Required Tritium Breeding Ratio of ITER

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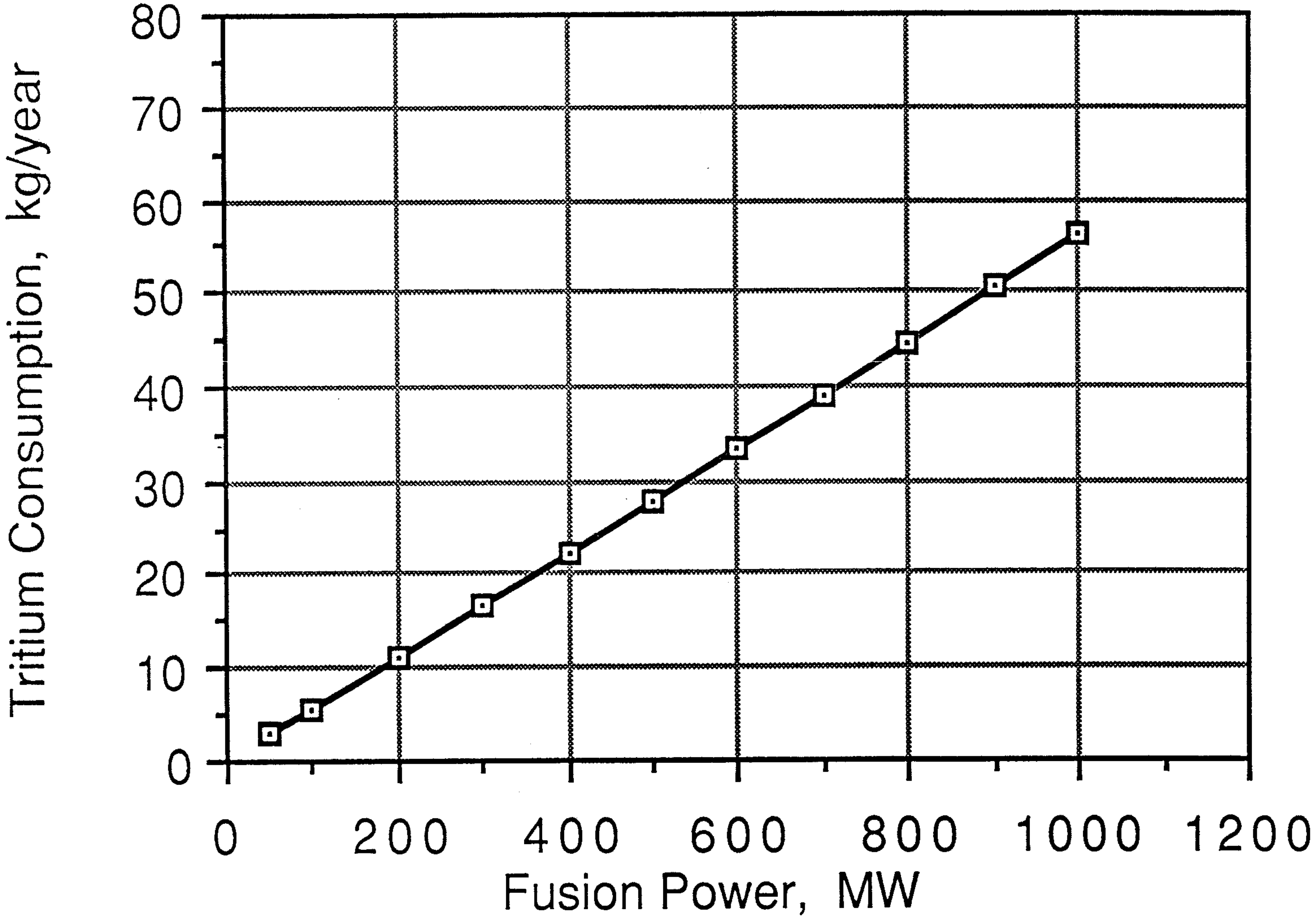
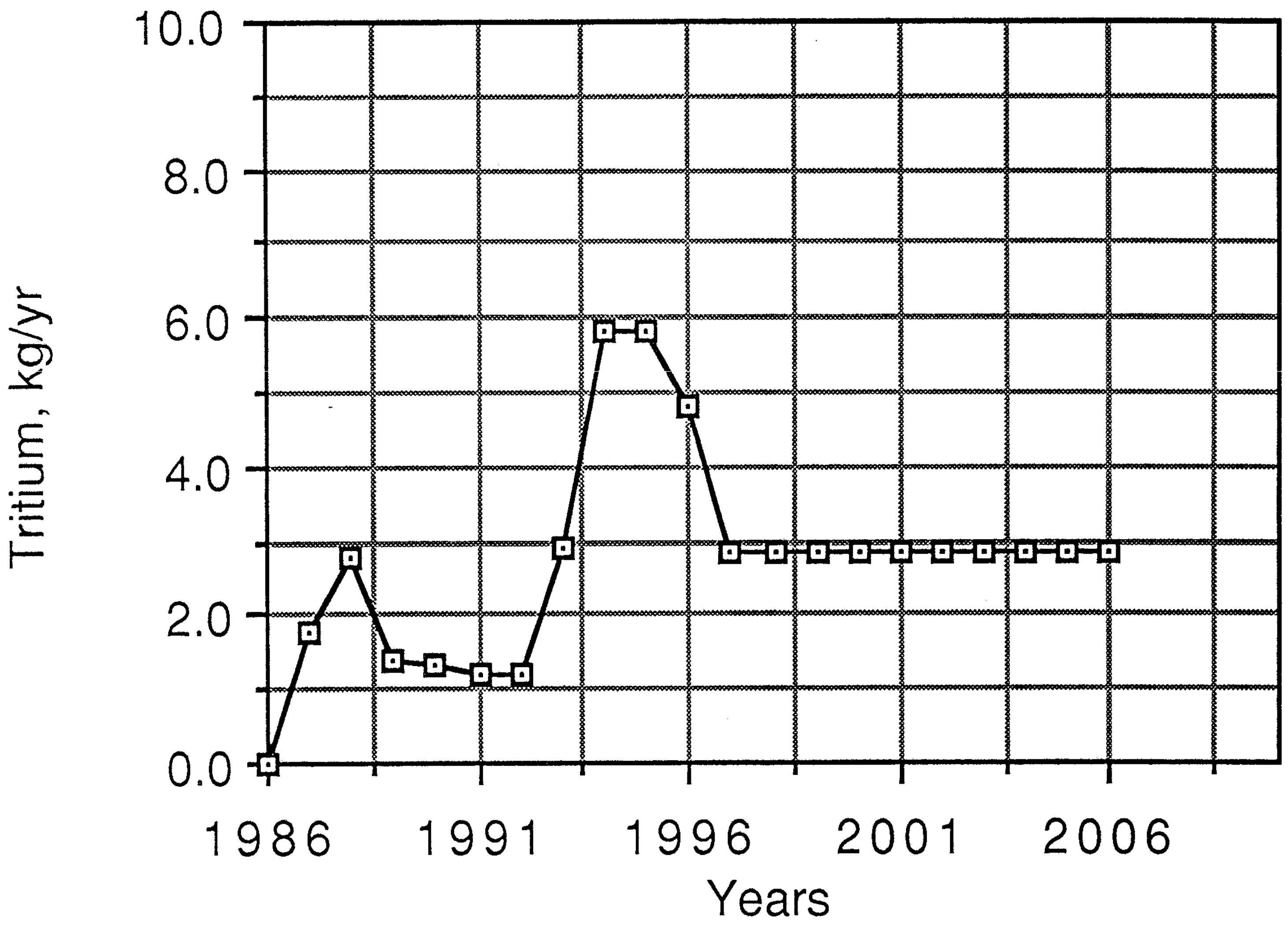
TRITIUM REQUIREMENT PER FULL POWER YEAR



