European ITER Site Studies: Lessons Learnt in Safety and Licensing[1]

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Abstract. On June 28th 2005, an agreement was reached amongst the ITER parties on the selection of the European Site of Cadarache in France. As consequence, the ITER generic site safety assessment had to be adapted to the French requirements in order to initiate the licensing process. It is precisely in this point that Europe has been working through the European ITER Site Studies programme. The main objective was: to contribute to the ITER Organization to fulfill in time the deliverable of licensing files to the French authorities. This paper details the main gained lessons by the European Organizations involved in the writing of supporting studies for these licensing files. The lessons learnt tackle a very wide range of technical and strategic aspects, some of them never considered before for a fusion facility. It could be mentioned, for instance, the application of international codes and standards to typical fusion components, the integration of the approach for accident evaluation, the definition of waste treatment strategies or the functional approach to zoning (radiological zoning, ventilation zoning…) of the facility among others. The effort has involved the European Fusion Development Agreement (EFDA) and the current Fusion for Energy organization, EURATOM Associations and European industries. Two facts have made specially challenging the task of support the licensing process: ITER being the first fusion reactor to be licensed as *Installation Nucléaire de Base* and the entry in force of a new nuclear regulation in France. So original and challenging scenario has lead to adaptation strategies and innovative for fusion approaches in safety and licensing studies.

1. Introduction

On June 2005, the ITER Parties reached an agreement on the selection of the European Site of Cadarache in France. In consequence, the ITER generic site safety assessments had to be adapted to the French requirements in order to initiate the licensing process. At this point, Europe initiated to anticipate work to contribute to the ITER Organization to fulfill in time the deliverable of licensing files to the French Authorities.

On January 2008, the main licensing file (the *Demande d'Autorisation de Création*) was delivered by the ITER Organization (IO) to the French Authorities. It has been the culmination of a join effort of many actors and this paper summarizes the collaboration between Europe and ITER involving the European Fusion community, the European industry and a number of EURATOM Associated Laboratories under the so called European ITER Site Studies programme (EISS). In addition, other IO partners contributed partly to these files but this contribution is not reported inhere.

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The EU joint effort has been primarily focused on the writing of the *Rapport Preliminaire de Sûreté* (RPrS), one of the essential documents of the *Demande d'Autorisation de Création* (DAC). EFDA under ITER leadership and, since its existence, by Fusion for Energy (F4E) have been implemented the writing of the RPrS and the preparation of its supporting documents. The executants of the work have been AIF (Agence ITER France) and several EURATOM Associations (CEA, CIEMAT, ENEA, VR/Studsvik). All of them have been working in full cooperation with IO under Quality Order 10th of August 1984 requirements in the scope of a contract called ITER Task Agreement (*see FIG. 1*).

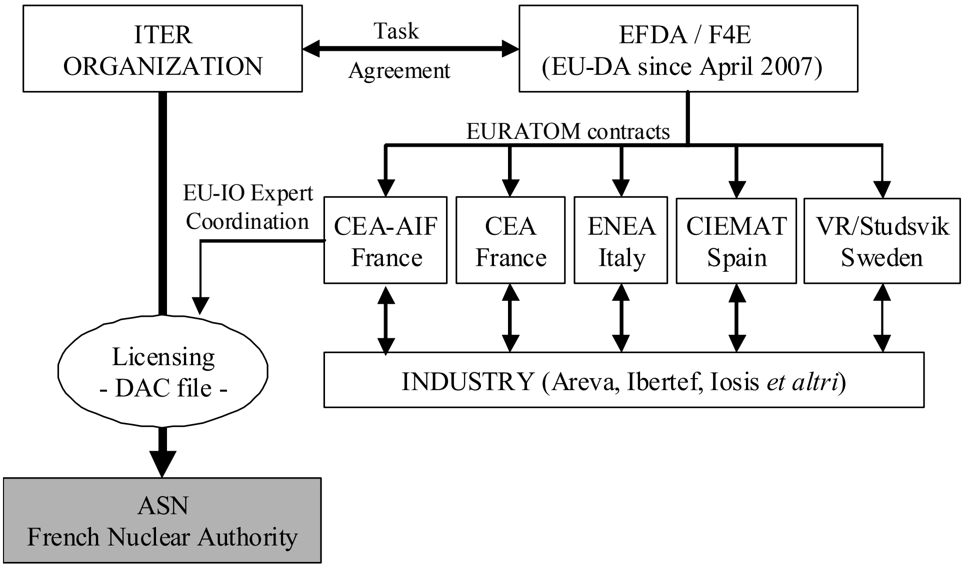

FIG. 1. Agreement and coordination of tasks in support of licensing in the framework of the EISS programme.

