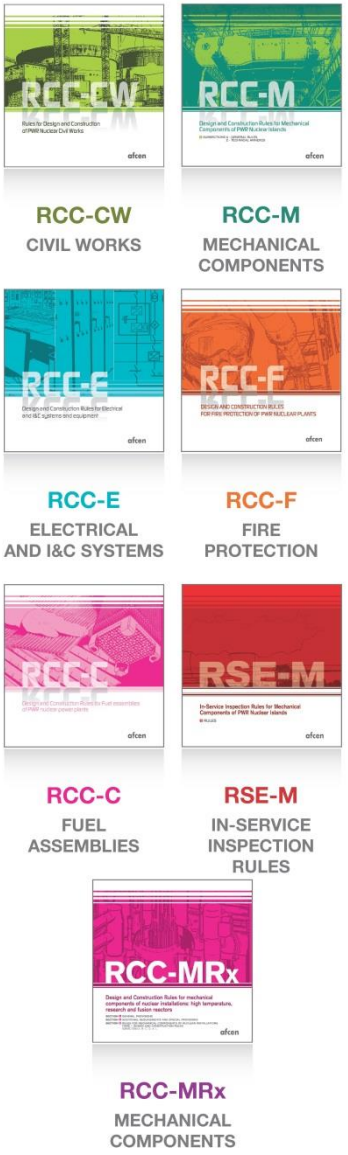
How do new materials and processes get into codes?

Cécile PÉTESCH
RCC-MRx chairwoman
CEA - Senior Expert in design codes and standards for mechanical components

- **Design codes vs new material**
  - **Why?** ***Interest to connect R&D to standardisation***
  - **What?** ***Example of RCC-MRx code***
  - **How?** ***Difficulties to introduce a new material***
- **Conclusion**



RCC-CW
CIVIL WORKS

RCC-M
MECHANICAL COMPONENTS

RCC-E
ELECTRICAL AND I&C SYSTEMS

RCC-F
FIRE PROTECTION

RCC-C
FUEL ASSEMBLIES

RSE-M
IN-SERVICE INSPECTION RULES

RCC-MRx
MECHANICAL COMPONENTS

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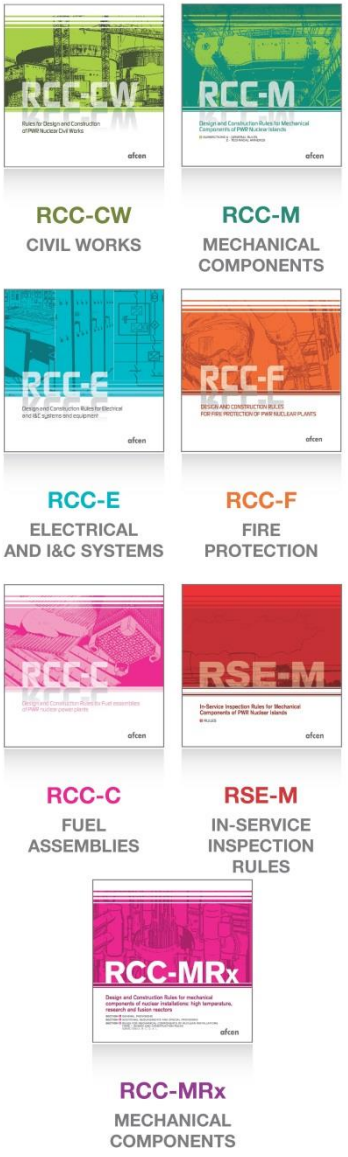
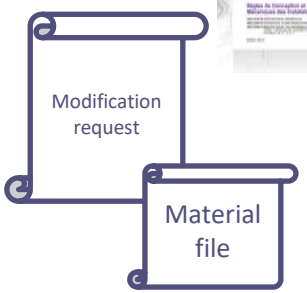
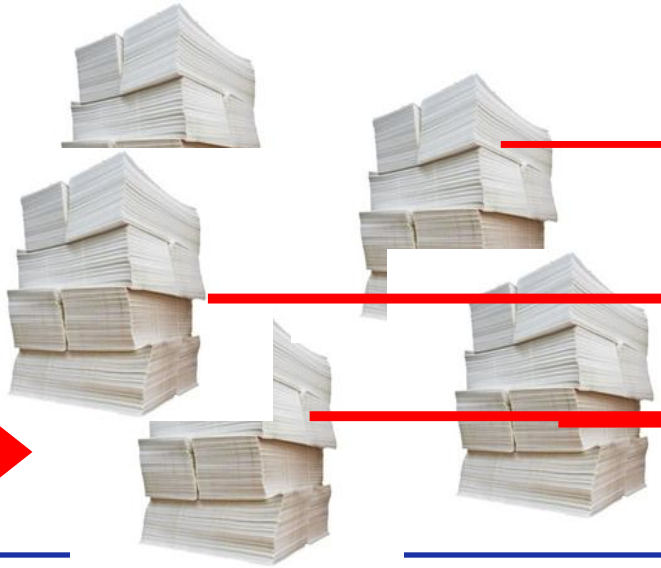


