic qualification of Structures, Systems and Components of Pressurised Heavy Water Reactors’, AERB/NPP-PHWR/SG/D-23, 2009 should be followed for seismic qualification.

4.4 Assessment of Equipment Survivability for Design Extension Condition with Core Melt

4.4.1 Equipment required to operate during and after design extension conditions with core melt (DEC-B) should be demonstrated, with reasonable confidence, to be capable of achieving the intended function under the expected environmental conditions. Type test may be used as far as reasonably practicable to confirm the behaviour of equipment under simulated severe accident conditions. Assessment of equipment survivability should be carried out, for its performance, for intended safety functions and for the necessary mission time, under DEC-B.

4.4.2 Environmental conditions and mission time, considered for qualification should be decided based on enveloping conditions from safety analysis predictions.

4.4.3 In case of any practical limitation of the test facility to simulate the severe accident loads specified for qualification, those cases may be justified by extrapolation methods or by other means.

4.4.4 Tolerance error for test instruments, used for qualification should be considered in test conditions by providing appropriate margins.

4.5 Extension of qualified life

4.5.1 Initial equipment qualification may yield a qualified life that could be less than the anticipated service life of the equipment due to conservatism applied in the qualification process, either by use of moderate ageing acceleration factor in simulation and testing or estimation of service conditions including loading conditions or higher safety margin considered in design. This could result in the equipment's condition being far from its end-of-life condition and there could be scope for extending the qualified life. The methodology used should be properly justified and adequately supported by validated data and models. Following methodology should be employed for extension of qualified life:

a) Carrying out Qualification Testing by appropriate ageing for proposed extended life on

   i) Test sample used for initial qualification or,

   ii) Identical equipment picked up from service or,

   iii) A new sample

   Subsequent to age conditioning, equipment performance should be demonstrated for applicable DBAs & DEC conditions, including seismic tests.

b) Installing similar redundant equipment in identical service conditions, removing them before the end of the qualified life of equipment in service, and type testing with further age conditioning to establish additional qualified life.

c) By evaluation of conservatisms applied in original assumptions for environmental conditions, functional criteria, and ageing acceleration factors to assess if the actual conditions are found to be less severe, the qualified life may be adjusted accordingly.

4.5.2 Further, to extend qualification, identify age-sensitive components of equipment and replace them with new identical components.

5 EQ PRESERVATION

5.1 General

5.1.1 Once equipment qualification is established, a systematic programme should be implemented to ensure that the qualified status of the equipment is preserved, during the entire lifetime of the plant. In order to meet this objective, qualified equipment should be stored, installed, commissioned, inspected, operated, maintained and replaced or modified in such a way that its qualification status is preserved. Plant configuration management should ensure consistency between design requirements, EQ preservation and plant documentation, whenever any change occurs in installation, maintenance or an item is modified or replaced.

5.2 Elements and Aspects of EQ preservation

5.2.1 Following are the important elements to be considered for each of the qualified equipment for EQ preservation:

a) Monitoring of Ageing Effect

b) Monitoring of Environmental Conditions

c) Surveillance and Condition Monitoring

d) Installation and Inspection

e) Maintenance and Replacement

f) Preservation of Protective Barriers

g) Procurement, Transport and storage.

All elements of the equipment qualification programme should be evaluated and taken into consideration when assessing the EQ status of qualified equipment. The elements of EQ preservation are described in the following sections.

5.2.2 Important aspects such as deviations or modifications with respect to existing installation, change in the design basis, change in regulatory requirement, changes in service conditions, need for changes based on operating feedback, etc. may affect the already established qualification of an equipment. These should be suitably addressed to preserve the Equipment Qualification status.

5.3 Monitoring of Ageing Effects

5.3.1 The EQ preservation programme should give due consideration to ageing effects on equipment in all operational states of the Nuclear Power Plant.

5.3.2 EQ perseveration programme should take in to account the ageing effects, caused by the environmental factors like temperature, irradiation, humidity, or vibration throughout the expected service life of the equipment.

5.3.3 Periodic preventive and predictive maintenance, condition monitoring, surveillance testing, identification of trends in equipment failures and operating experience reviews are some of the acceptable methods that should be used for identifying and mitigating an unanticipated ageing degradation that was not considered during the initial qualification.