EU has developed studies in support of the DAC files, and in particular for RPrS file in a wide range of technical aspects, many of them never considered before for a fusion facility, that IO has partly integrated in RPrS or in references once accepted and validated. The following points have tackled: safety related practices and approaches from current fusion device and description of the ongoing R&D activities for the validation of these safety approaches; preliminary identification of ITER safety operational limits and safety important components, the definition of the safety control system requirements; the analyses of maintenance and radioprotection programmes; basis for optimization of "human factor" related aspects of design and operation practices; fusion specific safety methodology and strategy; integration of new designs in the safety approach; the application of international codes and standards to typical fusion components; the definition of structural design criteria for buildings; the specification of waste management; and the evaluation of effects of external aggressions.

From the point of view of establishing the new paradigm of safety approach in fusion, relevant achievements have been obtained in the areas of codes and standards (Section 2), waste management (Section 3) and functional approach to zoning of the fusion nuclear plant (Section 4). Finally, the results obtain from this common EU-IO endeavor are summarized as lessons learnt for future fusion licensing processes (section 5).

The integration of the approach for accident evaluation and the systematic collection of the safety experience from experimental fusion devices (including the on-going R&D in support of fusion specific safety issues) have been also remarkable achievements but they are out of the scope of this contribution.

2. Codes and Standards

In the framework of the European ITER Site Studies, EFDA had coordinated the work to incorporate the structural and technological specificities of the ITER Vacuum Vessel (VV) in existing nuclear pressurized vessel codes in order to provide a clear regulatory and technical basis for it. RCC-MR (*Règles de Construction et Conception - Mechanique neutrons Rapides*) was selected to this aim for several reasons:

- ITER VV grade material is derived from Superphenix Grade 316 L(N) and covered by specification within RCC-MR. Associated design stress of 130 Mpa at 200°C is suitable for the VV design.
- Design rules for welds found in RCC-MR box type structures can be derived for the double wall structure of the Vacuum Vessel. RCC-MR has sections covering components with double shell and internal ribs connecting the two shells with or without leak tightness function. Hence, it is relevant to the ITER VV case.
- Applicability of RCC-MR to ITER VV does not call for many modification or Code exemptions, only a few additions and specificities remaining in the VV Appendix.
- Main deviations to Code practices are on extensive use of Non-Destructive Test of one-sided austenitic steel welds involving alternative methods to standard reflexion (creeping wave, tandem, phased array, etc.)

