Materials Selection Issues for High Wall Loading Concepts

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Material Selection Criteria:
(conventional approach)

- unirradiated thermophysical properties
- radiation effects
- low activation
- material availability / fabricability / joining technology, etc.

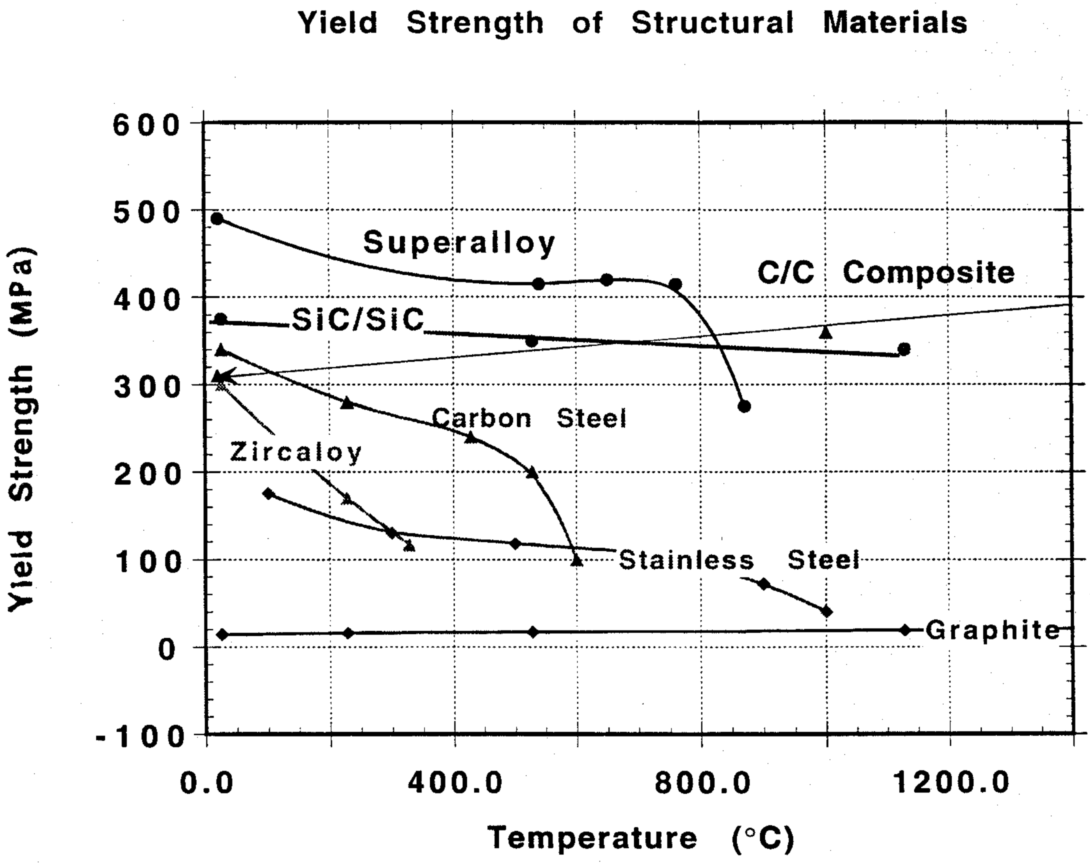
Possible Materials for High Wall Loading

- Low activation materials
  - Ferritic / martensitic alloys
  - Vanadium alloys
  - SiC / SiC composites

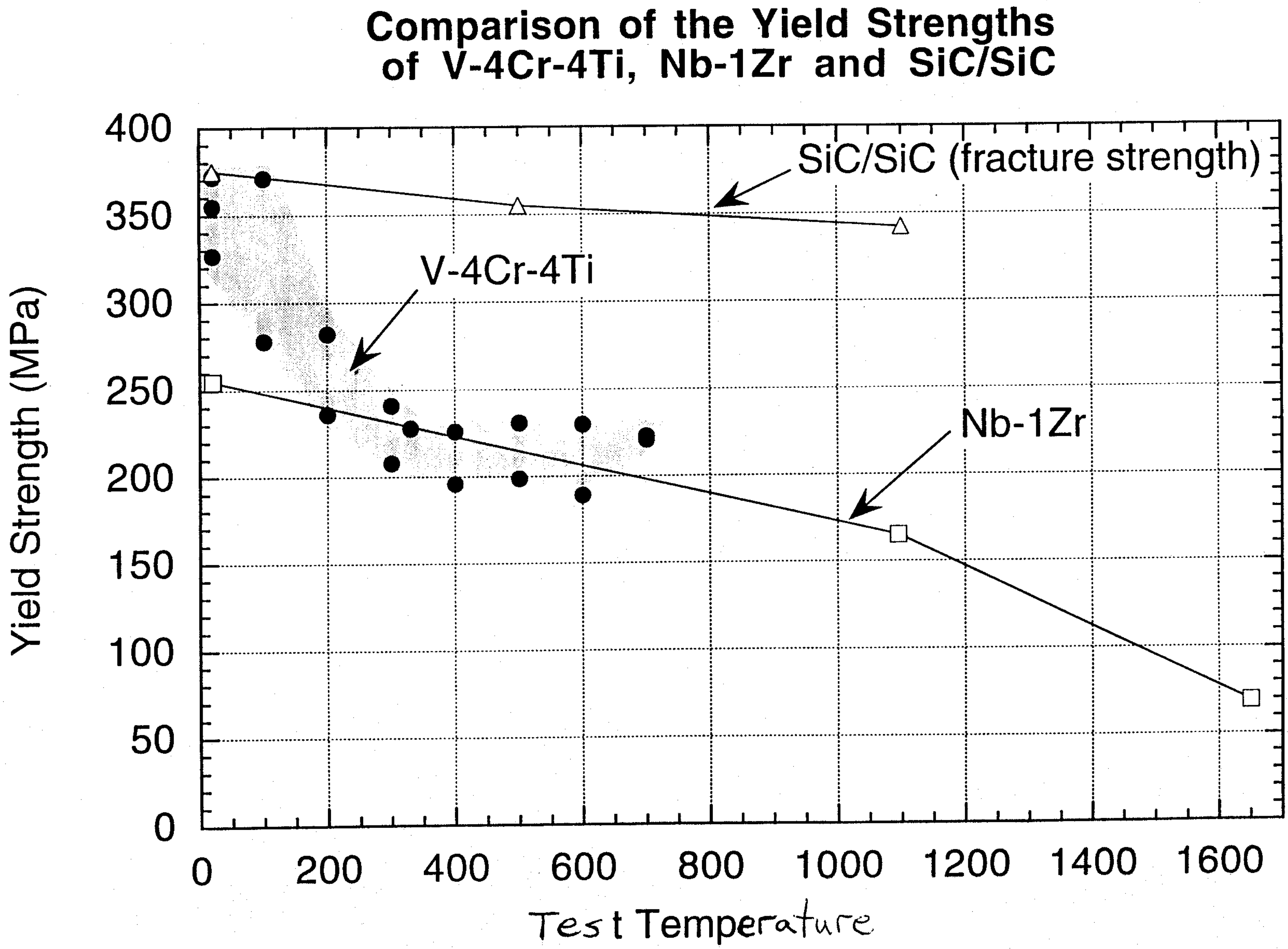
- Other conventional materials
  - Nb-1Zr
  - Cu alloys (DS Cu, CuCrZr, CuNiBe, Cu-Cr_2Nb, Cu-Nb)
  - C/C composites
  - Cu-graphite composites

