EQSA

Equipment Qualification
Services Alliance

tecnatom TÜVRheinland® element wood.

EQSA

Equipment Qualification Services Alliance

Welcome!

Andrea Sinnott
Director, Key Accounts
Wood

Overview

- Health & Safety
- Introduction to EQSA
- EQ opening comments
- Overview of the day

Health & Safety

- No Fire Alarm tests are planned - In the event of an Alarm, proceed to evacuate as instructed.
- Any health, safety concerns please contact Jess at the EQSA Registration Desk.
- Any other general enquiries please contact Jess or Esther at our Registration Desk

Introduction to EQSA

wood.

element

EQSA

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EQ – Opening Comments

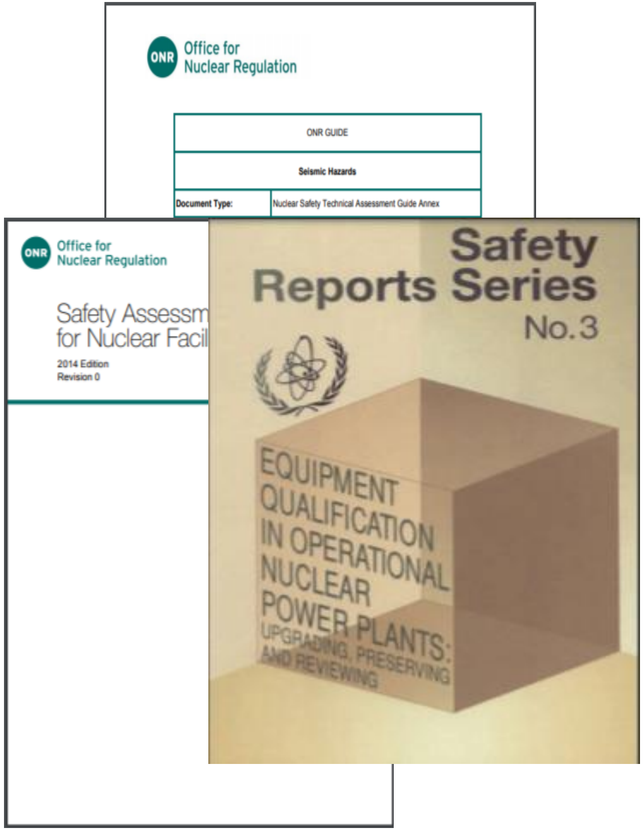
- Lots of information setting out EQ expectations ....

"......structures, systems and components will perform their allocated safety function(s) in all normal operational, fault and accident conditions identified in the safety case and for the duration of their operational lives."

Office for Nuclear Regulation, Safety Assessment Principles for Nuclear Facilities 2014 Edition, Revision 0

- But the "***How***" to do EQ in the most efficient / timely manner isn't always so obvious ...

- Today's seminar aims to offer thoughts and approaches to performing EQ in the most cost / time efficient manner



Overview of the day

08:15	**Registration, tea & coffee**
	Pugsley Lecture Theatre
09:00	Andrea Sinnott, Wood *Opening Welcome* *EQ & EQSA Introduction*
09:20	Richard McLaren, NNB Generation Company *HPC Equipment Qualification Lead* *"Operator perspective on EQ: expectations and approaches"*
10:00	Gavin Smith, ONR *Superintending Inspector & Professional Lead - Mechanical Engineering* *"Regulatory perspective on EQ"*
10:40	**Break**

Overview of the day

11:00	**Session 1** **Pugsley Lecture Theatre**	**Session 2** **1.15 Lecture Theatre**	**Session 3** **1.18 Lecture Theatre**
	Dr Sean Weller *Wood* *"A programmatic approach to EQ, including sequencing"*	*Daniel Martin* *Tecnatom* *"LOCA for I&C"*	Dr Jessica Gwyther *Wood* *"Materials Qualification, Ageing and Obsolescence'*
11:45	**Session 1** **Pugsley Lecture Theatre**	**Session 2** **1.15 Lecture Theatre**	**Session 3** **1.18 Lecture Theatre**
	James Daniels *Element* *"Electromagnetic Compatibility Testing: Challenges in a Nuclear Environment"*	Dr Victoria Smith *Wood* *"Accelerated radiation and thermal ageing to underpin EQ"*	*Guenther Schnuerer* *TÜV Rheinland* *"Type testing of Nuclear I&C in international project environment"*
12:30	**Networking lunch**		

Overview of the day

13:30	**Pugsley Lecture Theatre** Chris Stone *Element* *"Seismic Qualification and demonstration"*
14:15	Alan Poole *Wood* *"Qualification of Smart Devices / EC&I"*
15:00	**Time for Networking** **Tea & Coffee**
15:45	**Pugsley Lecture Theatre** **Open Panel Session with Speakers** ● Gavin Smith – ONR ● Guenther Schnuerer – TÜV Rheinland ● Dr Sean Weller – Wood ● ● Chris Stone – Element ● Dr Victoria Smith – Wood ● Alan Poole – Wood ● Daniel Martin - Tecnatom ● ● Dr Jessica Gwyther – Wood ● James Daniels – Element ● Richard McLaren – HPC Project ●
16:30	**Event Close**

Thank you

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Building **better energy** together

WELCOME

HPC Equipment Qualification

Richard McLaren
HPC Equipment Qualification Lead

Equipment Qualification on HPC

Content:

- HPC Project Overview and Status
- Equipment Qualification on HPC
  - Objectives related to Equipment Qualification
  - The approach to Equipment Qualification
  - Current Status
  - EQ Organisation, Roles and Responsibilities
  - Current areas of EQ focus
  - Overall Key Messages
- Contact Details

Hinkley Point C

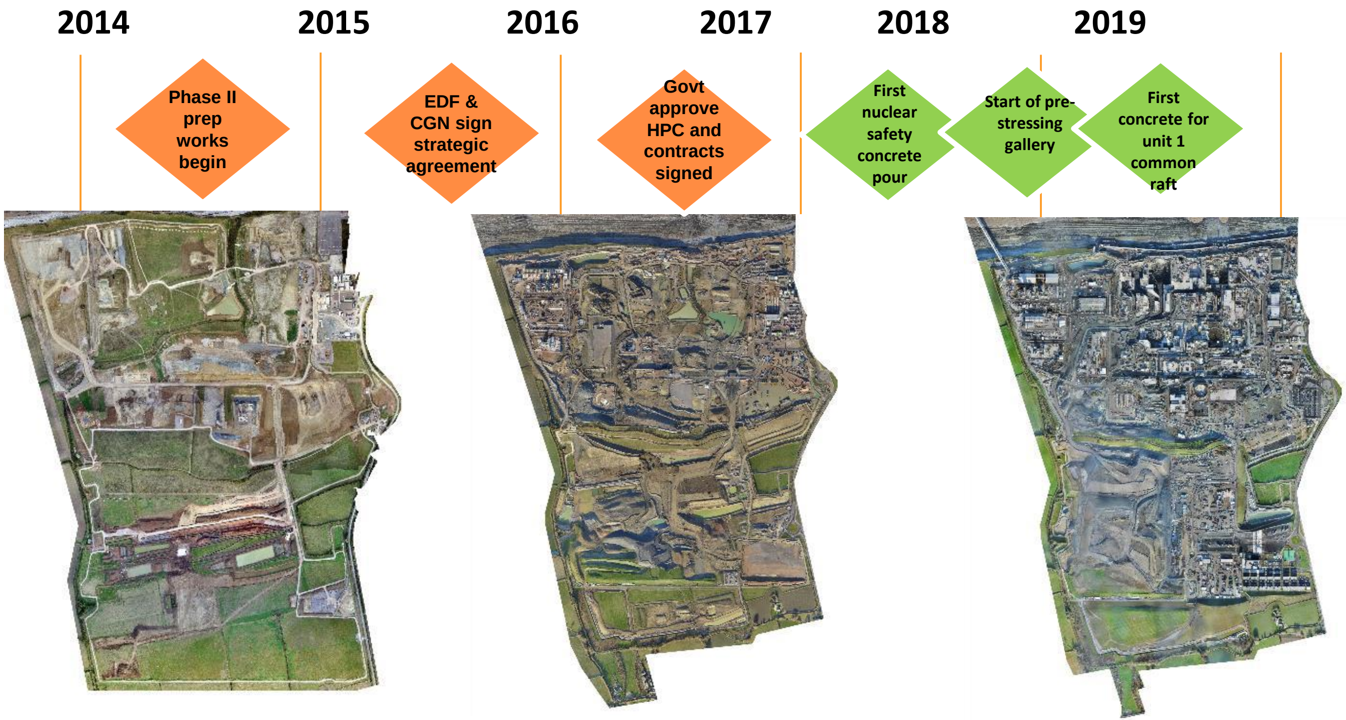
EPR design capable of generating **7% of the UK's electricity**

Enough to power **6 million homes**

Avoids the emission of **9 million tonnes** of CO_2 a year

£4bn into regional economy over lifetime of the project

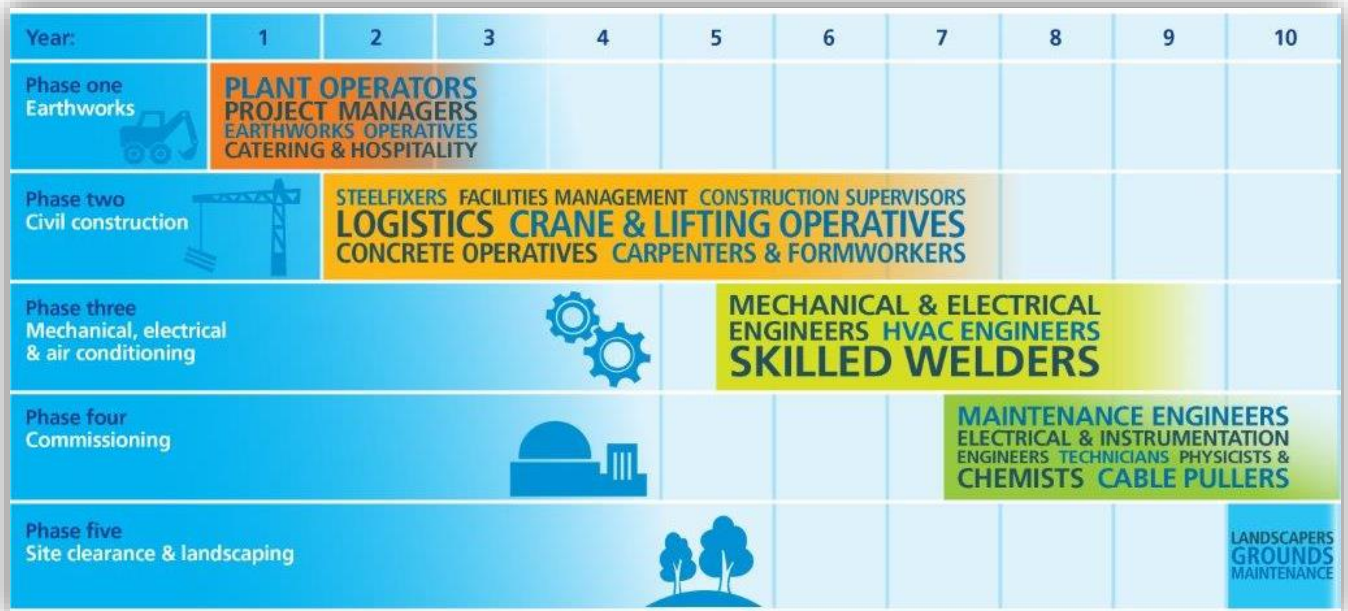
Construction site transformation



- Enabling site: Jetty, Cannington Bypass, Plazas, Welfare, Offices, Campus, Roads and Networks
- Circa 4,000 people daily through security and bussed to site
- 5.5 million m^3 of earthworks in the deep dig

- Unit 1 nuclear island common raft concrete
- Unit 1 pump house
- Unit 1 conventional island cooling pipes
- Commenced tunnelling works
- Poured 350,000 m^3 of concrete

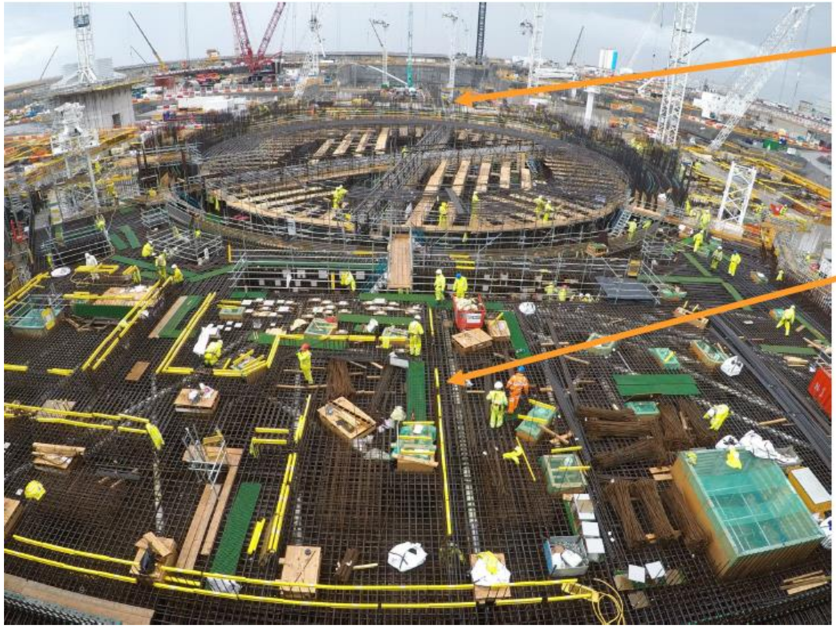
Workforce requirements each year of the Project



Drive for ‘25

2019
2020
2021
2022
2023
2024
2025
J0 - Common Raft Complete, Start of Reactor Buildings Construction JUNE 2019
Commence Turbine Pedestal Concrete Pouring
Complete Tunnelling of Cooling Water Intake 1
Simulator/ Training Building Access for Simulator 2
Complete Tunnelling of Cooling Water Outfall
Start MEH Installation in Nuclear Island
Start on Site Electrical Installation in Conventional Island Electrical Building (HF)
Completion of Intake Structures & Liaison Galleries
Commencement of Pre-Stressing Activities
Delivery to site of Standard I&C Batch 1 - for Electrical Systems Energisation
Start of Turbine Erection
Reactor Building (HR) Dome Lift complete
Delivery to site of Standard I&C Batch 2 and 3 for NI/CI Systems Energisation
Polar Crane Available
Reactor Pressure Vessel (RPV) Introduction into Reactor Building (HR)
Introduction of last Steam Generators into Reactor Building (HR)
First Energisation of Auxiliary Transformer (TA)
Primary Loop Handovers, start installation of Auxiliary Piping in Reactor Building
Water in Forebay
Main Control Room (MCR) Ready for Commissioning
Operations Staff Authorised and Ready for HPC Unit 1 Fuel
Start of Nuclear Cleaning
Start of Cold Functional Test (CFT)
Start of Hot Functional Test (HFT)
First Reactor Fuel on Site
First Synchronisation of Main Generator to Grid Under Nuclear Steam
Start of Commercial Operations (COD - Unit 1) JUNE 2025
Q1
Q2
Q3
Q4

Drive for ’25 – J0 Milestone

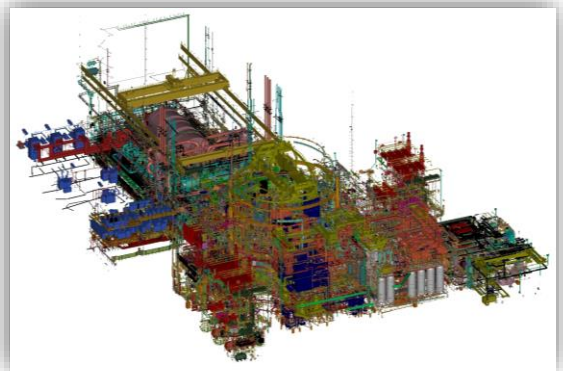


The third common raft pour was completed in May 2019

The final common raft pour was completed in June 2019 – J0 Milestone complete.

