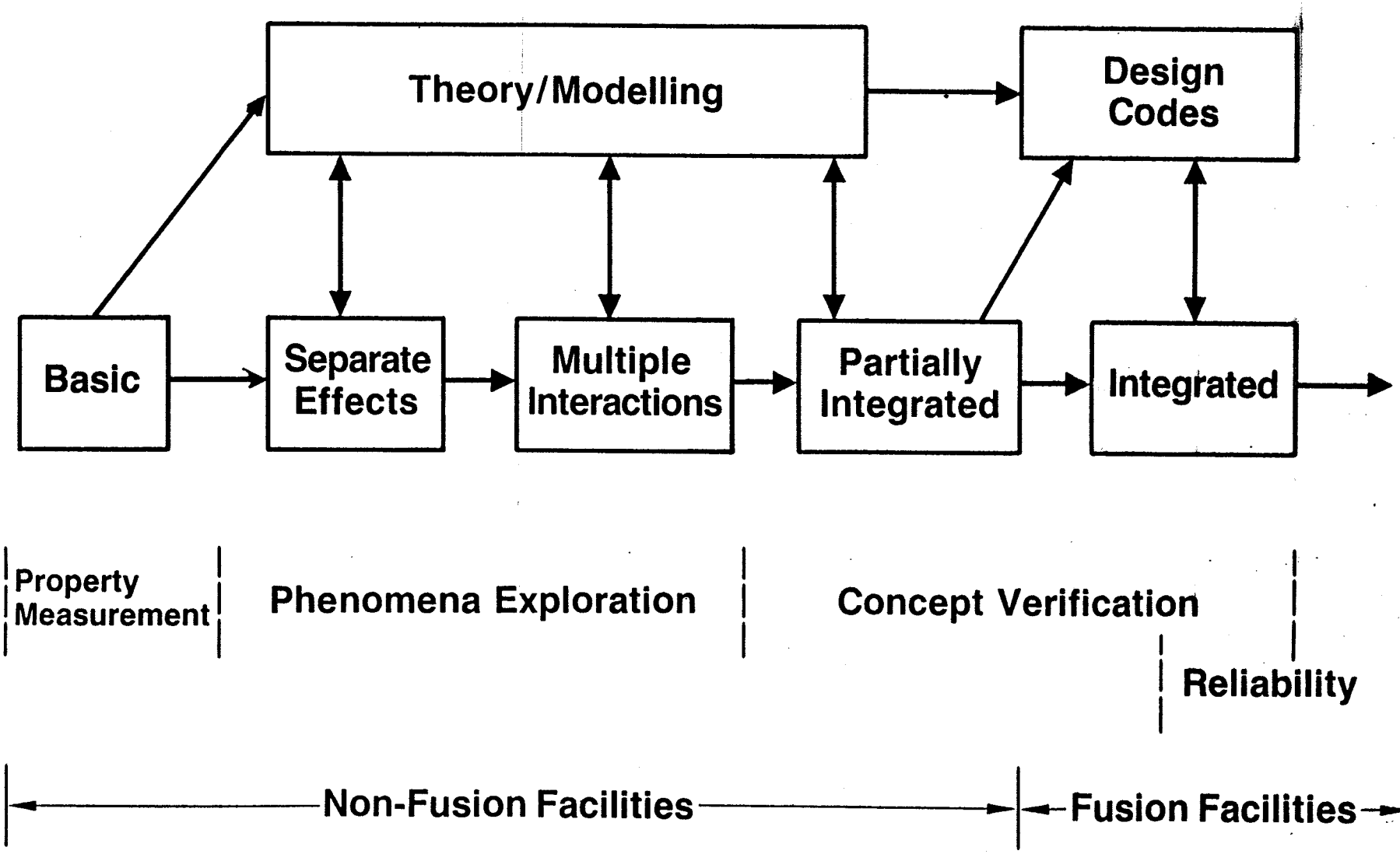
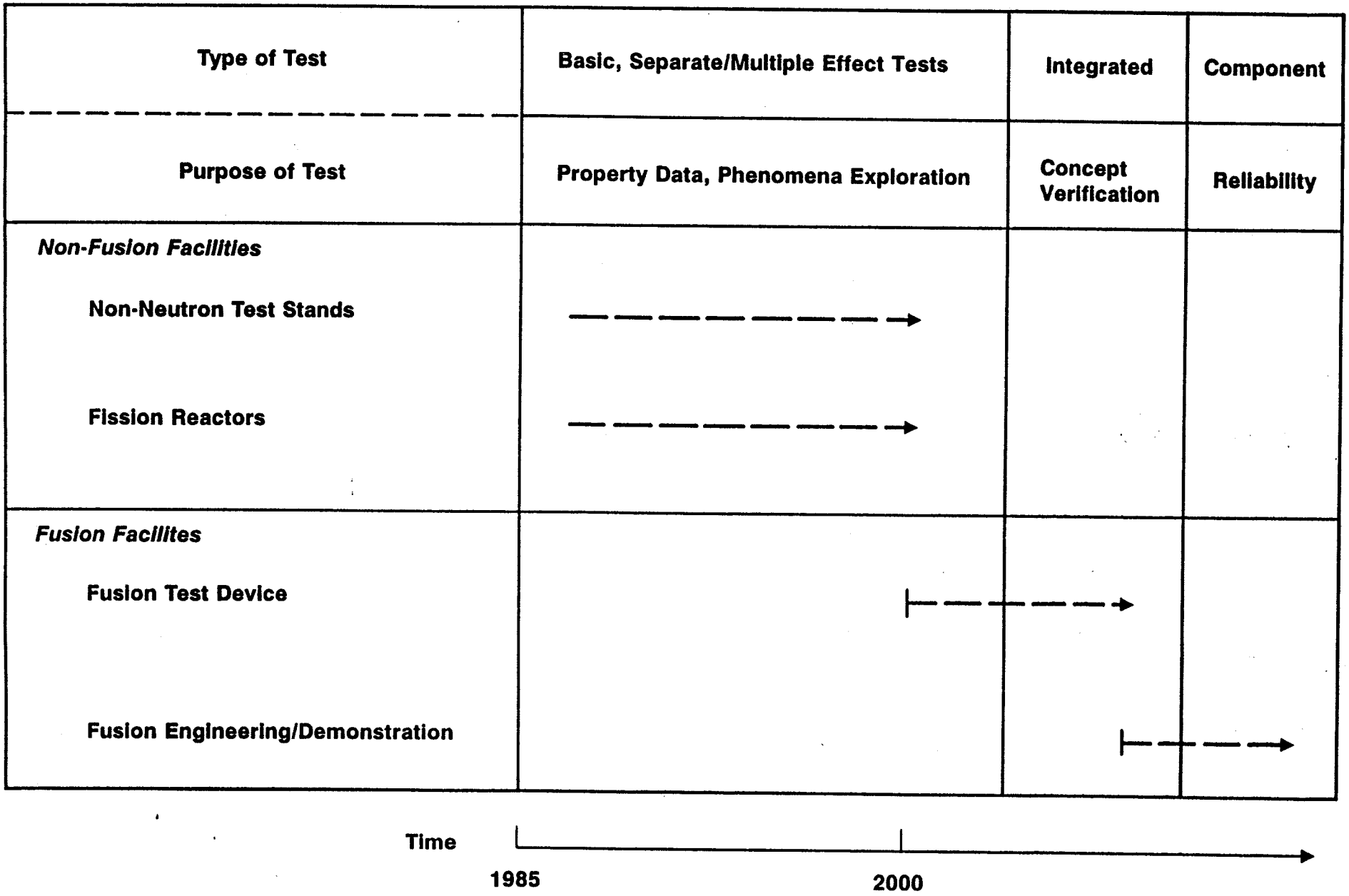
NUCLEAR TECHNOLOGY CONSIDERATIONS FOR ETR

MOHAMED A. ABDOU

PRESENTED TO ETR WORKSHOP
ROCKVILLE, MD
16 JULY 1986


Theory/Modelling
Design Codes
Basic
Separate Effects
Multiple Interactions
Partially Integrated
Integrated
Property Measurement
Phenomena Exploration
Concept Verification
Reliability
Non-Fusion Facilities
Fusion Facilities


Type of Test
Basic, Separate/Multiple Effect Tests
Integrated
Component
Purpose of Test
Property Data, Phenomena Exploration
Concept Verification
Reliability
Non-Fusion Facilities
Non-Neutron Test Stands
Fission Reactors
Fusion Facilites
Fusion Test Device
Fusion Engineering/Demonstration
Time
1985
2000

NUCLEAR TECHNOLOGY

- TOP LEVEL ISSUES
  - FUEL SELF-SUFFICIENCY
  - EFFICIENT, RELIABLE AND SAFE ENERGY CONVERSION AND USE
  - RADIATION PROTECTION OF COMPONENTS, PERSONNEL

- KEY COMPONENTS
  - BLANKET/FW
    LIQUID AND SOLID BREEDERS
  - SHIELD
  - TRITIUM PROCESSING SYSTEM
  - PLASMA-INTERACTIVE COMPONENTS
  - "MATERIALS"

