SP -100 Structural Alloy Selection

Main Criterion For Alloy Selection - (1985)

Technology in place and fabrication for Ground Engineering System (GES) can commence without an extensive development program.

Specific Requirements

1.) Strength and ductility adequate at operating temperatures as well as at launch temperatures.

2.) Strength and ductility should remain stable throughout the operating life of the reactor. If degradation does occur, the design must accommodate change. Special attention to:

a.) Aging and loss of strength during long times at high temperature.

b.) Leaching of interstitial elements such as C by liquid metal causing loss of strength.

c.) Radiation induced mechanical property changes as well as swelling of the material.

3.) Alloy must be compatible with both the nuclear fuel and the liquid metal coolant.

4.) Alloy must have low parasitic capture cross-section for neutrons. (Core size)

5.) Strength to weight ratio should be high

6.) Technology for fabrication and joining sufficiently advanced to fabricate required parts now.

7.) Existing data base so extensive that one can have confidence in the predicted engineering properties.

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No alloy has all the necessary properties , so must make trade-offs.

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Since the outlet coolant temperature is ≈ 1350°K, and the cladding temperature will be ≈ 1400°K, and it is a general rule of thumb that one should stay below 1/2 the absolute MP to avoid excessive creep, only refractory metals (Nb, Ta, Mo, Re, & W) are feasible to carry the coolant.

Re fails the fabrication test as well as the well-established industry test.

Note:

- **Nb -1Zr -0.1C (PWC -11) was in production 25 years ago and chosen for the SNAP -50**

- **Best Ta alloy is ASTAR-811C which is (Ta -8W -1Hf -0.7Re - 0.025C). Re and C help to improve creep strength at high temperatures.**

- **Mo -14Re is an alloy which has shown good creep properties but still is being developed.**

- **W -26Re has good ductility and has been subjected to some irradiation's.**

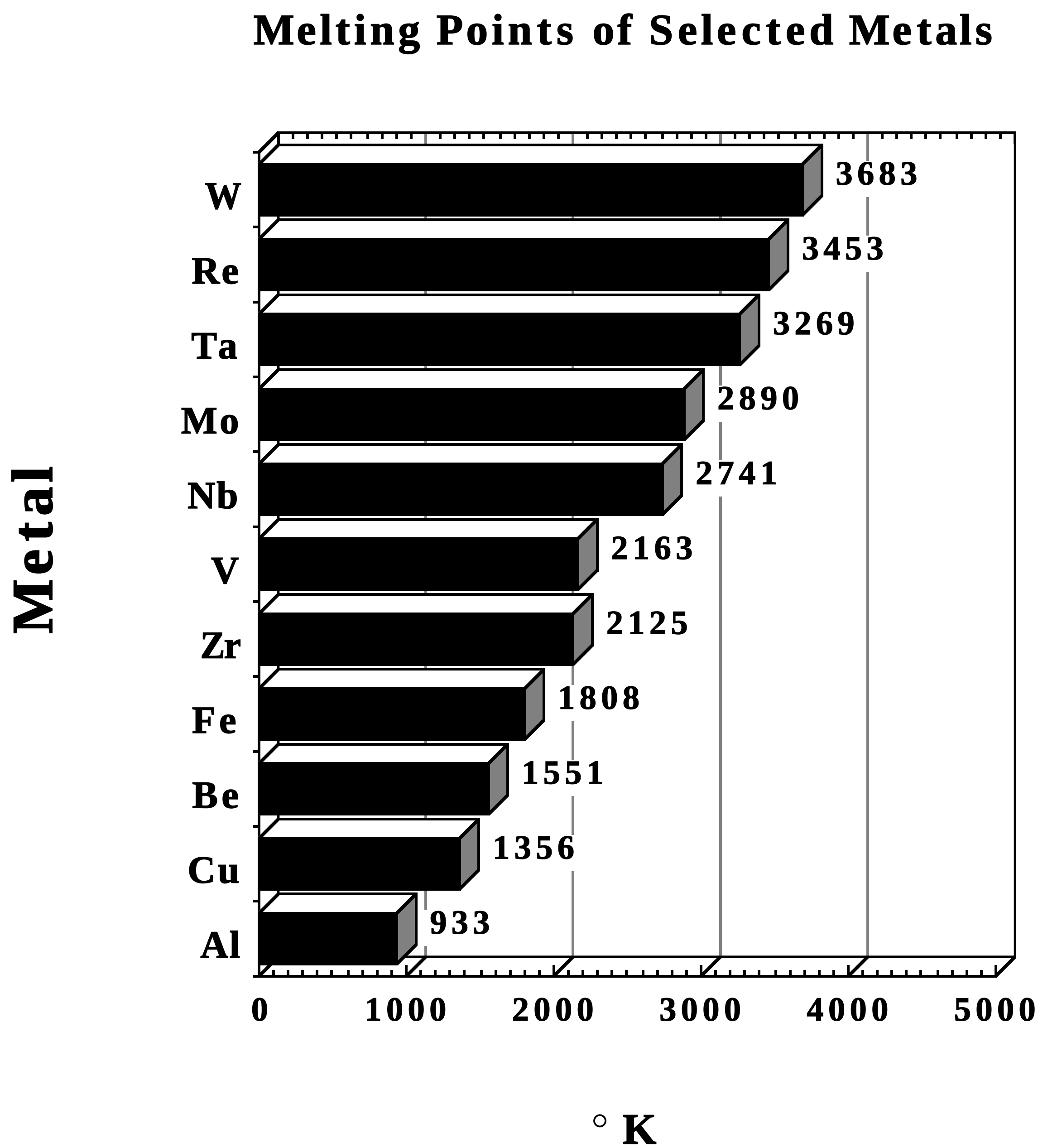
General Observations About Refractory Alloys