Drive for '25 – Path to Dome Lift

MEH delivery



At a glance….

- 380km of pipework,
- 20 000 valves,
- 200 pumps,
- 42 heat exchangers,
- 86 Filters,
- 120 Tanks,
- 6 325km of main power and I & C Cables,
- 404km of Cable Containment,
- 51 700 Supports,
- 218 LV Switchboards,
- 136 Transformers,
- 43 HV Switchboards,
- 3,000km of small power Cables,
- 47000 lighting units, to be installed in 4000 rooms in 75 buildings.

MEH JOINT VENTURE
Building our nuclear future

Balfour Beatty Bailey

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DOOSAN

ALTRAD SERVICES

中广核 CGN
Nuclear Power
China Nuclear Power Engineering Co.,Ltd.

ENGIE Ineo

Tunzini

BILFINGER

ENGIE Axima

edvance GROUPE EDF

boccard Alliance for success

Imtech

Wincanton

EDF ENERGY HPC CGN

HPC Supply Chain

Local, National and International partners working together to deliver Hinkley Point C

HPC – approach to quality in the supply chain

Parts made for Hinkley Point C have to pass **multiple stages of quality assurance, including independent assessment.**

Learning from Flamanville 3, the **Hinkley Point C project behaves as an "intelligent customer"** which can challenge, inspect, assess or even switch suppliers to protect its quality and schedule.

Key factors to drive quality:

- An unchanged design with stable regulation
- Experience of the supply chain through repetition
- Examining the supplier's ability to deliver quality and switching suppliers if necessary
- Independent third-party surveillance
- Increased testing, repeated inspection and measures to check against fraud

Links to Equipment Qualification

- Underpinning the safety case
- Reuse of FA3 qualification, where possible
- Maximise the opportunities for mutualisation
- Suppliers generally responsible for the delivery of the Qualification scope

Equipment Qualification on HPC - Objectives

Underpinning the Safety Case

- The nuclear regulation in the UK is non prescriptive and takes a **"goal" setting approach**.
- This means we must justify what performance standard or reliability is required to **underpin the specific safety case** and then justify how we will meet the requirements.
- If the "goal" or claim is achieving a particular reliability under hazard conditions then the argument is how this will be demonstrated and the **evidence is the qualification**.
- So the approach to Equipment Qualification is crucial **in underpinning the safety case** for operation and we must have accurate records (the **Qualification File**)

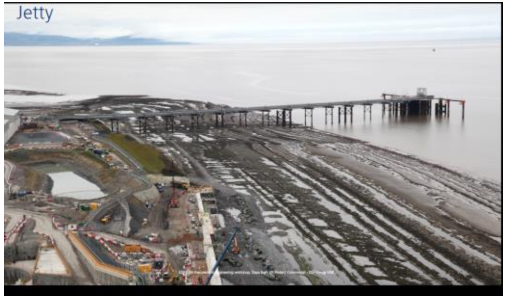
Conventional Island Unit 1
– Main Feedwater Pit

Equipment Qualification on HPC - Approach

A collaborative approach with Suppliers

- Ownership of qualification must start with the supplier / manufacturer. As you have **greatest knowledge** of the equipment.
- There are some aspects of the UK requirement that are **unique.**
- HPC and EDF have the **expertise to support** these unique areas or other difficult aspects.
- We will **support and provide advice.**
- Where you have problems meeting requirements, or believe there is a better way, **please talk to us.**
- Collectively we have the opportunity to optimise the use of facilities.
- Working in partnership supports achieving safety, quality, schedule and cost targets

Conventional Island Unit 1 – CRF Inlet Trench

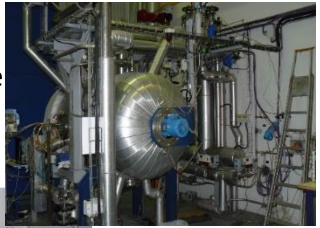


Equipment Qualification on HPC - Approach

Qualification may be achieved in 3 different ways

- **Analysis:** studies performed to show that the product satisfies the project requirements, generally using one of the following:
    - Analogy with the demonstration performed for previously qualified components
    - Calculations, justification of the design
    - OPEX from previous projects or other industries

- **Tests:** trials on a prototype in a laboratory, requiring specific protocols agree with the technical entity in charge of the review; facilities may include (depending on the component):
    - Seismic table
    - Climatic chambers
    - Loaded water circulation test loop
    - Irradiation pool

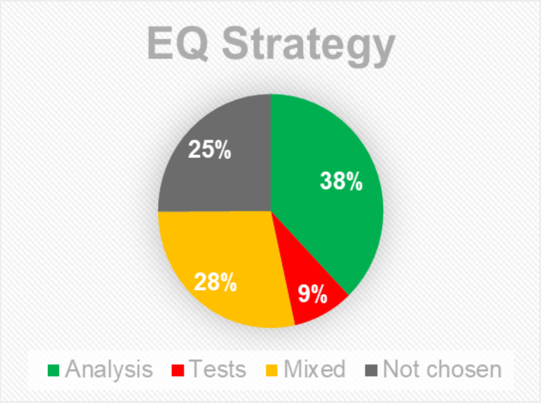


- **Mixed:** combination of both methods presented above where relevant

Equipment Qualification on HPC - Status

- **Some figures on Equipment Qualification:**
  - 200+ contracts across the HPC project (SOC > £10Bn)
  - 80+ contracts containing qualification (to Accidental Conditions)
  - ~340 equipment components identified (including Smart Devices), several additions and suppressions from the FA3 baseline, some components now shared between several contracts

  - Current baseline EQ strategy split*:
  - This is a deviation from the initial estimate (>70%analogy with FA3)
  - Review ongoing to rationalise and mutualise



* Baseline currently under review

Equipment Qualification on HPC - Status

More detailed progress of EQ by family of component (general overview)

- Areas for which qualification is well advanced:
  - Valves
  - Centralised I&C platforms
  - Pumps (for which EQ is by analysis)
  - Lifting and Handling
- Areas for which qualification is about to start or has just started:
  - Electrical distribution (relays, switchboards, cabinets, transformers, etc.), cables
  - Pumps (for which EQ is by tests)
  - Diesels
  - HVAC (HK2721 – preliminary work only)
  - Instrumentation
  - Dedicated I&C platforms
  - Smart Devices
  - Chillers

Equipment Qualification on HPC - Status

Intent	Status
High degree of qualification analogy with FA3	Significant diversion from original intent to FA3 analogy
Use of experienced suppliers with relevant capability	As above – new suppliers, increased risk in relation to qualification (incl. UK context)
Clear qualification requirements set out at contract commencement	Not always the case and changes in requirements leading to cost/schedule impacts
Qualification set out as a contractual requirements on all Suppliers	Suppliers not capable in some cases and requirements not clearly set out/understood
Limited review of transverse qualification issues and opportunities for mutualisation	Vertical approach to contracts limiting opportunities for mutualisation

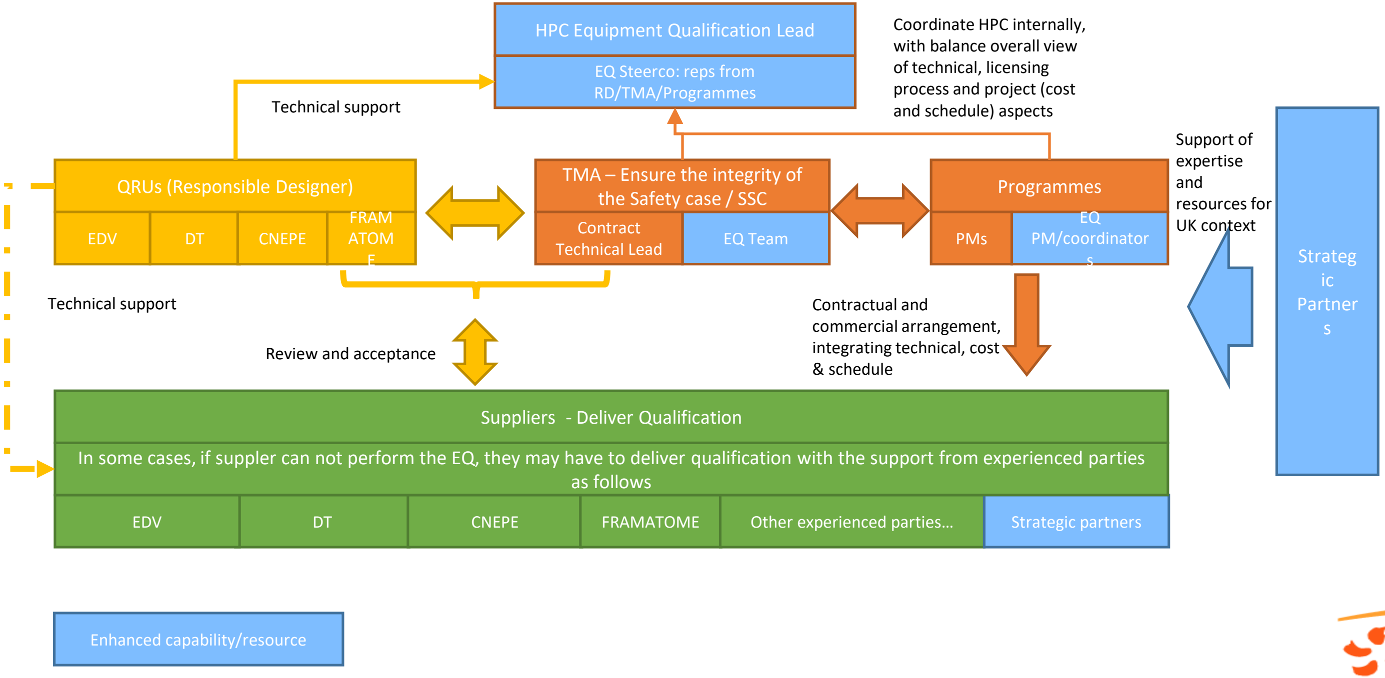
All leading to potential major impact to the overall project:

- **Increased costs of qualification**
- **Impact on schedule through delays in Delivery To Site**
- **Significant resource/time consuming**

Leading to a revised approach to the support to delivery of Qualification

Equipment Qualification on HPC - Organisation

Equipment Qualification (project level)



Equipment Qualification on HPC - Organisation

Benefits of the revised approach to support:

- Provide effective **coordination and leadership** to deliver **optimised Equipment Qualification** across the HPC project (through the **EQ Steering Committee**).
- Ensure **all existing qualification** information is taken into account, so as to **limit the additional testing** required for HPC.
- Pursue and **implement mutualisation** across components, contracts and programmes on the HPC project.
- Apply a **risk based approach** to implementation of Equipment Qualification (S1-S4).
- Ensure **strategic support** is available across the project, understood and implemented at HPC. To minimise impact of UK context not exaggerate effect.
- Support, develop and secure a **strategic Supply Chain** with qualification expertise for future projects.

Heat Sink Unit 1 – Pumphouse

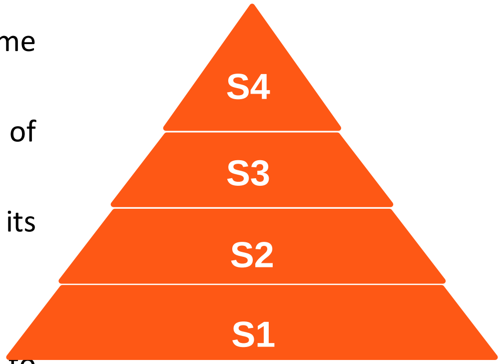
Equipment Qualification on HPC - Organisation

Risk based approach to Equipment Qualification

Generally the **contractor owns the EQ responsibility**. Depending on complexity of the qualification, experience of the supplier, feedback from the first exchanges & OPEX, the qualification strategy is graded into following four scenarios:

- S1 – qualification has been done before and is well understood
- S2 – approach to qualification is understood but there are some difficulties in achieving
- S3 – specialist third party support required for completion of qualification
- S4 – HPC project takes responsibility for qualification due to its unique nature

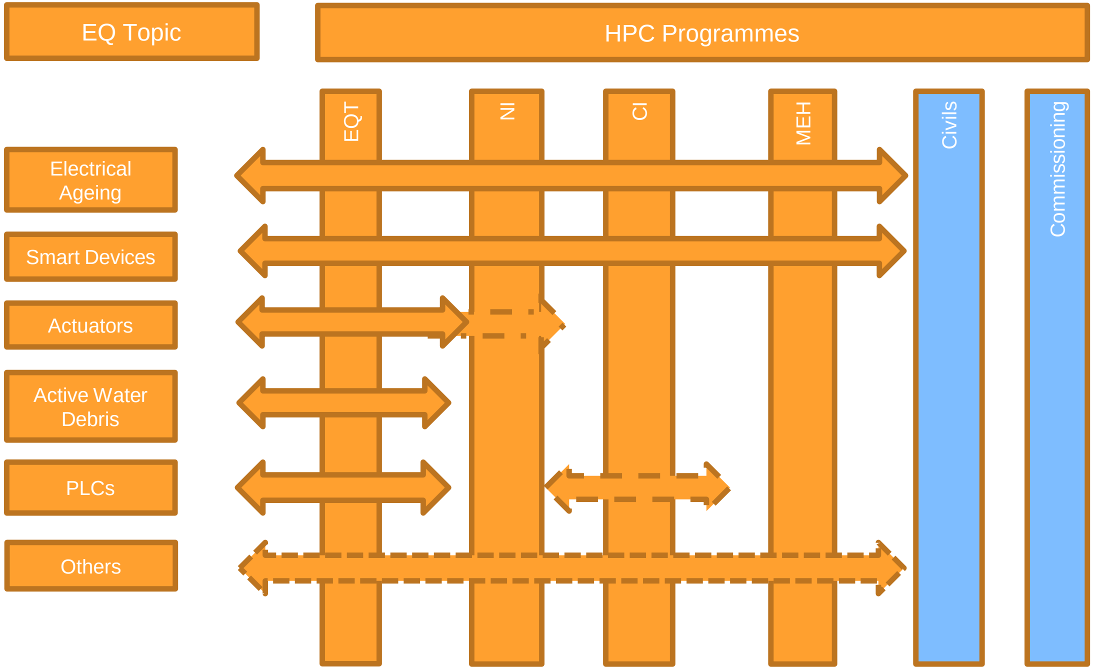
- Review of categorisation under way (validate the baseline).
- Consideration of testing sequencing, capacity and capability to be included.



Equipment Qualification on HPC - Focus

Key Workstreams

- Establish, validate and manage the EQ **Baseline.**
- Maximise mutualisation **Opportunities** and manage **Risk** related to EQ.



Equipment Qualification on HPC – Key Messages

Overall key messages:

- The HPC Programmes are focussed on **delivery of qualified equipment** to meet site need dates.
- In most cases **Suppliers remain responsible** for the qualification
- We are here to **help Suppliers** achieve that.
- Equipment Qualification will be **optimised across the HPC project** by ensuring that all existing qualification information is taken into account, so as to limit the additional testing required for HPC.
- We shall **pursue and implement mutualisation** across components, contracts and programmes on the HPC project.
- We aim to support, develop and secure a **strategic Supply Chain** with qualification expertise for future projects.

