Summary of ITER Test Program Meeting and Workshop

July 1989

Garching, FRG

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presented at the U.S. ITER Meeting

September 7, 1989

FEDC

UCLA

Test Program Workshop Attendance

July 1989

EC:
M. Chazalon
M. Dalle Donne
W. Daenner
P. Labbé
S. Malang
T. Reeve
D. Maisonnier

Japan:
T. Kuroda
H. Takatsu
H. Yoshida

USA:
M. Abdou
S. Brereton
R. Mattas
M. Tillack
S. Thomson

USSR:
I. Altovski
A. Sidorov
Y. Strebkov
G. Shatalov

Other Speakers:
E. Salpietro
F. Engelmann

Outline of Summary Report

1. Introduction and Summary

2. Test Program Descriptions
   - 2.1 Introduction
   - 2.2 General Description of Tests
   - 2.3 Space-Time Requirements
     - 2.3.1 Requirements from individual countries
     - 2.3.2 International allocation considerations
   - 2.4 Ancillary Equipment

3. Test Program Requirements
   - 3.1 Introduction
   - 3.2 Requirements of Parameters
   - 3.3 Requirements on Engineering
   - 3.4 Requirements of Machine on Testing

4. Test Article Preliminary Design

5. Homework

Appendices

A. Summary of Countries' Test Programs
   - A.1 EC
   - A.2 Japan
   - A.3 USA
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B. Agenda for July 1989 Meeting

C. List of Participants in July 1989 Meeting

D. Meeting Record: Presentations and Reports from Home Teams

Meeting Summary

(reviewed by each home team prior to distribution)

1. The space requirements for high-priority blanket and material tests for EC, Japan, USA, and USSR are shown in Fig. 1 at different years of operation. During the technology phase, ~54 m^2 of test area at the first wall in about 14 ports are required. These requirements far exceed the space available in ITER for testing (by a factor of 3–4). Therefore, two recommendations are made:

A. ITER designers should consider means for increasing the space available for testing. The maximum available space for testing needs to be specified by February 1990.

B. All countries should consider ways to reduce testing needs, **particularly through international collaboration on ITER tests.** Methods for collaboration include sharing of the same test articles and coordinating space and time utilization. Collaboration can include bilateral, trilateral, and multi-country agreements.

The space needed for an idealized common program was attempted during the group meeting, and it was found that the minimum number of ports is in the range of 7–8.

2. The requirements for ancillary equipment outside the torus, required to support the test modules (e.g., heat rejection systems, tritium processing, etc.) are extensive. The space required is large and there are several issues and needs such as accessibility and shielding. Further investigation of ancillary equipment needs as well as close coordination between the testing group and the ITER machine designers (particularly configuration and maintenance) are recommended.

