IAEA
International Atomic Energy Agency
Atoms for Peace and Development

OVERVIEW: DESIGN SAFETY, SAFETY ANALYSIS AND REGULATION

Technical Meeting on Synergies Between Nuclear Fusion Technology Developments and Advanced Nuclear Fission Technologies

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Outline of the Section 3.11

Section objective:

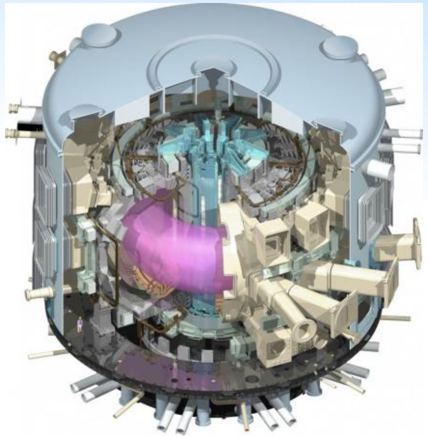
- To provide a high level overview of main differences between fission and fusion and potential impact on safety
- The chapter will also identify synergies between fission and fusion
- The chapter will not provide recommendation on approaches to be adopted

Proposed outline:

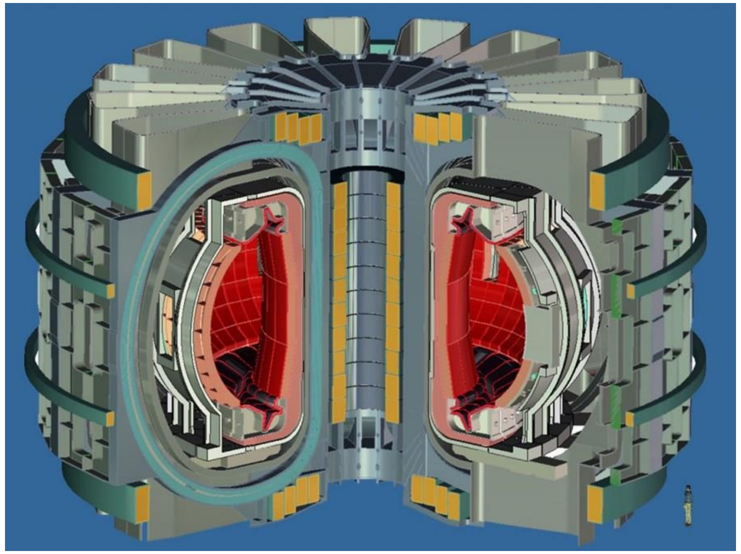
- 3.11.1 Introduction and scope
- 3.11.2 Regulatory
- 3.11.3 Design Safety and Safety Analysis
- 3.11.4 Siting and External Hazards considerations
- 3.11.5 Emergency Preparedness and Response

Summary of 3.11.1 Introduction and scope

- Development of the Fusion Energy as a new source of energy is rapidly progressing from **academic to industrial environment**
- There is substantial amount of knowledge and experience in fusion through the construction and operation of the fusion experimental devices around the world
- Fusion energy programs are moving towards fusion power plants (FPPs)
- This section will introduce at the high level main fusion evolution and characteristics to set up the context for the identification of synergies between fission and fusion
- An important message: fusion safety and regulation needs to be based on the particular features of this new source of energy



ITER (0.5 GW)



EU - DEMO (up to 2 GW)

Summary of 3.11.2: Regulatory

- A high-level overview of common issues and common approaches for regulatory framework over future fusion facilities
- Considering the difference of the existing legal and regulatory framework for fusion and fission facilities among Member States
- Considering the diversified types of future fusion facilities, with recognizing opportunity for homogenized regulatory approach.

Summary of 3.11.3: Design Safety and Safety Analysis

- High-level overview of key safety approaches for the design and safety analysis of fission facilities based on the safety standards. These may include a review of aspects such as safety functions, DiD, general design requirements, probabilistic and deterministic safety analysis.

- Consideration at the high-level key safety aspects of fusion power plants. For example, fusion devices characteristics that contribute to safety as well as conditions that could lead to radioactive release as well as the radioactive inventory and source term.

- Main commonalities and differences between fission and fusion will be identified at a very high level as well as the implications on safety approaches that are traditionally used for fission.