Sizewell C

Sizewell C would be an **exact copy of Hinkley Point C's nuclear and conventional islands,** saving UK context design work.

Four international EPRs will enter operation before Sizewell C receives final investment decision

In operation Sizewell C will be **units 7 and 8 of an operating international fleet.**

Sizewell C's construction costs **forecast to decrease by 20%** compared to Hinkley Point C.

One off supply chain costs not repeated at Sizewell C.

Further reductions could be possible from **productivity improvements .**

Contact Details:

HPC Equipment Qualification Lead

Richard McLaren

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Thank you

Any questions?

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Regulatory perspective on equipment qualification for nuclear installations

Gavin Smith CEng FIMechE

Superintending Inspector

Professional Lead Mechanical Engineering

Head of GB Transport Competent Authority – Radioactive material

- ONR is an independent statutory body. We are as far removed from Government as is possible. Government has no role in regulatory decision making
- Formed in April 2014 on the commencement of the Energy Act 2013
- Formerly an Agency of Health & Safety Executive (HSE)
- Began as Nuclear Installations Inspectorate (NII) in 1960
- The Energy Act 2013 set up ONR with the following purposes:
    - Nuclear safety
    - Nuclear site health and safety (conventional health and safety)
    - Nuclear security
    - Nuclear safeguards
    - Transport (of radioactive materials)

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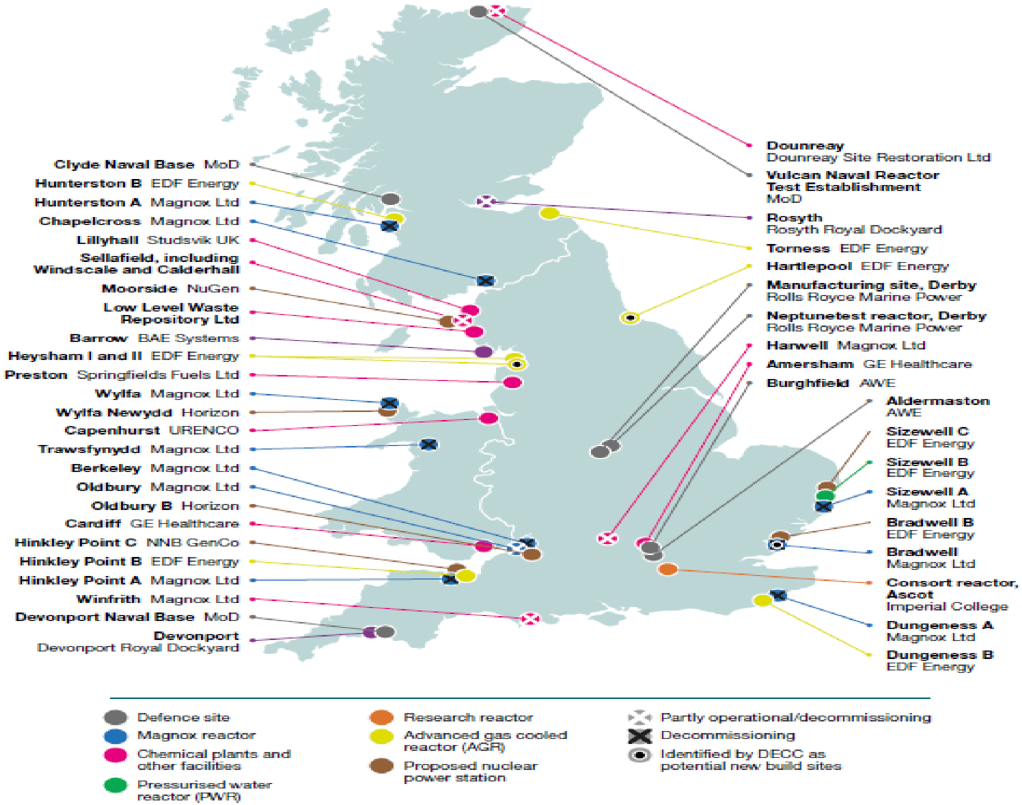

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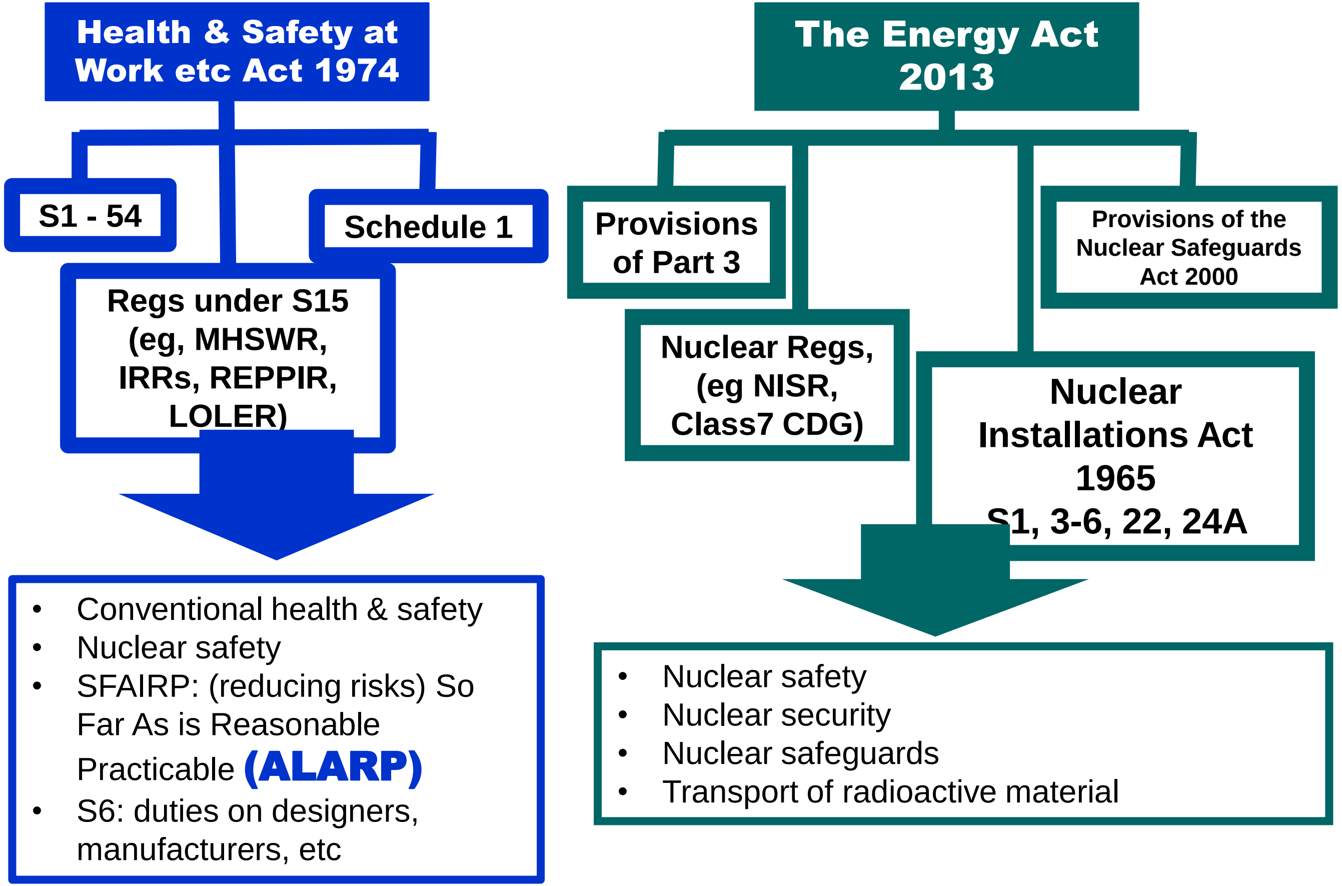

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ONR's regulatory philosophy

Non-prescriptive → goal setting

- Persuasive and influencing approach in the first instance (then use regulatory powers in accordance with our Enforcement Policy Statement)
- Develop and sustain an open and effective dialogue with licensees and other stakeholders
- Act in a way that supports and strengthens licensees' self-regulatory processes rather than providing a substitute for them

Supply chain

- **The Health and Safety at Work etc. Act (1974) – (HSWA74)**
- Section 6 - Section 6 requires that any person who designs, manufactures imports or supplies any article for use at work:
  - Section 6 requires that any person who designs, manufactures imports or supplies any article for use at work:
- Must ensure, so far as is reasonably practicable, that the article is designed and constructed as to be safe and without risk to health when properly used;
- Must carry out or arrange for the carrying out of such testing and examination as may be necessary to comply with the above duty;
- Must provide adequate information about the use for which it is designed and has been tested to ensure that, when put to use it will be safe and without risk to health

Introduction

- Industrial facilities need reliable equipment for economical operation and acceptable worker safety

  → achieved by procuring well-designed industrial-grade equipment and maintaining it properly

- More than this needed for safety related equipment in nuclear facilities due to role in ensuring public safety during a potential accident

  → need to demonstrate performance requirements are met or exceeded throughout installed life, even during extreme events

Guidance

- UK RGP for EQ is set out in ONR Safety Assessment Principles. ONR Technical Assessment Guides and IAEA safety standards provide additional information regarding ONR's expectations of the nature and content of safety cases for EQ.

- However more ONR guidance is required for harsh environments

- More on this later

Fundamentals

- Equipment qualification (EQ) is a fundamental requirement of the UK’s approach to safety assessment for nuclear facilities. – Risks reduced SFAIRP
- Requesting parties, Licensees and Dutyholders must demonstrate that all safety-related Systems, Structures or Components (SSCs) used in their reactor designs will function correctly and reliably on demand throughout their operational lives and within the parameters of the site-specific nuclear safety case.

What is Equipment Qualification?

IAEA SSR 2/1 ‘Safety of Nuclear Power Plant: Design’

Requirement 30:

- *A qualification program for items important to safety shall be implemented to verify that items important to safety at a nuclear power plant are capable of performing their intended functions when necessary, and in the prevailing environmental conditions, throughout their design life.*

NB: EQ <u>does not</u> establish a measure of equipment reliability


This publication has been superseded by SSR-2/1 (Rev. 1)

IAEA Safety Standards
for protecting people and the environment

Safety of
Nuclear Power Plants:
Design

Specific Safety Requirements
No. SSR-2/1

IAEA

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Safety Function

- The safety functions to be delivered within the facility, both during normal operation and in the event of a fault or accident, should be identified and then categorised based on their significance with regard to safety. **SAP ECS1**

- Category A – any function that plays a principal role in ensuring nuclear safety;
- Category B – any function that makes a significant contribution to nuclear safety;
- Category C – any other safety function contributing to nuclear safety.

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Link to Safety Case

Equipment Qualification inputs determined from facility safety cases

Safety Functions

- specific equipment purpose(s) to be accomplished for safety
- generally established in terms of required behaviour and duration (mission time)
- Master Equipment Qualification List

Service Conditions

- conditions under which specific equipment is required to perform specific Safety Functions
- dependent upon equipment location in facility
- generally established in terms of normal operation and accidents - Postulated Initiating Events (PIEs)

Link to Safety Case
- safety functions

Safety functions requiring demonstration by qualification include:

- Integrity
- Stability

Generally demonstrated by design, construction & inspection to applicable codes/ standards

e.g. piping, vessels, structures

- Operability

Generally demonstrated by testing

e.g. electrical, I&C, mechanical equipment

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Link to Safety Case
- service conditions

All systems, structures and components important to nuclear safety need to be qualified against range of postulated service conditions:

- Normal operation conditions
- Abnormal conditions – ‘mild’
- Accident conditions – ‘harsh’

*Generally considered part of **normal design** assurance processes*

*Temperatures, pressures, irradiation , etc **significantly** different to normal operation LOCA, Steam line high ,energy breaks fire flooding, Seismic*

Link to Safety Case
- service conditions

Environmental Service Conditions (plant area)

- Ambient temperature
- Ambient pressure
- Humidity
- Radiation
- Water/ chemical spray
- Submergence
- Seismic vibration
- EMC

Operational Service Conditions (system specific)

Electrical parameters

- Voltage
- Frequency
- Current

Vibration

Process fluid conditions

- Pressure
- Temperature
- Chemical composition
- Flow rate

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‘Harsh’ service conditions

- Environmental and/or operational conditions significantly different from normal

  → little confidence derived from normal factory tests, commissioning, normal operation and in-service testing

- Focuses on events with potential to produce multiple simultaneous “common-cause” failures in spite of design considerations of redundancy, diversity and physical separation
  - postulated accidents typically include LOCAs and steam line breaks
- Seismic vibration typically included as can lead to common cause failure across facility
  - other hazards generally addressed by physical protection/ separation
- Commonly referred to as Equipment Qualification for Accident Conditions (EQAC)

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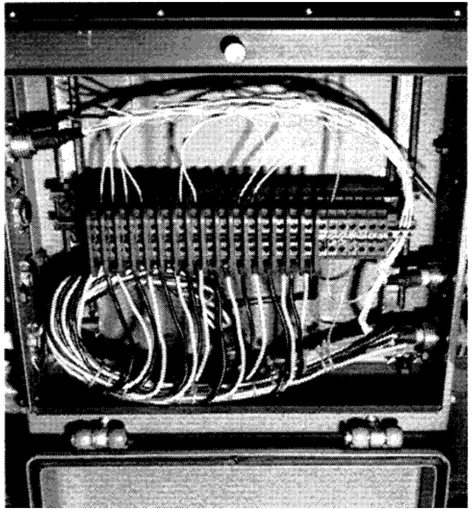
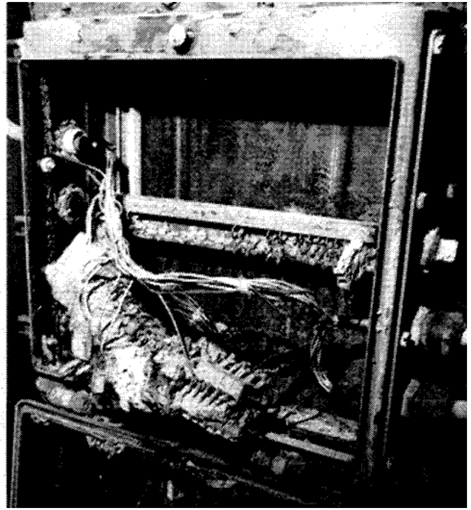
‘Harsh’ Service Conditions





Damage to terminal board inside an enclosure during LOCA test

[EPRI]

Equipment Qualified for ‘Harsh’ Service Conditions

- Equipment required for performance of safety functions during ‘harsh’ service conditions
  - including services as appropriate
- Equipment the failure of which under ‘harsh’ service conditions would prevent accomplishment of safety functions required from other equipment
  - particularly relevant to seismic qualification
- Equipment provided for severe accident monitoring purposes
- (crane collapse on to a class 1 electrical cabinet)

Ageing

- Qualification must demonstrate equipment capability for the duration of the equipment's installed life

  → qualification must address in-service ageing degradation that could occur **prior** to 'harsh' accident conditions

- Of special significance are the long-term effects of temperature and radiation on non-metallic materials
- Ageing evaluation is required to establish a qualified or installed life, after which equipment must be replaced or refurbished

