



EQSA

Equipment Qualification
Services Alliance

Material Qualification, Ageing and Obsolescence

Dr Jessica Gwyther
Wood



Overview

- Material qualification in the EQ life-cycle
- Typical materials requiring MQ (non-metallics and metallics)
- Degradation mechanisms
- Material selection
- Material properties testing
- Accelerated ageing
- Preserving EQ
- Life extension



Regulatory Requirement

ONR Safety Assessment Principle - EQU 1 Equipment Qualification

*“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.”*

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



Material Qualification (MQ)

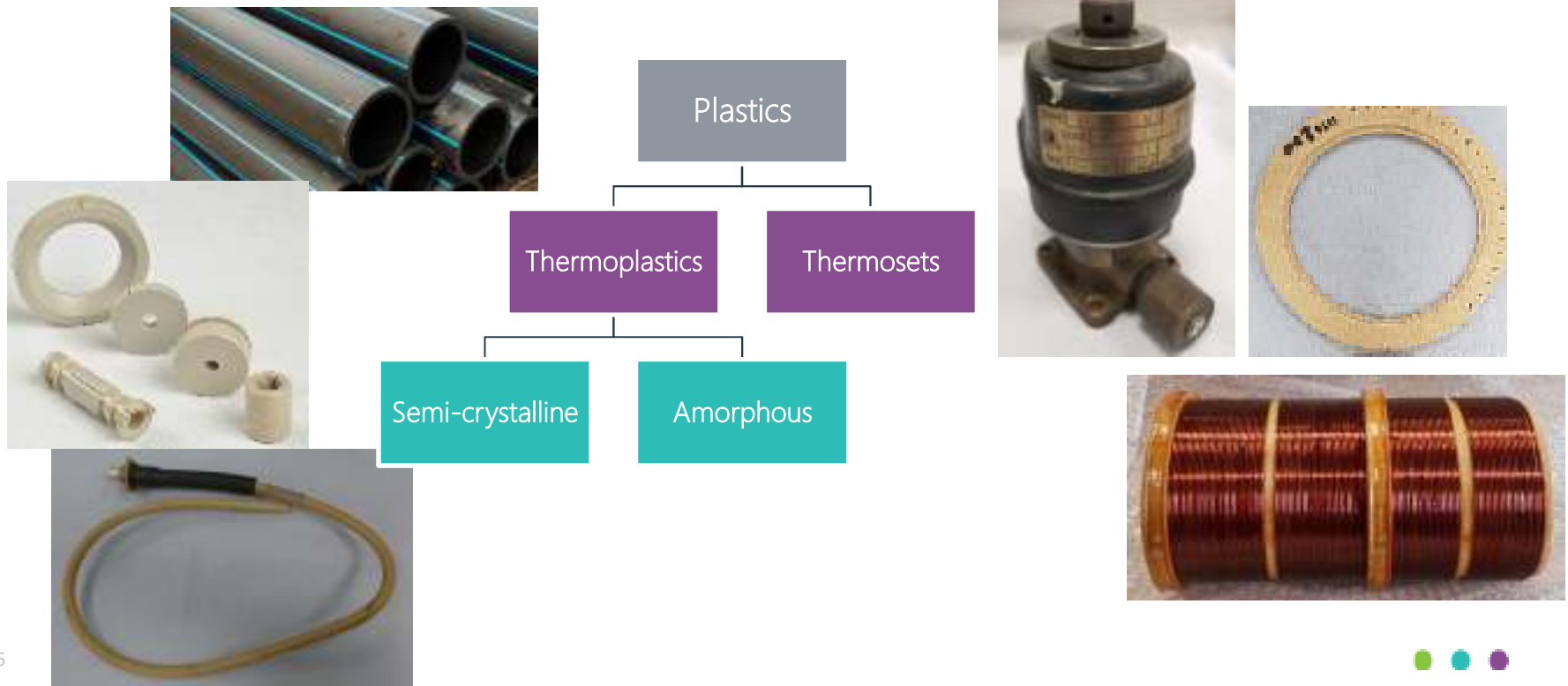
MQ in the EQ Life-Cycle

1. Design phase – equipment design and material selection
2. EQ strategy – equipment and material testing
3. Preserving EQ – maintenance scheduling and condition monitoring
4. Upgrading EQ – life extension by material testing



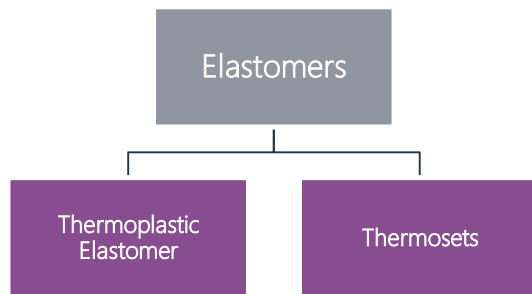
Material Qualification (MQ)

Typical Materials Requiring MQ (non-metallics)



Material Qualification (MQ)

Typical Materials Requiring MQ (non-metallics)



Oils, lubricants and greases

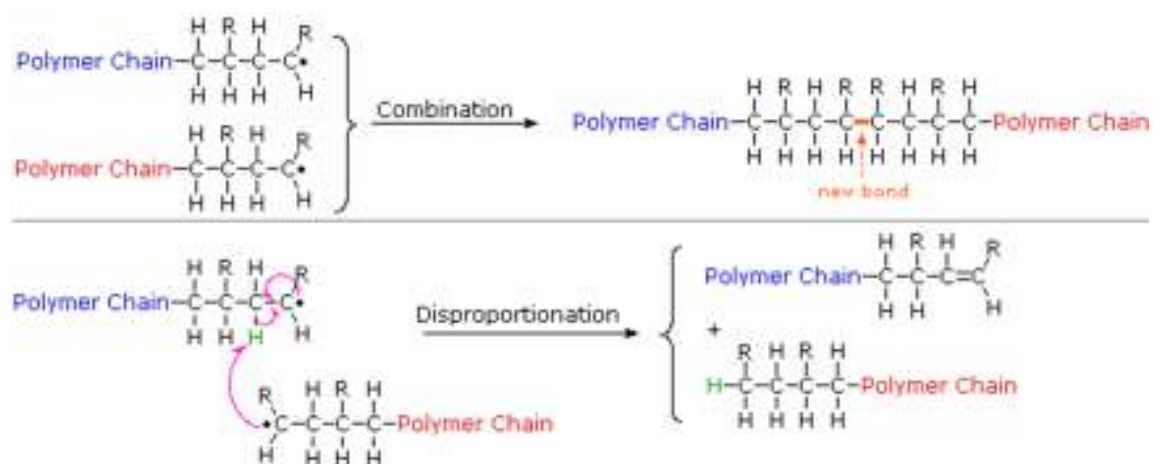
Paints, coatings, contaminants...