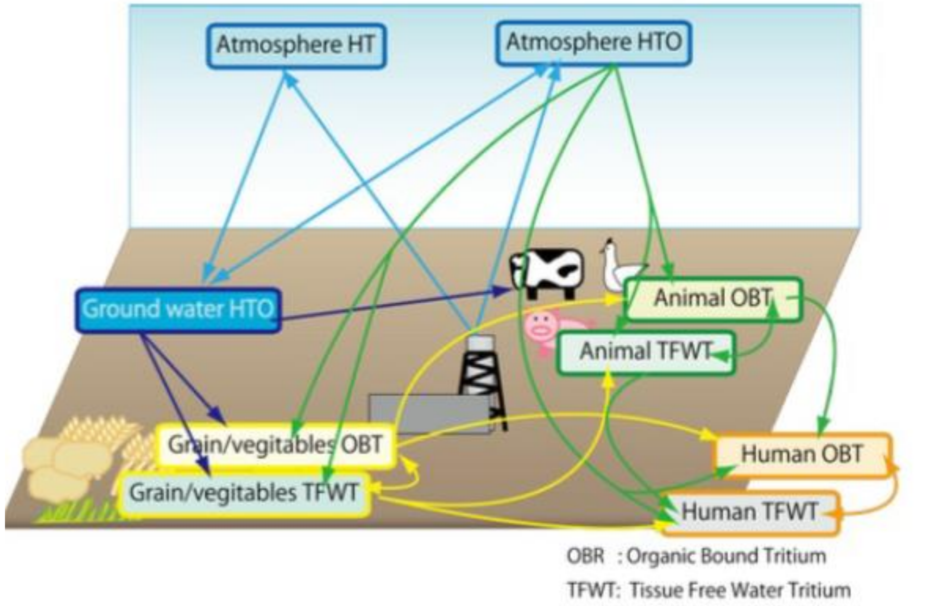
Summary of 3.11.3: Design Safety and Safety Analysis

Examples of differences between fission and fusion

Fusion power plant (FPP) is a facility that uses fusion reactions to generate commercial power in the form of electricity or heat

Safety functions of FPP may be related to:

- **Confinement** of the (toxic and) radioactive materials
- **Protection of the workers** from exposure
- **Heat removal**



Structure of NORMTRI model

Courtesy of INL

Summary of 3.11.3: Design Safety and Safety Analysis

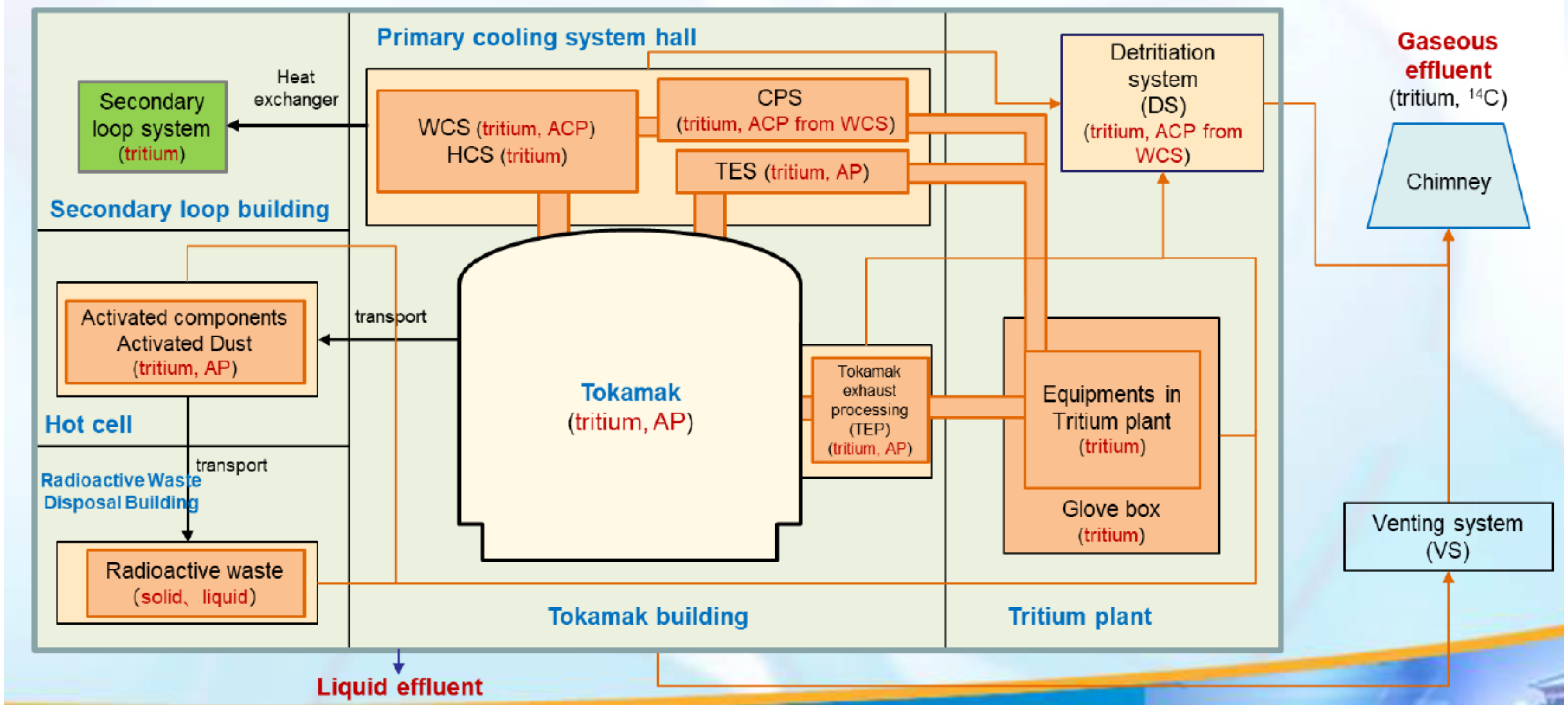
Examples of differences between fission and fusion

