Technical Issues of Leading U.S. Blanket and Other FNT Component Design Concepts

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Presented at the U.S./USSR Exchange I.7
Topical Meeting on the Possibility
for Joint Planning in the Area of
Fusion Nuclear Technology, Especially Blankets

Efremov Institute
Leningrad, USSR
6-9 July 1987

Technical Issues for FNT

A number of studies have identified and characterized the technical issues for the nuclear components (blanket, shield, high heat flux components, and tritium systems)

- FINESSE

- TPA

- BCSS

- Others

Primary Options
For Blanket Materials and Configurations

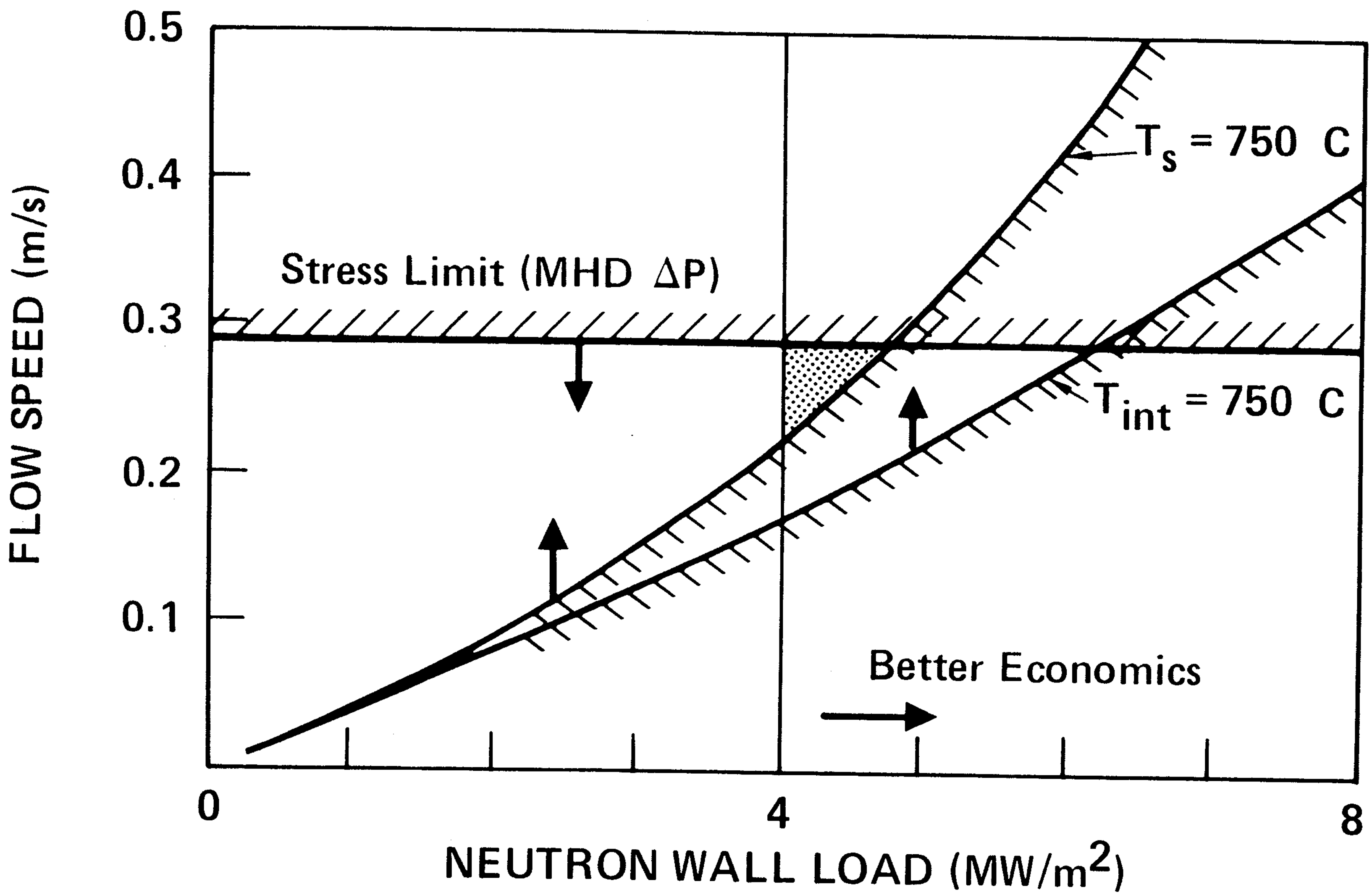
	LIQUID BREEDER			SOLID BREEDER	
Breeder	Li	LiPb	Flibe	Li_2O	Ternary ceramics
Coolant	Li, He	LiPb, He, H_2O	Flibe, He	He, H_2O	He, H_2O
Structural materials		Ferritic steels Refractory alloys		Ferritic steels Austenitic steels	
Multiplier		none, beryllium		beryllium	
Design configurations		Radial flow Poloidal flow Poloidal/toroidal flow Helical flow		Pin, Plate, Block Breeder/Multiplier Sintered Pellet or Sphere-pac Radial, Poloidal, or Toroidal Cooling	