Strength **- Even though the strength of Nb-Zr alloys is lower than others, its lower density and the addition of 0.1C to improve strength reduces this disadvantage.**

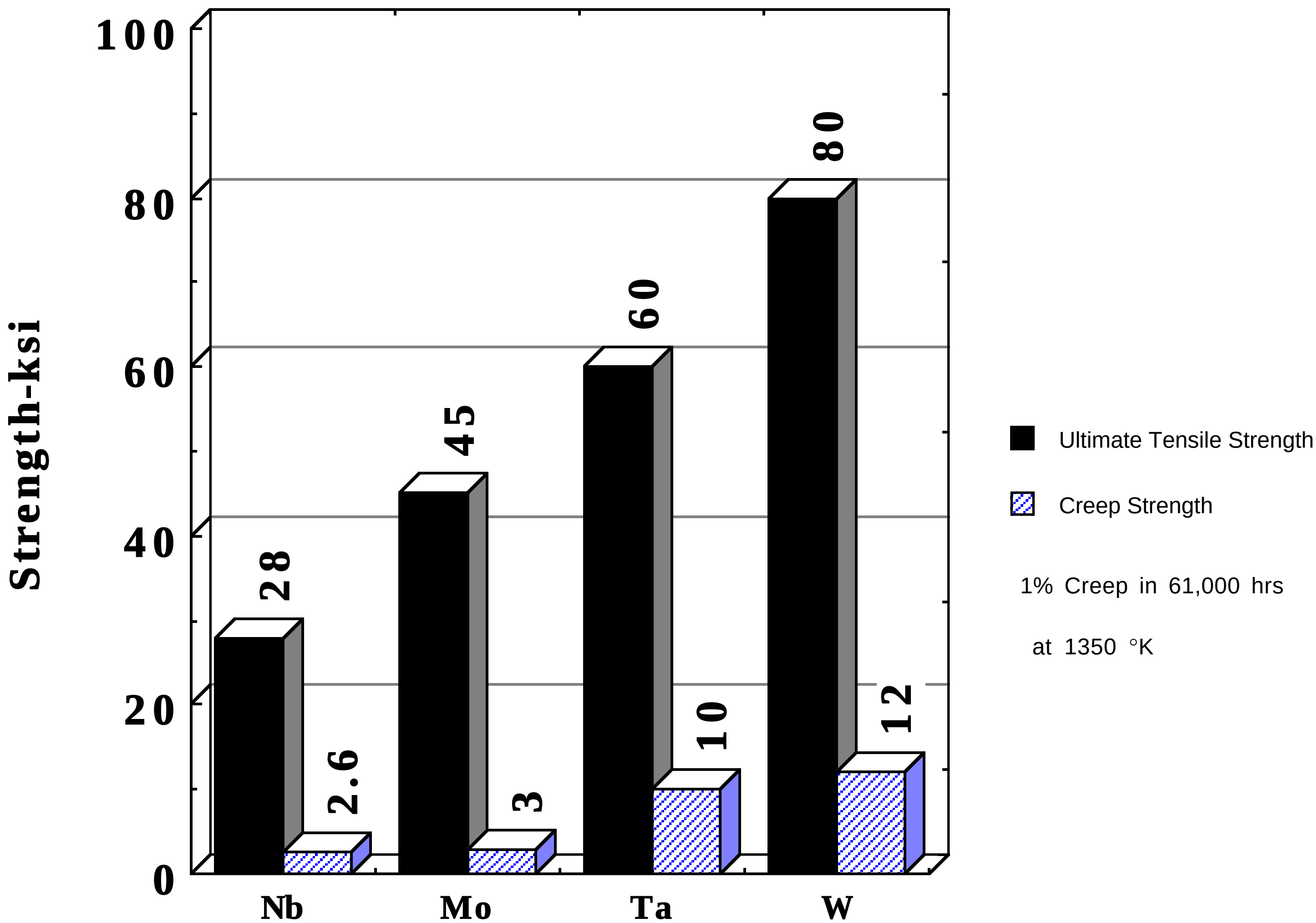
All the alloys except W-26Re have reasonable DBTT's. (5 figures)

