MOTIVATION FOR STEADY STATE OPERATION AS DESIGN BASIS FOR ETR

MOHAMED A. ABDOU
UCLA

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MOTIVATION FOR STEADY STATE OPERATION AS DESIGN BASIS FOR ETR

1. DEMONSTRATION OF STEADY STATE PLASMA OPERATION IS NECESSARY IN EXPLORING THE LONG-TERM REACTOR POTENTIAL OF THE CONFINEMENT CONCEPT.

2. STEADY STATE OPERATION SHOULD REDUCE THE FAILURE RATE AND IMPROVE THE RELIABILITY OF MANY OF THE BASIC ETR COMPONENTS. (EXTENDS ACHIEVABLE LIFETIME/FLUENCE).

3. STEADY STATE OPERATION WILL SUBSTANTIALLY IMPROVE THE USEFULNESS OF NUCLEAR TECHNOLOGY TESTING IN ETR

EFFECTS OF PULSING/STEADY STATE OPERATION ON NUCLEAR TECHNOLOGY TESTING

- PLASMA CYCLING MEANS TIME-DEPENDENT CHANGES IN ENVIRONMENTAL CONDITIONS FOR TESTING
  - NUCLEAR (VOLUMETRIC) HEATING
  - SURFACE HEATING
  - POLOIDAL MAGNETIC FIELD
  - TRITIUM PRODUCTION RATE

- RESULT IN TIME-DEPENDENT CHANGES AND EFFECTS IN RESPONSE OF TEST ELEMENTS THAT:
  - CAN BE MORE DOMINANT THAT THE STEAD-STATE EFFECTS FOR WHICH TESTING IS DESIRED
  - CAN COMPLICATE TESTS AND MAKE RESULTS DIFFICULT TO MODEL AND UNDERSTAND

- EXAMPLES OF EFFECTS
  - THERMAL CONDITIONS
  - TRITIUM CONCENTRATION PROFILES
  - FAILURE MODES/FRACTURE MECHANICS
  - TIME TO REACH EQUILIBRIUM

$$F = F_0 (1 - e^{-T/\tau})$$

Plasma Burn Time $> 3\tau$ (95%)

