DE LA RECHERCHE À L'INDUSTRIE

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JULES HOROWITZ REACTOR (JHR)

RCC-MRx[1] APPLICABILITY FOR THE DESIGN PHASE OF EXPERIMENTAL DEVICES

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[1] Design and Rules for Mechanical Components of Nuclear Facilities

JHR. RCC-MRx INTRODUCTION

1980 : *foundation of the* ***AFCEN***[2] *to define the rules for the design and the construction for mechanical components of nuclear islands.*
2009 : *the CEA*[3] *joins AFCEN.*
The purpose of the Association is to:

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

[2] French Association for Design and Construction Rules for Nuclear Island Components
[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.

⟷ **The relations, between "Safety levels" and "RCC-MRx classes" is defined by the safety studies.**

✓ **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 gives 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.

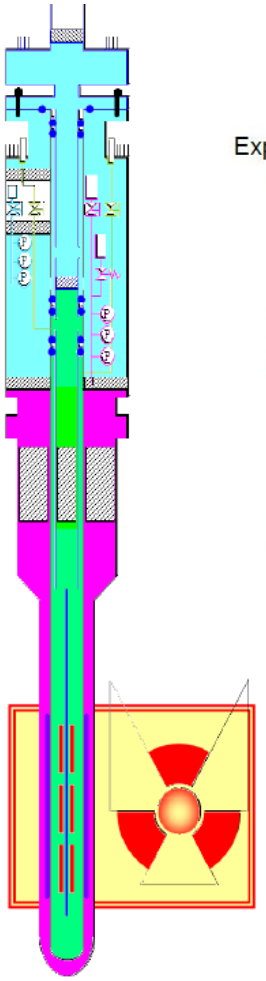
EQUIPMENT OR COMPONENT USED IN THE REACTOR TO PERFORM THE IRRADIATIONS.

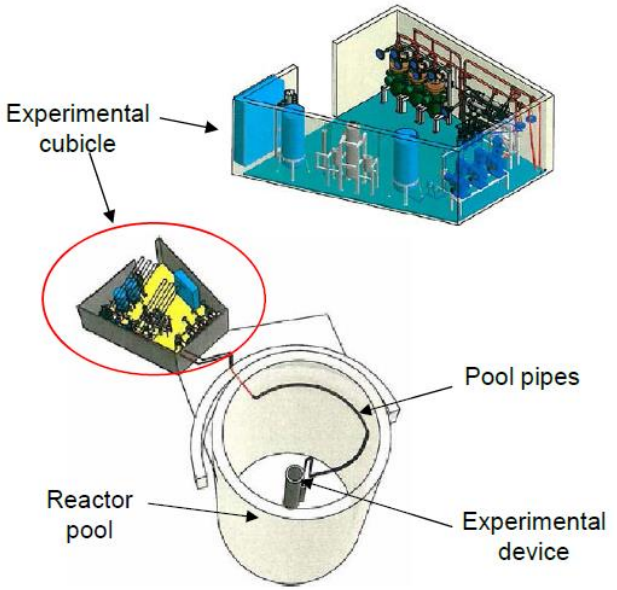
The experiments could sum up like this:

- ✓ 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”

JHR. RCC-MRx DESIGN PHASE RULES

GENERAL DESIGN RULES

SPECIFIC DESIGN RULES (key 3)

Analysis type

- elastic analysis (used the main time)
- inelastic analysis
- experimental analysis

Criterias

Operating Conditions

Level A	Level C	Level D
•Normal conditions •Incidental conditions	• Accidental conditions • Earthquake	• Hypothetical conditions

Safety levels

(RCC-MRx corresponding)

N1rx

N2rx

N3rx

N1 ≈ N2 ≥ N3

- Criteria level A → only elastic deformation with sufficient margins.
- Criteria level C → only elastic deformation with fewer margins.
- Criteria level D → margins with the limit of the plastic deformation.

Réacteur Jules Horowitz Reactor

JHR. RCC-MRx. DEVICES APPLICABILITY

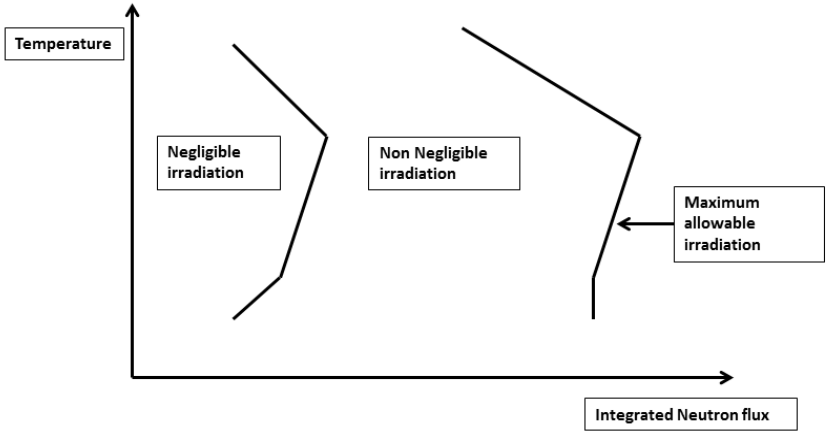
EXAMPLE : MOLY DEVICES [5]

