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SUB-CHAPTER 3.8 - CODES & STANDARDS USED IN THE EPR DESIGN

1. INTRODUCTION

The aim of this sub-chapter is to give an overview of the codes and standards used in the EPR design. As the set of codes and standards is part of the French regulatory regime, a general description of the structure of French safety regulation is given as an introduction of this sub-chapter. The contents of the codes and a comparison with international practice are then briefly described.

In general, technical regulation of nuclear facilities in France is organised within a hierarchical structure with four main levels. Sub-Chapter 3.8 - Table 1 gives a schematic presentation of the hierarchy of French safety regulation, the different levels being structured as follows:

- Level 1 includes the legal requirements issued by public authorities (parliament or government) with regard to nuclear safety, nuclear security and environmental protection. It comprises laws, decrees and orders. As an example, one of the main applicable laws is the French Act n°2006-686 of 13 June 2006: "Loi n°2006-686 du 13 juin 2006 relative à la transparence et à la sécurité en matière nucléaire",
- Level 2 includes all Basic Safety Rules (RFS) applicable to certain types of nuclear facilities and which lay down requirements. For the relevant type of facilities and within the scope of application covered by the RFS, compliance with these requirements is considered to be equivalent to compliance with French technical regulatory practice. Level 2 also includes all letters sent by the French Safety Authority to the nuclear operators which form the basis of technical regulation,
- Level 3 includes rules, codes and standards applicable to industrial practices which are adopted for the design, construction and commissioning of safety related equipment. French industry has issued these in the form of a set of rules for design and construction of PWRs, designated by the acronym RCC for the current plants in operation, or ETC (EPR Technical Codes) for codes specific to EPR. Application of these rules for the current fleet of NPPs is confirmed, by Basic Safety Rules,
- Level 4 includes all documents which are necessary to build and operate the plant which provide justification that the plant is designed and operated according to French regulatory requirements. This level contains documents such as the safety analysis reports, system descriptions, drawings, detailed design reports, etc. These documents are issued by the French utilities. They are either sent for assessment to the French Safety Authority or retained by the Utilities.

According to the French safety regulation structure, codes and standards are part of "Level 3".

The systems, structures and components are designed, constructed and tested according to up-to-date codes and standards, which comprise:

- The **technical code for mechanical equipment (RCC-M)**: Initially based on the US ASME code, RCC-M [Ref-1] lays down design rules (design basis and analysis of behaviour) and construction rules (specifications for manufacturing and inspection of equipment) for pressure vessels, reactor internals and nuclear island pipework and equipment supports. It codifies French industrial practice and benefits from experience from manufacture, inspection and operation of French units.
- The **technical code for critical defect size calculations for mechanical components (RSE-M Appendix 5.4)**: the RSE-M Appendix 5.4 [Ref-2] is used to supplement the RCC-M code in order to address the UK EPR fast fracture analysis of mechanical components. It codifies French industrial practice and benefits from significant R&D performed in France to support defect assessment methodology using analytical approaches.
- The **technical code for electrical equipment (RCC-E)**: RCC-E [Ref-3] [Ref-4] provides a supplement to international standards (IEC standards) and French standards (AFNOR standards), to include subjects which are not yet covered by the latter or to supply clarification when existing standards do not allow adequately for the specific requirements of the nuclear industry. The level of detail is thus somewhat variable. RCC-E applies to electrical and I&C equipment whose failure can have consequences for the safety of people or a significant effect on the availability of the plant.
- The **EPR Technical Code for Civil Works (ETC-C)**: the ETC-C [Ref-5] contains rules for the design, construction and testing of the EPR civil engineering structures. It describes the principles and requirements for safety, serviceability and durability conditions for concrete and steelworks structures on the basis of Eurocode design principles (European norms for structures) together with specific provisions for safety-class buildings. The section covering "design" lays down the essential actions and requirements by which buildings and structures are engineered.
- The **EPR Technical Code for Fire Protection (ETC-F)**: the ETC-F [Ref-6] contains requirements for fire protection (prevention, detection and suppression) in the design of the EPR Plant. It is based on the existing French RCC-I code (June 92 issue) applicable to current French nuclear plants, on French AFNOR standards and the relevant German KTA-Safety Standards (applicable to German plants). ETC-F is the result of a long process of development using experience from the construction program of French and German nuclear plants including feedback experience from fire events occurring in these units. ETC-F states requirements for fire protection but does not propose design solutions to meet these requirements.

The development of Design and Construction Rules is carried out within the "Association Française pour les règles de conception et de construction des matériels des chaudières électronucléaires" - AFCEN (French Society for Design and Construction Rules for Nuclear Island Components). AFCEN was created in 1980 by EDF, Framatome and Novatome to develop French Nuclear Codes and Standards for different types of plant. Sub-Chapter 3.8 - Table 2 summarises the current AFCEN organisation, including new Codes which are integrated: the RCC-MX code for experimental reactors, the ETC-C Civil Engineering Code and a new version of the ETC-F.

Representatives at the sub-committee level and above are from AREVA or EDF. At the Working group level, representatives from other industries and organisations are involved e.g. CEA, TECHNICATOME, DCN; in the future this is likely to be extended to French Nuclear Notified Bodies. Requests for interpretation or modifications may be proposed by all the international codes users.

2. TECHNICAL CODE FOR MECHANICAL EQUIPMENT (RCC-M)

2.1. INTRODUCTION

After around 20 years of use of ASME Code rules and the EDF specification for Fabrication and Control, EDF and AREVA decided to develop a design code of their own which was more in accordance with French industry practices, including developments in R&D and field experience. The 1st RCC-M version was published in 1984, and was used for the last 14 French plants and in some AREVA designed plants in other countries. Today, after more than 20 years of use and with developments in the ASME Codes, a number of detailed differences exist between the codes, but within a globally similar philosophy. The differences between RCC-M and the ASME Codes and the major reasons for these differences in relation to EPR design, are discussed below.

2.2. STRUCTURE OF SUB-SECTIONS AND RELATIONS BETWEEN SECTIONS AND SUB-SECTIONS

The general structure of the RCC-M code and the relation between sections and sub-sections is presented in Sub-Chapter 3.8 - Table 3.

2.3. COMPARISON ASME – RCC-M

2.3.1. Structure of the codes

The RCC-M structure is presented in Sub-Chapter 3.8 - Table 4, which also shows the correspondence with the equivalent ASME code sections. The structure is similar, although certain topics that are grouped within RCC-M are dispersed in ASME, such as fabrication requirements.

2.3.2. General considerations

Classification of components was covered in RCC-M A.4000 until the 2005 addendum. The classification took into consideration the component's safety function via the safety classification defined in Sub-Chapter 3.2 of the PCSR (as it is the case where the ASME code is applied) as well as the operating conditions of the component (pressure, temperature, fatigue risk), which might lead to an equipment upgrade depending on fatigue risk. Small components were identified (vessels with internal volume less than 100 litres, pumps with a driving power of less than 160 kW, small piping) and a specific sub-section, E, was dedicated to them.

In the RCC-M 2005 addendum, the main secondary system components may be classified class 1. As a result of the new regulation, no specific code can be imposed. The code classification must only take into account the safety classification and the classification N1 to N3 reflecting the potential radioactive release. The rules concerning the identification of the fatigue risk were moved to a specific sub-section (RCC-M C.3100), which requires that a specific technical evaluation is carried out if risk is significant. The same approach is used in EN or CODAP standards. Every hazard must be adequately covered, but has no impact on equipment classification.

The RCC-M code does not include provisions for certification and stamping of equipment as is the case with the ASME code. It is focused on technical aspects. Surveillance of activities by or on behalf of the owner and the contractor or suppliers must be covered in contractual documents.

2.3.3. Comparison of design rules

The relationship between loading conditions, damage prevention and safety margins in the 1974 French Government Order, is given in Sub-Chapter 3.8 - Table 5. These provisions are no longer included in current regulations, but help to explain some differences between the RCC-M and ASME codes for class 1 equipment. In order to satisfy the damage prevention criteria, appropriate criteria levels are specified in the various loading conditions.

As developed in RCC-M B.3100, each criterion corresponds to the prevention of a given set of damage levels, with appropriate safety margins.

Due to the fact that level 0 criteria apply in design conditions that envelope normal and upset conditions, the level A criteria specified in normal and upset conditions are restricted to damage conditions other than excessive deformation and instability.

