Fusion Technologies

Element	Element Leader
MFE Chamber Technology	M. Abdou
Safety	D. Petti
Tritium	S. Willms
Vacuum Vessel	B. Nelson
Remote Handling	M. Menon

Notes:

1 – IFE Chamber Technology is covered separately by W. Meier

2 – Tritium area plans are covered separately by Siemon /Willms

3 – Formatted budget/plan tables were distributed last week

Presented at DOE Budget Meeting, Germantown, April 4, 2000

Fusion Technologies (Summary)

Mission:

Identify and explore novel chamber technology concepts and develop technologies that: 1) in the near-term enable better capabilities in plasma experiments, and 2) in the long-term improve the economics and safety of fusion energy systems.

Five Year Goals:

- Understand and perform key R&D for evaluating liquid walls
- Operate liquid walls in an experimental physics device (e.g. NSTX)
- Advance novel concepts that can extend the capabilities of solid walls
  - International participation in key areas
- Evaluation and R&D of safety and environmental issues
- Develop tritium, remote handling, and vacuum technologies

Relationship to FESAC Goals:

Essential for MFE Goals 2-4 and IFE Goal 2
- Enable and enhance plasma experiments in the near term
- Innovation to reduce cost and time of fusion R&D path
- Major contributions to economic, safety, and environmental attractiveness of fusion energy systems

Fusion Technologies: Budgets (K$)

	FY 2000	FY 2001		FY 2002	
	(2/00 plan)	*Pres.*	*Increment*	*Baseline*	*Increment*
MFE Chamber	2903	2737	2300	2737	2700
Safety [a]	1560	1578	75	1578	125
Tritium	2300	2168	0	2168	0
Vacuum Vessel	10	0	50	0	50
Remote Handling	190	198	75	198	100
Fusion Technologies *	**6963**	**6681**	**2500**	**6681**	**2975**

* Note: These numbers do not include IFE Chamber Technology (covered by Wayne Meier separately).

a) includes safety for IFE ($331 K for FY 2001).

Safety and Environmental Activities

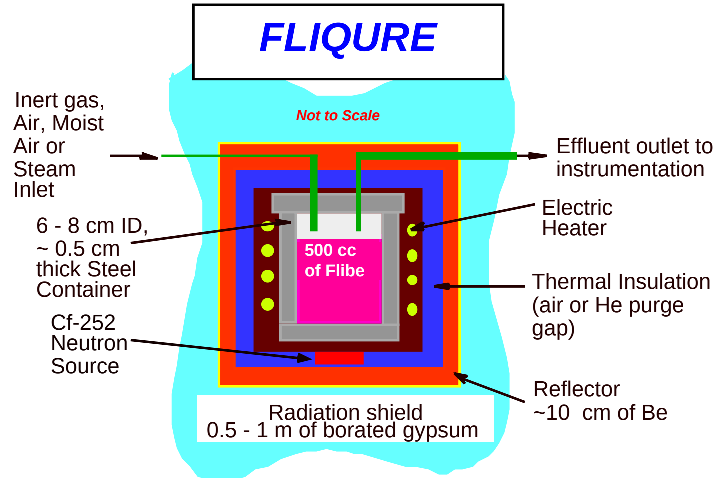
Goal: Characterize and assess the safety and environmental issues associated with magnetic and inertial fusion. Assist the various design teams in improving the safety and environmental attributes of their designs.