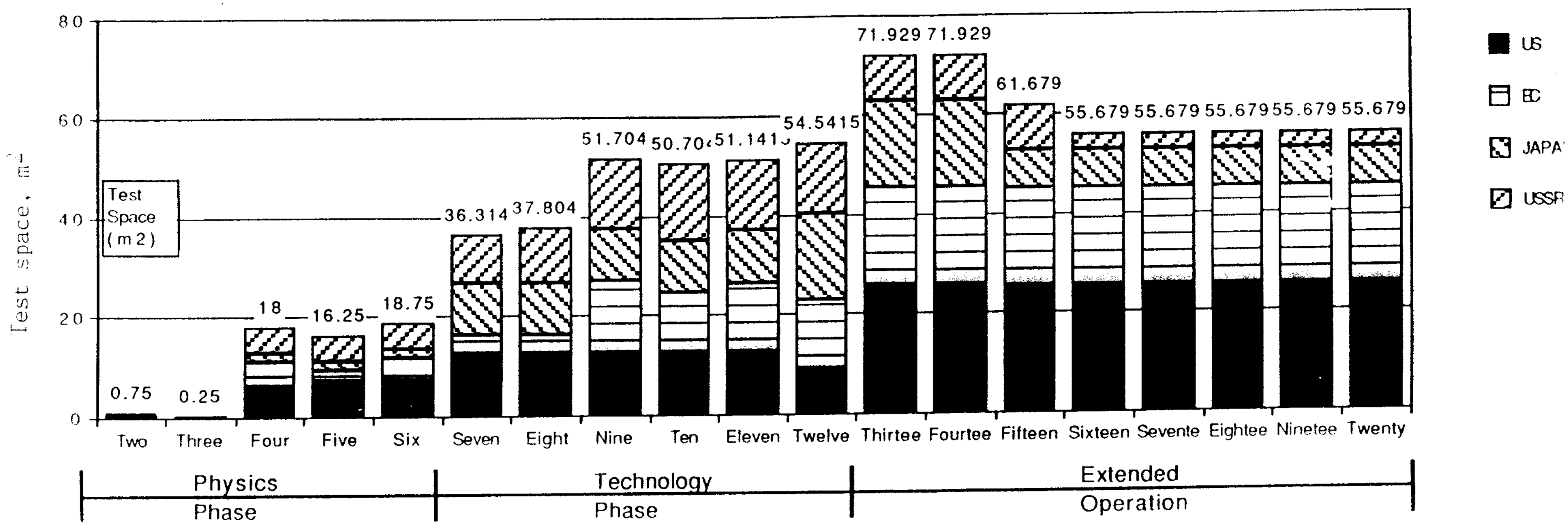

Fig. 1: Test space in m^2 at first wall required for high priority blanket and material tests. Requirements are shown for US, EC, Japan and USSR at different years of ITER operation.