- ✓ Production of Radio-elements.
- ✓ Devices on displacement system.
- ✓ Aluminium parts.

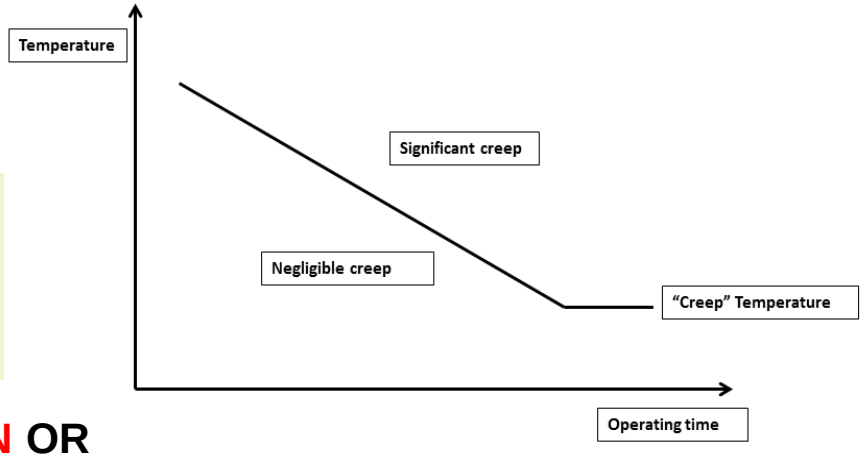
1) RCC-MRx Keys :

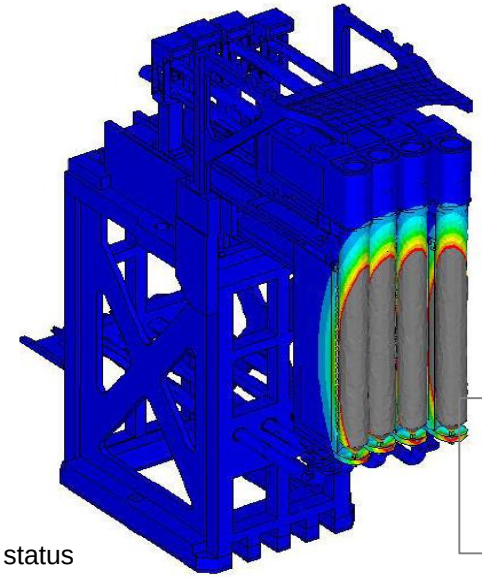
- ✓ Key 1: components of irradiation devices.
- ✓ Key 2 : class N2rx.
- ✓ Key 3 : vessel or box structure.

2) CASE STUDIED : NEGLIGIBLE IRRADIATION OR SIGNIFICANT :



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





CORE

Example:
Grey parts =
Significant irradiation

[5] MOLY production in the Jules Horowitz Reactor : Capacity and status of the development, 18th IGORR, M. Antony and Al, CEA, France.

JHR. RCC-MRx MECHANICAL ANALYSIS (1/2)

1) DEFINITION OF WORKING CONDITIONS:

