Remarks on "Do Fusion Power Plants Really Require Low Activation Materials?"

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Main Points

1)Low activation is not, and should not be, an absolute requirement.

There are much more fundamental requirements that an acceptable fusion energy source must meet.

2)Low activation is, of course, desirable. But it is only one of many criteria for attractiveness.

3)Innovative designs can change the classification of a given material from "High Activation" to "Low Activation." (Example)

4)The term "low activation" is a technically incorrect phrase that lacks intellectual content. When used as a slogan to articulate an R&D vision, it leads to a technically inconsistent and programmatically confused development path.

The Acceptance of an Energy Source Depends on Many Criteria

I. Feasibility / Practicality

II. Economics
- Cost
- Power (high wall load, high efficiency)
- Availability (low failure rate, short time to repair)

III. Safety
- Decay Heat
- Stored Energy
- Chemical Reactivity
- Off-Site Dose Potential
- Tritium Inventory
- Tritium Inventory and Permeation
- Biological Hazards Potential
- Radioactive Inventory of Volatile Material

IV. Environmental Impact
- Material Resource Utilization
- Routine Emissions
- Waste Disposal (Deep Disposal Index)

Power Density and Heat Flux in Fission Reactors

	PWR	BWR	HTGR	LMFBR	ITER-Type
Equivalent Core Diameter(m)	3.6	4.6	8.4	2.1	30
Core Length(m)	3.8	3.8	6.3	0.9	15
Average Core Power Density (MW/m^3)	**96**	**56**	**9**	**240**	**0.4**
Peak-to-Average Heat Flux	2.8	2.6	12.8	1.43	50

Suggested Fusion Goals

- Neutron Wall Load > 10 MW/m^2
- Minimize Peak - to - Average Power Density

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Average Heat Flux at the Interface of Fuel Rod and Coolant (MW/m^2)	0.6	0.5	0.2	1.1	5

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Current Design Concepts and Materials for First Wall / Blanket Based on Low Activation

Structural Material	Coolant	Breeder
Ferritic Steel	He	Ceramic breeder
Ferritic Steel	H_2O	Li Pb
Vanadium Alloy	Lithium	Lithium
SiC / SiC	He	Ceramic breeder