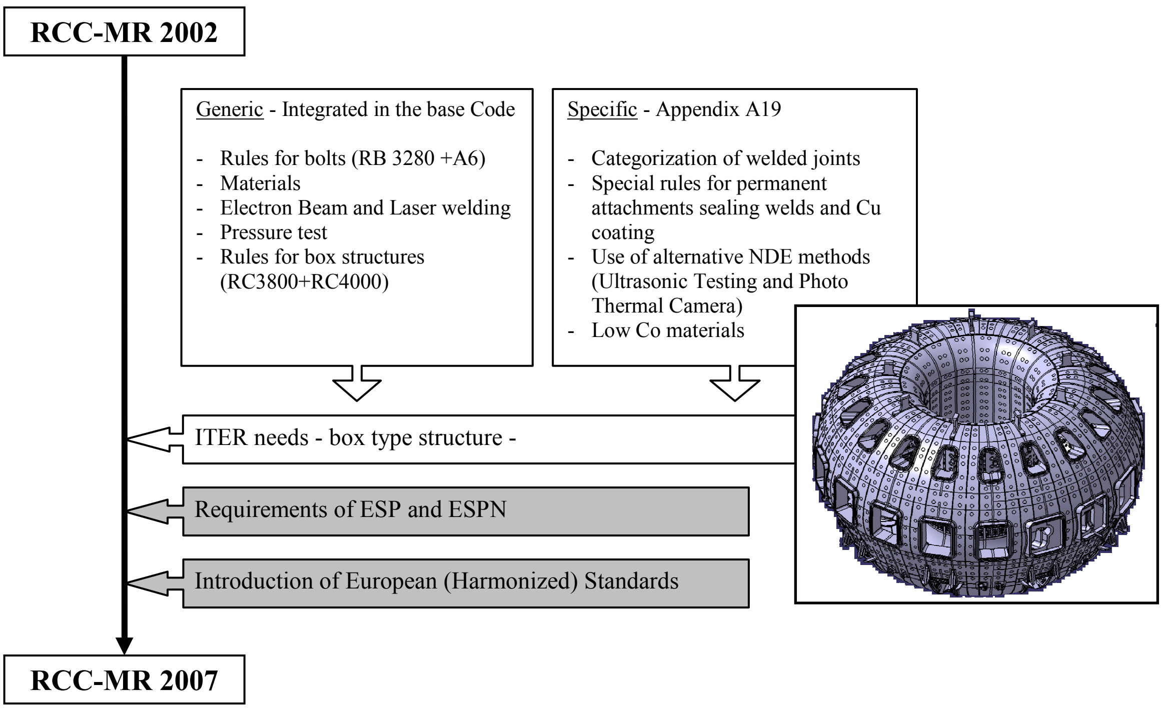

FIG. 2. Issues regarding the Vacuum Vessel and other improvements in the new edition of the RCC-MR

The RCC-MR 2007 [1] issue has been launched taking into account the new French regulation on pressure equipment [2] and nuclear pressure equipment [3]; the evolution of the European Harmonized Standards; and, specially significant for ITER, the specificities of the Vacuum Vessel as a welded box structure (see *FIG.* 2.). It includes the writing of new appendices A18 with specific requirements for equipment under regulation, A19 related to ITER VV and A20 for constructive recommendations for Inspection in Service.

In parallel, the preparation of a specific ITER technical code for buildings, the so called ISDC-B (ITER Structural Design Code – Buildings) has been brought forward that adapts state-of-the-art structural design criteria for civil works (EUROCODES) and general specifications for construction, to specificities of the configurations and loads of a fusion nuclear plant. The document has been based on the concept of the limit state design used jointly with the method of the partial factors, as stipulated in Eurocode EN 1990 [4], adapted to this particular project by taking account of particular specific situations, actions, and combinations of actions to be considered for the safety of the ITER installation.

The first part of ISDC-B is dedicated to the design specifications of the safety important buildings of ITER and is intended to be used with the construction rules defined in second part (topography, tolerances, earthworks, concrete works, formwork, reinforcement, base isolation and elastomeric bearings, leak-tight metal parts on containment, etc.).

Main situations and permanent, variable and accidental actions have been defined. The writing is open to other actions that may be defined in later detailed specifications issued by ITER and should be taken into account using the principles and procedures developed in this document. All the civil works, including structures and non structural elements shall be designed with a suitable structural strength, serviceability and durability, in conformity to the requirements, in the design situations and the corresponding acceptance criteria, as described in the ISDC-B, including referred standards.

3. Waste management

The waste management extensive studies have been conducted on the quantification, classification and management of the waste generated by ITER operation, maintenance and decommissioning, with particular attention to the fusion specific problem of tritium containing waste and the special requirements and treatments. Last year, due to the new regulatory framework and the requirements of the French regulator [5, 6], a final effort has been done to provide scenarios for managing the different types of waste that will be produced by ITER. The classification of radioactive waste according to the French regulation is described in TABLE I and the ITER suggested approach for each type of waste is detailed in the next paragraphs.

Very Low Level activated waste (non tritiated) could be processed in accordance with current procedures, i.e., it will be conditioned in big-bags or metal boxes and disposed of in an existing surface repository (the detritiation of this category of waste is under study, the formal decision will be taken by the end of the year 2008).

Very Low Level activated waste (tritiated) will be packed in standardized metal boxes then stored, awaiting the creation of a final outlet.