ANNUAL TRITIUM SUPPLY FROM ONTARIO HYDRO TRFS



Drolet et.al.
Nucl. Tech./Fus.
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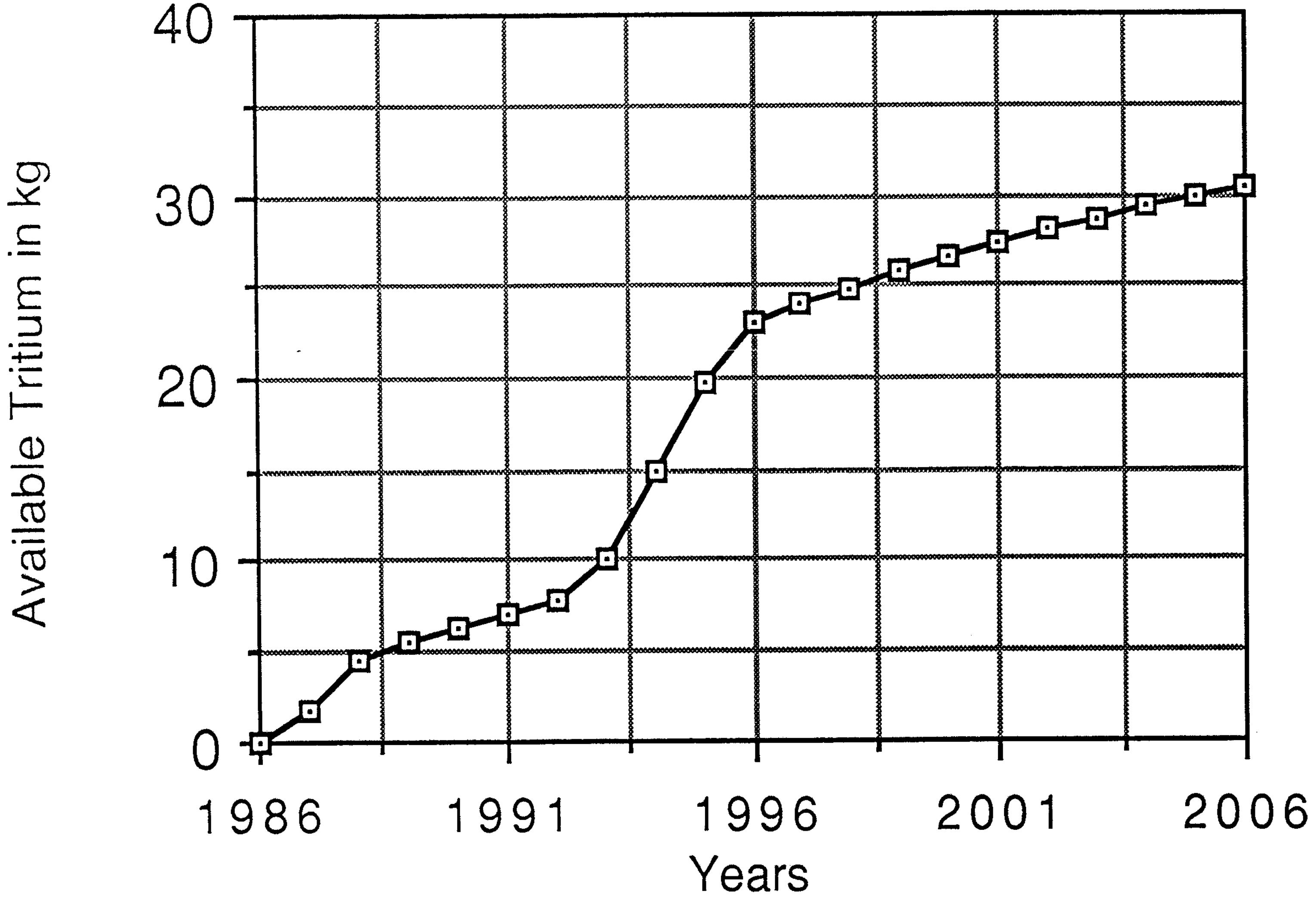
AVAILABILITY OF TRITIUM FOR NEXT 20 YEARS



The Calculational Model

- Model includes plasma downtime

- Time is discretized with interval Δ. In an interval, the device is up during $r\Delta (0 \leq r \leq l)$ and down during $(1-r)\Delta$

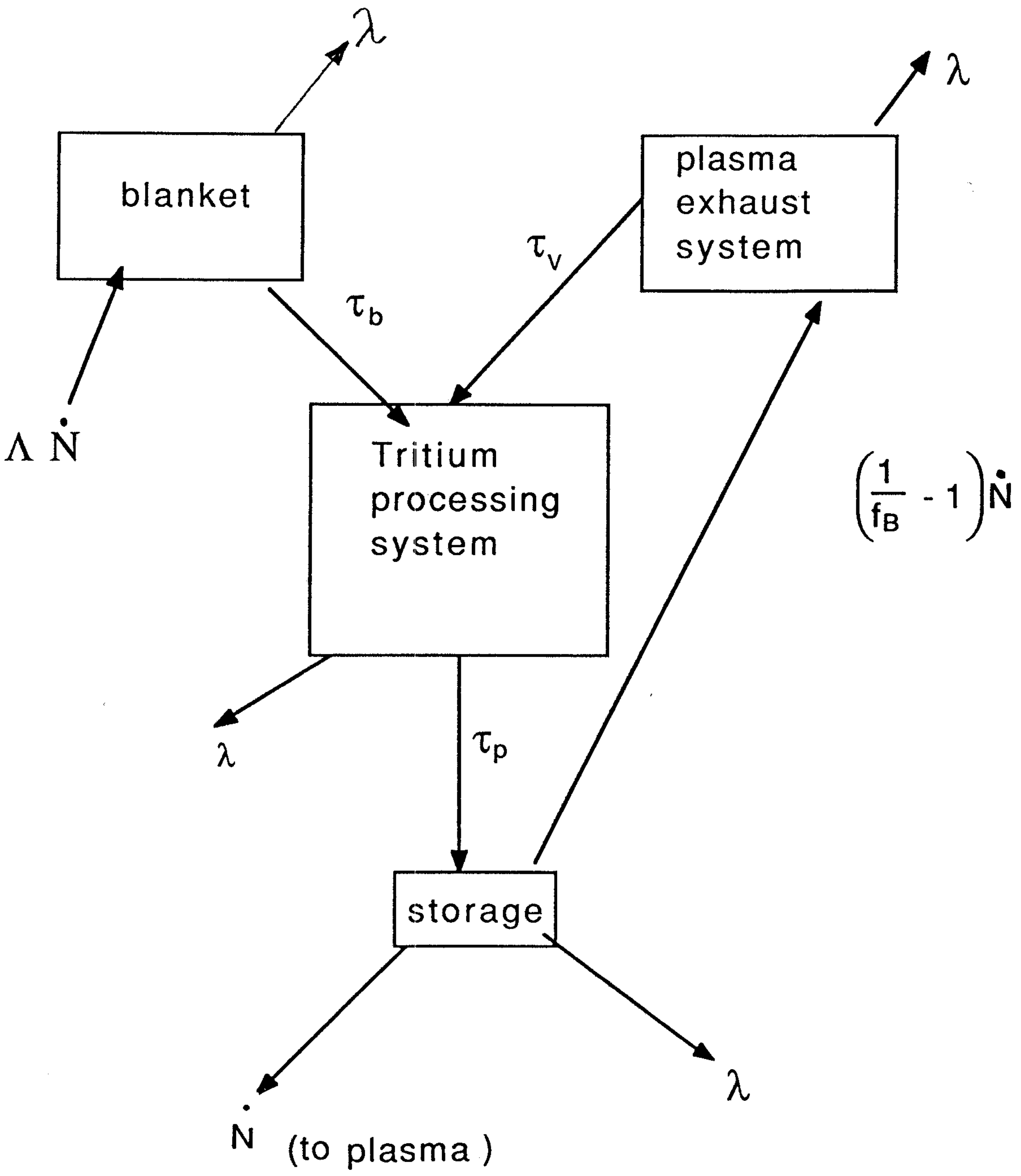
- Rate Equations are derived for the 4 subsystems in both $[n\Delta, n\Delta + r\Delta]$ and $[n\Delta + r\Delta, (n+1)\Delta]$, where n is a positive integer or zero