- Newly developed materials
  - Ti_3 Si C_2 composites

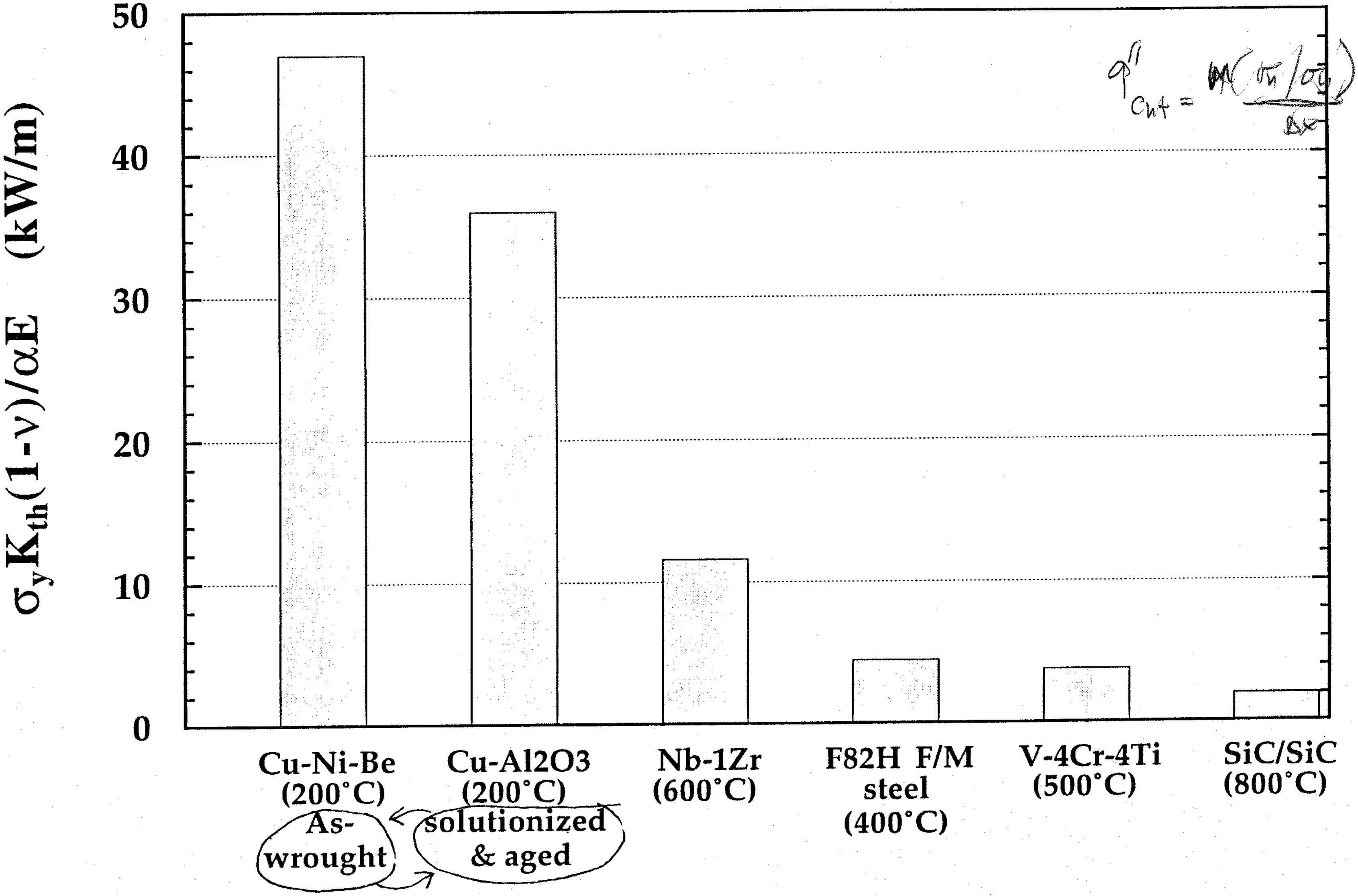
- "Innovative" materials
  - porous matrix metals & ceramics



