DEMO and Fusion Power Plant Conceptual Studies in Europe

7th International Symposium on Fusion Nuclear Technology

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Overview

Towards a fusion reactor

Power Plant Conceptual Study

DEMO issues

Conclusions

Towards a Fusion Reactor

Next Step -- DEMO -- FOAK Reactor -- Reactors

scientific and technological feasibility of fusion energy

ITER

Qualification of components and processes

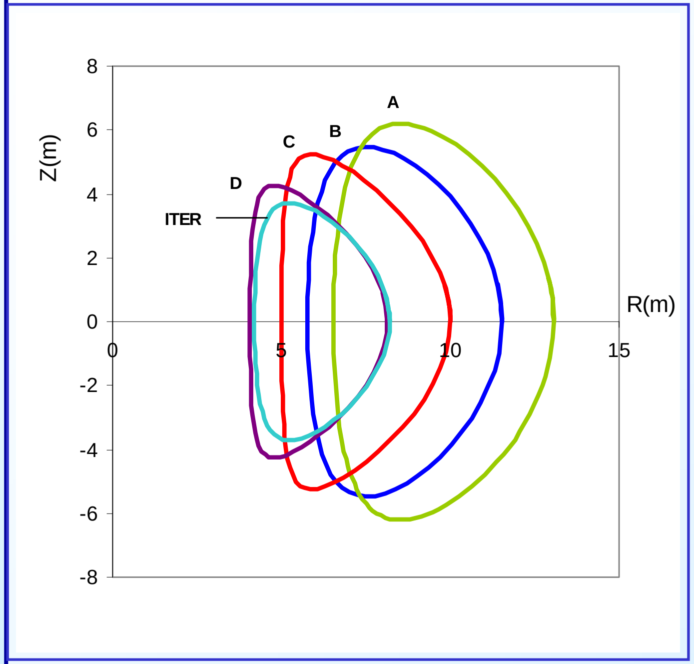
DEMO Studies

- High availability
- Safe and environmental-friendly
- Economically acceptable

Basic requirements clarified with Utilities and Industries

Power Plant Conceptual Studies

PPCS Models



4 plant models developed, ranging from “limited” to “very advanced” extrapolations in physics and technology, as examples of a spectrum of possibilities (e.g. 3 different coolants considered: water, helium and lithium-lead).

Models selected considering EU blanket concepts development program (DEMO and long term).

Systems code (PROCESS), subject to assigned plasma physics and technology rules and limits, determined the economic optimum for each model.

A 5th model, named AB, has been developed and was presented at this Symposium on Tuesday, 24.05.05 (S2-04-O-05: Breeding Blanket Design and Systems Integration for He-cooled Lithium-Lead Fusion Power Plant)

Fusion Reactors PPCS Parameters

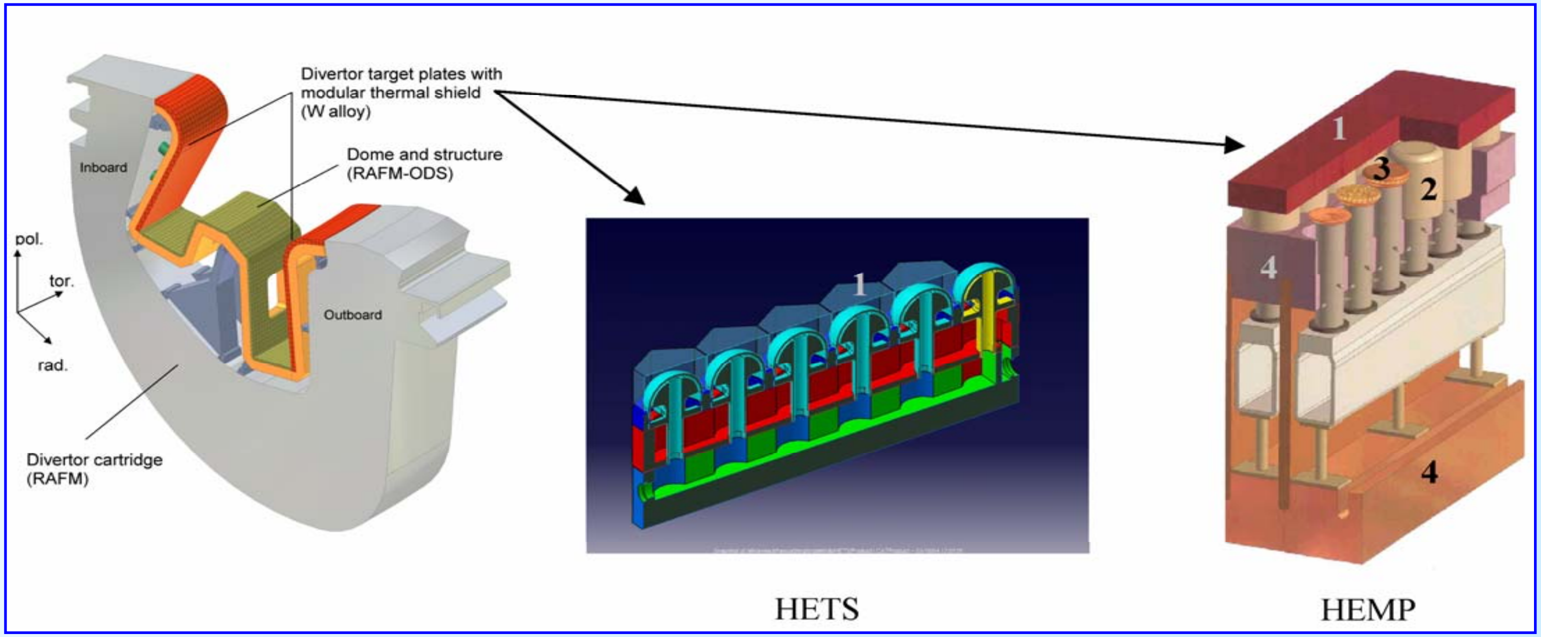
	limited extrapolation			advanced	
Parameter	A	B	AB	C	D
Unit Size (GW_e)	1.55	1.33	1.46	1.45	1.53
Fusion Power (GW)	5.00	3.60	4.29	3.41	2.53
Major Radius (m)	9.55	8.6	9.56	7.5	6.1
Net efficiency	0.31/0.33	0.36	0.34	0.42	0.60
Plasma Current (MA)	30.5	28.0	30.0	20.1	14.1
Bootstrap Fraction	0.45	0.43	0.43	0.63	0.76
P_{add} (MW)	246	270	257	112	71
Divertor Peak load (MWm^{-2})	15	10	10	10	5
Av. neutron wall load	2.2	2.0	1.8	2.2	2.4