<u>Time Constants</u>

Fast

Seconds

Flow Processes

Minutes

Thermal Processes

Hours

Tritium Processes
Material Interactions

Days

↓

Slow

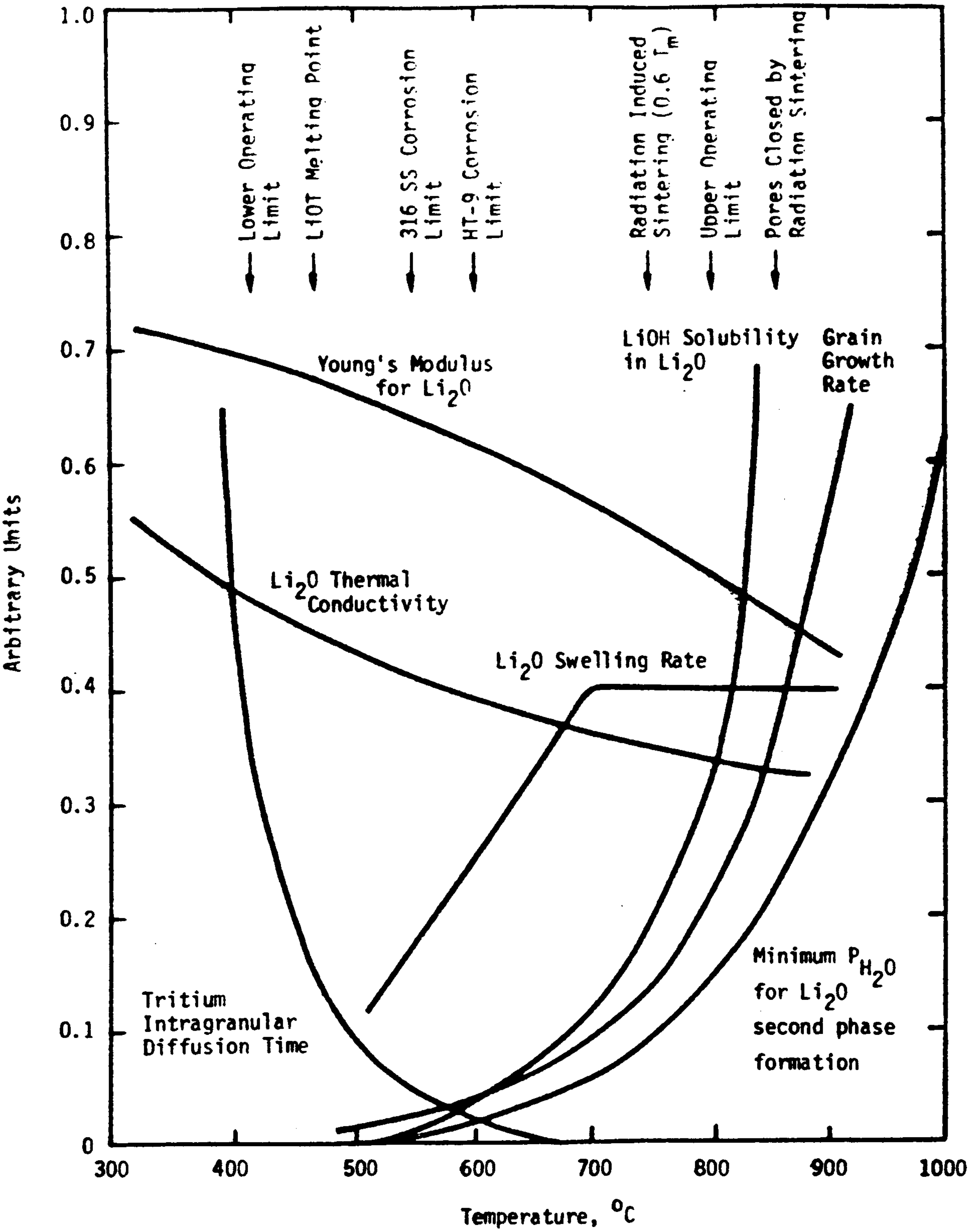
<u>Threshold Effects</u>

e.g., Ferritic DBTT (Temp. falling below T_D)
High Cycle Fatigue
Temperature-Dependent Chemical Reactions

<u>Mixed (Interrelated) Effects</u>

- Corrosion and Redeposition
  Slow process; but instantaneous rate is temperature dependent
- Tritium Processes
  Slow process; but time constant is temperature dependent

STRONG TEMPERATURE DEPENDENCE OF VARIOUS PHENOMENA



Pulsing strongly affects the solid breeder temperature distribution.