For class 2 equipment, the regulations were less developed and rules are closer to ASME provisions, except for some changes in structure (such as the introduction in RCC-M 3000 chapters of weld design covered in ASME 4000 chapters, integration in RCC-M C.3200 of rules for design by analysis covered in ASME III Appendices XIII and XIV, modification of the RCC-M B.3500, C.3500 and C.3600 structures to give a more harmonised and clear correspondence between loading condition categories and applicable criteria, and the integration of design rules for storage tanks in a specific sub-section).

2.3.3.1. Prevention of excessive deformation and plastic instability

The RCC-M B.3100 general chapter explicitly introduces the relation between the loading condition categories and damage prevention, according to the requirements in Sub-Chapter 3.8 - Table 5.

It also groups under the ASME Normal and Upset conditions with the same level 0 criteria under "Second Category Conditions", leading to the suppression of ASME level B service limits. This means that the 10% increase in allowable primary stresses under pressure loading due to upset conditions is not allowed by RCC-M. Exceeding the design pressure is consequently only permitted in a third category (emergency) condition.

Design methods are similar in RCC-M and ASME III codes. ASME NB 4000 provisions on weld design are covered in RCC-M B.3000, with ASME requirements extended to conform to French regulations.

Rules for reinforcement of openings are similar: they are covered in Appendix ZA of RCC-M, with a non-mandatory status, the proof of reinforcement being given by analysis. A 20% margin against excessive deformation is required in third category (emergency) conditions whereas ASME criteria allow a close approach to the excessive deformation threshold. Due to this 1.2 safety factor, RCC-M criteria are more stringent: for example, in RCC-M NB.3600 Equation (9) for limitation of primary membrane plus bending stresses in piping systems, the ASME 2.25 S_m limit is replaced by a 1.9 S_m criterion, providing the required additional 20% margin.

RCC-M assessment begins with the definition of component damage, from which stress classification results, which must be justified, taking into account the requirement to prevent the damages level. This has led to suppressing the ASME guidance rules for stress classification in the code for class 1 components. This guidance rule is nevertheless kept in RCC-M C.3000 for class 2 components. In case of elastic-plastic analyses, a direct verification of Sub-Chapter 3.8 – Table 5 safety margins against plastic instability has been included in B.3243 of RCC-M. Finally, the rules are similar but not identical and can lead to different final designs of nozzle reinforcement.

2.3.3.2. Buckling

The prevention of buckling under compressive loads is covered in RCC-M Appendix Z IV. Provisions are roughly equivalent to ASME rules and applicable diagrams are similar for materials of equivalent grades. For materials for which diagrams are not available, analytical expressions have been added in order to permit external pressure design using specified mechanical properties.

These requirements incorporate greater safety margins compared to ASME type diagrams. In the case of elastic-plastic analyses, a direct verification of the safety margins against elastic or elastic-plastic instability required by the 1974 French Government Order has been included in B.3243 of RCC-M.

2.3.3.3. Prevention of progressive deformation and ratchetting

Progressive deformation criteria are similar in the ASME and RCC-M codes. The main differences between codes concern the integration of the through-thickness thermal gradient (corresponding to the so-called ΔT_1 term in Equation (10) for piping systems). This is not connected with the prevention of progressive deformation damage, but is related to plastic strain correction determination in fatigue analyses. Where limits applicable to the range of the sum of primary and secondary stresses (the 3 S_m rule) are exceeded, a simplified elastic-plastic analysis is permitted in a similar way as in the ASME III code (equations (12) and (13) in the piping analysis rules are similar). The thermal stress ratchet rule (verification of Bree diagram) is also similar in both codes and must in any case be verified according to RCC-M.

2.3.3.4. Fatigue prevention

Fatigue analysis requirements are discussed in another section of the report. The RCC-M rules are basically similar to those of the ASME III, with differences in transient combinations, which are more developed in RCC-M, with alternative practices given in Appendix Z-H.

Fatigue exemption rules have been suppressed in the RCC-M class 1 section, as a result of the transient combinations rules: a transient, which can be negligible when considered alone, can become significant when combined with another transient. It is nevertheless agreed that, in practice, fatigue exemption rules can be applied to sub-cycles which are not likely to be combined with other transients. The fatigue exemption rules must not be confused with B.3624.4 provisions on rapid temperature fluctuation effects in zones where fluids at different temperatures can mix. These additional precautions result from the in-service experience. Where temperature differences between fluids before mixing exceed given thresholds, additional precautions must be considered in order to reduce the fatigue risk, such as design changes, reductions in roughness and residual stress levels, or improved in-service surveillance.

This approach results from the RCC-M philosophy, which is based on determination of fatigue usage factors in the low-cycle fatigue range, and on avoiding as far as possible stress fluctuations in the high-cycle fatigue region, where calculated usage factors are of less significance.

Where a simplified elastic-plastic analysis is applied, a plastic strain correction factor K_e must be applied to the elastically calculated stress range. The correction is calculated from the primary plus secondary stress range. The integration of through thickness thermal gradient in this stress range is likely to lead to too severe a correction if the ASME K_e correction of the "elastic follow-up" type is applied to the complete mechanical plus thermal stress. This has led to improved fatigue strain correction factors in RCC-M, with a correction which is a function of the mechanical and thermal components of the primary plus secondary stress ranges and corrections dedicated to each of these parts. These proposals are known and discussed by ASME committees.

Another particular aspect of RCC-M is the fatigue analysis of crack-like discontinuities (partial penetration welds for example), where a special approach has been developed establishing a relation between the stress range very close to the discontinuity and the number of allowable cycles specified by dedicated curves developed for representative configurations. A specific Appendix ZD has been prepared to cover this approach. The development of this method was the result of a lack of adequate guidance in NB-3222.4 of the ASME code, which states that "except for the case of crack-like defects... no fatigue strength reduction factor greater than five need be used".

In addition, compared to ASME NB 3661.2 limitation of Socket Weld joints to below DN50, the corresponding RCC-M B paragraph 3661.2 limits their use to inside diameters less than 25 mm.

A new approach which has been introduced in USNRC Regulatory Guide 1.207 or NUREG/CR 6909 to take into account water environmental conditions in the fatigue analysis has not been introduced in the RCC-M code. This code case is considered too conservative. Moreover the environmental effects in the fatigue analysis have not been confirmed by field experience and in particular the representativeness of mechanical loads applied to specimens in standard laboratory conditions towards thermal cyclic load imposed on a given structure in real conditions.

Complementary analyses are being performed internationally (including France, Europe and USA) to propose more realistic rules than NUREG/CR 6909.

2.3.3.5. Fast fracture prevention

Fast fracture is defined in the French regulations as covering brittle failure and ductile tearing. The rules in RCC-M Appendix ZG consequently cover the brittle to ductile transition and low upper shelf materials.

Appendix ZG contains three approaches:

- a first method based on application of exemption rules,
- a second method which takes into account a 1/4 thickness defect (not greater than 20 mm), a toughness reference curve similar to the ASME III Appendix G approach, but for which margins in RCC-M are greater than in the ASME Code. In RCC-M this approach may be used in faulted and accidental conditions with reduced margin coefficients, whereas the ASME code requires a case-by-case approach,
- a third approach which was developed and extended to all operating conditions for limiting cases. It considers an envelope defect covering potential fabrication and fatigue growth during plant life. Criteria are defined which prevent the risk of fast fracture with safety margins consistent with those applied against plastic instability.

Developments of RCC-M rules are under discussion, based on experience from application.

2.3.3.6. Design of specific components

In addition to the comments on piping rules given above, Appendix ZE provides an alternative method for the verification of level A criteria (progressive deformation and fatigue) which gives the possibility of combining results obtained through detailed and simplified analysis. The applied stress indices are slightly different.

Requirements for rapid temperature fluctuations in B.3624, and crack-like discontinuities, have been discussed previously.

Compared to the ASME code, the structure of RCC-M rules for valve design is harmonised with the piping design rules. The technical bases of both sets of rules are similar, the consideration of external loads on valves being slightly more severe in RCC-M at the request of the French safety authority. Detailed analysis is required for valves with an internal diameter larger than 25mm (compared to ASME 4" ND).

Class 1 pumps covered in the RCC-M are restricted to the pump types used for the primary pumps. For pumps of this type, the RCC-M refers to the rules applicable to vessels with limited supplementary provisions, which are in practice equivalent to those in the ASME III code.

2.3.3.7. Pressure tests

Pressure tests are conducted according to French regulations. Historically, French requirements were more stringent than US requirements (1.25 x the ratio of material resistance at test temperature, compared to resistance at design temperature, for class 1, and 1.5 times design pressure for class 2/3). Stress criteria are adapted accordingly.