5.3.4 Whenever a change in the effect of ageing is noticed, during the assessment and review, due to either changes in original environmental considerations or on account of an unknown ageing factor, the qualified life of the equipment should be reassessed.

5.3.5 In case a significant degradation of a qualified equipment is observed, appropriate revision of the maintenance practices and surveillance tests should be considered to ensure validity of the EQ programme on its qualified life. In case of any change, the related documents also should be updated to reflect the same.

5.3.6 Replacement of the degraded equipment should be considered, before end of service life, if required.

5.4 Monitoring of Environmental Conditions

5.4.1 Regular monitoring of the trend of the environmental conditions should be carried out to verify compliance with the conditions that were considered during the initial EQ of the equipment and the design limits of the equipment are not exceeded. The normal stressors associated with this activity are temperature, pressure, humidity, radiation field, vibration, electromagnetic and radiofrequency interference, presence of chemical agents etc. Corrective actions, in case of deviation should be taken so that the qualification status of the equipment is maintained.

5.4.2 The impact of the service conditions should be correlated with the qualified life and performance of the equipment. Based on the environmental conditions and the condition monitoring programme of the equipment, the residual qualified life assessment of the equipment should be carried out. This study can be utilized for the extension of qualified life of the equipment, if feasible.

5.5 Condition Monitoring and Periodic Surveillance

5.5.1 Condition monitoring and periodic surveillance of the equipment should be carried out to ensure that it would perform its intended function under specified service conditions and accident environment. It also provides information related to ageing degradation of the qualified equipment and supports activities necessary for preserving the qualification status of equipment.

Condition Monitoring

5.5.2 Periodic condition monitoring programme should be implemented to assess the degradation due to ageing in comparison with the original assumptions and to initiate corrective actions necessary to preserve the status of qualified equipment.

5.5.3 Condition monitoring includes visual inspection of the equipment, the physical state of the equipment and measurement of performance parameters to assess its ability to perform its intended function(s) under the specified service conditions.

5.5.4 Appropriate condition indicators, for a given type of equipment should be selected to detect changes caused by significant ageing mechanisms. These condition indicators should be measurable, linked to the functional degradation of the qualified equipment, and should be capable of indicating a consistent observable trend.

5.5.5 The results of condition monitoring should be used to assess the following:

a) Assessment of the ageing mechanisms and the original factors considered in the qualification and their effect on the performance of the equipment.

b) Identification of unknown factors, their effects and corrective action for the present situation and for future design inputs.

c) As the equipment approaches the end of its qualified life, additional periodic monitoring of its condition should be implemented to determine whether actual ageing is occurring at a slower rate than expected, which would indicate that it may be possible to extend the qualified life of the equipment. If actual ageing is found to be at a faster rate than expected, then appropriate action (re-evaluation/ replacement) should be taken.

Periodic Surveillance

5.5.6 Periodic surveillance should ensure that operation and maintenance activities do not compromise the status of qualified equipment by changing the approved configuration of mounting, protective barriers and interfaces. If such abnormalities in the configuration of the equipment are detected, corrective actions should be completed in a timely manner to preserve the status of qualified equipment.

5.6 Installation and Inspection

5.6.1 Appropriate installation of a qualified equipment is an essential part of maintaining the qualification of the equipment. The installed configuration should replicate the qualified configuration and also satisfy the design intent.

5.6.2 Traceability should be ensured between each installed equipment important to safety and the applicable evidence of qualification including upto the component. Traceability between the qualified configuration and the installed configuration should also be maintained.

5.6.3 Field inspection/plant walk down should be carried out prior to commissioning of the plant to confirm that installed equipment meet the specified EQ requirement.

5.6.4 Periodic field inspection/plant walk down should be carried out during plant operation phase to confirm that EQ is preserved.

5.7 Maintenance and Replacement

5.7.1 Maintenance activities should be carried out to preserve the qualified status of equipment in accordance with defined equipment qualification programme and maintenance procedures.

5.7.2 Maintenance programme should include following aspects:

a) Maintenance documentation

b) EQ Specific maintenance procedures

c) Appropriate preventive maintenance schedule in synchronization with condition monitoring

d) Replacement of equipment before the end of qualified life

e) Periodic replacement of components (e.g. seals, gaskets, lubricants, filters) which may have shorter qualified life.

f) Replaced equipment/spare parts should be identical to the original equipment. If the replaced equipment/ spare part is not identical, it should be appropriately qualified and all the documents should be updated.

