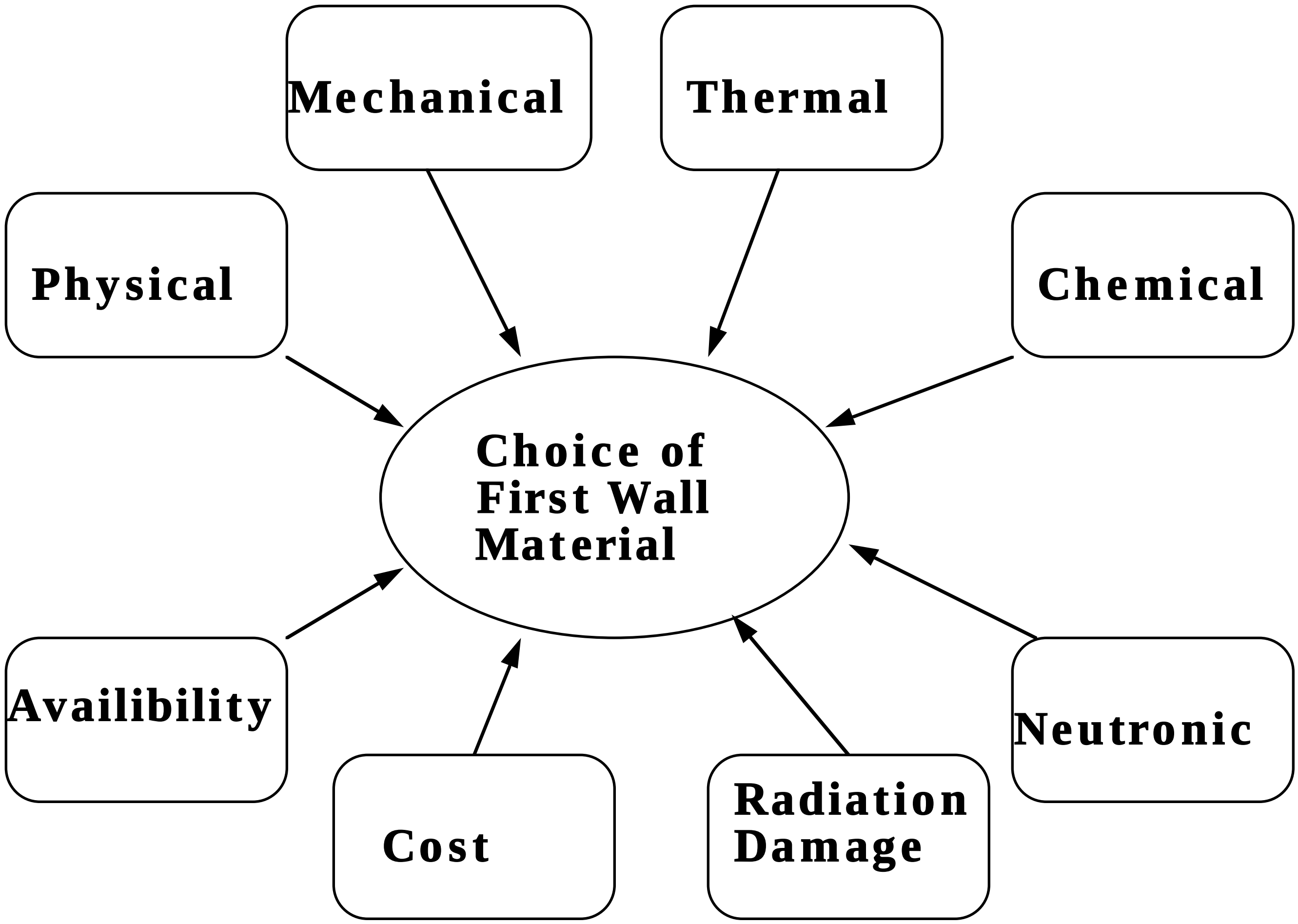
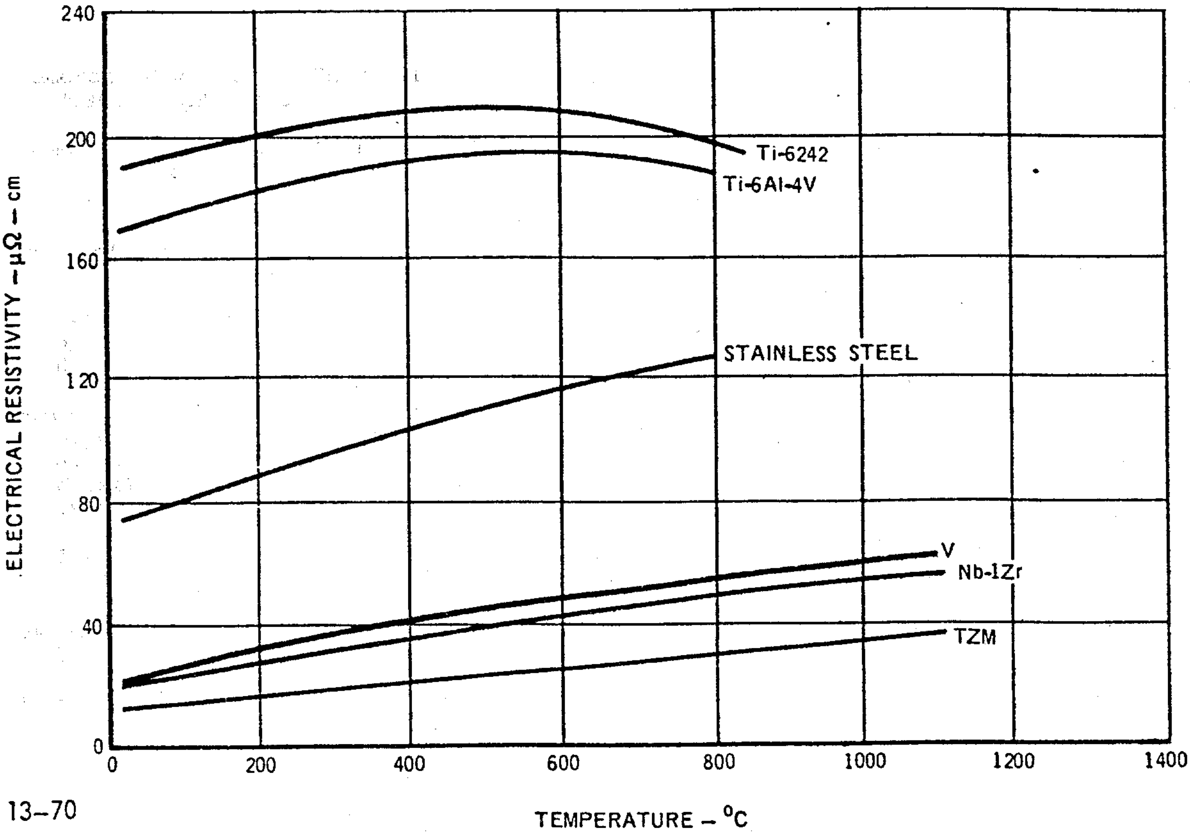

Mechanical
Thermal
Physical
Chemical
Choice of First Wall Material
Availibility
Cost
Radiation Damage
Neutronic

COMPARISON OF ELECTRICAL RESISTIVITY OF SEVERAL CANDIDATE CTR MATERIALS



13–70

Figure 2

ESTIMATED VAPOR PRESSURES OF CANDIDATE FIRST WALL MATERIALS

CANDIDATE FIRST WALL MATERIAL	PROPOSED MAXIMUM OPERATING TEMPERATURE (°C)	ESTIMATED VAPOR PRESSURE (atm)*
ALUMINUM	300	1.34×10^{-47}
TITANIUM	500	2.09×10^{-40}
316 SS	600	1.05×10^{-27}
VANADIUM	800	1.33×10^{-25}
NIOBIUM	1000	7.71×10^{-30}
MOLYBDENUM	1000	9.68×10^{-27}

*Based on the data of Reference 7; extrapolated using linear regression analysis of vapor pressure vs reciprocal temperature data.

Table 3

Thermal Stress

$$\sigma_{th} = \frac{\alpha E}{2k(1-\nu)}\left[w_s t + 0.5 w_n t^2\right]$$

Material Related | **Reactor Related**

α = coefficient of thermal expansion
E = Modulus of Elasticity
k = thermal conductivity
ν = Poison Ratio
w_s = surface heat flux
w_n = nuclear heat rate
t = thickness