Pressure tests constitute partial "verification" of design and construction. They should not have an impact on sizing of equipment. Test pressures and associated criteria in each code are consistent from this point of view. In case a more stringent test pressure is applied – for example in case of PED application – the code stress criteria must be re-evaluated accordingly. At present, European pressure equipment rules require a minimum test pressure of 1.43 x design pressure.

2.3.3.8. Class 2 and 3 pressure components

Rules for class 2 and 3 components cover the same general provisions as class 1 components, except they do not explicitly express the approach in terms of damage prevention. In the same way as in the ASME III code, a design by rules approach may be used. The difference lies in the fact that where fatigue loading is considered significant, a design by analysis must be employed where it exists. For valves and piping, a reference to class 1 provisions is included to cover complementary analyses, where required by the equipment specification.

Following experience from N4 plants, recommendations relative to the fatigue risk in zones where fluids at different temperatures mix have been included in RCC-M. Following a comparative evaluation of manufacturing criteria in RCC-M and ANSI B.16.34, the ANSI special class has been retained for class 1 and 2, and the standard class for class 3 for establishing the pressure-temperature rating of valves.

The modifications introduced in 1981 in the ASME III code equations to introduce a limit of tensile strength for the piping and to change the form of the moment term for class 2 and 3 piping have not been taken into account in the RCC-M code following technical analysis by AFCEN and the French Safety Authority; the RCC-M code rules remaining sufficiently safe with the initial equations [Ref-1] [Ref-2].

With regard to pump sizing, a specific study has been conducted under an agreement with the French Association of Pump Manufacturers. Pressure sizing rules and consideration of external loads on pump casings are covered in RCC-M. The RCC-M rules take into account manufacturers' practices, finite element analyses and experimental extensometer measurements on pumps subjected to pressurisation cycles.

2.3.3.9. Other equipment

Supports are covered in RCC-M Sub-section H. ASME provisions were considered together with AISC rules on which the ASME rules were based. Regulatory Guides 1.124 and 1.130 of the NRC [Ref-1] [Ref-2] were also considered for establishing stress criteria. As a general rule, a linear behaviour is required for supports in accident conditions. Standard supports are covered by a specific chapter, H.5000, which permits justification by tests.

Internals can be justified either under the RCC-M rules or by reference to the ASME III code. This is the only area where a direct reference to the ASME code is included in the RCC-M.

Storage tanks are covered by a specific sub-section, J. In the ASME code corresponding provisions are included in sub-sections NC and ND (3800 and 3900). The RCC-M objective was to obtain a more simple structure. The provisions are technically equivalent.

2.3.4. Summary of differences with the ASME code

Differences between RCC-M and ASME III codes with regard to design rules are summarised in the following:

- consideration of loading conditions in choosing the design by analysis approach;
- construction requirements related to ISI in Appendix ZS;
- a more explicit reference to damage for stress classification in class 1 components;

- primary stress criteria slightly more stringent in class 1 upset and emergency conditions;
- more detailed fatigue requirements, including the consideration of plastic strain correction factors and crack-like discontinuities;
- weld design requirements conforming to French regulations;
- detailed analysis required for valves above 25 mm ID;
- pressure test conditions;
- linear behaviour specified for supports in faulted conditions;
- rules for pressure sizing and consideration of external loads introduced for class 2/3 pumps;
- precautions specified in zones with mixing fluids;
- additional rules on fast fracture prevention.

The general approach and basic criteria are nevertheless similar in the RCC-M and ASME codes.

2.3.5. Materials

General material provisions are covered in chapters 2000 of the various sub-sections. These chapters include: general rules on selection of grades according to inter-granular corrosion susceptibility and cobalt content limitation, and lists of applicable procurement specifications presented in Section 2 of the RCC-M. RCC-M specified chemical compositions are generally in conformance with ASME II requirements for equivalent grades.

The differences between the codes concern essentially the use of complementary analyses and additional restrictions which are required in order to improve the following properties:

- Inter-granular corrosion resistance,
- limitation on carbon content,
- increase of chromium minimum content,
- control of delta ferrite content,
- product toughness (limitation on S, P and Si content): a minimum KV notch impact energy is required by the RCC-M, which necessitates low inclusions content.
- weldability of stainless steels, through a limitation of Boron content.

From the mechanical properties point of view, the requirements of the RCC-M are equivalent to those of the ASME code for equivalent grades. The RCC-M specifies, in addition, the verification at temperature of mechanical properties consistent with ASME tabulated values for design use.

In addition to the ASME code prescriptions, for low alloy steels RCC-M specifies a verification of mechanical properties after heat treatment, for mechanical properties at room and elevated temperature and not only after simulated stress-relief treatment.

Additionally, Charpy KV tests are also specified for stainless steels. As the RCC-M is dedicated to specific applications it includes provisions which would be expected to be specified, in the US, by contractors in equipment specifications. In particular, RCC-M it is the only code where product procurement specifications are accompanied by dedicated specifications for parts: a precise correspondence between the parts and the applicable specifications is given in the Chapter 2000 tables of the applicable sub-sections.

From this point of view, the RCC-M needs less additional specifications and includes more self-contained procurement specifications, avoiding the need for cross-references.

2.3.6. Manufacturing

General Manufacturing is covered in the 4000 chapters of the applicable sub-sections. RCC-M Chapters 4000 refer to Sections IV and V. They cover the general requirements in chronological order according to component manufacturing, and include provisions specific to the type and class of component covered by the sub-section, or requirements specific to particular components, such as for class 2 components which are part of the Main Secondary System.

Section V of the RCC-M is devoted to manufacturing. Some requirements are included in chapters 4000 of the NB, NC and ND sub-sections of ASME Section III.

Section V provisions are minimum requirements which must be completed by the Manufacturer where necessary. Aspects covered are:

- Marking procedures (chapter F.2000), describing the precautions to be taken in marking, general prescriptions about identification being covered in B, C, or D.1300 chapters,
- Cutting and repair without welding (chapter F.3000),
- Forming and dimensional tolerances (chapter F.4000) including requirements for qualification of forming procedures above given thresholds, and tolerances for parts to be joined by welding. Tube expanding qualification is also covered,
- Surface treatment (chapter F.5000), including electrolytic thin-plating, diffusion treatment (F.5500) and Cadmium coating (F.5600),
- Cleanliness (chapter F.6000), with cleanliness classes defined according to the types of systems and process fluids, and requirements defined on work areas, corrosion prevention, cleaning methods and preservation of cleanliness,
- Mechanical joints (chapter F.7000).
- Heat treatment (parts and components, chapter F.8000). This chapter includes, in particular, periodic checks of thermocouples and inspections of heating and control systems. Measurements and recordings are prescribed with time and temperature continuously monitored on the load unless alternative justification is provided.

2.3.7. Welding

Section IV of RCC-M deals with welding and Section V with other manufacturing processes. As welding is a key operation in manufacturing mechanical components, all aspects of the welding process are presented. The scope of Section IV is consequently wider than that of Section IX of the ASME code, covering aspects contained in other ASME Sections (sections II and III). The global logic for welding qualification and acceptance criteria is illustrated in Sub-Chapter 3.8 - Table 6. The objective in the RCC-M is to provide a single, homogeneous and complete text including specific processes such as weld overlay or friction welding.

Section IV covers:

- In S.1000, weldability and heat treatment of materials and the description of the "Welding Data Package", containing all the welding procedures that are to be applied in manufacturing,
- In S.2000, standardised acceptance conditions and a collection of filler material data-sheets.
- In S.3000, the qualification of welding procedures, with their main variables and scope of validity, with a possible application of alternative provisions in SA.3000, which refer to existing EN standards, supplemented where necessary.
- In S.4000, the qualification of welders and operators, referring to applicable EN 287-1 or EN ISO 9606-4 standards,
- In S.5000, the qualification of filler materials with aspects to be covered by the material supplier or the manufacturer,
- In S.6000, the technical qualification of production workshops, evaluating their capacity and technical resources,
- In S.7000, production welds, with all associated prescriptions. One difference with the ASME code is the requirement to manufacture production weld test coupons, which is common practice in Europe,
- In S.8000, a self-contained chapter covering weld-deposited hardfacing. In addition, appendices are included covering mechanical tests (App. S.I), classification of defects in welds (App. S.II), recommended welded assemblies for pipes (App. S.III). Welding and Brazing qualifications are covered in ASME Section IX (part QW).