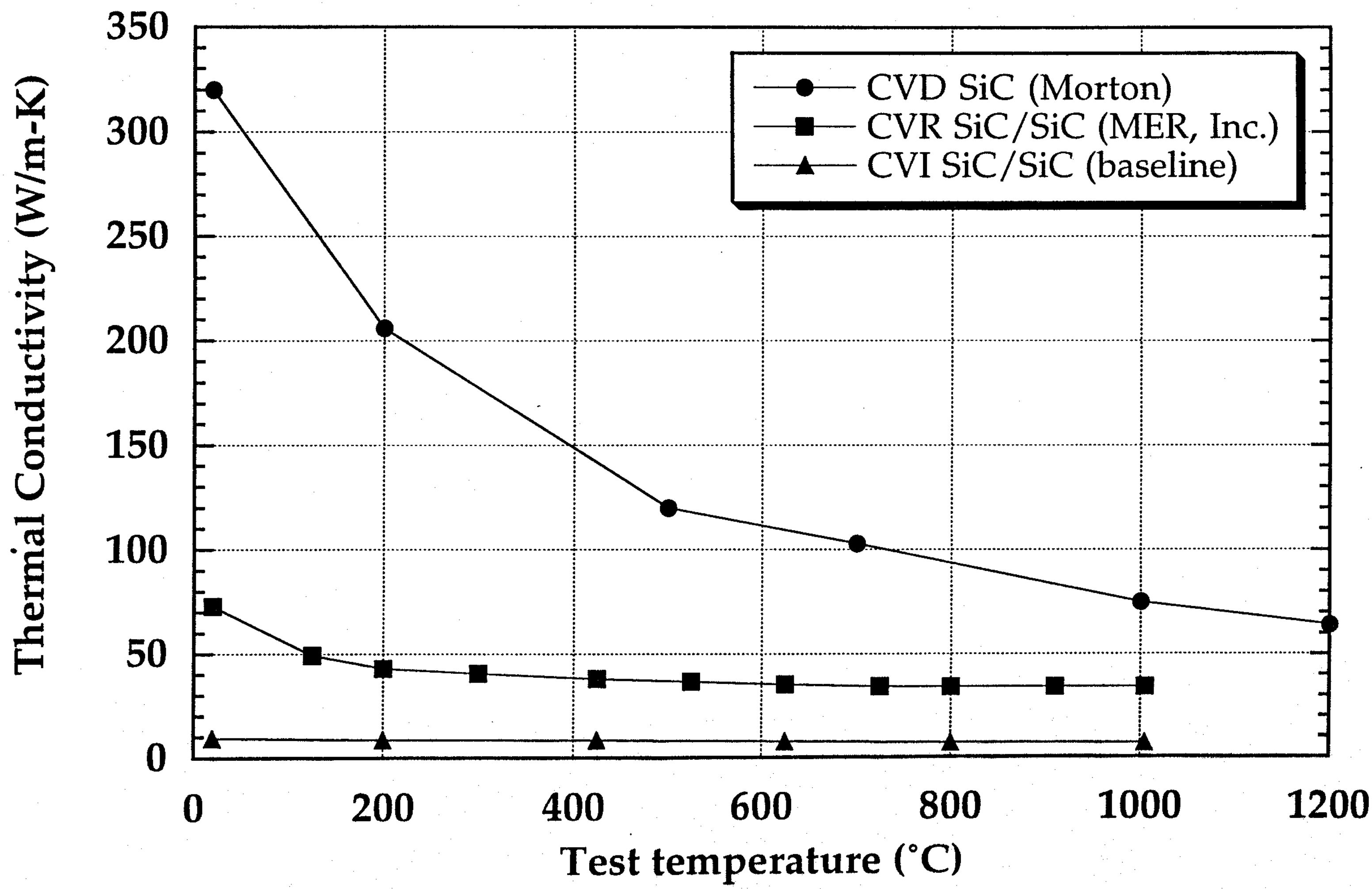
Yield Strength of Structural Materials
Yield Strength (MPa)
600
500
400
300
200
100
0
-100
Temperature (°C)
0.0
400.0
800.0
1200.0
Superalloy
C/C Composite
SiC/SiC
Carbon Steel
Zircaloy
Stainless Steel
Graphite


Comparison of the Yield Strengths
of V-4Cr-4Ti, Nb-1Zr and SiC/SiC
Yield Strength (MPa)
400
350
300
250
200
150
100
50
0
0
200
400
600
800
1000
1200
1400
1600
Test Temperature
SiC/SiC (fracture strength)
V-4Cr-4Ti
Nb-1Zr