- The equations are analytically solved with an initial condition

- The required TBR, Λ_R, is calculated by assuming an initial external tritium supply that is consumed during reactor operation such that a minimum pre-specified amount is left in the storage at the end of a given reactor lifetime.

- The model assumes that the tritium recovery mechanism is the same regardless of whether the plasma is on or off

Tritium Fuel Cycle Model



Notes

λ =Tritium decay constant

τ_b =tritium residence time in blanket

τ_v =tritium residence time in plasma exhaust system

τ_p = tritium residence time in tritium processing system

$\dot{N}$ = tritium burning rate

Λ = tritium breeding ratio

f_B = burnup fraction

Base Parameters used in the Analysis

Fusion Power, P_{fus}, 608.6 MW

Neutron wall load(average) 1.148 MW/m^2

Tritium Burnup Fraction, f_b,	5%
Tritium Residence Time in Blanket, τ_b,	10 days
Tritium Residence Time in Vacuum System, τ_v	2 hours
Tritium Residence Time in Tritium Processing System, τ_p,	1 day

Interval of Failure, Δ	30 days
Availability, r,	25%
Reactor Lifetime,	6 years

(accumulated neutron fluence = 1.72 MW•year/m^2)

Initial Tritium Requirement, $I_S(0)$	5 kg
Tritium at the End of Plant Life, $I_{S,min}$	0 kg

<u>Definition</u>

Externally supplied tritium, EST (Kg), for a given operation time, T, is:

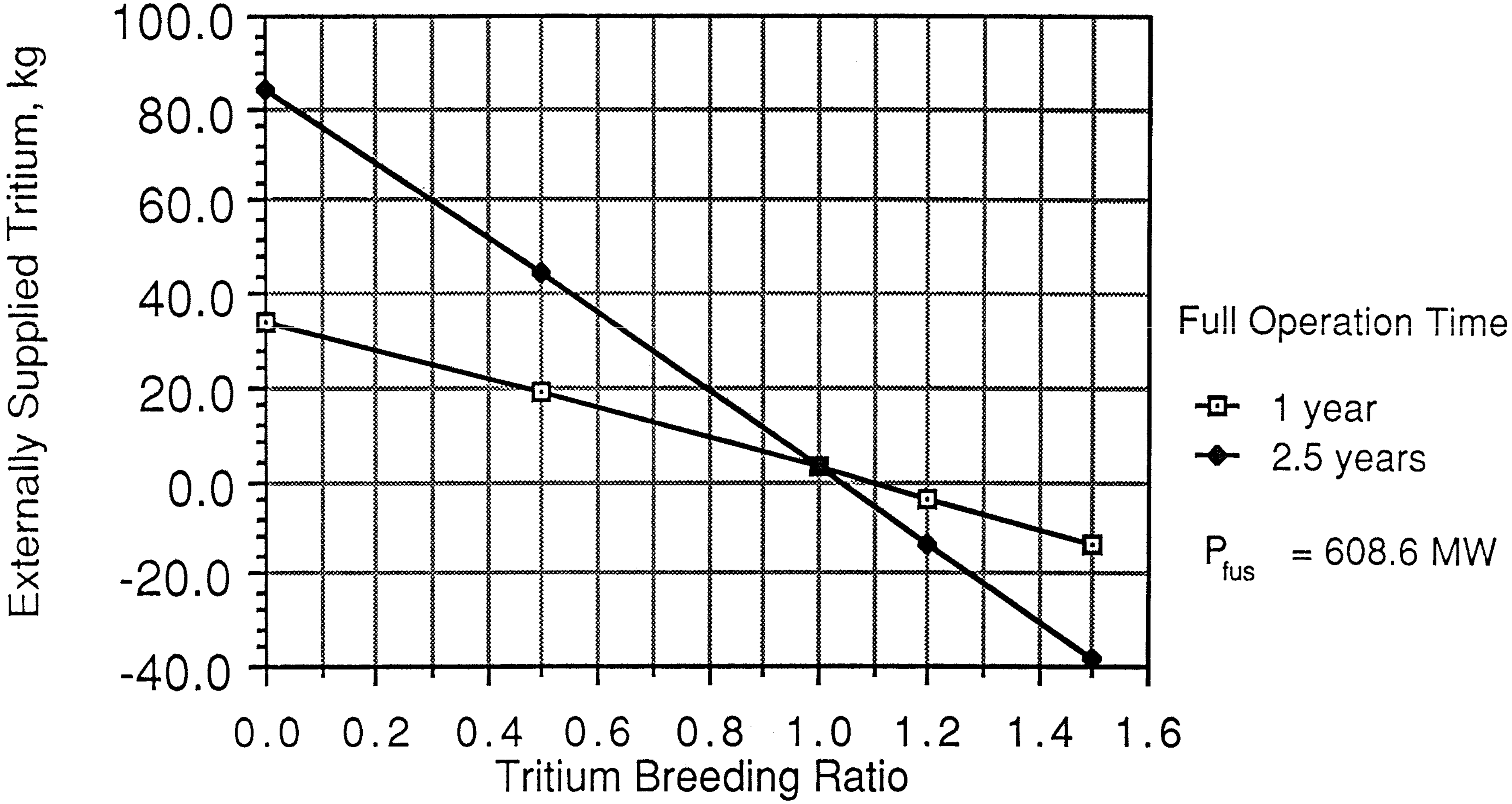
$$\text{EST (Kg)} = \dot{N}T - \Lambda \dot{N} T + \sum_i I_i(\infty)$$

