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Graded approach practices for the mechanical components of French research reactor projects

Claude PASCAL
RMR/RR
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Content

- Context
- Classification of SSCs
- Associated Requirements
- Design and construction rules
- Implementation of graded approach in design and construction rules
- Concluding remarks

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Context

- **No internationaly recognized standard already published applicable to mechanical components**
- **2 references:**
  - **Regulation**
  - **Design and construction rules**
- **Practices**

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Safety Context reminders: some Definitions

- **Safety function**
  - **A specific purpose that must be accomplished for safety.**
- **safety functions to be fulfilled by the design of a nuclear reactor in order to meet three general safety requirements:**
  - **(a) The capability to safely shut down the reactor and maintain it in a safe shutdown condition during and after appropriate operational states and accident conditions;**
  - **(b) The capability to remove residual heat from the reactor core after shutdown, and during and after appropriate operational states and accident conditions;**
  - **(c) The capability to reduce the potential for the release of radioactive material and to ensure that any releases are within prescribed limits during and after operational states and within acceptable limits during and after design basis accidents.**
- **This guidance is commonly condensed into a succinct expression of three main safety functions for nuclear power plants:**
  - **(a) Control of reactivity;**
  - **(b) Cooling of radioactive material;**
  - **(c) Confinement of radioactive material.**
- **Safety classified items (draft order INB)**
  - SSCs, sofware and hardware systems, of a nuclear facility or present within the facility ensuring or contributing to a safety function required for the safety demonstration

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Safety context

- **French regulation**
  - **Identification of SIC**
  - **Adequate quality shall be defined, obtained and maintained**
- **Basic safety requirements :**
  - Requirements assigned to safety classified items allowing the safety demonstration
- **QRA : safety related activity:**
  - **The importance for safety of an activity is appreciated on the basis of direct or potential consequences for the safety in case of inappropriate exercise of the activity**
- **Safety related requirements**
  - Requirements assigned to safety related activities aiming obtaining and maintain of a quality of those activities as regards their importance for safety

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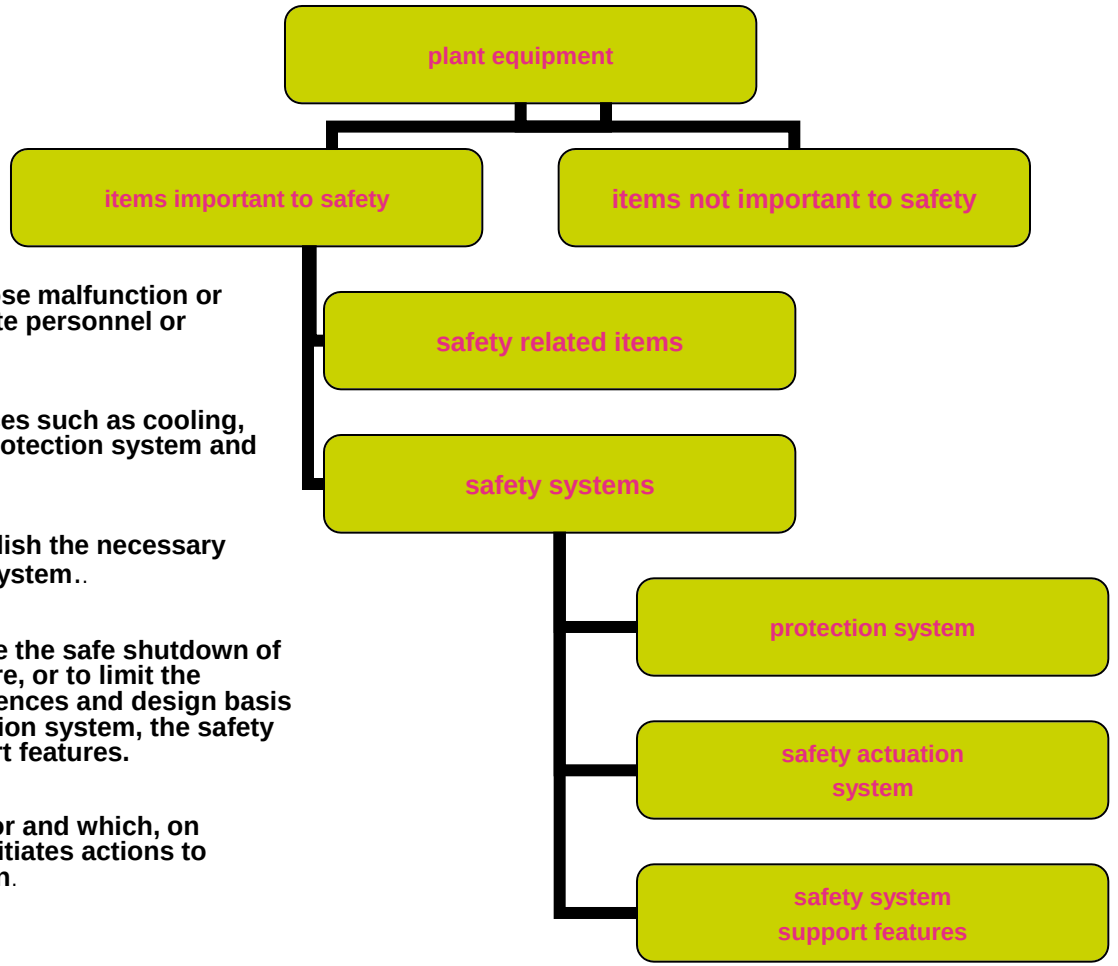
Safety classification principles : Reactor components and auxiliary system components