  → through life environment monitoring to confirm/ extend qualified life

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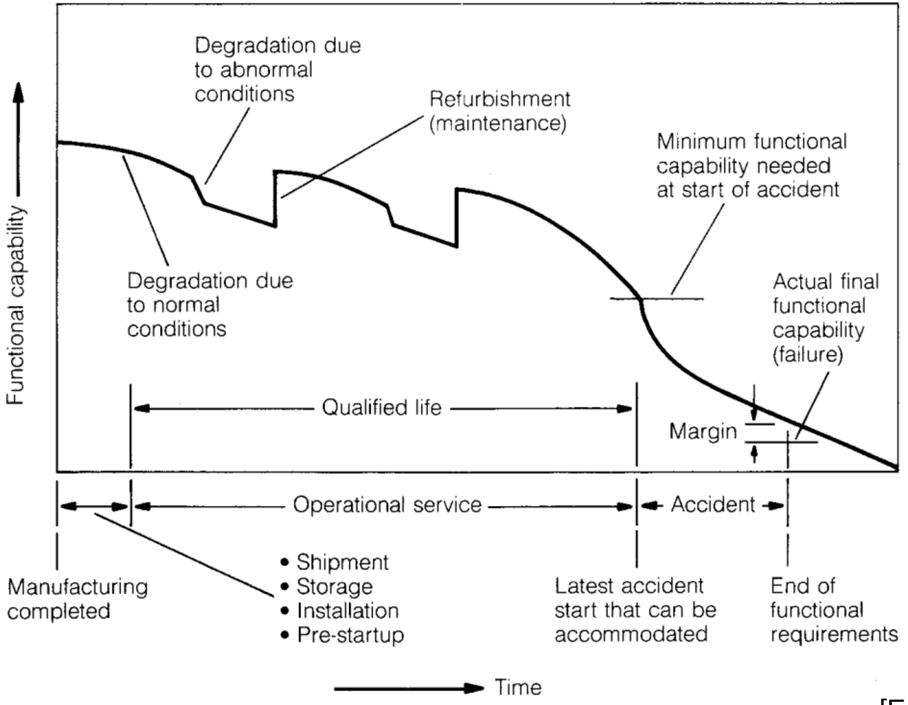
Ageing



[EPRI]

Qualification of Mechanical Equipment

Mechanical equipment generally less sensitive to ageing mechanisms and 'harsh' **environmental** service conditions with exception of:

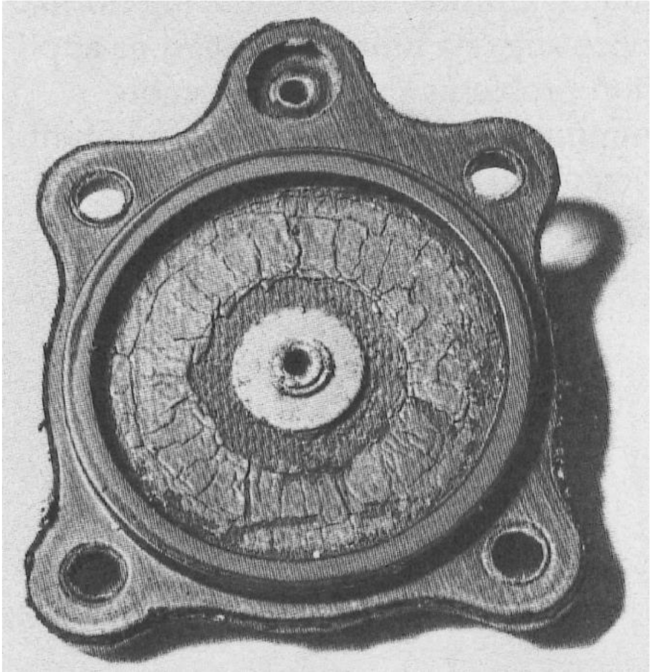
- non-metallic components
  - plastic/ rubber components (valve diaphragms, O-rings, seals)
  - lubricants
  - paints/ coatings (debris source term)
- seismic events

'Harsh' **operational** service conditions can be more challenging:

- valves needing to operate under high velocity two phase flow
- pumps needing to handle debris

Qualification of Mechanical Equipment

Effects of a LOCA test on a solenoid-operated valve diaphragm



[Franklin Research Centre]

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Key Elements of EQ Process

Design Inputs

- Identify PIEs
- Specify service conditions
- Develop list of equipment (functions & mission times)

Establishing EQ

- Define requirements
- Select method
- Establish qualification
- Define installation/ maintenance requirements
- Document results

Preserving EQ

- Installation & maintenance control
- Replacement control
- Modification control
- Service condition monitoring
- Personnel training
- Documentation

[IAEA]

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EQ Methods

EQ methods include:

- type testing
- analysis
- operating experience
- combination of the above

For complex systems (electrical, I&C etc.) type testing is preferred method:

- complexity of equipment
- wide variety of potential failure modes and mechanisms

Type testing includes ageing and accident simulation performed on a limited sample (usually one) of a “type” of equipment

Analysis in combination with partial test data can establish a strong technical basis for qualification

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Installation & Maintenance Control

It is important to determine which installation, operation and maintenance activities are critical to qualification

Example: electrical terminal block qualification

- tested with cables entering enclosure from the bottom
- licensee's arrangement includes top entry conduits

➡ top wire entry can direct excess moisture onto terminal blocks invalidating qualification results

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Modification Control

Potential impact of a modification typically needs to consider whether any of the following are effected:

- introduction of new equipment into building/ room experiencing ‘harsh’ service conditions
- location and/ or orientation of existing qualified equipment
- required safety functions/ mission times of existing qualified equipment
- service conditions[(1)]
  - normal operation – affect on equipment ageing
  - accident conditions

(1) modifications can result in particular building/ room changing from ‘mild’ service conditions during accidents to ‘harsh’ service conditions e.g. re-routing of pipework

Commercial of The Shelf (COTS) Items

Why

- can reduce costs and design effort
- no nuclear specific device available and use of well-proven commercial product could be more effective than development of a new item

Challenges

- tend to be more complex with unnecessary/ unintended functionalities
- often become obsolete in a shorter time
- commercial development processes may be less transparent and controlled - qualification is difficult without vendor cooperation
- maintenance of qualification during plant lifetime

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Codes & Standards

International standards

- IEC 60780
  - Electrical Equipment Important to Safety - Qualification
- IEC 60980
  - Recommended Practices for Seismic Qualification of Electrical Equipment

Local standards

- France – RCC-E
- US – IEEE/ ASME (1)
- Germany – KTA
- UK – n/a

(1) mechanical equipment

UK regulatory approach to EQ no different from other countries

Codes & Standards

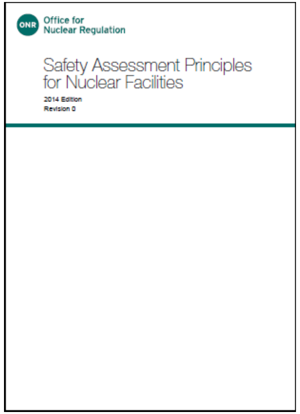
- General principles and methodologies are similar, in the UK licensees likely to adopt the standards from the equipment vendor's country

  → this was the case for Sizewell B and is the approach being followed by EDF for Hinkley Point C

- The UK approach to regulation has the potential to result in additional qualification requirements for overseas vendors in terms of:
  - extent of equipment to be qualified
  - the detailed safety functions to be qualified
  - the service conditions (variations in pressure, temperature, radiation, etc)

  → determined from safety case

ONR Guidance (1/3)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Safety Assessment Principles
for Nuclear Facilities

2014 Edition
Revision 0

Safety Assessment Principles (1)

Equipment qualification

Engineering principles: equipment qualification	Qualification procedures	EQU.1
Qualification procedures should be applied to confirm that structures, systems and components will perform their allocated safety function(s) in all normal operational, fault and accident conditions identified in the safety case and for the duration of their operational lives.		

(1) Whilst written for ONR inspectors the SAPs also provide information to stakeholders regarding ONR's expectations

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ONR Guidance (2/3)

- Current guidance is limited, only covers concepts at high level and doesn't draw out significance of qualification for 'harsh' service conditions
- No single source of guidance on design, implementation and preservation of an EQ Programme

→ need for EQ Technical Assessment Guide (TAG) focusing on **'harsh' environmental conditions** for equipment with **operability safety functions**

- Driven by needs of civil new build programme but applies to all new nuclear facilities with proportionate application to existing facilities
- Draft produced, will be shared with the Nuclear Industry Safety Directors' Forum in due course

[NB: seismic qualification for equipment mentioned in TAST-13, Annex 1]

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ONR Guidance (3/3)

- ONR inspectors do not prescribe specific qualification procedures and tests

→ licensees need to demonstrate that their own arrangements made under relevant licence conditions are adequate and able to satisfy the requirements of their safety case

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Summary - 3 things to remember

- **EQ** inputs determined from the facility safety case

- **EQ** Provides confidence that equipment can perform its intended safety function during normal operations and accident conditions

- **EQ** Must be persevered throughout the lifetime of the facility and contributes to reducing risks SFAIRP

How can you help

Support development of new ONR guidance

EQSA

Equipment Qualification
Services Alliance

tecnatom TÜVRheinland® element wood.

EQSA

Equipment Qualification
Services Alliance

tecnatom TÜVRheinland® element wood.

"A programmatic approach to EQ, including sequencing"

Dr Sean Weller
Wood

Overview

- EQ Project vs Programme
- EQ Project – Risks or Missed Opportunities?
- EQ Programme – taking advantage of opportunities…
- An approach to de-risking EQ Projects & Programmes
- Rationalisation – family groups, testing groups
- Sequencing: importance of order
- Sequencing: challenges in UK context
- Summary
- Questions?

EQ Project vs Programme (1)

Project*... application of:

- Processes
- Methods
- Knowledge
- Skills
- Experiences

...to achieve a defined project objective = *Qualification of Equipment to perform safety function in service environment (normal and/or accident conditions)*

* As defined by APM – Body of Knowledge

EQ Project vs Programme (2)

Programme*… a group of related projects managed in a coordinated way to obtain benefits not available from managing the projects individually

Related:

- *Common service environments*
- *Common safety function*
- *Common suppliers*
- *Common failure modes*
- *Common qualification standard or code*

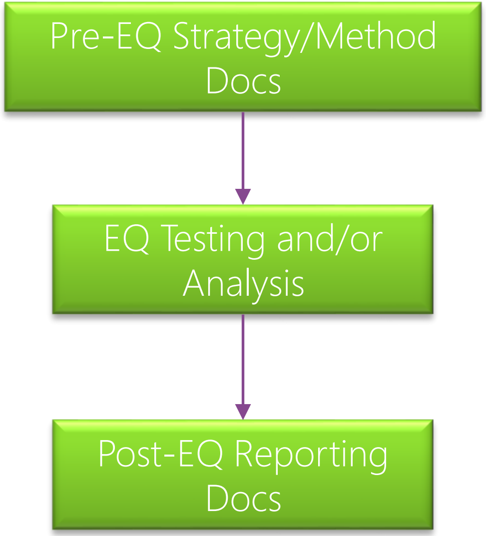
A programmatic approach helps identify opportunities and risks, as well as benefits not visible to separated tiers of the supply chain if EQ in their responsibility to deliver

* As defined by APM – Body of Knowledge

EQ Project – Risks or Missed Opportunities? (1)

- What are the common issues that are seen before, during and after individual EQ projects?

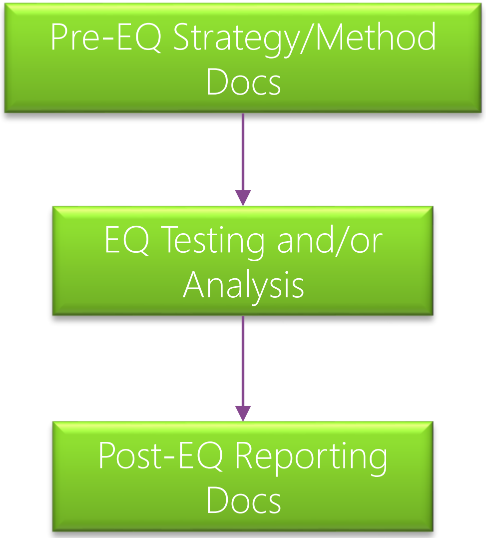
- Early or unexpected **test failures** – overly conservative, non-representative of service, poor test setup, unexpected facility issues
- **Acceptance criteria** realistic? Have they been defined?
- Access to manufacturers data or expertise if relying on analysis – performing **duplicate**/similar tests already performed on similar products
- **Under or over-budgeting** – inconsistent regulatory/standards knowledge in supply chain – assuming info to be provided for "pre-qualified" items is sufficient for meeting expectation of EQ by analysis



EQ Project – Risks or Missed Opportunities? (2)

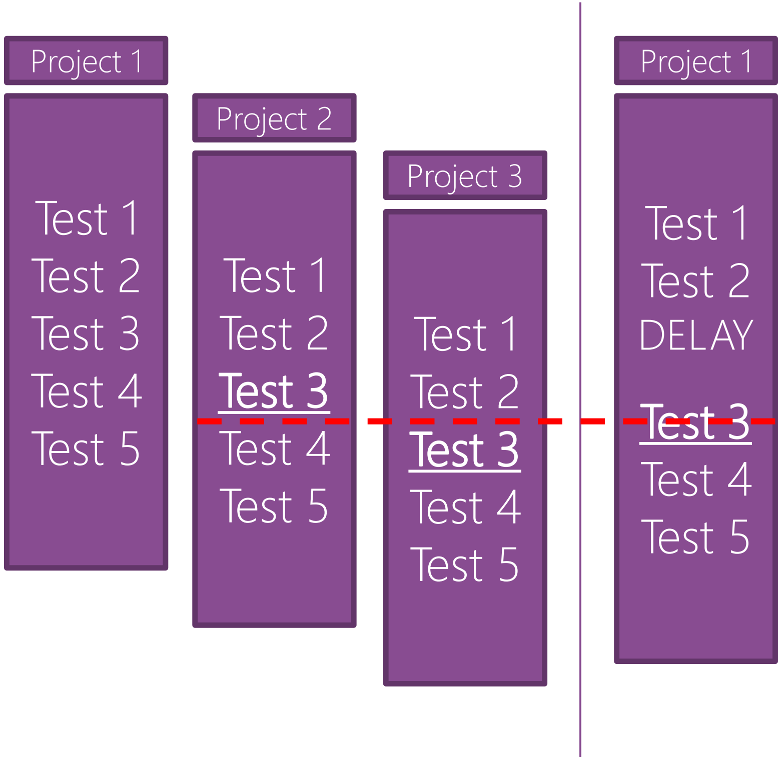
- What are the common issues that are seen before, during and after individual EQ projects?

