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RCC-MRx\textsuperscript{[1]} APPLICABILITY FOR THE DESIGN PHASE OF EXPERIMENTAL DEVICES

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\textsuperscript{[1]} Design and Rules for Mechanical Components of Nuclear Facilities
1980: foundation of the AFCEN\textsuperscript{[2]} to define the rules for the design and the construction for mechanical components of nuclear islands.

2009: the CEA\textsuperscript{[3]} joins AFCEN.

The purpose of the Association is to:

- draw up detailed and \textit{practical rules for design, manufacture, installation, commissioning and in-service inspection of components for nuclear islands},
- revise rules on the basis of experience, technological advances and changes in regulatory requirements.

2012: RCC-MRx, developed especially for Sodium Fast Reactors (SFR), Fusion Reactors (FR-ITER) and Research Reactors (RR) like the Jules Horowitz Reactor (JHR).

The RCC-MRx code is split in three main sections:

1. Description of the \textbf{general methodology} and how to manage the rules (\textit{quality and management systems}) during the project.
2. Introduction of the links between the code and the \textbf{French regulations} like the directive for nuclear pressured equipment (ESPN). This chapter introduces also the use of some \textbf{European Standards for component with low safety level}.
3. Description of all \textbf{the technical rules} needed for the design, the manufacturing, installation and in service inspection of a nuclear equipment.

\textsuperscript{[2]} French Association for Design and Construction Rules for Nuclear Island Components
\textsuperscript{[3]} French Atomic Energy Commission
HOW TO MANAGE THE ANALYSIS?

→ THE FIRST STEP IS TO DEFINE THE EQUIPMENT AND THE RULES WHICH ARE APPLICABLE.

- **Key 1**: Define if the concern equipment or facility is:
  - components of nuclear reactor and its auxiliary systems,
  - or examination, handling or drive mechanisms,
  - or components of irradiation devices.

- **Key 2**: This key gives the required RCC-MRx class:
  - Class N1Rx,
  - Class N2Rx,
  - Class N3Rx.

- **Key 3**: This key indicates the type of component to which the component is attached:
  - Vessel, tank – Pumps – Valves – Pipping – Bellow – Heat exchanger – Box structure

- **Keys 4, 5 and 6**: These keys give some indications in case of particular component:
  - "Catalogue Component" (= manufactured product).
  - component subjected to Pressure Equipment Regulations applicable in France.
  - class 3 components if applicable European standards are used for.

The relations, between “Safety levels” and “RCC-MRx classes” is defined by the safety studies.
EQUIPMENT OR COMPONENT USED IN THE REACTOR TO PERFORM THE IRRADIATIONS.

The experiments could sum up like this:

- Tests of samples in the reactor (material, fuel, ...),
- Measurement of the material properties under neutron flux,
- Reproduction of working conditions and accidental conditions in reactors,
- Production of radio-isotopes.

The “DEX” is composed of:

- An in-pile part: the device contains the samples and is inserted in or near the core,
- A cubicle to reproduce the working conditions with the cooling circuit and the instrumentation,
- All the equipment needed for the operating (tools).

[4] Experiment Device or “DEX”
- Criteria level A \(\rightarrow\) only elastic deformation with sufficient margins.
- Criteria level C \(\rightarrow\) only elastic deformation with fewer margins.
- Criteria level D \(\rightarrow\) margins with the limit of the plastic deformation.
1) RCC-MRx Keys :
✓ Key 1: components of irradiation devices.
✓ Key 2: class N2rx.
✓ Key 3: vessel or box structure.

2) CASE STUDIED: NEGLIGIBLE IRRADIATION OR SIGNIFICANT:

3) NEGLIGIBLE CREEP OR SIGNIFICANT: → DEFINITION OF THE LIMIT TEMPERATURE.

EXAMPLE: MOLY DEVICES [5]
✓ Production of Radio-elements.
✓ Devices on displacement system.
✓ Aluminium parts.

1) DEFINITION OF WORKING CONDITIONS:
- Normal.
- Incidental.
- Accidental.

2) DEFINITION OF RX CRITERIA:
- Rx class.
- Type of loadings (monotonic, cycling).
- Materials properties.

3) MECHANICAL CALCULATIONS
- Used of Finite Elements Software.
- Representative model.
- Define conservatives calculations:
  - Example: Seismic condition
  - Modal/spectral analysis
  - Level C criteria

Example: Mechanical calculation: stresses in shell and beam
4) POST PROCESSING OF THE DATA

- Identification of each type of stresses.
- For mechanical calculations: only primary stress.
- Comparison to the RX criteria:

\[
\sigma_m(P) \leq Sm \\
\sigma_m(P) + \sigma_b(P) \leq 1.5 \times Sm
\]

*Note: with \( m \) for membrane, \( b \) for bending and \( Sm \) for mechanical limit of the material (depending of the Rx level criteria).*

*Example:* Linearization of stress to obtain membrane and bending stresses.
1) DEFINITION OF THE DIFFERENT TYPE OF STRESSES:
The thermal stresses are defined in secondary stresses and involves a separate analysis.

2) ANALYSIS:
- Performing separately of the mechanical and the thermal analysis.
- Comparison of each stresses to Rx criteria: separately and added.

Note: for the cycling analysis, deformation analysis is performed and compared to Rx Criteria.
The RCC-MRx code give many TECHNICAL RULES FOR THE DESIGN AND THE MANUFACTURING of JHR facility and for the experimental devices.

The code gives also a SET OF MATERIAL PROPERTIES (usually used in nuclear facility) required to perform the different analyses.

For the studies, the main part of the code is THE RULES TO MAKE THE MECHANICAL AND THE THERMOMECHANICAL CALCULATIONS TO EXTRACT THE GOOD STRESSES. These rules are also adapted to the safety studies (Rx levels) and to the type of equipment (pipping, shell, pump…) by providing many criteria adapted to each case.

These rules provide a SHARED TECHNICAL FRAMEWORK WITH THE FRENCH SAFETY AUTHORITIES to work safely during the design, the dimensioning and the manufacturing of the equipment.

Thanks for your attention