Stability of Properties **- More data is required on long term strengthening of Nb-Zr alloys with C at temperatures of 1550°K.**

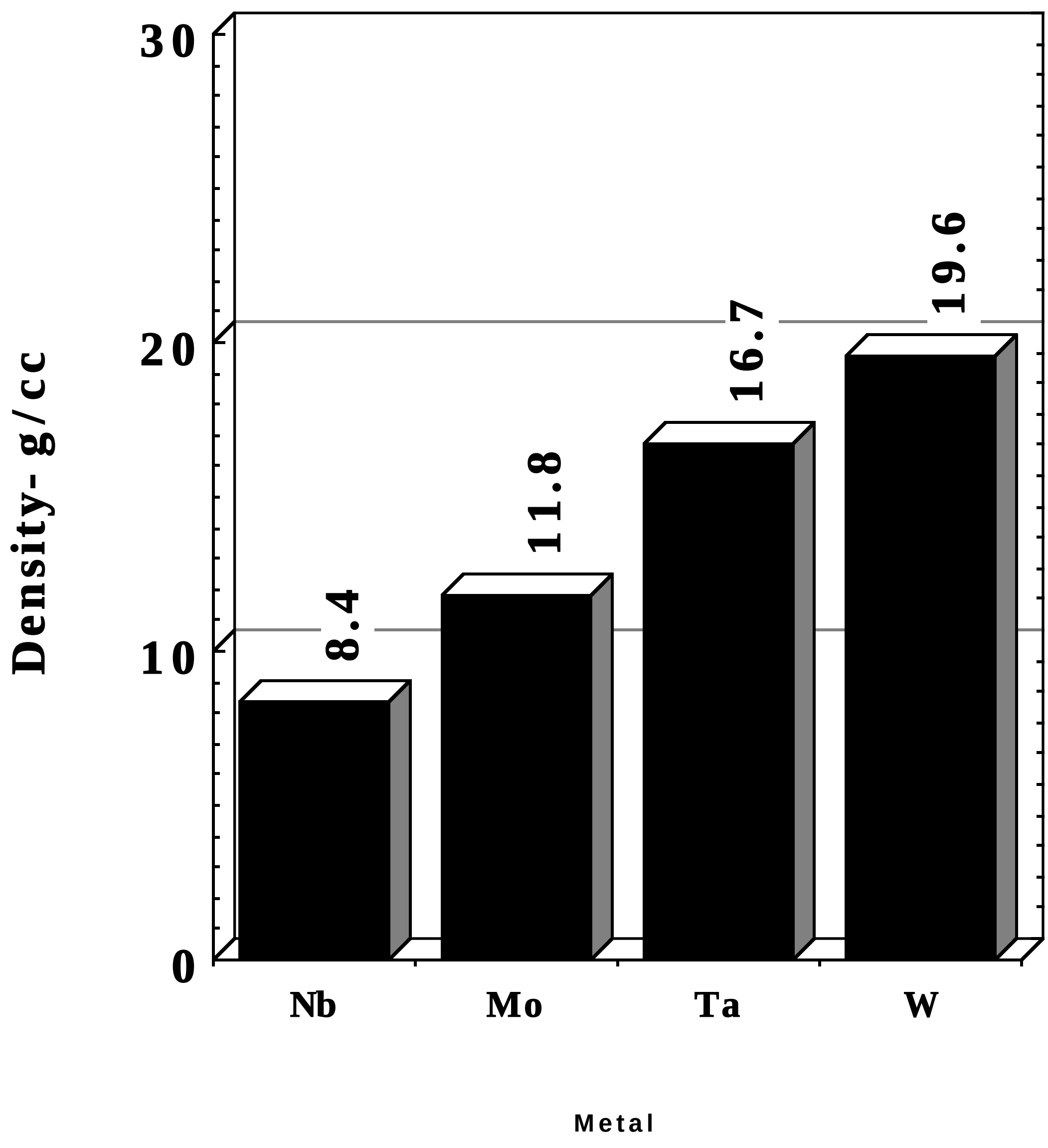
Carbon is not leached from PWC-11 provided the entire loop is made from the same alloy and ΔT's are low.