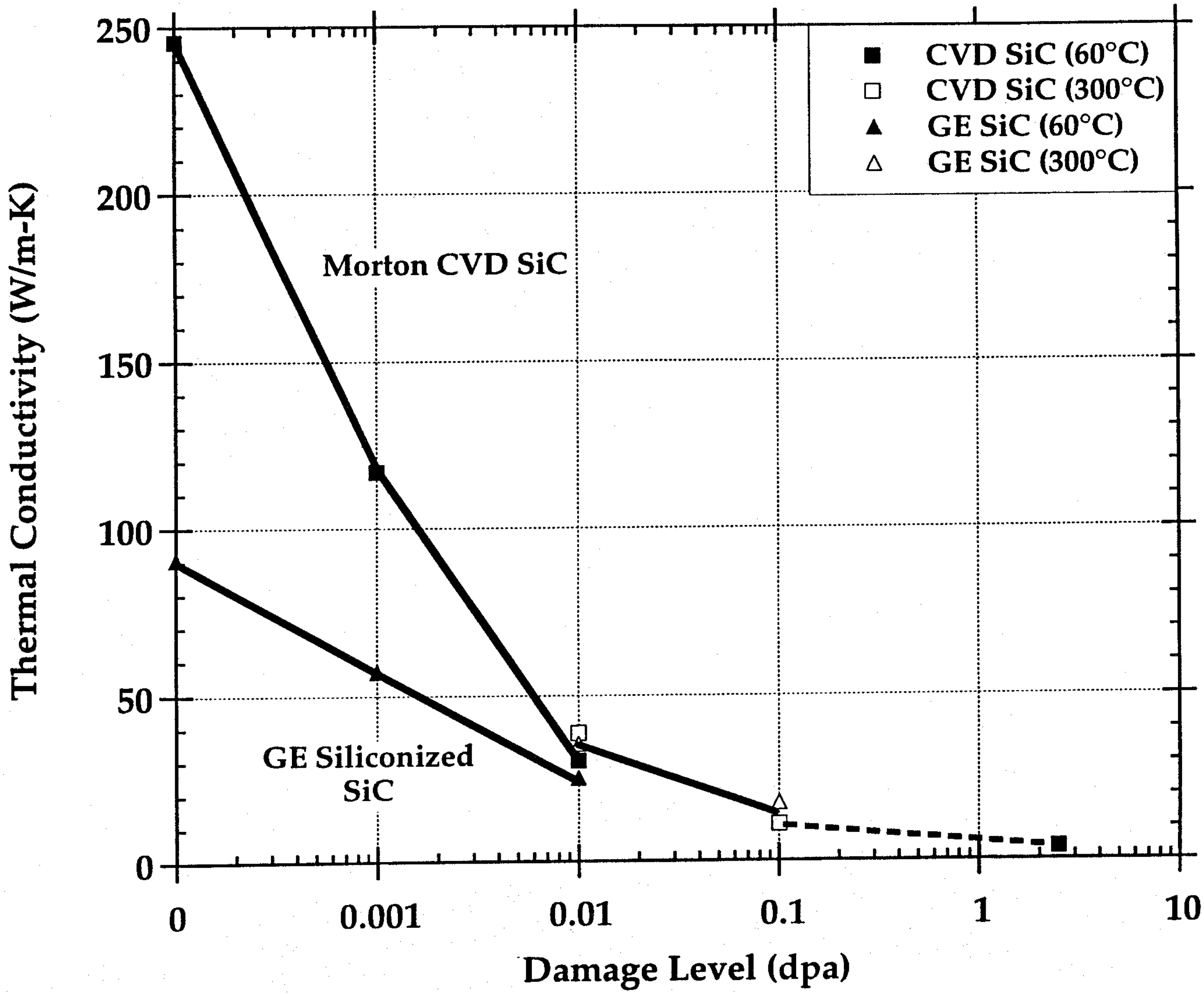
COMPARISON OF THERMAL STRESS PARAMETERS



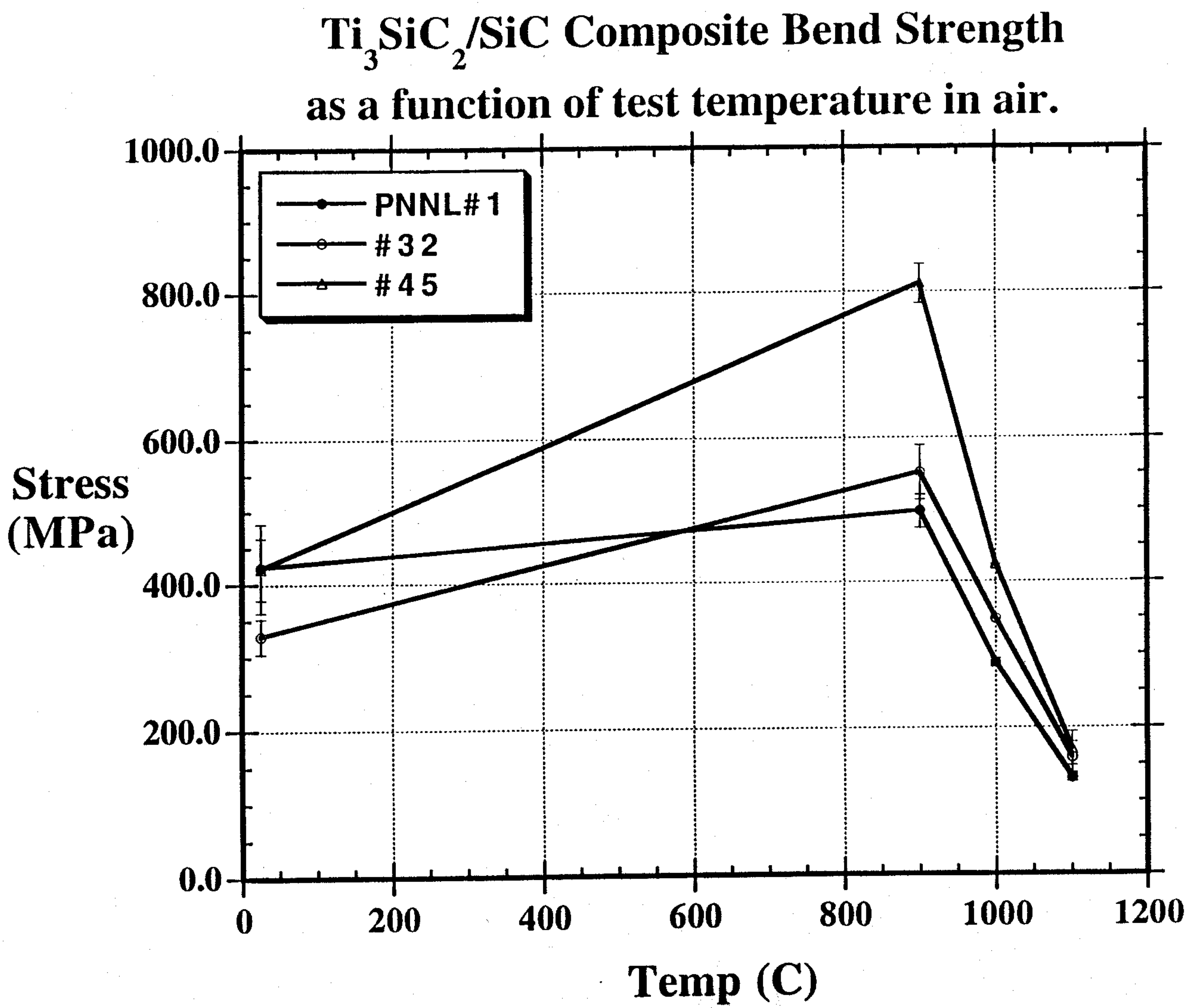
Large Improvements in the Thermal Conductivity of SiC have been Achieved in the Past Five Years



