

UCLA Fusion Technology Program

(Prof. Mohamed A. Abdou)

Briefing to Dean A. Frank Wazzan
June 14, 1990

UCLA Fusion Technology (Prof. Mohamed Abdou)

- Program initiated by Prof. Abdou at UCLA in Fall 1983

Focus

Engineering Core of Fusion Reactors

- Energy Conversion
- Tritium Breeding
- Tritium Transport and Release
- High Heat Flux Components
- Radiation Protection

Technical Disciplines

- Heat Transfer
- Fluid Mechanics
- Materials
- Thermodynamics
- Neutronics
- Structural Mechanics
- Mechanical/Chemical/Nuclear/Materials Engineering

Name: Often called "Fusion Nuclear Technology" (FNT)

UCLA Fusion Technology (Prof. Mohamed Abdou)

- FNT program initiated in Fall 1983 by Prof. Abdou
(Did not exist prior to Abdou's joining UCLA)

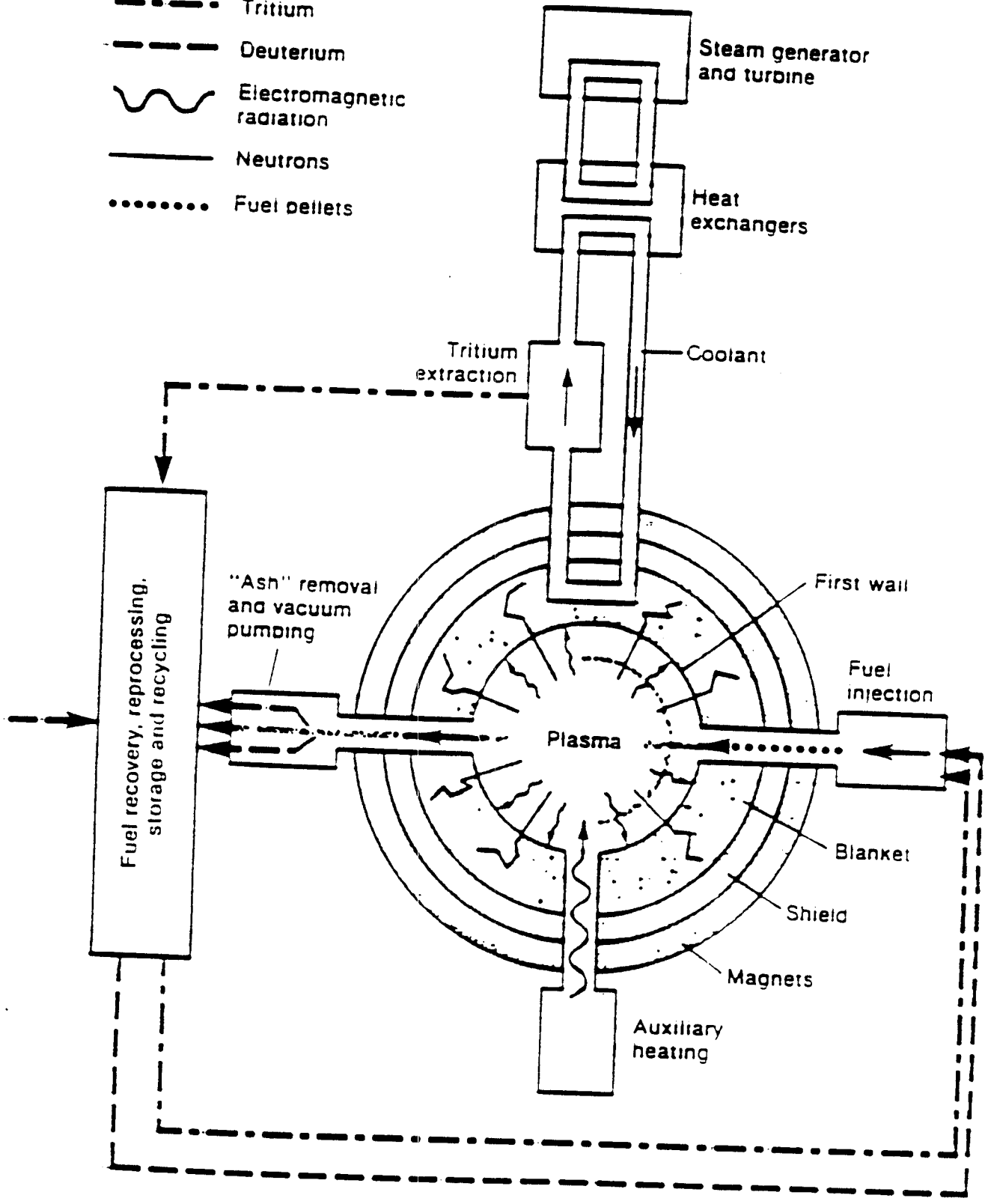
Smooth start was facilitated by the support of (Assoc.)
Dean Wazzan
- **Now:** FNT program at UCLA is Number 1 Worldwide
"Internationally recognized as the **BEST** in any
University in the world"
(quality, quantity, impact, teaching and research)
- **Extramural Research Grants**
1983 - 1990: 11.6 million dollars
1991 - 1992: 3 million dollars
Future: Substantial Growth Potential
- Innovative First Rate Research most suited to
University environment; analytical and experimental
- **Student support**
(1983 - 1990)
Graduate Students: 18
Undergraduate Students: 14