The ASME code primarily deals with qualification. The RCC-M S.7000 chapter defines in addition: the examinations to be made, the stage at which they must be conducted (before, during or after welding), the methods to be used, the extent of examination, and the acceptance criteria.

As a result, RCC-M constitutes a more self-contained set of prescriptions than the corresponding 4000 chapters of the ASME sub-sections, and requires less use of complementary requirements in specifications.

2.3.8. Non-destructive examination

Non-destructive examination methods are covered in Section III. This section covers:

- In MC.1000, mechanical, physical, physicochemical and chemical testing,
- In MC.2000, ultrasonic examination methods,
- In MC.3000, radiographic examination methods,
- In MC.4000, liquid penetrant examination methods,
- In MC.5000, magnetic particle examination methods,
- In MC.6000, eddy current examination of tubular products,
- In MC.7000, other examination methods (visual examination, determination of surface conditions, leak testing methods),
- In MC.8000, qualification and certification of non-destructive examination personnel,
- In MC.9000, terminology.

Examinations to be made on products, parts and components (where, when and criteria to be met) are included in Section II for product and part procurement and in Section IV for welding.

The RCC-M approach for NDE is as follows:

- Manufacturing conditions must include appropriate precautions to achieve an appropriate quality level to limit the risk of defect creation,
- NDE is used to assess the required quality level and to detect any deviation in the manufacturing process,
- When unexpected defects appear, a three-step approach is applied: understanding why such defects appear, modifying affected manufacturing parameters, and carrying dedicated NDE to insure that these defects do not appear in the future. In the area of volumetric non-destructive examination, RCC-M places greater importance on ultrasonic examination and requires a double volumetric examination (ultrasonic plus radiographic examination) for the main class 1 primary components.

Criteria may also be different in RCC-M and ASME: for example, in the case of Ultrasonic Testing of plates, the ASME code refers to back wall echo for calibration and acceptance criteria, whereas the RCC-M refers to equivalent Flat Bottom Hole.

The RCC-M criteria can be considered either equivalent or more stringent. Each time a European standard is issued, the RCC-M code is updated to refer to the standard, associated criteria being adjusted to reach an equivalent level of quality.

Qualification of non-destructive examination personnel refers to European EN 473 practices [Ref-1]. Nevertheless, RCC-M allows manufacturers abroad to use personnel certification in force in their own country, if it is delivered by an independent organisation, following equivalent standards.

2.4. CONCLUSIONS

The RCC-M Code objectives and technical scope are similar to those of the ASME III – Division 1 and related sections. Both codes set down minimum requirements which must be supplemented by provisions specific to the application. Due to its more specific scope, RCC-M may include more detailed technical requirements which under US practice would be part of the component specification. On the other hand, the ASME Code includes provisions which are outside RCC-M scope and which are treated differently, such as overpressure protection, requirements applicable to the owner, contractor agreement by the ASME or verification by registered professional Engineers, ASME quality system certificates for material manufacturers, and certification by Authorised Inspectors. Some differences with the ASME Code have been highlighted. It has been noted that RCC-M uses some ASME material, particularly in the design section, with permission of the ASME.

Differences are due to organisational changes and requirements from discussions with Clients and French Safety Authority. The RCC-M code is applicable to French PWR technology and includes all necessary specific topics. Like the ASME Code, evolution of the RCC-M is continuously in the light of industrial experience (new products or processes), related standards, results of Research and Development work, and operational experience. To summarise, RCC-M is an adaptation of the ASME approach to the French and European standardisation context, with organisational aspects excluded to permit its adaptation to international projects. Although the RCC-M and ASME codes may contain different sets of requirements, they result in components of an equivalent level of quality.

3. TECHNICAL CODE FOR ELECTRICAL EQUIPMENT (RCC-E)

3.1. ORIGINS OF THE CODE

3.1.1. General

The RCC-E code (technical code for electrical equipment) is a unique example of a code which gathers all requirements applicable to the electrical components (I&C included) of a nuclear power plant. It makes references to international standards (IEC standards) and French standards (AFNOR standards).

RCC-E is published by AFCEN.

Five editions of the RCC-E have been published by AFCEN which are the 02/1981, 07/1984, 01/1993, 10/2002, 12/2005 editions.

Between editions, any user or reader may send requests for modification to AFCEN. If justified, AFCEN will issue a modification sheet, which will then be incorporated into the next edition of the code.

3.1.2. Scope and application

The RCC-E comprises a set of technical rules to be applied and implemented by a contractor, manufacturer or supplier in the design and construction of electrical equipment.

It is the responsibility of the prime contractor and the contractor to define the list of electrical equipment and systems to be produced in accordance with the RCC-E.

As a minimum, this list must include all safety classified electrical systems and equipment.

Some chapters concern all users - engineers, manufacturers or suppliers- and others concern, more specifically, engineering organisations (as indicated in the "note to the user").

The requirements of the code are referred to in the contractual documents of EDF or main suppliers, especially in the technical specifications of electrical and I&C equipment.

3.1.3. Contents of the RCC-E

The RCC-E is divided in six volumes as follows:

- Volume A: General and quality requirements
- Volume B: Qualification
- Volume C : Functional system design
- Volume D: Installation
- Volume E : Constituent parts of equipment
- Volume MC: Verification and testing methods

3.2. FRENCH EXPERIENCE

RCC-E was used for the first time on the 1300 MW plants (P4 series) in the 1980s. The previous plant series (900 MW) were built before the first edition (1981).

The code is a collection of specifications which existed previously in several documents, and have been gathered in a single document.

Thus the code presents the French practice for all existing PWR plants and for the EPR plant.

RCC-E has also been applied to export units derived from French 900 MW plants, in China, South Korea and South Africa. RCC-E 2002 is used as a mandatory code for the Chinese 1000MW series called CPR1000.

The last edition (12/2005) of RCC-E takes into account the EPR design. Because of the new application, project data in the previous edition were transferred from the code, and placed in a complementary document called the "Book of Project Data" (BPD) which is specific to a given Project.

Two BPDs have already been issued, one for EPR, and one for existing French existing plants (PWR).

3.3. RCC-E VERSUS U.S. AND INTERNATIONAL PRACTICE

It is believed that there is no equivalent code to RCC-E in the US. IEEE standards are used in the US; they consist of separate documents.

IEEE standards were used in the 1970s, for the construction of the 900 MW French plant series, (e.g. IEEE 323 dealing with Equipment Qualification).

After 1980 and especially for the N4 series, EDF replaced US practices with French regulations and adopted French or European standards. The current edition of RCC-E is widely based on IEC standards.

The IEC standards referred to in the RCC-E are listed with the date of the applicable edition. Unless otherwise stated, the applicable version is the latest published version when this code was sent out, including any amendments or technical corrigenda to IEC standards. Where necessary, specific condition of application of standards are specified in the paragraphs in which these standards are referred to.

If, when used, a more recent edition of a standard is published which diverges from the specifications laid down in the version listed below, the user must ask the author of the requirement which edition is applicable.

3.4. IMPACT OF UK INDUSTRY PRACTICES

A comparison has been made between EPR Flamanville and UK practices, in terms of system voltages and systems neutral connections, and interpretation of UK Statutes.

The conclusion has been reached that there is no technical or legal reason, why the electrical system design for the UK EPR need be different from the design being implemented at Flamanville.

4. EPR TECHNICAL CODE FOR CIVIL WORKS (ETC-C)

4.1. INTRODUCTION

The EPR Technical Code for Civil works (ETC-C) was initially developed for EPR safety classified structures by EDF and German Utilities [Ref-1].

ETC-C serves as the basis for the design and construction of structures of C1 classified EPR buildings and describes the safety principles and requirements for concrete and steel structures, including metallic liners, as well as the specific arrangements relating to this class of structures.

The general architecture of the Code comes from RCC-G (Design and construction rules for civil works – July 88) used for French NPPs in which design, construction and testing rules are presented, based on French experience feedback.

The ETC-C code incorporates design experience feedback from a number of pre-stressed concrete containments which were erected using the same or very similar safety concepts. This is allowed by Chapter "Design assisted by testing" in EN 1990.

The ETC-C contents were adapted for the EPR Project to take into account more severe loading scenarios (severe accidents, external hazards) and evolutionary improvements in the design and construction rules applicable in the civil technical field.