5.8 Preservation of Protective Barriers for Equipment

5.8.1 Protective barriers, enclosures, shields or sealing devices are used to protect qualified equipment from adverse environmental conditions. Integrity of such barriers should be maintained through appropriate preservation measures. If any protective barrier is required to be replaced or removed, it should be carried out with proper assessment to ensure that it will not change the qualification status of the equipment. Changes made in protective barriers should be documented.

5.9 Procurement and Storage

5.9.1 Procurement of qualified equipment and spare parts should be in accordance with the specifications for the applicable service conditions.

5.9.2 All qualified equipment/ spare parts procured should be tested and inspected upon receipt and stored in conditions specified by the manufacturer.

5.9.3 Qualified equipment (including sub-assemblies, spare parts etc.) in storage should be marked as qualified.

5.9.4 For the storage of qualified equipment, a shelf life programme for degradable material (e.g., elastomers, plastics, insulation systems, cable and cable glands) should be established to ensure that, upon installation, the status of qualified equipment is preserved. A reliable means should be established to ensure that shelf life expiry dates are not exceeded.

6 ASSESSMENT OF EFFECTIVENESS OF THE EQ PROGRAMME

6.1 General

6.1.1 EQ programme should cover all aspects of the EQ process and associated activities needed to establish and preserve the qualification status of equipment. Effectiveness of the EQ programme should be assessed starting from initial stage of establishment of EQ and periodically thereafter by the operating organisation. It should conduct periodic audits as well as routine evaluation of EQ programme to ensure that its objectives are achieved.

6.1.2 The assessment of the effectiveness of the EQ programme should include the evaluation of the following:

a) EQ programme

b) EQ process of the Vendors and Manufacturers of qualified equipment

c) EQ test facilities

6.2 Audit of Equipment Qualification Programme

6.2.1 Following review/audits of the EQ programme should be performed by qualified and trained personnel:

a) Audit should cover all aspects and activities of EQ programme. This should be performed when the programme is first established and periodically afterwards.

b) Audit should cover relevant aspects and activities of an EQ programme which should be conducted more frequently and often in response to incidents suggesting possible weaknesses in specific areas and based on operating experience.

c) All aspects related to EQ should be considered, during plant's Periodic Safety Review as per AERB safety guide "Periodic Safety Review for Nuclear Power Plants", AERB/NPP/SG/O-12, 2022

d) It is desirable that review/audit covering vendor and manufacturer's quality management programmes and processes relevant to equipment qualification should be carried out.

6.3 Assessment of effectiveness of EQ Programme

6.3.1 The assessment of the effectiveness of EQ programme should be an active and ongoing process. Periodic assessment of EQ programme should be carried out. This should typically cover documents and/or activities that contribute to the effectiveness of the EQ programme. Typical checklist of periodic assessment is given in Appendix - 4.

6.3.2 Routine surveillance of EQ programme should focus on relevant plant operation, maintenance, procurement and material control activities. Surveillance should be performed by qualified and trained plant personnel. Record of all these activities should be maintained at site.Typical checklist of routine surveillance is given in Appendix - 5.

7 QUALITY ASSURANCE, TRAINING AND DOCUMENTATION

7.1 General

7.1.1 Quality Assurance, training and documentation are essential activities for an EQ programme. The guidance related to these activities are described below.

7.2 Quality Assurance

7.2.1 EQ is achieved and preserved with a high degree of confidence only when the broad spectrum of related activities is correctly performed and documented as per the established Quality Assurance Programme.

7.2.2 Equipment qualification activities, including the assessment/reassessment of the status of qualified equipment, should be performed according to approved procedures and controls.

7.2.3 Quality assurance programme of equipment qualification should include variety of elements, such as equipment design control, procurement documentation control, manufacturing quality control, qualification assessment (e.g. testing, analysis, combined testing and analysis, and experience), transportation, storage, installation and commissioning, installation surveillance and maintenance, periodic testing and documentation.

7.2.4 QA programme should cover various types of organization and personnel performing EQ related activities viz. equipment manufacturers, material and parts suppliers, testing laboratories etc.

7.2.5 Instruments/equipment including data acquisition tools used for equipment qualification test should be calibrated and calibration records should be maintained.

