Blanket Issues and Near Term R&D Needs and the Role of ITER in Blanket Development

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Blanket Issues and Near Term R&D Needs and the Role of ITER in Blanket Development

Presentation Outline

• General Framework for Blanket Development

• Issues for Commercial Blankets

• ITER Blanket Concepts, Issues

• Blanket Testing in ITER

• R&D Needs for Next 15 Years

• R&D Needs for Next 3 Years
Framework for Fusion Nuclear Technology Development
Primary Options
For Blanket Materials and Configurations
For Commercial Reactors

LIQUID BREEDER

Breeder

Coolant

Structural materials

Multiplier

Design configurations

Li

Li, He

Li, He

none, beryllium

Radial flow

Poloidal flow

Poloidal/toroidal flow

Helical flow

LiPb

LiPb, He, H₂O

LiPb, He

Flibe

Flibe, He

Ferritic steels

Refractory alloys

Ferritic steels

Austenitic steels

Li₂O

Li₂O

He, H₂O

He, H₂O

Ternary ceramics

beryllium

Pin, Plate, Block Breeder/Multiplier

Sintered Pellet or Sphere-pac

Radial, Poloidal, or Toroidal Cooling
Helium-Cooled Solid Breeder Blanket Design
Specific Blanket Issues

• Key issues were evaluated and documented in terms of:
  - Issues description
  - Status of data base
  - Required data
  - Required resources
The issues have not changed and have not been resolved. PACE of World Blanket R&D Programs is Very Slow

• The most important structural material R&D issues are welding/fabrication and radiation induced embrittlement concerns for both ferritic steels and vanadium alloys. Chemical reactivity of vanadium is also an important issue.

• Major issues for liquid metal blankets include MHD and corrosion concerns. MHD research should include the testing of insulators. Lithium (and to some extent LiPb) chemical reactivity is a key issue. Development of non-water cooled near-plasma components will be necessary, particularly for blankets that contain lithium.

• Tritium recovery/control is a major issue for all designs except those using liquid lithium as a breeder and coolant. The form of the released tritium (T₂/HT or T₂O/HTO) and the chemical form of tritium in various fluid streams are important issues for tritium control for solid breeders.
Specific Blanket Issues (cont'd.)

- Achieving adequate tritium breeding is a key issue for many designs. In general, it is more severe for solid compared to liquid breeders.

- The key issues for solid breeders (in addition to those discussed above) include the temperature limits for tritium release, heat transfer control between the lithium ceramic and coolant, difficulty of handling power variations and the radiation induced swelling of the ceramic (particularly \( \text{Li}_2\text{O} \)). Initial fabrication of sphere-pac breeder and beryllium and refabrication (recycling) of all forms by remote handling techniques are also areas of concern.

- The most important concern related to first wall issues is the verification of the capability of a stress relief structure (orthogonally grooved first wall) to simultaneously handle heat and particle fluxes.

- Additional items include: thermal, chemical and radiation stability of molten salts; Be reprocessing efficiency; Be chemical interaction with molten salts; activation of LiPb and molten salts; and electromagnetic effects such as large pressures and torques due to plasma disruptions.
ITER Requires Basic Tritium-Producing Blanket

REQUIRED TBR VS. NEUTRON FLUENCE

Required TBR

Fluence, MW*year/m**2

Availability
- 5%
- 15%
- 25%

3 years
Blanket Material Options Considered For ITER

Breeder
- Solid Breeder
  - Li Pb
- Li OH
- LiNO₃
- ³He

Coolant
- H₂O, He
- H₂O
- H₂O
- He, H₂O

Structure
- Austenitic Steel
- Austenitic Steel

Multiplier
- Beryllium
- Beryllium
AQUEOUS LITHIUM SALT BLANKET DESIGN FOR ITER
He-Cooled Solid Breeder Blanket Design for ITER
$^3$He Blanket for ITER (USSR)
Observations on Concepts Proposed for ITER
Basic Blanket by All Countries

- No Lithium

- Water-cooled LiPb only Proposed by USSR

- Aqueous Blanket Proposed as an Option by EC, USA
  - Simple design, fabrication
  - Not reactor relevant
  - Has most safety/environmental concerns

- Solid Breeder Blankets Proposed by All Countries
  - Water-cooled: at low temperature
  - Helium -cooled: Most reactor relevant
  Most safety advantages

