ETR: FUSION NUCLEAR TECHNOLOGY TESTING REQUIREMENTS AND ENGINEERING SCALING

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Fusion Nuclear Technology

- Top Level Issues

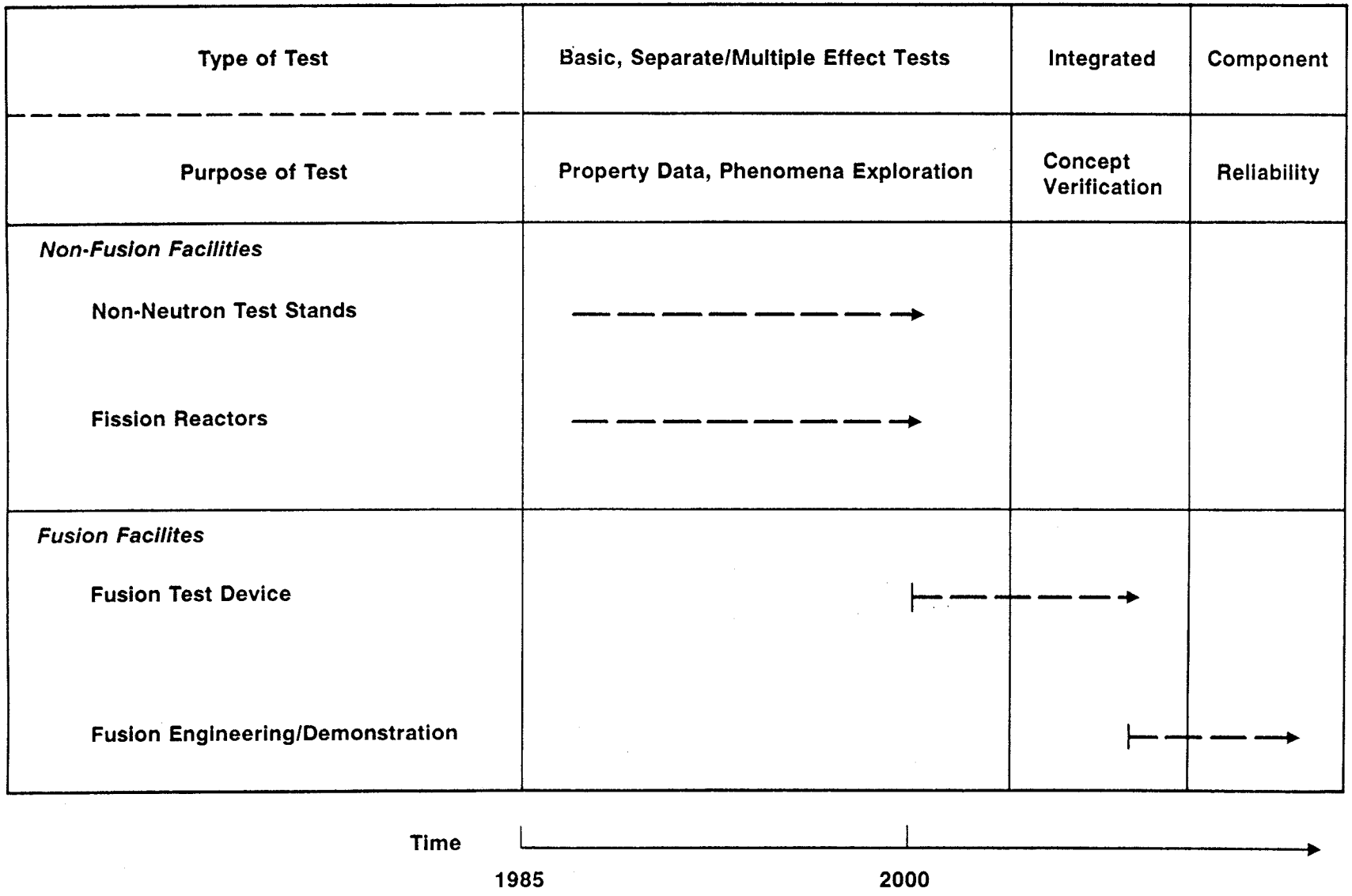
  - Fuel Self-Sufficiency

  - Efficient, Reliable and Safe ENERGY CONVERSION and Use

  - Radiation Protection of Components, Personnel

Suggested ETR Nuclear Mission

Demonstrate the performance of nuclear components and tritium self-sufficiency at reactor-relevant conditions


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

FNT R&D Framework

- Non-Fusion Testing (+ Model Development)

  Non-Neutron Test Stands
  Fission Reactors
  14 MeV Neutron Sources

  - Support Conceptual Design Screening and Evolution

  - Initial Validation of Theory and Models

  - Provide Data for Design, Construction and Operation of Test Elements and Modules in ETR

- Fusion Testing

  - Verify Theory/Models, Design Codes

  - Data for Concept Selection

  - Demonstrate Performance Level Extrapolatable to Reactor (Quantify?)