7.2.6 Traceability should be established between the qualification documentation, conclusions from each qualification test or analysis, and the configuration of the installed equipment, to ensure that installed configuration corresponds to the as-tested configuration.

7.3 Training

7.3.1 The personnel involved in equipment qualification activities (including contractors, and personnel involved in the oversight of these activities) should be trained, so that they are competent and possess the necessary knowledge and skills. This training should be part of the equipment qualification programme.

7.3.2 A systematic approach for training should be used to plan, prepare, implement and evaluate the training imparted.

7.4 Documentation

7.4.1 Documentation should provide information necessary to verify qualification. Documented evidence of qualification of equipment should be available in an auditable form till the life of the plant. These records should be organized in an understandable and traceable manner. The records should be in a form allowing independent verification.

7.4.2 Records demonstrating that EQ has been established, should contain information on the specific equipment being qualified, the demonstrated safety functions, applicable service conditions, test specifications, qualification methods, results, limitations, justifications and relevant supporting technical data.

7.4.3 A master list of all the equipment which require qualification should be maintained. This list should contain identity of the equipment, safety function, mission time, location etc. as given in Appendix - 1.

7.4.4 Type test data, operating experience data, analysis data and basis of extrapolations, wherever applicable, should also form part of the documentation.

7.4.5 A typical list of qualification documents to be maintained is given in Appendix - 6.

APPENDIX 1: TYPICAL FORMAT OF MASTER-LIST

Sr no	Equipment Instrument	Make Model No. Mfg. date	Location	Environmental Conditions		Method of qualification	Function during				Mission Time	Test report no. / QAN no. / OEM no.	Qualification Status	Service Life	Qualified Life	Remarks
				Normal condition	Accident condition		Normal condition	DBA (e.g LOCA)	DEC-A (e.g LOCA + ECCS failure)	(DEC-B)						
1.																
2.																
3.																
4.																
5.																

APPENDIX-2: TYPICAL PROCESS USED FOR IDENTIFICATION OF EQUIPMENT REQUIRING EQ

1. The systems required to perform safety function, post-accident monitoring and mitigation of the accidents, which result in harsh environments, are identified.
2. Within these systems, the equipment (e.g. motors, transmitters, sensors etc.) are tabulated along with their required functions, locations$, and the required mission time.
3. Mechanical, Electrical and Process & Instrumentation (P&I) drawing are reviewed to identify support systems (e.g. electric power distribution equipment, diesel generators, component cooling water etc.) and equipment/components required by the systems identified in Sl No.1.
4. Equipment layout drawings are reviewed to verify that failure of unqualified SSCs do not influence performance of qualified equipment during and after DBE, DEC conditions.
5. Electrical circuit diagrams are reviewed to identify other electrical devices, which are located in the harsh environment, and deliver necessary functions mentioned in Sl. No 1 above. Such devices may include junction boxes, cables, connectors, relays and containment electrical penetrations etc.
6. Review of engineering drawings to identify such non-qualified equipment located in the harsh environment whose failure may prevent the accomplishment of safety functions delivered by qualified equipment.
7. Equipment specifications and procurement documents are reviewed to identify the manufacturer, model and other identification information for the selected equipment.

$ Items located inside containment/outside containment, but within nuclear island are generally considered in EQ programme.

APPENDIX-3: ARRHENIUS METHODOLOGY IN PREDICTING MATERIAL AGEING

Arrhenius methodology is an established approach for describing the relationship between material life and temperature, the Arrhenius model is valid when a dominant chemical reaction controls the thermal ageing process. Other reactions can occur, and if they are not predominant, the use of the Arrhenius equation is still valid. The Arrhenius equation for chemical reaction rate is as follows:

Equation 1

$$R = A\, e^{(-Ea/\, k_B\, T)}$$

Where,

R = specific reaction rate

A = frequency factor

e = the base of natural logarithms = 2.718

E_a= activation energy of the reaction

k_B= Boltzmann's constant (1.38 x 10^{-23} J/K)

T = absolute temperature

An adaptation of Equation 1 to represent material life, which is inversely proportional to the chemical rate, leads to the following equation:

Equation 2

$$\text{Ln}\, t = (E_a/k_B) \times (1/T) + \text{constant (see Note 1)}$$

Where.

t = material life

E_a= activation energy of the reaction

k_B= Boltzmann's constant (1.38 x 10^{-23} J/K)

T = absolute temperature

Notes:

(1) A minimum of three test data points should be used to determine the values of Ea and the constant for a particular material and application. The Ea for a compound is a variable dependent on the changes in the material composition, Immersion fluid (e.g., air, oil, water), failure mode and level of physical property associated with failure. Caution should be used to ensure that the selected Eais appropriate for the material.

