TOWARDS A FUSION SPECIFIC REGULATORY FRAMEWORK BASED ON THE APPLICABILITY OF THE CURRENT NUCLEAR FRAMEWORK

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GRS together with KIT investigated how a legal and regulatory framework for fusion facilities could look like. The work started with screening and reviewing information on international approaches for existing fusion regulation. In a next step, safety requirements specifically needed for fusion facilities were identified considering the main differences between fission and fusion facilities and the specific safety issues related to fusion systems, structures, and components. Then European Council Directives, Directives of the European Parliament, IAEA Safety Standards, IAEA Safety Guides, and other international documents applicable or adoptable to fusion facilities were screened and categorized. Based on these inputs, recommendations for the implementation of a legal and regulatory framework specifically needed for fusion facilities were derived and an action plan to develop such a framework has been proposed. The results of this study were documented in a report [1].

Based on the screening of different international approaches for fusion regulations information about the approaches of China, France, Germany, Korea, Russia, United Kingdom, and USA were used for a compilation and review. At present, no country was found that has a dedicated comprehensive fusion-specific regulatory framework for the whole lifecycle from siting to decommissioning of fusion facilities. The safety requirements applied to fusion facilities are based primarily on experience with activities related to fission facilities. All investigated countries follow the typical "regulation hierarchy pyramid" approach (see fig. 1) consisting of legislation, requirements, guidance, and codes and standards with increasing technical level of detail.

Some of these countries (France and U.K.) have already regulated fusion facilities using tritium. There are also ongoing activities in different countries, e. g. China, Korea, U.K. and the U.S., on how to advance the regulation of fusion facilities with involvement of different stakeholders. In some of the countries (e. g. China and Germany), the application of the regulation for nuclear power plants is limited to facilities using fissile material (uranium, plutonium, thorium). The last point is related to the way different countries legally define the term "nuclear facilities". In some countries, it is limited strictly to the use of fissile materials while other apply it to facilities using any kind of radioactive material.

It was found that in any way the regulation of radiation facilities and radiation protection is applicable to fusion facilities and form the basis for licensing. But there is a gap in the existing

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licensing approaches for fusion facilities or fusion power plants with respect to their higher radiological hazard potential compared with typical radiation facilities and their lower radiological hazard potential compared to fission power plants.

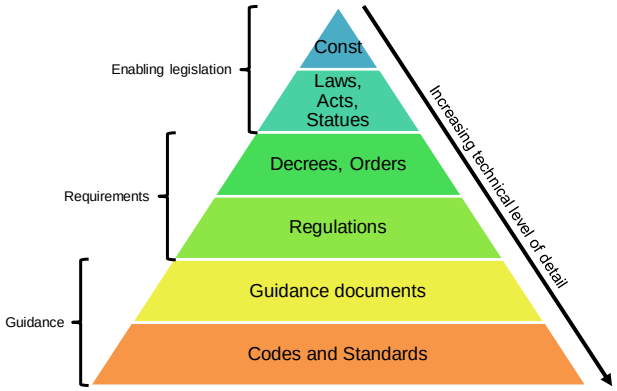

FIG. 1. Typical structure of a legal and regulatory framework (based on [2])

It was also found that different countries use the thermal power of reactors/research reactors in a graded approach. Based on the thermal power, the requirements applied in licensing are modified. For fission reactors the thermal power is also an approximate measure for the radioactive inventory and therefore, for a potential source term in the case of severe accidents. If this approach is applied to fusion facilities, no benefits are given to credit their less radio-toxic inventory compared to fission facility. Thus, thermal power is not a suitable parameter for grading safety requirements for fusion facilities, as it is usually applied for fission reactors.