Low-Temperature Neutron Irradiation Causes a Dramatic Decrease in SiC Thermal Conductivity



L.L. Snead, S.J. Zinkle, D.P. White
J. Nucl. Mater. (1997) in press



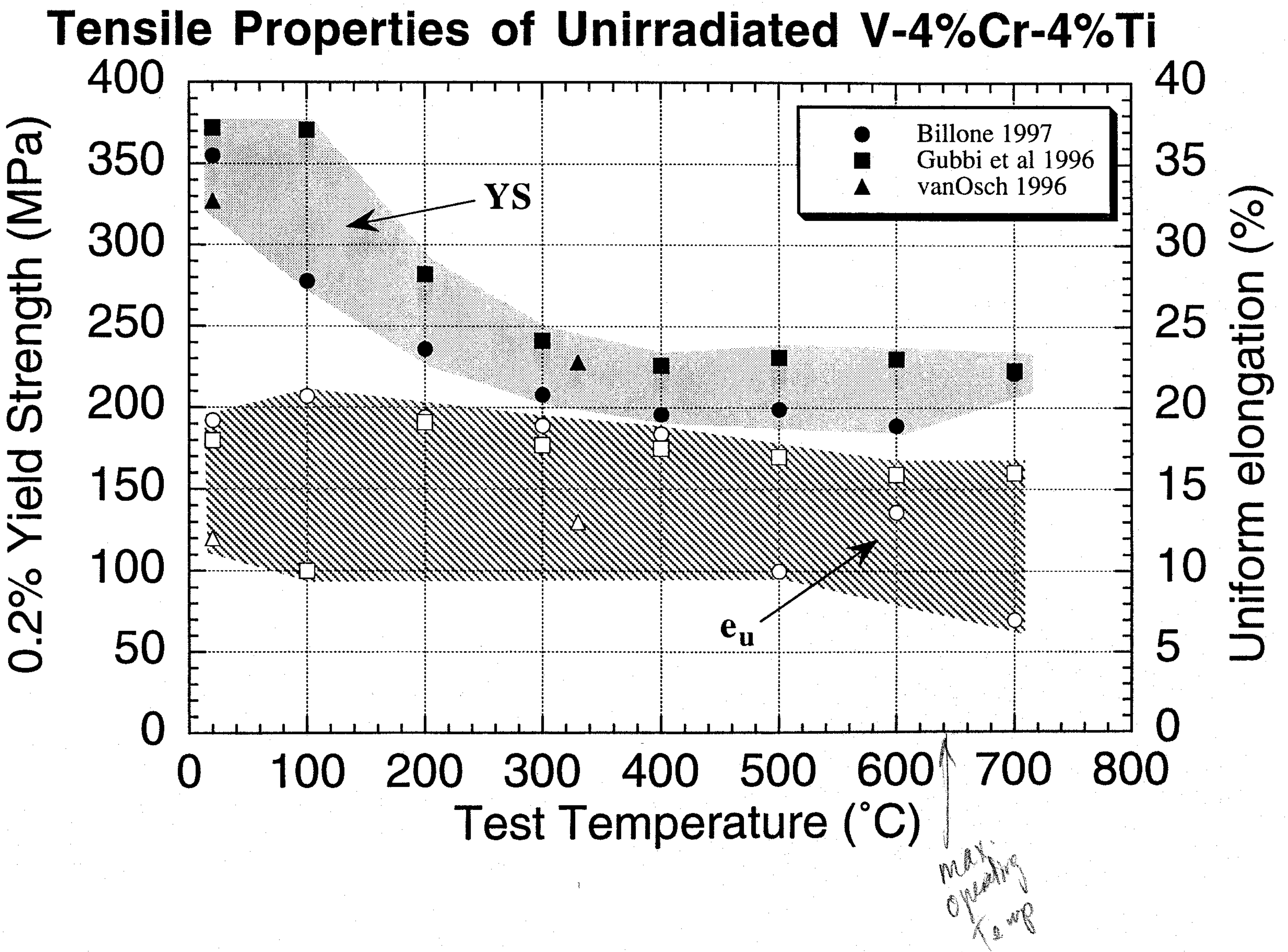
Ti_3SiC_2/SiC Composite Bend Strength
as a function of test temperature in air.
PNNL#1
#32
#45
Stress (MPa)
1000.0
800.0
600.0
400.0
200.0
0.0
0
200
400
600
800
1000
1200
Temp (C)