Graduate Students Major: (Fusion, Thermal, Fluid,
Nuclear)
Undergraduate Students Major: (Mechanical,
Aerospace, Electrical, Chemical, others)
- Interaction and collaboration with other **faculty**

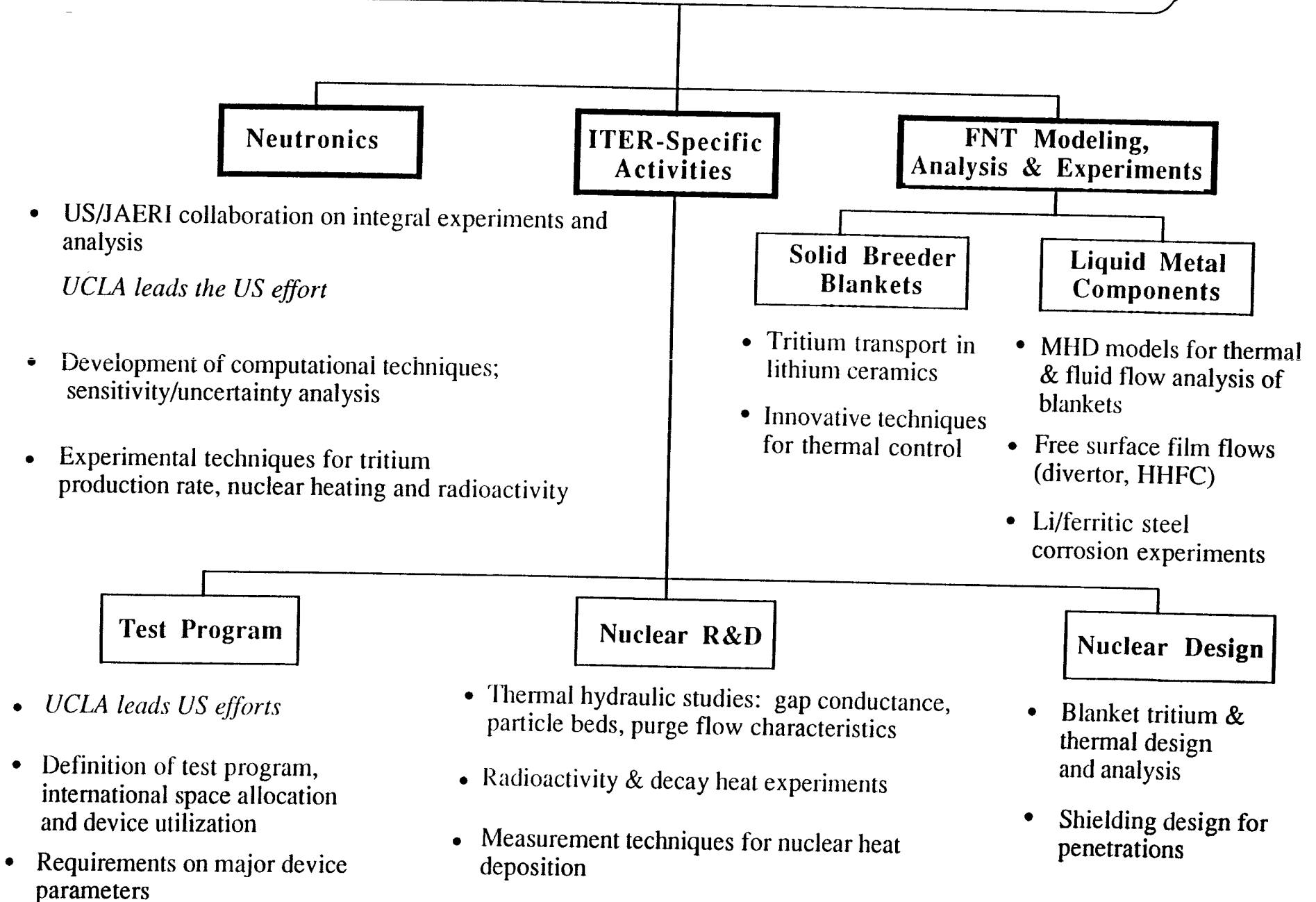
- **Publications:** Journal Publications: > 15 per year
 Many conference papers.
 Major Topical report with UCLA/SEAS logo.
- Many scholars and first rate researchers from Japan, Canada and Europe joined the program (at their own organization's expense) for training and participation in research
- Former UCLA FNT students are quickly moving to leadership positions in several organizations around the world
- Strong interaction with:
 - Industry - National Laboratories
 - Universities
- **Lead Role**
 (DOE decision for domestic programs and international collaboration)
 - Neutronics
 - Solid Breeder Thermomechanics Experiments and Modelling
 - Tritium Transport Modelling
 - **ITER** Technology Testing (Experiments, Models)
- Collaborative **International** agreements between UCLA and:
 - Soviet Union (several organizations)
 - JAERI
 - Japanese Universities (Tokyo, Osaka)
 - KfK (Germany) - France (CEA)
 - Belgium (MOL) - Canada (CFFTP)
 - China (PRC)