The code was updated in 2006 [Ref-2] in accordance with the evolution of the EPR Design (initial Basic Design (BD) and subsequent Basic Design Optimisation Phase (BDOP) and used for Flamanville 3. The final feature of the EPR containment design (2001) combines:

- the PWR 900 MWe concept of disjunction between leak tightness (by steel liner on the whole inner face of pre-stressed shell) and mechanical resistance
- the PWR 1300 MWe and 1450 MWe concept of a double wall containment with an annulus under sub-atmospheric pressure.

The ETC-C code translates, in applicable construction rules and relevant criteria, the safety requirements defined for the EPR civil structures presented in Sub-chapter 3.3 of the PCSR, and in particular the requirements for category 1 safety-classified structures. The code was updated in 2010 within AFCEN framework [Ref-3] to take into account feedback from the design and construction of the first EPR plants and from the assessment performed during the EPR UK GDA.

The AFCEN ETC-C 2010 code shall be used with its UK Companion Document [Ref-4], which includes additional UK specific rules.

The UK companion document (UK-CD) of the ETC-C AFCEN 2010 provides additional or amended requirements for application of the code in the design and construction of EPRs built in the United Kingdom. Where inconsistencies exist between the AFCEN 2010 version of the ETC-C and the UK companion document, the requirements in the UK companion document shall be used.

4.2. CONTENT OF THE ETC-C DOCUMENT

The main aim of the ETC-C document is to provide engineers responsible for detailed design and construction of civil structures with the necessary means to follow the codes and rules in force. It covers various aspects of the design and construction of EPR units.

ETC-C consists of four parts addressing General Design, Construction and Test Requirements for every C1 safety-classified building. Nevertheless, the ETC-C document is considered as a whole.

The structure and the scope of ETC-C is defined within the ETC-C document itself.

ETC-C defines:

- the actions and combinations of actions to be taken into account in the design of civil works;
- the rules or criteria needed to design the C1-classified structures, for concrete structures, for metal parts involved in the tightness of the containment, for pool and tank liners, for structural steelwork, for anchorages and for geotechnical issues.

ETC-C provides the construction criteria (concrete, reinforcement, prestressing system, leaktightness of metal parts, etc).

ETC-C provides the main principles for containment testing, covering the initial acceptance test and subsequent periodic tests.

Part 1 provides the rules applicable to the design of concrete and metallic structures, considering load combinations representative of:

- all situations (normal, incident and accident) due to internal events and hazards occurring in the plant,
- external hazards.

Loading conditions arising in the construction phase are also considered in order to ensure the security, stability and durability of the civil structures. Design calculations assume a 60 year operating life (particularly for the calculation of shrinkage/creep and pre-stressing losses).

ETC-C provides general requirements, based on the limit state concept used in conjunction with the partial factor method as developed in Eurocodes (EN1990, EN1991, EN1992, EN1993 and EN1997) [Ref-1] to [Ref-5] and adapted to this particular project.

General rules and rules for buildings of EC2 (Eurocode 2 - European norm for concrete structures) may be applied as far as possible and must be amended or completed for the design of nuclear plants (no specific section for nuclear plants is included in the EC2).

Due to feedback experience of French and German operating plants (creep and shrinkage for containment as an example) and the foreseeable lifetime, relevant criteria are then chosen in accordance with the retained load cases in order to meet the safety objectives.

The design of prestressing includes feedback from French experience, each prestressing cable being composed of 55 x 15 mm strands (instead of the standard 37 strands) to provide a much higher tensile strength.

The use of prestressing systems without grouting is not considered in this project.

A high Performance Concrete (HPC) with a strength of 60 MPa (as opposed to normal concrete of 36 MPa strength, as used in the 1300-1450 PWR series), is required for the inner containment wall. Such a solution has already been used in the construction of the Civaux 2 unit with favourable feedback.

In addition to the general rules, specific chapters are dedicated to:

- the design of the internal concrete containment wall,
- the design of the liner and of the metal components of the containment (penetrations and plates),
- the design of steel liners for pools.

Detailed methods and calculations are defined in annexes to this part 1 such for seismic analysis, shrinkage and creep, impact and perforation etc.

Part 2 of the ETC-C deals with specific construction rules and is divided into different separate chapters concerning:

- materials: soil, concrete, formwork, rebars, prestressing,

- penetrations, liner for containment and pools, steelwork,
- tolerances.

The technical specifications and the objective of these rules are defined by reference to existing European standards.

In the absence of these standards, technical specifications are defined in UK Companion Document by reference to internationally accepted standards, UK standards or current UK good practice.

Part 3 concerns overall leak-tightness and strength tests in order to provide experimental confirmation of reactor containment integrity.

Before the structure is commissioned, the reactor containment undergoes an ambient-temperature pressurisation test called the “pre-operational” or “acceptance” test during which its strength and leak-tightness are validated.

During the plant operating phase, leak tests are carried out on the containment inner wall and penetrations.

4.3. COMPARISON WITH INTERNATIONAL PRACTICE

In ETC-C, international practice is considered through several aspects:

- The principles of the Eurocodes are used to define the actions and the load safety factors and to define the combination and the criteria for the concrete and steel structures. Section 2 of Eurocode n°2 (**EC2**) is adapted and replaced by chapter 4 of ETC-C because EC2 defines criteria mainly for normal conditions while the EPR design requires criteria for numerous accident conditions.
- The design of the steel liner on the inner containment is similar to that implemented in the French 900 MWe plant series for which ASME criteria were used,
- In ETC-C, the ASME criteria were adapted for the containment liner because of severe accident conditions (high level of temperature with simultaneous high pressure in the reactor building).

5. EPR TECHNICAL CODE FOR FIRE PROTECTION (ETC-F)

5.1. INTRODUCTION

ETC-F is based on the existing French RCC-I (June 92 issue, applicable to French plants) and the relevant German KTA-Safety Standards (applicable to German plants). It consists of rules governing:

- Design principles including the protection concept and personal security¹,
- Structural measures as well as measures for components and equipment.

Generally speaking, ETC-F provides requirements and does not propose design solutions to meet the requirements.

ETC-F is the result of a long process of development which took place during the construction program of the French and German nuclear plants, in which benefit was taken from feedback experience from all fire events recorded in these units.

From the outset EDF decided not to rely only on conventional fire brigades either on the site or in the vicinity of the plants for fire protection. Therefore specific provisions were made in the design of buildings of the nuclear plant with regard to confinement, the separation between divisions, access, and the radiological risk to individuals in case of fire. The decision was taken to justify that fire should be capable of being managed passively to the greatest extent possible (by implementation of fire compartments, fire cells and automatic extinguishing systems).

This decision led to the need for an extensive demonstration of the ability of the various equipment and systems to manage any fire which could occur in a way that nuclear and personnel safety would not be jeopardised. Rigorous qualification tests were done for the various equipment items involved in the fire demonstration. An extensive research program was performed in parallel to determine the effect of fire events on equipment that acted as or in support of a fire barrier.

The first step of this approach was the creation of a guideline by EDF: "Directives Incendie" which was issued in 1975, upgraded in 1980, and following amended was finally accepted by the Safety Authorities in 1987.

The second step was to update the requirements in RCC-I 1997 (Règles de conception et construction Incendie) developed for N4 plants. In parallel new "Directives Incendie" based on the RCC-I 1997 were written, accepted by the Safety Authorities, and applied to all 58 French operating plants

The third step was to merge French and German practices in a common and harmonised approach in consultation with French and German Safety Authorities. This process took place over approximately ten years coinciding with the different phases of the EPR project.

ETC-F is the product of these improvements and EPR takes advantage of the upgrading of fire related protection measures that has resulted.

The French and European regulatory texts or standards for fire protection are listed in ETC-F.

The UK EPR fire design principles as described in ETC-F have been compared with, and shown to be in compliance with, the fire safety principles in IAEA standard NS-G-1.7 (Protection against Internal Fires and Explosions in the Design of Nuclear Power Plants [Ref-1]).

¹ For personal security, requirements defined in Chapter 11 of the European Utility Requirements (Volume 2 – revision C) have been considered in the EPR design in addition to the ETC-F requirements

5.2. CONTENT OF THE ETC-F DOCUMENT

ECT-F contains prescriptions related to protection against internal fires applied in all the technical buildings of a nuclear plant. It is divided into five parts:

- Overall design safety principles to be applied ,
- Basic design options to implement for the fire protection,
- Overall design and construction options,
- Overall layout requirements related to the equipment for fire protection,
- Quality assurance considerations.