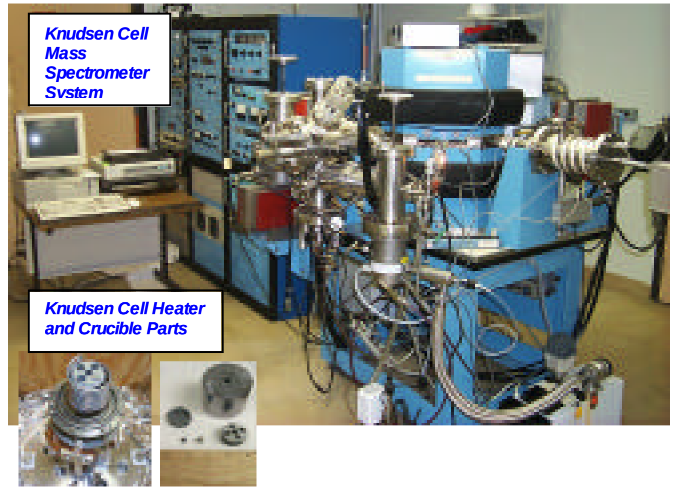
FY-01/02 Activities

- Measure chemical reactivity of LiSn
- Measure vapor pressure and mobilization from unirradiated Flibe
- Measure mobilization from irradiated Flibe in FLIQURE
- Complete measurements of chemical reactivity of LiSn
- Participate in international thermal hydraulic safety experiments benchmarking activity
- Develop waste management criteria for clearance and recycling
- Dust characterization and chemical reactivity
- Provide safety support to ARIES, APEX, IFE and FIRE teams

Supplemental Request

- Dust transport in IFE systems
- Mobilization from irradiated SiC





Remote Handling

Mission

Development of a frequency modulated coherent laser radar (FM CLR) for remote metrology, mapping, inspection, and motion detection of plasma facing surfaces and fusion reactor components

FY – 01 / 02 Activities

- Conduct measurements of PFC structures in NSTX for comparison with baseline measurements during the machine opening
- Conduct range measurements through a laser window
- Design and build an in-vessel compatible FM CLR system for measurement of divertor stripes pattern in LHD (funding from Japan?)
- Characterize the spherical torus component motion during high power operation

Supplemental Funding

- Design and build a universal deployment mechanism for use in different fusion experiments
- Relate PFC motion to J x B forces using TSC modelling

MFE Chamber Technology

Key Programs

- APEX
- Support to ALPS
- Pebble Bed Thermomechanics
- Neutronics
- Sn-Li / Flibe Date Base

Mission

- Identify and explore novel concepts for the Chamber Technology that have high potential to:

    1. In the near-term: enable plasma experiments to more fully achieve their scientific research potential
    2. In the long-term: substantially improve the attractiveness of fusion as an energy source.
    3. Lower the cost and time for R&D

- Advance the underlying engineering sciences, and resolve critical feasibility and attractiveness issues for the Chamber Technology

Chamber Technology

5 – Year Goals

Liquid Walls (LW's)

1. Develop a more fundamental understanding of free surface fluid flow and plasma-liquid interactions
2. Operate flowing LW's in an experimental physics device (e.g. NSTX)
3. Initiate construction of an Integrated Thermofluid Research Facility for MFE/IFE
4. Understand advantages & implications of LW's in fusion systems.

Solid Walls

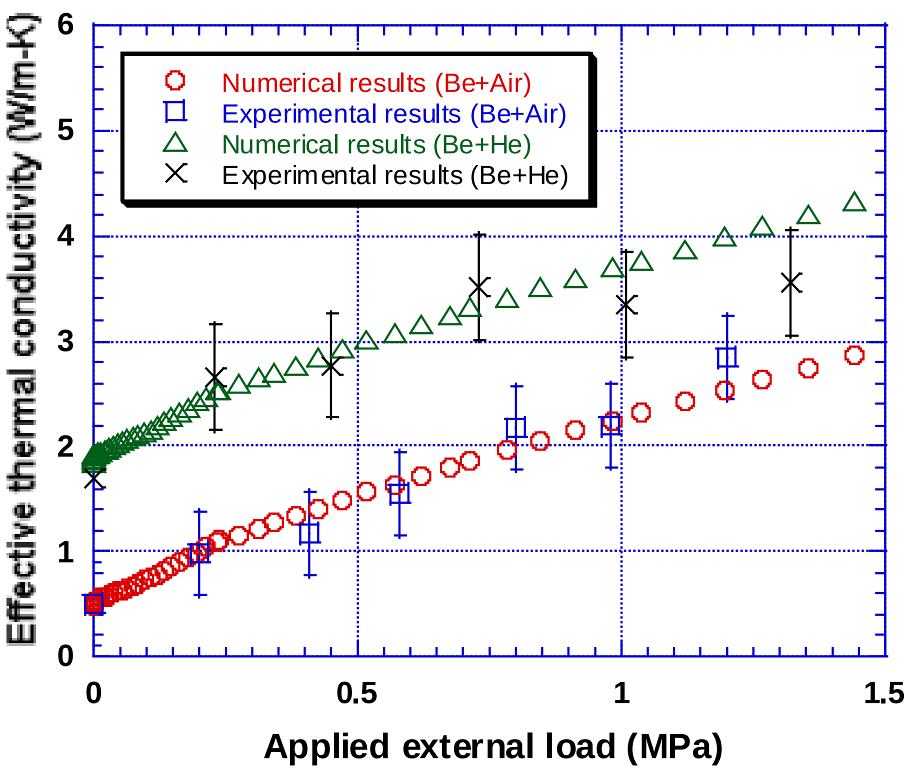
5. Advance novel concepts that can extend the capabilities and attractiveness of solid walls
6. Contribute to international effort on key feasibility issues where US has unique expertise