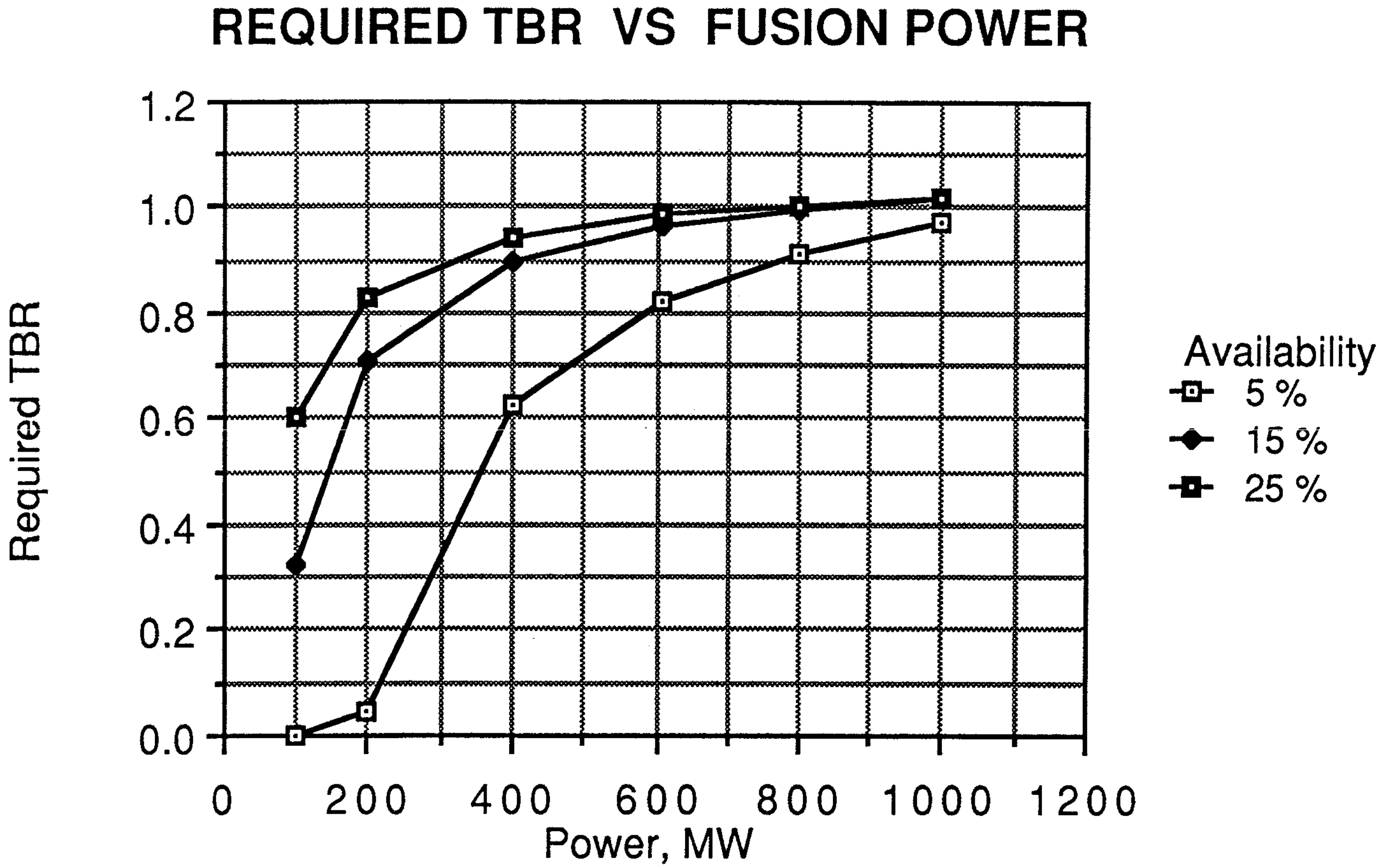
Where $\dot{N}$ = Tritium burning rate (Kg/yr)
Λ = TBR
$I_i(\infty)$ = Amount of saturated tritium in subcomponent i <u>other than</u> storage

Note:

$I_i(\infty)$ depends on parameters such as Λ, τ_i, λ, $\dot{N}$

TRITIUM REQUIREMENT AS A FUNCTION OF TBR





Life Time = 6 Years

τ_b = 10 days $I_s(0)$ = 5 Kg

τ_v = 2 hrs. Δ = 30 days

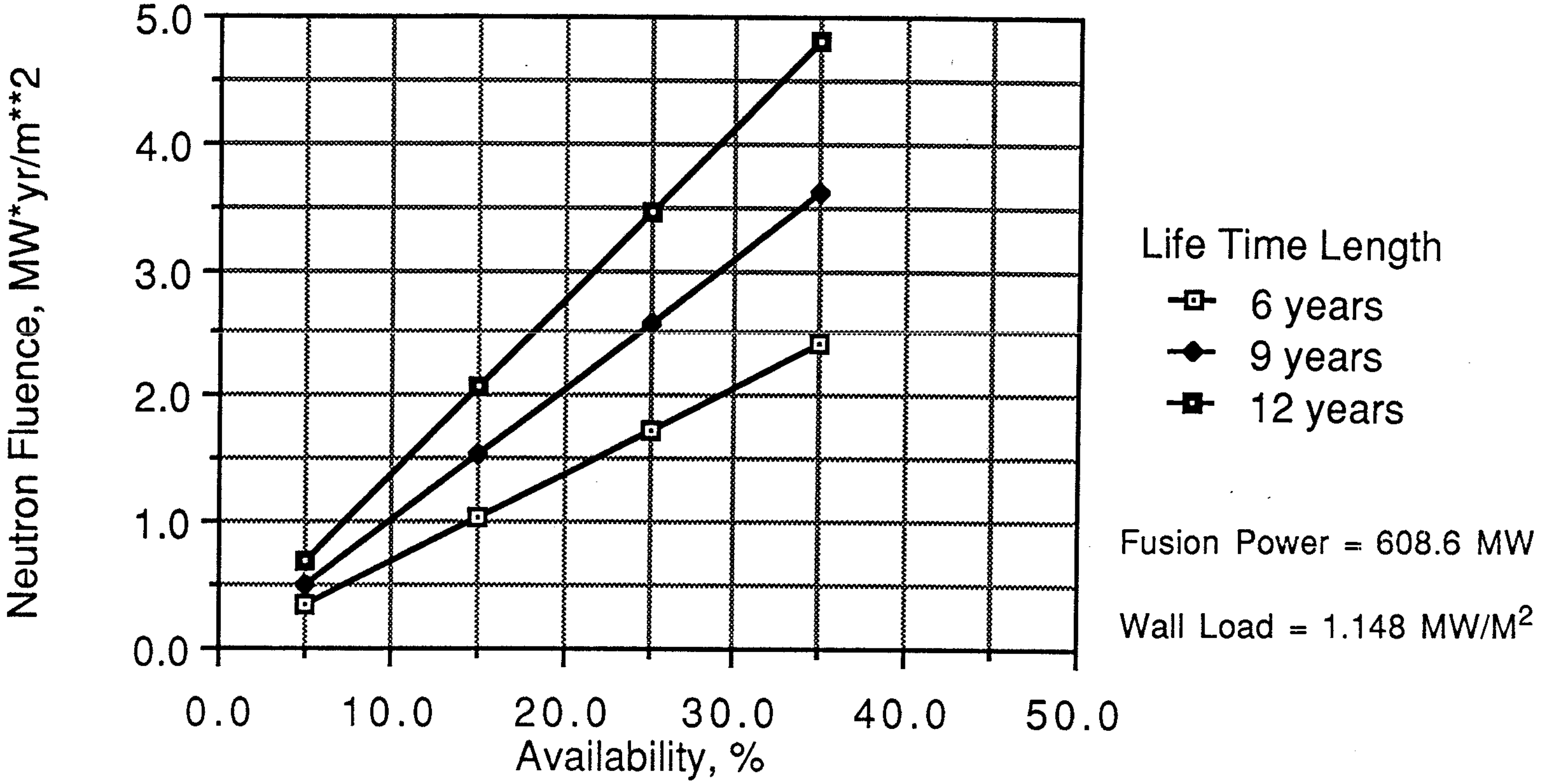
τ_p = 1 day $I_{s,min}$ = 0 Kg

f_b = 5 %

Impact of Fusion Power and System Availability on the Required TBR

- The required TBR increases with fusion power.
  - The percentage increase in TBR is larger for smaller fusion power (< 400MW)
  - Changes in required TBR are small for fusion power > 600 MW with availability > 15% (required TBR ~1.0)
  - Larger fusion power devices are more demanding on external supply to compensate for uncertainty in achievable TBR

