GRADED APPROACH AND PRACTICES FOR THE MECHANICAL COMPONENTS OF FRENCH RESEARCH REACTOR PROJECTS

C. PASCAL
AREVA TA Research and Modular Reactor Division,
Aix en Provence Cedex 3,
France

Abstract

The graded approach has been implemented for a long time for research reactor projects in France. The purpose of this paper is to focus on their implementation for mechanical components and the associated lessons learned from research reactor projects and operations. The presentation and the full paper will present the implementation of the graded approach, the main requirements associated with the safety classes, the principles of their implementation into the design and construction codes, the principles of interaction with the nuclear pressure equipment regulations and the provisions taken into account in the design and construction code and the benefits of these practices and the lessons learned in this field on the basis of some examples.

1. INTRODUCTION

The graded approach has been implemented for a long time for research reactor projects in France. The purpose of the paper is to focus on its implementation for mechanical components and the associated lessons learned from research reactor projects and operations. These issues are taken into account in the implementation of the graded approach for mechanical components.

The practices integrate the lessons learned from 60 years of French research reactor design and operation and are based on the following features:

- 3 classes of safety classified components according to their importance with regard to safety;
- The associated requirements are graded and deal mainly with management, design, qualification, construction, inspection, testing and in service inspection and testing.

2. CONTEXT

2.1. Safety classification

Typically, a safety classification process based on 3 safety classes is used for French research reactors. The precise criteria are expressed for each project in accordance with [1] and the typical approach is as follows:

- All systems, structures and components (SSCs) are classified on the basis of their importance to safety;

- The safety classification of an item of plant is determined on the basis of the following categories:

  - Safety Class (SC) 1: Any SSC that forms a primary means of ensuring nuclear safety;

- o Safety Class 2: Any SSC that makes an important additional contribution to nuclear safety, or any SSC whose failure may challenge another SC-1 or 2 item;
- o Safety Class 3: Any other SSC that is not allocated to SC-1 or 2, or any SSC whose failure may challenge another SC-3 item.

Depending on the reactor's main features and characteristics, the classification leads to nuances for the safety systems and the components whose failure would lead to severe consequences. Sometimes, such SSCs do not exist for low power research reactors for which the removal of the residual power is not necessarily a stringent issue.

However, the SSCs required to ensure a reactor trip are always classified as SC-1.

2.2. Specificities of mechanical components for research reactors

Mechanical components have to fulfil the confinement, containment, guiding or support functions. In addition, they may have the following specificities:

— Use of low neutron capture materials such as aluminium or zirconium alloys for the reactor block components operating at low pressure and temperature;
— Use of slender structures for the experimental devices operating up to extremely severe pressure and temperature conditions;
— Highly aggressive irradiation conditions inducing nuclear heating and neutron embrittlement of mechanical structures.

Any resulting specific mechanical damage must be prevented by the design and construction rules. At the time that the JHR (Jules Horowitz Reactor) project was launched, there were no formalized rules available.

The pre-existing collection of rules used to design and construct the former generation of research reactors was obsolete, in particular, with regard to the referenced standards, the evolving regulations and the progress of the state of art in the industry. Therefore, the RCC-MX project was launched and completed to provide a reference for the design and construction of the JHR components and the irradiation devices.

2.3. Graded approach to safety classification

With regard to the grading of requirements applicable to SSCs reflecting of the associated safety classification, each project defines the implementation provisions of the following principles for the management of activities, the activities themselves and the SSCs:

— Management of activities:

- o The grading deals mainly with the management system requirement, in particular, the level of detail in the planning of the activities, the level of traceability, the configuration management including change management, the purchasing and surveillance requirements, the management of non-conformances, the level of in-process controls and the need for hold and witness points. In particular, extensive traceability is required for SC-1&2 systems;

— Activities:

- o For the design, the grading deals mainly with the level and detail of the analysis of the design, the degree of verification of the design and the need for alternative

calculations to be carried out. All SC-1&2 systems are subjected to extensive analysis of the design;
  - For the qualification, the grading deals with the methods which are acceptable such as qualification by testing (preferred for SC-1&2 systems), qualification by analysis (mainly for SC-2&3 systems);
  - For the manufacturing and construction, the grading deals mainly with the raw material component or the basic components procurement specification, the qualification of construction processes (such as forging) and the qualification of personnel, together with the level of detail for inspection and test plans. For SC-1&2 systems, extensive inspection and testing plan are required in order to validate the process step by step. For SC-3 systems, the main test and inspection activities are carried out on the final product;
  - For the commissioning, the grading deals mainly with the control of commissioning tests from inactive commissioning through active commissioning to handover to full operations;
  - For the facility operations, the grading of the SSCs deals mainly with the maintenance, surveillance, testing, inspection and operating procedures documentation;

- Products:

  - For the SSCs, the grading deals mainly with their capability to fulfil their safety function especially in terms of reliability.