Pebble Bed Material Systems Thermomechanics and Interactions

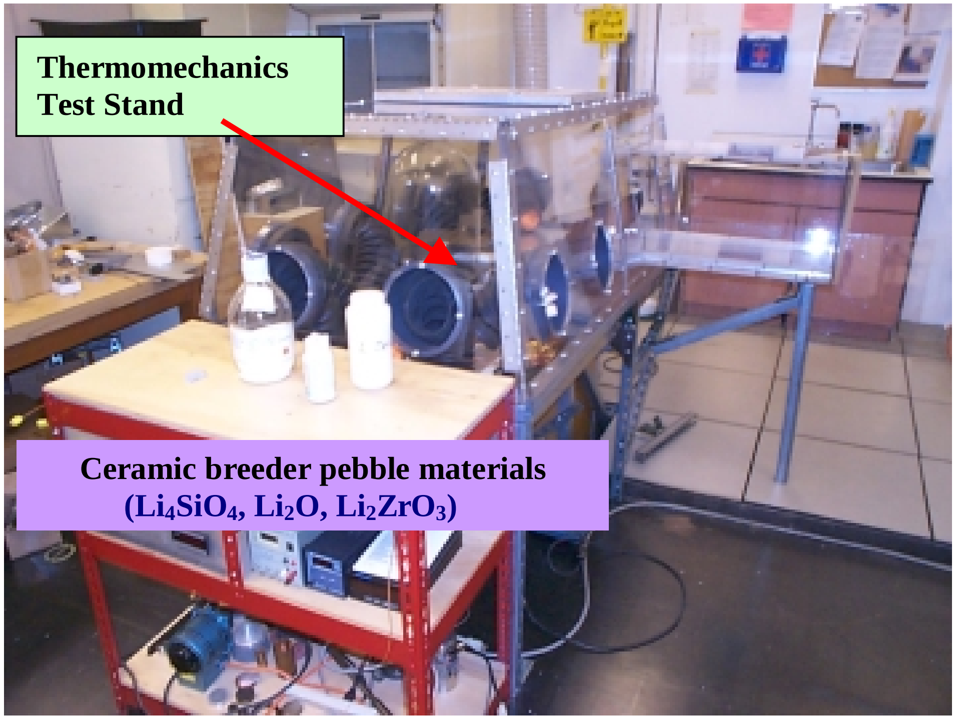
Principal FY1999/2000 Achievements:

Advanced 3-D modelling capabilities and conducted experiments on thermomechanics, deformation, and fundamental properties for pebble bed ceramics and Be

- 3-D Numerical simulation results reproduce the effects of the external loads on the beryllium packed bed thermal conductivity. Effective thermal conductivity increases as a result of an increase in contact area



- Glove box and enclosure facilities approved for large scale Be handling (for thermomechanics experiments)
- Approval underway for Flibe (solid and molten forms) handling