Material Qualification (MQ)

Degradation Mechanisms

- Exposure to thermal and/or radiation conditions results in chemically excited states.
- Changes to the chemical structure of the polymer.
- Formation of free radicals Polymer (RH) $R\cdot + H\cdot$



Material Qualification (MQ)

Degradation Mechanisms

- **Chain Scission** – polymer chain fragments, reduction in M_n .
Side reactions due to low M_n fragments escaping as gas.
- **Cross Linking** – formation of covalent bond between molecules.
- **Oxidation** – production of free radicals can lead to oxidation.

Changes in the physical properties of the polymer (e.g. thermal, mechanical, solubility...)

These changes may affect the critical properties of the material that are necessary for it to perform its safety function.



Material Qualification (MQ)

Materials Properties Testing (metallics)

Testing facilities for mechanical and corrosion resistance properties

- High temperature PWR corrosion capability
- Fatigue testing in the corrosive gas facility
- Crack growth under thermo mechanical fatigue
- High temperature facility
- CO₂ test facility
- Large scale materials testing
- Test rig build and operation facility
- Metallographic examination – includes active samples
- Remote operations



Materials Qualification (MQ)

Materials Properties Testing (metallics)



1. Material Selection

New Material – design phase, obsolescence, changes in legislation...

Technical Guidance

- Certified products and manufactures (OPEX, long-term ageing studies...)
- Chemical specifications
 - Prevent corrosion and contamination of systems
 - Prohibited chemical species
 - Chemical species with content limitation (Cl, Br, F and S)

ELEMENTS		
Lead	Aluminium	
Mercury	Bismut	
Tin	Arseni	
Zinc	Coppe	
Cadmium	Rare earth el	
Antimony	Gallium	
Silver	Indium	
Cobalt	Ferric iron	

Specifications		
Maximum allowable total content values:	Halogens (Cl + F + Br)	200 ppm
	Sulphur	200 ppm
Maximum allowable soluble content values (*):	Halogens (Cl + F + Br)	200 ppm
	Sulphur	200 ppm

(*): maximum operating temperature must also be given.



1. Material Selection

Material Compliance and Compatibility

Specifications

Maximum allowable total content values:	Halogens (Cl + F + Br)	200 ppm
	Sulphur	200 ppm

Maximum allowable soluble content values (*):	Halogens (Cl + F + Br)	200 ppm
	Sulphur	200 ppm

(* maximum operating temperature must also be given.)

- For total halogen and sulphur analysis oxygen combustion followed by anion Ion Chromatography (IC)
- For soluble content leaching followed by anion IC
- Results as certificate of analysis



1. Material Selection

Material Compliance and Compatibility

- Obsolescence (supply chain or material)
- Changes to legislation, e.g. REACH (Registration, Evaluation, Authorisation & Restriction of Chemicals)
 - e.g. potassium chromate and fire resistant fluids
- Material compatibility testing



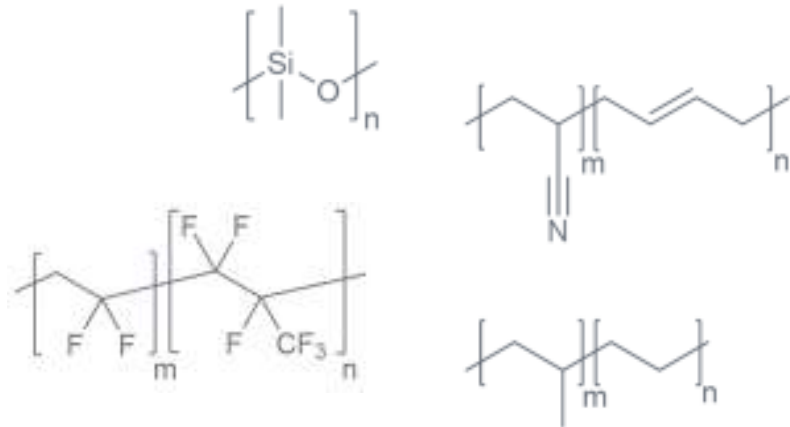
2. EQ Strategy

Material Properties Testing

- MQ can form part of the overall EQ strategy
- Materials properties testing can be carried out pre- and post-conditioning
- Standards we test to - BS EN ISO, ASTM,...
- UKAS accredited labs

Fourier Transform – Infrared Spectroscopy (FTIR)