(2) Using Equation 2, the life of organic materials can be estimated within the range of a device's operating temperatures to obtain an estimate of the effects of short-time temperature excursions and to estimate the life of materials over varying temperatures.

(3) A prediction calculated outside the range of the material test data points can cause erroneous predictions if the chemical reactions controlling the ageing process are different or if other conditions affecting the ageing process become significantly different. Therefore, the Arrhenius methodology is applicable only if all the assumptions behind the use of the Arrhenius equations are met.

APPENDIX-4: TYPICAL CHECKLIST OF PERIODIC ASSESSMENT

A-4.1 Responsible Organization Equipment Qualification programme activities

i) The adequacy of qualification documentation in terms of programme implementation and technical accuracy

ii) Availability of updated master list and qualification reports

iii) EQ programme document describing key programme elements and responsibilities

iv) Methods and criteria utilized in the EQ programme reflecting required licensing and design basis

v) Original assumptions, regarding the safety, operability and performance of equipment remain valid

vi) Qualification documentation should be traceable and auditable. This includes

a. Test and analysis documentation,

b. Procurement documents

c. Information related to production QA

d. Storage, transportation and installation requirements, and

e. Surveillance and maintenance requirements

f. Evaluation of operating experience and information from feedback programmes

vii) Evidence to assess following aspects:

a. The continued validity of technical basis and assumptions used in modelling of qualified life (e.g. activation energy levels, material compositions, assumed environmental conditions and other parameters).

b. The installed equipment matches with the qualified equipment and are installed correctly (e.g. mounting, connections and conduit seals comply with the qualified configuration documentation, actuators and hydraulic or pneumatic lines are connected and arranged in accordance with design requirements)

c. The as-built design of the installation, including any recent modifications

d. Maintenance of equipment and any protective barriers as per design configuration

viii) Verification of installed equipment through physical inspection for their condition, working order and protection

ix) Documentation and implementation of measures required to preserve qualification during equipment's qualified life

x) Personnel qualification and training to establish and preserve equipment qualification programme

xi) Availability of an established surveillance programme (including testing, inspection and condition monitoring activities) to ascertain the performance of the equipment and ensuring that the ageing degradation and functional capability of the equipment remains acceptable. A correction and feedback process to address unanticipated degradation identified during surveillance or maintenance should be in place

xii) A programme to analyse premature degradation or failures of qualified equipment and to implement appropriate corrective actions, including revisions of qualification conclusions on qualified equipment

xiii) A feedback programme to gather and review information relevant to the status of qualified equipment. Such information includes, but is not necessarily limited to, plant operating experience, generic operating experience from other plants, significant event reports, feedback from vendor and manufacture qualification data, research and development results etc.

xiv) The effectiveness of training relevant to equipment qualification

xv) The effectiveness of configuration management (e.g. Identification of corrective actions and timely implementation etc.)

xvi) Maintenance activities relevant to equipment qualification

A-4.2 Activities of Vendors and Manufacturers of Qualified Equipment

i) Ensuring the availability of vendor and manufacturer quality management programmes and processes relevant to equipment qualification

ii) Ensuring equipment qualification activities are being performed in accordance with regulatory requirements

iii) Personnel involved in design, manufacturing and equipment qualification activities are qualified and trained in relevant EQ aspects

A-4.3 Activities for EQ test including test facilities

i) Effectiveness of the QA/QC programme, including appropriate control of contracted services

ii) Procedures for:

a) Generating a specific test plan and procedure for each testing activity

b) Proper identification and control of test specimens throughout the test cycle

c) Control of measurement and testing equipment calibration

d) Witnessing of test and data collection by QA personnel

e) Recording, evaluating and documenting failures and anomalies which may occur during tests

f) Control of receipt, storage and handling of test specimens

g) Preparation, review and approval of test reports

h) Appropriate training of personnel involved in testing

iii) Documentation verifying that the related personnel are qualified

iv) Actual qualification test reports and supporting documentation

v) Physical inspection of the test facility for compliance with its own procedures

vi) Acceptance criteria for evaluation of test results

APPENDIX 5: TYPICAL CHECKLIST OF ROUTINE SURVEILLANCE

A 5.1 Operation, maintenance, procurement and material control activities

i) Review sample maintenance and surveillance procedures to verify that applicable maintenance and parts replacement requirements have been incorporated.