One consequence of these requirements, in particular the traceability, is that the SC-1&2 components are specifically designed and manufactured for their nuclear application.

Commercial off the shelf (COTS) components are acceptable for SC-3 after they have been subject to a formal qualification.

2.4. Requirements of the nuclear pressure equipment regulation

The nuclear pressure equipment regulation concerns:

- Pressure equipment specifically designed for nuclear applications, which are used or aimed to be used in a nuclear facility, directly ensuring the facility remains within its operating conditions and to ensure the confinement of radioactive substances;
- Pressure equipment for which there is the potential (in the event of a failure) for a radiological release of greater than 370 MBq.

The regulatory requirement consists mainly of:

- Essential safety requirements (in addition to the requirements issued from the Pressure Equipment Decree which transposes the EC Pressure Equipment Directive within the French regulations);
- Material characteristics;
- Inspection and testing, in particular, inspection of welds;
- Compliance assessment with regard to the essential safety requirements.

Naturally, these requirements interact directly with those considered in the design and construction of safety classified components. Some adaptations of the design and construction rules were required to fulfil them.

3. DESIGN AND CONSTRUCTION CODE FOR MECHANICAL COMPONENTS

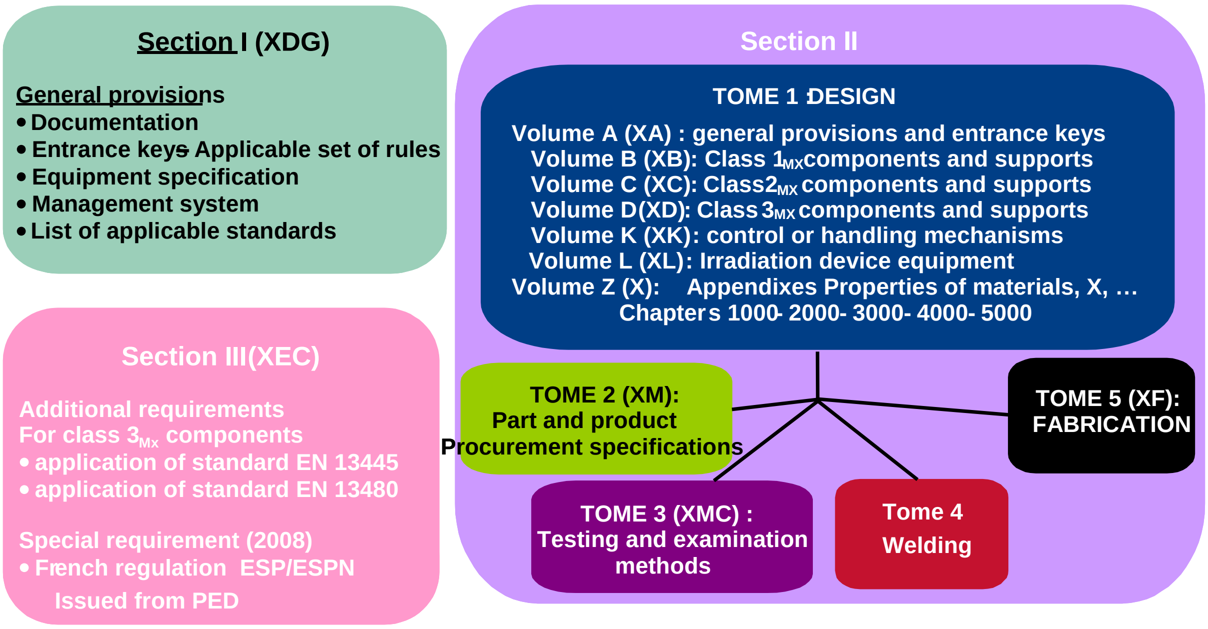
3.1. RCC-MX overview

To facilitate the implementation of this graded approach in an operational way for projects, these requirements have to be specified in detail. As a result, the CEA and 2 AREVA's companies (AREVA TA and AREVA NP) launched the preparation of a new design and construction code called RCC-MX. The objectives of having a code available for the design and procurement of the JHR components and the design and procurement of new irradiation devices were respectively achieved in 2005 and 2008.