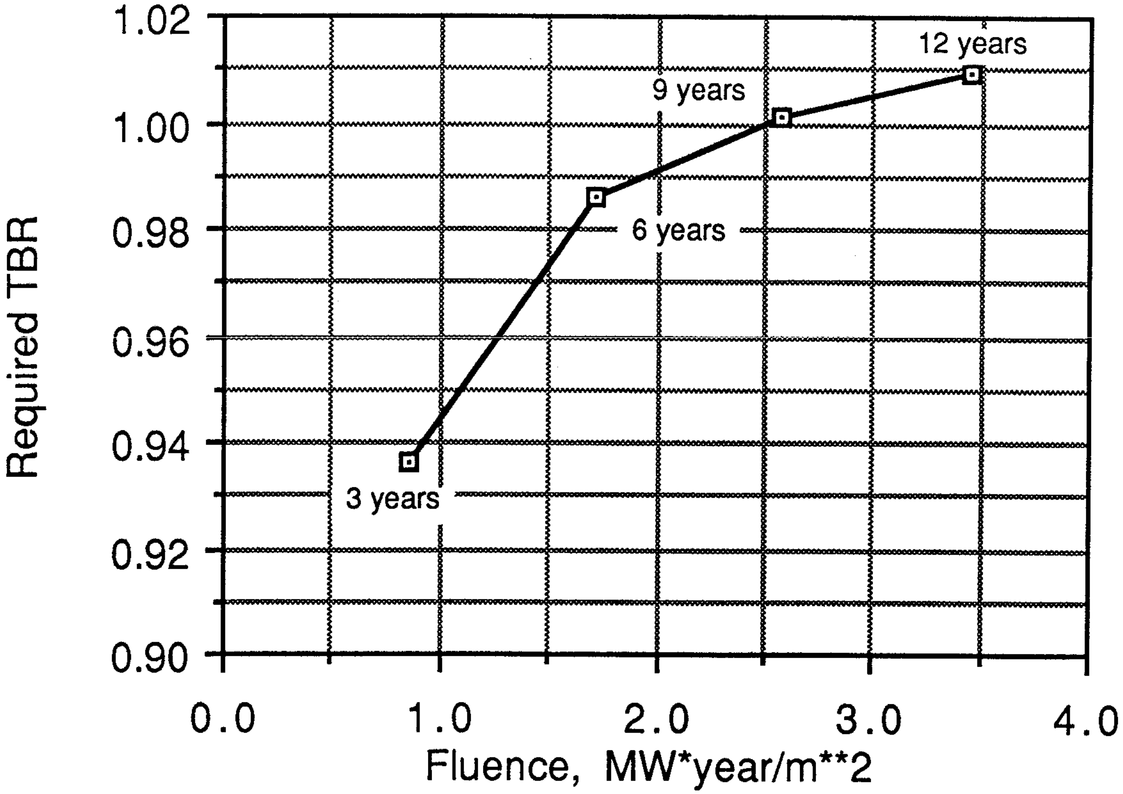
NEUTRON FLUENCE VS. AVAILABILITY



Fusion Power = 608.6 MW

Wall Load = 1.148 MW/M^2

REQUIRED TBR VS. FLUENCE (fixed availability)