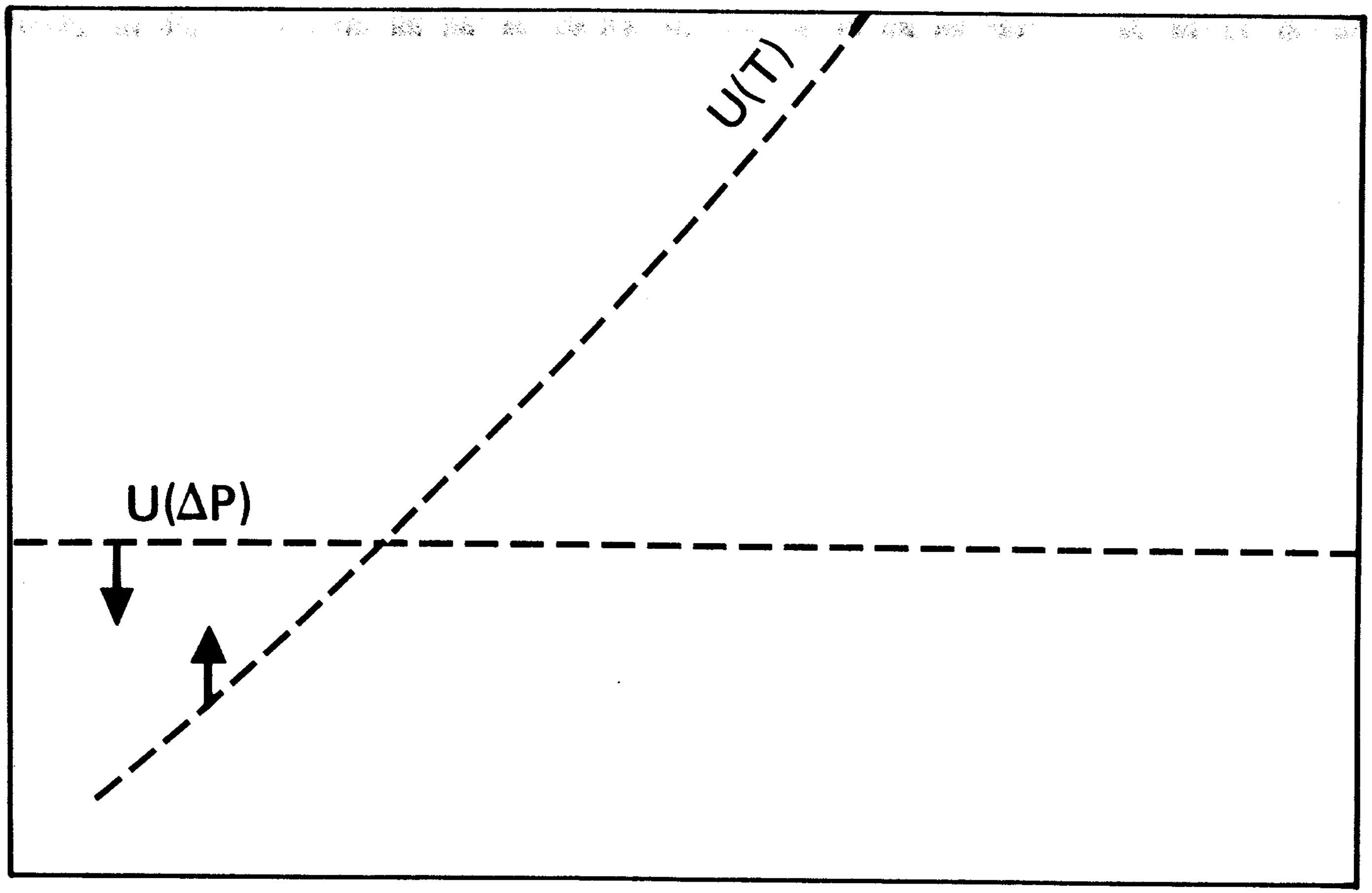
Further experimental work is required prior to selection.

