ITER Test Program

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<u>Outline</u>

1) TBWG Comments on the ITER Tritium Breeding Blanket Design
   TBWG charge- to inject appropriate expertise and to ensure that results of the blanket development plans of each Party are available to the ITER breeding blanket
2) Near Term Focus on ITER Test Blanket DDDs
3) Priority Tasks during the 2 year ITER Transition Period
   - additional work to be done in TBWG
   - test module R&D

Presented at the US Home Team Meeting
ITER Project Office, San Diego
April 29-30, 1997

Recent Events of ITER Blanket Testing Program

- Informal TBWG meeting on design review of ITER tritium breeding blanket and remote handling procedures for blanket test modules was held at Garching JWS on Feb. 27-28, 1997

  (Due to the lack of the US funding on the ITER tritium breeding blanket design, the US comments on the JCT design were expressed as the experts' opinions. EU and JA proposed alternative designs based on a beryllium pebble bed.)

- The TBWG-4 meeting was held on April 16-17, 1997 at JAERI Headquarters

  - formulation of the TBWG comments on the JCT's design of the ITER tritium breeding blanket
  - defining parties' collaborative efforts on DEMO-relevant breeding blanket R&D
  - agreement on further work on the Test Program definition and analysis

- The 5th meeting of TBWG will be held at UCLA on Oct. 6-8, 1997

Highlights of TBWG-4

- TBWG Comments on the ITER Breeding Blanket Design
  - TBWG supports the JCT conclusion that the modules below the equatorial plane should be used for the breeding blanket to achieve the TBR of 0.8, and that an increase in the radial thickness of the breeding zone, as suggested by the JCT, should be seriously considered.
  - The TBWG has serious concerns about the porous beryllium option, particularly with regard to design implications and performance, the limited data base, fabricability of component assemblies, R&D efforts, and also, in the view of some Parties, future reactor relevance. *[Potential advantages on the use of porous beryllium relative to beryllium pebbles are a high thermal conductivity resulting in lower operating temperature and a lower tritium inventory and lower swelling at a given temperature.]*
  - TBWG recommends, for comparison, further 3D calculations of TBR, EM and thermomechanical characteristics and an industrial assessment of fabricability including assembly should be carried out for the alternative designs based on a beryllium pebble bed and for the JCT's design.

- Possible areas of cooperation on DEMO-relevant breeding blanket R&D between parties were presented by each Party. In general, Parties are willing and ready to collaborate on most of the R&D areas. It was agreed to utilize the existing IEA implementing agreements for further formalization.

4. TBR Performance

* Approximate Procedures for Global TBR Estimates not Adequately Applied:

  * TBR without Baffle, Limiter, and Equatorial Ports using Neutron Coverage only:

IDR (old)	TBR ~ 0.91
DDR (welded)	TBR ~ 0.77
REF (flexible)	TBR ~ 0.73

  * Corrections for gaps, module structures, etc. not quantified

* Doubts on EU HT 3-D Calculations Unjustified

  * Geometrical corrections for gaps, module structures, etc. quantified:

inboard	~18.5 %
outboard	~21.0 %

  * Neutronics Efficiency of geometrical corrections is larger by at least 30 %, as confirmed by separate calculation (poloidal headers replaced by Breeding Blanket configuration)

  * Very recent calculation leads to further decrease of Global TBR (0.563 --> 0.515)

Global TBR for DDR Configuration

JCT Local TBR	*	inboard	1.15
	*	outboard	1.38

Coverage	Full	Red.
Approximate Procedure:		
Correction for Neutron Coverage	1.26	0.77
with improved procedure for reduced coverage		0.80
Correction for Gaps, Module Structures etc.	1.00	0.64
Actual 3-D Results reported	0.93	0.56
New Result		0.52

3-D Effects neglected in approximate methods:

* difference between geometrical and neutronics "efficiency" of gaps & structures
* neutron source anisotropy
* non-linear variation of nuclear responses with neutron wall loading
* correct spectrum and angular distribution of backscattered neutrons
* spectral shifts in mixed configurations

Alternative designs based on beryllium pebbles proposed by the EU and JA exhibit comparable local TBR

