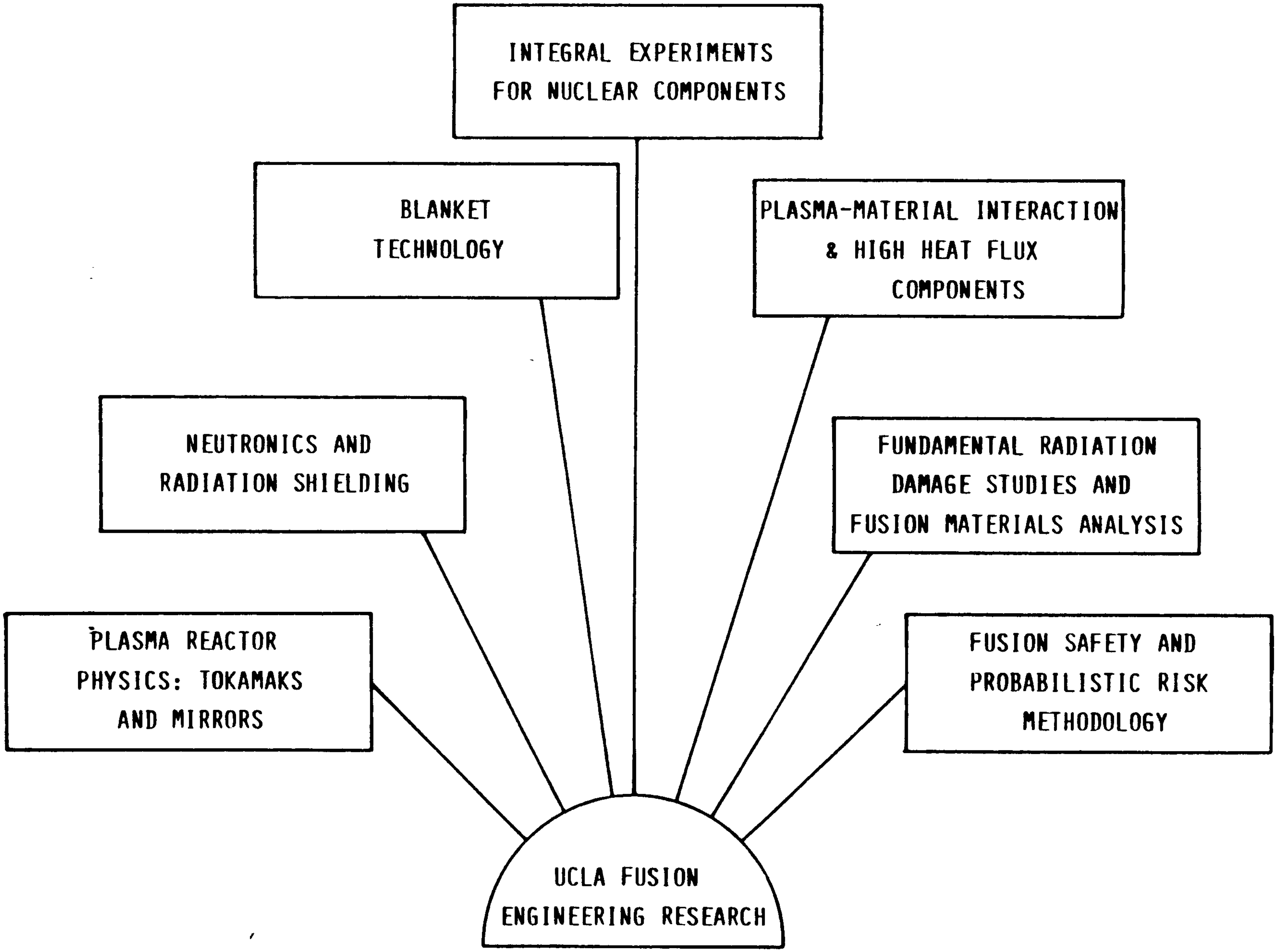
Presentation to
J. Bostock

UCLA
August 23, 1984

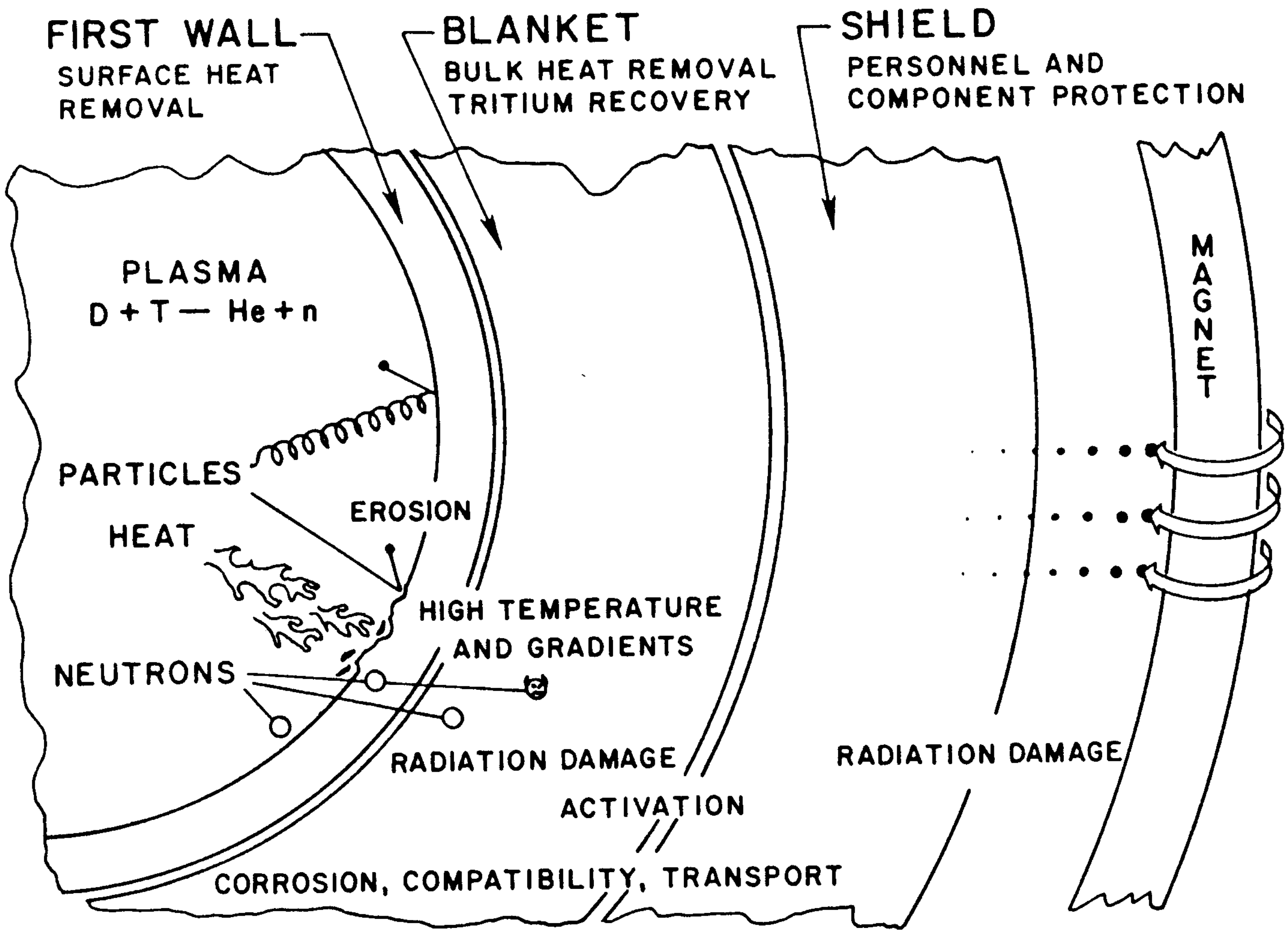

INTEGRAL EXPERIMENTS FOR NUCLEAR COMPONENTS
BLANKET TECHNOLOGY
PLASMA-MATERIAL INTERACTION & HIGH HEAT FLUX COMPONENTS
NEUTRONICS AND RADIATION SHIELDING
FUNDAMENTAL RADIATION DAMAGE STUDIES AND FUSION MATERIALS ANALYSIS
PLASMA REACTOR PHYSICS: TOKAMAKS AND MIRRORS
FUSION SAFETY AND PROBABILISTIC RISK METHODOLOGY
UCLA FUSION ENGINEERING RESEARCH