Why?

Codes and standards



New Material

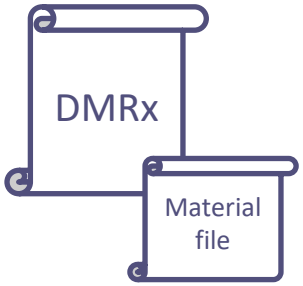


Nuclear Industry

EDF iter framatome ensa SCK·CEN

Why?

Codes and standards



New Material

REGULATOR

Why?

- For innovative reactors, standardization is one way to reach a highest technology readiness level, giving a frame and a direction for research
- Need for the users to have a public document as a tool for discussion with other developers, industries, regulators, notified bodies or third parties
- A more and more strong willingness of the users to be involved in the developments of rules adapted to their needs
- The earlier the standardization is integrated in the design process, the easier to transfer a concept to an industrial component is

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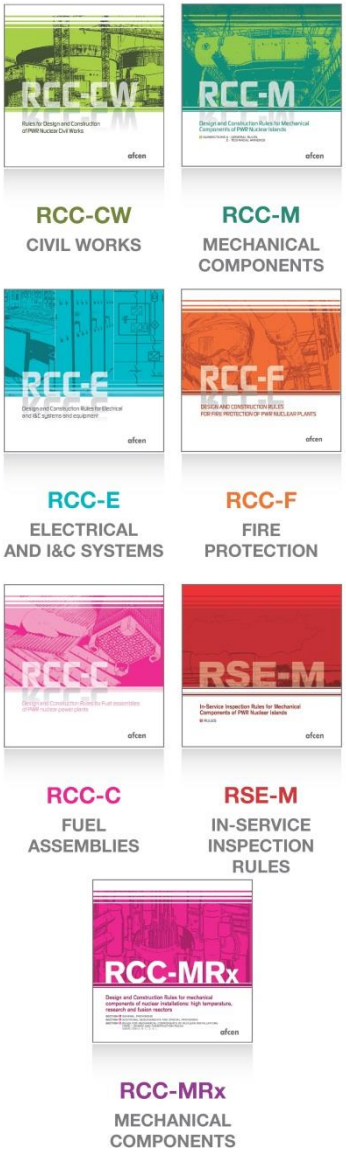
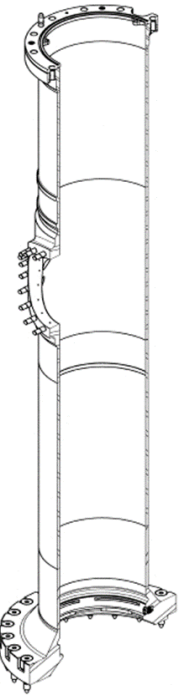
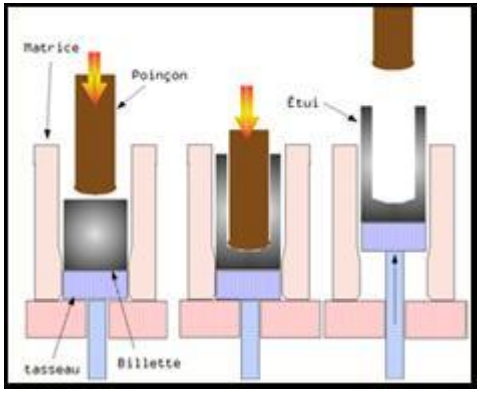