Nuclear Power Core

		Model A	Model B	Model AB	Model C	Model D
blanket	Structural material	Eurofer	Eurofer	Eurofer	Eurofer	SiC/SiC
blanket	Coolant	Water	Helium	Helium	LiPb/He	LiPb
blanket	Coolant temp. in/out (°C)	285 / 325	300 / 500	300 / 500	480 / 700 300 / 480	700 / 1100
blanket	Breeder	LiPb	Li_4SiO_4	LiPb	LiPb	LiPb
blanket	TBR	1.06	1.12	1.13	1.15	1.12
divertor	Structural material	CuCrZr	W alloy	W alloy	W alloy	SiC/SiC
divertor	Armour material	W	W	W	W	W
divertor	Coolant	Water	Helium	Helium	Helium	LiPb
divertor	Coolant temp. in/out (°C)	140 / 167	540 / 717	540 / 717	540 / 717	600 / 990

Key Technical Innovations
helium-cooled divertor concept

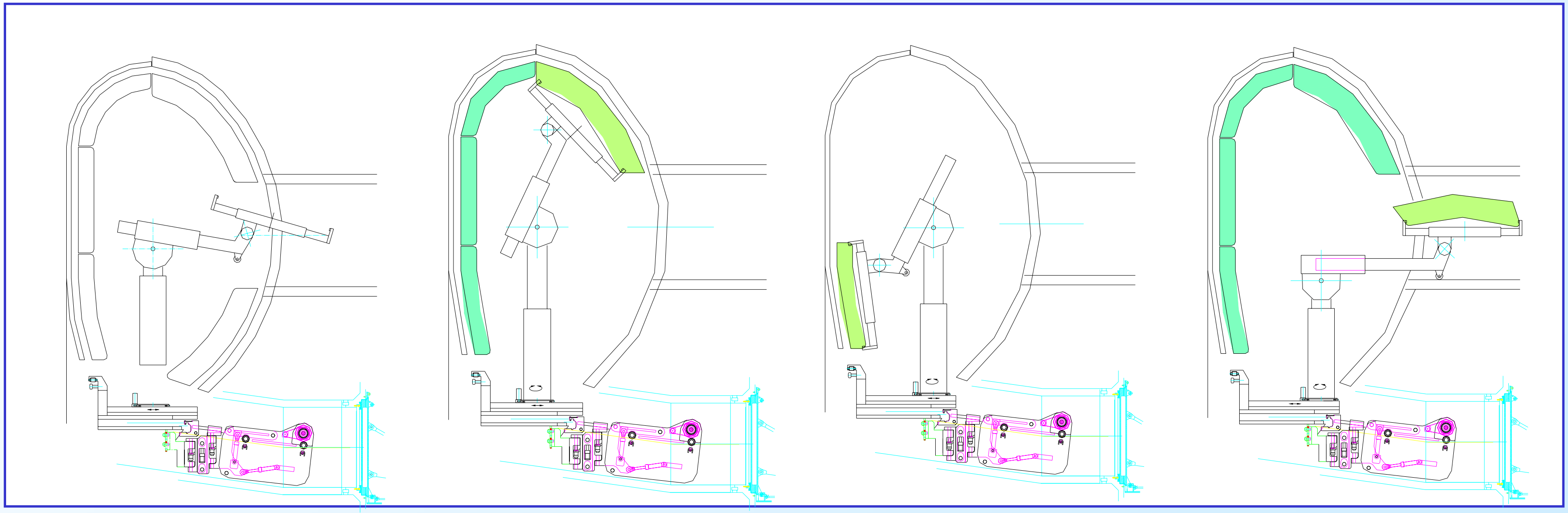
Concept permitting high tolerable heat flux of 10 MW/m^2