Fig. 2-3Test Space by Type

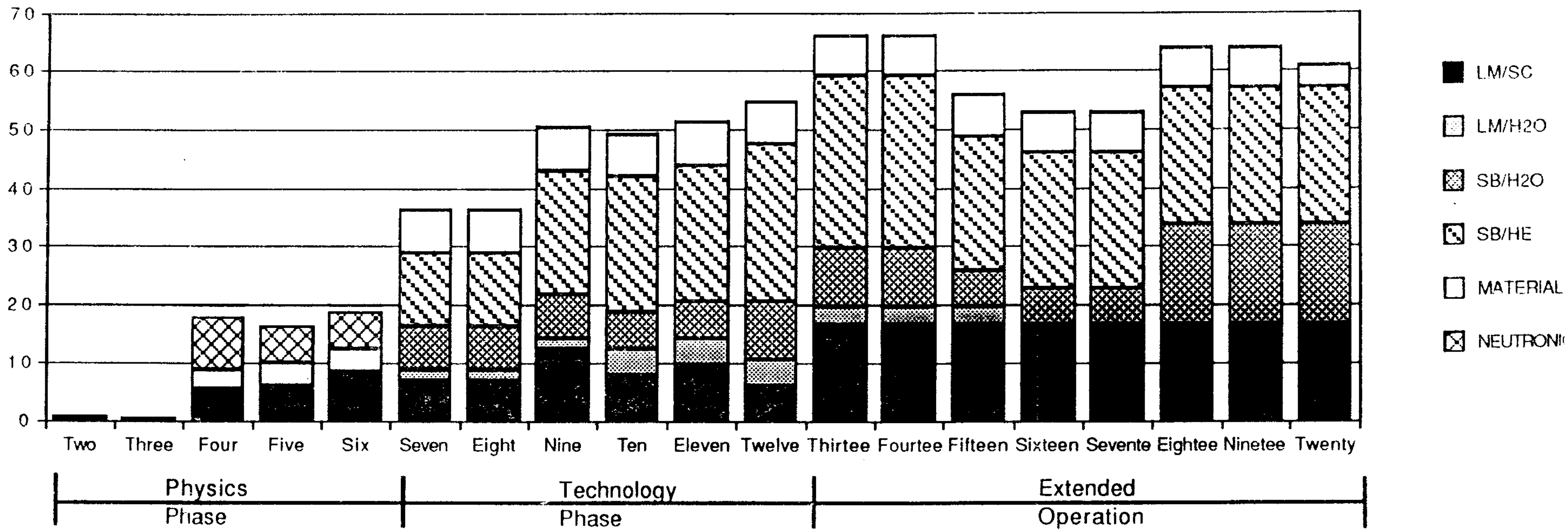

Fig. 2-4Test Space by Test Vehicle Type

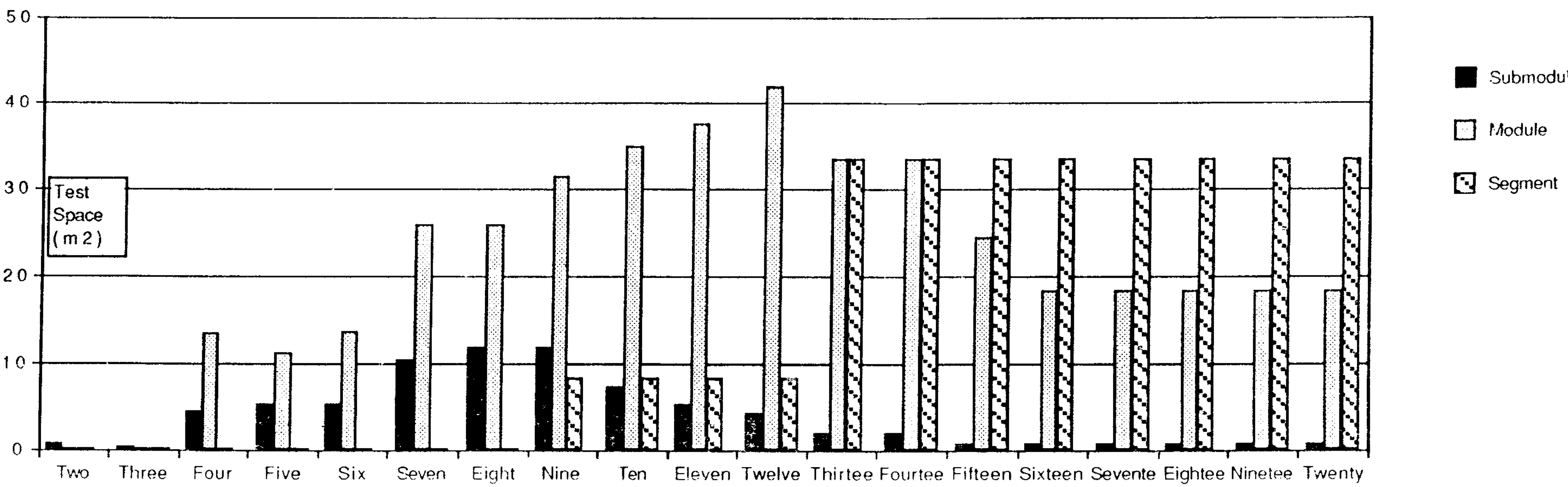

Table 3.3 Testing Space Required Within the Machine
(if the programs of the 4 parties would be simply added)

	pre-technology phase		technology phase		extended operation	
For Specimen, Submodule, and Module Tests						
1) ceramic/helium-cooled	2 m^2	1 port	15 m^2	5 ports	7 m^2	2 ports
2) ceramic/water-cooled			9 m^2	3 ports	5 m^2	2 ports
3) liquid metal/self-cooled			11 m^2	3 ports	6 m^2	2 ports
4) liquid metal/water-cooled			9 m^2	3 ports	4 m^2	1 port
5) basic neutronics tests	8 m^2	3 ports				
6) basic materials tests	3 m^2	1 port	7 m^2	2 ports	7 m^2	2 ports
7) other tests (PFC...)		1 port		1 port		1 port
For Segment Tests						
1) ceramic/helium-cooled			1 segment		2 segments	
2) ceramic/water-cooled					1 segment	
3) liquid metal/self-cooled					1 segment	
4) liquid metal/water-cooled					1 segment	