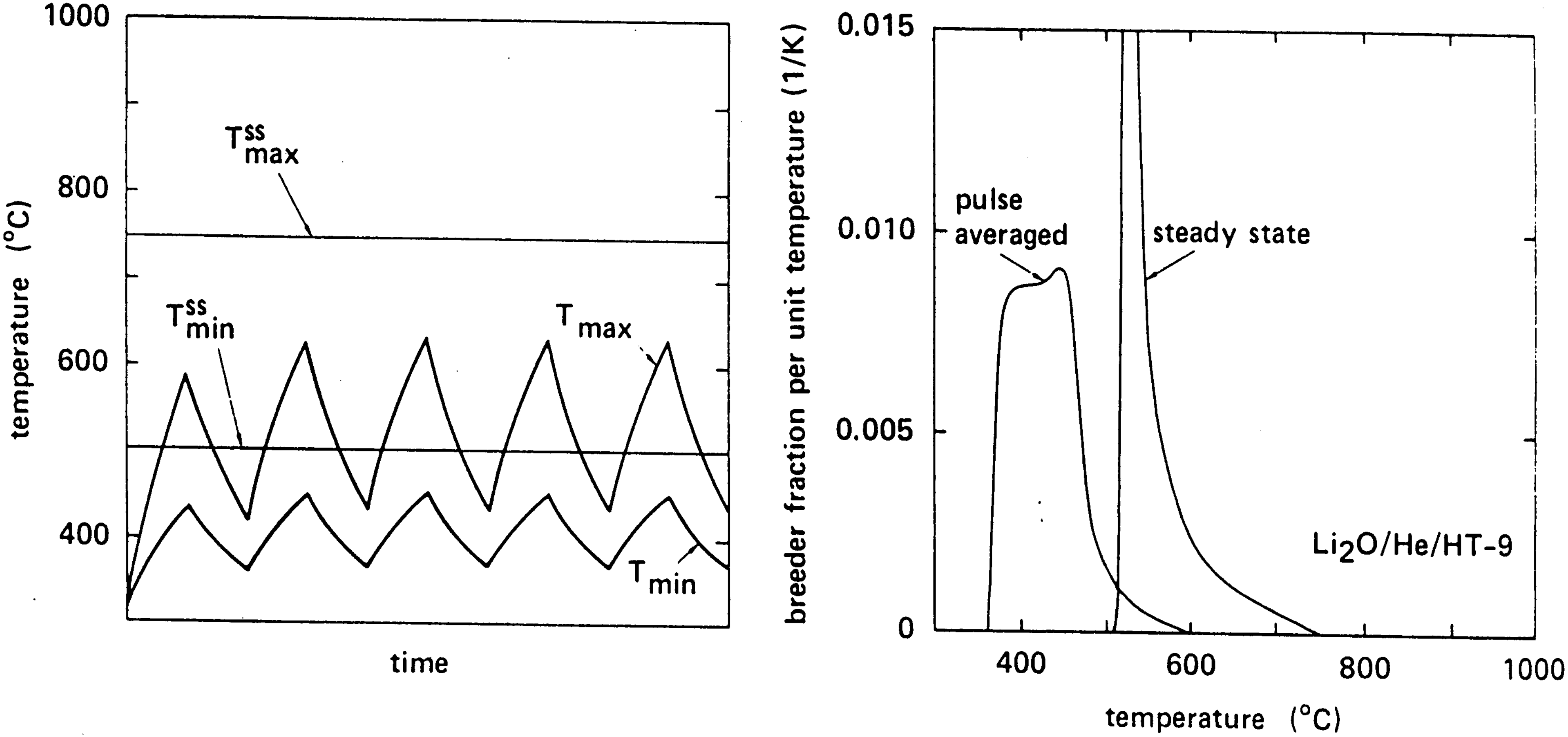


Table 1.3-5 Approximate Characteristic Time Constants in Representative Blankets

Flow	
Solid Breeder Purge Residence	6 s
Liquid Breeder Coolant Residence	30 s
Liquid Breeder Cooling Circuit Transit	60 s
Thermal	
Structure Conduction	4 s
Structure Bulk Temperature Rise	20 s
Liquid Breeder Conduction (Li)	30 s
Solid Breeder Conduction (½-cm plate)	50-100 s
(1-cm plate)	200-400 s
Coolant Bulk Temperature Rise (200 K at 4000 MW_t)	
Li	100 s
LiPb	1500 s
Solid Breeder Bulk Temperature Rise ($LiAlO_2$, 300-1000°C)	
Front (Near Plasma)	120 s
Back (Away from Plasma)	1800 s
Material Interactions	
Dissolution of Fe in Li (500°C)	40 days
Tritium	
Diffusion Through Solid Breeder ($LiAlO_2$, 0.2 μm grains)	
1250 K	8-200 s
750 K	13-300 hours
Surface Adsorption ($LiAlO_2$)	3-10 hours
Diffusion Through SS316	
800 K	10 days
600 K	150 days
Inventory in Solid Breeder (Water-Cooled $LiAlO_2$, 0.2 μm grains)	
67% of equilibrium	6 months
99% of equilibrium	4 years
Inventory in Liquid Breeder	
LiPb	30 minutes
Li	30 days