  - **Scheduling** – pinch points in scarce facilities at testing partners – irradiation, seismic, thermodynamic accident chambers
  - **Approval bottlenecks** at Tier 1 / Licensee
  - **Transportation** – loss or damage during transport (site to site, lab to lab, manufacturer to test partner)



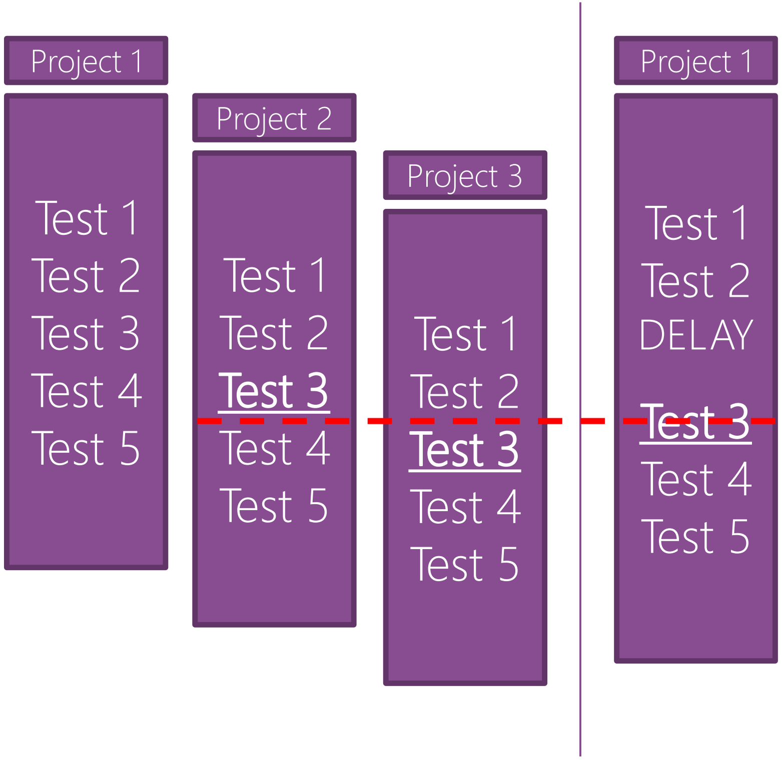
EQ Programme (1) – taking advantage of opportunities

- Scheduling
  - "**pinch points**" - Tier 2 or Tier 3 no visibility, need flexibility if one project is late, or running ahead of time – e.g. project 1 delay, opportunity of project 2 and 3 testing earlier?
  - Use of large chambers/ovens **applying the same test conditions** – prolonged operations bespoke chambers
  - **Common transport/handling specifications** – identify couriers, educate in requirements, common pick up/set down procedures and contacts



EQ Programme (2) – taking advantage of opportunities

- Scheduling
  - Identify particularly challenging (**higher risk of testing failure**) items – test multiples in parallel / staggered "conditioning", cost of additional items < repeat testing on critical path OR low cost early stage testing – buy a component, test it, see what happens – feedback to designers?
  - Licensee / Tier 1 **approvals** of pre- and post-testing documentation – avoiding **bottlenecks**, better management of "sampling" and "witnessing" of EQ across supply chain – creating **consistent templates and formats** – 25% surveillance of inconsistent documents same effort as 100% of consistent documents



EQ Programme (3) – taking advantage of opportunities

- Cross-plant Components
  - For example, temperature transmitters are used in multiple places across large reactor constructions – even if "over-specified" for system A but used and qualified on system B, an analogy could be made for use on system A – the cost of an "over-specified" temperature transmitter would out-way a complete duplicate qualification that is only slightly different in requirements

- Project OpEx / Programme Evolution
  - Oversight of testing, failure of similar items, similar setup, same test facilities could indicate a counterfeit/fraudulent item – greater CFSI vigilance

  - A contract/system could qualify a product early in overall reactor project that could then be suitable with only analysis to be qualified for use on another contract/system

  - Identify any trends in shortfall in data quality provided by suppliers

An approach to de-risking EQ Projects & Programmes

1. Assessing the GAP

- Gather background data, including existing EQ data
- Rationalise equipment list info families to reduce EQ scope
- Gap analysis (e.g. standards compliance matrix) with respect to UK Context

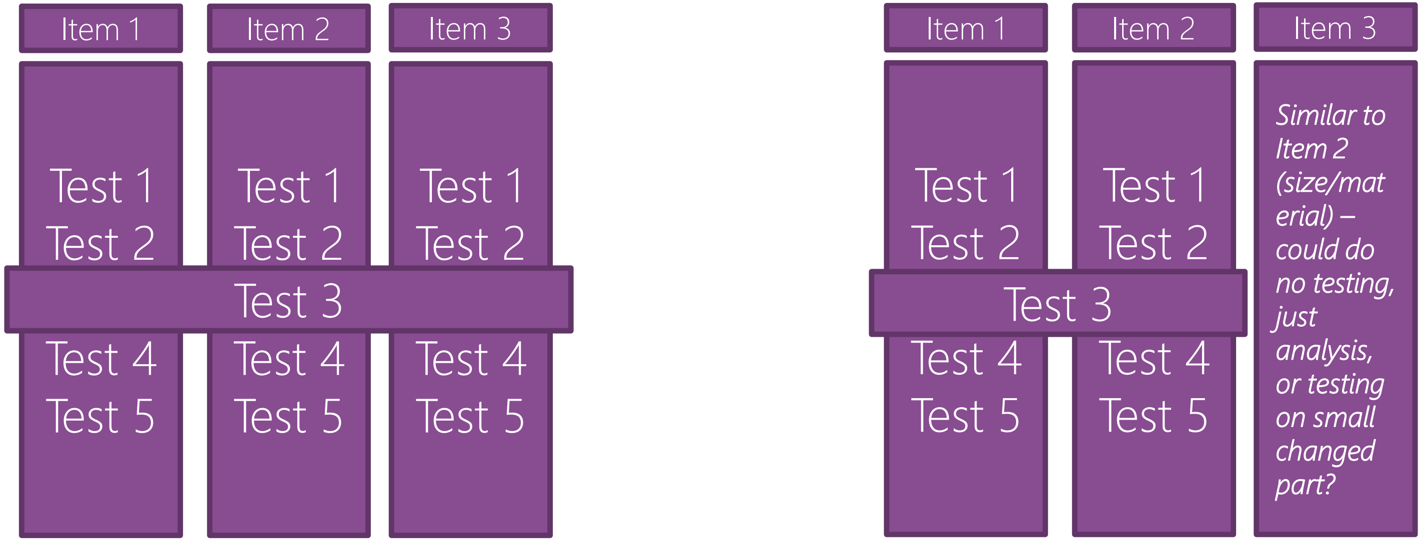
2. Close the GAP

- Create the regulator compliant EQ Plan
- Include existing EQ data that already closes the gap
- Rationalise list of tests and analysis required and write EQ procedures

3. Satisfy the regulator

- Test, with independence - grouping tests where possible to reduce time/cost
- Desktop analysis where more time/cost effective than testing
- Compile lifetime qualification reference file
- Recommendation for "preserving EQ" for lifetime, e.g. maintenance schedule, condition monitoring

Rationalisation – family groups, testing groups



Example - Test 3 – each item is in an environment with a slightly different max. service temperature (60°C, 65°C and 70°C) – study the possibility of testing all at worst case without being unrepresentative or testing beyond items capability – 3 x £10k or 1 x £15k test – multiple this via a programme with many items, a huge saving, as well as a more consistent test (in the same oven) could result – crucial to study upfront to take advantage of opportunity

Sequencing: importance of order (1)

- Importance for Accident Conditions
  - Service life must be accurately simulated prior to the occurrence of an accident
  - Example: earthquake could occur at Year 1 Day 1 or Year 59 Day 364

- Importance of adherence to codes/standards
  - RCC-E used at HPC (BTR.80.C.12 + equipment specific specs) "Assessment of Behaviour Over Time"
  - Completion of ALL, in sequence for control equipment = 40 year "hypothetical" service life

  - French fleet vast OpEx using well established code – EDF specs adapted, in most cases, adapted programme for specific equipment (use of 10°C Arrhenius law/approximation)

  - Removal of tests possible for normal condition equipment (RCC-E B3000, potentially K3) if existing evidence? but can be difficult to argue a removal of test and replacement with existing data (particularly for K2, K1, K3ad) or even reordering…

Sequencing: importance of order (2)

- Importance of adherence to codes/standards… continued / opportunities?
  - Removal of tests possible for normal condition equipment (RCC-E B3000, potentially K3) if existing evidence? but can be difficult to argue a removal of test and replacement with existing data (particularly for K2, K1, K3ad) or even reordering…

Example: if it can be proven that radiation ageing doesn't result in effect on seismic performance, can the ageing and accident radiation be completed together, limiting transportation/setup time and risk going from irradiation cell, to seismic table, back to irradiation cell?

I	Limits			Behavior Over Time												Accident					F
Initial Tests	Limit Tests	Water Penetration	EMC	Vibration	Dry heat	Cold Test	Fast Temp Variation	Humidity (cyclic)	Mechanical Shock	Tight/Untight Ops	Salt Mist	Long Term Drift at Ambient	Accelerated Ageing / Pressure	Pressure Variation & Surges	Irradiation Ageing	Seismic	Accident Irradiation	Thermodynamic	Post-Fukushima	Third Barrier	Final Tests

Sequencing: challenges in UK context

- Not recommended to mix standards, but has been seen for upgrading / extending EQ in France for items qualified to RCC-E

- <u>UK Context</u>
    - IEEE standards used - concept of qualification life and life extension (and condition monitoring) – based on Arrhenius model for time-ageing effect
    - Can be suitable for simple equipment – often asks for defined "materials" activation energy – not suitable for all materials, and relates to specific reaction/technique/material – so caution required
    - For RCC-E normal conditions (B3000), tendency to assume paper-exercise only as "normal conditions", however important to simulate life before seismic event (many B3000 items are still SC2 – requiring to be structural sound / stay in place)
    - Options:
        - Simulate by just performing tests that "age" component – causes a mix of standards
            - Choice is: completing all in sequence as per RCC-E to build 40 year "hypothetical life" vs. using IEEE and Arrhenius to age appropriately and then perform seismic testing – time/cost is vastly different
        - Do not do ageing testing assuming "normal conditions" are all benign and just do seismic testing
            - Risk: ageing, however small, not appropriately considered

Summary

- Programmatic approach **opens opportunities** and ability to mitigate risks early, and provides consistent delivery
- Nature of programmes vs projects means that **"benefits"** are obtained where they otherwise would not be
- Once programme opportunities are identified, the **flexibility of standards and approaches**, acceptable in UK context, can be explored
- To do this, a common view on how **standards are converging** and how they relate to IAEA guidance (update due and in progress) needs to be determined on large international projects with international stakeholders to realise benefits of a programmatic approach
- Full benefits realised with **careful planning and full upfront justification** with equipment **supplier cooperation**

Questions?

EQSA

Equipment Qualification
Services Alliance

tecnatom TÜVRheinland® element wood.

EQSA

Equipment Qualification Services Alliance

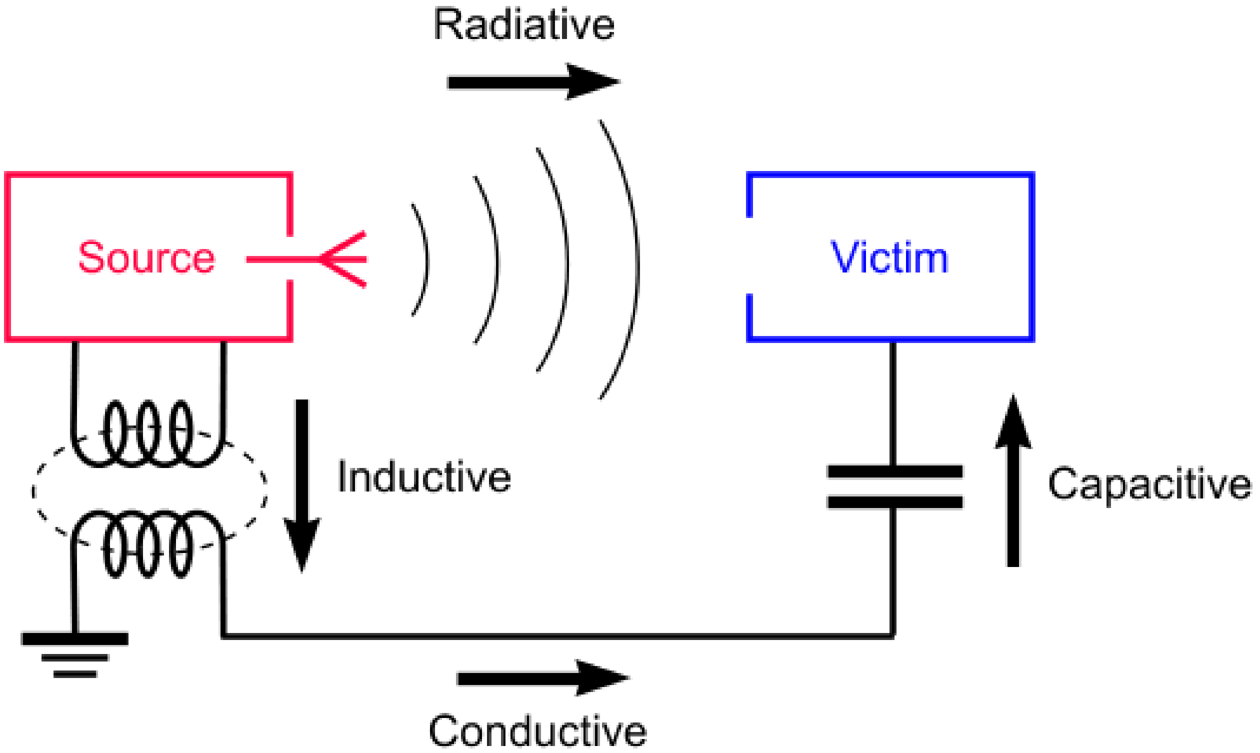
tecnatom TÜVRheinland® element wood.

EMC Testing: Challenges in a Nuclear Environment

James Daniels
Element Materials Technology

ElectroMagnetic Compatibility (EMC)

The fundamentals;



CE Marking

A passport to EU trade

Any product bearing the CE mark has met all of the appropriate provisions of the relevant EU product legislation

CE Marking

- The CE mark on a product is a manufacturer's Self-Declaration that the product placed on the EU market complies with all of the relevant Essential Requirements of the relevant EU Directives
- The CE Mark must be affixed before the equipment is Placed on the Market (or put into service) for the first time within the EU
- A product is made available on the market when supplied for distribution, consumption or use on the Union market in the course of a commercial activity, whether in return for payment or free of charge.