NUCLEAR CONSIDERATIONS AND ISSUES FOR ETR DESIGN

- **MAJOR PARAMETERS OF DEVICE**
  - DEVICE COST DRIVERS
  - MAJOR IMPACT ON TEST USEFULNESS
- **TRITIUM SUPPLY**
  - EXTERNAL SOURCES
  - BREEDING BLANKET
- **ENGINEERING DESIGN OF DEVICE**

  E.G.,
  - ACCESS TO PLACE, REMOVE TEST ELEMENTS
  - PROVISION FOR ANCILLARY EQUIPMENT
  - ACCOMMODATION OF FAILURES IN TEST ELEMENTS

MAJOR PARAMETERS

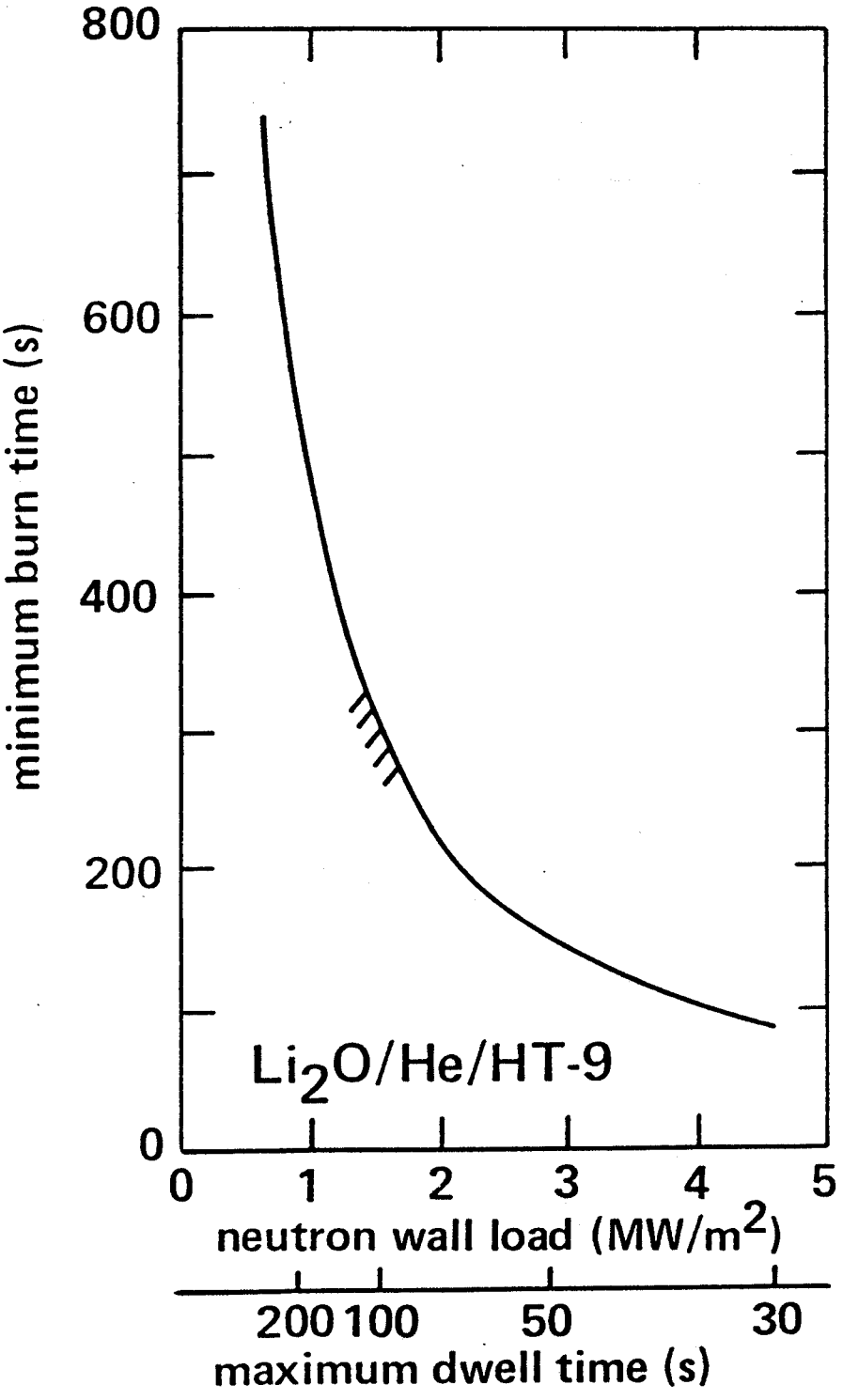
- NEUTRON WALL LOAD
- SURFACE HEAT LOAD
- PLASMA CYCLE BURN/DWELL TIMES
- MINIMUM CONTINUOUS TIME
- AVAILABILITY
- FLUENCE
- MAGNETIC FIELD STRENGTH
- TEST AREA/SIZE

SCALING OF MAJOR PARAMETERS

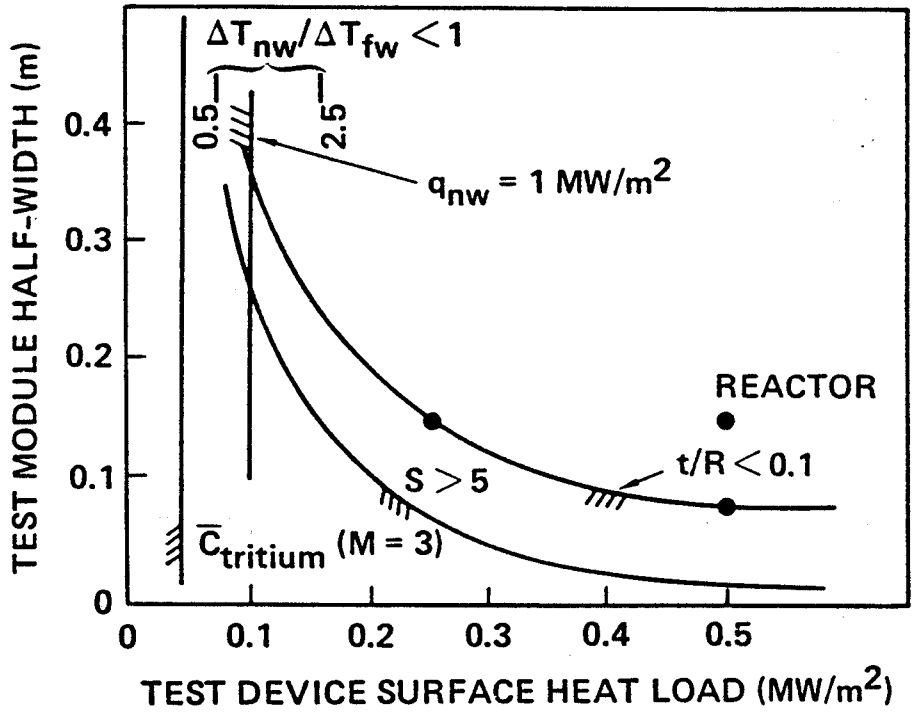
- COST FORCES SCALED-DOWN CONDITIONS
- "LOOK-ALIKE" TEST MODULES ARE USELESS
- "ACT-ALIKE" TEST MODULES ARE NECESSARY
- ENGINEERING SCALING LAWS MUST BE FOLLOWED
  - PRESERVE IMPORTANT PHENOMENA
  - TRADE-OFFS AMONG PARAMETERS

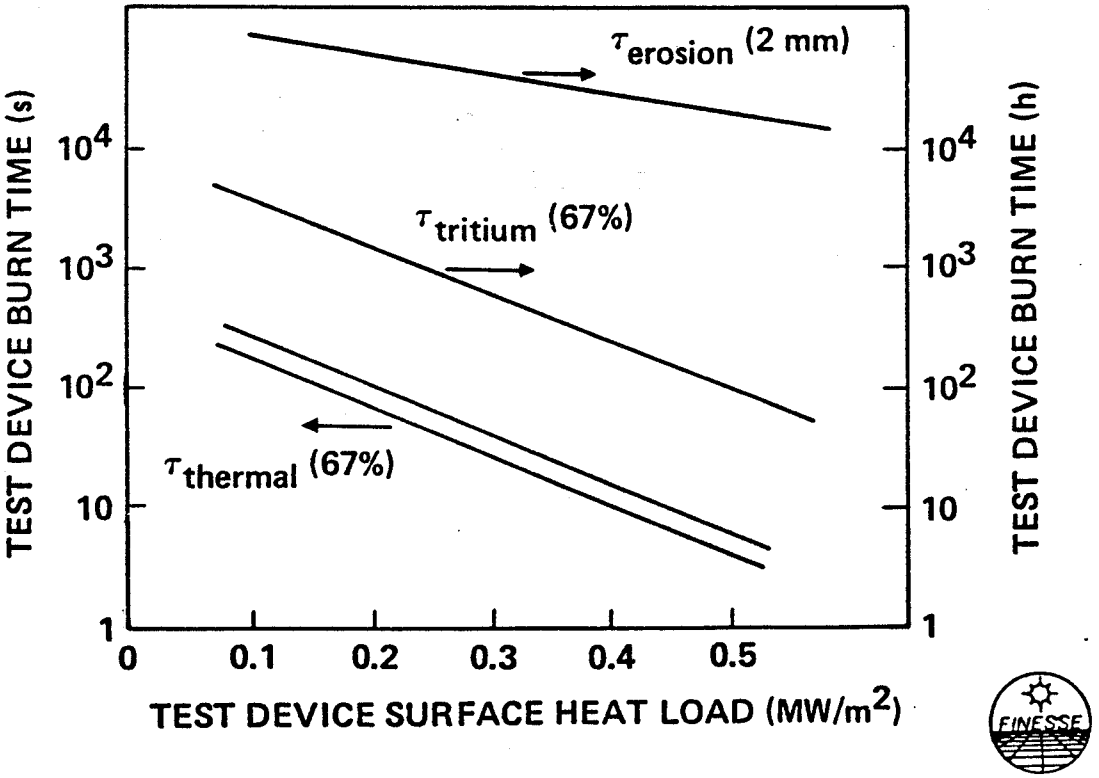
NOT ALL PARAMETERS CAN BE SCALED DOWN SIMULTANEOUSLY

Burn and dwell time requirements for maintaining solid breeder temperature distribution



