TRITIUM PERMEATION ISSUES

DAI-KAI SZE
ARGONNE NATIONAL LABORATORY
ARGONNE, IL

PRESENTED AT THE APEX-ALPS MEETING
ALBUQUERQUE, NEW MEXICO
JULY 27-31, 1998

Permeation Issues

- A most important parameter is the comparison between Δp/pass with the allowable tritium partial pressure

- If Δp/pass is much less than the allowable tritium partial pressure, than the tritium recovery can be done by a side stream of the coolant, and recovery efficiency does not have to be too high.

- If Δp/pass is greater than the allowable tritium partial pressure, than the entire coolant stream has to be processed for tritium recovery,and the recovery system efficiency has to be very high.

IMPORTANT POINT

- **It is much easier to take tritium out of the coolant/ breeding material, than to keep tritium in them. This is especially true for a high temperature system.**

- **The development of insulating coating is not sufficient to resolve this problem.**

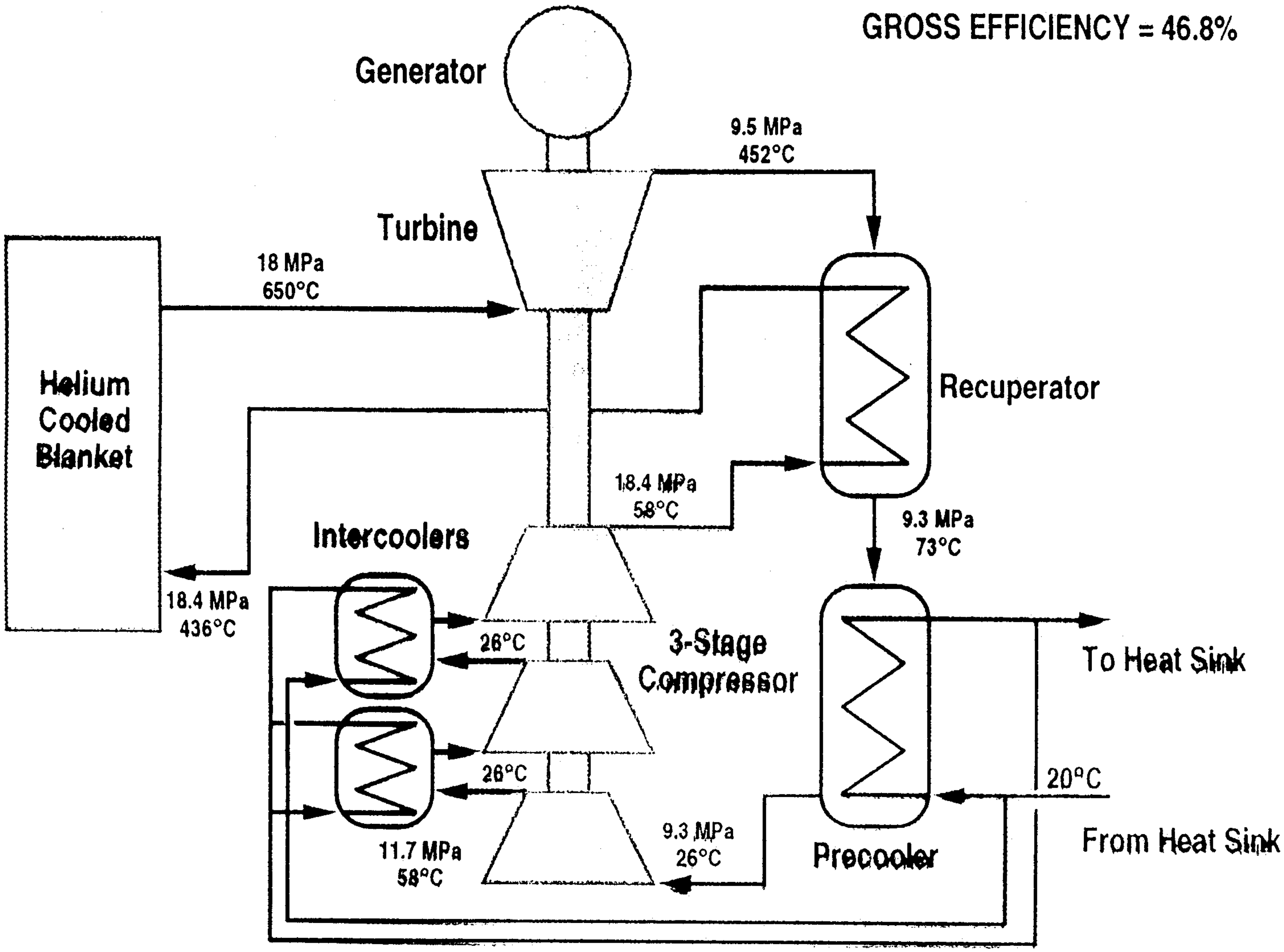
- **Low permeation materials, most likely used at very high temperature, will have similar permeability as the high permeation materials used at a moderate temperature.**