ii) Review maintenance activities to verify timely performance of special EQ related maintenance requirements and appropriate engineering evaluations for any postponed or missed activities.

iii) Review selected maintenance activities to verify that correct tools, materials and procedures are being used to perform the required special EQ maintenance and that the qualified configuration is being preserved.

iv) Review equipment surveillance activities to verify timely and correct performance of prescribed tests, inspections and condition monitoring tasks and generation of required records/reports.

v) Verify that failures, abnormal conditions, system modifications and the replacement of component parts have been properly documented in accordance with the plant procedures.

vi) Perform periodic walk downs of plant equipment and systems to identify any abnormal conditions of qualified equipment such as missing bolts, covers, loose glands and nuts, open JBs, exposed wiring, damaged flexible conduits, plugged grease fittings etc.

vii) Perform periodic observations of maintenance shops (I&C, electrical and mechanical) activities to verify that qualified equipment repair is being conducted in accordance with approved procedures and OEM instructions.

viii) Review the repair of qualified equipment at the on-site maintenance facility to verify that proper materials are being used, repair and tests are being conducted in accordance with approved procedures and that the required qualification documentation is being created correctly.

ix) Review the implementation of control and tracking of material with expiry date including parts, components and subcomponents.

x) Inspect warehouse facilities to verify that storage and in-storage maintenance requirements are being implemented properly.

xi) Review the control of documents associated with parts specification and procurement.

xii) Review the requirements associated with receipt inspection and their implementation.

xiii) Review sample system equipment and system design changes documentation to verify that EQ requirements have been adequately addressed.

xiv) Verify that proper tagging is provided and maintained for qualified equipment.

APPENDIX 6: TYPICAL LIST OF DOCUMENTS TO BE MAINTAINED

A 6.1 Documents related to establishment and preservation of EQ

a) EQ master list

b) Qualification test procedure and test report

c) List of life limiting items and their replacement intervals

d) Maintenance requirements and intervals

e) Calculations and analysis reports (seismic stress evaluation, qualified life, etc.)

f) Walk down verification checklists.

A 6.2 Configuration management history

a) Design and technical specifications

b) Original equipment manufacturers (OEM) test reports, catalogue and data sheets, vendor drawings, etc.

c) Installation details

d) Detailed layout drawing

e) Parts list

f) The equipment qualified configuration documents in an auditable form

A 6.3 Procedures controlling preservation activities and work practices

a) EQ Preservation manual

b) Maintenance procedures

c) Failure analysis procedures

d) Surveillance and testing procedures

e) Equipment and parts procurement procedures.

A 6.4 Activity and equipment history

a) Equipment operation, maintenance, parts replacement and failure history

b) Equipment operating and service conditions (normal, abnormal, transient, etc.)

c) EQ test report

d) Walk down verification checklists

e) Parts substitution and associated engineering justifications

f) Historical data from condition monitoring programmes.

A 6.5 All non-conformities and deviations, identified during the equipment qualification process should be analysed with conclusions made as to whether any further actions or considerations are necessary.

A 6.6 Summary of qualification results along with the basis for EQ assessment specifying limitations and the connecting warnings, qualified lifetime, necessary guidance for long term maintenance and preservation of the qualified status of the equipment.

i) Manufacturer data in support of equipment qualification;

ii) Reports of relevant operating experience.