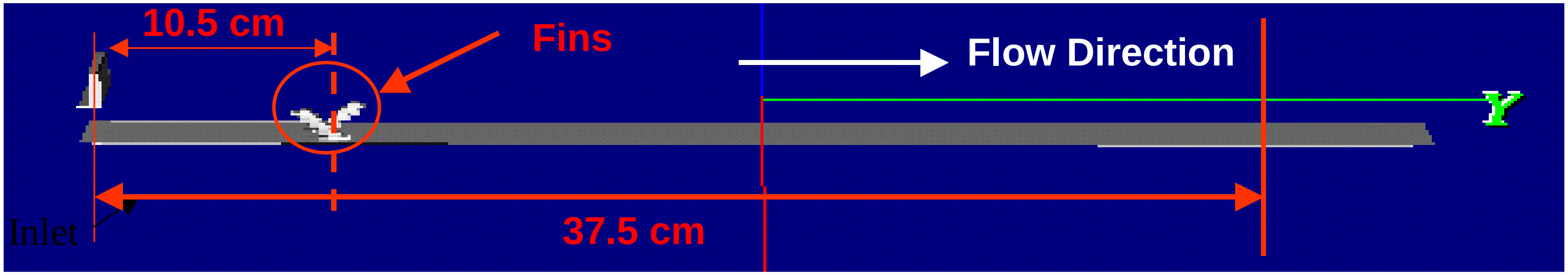
Be handling and thermomechanics test facility

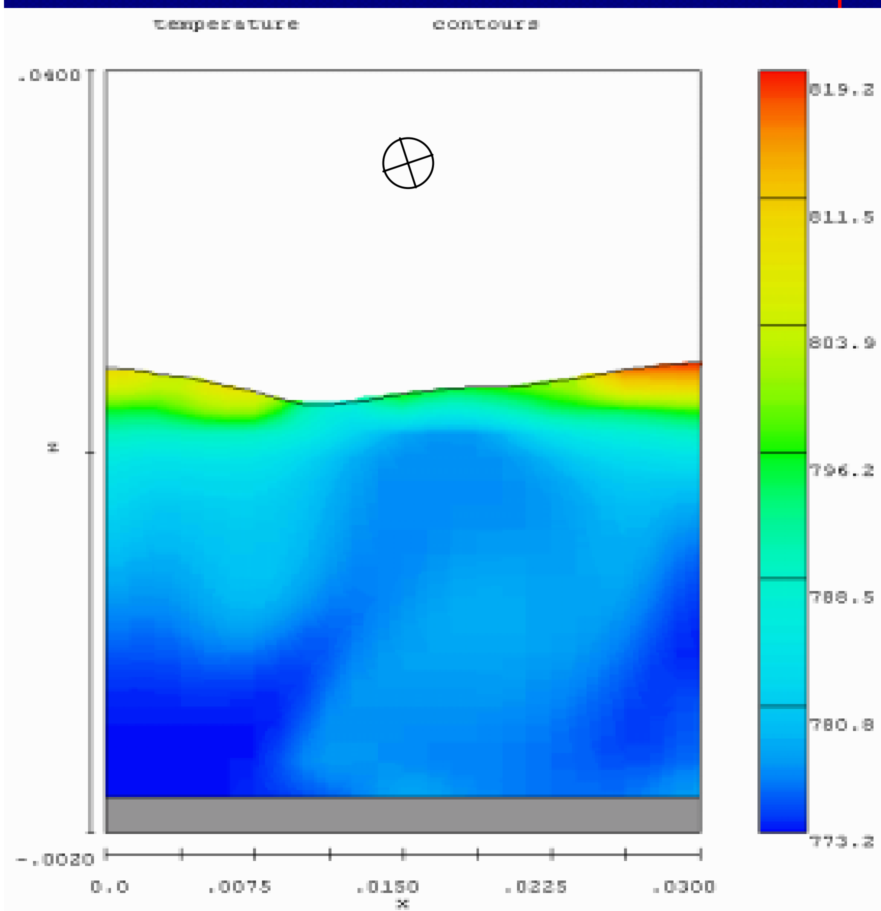
APEX: FY 99 / 00 Achievements (examples)