This new design and construction code dedicated to research reactor components, their auxiliary systems and irradiation devices integrates the following features:

— Same philosophy as the family of RCC codes:

  - RCC-MX classes: the so-called level Class 1MX, Class 2MX, Class 3MX corresponding to a decreasing requirement for assurance of the safety level with regard to the different levels of mechanical damage to which they may be subjected due to various loads in different specified conditions;
  - Same organisation of the sections and chapters;
  - Same logic;
  - Common set of rules (as far as possible);



— Irradiation devices with possibility of using COTS;

— Provisions for COTS utilization in Class 3MX;

— For Class 3MX pressure equipment, an alternative choice is proposed between Section II chapters XD (similar to RCC-M and RCC-MR) and Section III using harmonized European standards and the use of product standards : EN standards 13445 (vessels) and 13480 (pipes);

— Possibility of using standards for finished products (e.g. pumps, valves etc.);

— Specificities aimed at satisfying the French regulations are grouped into a specific section (for ESP, ESPN).

It integrates the lessons learned from previous rules and projects and formalizes industrial practices. These rules are developed by adding complementary requirements and precision as additional layers around the up-to-date international standards (ISO International or EN European standards). In particular, for Class 3 equipment, provisions are defined allowing the use of COTS.

A huge effort has been applied by collecting the available irradiated material data and is continued through a major characterization program of materials especially focused on irradiated material properties and aluminium and zirconium alloys.

3.2. Main features of the code as regards the graded approach

With regard to the graded approach, the code comprises the following main options:

Design	1 MX	2 MX	3 MX
Structural and stress analysis	Complete including irradiation, creeping and notch effect	Complete including irradiation, creeping and notch effect	No irradiation or creeping
Stress analysis	Sm	Sm	S Fatigue analysis not required
Bolts	Smb	Smb	Sb Fatigue analysis not required
Welding	Design rules XB Compatibility with volumic NDE	Design rules XC Compatibility with volumic NDE	Design rules XD
Pumps	1&2 Rules	1&2 Rules	3 Rules
Pipes	1 Rules	1 Rules	1 Rules using S or alternative rules
Bellows	1 Rules	1 Rules	1 Rules using S

Procurement of products and parts& manufacturing	1 MX	2 MX	3 MX
Procurement according standards		Parts standards possible for irradiation devices only (fittings and bolts)	Parts standards possible for irradiation devices only (fittings and bolts)
	Differences according to products and levels dealing with inspection and its extension		
Casted products	Casted products	Casted products	Casted products
Procurement according TRS (technical reference specification)	Differences according products and levels dealing with inspection and its extension		
COTS	No	No	Yes
Qualification of welding processes	Iso standard for destructive test + 1 MX NDE	SameIso standard for destructive test + 1 MX NDE	Iso standard for destructive test + 1 MX NDE
Qualification of welders and operators	Iso standard + Radiographic testing for full penetration BW	idem 1 MX	idem 1 MX
Production welding	Acceptance criteria 1 MX	Acceptance criteria 2 MX Welding coupon 1 MX	Acceptance criteria 3 MX Welding coupon 1 MX

	Welding coupon 1 MX		
Technical program of manufacturing	Qualification before manufacturing of parts and raw products	Qualification before manufacturing of parts and raw products when requested in the technical reference specification	No qualification before manufacturing

So in most of the cases, the projects select a direct correspondence between the safety class and the design and construction class of the code. The projects already have to define in their specifications those items which are not defined within the code such as design review, need for independent assessment etc.

4. FINAL REMARKS - CONCLUSIONS

Even if the graded approach for mechanical components is not formalized in a regulatory text, the French practices are well established for mechanical components. The requirements to be applied are formalized by each project. They implement the principles defined in ref [1] and are based on the utilisation of a design and construction code which proposes 3 design and construction classes for which a graded approach is integrated. An internationalisation of the code currently in use for the JHR design and manufacturing is on going. It should be published by the end of 2012.

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Research Reactors, IAEA Safety Standards NS-R-4, IAEA, Vienna (2005).