FUSION

- Plasma
- Technology
  - Magnets
  - Plasma Heating
  - Nuclear

NUCLEAR TECHNOLOGY

- Handling of Plasma Particles and Energy Conversion
  - Plasma-Interactive Components (First Wall, Impurity Control and Exhaust, etc.)
  - Blanket
  - Shield
  - Tritium System



OPERATIONAL CONSIDERATIONS

- EFFICIENT REMOTE MAINTENANCE
- FLOW TRANSIENTS
- RAPID SHUTDOWN

FINESSE

- Carried Out by a Number of Organizations from Universities, National Laboratories, and Industry

- Significant International Participation

  Germany (France, Italy)
  Japan
  Canada

  - All World Programs Face the Same Issues
  - International Cooperation is Scientifically and Economically Beneficial in this Area

- UCLA Role

  - Technical Leadership
  - Source of New Ideas
  - Resource of Advanced Research Capabilities
  - A Number of Faculty and Graduate Students Are Involved

SCOPE OF FINESSE

- A Study on the Issues, Phenomena, and Experiments for Fusion Nuclear Technology

- Scope:

  - Understand the Basic Scientific Phenomena Governing the Behavior and Performance of Nuclear Components in the Fusion Environment

  - Identify and Characterize those Fusion Nuclear Technology Issues for which New Knowledge is Essential through:

    * Development or Extension of Theoretical Models
    * Conducting Experiments

  - Develop the Scientific Basis for the Technical Discipline of Fusion Engineering Experiments

    * Purpose: Develop Innovative Ideas and Technical Criteria for Selection of High-Payoff, Low-Cost Fusion Engineering Experiments

    * Type of Experiments:
      (1) Basic
      (2) Single Phenomenon
      (3) Multiple Phenomena/Interactive
      (4) Integral

    * Type of Facilities:
      (1) Small-Scale Non-Nuclear Test Stands
      (2) Accelerator-Based Neutron Sources
      (3) Fission Reactors
      (4) Multiple Environment Facilities
      (5) Fusion Facilities

WHY SHOULD RESEARCH BE CARRIED OUT NOW ON FUSION TECHNOLOGY?

1. Important to Fusion

- Many of Fusion's Unresolved Issues are in Nuclear Technology. These Issues Relate to:

  - Feasibility
  - Attractiveness (Safety, Economics)

- Requires Long Lead Time

2. Important to Science and Technology

- The Fusion Environment is Unique:

  - Environmental Conditions: Plasma Particles, Neutrons, γ-rays, Magnetic Field, Heating, Tritium

  - System: Many Components with Diverse Functional Requirements

  - Phenomena: New Phenomena, Interactive Effects among Environmental Conditions, Elements within Components and among Components

- Therefore:

  - Research is at the Very Forefront of Knowledge in Many Scientific Disciplines (e.g., Materials, Chemistry, Thermal, Nuclear)

  - Technologically Challenging: Stimulates Advances in Technology

EXAMPLES OF RESEARCH AREAS IN FUSION NUCLEAR TECHNOLOGY
(EXAMPLES FROM FINESSE EFFORT)

LIQUID METAL BLANKETS

- LIQUID METAL FLUID FLOW (EFFECTS OF MAGNETIC FIELD AND NEUTRON BULK HEATING IN COMPLEX GEOMETRIES)
  - ANALYSIS OF EDDY CURRENTS AND ACTING FORCES
  - STUDY EFFECTS ON FLUID FLOW CHARACTERISTICS (TRANSITION FROM TURBULENT TO LAMINAR, CHANGES IN VELOCITY PROFILES)
  - MODELS FOR ESTIMATING MHD PRESSURE DROPS (PRESSURE STRESSES)
  - EFFECTS ON HEAT TRANSFER
- CORROSION OF STRUCTURAL MATERIALS BY LIQUID METALS