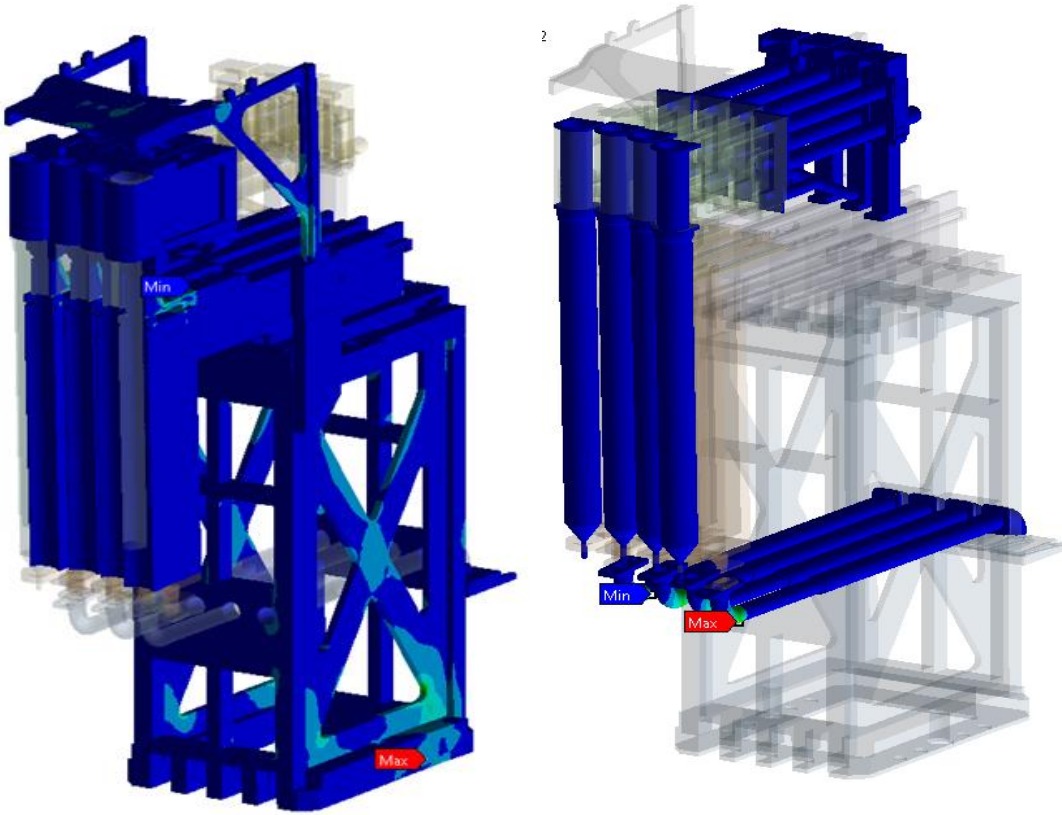
- ✓ Normal.
- ✓ Incidental.
- ✓ Accidental.

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

JHR. RCC-MRx MECHANICAL ANALYSIS (2/2)