CE Marking

Example Directives;

- Electromagnetic Compatibility (EMC) Directive 2014/30/EU
- Low Voltage Directive 2014/35/EU
- Radio Equipment Directive (RED) 2014/53/EU

Persons placing products on the market in the EU must ensure products in scope meet the essential requirements of the directive, and the administrative requirements have been complied with (Followed the appropriate Conformity Assessment procedure; compiled Technical Documentation; complete a Declaration of Conformity, and; affix the CE marking)

CE Marking

Scope of the EMC Directive

'Equipment' means any **apparatus** or **fixed installation**

- **Apparatus** - any finished appliance or combination thereof made commercially available as a single functional unit, intended for the end user and liable to generate electromagnetic disturbance, or the performance of which is liable to be affected by such disturbance

- **Fixed installation** - a particular combination of several types of apparatus and, where applicable, other devices, which are assembled, installed and intended to be used permanently at a predefined location

CE Marking

Fixed installations

A fixed installation shall be installed applying **good engineering practices** and respecting the information on the intended use of its components, with a view to **meeting the protection requirements**. Those good engineering practices shall be **documented** and the documentation shall be held by **the person(s) responsible** at the disposal of the relevant national authorities for inspection purposes for as long as the fixed installation is in operation (no CE mark)

Apparatus **placed on the market** which may be **incorporated** into a fixed installation is subject to all relevant provisions for apparatus set out in the Directive, however, the provisions of Articles 5, 7 (obligations of manufacturers), 8 and 9 **are not compulsory** where it is **not commercially available** (e.g. CE marking is **optional**)

CE Marking

Essential requirements

Equipment shall be so designed and manufactured, having regard to the state of the art, as to ensure that:

(a) the electromagnetic disturbance generated does not exceed the level above which radio and telecommunications equipment or other equipment cannot operate as intended **EMISSIONS**

(b) it has a level of immunity to the electromagnetic disturbance to be expected in its intended use which allows it to operate without unacceptable degradation of its intended use **IMMUNITY**

(Performance)

CE Marking

Complying with standards

- The Official Journal of the EU (OJEU) lists all the harmonised standards that provide a presumption of conformity
- Difficulties can however arise if no specific standard exists for the product or if 'additional' issues need to be considered because of the use of the equipment and/or the environment to which it is exposed
- In the case of doubt as to the applicability of a particular standard external expert assistance should be sought

NOTE: Standards are not usually mandatory

CE Marking

The OJEU

Commission communication in the framework of the implementation of Directive 2014/30/EU of the European Parliament and of the Council on the harmonisation of the laws of the Member States relating to electromagnetic compatibility

(Publication of titles and references of harmonised standards under Union harmonisation legislation)

(Text with EEA relevance)

(2018/C 246/01)

ESO [1]	Reference and title of the standard (and reference document)	First publication OJ	Reference of superseded standard	Date of cessation of presumption of conformity of superseded standard Note 1
(1)	(2)	(3)	(4)	(5)
CEN	EN 617:2001+A1:2010 Continuous handling equipment and systems — Safety and EMC requirements for the equipment for the storage of bulk materials in silos, bunkers, bins and hoppers	13.5.2016		
CEN	EN 618:2002+A1:2010 Continuous handling equipment and systems — Safety and EMC requirements for equipment for mechanical handling of bulk materials except fixed belt conveyors	13.5.2016		

EMC Standards

Standards for the Nuclear Environment

No standards in OJEU in respect to the nuclear environment

- BS 62003:2009 (IEC 62003 Ed. 1) Nuclear power plants - Instrumentation and control important to safety - Requirements for electromagnetic compatibility testing (Not an EN)
- EN 61000-6-5:2015 Electromagnetic compatibility (EMC) — Part 6-5: Generic standards- Immunity for equipment used in power station and substation environment (recently published in OJEU)

- EN/IEC 61326-3-1 & EN 61326-3-2 EMC for Functional safety

EMC Standards

Product specific standards, such as;

EN 55011	Industrial, Scientific and Medical Equipment
EN 55032 & 35	Information Technology equipment
EN 61326 - 1	Measurement, Control and Laboratory
EN 61439-1	Low-voltage switchgear and controlgear assemblies

Generic standards;

EN 61000-6-1	Immunity Residential & Light Industrial
EN 61000-6-2	Immunity Industrial Environments
EN 61000-6-3	Emissions Residential & Light Industrial
EN 61000-6-4	Emissions Industrial Environments

EMC Standards

EMISSIONS

-	Radiated Emissions
-	Conducted Emissions
EN 61000-3-2	Harmonic Emissions ≤ 16A per phase
EN 61000-3-3	Limitation of voltage changes and Flicker ≤ 16A
EN 61000-3-11	Harmonic Emissions >16A to ≤ 75A per phase
EN 61000-3-12	Limitation of voltage changes and Flicker ≤ 75A

IMMUNITY

EN 61000-4-2	Electrostatic Discharge
EN 61000-4-3	Radiated RF, EM Fields
EN 61000-4-4	Fast Transient/Burst
EN 61000-4-5	Surge
EN 61000-4-6	Conducted disturbances induced by RF fields
EN 61000-4-8	Power frequency magnetic field
EN 61000-4-11	Voltage dips, short interruptions & voltage variations

EMC Standards

EN 55011:

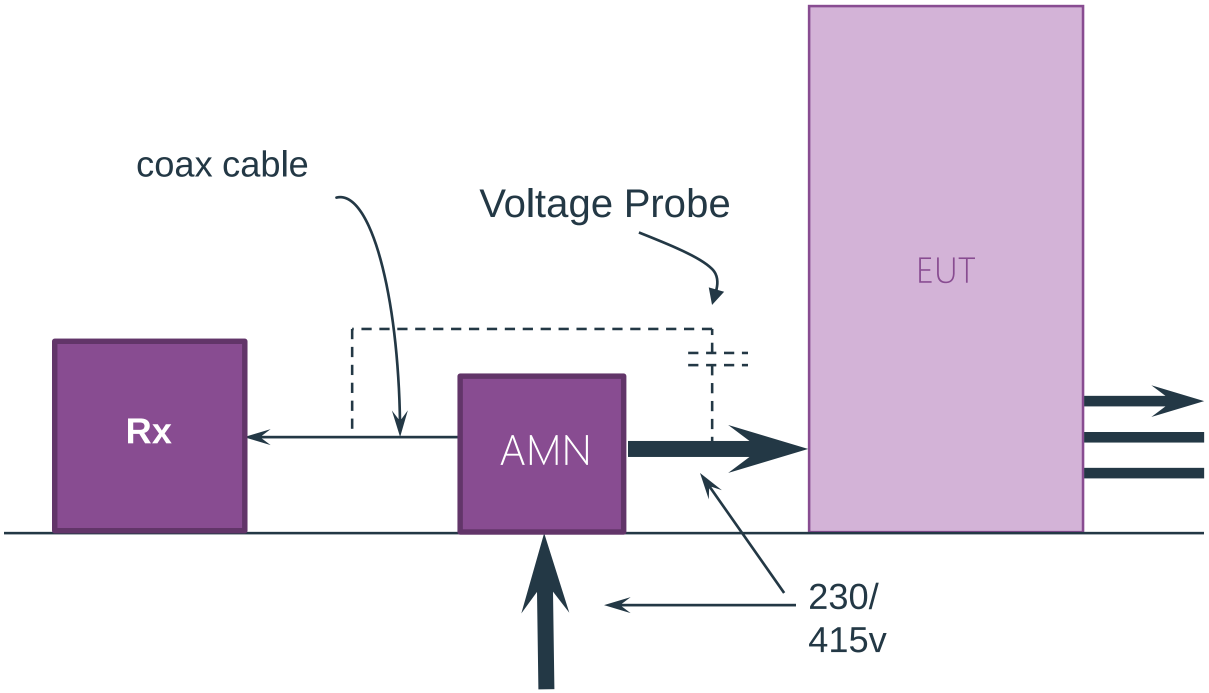
Group 1	Other than Group 2
Group 2	RF energy (9 kHz to 400 GHz) is intentionally generated
Class A	Equipment suitable for use in all locations other than Class B
Class B	Equipment suitable for use in locations in residential environments (and in establishments directly connected to a low voltage power supply network which supplies buildings used for domestic purposes)

EN 61326-1 different:

- Residential, commercial and light-industrial
- Industrial
- Special

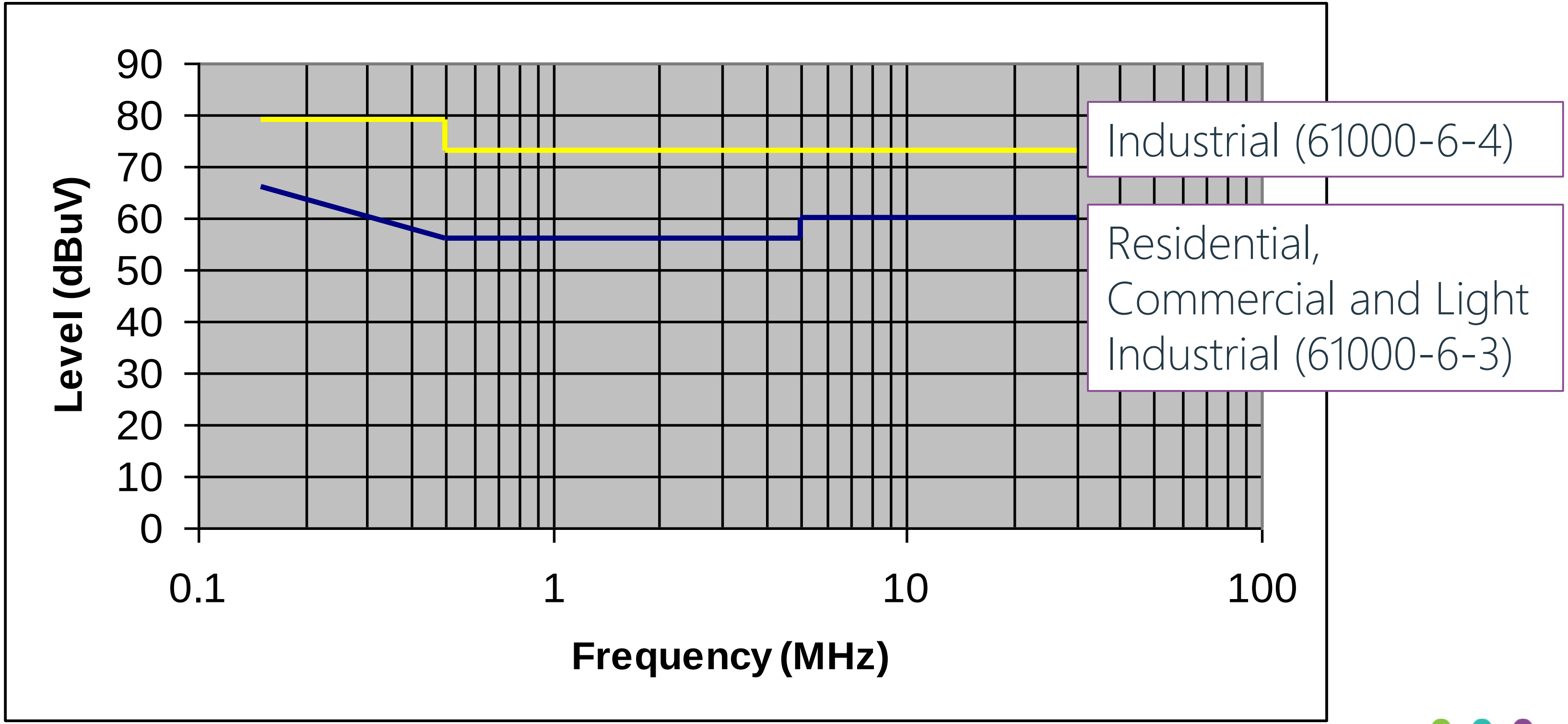
EMC Standards - Emissions

Conducted Emissions – Test set-up



EMC Standards - Emissions

Conducted Emissions – (Peak) Limits

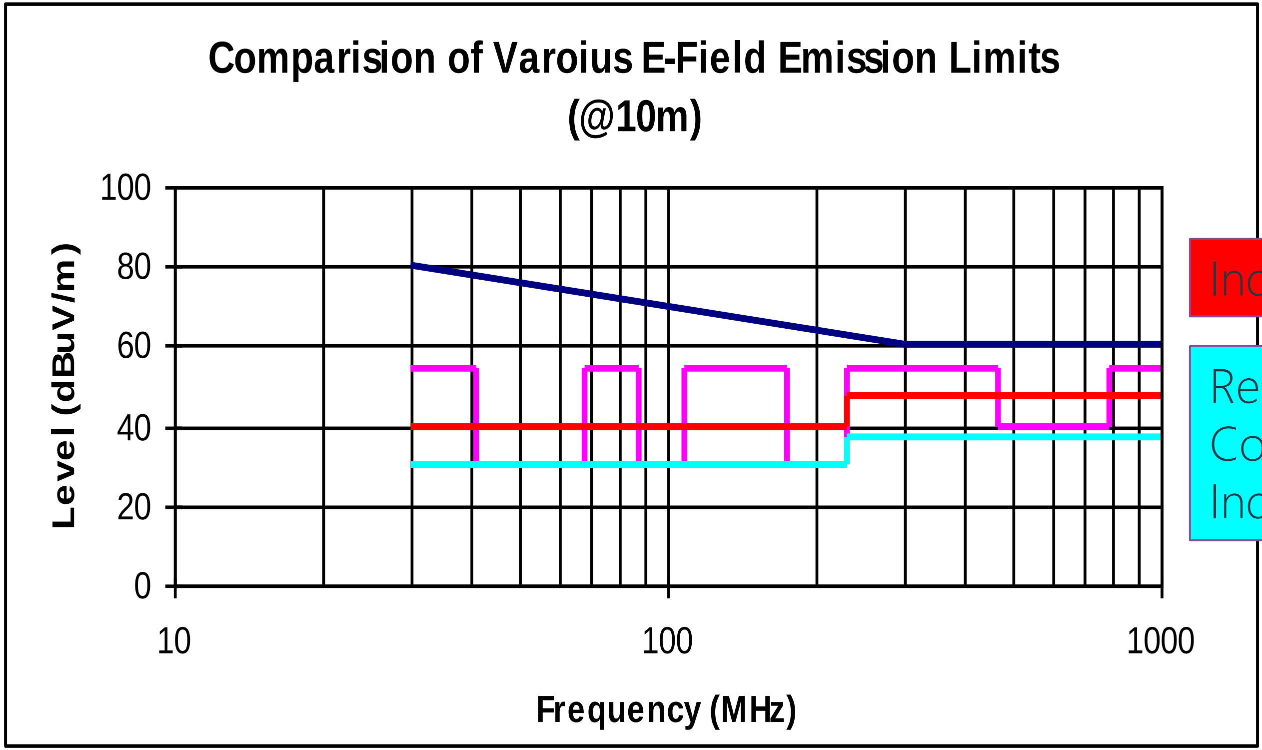


EMC Standards - Emissions

Radiated Emissions – Test set-up

EMC Standards - Emissions

Radiated Emissions – Limits



Industrial (61000-6-4)

Residential, Commercial and Light Industrial (61000-6-3)

Group 1 (non-intentional radiators)

EMC Standards - Immunity

Performance criteria (EN 61000-6-2)

- **Performance criterion A:** The EUT shall continue to operate as intended during and after the test. No degradation of performance or loss of function is allowed below a performance level specified by the manufacturer, when the EUT is used as intended. **CONTINUOUS TESTS**

- **Performance criterion B:** The EUT shall continue to operate as intended after the test. No degradation of performance or loss of function is allowed below a performance level specified by the manufacturer, when the EUT is used as intended. The performance level may be replaced by a permissible loss of performance. However, during the test degradation of performance is allowed but no change of actual operating state or stored data is allowed. If the minimum performance level or the permissible performance loss is not specified by the manufacturer, either of these may be derived from the product description and documentation and what the user may reasonably expect from the equipment if used as intended. **TRANSIENT TESTS**

- **Performance criterion C:** Temporary loss of function is allowed during the test, provided the function is self-recoverable or can be restored by the operation of the controls. **VOLTAGE DIPS (LIMITED)/INTERRUPTS**

- **If, as a result of the application of the tests, the EUT becomes dangerous or unsafe, it shall be deemed to have failed the test**