- The Most Innovative Idea is $^3$He Proposed by USSR, USA

  Primary concern: Helium supply

  $^3$He Burnup: 8-10 kg/yr (25% availability)

  Supply
  1 kg/yr in US market from US
  1 kg/yr in US market from USSR
Present Status of Blanket Design Option Selection

• Many Options Have Been Proposed for Commercial Reactors
  - All have problems
  - Require extensive R&D

• New Ideas for Substantially Different Concepts are Still Being Proposed
  e.g., - MHD generators
         - Solid-state conversion of radiation
         - Helium/ceramic particulates

• Options for ITER
  - Some reactor relevant: can benefit from present R&D
  - Some not reactor relevant require new specific R&D

<table>
<thead>
<tr>
<th>Many Proposed Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need Extensive R&amp;D, New Facilities</td>
</tr>
<tr>
<td>Present World Funding is Not Sufficient</td>
</tr>
</tbody>
</table>
Suggested Strategy
For the Many Blanket Options

• Maintain Strong Core R&D Program for Liquid Metal and Solid Breeder Blankets
  - Objective: Provide data base necessary to construct, operate test modules, sectors in ITER
  - Attempt to narrow options whenever possible
  - Should stabilize, protect from near-term device frequent change in focus

• Pursue ITER Specific R&D Program
  - Minimize by selecting reactor-relevant options
  - The list will change from year to year

• Encourage Small but Significant Amount of Research on New Innovative Ideas. Need Improvements in:
  - Economics potential
  - Inherent safety
  - Environmental impact
Testing in ITER

 ITER will be the First Opportunity for Fusion Testing

 Successful Nuclear Testing in ITER Requires

 1. Extensive R&D in non-fusion facilities prior to ITER because:
    - ITER testing is expensive and time-limited
    - Need a reasonable level of confidence in test modules prior to insertion in ITER to assure reasonable ITER availability

 2. ITER design has certain performance parameters and features to achieve the desired goal (provide definitive data for the DEMO)
    - Wall load (> 1 MW/m²)
    - Neutron fluence (> 3 MW·y/m²)
    - Steady state
    - Ease of replacement/maintenance
Overall ITER Availability Depends on:
- Availability for Basic Device Components
- Availability for Test Program Elements

Successful Testing in ITER Requires Extensive Testing in Non—Fusion Facilities Prior to ITER
Many Blanket Tests in ITER Require Continuous Operation (weeks at 100% availability)

This requires that the overall test program has high reliability, long mean time between failures.

![Graph showing reliability over mean time between failures for different operation times: 1 Day Continuous Run, 1 Week, 2 Weeks.](image)
TEST SCENARIO FOR BLANKET TESTING AND SELECTION
SPACE-Time Utilization Logic for ITER Tests
Some Conclusions on Blanket Testing in ITER
(Based on USA Study)

- In addition to blanket submodule and module tests, some SECTOR Tests will be necessary for
  - Verification of tritium self-sufficiency (e.g., solid breeders)
  - Blanket concepts whose unit size is large (e.g., some self-cooled liquid metals)

- Water Cooling of the Basic Machine (blanket and/or divertor) Hampers Testing of Hot Surfaces and Lithium Blanket

- Safety Guidelines
  - Limit lithium volume to ~1 m³
  - Double-wall test module except at first wall
  - For large volume lithium, double wall at the first wall is also necessary
### TYPES OF EXPERIMENTS AND FACILITIES FOR LIQUID METAL BLANKETS

<table>
<thead>
<tr>
<th>Issues</th>
<th>Basic Properties</th>
<th>Separate Effects</th>
<th>Multiple Interactions</th>
<th>Integrated</th>
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<tbody>
<tr>
<td>Tritium Self-sufficiency</td>
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<tr>
<td>MHD Effects</td>
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<td>Material Interactions</td>
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<td>Structural Response</td>
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<tr>
<td>Tritium Recovery and Control</td>
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**Level of Integration**

- Cross-Section Data
- Blanket Neutronics Facility
- MHD Fluid Flow
- MHD Heat Transfer
- MHD Mass Transfer
- Thermo-Mechanics Integrated Facility
- Partially Integrated Test Facility
- Fusion Test Facility

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3 Some experiments or facilities already exist

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**Note:** Neutron test.
TYPES OF EXPERIMENTS AND FACILITIES FOR SOLID BREEDER BLANKETS