In principle, the different approaches for regulations can be assigned to two different categories: either a prescriptive approach or a goal-oriented (or performance based) approach. In the prescriptive approach, the regulations contain explicit requirements the licensee needs to fulfil. These requirements are based on the specific technology used for the facilities. The level of detail can go down to specific safety systems to be installed in the facility. In a goal-oriented approach, the regulation sets safety goals like the containment of the radioactive inventory. It is the task of the licensee to prove to the authorities that the chosen design and way to operate the facility fulfil the given goals. Examples for a prescriptive approach are the nuclear regulations in China, Germany, Korea, and the U.S. Examples for a more goal-oriented approach are the regulations in France and the U.K. Depending on the maturity of the technology, the two approaches have different advantages and disadvantages. The examples of licensing ITER and JET have shown that more goal-oriented regulations have already been successfully used to license these fusion facilities.

To identify safety requirements specifically needed for fusion facilities it is necessary to analyse the main differences between fusion and fission facilities firstly. Significant ones are the different radioactive inventories of the facilities, their distribution inside the facility and the radiological consequences of potential releases. They differ by several orders of magnitude in the case of a purely hypothetical release of large amounts of this radioactive inventory [3]. For a fusion facility, power excursion or re-criticality can be excluded, which can be a significant threat at a nuclear fission facility. Based on the different technologies of fusion and fission facilities there are also differences in the technical safety concepts. For fission facilities a

considerable amount of operational experience has been collected whereas fusion facilities (with power plant like boundary conditions) need to be considered as first of its kind.

The second step for the identification of fusion specific safety requirements was the assessment of specific safety issues for fusion systems, structures, and components (SSC). This assessment has been based on facilities with magnetic confinement, in particular the tokamak design. Possible sources of energy in a tokamak were identified which might release the stored energy following postulated initiating events. In addition, types of ionizing radiations (e.g. neutron, prompt and delayed γ radiation), non-radiological hazards and activated materials and activation products were identified. Further topics investigated were occupational safety issues, mobilized fraction to environmental release in accident case, long-lived radionuclides, the ways used to analyze the safety of fusion facilities concepts, and the results of such analyses including the identified postulated accidents, accident analyses, confinement strategies and radioactive waste management.

As further input for a possible future fusion specific regulatory framework the existing different European Directives were screened and categorized. These Directives do not address fusion specific requirements but place requirements generally applicable to all facilities. European Council Directives are mandatory for all EU Member States and must be transposed into national laws.

The European Basic Safety Standards Directive 2013/59/Euratom of 5 December 2012 lays down uniform basic safety standards for protection of the health of individuals subject to occupational, medical, and public exposures against the dangers arising from exposure to ionising radiation. This Directive was not developed considering fusion facilities, but it provides basic safety standards which are applicable and must be met with respect to occupational and public exposure. It defines requirements for topics such as a legal system for radiation protection, justification, and regulatory control of practices.

Council Directive 2009/71/Euratom amended by Directive 2014/87/Euratom of July 2014 establishes a regulatory framework for the nuclear safety of nuclear installations. It applies to civilian nuclear installations and by the definition of nuclear installations used it does not apply to fusion facilities. Nevertheless, the general requirements of this directive could be applied to fusion facilities.

Council Directive 2011/70/EURATOM of 19 July 2011 established a framework for the responsible and safe management of spent fuel and radioactive waste. This Directive is directly applicable to fusion facilities producing radioactive waste through activation processes.

Commission Regulation (Euratom) No 302/2005 of 8 February 2005 on the application of Euratom safeguards applies to fissile materials and therefore, not to fusion facilities. This regulation might need to be extended to fusion facilities as those are expected to have large tritium inventories.

There are other non-nuclear Council Directives related to non-radioactive hazards, which need to be fulfilled for fusion facilities due to the provision of general rules and requirements not specific to certain facilities (e. g. Workers exposure to Chemical Agents (98/24/EC), Workers exposure to Carcinogens or Mutagens (2004/37/EC), Worker exposure to electromagnetic fields (2013/35/EU), Substances in electrical and electronic equipment (2011/65/EU)).