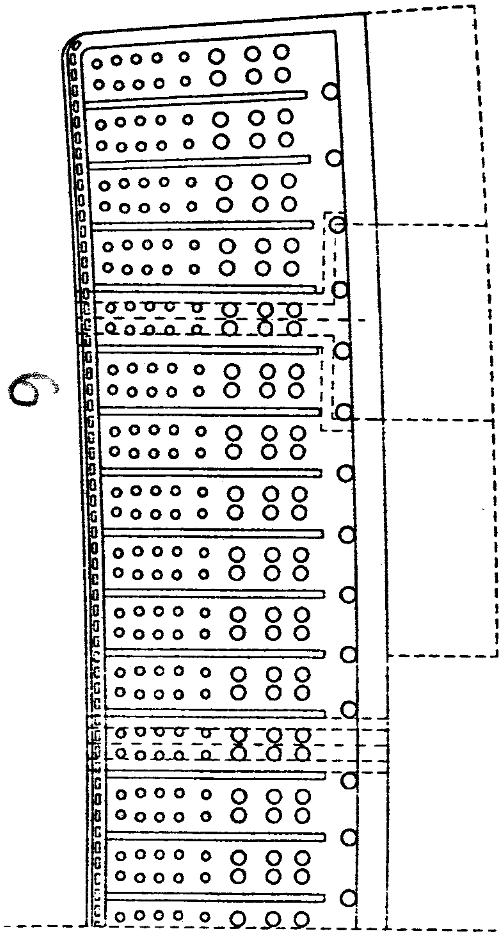


Fig. 2
Module #19 toroidal half-section (midplane)

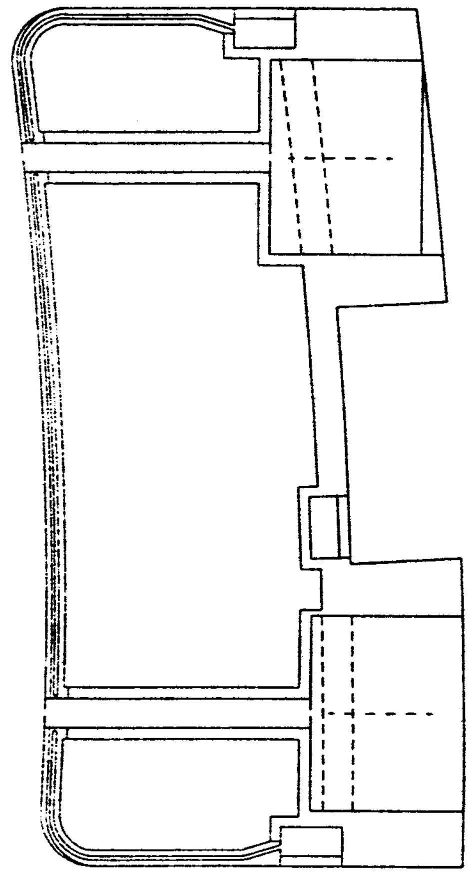
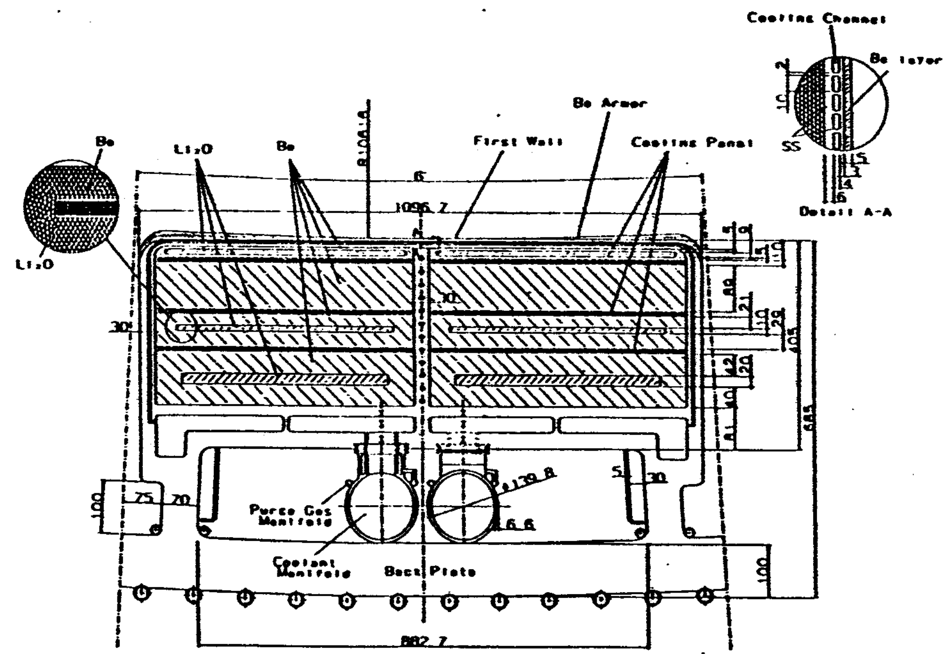