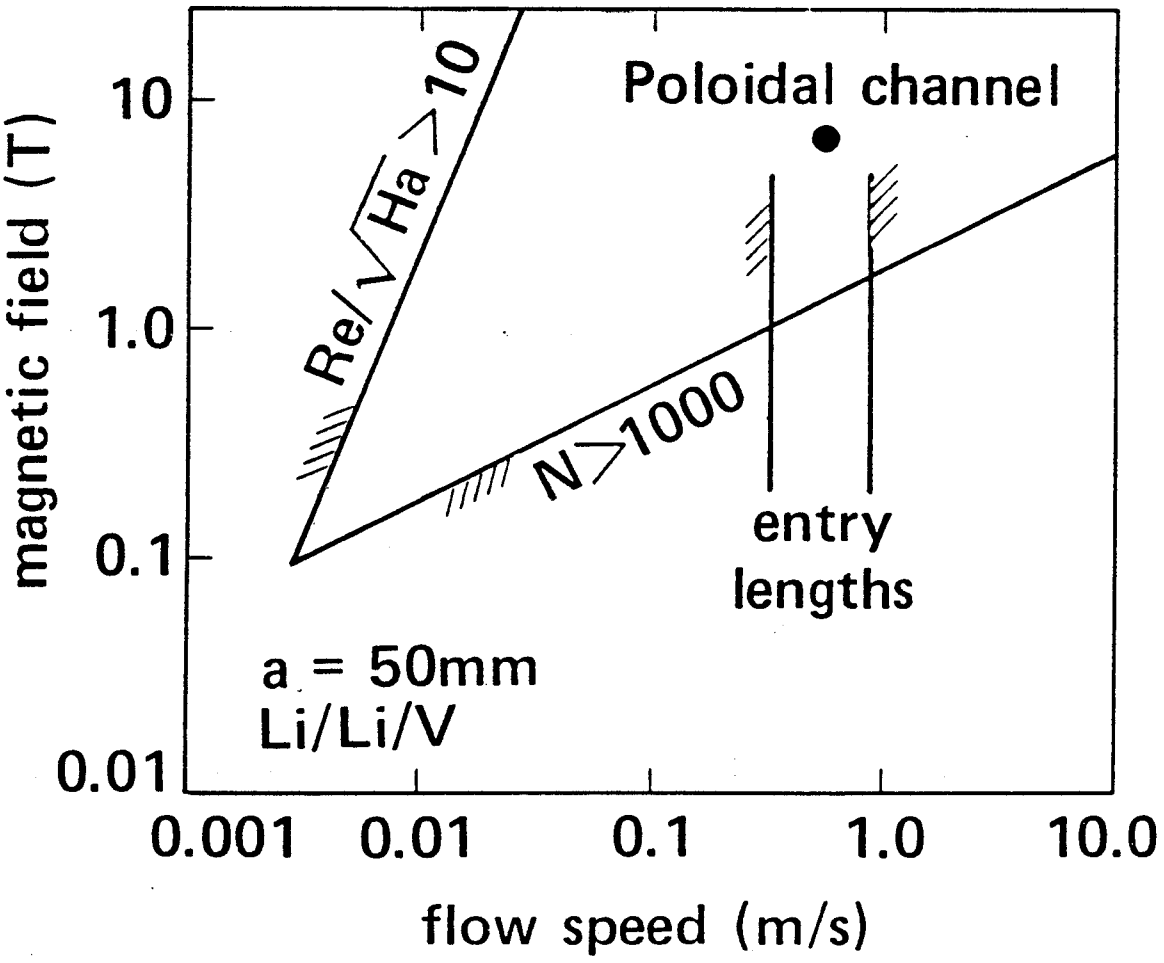
Li_2O/He/HT-9 FIRST WALL SCALING



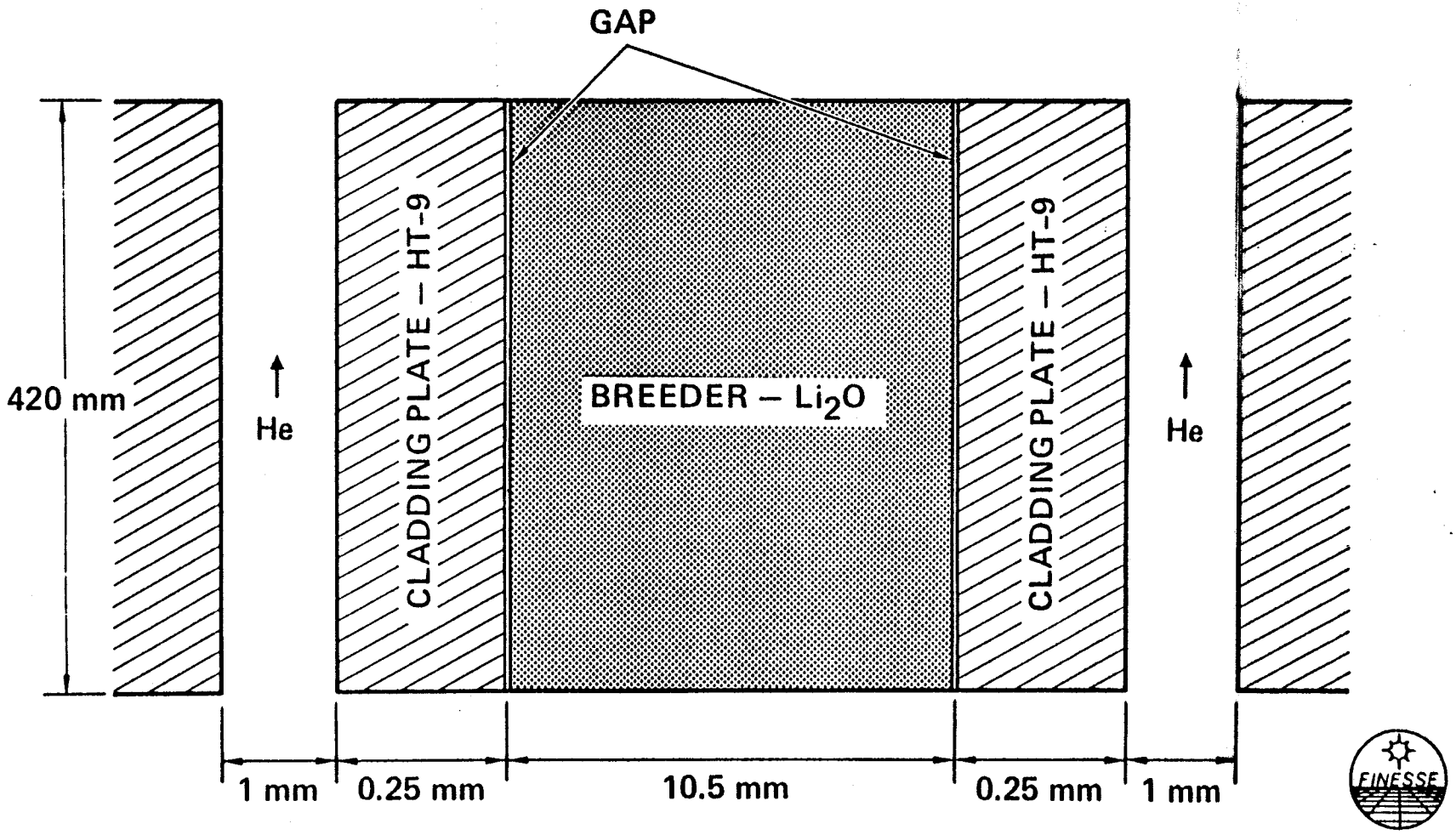


FINESSE

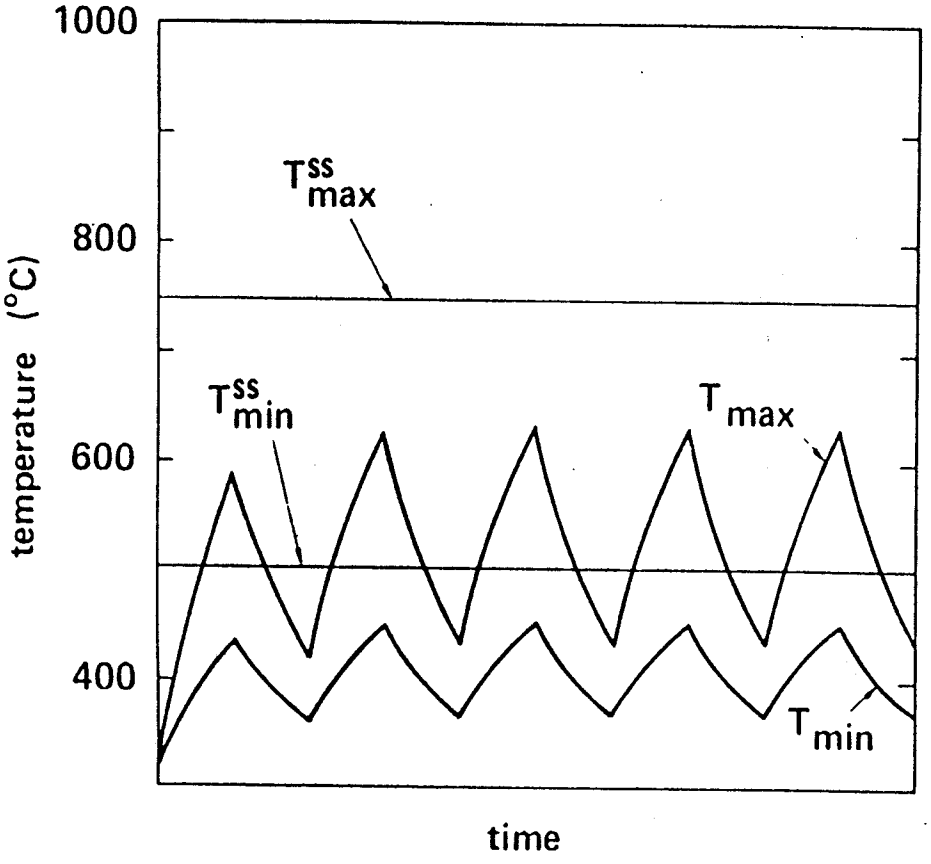
Preserving the MHD flow and heat transfer regimes