$$\text{Figure of Merit} = \frac{\sigma_{th}(T)}{\sigma_y(T)}$$

COMPARISON OF MODULUS OF ELASTICITY FOR SEVERAL CANDIDATE CTR MATERIALS

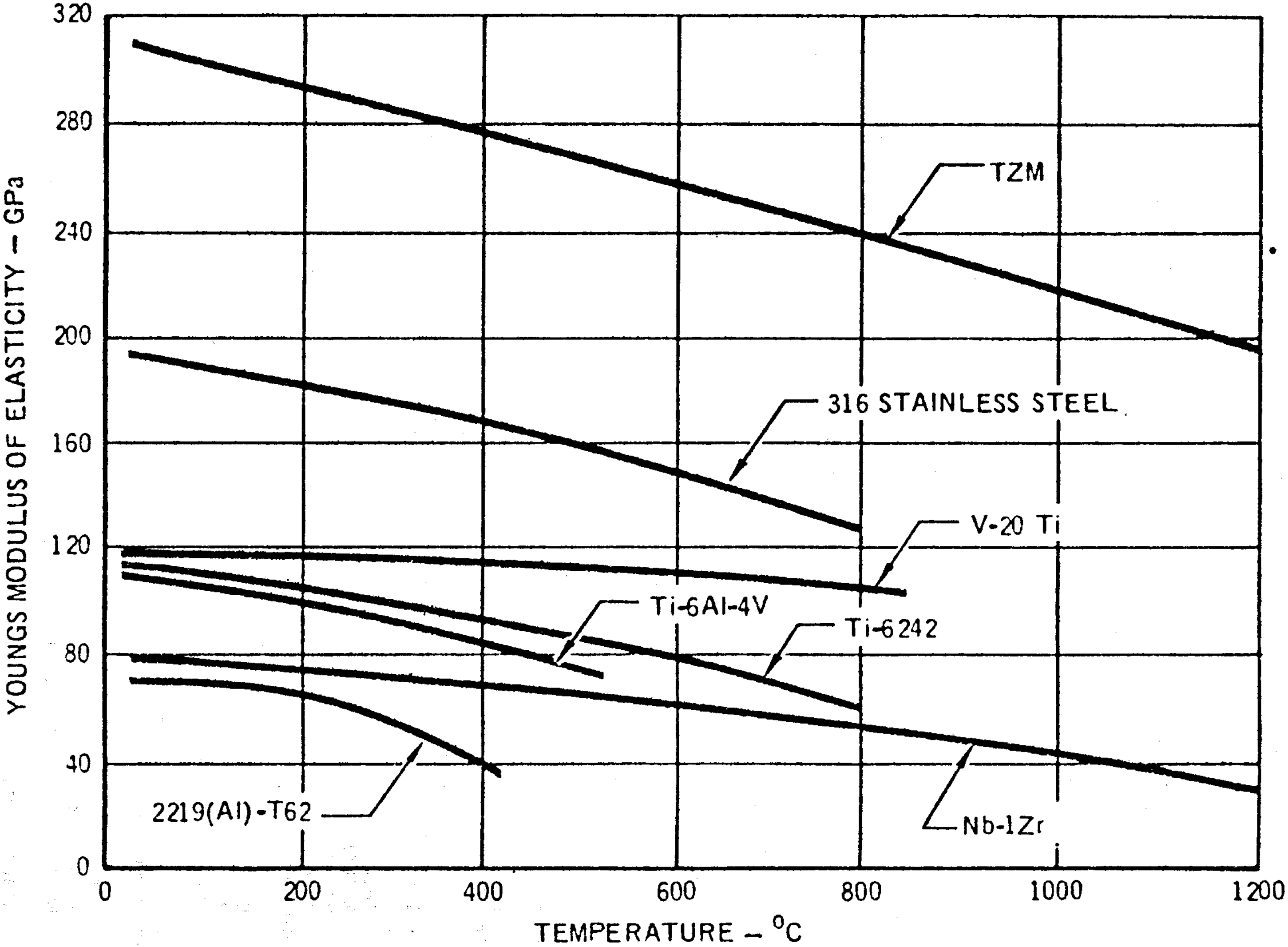
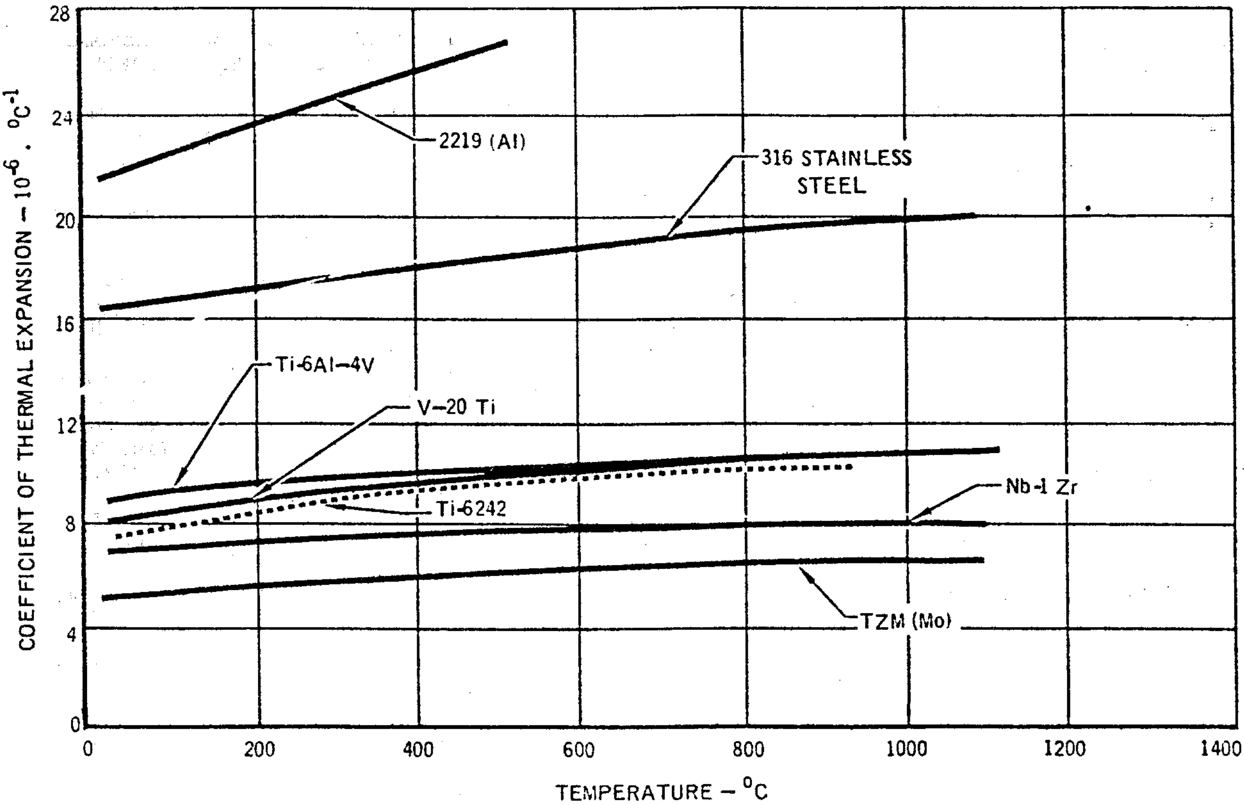


Figure 6

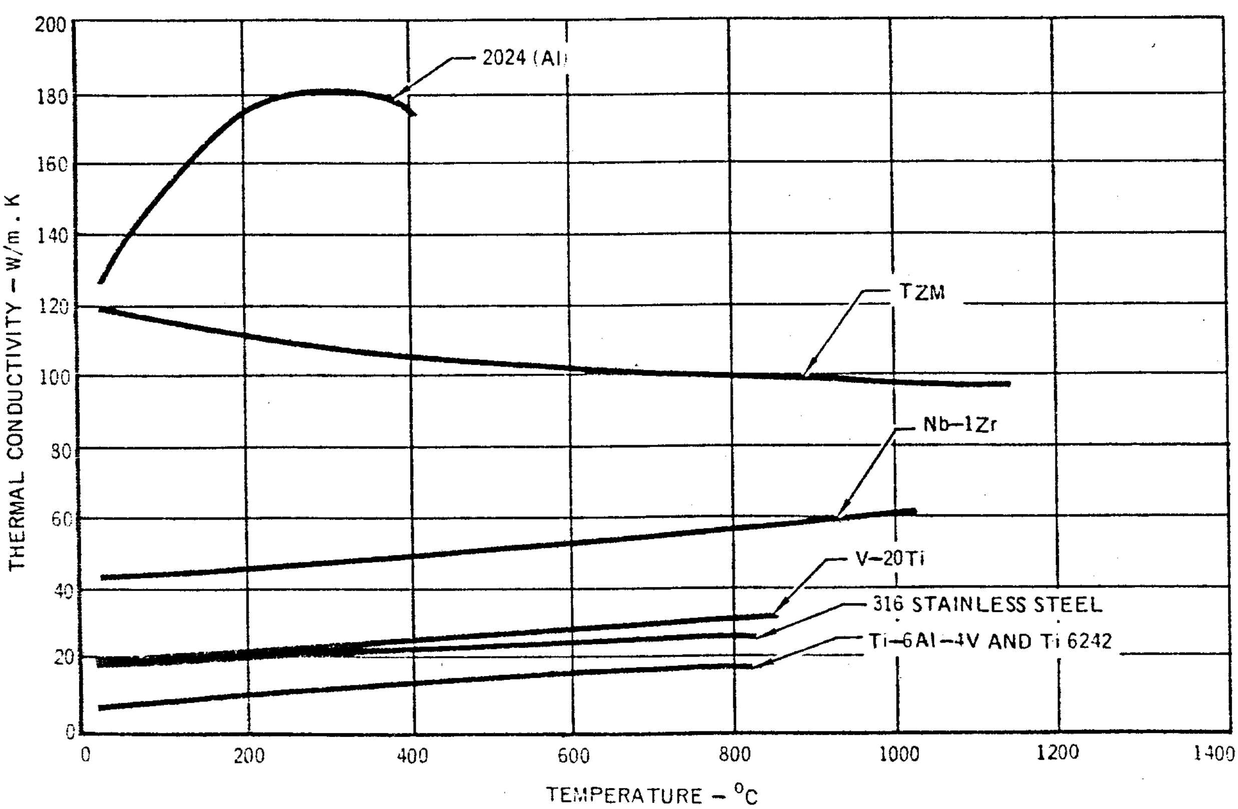
COMPARISON OF THE COEFFICIENT OF THERMAL EXPANSION FOR SEVERAL CANDIDATE CTR MATERIALS