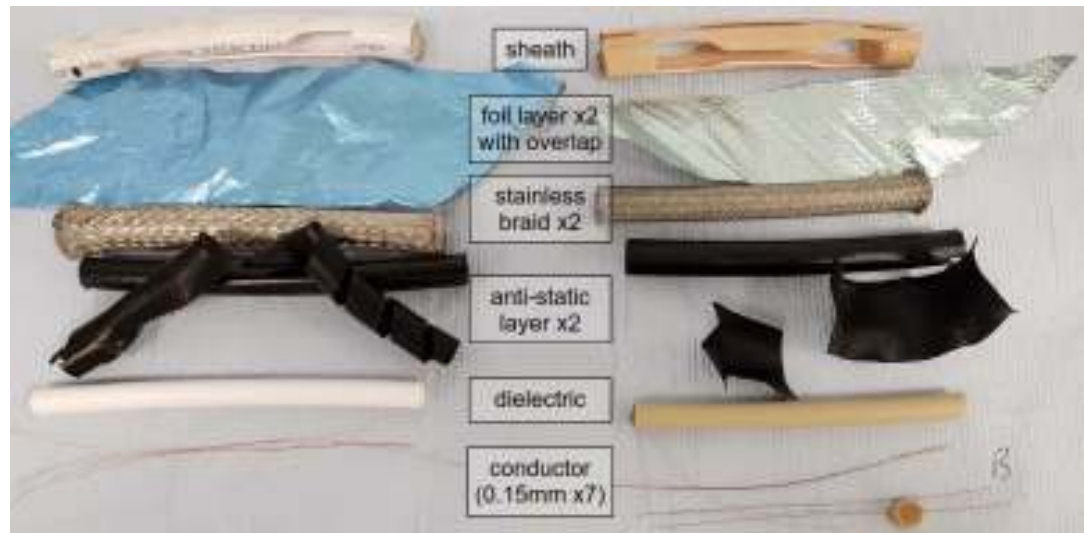
- Molecular level chemical characterisation
 - Comparison of aged versus unaged material
 - Presence or absence of oxidation products
 - Crosslinked species
-
- Headspace Analysis
 - Mass Spectrometry
 - Gel Permeation Chromatography (GPC)...



2. EQ Strategy

Material Properties Testing

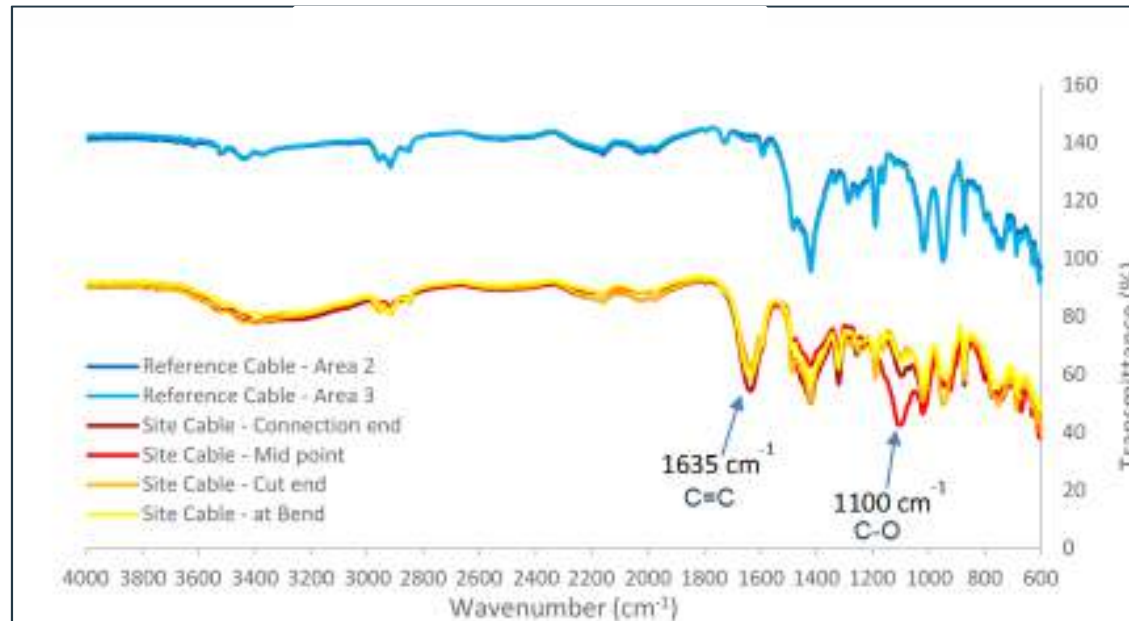
- Example, cable ageing



2. EQ Strategy

Material Properties Testing

- Example, FTIR spectra of cables' outer PVC sheaths

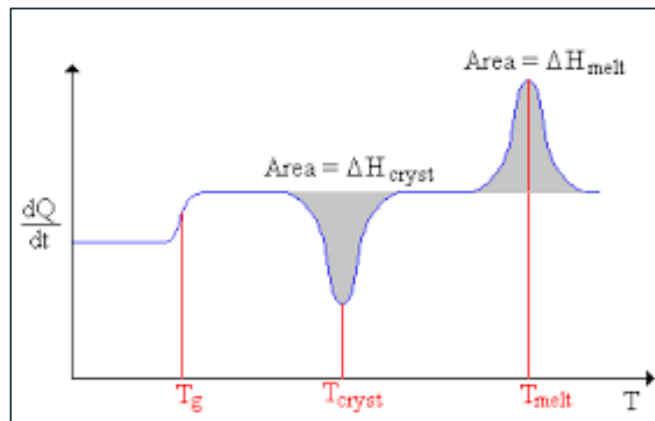


2. EQ Strategy

Material Properties Testing

Thermal Analysis

- Macromolecular analysis, measuring thermal transitions (T_g , T_m , T_c and ΔH)
- Differential Scanning Calorimetry (DSC)
- Thermogravimetric Analysis (TGA)
- Dynamic Mechanical Analysis (DMA)



2. EQ Strategy

Material Properties Testing

Mechanical

- Characterisation of bulk, physical properties
- Compression
- Elongation at break
- Flexural
- Hardness...

Imaging

- Scanning Electron Microscopy (SEM)
- FTIR microscopy
- Optical microscopy



Material properties at molecular level (e.g. FTIR) macromolecular level (e.g. thermal analysis) and in the bulk (e.g. mechanical testing) can be cross referenced and correlated to build up an in depth understanding of degradation pathways that occur during ageing.