Melting Points of Selected Metals
Metal
W
Re
Ta
Mo
Nb
V
Zr
Fe
Be
Cu
Al
3683
3453
3269
2890
2741
2163
2125
1808
1551
1356
933
0
1000
2000
3000
4000
5000
° K

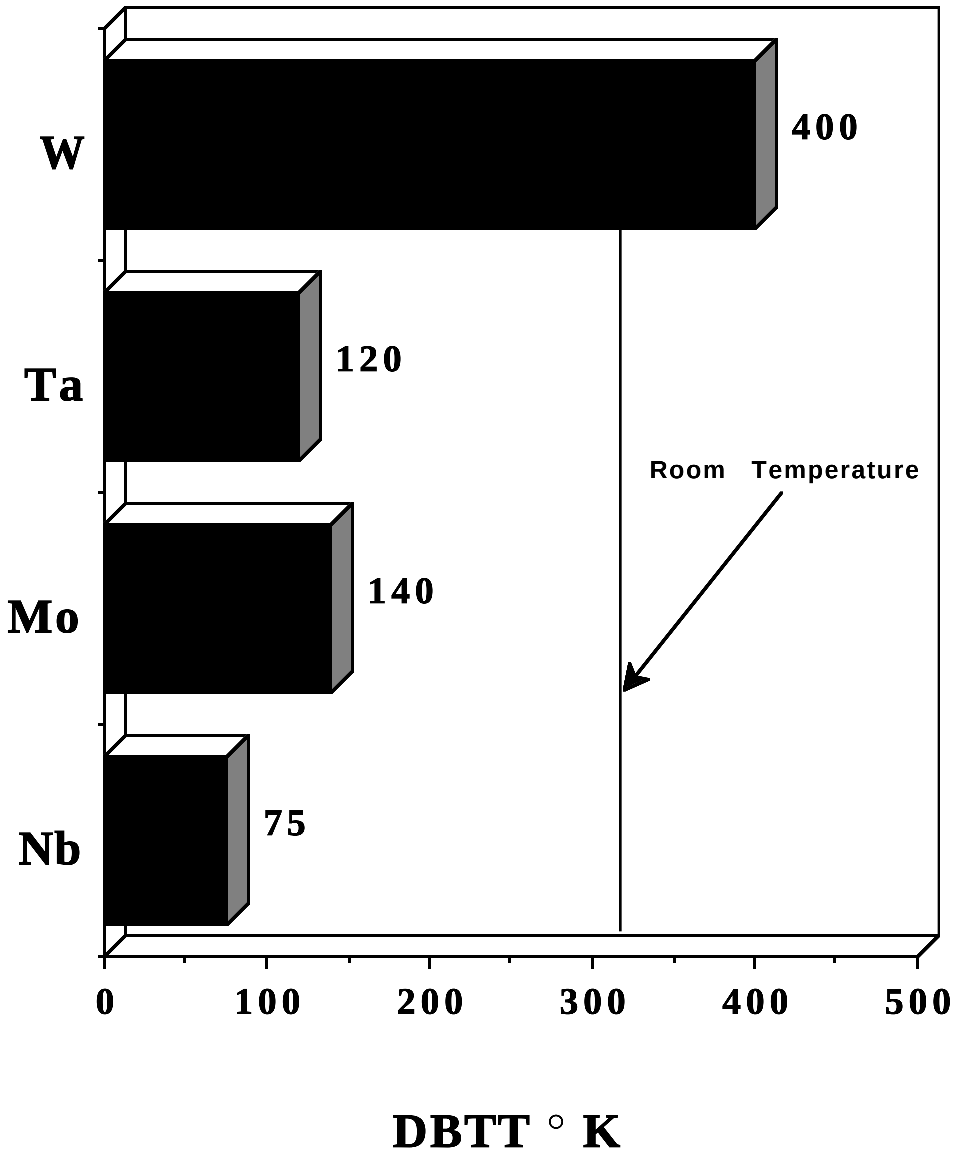
Strength Comparison Between Refractory Alloys