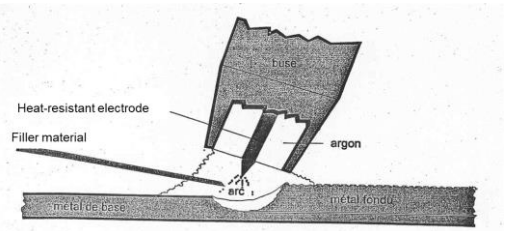
RCC-MRx:

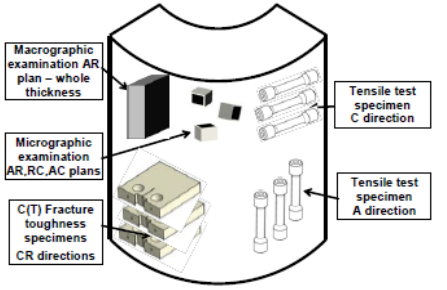
DESIGN & CONSTRUCTION RULES FOR MECHANICAL COMPONENTS OF NUCLEAR INSTALLATIONS: HIGH TEMPERATURE, RESEARCH AND FUSION REACTORS

- **VOLUME I** Design
- **VOLUME II** Materials
- **VOLUME III** Examination Methods
- **VOLUME IV** Welding
- **VOLUME V** Manufacturing operations









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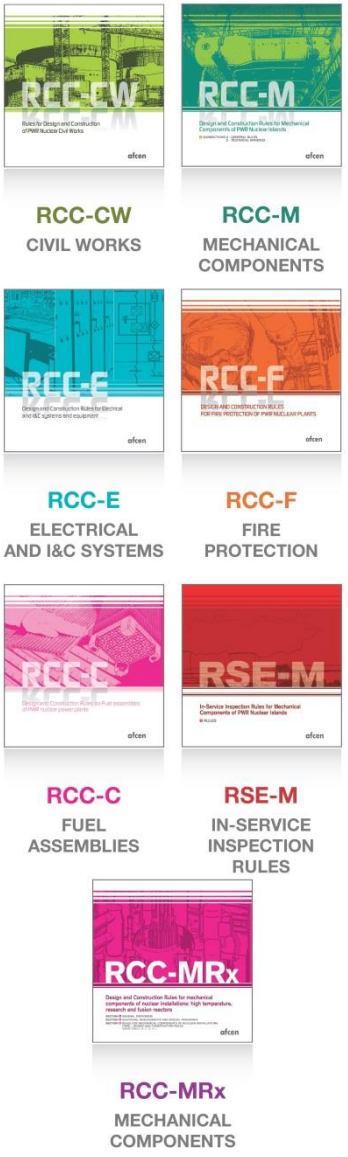


Prior to the code

- **Pre-codification step**
- Define a material prior to its introduction in a code
- Based on mechanical tests

Characterisation

- Chemical composition
- Fabrication main parameters
- Mechanical properties

Stability, reproductability

In the code

Procurement

- **First step of the code**
- Demonstration of the conformity of the selected material to the code materials
- Based on mechanical tests

Design

- **Second step of the code**
- Define the component using the material properties
- Based on design data

Introduction of a new material in RCC-MRx

Material: general process

Introduction of a new material in RCC-MRx : Material file required

Prior to the code

- **The use of new materials and products shall be preceded by a Material File including:**
  - **Technical Qualification Report** (RB 2210 - RM 014-0) on the part or product qualification and on the shop qualification*, if required by the Equipment Specification*,
  - **new Reference Procurement Specification**(s) with the same table of contents as the present RPS in Tome 2, possible with a reference to a published product standard,
  - if necessary a **new Properties Group** (A3 and A9) with the same table of contents as the present Properties Groups.