2. EQ Strategy

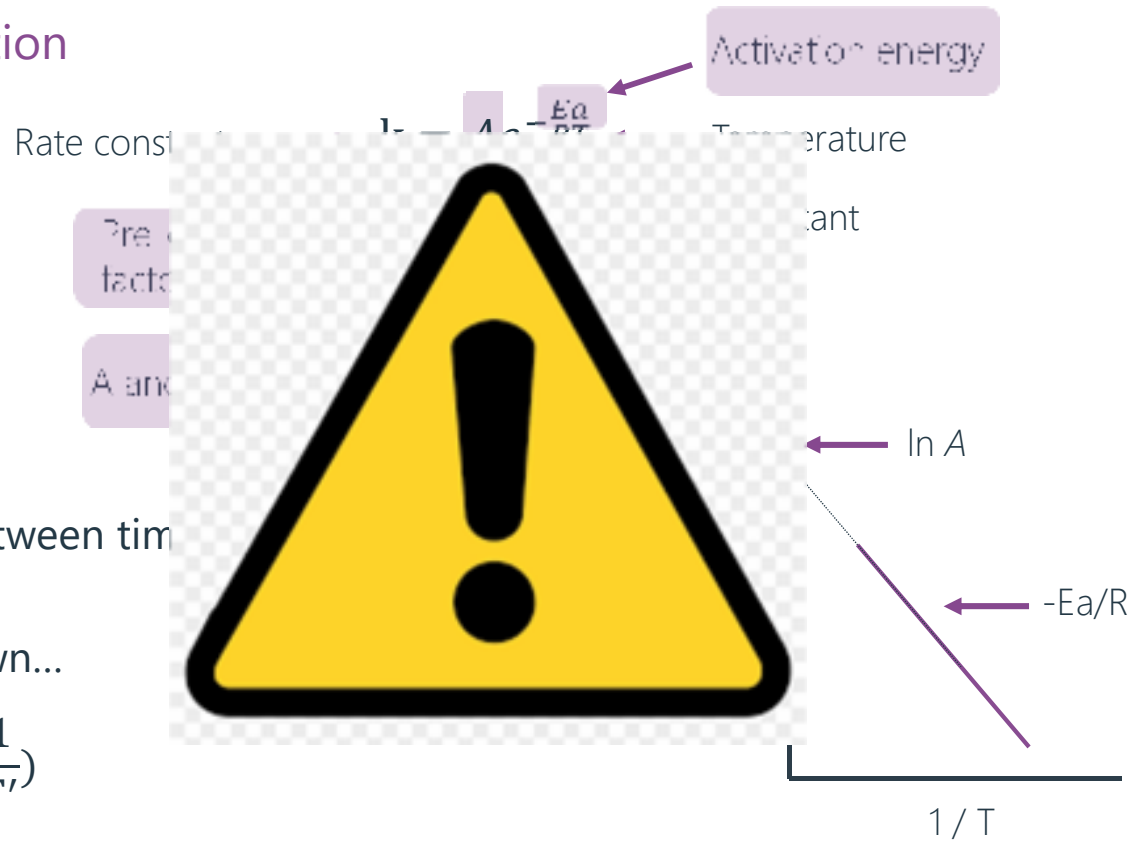
Accelerated ageing

- Arrhenius equation
- Empirical rule or 10°C rule
 - each 10°C increase in the test temperature corresponds to a reduction of the duration of the test by half
- Empirical predicative models
 - Combination of accelerated ageing, long-term ageing and monitoring assessment
- Superposition model



2. EQ Strategy

Arrhenius equation



Relationship between time

Once E_a is known...

$$\ln \frac{k'}{k} = \frac{E_a}{R} \left(\frac{1}{T} - \frac{1}{T'} \right)$$

2. EQ Strategy

Arrhenius equation

- No such thing as a 'material's activation energy...'
- An activation energy is associated with a **specific reaction** measured using a **specific technique** for a **specific material**
- Not all materials follow Arrhenius behaviour

If presented with activation energies as 'evidence' of a materials qualified life, ask:

- Correct material and formulation?
 - polymeric materials are sensitive to manufacturing and processing methods
- What is the reaction? Degradation route?
- How was it measured? Appropriateness of technique?



Preserving EQ

Condition Monitoring

- Condition monitoring and material assessment
 - Built into maintenance schedules based on judgements and recommendations in original qualification
 - Assessment of the condition of materials aged in-service
- Combination of accelerated ageing of unused materials (base-line data) and service-aged samples to populate life-prediction models
- Opportunity to upgrade / extend (or reduce) qualified life depending on true in-service conditions



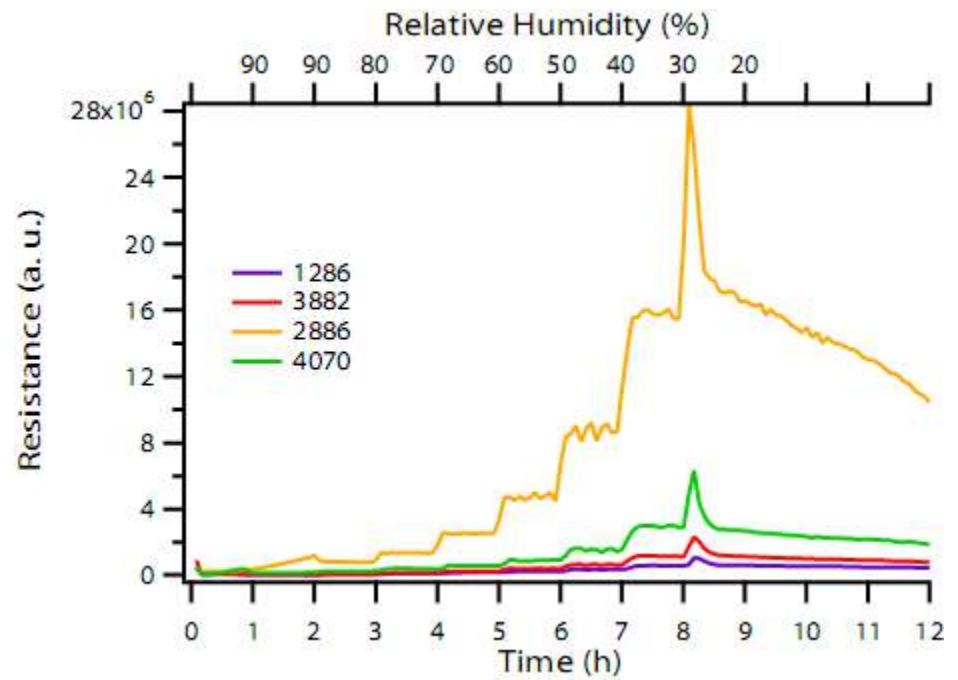
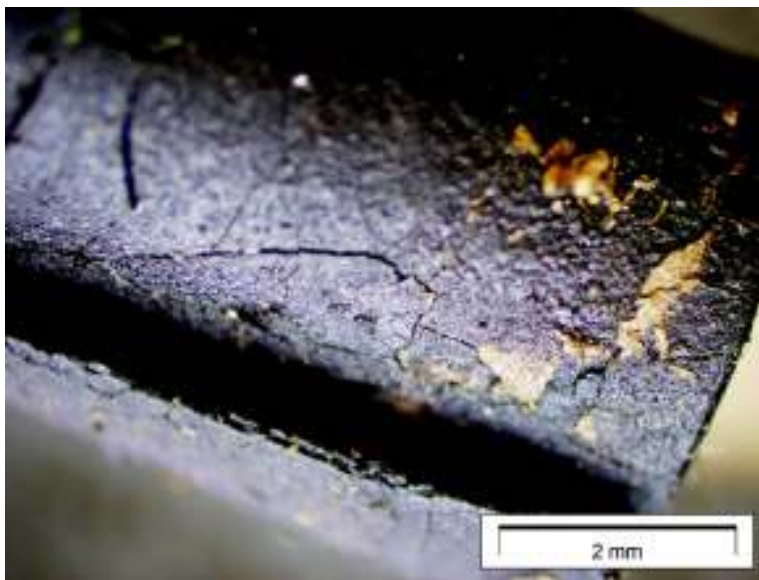
Lessons Learned...