Figure 1-5.—Systems in the Fusion Power Core

- Tritium
- - - Deuterium
- ~ ~ ~ Electromagnetic radiation
- Neutrons
- Fuel pellets



UCLA Fusion Nuclear Technology (FNT) Activities



Thermal Control Experiments and Modeling

Objectives:

- Develop concepts for stable and predictable thermal resistance between blanket elements
(early design concepts employed thin He gaps, which are subject to large uncertainties and possible changes during operation)
- Develop active control mechanisms to accommodate uncertainties and operational flexibility:
 - Uncertainties in solid breeder temperature window remain – particularly in the fusion environment
 - Guidelines for operating power level changes in ITER specify $\pm 50\%$
 - Poloidal power variation in ITER is almost a factor of 2
- Establish the allowable range of operating conditions for the He purge

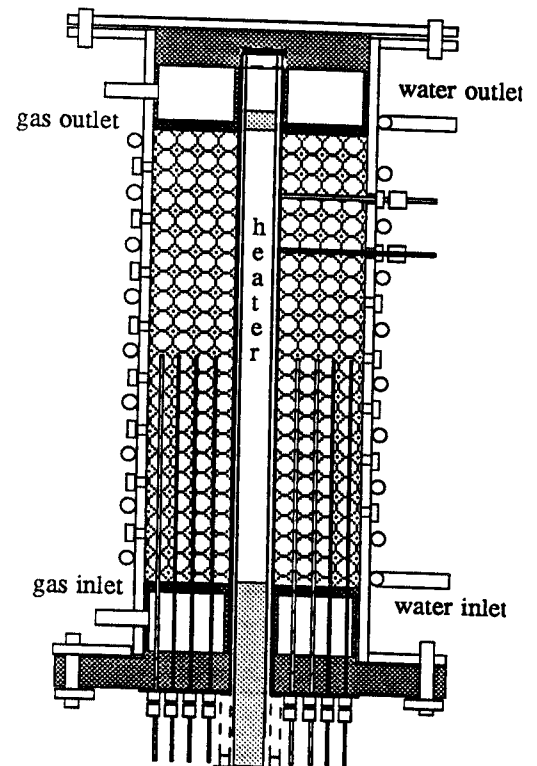
Particle Bed Experiment

Measurements include effect on conductivity of:

- Particle surface characteristics
- Bed packing and particle sizes
- Change in gas pressure
- Change in gas composition
- Gas flow rate

Initial Results:

Metallic particle beds were shown to provide predictable and controllable thermal resistance. Up to a factor of 2 change in conductivity was demonstrated by varying gas pressure and/or composition

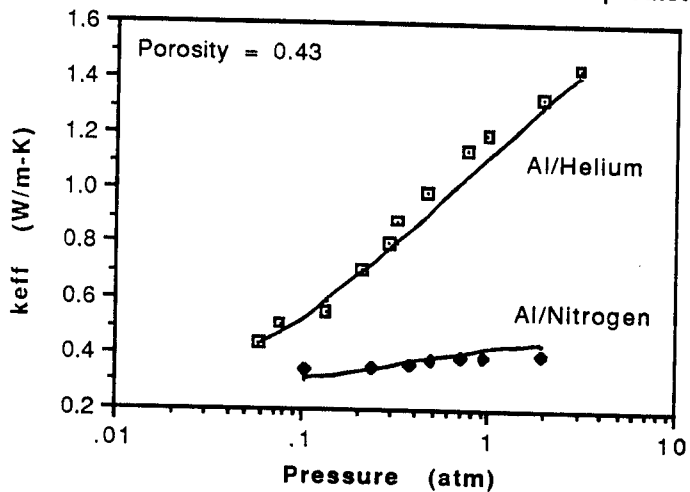


EXPERIMENTAL RESULTS AND MODELING ANALYSIS OF PACKED BED CONDUCTANCE FOR ITER BLANKET APPLICATION

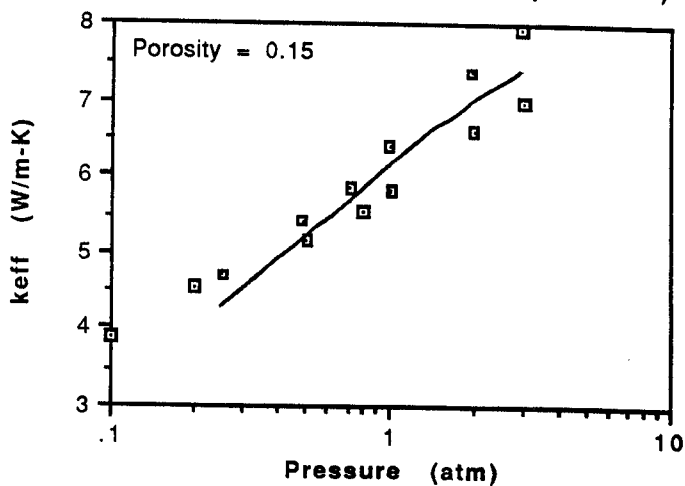
- A model for the effective thermal conductivity of packed beds has been developed for the purpose of analyzing the experimental results. Its capabilities include accounting for: multi-size beds, surface characteristics, contact area, pressure variation and porosity, which are key parameters for the present analysis.
- For single-size Al/He packed bed (representative of Be/He):
 - Substantial control of k_{eff} can be achieved through pressure variation and/or gas composition change.
 - E.g. Increasing the pressure from 0.2 to 2 atm increases k_{eff} by 90% for 0.12 mm single-size bed charging.

Changing the gas from N₂ to He at 1 atm increases k_{eff} by a factor of 2.5 or more.
- Use of binary mixture in the range of 4 mm/0.1 mm seems very attractive for blanket application. It results in high packing fraction (about 0.83), higher k_{eff} , and significant k_{eff} controllability (about 60% increase for a pressure increase from 0.2 to 2 atm).

Pressure Dependence of k_{eff} for 0.1-mm Al Powder Bed in He and N₂ (lines represent model predictions)