In particular, ETC-F takes into account:

- French environmental regulatory requirements (administrative order of December 31st 1999 modified by order of January 31st 2006) which state the general technical regulations implemented to prevent and limit the risks due to fire in the operation of nuclear facilities,
- The ATEX regulation (implemented through French Government Decree no. 2002-1553 of December 24th 2002) which concerned provisions for the prevention of explosions in the workplace, Improved fire resistance requirements and new rules defining fire duration (EPRESSI method),
- The concept of random failure.

The main aim of ETC-F is to provide engineers responsible for the detailed design or construction, with the means of implementing the codes and rules in force.

5.3. SAFETY CONCEPT OF THE ETC-F

The basic requirement is that equipment which forms part of a system performing a safety function must be protected against the effects of a fire so they can continue to fulfil their function, despite a fire inside the basic nuclear facility with the characteristics of the reference fire.

A fire must not result in the loss of more than one train of a F1 system.

The simultaneous occurrence of two or more fires with independent causes which affect different rooms in the same plant unit or different units is not taken into account. A fire is postulated to break out only in normal unit operating conditions (from power state to shutdown state) or in post-accident situation after the controlled state has been reached.

All fire protection equipment and systems required for safety purposes are classified F2.

The random failure of an active equipment item within the fire protection systems must not lead to a common mode failure of redundant systems needed to perform an F1 safety function, even if the function is not needed following such an event. The redundancy requirement (whether functional or not) arising from the application of this principle is implemented by the principle of train separation. An explosion must not result in the loss of stability/integrity of the fire boundaries and barriers required for safety.

Nuclear safety is ensured by means of passive fire protection provisions such as:

- reduction of the fire load,
- prevention of the spreading of fire within a fire compartment/cell,
- prevention of the fire from spreading to other fire compartments/cells or other buildings.

5.4. DEFENCE IN DEPTH PRINCIPLES APPLICABLE IN THE ETC-F

The fire protection system must be designed following the principle of using different levels of defence in depth, as follows:

5.4.1. Fire prevention

Non flammable or hardly inflammable materials, are used for structures equipment and fluids, as far as is technical reasonable. Ignition sources are avoided.

One cause of fire is associated with cable insulators. Application of the fire prevention concept results in the application of fire retardants and the use of halogen free and low smoke emission cable insulation material. This special cable insulation material gives a high level of personnel protection against effects of smoke.

The fire load on mechanical systems is reduced by implementation of integrated oil systems.

5.4.2. Fire containment

All buildings act as individual fire zones and are further divided into fire compartments and/or fire cells in accordance with the following separation principles:

- Requirement for separation of redundant trains of safety systems,
- Requirement for isolation of areas with potentially high fire loads (e.g. oil rooms),
- Requirement for provision of protected stairways and escape routes for personnel protection.

Fire compartments are completely surrounded by fire resistant walls and ceilings, with fire resistant sealing devices for openings and penetrations.

5.4.3. Fire control

5.4.3.1. Automatic detection

The general fire detection network should be designed in such a way as to provide:

- rapid detection of the outbreak of fire,
- information on the locality of the source of the fire,
- monitoring of the spread of the fire,
- triggering of an alarm and automatic actions.

5.4.3.2. Fire fighting features

A location must be equipped with a fixed fire extinguishing systems when it meets one of the following conditions:

- There is the possibility of flash over and a fire load of solid combustible greater than 18,000 MJ,
- The fast kinetic fuel capacity is greater than 100 litres.

The fixed fire-fighting features can be sprinkler systems or water-mist systems or inert gas systems if:

- the fire barrier performance of the compartment is not compatible with the risk (EPRESSI methodology),
- the location is a fire containment compartment (radioactive or toxic),
- the accessibility to the location is not easy.

5.4.3.3. Smoke control system

A natural or mechanical smoke exhaust system is required for:

- rooms located on the ground floor and on the above floors, larger than 300 m²,
- blind rooms,
- basement rooms larger than 100 m²,
- all staircases.

In order to meet these requirements, three systems may be used:

- smoke protection is provided in the protected rescue routes either naturally or mechanically, using one of the methods below,

- smoke control is provided by creating a negative pressure between the fire-affected room and adjacent rooms to prevent gases and smoke, possibly charged with toxic products, from spreading outside this room,
- smoke exhaust is achieved in non-confined building (i.e. turbine hall) through air intakes and smoke outlets communicating with the outside directly or by means of ducts arranged to ensure satisfactory scavenging of the room or building.

5.5. EPRESSI METHODOLOGY FOR ETC-F APPLICATION

The EPRESSI methodology is a means of justifying that the performance of qualified equipment which contributes to the successful operation of fire barriers in a fire sector, is able to withstand the effect of the reference fire (developed fire) within the fire sector in which it is installed.

The prerequisite is that such equipment should be qualified through regular performance tests (typically defined by the Order of 22 March 2004 [Ref-1], and head French Standard NF EN 13501-02 [Ref-2]. From these, tests performance curves can be derived (dependant of the type of fire: quick development and short duration or long duration and gradual development) which are compared with the reference fire appropriate to the fire cell.

The reference fire within each fire cell is determined through a mathematical calculation using the qualified code MAGIC (certified by USNRC) [Ref-3].

This methodology provides “a posteriori” justification of the ability of the fire zoning to withstand the fire in a given fire compartment/cell.

5.6. ANALYSIS OF FIRE VULNERABILITY IN THE REACTOR SAFETY CASE

The fire vulnerability analysis aims to demonstrate the absence of common cause failure and to show that the potential risk remains below an acceptable level. The analysis shows that the objective of achieving a satisfactory safety level of fire protection has been achieved. This analysis is performed by a complete analysis of all the fire volumes within the plant.

6. TECHNICAL CODE FOR MECHANICAL EQUIPMENT – LIMITING DEFECT SIZE CALCULATION (RSE-M)

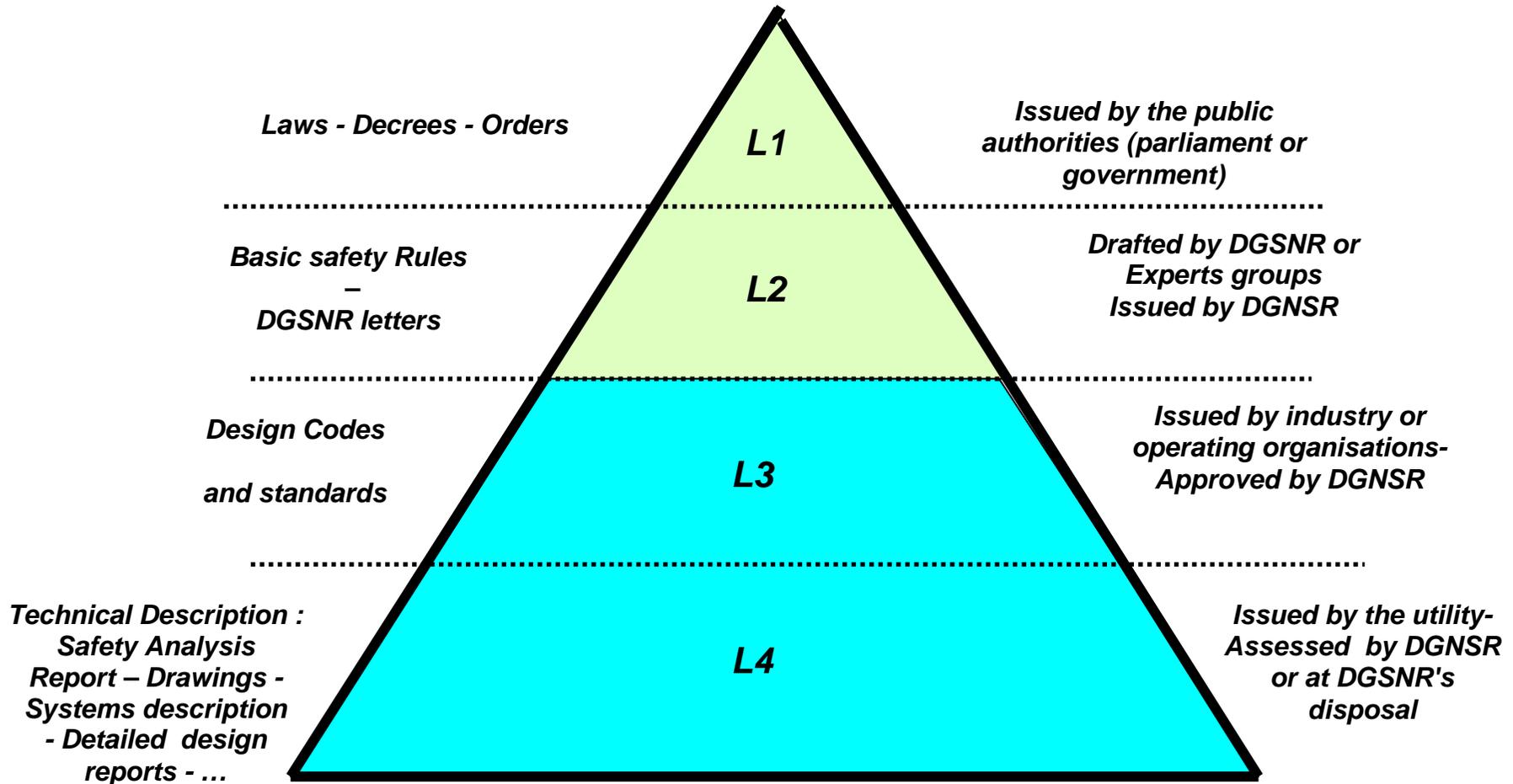
The assessment of fast fracture risk for mechanical components and piping whose gross failure can be discounted (High Integrity Components) requires the actual critical defect size to be determined to compare with the detectable defect size, taking into account all potential loads including mechanical loads, thermal loads and residual stresses. Since the conventional approach of the RCC-M code is too conservative for the evaluation of stress intensity factors in the case of secondary stresses and does not enable residual stresses to be introduced easily, the basic formulae for stress calculations and the formulae for plastic corrections from the RSE-M code Appendix 5.4 are used for the UK EPR demonstration.