  - Demonstrate Adequate Level of Reliability (Quantify?)

FNT Testing Requirements

- **Major Parameters of Device**
  - Device Cost Drivers
  - Major Impact on Test Usefulness

- **Engineering Design of Device**

  E.G.,

  - Access to Place, Remove Test Elements
  - Provision for Ancillary Equipment
  - Accommodation of Failures in Test Elements

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

MAJOR PARAMETERS

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

FNT Recommended Parameters

Parameters	ETR		Reference Reactor
	Minimum	Desirable	
Neutron Wall Load, MW/m^2	1	2 - 3	5
Surface Heat Load, MW/m^2	0.2	0.5	1
Plasma Burn Time, s	500	> 1000[A]	Steady
Magnetic Field,[B] T	3	5	7
Continuous Operating Time	Days	Weeks	Months
Availability, %	20	30 - 50	70
Fluence,[B] $MW \cdot y/m^2$	1 - 2	3 - 6	15 - 20
Test Port Size, m^2 x m	0.5 x 0.3	1 x 0.5	
Total Test Area, m^2	5	10 - 20	

[A]Steady-state preferred

[B]At test article

How Good Are Present Designs?

	Recommended		TIBER-II	NET
	Minimum	Desirable		
Neutron Wall Load, MW/m^2	1	2 - 3	2/1.3	1
Plasma Burn Time, s	500	> 1000[A]	Steady	600
Magnetic Field,[A] T	3	5	4.5	3.9
Availability, %	20	30 - 50	30	25
Fluence, $MW \cdot y/m^2$	1 - 2[B]	3 - 6[B]	3[C]	0.8[C]
Fusion Power, MW	< 50		300	600

[A]At outboard region

[B]At test module

[C]Device lifetime

Observations

- Present TIBER-II Design Reasonably Satisfies Most of the Presently Recommended FNT Values for Device Major Parameters

- From FNT Standpoint, TIBER-II is Preferable to NET in the Following Areas:

  Burn time

  Fluence

  Wall Load

- Areas Requiring Analysis/Review and Possible Change (if necessary) in TIBER:

  - Space available for testing (area at first wall adequate) depth; accommodation of manifolds, feed lines, etc.

