ITER Test Program Progress Report & Status
November 2, 1994

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Presented at ITER US Home Team Meeting, Nov. 2-3, 1994

International Thermonuclear Experimental Reactor

B&R	WBS1	WBS2	TA	JCT TASK ID	TASK ID	MS ID	MS CAT	IND	INS	TAL	TASK DESCRIPTION	DATE	REV DATE	COMPLETE	TECH	SCH	COST	IUA	PMY	OPEX	EQEX
2B	N2			D3	2	0	0		UL	Abdou	**Integration of Test Modules in the Main Blanket and Vacuum Vessel Design**						1*		0.50		
2B	N2			D3	2	1	2		UL		Integration of parties' test program into an ITER test program	Sep-94			1	2**					
2B	N2			D3	2	2	2		UL		Interface between the test program and the ITER basic device	Dec-94			1	1					
3A	E5			D2	1	0	0		UL	Abdou	**Test Program Development**						1*		0.25		
3A	E5			D2	1	1	2		UL		Test program by party	Apr-94			1	1					
3A	E5			D2	1	2	2		UL		Integration of parties' test programs into an ITER test program	Sep-94			1	2**					
3A	E5			D2	1	3	2		UL		Interface between the test program and the ITER basic device	Dec-94			1	1					
3A	E5			TBD	3	0	0		UL	Abdou	**Test Program Development and Integration*** **	Dec-95							2		
3A	E5			NA	3	0	0		UL	Abdou	**Industrial Support**									200	0
3A	E5			NA	3	1	2	TBD	UL		Blanket Test Article Design	Jul-95									
3A	E5			NA	3	2	2	TBD	UL		Ancillary Equipment & Space Allocation & Layout	Sep-95									
3A	E5			NA	3	3	2	TBD	UL		Test Port Assembly Design, Remote Handling, and Engineering Interface	Sep-95									

*Supplementary support provided by various organizations

** Postponed due to delay in TPWG

***Proposed new design task

ITER Test Program
Progress Report and Status

- Final Report for D2 and D3 (1994)

    - Report is being prepared

    - The report will be sent to Garching by December 15, 1994

    - The report will document US effort and technical analysis

        - pulsing effects
        - fluence requirements
        - example test article designs
        - issues of interface
        - auxiliary equipment and facility requirements

- (Informal) Meeting was Held August 30-31, 94 in Karlsruhe, Germany.

  The meeting discussed:

    - technical issues
    - charter for TPWG
    - international program coordination
    - report writing for 1994

Progress Report and Status (cont'd)

- Charter for Test Program Working Group

  - An agreed on charter is now ready to be submitted for MAC's approval in early December

  - Work will be limited to Blanket/First Wall and its supporting system (tritium processing, materials, safety etc.)

  - TBWG will report to MAC and prepare annual reports

  - Eight members, one from each HT and 4 from JCT

- US Industry Effort on Test Program

  - $200K to industry in FY 95

  - Tasks have been defined

    - test article design
    - auxiliary equipment and facility requirements
    - engineering interface and test port design

  - Effort to select industrial participant(s) is underway

Resolved and Open Issues That Affect Test Program

- Tests will start from Day 1 of DT operation in BPP
- BPP will have a fluence of 0.3 MW•y/m^2
- EPP fluence?
- Burn/ dwell times and pulsing effects
- Plasma exposure of test module first wall
- Development criteria for extent of R&D required to qualify a concept to be tested in test modules on ITER
- Safety criteria for test modules

Test Program Effort (Fourth Quarter, FY94)

UCLA Efforts

- Coordinated international test program activities. Prepared draft charter concerning the formation of TPWG.
- Performed neutronics, thermalhydraulics and thermo-mechanical analyses for DEMO water-cooled solid breeder blanket concept (which is one of the US concepts to be tested in ITER). The results were used to guide the ITER test article design.
- Designed ITER water-cooled test article in which DEMO thermomechanical and tritium transport behaviors are preserved.
- Began to address the implications of engineering scaling concept and to determine how many test articles required in order to fulfill an integrated test.
- Preparing the yearly progress report due to JCT

Efforts from Other Organizations

- Received input on divertor testing from MDAC/SNL
- Preliminary test report for rf antenna from ORNL
- Preliminary report on self cooled Li/V from ANL
- Suggestions on initiating effort in safety criteria for test program, from INEL

Progress on International Test Port Coordination

- 4 helium-cooled solid breeder blanket concepts have been submitted to the international test port coordinator:

  - MANET/Li_40Si0_4 (EU)
  - TiAl/Li_20 (JA)
  - SiC/Li_20 (US)
  - RF concept

  However, no mechanism has yet been developed to accommodate all the concepts proposed due to space limitation, design complexity, and a large variety of designs.

- A preliminary strategy for water-cooled solid breeder test port utilization: 1) to divide the test port into two equal spaces for the two concepts proposed; 2) to begin test immediately after the D-T operation; and 3) to incorporate segment test during EPP.

- No progress can be made with regard to the self-cooled LM port allocation because the safety concern associated with the presence of lithium inside a water-cooled torous has not been resolved.

- The test port coordination for the design concept of separately cooled liquid breeder concept is somewhat straightforward because only one concept is proposed (from EU).

- Only the US is interested in performing plasma facing component tests in ITER.

Attachment: Design Task Proposal for 1995-1998
Test Program Development and Integration

Task No. -- TBD

Background and Objective

The development of a viable test program on ITER is critical for the mission success of ITER and for the world interests for the successful development of fusion energy. The objective of this task is to develop a detailed description of a test program on ITER which is consistent with the ITER mission and serves the interests of parties, and to successfully integrate the test program developed into the ITER basic device.

The test program development and integration involves an iterative process between the parties and JCT. As the ITER design gets into more details, as the facility design is developed, as the ITER operations scenario evolves and as the safety evaluation continues, many interactions between the test program and the machine design and operation are expected. Consequently, a continuation of the process is necessary which calls for the task proposed to be continued throughout EDA.

Task Description

The following tasks will be continued throughout EDA:

A) Evaluation of Parties' Test Program Proposals

Evaluate proposals (mostly already) submitted by each party for testing on ITER.

B) Develop Strategy for Integration of Parties' Test Programs

Evolve a strategy for integrating the parties' test program requirements into one effective test program for ITER. The strategy should aim at avoiding duplication, minimizing cost to the parties and reducing the burden on ITER. Explore options for sharing test articles and information among two or more parties to the maximum possible extent.

C) Interface Between the Test Program and the ITER Basic Device

1. Define and describe a test program on ITER based on ITER capabilities and the strategy developed in task B above. The description should include the space-time-party matrix for ITER utilization. Suggest to JCT possible areas of improvement in design to increase the benefits from ITER testing.

2. Working closely with JCT designers, develop engineering details for incorporating the test articles/modules into the test ports. Engineering issues related to placement of different types of modules (e.g. sharing the same test port by blankets that have the same coolant or alternatively by blankets that have the same breeder, etc.) should be addressed. Designs of support lines (coolant manifolds, tritium recovery, data acquisition, etc.) should be developed and integrated into ITER design.

3. Define auxiliary (ancillary) equipment requirements around the device, including space and location, for heat rejection, tritium extraction and processing, coolant processing, etc.

4. Working with the JCT, address operational and maintenance (insertion/ removal/ retrieval) issues. Modify test articles and support systems to solve engineering problems that JCT can not accommodate through design changes.