TABLE I. French classification of radioactive waste

<table>
<tr><th></th><th>Short-lived (≤ 31 years)</th><th>Long-lived (> 31 years)</th></tr>
<tr><td>Very low level</td><td colspan="2">Surface disposal facility</td></tr>
<tr><td>Low level</td><td rowspan="2">Surface disposal facility (being examined for tritiated waste)</td><td>Being examined</td></tr>
<tr><td>Intermediate level</td><td>Deep disposal. Operational from 2025</td></tr>
<tr><td>High level</td><td colspan="2">On going studies, but not needed for ITER</td></tr>
</table>

Low and Intermediate Level activated waste (non tritiated) will be processed in accordance with current procedures, i.e., it will be conditioned in metal drums, concrete containers or metal boxes and immobilized in a cement matrix. Metal waste could be melted. A large part of these wastes can be stored in existing surface repositories.

Low and Intermediate Level activated waste (tritiated) will be conditioned in the same way as non tritiated waste after a potential detritiation treatment. This waste will be stored within an intermediate storage before to be admissible in existing surfaces storage.

Pure tritiated waste will not be immobilized, as concrete is non-confining for tritium. Furthermore, tritiated waste is not currently accepted in surface disposal facilities. This waste will be stored in the ITER facility until the dismantling phase and evacuate to the adequate final outlet. It will therefore be treated before being conditioned in steel drums. Metal waste could be melted into ingots, and would then be considered as Very Low Level activated waste.

Finally, Intermediate Level and Long Lived activated waste will be cut into smaller pieces (because of their large size), detritiated, conditioned in cylindrical stainless steel containers, stored within ITER facility until the dismantling phase and evacuate to final outlet .

Very low level activated waste will be handed over to the host country after 6 months, while Low and Intermediate Level activated waste will be stored on the ITER site until decommissioning as well as purely tritiated waste.

4. Zoning

A deep review of the functionalities of ITER plant has provided a sound and manageable basis for the ITER plant zoning. The work has allowed the classification and grouping of ITER building “rooms” in zones according to: nuclear grade ventilation requirements, radiological inventory, risk of conventional and radioactive contamination and personnel radiological exposure, deflagration risks, waste management and beryllium concentration. Next paragraphs give a short overview of the basis for the ventilation, fire and beryllium zoning, as example of the task.

The ventilation zoning method applied for ITER is based on the estimated atmospheric contamination according to ISO standard 17873 "Nuclear facilities. Criteria for the design and operation of ventilation systems for nuclear installations other than nuclear reactors" [7]. In this sense, TABLE III matches confinement classes with the ventilation requirements and the color coding applied for ventilation zoning in the Tokamak building, the Tritium plant, the Hot Cell building, and the Low-Level Radwaste building.

TABLE III. ITER ventilation zone

Confinement Class	Application for ITER	Ventilation Zone Color Code
C1	Normal HVAC	
C2	Normal HVAC with filtered exhaust and able to be detritiated/filtered	
C3	Filtered exhaust and detritiated depending upon contamination expected	
C4	Recirculated filteredand detritiated with filtered and detritiated exhaust stream	

The fire zoning has been set up to limit the spread of fire and fumes and confine the fire within predefined volumes to allow enough time to extinguish the fire. Fire safety zoning includes fire sectors and confinement sectors in accordance with regulations. Content and function of each room has been analyzed and fire sectors have been established according to the radioactive material which may be present in greater than trace quantities, and the safety important components (SIC) in the room. Fire safety zoning has been then developed in order to segment the radioactive materials (in order to limit the radioactive inventory potentially vulnerable to a single fire) and to separate redundant SIC to the extent practicable so as to reduce the potential impact of fires. Fire zones have been designed so that fires initiating in a zone will not propagate outside that zone, and fires initiating outside the zone will not propagate into that zone.

Provisions for fire prevention, fire detection, limiting fire consequences and fire fighting have been also defined in the framework of the EISS programme. In rooms where workers cannot enter, fire extinguishing systems spread water mist or dry chemicals. In rooms where personnel can enter, fire fighting tools are portable extinguishers and fire hoses. The Detritiation System stays operational in case of fire. It is protected from fire in order to prevent HEPA filters and exhaust filters from degradation. The detritiation function continues, possibly with reduced efficiency. Redundant trains are in separate fire zones or sectors.

The same measures implemented in fire sectors have been implemented in fire zones, except that the boundaries of fire zones may use any of various means to limit the migration of fire, including physical separation.