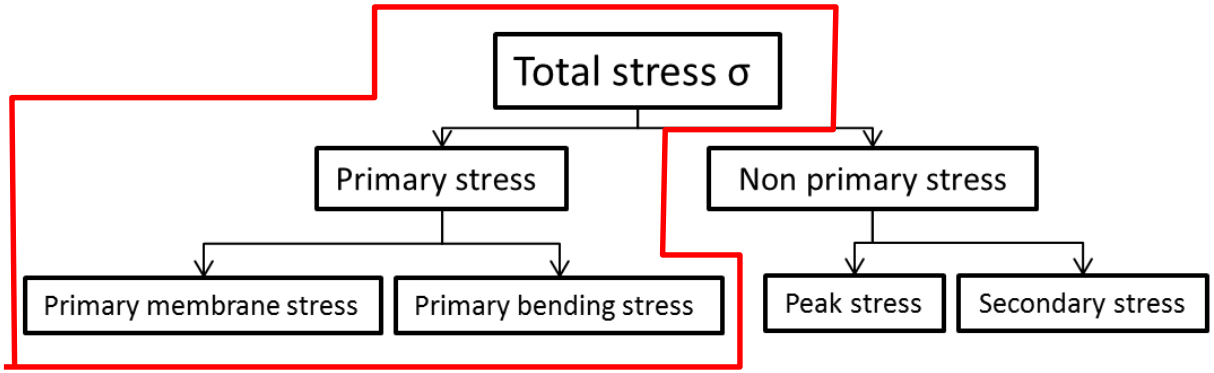
4) POST PROCESSING OF THE DATA

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

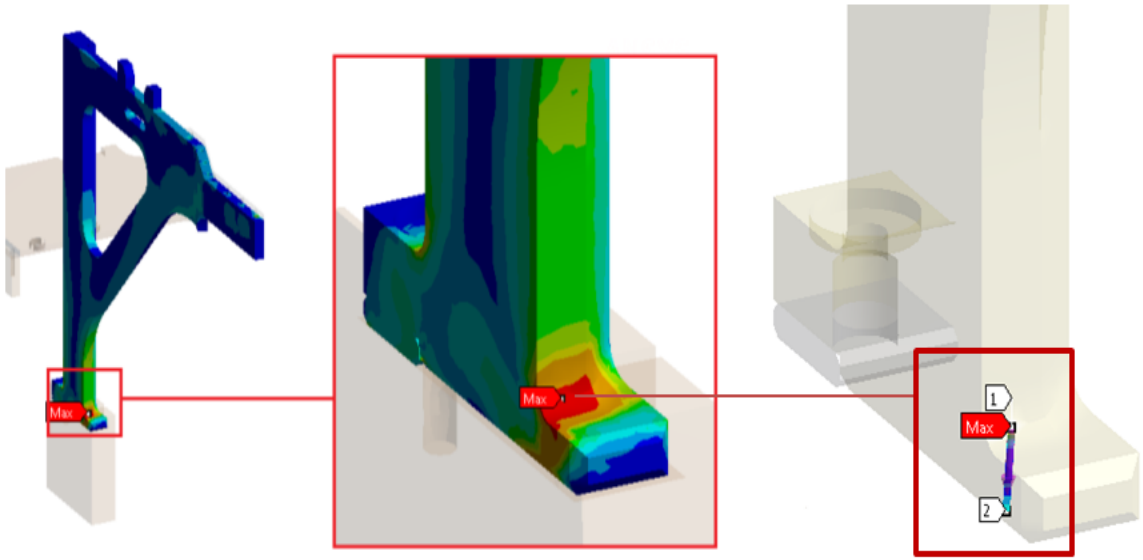
$$\sigma_m(P) \leq Sm$$

$$\sigma_m(P) + \sigma_b(P) \leq 1{,}5\,xSm$$

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



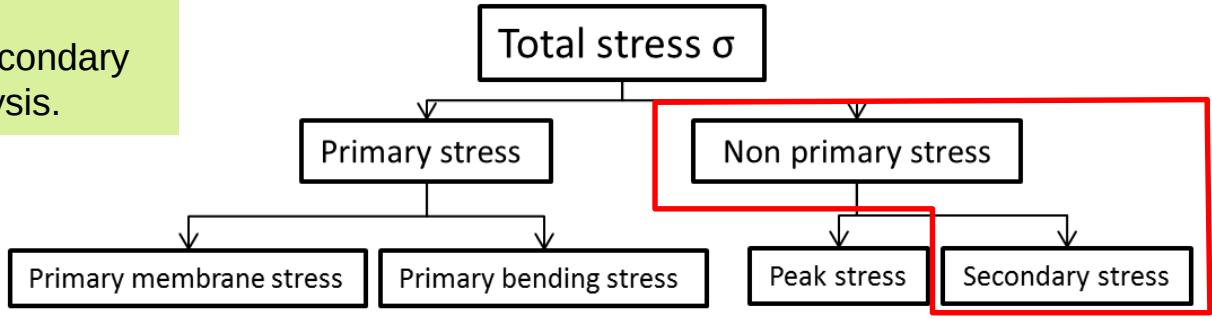
Example:
Linearization of stress to obtain membrane and bending stresses.



JHR.RCC-MRxTHERMOMECANICAL ANALYSIS

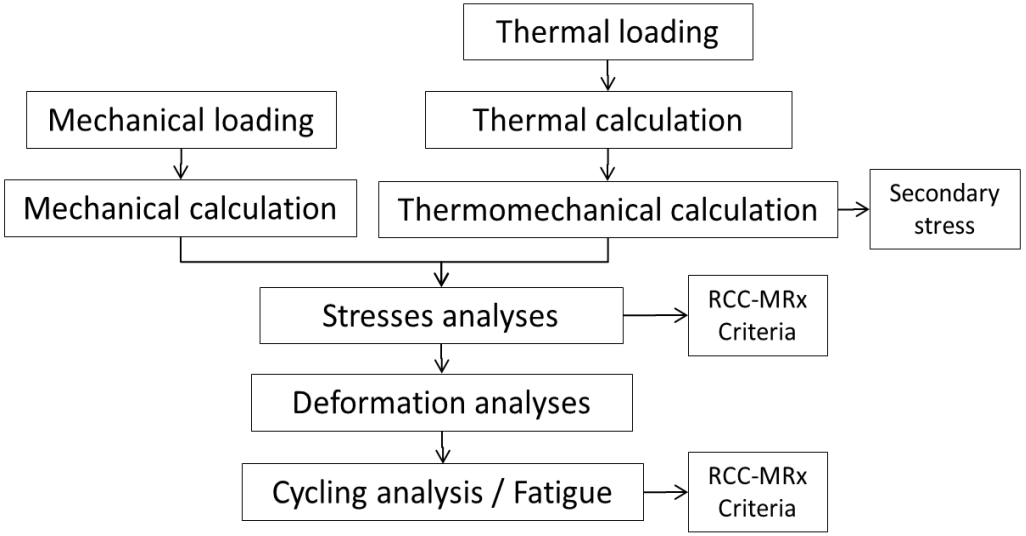
1) DEFINITION OF THE DIFFERENT TYPE OF STRESSES :

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.

JHR.RCC-MRx. MAIN CONCLUSIONS

- ✓ 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

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