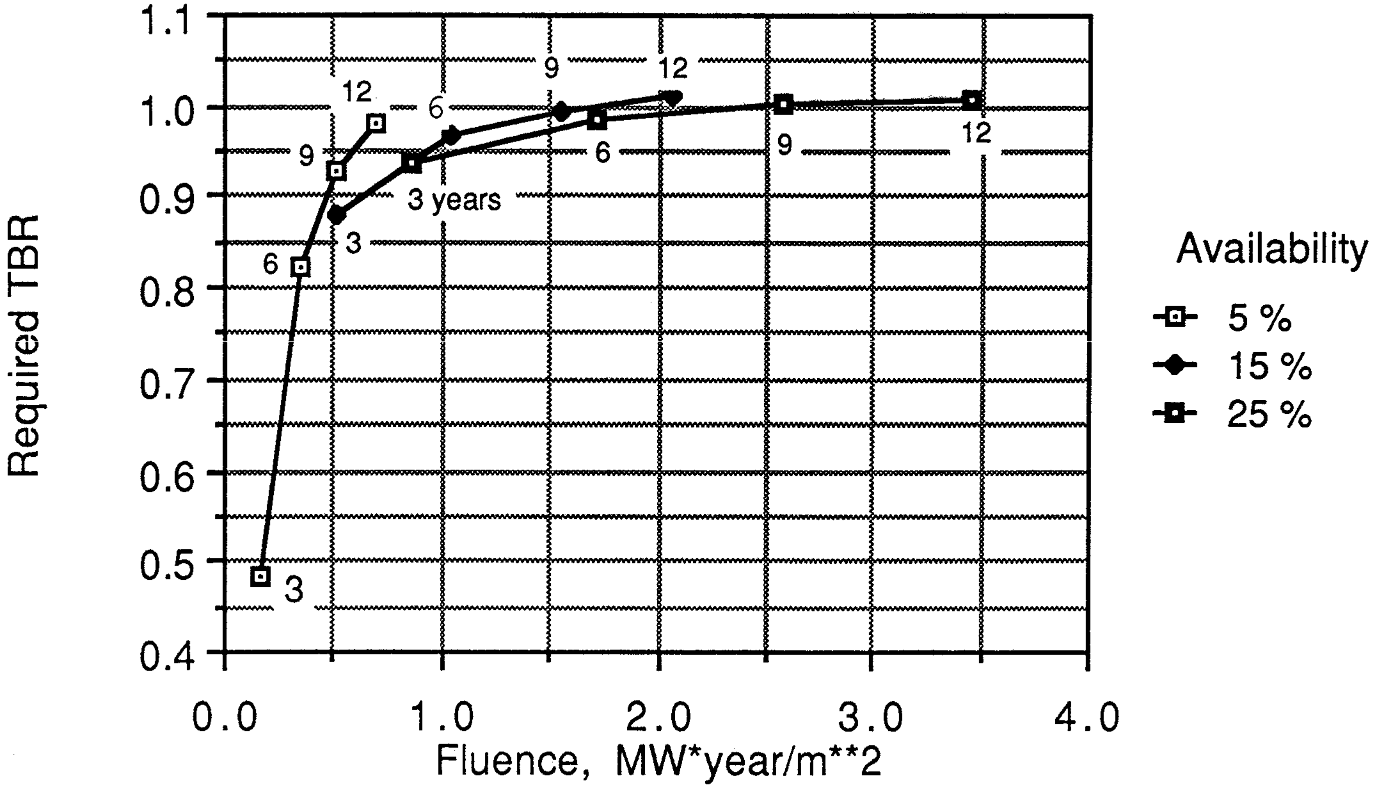


Fusion Power = 608.6 MW
Wall load = 1.141 MW/M^2
Availability = 25%

τ_b = 10 days
τ_v = 2 hrs.
τ_p = 1 day
f_b = 5 %

Δ = 30 days
$I_S(0)$ = 5 Kg
$I_{s,min}$ = 0 Kg

REQUIRED TBR VS. NEUTRON FLUENCE



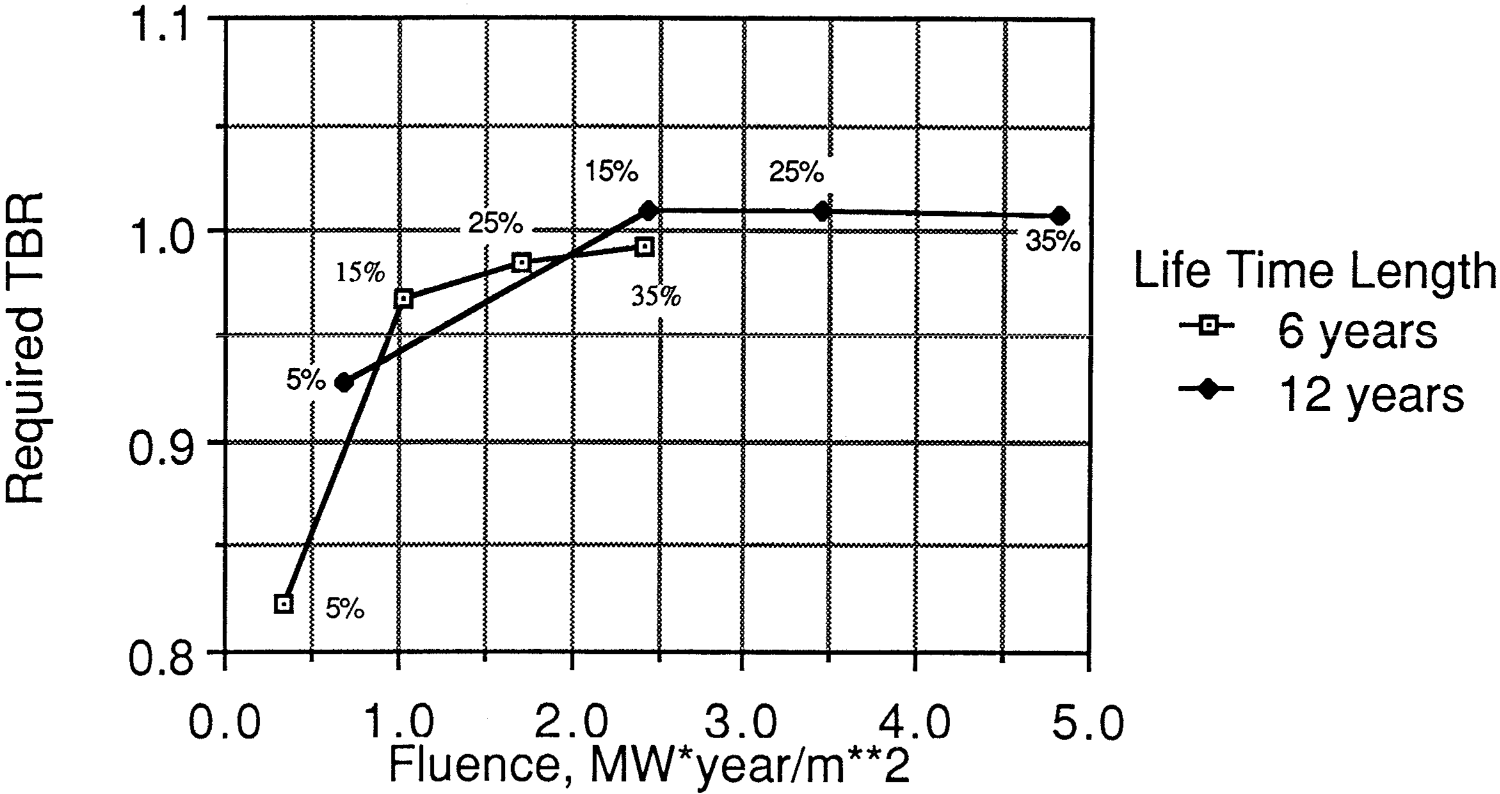
Fusion Power = 608.6 MW
Wall load = 1.148 MW/M^2

τ_b = 10 days　　$I_S(0)$ = 5 Kg

τ_v = 2 hrs.　　$I_{s,min}$ = 0 Kg

τ_p = 1 day
f_b = 5 %

REQUIRED TBR VS. FLUENCE (FIXED LIFE TIME)