13-187A

Figure 9

COMPARISON OF THE THERMAL CONDUCTIVITY FOR SEVERAL CANDIDATE CTR MATERIALS



13-189

Figure 10

EFFECT OF TEMPERATURE ON THE YIELD STRENGTH OF SEVERAL CANDIDATE CTR MATERIALS

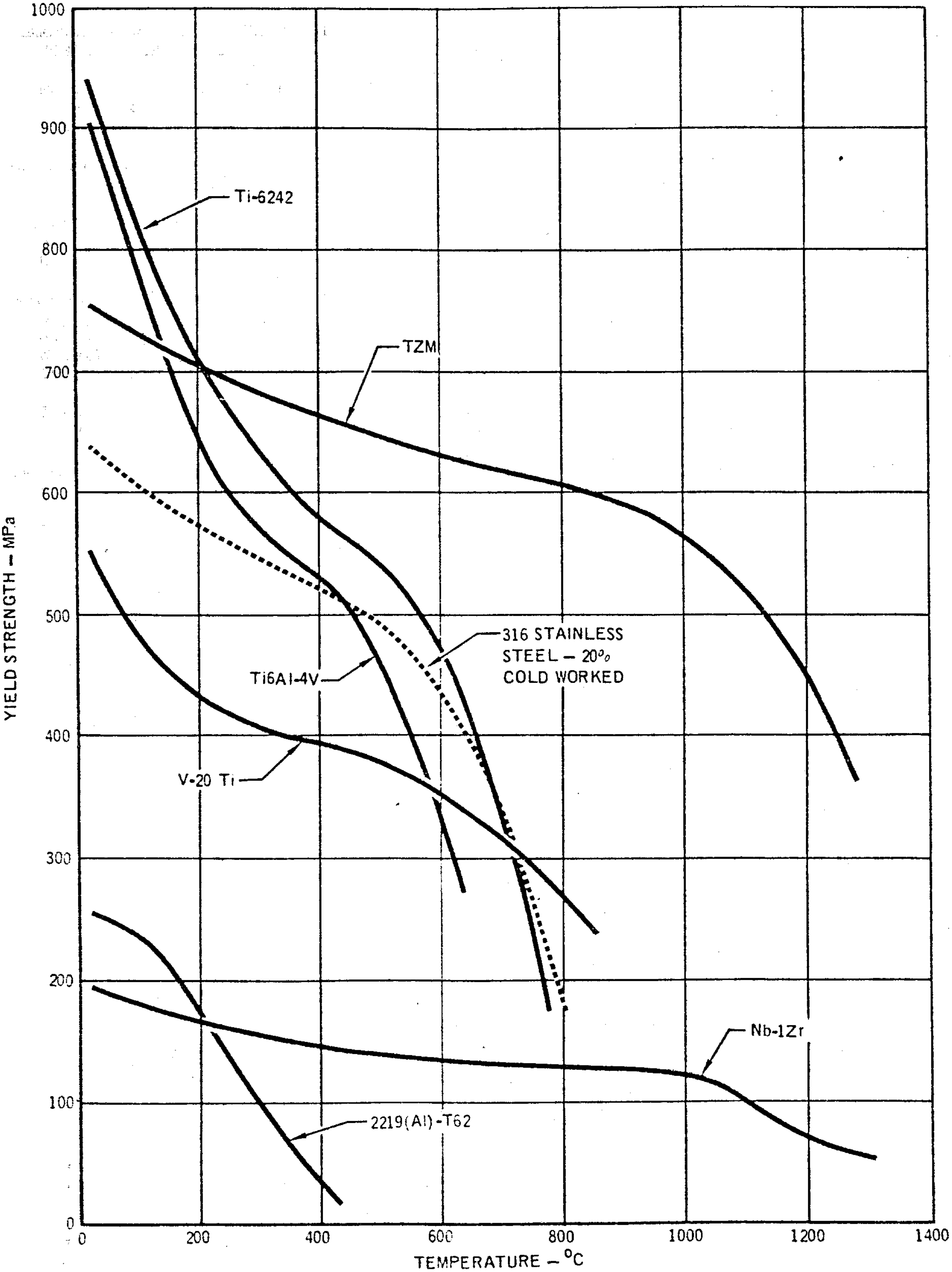
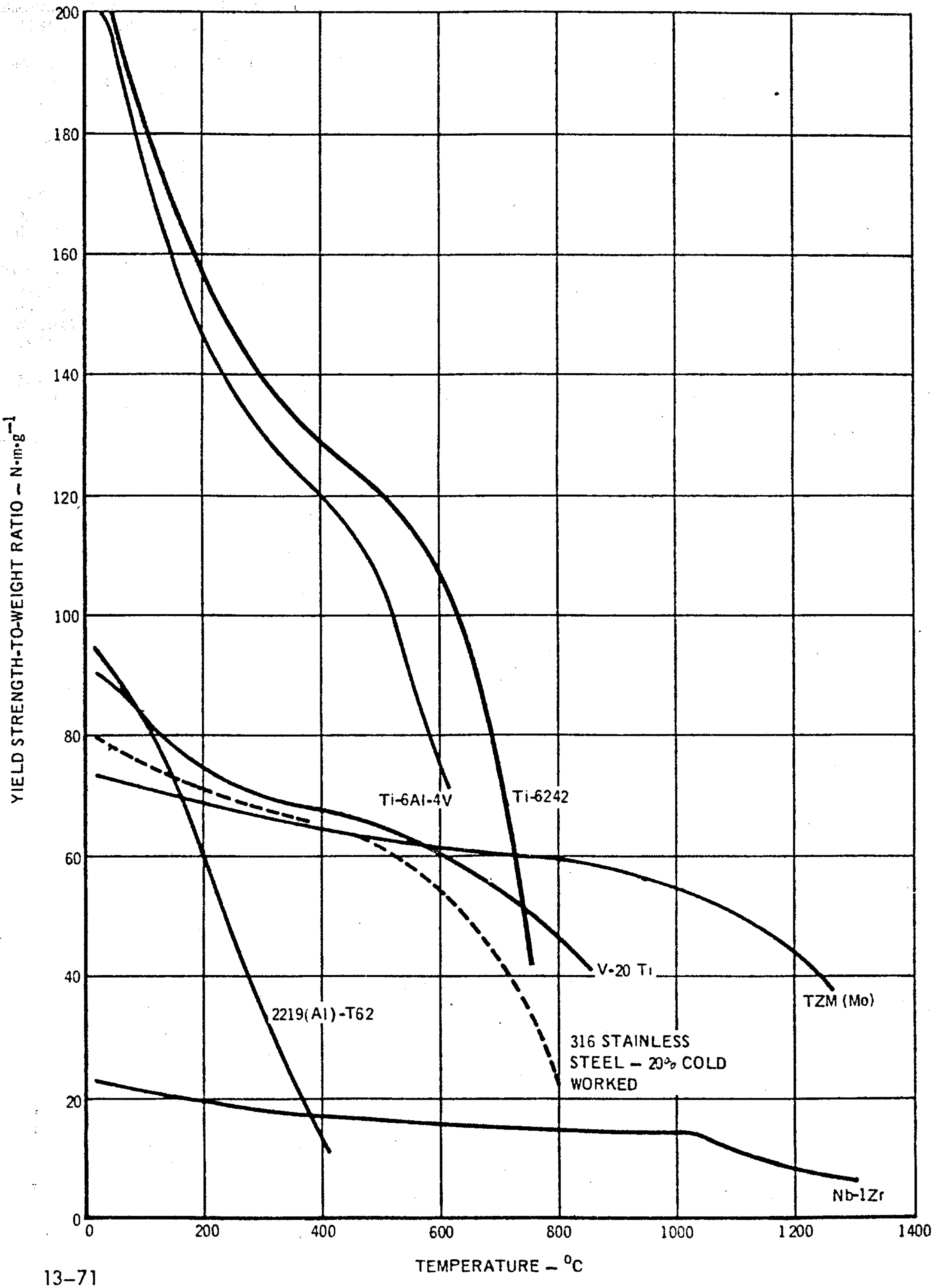