Generic Liquid Metal Blanket Issues

- Tritium Self-sufficency
- Magnetohydrodynamic (MHD) Effects
  —Fluid Flow (including pressure drop)
  —Heat Transfer
- Material Interactions (e.g., Corrosion)
- Structural Response in the Fusion Environment
  —Irradiation Effects on Material Properties
  —Response to Complex Loading Conditions
  —Failure Modes
- Tritium Recovery and Control

Design Window Is Narrow For Best Liquid Metal Blanket (Li/V)





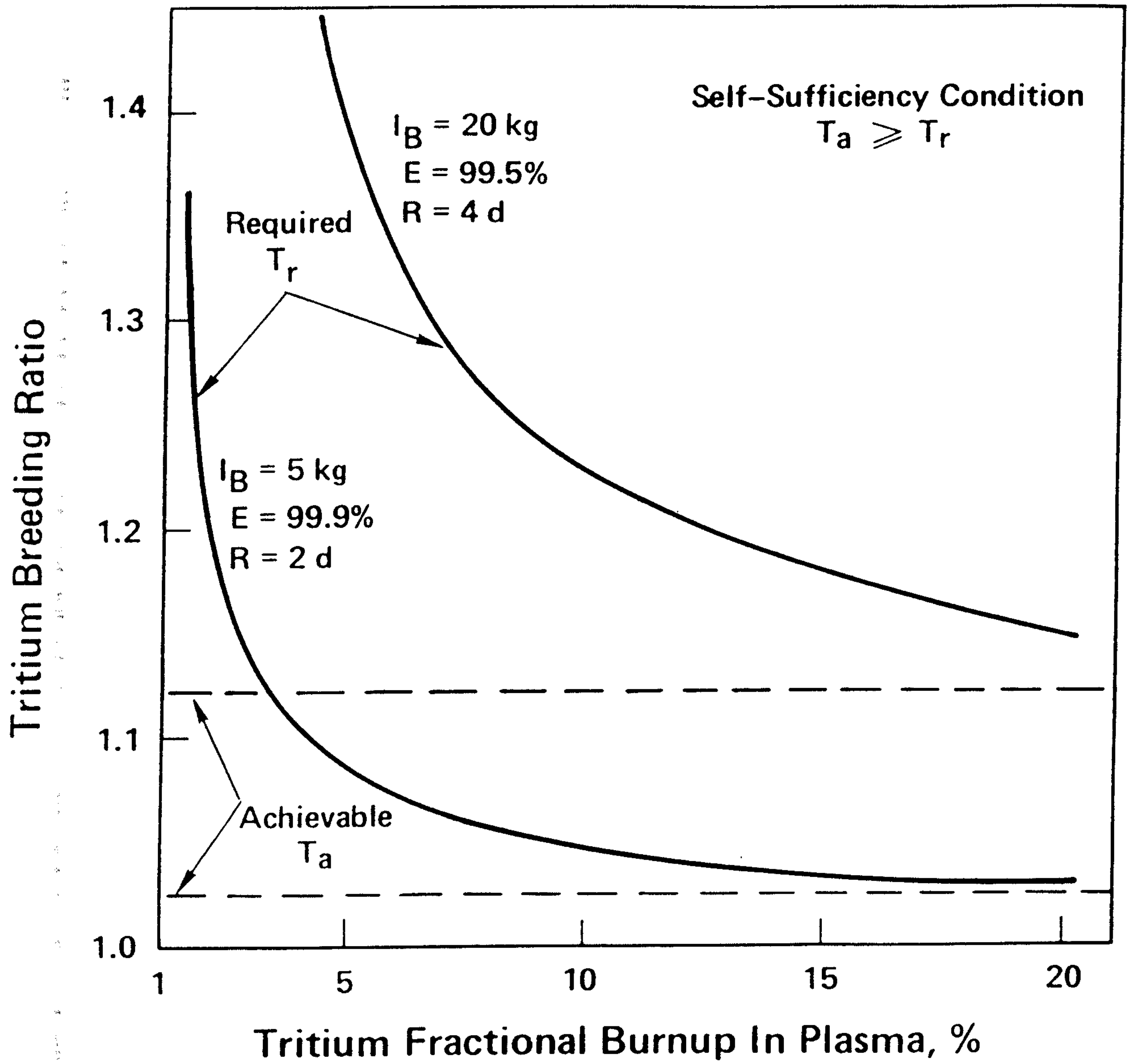
U(T): Any of:
T_s = 650 C
T_{int} = 550 C
h_m = 0.7h

Uncertainties in MHD, Corrosion, Heat Transfer, Radiation Effects Represent Major Issues

Generic Solid Breeder Blanket Issues

- Tritium Self-sufficiency
  —Achievable Breeding Ratio
  —Required Breeding Ratio
- Breeder/multiplier Tritium Inventory and Recovery
- Breeder/multiplier Thermomechanical Behavior
- Corrosion and Mass Transfer
- Structural Response and Failure Modes in Fusion Environment
- Tritium Permeation and Processing from Blanket

Tritium Fuel Self Sufficiency



Critical areas :

- Tritium burnup in plasma
- Neutronics data, methods, modelling
- Tritium inventory in blankets
- Tritium processing