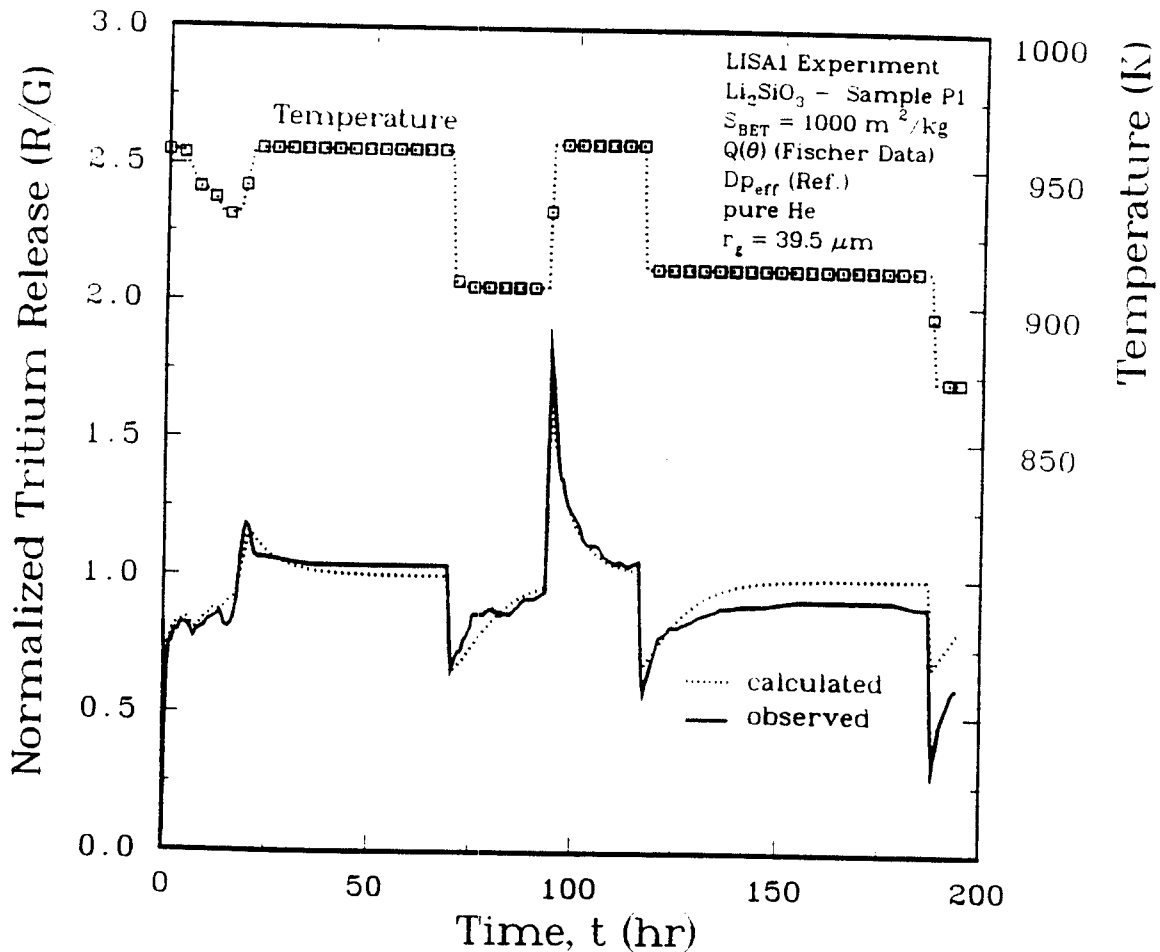


Pressure Dependence of k_{eff} for 4mm+0.1mm Al/He Binary Bed (line represents model prediction)



TRITIUM RELEASE FROM SOLID BREEDERS

- Completed and ongoing irradiation experiments in fission reactors
 - Presently, primary program is BEATRIX-II, an international collaboration on material fabrication, irradiation and analysis. Participants are U.S., Japan and Canada.
- Models are being developed and have been successful in reproducing experimental results.
- The figure shows example results from the LISA I experiment, which was performed in the SILOE reactor, France, and corresponding results predicted by MISTRAL, a model developed at UCLA for tritium transport in solid breeders.



Liquid Metal Studies at UCLA

MHD Full Solution and Heat Transfer Modeling:

MH3D code benchmarked at high N with Hunt's analytic solution ($Ha=100$)

KAT code code written for general rectangular coordinates;
tested in rectangular ducts up to $Ha=200$

* plan to analyze upcoming Soviet orifice experiment

Heat Transfer completed studies of effect of field angle and aspect ratio
on heat transfer in rectangular ducts

* joint analysis ongoing with Soviets on slotted-duct design

Core Solution

Iterative method developed and applied to numerous geometric elements.
– e.g., joint analysis of KfK bend experiment

Direct integration method also used for selected geometries.
– e.g., used for analysis of Soviet design with cylinder obstructions

