Karlsruhe Institute of Technology

EUROfusion

[1] Institute of Neutron Physics and Reactor Technology (INR)
P.O. Box 3640 76021 Karlsruhe, Germany
[2] EUROfusion, Boltzmannstr. 2, 85748 Garching, Germany
[3] UKAEA, CCFE, Abingdon, Oxfordshire, OX14 3DB, UK

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Proposal of the Confinement Strategy for EU DEMO

Xue Zhou Jin[1], Dario Carloni[1], Robert Stieglitz[1], Sergio Ciattaglia[2], Jane Johnston[3], Neill Taylor[3]

Introduction

Following the European roadmap to the realisation of fusion energy, a demonstration fusion power plant (DEMO) is currently in pre-conceptual design phase until 2020. In this context an external stakeholder group formulated a nuclear licensed manufacturing and construction (M/C) mission statement as the top level requirement for a DEMO, translating essentially to the confinement of radioactive and hazardous materials as the most fundamental safety function in normal, abnormal and accidental situations. Taking a bottom-up approach at system level, the confinement function is identified for the main systems at the PBS level 1. Consequently, a confinement strategy has been proposed.

Safety relevant sources and hazards

- **Energy**
  - ***In operation: enthalpy in structure and coolant, plasma thermal energy, magnetic energy, disruption mechanical energy***
  - ***Decay heat after the plasma shutdown***
  - ***Energy from exothermal chemical reactions (W/Be/PbLi - air/steam), dust explosion, overpressure scenarios, spills of cryogenic or hot He into the VV and containment, etc.;***
  - ***Energy release due to postulated H_2 explosion***
- **Radioactive sources**
  - ***Tritium in different facility regions (VV, PHTS, fuel cycles)***
  - ***Dust in the VV***
  - ***Activated corrosion products (ACPs)***
  - ***Neutron sputtering products***
  - ***Activated materials***
  - ***Radioactive isotopes from noble gases (Ne or Ar) used for plasma seeding***
  - ***N_2 seeding for ELM mitigation, N_2 impurity in structure, injected N_2 to avoid H_2 explosion.***
- **Internal hazards**
  - ***Internal fire, explosion, flooding***
  - ***Thermal releases***
  - ***Plasma transients / disruption***
  - ***Missile effects and pipe whip***
  - ***Loss of vacuum, coolant, heat sink, cryogenics***
  - ***Mechanical, chemical and toxic, magnetic and electromagnetic risks***
- **External hazards**
  - ***Natural environment (earthquakes, extreme climatic conditions, flooding, fire)***
  - ***Human activities (air crash, station blackout, etc.)***

Confinement systems

- **First confinement system**
  - ***First barrier***
    - *VV and its extensions (incl. NB cell, VVPSS in case of accident)*
    - *Blanket-, divertor- and VV-PHTS*
  - ***Second barrier***
    - *VVPSS & connections to the VV*
    - *Drain tank*
    - *PHTS-HX*
    - *Glove boxes*
    - *CPS, TER*
    - *Emergency cooling system*
    - *Isolation valve*
- **Second confinement system**
  - ***Third barrier***
    - *Active systems: HVAC system, N-VDS, TEP system, S-VDS, EDS*
    - *Common discharge point, EV*
    - *Tokamak and tritium building*

Barriers in maintenance

- **First confinement system**
  - ***First barrier***
    - *VVPSS, drain tank*
    - *Emergency cooling system*
    - *Cryostat (if vacuum is unaffected)*
    - *CCD, transport cask (ITER) or hot cell (advanced concept)*
- **Second confinement system**
  - ***Second barrier***
    - *HVAC system, ADS, VDS, EDS*
    - *Common discharge point*
    - *Tokamak building*
    - *Crossing structure to the AMF*
    - *AMF*

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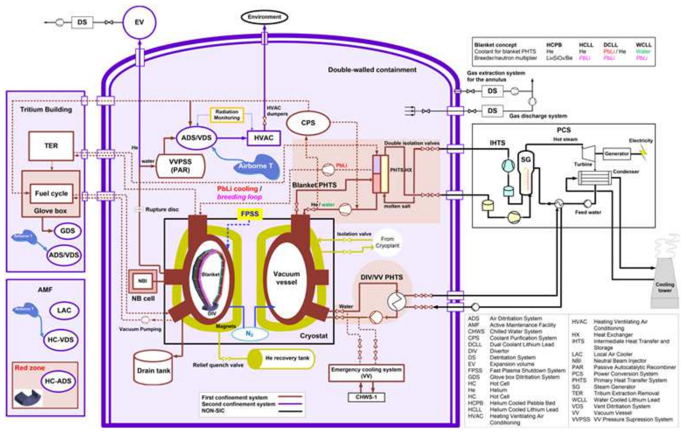
Objectives of DEMO confinement

- **to protect every inventory of radioactive, toxic or hazardous material:**
  - ***to prevent mobilisation into rooms where personnel could be exposed,***
  - ***to prevent release to the environment that could lead to public exposure.***
- **to meet DEMO general safety objectives in compliance with the environment in operational / accidental situation,**
- **to reduce potential impacts to the extent reasonably practicable.**

DEMO main systems at the PBS level 1

Active system		Passive system
• Magnet system (-) • Tritium, fuelling, vacuum (TFV) (+/-) • Tritium extraction removal (TER) • EC system (+) • NBI system (+) • IC system (+) • Plasma diagnostic & control system (+/-) • Blanket-PHTS (+) • VV-PHTS incl. emergency cooling system (+) • DIV-PHTS (+)	• VVPSS (+) • RM system (+) • BOP (-) • Cryoplant & cryodistribution (-) • Electrical power supply systems (-) • Plant Control System (-) • Auxiliaries system (-) • Radwaste treatment (+)	• VV (+) • Divertor (-) • BB system (-) (HCPB, HCLL, DCLL, WCLL) • Limiter (-) • Cryostat (-) • Thermal shields (-) • Buildings (tokamak & tritium buildings) (+) • Radwaste storage (+)
(+) with confinement function, (-) no confinement function.		

Confinement scheme



Assignment of sources to confinement barriers

Source		Barrier active	Barrier passive
Energy	Decay heat	Emergency cooling system	PCCS (WCLL)
	Chemical reaction energy	Emergency cooling system	PCCS (WCLL)
	Dust explosion	N_2 dilution, O_2 limitation	VV
	Overpressure scenarios	VVPSS, drain tank	VV, EV, rupture disc
	Spills of cryogenic / hot He into the VV	-	VV, EV, rupture disc
	H_2 explosion	N_2 injection	VV, PAR
Radioactive source terms	Tritium	S-VDS, EDS, isolation valve	VV, emergency storage system
	Dust / ACPs	Isolation valve	VV
	Activated materials	-	VV

Conclusion

- **Based on the DEMO main systems identified with the confinement function, a confinement strategy has been proposed: two confinement systems and three associated barriers during normal operation, and two barriers in maintenance.**
- **The main safety systems and devices have been proposed.**
- **Not all source terms are covered by both active and passive barriers. More passive safety systems are required.**
- **Identify the confinement function for the sub-systems & components accompanying the development of PBS levels in future.**
- **Open issues: source inventories, provision of the He EV, discharge of the huge amount of magnet energy in accident scenarios, leak conditions, wall & composite liner options for the tokamak building taking into account cost implications, additional passive / active methods , maintain confinement for different plant states (cold and hot standby, maintenance).**