<table>
<thead>
<tr>
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<td>Response</td>
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<td>Tritium</td>
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<td>Adsorber, Catalyst Characterization</td>
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<td>Oxidation Kinetics Loop</td>
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<tr>
<td>Neutron Test</td>
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</table>

Some Experiments and Facilities Exist
SOLID BREEDER BLANKET TEST PLAN

MAJOR TASKS

Breeder Characterization and Development
- Fabrication/properties
  - Closed Capsule
  - Open Capsule

Multiplier Characterization and Development
- Fabrication/properties
  - Closed Capsule
  - (Discrete Multiplier)

Blanket Thermal Behavior
- Breeder Thermal Behavior
  - (Sub)module Thermomechanics

Advanced In-Situ Tritium Recovery
- Open Capsules Subassembly 1

Neutronics and Tritium Breeding
- Simple Geometry
  - Engineering Mockup

Nuclear Submodules
- Submodule 1
  - Submodule 2

(Structural Response)
- Material Irradiation

(Tritium Permeation and Processing)
- Permeation Rate Measurement
- Material Characterization

LEGEND
- Initiate Task
- Terminate Task
- Evaluation Point
- Operate Major Experiment
- Terminate Major Experiment
- Information Flow - Optional

Fusion Experimental Module
Major Tasks for Liquid Breeder Blankets
(Next 15 years)

• MHD Effects
  - Momentum and heat transfer facilities (LMF1, LMF2)
  - Instrumentation development
  - Insulator development

• Material Compatibility
  - Corrosion loops (including bimetallic loop)
  - MHD mass transfer facility (MHDM)

• Tritium Recovery and Control
  - Tritium extraction tests
  - Tritium transport loop

• Tritium Breeding

• Structural Response and Failure Modes

• Thermomechanics Integration Facility (TMIF)

• Analysis and Model Development
Major Tasks for Solid Breeder Blankets
(Next 15 years)

• SB Material Development and Characterization
  - Tritium retention and release
  - Thermophysical and thermomechanical properties
  - Fabrication and recycling techniques

• Multiplier Material Development and Characterization
  - Swelling in beryllium
  - Tritium retention and release
  - Irradiation creep and mechanical properties
  - Breeder/multiplier compatibility

• Blanket Thermal Behavior
  - Corrosion, mass transfer and chemical interaction kinetics
  - Breeder/multiplier temperature profile and thermo-mechanical effects of breeder/cladding interaction
  - Non-neutron blanket (sub)module thermomechanics

• Neutronics and Tritium Breeding
  - Simple geometry mockups
  - Engineering mockups

• Advanced In-Situ Tritium Recovery
  - Two or more instrumented and purged assemblies with multiple capsules

• Nuclear submodule experiments
  - Two or more nuclear submodule assemblies
NEAR-TERM INITIATIVES
(Next 3 Years)

Note
- Agreed upon in the U.S. Fusion Technology Community
- Assumes International Cooperation
Examples of Major Near-Term Needs
(Next ~3 Yrs)

1. Liquid Metal Flow Facility (LMF1)

Facility with capabilities for experiments on MHD fluid flow, heat transfer and pressure drop in relevant geometry

2. Advanced Solid Breeder Tritium Recovery Experiment

Experiments in fission reactor to study (in-situ) tritium recovery with local reactor-relevant conditions

3. Engineering Tritium Breeding Experiments

Extend the capabilities of tritium breeding experiments to include more prototypical neutron source and test section geometry and materials

4. Blanket Tritium Processing

Part of simulation of the full tritium fuel cycle

5. New/Innovative Ideas

Initiate small but significant effort to stimulate and evaluate new innovative design ideas to improve economics, safety and environmental impact potential
Objectives of LMF1


- Measure velocity, pressure, temperature, and electric potential distributions

- Develop and test instrumentation (in NaK environment)

- **Validate** MHD flow, pressure, and heat transfer predictive capability for:
  - Segments of blanket modules
  - Sections of divertor/limiter

- Obtain **design data** for segments of blanket modules and high heat flux components

- Explore techniques to reduce pressure drop and enhance heat transfer
## Characteristics of Required Major Liquid Breeder Experiments

