Surface and Volumetric Heat Deposition and Tritium Breeding Issues in Liquid-Protected FW

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    - Li17Pb83
    - SiC, V, Fe

- X-rays Transmission Coefficient Through layers of Various Thicknesses

- Profiles of Power Deposition Rate from 1 MW/m2 Surface Wall loads on Layers up to 5 cm thick:

    - From Mono-Energetic X-rays
    - From Classical Bremsstrahlung Spectrum
    - Comparison

- Volumetric Heat Deposition Rate from 7 MW/m2 Neutron Wall Load Incident on 5 cm/50 cm/15 cm Liquid Layer/Liquid-Structure (20:80)/reflector

    - Li/(Li-V4Cr4TI)/FS-H2O(90:10)
    - Flibe/(Flibe-FS/FS-H2O(90:10)
    - Li17Pb83/LiPb-SiC/FS-H2O(90:10)

- The surface wall load is caused by the x-rays radiated from the hot plasma whose magnitude and spectrum strongly depends on the plasma operating conditions (e.g. electron temperature, impurities, etc.).

- Most of the emitted x-rays are in eV-keV energy range and photoelectric absorption is the main process for bearing with this surface wall load.

- Whether or not this load is absorbed at the surface or volumetrically distributed throughout the liquid layer, is mainly dependent on the x-rays attenuation characteristics of the type of layer under consideration. On the other hand volumetric heating from incident neutrons is more or less deposited evenly through the layer with much lower steepness.

- <u>The spectrum of the classical Bremsstrahlung radiation is used as a representative spectrum</u> and considered as the main contributor to this surface wall load. Comparison is also made to the case where these x-rays are considered as mono-energetic energy source.

$$E_x \cdot \frac{dN}{dE_x} = \frac{\alpha . n_e . n_i . g_{ff} . e^{-\frac{E_x}{T_e}}}{\sqrt{T_e}} \quad , \qquad T_e \text{ in eV}$$

T_e = electron temperature

$\alpha = 9.6 \times 10^{-20}$ $eV^{1/2}\ m^3\ s^{-1}$

g_{ff} = Gaunt Factor ~ unity

- The more practical x-rays spectrum of ITER is now under examination and will be applied to present work. It was provided to UCLA by Doug Post and Robert Woolley on 1/11/98. It consists mainly of Bremsstrahlung spectrum and line radiation from impurities.

> "Output was done using a circular cylindrical with a radius of 4 m. The volume and surface area for such a cylinder are 20% (volume) and 10% (surface) greater than for the actual ITER elliptical shape. The density profile was flat with $n_e = 10^{20}\ m^{-3}$. The temperature was parabolic (T_e = 20 keV $(1-(r/a)^2)$). The impurity mixture was 64 % H, 10 % He, 2 % Be, 1% C, and 0.2 % Ne. The radiation losses were mostly bremsstrahlung, but there are losses from line radiation from the impurities and from radiative recombination. The line radiation losses are underestimated by perhaps as much as 50% or more because the calculation did not include transport effects". (Doug Post Memo, 9 January, 1998)

- The attenuation length for 1 keV x-rays inside Li, Flibe, and Li17Pb83 are 100, 1, and 0.2 microns, respectively. The corresponding length at 10 keV are 1.5×10^5, 1000, and 10 microns.

  - Atten. coefficient of Li is ~ 2 orders of magnitude lower than in Flibe
  - Atten. coefficient of Flibe is 1-2 orders of magnitude lower than in Li17Pb83

- This resulted in an appreciably larger heat deposition rate (HDR) in Li than in Flibe at larger depth. For example, for mono-energetic x-rays of 10 keV, HDR in Li and Flibe are 6.1 and 0.009 w/cc respectively at depth of 1 cm (6.5 and 1170 w/cc at surface) .

- If surface load is assumed to be constituted of Brem. radiation at Te = 1-keV, these values are 9 and 5 w/cc, respectively at 1 cm depth. However, the HDR at the surface is much larger in this case (8.6×10^4 and 4×10^5 w/cc). This is due to the fact that Brem. spectrum has a very low energy tail (Ex<100 eV) which is basically absorbed at the surface.

- The fraction of this tail is ~ 0.01 at Te = 10 keV (0.03 at Te = 2 keV). This suggest that part of the surface wall load can be treated as truly surface load where as the rest is considered to be deposited volumetrically throughout the protecting layer.

Volumetric Heat Deposition Rate

- **Maximum heat deposition rate (w/cc, 7 MW/m2) in the convective layer is larger in the Flibe than in the Li case**

	Flibe	Lithium
Natural	**50 w/cc**	**38 w/cc**
25% Li-6	**55 w/cc**	**44 w/cc**
50%Li-6	**60 w/cc**	**49 w/cc**
90%Li-6	**64 w/cc**	**54 w/cc**

It is larger in Flibe than in Lithium by 30% (natural Li-6) to 18% (90% Li-6)

- **Heat deposition rate (HDR) increases in the layer as Li-6 enrichment increases due to the enhancement in Li-6(n,α) reaction which is exothermic (Q ~ 4 MeV). The reverse trend occurs at the back zone of the blanket and reflector.**

- **The steepness of the heat deposition profiles in Lithium/(Li-V4Cr4Ti) blanket is much less than in the Flibe/(Flibe-FS).**

- **In the convective layer, the HDR profile of Flibe (natural Li6) is similar to those for Lithium (50%Li6) and HDR profile of File (25%Li6) is similar to those of Lithium (90%Li6)**
- **In the convective layer of Lithium, HDR is due mainly to neutrons heating. Non-negligible contribution from gamma heating exists in the case of Flibe.**

Tritium Production Rate (TPR)

- **TPR from Li-6 is the main contributor to the integrated tritium production rate (except in case of Li/(Li-V4Cr4TI) blanket with natural Li-6 where contribution from Li-6 and Li-7 are comparable).**

- **There is a steepness in TPR profile from Li-6 near the front surface of the convective layer due to absorption of low-energy neutrons reflected to the layer by the Inboard blanket (ITER Configuration).**

- **In the convective Lithium layer (and the system), there is an optimal Li-6 enrichment (~ 25% Li-6) beyond which TBR begins to decrease. This is not the case for Flibe blanket where TBR shows steady increase with Li-6 enrichment.**

- **Total TBR in the Li/(Li-V4Cr4Ti) system is ~ 1.05 at 25% Li-6 enrichment (no T is bred in the I/B). The corresponding value in the Flibe/(Flibe-FS) system is ~ 0.85 (lower by ~ 25%).**

- **The contribution to total TBR in the system from the convective layer is ~ 23% in Li/(Li-V4Cr4Ti) system at all enrichments. The corresponding contribution in the Flibe/(Flibe-FS) system increase by enrichment (26%-32%).**