- **IAEA principles from NS R 4**



- ***item important to safety.***
  - **An item that is part of a safety group and/or whose malfunction or failure could lead to radiation exposure of the site personnel or members of the public.**
- ***safety system support features***
  - **The collection of equipment that provides services such as cooling, lubrication and energy supply required by the protection system and the safety actuation systems**
- ***safety actuation system.***
  - **The collection of equipment required to accomplish the necessary safety actions when initiated by the protection system..**
- ***safety system.***
  - **A system important to safety, provided to ensure the safe shutdown of the reactor or residual heat removal from the core, or to limit the consequences of anticipated operational occurrences and design basis accidents. Safety systems consist of the protection system, the safety actuation systems and the safety system support features.**
- ***protection system***
  - **System which monitors the operation of a reactor and which, on sensing an abnormal condition, automatically initiates actions to prevent an unsafe or potentially unsafe condition.**

Safety classsification Implementation principles

- **All systems, structures and components (SSCs) are classified on the basis of their importance to safety.**
- **Typically, a safety classification process based on 3 safety classes is used**
- **The safety classification of an item of plant is determined on the basis of the following categories:**
  - **Safety Class (SC) 1: any SSC that forms a primary means of ensuring nuclear safety.**
  - **Safety Class 2:**
    - any SSC that makes an important additional contribution to nuclear safety,
    - any SSC whose failure may challenge another SC-1 or 2 item.
  - **Safety Class 3:**
    - any other SSC that is not allocated to SC-1 or 2,
    - any SSC whose failure may challenge another SC-3 item.