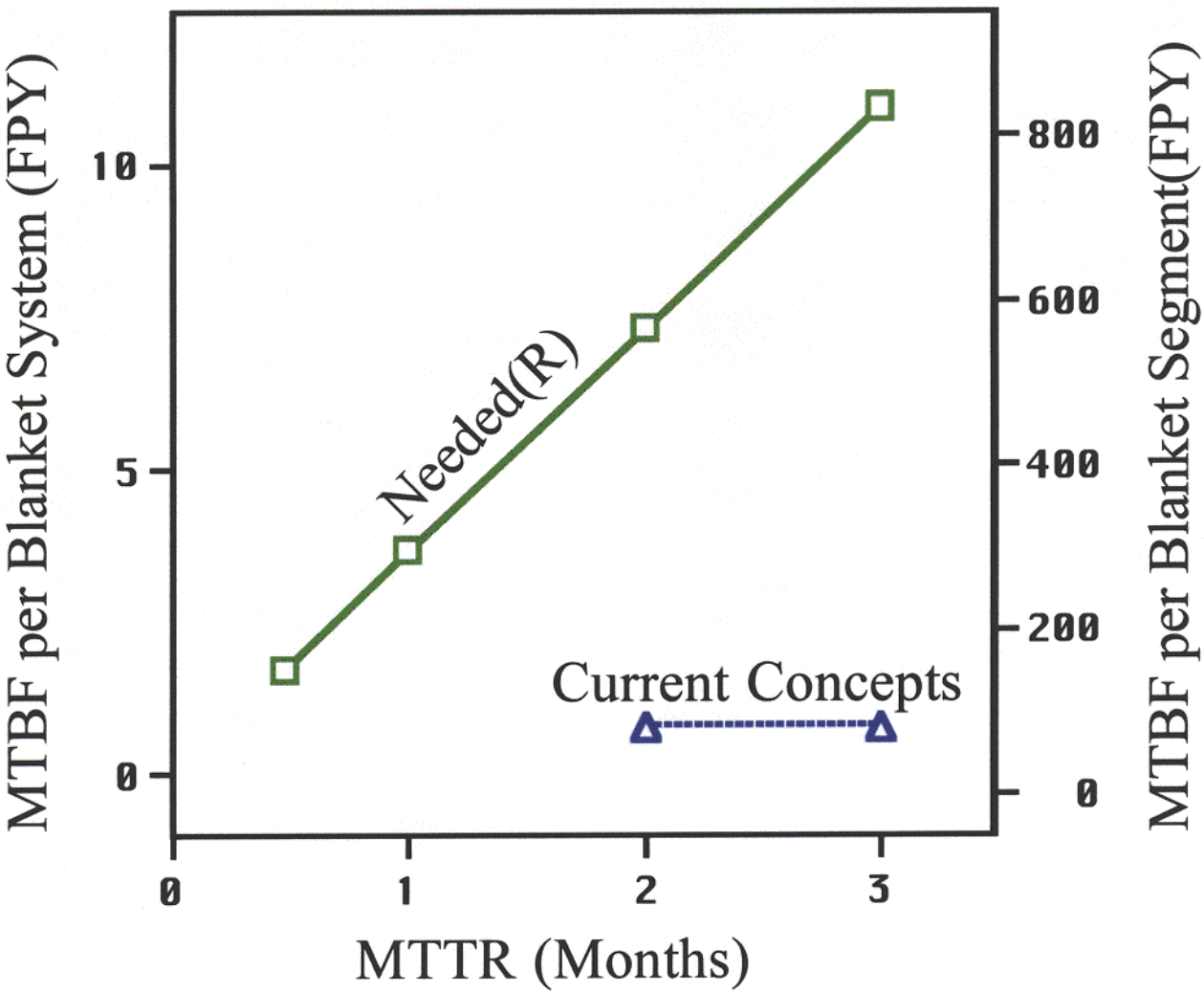
Are any of these concepts capable of meeting the economic competitiveness requirements?

