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ESTABLISHING EQ

Module 4



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Presentation

- **Session 4.1: Design input for EQ**
 - Identifying PIEs
 - Specifying service conditions
 - Identifying safety functions and equipment requiring qualification
- **Session 4.2: Establishing EQ**
 - Selecting EQ method
 - Assessing ageing effects
 - Defining installation and maintenance requirements
 - EQ documentation

Design input for EQ

Session 4.1



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Phase I - Design Input defines plant specific information that is needed for Phase II — Establishing EQ:

- PIEs requiring qualification
- Service conditions
- Safety functions and equipment requiring qualification

Identifying PIEs

- PIEs must be considered during the design input phase of the EQ process.
- PIEs vary according to NPP type, age, location and regulatory requirements.
- Information needs to be available defining the plant normal, transient and accident (PIE) states that have to be accommodated by NPP systems and equipment.

- The scope of qualification efforts can vary significantly on the basis of the assumed set of PIEs, the severity of the PIE service conditions, and the equipment requiring qualification.
- Minor changes to some factors such as safety analysis assumptions and equipment locations can reduce the scope of qualification while maintaining acceptable level of plant safety.

Specifying service conditions

- The PIE service conditions for which qualification is to be established need to be selected so as to provide confidence in equipment performance during expected PIE conditions.
- A representative combination of environmental and operational conditions is preferred to combining the most limiting conditions, unless the most limiting combination is considered credible by a PSA or is a specific regulatory requirement.

Operational conditions

- Mechanical loading conditions (thrust, torque, cycling, vibration)
- Power loading conditions (voltage, frequency, current)
- Signal conditions (e.g. electromagnetic interference)
- Process system conditions (fluid pressure, temperature, flow rate, 2-phase flow, chemistry)

Environmental conditions

- Ambient temperature
- Pressure
- Humidity/Steam
- Radiation
- Water/Chemical Sprays
- Fluid Submergence

Vibratory limits that have to be tolerated by safety equipment:

- Safe shutdown earthquake (SSE or SL-2)
- Operating basis earthquake (OBE or SL-1)

Service conditions during normal operation

- Used to qualify equipment for mild environment applications or evaluate the effects of in-service ageing degradation
- Should be representative of those occurring at the device location
- When used to assess ageing effects, it is important that representative, yet conservative, values are defined

Identifying safety functions and equipment requiring qualification

- Three main safety functions for NPPs:
 - Control of reactivity
 - Cooling of radioactive material
 - Confinement of radioactive material

Equipment that requires qualification

- Equipment required for performance of safety functions
- Equipment whose failure under accident conditions would prevent accomplishment of safety functions

Developing a list of NPP equipment and functions requiring qualification

- Main sources of information that are used to develop a list of NPP equipment and functions requiring qualification consist of design basis documents, NPP safety and system analyses and plant equipment lists.
- Supplementary information sources (drawings, specifications and in-plant inspections) are needed to identify equipment interfaces and other auxiliary circuit devices requiring qualification.

Formalized EQ equipment list

- Identifies NPP equipment items included in the qualification programme.
- Can be a subset of a more detailed NPP equipment list.
- A valuable reference document during the planning and performance of engineering, procurement, installation, operation and maintenance activities.

Establishing EQ

Session 4.2



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EQ activities required to demonstrate qualification of a specific equipment

- Selecting EQ method
- Assessing ageing effects
- Defining installation and maintenance requirements
- EQ documentation

Selecting appropriate EQ method

Prerequisite – Design input phase completed:

- Equipment selected
- Performance requirements & service conditions defined

Recognized EQ methods:

- Testing
- Analysis
- Operating experience
- Combination of above methods

Each method is discussed bellow.

- Verifies required equipment performance by a series of tests subjecting equipment test samples to limiting environmental and operational conditions, with appropriate margin.
- Is performed according to a test plan or specification that contains sufficient details to describe the required test conditions and performance objectives.
- Test results are documented in a qualification test report which describes the test plan, equipment, configurations, results and problems.

Testing considerations

Aims:

- To simulate real service conditions (installation, normal, accident) and associated ageing effects
- To provide for required accuracy and reproducibility of measurements and data acquisition

Limitations:

- Equipment size
- Too severe environmental conditions

Analysis

- Generally limited to evaluating the effects of a single service condition (e.g. seismic vibration or temperature) on equipment performance
- Widely used to demonstrate seismic qualification of equipment where testing is impractical, equipment is easily modelled (no secondary structures) and no complex equipment functions are required

Operating experience

- Important data source establishing qualification for existing equipment during PIE conditions that are similar to normal conditions in operating NPPs
- Of limited usefulness for qualification to harsh environmental conditions due to inadequate data on equipment performance during such severe service conditions
- Equipment performance in non-NPP facilities during earthquakes has been documented and conservatively applied to establish seismic qualification for NPP equipment

Combined methods

- Analysis in combination with partial test data supporting the model assumptions can establish a strong technical basis for qualification.
- It may be possible to analytically extrapolate operating experience data to qualify equipment for more severe service conditions.

