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# ITER Licensing Process Follow-up: A Part of K-DEMO Safety Study

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## 1. Introduction

Though Korean Institute of Nuclear Safety (KINS) experienced to analysis and develop the fusion safety regulation for an operation permit of Korean Superconductor Tokamak Advanced Research (KSTAR) [1], the first fusion facility in Korea was treated as a radiation generator, not a power plant, due to the Notification No. 2001-09 related to a subject applied as radiation generator from Ministry of Education and Science Technology in South Korea. The fusion DEMO program of Korea (referred as K-DEMO) has been progressed since 2009 to take advantages of an early mover, while carrying out scientific researches on KSTAR and International Thermonuclear Experimental Reactor (ITER) [2].

The K-DEMO program is a huge program and is in second phase planed for R&D from 2012 to 2021 [2]. One of the big part of this program, the fusion regulation and licensing in South Korea, can be classified into following three stages: 1) the licensing of the KSTAR classified to a radiation generating device on the basis of the existing nuclear regulations, 2) the verification of the design of the Test Blanket Module (TBM) and minimization of occupational irradiation damages due to tritium behaviors for ITER, and 3) fundamental safety analysis [3], as a part of K-DEMO program with domestic universities funded by National Fusion Research Institute of Korea (NFRI). Kyung Hee University has studied safety analysis of K-DEMO since 2010, and surveyed ITER safety regulation and licensing process since 2012. In 2013, NFRI has carried out “Development, Operation, and Management of core technologies for ITER” to secure the core original technologies and expend the base of domestic specialist at a fusion area by pursuing and developing non-supply technologies for ITER. As a part of this project, our research group covers the follow-up survey of ITER safety regulation, licensing process, environmental safety analysis and quality analysis for the future K-DEMO regulation. From this project, the newest technical backup data and experience to be able to perform faster regulation task upon request of the demonstration plant licensing for the development of materials for safety-related design criteria and regulatory requirements are expected.

In this context, this paper discusses the progress of surveying the safety and licensing of ITER for K-DEMO funded by NFRI.

## 2. Status of Regulation and License on Fusion Energy

### *2.1 Korean Status*

Considering the fact that it takes 10~15 years to establish a new regulatory process, the development of K-DEMO’s safety regulation and licensing process and surveying ITER’s should be carried out simultaneously. KINS analyzed ITER's licensing progress in 2007 to provide a strategic roadmap for fusion safety regulation. Due to environmental changes, a revised version of this document has been published in 2010 [4]. Despite of the limitation of this roadmap based on the perspective from the existing nuclear power plants, this roadmap is an important milestone because KINS is expected to become a competent regulatory body for future fusion power plants. For those reasons, the KINS’s reports was a good starting point of our survey.

The report, “Fusion Nuclear Safety Infrastructure utilizing ITER Project, 2009 [5]”, was purposed to secure the safety assessment methods from the verification of ITER’s performance and safety and to apply this methods to future fusion DEMO and commercial plants. The scope and contents of the project was survey and analysis of the regulation system and safety criteria in France, permission of ITER construction, safety analysis report, quality assurance activities, and improvement of technologies and expertise in regulation.

### *2.2 ITER Licensing Process*

The ITER’s licensing process has been accompanied by the ITER project from design to construction since the facility was allowed to install and operate at its side at Cadarache, France. In 2008 ITER Organization (IO) submitted a set of documents including the preliminary safety report (in French, Rapport Preliminaire de Surete, RPrS) and an environmental impact study to the French nuclear safety authorities (ASN) for ITER’s licensing. The revised version of those documents were submitted to reveal the topics about highest concerns of regulatory in 2010 [6]. During 2010-2011, extensive examination of safety files was carried out by ASN and their technical advisors. In parallel, public enquiry was held in towns surrounding ITER and, Environmental Authority in France also assessed the safety files. In July 2012, ASN announced its decision to grant the decree to authorize the creation of the ITER facility [7].

The summaries of main content of RPrS were referred [8,9].

From this licensing process of the first nuclear installation in fusion, some important lessons and safety issues were learned. According to Carlos [10], French Regulator expressed his worries about the shortage of safety culture in the fusion science experience for this complex and delicate project when the "Authorisation of Creation" was submitted for the first time in 2008. Consequently, the main effort has been focused in convincing to the nuclear authorities on the safety of a fusion installation. The design and operation of tokamak and its auxiliary systems were adjusted with the pre-defined existing methodologies which had been applied only to fission installations. In parallel progressive, the improvement of a common understanding on nuclear safety and licensing process was highlighted.