  STUDY NEW PHENOMENA AND DEVELOP MODELS FOR PREDICTING CORROSION IN NON-FULLY-DEVELOPED FLOW IN THE PRESENCE OF MAGNETIC FIELD, BULK HEATING, AND RADIATION EFFECTS

SOLID BREEDER (CERAMIC) BLANKETS

- TRITIUM RECOVERY
  - STUDY THE VARIOUS PHENOMENA ASSOCIATED WITH TRITIUM RELEASE AND TRANSPORT IN SOLID BREEDER CERAMICS
  - EFFECT OF RADIATION ON TRITIUM RETENTION/RELEASE
  - PURGE GAS FLOW THROUGH POROUS MEDIA
  - TRITIUM PERMEATION THROUGH STRUCTURAL MATERIALS AND TRITIUM BARRIERS

- <u>Tritium Production</u>

  - Neutron Transport in Heterogeneous Media with Complex Geometries

  - Changes in Tritium Reaction Rates with Materials Choices, Lithium Burnup, and Geometrical Deformation

<u>High Heat Flux Components</u>

- In-vessel Components Exposed to Plasma Particles and Neutrons under High Heat Flux Conditions

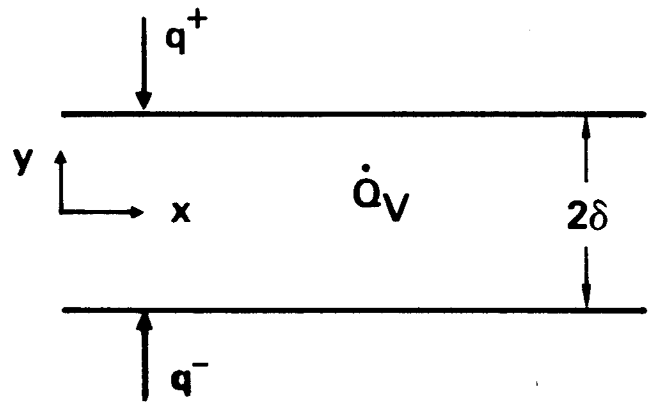
  - Surface Effects: Erosion and Redeposition

  - Heat Removal in Structural Elements (Critical Heat Flux, Flow Stability, Stresses)

  - Properties and Behavior of Bonds for Dissimilar Materials

NUSSELT NUMBER DEPENDS ON VOLUMETRIC HEATING

Consider laminar channel flow with heat generation and surface heat flux:



Velocity profile

$$U = \frac{2n+1}{2n}\left[1 - (y/\delta)^{2n}\right] U_b = f\,(y/\delta)\, U_b$$

The Nusselt numbers are calculated as:

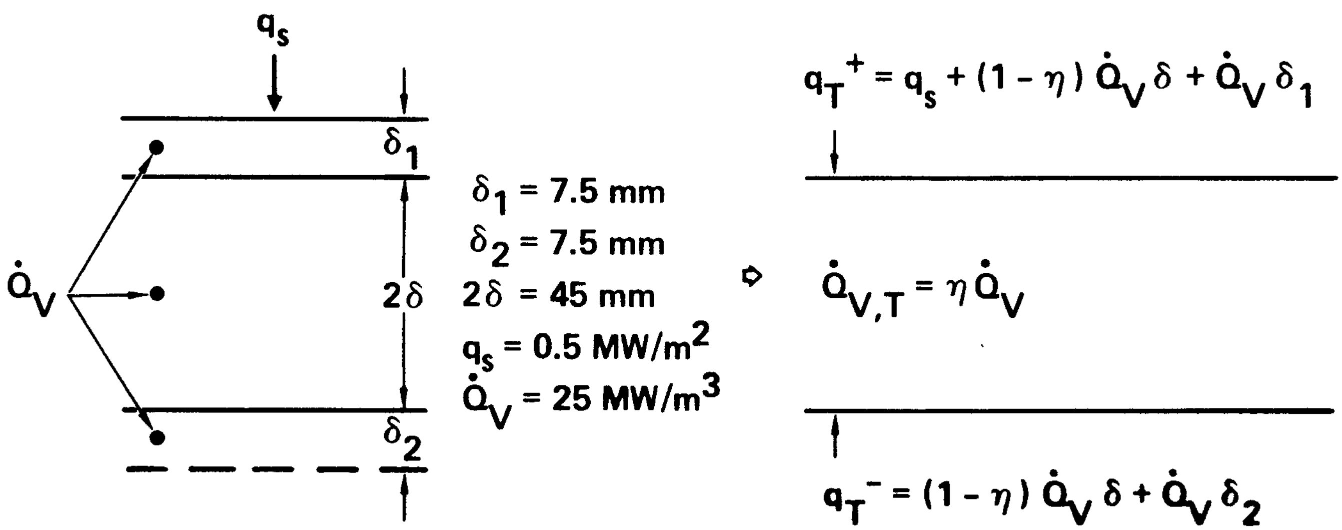
$$\frac{1}{Nu^{\pm}} = ¼ - I_1/8 - (I_1/16)(q^{\mp}/q^{\pm} - 1) + (I_2/4)(\dot{Q}_V\,\delta/q^{\pm})$$

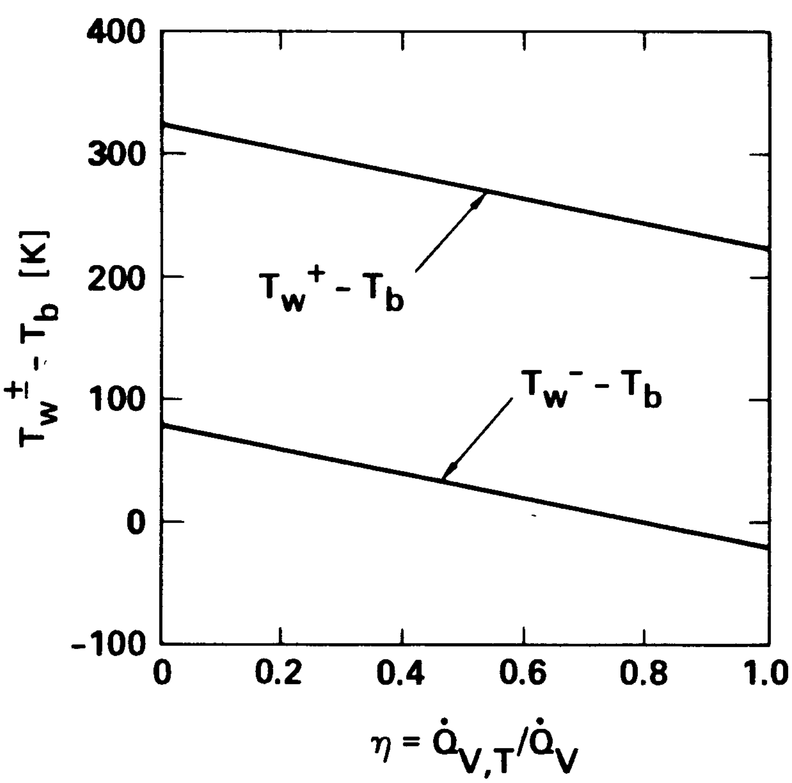
where

$$I_1 = \int_{-1}^{1} d\eta\; f(\eta) \int_{-1}^{\eta} d\eta \int_{-1}^{\eta} d\eta\; f(\eta)$$

