Adequacy of R & D and Incremental Cost/Risk/Benefit For ITER Driver Blanket

ISCUS Subgroup

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Topics

- General Design Features and Parameters
- Key Technical Issues
- Highlights of R & D
- Incremental Cost/Benefit/Risk

	PHYSICS PHASE	TECHNOLOGY PHASE
Fusion Power, MW	1100	860
Neutron Wall Load, MW/m^2	(MIN/MAX)	
Inboard	0.4/1.1	0.3/0.9
Outboard	0.8/1.5	0.6/1.2
DT Flat Burn Time, s	Up to 400	2300
Minimum Dwell Time, s	200	200
Number of DT Pulses	10^4	5×10^4
DT Fluence Goal, MWa/m^2	0.05	3
Operating Temperature Limits, °C		
Austenitic Steel (316)		
Structural Component		<400
Short Term		<800
Aqueous Interface		<150
Ceramic Breeder Temperature Range		
Li_2O		370-1000*
$LiAlO_2$		450-900
Li_2ZrO_3		370-1000
Beryllium		<600

* Special attention should be given to avoid mass transport above 800°C.

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Tritium Breeding Blanket Design Specifications

First Option Blanket Structural Material	Ceramic Breeder Austenitic Steel (316)
Coolant	Water: 60-100°C, <15 MPa
Breeder Material	Li_2O or Ternary ($LiAlO_2$, Li_2ZrO_3)
^6Li Enrichment	50-95%
Neutron Multiplier	Beryllium
Breeder Configuration	Layered or Breeder-In-Tube
Breeder and Multiplier Clad	Austenitic Steel (316)
Breeder Temperature Control	Gradient in Beryllium or Helium Gas Gap
Tritium Recovery Method	Continuous In-Situ Purge Gas: He + (0.2-1%) H_2
Coolant Flow Direction	
Inboard-First Wall	Poloidal
Blanket	Poloidal or Toroidal
Outboard-First Wall	Toroidal
Blanket	Toroidal or Poloidal

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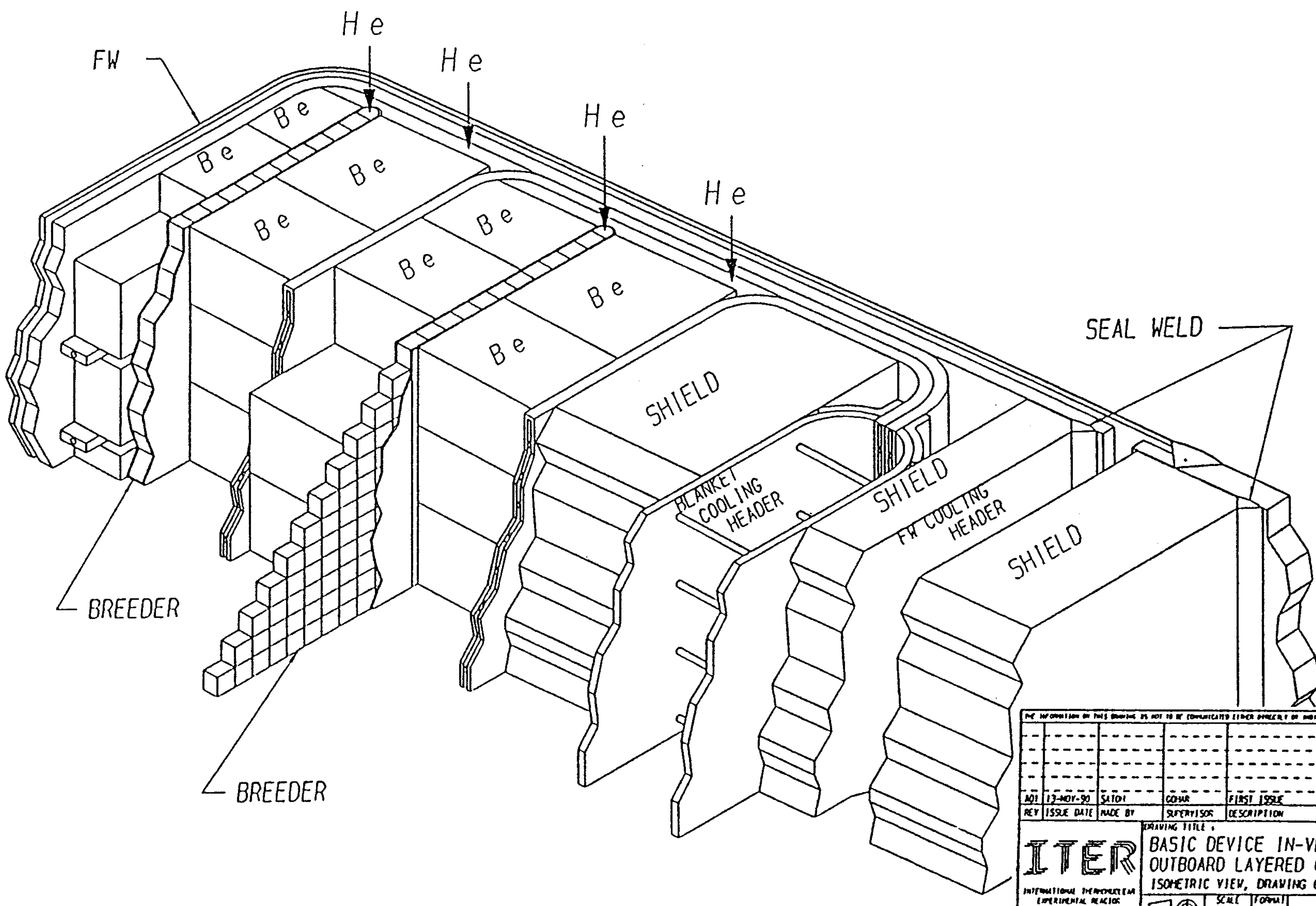
LAYERED CERAMIC BLANKET DESIGN