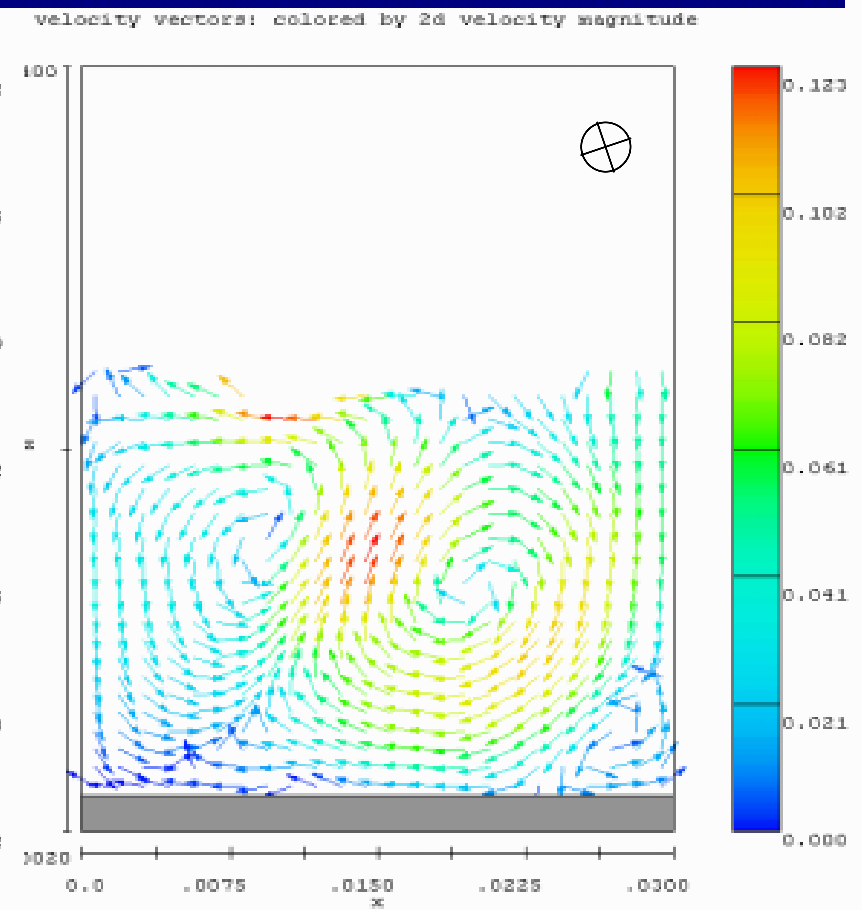
- See APEX website: www.fusion.ucla.edu
- See Interim Report (~ 700 pages)

- Explored, identified, and analyzed promising concepts with high potential for attractiveness
  1. Liquid walls (with many variations: LM, flibe, restraining forces, etc.)
  2. High-temperature refractory alloy with novel 2-phase Li heat removal
- Identified, characterized, and prioritized key issues
- Sophisticated, time-dependent, 3-D, CFD and heat transfer modelling and experiments for free surface fluid flows and turbulence
  - High conductivity, low Pr liquid metals (with MHD)
  - Low conductivity, high Pr molten salts (flibe)
- In collaboration with ALPS, initiated strong modelling activity on plasma edge modelling and plasma-liquid surface interactions
- Explored novel schemes for fluid flow around penetrations and for enhancing free-surface turbulence
- Modelling and computation of LW's – bulk plasma interaction, e.g. MHD stability (PPPL, U. of Texas)
- Initiated joint technology-physics efforts to explore issues of flowing liquid walls in plasma experiments (e.g. NSTX)
- Innovative isothermal evaporation cooling with high-temperature solid wall
- Issued a comprehensive Interim Report that documents analysis and results

3D Numerical Simulations Show Effectiveness of Surface Renewal Mechanism on Decreasing Free Surface Temperature of Flibe