Table 3.4 Proposal for Minimum Testing Space in the Machine

	pre-technology phase	technology phase	extended operation
For Specimen, Submodule, and Module Tests			
1) ceramic/helium-cooled		2 port	1 port
2) ceramic/water-cooled		1 port	1 port
3) liquid metal/self-cooled	1 port	1 port	1 port
4) liquid metal/water-cooled		1 port	1 port
5) basic neutronics tests	1 port		
6) basic materials tests	1 port	1 port	1 port
7) other tests (PFC...)	1 port	1 port	1 port
TOTAL	4 ports	7 ports	6 ports
For Segment Tests			
1) ceramic/helium-cooled			either/
2) ceramic/water-cooled			or 1 segment
3) liquid metal/self-cooled			either/
4) liquid metal/water-cooled			or 1 segment

Table 3.5 Ancillary System Requirements

Test Type	Test Article	Power	Fluids	Coolant Conditions	Tritium Extraction Needs	Space Requirements
Ceramic/He	Submodule	0.05–1 MW	He cooling, He purge	5.6 MPa,	50–1000 Ci/day	250–500 m^3
	Module	4–6 MW	"	250–550°C	0.4–0.6 gT/day	1500–2500 m^3
	Segment	10–20 MW	"		1–2 gT/day	3000 m^3
Ceramic/H_2O	Submodule	0.05–1 MW	H_2O cooling, He purge		50–1000 Ci/day	250–500 m^3
	Module	4–6 MW	"		0.4–0.6 gT/day	1000–2000 m^3
	Segment	10–20 MW	"		1–2 gT/day	2000 m^3
Liquid Metal/Self	Submodule	~1 MW	LiPb – Li		<0.1 gT/day	250 m^3
	Module	4–6 MW	"		0.4–0.6 gT/day	500–1000 m^3
	Segment	10–20 MW	"		1–2 gT/day	1000–2000 m^3
Liquid Metal/H_2O	Submodule	~1 MW	H_2O cooling, LiPb	10–15 MPa	<0.1 gT/day	
	Module	4–6 MW	"	285–325°C	0.4–0.6 gT/day	500–1000 m^3
	Segment	10–20 MW	"		1–2 gT/day	1000–2000 m^3
Materials	Specimens	10 kW (total)	He, H_2O, liquid metal (temp. control coolant) He purge		<10 Ci/day	

Meeting Summary, cont'd.

3. Until now, only blanket and material tests have been considered. Tests for other components, such as high heat flux components, need to be addressed.

4. The driver blanket and ITER phased operation were the subject of important discussion. If the driver blanket is to be installed between the physics and technology phases, then confirmation tests of the driver blanket should be performed during the physics phase. Joint discussions between the blanket and test groups are suggested to address a number of key questions on the driver blanket.

5. Testing of plasma-facing components (PFC) in ITER during the physics phase should receive high priority in order to provide data for PFC performance in the technology phase.

6. It is recommended that the ITER design groups, particularly configuration and maintenance, provide early evaluation of the test program design and operation issues. Examples of areas requiring attention include: test modules with plasma/vacuum exposure, test module insertion/removal procedures and required time, ancillary equipment space and shielding. Engineering guidelines should be provided to the testing group.

Table 3.6 Handling Requirements

Test Articles	Typical Size/ Weight	No. of Articles		Frequency of Load/Unload	No. of Load/Unload per Year	
		With Plasma Access	No Plasma Access		With Plasma Access	No Plasma Access
Materials specimen	1-100cc/<1kg		Thousands	1-3 /yr.		Thousands
Submodule	0.05-0.2m ^{3} /1t	10 - 20	10 - 20	2 /yr	20 - 40	20 - 40
Module	0.5-2m ^{3} /<10t	5 -10	5 -10	1 /yr	5 -10	5 -10
Segment	10 m ^{3} / 30t	4		0.1-0.5 /yr	0.5-2	

Meeting Summary, cont'd.