Qualifying for the limiting 'worst case' application

- An equipment design should be qualified for the most limiting combination of service conditions and functions for all plant applications, if possible.
- If qualification is successful for the most limiting conditions and functions, it can be easily extended to applications with less severe conditions and functions.

Assessing ageing effects

- Qualification programmes require ageing to be specifically considered when qualification is established for electrical and mechanical equipment located in harsh environments.
- Some Member States require significant ageing mechanisms to be evaluated even for equipment located in mild environments.
- Other Member States, as an alternative to formal evaluation and the use of type test ageing simulations, rely on maintenance, surveillance, failure tracking and root cause evaluations to identify the end of life for devices installed in mild environments.

Ageing – general process in which the characteristics of a component change with time or use

Natural ageing – ageing of a component that occurs under actual service conditions

Accelerated ageing – artificial ageing where the simulation of natural ageing approximates, in a short time, the ageing effects of long term service conditions

Ageing assessment – evaluation of appropriate information, documentation or experience to determine the ageing effects on the current and future ability of a component to function within acceptance criteria

Significant ageing mechanism – mechanism that can produce concurrent common cause equipment failures under mild environment or contribute to common cause failures under seismic or harsh environment

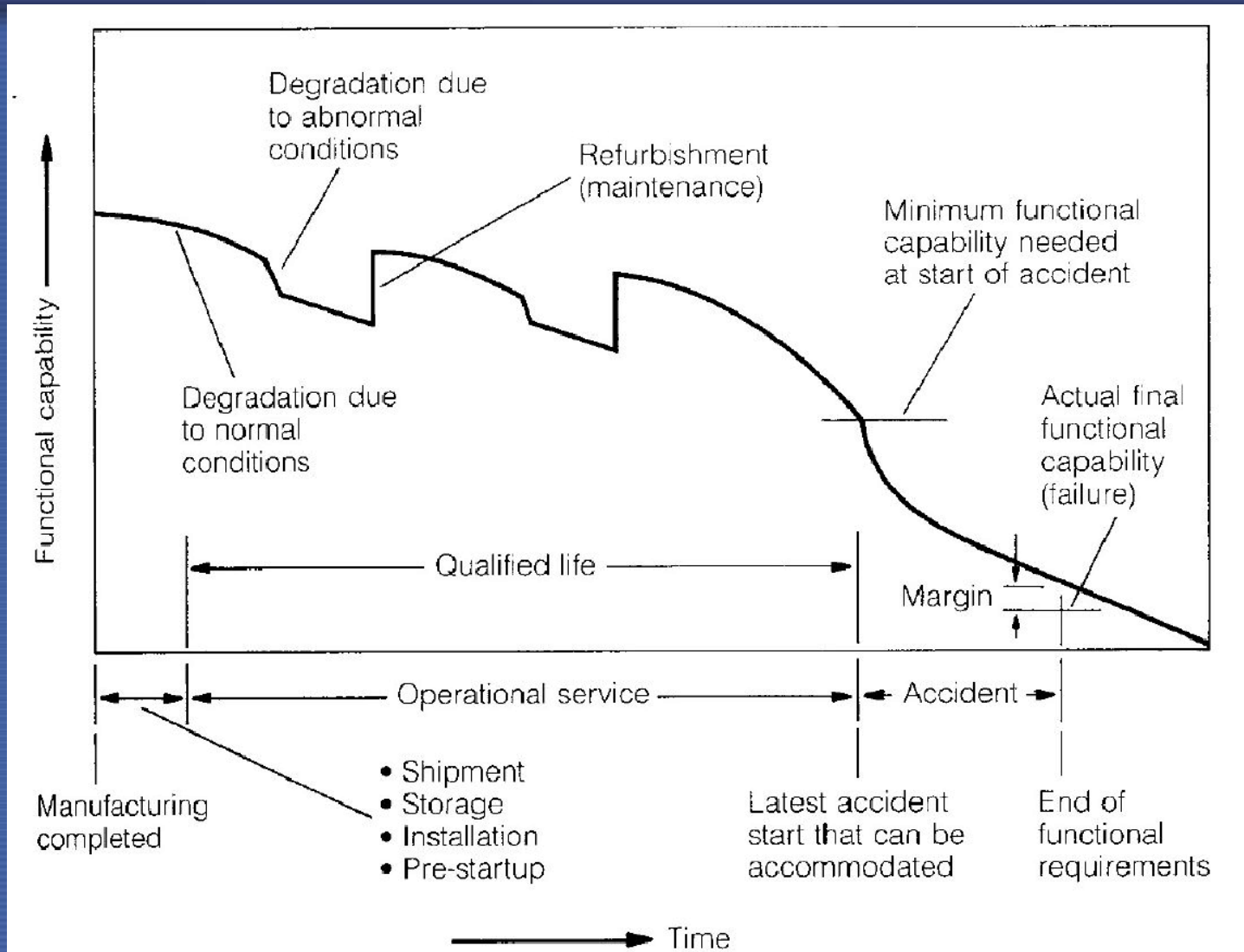
Service conditions related to potentially significant ageing mechanisms