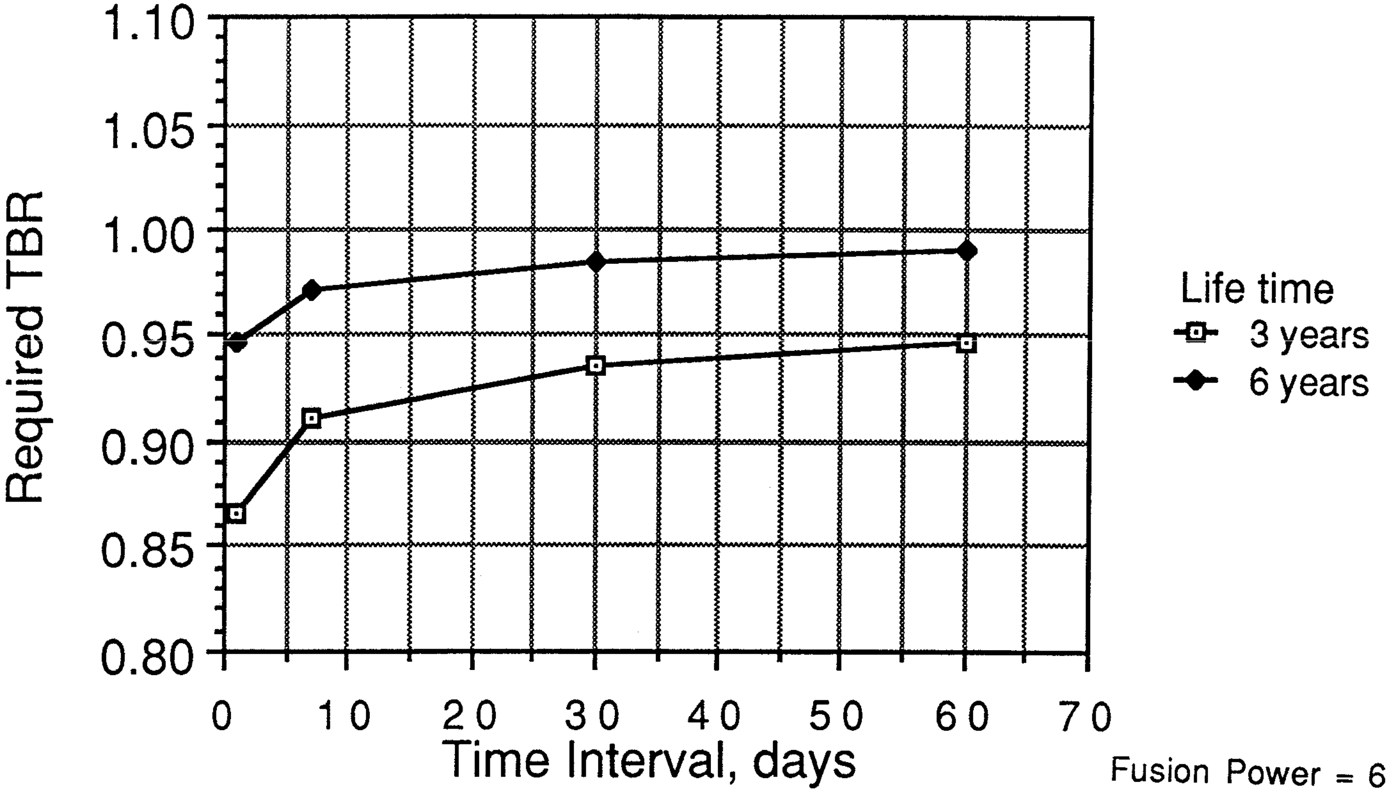


Fusion Power = 608.6 MW
Wall Load = 1.148 MW/M2

τ_b = 10 days
τ_v = 2 hrs.
τ_p = 1 day
f_b = 5 %

$I_s(0)$ = 5 Kg
Δ = 30 days
$I_{s,min}$ = 0 Kg

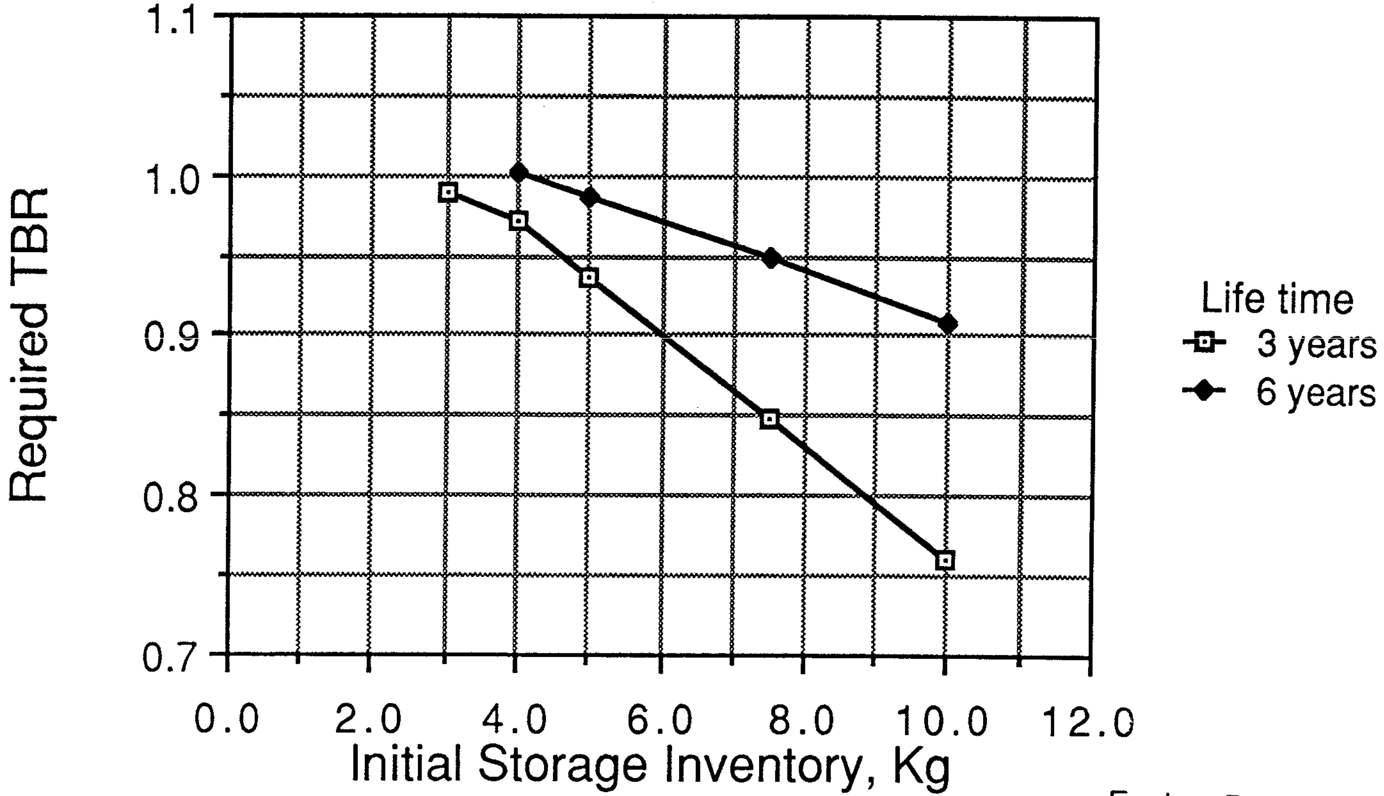
REQUIRED TBR VS. INTERVAL OF FAILURE



Fusion Power = 608.6 MW
Availability = 25%

τ_b = 10 days $I_s(0)$ = 5 Kg
τ_v = 2 hrs.
τ_p = 1 day $I_{s,min}$ = 0 Kg
f_b = 5 %