Figure 4

STRENGTH-TO-WEIGHT OF VARIOUS CTR MATERIALS



13–71

Figure 1

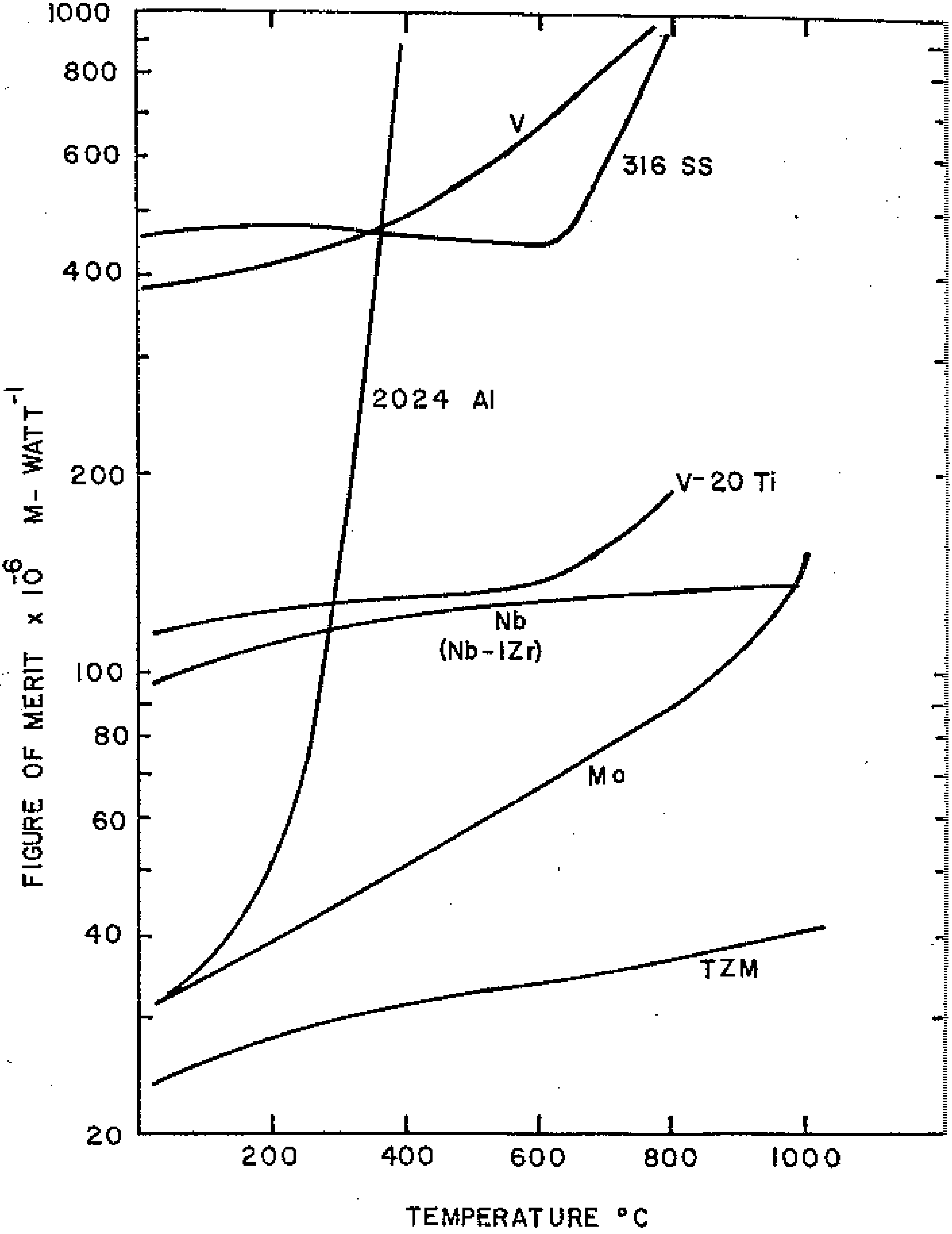
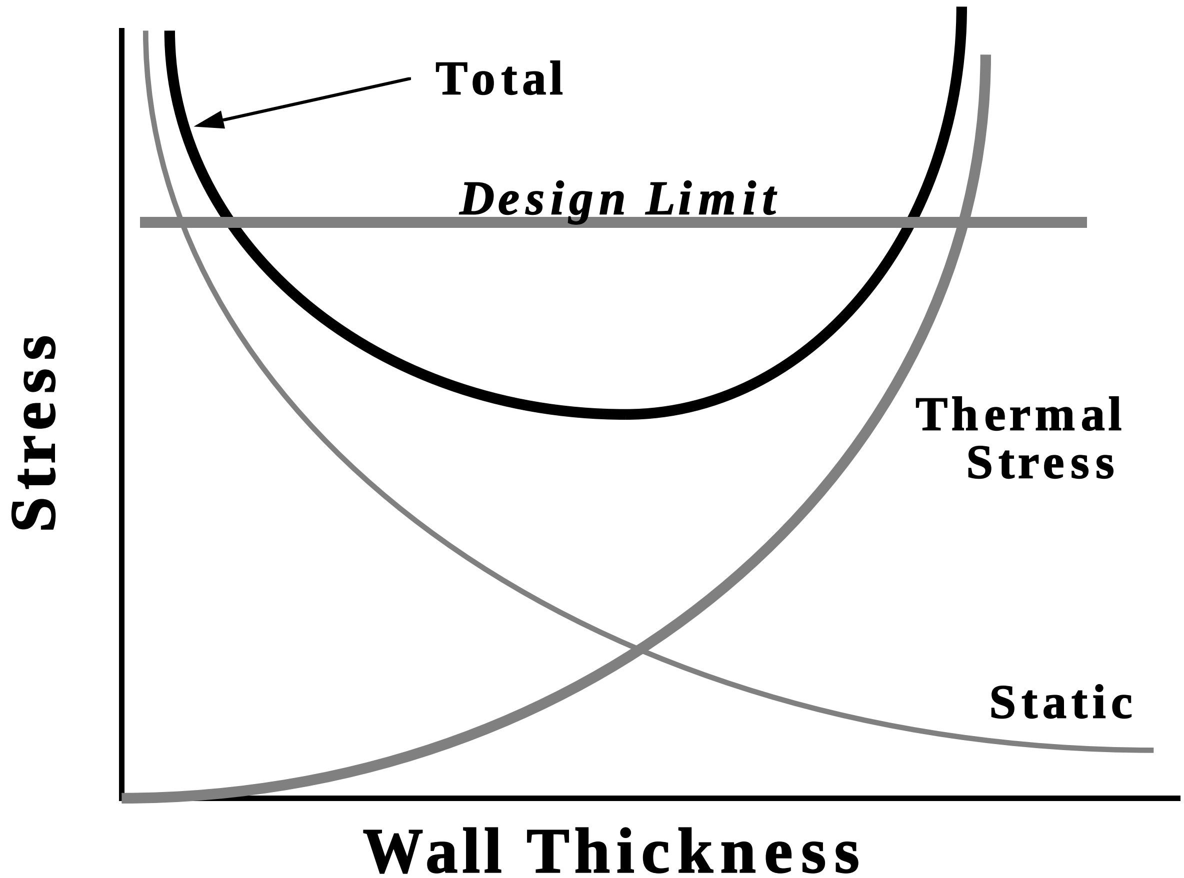


FIG IX-B-12 THERMAL STRESS FIGURE OF MERIT-CTR MATERIAL USING YIELD STRENGTH

First Wall Heat Flux Limits



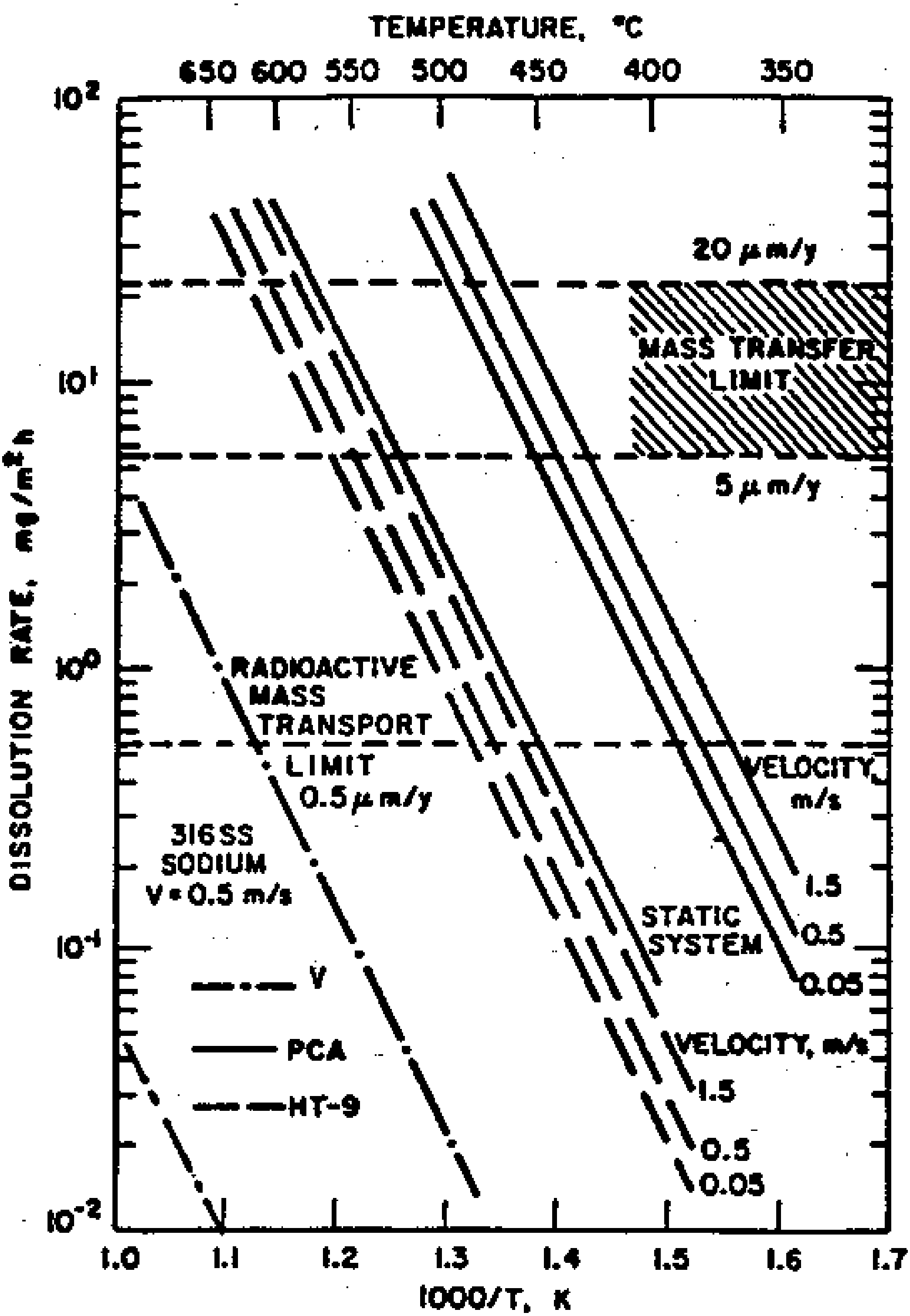


Figure 6.2-4. Effect of temperature on the corrosion rate of PCA and HT-9 alloy in flowing lithium.