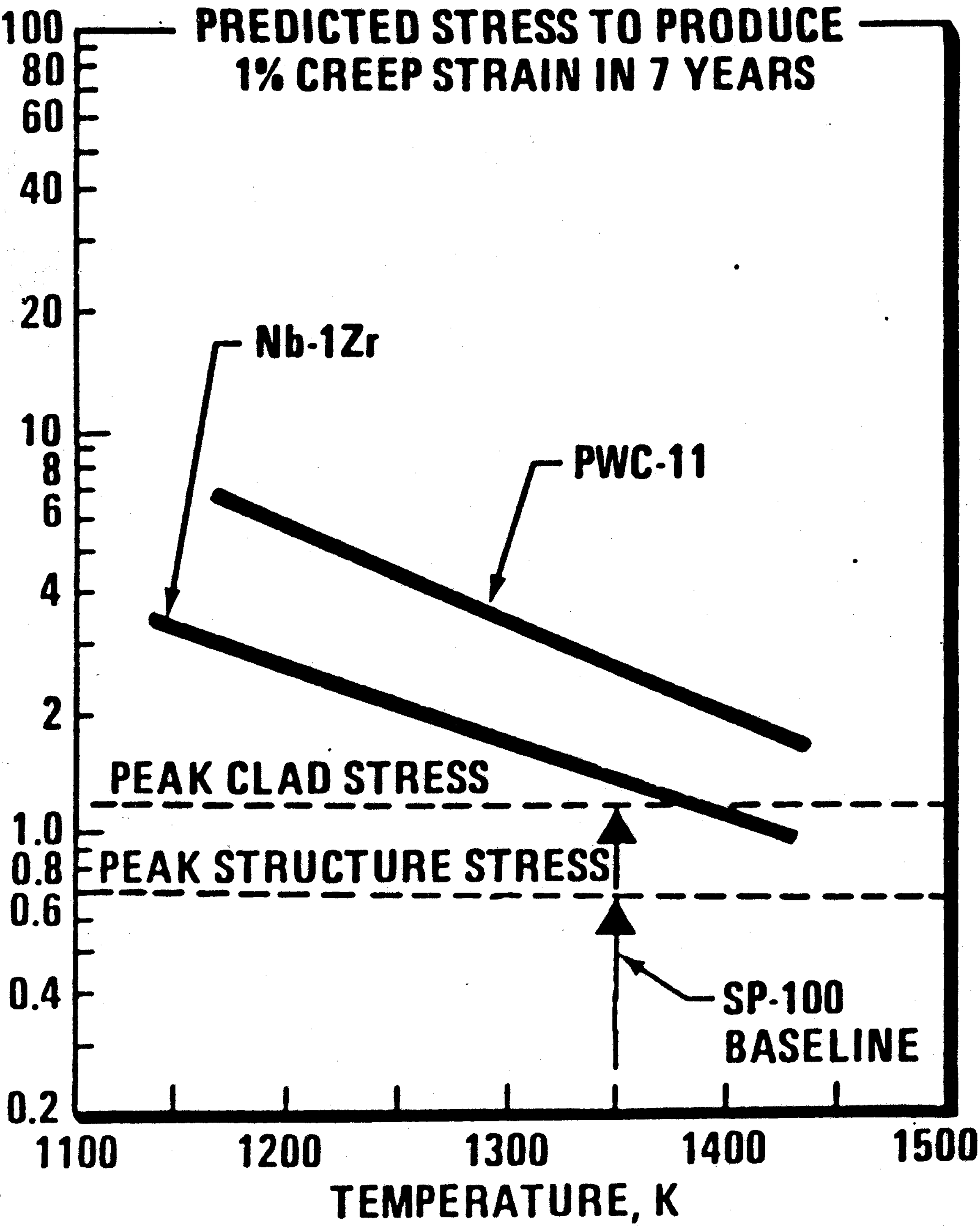


Density Comparison of Refractory Alloys