REQUIRED TBR VS. INITIAL INVENTORY

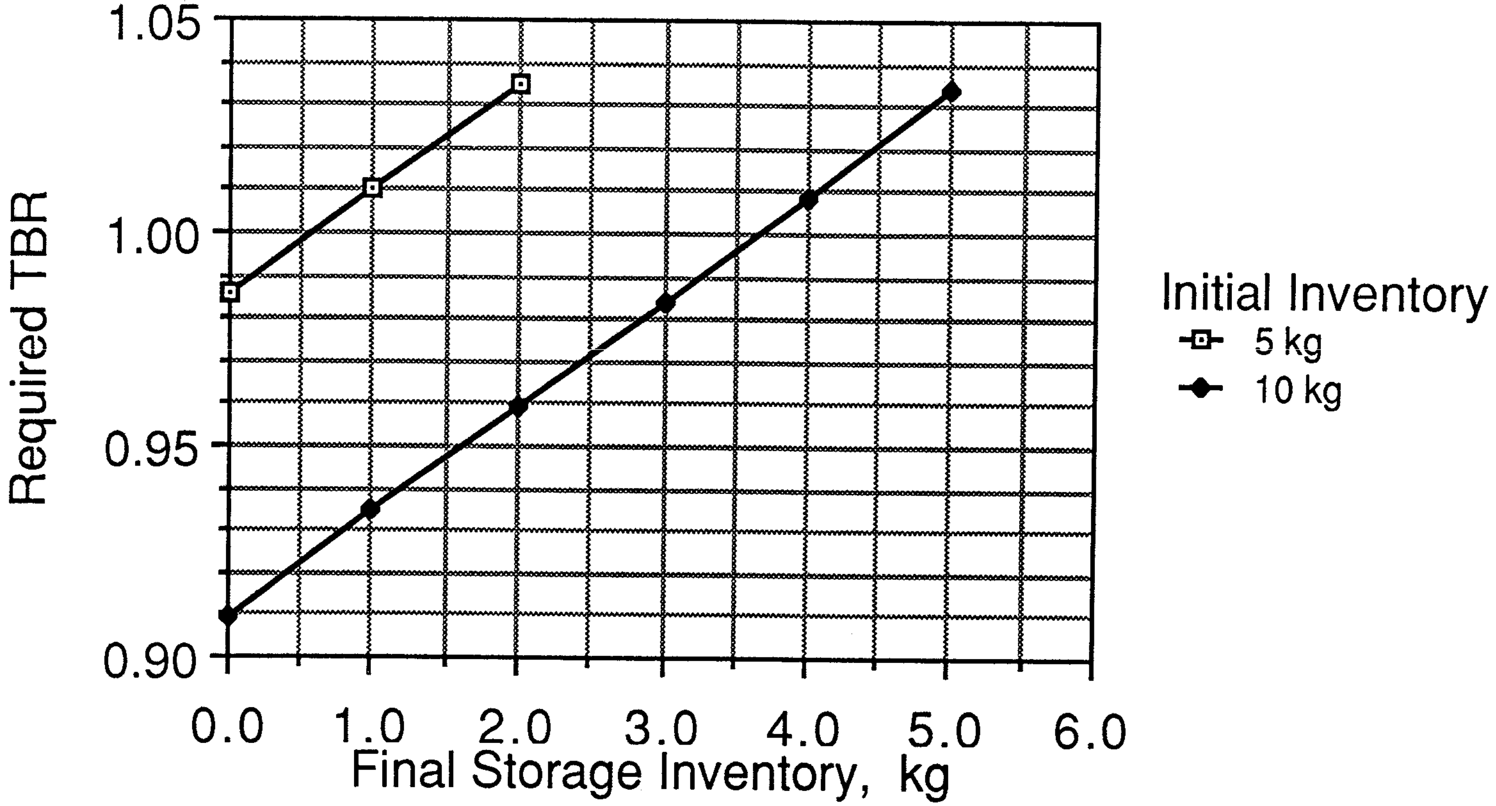


Fusion Power = 608.6 MW
Availability = 25%

τ_b = 10 days
τ_v = 2 hrs.
τ_p = 1 day
f_b = 5 %

$I_s(0)$ = 5 Kg
Δ = 30 days
$I_{s,min}$ = 0 Kg

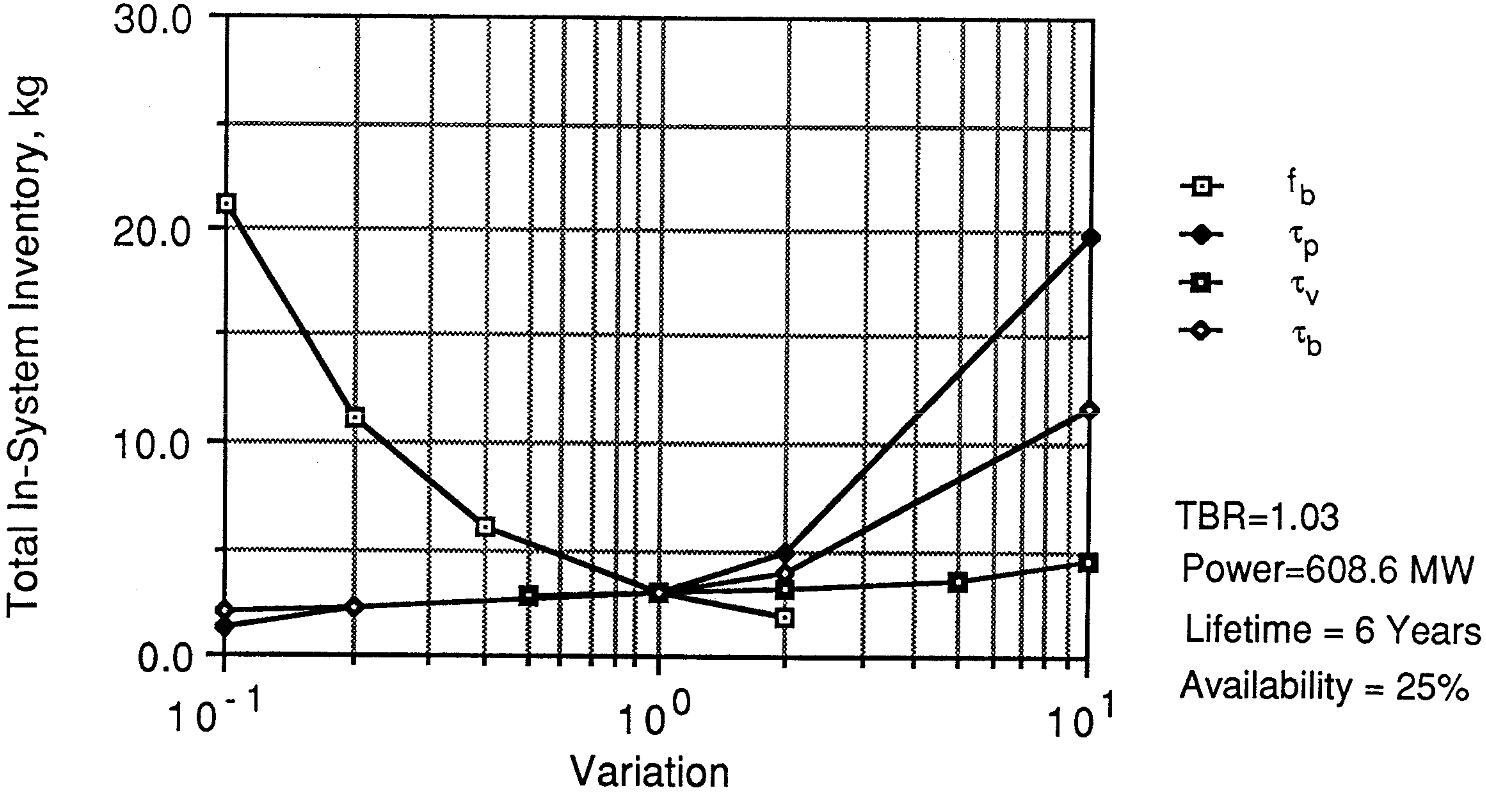
REQUIRED TBR VS. FINAL STORAGE INVENTROY



Fusion Power = 608.6 MW
Availability = 25%

τ_b = 10 days Δ = 30 days
τ_v = 2 hrs. Lifetime = 6 years
τ_p = 1 day
f_b = 5 %

VARIATION OF TRITIUM INVENTORY



TBR=1.03
Power=608.6 MW
Lifetime = 6 Years
Availability = 25%

Δ = 30 days
TBR = 1.03
$I_{s,min}$ = 0 Kg

Remarks

- With 5 kg of tritium at the beginning of ITER operation, the required tritium breeding ratio (TBR) for a reactor with a range 600 ~ 800 MW fusion power is about unity (0.986 at 608.6 MW.)

- If the availability of the reactor is lower than 25%, the required TBR could be much smaller (i.e., 0.82 for a 608.6 MW fusion power reactor with 5% availability)

- The 608.6 MW reactor will achieve an accumulated neutron fluence 1.8 MW year/m^2 after 6 years of operation with 25% availability, and a required TBR=0.986.

- If more than 5 kg of tritium is externally available to operate the reactor, the required TBR for the same fusion power can be decreased; for example if10 kg of tritium is available, <u>the required TBR</u> is <u>0.956</u>

- Since there is at least 5% uncertainty in the estimation of the achievable TBR, <u>the required TBR</u> (i.e., the design value for TBR) must be larger than 0.986 + 0.986 x 0.05 = <u>1.035</u>

- There is a large uncertainty in tritium burn-up fraction and tritium residence time. For the TBR obtained in this study, the unexpected shortage of TBR due to these and other uncertainties can be overcome by supplying more tritium externally.