Specific Blanket Issues

- Key issues were evaluated.
- Each is documented in terms of:
  - Issue description
  - Required data
  - Status of data base
  - Required resources
- The most important *structural material* R&D issues are *welding/fabrication* and *radiation induced embrittlement* concerns for both ferritic steels and vanadium alloys. *Chemical reactivity of vanadium* is also an important issue.
- Major issues for *liquid metal blankets* include *MHD effects* and *corrosion* concerns. MHD research should include the testing of insulators, particularly for tokamak applications. Lithium (and to some extent LiPb) *chemical reactivity* is a key issue. Development of *non-water cooled near-plasma components* will be necessary, particularly for tokamak blankets that contain lithium.
- *Tritium recovery/control* is a *major* issue for all designs except those using liquid lithium as a breeder and coolant. The form of the released tritium (T_2/HT or T_2O/HTO) and the chemical form of tritium in various fluid streams are important issues for tritium control for solid breeders.

Specific Blanket Issues (cont'd.)

- Achieving adequate *tritium breeding* is a *key* issue for many designs, but particularly for Li_2O without neutron multipliers. In general, it is more severe for tokamaks than tandem mirrors and more severe for solid breeders compared to liquid breeders.

- The key issues for *solid breeders* (in addition to those discussed above) include the *temperature limits* for tritium release, *heat transfer control* between the lithium ceramic and coolant, difficulty of handling *power variations* and the *radiation induced swelling* of the ceramic (particularly Li_2O). Initial fabrication of sphere-pac breeder and beryllium and refabrication of all forms by remote handling techniques are also areas of concern.

- The most important concern related to *first wall issues* is the verification of the capability of a *stress relief structure* (orthogonally grooved first wall) for tokamaks to simultaneously handle heat and particle fluxes.

- Additional items include the thermal, chemical and radiation stability of molten salts; Be reprocessing efficiency; Be chemical interaction with molten salts; activation of LiPb and molten salts; and electromagnetic effects in tokamaks such as large pressures and torques due to plasma disruptions.

Generic Issues for Radiation Shielding

1. Design criteria of sensitive components in SCM, vacuum, NBI, RF systems and control system

2. Effectiveness of bulk shield
   - composition and thickness of shield materials
   - deep penetration of high energy neutron (14 MeV), including cross section windows

3. Penetrations and their shield effectiveness for NBI, RF ports, and coolant pipes
   - streaming and partial shield
   - modeling procedure

4. Occupational exposure
   - induced activity and dose distribution
   - radioactive corrosion materials
   - remote maintenance system

5. Public exposure
   - sky shine
   - radioactive waste of shield materials

6. Shield compatibility with blanket and magnet including assembly/disassembly and field penetration

RADIATION SHIELDING
REQUIRED ACCURACY AND STATUS

Location/Response	Required Accuracy	Present Status
First Wall/Divertor		
Nuclear heating	total 2%, local 10%	50%
Atomic displacement	10%	
Gas production	10%	
Transmutation	20%	
Induced activity	30%	50% ~ factor 3
Blanket		
Tritium production rate	gross 3~5%, local 10%	gross 10%, local 20%
Nuclear heating	20%	
DPA	20%	
Gas production	20%	
Induced activity	50%	factor 2~5
Bulk Shield		
Nuclear heating	20%	factor 2~5
DPA	30%	
Induced activity	factor 2	factor 5~10
Superconducting Magnet		
Nuclear heating	gross 30%, local 50%	factor 5~10
DPA	gross 30%, local 50%	
Gas production	gross 50%, factor 2	
Dose	gross 30%, local 50%	
Induced activity	factor 2	
Penetration Functional Equipment (e.g., vacuum, pump, RF, and NBI)		
Nuclear heating	gross 30%, local 50%	gross factor 2, local factor 10
DPA and gas production	50%	
Induced activity	factor 2	
Reactor Room (outside the shield and inside the reactor bldg.)		
Biological dose during operation	factor 3	
Biological dose after shutdown	factor 2	
External Biological Dose (outside plant site)	factor 3	

*Assumed DEMO class reactor

PMI/HHF PROGRAM ELEMENTS

- PARTICLE CONTROL, RECYCLING, EXHAUST
- IMPURITY CONTROL AND MATERIAL EROSION
- HIGH HEAT FLUX AND HEAT REMOVAL

GENERAL ISSUES

- PLASMA EXHAUST, RECYCLING AND GAS RETENTION
- IMPURITY GENERATION, EROSION AND REDEPOSITION, WALL CONDITIONING
- DISRUPTIONS AND OFF-NORMAL LOADS
- HEAT REMOVAL AND THERMOMECHANICAL RESPONSE OF IN-VESSEL COMPONENTS
- TRITIUM PERMEATION AND RETENTION
- COATINGS, SURFACE, AND BULK STRUCTURAL PROPERTIES OF HHF COMPONENTS