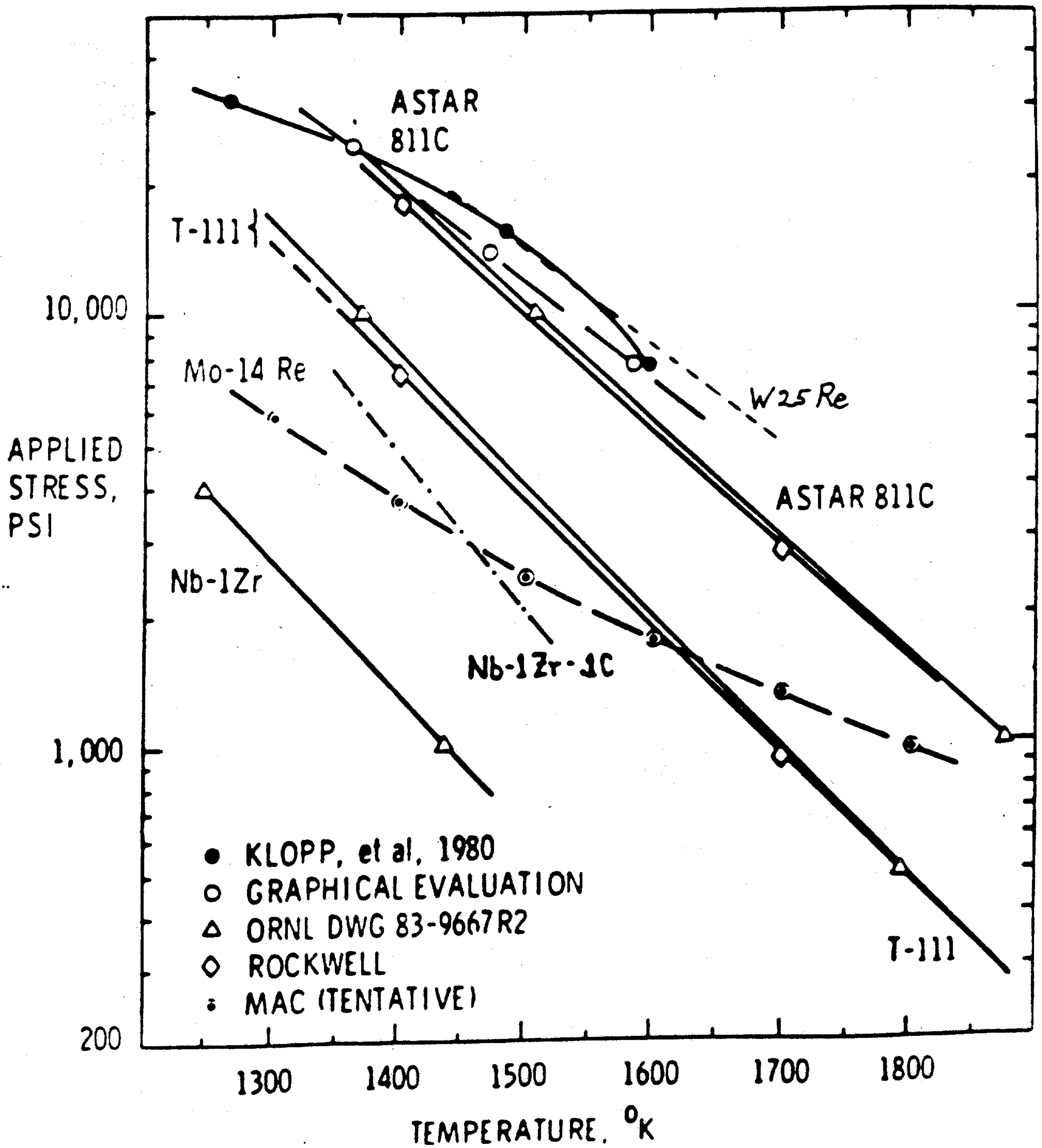
Ductile to Brittle Transition Temperature for Refractory Metals