5. Assist JCT in assessment of safety implications of conducting the Test Program. Make appropriate changes in the Test Program accordingly.

6. Work with JCT on developing the ITER Device Operations Plan.

Schedule

Jan. 1995 - June 1998

Meeting Plan

1w x 7

Resources and Credits

- JCT will allocate sufficient internal resources for working on the test program development and integration.

- The Home Teams will provide resources to support the task proposed. The level of effort on the test program by each Party (Home Team and the base program) is expected to be about 2-3 PMY per year.

- JCT will provide credits totalling 8 PMY per year to the Home Teams on work on the test program. This credit will not cover the R&D necessary to develop and construct the test articles. JCT credits for the test program will appear under a "test program" category in ITER Design task agreements, not as a part of credits for other areas or components.

Deliverables

- An annual report will be prepared to describe progress and issues of the test program.

- A final report will be prepared at the end of EDA to fully describe the ITER Test Program.

- Progress reports and/or presentations to the ITER Director or ITER management and advisory committees should be made upon request.

Industrial Support to the ITER Test Program

Task Description, Schedule, and Deliverables

Task 1
Blanket Test Article Design, (including instrumentation and supply lines)

Task Objective
Develop designs of test articles for three US DEMO blanket concepts

A) Li/V self cooled
B) He/Li_2O/Be/SiC
C) H_2O/$LiTiO_3$/Be/FS

For each concept, no more than 2 configurations are allowed. Test articles include submodules for Scoping Stage and modules for Concept Verification Stage.

Task Approach

1. Starting with the DEMO reference designs, identify the key issues, phenomena, behavior, and integrated effects in the DEMO blanket that must be preserved in the test articles (e.g. temperature, stress, tritium release, corrosion, failure modes).

2. Perform analysis and design activity using engineering scaling to develop test article designs that reproduce phenomena and behavior anticipated in DEMO. Note that since power density in ITER is lower than that of DEMO, two or more test articles are required for every given single DEMO blanket design; each article emphasizes a group of phenomena.

3. Decide on the number and size of the test articles for each blanket design in each testing stage (scoping stage and concept verification stage).

4. Develop final detailed designs for the test article. Output information should include calculations and drawings to show:

   a) test article configuration, materials, and dimensions

   b) response of the test article (temperature, stress, etc.)

   c) instrumentation, specifications and locations inside the test articles and instrumentation lead/supply lines

   d) coolant lines supplying the test articles including dimensions and flow rates

Task 2
Ancillary Equipment and Space Allocation and Layout

Task Objective

Develop a description of all ancillary equipment to support all tests in the ITER test program. Evaluate the space requirements and develop and outline design of the various support rooms outside the ITER machine but inside the reactor building.

Task Approach

1) For each blanket test article (e.g. liquid metals, helium-cooled) and other test articles (PFC, materials, etc.) estimate the requirements for ancillary equipment to support test module operations. Examples include tritium lines processing plant, coolant heat rejection, coolant storage, purification, etc.

2) Develop outline designs for each support area (heat rejection for liquid metal concepts, heat rejection for helium cooled concepts, tritium processing plants, etc.) and location inside the reactor building.

3) Provide a summary of space, power supply, and other requirements.

Task 3
Test Port Assembly Design, Remote Handling, and Engineering Interface

Task Objective

Develop a design for each test port that allows simultaneous testing of several test articles with rapid insertion and removal. Address issues related to engineering interface of the test program with the basic ITER device.

Task Approach

1) Starting with the present ITER test port configuration, develop options for design of the test port to accommodate several test modules. Design should include support structure for test modules, access for supply lines (coolant, tritium extraction, instrumentation, etc.), and connections and vacuum seals.

2) Evaluate remote maintenance techniques and operations to place, remove, and replace test modules in a manner consistent with ITER basic design. Provide estimate of time required to replace test modules and description of the operations (vacuum seal, break, disconnects, reconnect, reweld, etc.) involved.

3) Evaluate impact on remote replacement of a failed test module (e.g. distortion of dimensions) and possible schemes to recover the test module.

4) Provide final design of the test port assembly design and detailed description of maintenance operations and time involved. Provide an assessment of any outstanding issues for the engineering interface between the test program and the basic device and suggest solutions to resolve these issues.

5) Support the US Home Team effort in interfaces with the ITER JCT and the International ITER Test Program Working Group (TPWG).

Time Schedule and Deliverables

Task 1:	Blanket Test Article Design
Task 2:	Ancillary Equipment and Space Allocation and Layout
Task 3:	Test Port Assembly Design, Remote Handling, and Engineering Interface

Level of Effort

Task 1:	20%
Task 2:	20%
Task 3:	60%

Time Schedule:

Overall:	November 15, 1994 to September 30, 1995 (renewable)
Task 1:	January 1, 1995 to August 1, 1995
Task 2:	March 1, 1995 to September 30, 1995
Task 3:	Continuing from beginning of contract to the end

Deliverables

1) Due: March 15

Progress report including technical evaluations, calculations and engineering drawings for Tasks 1 and 3. The report should present options for test module designs, test port design and maintenance procedures with recommendations for preferred options.

2) Due: June 30

Progress report on Tasks 1, 2 and 3. The report should include engineering drawings of ITER Test Ports, ancillary equipment layouts, and illustration of test modules maintenance procedures.

3) Due: September 30

Final report on Tasks 1, 2 and 3 for FY 95. The report must include all the results of technical evaluation, calculations and engineering drawings.