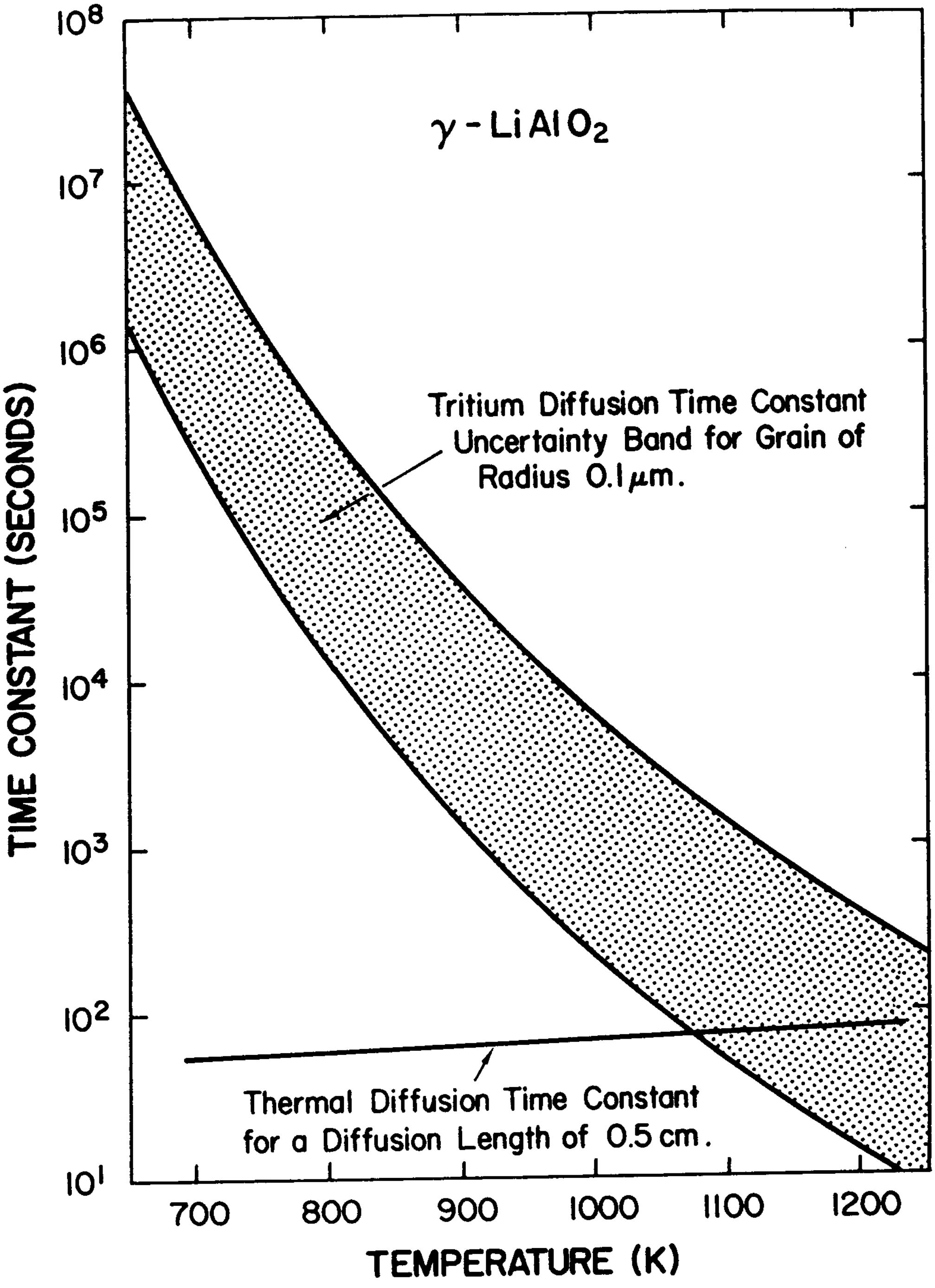


Figure 1.3-2 Tritium and thermal diffusion time constants as a function of temperature (γ-LiAlO$_2$)