Thermocouple Cables



Lessons Learned...

Measurement of IR of neoprene sleeves



The background is a solid teal color. It features three overlapping semi-circular shapes of varying shades of teal, creating a layered effect. The largest semi-circle is in the center, with two smaller ones overlapping it from the left and right sides.

Thank you



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Type testing of Nuclear I&C in international project environment

Guenther Schnuerer
TÜV Rheinland



Content and Keywords

- Qualification of nuclear I&C
- *Certificates* and its benefits
- *Third party* approach, based on
 - *Type testing* / Type approval
 - *Inspection*
- Type testing in accordance with ISO 17065
 - HW/SW of nuclear I&C
- Inspection in accordance with ISO 17020
 - HW/SW of nuclear I&C



Qualification of nuclear I&C

- **Type-Testing, Inspections and Certifications:**

Type-Test of (I&C) components / Platform-Tests (based on international standards and accredited certification body => third party)

⇒ Output: Type -Test Report

- Certificates are based on the Type- Test Report

Inspections of (I&C) components and platforms (based on international standards, conformity assessments (QA process, procedures and products) by accredited inspection body => third party)

⇒ Output: Inspection Report

- Certificates are based on the Inspection Report

In case of Product-Series Product-Certificates, Type-Test,-System-Test and Inspection-Reports can be issued

Benefits of Certificates

- For companies
 - Better acceptance of products and services eases market access or makes it possible
 - Tested once, accepted everywhere: International comparability and recognition [...]
 - Proof of competence facilitates the selection of a suitable service provider for the conformity assessment of goods and services
- For consumers
 - more consumer trust in the quality of products and services - notwithstanding a complex global market
 - less production errors or recalls
- For legislators
 - flexible alternative to legislation



References:

- **Excerpt of current nuclear I&C qualifications**
 - FirmSys, China
 - FitRel, China
 - HOLLIAS-N, China
 - SPPA-T2000, Germany
 - TELEPERM XS, Germany
 - TPTS-SB, Russia
 - TPTS-NT, Russia
 - SPINLINE, France
 - SNPAS, China



Third party – commonly definition

<https://en.wiktionary.org>

- Someone **not directly involved** in a transaction. A third entity in the Seller (first party) and Customer (second party) relationship.
- Someone only incidentally or tangentially connected to an incident or dispute; someone other than the principals; a bystander or **independent witness**.
- A political party in opposition to the main parties in a two-party system



https://en.wikipedia.org/wiki/Independent_test_organization

- An **independent test organization** is an organization, person, or company that tests products, materials, software, etc. according to agreed requirements. The test organization can be affiliated with the government or universities or can be an **independent testing laboratory**. They are independent because they are not affiliated with the producer nor the user of the item being tested: **no commercial bias is present**. These "contract testing" facilities are sometimes called "third party" testing or evaluation facilities.



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Third party – ISO/IEC 17000:2004

- **first-party conformity assessment activity**
conformity assessment activity that is performed by the person or organization that provides the object
- **second-party conformity assessment activity**
conformity assessment activity that is performed by a person or organization that has a user interest in the object
- **third-party conformity assessment activity**
conformity assessment activity that is performed by a person or body that is independent of the person or organization that provides the object and of user interests in that object
- **conformity assessment**
demonstration that specified requirements relating to a product, process, system, person or body are fulfilled

NOTE 1 The subject field of conformity assessment includes activities defined elsewhere in this International Standard, such as testing, inspection and certification, as well as the accreditation of conformity assessment bodies.