Other Requirements

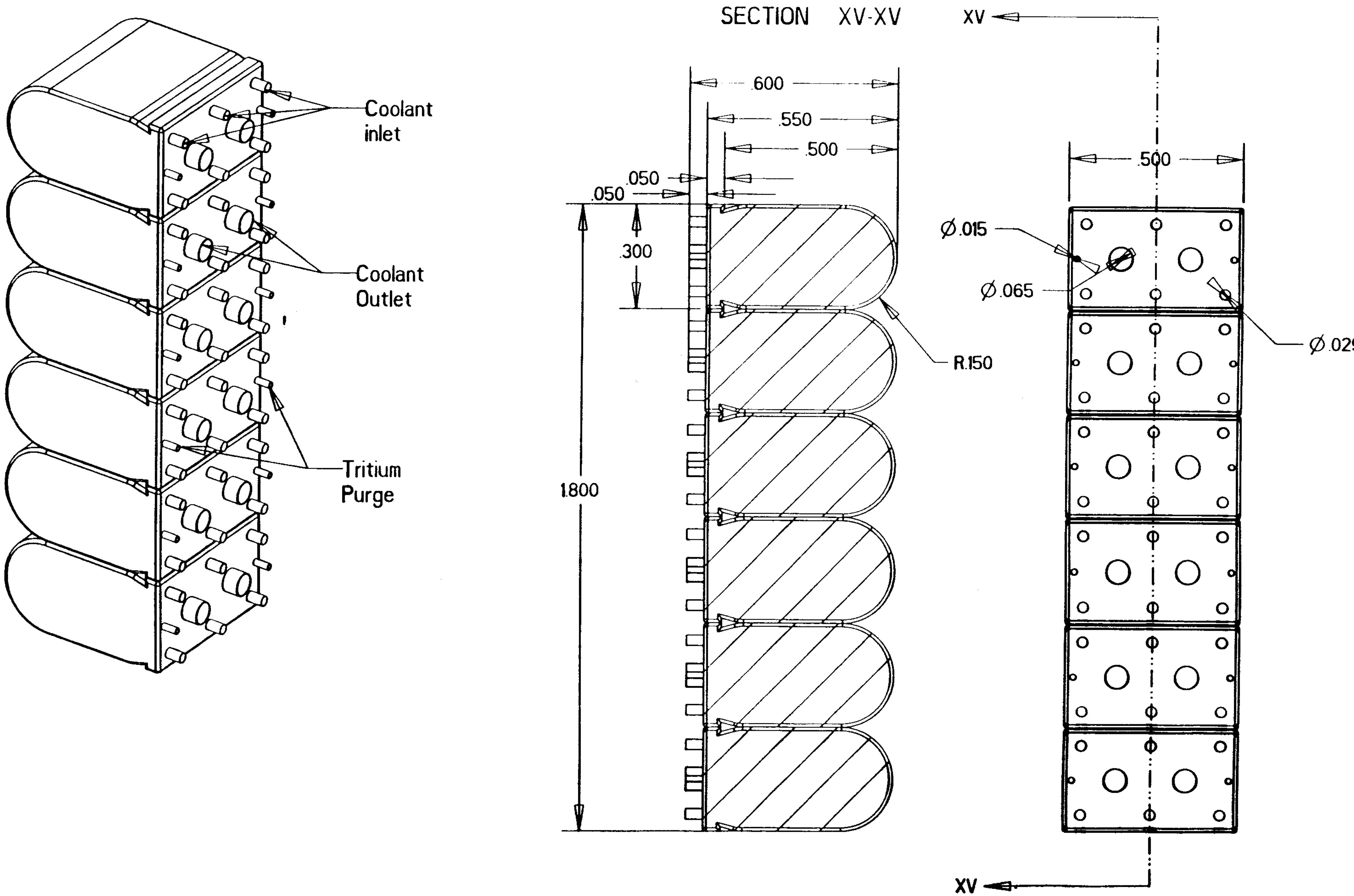
- The industrial team will support the US Home Team effort in interfaces with JCT on the test program.
- A key person from the industrial team will support the US Task Area Leader for the Test Program in interfaces with the International ITER Test Program Working Group (TPWG).

Appendix

ITER Water-Cooled Solid Breeder Test Module Design Analysis

Water/FS/SB Blanket Test Module Setup

UCLA: Draft 8/21/94



UCLA
SS:9508_SICBL_SETUP

Dimensions: m

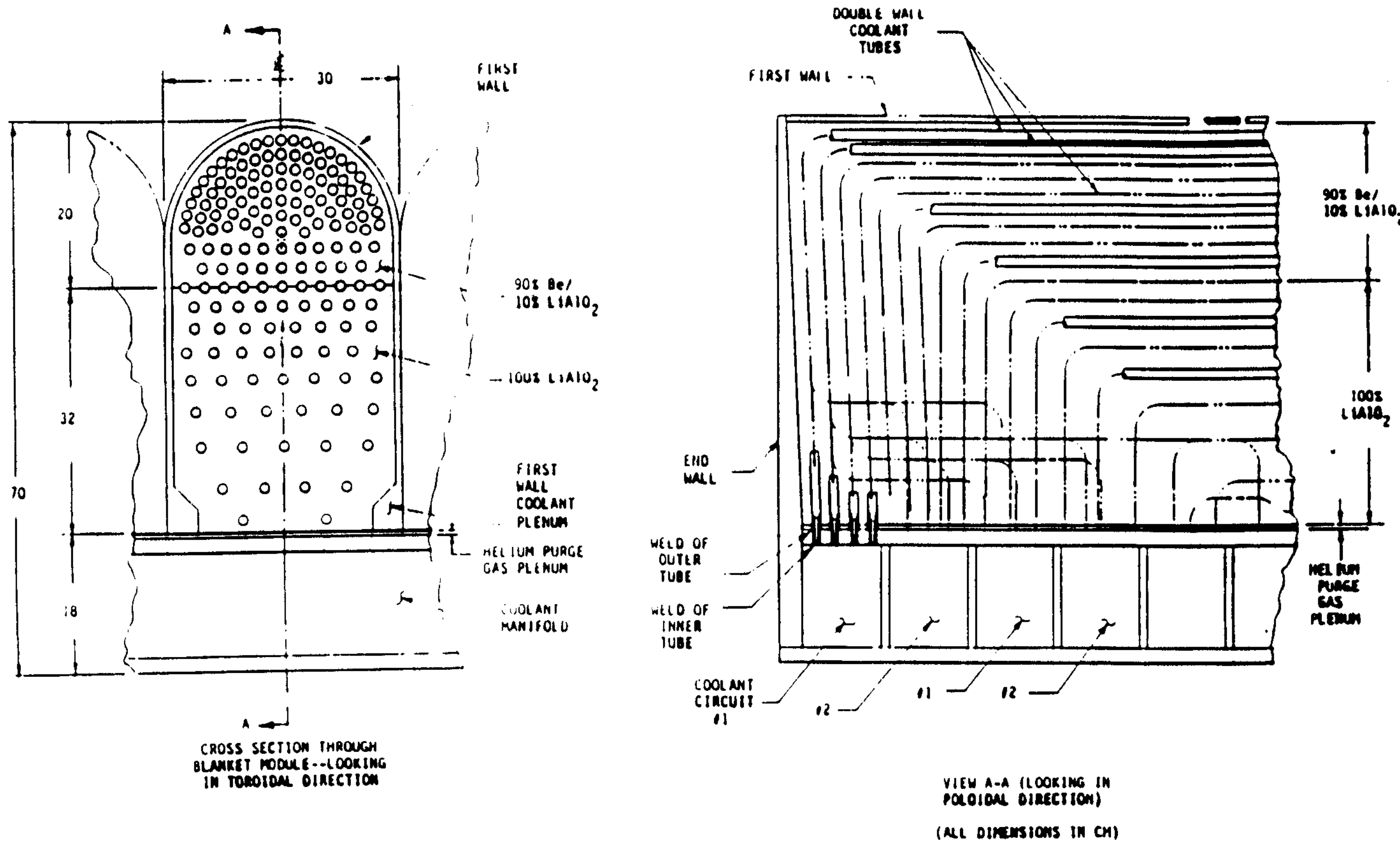


Fig. 9.4-1. Reference design configuration for $LiAlO_2/H_2O$/FS/ Be concept-tokamak

