First steps towards a European design and construction code for research reactors

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Overview of the presentation

- Need for a nuclear design and construction code for research reactors
- Overview of the RCC-MX
  - Design, Material specification, Examination and testing methods, Welding, Fabrication
- Use for projects
- Future of the code
- Conclusion

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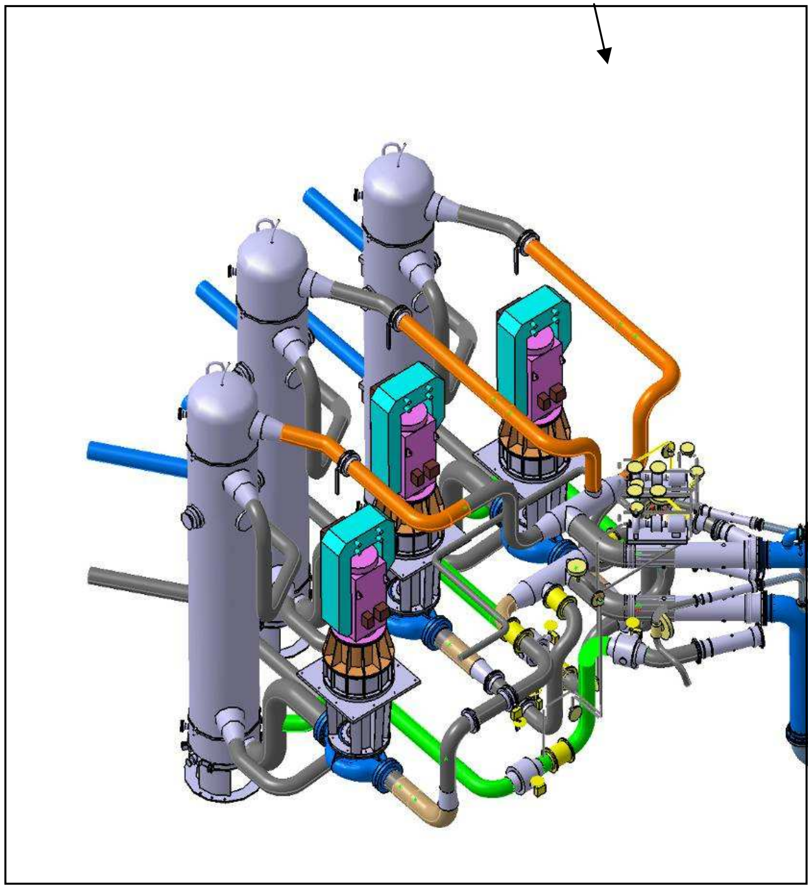
Need for research reactors

Reactor

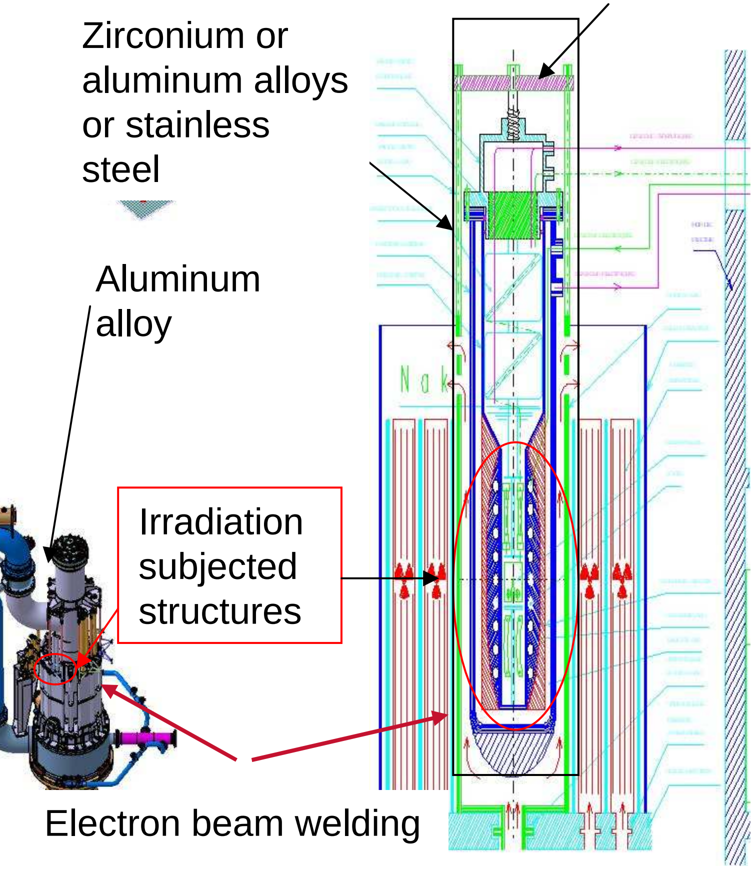
Stainless steel
Demineralized water
e.g. Ps 16 bars T < 80°C