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Existing (e.g., ALEX)</th>
<th>Needed</th>
<th>Needed</th>
<th>Needed</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>LMF(^a)</td>
<td>MHDM(^b)</td>
<td>TMIF(^c)</td>
</tr>
<tr>
<td>Fluid</td>
<td>NaK (100°C)</td>
<td>NaK</td>
<td>actual materials</td>
<td>actual materials</td>
</tr>
<tr>
<td>Testing volume</td>
<td>0.2 m(^3)</td>
<td>1-5 m(^3)</td>
<td></td>
<td>1-5 m(^3)</td>
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<tr>
<td>Magnetic field</td>
<td>2 T</td>
<td>4-6 T</td>
<td></td>
<td>4-6 T</td>
</tr>
<tr>
<td>Configuration</td>
<td>simple geometry</td>
<td>elements of complex geometry</td>
<td>submodule/prototypic</td>
<td></td>
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</tbody>
</table>

\(^a\)Liquid Metal Flow Facility  
\(^b\)MHD Mass Transfer Facility  
\(^c\)ThermoMechanical Integration Facility
# LMF Facility Parameters

## Loop Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Working Fluid</td>
<td>NaK Eutectic</td>
</tr>
<tr>
<td>Inventory of Working Fluid</td>
<td>700 liters</td>
</tr>
<tr>
<td>Loop Materials</td>
<td>Predominantly 300 Series S/S</td>
</tr>
<tr>
<td>Volumetric Flow Rate Through Test Articles</td>
<td>1-25 liters/s</td>
</tr>
<tr>
<td>Pump Outlet Pressure</td>
<td>1 MPA</td>
</tr>
<tr>
<td>Pump Outlet Temperature</td>
<td>≤ 100°C</td>
</tr>
<tr>
<td>Test Article Conditioning Temperature (at low pressure and flow rate)</td>
<td>300°C</td>
</tr>
<tr>
<td>Overall Length of Test Article (between flanges for test section replacement)</td>
<td>~10 m</td>
</tr>
<tr>
<td>Cost (excluding cost of test articles)</td>
<td>$1 M</td>
</tr>
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</table>

## Magnet Parameters

<table>
<thead>
<tr>
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<th>Value</th>
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<tbody>
<tr>
<td>Peak Field</td>
<td>5 T</td>
</tr>
<tr>
<td>Warm Bore</td>
<td>1.2 m</td>
</tr>
<tr>
<td>Uniform Field volume</td>
<td>1 m x 0.3 m x 3 m</td>
</tr>
<tr>
<td>Field Uniformity</td>
<td>± 5%</td>
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<tr>
<td>Magnet Cost</td>
<td>$15 M</td>
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</table>
Example of a test section simulating the BCSS liquid-metal-cooled blanket design. Measurements of velocity and temperature profiles.
Advanced In-Situ Tritium Recovery
Experiments for Solid Breeders

Facilities: Fission Reactors
Fast, Thermal: USA, EC, Japan

Objective:

• Data to Support Selection of Solid Breeder Blanket for ITER

• Study Tritium Recovery with Local Reactor-Relevant Conditions
  - Moderate to high burnup
  - Temperature gradient
  - Purge flow
  - Breeder/clad mechanical and chemical interactions

• Data on Tritium Extraction/Processing Interface

Experiments:

• Key Combinations of Solid Breeder Materials and Neutron Multipliers

• Representative Geometries
## Parameters for Near-Term Solid Breeder Experiments in Fission Reactors

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Advanced In-Situ Tritium Recovery</th>
<th>Nuclear Submodule</th>
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<tbody>
<tr>
<td>Test geometry</td>
<td>Subassembly with multiple capsules</td>
<td>Blanket breeder section or unit cell</td>
</tr>
<tr>
<td>Material</td>
<td>Multiple</td>
<td>One per submodule</td>
</tr>
<tr>
<td>Temperature</td>
<td>350-1200°C</td>
<td>Reactor blanket profile</td>
</tr>
<tr>
<td>Temperature gradients, °C/cm</td>
<td>100-1000</td>
<td>100-1000</td>
</tr>
<tr>
<td>Breeder thickness, cm</td>
<td>0.5-5</td>
<td>0.5-5</td>
</tr>
<tr>
<td>Purge gas</td>
<td>Helium, plus O₂, H₂ and/or H₂O</td>
<td>Helium, plus O₂, H₂ and/or H₂O</td>
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<tr>
<td>Purge flow rate, m³/s-gᵃ</td>
<td>0.01-0.1</td>
<td>0.01-0.1</td>
</tr>
<tr>
<td>Burnup, at.% Li</td>
<td>3-10</td>
<td>3-10</td>
</tr>
<tr>
<td>Heat generation, MW/m³</td>
<td>30-100</td>
<td>30-100</td>
</tr>
<tr>
<td>Irradiation time, yrs</td>
<td>1-3</td>
<td>1-3</td>
</tr>
</tbody>
</table>