Other sources that were investigated as input for a fusion specific regulation were IAEA Safety Standards and Guides (see fig. 2). Currently, there are no dedicated IAEA safety standards for fusion facilities.

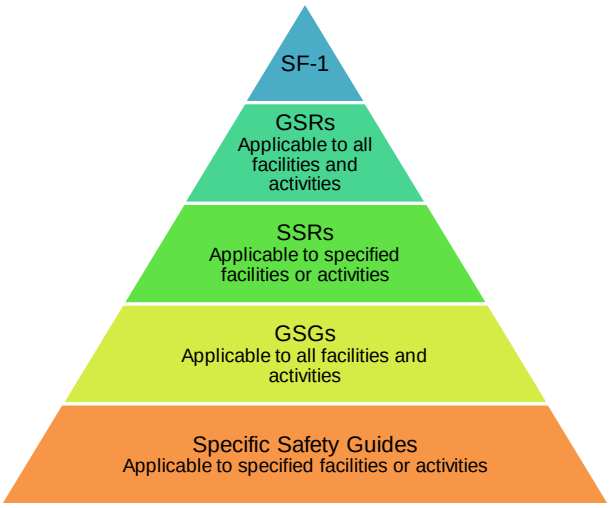

FIG. 2. Hierarchy of IAEA safety requirements and guides [4]

The IAEA Safety Standard Series No. SF-1 “Fundamental Safety Principles” has the objective to establish the fundamental safety objective and ten safety principles as well as their intent and purpose. Due to the generic nature, it is fully applicable to fusion facilities. It was also found that most of the General Safety Requirements are directly applicable due to their high level of abstraction and their general requirements. In principle, most of the Specific Safety Requirements could be applied. More than 70 IAEA safety guides were screened including the topics site evaluation, design, construction and commissioning, operation, decommissioning and waste management, radiation protection, leadership and management, and safety assessment. Most of the guides were found to be applicable in principle. Their content could complement requirements applicable to all radiation facilities to enhance the safety of future fusion facilities, provided it is done in a proportionate and targeted manner. Some guides are fully applicable, others not at all.

Based on evaluation of the existing European regulation and the IAEA safety requirements the following recommendations are made how a legal and regulator framework for fusion facilities could be implemented. The requirement for fusion facilities can be directly derived from the principles of the IAEA SF-1 and the General Safety Requirements Part 1.

For the legal framework it is recommended to use Council Directive 2009/71/Euratom as basis, because it establishes important aspects like defining the competent regulatory authority, establishing a licensing procedure and a system for operational experience feedback, requiring initial assessment of safety and regular reassessment of safety, defining a high-level safety objective and its implementation as high level requirements, and establishing an adequate on-site emergency organization. But currently fusion is out of scope of this Directive. Therefore, it is recommended to discuss how similar requirements could be established for fusion facilities.

For the regulatory framework it is recommended to follow the IAEA general safety requirements, especially for the topics siting, leadership and management, safety assessment,

and decommissioning with fusion specific adoptions such as the postulated initiating events to be considered.

For a safety concept for fusion facilities, recommendations are provided for the following topics:

— Safety objectives, derived from European Directives and the IAEA safety requirements including fundamental and supporting safety functions
— Establishment of a defense in depth concept and its implementation
— Concept of multi-level confinement of the radioactive inventory
— Protection against internal and external hazards
— Establishment of a graded approach for regulation
— System for operating experience feedback

Fusion specific safety requirements need to address the aspects of various energy sources, radioactive inventory, and safety relevant SSCs.

It is also recommended to develop international harmonized codes and standards in a consistent way with high level safety requirements.

Recommendations for the interface between safety, security and safeguards were given. They apply to the whole lifetime of a facility and are based on IAEA safety requirements and other IAEA and WENRA documents.

Finally, an action plan was proposed with the aim to guide the development and implementation of a fusion specific legal and regulatory framework. For the different steps the involved stakeholders were identified.

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