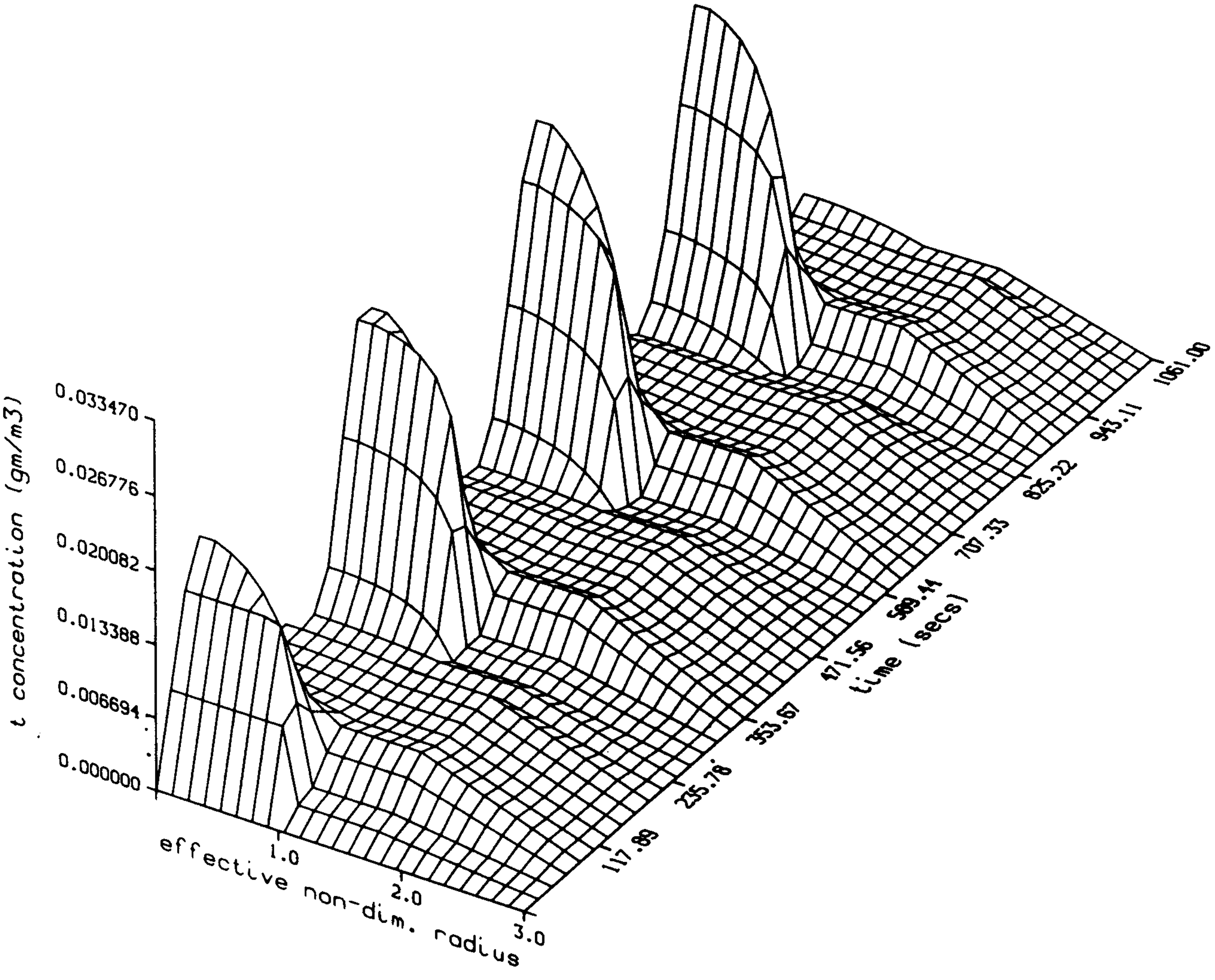


Figure 1.3-3 $LiAlO_2$ diffusive tritium concentration profiles with 200-s burn, 50-s dwell, and 12-s ramp times (microscopic calculation)

