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Proposal of the Confinement Strategy for EU DEMO

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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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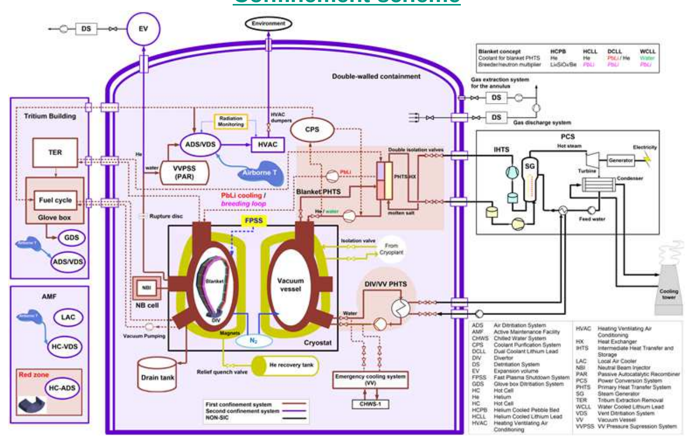
Objectives of DEMO confinement

- **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	**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).**