Prior to the code

The table of contents of the Material File shall be:

1. Introduction
- Presentation of the grades
- Codes and standards dealing with these parts or products
- **Reference Procurement Specifications in Tome 2**
- Industrial application and experience

2. Physical properties

3. Base metal and welded joints mechanical properties for design and analysis
- Justification of the applicability of the Design Rules (RB 3000) for the specified usage conditions
- Basic mechanical properties
- Mechanical properties when creep is significant (if necessary)
- Mechanical properties when irradiation is significant (if necessary)
- Guaranty of the consistency between the properties of the final part laid-on the plant and the material properties used to design the component

4. Manufacturing
- Industrial experience
- Metallurgy

5. Fabrication
- Industrial experience
- Forming operation ability

6. Welding
- Weldability (RS 1300)
- Industrial experience for the welding procedure qualification
- Industrial experience for the repair welding procedure qualification

7. Controllability

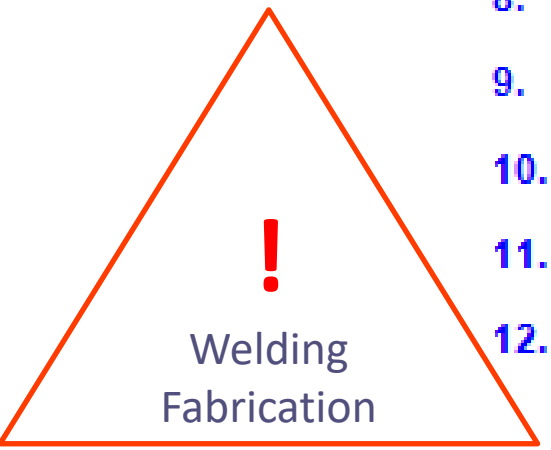
8. In service behavior
- Thermal ageing, corrosion, erosion-corrosion, irradiation, …

Reference Procurement Specification

In the code

Contents of a RPS

1. *Scope*
2. *Melting process*
3. *Chemical requirements and physico-chemical characteristics*
4. *Manufacture*
5. *Mechanical properties*
6. *Surface examination - Surface defects*
7. *Volumetric examination*
8. *Removal of unacceptable areas*
9. *Dimensional check*
10. *Marking*
11. *Cleanliness - Packaging – Transportation*
12. *Test reports*



new Properties Group

In the code

Prevention of:

- Excessive strain
- Plastic Instability

- Progressive strain

- Fatigue
- Creep
- Irradiation

- Fast fracture

Design data

Yield stress
Tensile strength
Tensile stress-strain curves

Cyclic curves

Fatigue curves

Creep strain curves

Same data in irradiated states

J_{IC} and J-R curve, fatigue crack growth curve

A3/A9 properties

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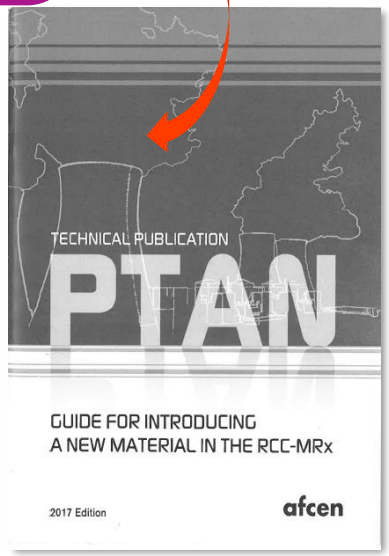
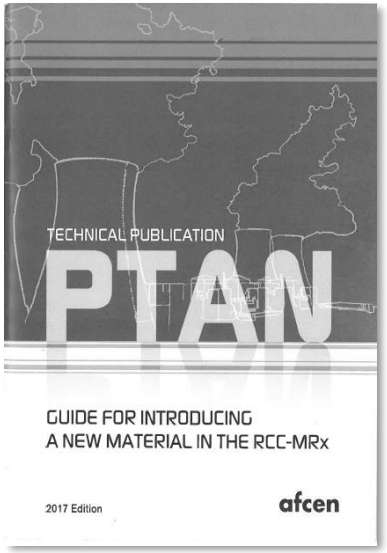