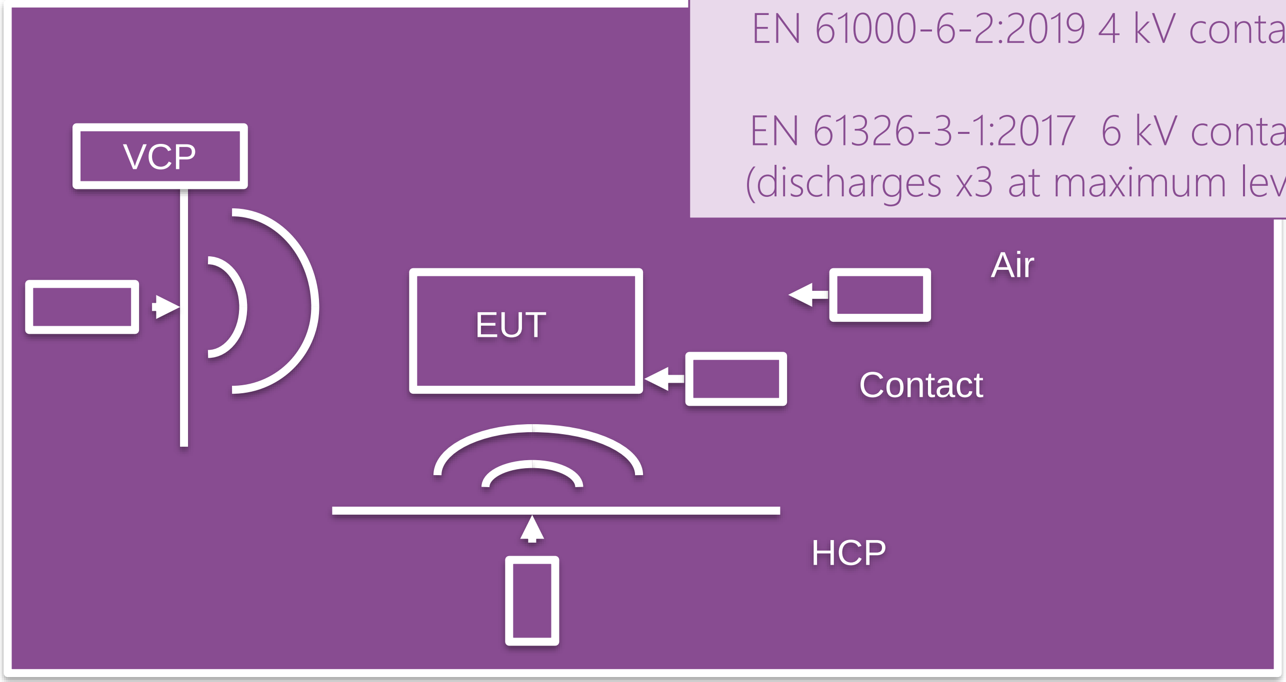
EMC Standards - Immunity

ESD – EN / IEC 61000-4-2

Test Level

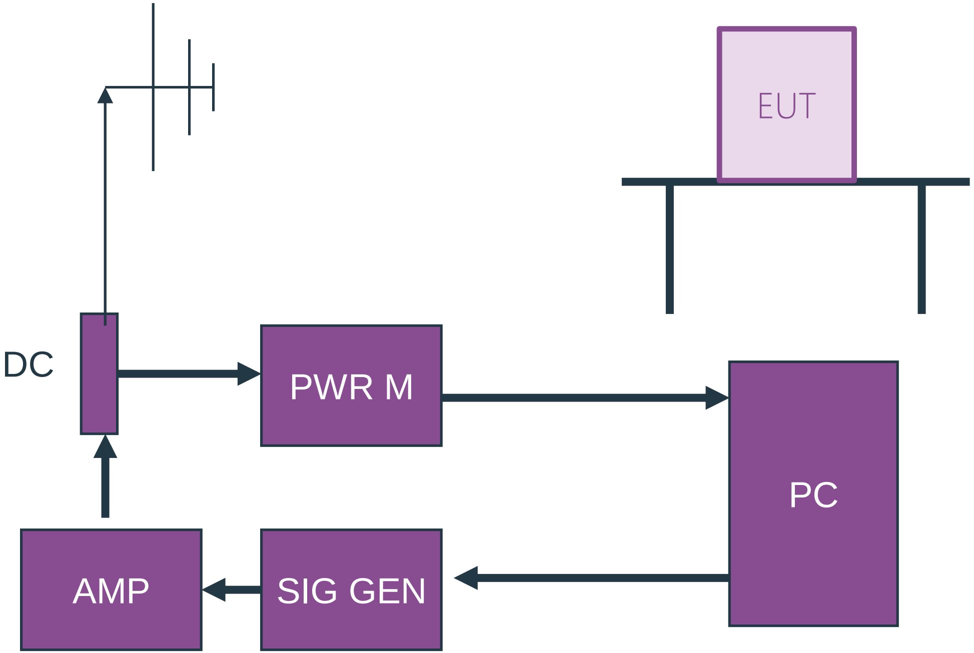
EN 61000-6-2:2019 4 kV contact - 8kV air

EN 61326-3-1:2017 6 kV contact - 8kV air
(discharges x3 at maximum level for SIL 3)



EMC Standards - Immunity

Radiated Immunity – EN / IEC 61000-4-3



EMC Standards - Immunity

Radiated Immunity – Test levels

Interference Source	Frequency Range (MHz)	Field Strength (V/m)
VHF Radio	160-169	30
TETRA + UHF	380-465	30
Mobile phone	790-879	30
Mobile phone	880-921	40
Mobile phone	1700-1780	40
Mobile phone + cordless phone	1880-1980	14
Bluetooth + WiFi	2400-2480	10
Mobile phones	2500-2690	14
WiFi	5150-5350	10
WiFi	5470-5730	30
ISM + SRD's	5730-5880	4

EN 61000-6-2:2005

80-1000MHz – 10V/m
1400-2000MHz – 3V/m
2000-2700MHz - 1V/m

EN 61000-6-2:2019

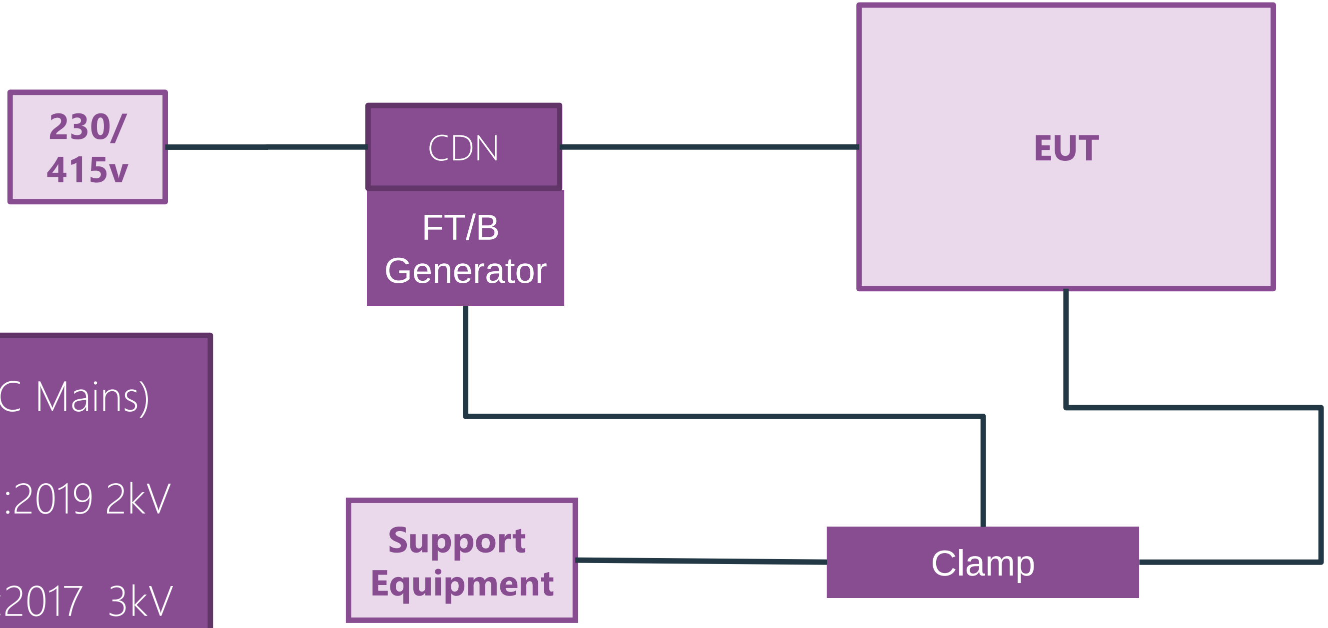
80-1000MHz – 10V/m
1400-6000MHz – 3V/m

EN 61326-3-1:2017

80-1000MHz – 20V/m
1400-2000MHz – 10V/m
2000-6000MHz - 3V/m

EMC Standards - Immunity

Fast Transients/Burst – EN / IEC 61000-4-4



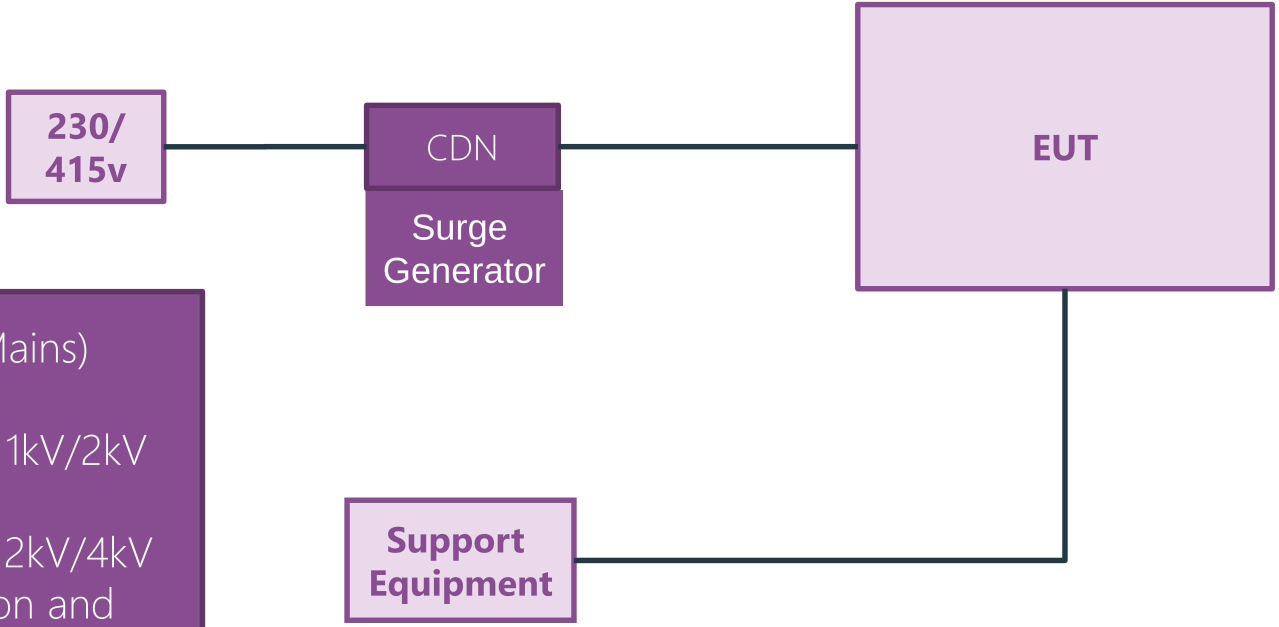
Test Level (AC Mains)

EN 61000-6-2:2019 2kV

EN 61326-3-1:2017 3kV

EMC Standards - Immunity

Surges – EN / IEC 61000-4-5



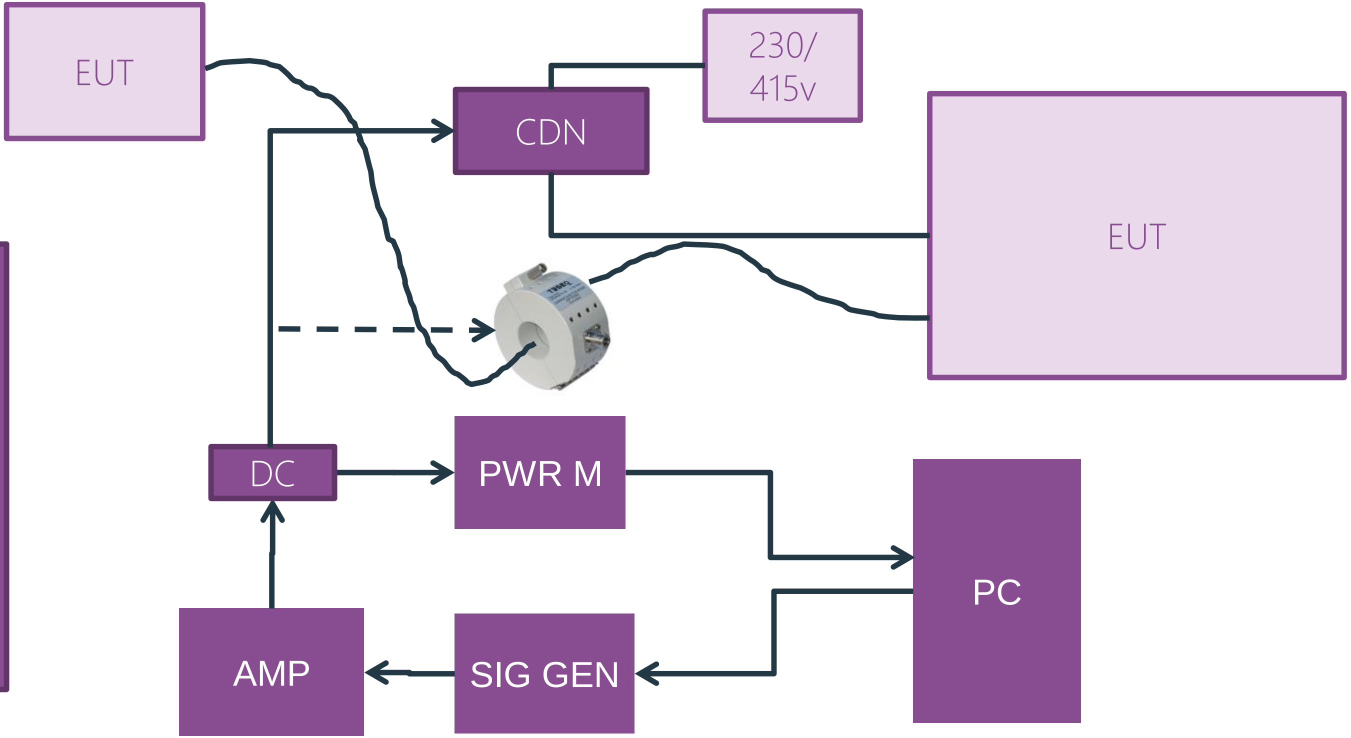
Test Level (AC Mains)

EN 61000-6-2:2019 1kV/2kV

EN 61326-3-1:2017 2kV/4kV
(Increased duration and
number of pulses for SIL 3)

EMC Standards - Immunity

Conducted Immunity – EN / IEC 61000-4-6



Test Level
(AC Mains)

EN 61000-6-2:2019
10 V/m

EN 61326-3-1:2017
10 V/m

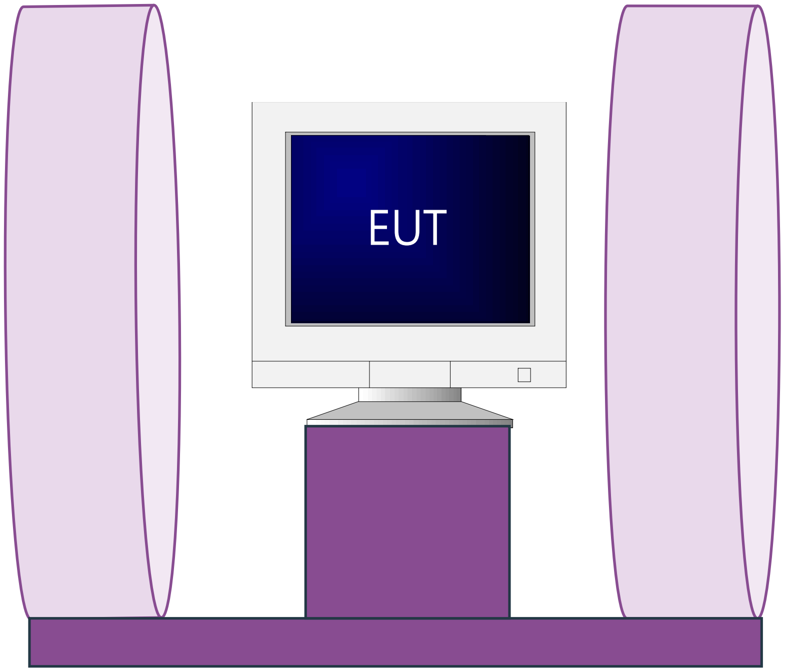
EMC Standards - Immunity

PF magnetic fields – EN / IEC 61000-4-8

Test Level

EN 61000-6-2:2019
30 A/m

EN 61326-3-1:2017
30 A/m



Helmholtz Coils

EMC Standards - Immunity

Voltage dips/short interruptions – EN / IEC 61000-4-11/34

Test Level (AC Mains)