PREDICTED STRESS TO PRODUCE
1% CREEP STRAIN IN 7 YEARS
100
80
60
40
20
10
8
6
4
2
1.0
0.8
0.6
0.4
0.2
Nb-1Zr
PWC-11
PEAK CLAD STRESS
PEAK STRUCTURE STRESS
SP-100
BASELINE
1100
1200
1300
1400
1500
TEMPERATURE, K

REFRACTORY METAL ALLOYS
STRESS FOR 1% CREEP IN 10,000 HR



***Radiation Effects* - Because of the very high temperatures of operation, most of the radiation damage is annealed out and only minimal swelling (<1%) is expected in all of the alloys.**

***Neutronic Considerations* - The cross sections of the Nb and Mo alloys are low compared to the W and Ta alloys. Since the reactor is criticality limited, a mass penalty would have to be paid if the W and Ta alloys were used.**

***Compatibility with Lithium* - All the alloys are compatible with Li at the temperatures of interest. Be careful to keep oxygen below 200 ppm**

***Compatibility With UN* - Experiments have shown that W and Mo alloys are compatible with UN at the SP -100 operating temperatures. However, Nb and Ta alloys require a W barrier between the fuel and the cladding.**

***Fabrication/Joining* - Complete Li loops have been fabricated with from both Nb -1Zr and T -111 alloys. Because of the difficulty of welding W and Mo alloys, no loops have been fabricated.**

Availability **- At present only Nb-Zr alloys are readily available in commercial quantities. Mo -Re alloys are in the developmental stage and W -26 Re is only available as a powder metallurgy product.**

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Summary of the Tradeoffs for SP -100 Structural Alloys

W -26Re

- **Large neutron Penalty (vs. PWC -11)**
- **Large density Penalty (vs. PWC -11)**
- **Developmental needs**
- **Has unacceptable DBTT (>200 °K)**

ASTAR 811C

- **Large neutron penalty (vs. PWC -11)**
- **Large density penalty (vs. PWC -11)**
- **Difficult to fabricate & weld (vs. PWC -11)**
- **Large number of pin failures (15 out of 49)**