requires sufficient magnetic field strength.

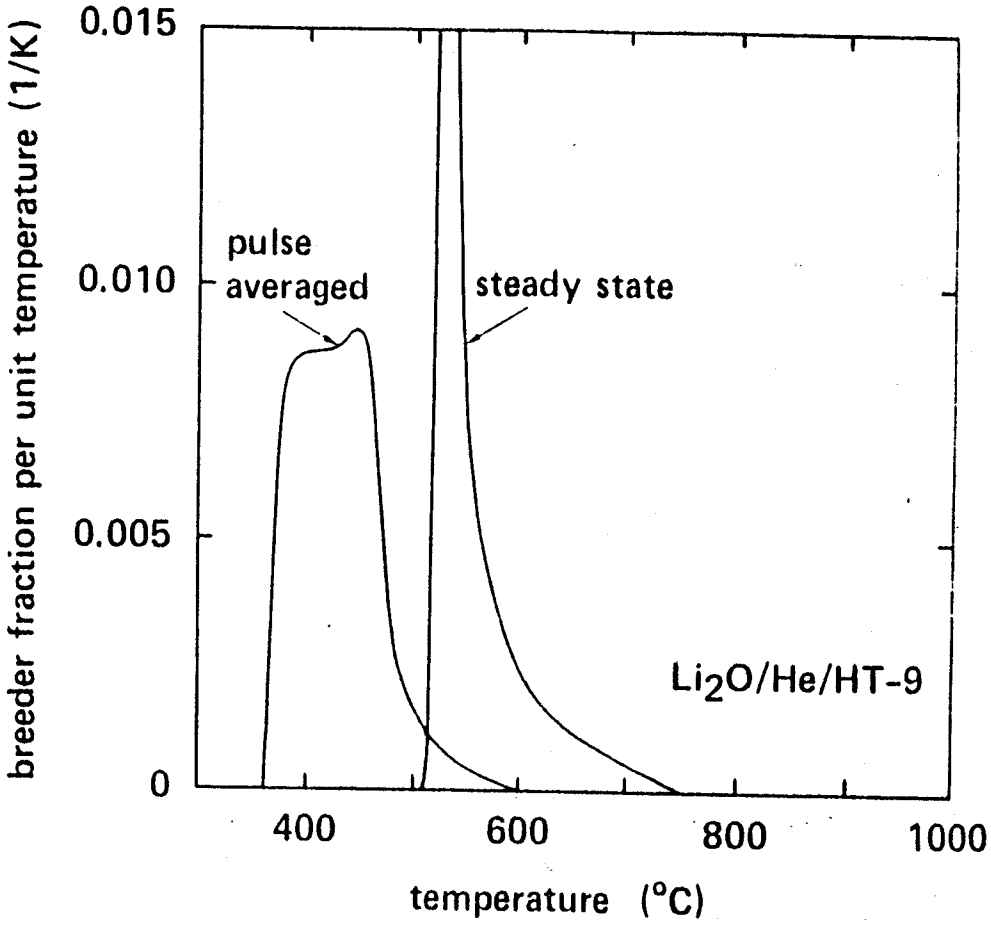


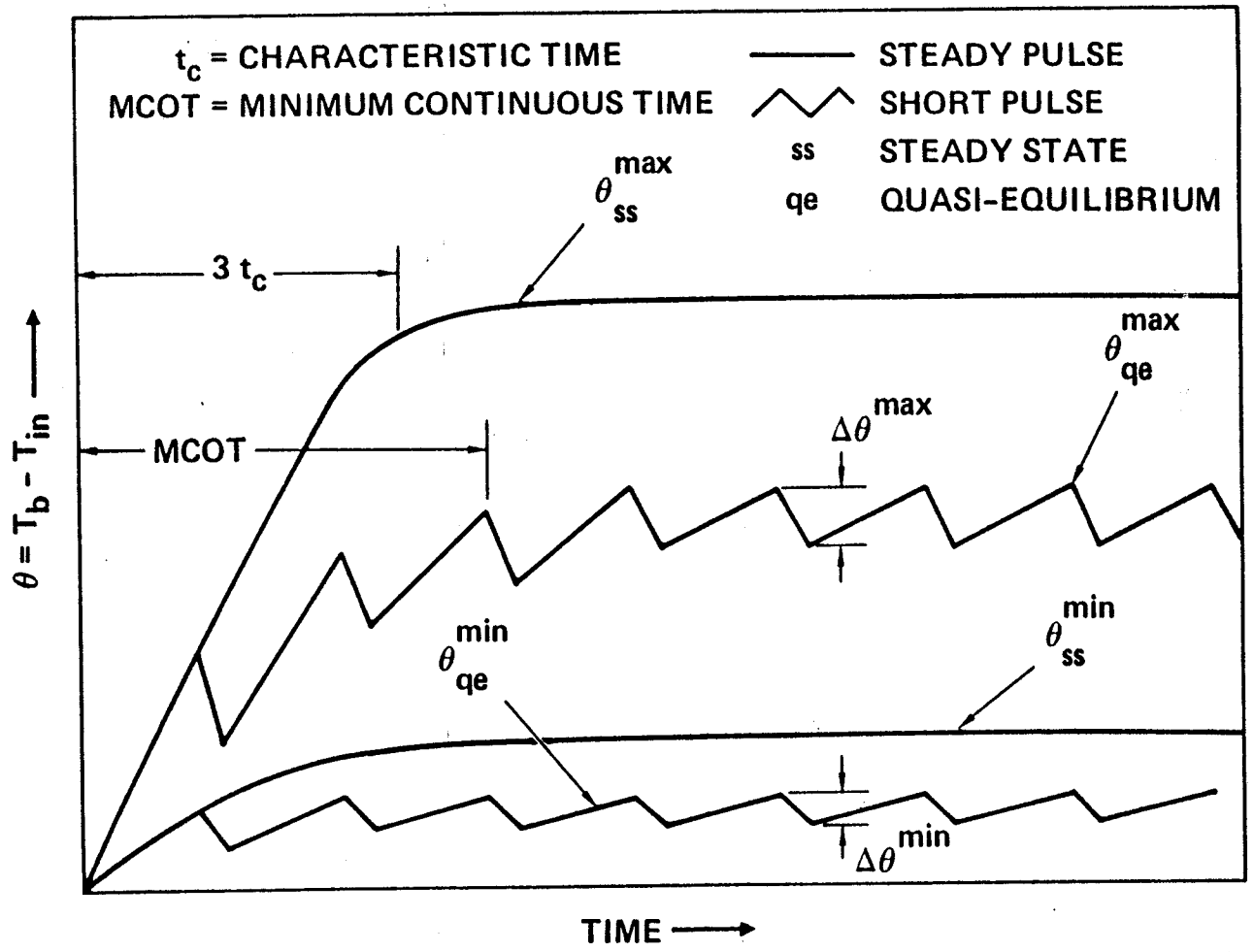
BLANKET MODEL



Pulsing strongly affects the solid breeder temperature distribution.