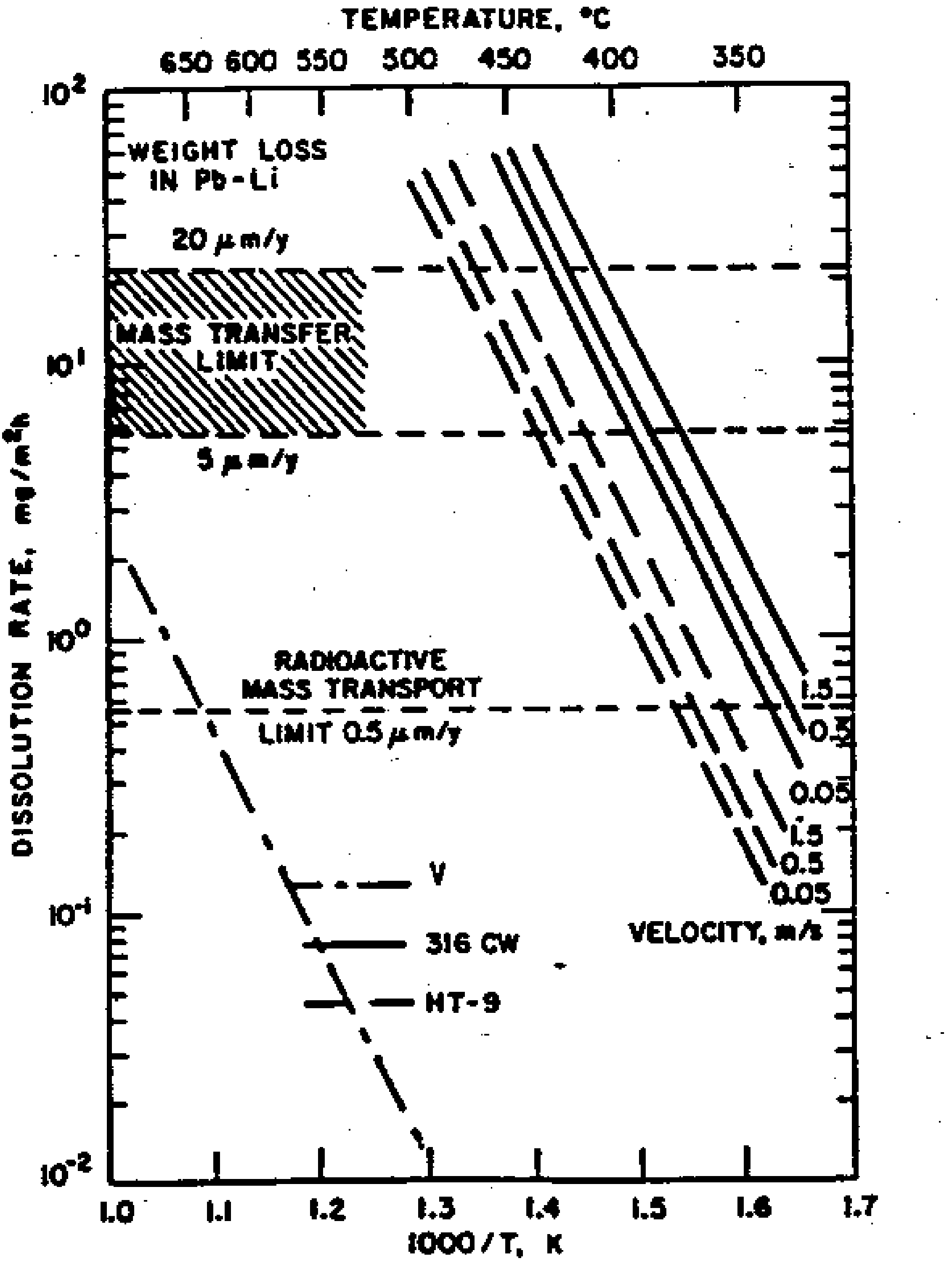


Figure 6.2-5. Effect of temperature on the corrosion rate of 20% cold worked Type 316 stainless steel and HT-9 alloy in flowing Pb-17Li.

TEMPERATURE DEPENDENCE OF THE EQUILIBRIUM DISTRIBUTION COEFFICIENTS FOR OXYGEN BETWEEN SELECTED REFRACTORY METALS AND LITHIUM

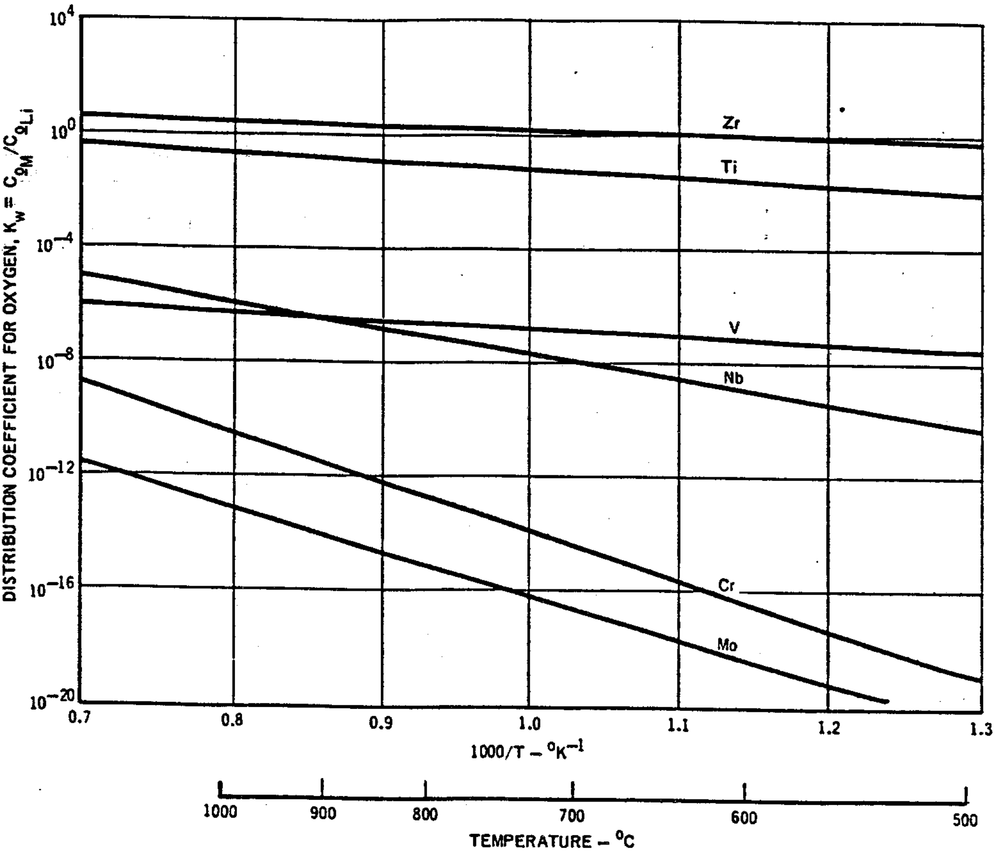


Figure 28

TEMPERATURE DEPENDENCE OF THE EQUILIBRIUM DISTRIBUTION COEFFICIENTS FOR CARBON BETWEEN SELECTED REFRACTORY METALS AND LITHIUM

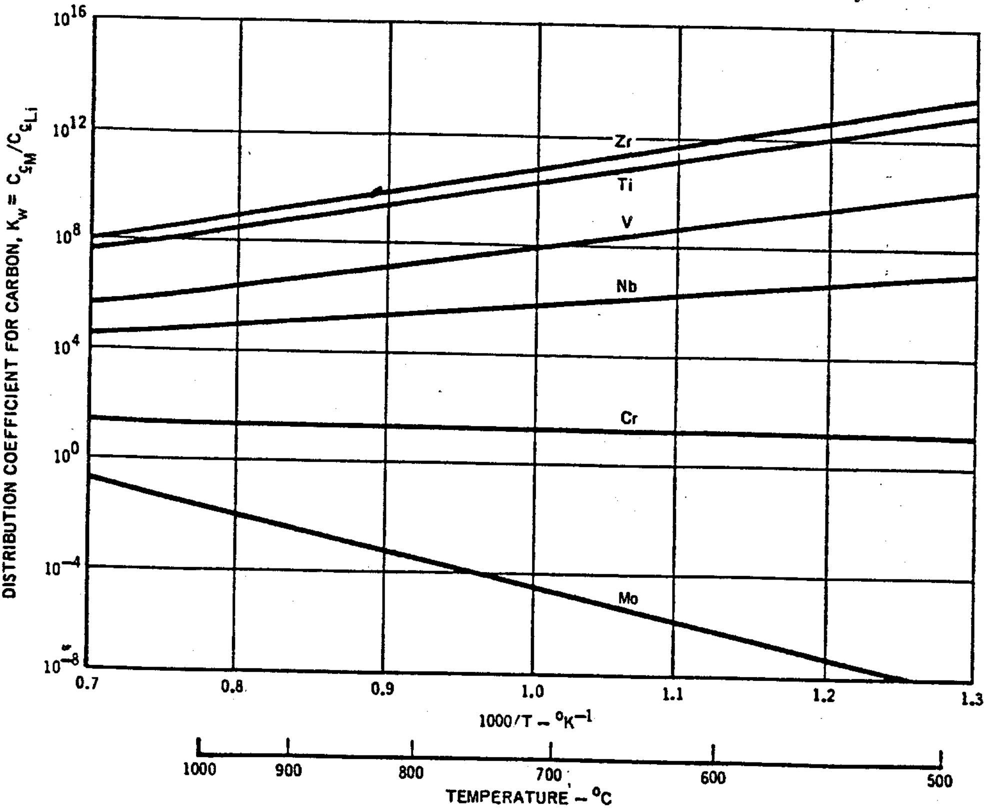
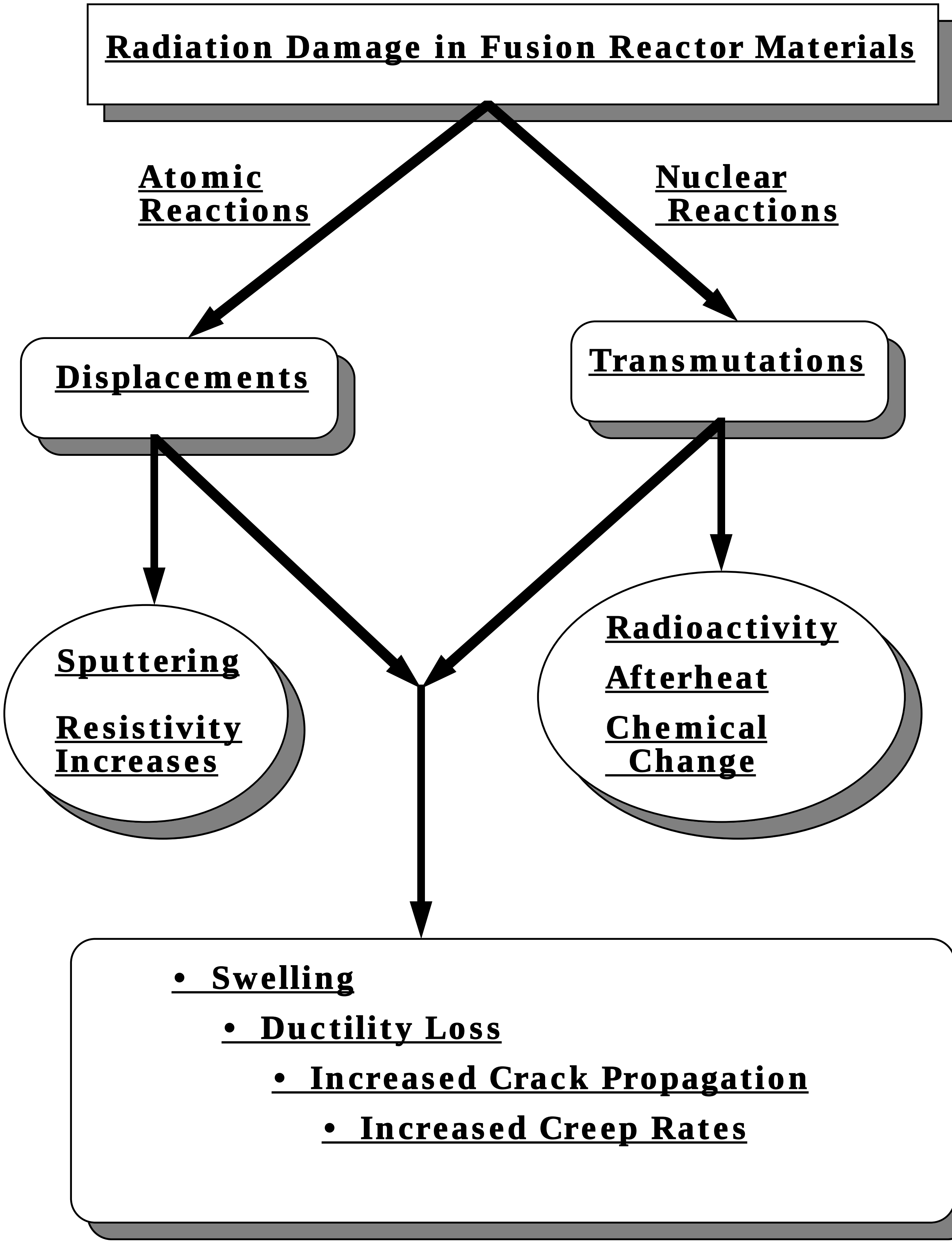