Mo -14Re

- **Developmental needs**
- **Small density penalty (vs. PWC -11)**

Nb -1 Zr

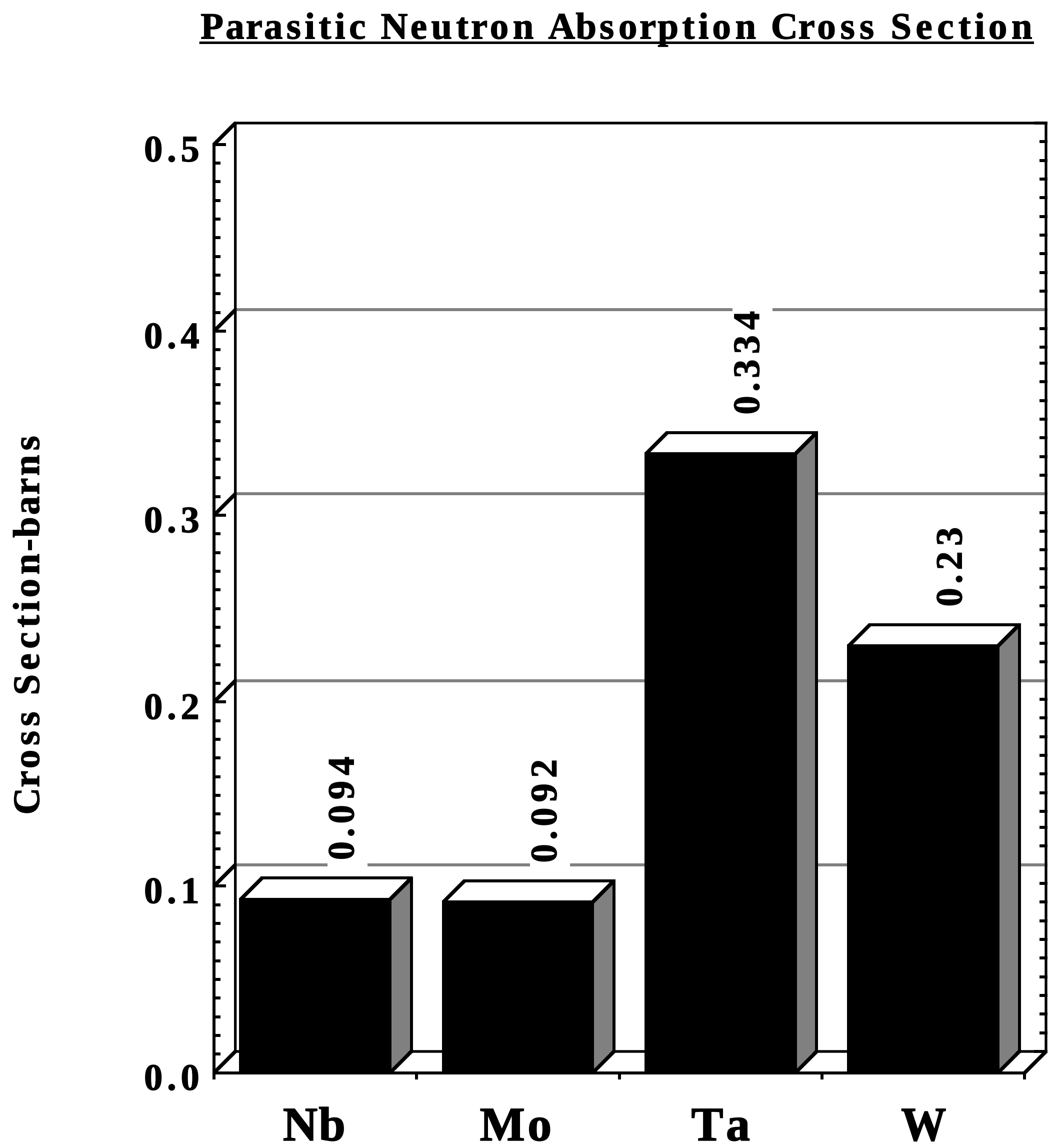
- **Low strength (mitigated by adding 0.1% C and a low density design which induces low stresses)**

Fuel Clad Interaction Data

Fuel	Cladding	Irradiated	Failed
UO_2	Nb -Zr	32	0
UO_2	T-111	1	0
UN	Nb -Zr	61	o
UN	T-111	43	15

Cladding Summary

	Nb -Zr	93	0
	T-111	44	15


Parasitic Neutron Absorption Cross Section
Cross Section-barns
0.5
0.4
0.3
0.2
0.1
0.0
0.094
0.092
0.334
0.23
Nb
Mo
Ta
W

Summary of Selected Properties of Refractories

	Easy	Moderate	Difficult	???
Fabricability	Nb-1Zr	Ta(Astar)	W-26Re	Mo-14Re
Weldability	Nb-1Zr	Ta(Astar)	W-26Re	Mo-14Re

	Nb-1Zr	Ta(Astar)	W-26Re	Mo-14Re
Availibility	**Yes**	No	No	No