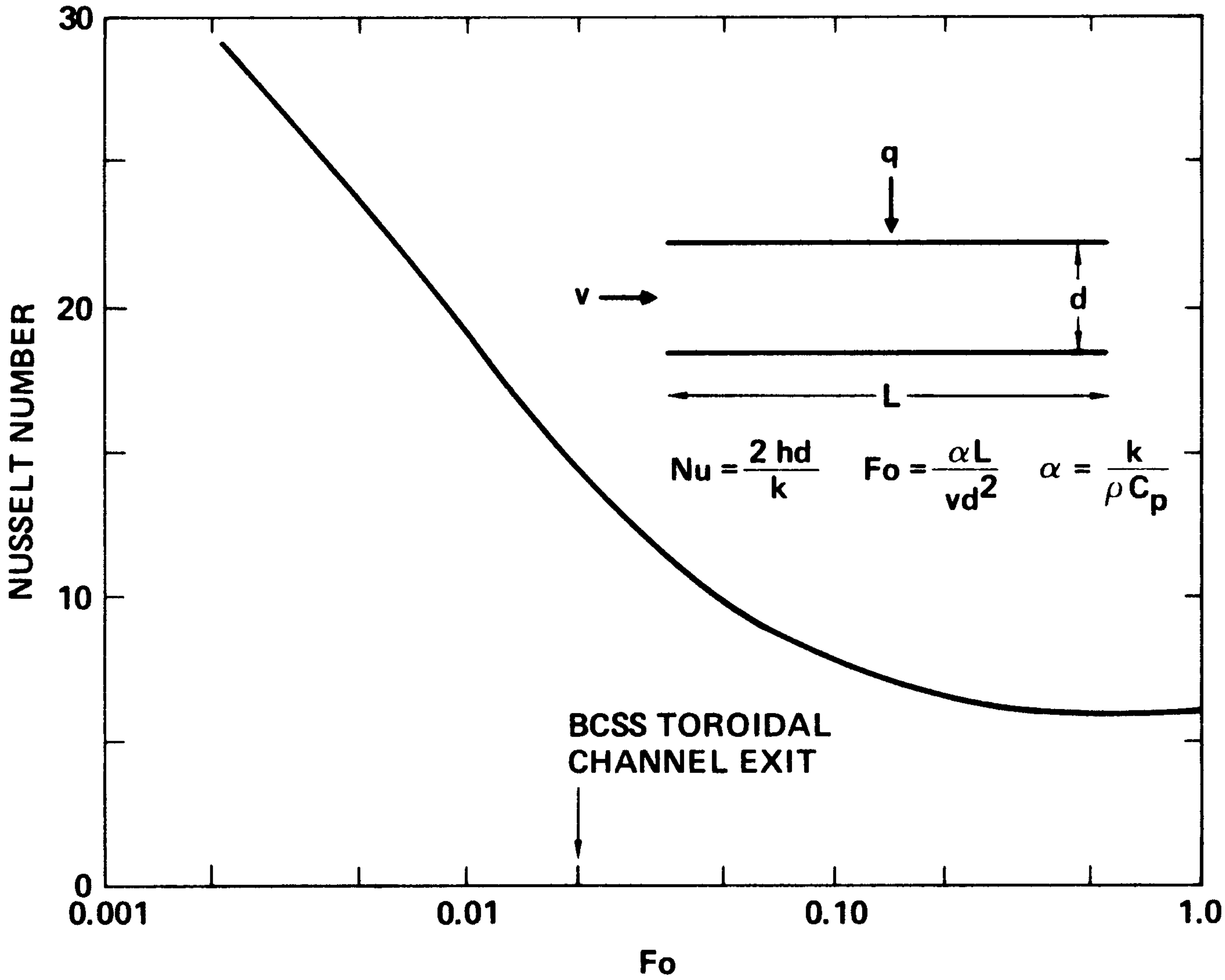
$$I_2 = ½ \int_{-1}^{1} d\eta\; f(\eta) \int_{-1}^{\eta} d\eta \int_{-1}^{\eta} d\eta\; [f(\eta) - 1]$$