	DIN EN ISO/IEC 17000	
ICS 01.040.03; 03.120.20	Teilweiser Ersatz für DIN EN 45023:1995-07	
Konformitätsbewertung – Begriffe und allgemeine Grundlagen (ISO/IEC 17000:2004); Dreisprachige Fassung EN ISO/IEC 17000:2004		
Conformity assessment – Vocabulary and general principles (ISO/IEC 17000:2004); Trilingual version EN ISO/IEC 17000:2004		

Attestations of parties

- **Attestation**
issue of a statement, based on a decision following review, that fulfilment of specified requirements has been demonstrated
- **Declaration**
first-party attestation
- **Certification**
third-party attestation related to products, processes, systems or persons
- **Accreditation**
third-party attestation related to a **conformity assessment body** conveying formal demonstration of its **competence** to carry out specific conformity assessment tasks

	DIN EN ISO/IEC 17000	
ICS 01.040.03; 03.120.20	Teilweiser Ersatz für DIN EN 45023:1995-07	
Konformitätsbewertung – Begriffe und allgemeine Grundlagen (ISO/IEC 17000:2004); Dreisprachige Fassung EN ISO/IEC 17000:2004		
Conformity assessment – Vocabulary and general principles (ISO/IEC 17000:2004); Trilingual version EN ISO/IEC 17000:2004		

Attestation – TÜV Rheinland Certificate

- Direct Link to certificate in TÜV database
- Unique Certificate No.
- Certificate Holder / Manufacturer
- Subject: states together with type designation the assessed product, system etc.
- Type designation
- Applied codes and standards, i.e. IEC 61513, IEC 60880 (maybe only in extracts)
- Scope and Result: States the explicit scope with all limitations and the results of the assessment
- Specific Provisions: provides restrictions, additional requirements
- Assessment Report with full information



Types of Conformity assessment

Requirements for bodies certifying products, processes and services

- EN ISO/IEC 17020: Conformity assessment – Requirements for the operation of various types of bodies performing inspection (2012) => **Inspection approach**

=> Scope: This International Standard contains requirements for the competence of bodies performing inspection and for the impartiality and consistency of their inspection activities.

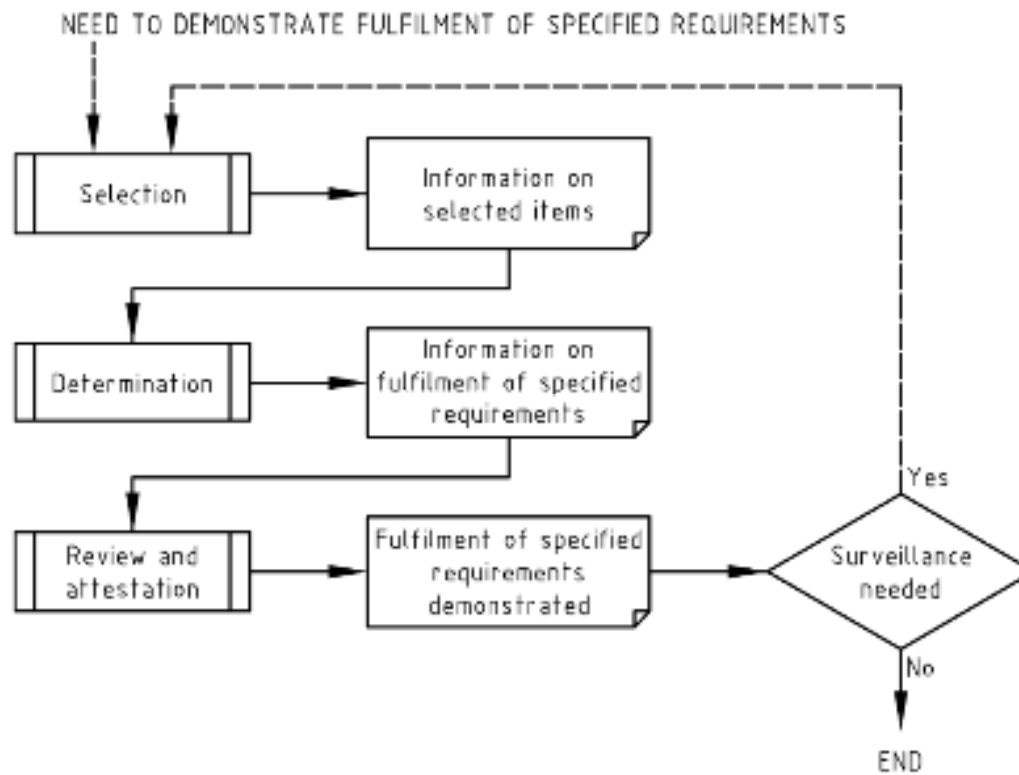
or

- EN ISO/IEC 17065: Conformity assessment — Requirements for bodies certifying products, processes and services (2012) => **Type Test approach**

=> Scope: This International Standard contains requirements for the competence, consistent operation and impartiality of product, process and service certification bodies.



Functional approach to conformity assessment



EN ISO/IEC 17020, Conformity assessment

*Requirements for the operation of various types of bodies performing **inspection***

Examination of a product, process, service, or installation or their design and **determination of its conformity** with specific requirements or, on the basis of professional judgment, with general requirements

NOTE 1 Inspection of processes can include personnel, facilities, technology or methodology.

