ITER: TEST PROGRAMME

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THIRTEENTH INTERNATIONAL CONFERENCE ON PLASMA PHYSICS AND CONTROLLED NUCLEAR FUSION RESEARCH

Washington, DC, United States of America, 1 - 6 October 1990
ROLE OF ITER IN TECHNOLOGY DEMONSTRATION

Two elements of ITER

1) Basic Machine

Conservative design of the machine components (including basic blanket) maximizes reliability, flexibility and safety of ITER

2) Test Programme

Space for test modules allows for testing of advanced concepts and partial (powerful) demonstration of the ultimate potential of fusion
Examples of "Accomplishments" Through Testing in ITER

- Performance Attractiveness
  - Demonstrate ability to operate with parameters adequate for electricity generation
  - Demonstrate operation of the entire fuel cycle
  - Demonstrate temperature limits of materials
  - Obtain data crucial to tritium self-sufficiency

- Safety Demonstration
  - Inherent safety
  - Response to transients and off-normal operating modes
  - Operating experience with tritium, radioactive materials, hazardous chemicals (e.g., liquid metals, Be)

- Environmental Demonstration
  - Direct measurement of induced radioactivity, after heat
  - Demonstration of low activation options (e.g., Li/V, Li2O/SiC, etc.)

- Others
## Nuclear Testing Requirements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Recommendations</th>
<th>ITER Reference Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutron Wall Load (MW/m²)</td>
<td>≥ 1, ≥ 2</td>
<td>1.3</td>
</tr>
<tr>
<td>Plasma Burn Time</td>
<td>≥ 1000 s, 1-3 hours to steady state</td>
<td>2500 s</td>
</tr>
<tr>
<td>Dwell Time</td>
<td>a, &lt; 20 s, 200 - 400 s</td>
<td>200 - 400 s</td>
</tr>
<tr>
<td>Continuous Test Duration (100% availability)</td>
<td>&gt; 1 week, 2 weeks</td>
<td></td>
</tr>
<tr>
<td>Average Availability</td>
<td>10 - 15%, 25 - 30%</td>
<td>18%</td>
</tr>
<tr>
<td>Total Neutron Fluence (MW·y/m²)</td>
<td>1.5, 4 - 6</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Most Critical Nuclear Issues for Testing in the Fusion Environment Have Two Characteristics:

1) Processes with long time constants
2) Crucial dependence on other processes with short time constants
   (It takes a long time to establish equilibrium; a short time to ruin it)
VARIATION OF TEMPERATURE WITH TIME FOR DIFFERENT DWELL TIMES
(LIALO2 BREEDER)

temperature (k)

95%---------

1400

1300

1200

1100

1000

900

800

700

600

0  100  200  300  400  500  600
time (s)

dwell (s)

burn = 200 s
ramp = 0 s
FLUENCE EFFECTS

- **0-0.1 MW-yr/m²** (at test module)

  Some changes in thermophysical properties of non-metals occur below 0.1 MW-yr/m² (e.g., thermal conductivity)

- **0.1-1 MW-yr/m²** (at test module)

  Several important effects become activated in the range of 0.1-1 MW-yr/m²
  - Radiation creep relaxation
  - Solid breeder sintering and cracking
  - Possible onset of breeder/multiplier swelling
  - He embrittlement

  Correlation of materials data with fission reactors and 14 MeV sources can be done with 1 MW-yr/m²

- **1-3 MW-yr/m²** (at test module)

  Numerous individual effects and component (element) interactions occur here, particularly for metals, e.g.:
  - Changes in DBTT
  - Changes in fracture toughness
  - He embrittlement
  - Breeder burnup effects
  - Breeder swelling
  - Breeder/clad interactions

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Credible concept verification requires attainment of fluence within a factor of 2-3 of DEMO
ITER Test Program Description

Physics Phase: 6 years

- Machine checkout
- Physics testing
- Some technology testing

Technology Phase: 8 years

- Technology testing
  - Test modules
  - Information from basic device

Space Available for Testing

- Physics phase: 3 ports
- Technology phase: 5 ports

Each port is 1m x 3m at first wall
INTERNATIONAL ASPECTS OF ITER TEST PROGRAM

- There is neither sufficient space nor time to serve the needs of four independent national programs

- International collaboration is necessary

- A scheme has been developed for sharing space and time on ITER among the four parties

- Such collaboration involves issues that extend beyond collaboration on construction of ITER

  - It involves the world Base Programme

  - This is an additional benefit from ITER as it encourages collaboration on Base Programme
Fig 2.5-1 Test Sequence for Liquid Metal Blankets

Liquid Metal Cooled Tests

2 Years

<table>
<thead>
<tr>
<th>Li (US Lead)</th>
<th>LiPb (EC Lead)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Li (SU Lead)</td>
<td>Basic Tests or LiPb (J Lead)</td>
</tr>
</tbody>
</table>

Separate First wall

1 Year

<table>
<thead>
<tr>
<th>Li</th>
<th>LiPb</th>
</tr>
</thead>
</table>

First Wall Exposed to Plasma

4 Years

<table>
<thead>
<tr>
<th>Li or LiPb Alternating</th>
</tr>
</thead>
</table>

First Wall Exposed to Plasma

1 Year

<table>
<thead>
<tr>
<th>Li or LiPb Full Segment</th>
</tr>
</thead>
</table>

First Wall Exposed to Plasma

Water Cooled Tests

2 Years

<table>
<thead>
<tr>
<th>LiPb (EC Lead)</th>
<th>LiPb (SU Lead)</th>
</tr>
</thead>
</table>

Separate First wall

5 Years

<table>
<thead>
<tr>
<th>LiPb Common Design</th>
</tr>
</thead>
</table>

First Wall Exposed to Plasma

1 Year

<table>
<thead>
<tr>
<th>LiPb Full Segment</th>
</tr>
</thead>
</table>

First Wall Exposed to Plasma
### Fig. 2.3.-1 Blanket Test Schedule

<table>
<thead>
<tr>
<th>Port</th>
<th>Physics Phase</th>
<th>Technology Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM Port 1 (#13)</td>
<td>System Check-out / LM-MHD Tests / Water-cooled LM MHD &amp; MHD/TH Tests</td>
<td>Liquid Metal Cooled Designs</td>
</tr>
<tr>
<td></td>
<td>Neutronics Tests</td>
<td>Screening Tests / Extended Performance / Segment Tests</td>
</tr>
<tr>
<td></td>
<td>Plasma Facing Materials Tests</td>
<td></td>
</tr>
<tr>
<td>Materials Port (#10)</td>
<td>System Check-out / Environment Characterization</td>
<td></td>
</tr>
<tr>
<td>SB Port 1 (#8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
</tr>
<tr>
<td>SB Port 2 (#9)</td>
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<td></td>
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</tbody>
</table>
Fig. II.6.37  Testing Schedule for Helium- and Water-Cooled Solid Breeder Blankets
Fig. II.6.39 Examples of Test Module Design
(Ancillary Equipment)
Space allocation during the Technology Phase

Ancillary Room 2
Material Tests (340 m²)
Water-Cooled Solid Breeders (450 m²)
PFC and other tests

Ancillary Room 1
He-Cooled Solid Breeders (700 m²)
Liquid Metals (300 m²)

Tritium Processing Room
space reserved for the test program

SB/H₂O Materials

SB,MAT
SB,PFC

1 2 3 4 5 6 7 8 9 10 11 12 13