REV	ISSUE DATE	MADE BY	SUPERVISOR	DESCRIPTION	ST	α
A01	13-NOV-90	SATOI	GOHAR	FIRST ISSUE	/	/

ITER — INTERNATIONAL THERMONUCLEAR EXPERIMENTAL REACTOR

DRAWING TITLE: BASIC DEVICE IN-VESSEL SYSTEM OUTBOARD LAYERED CERAMIC BLANKET ISOMETRIC VIEW, DRAWING OUT OF SCALE

DRAWING SEQUENTIAL NUMBER: 00000

SCALE: - | FORMAT: A2 | YG3322-5 | REV A01

ITER TRITIUM BREEDING POTENTIAL

- Current Design Potential

  - The net tritium breeding ratio is in the range of 0.8 to 0.9 based on the following assumptions:

    - Reliable and safe blanket operation
    - No tritium breeding form the sixteen ports
    - No tritium breeding in the divertor zones
    - Limited inboard blanket thickness (about 10 cm)
    - Copper loops for the plasma operation

  - Higher net tritium breeding is attainable with design improvements.

Cost Issues and External Tritium Sources

* ITER Tritium Burn Rate

PHASE	AVAILABILITY %	Burn Rate, Kg/y	Fluence, MWa/m^2	Total Tritium Burned for Phase Kg
Physics		0.5	0.05	3
Technology	10 30	6 18	1 3	60 180

*Tritium Cost Without Breeding

- Tritium unit cost is $29,000 per gram (DOE price as of 10/29/88).
- Tritium cost per phase

Physics	$0.23 Billion
Technology	$1.70 Billion for 1 MWa/m^2 $5.20 Billion for 3 MWa/m^2

(The physics phase cost includes 5 Kg tritium inventory cost in the different reactor components)

Cost Issues and External Tritium Sources (cont.)

* Tritium cost with breeding blanket for different tritium supply rates[a]

Supply Rate Kg/y	Required TBR	Total Tritium Purchased Kg	Total Cost of Tritium B$
1	0.94	36	1.04
2	0.84	52	1.51
3	0.74	68	1.97
4	0.64	84	2.44

[a] Assuming 20 Kg of tritium available at the start up and a total inventory of about 5 Kg in the different ITER systems.

* Based on the know external tritium supplies of about 2 Kg/year and economic benefits a TBR > 0.8 is required for ITER.

Key Technical Issues

- Issues Common to Driver and Non-Driver Blankets
  - Radiation induced embrittlement of steel structure
  - Aqueous stress corrosion cracking
  - Cooling system reliability and chemistry control

- Issues Unique to Driver Blanket
  - Demonstration of breeder temperaure control
  - Characterization of ceramic breeder performance
  - Integrated module tests

ITER Driver Blanket R & D

- A detailed list of R & D items was prepared by the ITER team with input from home teams

- The driver blanket R & D was reviewed in the US several times prior to the ISCUS Review

- The R & D list includes:

  - Issues to be addressed
  - Results to be achieved
  - Specifications
  - Milestones
  - Facility requirements

ITER Driver Blanket R & D

<u>Main R & D Items</u>

1. Blanket Material Development

    - Ceramic breeder performance
    - Beryllium multiplier performance
    - Insulator performance

2. Fabrication and Scalable Model Testing

    - Fabrication capability of materials
    - Fabrication capability of blanket modules
    - Integrated out-of-reactor tests
    - Integrated in-reactor tests

3. Blanket/Shield Neutronics

    - Bulk and penetration shielding
    - Radioactivity and afterheat
    - Tritium breeding
    - (Nuclear heating) [Missing from present plan]

4. Structural Material R & D

    - Austenitic steel
    - PFC structure
    - Advanced structure

Q: Will the R & D specified in the Iter Long Range Technology Plan plus the ongoing R & D base program provide by 1996 the data base for driver blanket technology that is adequate to support a construction decision for ITER?