Regarding the beryllium zone, the exposure limit value for workplace exposure to beryllium and beryllium compounds published by the French Ministry of Labour is 2 $\mu g/m^3$ on average over an 8-hour period. The occupational beryllium exposure threshold adopted for the Tokamak, the Hot Cell and Tritium buildings has been defined to be 0.2 $\mu g/m^3$ (i.e. 1/10 of the legal average exposure limit value) for atmospheric concentration and 20 $\mu g/m^2$ for surface contamination. The beryllium zoning criteria adopted to the above mentioned buildings has been categorized in beryllium non-controlled zone, beryllium controlled zone and beryllium breathing protection zone.

5. Lessons Learnt in Safety and Licensing

Two facts have made specially challenging the task of support the licensing process: ITER being the first fusion reactor to be licensed as *Installation Nucléaire de Base* and the entry in force of a new nuclear regulation in France [8]. So original and challenging scenario has lead to adaptation strategies and innovative for fusion approaches in safety and licensing studies.

The outcome of the safety and licensing tasks of the European ITER Site Studies programme, integrated in the coherent framework provided by the regulatory process of ITER is considered a valuable asset to be used in the future, i.e. for the preparation of the final safety documentation for the authorization of ITER to operate, but also as a basic input for the safety design of future fusion plants.

Obviously, safety improvement will always been practiced for future designs. It is a continuous process especially due to two principles: the continuous integration of the most recent state-of-the-art in science and technology and the use of the feedback from operating experience. ITER being an example of licensing a fusion installation, it is expected that all the results will be a valuable database for future fusion reactors.

For all the possible version of future fusion reactors or related fusion installations, it should be considered, since an early phase, that a fusion plant is not only a fusion-machine reactor, or a D-T target. The same importance should be paid to all the nuclear or radiologically controlled buildings and to their integration and interfaces by considering the safety functions of the SSC (Systems, Structures and Components) inside them. Even tritium laboratories and hot cells (that are classical nuclear installations) are not comparable to fusion plants. Fusion plants will have specific features related to the large size that the systems and components could have, from the today's extrapolations.

Beyond the technical concerns, i.e. at project level, the main lessons learned in the field of the above topics are the following. On one hand, codes and standards must drive the design of the SSC together with the functional and safety requirements since the early stages of the project. The design of the fusion systems based only on their functionalities implies, eventually, an adaptation of the design to licensing requirements. This adaptation at advanced stages of the project is very complex and expensive.

On the other hand, fusion waste will require an adaptation of the radwaste acceptance criteria and radwaste processes and storage whichever country hosts the fusion plant. Discussion of the fusion community and fusion project owner with national nuclear authorities will be a necessary step in the project schedule.

Finally EISS has contributed to instill safety and quality culture in the fusion community. The process of the licensing has driven the fusion experts to incorporate the high standards of work from other nuclear fields in the day-by-day activities. The safety and quality culture is an essential requirement, not only to successfully get the operation permits, but to achieve the programmatic objective of the safe operation of ITER.

Acknowledgments

This report was prepared as an account of work by or for the ITER Organization. The Members of the Organization are the People's Republic of China, the European Atomic Energy Community, the Republic of India, Japan, the Republic of Korea, the Russian Federation, and the United States of America. The views and opinions expressed herein do not necessarily reflect those of the Members or any agency thereof. Dissemination of the information in this paper is governed by the applicable terms of the ITER Joint Implementation Agreement.

References

[1] AFCEN, 'Règles de Conception et de Construction des Matériels Mécaniques des Ilots Nucléaires RNR (RCC-MR)', 2007.

[2] French Decree 13th December 1999 concerning pressure equipment (amended by Decree 2003-1249 dated 22nd December 2003 and by Decree 2003-1264 dated 23rd December 2003).

[3] French Order dated 12th December 2005 concerning nuclear pressure equipment.

[4] EN 1990:2002 Eurocode - Basis of structural design

[5] French Programme Act No. 2006-739 concerning the sustainable management of radioactive materials and wastes, dated 28th June 2006.

[6] French Decree 16th April 2008 on Article L.542-1-2 of environmental code.

[7] ISO STD 17873 – Nuclear Facilities – Criteria for the design and operation of ventilation systems for nuclear installations other than nuclear reactors (2004).

[8] French Programme Act No. 2006-686 on transparency and security in the nuclear field, dated 13th June 2006.