Irradiation devices

Coolant , temperature and Pressure depending on the experimental program

Zirconium or aluminum alloys or stainless steel



No existing, appropriate, design and construction code meeting all these requirements

RCC-MX

- To address these issues, CEA and 2 AREVA entities (AREVA TA and AREVA NP) launched, in 1998, the preparation of a new design and construction code called RCC-MX
- **Requirements:**
  - Reference for technical and contractual relationship for the entire project
  - Scope: research reactor components and associated irradiation devices (metallic structures)
  - Covers ambient conditions during operation: irradiation, high temperature (creeping)
  - Covers all materials used in the research reactor field including aluminium and zirconium alloys
  - Compliance with regulations in the fields of quality for nuclear safety, pressure equipment directive (PED)
  - Integrates best industrial practices and use of industrial standards
  - Use of COTS (off-the shelve Components)
  - Includes lessons learned from several decades of research reactor design, construction, operation, and decommissioning
  - Applicable for new research reactor projects (JHR) and new components or replacement of components

RCC-MX Structure

Section I (XDG)

General provisions

- Documentation
- Entrance keys Applicable set of rules
- Equipment specification
- Management system
- List of applicable standards

Section III (XEC)

Additional requirements
For class 3_{Mx} components

- application of standard EN 13445
- application of standard EN 13480

Special requirement (2008)

- French regulation ESP/ESPN

Section II

TOME 1 DESIGN

Volume A (XA) : general provisions and entrance keys
Volume B (XB): Class 1_{MX} components and supports
Volume C (XC): Class 2_{MX} components and supports
Volume D (XD): Class 3_{MX} components and supports
Volume K (XK): control or handling mechanisms
Volume L (XL): Irradiation device equipment
Volume Z (X): Appendixes Properties of materials, X, …
Chapters 1000- 2000- 3000- 4000- 5000

TOME 2 (XM): Material procurement specifications

TOME 3 (XMC) : Testing and examination methods

Tome 4 Welding

TOME 5 (XF): FABRICATION

RCC-MX Key features

- **The scope of application of the RCC-MX design and construction rules is limited to metallic mechanical components:**
  - **Considered to be important in terms of nuclear safety and/or operability,**
  - **Ensuring containment, partitioning, guiding, securing and supporting,**
  - **Containing fluids such as pressure vessels, pumps, valves, pipes, bellows, box-type structures, heat exchangers and their supports.**

Key Code Design Features

- **Same philosophy as the RCC codes family**
- **3 RCC-MX classes:**
  - **3 design and construction classes Class 1MX, Class 2MX , Class 3MX corresponding to a decreasing assurance of the safety level:**
    - regard to different mechanical damages they may be subjected
    - due to various loads in different specified conditions.
- **Irradiation devices with :**
  - **Possibility of using COTS (component off the shelve)**
- **4 conditions are considered:**
  - **3 levels of design criteria are considered: A, C, D**
- **Formalize the best practices**

RCC-MX Tome 1 design rules

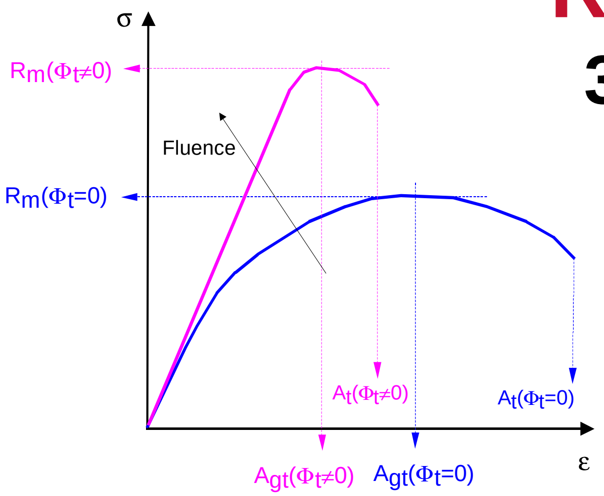
Tome 1 includes:

- **General Rules for analysis**
- **Specific design rules for vessels, supports, pumps, valves, piping, bellows, box structures, heat exchangers**
- **Technical appendixes**
  - **X1 Guide for seismic analysis**
  - **X2 Design of bolted assemblies**
  - **X3 Characteristics of materials**
  - **X4 Design rules for mechanical connectors**
  - **X5 welded joint factors**
  - **X6 Shells under external pressure**
  - **X7 Design rules for dished heads**
  - **X8 Rules for linear type supports**

RCC-MX (X3 appendix) :

	Ref.	Material	Creep data	Irradiation data
1	X3.10NAS	Carbon steels type P235GH		
2	X3.11NAS	Carbon steels type P265GH		
3	X3.12NAS	Carbon steels type P295GH		
4	X3.11AS	Low-alloyed steel type 25CrMo4, 42CrMo4, 30CrNiMo8		
5	X3.13AS	Low-alloyed steel type 16MND5		
6	X3.1S	Austenitic stainless steel X2CrNiMo17-12-2(N) solution annealed (316 LN)	X	X
7	X3.3S	Austenitic stainless steel X2CrNiMo17-12-2 solution annealed (316 L)	X	X
8	X3.4S	Austenitic stainless steel X2CrNi18-9 ou X2CrNi19-11 solution annealed	X	
9	X3.7S	Austenitic stainless steel X2CrNiMo17-12-2 work hardened (about 20%)	X	X
10	X3.8S	Martensitic stainless steel X4CrNiMo16-05-01 quenched tempered	X	
11	X3.10S	Austenitic stainless steel X6NiCrTiMoVB25-15-2 secondary hardened	X	
12	X3.1A	Aluminum alloy 5754-O (AG3 NET)	X	X
13	X3.2A	Aluminum alloy 6061-T6	X	X
14	X3.1Z	Zirconium alloy ASTM R60802 recrystallized (Zircaloy 2)	X	X
15	X3.2Z	Zirconium alloy ASTM R60804 recrystallized (Zircaloy 4)	X	X

Consistence: Product acceptance / values for analysis



RCC-MX design (XB / XC / XL 3000): stress analysis rules

Under significant irradiation decrease of ductility At

Limiting curves**:**

maximal irradiation

significant irradiation

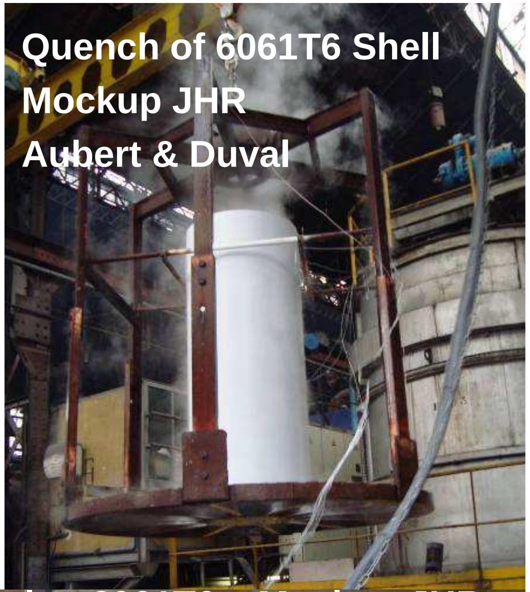
N1&N2 Mx	Negligible Creep	Significant creep
Negligible irradiation	Classical rules (type P damage, type S damage) + notch effect (Fracture mechanics) buckling	type P damage: Sm including correction for thermal ageing Sr, St : tabulated values = f(θ, t)) type S damage: deformation criteria, fatigue criteria
Significant irradiation	New rules : extended (type P damage, type S damage) + notch effect (Fracture mechanics) P+Q et P+Q+F	rules (type P damage, type S damage) New rules (limited domain: material, temperature range)