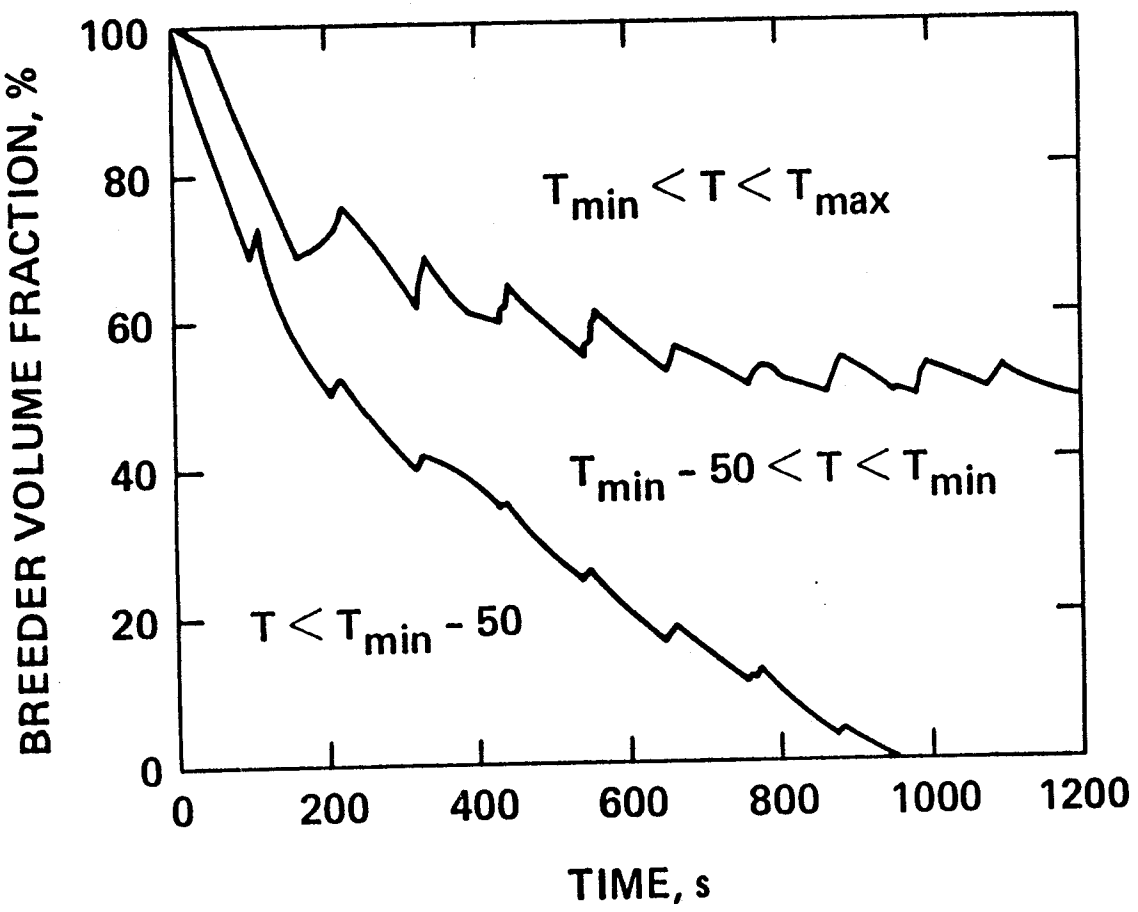




$$t_c = \frac{\rho_b C_{p_b} \delta_b}{h} \frac{\frac{2}{3} + \frac{2k_b}{h\delta_b}}{\frac{2k_b}{h\delta_b}} \qquad \theta_{qe} = \theta_{ss} \frac{1 - e^{-t_b/t_c}}{1 - e^{-(t_b + t_d)/t_c}} \qquad \Delta\theta = \theta_{qe}(1 - e^{-t_d/t_c})$$

PULSING IMPACTS TESTING THE DEPENDENCE OF TRITIUM RECOVERY ON TEMPERATURE

(t_b = 100 s, t_d = 10 s)



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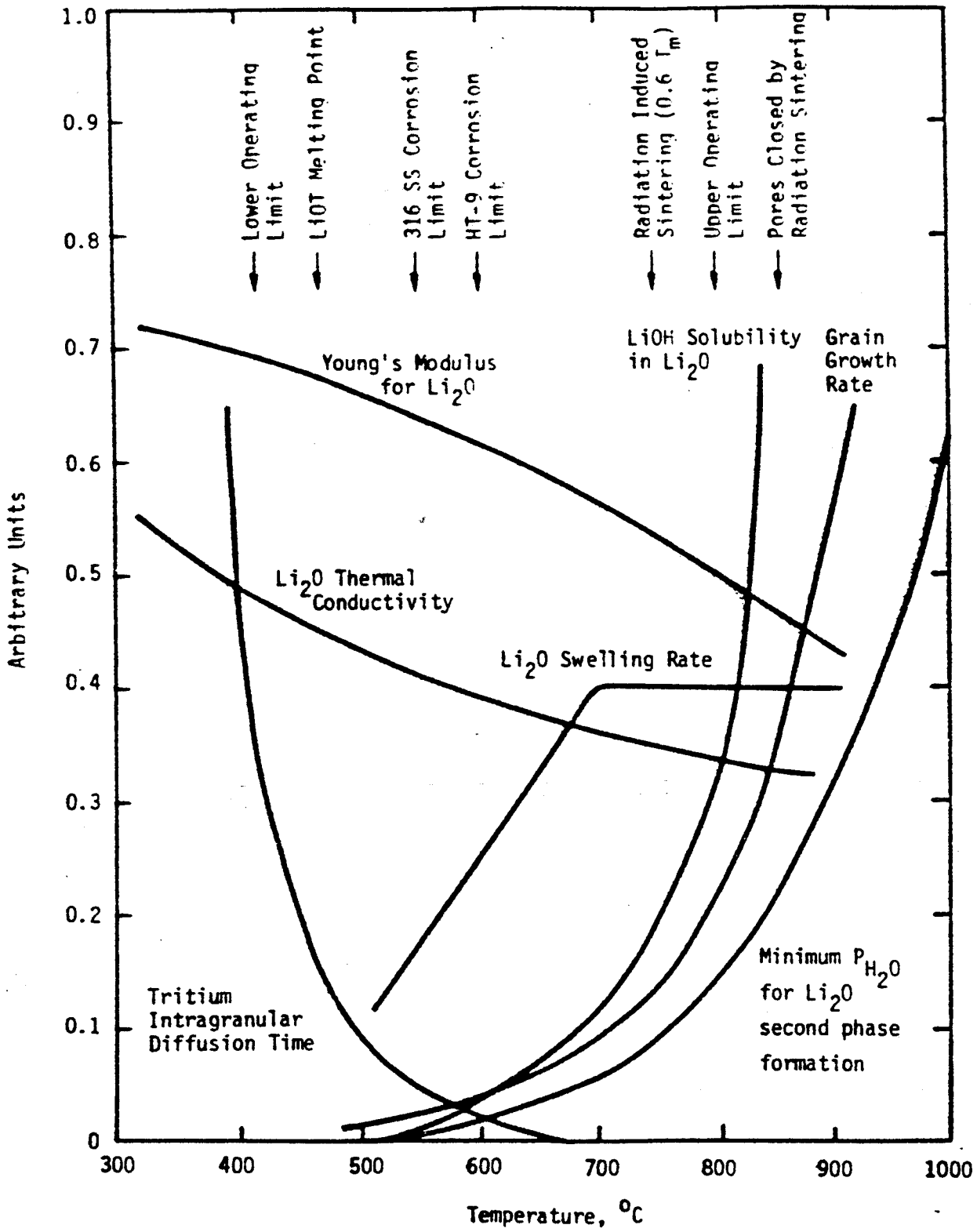
STRONG TEMPERATURE DEPENDENCE OF VARIOUS PHENOMENA