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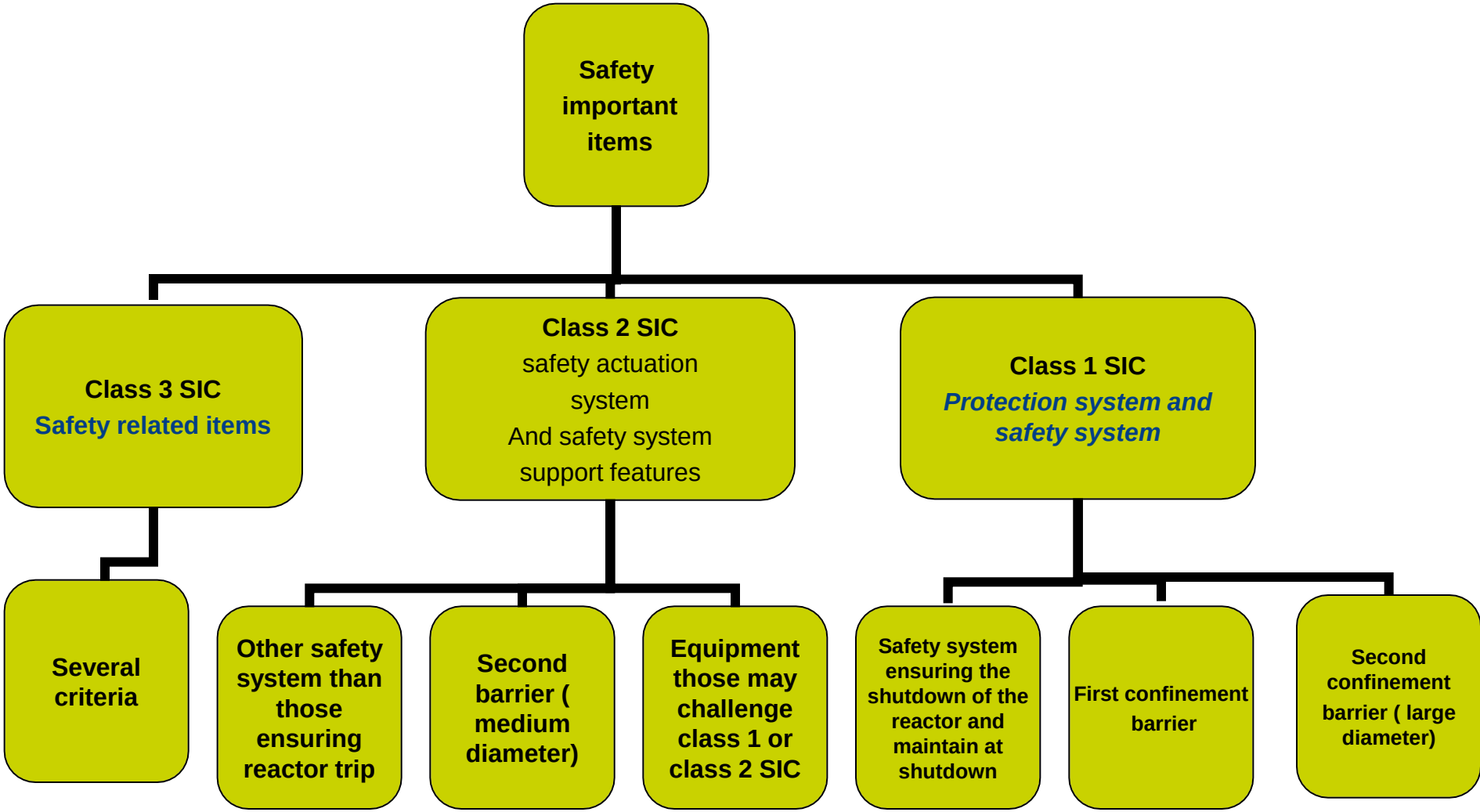
Classification principles : implementation for the JHR project



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Example of implementation : Safety classification

JHR primary pumps

Safety functions involved

- Core cooling
- Confinement

Basic safety requirements

- Ensure the second confinement barrier::
  - pressure boundary : safety class 1
  - Volute casing and more generally the pressure boundary contribute to second confinement barrier (leak-tightness is specified))
- Ensure a specified flow rate after the onset of loss of power including in the event of seismic aggression
  - Shaft and flywheels : safety class 2

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Classification principles : implementation of the graded approach

- **Generally speaking, for each safety class, the quality related actions and their safety related requirements are defined within a graded approach**
- **Usually, a shortcut is used by establishing directly the correspondence with the level of design and construction code**
- **For the JHR project, for mechanical components :**
  - **SIC 1** → class 1 MX
  - **SIC 2** → class 2 MX
  - **SIC 3** → class 3 MX

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Graded approach
Management aspects

- **Each project defines the implementation provisions of the following principles for the management of activities, the activities themselves and the SSCs.**
- **Management of activities**
  - **The grading deals mainly with the management system requirement, in particular,**
    - the level of detail in the planning of the activities,
    - the level of traceability,
    - the configuration management including change management,
    - the purchasing and surveillance requirements,
    - the management of non-conformances,
    - the level of in-process controls and the need for hold and witness points.
- **In particular, extensive traceability is required for SC-1&2 systems.**

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Graded approach
Activities and products