  - Ease of insertion, replacement

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

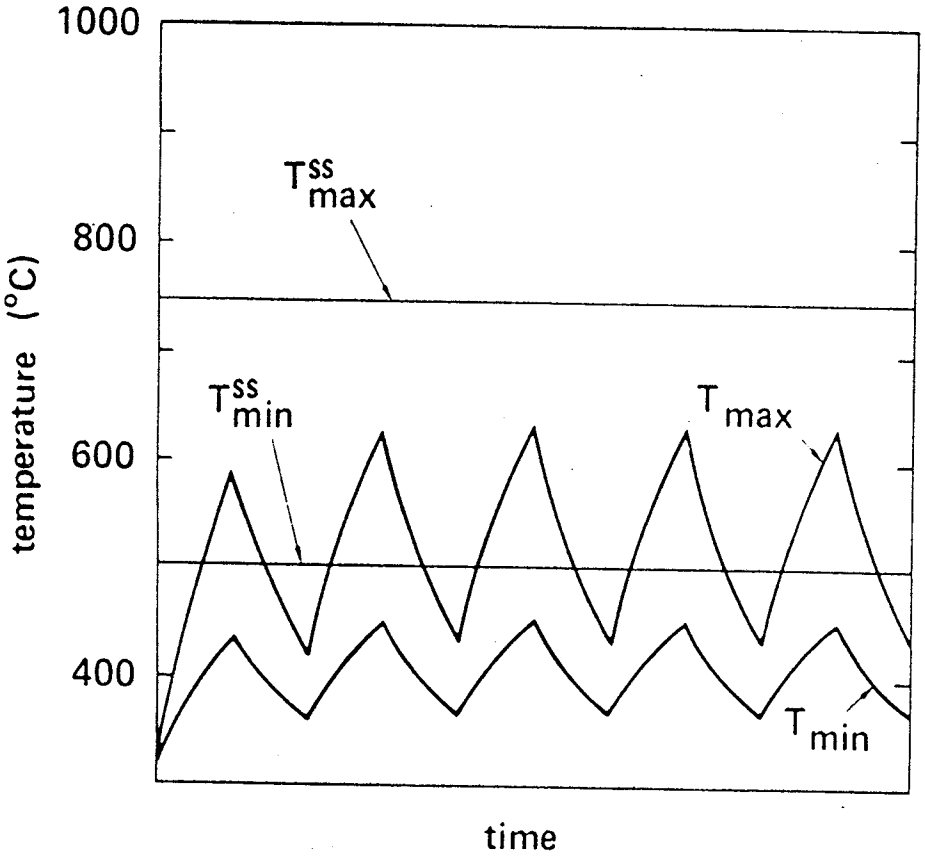
- RESULTS IN TIME-DEPENDENT CHANGES IN RESPONSE OF TEST ELEMENTS

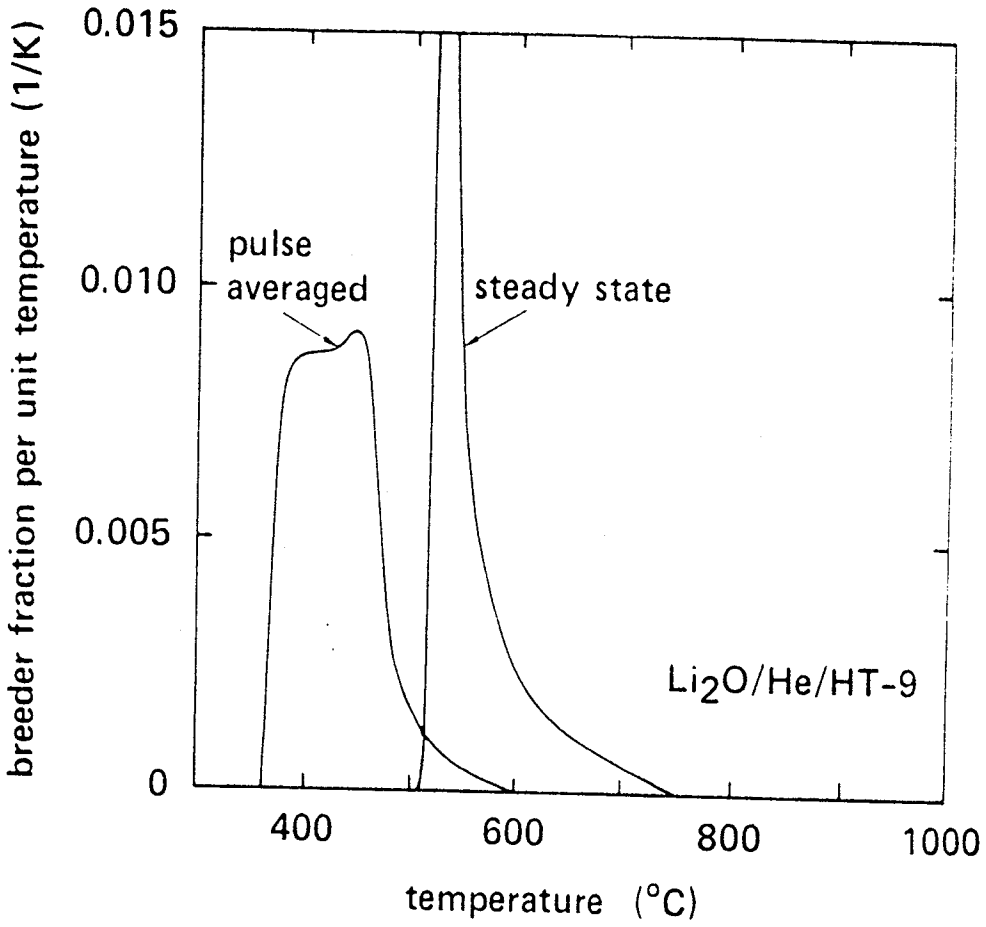
  - EFFECTS CAN BE, IN SOME CASES, MORE DOMINANT THAN THE STEADY STATE EFFECTS FOR WHICH TESTING IS DESIRED
  - EFFECTS CAN COMPLICATE TESTS AND MAKE RESULTS DIFFICULT TO MODEL AND UNDERSTAND

- EXAMPLES OF EFFECTS

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

Pulsing strongly affects the solid breeder temperature distribution.