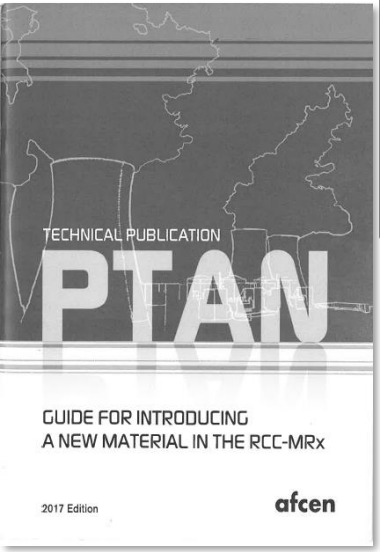
How?

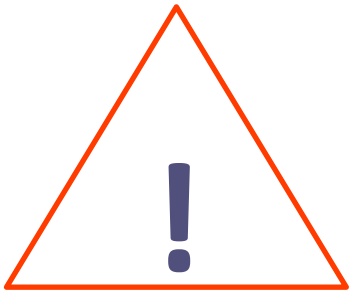
Prior to the code



Prior to the code

A3.X.5: Data for the analysis - Creep - Thermal ageing						
§	Properties	Test type	Relevant standards	Number of tests	Temperature Range	Comments or RCC-MRx requirements
.51	Thermal ageing factor	Ageing treatment Tensile test Fracture mechanics Other tests if necessary	Tensile: tab. A3.X.4 Fracture mechanics: tab. A3.X.8	Tensile: tab. A3.X.4 Fracture mechanics: tab. A3.X.8	Tensile: tab. A3.X.4 Fracture mechanics: tab. A3.X.8	• Ageing treatment intended to characterise the material, representative of ageing expected in envisaged service conditions. Includes at least: • A study of the candidate material's micro structure and of its change during ageing. • Determination of the conventional plastic behaviour. • Determination of the fracture behaviour.
.53	Creep fracture stress S_r	Creep test	EN ISO 204 ASTM E2714 ECCC	≥ 3 heats ≥ 4 tests per heat and per temperature Recommended: 2 tests per T at same stress	T_{border}-25°C to T_{max}+50°C $\Delta T \leq 50°C$ If thermal ageing of the material: $\Delta T \leq 25°C$ Temperature-holding periods such that the variation in fracture time is less than a factor 10.	• Interruptive creep tests and multiple specimen testing machines are forbidden. • Strain monitoring mandatory during the test by extensometry or optical means. • See RMC 1290 and A3.GEN.31 • $T_{fracture} \geq 500$ h systematically. • $T_{fracture} \geq 10{,}000$ h per temperature and per heat. • If thermal ageing, $T_{fracture} \geq 30{,}000$ h for at least 1 test. • $T_{fracture} \geq \frac{1}{3} \times$ life time for at least 1 test • Recommended: ECCC (see Appendix 2). • Recommended: proportional cylindrical specimens with a 10 mm diameter calibrated area.
.54	Creep-strain rule					
.55	Fatigue-creep interaction diagram	Not supplied	ASTM E2714 ASTM E606M ISO 12106	Not supplied	Not supplied	• Programme and tests representative of the envisaged operating conditions (temperature, number of cycles, etc.). • ASTM E2714 specific to the fatigue-creep tests • ASTM E606M and ISO 12106 providing recommendations for the fatigue tests with holding time.





Guideline: for a **new(=not codified)** material
If material already codified, you can do less!

Probationary Phase Rules

dedicated part of the code:

- *to collect the results of research and development or pre-normative developments*
- *which not always have sufficient feedback to be included in the code*
- *To be completed to be part of the code*

Interest to start the standardization work in parallel to the qualification..