Conclusion

- Tritium permeation is an important issue which has not received enough attention.
- It will be difficult to limit tritium leakage rate to below 100 Ci/d, especially for high temperature systems.
- Multiple layers of barrier may be required to reduce the tritium permeation.
- The multiple barriers approach is not only costly, but also results in reducing power converting temperature.
- To reduce tritium permeation concerns, non-water power converting systems are preferred.

FUSION DIRECT HELIUM BRAYTON CYCLE POWER COVERSION

GROSS EFFICIENCY = 46.8%



190-95

GENERAL ATOMICS

TRITIUM PERMEATION CONCERNS

- Hydrogen has very high permeability across most of the metallic structure, especially at high temperature.
- A primary heat exchanger has a very large surface area (~25000 M2), and a very thin wall (~1 mm).
- Most of the coolant and breeding material will have high tritium partial pressure.
- Therefore, tritium control is a very difficult technical problem.
- MSBR, LMFBR, and CANDU all have problems associated with tritium containment.
- The amount of tritium they have is very small when compared to the amount of tritium D-T fusion has.

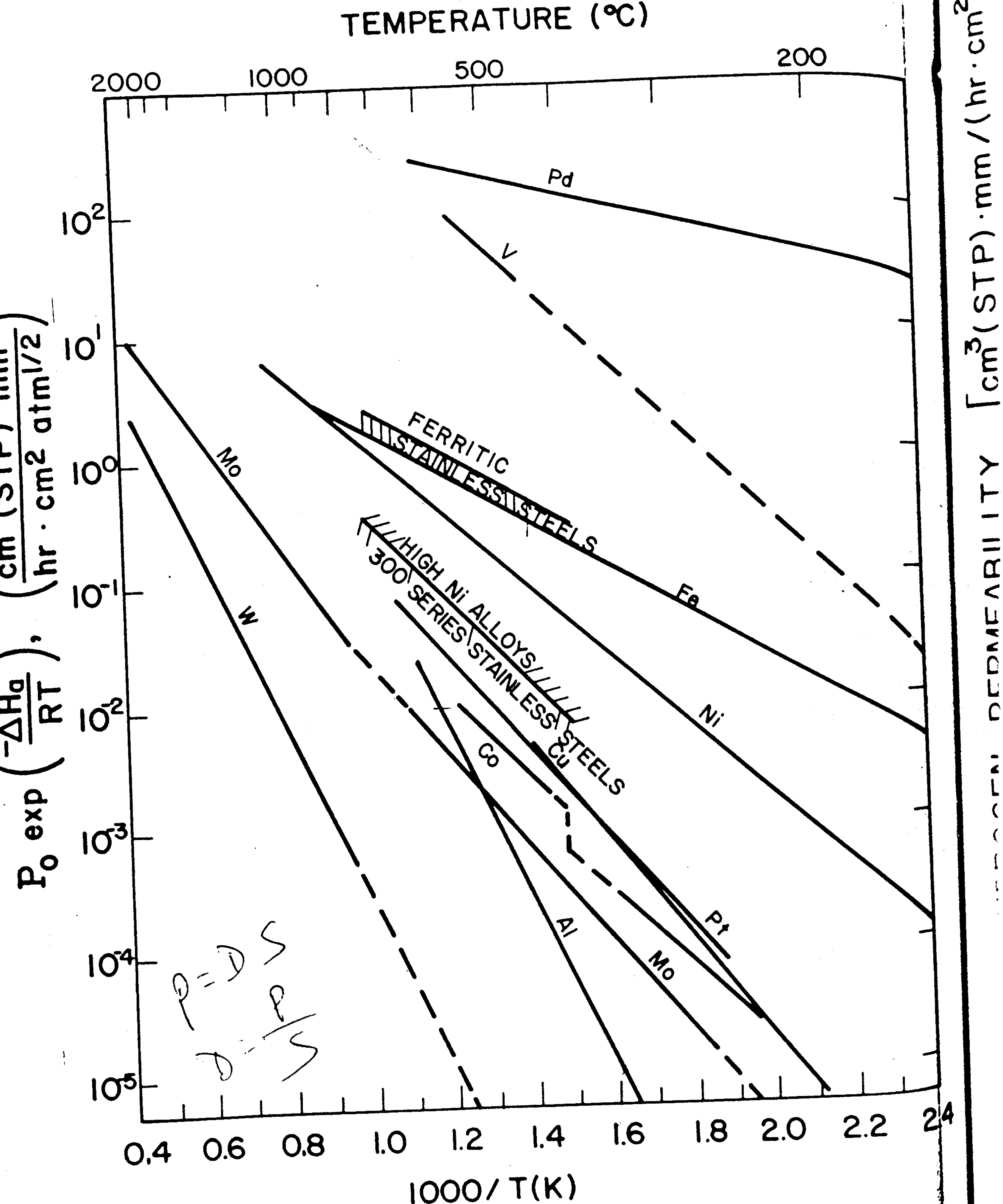
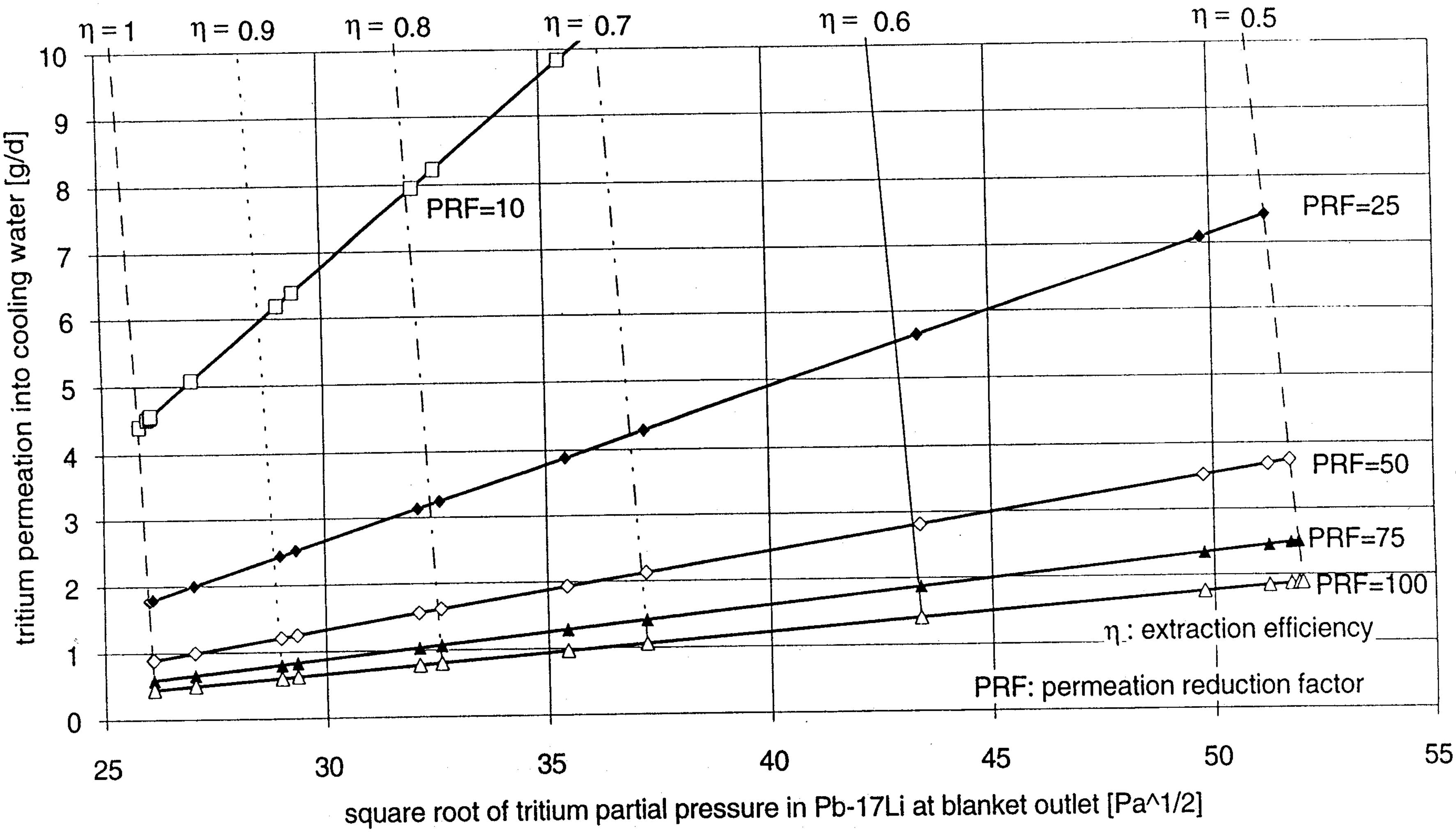