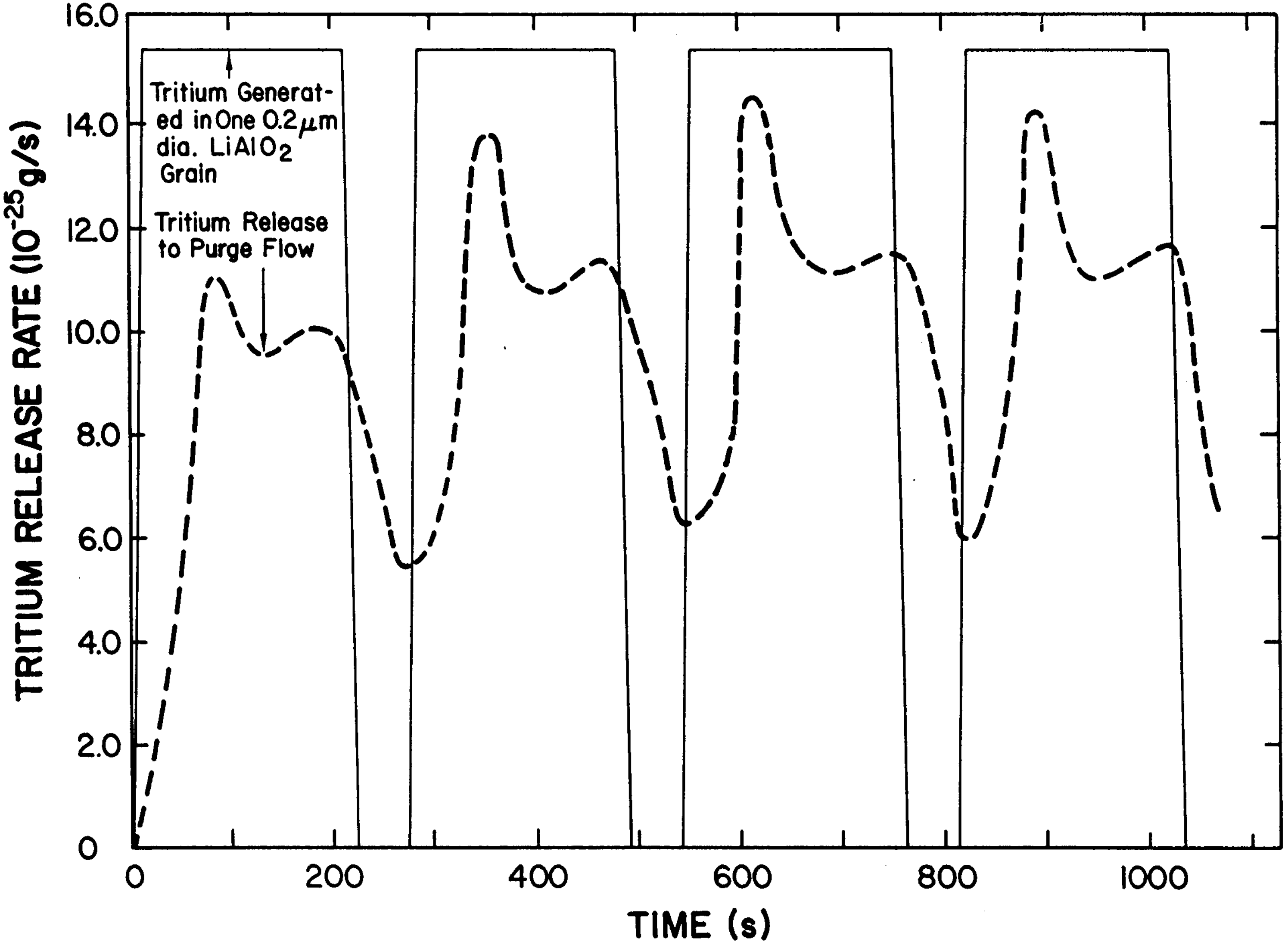
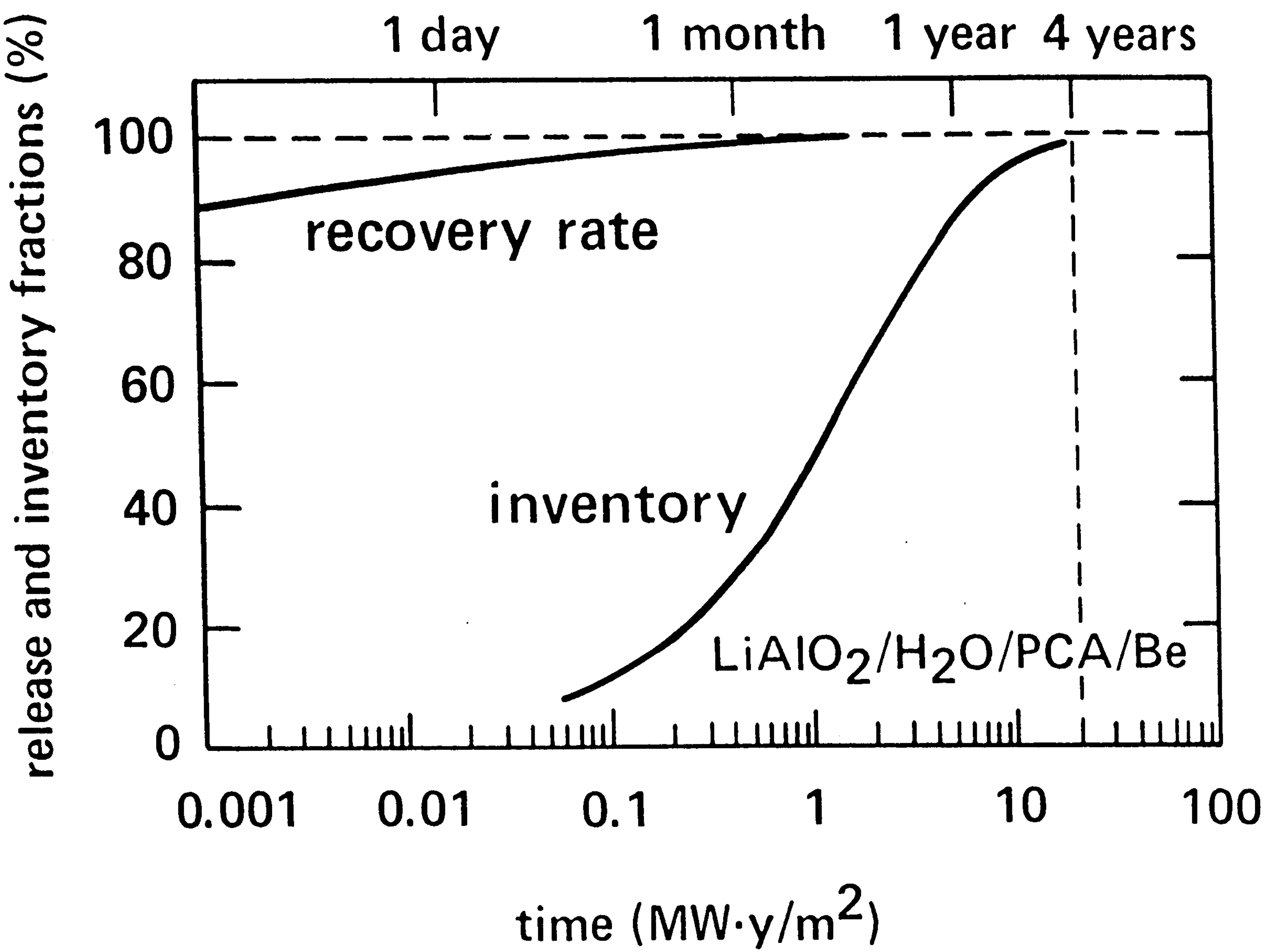


Figure 1.3-4 Transient tritium release rate from 0.2 μm grain $LiAlO_2$ (for 200-s burn, 50-s dwell, and 12-s ramp times)

Reaching tritium inventory and recovery equilibrium may require long test times



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, $m^2 \times m$	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*	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

*STEADY-STATE PREFERRED