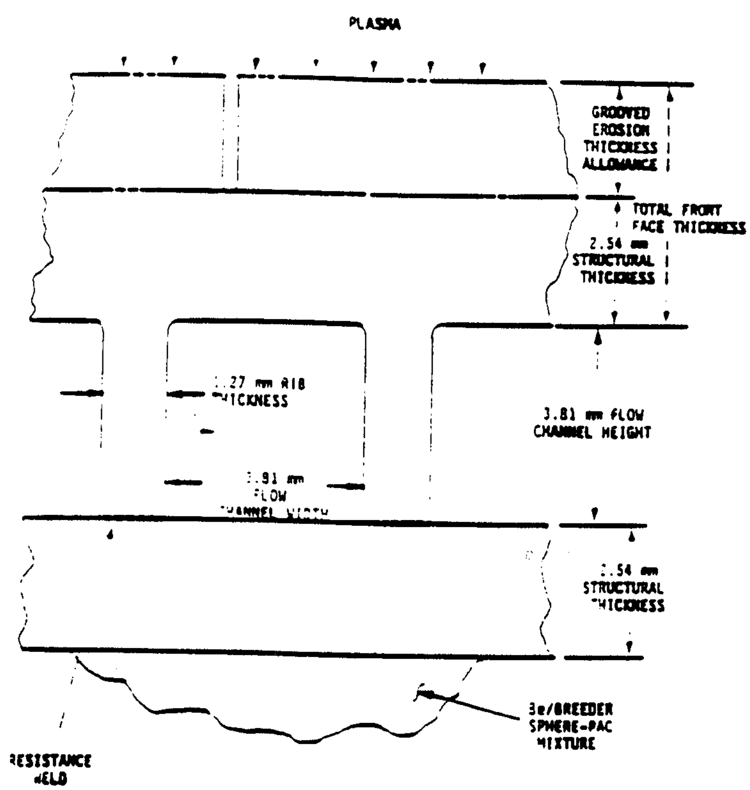


Fig. 9.4-2. First wall configuration, $LiAlO_2/H_2O$/FS/Be

Table 1. Major Parameters of The Reference Li_2TiO_3/Be/H_2O/FS DEMO Blanket

Materials	
breeder	Li_2TiO_3, 90% TD
multiplier	Be, 90% TD
coolant	high pressure , high temperature water
structure	ferritic steel
purge gas	helium
Major Design Guidelines	
neutron wall load, MW/m^2	3
peak surface heat flux, MW/m^2	1
average surface heat flux, MW/m^2	0.5
Temperature Limits	
breeder min/max, C	420/930
Be/breeder max, C	650
structure min/max, C	250/550
Design Configuration	
first wall	separately cooled through channels with rectangular cross section
blanket	lobular shape modules, breeder out of tube (BOT), 10% Li_2TiO_3 and 90% Be binary particle bed (blanket front), 100% Li_2TiO_3 particle bed (blanket back), cooled by high pressure/high temperature water flowing through double walled coolant tubes
First Wall/Blanket Dimensions	
Inboard	
thickness (including the manifold), cm	35
manfold thickness, cm	7
structure/coolant volume ratio in the manfold	25/75
first wall thickness (including the coolant channel), mm	8.89
module poloidal width, cm	30
outboard	
thickness (including the manifold), cm	70
manifold thickness, cm	18
structure/coolant volume ratio	25/75
first wall thickness (including the coolant channel), mm	8.89
module poloidal width, cm	30
Operating Input Parameters	
coolant pressure, MPa	15.2
coolant temperature, C inlet/outlet	280/320
purge gas pressure, MPa	0.1-0.6
purge gas temperature, C	350-400

Table 10. Major Parameters of The $Li_2TiO_3/Be/H_2O/FS$ Test Module

Materials	
breeder	Li2TiO3, 90% TD
multiplier	Be, 90% TD
coolant	high pressure , high temperature water
structure	ferritic steel
purge gas	helium
Major Design Guidelines	
neutron wall load, MW/m2	1
peak surface heat flux, MW/m2	0.5
average surface heat flux, MW/m2	0.25
Temperature Limits	
breeder min/max, C	420/930
Be/breeder max, C	650
structure min/max, C	250/550*
Design Configuration	
first wall	separately cooled through channels with rectangular cross section
blanket	lobular shape modules, breeder out of tube (BOT), 10% Li2TiO3 and 90% Be binary particle bed (blanket front), 100% Li2TiO3 particle bed (blanket back), cooled by high pressure/high temperature water flowing through double walled coolant tubes
First wall/Blanket Dimensions	
first wall thickness (including the coolant channel), mm	17.8
blanket thickness (including the manifold), cm	~65
manifold thickness, cm	18
structure/coolant volume ratio	25/75
test module toroidal length, m	~1
test module poloidal width, cm	30-60
Operating Input Parameters	
coolant pressure, MPa	15.2
coolant temperature, C inlet/outlet	280/320
purge gas pressure, MPa	0.1-0.6
purge gas temperature, C	350-400

* minimum temperature is based on the DBTT values and the maximum temperature is determined by the surface heat flux limits for the ferritic steels

Figure A-1 a. The ANISN 1-D Neutronics Model of the Test Module.
Plasma Minor Radius is 194 cm.

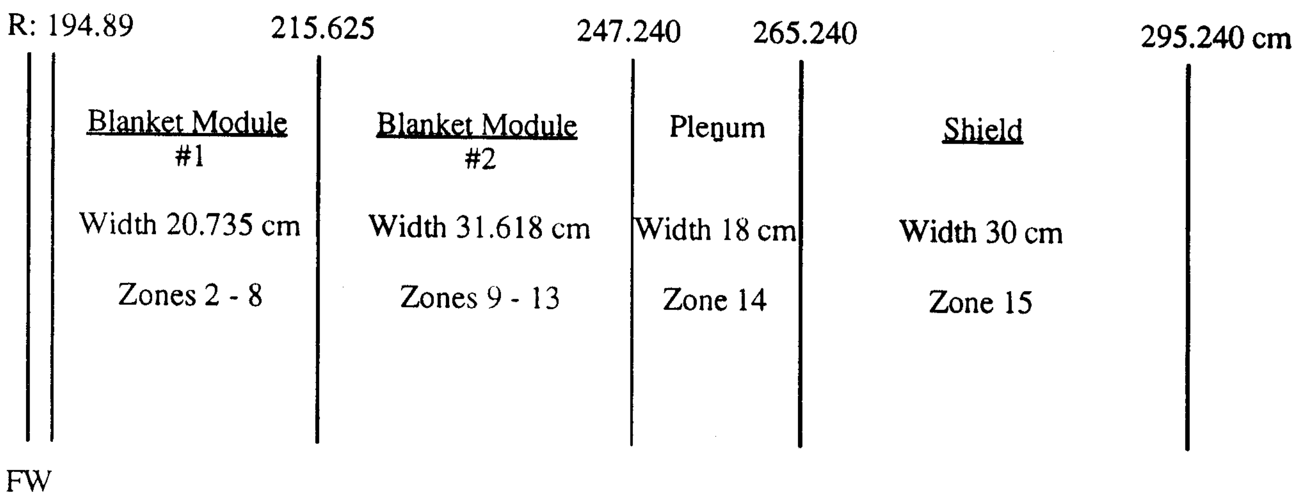


Figure A-1 b. The ANISN 1-D Neutronics Model of the Blanket (DEMO)
Plasma Minor Radius 194 cm.