7. The testing group **did not** plan to discuss "the requirements of testing on ITER major parameters such as wall load, fluence, burn cycle, etc." during July 1989 because: (1) this topic was addressed in detail in July 1988, and (2) the need to move forward and use the group time for other important issues of the test program. However, based on a request from a member of the physics group, the question of burn cycle was briefly discussed and the testing group concluded the following:

> *Steady state is a highly desirable ultimate goal for ITER during the technology testing phase. If plasma pulsing is unavoidable, then long burn times (in the range of 1–3 hours) and short non-burn times (<70 seconds) are needed. If the non-burn time exceeds ~70 s, then the burn time should be much longer than 1000 s, and should approach 3000 s.*

8. The question of the minimum continuous operating time (periods with high availability approaching 100%) was raised by one group which suggested that the recommendation of July 1988 be reconsidered. This area is difficult because it involves many complex technical areas (note that the ITER Terms of Reference document mentioned this topic). Homework was specified for winter 1990.

9. The testing group favors an "extended operation phase" beyond the technology phase. During this extended operation phase, segment/sector tests are highly desirable.

Table 3.2 Reference Wall Load and Accumulated Fluence Scenario

Year	Plasma	Neutron Wall Load (MW/m²) Average	on Port	Availability	Duty Cycle	Accumulated Fluence (MW-a/m²) Average	on Port
Physics Phase							
1	H	0	0	1%	<50%	0	0
2	H	0	0	1%	<50%	0	0
3	D/^{3}He						
4	D/T	1.0	1.4	1%	<50%	.005	0.007
5	D/T	1.0	1.4	1%	<50%	.01	0.014
6	D/T	1.0	1.4	1%	<50%	.015	0.021
Possible Configuration Change (1–2 years)							
		0	0	0		0	0
Technology Phase							
7	D/T	1.0	1.7 *	≤10%	85% #	0.10	0.17
8	D/T	1.0	1.7	≤10%	85%	0.19	0.31
9	D/T	1.0	1.7	≤10%	85%	0.27	0.46
10	D/T	1.0	1.7	(10–)25%	85%	0.48	0.82
11	D/T	1.0	1.7	(10–)25%	85%	0.70	1.18
12	D/T	1.0	1.7	(10–)25%	85%	0.91	1.54
Extended Operation							
13	D/T	1.0	1.7	≥25%	85%	1.12	1.90
14	D/T	1.0	1.7	≥25%	85%	1.33	2.26
15	D/T	1.0	1.7	≥25%	85%	1.55	2.62
16	D/T	1.0	1.7	≥25%	85%	1.76	2.98
17	D/T	1.0	1.7	≥25%	85%	1.97	3.34
18	D/T	1.0	1.7	≥25%	85%	2.18	3.71
19	D/T	1.0	1.7	≥25%	85%	2.40	4.07
20	D/T	1.0	1.7	≥25%	85%	2.61	4.43

* may be 1.4 during technology phase, depending on whether rebuild occurs between phases

assumes inductive current only: may be as low as 67%, depending on current drive scenario

Summary of Homework and Meetings Scheduled

Meetings in Garching:

Winter 1990 (1 week)	Feb. 19–23
Summer 1990 (3 weeks)	July 16–Aug. 3

Winter meeting: address all test program issues that can significantly affect the ITER machine design (e.g., configuration, maintenance, shielding).

Summer meeting: address all aspects of the test program. A complete definition of the ITER test program will be completed by the summer 1990 meeting. A report also will be written, to be included in the ITER final conceptual design report.

Other Meetings:
In addition, other specialists meetings and communications concerning the testing issues are planned. In particular, one each for solid breeder and liquid metal blanket testing.