Fluence Requirements

- Fluence Achievable in Test Module is Considerably Less (factor of 2 or more) Than the Test Device "Lifetime Fluence"

  - Attenuation in device first wall and other in-vessel components reduces flux at test modules
    (Most test modules must be isolated from the device "vacuum")

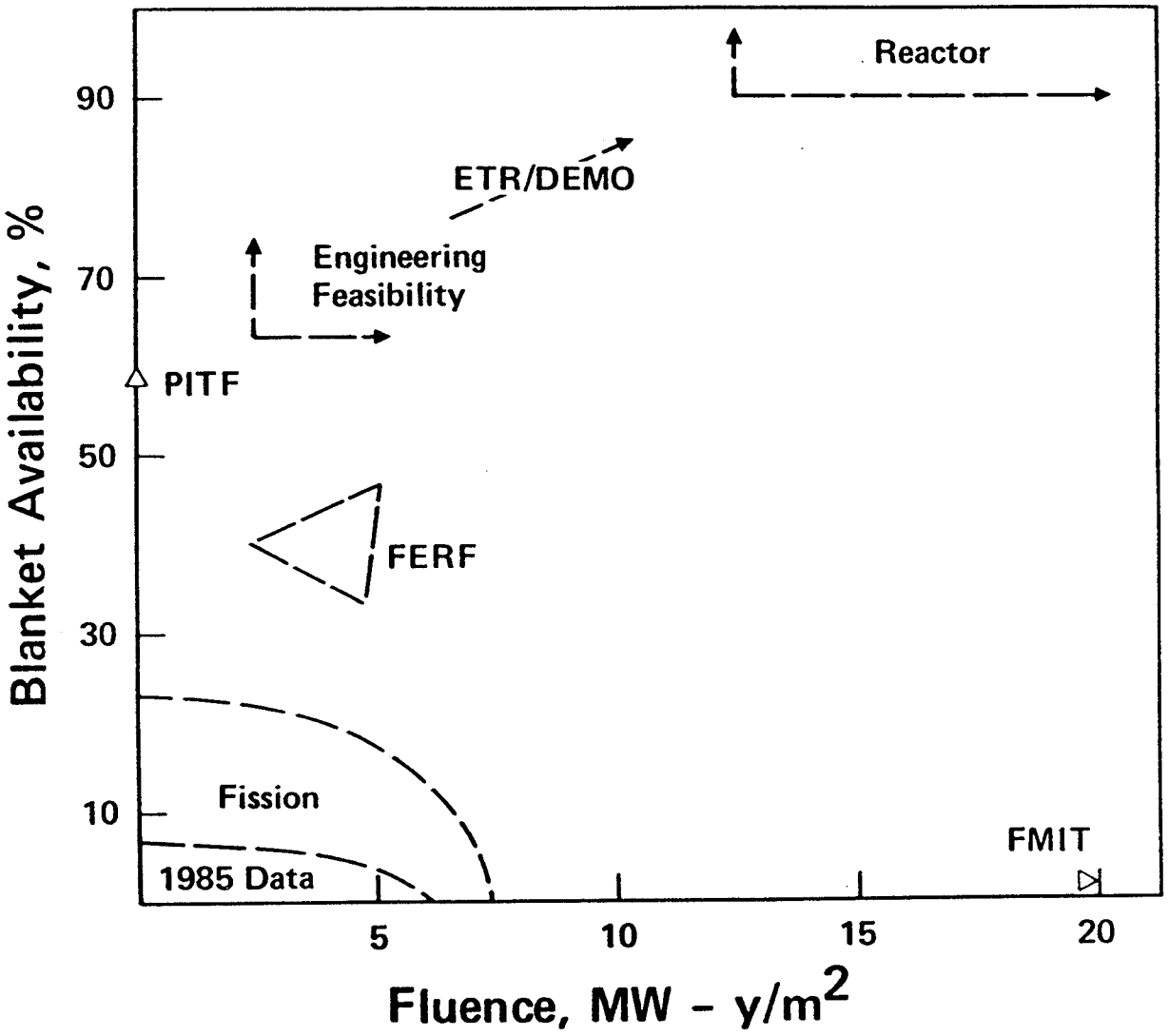
  - There is inevitably a long period of fail/replace/fix for test module
    (Remember: first time to test in fusion environment)