PULSING/STEADY STATE OPERATION

- PLASMA CYCLING MEANS TIME-DEPENDENT CHANGES IN ENVIRONMENTAL CONDITIONS TESTING

  - NUCLEAR (VOLUMETRIC) HEATING
  - SURFACE HEATING
  - POLOIDAL MAGNETIC FIELD
  - TRITIUM PRODUCTION RATE

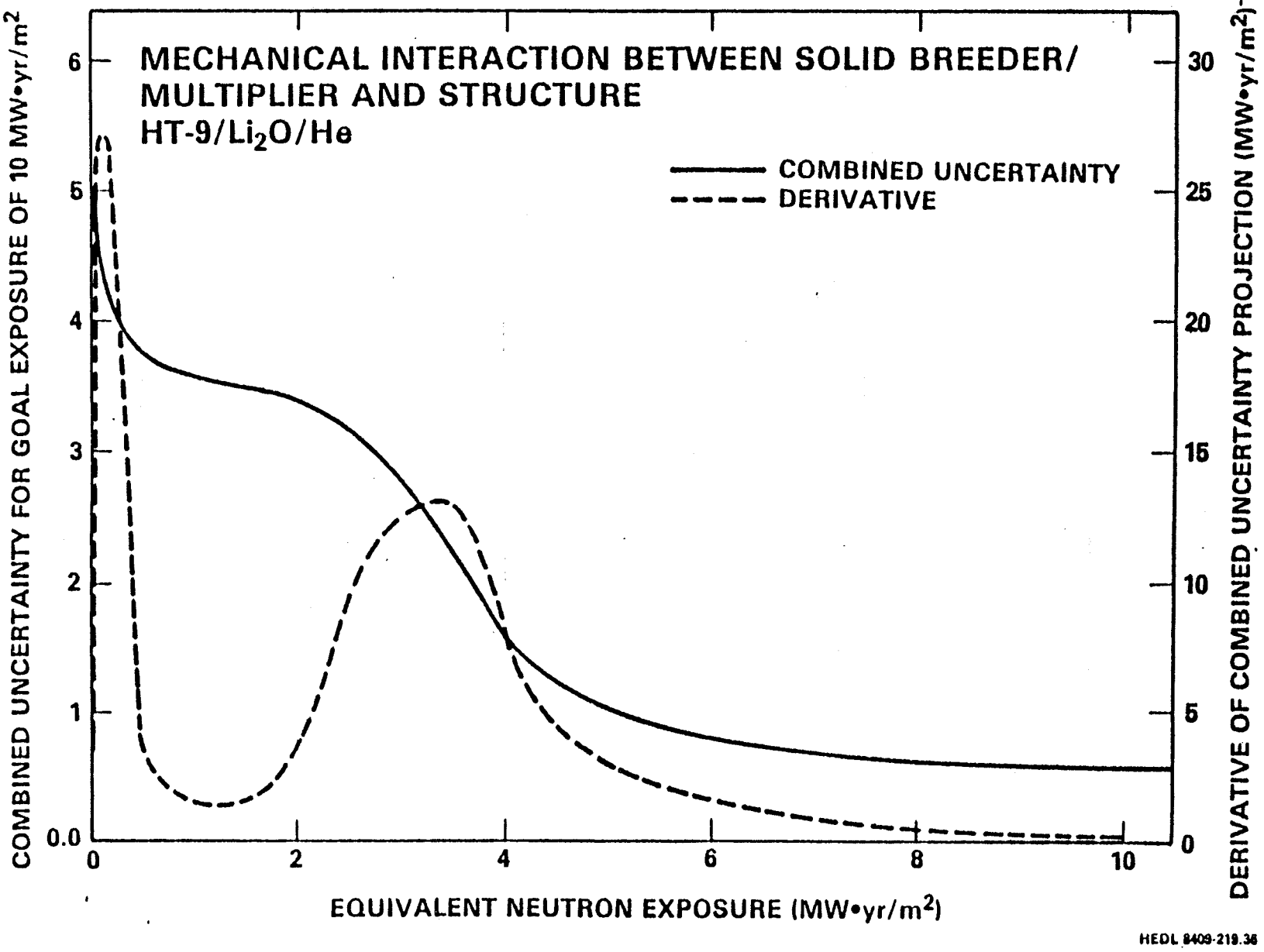
- RESULTS IN TIME-DEPENDENT CHANGES IN RESPONSE OF TEST ELEMENTS

  - EFFECTS CAN BE, IN SOME CASES, MORE DOMINANT THAN THE STEADY STATE EFFECTS FOR WHICH TESTING IS DESIRED
  - EFFECTS CAN COMPLICATE TESTS AND MAKE RESULTS DIFFICULT TO MODEL AND UNDERSTAND

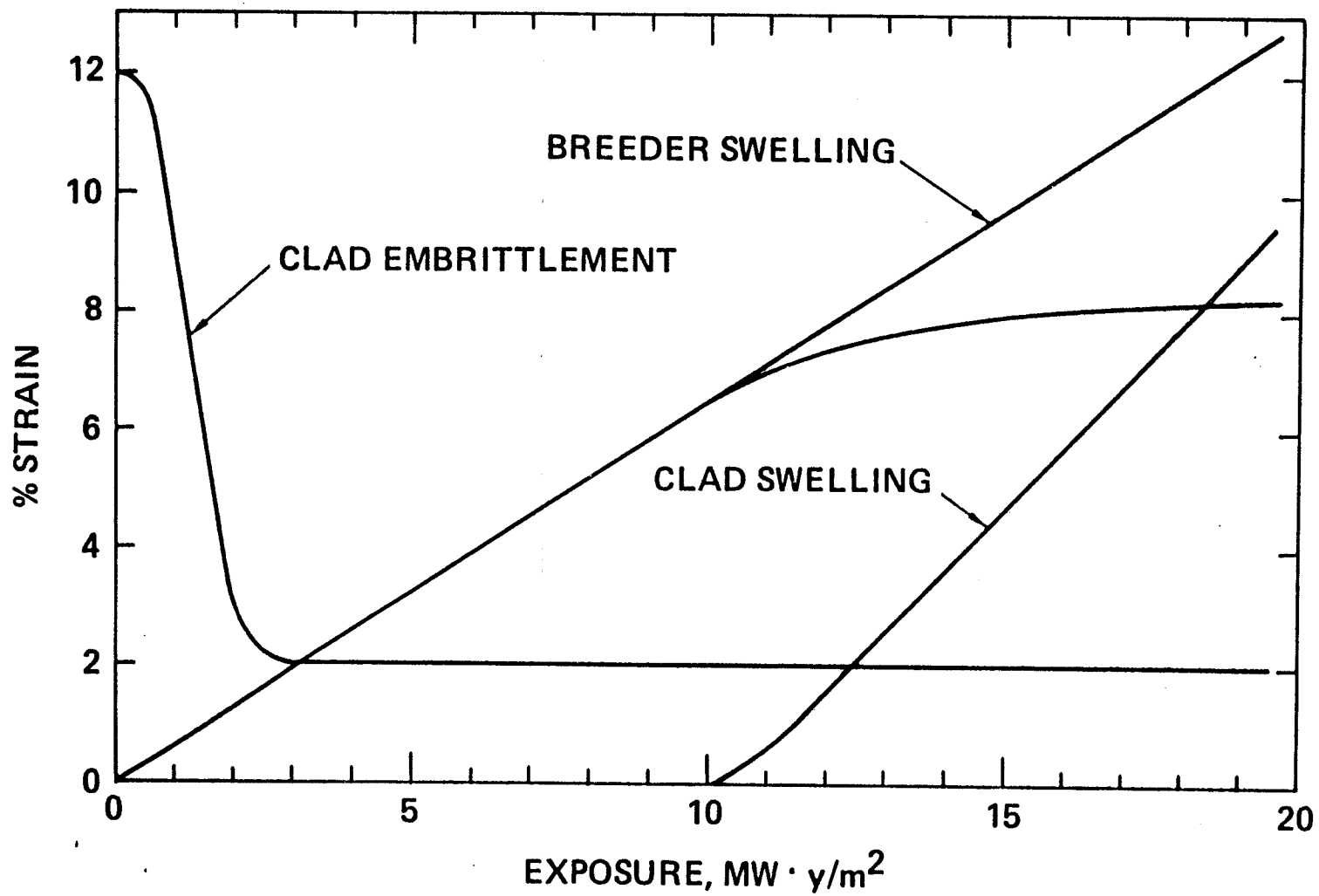
- EXAMPLES OF EFFECTS

  - THERMAL CONDITIONS
  - TRITIUM CONCENTRATION PROFILES
  - FAILURE MODES/FRACTURE METHODS
  - TIME TO REACH EQUILIBRIUM

EXAMPLE OF BENEFIT Vs. FLUENCE



CLAD/BREEDER MECHANICAL INTRACTION
(ESTIMATES FOR Li_2O/HT-9/He)



