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2022 RCC-MRX CODE EDITION: CONTEXT, OVERVIEW, ON-GOING DEVELOPMENTS

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ABSTRACT

The 2022 edition of the RCC-MRx Code will be issued, by the end of 2022, in French and English versions by AFCEN. This Code sets up rules applicable to components operating at high temperature (based on Sodium Fast reactors community feedbacks), to components operating with a significant irradiation (based on research reactor community feedback) and to specific components dedicated to fusion reactors (such as the Vacuum Vessel of Iter).
This new edition is enriched by an important feedback of the users, such as Jules Horowitz Reactor or SFR community, but also keeps on extending it applicability domain with the feedbacks from ITER and MYRRHA projects. One of the long term objective for the code is to cover the needs of GEN IV innovative reactors, of fusion reactors, …
In parallel, in compliance with the EC's objectives and its own policy of openness, the RCC-MRx is involved since 2011 in the CEN Workshop 64, which has the objective to take into account the needs and expectations of European stakeholders (operators, designers, constructors, suppliers…). The end of the workshop is (for the moment) planned for 2022, and some of the modifications proposed by the participants to this workshop are integrated in 2022 edition of the code.
This paper gives an overview of the realized work and also identifies the work to be done for a development of a standard such as RCC-MRx code.

INTRODUCTION

The design and construction rules for mechanical components of nuclear installations (RCC Codes) published by AFCEN primarily apply to safety class components. These Codes are used as a basis for contractual relations between Client and Supplier, in which case they shall be accompanied by a list of components to which they shall be applied.
RCC-MRx code is developed for components operating at high temperature (based on Sodium Fast reactors community feedbacks), for components operating with a significant irradiation (based on research reactor community feedback) and for specific components dedicated to fusion reactors (such as the Vacuum Vessel of Iter).

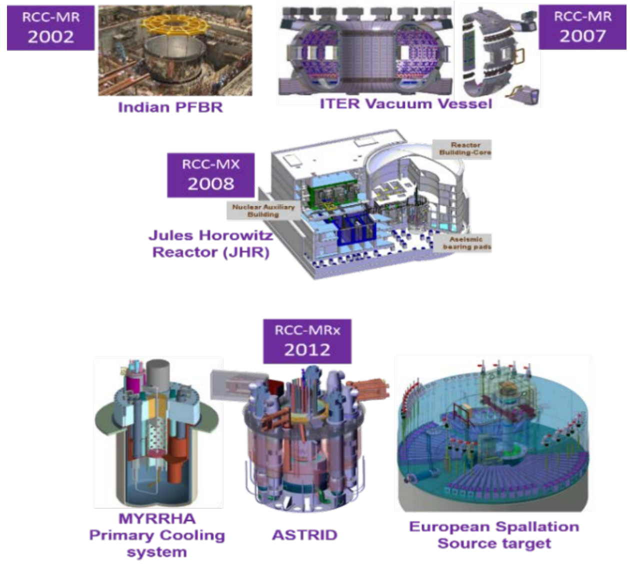


Figure 1: Illustration of code references

The new 2022 edition of RCC-MRx is being finalized now to be published by the end of 2022. As usual, it takes into account the feedback from the projects using the code with the objective to clarify the code with some harmonisation actions and a constant work on the improvement of the modularity.

A particular attention is paid to international partners and international collaboration. CEN Workshop 64, which has the objective to take into account the needs and expectations of European stakeholders, is one good example of the willingness of the RCC-MRx sub-committee to open to international partnership. Thru this workshop, some modifications of the code are proposed and introduced in this 2022 edition.

Last part of this article will develop the identified topics to consider in the following years.

BRIEF OVERVIEW OF RCC-MRX CODE

AFCEN

RCC-MRx [1] is one of the seven codes published by AFCEN (figure 2). AFCEN is an international association. Its members are companies from the nuclear or conventional energy sector (when operating in the nuclear sector), whose activities are related to the technical fields covered by AFCEN codes.