Figure 29

Compatibility Limits

Alloy	Coolant	Tmax °C
Al	Li	< 200
316 SS	Li	< 550
HT-9	Li	< 550
V	Li	< 800
Nb	Li	< 800
Mo	Li	< 1000
316 SS	Pb-Li	< 450
HT-9	Pb-Li	< 500
V	Pb-Li	????
Nb	Pb-Li	????
Mo	Pb-Li	????
316 SS/HT-9	Helium	< 600
V, Nb	Helium	< 600
Mo	Helium	< 1000


Radiation Damage in Fusion Reactor Materials
Atomic Reactions
Nuclear Reactions
Displacements
Transmutations
Sputtering
Resistivity Increases
Radioactivity
Afterheat
Chemical Change
• Swelling
• Ductility Loss
• Increased Crack Propagation
• Increased Creep Rates

Fundamentals of Radiation Damage

Number of Vacancy/Interstitial Pairs produced by the ith reaction per incident particle of energy E per second , $N_d^i(E)$

$$N_d^i(E) = N_o \int \varphi(E) \sigma^i(E) K(E,T) \nu(T) dT$$

Where:

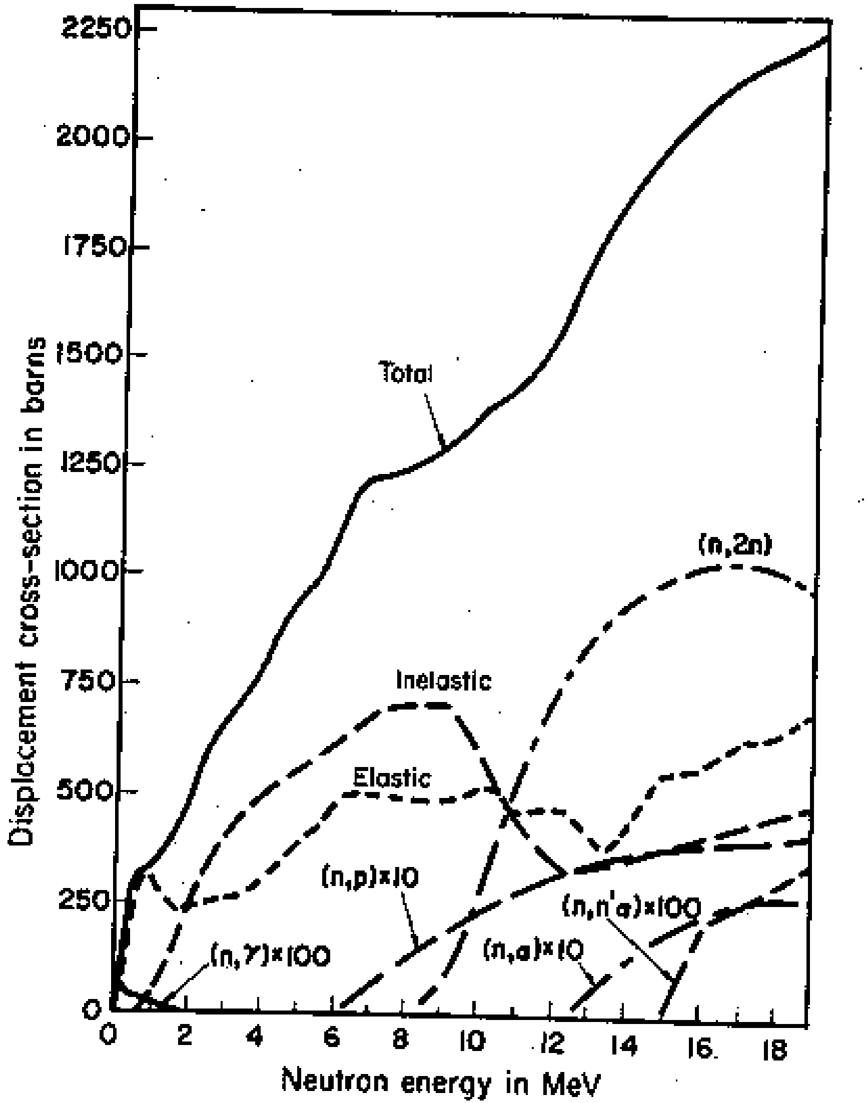
N_o = Atomic Density

ϕ (E) = Flux of particles of energy E

σ^i (E) = Probability that the incident particle with energy E, causing reaction i, will undergo an interaction with a matrix atom

K(E,T) = Probability that if an interaction takes place, it will produce a primary knock-on-atom (PKA) with energy T