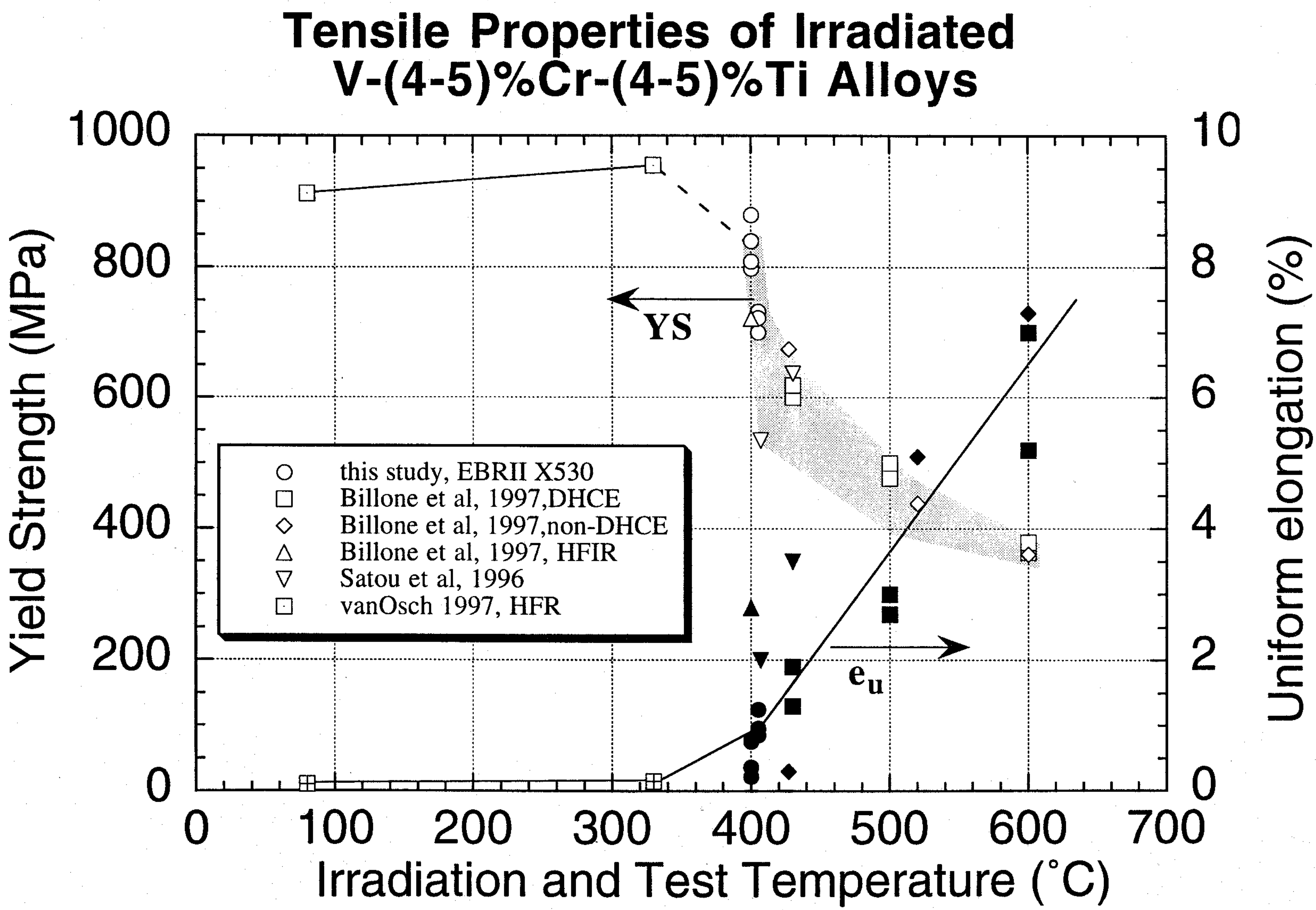
Conclusions

- Low activation materials may be able to meet the APEX neutron wall loading goal of $7 MW/m^2$ (if 3 mm wall thickness is viable)

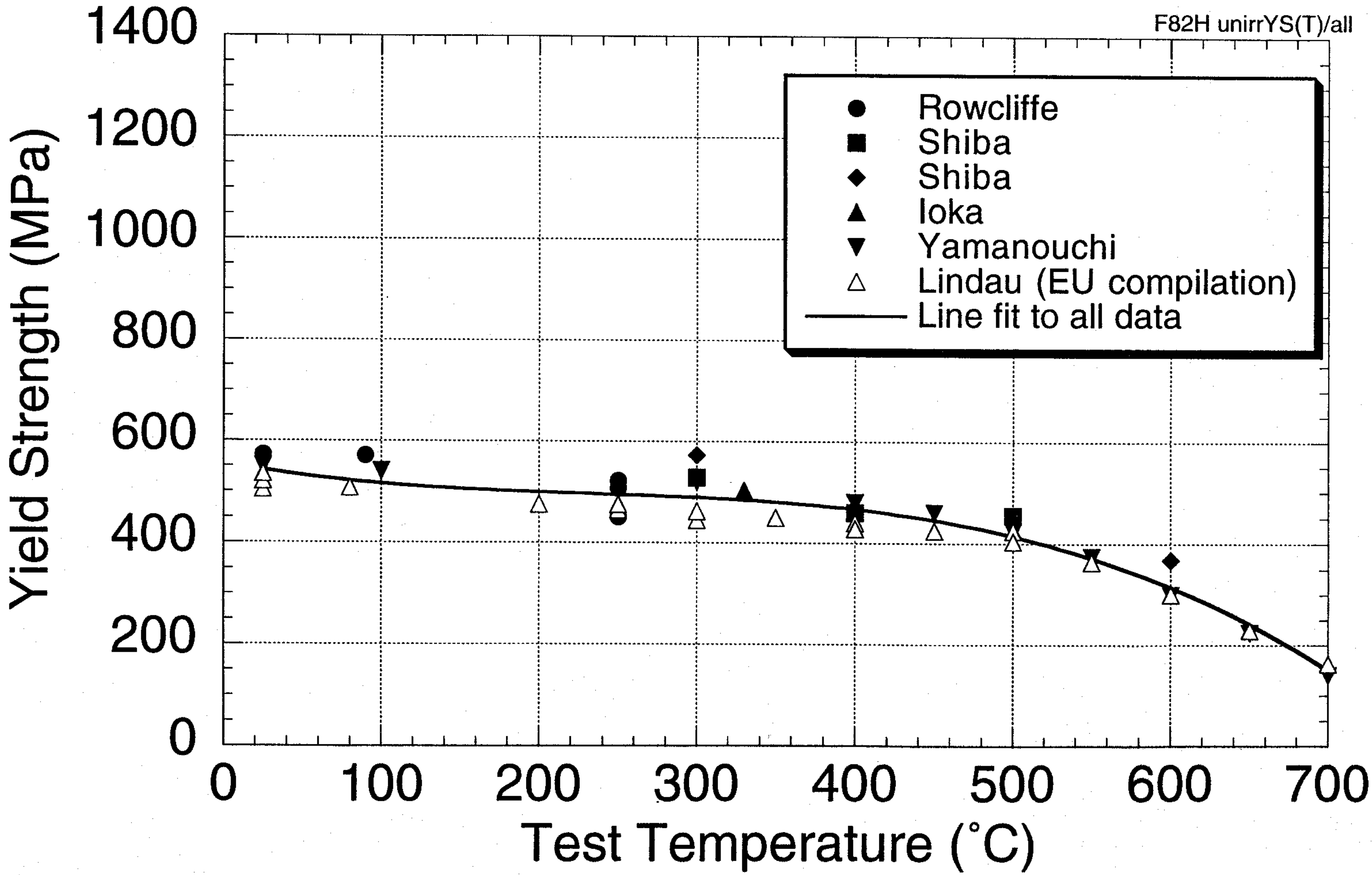
- Alternate materials (e.g. $Ti_3\ Si\ C_2$) and design philosophies (e.g. porous membranes) may allow additional increases in wall loading