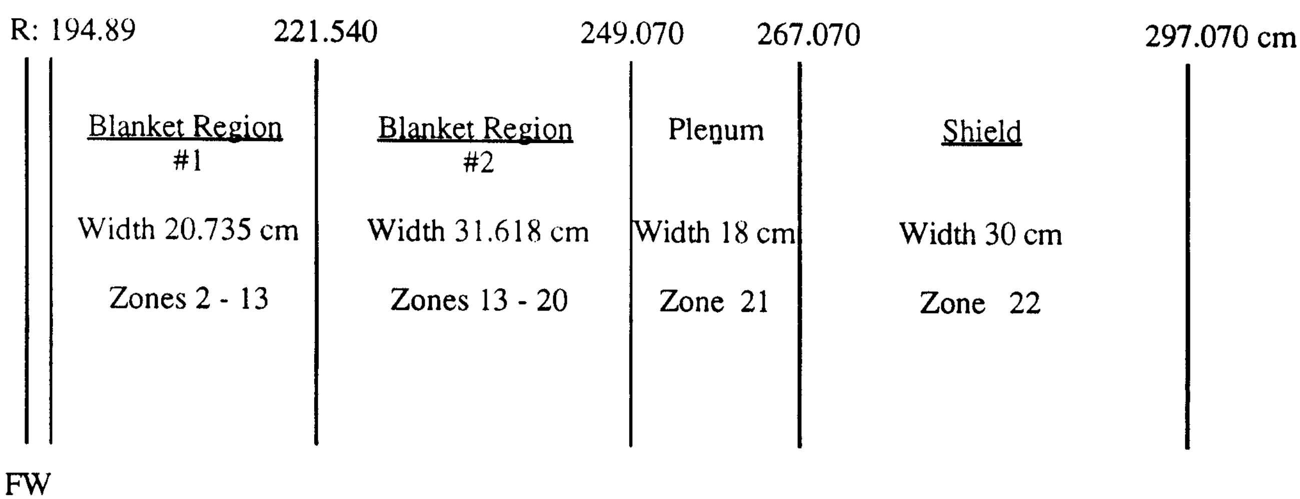


Table A-1b. Material Volume Fractions and Zone Thickness for the ITER Blanket Model(o/o)

Material Zone	Ferritic Steel	H_2O	Li_2TiO_3	Be	Thickness, d (cm)
FW	67.86	32.14	0	0	0.89
2	15.0	21.80	6.30	56.90	1.90
3	13.3	19.20	6.70	60.70	2.02
4	12.3	17.80	7.00	62.90	2.10
5	11.4	16.50	7.20	64.90	2.18
6	10.5	15.20	7.40	66.80	2.27
7	9.60	14.00	7.60	68.70	2.37
8	8.70	12.70	7.90	70.70	2.49
9	7.80	11.30	8.10	72.90	2.64
10	6.80	9.80	8.30	75.10	2.83
11	5.40	7.80	8.70	078.20	3.18
12	7.60	11.0	81.40	0	2.67
13	7.70	11.2	81.10	0	2.65
14	6.10	8.90	85.00	0	2.97
15	4.90	7.20	87.90	0	3.31
16	3.90	5.60	90.50	0	3.73
17	3.00	4.30	92.70	0	4.26
18	2.20	3.20	94.60	0	4.97
19	1.70	2.50	95.80	0	5.64
Plenum	25	75	0	0	18
Shield	Stainless Steel	0	0	0	30

Table A-1a. Material Volume Fractions and Zone Thickness for the Test Module Model(o/o)

Material Zone	Ferritic Steel	H_2O	Li_2TiO_3	Be	Thickness, d (cm)
FW	37.86[a]	32.14	0	0	0.89
2	9.55	13.90	7.65	68.90	2.379
3	8.02	11.60	8.03	72.35	2.599
4	7.13	10.30	8.25	74.32	2.757
5	6.33	9.18	8.45	76.04	2.925
6	5.58	8.09	8.63	77.70	3.116
7	4.85	7.02	8.81	79.32	3.344
8	4.15	6.01	8.94	80.90	3.615
9	1.98	2.87	95.10	0	5.231
10	2.52	3.65	93.80	0	4.641
11	1.53	2.22	96.20	0	5.947
12	1.06	1.54	97.40	0	7.137
13	0.722	1.05	98.20	0	8.662
Plenum	25	75	0	0	18
Shield	Stainless Steel	0	0	0	30

Figure A-4 b. Tritium Generation Rate in the DEMO Blanket Module.
Wall Loading 3 MW/m2.

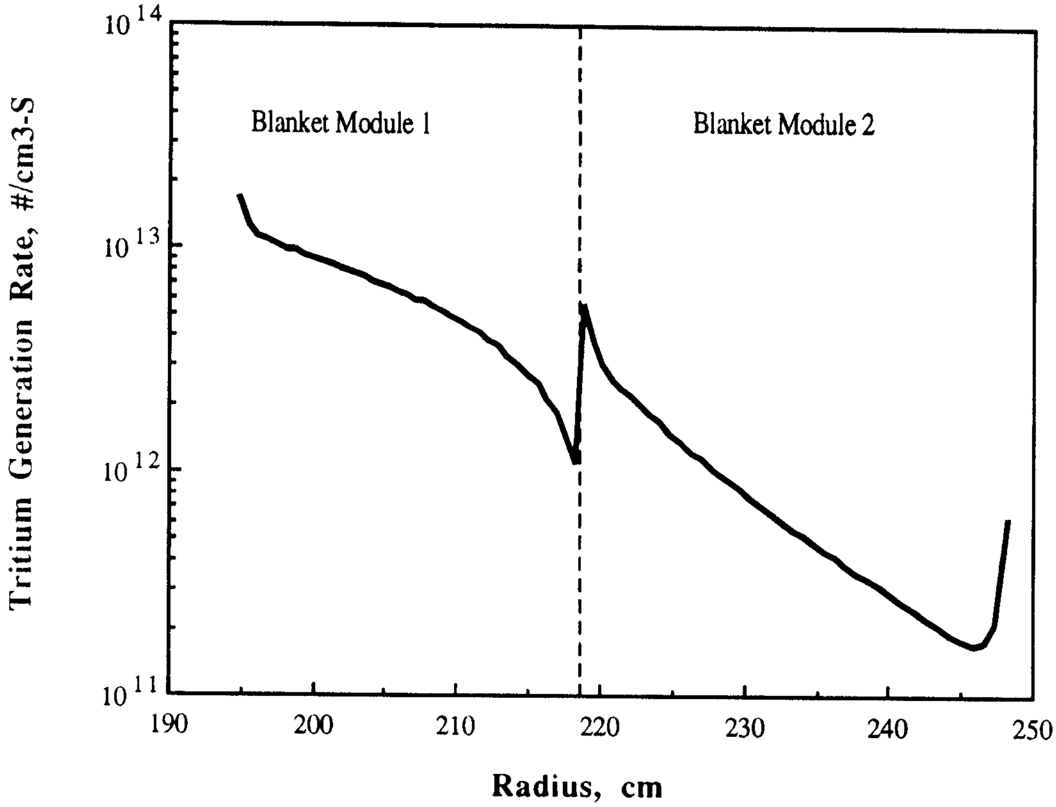


Figure A-4 a. Volumetric Tritium Generation Rate in the Test Module.
Wall Load = 1 MW/m2.