ᵃNormalized per gram of solid breeder material
NUCLEAR SUBMODULE

SECTION A-A
HELIUM COOLANT DOWNCOMER
103 mm ID TUBE
1 mm GAP BETWEEN PLATES
11 mm Li$_2$O PELLET INSIDE .25 mm CLAD
RECTANGULAR FLOWTUBE

Sweep Gas Inlet
Sweep Gas Outlet
Sweep Gas Connection
Lithium Oxide Blocks with Sweep Flow Channels
Crush Washer
Plate Cladding

DETAIL OF SWEEP GAS FLOW SYSTEM
EXPERIMENTAL SYSTEM FOR PHASE-2 OF US/JAERI PROGRAM ON BLANKET NEUTRONICS

SCHEMATIC OF REACTOR MODEL
ADVANCED LINE SOURCE FOR TRITIUM BREEDING EXPERIMENTS

TARGET ASSEMBLY

ANNULAR TEST MODULES

DETECTOR

PEDESTAL

DRIVE CONTROL

MOVABLE CARRIAGE

POSITION SENSING DEVICE

RAILS

DIRECTION OF MOTION
Examples of ITER-Specific Near-Term Blanket R&D

**Beryllium Technology**

- Irradiation effects on swelling and mechanical integrity

- Reduce uncertainties in \((n,2n)\) multiplication and secondary neutron energy/angular distributions

- Compatibility with solid breeder materials under irradiation

- Compatibility with stainless steel under irradiation

- Thermomechanical performance of beryllium for gap conductance

**Solid Breeders**

- Purge gas flow heat transfer, pressure drop in sphere-packed beds

- Thermal gap conduction experiments

- (Add tritium release tasks to BEATRIX and other programs)

- Tritium release models

- \(H_2O\)/solid breeder safety
ITER Specific Blanket R&D (cont'd.)

Neutronics/Shielding
- Be (n,2n) integral experiments and sensitivity analysis
- Nuclear heating (kerma factor) measurements in integral experiments
- Radioactivity, decay heat measurements
- Streaming/shielding experiments
- Improve radioactivity libraries and codes

Aqueous Blanket
- Radiolysis
- Stress corrosion of austenitic steels
- Tritium recovery
- Chemistry control

LiPb Blanket
- Corrosion
- LM MHD (for test modules)
- Reactions with H₂O and air
- Tritium recovery and permeation barriers

³He Blanket
- Helium leakage
- Tritium inventory in structure
Concluding Remarks

- Present Status for FNT:
  - We now understand the technical issues
  - Technical R&D plans to resolve the issues exist

- Some Progress has been Made over the Past Several Years
  But the Present Pace is Too SLOW
  - Almost all issues identified 5 years ago remain the same
  - Only a modest part of R&D identified earlier has been carried out

- Timely Development of FNT will Require Faster Pace, More Resources
  - Need new facilities with adequate capabilities
  - Enhance modelling activities

- Both Liquid Metal and Solid Breeder Blankets Must be Pursued
  - They both have serious issues
    Feasible? Attractive?
  - Definitive selection does not appear possible prior to testing in a fusion facility (ITER)
Concluding Remarks (cont'd.)

• R&D in Non-Fusion Facilities (neutron sources, liquid metal test stands, fission reactors, etc.) has Two Goals
  1) To construct and operate test modules in ITER (LM & SB)
  2) Data for basic ITER blanket (specific type)
Carrying out #2 should not be at the expense of #1

• There are many Benefits for Selecting the ITER Basic Blanket to be Reactor Relevant

• Serious Concerns About the Attractiveness of our Present Concepts for Fusion Reactors Persist

Need some effort to enhance potential:
  Economic
  Safety
  Environmental Impact

1. Plasma
   (high β, steady state, disruption free, etc.)

2. Plasma Technology
   (high field magnets, current drive, plasma interactive components)

3. Nuclear Technology
   Innovative New Ideas
   - to reduce balance of plant
   - inherent safety
   - low long term activation
   - simpler designs
   - etc.
APPENDIX
U.S. Activities on Liquid Metal Blankets