- **For the design, the grading deals mainly with:**
  - **the level and detail of the analysis of the design, the degree of verification of the design and the need for alternative calculations to be carried out.**
  - **All SC-1&2 components are subjected to extensive analysis of the design.**
- **For the qualification,**
  - **the grading deals with the methods which are acceptable such as qualification by testing (preferred for SC-1&2 systems), qualification by analysis (mainly for SC-2&3 systems).**
- **For the manufacturing and construction, the grading deals mainly with:**
  - **the raw material component or the basic components procurement specification,**
  - **the qualification of construction processes (such as forging) and the qualification of personnel,**
  - **For SC-1&2 systems, extensive inspection and testing plan are required in order to validate the process step by step. For SC-3 systems, the main test and inspection activities are carried out on the final product.**
- **For the commissioning, the grading deals mainly with the control of commissioning tests from inactive commissioning through active commissioning to handover to full operations.**
- **For the facility operations, the grading of the SSCs deals mainly with the maintenance, surveillance, testing, inspection and operating procedures documentation**
  - **Inspection: 100% inspection possible for Class 1&2**
  - **Testing : periodic testing for SC 1,2&3**
- **For the SSCs, the grading deals mainly with their capability to fulfil their safety function especially in terms of reliability.**

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Consequences

- **One consequence of these requirements, in particular the traceability, is that the SC-1&2 components are specifically designed and manufactured for their nuclear application.**
- **Commercial off the shelf (COTS) components are acceptable for SC-3 after they have been subject to a formal qualification.**

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RCC-MX (XDG 2300) : JHR Context and Scope

- **RCC-MX is a collection of technical rules equivalent to a code for:**
  - Design and construction
  - Mechanical components of research reactors, their auxiliary systems, and their irradiation devices.
  - Developed within the framework of the Jules Horowitz Reactor
- **RCC-MX can be used for design and construction:**
  - Of new research reactor projects, their auxiliary systems and associated irradiation devices.
  - It can be used for design and construction of new components or new irradiation devices for existing reactors.
- **The scope of application of the RCC-MX design and construction rules is limited to metallic mechanical components:**
  - **Considered to be important regarding nuclear safety and/or operability,**
  - **Ensuring the provision of containment, partitioning, guiding, securing and supporting,**
  - **Fluid-containing systems such as pressure vessels, pumps, valves, pipes, bellows, box-type structures, heat exchangers and their supports.**

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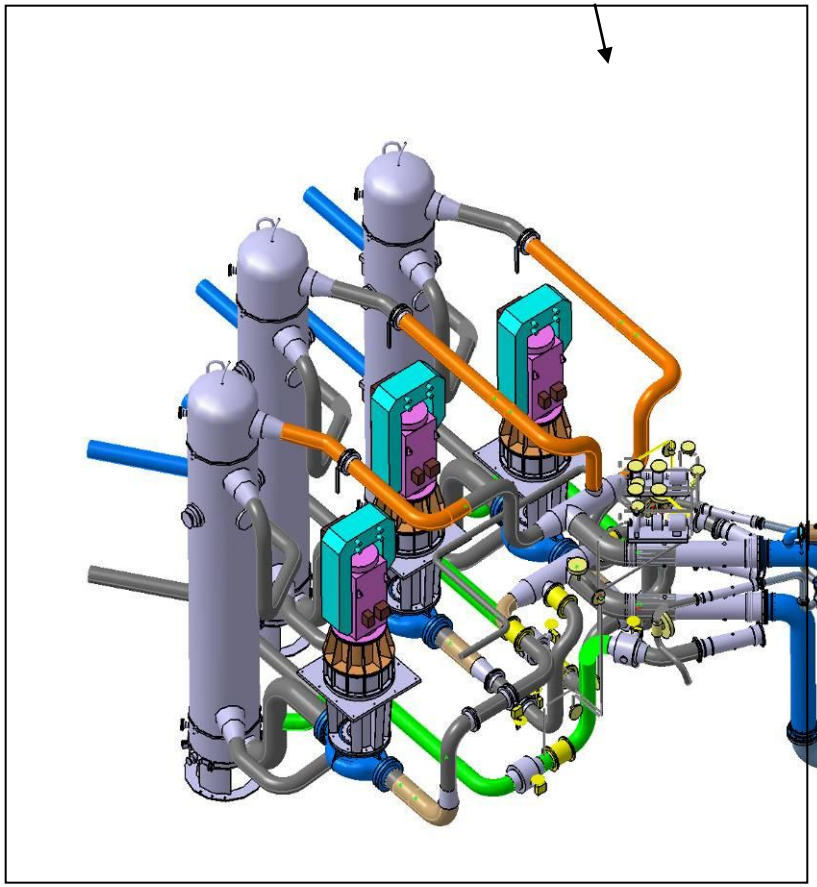
RCC-MX Scope Metallic Structures Issues Addressed