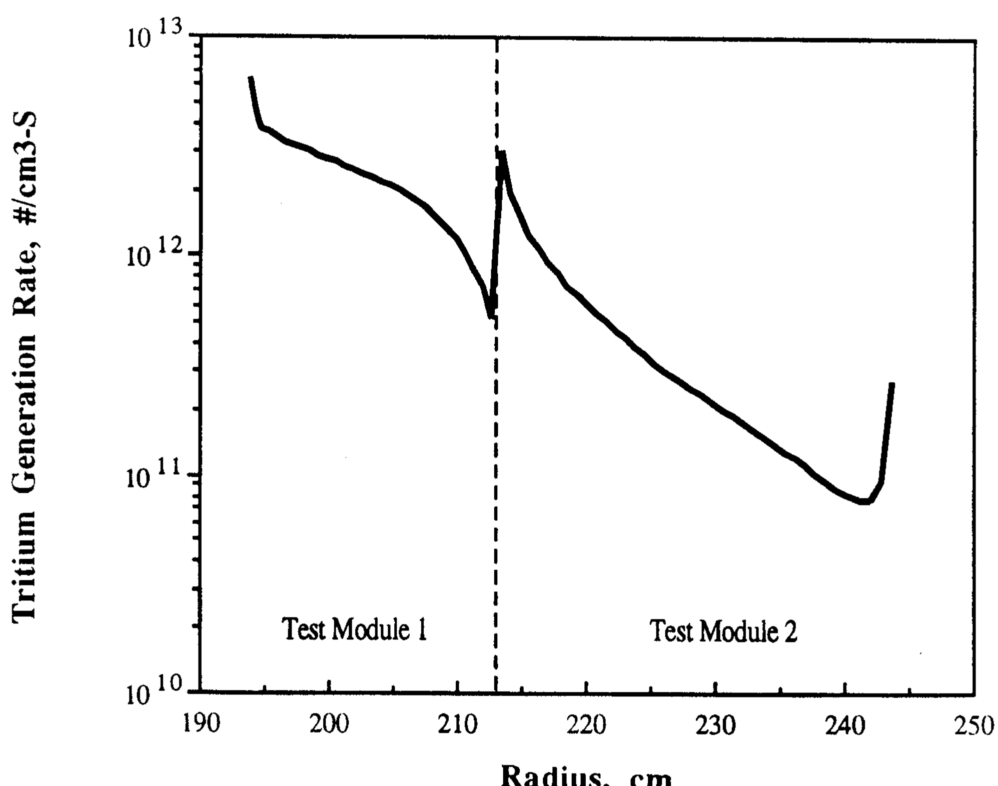


Figure A-5 d. The Nuclear Heating Rates in the Multiplier and Breeding Material of the DEMO Blanket Module. Neutron Wall Loading 3 MW/m3.

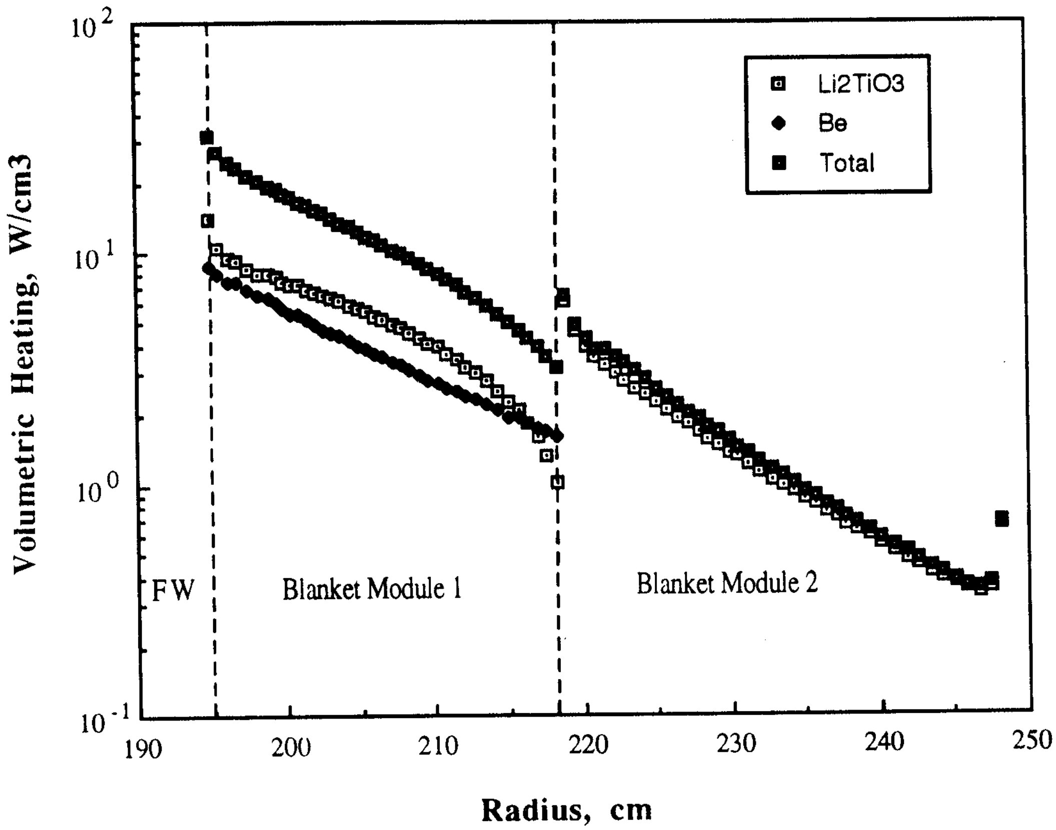
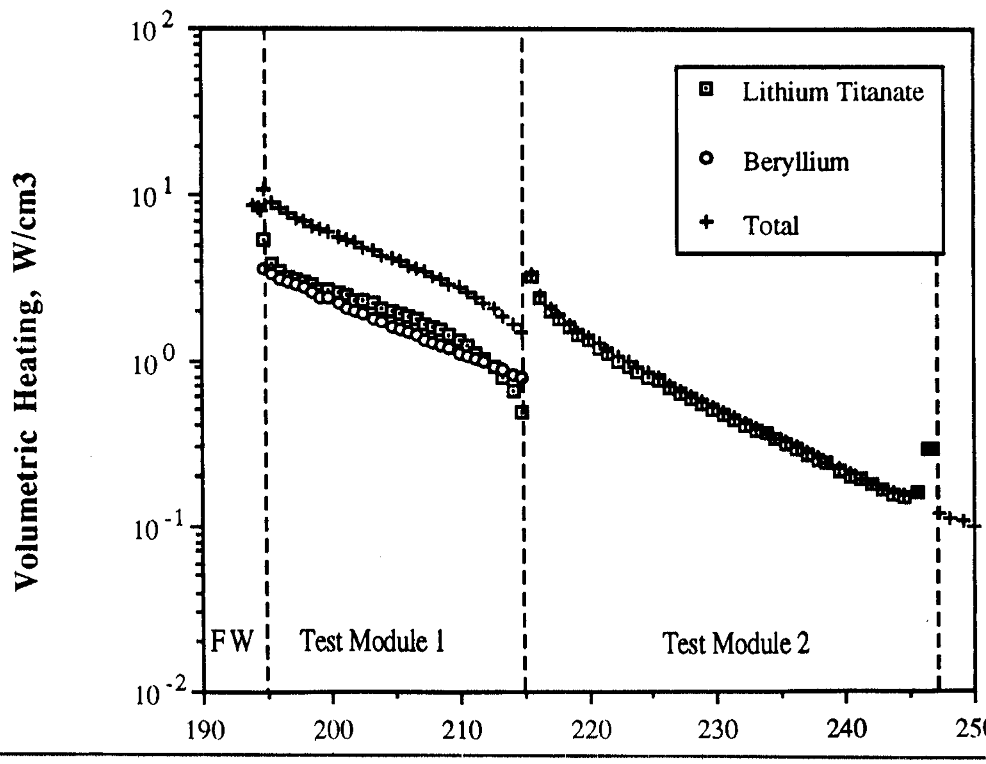
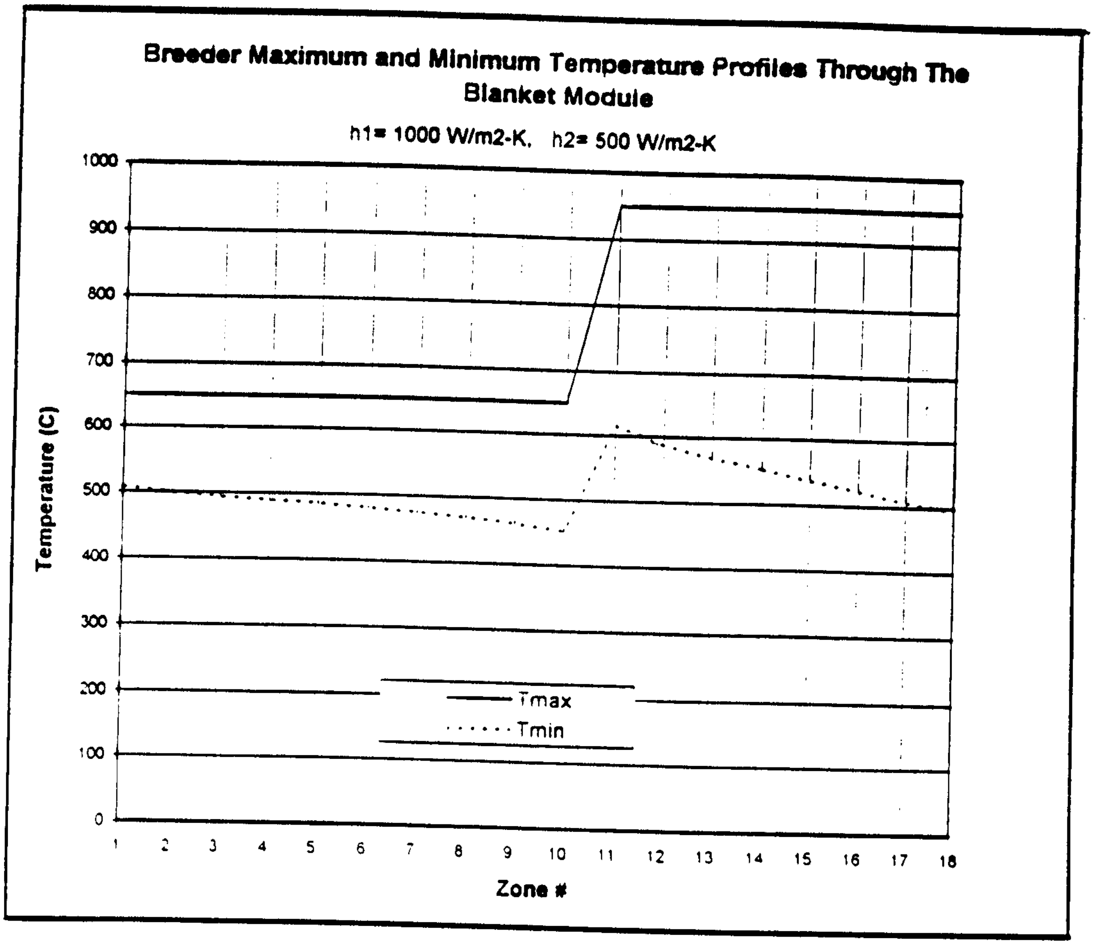