Fig. 3
Module #19 poloidal section



Cross sectional view of the layered pebble bed type blanket at outboard midplane

Near Term Focus on ITER Test Blanket DDDs

1) Blanket test module **OPERATIONAL PLAN**

2) Safety analysis and decay heat curves in response to TAC-11 recommendation

   - to be incorporated into NSSR-2

3) DDDs revisions to be compatible with the integrated test port design concept

   - The new concept is to support the test modules at the vacuum vessel as opposed to at the backplate designed previously.

4) Revised 2nd draft DDDs due mid-summer for TAC review

5) Formalization of parties' collaborative efforts on ITER DEMO test module R&D

Conclusions

- keep safety relevant systems to a minimum.
  ==> Increase operational / experimental flexibility and minimize regulatory intervention.

- DDD of ITM's mature enough to start safety assessment and integration into ITER safety approach (NSSR-2)

- important PIE's identified sufficiently for NSSR-2; sequence development needs further work

- for NSSR-2 just focus on BPP approach, EPP ITM's need to be re-licensed if more advanced approach is justified by BPP operating experience

- confinement approach needs to be developed. recommendation to implement confinement approach not depending on experimental ITM components.

- decay heat curves urgently needed (concern with WC and manganese steel in US HT liquid Li design)

- need to complete SADL type information, develop AAS with contact persons

- safety analysis performed by HT's should be documented in DDD's. If sufficient consistency with ITER safety approach by August 97, SEHD may decide to summarize safety analysis of ITM's in an Appendix of NSSR-2. (best responce to TAC-11 request)

Schedule:

- April 97: contact person assigned (ITM & SEHD)
  Contact SEHD: H.-W. Bartels, e-mail: bartelh@iterus.org
- August 97: final results documented for NSSR-2

Priority Tasks during the 2 year ITER Transition Period

TBWG-4 agreed in April 97 (in the presence of the ITER Director and Deputy Director) that further work needed must include the following:

1. Criteria for qualifying a blanket module or submodule for actual insertion and testing in ITER

2. Definition of test module instrumentation and verification of capability to perform in the ITER fusion environment (magnetic field, radiation, heating, etc.)

3. Analysis to show that the results to be obtained from the test modules as designed can be extrapolated to DEMO and reactor conditions (e.g. higher wall loads and the need to demonstrate tritium self sufficiency)

4. Further discussion among the parties to define possible collaboration and operation of test articles (and proceeding with collaborative R&D efforts under IEA Implementing Agreement)

Priority Tasks during the 2 year ITER Transition Period

Test Module R&D is the Key to Realize Meaningful Testing on ITER

- The time-scale for R&D of ITER Breeding Blanket and DEMO Breeding Blanket is the SAME: both will have test modules at the beginning of ITER operation

- It is necessary to support R&D experiments now in non-fusion facilities (laboratory non-neutron test stands and fission reactors) to:
  1. reduce the risk to ITER from excessive failure of test modules,
  2. assess the DEMO-relevance of the test blanket concepts, and to assure that the results of testing from ITER provide meaningful information on the feasibility and attractiveness of blankets, and
  3. effectively utilize the limited testing time available in ITER.

- Collaboration on test program needs to be negotiated as part of the construction agreement
  - conducting experiments in selected key areas that can make contributions of value to our international partners and gain access to the current international program, and
  - continuing to involve through the IEA collaborative efforts to develop the data base for ITER test modules and for the low activation structural materials

TBWG Comments on the ITER breeding blanket design

The JCT presented a breeding blanket design to the TBWG based on the following design constraints :