AFCEN has two main purposes:

- produce up-to-date codes offering accurate and practical rules for the design, construction and in-service inspection of components for use in industrial or experimental nuclear facilities (RCC- and RSE- codes),
- ensure certified and readily-available training programs enabling code users to achieve a high level of expertise, knowledge and practical skills in using AFCEN codes.

AFCEN codes:

- encompasse a broad spectrum of technical fields, including mechanical engineering, electricity and I&C systems, nuclear fuel, civil engineering works and fire protection systems,
- have been evolving over the last 35 years to reflect changes in safety requirements, technological progress and international feedback based on users' practices,
- can adapt to the specific local regulations applicable in different countries.

Codes are continually updated to incorporate feedback from international industry best practices and are published in English and French.

Figure 2: Illustration of the seven AFCEN codes

RCC-MRx

RCC-MRx code is developed for components operating at high temperature, for components operating with a significant irradiation and for specific components dedicated to fusion reactors.
The scope of application of the RCC-MRx code is limited to mechanical components:

- considered to be important in terms of nuclear safety and operability,
- playing a role in ensuring leaktightness, partitioning, guiding, securing and supporting,
- containing fluids such as pumps, valves, pipes, bellows, box structures, heat exchangers, irradiation devices, handling and driving mechanisms and the associated supports, when existing..

The RCC-MRx Code constitutes a single document that covers in a consistent manner the design and construction of mechanical components of Nuclear Installation within its scope of application.
RCC-MRx has some specificities:

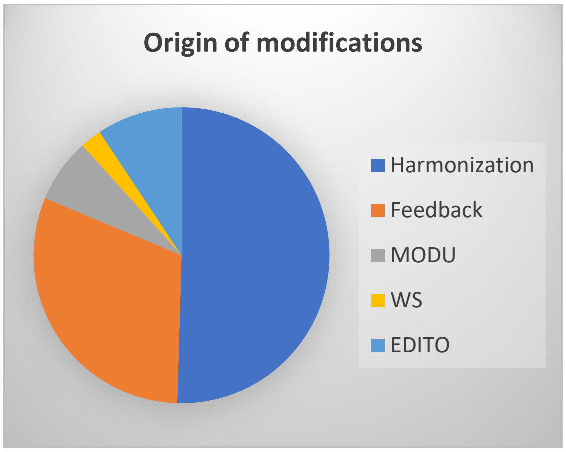
- It provides an ensemble of consistent design, manufacturing and materials rules.
- It provides rules for high temperature operation (creep and creep-fatigue irradiation because of mechanical resistance of structures close to neutron sources) [2].
- It provides rules for the design of irradiated components [3].

As every code and standard, RCC-MRx evolve regularly thru Modification Requests drafted by users, projects, R&D results... The 2022 edition is the results of 4 years of work of RCC-MRx sub-committee. The main new features and topics under development are presented here after.

MAIN NEW FEATURES IN RCC-MRx 2022

The new edition includes more than 220 modifications (included in the code since the last edition, in 2018). These modifications can be analysed regarding the origin or regarding the parts of the code concerned (figure 3).

These modifications have five major roots: harmonization actions, feedback from the users and the projects, improvement of the modularity of the code, modifications coming from CEN Workshop 64 and editorial modifications. All the parts of the code are updated but Tome 1 (design rules) and Tome 2 (materials) are the most modified parts.



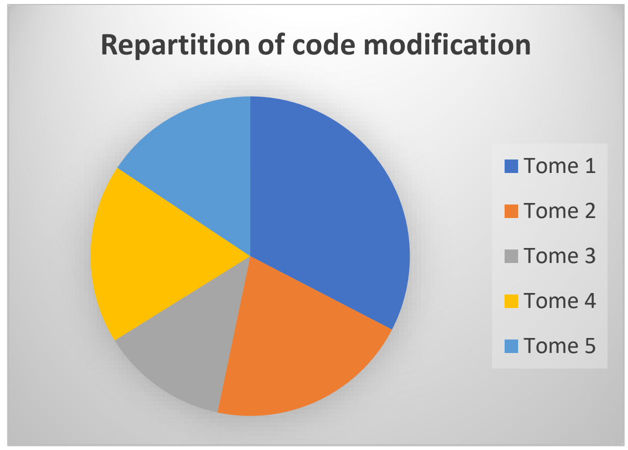


Figure 3: origin and repartition of code modifications

The following paragraphs illustrate some example of new features introduced in RCC-MRx 2022.