Homework Objectives (July 1989–July 1990):

1. revise and complete the definition of thetest program for all countries
2. address engineering details that affect the ITER machine design.

Major Homework Items

1. Definition of the Test Program

Continuation and refinement of ongoing work.

Tests for components other than the blanket (e.g., high heat flux components, neutronics tests) should be included.

A format was developed in July 1989, including items such as: the size of the test article, duration of tests, materials of construction, coolants, boundary conditions (for example, requirements on exposure to plasma and vacuum, and the need for surface heat flux)

2. Engineering Design of Test Modules

Emphasis on external boundary connections, e.g., coolant lines and manifolds, tritium removal lines.

Drawings for at least some representative test articles, sufficiently detailed to allow ITER machine designers to evaluate configuration & maintenance options.

3. Ancillary Equipment Description

- heat and power systems
- emergency and safety systems
- space
- loaction (maximum distance from machine)
- fluid types and flow rates
- power

4. Test Parameter Requirements

New questions were raised during July 1989, including:

1. plasma burn time
2. plasma dwell time
3. minimum continuous operating time.

5. Sector Tests

The need and strategy for such tests should be examined.

Major Homework Items, cont'd.

6. Explore Options for Test Program Allocation Among Countries

Space available for testing on ITER is not sufficient to satisfy the space requirements for tests by all countries

Thus, various forms of collaboration on tests should be considered, including bilateral, trilateral, or multi-country. Collaboration may take place on some tests, while others can be performed separately by each country.

Forms of collaboration can vary from:
1. sharing the same test article (joint construction, testing, information analysis)
2. coordinating space use for tests within the same port
3. coordination of time use (sequential tests) for the same space

7. Other Issues

Home teams should report on any other issues related to testing that may be uncovered while developing of the test program definition.

Also, each party should address the safety and engineering issues most relevant to their proposed tests (e.g., lithium hybrid, etc.)

8. Assess Tests for the Driver Blanket

Decision by ITER design team expected by end of summer 1989 on blanket change between phases

The testing groups should address the tests for the driver blanket in a manner consistent with the ITER design decision.

9. R&D for the Test Program

The test modules to be installed in ITER require R&D programs separate from the R&D program for the basic ITER device. the operating conditions in the test modules will be more severe than those of the basic machine due to the need to demonstrate high performance, tritium self-sufficiency, and recovery of useful heat.

Homework

The testing group recommends the following two meetings in Garching:

1. Winter 1990: 1 week from Feb. 19–23
2. Summer 1990: 3 weeks from July 16–Aug. 3

The purpose of the winter meeting is to address all test program issues that can significantly affect the ITER machine design (e.g., configuration, maintenance, shielding).

The winter meeting is crucial to provide timely feedback to ITER machine design. The summer meeting will address all aspects of the test program. A complete definition of the ITER test program will be completed by the summer 1990 meeting. A report also will be written, to be included in the ITER final conceptual design report.

It is suggested that reports from the home teams be distributed to other participants at least one month prior to the meeting. The winter report should be distributed by early December 1990 to allow sufficient time for interaction.

In addition to the above meetings at Garching, other specialists meetings and communications concerning the testing issues are encouraged. In particular, Prof. M. Dalle Donne will arrange for a meeting and/or communication concerning solid breeder tests, and Dr. Richard Mattas on liquid metal blanket testing.

The homework for the period July 1989–July 1990 is aimed at:

1. revising and completing the definition of thetest program for all countries
2. addressing engineering details that affect the ITER machine design.

Major Homework Items

1. Definition of the Test Program

(partial report for winter 1990 meeting, complete report in summer 1990)

The description developed by each country for July 1989 is to be revised and made more complete. Priorities for various tests should be clarified. Tests for components other than the blanket (e.g., high heat flux components, neutronics tests) should also be included. The information should specify the size of the test article, duration of tests, materials of construction, coolants, and other relevant information. The format developed in July 1989 should be used. Specify any significant requirements and boundary conditions; for example, requirements on exposure to plasma and vacuum, and the need for surface heat flux.