RPP	Title	Purpose
RPP1	Management system	Establishment and use of a quality management system
RPP2	Properties of chrome alloy steels from Annex A3.18AS	Properties of chrome alloy steels from Annex A3.18AS – cyclic behavior and creep
RPP3	RM 243-2 thick plates	Extension of application of RM 243-2 to thick plates (up to 250 mm)
RPP4	Steel X10CrWVTa9-1	Introduction of steel X10CrWVTa9-1
RPP5	A3.2A casing 6061-T6	Complement to Appendices A3.GEN and A3.2A to be considered using S-RPS RM 522-7: Type 6061 T652 Al-Si-Mg alloy forged blanks for the core casing
RPP6	US inspection of welds on aluminium alloys	Introduction of measures for US inspection of welds on aluminium alloys Comments: not anymore in PPR, now integrated in tome III
RPP7	A16 – Locating defects	Definition of a general procedure for locating defects
RPP8	Use of the SMC2 method	Extension of the method of Seismic Moments Classification SMC2 to type S damages
RPP9	800H Alloy	Introduction of bars and tubes RPS in alloy 800H and the associated appendix A3
RPP10	Swelling of 6061-T6 alloy	Modification of chapter A3.2A.69 dealing with swelling of 6061-T6 alloy
RPP11	18MND5 steel	Introduction of two G-RPS for the procurement of 18MND5 alloy steel forgings and plates, and of the associated properties group A3.12AS.
RPP12	NiCr19Fe19Nb5Mo3 Alloy	Introduction of the NiCr19Fe19Nb5Mo3 alloy, so-called Inconel 718®
RPP13	Eddy current examination of steam generator tubes procured following RM 414-1	Introduction of requirements regarding the reference tube to be used for eddy current examination of steam generator tubes procured following RM 414-1
RPP14	Guidelines for innovative coolants	Introduction of guidelines for the use of the Code in innovative coolant environment
RPP15	Aluminium alloys hard anodizing	Introduction of hard anodizing surface treatment for aluminum alloys

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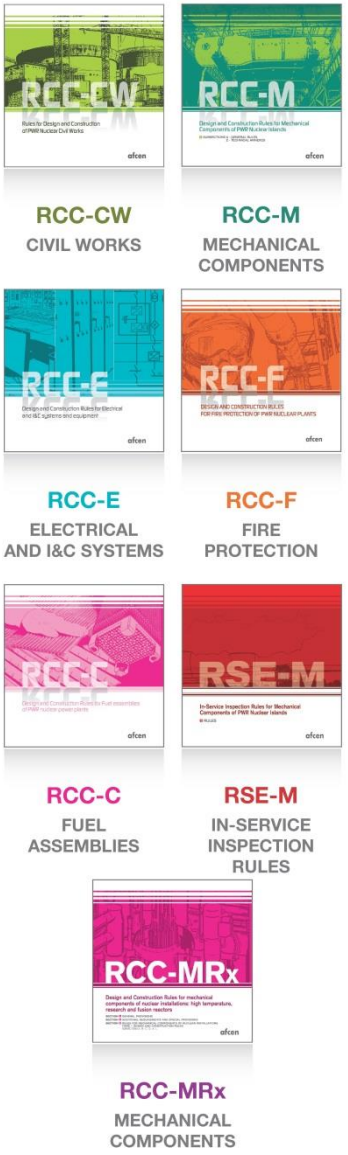

Example of Eurofer

RCC-MR 2007
- Eurofer was not codified

RCC-MRx 2012
- Introduction of Eurofer (1RPS and associated A3.19AS)
- Physical properties, Basic data

RCC-MRx 2015
- Properties group A3.19AS was completed
- Creep data, fracture mechanics data

RCC-MRx 2018
- irradiation data

Material file
+
Modification requests

Conclusion

- Innovative reactors are strongly linked with innovative materials and processes
- The nuclear industry has specificities in term of quality insurance and qualification that could make the transfer from R&D to industry really challenging
- Codes and standards and more generally standardization can facilitate the transfer from research to industry
- But this means a strong collaboration between all partners in a supported framework

Thank you
Any question?

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