Free Surface Film Flow Studies

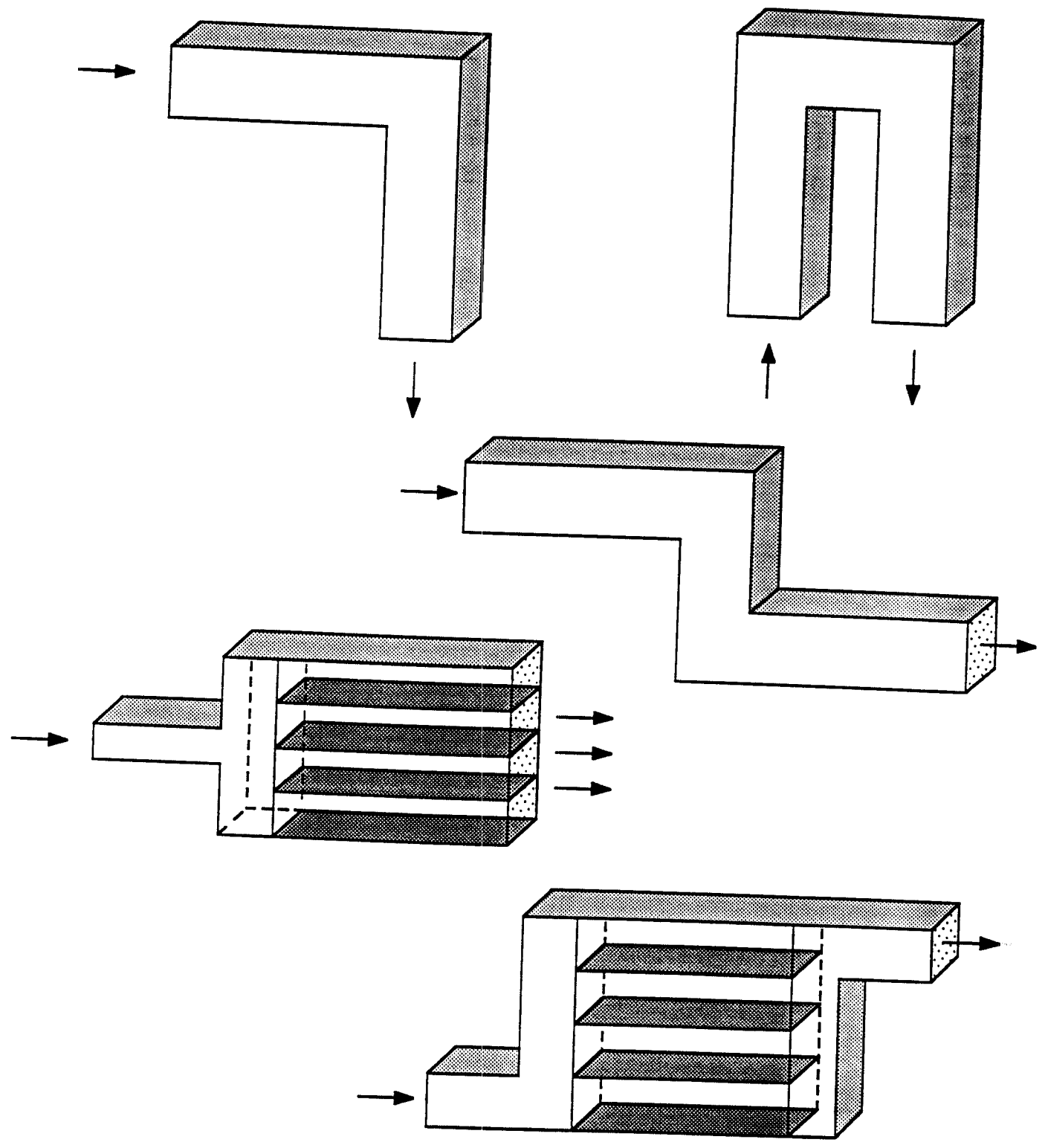
Assessment of coplanar and quasi-longitudinal film flows based on
– stability
– heat removal capability

International collaboration:

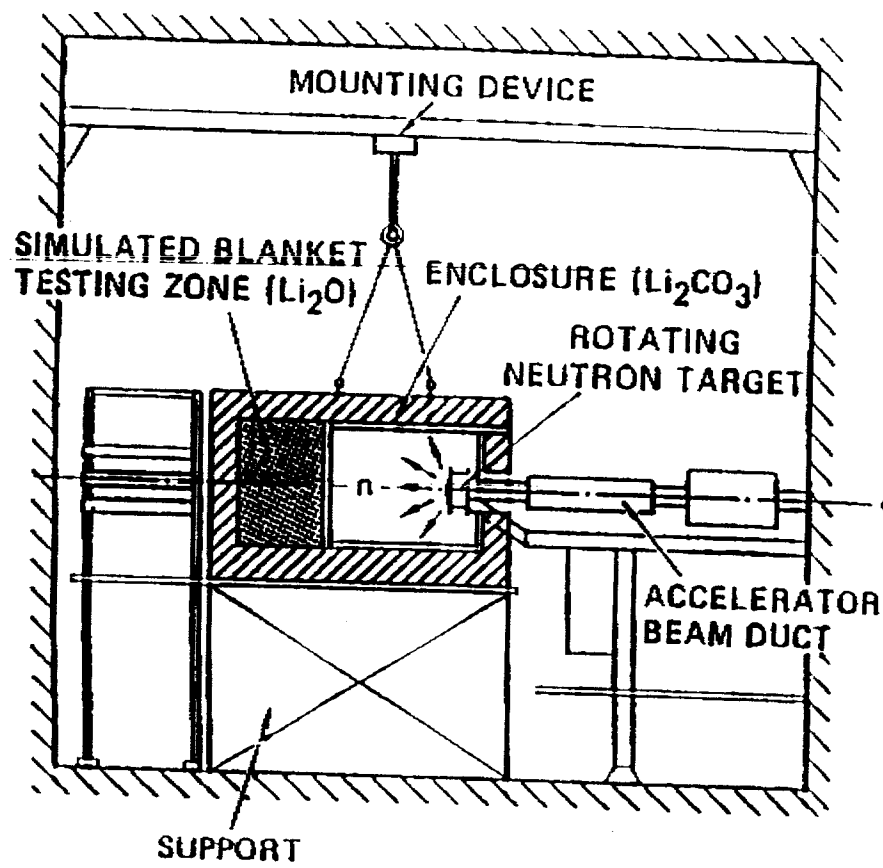
KfK staff assignment, joint analysis of KfK blanket elements
USSR staff assignment, joint analysis, workshops
JAERI staff assignment to UCLA, joint effort on full solution

Examples of Geometries Which Can Be Analyzed Using the KAT Code

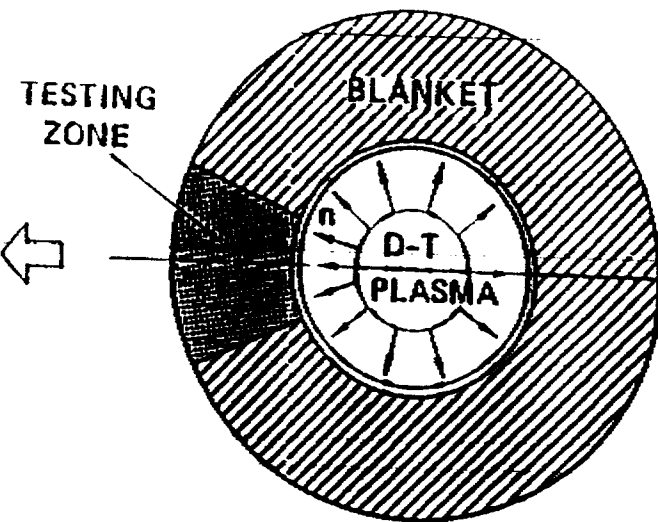
(for all cases the magnetic field is completely arbitrary)



EXPERIMENTAL SYSTEM FOR PHASE-2 OF US/JAERI PROGRAM
ON BLANKET NEUTRONICS



SCHEMATIC OF REACTOR MODEL



NEUTRONICS

The current focus is on performing integral experiments and analyses in collaboration with JAERI:

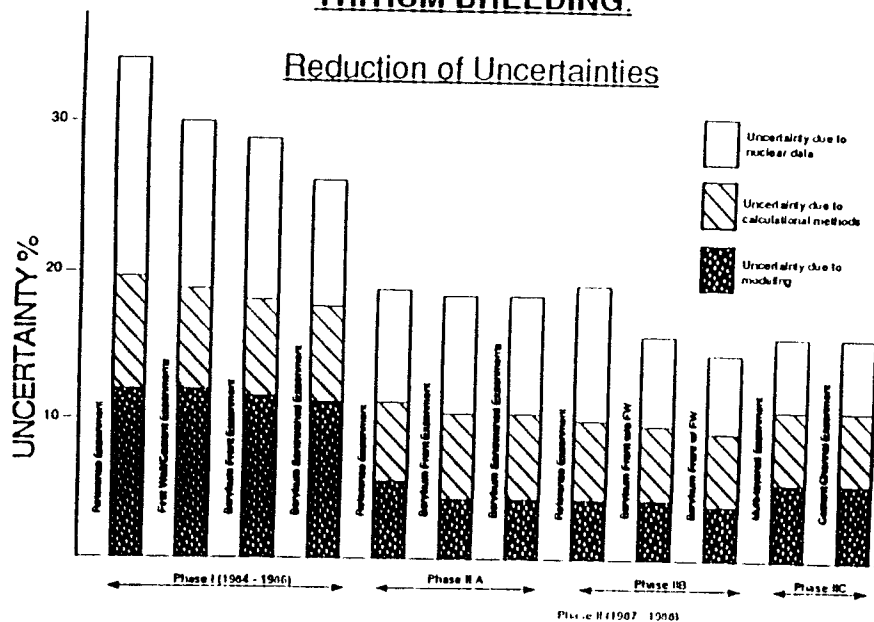
OBJECTIVES

- To provide guidance in resolving key design issues
 - Tritium self-sufficiency (feasibility, economics, safety)
 - Induced activation and afterheat levels (safety, environmental impact)
 - Total heat deposition and heating rate profiles (economics, safety)
- To develop the neutronics technology needed for the next fusion experimental reactors through development of various measuring techniques for tritium production and nuclear heat deposition/decay heat measurements

APPROACH

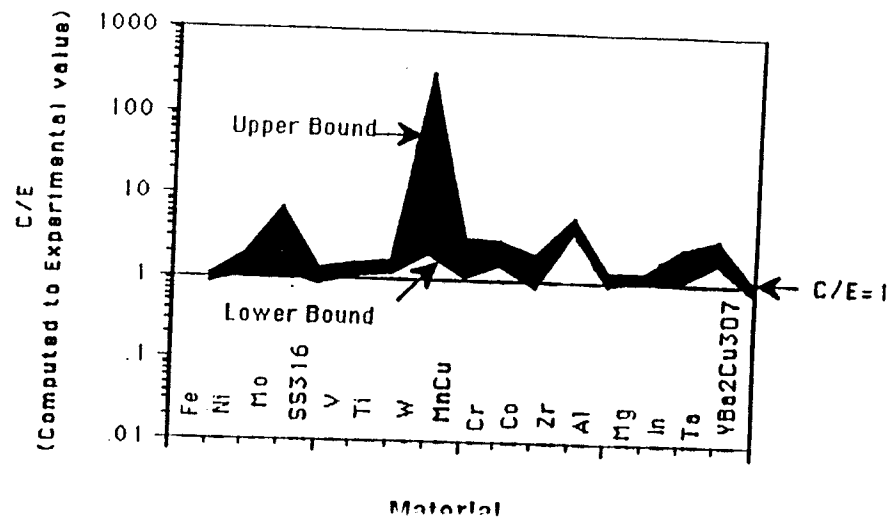
- Experimental configurations proceed from a simple, one material (Li_2O) to more prototypical blanket. Source conditions proceed from a 14 MeV localized (point) source to a volume distributed (simulated line) source
- Measured quantities (T production, afterheat) are compared to calculated values to check prediction accuracies. Actions are taken to improve uncertainties due to modeling/nuclear data deficiencies (e.g., $\text{Be}(n,2n)$ cross-section has improved)

TRITIUM BREEDING:



RADIOACTIVITY/DECAY HEAT MEASUREMENTS:

Large Discrepancy between Measurements and Calculations



TRITIUM BREEDING SELF-SUFFICIENCY: LINE SOURCE DEVELOPMENT

- A new innovative technique of line source has recently been developed to simulate volumetric fusion neutron source in the framework of phase IIIA of USDOE/JAERI Collaborative Program.
- Line source was realized by moving a blanket assembly mounted on a deck with respect to a stationary point source during phase IIIA experiments (October - December, 1989). This development has opened up a whole lot of new possibilities for performing experiments for resolving issues impacted by spatial distribution of source neutrons.