Fig. IX-5 Intrinsic hydrogen permeability as a function of temperatur

TRITIUM PERMEATION CALCULATION FOR EC WATER-COOLED LiPb BLANKET

- The EC water-cooled blanket is at 280°C.
- To limit the tritium permeation rate to water to < 1g/ FPD requires a very efficient tritium permeation barrier.
- Also, the tritium extraction efficiency has to be about 90%.
- The APEX blanket is at a much higher temperature.
- Also, the allowable tritium permeation rate is lower (10 to 100 Ci/d).

Fig. 6.9: Tritium permeation from Pb-17Li into cooling water (without FW contribution) as a function of extraction efficiency and permeation reduction factor [7.9]



Typical Blanket Conditions

Temperature	500° C
Heat transfer surface area	25,000 m^2
Wall thickness	1 mm
Material	FS
Thermal power	3000 MW
Tritium production rate	450 g/FPD
Coolant temperature rise	200° C

Material Properties

	Density, g/cc	Cp, j/g-C	Molecular Weight	Ks Atom frac/Pa$^{1/2}$
Li	0.5	4.2	7	6.6×10^{-3}
LiPb	9.2	0.19	173	9.6×10^{-9}
Flibe	2.0	2.4	99	10^{-2} *

*Flibe obeys Henry's law. The unit is mole TD/liter-atm.

Tritium Parameters

	Flow rate, g/s	Δc/pass, appb	Δp/pass, Pa
Li	3.6×10^{6}	3.36	2.6×10^{-13}
LiPb	8.0×10^{7}	3.75	0.15
Flibe	6.3×10^{6}	27.4	5.5
He/Solid breeder			5.5*

*Tritium pressure in the purge.

Allowable Tritium Partial Pressure

Temperature	500° C
Area	2.5×10^4 m^2
Allowable tritium leakage rate	100 Curie/d
Oxide barrier factors	1 and 100
Tritium permeability	0.55 mol T_2 - mm/d-m^2-atm
Allowable tritium partial pressure	

With no barrier	With barrier factor of 100
1.5×10^{-9} Pa	1.5×10^{-5} Pa