EN 61000-6-2:2019 and
EN 61326-3-1:2017

0 % during 1 cycle
40 % during 10/12 cycles
70 % during 25/30 cycles
0 % during 250/300 cycles

EMC Standards - Immunity

Conducted common-mode voltage – EN / IEC 61000-4-16

Test Level (AC Mains)

EN 61000-6-2:2019
NONE

EN 61326-3-1:2017
1 V to 10 V, 20 dB/Decade (1,5 kHz to 15 kHz)
10 V (15 kHz to 150 kHz)

EMC Standards - Immunity

IEC 62003 – Nuclear I&C equipment important to safety

a) surge disturbances of large energy;
b) voltage dips, short interruptions, voltage variations;
c) electrical fast transients/bursts;
d) electrostatic discharges;
e) radio-frequency electromagnetic field, radiated;
f) power frequency magnetic field;
g) pulse magnetic field;
h) conducted disturbances, induced by radio-frequency field;
i) oscillatory damped disturbances;
j) fluctuations of power supply voltage;
k) conducted common mode disturbances in the range of 0 Hz to 150 Hz;
l) variations of power frequency in supply systems;
m) harmonics and interharmonics distortion of power supply waveform;
n) damped oscillatory magnetic field

Severity of EM environment	Immunity level
Light	I
Middle	II
Harsh	III
Severe	IV

EMC Risk Assessment

The EMC directive (2014/30/EU) requires;

The [technical] documentation shall make it possible to assess the apparatus conformity to the relevant requirements, and shall include **an adequate analysis and assessment of the risk(s)**

(Not a requirement of the previous EMC Directive)

(In regards to the EMC Directive) the concept of risk refers to risks in relation to the electromagnetic compatibility protection aims (e.g. the Essential Requirements) and **not** to safety.

EMC Risk Assessment

Standards cover a limited frequency range;

150 kHz 80 MHz 1 GHz 1.4 GHz 2.7 GHz 6 GHz

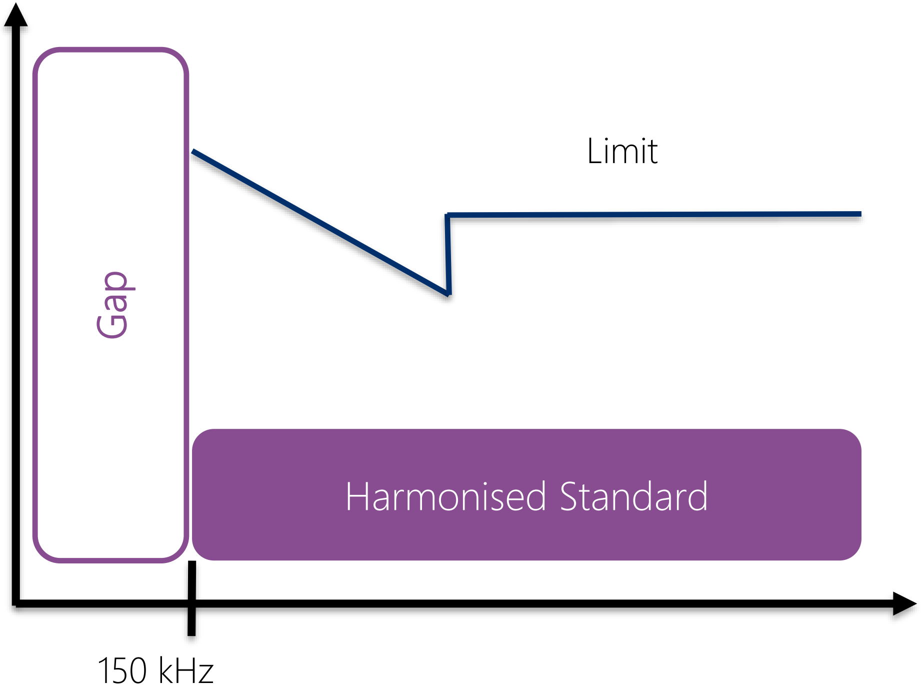
Immunity below 150 kHz and above 1 (or 2.7, or 6) GHz?

Standards shortfall is relevant for most products

EMC Risk Assessment

Limited immunity testing (frequency range);

134.2 kHz



EMC Risk Assessment

Examples;

- Not all modes/configurations considered
- Limited frequency range
- Aging
- Environmental conditions
- Foreseeable misuse/faults
- State of the art not represented by standard(s)
- Not all ports/cables considered
- Ongoing conformity not ensured

Equipment Qualification

Procurement. Be conscious of;

- CE marking is **self-declaration.** Options include;
  - Compliance with harmonised standard in full
  - EMC Assessment
  - Combination of testing and assessment
- EMC Directive includes **OPTIONAL** EU Type Examination (by Notified Body)
- Testing by self/non-accredited lab/UKAS accredited lab
- Standards are usually voluntary

EMC for Functional Safety

- Where incorrect functioning of an electronic system could increase safety risks, we say that it presents FUNCTIONAL SAFETY risks

- Functional Safety: *'The part of the overall safety that depends on the correct functioning of the electrical/electronic/ programmable electronic (E/E/PE) safety-related systems and other risk reduction measures'*

- In other words, functional safety is concerned with safety risks caused by errors, malfunctions and faults in the operation of hardware and software

EMC for Functional Safety

Standards;

- EN 61508:2010, Functional safety of electrical/electronic/ programmable electronic safety-related systems
  (seven parts)
- EN 62061:2005+A2:2015, Safety of machinery. Functional safety of safety-related electrical, electronic and programmable electronic control systems
- EN 61511-1:2017+A1:2017, Functional safety. Safety instrumented systems for the process industry sector. Framework, definitions, system, hardware and software requirements

EMC for Functional Safety

Unfortunately, the usual approach to EMC – testing to EMC emissions and immunity standards – is inadequate for functional safety engineering; it can't provide sufficient confidence (that EMI won't cause dangerous malfunction) to reach the lowest level of compliance to EN / IEC 61508 – SIL 1

However, EN 61000-1-2:2016 is a requirement under EN / IEC 61508

EN IEC 61000-1-2:2016 (Ed. 1.0)

Electromagnetic compatibility (EMC). General. Methodology for the achievement of functional safety of electrical and electronic systems including equipment with regard to electromagnetic phenomena

(not in OJEU)

EMC for Functional Safety

Traditional immunity testing inadequate. Why?

Risks must be sufficiently low **throughout the entire life of the product**

- Normal immunity testing only covers one type of disturbance at a time
- Normal immunity testing does not simulate real-life EM exposure
- EMC 'risk analysis' is not normally done for normal immunity testing
- Normal immunity testing uses one RF test frequency at a time
- Normal immunity testing does not simulate foreseeable EM exposure
- Only a representative sample is tested for EMC
- Faults are not addressed by normal immunity testing
- Normal EMC immunity testing takes no account of the foreseeable physical environment, or ageing
- Performance criteria used for normal immunity testing might be inappropriate for safety purposes
- Normal immunity testing might use inappropriate compatibility margins
- EMC testing does not address maintenance, repair, refurbishment, upgrades

Standards are often out-of-date by the time they are published

EMC for Functional Safety

You could…extend traditional EMC testing to improve its adequacy, e.g.

- Increased frequency ranges
- Higher test levels
- More angles/polarizations
- Spot test frequencies that a design is especially susceptible to

- Then repeat after accelerated ageing to simulate the effects of different environments over the entire lifecycle
- But…such testing would only assist in verifying and validating that the product's resilience to EMI is sufficient
- Additional testing can get expensive – and still be inadequate

EMC for Functional Safety

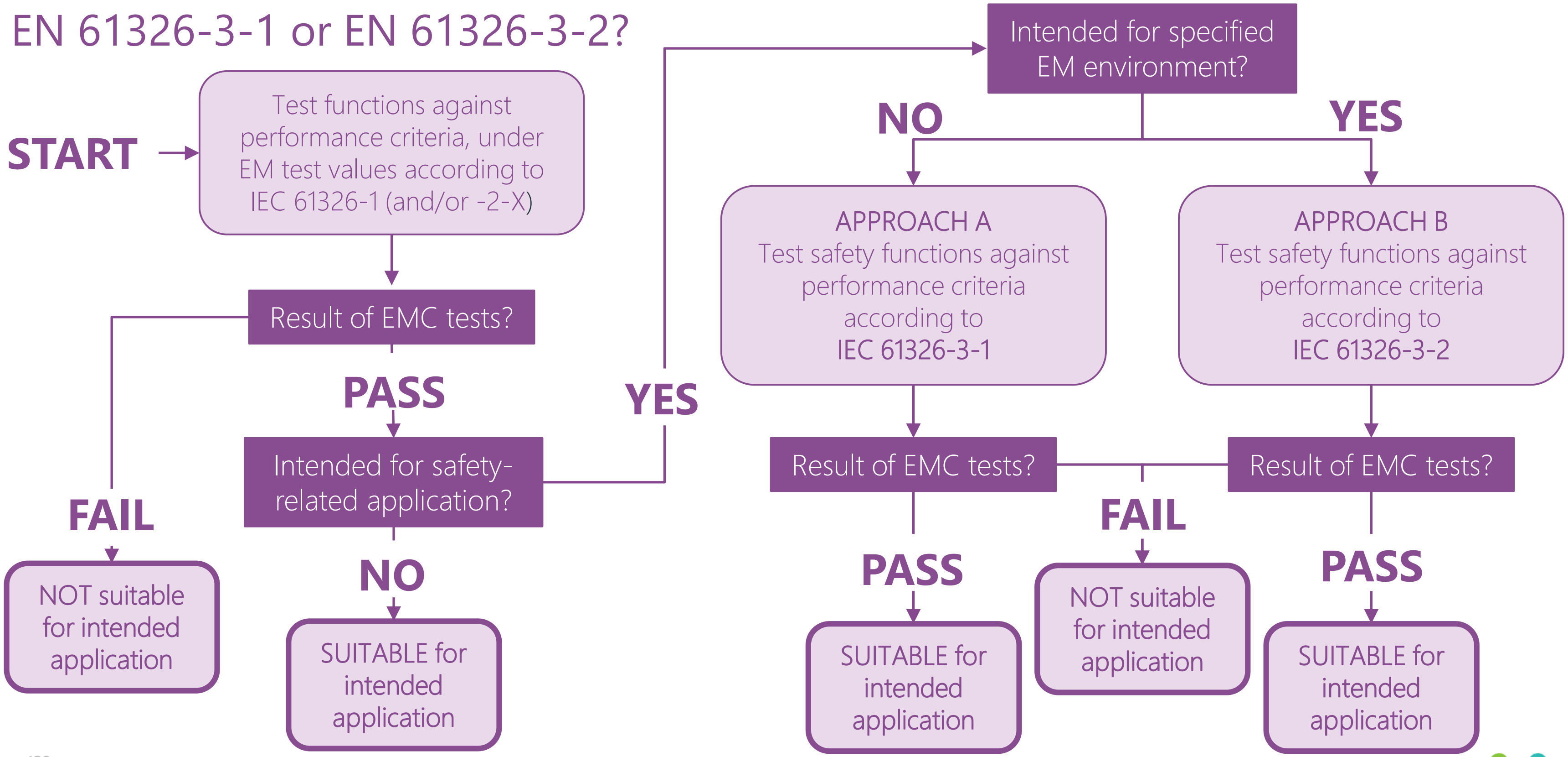
Or; - Standards;

- EN 61326-3-1:2017. Electrical equipment for measurement, control and laboratory use. EMC requirements. Part 3-1: Immunity requirements for safety-related systems and for equipment intended to perform safety-related functions (functional safety) - **General industrial applications**

- EN IEC 61326-3-2:2018. Electrical equipment for measurement, control and laboratory use. EMC requirements. Part 3-2: Immunity requirements for safety-related systems and for equipment intended to perform safety-related functions (functional safety). Industrial applications with **specified electromagnetic environment**

EMC for Functional Safety

EN 61326-3-1 or EN 61326-3-2?



EMC for Functional Safety

- EN IEC 61508 is the basic standard for Functional Safety

- Unfortunately, it contains no specific EMC requirements, so this addressed by EN IEC 61000-1-2. This standard contains T&Ms for use in design – further detailed in IET's 'Overview of T&Ms related to EMC for Functional Safety' guidance document (2013)

  Now replaced by IET's 2017 Code of Practice on Electromagnetic Resilience (in support of Functional Safety) – practical guide to complying with IEC 61000-1-2

  (Record and Verify, as per guidance in EN IEC 61508 –
  if it isn't written down, it didn't happen!)

EMC for Functional Safety

Consider **T&Ms** (IET 2013);

- Consideration of system requirements and design specifications
- Separation of safety-related system safety functions from non-safety functions
- Consideration of EMC when integrating or combining safety components
- Diversity and redundancy (hardware and software)
- Fault detection and recording of events for diagnosis
- Self-detection of an EMI-induced corruption
- Improving the resilience of communication links
- Adequate installation, operation and maintenance instructions
- Protection from persistent interference (incl. monitoring retries, independent detection of EM disturbance)
- Design for ease of EMC maintenance
- Modification limitation and protection
- Protection against operator error
- Compliance with EMC standards over the entire lifecycle
- Use of protection against physically damaging EM disturbances
- Use of good EMC practices
- Defensive programming
- Use of fibre-optics
- Avoid use of recursion
- Use of electromechanical components
- Error detection and correction
- Diagnostic checking by additional/redundant hardware
- Monitored redundancy
- Self-testing of hardware
- Program sequence monitoring
- Power hold-up
- Monitoring of ventilation, cooling and heating
- De-rating
- Safety-related system verification and validation (FMEA, FTA, etc.)

EMC for Functional Safety

The solution?

Application of additional techniques and measures

Good EMC design practices used

Compliance with EMC test standards

Consideration of additional risks -
Modes / Configurations
Life of the product / Ageing
Expected EM environment
Possible disturbances
(EMC RISK ASSESSMENT)

Result:
Risk of non-conformity to the requirements of the legislation is
LOW

EMC for Functional Safety

A test plan should (at least) include/consider:

- Test description
- Configuration of EUT during testing
- Modes
- All ports/cables
- Operation conditions of EUT during testing
- Specification of performance criteria

EMC for Functional Safety

Performance Criteria	Performance
A	During testing, normal performance within the specification limits
B	During testing, temporary degradation, or loss of function or performance which is self-recovering.
C	During testing, temporary degradation, or loss of function or performance which requires operator intervention or system reset occurs.
FS	The functions of the EUT intended for safety applications • are not affected outside their specifications; or • may be disturbed temporarily or permanently if the EUT reacts on a disturbance in a way that detectable, defined state or states of the EUT are: – maintained, or – achieved within a stated time. • Also, destruction of components is allowed if a defined state of the EUT is maintained or achieved within a stated time.

Summary

Consider appropriate standards

EMC Risk Assessment

Functional Safety for EMC

Thank you.

Questions?

EQSA

Equipment Qualification
Services Alliance

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