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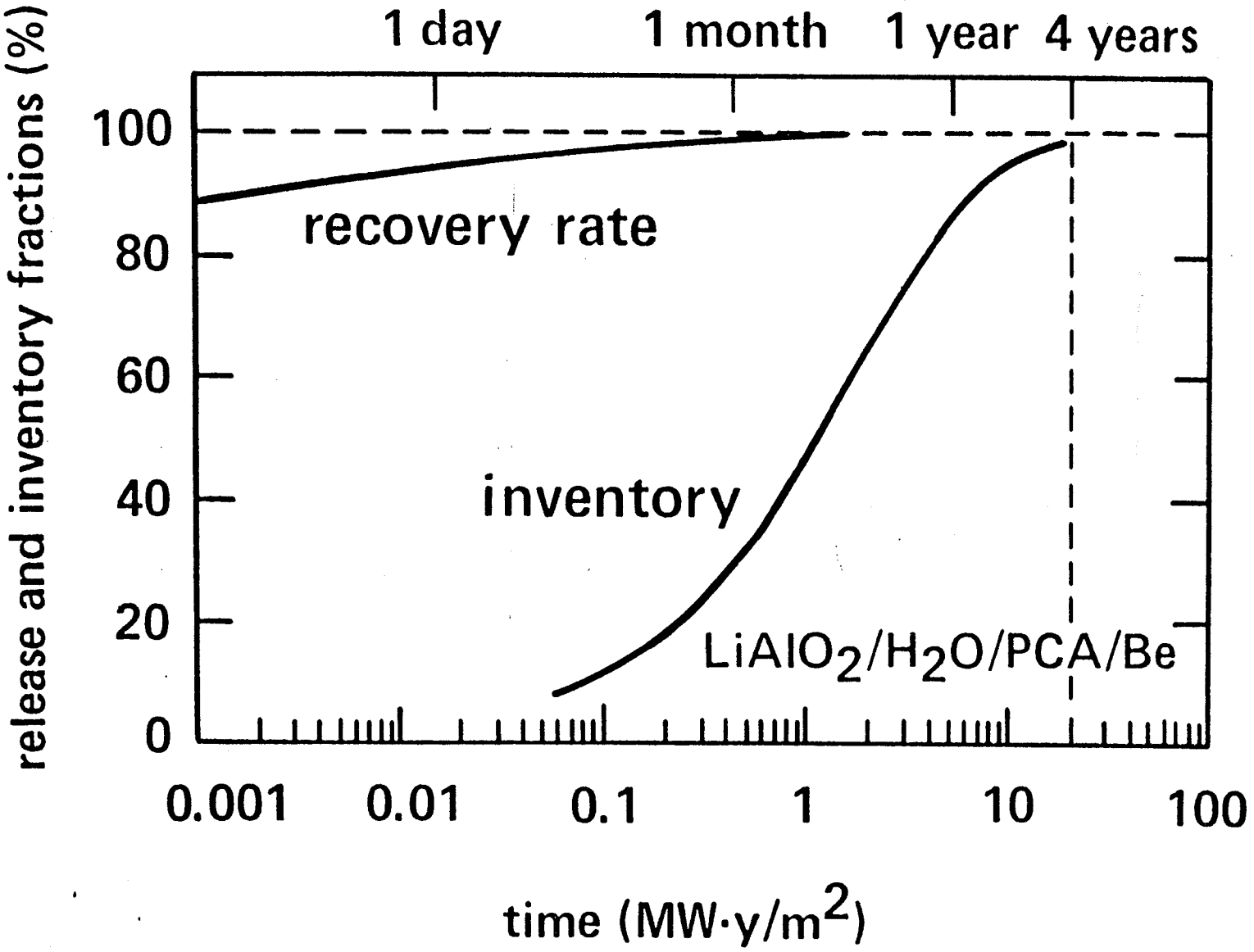
Reaching tritium inventory and recovery equilibrium may require long test times



FUSION NUCLEAR TECHNOLOGY TESTING REQUIREMENTS ON FUSION FACILITY PARAMETERS

Fusion Device Parameter	Minimum	Substantial Behefits
Neutron Wall Load, MW/m^2	1	2 - 3
Surface Heat Load, MW/m^2	0.2	0.5
Plasma Burn Time, s	1000	STEADY STATE
Continuous Operating Time	Days	Weeks
Availability, %	20	50
Fluence, $MW \cdot y/m^2$	1 - 2	2 - 6
Test Port Size, m^2 x m	0.5 x 0.3	1 x 0.5
Total Test Area, m^2	5	10