Characteristics of a FPP in terms of safety - hazard potential:

Important elements of an FPP hazard potential are:

- The **inventory** (total amount of radioactive materials present in relevant closed and confined volumes at the FPP) and the **source term**
- The **neutron activation** of components (leads to potential radiological hazards that need to be carefully controlled)
- The **energy deposed** (leads to potential impact onto the confinement barriers which could be damaged)

Radioactive Source Terms



Courtesy of CNNC

- Radioactive source terms in fusion reactor (e.g. Tritium, activated products (AP, including dust) and activated corrosion products (ACP)) are different

Summary of 3.11.4:
External Hazards – Siting and Design issues

While the nuclear safety principles can be restated from the tradition of the fission reactors, it is generic convincement that in order to develop robust safety cases, significant work is needed to tailor the safety approaches developed for fission to the sophisticated safety engineering solutions, in order **to develop "sustainable" safety approaches** for fusion reactors. This is particularly true for the site-design combination that requires a dedicated optimisation effort to protect the fusion reactors against external hazards.

Three important aspects need to be addressed in a fission-to-fusion migration of safety concepts and practices in relation to EEs:

1. An appropriate safety analysis (with EE initiators and Postulated Internal events) of the fusion reactors is needed to define **the number of DID levels, their characteristics and the need for classification of the relevant SSCs in relation to EEs**

2. All items important to safety shall be designed to withstand the effects of external hazards and common cause failure generated by hazards, with reference to **specific performance goals**. Appropriate safety analysis methods have to be developed for safety margin assessment in relation to EEs

3. The scope of the site evaluation must consider factors related to **interaction between the site and the installation**. The scope and level of details of the site evaluation process must be determined in accordance **with a graded approach**, i.e. the application of the safety requirements for site evaluation have to be commensurate with the potential radiation risk posed to people and the environment. The process should be developed with reference to a **technology neutral** framework.

Summary of 3.11.4:
External Hazards – Siting and Design issues

- External Hazards are potential initiators of accident sequences and may challenge the plant response capability: all items important to safety shall be designed to withstand the **effects of hazards and common cause** failure generated by hazards.
- **Performance goals** should be adapted to fusion reactors to apply a safety assessment process and a suitable grading approach
    - Safe shutdown -> Operation?
    - Integrity -> Vibration?
    - Temperature for integrity -> Temperature for operation?
- A methodology is needed for an **overall optimization of safety measures against external hazards** supporting effective and balanced implementation of the defence-in-depth concept. **Grading should be applied** to all the following steps:
    - EE screening (on probability, risk, etc.)
    - Hazard development (site investigation, modelling)
    - Design basis development
    - Performance values identification
    - Design safety assessment
    - Operational safety
    - Decommissioning

Summary of 3.11.5 Emergency Preparedness and Response

- **Specific presentation** on identifying synergies between fission and fusion power reactors in the area of Emergency Preparedness and Response (EPR) will be provided as **next TM agenda item**

- Will introduce **IAEA Safety Standards in the area of EPR**

- Will present main highlights from the 2021 review to assess the applicability of these Safety Standards to "Next Generation Reactors"

- Will highlight **key questions** that will need to addressed to develop **EPR guidance for fusion reactors**

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Thank you!

Questions?