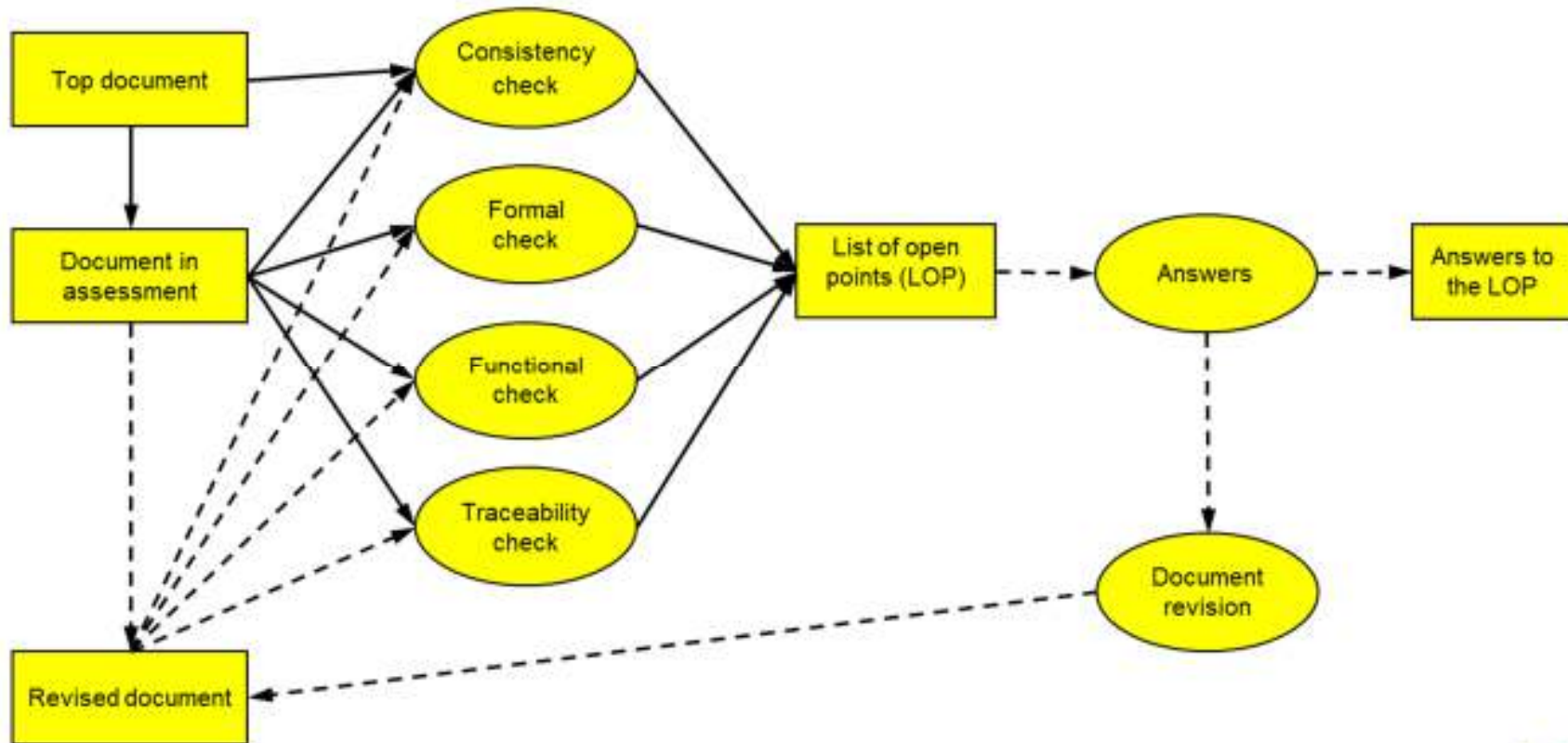
NOTE 2 Inspection procedures or schemes can restrict inspection to examination only.

NOTE 3 Adapted from ISO/IEC 17000:2004

NOTE 4 The term “item” is used in this International Standard to encompass product, process, service or installation, as appropriate.



Review procedure



Inspection Program for nuclear I&C

for systems and components

- Planning: definition of inspection scope in **inspection plan**
- Inspection: Technical and QA documentation (e.g. V&V plan), tests and fabrication
- **Inspection-Documentation contains:**
 - Inspection team data, identification of the issuing body;
 - Project data and scope of the inspection
 - List of documents inspected
 - Inspection records
 - Observations form LOP or Action Item List describing findings, deviations etc.
 - Inspection results



References

- EN ISO/IEC 17000: Conformity assessment - Vocabulary and general principles (2004)
- EN ISO/IEC 17020: Conformity assessment – Requirements for the operation of various types of bodies performing inspection (2012)
- EN ISO/IEC 17025: General requirements for the competence of testing and calibration laboratories (11/2017)
- EN ISO/IEC 17065: Conformity assessment — Requirements for bodies certifying products, processes and services (2012)



Example: Accreditation as Certification Body

Scope (translated):

Functional safe products,
applications and systems including
Functional Safety management;
Security

... but, to which standards and regulations?



Deutsche Akkreditierungsstelle GmbH

Anlage zur Akkreditierungsurkunde D-ZE-11052-02-00
nach DIN EN ISO/IEC 17065:2013

Übergangsfrist: 22.01.2020 bis 02.09.2017 Ausstellungsdatum: 12.01.2018

Umschreibendes:

TÜV Rheinland Industrie Service GmbH
Zertifizierungsstelle Energiesysteme, Renewables, Grid & Automation
Am Grauen Stein 27, 51109 Köln

Zertifizierungen von Produkten in den Bereichen:

On- and Offshore Windenergieanlagen und deren Komponenten;
Netzintegration von Erzeugungseinheiten und Anlagen einschließlich Komponenten und deren
Kommunikation;
Systembereitstellungen bei dezentralen Erzeugungseinheiten und Anlagen strukturell
komplexer;
Funktions sichere Produkte, Anwendungen und Systeme einschließlich Functional Safety
Management;
Security