Users' feedback: essential element of the code evolution

SFR

First of all, regarding SFR feedback, the new edition of the code will take into account some weaknesses highlighted by ASTRID project, in particular the excessive conservatism of certain rules for creep-fatigue.

1. A clarification of alternative rule for creep-fatigue. Today in the code there is an alternative rule for creep fatigue if the holding time is not located at one of the extrema of the cycle (RB 3262.1124). However, due to application difficulties and lack of validation, this rule is not used. To assess the validity of the RCC-MRx alternative rule and propose possible improvements, the following actions were carried out:
    - Non-linear calculations using Chaboche's elasto-viscoplastic behaviour model on elementary load cases of increasing complexity
    - Fatigue-relaxation testing of 316L(N) steel with holding time at extrema and not at extrema, at 550 and 600°C

   Main conclusions of this tests and calculation are: current rule is conservative, distinction between cycle A and cycle B is not so clear, and when holding time is not at extrema, the current rule is over conservative.

   The code is then modified as followed: Clarification of definition of cycle A and cycle B and modification of stress at holding time for cycle B.

2. In the RB 3262 creep-fatigue rule, it appeared that the symmetrical coefficient Ks used to calculate the stress at the holding time σ_k was too conservative when the cycle is not completely dissymmetrical.

   A modification request was then drafted to reduce this over-conservatism by using the methodology already introduced for pipes. This proposal is also based on new high cycle fatigue tests on 316(L)N and FE calculations (see Figure 4). In the next edition of the code, a new symmetrical coefficient Ks' is thus introduce to deal with over conservatism.

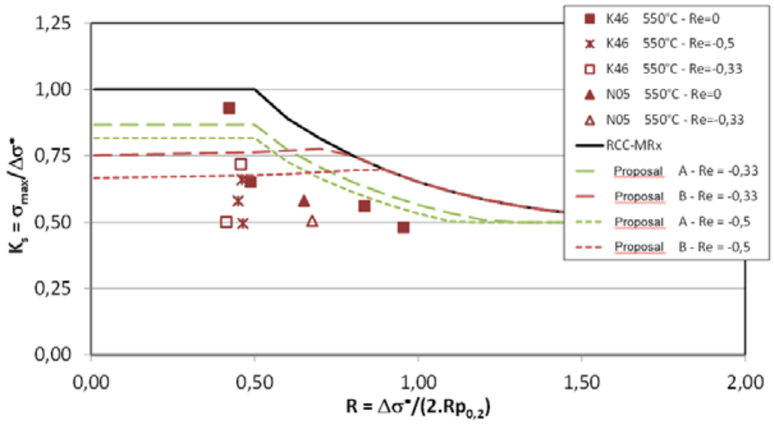


Figure 4: proposition of a new Ks' in RB 3262

3. Feedback from ASTRID project also enable the development of a new reference data sheet of filler materials for stainless steel used at high temperature. For filler material type 19Cr12Ni2Mo, RCC-MRx 2018 provide reference date sheets for covered electrode (RS 2711.1) and for wire/flux couple for submerged arc welding (RS 2713.1) but nothing for TIG welding. Thanks to work that started for SFR and was finalized during ASTRID project the 2022 edition of RCC-MRx will propose this new reference data sheet in RS 2712.1.