ν(T) =Number of atoms subsequently displaced by the PKA



idual contributions to the total niobium displacement cross

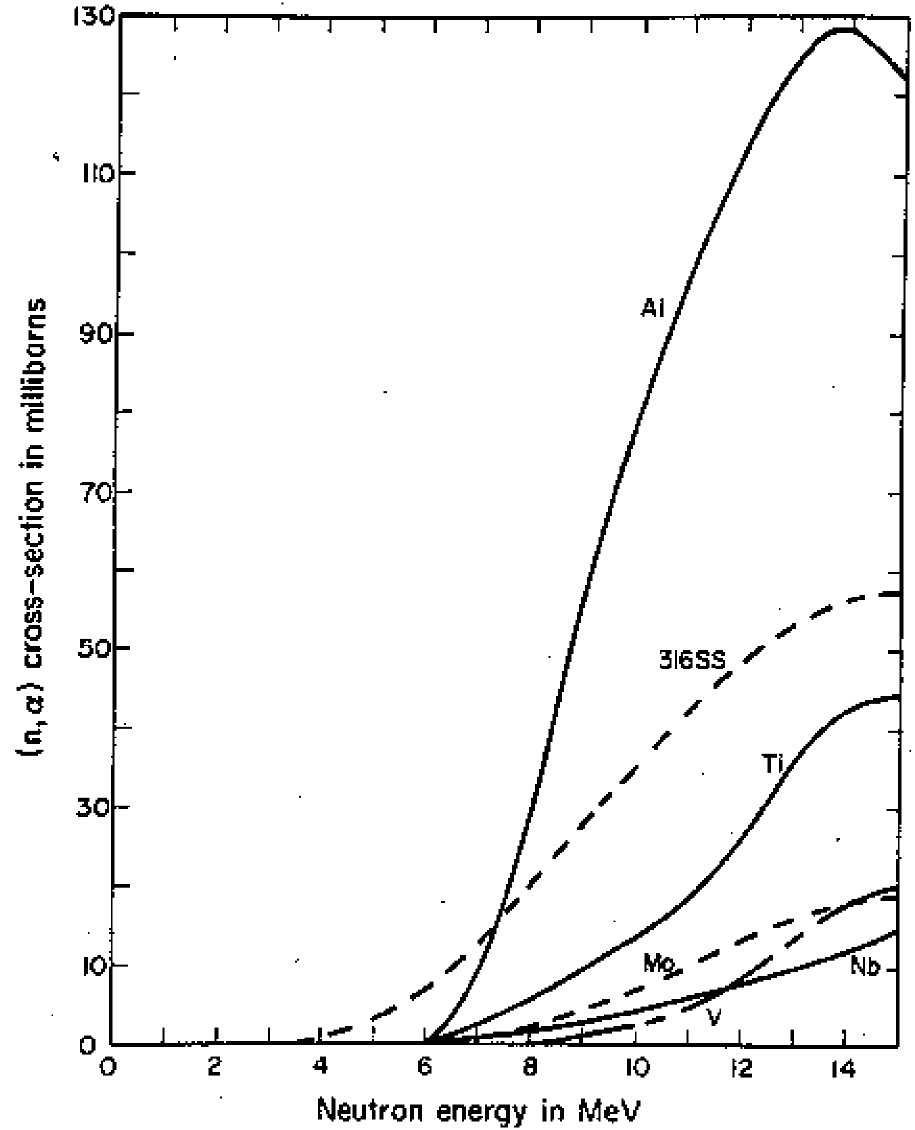
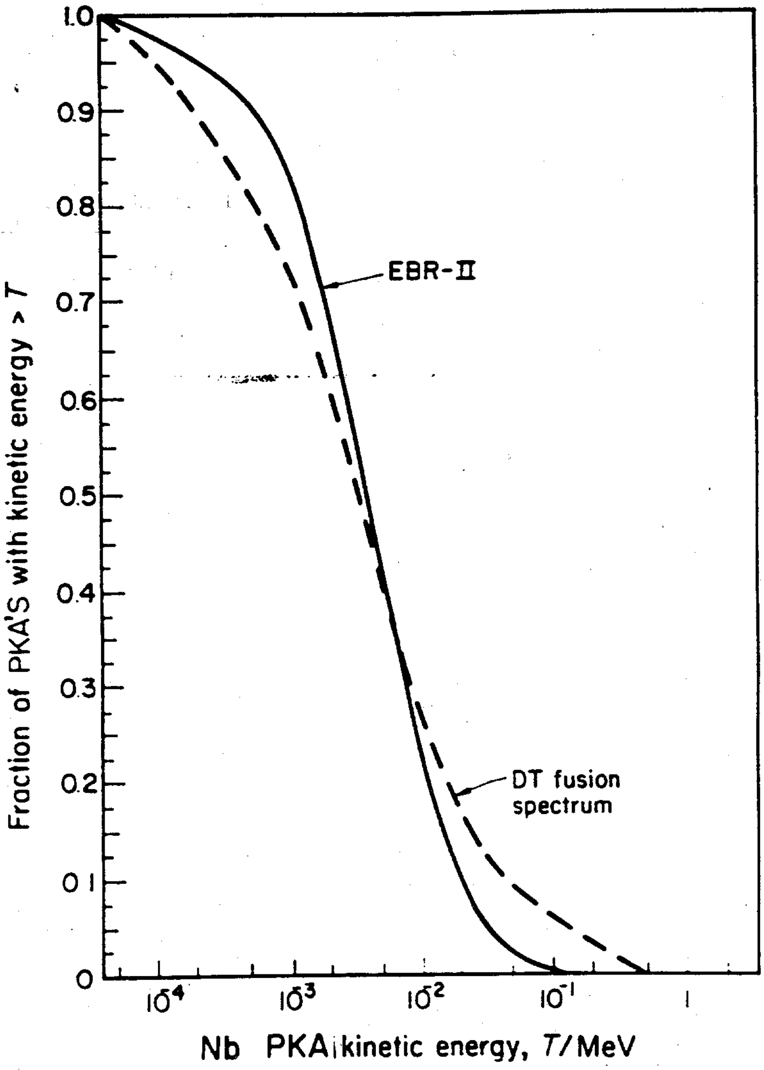
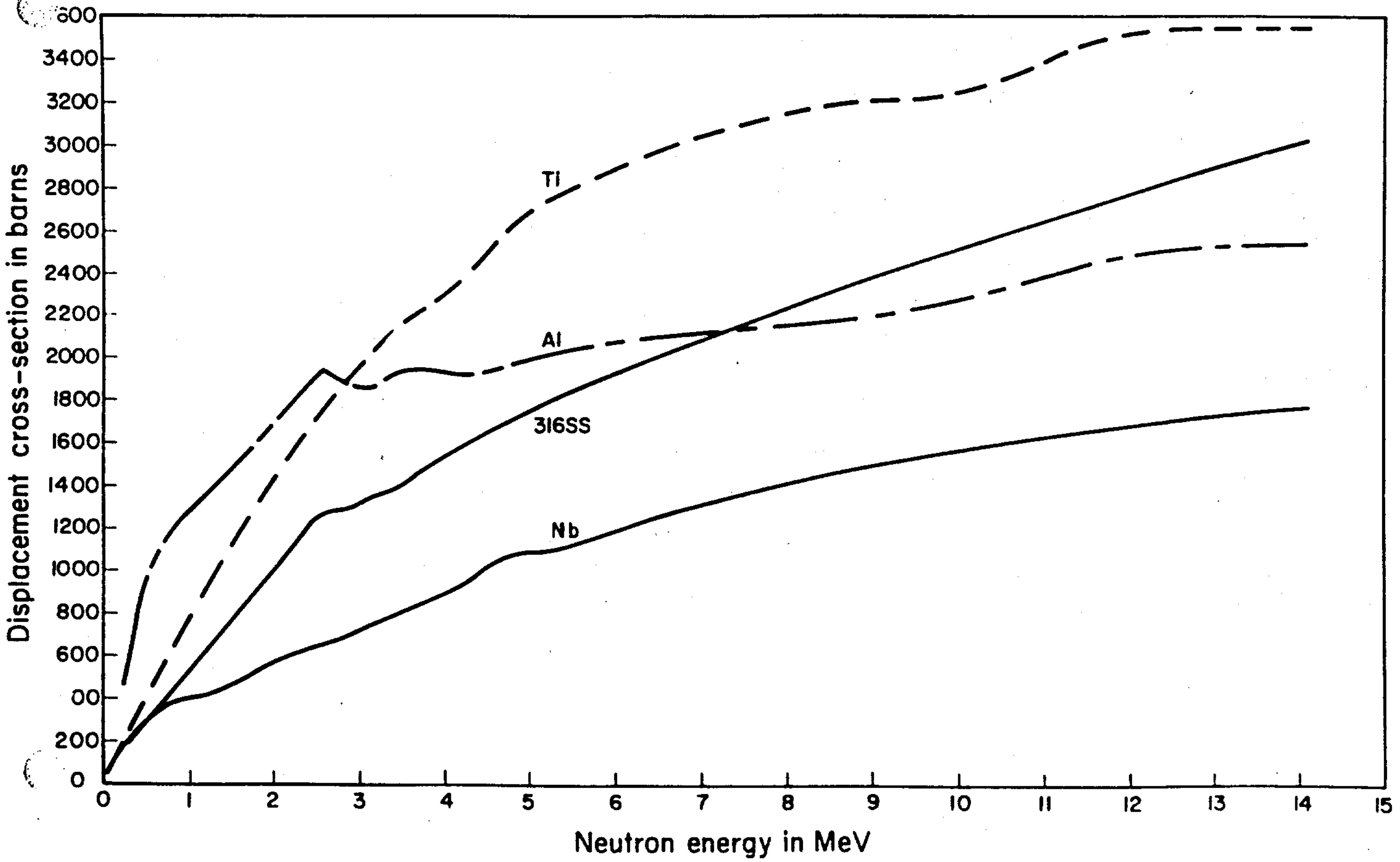


Figure 15. Helium gas production cross-section.



Fraction of PKA'S with kinetic energy > T
EBR-II
DT fusion spectrum
Nb PKA kinetic energy, T/MeV



Displacement cross-section in barns
Ti
Al
316SS
Nb
Neutron energy in MeV

Displacements per $\frac{MW}{m^2}$

Definition of dpa (displacements per atom) is the number of times that an atom is displaced for a given fluence.