The development and validation of these formulae [Ref-1] have been undertaken since 1995 between CEA experts (in charge of the development of RCC-MR code devoted to Fast Breeder Reactors and more specifically to the fracture mechanics Appendix A16) and AREVA/EDF experts (in charge of the development of the RSE-M code devoted to Pressure Water Reactors and more specifically to the fracture mechanics Appendix 5.4). This development program is supported by the IRSN (the technical support entity of the French Nuclear Safety Authority).

Since 1995 a large number of formulae have been developed in RSE-M for pipes, elbows, thickness transitions, for a large variety of defect sizes and positions (internal, external, circumferential, longitudinal, flank, cracks) and for a large variety of loadings (pressure, bending, thermal transients...). The formulae have been validated under the leadership of the CEA with comparison against a database made up of around 2000 finite element reference cases (2D and 3D, mechanical and thermal loading) established using the ASTER, CASTEM and SYSTUS finite element codes. This development and validation group continues to update and validate the code.

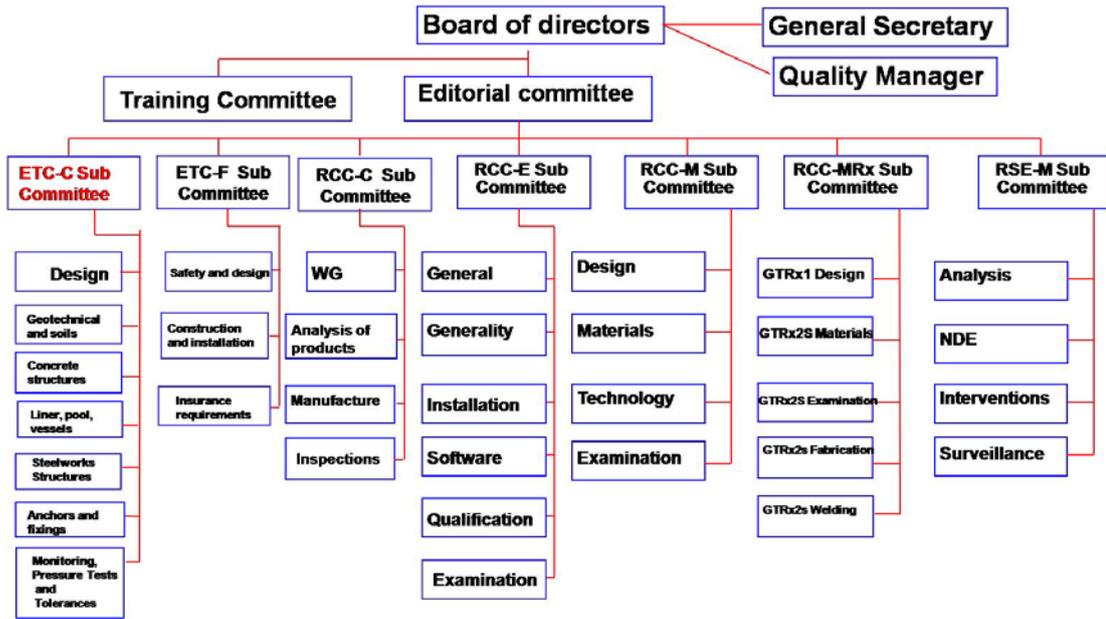
SUB-CHAPTER 3.8 - TABLE 1

Position of codes and standards in the structure of the French safety regulation



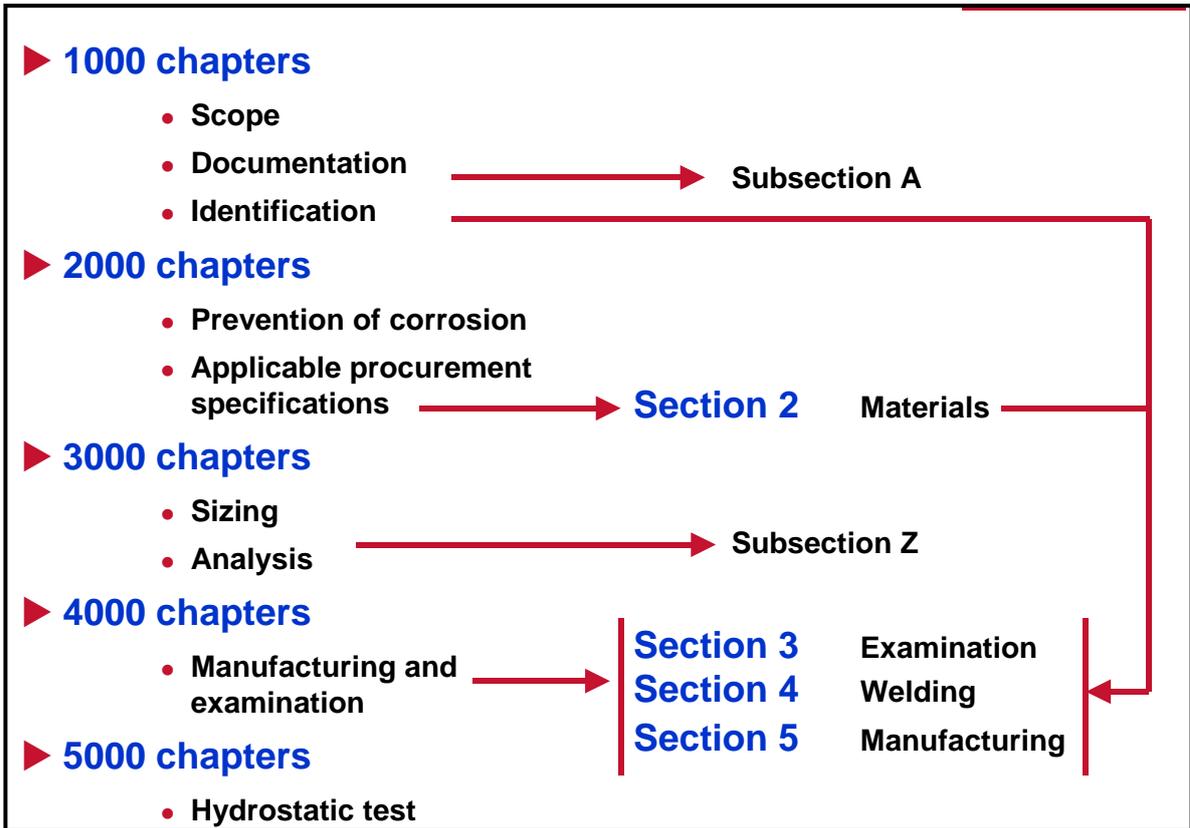
SUB-CHAPTER 3.8 – TABLE 2

AFCEN Organisation



SUB-CHAPTER 3.8 – TABLE 3

RCC-M structure



SUB-CHAPTER 3.8 – TABLE 4**Correspondence between RCC-M and ASME Code**

RCC-M Code [Ref-1]		ASME Code
Volume I	Nuclear Island Components	Section III
Volume II	Materials	Section II
Volume III	Examination methods	Section V
Volume IV	Welding	Section IX
Volume V	Fabrication	Various parts of Section III
Sub-Section A	General requirements	NCA
Sub-Section B	Class 1 components	NB
Sub-Section C	Class 2 components	NC
Sub-Section D	Class 3 components	ND
Sub-Section E	Small components	None
Sub-section G	Reactor internals	NG
Sub-section H	Supports	NF
Sub-section J	Storage tanks	NC/ND 3800-3900
Sub-section Z	Technical appendices	Appendices