<u>JHR</u>

Then, a lot of feedback coming from JHR have been introduced in the code, three examples are given to illustrate this strong link between the code and the project:

1. A new RPS for high-strength bolting in NiCr19FeNb5Mo3 is added in the RPP part of the code. This modification request is built to answer the need to have high strength bolting respecting the requirements of ESPN regulation. This rule is based on ASME Section III Division 1 and procurement according to ASTM B637-03 with complements, and specific heat treatment is proposed to comply with the ESPN requirements (tensile test and KV).
2. Feedback from procurement is also introduced in the code, regarding aluminium flanges obtained by ring forging using Al-Mg-Si alloy, for core vessel. This Reference Procurement Specification was not in the code yet, but new procurements were analysed and it is now possible to have consistent values in the RPS and in the associated Appendix A3. Edition 2022 will be completed with this new RPS.
3. Welding part of the code is also improved to take into account the feedback from JHR.
   - GMAW of aluminium alloys are susceptible of lack of fusion hardly detectable by radiographic testing, namely for relatively high thickness multipass welds. For that kind of defect, a complementary UT may improve the capabilities of detection. As well as for Zr alloys it is not proposed to make it mandatory but to alert the specifier on the opportunity to add that NDE for levels 1 and 2.
   - aluminium welds criteria for open porosities have also been modified. After machining of MIG welding of shells for the core vessel there are difficulties to fulfil RCC-MRx requirements of RS 7461 (N1Rx and N2Rx) concerning surface pores / surface porosities. To take into account this feedback, the code is modified and a deviation to the absence of such defects is authorized submitted to a file justifying the acceptability (design) and to be accepted by the Prime Contractor.

Fusion

Regarding fusion projects, one important topic is under evaluation, the introduction of CuCrZr material in the code with 3 parts:

- First one deals with a new RPS for forgings.
- Second part is the associated material appendix (in Volume A3) with the mechanical caracteristics for this material.
- Last is the creation of a new volume in the code, Volume I, dedicated to component under vacuum.

Harmonisation: improvement of REC 3200

The REC part of the code is dedicated additional requirements and special provision, the REC 3000 gives special instructions for component subject to regulation and the REC 3200 deals with equipment subject to pressure equipment regulations applicable in France. A huge work have been realised between 2018 and 2021 to update the code regarding the European and French regulation for pressure equipment and nuclear pressure equipment, with the objective to propose to the final user of the code, technical solutions to answer as far as possible to essential safety requirements of those regulations. This work has been done taking into account users feedback but also the work made in RCC-M sub-committee.

Finally, ten Modification Requests of the code have been drafted and validated, the following table gives the topics covered.

Table 1: Topics treated by update of REC 3200

Modification Request number	**Scope**	**Modification Request number**	**Scope**
DMRx 21-051	hasard analyse	DMRx 21-056	inspectability
DMRx 21-052	material conservation	DMRx 21-057	materials
DMRx 21-053	visual examination	DMRx 21-058	instruction notice
DMRx 21-054	miscellaneous	DMRx 21-059	technical qualification
DMRx 21-055	assemblies and functions	DMRx 21-060	Rp1.0

Some works are still on the table in RCC-M sub-committee for the next years on this topic. RCC-MRx sub-committee will probably have to analyse and take into account this work for the next edition.

Best modularity of the code: new organisation of Tome 2

Projects using the code highlight difficulties in deploying self-supporting RPSs even general RPS. Material manufacturers often prefer procurement according to standards even with additional tests.

To try to answer this difficulty, an important work has been performed for this new edition of the RCC-MRx, regarding Tome 2 which is substantially restructured. In edition 2022, procedures for the procurement of products or half-products with reference to a selection of standards are simplified.

This restructuring will be based on the following principles:

- For standard/grade pairs currently covered by both RM030 and STR-G, only one mode of supply is maintained.
- Requirements complementary to those of the standards are clearly expressed.
- Special RPS and general RPS not based on standards are maintained.

CEN WORKSHOP 64

3 phases from 2011 to 2022

Proposed by the European Sustainable Nuclear Industrial Initiative (ESNII) and AFCEN, the CEN Workshop on "Design and construction codes for mechanical equipment of innovative nuclear installations" (CEN/WS 64) was set up in 2011. As a result of the Phase 1, it appeared that this experience should be the base for a true European process for future developments of the AFCEN Codes, in particular for stakeholders with potential medium or long term projects or desiring to learn more about the Codes and their evolution process, in order to appropriately introduce their requirements into the Codes and to identify the associated pre-normative research needs.