$$\frac{N_d}{N_o} = \varphi t \sigma_d$$

Example of 1 $\frac{MW}{m^2}$

$$\varphi = 4.43x10^{13} \frac{n}{cm^2 - s}$$

$$\sigma_d = 3,000b$$

$$\frac{N_d}{N_o t} = 4.43x10^{13} \bullet 3x10^{-21}$$

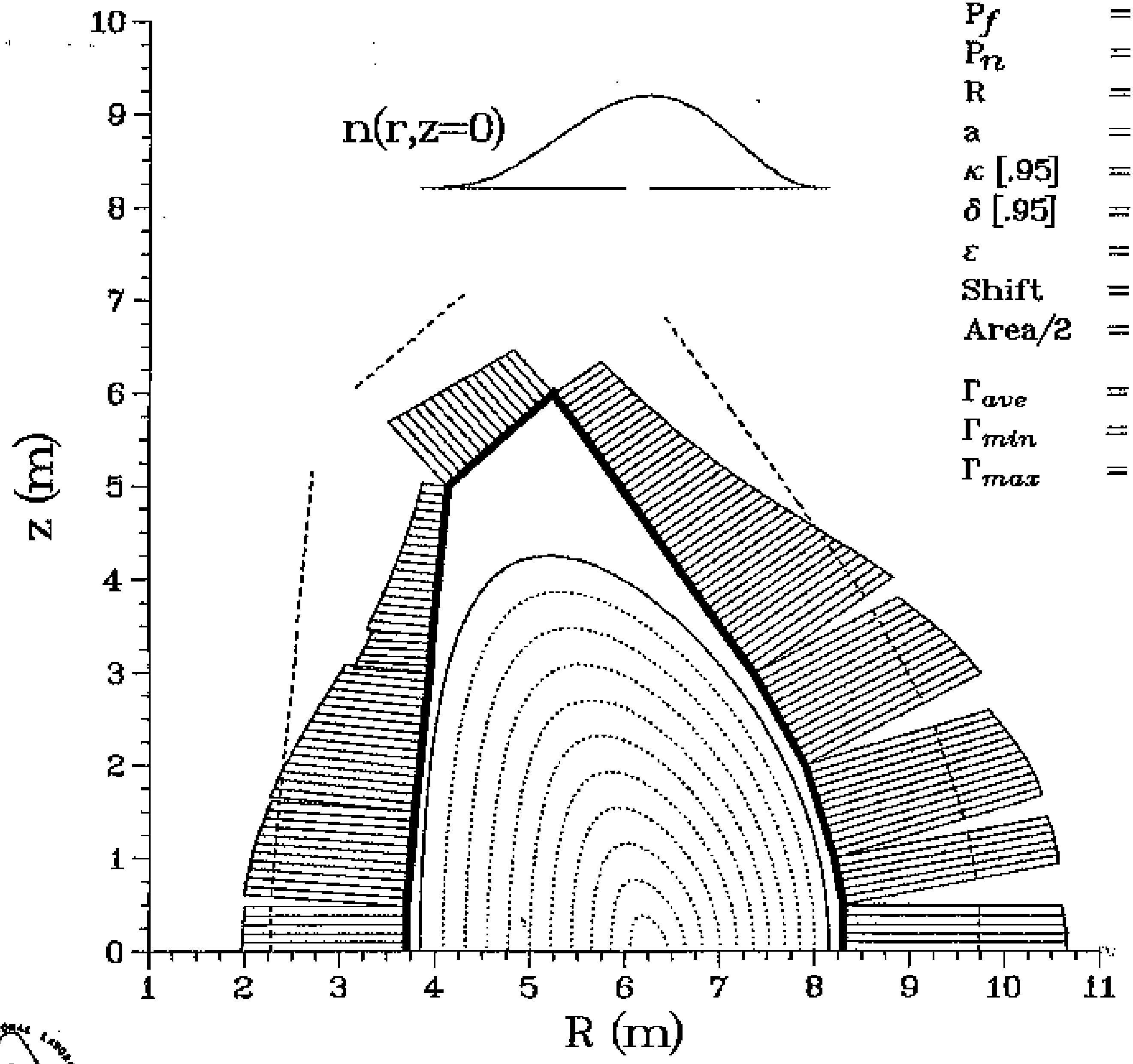
$$= 1.3x10^{-7} \frac{dpa}{s}$$

$$\approx 4 \frac{dpa}{FPY}$$

Damage Rate in CTR materials	
Material	**dpa/FPY per MW/m^2**
316 SS	10
V	12
Mo	8
SiC	30
Al	17

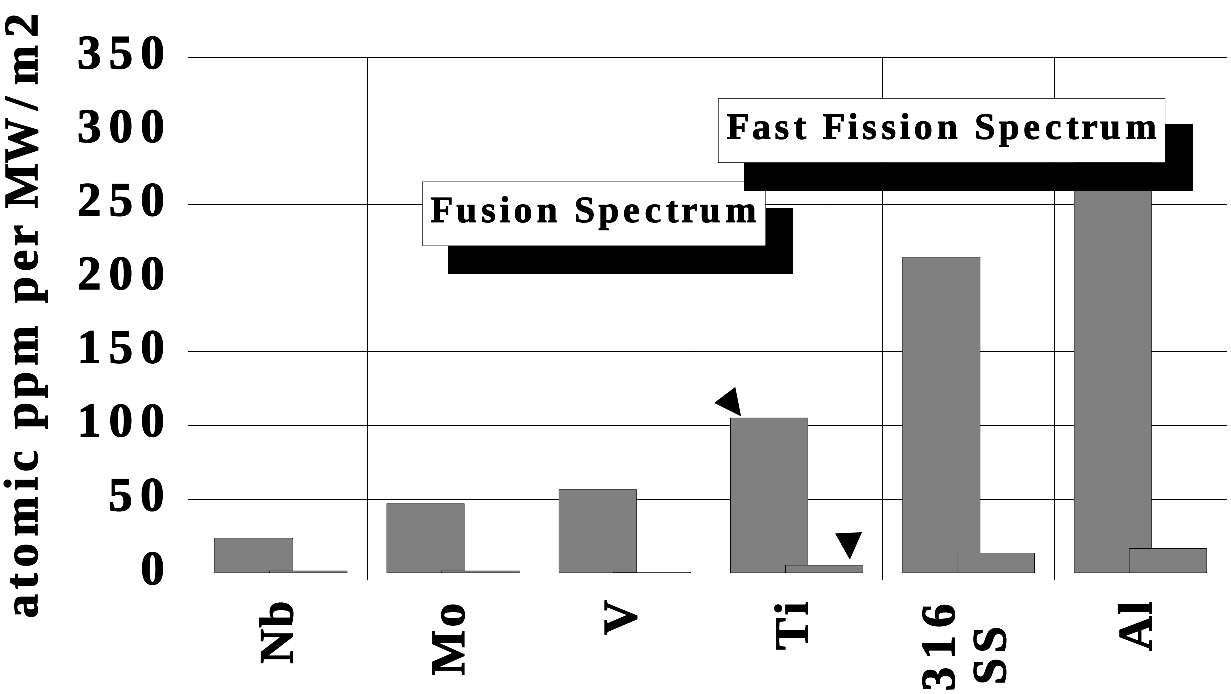
ITER Neutron Wall Loading Distribution

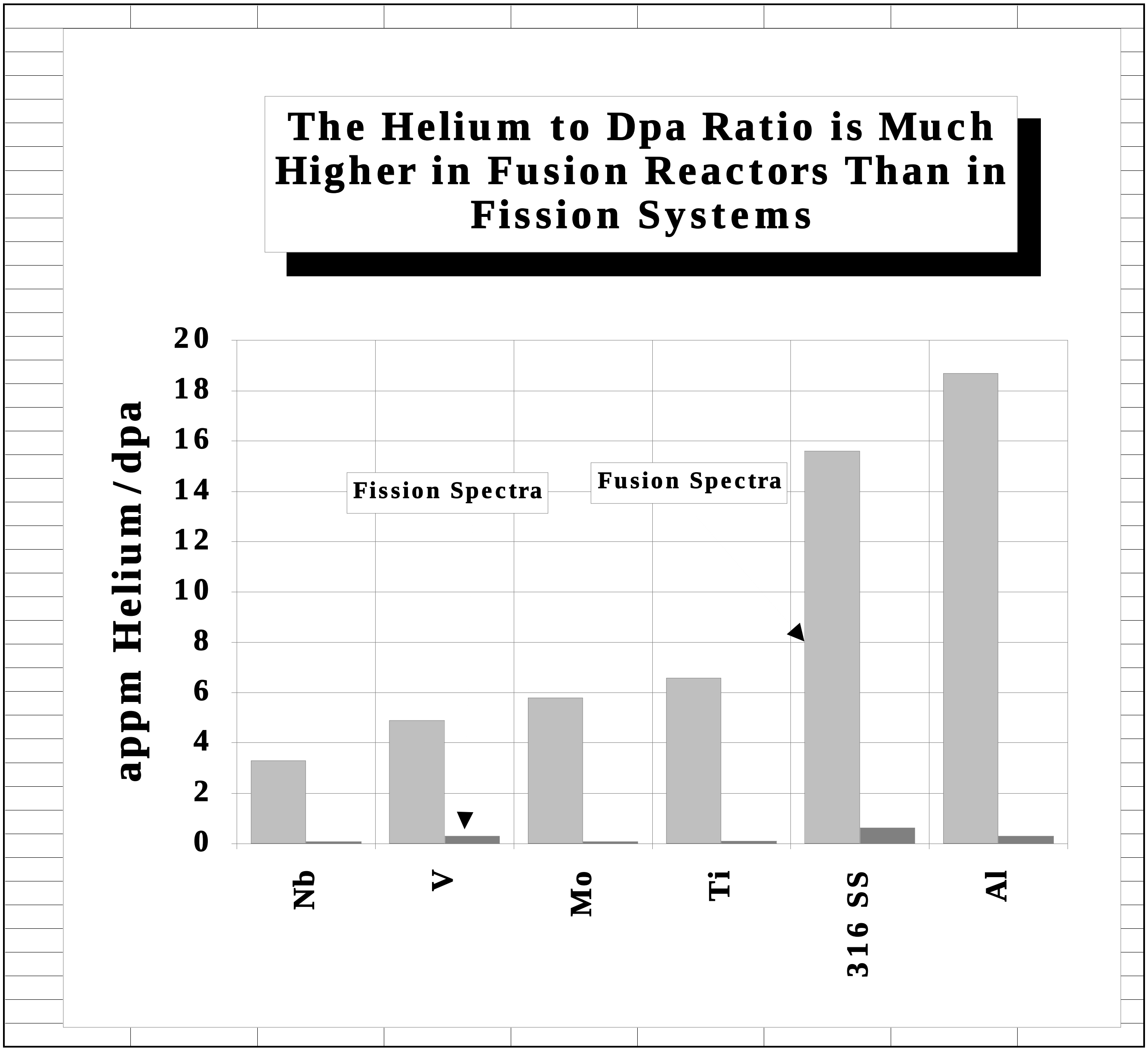
Pysics Phase 1100 MW



P_f	=	1100.
P_n	=	881.25
R	=	6.
a	=	2.15
κ [.95]	=	1.982
δ [.95]	=	0.383
ε	=	3.
Shift	=	0.255
Area/2	=	471.836
Γ_{ave}	=	0.934
Γ_{min}	=	0.175
Γ_{max}	=	1.54

The Production of Helium Gas in Metals and Alloys is much Greater than in Fission Reactors




The Helium to Dpa Ratio is Much Higher in Fusion Reactors Than in Fission Systems
appm Helium/dpa
20
18
16
14
12
10
8
6
4
2
0
Fission Spectra
Fusion Spectra
Nb
V
Mo
Ti
316 SS
Al