WALL TEMPERATURE AS A FUNCTION OF VOLUMETRIC HEATING IN TEST MODULE WITH TOTAL ENERGY INPUT PRESERVED

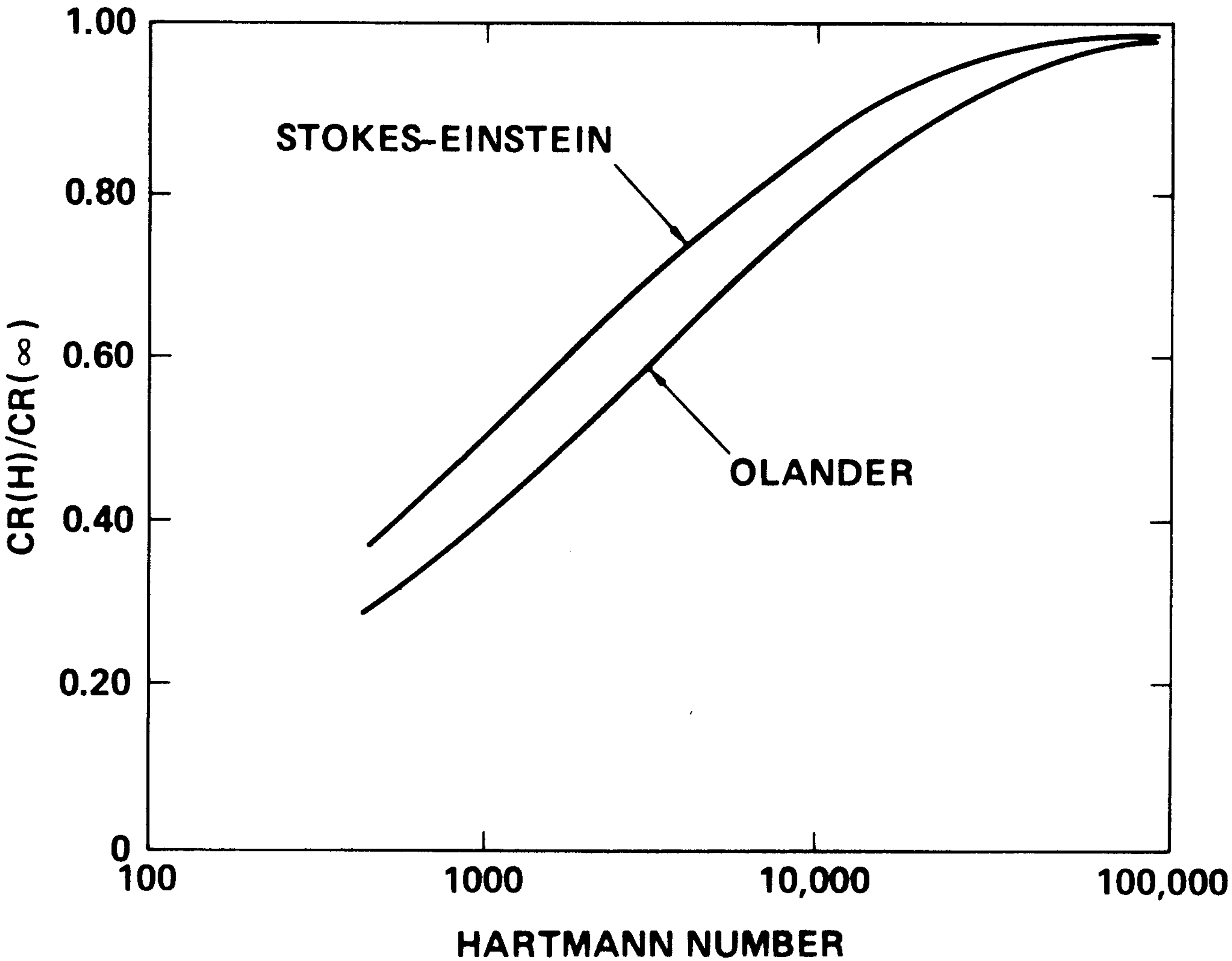




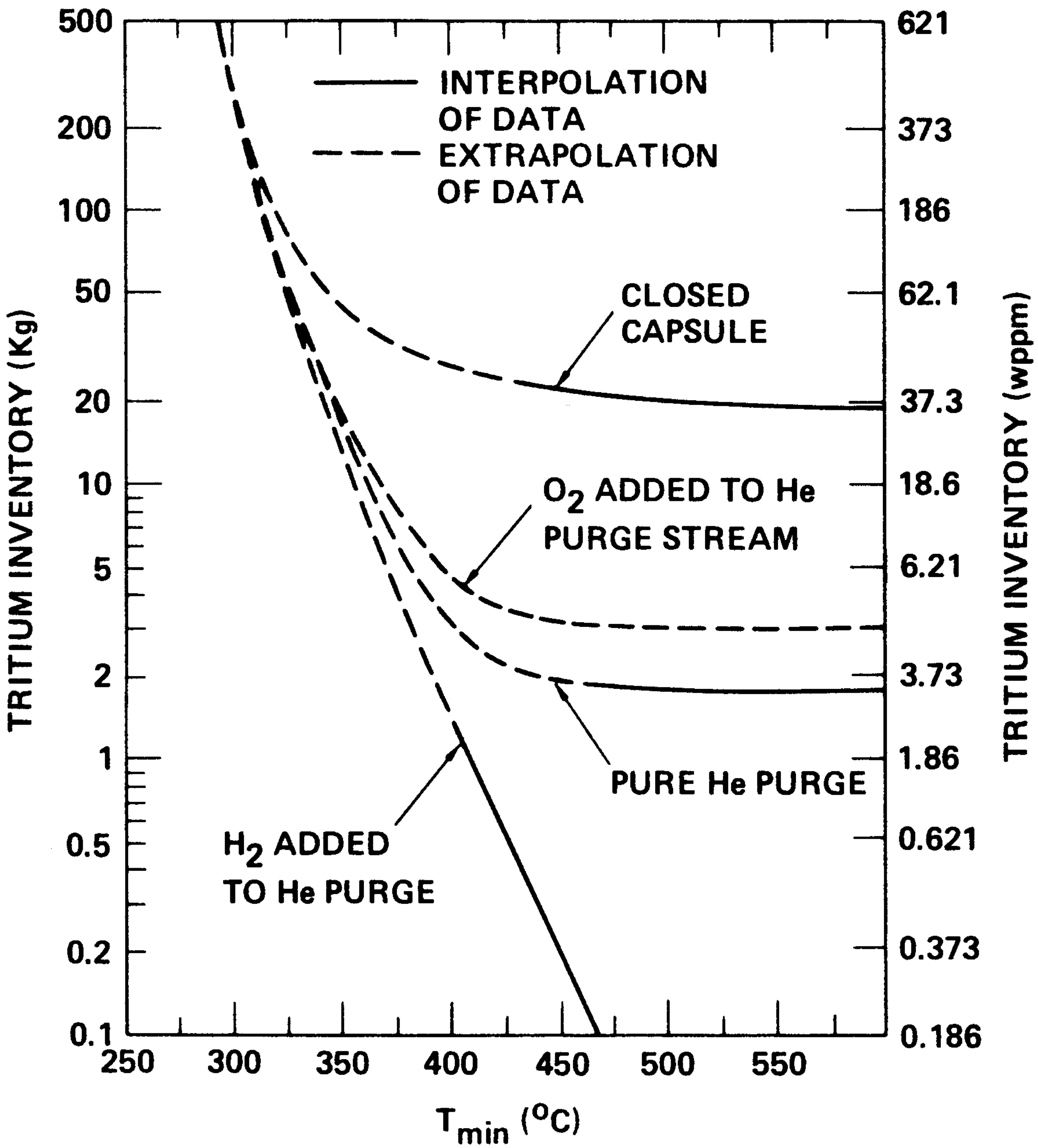
LIQUID METAL HEAT TRANFER COEFFICIENT FOR NON-FULLY DEVELOPED FLOW DEPENDS ON TEST MODULE GEOMETRY AND FLOW CHARACTERISTICS



CORROSION RATE DEPENDENCE ON MAGNETIC FIELD STRENGTH



FINESSE



Model predictions for tritium inventory as a function of the minimum blanket temperature for the BCSS (LOBE-2B) $LiAlO_2/H_2O/Be/HT\text{-}9$ blanket. A maximum temperature of 950°C and a tritium generation rate of 866 g/day are assumed.