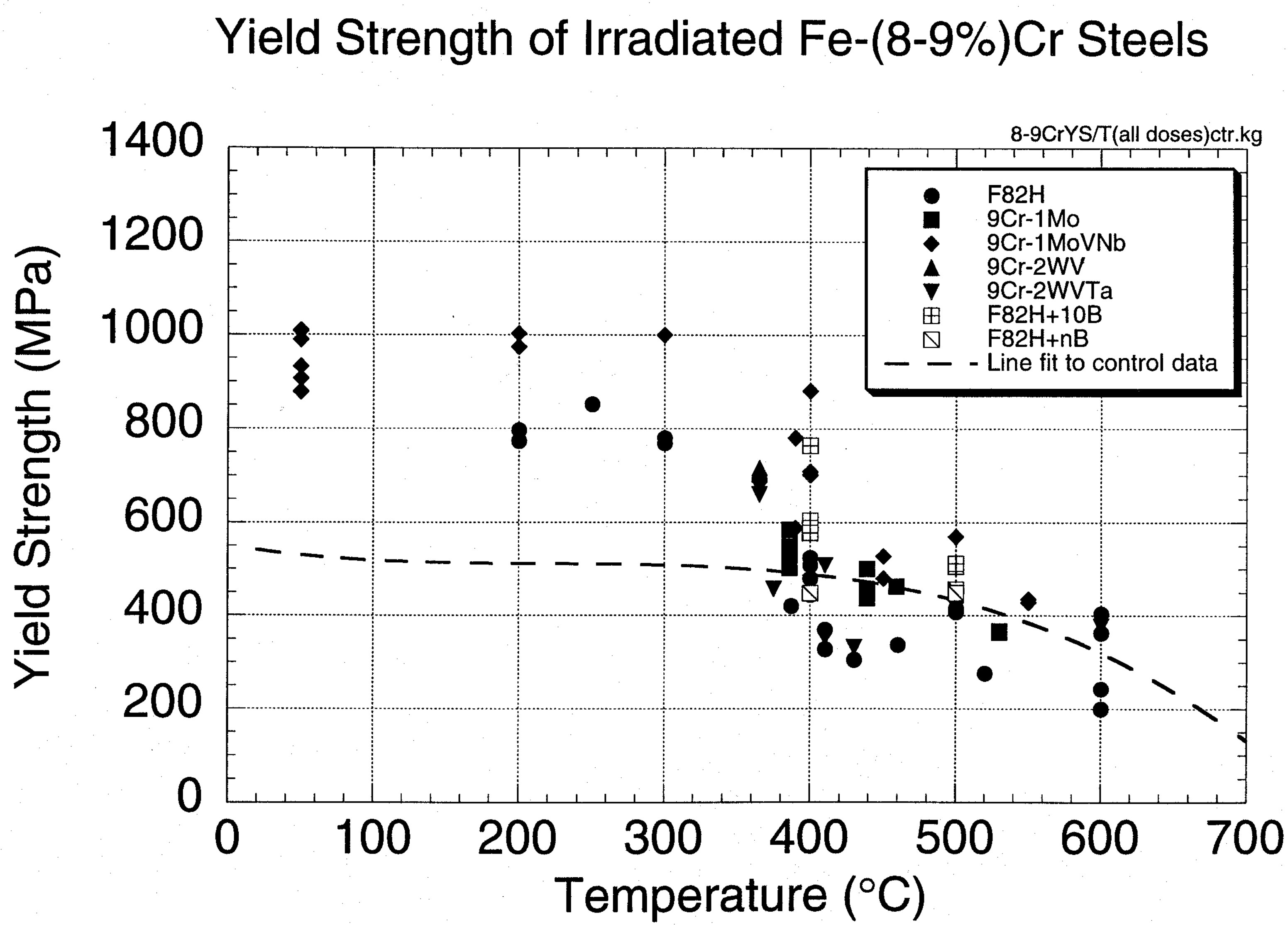
- The material operating limits are determined by the temperature-dependent thermophysical properties (taking into account radiation effects)