For the technical point of view, the main risks related to tritium contained in several buildings (tokamak building, tritium plant, hot cells and waste building) and activated dust able to contain the toxic element beryllium, material identification and quantification which can be irradiated and activated, and the correct control of safety and radiation protection for the facility were discussed. In addition, as regards to a vacuum vessel, the importance of designing the first confinement barrier, securing against the hydrogen explosion, and ensuring the solid methodology of in-service inspections was considered. Additionally, he also pointed out some issues involved with supports structures and operating conditions, and waste. The success of the licensing process is based on demonstration of the robustness of the first and second confinement system. In safety point of view, electro-magnetic forces and in-vessel dust explosion should be treated as important safety issues for future plants.

## 3. Results and Discussion

In our study, we attempted to update the existing report due to the fact that the reference documents of KINS's report were revised and changed. Considering that the researches of KINS was ended before ITER's construction license issued in 2012, it is naturally needed to study this newest license and trace the important issues about an operation license.

KINS carried out "Development of Licensing Technology for Future Type of Reactor [11]" from 2010 to 2012. The part of this project proposes the safety philosophy for future nuclear reactors in South Korea, which prepares the licensing procedure for demonstration of future nuclear reactors with investigations of safety philosophies from International Atomic Energy Agency, Western Europe Nuclear Regulation, Generation IV International Forum, and U.S. Nuclear Regulatory Commission and collections of domestic specialists' opinions. KHU has worked on the development of fusion safety philosophy for K-DEMO referring to fusion safety documents from U.S. Department of Energy [12] and ITER [8,9]. As a base research to complete this safety philosophy and elicit adequate regulation requirements, the state-of-the-art technologies associated with the fusion DEMO plants were gathered, reviewed and updated by Korean fusion safety advisory group in a periodic manner. The technologies were classified as Product Breakdown Structure (PBS). The advisory group consists of specialists from domestic universities, industries, and national institutes. Table.1 explains contents of this research more.

Table 1 Survey template for the safety regulation of K-DEMO

| Headings | Description | Purpose |
|---|---|---|
| PBS | Product Breakdown Structure | General |
| Safety Grade | Safety/Non-Safety, Nuclear/Non-Nuclear and so on | Comparison with Korean licensing |
| Codes & Standards | System design, manufacture, test, and inspection | Comparison with Korean licensing |
| Computer Codes | Simulation programs for safety analyses (for ITER and other applications) | Licensing & Safety analysis |
| Major Safety Issues | Reference events (incidents & accidents) for safety analyses | Basic Safety Analysis |

This survey was performed to collect opinions of specialists at 14 different area (Magnet, Vacuum Vessel & VVPS, Blanket & Divertor, Fueling and Wall Conditioning, Machine Assembling, Remote handling, Cryostat, Cooling Water, Thermal Shield, Vacuum Pumping, Tritium Plant, Cryoplant and Cryo-distribution, Power Supplies (Coil/H&CD/SSE), Command Control and Data Acquisition including Interlock / Poloidal Field Control, ICH&CD, ECH&CD, NB& H&CD, LCH&CD, Diagnostics, TBM, Buildings & Layout, Hot Cell, Radiological & Environmental Monitoring and Liquid & Gas Distribution) from July to August in 2013. In this process we could update the prior data to newest of each area and arouse experts' necessity to own identical view of licensing and safety mutually. The part of survey results is in Table 2 on account of limited space.

Various insights of actual researchers or regulators were gathered from the survey. First of all, most experts pointed out that as far as "Safety grades" and "Codes and Standards" were concerned, checking the European standards for ITER and comparing it with the existing domestic standards were a good starting point. They can make research plan more optimal and concise although Korean nuclear law or regulation process is quite different from other countries'.