- **Experiments**
  - MHD Momentum Transfer
    ALEX Facility at ANL
  - MHD Heat Transfer
    None (plans exist)
  - Corrosion/Compatibility
    • Loops at ANL, ORNL
    • No MHD work yet
  - Electromagnetics
    FELIX Facility at ANL (stand-by)

- **Modelling**
  (Analytical, Numerical, Computational)

  UCLA
  ANL
  U. of Illinois
U.S. Activities on Solid Breeder Blankets

- Mostly in Collaboration with Other Countries

- Fabrication and Material Characterization
  ANL, Hanford

- Irradiation Experiments (Hanford, ANL)

  BEATRIX - Exchange of materials and shared
  irradiation testing: Belgium, Canada,
  England, France, West Germany, Italy,
  Japan and Netherlands

  1) Closed capsule tests to evaluate lifetime

  2) Open capsule tests to evaluate purge flow
     tritium recovery

- Modelling (ANL, UCLA)

  - Tritium Transport, Inventory

  - Thermonuclear Behavior
U.S. Neutronics Activities

• Almost All Activities are Part of International Agreements

• Main Program: U.S.-Japan
  - Facility: FNS at JAERI
  - U.S. organizations: UCLA, ANL, ORNL, LANL
  - Objectives:
    1) Validation of methods, data for tritium breeding, nuclear heating, induced radioactivity
    2) Screen candidate materials and configurations
    3) Develop neutronics technology for next device (ITER)

• Modest Effort on Data, Method Improvement

• Observations
  - Fission program decline reduces resources
  - Japan and EC programs are increasing
### Features and Objectives of Major Liquid Breeder Experiments

<table>
<thead>
<tr>
<th>Features of Experiments</th>
<th>ALEX</th>
<th>Magnetic Transport Phenomena Facilities</th>
<th>TMIF</th>
<th>PITF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>LMF</td>
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<td>MHDM</td>
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<tr>
<td>Simple Geometry of a channel</td>
<td>• Basic elements of relevant geometry</td>
<td>• Basic elements of relevant geometry</td>
<td>• Actual materials and geometry</td>
<td>• Prototypic blanket module</td>
</tr>
<tr>
<td>NaK</td>
<td>• Relevant material combinations</td>
<td>• Relevant material combinations</td>
<td>• Transport loop</td>
<td>• Transport loop</td>
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<td></td>
<td>• Transport loop</td>
<td>• Transport loop</td>
<td>• Relevant environmental and operating conditions</td>
<td>• Prototypic environmental and operating conditions</td>
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<tr>
<td></td>
<td>• Relevant T, ΔT, impurities, V</td>
<td>• Relevant T, ΔT, impurities, V</td>
<td>• Measure dissolution and deposition rates</td>
<td>• Measure integral quantities</td>
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<tr>
<td></td>
<td>• Long operating time per experiment</td>
<td>• Long operating time per experiment</td>
<td>• Measure integral quantities</td>
<td>• Measure integral quantities</td>
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<tr>
<td>Measure velocity profile, electric potential, pressure drop</td>
<td>• Measure V and T profiles; pressure drop, temperature, electric potential</td>
<td>• Measure dissolution and deposition rates</td>
<td>• Measure integral quantities</td>
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</tr>
<tr>
<td>Develop and test velocity profile instrumentation in NaK environment</td>
<td>• Develop and test instrumentation</td>
<td>• Develop and test instrumentation</td>
<td>• Design data for blanket test module</td>
<td>• Engineering design data</td>
</tr>
<tr>
<td>Validate MHD in simple geometry (basic heat transfer data may be possible in upgrade)</td>
<td>• Validate MHD heat transfer</td>
<td>• Validate MHD heat transfer</td>
<td>• Confirm and refine configurations</td>
<td>• Reliability data in non-fusion environment</td>
</tr>
<tr>
<td></td>
<td>• Design data (ΔP, T) for configuration screening</td>
<td>• Design data on MHD heat and mass transfer</td>
<td>• Verify techniques to reduce corrosion and corrosion effects</td>
<td></td>
</tr>
</tbody>
</table>
Motivations for Fusion Nuclear Technology Program

- Resolve Some of the Most Critical Unresolved Feasibility Issues for Fusion

- Substantially Enhance the Potential Competitiveness of Fusion Reactors
  - Economics
  - Safety and Environment

- ITER: Near-Term Fusion Devices That Burn Tritium Will Have New Challenging Nuclear Issues
  e.g., BLANKET to Produce Tritium Radiation Shield for Complex System

- Time Scale for FNT Development is Long