Figure A-5 b. The Nuclear Heating Rates in the Multiplier and Breeding Material of the Test Module. Neutron Wall Loading 1 MW/m2.




Breeder Maximum and Minimum Temperature Profiles Through The Blanket Module
h1= 1000 W/m2-K. h2= 500 W/m2-K
Temperature (C)
Zone #
Tmax
Tmin

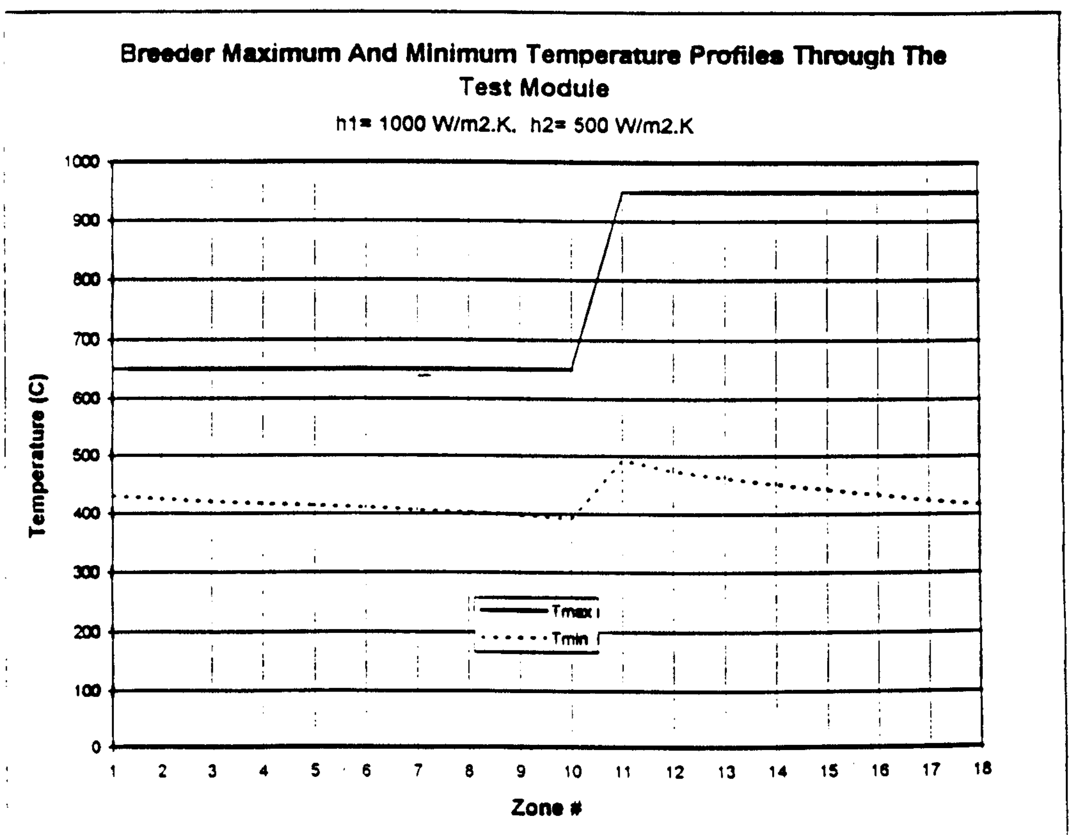

Breeder Maximum And Minimum Temperature Profiles Through The Test Module
h1= 1000 W/m2.K. h2= 500 W/m2.K
Temperature (C)
Zone #
Tmax
Tmin

Figure 16

Thermal Plus Coolant Stresses Through The Test Module First Wall Under ITER Operating Conditions