Based on the results of this Phase 1, and the recommendations of the CEN-CENELEC Focus Group on nuclear energy, the European Commission, in the framework of ENEF (European Nuclear Energy Forum) decided to support a CEN/WS 64 phase 2 with the target to enlarge the scope to the codes for PWR mechanical equipment and civil engineering of GEN II to GEN IV nuclear installations

Then, since 2019, a phase 3 has started, it is proposed to participant members to:

- Identify and recommend medium-long term orientations in the evolution of AFCEN codes;
- Identify the R&D needs associated with these recommendations.

To date, 19 members participate in this Workshop, coming from 11 countries and representing utilities, manufacturers, design offices, study centers, safety authorities and TSOs. Figure 4 summarize the organization of the Workshop.
As the phase 3 is nearly over, we are now considering a phase 4. RCC-MRx sub-committee is highly convinced of the benefits of the Workshop and will be part of the phase 4.

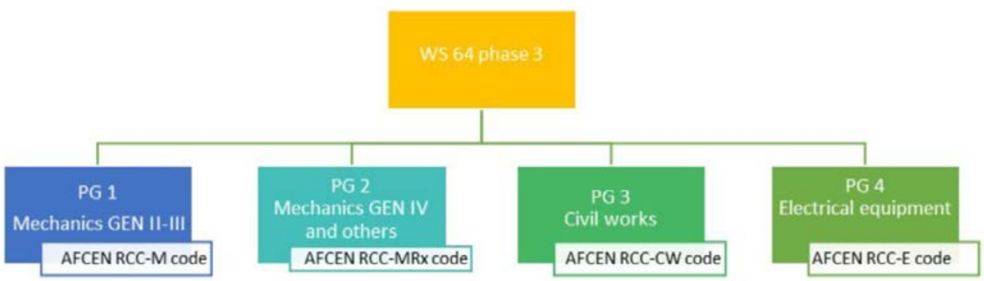


Figure 5: Organization of CEN Workshop 64 Phase 3

Results of Phase 3 for RCC-MRx

The workshop is still running, but there are already some Code Evolution Proposals and one R&D proposal in the PG2, dedicated to RCC-MRx code.
Regarding code evolution proposals, 5 requests have been drafted by the Workshop. All this Code Evolution Proposals have been transmitted to AFCEN RCC-MRx sub-committee, and all of them will be introduced in 2022 edition of the code. The topics are:

- Introduction of an alternative method for creep fatigue, for material with cyclic softening behaviour. [4]
- Small Punch testing for material properties screening and in-service inspection in appendix A20
- Introduction, in the REC part of the Code, of additional requirements and special instructions for equipment subject to NQA-1 when NQA-1 is amend to comply Belgian and European regulation, for a facility build in Belgium.

- Creation of a new chapter “other material selection parameters” in RB 2000 part of the code. It enable to to introduce the materials comparisons based on screening tests and especially based on small punch test techniques according to EN 10371 (although standard specimen tests are preferable).
- Last topic do not directly deals with RCC-MRx code, but with an associated document which is called PTAN new material [5]. The idea here is to extend the scope of the document to cover also the introduction of welds.

The topic of Small Punch Test has been deeply discussed in the Workshop, in addition to the 2 Code Evolution Proposals there is also a R&D proposal on this item: “Using the small punch test techniques for estimation of material properties in support of material development and in-service life management”. The proposal presents a comprehensive test program to validate the use of the small punch test for various applications, such as ageing factors, but it also provides the path forward to fully exploit other features such as multi-axiality effects, inherent in the small punch test of components. It has become necessary for inclusion of the small punch test in design codes. Moreover, a deeper understanding will also allow further development of small punch test standard. The proposed 3 years project consists of 7 Work Packages. At the end of this project it is foreseen that the SPT testing techniques have a substantial materials data base for qualifying the test method for some industrial key-tasks and RCC-MRx in particular.

TOPICS UNDER DEVELOPMENT

As already mentioned, RCC-MRx code is always evolving to fit the needs of projects. Next edition is now planned for 2025, and RCC-MRx sub-committee has already identified a certain number of topics for potential integration in the code.