High Efficiency Thermal Shields

HE-cooled Modular divertor concept with integrated Pin array

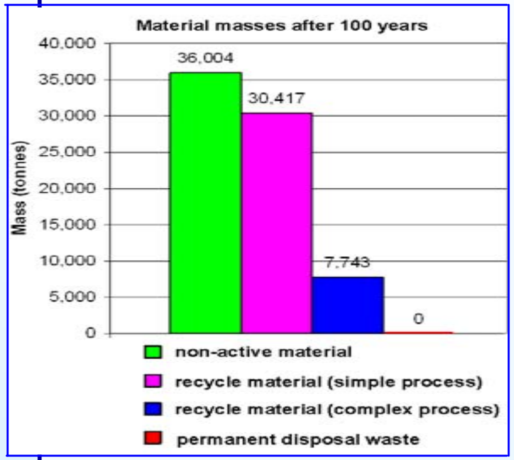
Key Technical Innovations maintenance



PPCS investigated alternative segmentation of blanket in "large modules" without affecting the overall mechanical structure.

Availability of models A and B (189/162 modules, 54 cassettes): between 73 and 80 %

PPCS Safety, Environmental & Economic Assessment



Total loss of coolant: no melting, without relying on any active safety system.

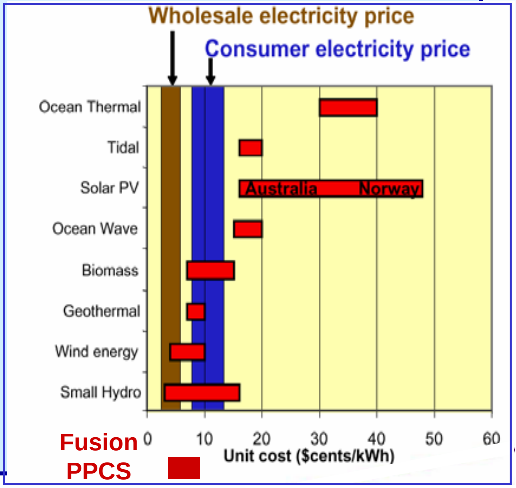
Doses to the public after most severe accident driven by in-plant energies: no evacuation.

No need of deep geological disposal for rad-waste.

Internal cost of electricity ranges from 5-9 (model A) to 3-5 (model D) Eurocents/kWh depending on the assumed degree of maturity of the technology considered.

External cost ranges from 0.06 to 0.09 Eurocents/kWh.

Even the near-term Models are acceptably competitive.



DEMO

- ITER objectives and design are well established, but this is not the case for DEMO.
- Work on PPCS "near-term" models A, B and AB can assist in the selection of the main parameters and technical choices for DEMO.

DEMO Physics Drivers

Plasma current and bootstrap fraction determines the power required for H&CD. Even with efficiencies of 60%, the recirculating power for H&CD severely affects the economic performances of models A, B and AB.

	Model A	Model B	Model AB
Fusion power (MW)	5000	3600	4290
Blanket& Divertor Power (MW)	5739	4937	5145
Pumping power (MW)	110	375	418
H&CD power to the plasma (MW)	246	270	286
Gross electric power (MWe)	2066	2157	2353
NET electric power (MWe)	1546	1332	1458
Plant efficiency (net electric power/fus. Power)	31 (33) %	36 %	34 %

Plasma current also drives the mechanical loads on the internals and on the VV.

Practically, both the plasma current and the power required for H&CD should be minimised in DEMO and in future power plants.

DEMO Technology Drivers

Choice of helium as primary coolant raises 3 main questions:

- structural material for a He-cooled divertor with an operating window in the range 600-1300°C;
- structural material for a blanket allowing for a higher He outlet temperature than that permitted by EUROFER (500°C) in order to increase the thermodynamic efficiency of the power conversion;
- and, although not fusion specific, the availability of proven technology for the balance of plant.

The definition / validation, of a maintenance scheme able to guarantee an acceptable plant availability remains a major concern

Conclusions (1/2)

- Plasma performance only marginally better than the design basis of ITER is sufficient for economic viability of fusion reactors
- A first generation of commercial fusion power plant will be economically acceptable, with major safety and environmental advantages
- During the PPCS, a conceptual design of a helium-cooled divertor capable of tolerating a peak heat load of 10 MW/m^2 and the definition of a maintenance concept capable of delivering high availability (75%) were developed

Conclusions (2/2)

- PPCS conclusions confirm that the main thrusts of the European fusion development programme are on the right lines: ITER; materials, development of blanket models
- More work should be undertaken on the development of divertor systems (started) and of maintenance procedures
- Performance of a DEMO conceptual study (started)

PPCS Final Report:

www.efda.org (path: Downloads/EFDA Reports)