LIST OF ABBREVIATIONS

AERB	Atomic Energy Regulatory Board
ACNRS	Advisory Committee on Nuclear and Radiation Safety
DBE/ DBA	Design Basis Event/ Design Basis Accident
IAEA	International Atomic Energy Agency
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
DEC	Design Extension Condition
DID	Defence in Depth
EMI/ EMC	Electromagnetic Interference/ Electromagnetic Compatibility
MSLB	Main Steam Line Break
NPP	Nuclear Power Plant
OEM	Original Equipment Manufacturer
PHWR	Pressurized Heavy Water Reactor
LOCA	Loss of Coolant Accident
SSC	Structures, Systems and Components
QA/ QC	Quality Assurance/ Quality Control

8 BIBLIOGRAPHY

1. ATOMIC ENERGY REGULATORY BOARD, 'Design of Pressurised Heavy Water Reactor Based Nuclear Power Plants', AERB/NPP-PHWR/SC/D (Rev-1) AERB, Mumbai, (2009).
2. ATOMIC ENERGY REGULATORY BOARD, 'Design of Light Water Reactor Based Nuclear Power Plants', AERB/NPP-LWR/SC/D AERB, Mumbai, (2015).
3. ATOMIC ENERGY REGULATORY BOARD, 'Design of Fast Breeder Reactor based NPPs, AERB/NPP-FBR/SC/D AERB, Mumbai, (Draft).
4. ATOMIC ENERGY REGULATORY BOARD, 'Site Evaluation of Nuclear Facilities', AERB/NF/SC/S (Rev-1) AERB, Mumbai, (2014).
5. ATOMIC ENERGY REGULATORY BOARD, 'Nuclear Power Plant Operation', AERB/NPP/SC/O (Rev-1) AERB, Mumbai, (2008).
6. ATOMIC ENERGY REGULATORY BOARD, 'Quality Assurance in Nuclear Power Plants', AERB/SC/QA (Rev-1) AERB, Mumbai, (2009).
7. ATOMIC ENERGY REGULATORY BOARD, 'Safety Classification and Seismic Categorization of System, Structures and Components of Pressurised Heavy Water Reactors, AERB/NPP-PHWR/SG/D-1 AERB, Mumbai, (2009).
8. ATOMIC ENERGY REGULATORY BOARD, 'Design Basis Events for Water Cooled Nuclear Power Plants', AERB/NPP-WCR/SG/D-5 R1 AERB, Mumbai, (2020).
9. ATOMIC ENERGY REGULATORY BOARD, 'PHT System for PHWRs', AERB/NPP-PHWR/SG/D-08 AERB, Mumbai, (2003).
10. ATOMIC ENERGY REGULATORY BOARD, 'Safety systems for Pressurised Heavy Water Reactor Based Nuclear Power Plants', AERB/NPP-PHWR/SG/D-10 AERB, Mumbai, (2005).
11. ATOMIC ENERGY REGULATORY BOARD, 'Emergency Electric Power Supply Systems for Pressurized Heavy Water Reactor', AERB/SG/D-11 R1 AERB, Mumbai, (2020).
12. ATOMIC ENERGY REGULATORY BOARD, 'Safety related instrumentation and control for Pressurised Heavy Water Reactor Based Nuclear Power Plants', AERB/NPP-PHWR/SG/D-20 AERB, Mumbai, (2003)
13. ATOMIC ENERGY REGULATORY BOARD, 'Seismic qualification of structures, systems and components of pressurised heavy water reactors', AERB/NPP-PHWR/SG/D-23 AERB, Mumbai, (2009).
14. ATOMIC ENERGY REGULATORY BOARD, 'Computer Based Systems for Pressurised Heavy Water Reactor Based Nuclear Power Plants', AERB/NPP-PHWR/SG/D-25 AERB, Mumbai, (2010).
15. ATOMIC ENERGY REGULATORY BOARD, 'Accident Management Programme for Water Cooled Reactor based Nuclear Power Plants', AERB/NPP-WCR/SG/D-26 AERB, Mumbai, (2020).
16. ATOMIC ENERGY REGULATORY BOARD, 'Periodic Safety Review for Nuclear Power Plants', AERB/NPP/SG/O-12 R1, AERB, Mumbai, (2022).
17. ATOMIC ENERGY REGULATORY BOARD, 'Life Management of Nuclear Power Plants' AERB/NPP/SG/O-14 AERB, Mumbai, (2005).
18. INTERNATIONAL ATOMIC ENERGY AGENCY, 'Safety Fundamentals, Fundamental Safety Principles', IAEA SF-1, IAEA, Vienna (2006).
19. INTERNATIONAL ATOMIC ENERGY AGENCY, 'Equipment Qualification in operational Nuclear Power Plants: upgrading, preserving and reviewing', 'IAEA Safety Series-3', IAEA, Vienna (1998).