Reactor

Stainless steel
Demineralized water
e.g. Ps 16 bars T < 80°C



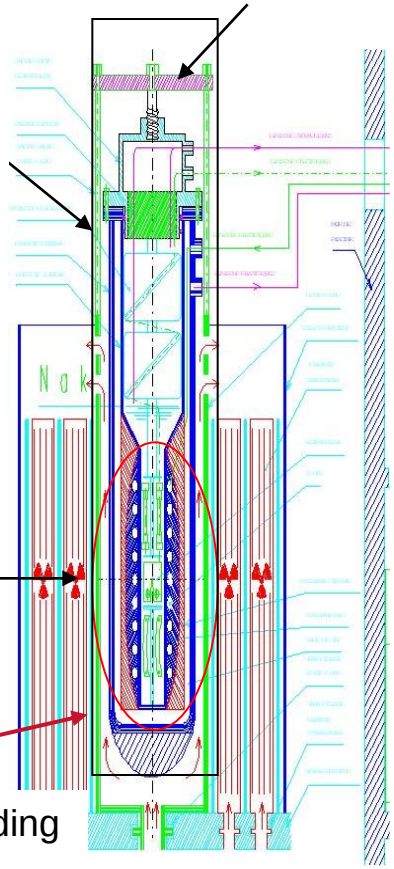
Irradiation devices

Coolant , temperature and pressure depending on the experimental program

Zirconium or aluminum alloys or stainless steel

Aluminum alloy

Irradiation subjected structures



Electron beam welding

No existing, appropriate, design and construction code meeting all these requirements before the creation of RCC-Mx

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Graded approach implementation within RCC-MX

		N 1 Mx	N2 Mx	N 3 Mx
Design	Structural and stress analysis	Complete including irradiation, creeping and notch effect	Complete including irradiation, creeping and notch effect	No irradiation nor creeping
	Stress analysis	Sm	Sm	S
	Bolts	Smb	Smb	Sb Fatigue analysis not required
	Welding	Design rules XB… Compatibility with volumic NDE	Design rules XC… Compatibility with volumic NDE	Design rules XD…
	Pumps	1&2 Rules	1&2 Rules	3 Rules
	Pipes	1 Rules	1 Rules	1 Rules using S or alternative rules
	Bellows	1 Rules	1 Rules	1 Rules using S

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Graded approach implementation within RCC-MX

		N 1 Mx	N2 Mx	N 3 Mx
Procurement	Procurement according standards		Parts standards possible for irradiation devices only (fittings and bolts)	Parts standards possible for irradiation devices only (fittings and bolts)
		Differences according products and levels dealing with inspection and its extends		
	Casted products	Casted products	Casted products	Casted products
	Procurement according TRS (technical reference specification)	Differences according products and levels dealing with inspection and its extends		
	COTS	No	No	yes
Welding	Qualification of welding processes	Iso standard for destructive test + 1 MX NDE	same	same
	Qualification of welders and operators	Iso standard + Radiographic testing for full penetration BW	same	same
	Production welding	Acceptance criteria 1 Welding coupon 1	Acceptance criteria 2 Welding coupon 1	Acceptance criteria 3 Welding coupon 1
Fabrication	Technical program of manufacturing	Systematic qualification before manufacturing	Qualification when requested in the technical reference specification	No qualification before manufacturing

Concluding remarks

- **Practices for graded approach implementation for mechanical components of French research reactors consider:**
  - **3 safety classes**
  - **Common principles tailored for each project**
  - **Use of design and construction rules integrating graded approach: RCC-MX**
  - **A basis is provided by the RCC-MX, each project tailors the implementation in addition to the code**
- **Actions in progress to enlarge the application of these rules**
  - **RCC-MX became RCC-MRx under AFCEN Umbrella**
  - **CWA (Cenelec Workshop Agreement) in Progress to cover different projects such as MYRRHA, ESS, ASTRID, ALFRED,…with European partners from UK, Belgium, Italy, Sweden, Finland, France**

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