Current Design Concepts and Materials (Low Activation) for First Wall / Blanket

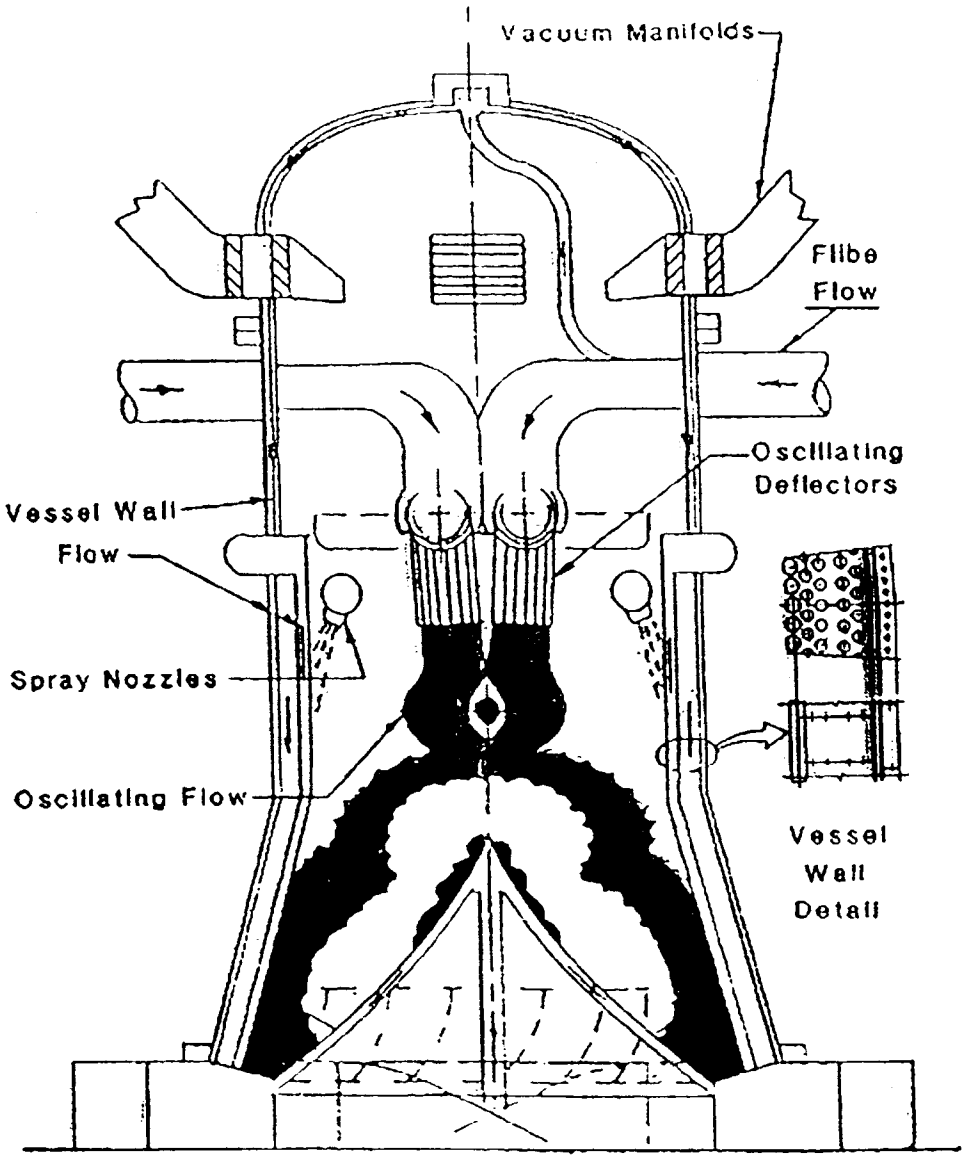
Do NOT Have the Capability to Meet the Fusion Challenge

Concept	Wall Load Capability MW/m^2	Other Observations
Ferritic / He / Breeder **Ferritic / H_20 / Li Pb**	**2**	• Magnetic material • Fracture toughness
Vanadium Alloy / Lithium	**2.5**	• V works only with lithium • Is lithium acceptable? • Not feasible until a self healing coating is found
SiC / SiC / He / Breeder	**1.5**	• Serious feasibility issues • Do NOT know how to design • Poor thermal conductivity

Current FW/B Design Concepts are NOT Capable of Meeting the Challenging Reliability and Maintenance Requirements



Example of Innovation: IFE Liquid Wall Protection Schemes



High Risk / High Payoff

- Conventional stainless steel would become "low activation material" in IFE solid FW
- Much reduced loading conditions at FW; hence much higher core power density capability
- Radiation effects at the FW are eliminated as a serious issue

Suggested Guidelines for Materials and First Wall / Blanket R&D

1) Focus on **material systems** with compatible combinations of coolants, breeders, multipliers and structural materials. Highest priority must be given to **feasibility issues** and satisfying the FPT functional requirements.

2) **Economic competitiveness** must be a key goal. This requires high power density capability (wall loads > 5 MW/m^2), high temperature, low failure rates, and fast maintainability.
   – New concepts and possibly a new set of materials need to be explored.

3) Attempt to select only a combination of materials and design concepts for which **passive safety** can be realized.

4) Include low activation as one of the many criteria for which tradeoffs are performed to select the most practical and attractive system.

6) Realize that selecting low activation structural material is not the only means to realizing a low activation system. Thick liquid walls, for example, as proposed for IFE allow practically any structural material to be low activation. Furthermore, coolants, breeders, and multiplier materials have about ten times the material volume of structural materials and hence, their activation characteristics are as important as those of the structural materials.