Verwendete Abkürzungen: siehe letzte Seite

1 On- und Offshore Windenergieanlagen und deren Komponenten

ISO 9000:2015
ISO 9001

Wind Alliance - Part 22: Conformity testing and certification

DIN EN ISO 15189:2013
DIN EN ISO 15189

Durchführung von Prüfungen und Zertifizierungen von
Windenergieanlagen



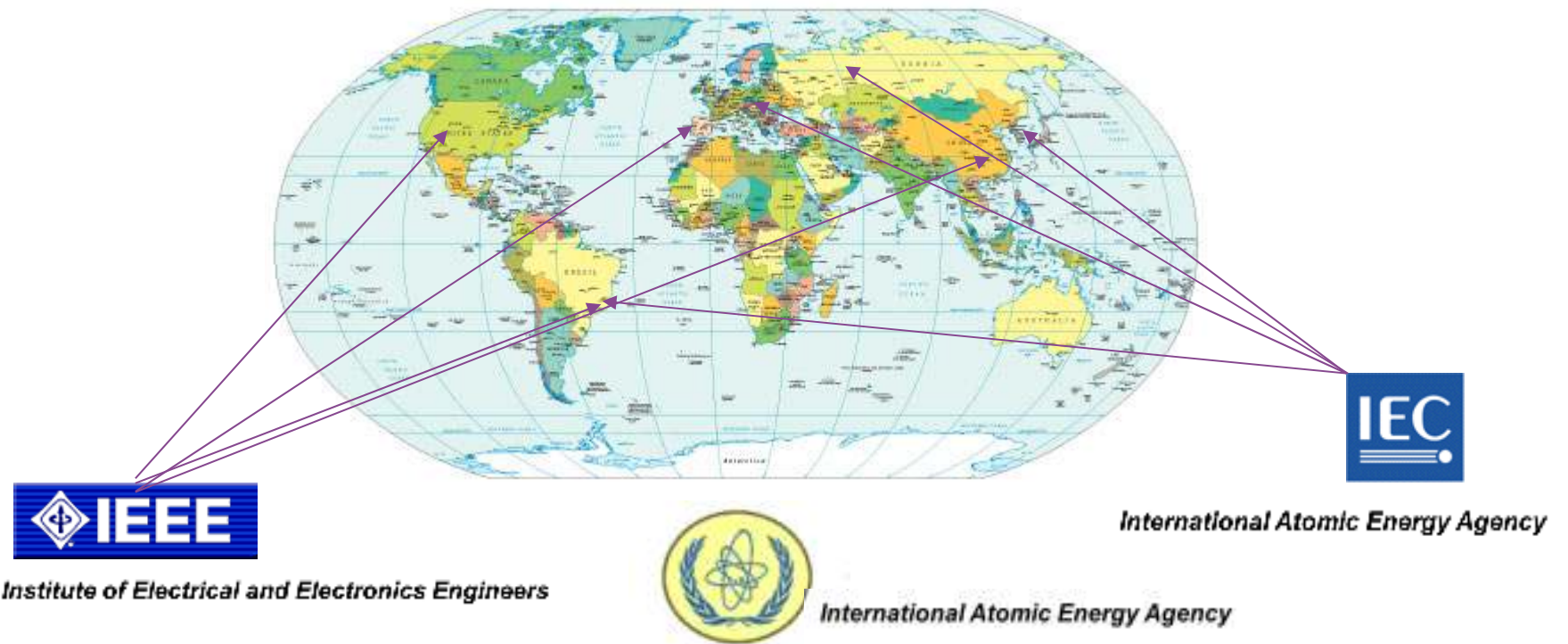
Adobe Acrobat
Document

International accepted Standards nuclear I&C

System, IEC 61513 Cat. A, B, C			Categorisation IEC 61226
Hardware IEC 60987 Cat. A, B, C	Software IEC 60880 Cat. A	Software IEC 62138 Cat. B, C	Cat. A, B, C
El. Equipment IEC 60780	HDL prog. Dev IEC 62566 Cat. A	HDL prog.Dev. IEC 62566 Cat. B,C	others, like IEC 62340, IEEE Std 1012™-2004, IEEE Std 7-4.3.2™-2010



International accepted nuclear I&C Standards



Nuclear I&C Standards

- EN IEC 60880: Instrumentation and control systems important to safety - Software aspects for computer-based systems performing category A functions (2006)
- EN IEC 61226: Instrumentation and control important to safety - Classification of instrumentation and control function (2009)
- EN IEC 62138: Instrumentation and control systems important to safety - Software aspects for computer-based systems performing category B or C functions (2018)
- EN IEC 62566: Instrumentation and control important to safety - Development of HDL-programmed integrated circuits for systems performing category A functions (2012)
- EN IEC 60987: Instrumentation and control important to safety - Hardware design requirements for computer-based systems (2007))
- EN IEC 60780: Electrical equipment important to safety – Qualification (2016)
- EN IEC 62340: Instrumentation and control systems important to safety - Requirements for coping with common cause failure (CCF) (2007)



In addition

- IEEE Std 1012™-2012: Standard for System and Software Verification and Validation
- IEEE Std 7-4.3.2™-2010: Standard Criteria for Digital Computers in Safety Systems of Nuclear Power Generating Stations



Any questions or remarks?





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Software qualification

Demonstration that the software meets requirements given by standards regarding

- Life cycle
- Documentation
- Configuration management
- Requirements specification
- Design
- Implementation
- Tests
- Verification & Validation
- Modification procedures

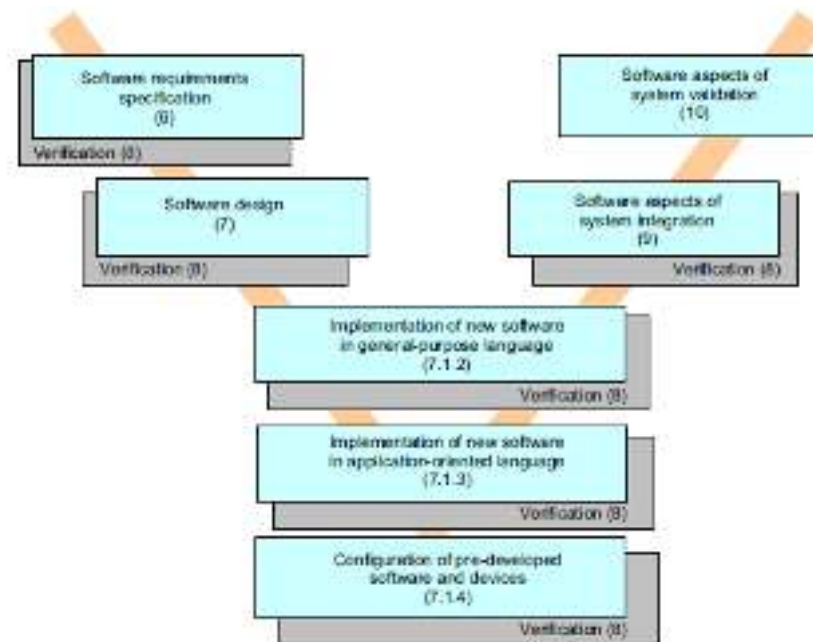


Figure 3 – Development activities of the IEC 60880 software safety lifecycle

In addition

=> analysis of development documents:

- Criticality analysis
- Requirements allocation analysis
- Traceability analysis
- Interface analysis
- Hazard analysis
- Security analysis
- Risk analysis





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