2. Engineering Design

(partial report for winter 1990, complete report for summer 1990)

Develop design of test modules with emphasis on external boundary connections, e.g., coolant lines and manifolds, tritium removal lines. Drawings for at least some representative test articles should be sufficiently detailed to allow ITER machine designers to evaluate configuration and maintenance options.

3. Ancillary Equipment

(partial report for winter 1990, complete report for summer 1990)

Ancillary equipment for all tests should be defined and described. The description should include:

- heat and power systems
- emergency and safety systems
- space
- loaction (maximum distance from machine)
- fluid types and flow rates
- power

Major Homework Items, cont'd

4. Test Parameters

(report for winter 1990 meeting)

The testing requirements on ITER parameters (e.g., wall load, fluence) have been investigated and discussed in 1988 and 1989. During the July 1989 session, new questions were raised concerning: 1. plasma burn time, 2. plasma dwell time, 3. minimum continuous operating time. In some of the physics scenarios, the dwell time is very long (1000 s or longer in some cases). In the past, the impact of the dwell time on the value of testing was investigated by the testing group. However, these new values of long dwell time raise new concerns, e.g., the ability to keep the test modules in an "active" hot status for the next cycle. Therefore, questions related to the requirements on burn time and dwell time need further investigation.

Another question relates to the minimum continuous operating time (COT). The definition of COT is the period of time during which the machine has 100% availability. At the end of COT, the machine can be shut down and the conditions in the test modules can not be guaranteed. thus, tests following the shutdown of the machine may have "cold" startup conditions. In contrast, tests during the COT period can be performed at steady state or during a number of successive plasma pulses.

The value of COT was determined previously in the testing group meeting of July 1988. This value needs to be investigated further. New results should be reported in the winter 1990 session.

5. Sector Tests

(partial report in winter, full report in summer)

It has been proposed that full segment or sector tests be performed, particularly during the extended operation phase (see machine operating schedule). The need and strategy for such tests should be examined.

Major Homework Items, cont'd

6. Test Program Allocation Among Countries

(reports on progress during the winter 1990 meeting)

During the July 1989 session, it was clear that the space available for testing on ITER is not sufficient to satisfy the space requirements for tests by all countries. Thus, it is suggested that various forms of collaboration on tests be considered. Parts of the collaboration can be bilateral (two countries), trilateral (three countries) or for all countries. Collaboration also take place on some tests, while other tests can be performed separately by each country. Forms of collaboration can vary from:

1. sharing the same test article (joint construction, testing and information analysis)
2. coordinating space use for tests within the same port
3. coordination of time use (sequential tests) for the same space

Parties are encouraged to explore the various options for collaboration. The meetings for solid breeder and liquid metals specified earlier should help in this regard.

7. Other Issues

Home teams should report on any other issues related to testing that may be uncovered while developing of the test program definition. Also, each party should address the safety and engineering issues most relevant to their proposed tests (e.g., lithium hybrid, etc.)

Major Homework Items, cont'd

8. Tests for the Driver Blanket

(partial report winter 1990, complete report summer 1990)

ITER operation may involve a physics phase and a technology phase, with installation of the driver blanket between the two phases. In such a case, some confirmation tests of the driver blanket should be performed during the physics phase. On the other hand, if the driver blanket is installed prior to the physics phase, then such tests are not possible. When the decision is made on ITER design (expected by the end of summer 1989), the testing groups should address the tests for the driver blanket in a manner consistent with the ITER design decision.

9. R&D for the Test Program

(report by summer 1990)

The test modules to be installed in ITER require R&D programs separate from the R&D program for the basic ITER device. the operating conditions in the test modules will be more severe than those of the basic machine due to the need to demonstrate high performance, tritium self-sufficiency, and recovery of useful heat.