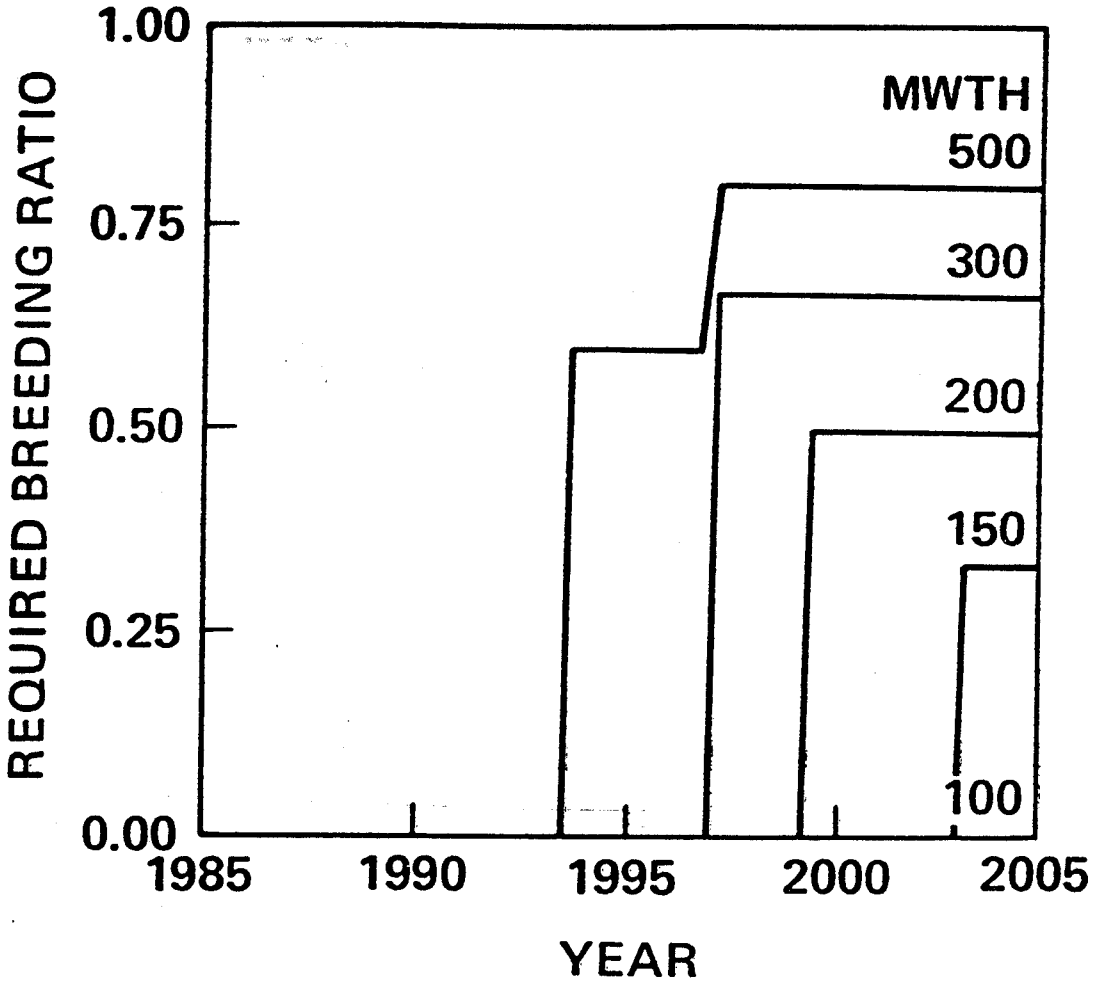
SUMMARY OF TRITIUM SUPPLY

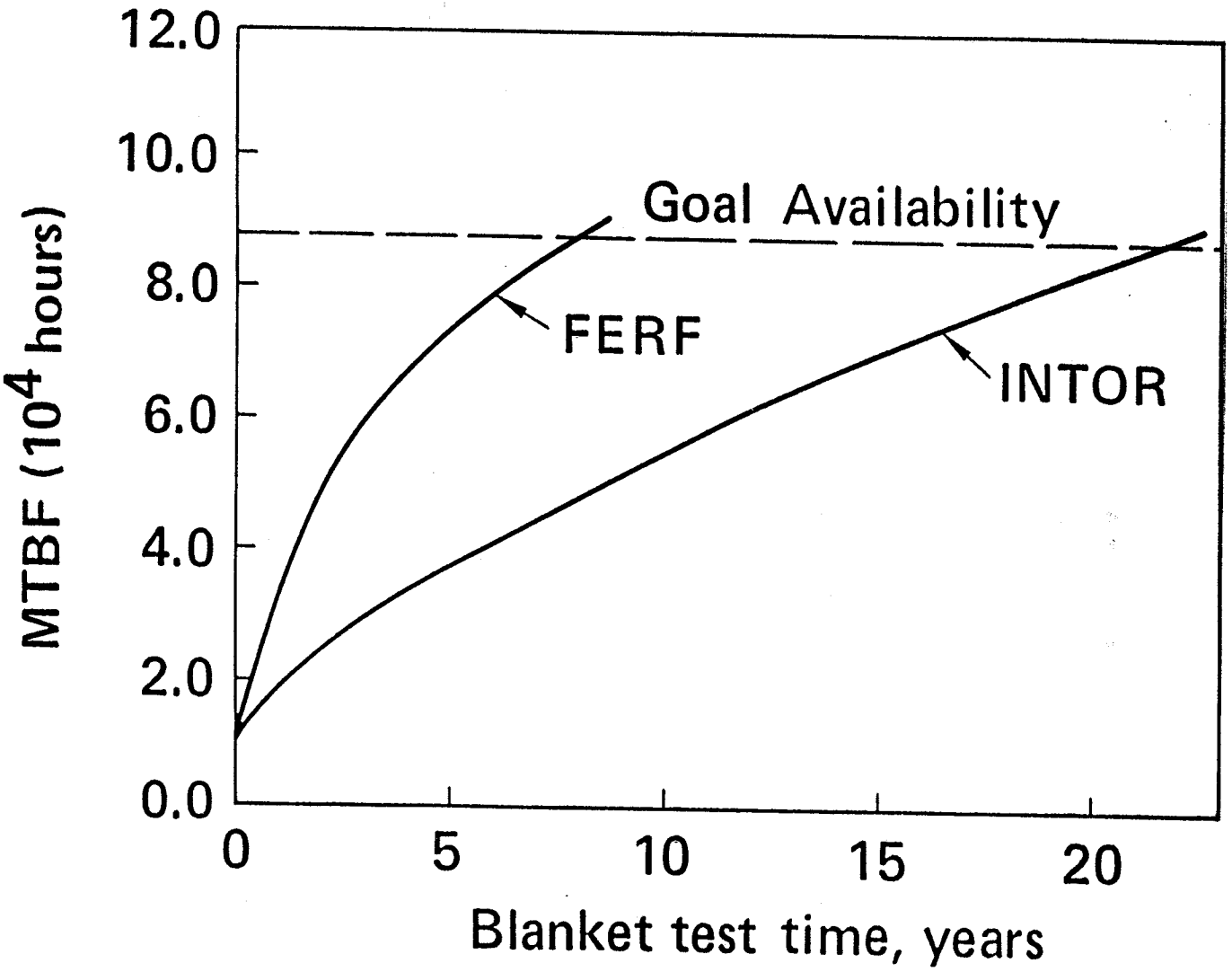
- ATMOSPHERE 1000 KG NOT RECOVERABLE
- US WEAPONS 15 KG/YR (GUESS)
- CANDU

PLANNED ONTARIO HYDRO	2.5 KG/YR
DOUBLE THROUGHPUT	0.2 KG/YR
ENHANCED PRODUCTION (?)	1 KG/YR

- ^{3}HE CONVERSION (N,P) 1 KG/YR

REQUIRED TRITIUM BREEDING RATIO DEPENDS
STRONGLY ON FUSION POWER




12.0
10.0
8.0
6.0
4.0
2.0
0.0
MTBF (10^4 hours)
Goal Availability
FERF
INTOR
0
5
10
15
20
Blanket test time, years

TRITIUM SUPPLY ISSUE

- NUCLEAR TESTING REQUIRES:

  FUSION POWER < 100 MW

- DEVICE POWER DICTATED BY PHYSICS

- APPROACHES TO SOLVING TRITIUM SUPPLY:

  1. REDUCE NEED
     - A. REDUCE POWER : CHALLENGE
     - B. REDUCE TESTING TIME : REDUCES BENEFITS

  2. PROVIDE EXTERNAL SUPPLY
     - ONLY WEAPON SUPPLY BEYOND CANDU
     - PROBLEMATIC FOR FUSION?

  3. BREEDING BLANKET IN ETR
     - RELIABILITY PROBLEMS
     - REQUIRES ACCELERATED BLANKET R&D

RECOMMEND: CAREFUL ANALYSIS BEFORE ETR DESIGN IN SELECTED

COMMENTS ON ONGOING INTERNATIONAL DISCUSSION ON NUCLEAR TECHNOLOGY

- FINESSE International Workshop (March 1985)
  - Agreement on Issues
  - Some Differences in Priorities on Blanket Types

- TWP (FNT, March 1986)
  - Agreement on Issues
  - Differences between NET, FER
  - Recommend Actions to Implement

- IAEA/Yalta (June 1986)
  - Agreement on Issues
  - Recommend Actions

- Ongoing Bilaterals

  E.G., Fusion Neutronics (US/JAERI)

SUMMARY OBSERVATIONS

- NON-FUSION TESTING MUST START NOW TO CONSTRUCT TEST MODULES BY YEAR 2000

- VERIFICATION OF NUCLEAR TECHNOLOGY CONCEPTS REQUIRES FUSION TESTING

  - SUCH VERIFICATION IS NEEDED AT THE EARLIEST OPPORTUNITY (~ YEAR 2000-2010)

  - DEVELOPMENT PHASE BEGINS AFTER CONCEPT VERIFICATION, WILL REQUIRE LONG TIME

- NUCLEAR TECHNOLOGY TESTING SHOULD BE A PRIMARY ELEMENT IN ETR MISSION

  (IF NOT: WHERE ELSE? WHEN?)

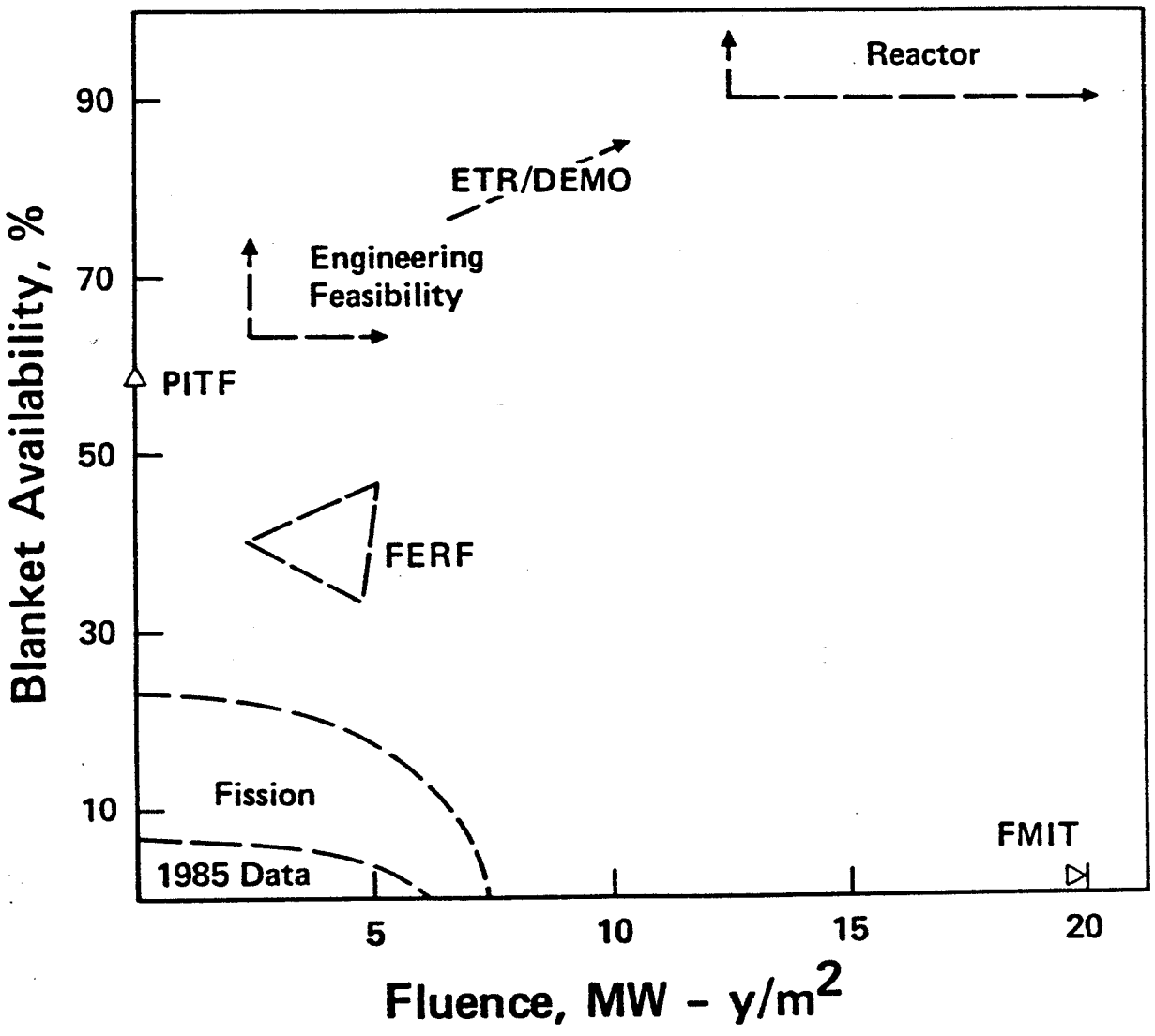
SUMMARY OBSERVATIONS (CONT'D.)

- FNT IMPOSES IMPORTANT REQUIREMENTS ON MAJOR PARAMETERS AND DESIGN OF ETR. ENGINEERING SCALING LAWS HAVE BEEN DEVELOPED IN FINESSE TO PERMIT TRADE-OFFS

- TRITIUM SUPPLY ISSUE REQUIRES CAREFUL ANALYSIS
  - EXTERNAL SUPPLY
  - BREEDING BLANKET

- EARLY STAGES OF ETR STUDY SHOULD FOCUS ON MISSION, TRADE-OFFS

Obtaining Availability and Fluence Data For Blanket Is Most Difficult



FINESSE