A: Yes (with minor additions)

Question:

Should ITER have a breeding blanket?

Answer can be obtained through Cost/Benefit/Risk Analysis

Remarks

- Eliminating breeding material does not make the blanket disappear

- A non-breeding blanket will still have to remove the heat, will have coolant tubes, will have first wall, and non-breeding material such as steel

- Features of the blanket, particularly the amount of beryllium, and the TBR can be adjusted depending on the cost/benefit/risk analysis results

Breeding Vs. Non-Breeding Blanket

Cost

- Tritium
- Construction
- Incremental R & D

Benefits

- Tritium Requirements
- Data Base for DEMO

Rists

- Limitations on Machine Performance
- Reliability
- Safety
- Technical Issues

ITER Fluence?

- Question is crucial to Breeding Vs. Non-Breeding blanket question.

- Answer (from previous ISCUS presentation, ITER report and numerous other presentations and reports)

Strongly Recommended:	$3MW.y/m^2$
Minimum:	$1MW.y/m^2$

Incremental Cost Associated with the Breeding Blanket

*ITER R&D Blanket Cost

ITEM	Total Blanket R&D Cost	Breeding R&D Cost	Non Breeding R&D Cost	DEMO Relevant R&D Cost
Driver Blanket Materials Development	19	14	5	19
Fabrication and Module Testing	57	20	37	57
Alternate Driver Blanket	25	25	0	25
Blanket & Shield Neutronics	10	3	7	10
Test Module Interfaces	10	0	10	5
TOTALS	121	62	59	116
FW/BL Structure	25	0	25	25

INCREMENTAL COST ASSOCIATED WITH THE BREEDING BLANKET (CONT.)

- Beryllium dominates the blanket cost.
  - Be unit cost (65-85% dense cold-pressed) is $600/Kg.
  - Be inventory 206 MT.
  - Total Be cost is about $124M.
- The cost of the blanket tritium recovery system is very small relative to the total cost of the fuel cycle system.
- The incremental R&D cost for the driver blanket is about $62M, which is about 7% of the total long-term R&D cost for ITER.
- Essentially all of the Breeding Blanket R&D is demo relevant.

BENEFITS OF BREEDING BLANKET FOR ITER

- Substantial benefits in addition to the economics of tritium production are gained from a breeding blanket for ITER.

- Ceramic breeder materials performance under reactor relevant conditions (temperature, burnup rate, purge gas conditions, etc.)

  - Radiation effects
  - Thermo-mechanical performance
  - Tritium retention
  - Neutronics performance

- Beryllium Performance

  - Tritium retention
  - Irradiation induced swelling/creep
  - Mechanical performance

- Tritium Recovery System

  - Tritium transport
  - Cyclic effects
  - Tritium/impurities release from beryllium

- Engineering Benefits

  - Materials and blanket fabrication methods
  - Reliability data base from blanket operation
  - Blanket auxiliary systems (manifolds, maintenance systems, etc.) performance

BENEFITS OF BREEDING BLANKET FOR ITER (CONT.)

- Demonstration of blanket performance for extended operation is essential for commitment to a DEMO.
- Safety Benefits
  - Reducing tritium transportation shipments
  - Reduced tritium inventory on site
  - Reduced decay heat relative to non-breeding blanket
- Radioactive Waste Generation
  - Reduced activation and biological hazard potential relative to non-breeding blanket
- Tritium Requirements
  - Tritium resources will not limit ITER availability

Risks of Breeding Blanket for ITER

Reliability/Availability

- Blanket risk is much lower than for PFC
- First Wall failure rate much higher than for the blanket: Same for breeding and non-breeding
- Most failures in the blanket are associated with the structure and coolant: Same for breeding and non-breeding

Safety

- Additional tritium inventory in the blanket is small compared to total inventory in the system and is not "vulnerable"
- Reduced tritium inventory on site
- Reduced tritium transportation problems
- Breeder/coolant interaction can be controlled

Technical Issues

- Many are common to breeding and non-breeding
- Breeding blanket issues can be adequately addressed through the identified ITER R & D

Breeding Blanket is strongly recommended (necessary) for ITER to meet its objectives at lower cost, higher benefit with an increment or reduction in risk that is small