Table 2 Part of Survey Result for the safety regulation of K-DEMO

| PBS | Magnet systems | Vacuum Vessel & VVPS system | EC H&CD System | Radiological & Environmental Monitoring |
|---|---|---|---|---|
| **Safety Grade** | Pipes and Manifolds: SEP Category I | ESPN-NPE(Nuclear Pressure Equipment)Order2005<br>- Main Vessel: Category IV, Level N2<br>- Main Port: Category IV, Level N2<br>- Upper PE: Category IV, Level N3<br>- Center PE: Category III, Level N3 | PED or ESPN–<br>Some equipment can be excluded to apply of PED | None |
| **Codes & Standards (Design, Manufacture, Test, Inspection)** | Magnetic Structure Design Standard-Technical specification based on ASME<br>Permission Criterion based on ASME XI | RCC-MR Code Edition 2007<br>-Section1 Subsection "C" Class 2 component (RC)<br>Design Rules: RCC-MR RC 3800 & Appendix 19 – Section2 Material Main: SS304L(N)-ITER Grade<br>Support: SS304L (EN grade 1.4307)<br>IWS: 304B4/304B7 (UNS S30464/7)<br>Screw: Alloy 718, Steel 660 (En Grade), XM-19(B8R)<br>RCC-MR Code Edition2007<br>-Section3 Examination Methods(RMC) | Non-irradiated Items(Vessel: ASME Section VIII Div.2/ Pipes: ASME B31.3 or related to EN standard)<br>Irradiated Items (In-vessel equipment Design: SDC-IC)<br>SDC IC [SDCIC00] for irradiated items/ ASME Section VIII Div.2 for vessels / ASME B31.3 for piping / ASME B73.1M/B73.2M for pumps ASME Section III-NF for support /ASME B32.3, Appendix X/EJMA for bellows | Appropriate ISO or other recognized standards: Based on Guides or Law related to Nuclear Power Generation Regulation |
| | Magnetic Structure Manufacture Standard-Technical specification based on ASME<br>Permission Criterion based on ASME XI | RCC-MR Code Edition 2007<br>-Section4 Welding (RS)<br>-Section5 Fabrication (RF)<br>Procurement Agreement Specification<br>Mandatory Appendices | Documented mass based on qualified development R&D for diamond window manufacture and fabrication (s) at VV closure plate. / Commercial gas/ vacuum barrier at port cell door | Procedures and works must be acceptable to the quality assurance tests that are indicated as requirements on these applicable codes.: Based on Guides or Law related to Nuclear Power Generation Regulation |
| | 100% inspection of materials and welds for surface and internal flaws or cracks (X-ray, ultrasonic and/or de-penetrate) to ASME | RMC 2000 Ultrasonic Examination<br>RMC 3000 Radiographic Examination<br>RMC 4000 Liquid Penetrant Examination<br>RMC 7000 Other Examination Methods<br>Procurement Agreement Specification<br>Mandatory Appendices | Irradiated Items (In-vessel equipment Design: SDC-IC)<br>SDC IC [SDCIC00] for irradiated items | Appropriate Quality Control tests during manufacturing and verified upon receipt, procurement Specification: Based on Guides or Law related to Nuclear Power Generation Regulation |
| | ASTM standards or equivalents with acceptance / repair criteria in Procurement Specification<br>Radiography of welds for Gravity Support assembly<br>Leak test of Cryostat feed through (outer wall only) | Procurement Agreement Specification<br>Mandatory Appendices-Pressure Test<br>- Flow Test<br>- Vacuum Leak Test<br>- Baking and Out gassing Test | PED requirement | PED-tbd |
| **Computer Codes (<u>ITER</u>, Similar, <u>Domestic</u>)** | Vincenta(Russia), Super Magnet Code set (CryoSoft), etc. | ANSYS (Commercial Multi-purpose Structural Analysis Software) | CRONOS/REMA (or LUKE/C3PO)<br>ANSYS (commercial code, thermal analysis) | Coolant Crude: PACTITER (CEA)<br>Activation: FISPACT<br>Neutron Transport: MCNP, TRIPOLI-4, etc. |
| | SMAD Code Set (Domestic developed) | | Toray-GA, CRONOS/REMA, LUKE/C3PO | Atmospheric Diffusion: Not yet confirmed<br>Atmospheric Diffusion: RASCAL |
| | SMAD, Super Magnet, etc. | | Toray-GA,<br>CQL3D | Activation: FISPACT<br>Neutron Transport: MCNP, McCARD<br>Atmospheric Diffusion: RASCAL |
| **Major Safety Issues** | Super Magnet LEAD in Cryostat, Tritium leakage by VV damage from Arc in BUS | Vertical Displacement Event, Seismic Events, Coolant off-normal events LOCA and LOFA | Tritium barrier (CVD diamond RF window at the launcher in torus)<br>Breakdown Risk | Coolant Crude, Tritium Atmospheric Diffusion Model verification |

Secondly, as regards computer codes, some analysis codes or simulators were not yet developed nor adopted for safety analysis and regulations. Experts in areas related to safety important equipment were concerned about the delay of DEMO plan due to insufficiency of effort. Last, major safety issues were offered for further study to write Phenomena Identification and Ranking Table (PIRT) for K-DEMO performed by KHU. The present questions or bottle-neck problems in conjunction with safety and regulation were revealed by this PIRT process.

In addition, we discussed with our advisory group about securement of economic efficiency and plant reliability and safety for K-DEMO. They mentioned researchers, designers, manufacturers and regulators should own the identical safety philosophy in common. Many researchers are not interested in licensing or safety of their own techniques. Moreover, the regulation or licensing for high technology is not easy to access and share. In this point of view, it is recommended to hold an annual meeting with researchers studding supply and non-supply technologies for ITER. In this meeting, the present status of ITER regulation and licensing can be reported, which can lead to propagate safety culture to researchers. Additionally, they can discuss their ideas for Korean fusion licensing and regulation.

## 4. Conclusions

The regulation and licensing process for a fusion power plant has been expected to be quite different due to diverse properties of traditional nuclear facilities. To overcome this, not only various safety issues should be analyzed, but safety objectives, regulatory requirements, and design variables should also be established in detailed design phase. We expected our survey will contribute on general and technical safety principles for national fusion power plant technology plan.

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