Tensile Properties of Unirradiated V-4%Cr-4%Ti
0.2% Yield Strength (MPa)
Uniform elongation (%)
Test Temperature (˚C)
Billone 1997
Gubbi et al 1996
vanOsch 1996
YS
e_u
0
100
200
300
400
500
600
700
800
0
50
100
150
200
250
300
350
400
0
5
10
15
20
25
30
35
40
max. operating Temp


Tensile Properties of Irradiated
V-(4-5)%Cr-(4-5)%Ti Alloys
Yield Strength (MPa)
Uniform elongation (%)
Irradiation and Test Temperature (˚C)
YS
e_u
this study, EBRII X530
Billone et al, 1997,DHCE
Billone et al, 1997,non-DHCE
Billone et al, 1997, HFIR
Satou et al, 1996
vanOsch 1997, HFR
0
200
400
600
800
1000
0
2
4
6
8
10
0
100
200
300
400
500
600
700

Yield Strength of Unirradiated F82H Ferritic/Martensitic Steel




Yield Strength of Irradiated Fe-(8-9%)Cr Steels
8-9CrYS/T(all doses)ctr.kg
Yield Strength (MPa)
Temperature (°C)
F82H
9Cr-1Mo
9Cr-1MoVNb
9Cr-2WV
9Cr-2WVTa
F82H+10B
F82H+nB
Line fit to control data
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500
600
700

1,2 1,4 1,6 1,8 2 2,2 2,4
Irradiation Dose in dpa

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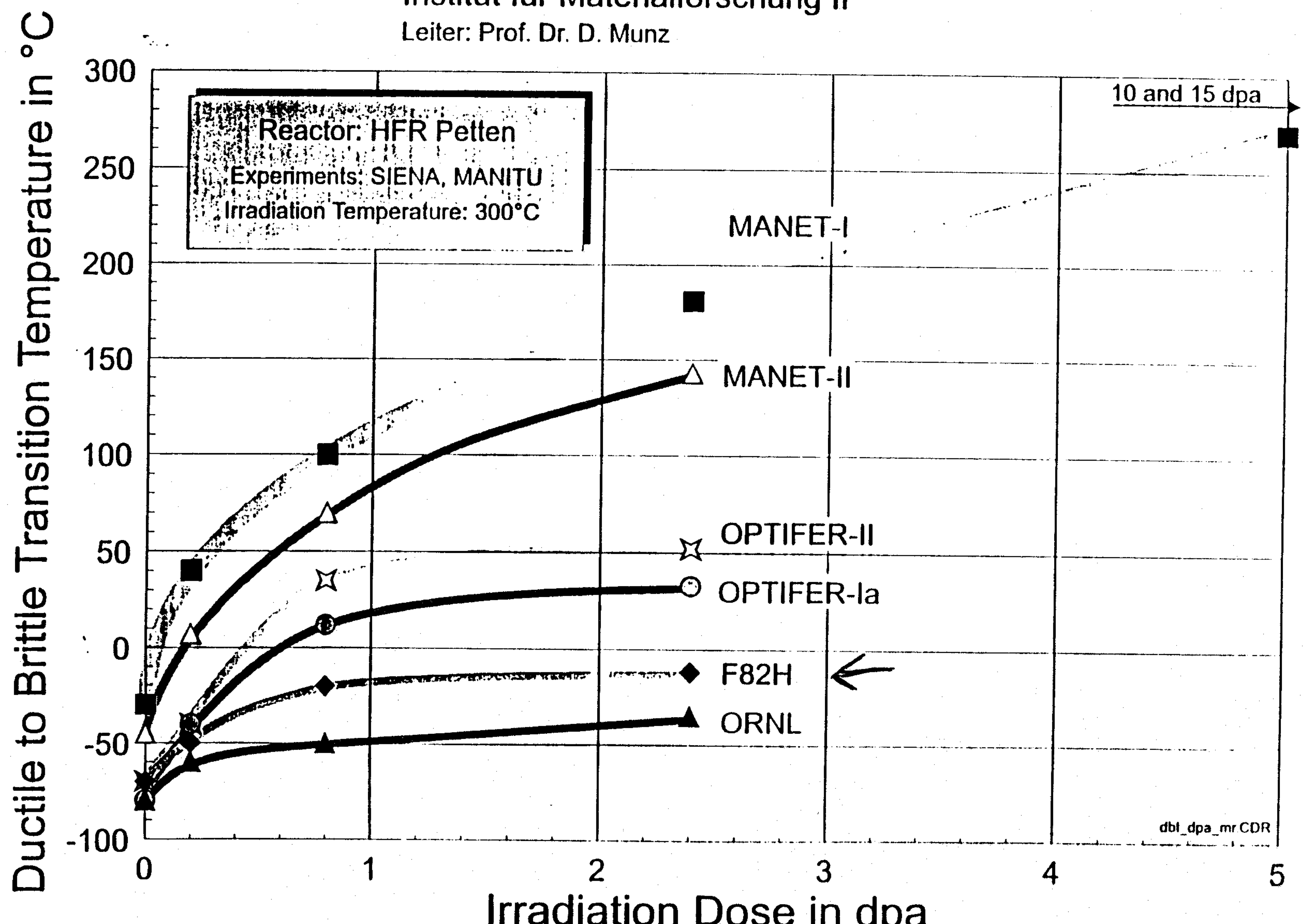
Leiter: Prof. Dr. D. Munz



M. Rieth, Irradiation project manitu 300°C, Rev. 30.08.1996

9CR-2WVTa IS IMPROVEMENT OVER CONVENTIONAL STEELS