- The breeding blanket should have a modular design similar to the shielding blanket for installation and removal by remote handling equipment through the equatorial ports. The segmentation of the breeding blanket modules should be the same as that of the shielding modules
- Breeding blanket modules should be attached and supported from the back plate in a manner similar to that for the shielding blanket modules
- The blanket system (modules and attachments) must withstand the induced electromagnetic loads resulting from plasma disruption events
- The breeding blanket should be designed for a neutron fluence in the range of 1 to 3 $MW.a/m^2$ at the FW boundary
- The breeding blanket should use water coolant at 4 MPa inlet pressure and inlet/outlet temperature of 140/190 °C
- Ceramic breeder should be used
- Maximum temperature of the beryllium neutron multiplier must not exceed 500 °C taking into consideration different design uncertainties.
- The radial thickness of the blanket module shall be 30 cm for inboard and 40 cm for the outboard including beryllium tiles, module coolant manifolds, and module end wall structure
- The blanket module must protect the vacuum vessel and the toroidal field coils from excessive nuclear heating and radiation damage as defined in the GDRD
- The blanket should use 316LN Austenitic Steel structure material

Using all modules below the equatorial plane except the lower baffle modules, the net TBR for this design, as calculated by the JCT, is 0.8. By increasing the thickness by 5 cm on the inboard and 3 cm on the outboard, the TBR could be increased by about 10 %. With an annual external tritium supply of 1.5 kg/y, a TBR >0.8 is necessary to achieve 1 Mwy/m2, assuming full power operation over a period of 10 years.

The TBWG supports the JCT conclusion that the modules below the equatorial plane should be used for the breeding blanket to achieve the TBR of 0.8, and that an increase in the radial thickness of the breeding zone, as suggested by the JCT, should be seriously considered.

This blanket design is based on the use of porous beryllium for which the potential advantages relative to beryllium pebbles as put forward by the JCT are, among others : a high thermal conductivity resulting in lower operating temperature, a lower tritium inventory and lower swelling at a given temperature.

Nevertheless, the TBWG has serious concerns about this porous beryllium option, particularly with regard to : design implications and performance, the limited data base, fabricability of component assemblies, R&D efforts, and also, in the view of some Parties, future reactor relevance.

Due to these concerns, one alternative design based on beryllium pebbles should be developed to a level which will permit a comparison with the current JCT design. Alternative designs based on a beryllium pebble bed were presented by the EU and JA, which exhibit comparable local TBR. For the comparison, 3D calculations of TBR, electromagnetic and thermomechanical characteristics and an industrial assessment of fabricability including assembly should be carried out for each design.

Possible areas of cooperation between the Parties

	EU	JA	RF	US
Ceramic breeder :			Si	
pebble fabrication technology (information exchange)	P	I		P
basic research on tritium release mechanisms	I	P		P
characterization of pebbles	P	P	P	
engineering-oriented material test of pebbles	P	P		I
irradiation tests in fission reactors	P	P	P	(P)
PIE	P	P	P	(P)
characterization of pebble beds	P	P		P
engineering tests of pebble beds	P	P	P	P
Beryllium :				
pebble fabrication technology (information exchange)	I	I		P
characterization of pebbles	P	P		
engineering-oriented material test of pebbles	P	P		I
irradiation tests in fission reactors	P	P	P	
PIE	P	P	P	P
characterization of pebble beds	I	P		P
engineering tests of pebble beds	P	P	I	P

"BEATRIX"

(incl. mechanical interaction [illegible])

Possible areas of cooperation between the Parties

	EU	JA	RF	US
Helium-cooled Ceramic breeder blanket :				
out-of-pile small/med. scale mock-up tests	I	P	P	P
~~comparative~~ in-pile functional test (on mock-up)	(P)	P	P	I (P)
tritium recovery system for Helium sweep gas	I	P		(P)
Permeation barrier development (inc. irrad.testing) PbLi	P	(P)	P	I
pressurized water environment	P	P	P	
helium environment	I	P	P	I
Liquid metal blankets		(P)	P	P
Insulation coating for Li				
~~Tritium permeation barrier development inc. radiation testing~~	~~P~~	~~P~~		
Study of MHD issues	P	(P)	P	P
Small & med. Size Mock-ups MHD/HT tests			P	I
in-pile test in Li loop.			P	I
PbLi circuit technology	(P)		P	

Possible areas of cooperation between the Parties

	EU	JA	RF	US
Structural Materials (IEA Fusion Materials IA)				
on going. Characterization of RAF - F82H	P	P		P
Irradiation tests in fusion reactor	P	P		P
~~Irradiation tests of ceramic breeder materials~~	~~P~~	~~P~~		~~P~~
Structural Materials				
HIP technology for RAF steels for fabrication of blanket modules	P	P		
Vanadium alloy development and characterisation		(P)	P	P
(″ ″) In-reactor tests	(P)	(P)	P	P

Development of Shield in progress. Charact. of New heat of RAF. P