Openning to other codes

A collaborative work has been done about code evaluation comparison using two high temperature design/assessment methods [R6], namely RCC-MRx and R5. One conclusion of this work is that both methods are appropriately conservative and gave robust results for the creep and creep fatigue evaluations. In the future, it is envisaged to reference as an alternative method, other methodologies developed in other code or reference.

Integration of innovative process: Additive Manufacturing example

With the objective of qualification of this innovative process, NUCOBAM (NUclear COmponent Based on Additive Manufacturing) is a European research project coordinated by CEA, which aims to establish a methodology for qualifying nuclear components made by additive manufacturing. The grade of interest is 316L stainless steel and the process is the L-PBF (laser powder bed fusion). Two components are to be manufactured: a safety valve block body, and an anti-debris filter (fuel assembly component). These two components will be tested under working conditions (pressure, heat and irradiation) to demonstrate that they meet in-service requirements in agreement to conventional manufactured components. The interest of this project is to associate to the technical developments an aspect of standardization and resulting qualification methodology for nuclear components will be proposed for standardization in ASME [8] and RCC-M [9] codes. Started in 2020, NUCOBAM project will run for 4 years bringing together 13 partners from 6 different countries all of them working in the nuclear industry: CEA, EDF, Framatome, IRSN and Naval Group (France), ENGIE Laborelec, Tractebel and SCK·CEN (Belgium), CIEMAT (Spain), USFD (England), VTT (Finland), Ramén Valves (Sweden) and the European Research Centre (JRC).

Harmonization initiative

Another initiative, called HARMONISE (towards harmonisation in licensing of future nuclear power technologies in Europe) is proposed in Europe with the objective to propose some recommendations to face in an harmonised way the licencing of innovative reactors that are not especially handle in the existing licencing frame. Here again the interesting point is that codes and standards are part of the proposal.

Development of rules for high irradiation

For edition 2025, RCC-MRx sub-committee has planned to work on irradiation rules with the objective to extend the current scope of the code to higher irradiation domain. The idea is not to extend the field of validity of the current rules, but to integrate into the code new rules that take into account levels of irradiation beyond what is covered by the code today.

NOMENCLATURE

AFCEN	International association that publish RCC codes
ASME	American Society of Mechanical Engineers
ASTRID	Advanced Sodium Technological Reactor for Industrial Demonstration
CEN	European Committee for Standardization
CEN-CENELEC	European Electrotechnical Committee for Standardization
ENEF	European Nuclear Energy Forum
ESNII	European Sustainable Nuclear Industrial Initiative
ESPN	Regulations of the Under Pressure Nuclear Equipment in France
GMAW	Gas metal arc welding
JHR	Jules Horovitz Reactor
NQA-1	Nuclear Quality Assurance
NDE	Non Destructive Examination
PED	Pressure Equipment Directive
PTAN	AFCEN Technical Publication
RCC-CW	Rules for design and construction of PWR nuclear civil works
RCC-E	Design and construction rules for electrical and I&C systems and equipment
RCC-M	Design and Construction Rules for Mechanical Components of PWR Nuclear Islands
RCC-MR	Design and construction rules for mechanical components of nuclear installations applicable in high temperature structures
RCC-MRx	Design and Construction Rules for mechanical components of nuclear installations: high-temperature, research and fusion reactors
RCC-MX	Design and construction rules for mechanical components of research reactors, their auxiliaries and their associated experimental devices
RPP	Probationary Phase Rule
RPS	Reference Procurement Specification
R5	Procedures for Assessing Structural Integrity of Components under Creep and Creep-Fatigue
SFR	Sodium Fast Reactor
SPT	Small Punch Test

CONCLUSION

This article shows it is challenging to develop a standard for innovative reactors, as the community is wide and with a strong diversity.

Challenges are multiple and it is a permanent work to follow the developments. To face these challenges, and to answer to the users requests on harmonization and simplification, we are convinced that a collaborative work between all the stakeholders of the innovative world, which represent a large community but with multiple faces, is the best way to reach the objective to deliver tools adapted to the future.

ACKNOWLEDGMENTS
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