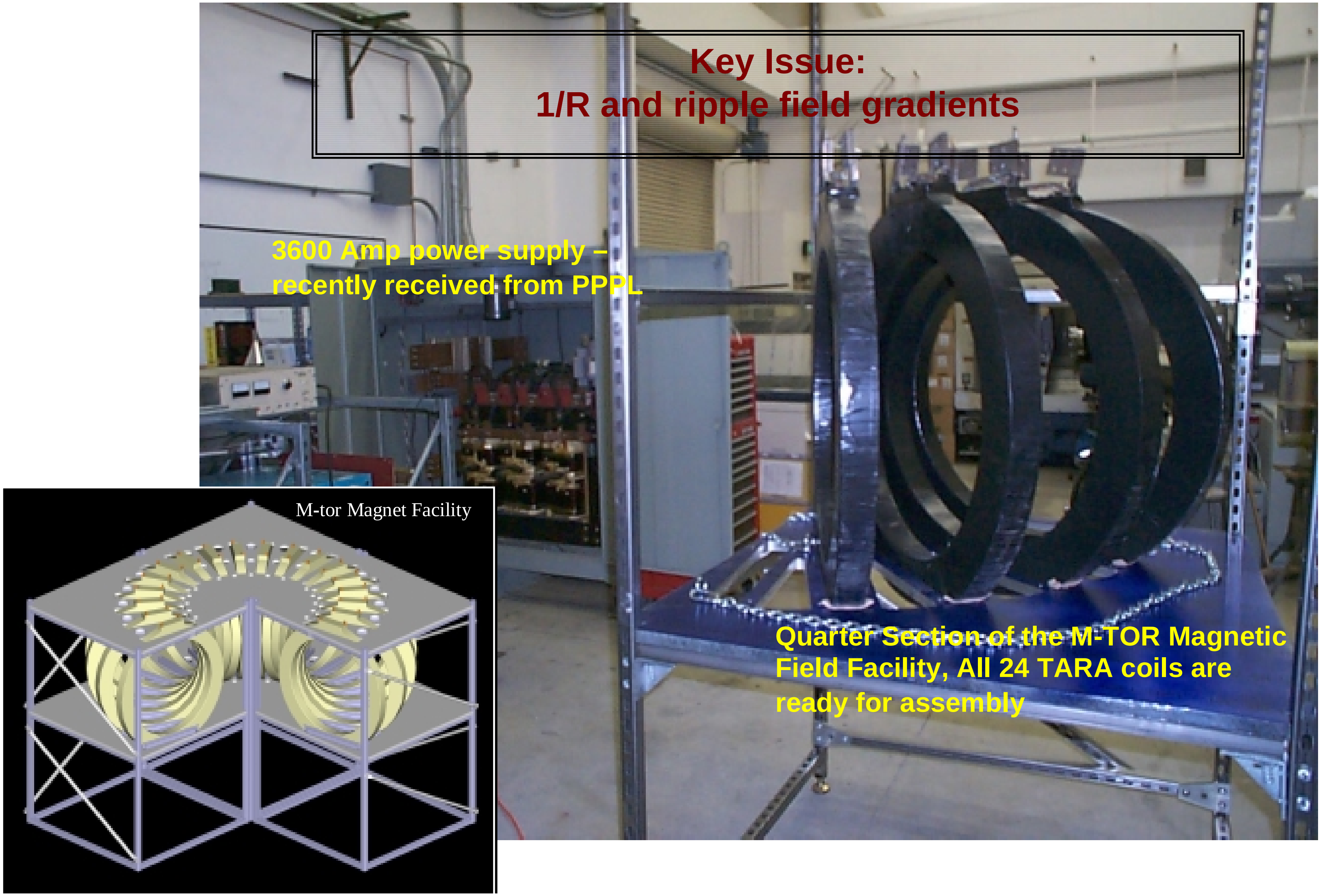




2-D Temperature Distribution 37.5 cm away from inlet

2-D Velocity Magnitude Distribution 37.5 cm away from inlet

LM-MHD free-surface flow experiments in M-TOR facility (tokamak field simulator)



APEX Major Tasks for FY 00/01/02

Task I: Explore options and issues for implementing a flowing liquid wall in a major experimental physics device (NSTX is used as an example). Characterize the technical issues develop an R&D plan, initiate R&D.

(Lead Organizations: UCLA, PPPL, SNL) (Ying)

Task II: Explore high pay-off liquid wall options. Include: a) tokamaks and other confinement schemes, b) flibe and liquid metals (Li, SnLi), c) concepts with physics advantages, and d) concepts with engineering advantages. Include modelling and experiments R&D.