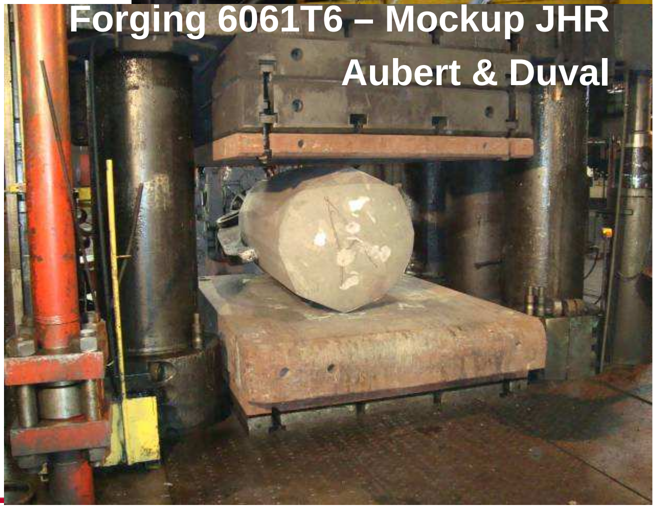
RCC-MX tome 2 : Material specifications

- **Possible routes for material procurement:**
  - **Compliance with section II requirements XB,XC, XD, XL 2000 referring to:**
    - Reference Procurement Specification from tome 2 including lessons learned from past procurement and/or qualification of parts
    - Use of standards defined in tome 2 : Acceptable standards and grades in EN or ASME standards :
      - Option selection, additional requirements
      - Additional tests
  - **Alternative for class 3_{MX}: EN standards 13445 (Vessels) and 13480 (pipes)**
  - **For class 3_{MX} :**
    - possibility of procurement without specific checking
    - Possibility to use standards for finished product,
- **Special provisions for procurement of small quantities of products**

RCC-MX tome 2 : Material specifications

- **General provisions:**
  - **Mechanical characteristics**
  - **Technical qualification of parts**
  - **Introduction of a new grade or a new fabrication mode**
  - **Supplier qualification for an alloy or steel used in the creep domain**
  - **Heat treatment**
- **Procurement on the basis of standards:**
  - **Standards and grades applicable for different type of products:**
    - casting, forging, plates, pipes & tubes, rolled bars and flats, bolts,
    - studs and threaded parts
  - **Chemical analysis of melts and heat treatment**
  - **Manufacturing program**
  - **Additional tests**
- **Reference procurement specifications (49):**
  - **Covering different types of products:**
    - casting, forging, plates, pipes & tubes, rolled bars and flats, screws,
    - studs and threaded parts,
  - **9 for unallied steels,**
  - **5 for low-allied steels,**
  - **23 for stainless steels**
  - **9 for aluminum alloys**
  - **4 for zirconium alloys**
  - **Reference procurement specification is confirmed by a qualification process and a technical manufacturing program**





RCC-MX tome 3: Test and examination methods

Tome 3 includes:

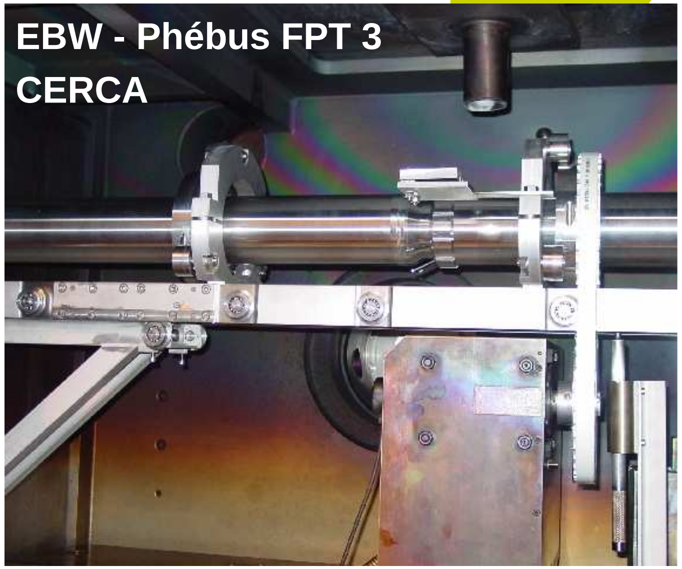
- Mechanical, Physical and chemical test
- Ultrasonic examination (Castings, Forged parts, Plates, Tubes, Welded joints)
- Radiographic examination
- Liquid penetrant examination
- Magnetic particle examination
- Eddy current examination of tubular products
- Others examination methods
  - Visual examination
  - Determination of surface conditions
  - Leak detection methods
- Qualification and certification of NDT personnel


RX - Phébus FPT 3
CERCA

RCC-MX Tome 4: Welding

Tome 4 includes:

- Acceptance of filler materials
- welding procedure qualification:
  - Arc welding of Steels and Nickel alloys, Aluminum alloys, Zirconium alloys
  - Weld repair
  - Heterogeneous welding joints
  - Welding of tubes on exchanger plates
  - Socket weld of pipes
  - Electron beam welding,
  - Laser Beam welding,
  - Diffusion welding
  - Friction welding
  - Seal lip weld
  - Fillet welds not having a mechanical strength function
  - Cladding
  - Homogeneous filling.
- Qualification of filler materials
- Technical qualification of production workshops
- Production welds
  - In particular special provisions for the aluminum alloy welding and zirconium alloy welding



RCC-MX Tome 5: Fabrication

Tome 5 includes:

- Marking procedure
- Cutting – repair without welding
- Forming and tolerances

(including special provisions for aluminum and zirconium alloys)

- Surface treatments
- Rules for cleanliness
- Bolted assemblies & brazed assemblies
- Heat treatments

Drilling of barrel core
JHR mockup

Nicrobraz - Phébus FPT 3
CERCA

Zr4 sheet forming – CABRI BEP
MECAGEST

use of the RCC-MX for Projects

JHR:

- **The RCC-MX is the Reference for technical and contractual relationship for the entire JHR project:**
  - **The code was selected in the contract between the holder (CEA) and the prime contractor,**
  - **The code is being used for the design and procurement of reactor components, components of reactor auxiliaries and irradiation devices,**
  - **The code has been examined by the IRSN (TSO of the French nuclear safety authority) and the subsequent updates are completed**

OSIRIS:

- **manufacturing of an ISABELLE 4 irradiation device**

ORPHEE:

- **Manufacturing of the in-pile assemblies of the cold neutron sources**

» **The lessons learned from design and manufacturing are being integrated by means of the improvement process of the code**

Future of the code

- **Key issues:**
  - **Maintain the code up-to-date:**
    - **Industrial practices**
    - **Evolution of the standards and regulations**
    - **integrate within the code, the lessons learned from use (technical, cost, …)**
  - **Complete the characteristics of irradiated materials (appendix X3):**
    - **dedicated Irradiation programs**
    - **post-mortem characterization of irradiated components**
- *Important cost for the French research reactor community*
- **Relevance of the code driven by:**
    - **Structure design and construction**
    - **Material**
    - **Ambient conditions during operation (temperature, irradiation,…)**
    - **loadings**
- *It is possible to enlarge the scope of the code for new reactors facing the same issues*

Future of the code

Approach:

- **Integration within the Afcen framework, French Society for Design and Construction Rules for Nuclear Island Components**
  - Group together CEA RCC-MX (Research, test and experimental reactors) with Afcen RCC-MR (Sodium Fast Reactors, High Temperature Reactors and Fusion Reactors).
  - RCC-MRx = Afcen code resulting from the merging of RCC-MX in RCC-MR:
    - Private drafts RCC-MRx 2009 and 2010 (french and english version),
    - Public RCC-MRx edition to be published by Afcen by the end of 2011 or 2012.

- **First steps towards a European design and construction code:**

RCC-MRx is being proposed as a basis for the development of a European / international design and construction code for mechanical components in :

- Research Reactors (RR)
- Sodium Fast Reactors (SFR), High Temperature Reactors (HTR) and
- Fusion Reactors (FR – ITER)

Two international collaborations are starting:

- in the frame of the FP7 ESNII Task Force for pre-normative R&D for mechanical components of GEN IV reactors such as Sodium Fast Reactors (SFR), High Temperature Reactors (HTR) and Fusion Reactors (FR – ITER)
- Under the CEN umbrella, a workshop of different institutes and industrials is starting aiming to adapt the code for innovative reactors (MYRRHA, ASTRID, ALLEGRO) by means of CWA (CEN workshop agreement)

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Conclusion

- **The added values of RCC-MX and RCC-MRX are:**
  - **To collect and formalize the knowledge for design and construction of research reactors and fast breeders**
  - **Consistency with the PED and ESPN regulations**
  - **To propose**
    - **specific materials (aluminium alloys, Zirconium alloys, …) specific of research reactors**
    - **Modern welding processes (Electro Beam, …;,)**
  - **To take into account:**
    - **thermal creep : High temperature , Other material such as aluminium alloys at medium temperature**
    - **irradiation inducing an evolution of the properties of materials** (stainless steel, aluminum or zirconium alloys) **and irradiation creep**
    - **up to date European standards such as “harmonised standards”.**
  - **Required provisions for use of components from catalogue**
  - **Living code integrating the lessons learned from past and ongoing project**

- **The RCC-MRx is proposed as basis for international collaborations**

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