- Temperature
- Thermal cycling
- Radiation
- Humidity
- Voltage
- Vibration
- Corrosion
- Erosion
- Operation (cyclical or continuous)

Approaches to address significant ageing mechanisms

- **Qualified life approach (USA):**
use accelerated ageing tests of thermal, radiation and cyclic ageing effects to define a qualified life for harsh environment electrical equipment; equipment has to be replaced, life limiting materials replaced, or a new longer qualified life established before the end of its qualified life.
- **Qualified condition approach (France, Germany):**
equipment is artificially aged to a measurable degraded condition and its required functionality under specified PIE conditions demonstrated; equipment is then acceptable for continued service if it has not degraded below the qualified condition (using measurable condition indicators)

Illustration of equipment functional capability and qualified life



Accelerated ageing models

- The objective of accelerated ageing tests is to reach the degraded state of an equipment that would exist at the end of its installed life, before a PIE.
- Qualified life values based on accelerated ageing tests rely on reasonably accurate ageing models correlating accelerated and normal conditions. Unfortunately, relatively few such ageing correlations exist.
- Arrhenius model is the most widely recognized model for accelerated thermal ageing.

Defining installation and maintenance requirements

- When establishing qualification it is important to determine which installation, operation and maintenance activities are critical to qualification and have to be performed.
- Service conditions, required functions and operating experience are used to modify and supplement manufacturer information.

Certain installation, maintenance, and operation activities may be critical to qualification:

- torquing cover on transmitter (environmental seal)
- SOV orientation (PI E operability)
- motor mounting bolts grade & size (seismic capability)

Other activities may not be critical to qualification:

- cycle MOV monthly
- use XYZ thread sealant
- install conduit seal (for a non steam PIE application)

- **Service conditions, required device functions, and operating experience are used to modify or supplement manufacturer recommendations.**
- **Critical activities may require witnessing or QA inspection to verify compliance with requirements.**
- **Critical activities may require special training and certification.**

Factors to consider when evaluating installation requirements:

- ***mounting orientation***
- ***electrical connections and interfaces***
- ***process connections and interfaces***
- ***environmental sealing***
- ***torquing values***
- ***seal and gasket renewal***
- ***special tools***
- ***special training or certification***
- ***acceptance testing***
- ***identification and labeling***

- In cases where moisture can accumulate inside unsealed or inadequately sealed enclosures then provisions should be provided to drain moisture to prevent failures.
- Some terminal blocks tested with field wires entering enclosure from the bottom but NPP arrangements include top entry conduits. Top or side conduit and wire entry can direct excess moisture onto terminal blocks.

EQ documentation

- When EQ is established under a formal qualification programme, documents and data supporting qualification must be available in an auditable form.
- Auditable means sufficient information is organized such that an individual knowledgeable in EO could reach similar conclusions.
- It is not necessary that all EO documents be maintained in a single EQ file. If not in a single EO file documents should be referenced and readily available for review.

EQ files should contain summary information identifying:

- **Equipment being qualified**
- **Required functions and service conditions**
- **Qualification conclusions and limitations**
- **Installation, maintenance, and replacement activities necessary for qualification**

French EQ Documentation Summary

Principal Documents:

- **Equipment Procurement Specification** – kept by utility or manufacturer
- **Identification File** - utility
- **Qualification File** - utility
- **Reference File** - manufacturer
- **Installation Specification** - utility
- **Maintenance Procedures** - utility

US Utility EQ Documentation Summary

- List of applicable plant equipment items
- Similarity analysis between installed and qualified equipment
- Summary qualification conclusions including EQ checklist and evaluation of qualification data
- Qualification reports (test, analysis, or operating experience)
- Installation requirements
- Maintenance, surveillance, and replacement requirements
- Analysis of industry or NRC notifications affecting qualification
- Analysis of equipment operational problems

Comparisons of French and US EQ Files

Most significant differences are:

- French utility involvement in manufacturer modification process
- French utility capability to have others manufacture identical equipment

Most of the differences are related to French plant standardization and the relative uniqueness of virtually all USA plants and their ownership by a number of different utilities.