1 MW/m2 Wall Load, 0.5 MW/m2 Surface Heat Flux

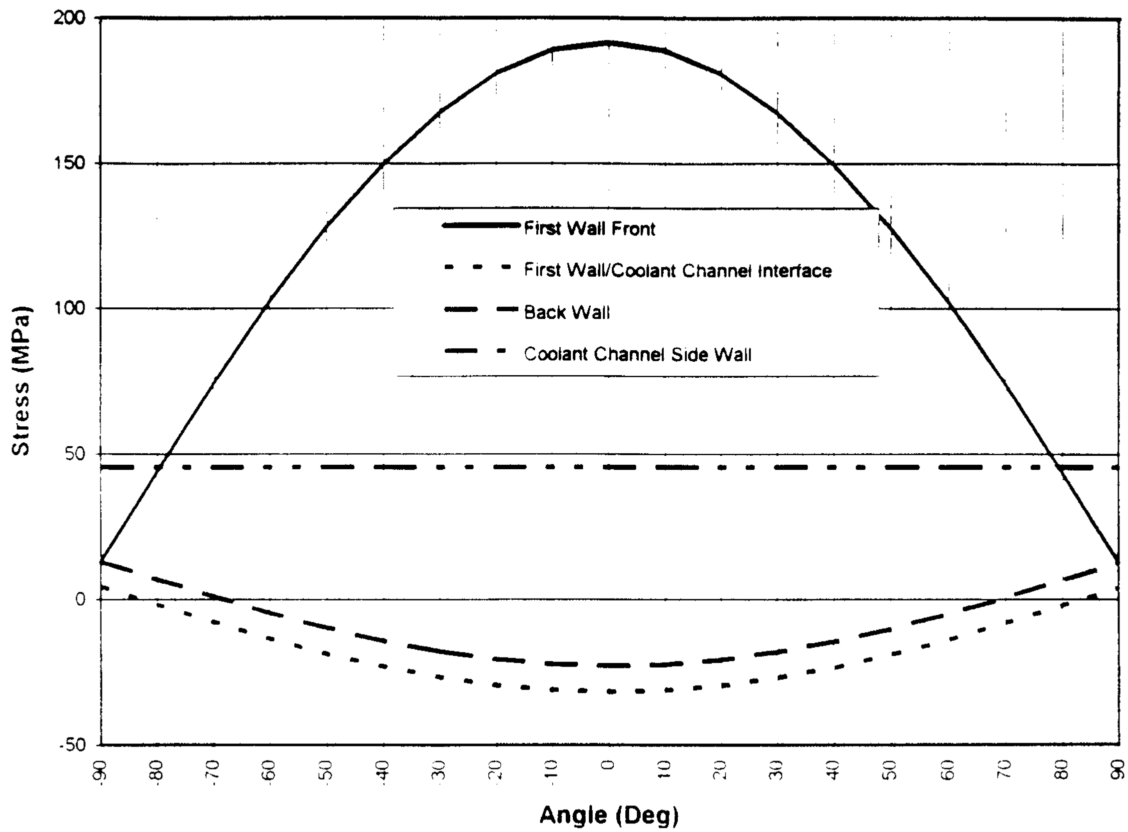
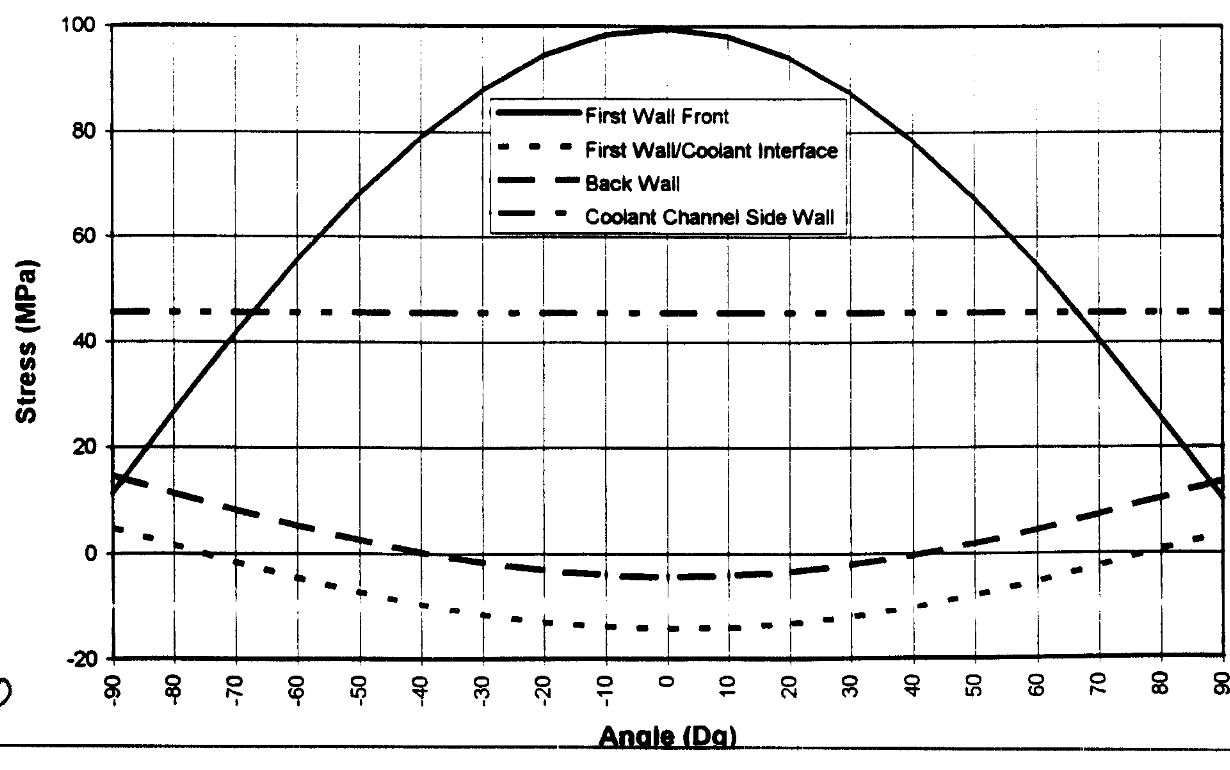


Figure 10

Thermal Plus Coolant Stresses Through The First Wall Under DEMO Operating Conditions

3 MW/m2 Wall Load, 0.5 MW/m2 Surface Heat Flux



Coolant Tube Spacings Through DEMO and ITER Test Blanket Modules

Blanket Zone	Coolant Tube Loacation (Depth into blanket, cm)		Coolant Tube Radial Spacing, cm		Coolant Tube Poloidal Spacing, cm		No. of Tubes/ per toroidal span	
	DEMO	ITER	DEMO	ITER	DEMO	ITER	DEMO	ITER
Front Zone Compositions: 90% Be & 10% Li2TiO3	1.90	2.38	1.90	2.38	1.90	2.38	25	20
	3.92	4.98	2.02	2.60	2.02	2.60	20	16
	6.02	7.74	2.10	2.76	2.10	2.76	17	13
	8.20	10.67	2.18	2.93	2.18	2.93	13	10
	10.47	13.79	2.27	3.12	2.27	3.12	9	7
	12.84	17.13	2.37	3.34	2.37	3.34	6	4
	15.33	20.75	2.49	3.62	2.49	3.62	3	2
	17.97		2.64		2.64		11	
	20.8		2.83		2.83		11	
	23.98		3.18		3.18		10	
Back Zone Composition: 100% Li2TiO3	26.65	25.39	2.67	4.64	2.67	4.64	11	6
	29.3	31.34	2.65	5.95	2.65	5.95	11	5
	32.27	38.48	2.97	7.14	2.97	7.14	10	4
	35.58	47.14	3.31	8.06	3.31	8.06	9	3
	39.31		3.73		3.73		8	
	43.57		4.26		4.26		7	
	48.54		4.97		4.97		6	
	54.18		5.64		5.64		5	