- The Level of Fluence Recommended by FNT Should be Achieved at the Test Module

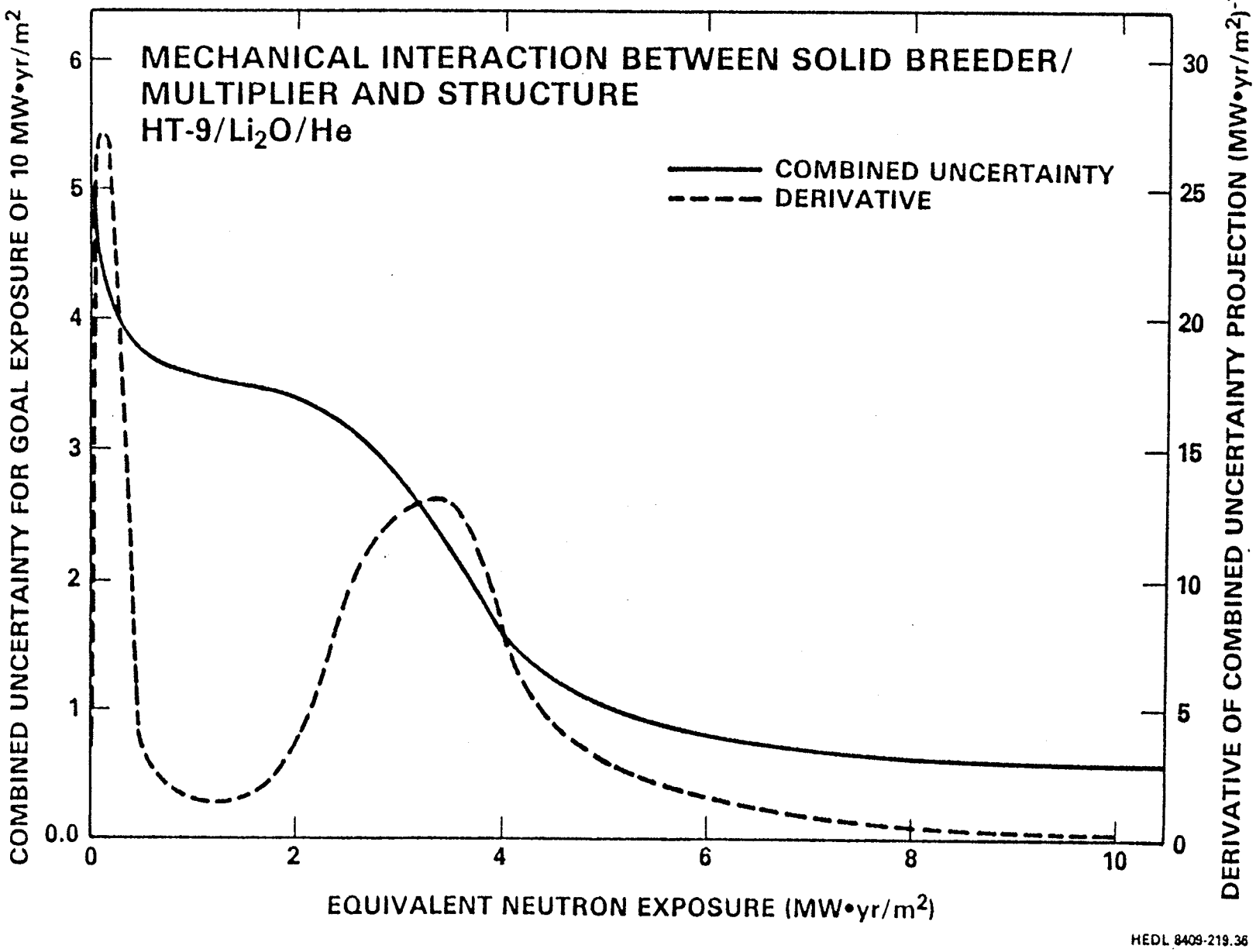
- Recommendation:

  TIBER-II fluence should be enhanced or at least maintained at the present 3 $MW \cdot Y/M^2$.
  (Do <u>not</u> reduce)

Obtaining Availability and Fluence Data For Blanket Is Most Difficult



EXAMPLE OF BENEFIT Vs. FLUENCE



Reaching tritium inventory and recovery equilibrium may require long test times