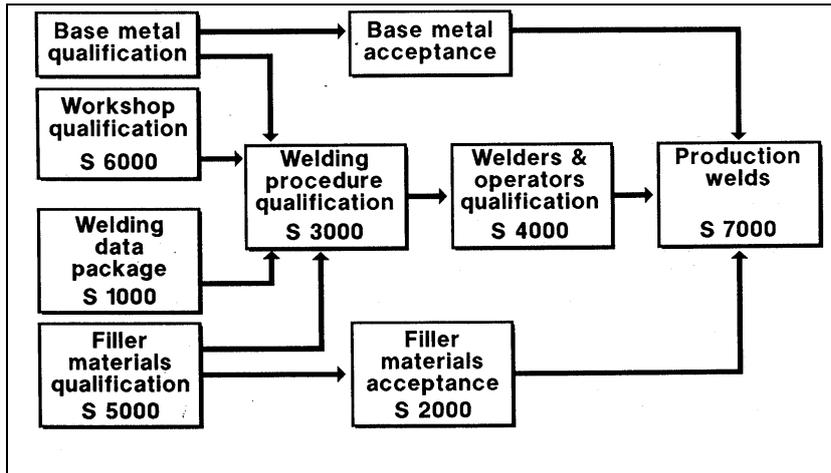
SUB-CHAPTER 3.8 – TABLE 5

Evaluations required by the February 26, 1974 French Government Order [Ref-1]

Damage ↓ RCC-M criteria level →	Loading conditions			
	First category (Design condition)	Second category (Normal and upset conditions)	Third category (Emergency conditions)	Fourth category (Faulted conditions)
	Level 0	Level A	Level C	Level D
Excessive deformation	1.5		1.2	Estimation not required
Elastic, plastic and elastic- plastic instability	2.5		2	1.1
Progressive deformation or ratchetting	Estimation required		Estimation not required	Estimation not required
Fatigue	Estimation required		Estimation not required	Estimation not required
Fast fracture	Estimation required		Estimation required	Estimation not required

SUB-CHAPTER 3.8 – TABLE 6

Key aspects of welding qualification and acceptance criteria



SUB-CHAPTER 3.8 – REFERENCES

External references are identified within this sub-chapter by the text [Ref-1], [Ref-2], etc at the appropriate point within the sub-chapter. These references are listed here under the heading of the section or sub-section in which they are quoted.

1. INTRODUCTION

[Ref-1] Design and Construction Rules for Mechanical Components of PWR Nuclear Islands. RCC-M 3rd modification. AFCEN. June 2007 supplemented by RCC-M Modification Sheet FM 1060. (E)

[Ref-2] RSE-M – In-Service Inspection Rules for the Mechanical Components of PWR Nuclear Power Islands. Appendix 5.4 – Determination of the main parameters. AFCEN. 1997 Edition supplemented by 2005 modification. (E)

[Ref-3] Design and Construction Rules for Electrical Components of PWR Nuclear Islands. RCC-E. AFCEN. Edition December 2005. (E)

[Ref-4] Book of project data completing the RCC-E December 2005 requirements for the EPR. ENSEMD050222 Revision C. EDF. 2007. (E)

[Ref-5] EPR Technical Code for Civil works. ETC-C 2010 Edition. AFCEN. 2010. (E)

[Ref-6] ETC-F. EPR Technical Code for Fire Protection. ETC-F Version G. ENGSIN050312 Revision B. EDF. August 2007. (E)

2. TECHNICAL CODE FOR MECHANICAL EQUIPMENT (RCC-M)

2.3. COMPARISON ASME – RCC-M

2.3.3. Comparison of design rules

2.3.3.8. Class 2 and 3 pressure components

[Ref-1] UK EPR. NESP-F.09.0480. AREVA. September 2009. (E)

[Ref-2] UK EPR. RCC-M requirements for design analysis of class 1/2/3 piping. Review of ASME reports. NEEM-F 09 1383 Revision A. AREVA. December 2009. (E)

2.3.3.9. Other equipment

[Ref-1] Service Limits and Loading Combinations for Class 1 Linear-Type Supports. Regulatory Guide 1.124. NRC. 2007. (E)

[Ref-2] Service Limits and Loading Combinations for Class 1 Plate-And-Shell-Type Supports. Regulatory Guide 1.130. NRC. 2007. (E)

2.3.8. Non-destructive examination

[Ref-1] Essais non destructifs — Qualification et certification du personnel END — Principes généraux.
[Non-destructive testing – Qualification and certification of END employees – General principles.]
NF EN 473. AFNOR. 2008

4. EPR TECHNICAL CODE FOR CIVIL WORKS (ETC-C)

4.1. INTRODUCTION

[Ref-1] Development Path for ETC-C (Rules for EPR Civil Works). ENGSGC090215
Revision A. EDF. September 2009. (E)

[Ref-2] ETC-C (EPR Technical Code for Civil works). ENGSGC050076 Revision B. EDF.
April 2006. (E)

[Ref-3] EPR Technical Code for Civil works. ETC-C 2010 Edition. AFCEN. 2010. (E)

[Ref-4] UK Companion document to AFCEN ETC-C - Part 1. ENGSGC110015 Revision E.
EDF. August 2012. (E)

4.2. CONTENT OF THE ETC-C DOCUMENT

[Ref-1] Eurocode: Basis of Structural Design. EN 1990:2002. (E)

[Ref-2] Eurocode 1: Actions on structures. EN 1991-1-1:2002/AC:2009. (E)

[Ref-3] Eurocode 2: Design of concrete structures. EN 1992-1-1:2004/AC:2010.(E)

[Ref-4] Eurocode 3: Design of steel structures. EN 1993-1-1:2005/AC:2009. (E)

[Ref-5] Eurocode 7: Geotechnical design. EN 1997-1:2004/AC:2009. (E)

5. EPR TECHNICAL CODE FOR FIRE PROTECTION (ETC-F)

5.1. INTRODUCTION

[Ref-1] IAEA Safety Standards Series. Protection against Internal Fires and Explosions in the Design of Nuclear Power Plants. Safety Guide No. NS-G-1.7. IAEA. 2004. (E)

5.5. EPRESSI METHODOLOGY FOR ETC-F APPLICATION

[Ref-1] Arrêté du 22 mars 2004 portant approbation de dispositions complétant et modifiant le règlement de sécurité contre les risques d'incendie et de panique dans les établissements recevant du public (dispositions relatives au désenfumage).
[Order of 22 March 2004 approving provisions supplementing and amending the rules of safety against fire and panic in establishments open to the public (provisions relating to smoke).]

French order. 2004

[Ref-2] Classement au feu des produits de construction et éléments de bâtiment - Partie 2: classement à partir des données d'essais de résistance au feu à l'exclusion des produits utilisés dans les systèmes de ventilation.

[Fire classification of construction products and building elements - Part 2: classification from the test data of fire resistance with the exclusion of products used in ventilation systems.]

NF EN 13501-2. AFNOR. May 2004

[Ref-3] Qualification file of Fire Code Magic version 4.1.1. HI-82/04/022 Revision B. EDF. December 2005. (E)

6. TECHNICAL CODE FOR MECHANICAL EQUIPMENT – LIMITING DEFECT SIZE CALCULATION (RSE-M)

[Ref-1] Summary of the FMA approaches introduced in RSE-M Appendix 5.4 and RCC-MR Appendix A16 - illustration of their pertinence through an example.
PEER-F 10.1989 Revision A. AREVA. December 2010. (E)

SUB-CHAPTER 3.8 – TABLE 4

[Ref-1] Design and Construction Rules for Mechanical Components of PWR Nuclear Islands. RCC-M 3rd modification. AFCEN. June 2007. (E)

SUB-CHAPTER 3.8 – TABLE 5

[Ref-1] Arrêté du 26 février 1974 relatif à la construction du circuit primaire principal des chaudières nucléaires à eau.

[Order of 26 February 1974 for the construction of the main primary circuit nuclear boiler.]

French order (1974) modified in 2000