(Lead Organizations: UCLA, PPPL, Univ. of Texas) (Morley)

Task III: Investigate Practical Engineering Issues associated with the design of liquid walls in a high-power density fusion energy system

(Lead Organizations: ANL, SNL, ORNL, UCLA) (Sze/Nelson/Nygren)

Task IV: Investigate Key Issues and develop a practical design for high-temperature, high power density solid wall with primary focus on lithium vaporization scheme, EVOLVE

(Lead Organizations: GA, UW, FZK) (Wong)

APEX Major Tasks for FY 00/01/02 (cont'd)

Cross-Cutting Tasks (support Tasks I-IV)

Task A: Plasma-Liquid Surface Interactions and Plasma-Edge Modelling

(Lead Organizations: LLNL, ANL)

(Rognlien working with ALPS/APEX Edge Modelling Group led by Brooks)

Task B: Liquid-Wall Bulk Plasma Interactions

(Lead Organizations: PPPL, Univ. of Texas) (Kaita)

Task C: Materials

(Lead Organizations: ORNL, UCLA) (Zinkle)

Task D: Safety and Environment

(Lead Organizations: INEEL, UW) (McCarthy)

Incremental Funding

- There are a number of modest requests (~ 5%) for enhancement of efforts in a number of areas. These are described in the VLT formatted Budget Tables

- There are two key initiatives that are very important to the overall fusion program and they involve a number of technical areas and several institutions:

  1. **DOE-Monbusho Initiative**

  2. **Joint Physics-Technology, Joint MFE/IFE, National Initiative for Liquid Walls**

DOE-Monbusho Initiative

Background:

- DOE and the US technology community have been working with the Japanese Universities on a proposal to be submitted to Monbusho.
- The proposed budget is $2M/year (for 6 years) to be provided by Japan to US institutions for research in US facilities. These funds will need to be matched with US funds.
- About 50% (i.e. $1M/yr) will be for research in the US on self-cooled liquid breeders in areas of chemistry, safety, thermofluids, and tritium (the other 50% is for materials). The initial work on liquid breeders will focus on flibe.

Request for Incremental Funding

Request: If the DOE-Monbusho proposal is approved, we suggest that the US matching funds be provided to the respective technical areas/institutions as supplemental funds (rather than be taken out of base budgets)

Funds: ~ $500K in FY 2001, $1M in FY 2002

Rationale: Capitalize on the flow of funds from Japan to enhance research in key technical areas and upgrade facilities that have been seriously under-funded.

National Initiative for Liquid Walls

Purpose:

To realize the 5-year goals that emerged from the “sense” of community leaders at Snowmass

A. Operate Flowing Liquid Walls in a major experimental physics device (e.g. NSTX)

Joint Physics – Technology Initiative

B. Construction of an Integrated Thermofluid Research Facility to simulate flowing liquid walls for both IFE and MFE

Joint IFE/MFE Initiative

Observation:

- These goals have been adopted by the Chamber Technology community. Research efforts toward these goals were initiated in FY 2000.

- However, the resources and efforts are too small to realize the goals.

National Initiative for Liquid Walls (cont'd)

Request

a) Provide adequate incremental funding (beginning with ~ $1M in FY 2001) to perform the necessary modelling, experiments, analysis at an R&D pace adequate to operate flowing liquid walls in a major experimental physics device (using NSTX as an example)

- This will be a multi-institution, physics and technology effort

b) Provide incremental funding (beginning with $200K in FY01) to define, design, and perform the necessary R&D for the integrated Thermofluid IFE/MFE Research Facility

- The effort in FY01 will be a national IFE/MFE group to define goals, objectives, requirements, and major features of the facility

- Efforts in subsequent years are for the national team to design and perform the necessary R&D

National Initiative for Liquid Walls –
Research Example: MHD Effects of LM Walls

A) Enhanced effort in plasma MHD stability modelling with liquid metal walls

B) Establishment of Computational LM-MHD Group to develop models predicting LW behavior in realistic field conditions

- multi-component fields, temporally and spatially varying fields
- complex inlet, wall, penetration and drain geometries
- injected electric currents for active LW control or from plasma halo

C) Enhancement of Experimental LM-MHD Simulation effort with much needed hardware upgrades and personnel.

A, B, and C will work together to better understand and predict the MHD interaction of the coupled tokamak plasma / LM wall system – before introduction into a major experimental plasma device