20. INTERNATIONAL ATOMIC ENERGY AGENCY, 'Safety of Nuclear Power Plants: Design Specific Safety Requirements', IAEA SS-R-2.1, IAEA, Vienna (2012).

21. INTERNATIONAL ATOMIC ENERGY AGENCY, 'Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants' IAEA/SSG-48, IAEA, Vienna (2018).

22. INTERNATIONAL ATOMIC ENERGY AGENCY, 'Assessment of Equipment Capability to Perform Reliably under Severe Accident Conditions', IAEA-TECDOC-1818, IAEA, Vienna (2017).

23. INTERNATIONAL ATOMIC ENERGY AGENCY, 'Equipment Qualification for Nuclear Installations", IAEA/DS-514 J, IAEA, Vienna (Jun 2020).

24. US NUCLEAR REGULATORY COMMISSION, 'Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants', guide 1.89 R1, USNRC (1984).

25. IEEE Standard for Qualifying Continuous Duty Class 1E Motors for Nuclear Power Generating Stations, IEEE-334-2006.

26. IEEE Standard for Seismic Qualification of Equipment for Nuclear Power Generating Stations, IEEE-344-2013.

27. IEEE Standard Criteria for Accident Monitoring Instrumentation for NPPs, IEEE-497-R2-2010.

28. IEC/IEEEE Standard for Nuclear facilities - Electrical equipment important to safety – Qualification, IEC/IEEE-60780-323-2016.

29. Canadian standard for Environmental Qualification of Equipment for CANDU Nuclear Power Plants'CSA-290.13-2015.

30. EPRI Technical Report on Assessment of Existing Plant Instruments for SAM, TR-103412 ,2010.

31. ASME QME-1,2012, Qualification of Active Mechanical Equipment used in Nuclear Facilities.

LIST OF PARTICIPANTS

IN-HOUSE WORKING GROUP

Dates of Meeting:

July 2018-January2019

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Shri Harpal Singh, NPSD	Member
Smt. Susmita Mukherjee. NPSD	Member
Shri Devendra Upadhyay, OPSD	Member
Shri Pratik Gogad, OPSD	Member
Shri Kuldeep Sangwan, OPSD	Member Secretary

TASK FORCE

Dates of Meeting

August 22, 2019	January 09,2020	November 26,2020
September 16,2019	September 03,2020	December 04,2020
October 16,2019	September 25, 2020	May 06,2021
November 06,2019	October 09,2020	May 10,2021
December 05,2019	November 12,2020	September 14, 2021
		September 20, 2021

Members and Invitees:

Shri T. Premachandran, Former, NPCIL	-	Convener
Shri R U Parmar, AERB	-	Co-Convener
Shri Bhramprakash, NPCIL	-	Member
Shri J. Arunan, Former, AERB	-	Member
Shri P. Mohanty, NPCIL	-	Member
Shri Raj. B. Solanki, AERB	-	Member
Shri D.V. Pimpale, AERB	-	Member
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Shri DhaneshNagrale, AERB	-	Member
Shri Rajnish Kumar, AERB	-	Member
Shri Nishant Kumar Sangam, AERB	-	Member
Shri Harpal Singh, AERB	-	Member Secretary
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Shri Parnav Nair, AERB	-	Invitee
Shri Rohit Mahlonia, NPCIL	-	Invitee

ADVISORY COMMITTEE ON NUCLEAR AND RADIATION SAFETY (ACNRS)

Dates of meeting:

December 29, 2018

February 12, 2021

July 21, 2022

Members of ACNRS

Shri S. S. Bajaj (Chairman)	:	AERB (Former)
Shri C.S.Varghese	:	AERB
Shri D. K. Shukla	:	AERB (Former)
Dr. M.R. Iyer	:	BARC (Former)
Prof.C.V.R. Murty	:	IIT, Chennai
Shri S.C. Chetal	:	IGCAR (Former)
Shri H.S. Kushwaha	:	BARC (Former)
Shri S.K. Ghosh	:	BARC (Former)
Shri K.K. Vaze	:	BARC (Former)
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Shri A.R. Sundararajan	:	AERB (Former)
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Shri Sanjay Kumar	:	NPCIL
Dr.A.N. Nandakumar	:	AERB
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