December 28, 1999

APEX evaporation topics

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Evaporation rate corrected for condensation

When the density of the evaporating Flibe is sufficient, collisions take place that returns some of the molecules to the surface. This is condensation. The figure below shows this effect for spacings between the liquid and the edge plasma of 0, 0.2 m and 0.5 m.

$$J = \frac{n\bar{v}}{4}\left[e^{-n\sigma x} + \varepsilon(1 - e^{-n\sigma x})\right]$$

where n is the density of BeF_2 molecules which have just evaporated and enter the space of width, x, between the liquid wall and the edge plasma and σ is the elastic collision cross section[1].

$$\sigma = \sqrt{2}\pi D^2$$
$$D = 0.323\, nm$$
$$\sigma = 4.64 \times 10^{-19}\ m^2$$

The first term represents the uncollided evaporating material. The second term is the collisional source for diffusion of which a fraction ε diffuses towards the edge plasma. We can see this effect becomes strong by noting the mean free path is about 1 m at 550 C. The value of ε is taken from the literature[2] as 0.3.

A better analysis should be carried out using a two fluid diffusion model. Better yet would be a monte carlo calculation.

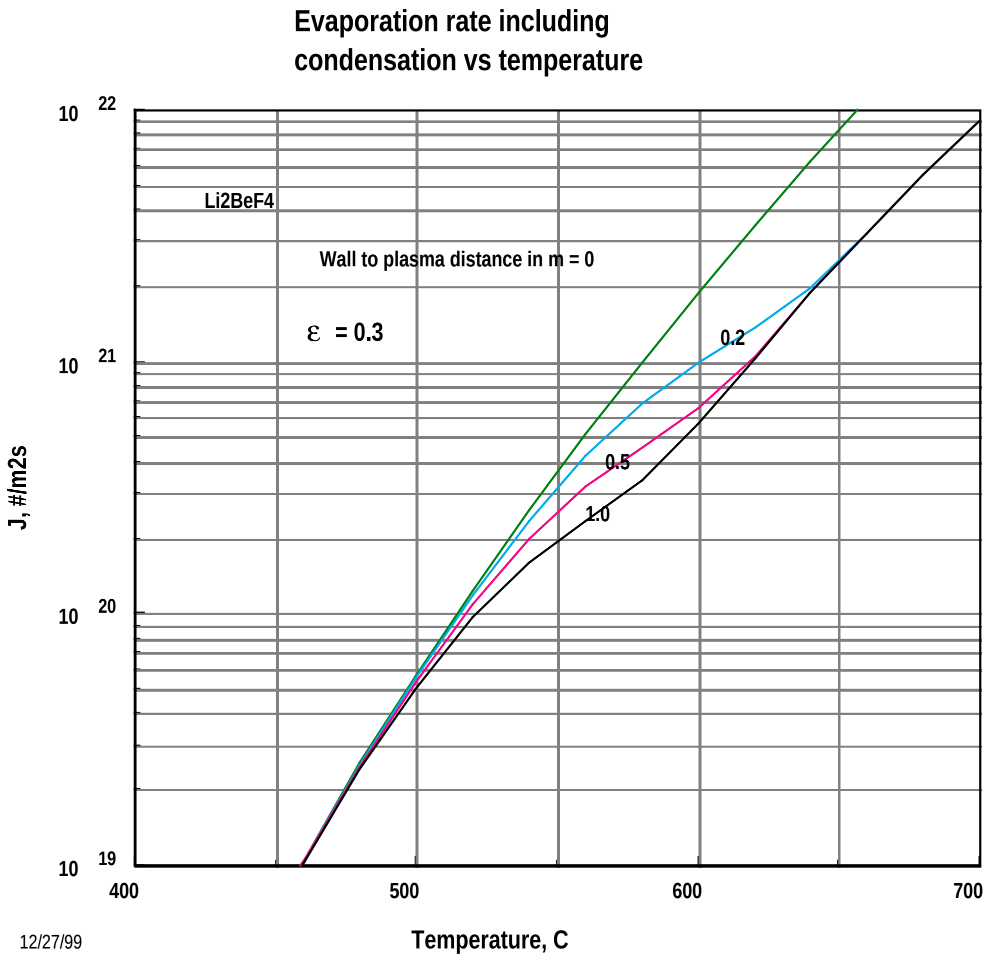

Fig. 1. Evaporation rate including a correction for condensation.

Table 1
Evaporation rate a various temperatures for Flibe

Temp, C	n, BeF_2 / m^2s	J, x=0, # / m^2s	J, x=0.2 m, # / m^2s	J, x=0.5, # / m^2s
500	$3.9x10^{17}$	$5.70x10^{19}$	$5.56x10^{19}$	$5.36x10^{19}$
505	$4.8x10^{17}$	$7.07x10^{19}$	$6.85x10^{19}$	$6.53x10^{19}$
550	$2.4x10^{18}$	$3.66x10^{20}$	$3.14x10^{20}$	$2.56x10^{20}$
555	$2.9x10^{18}$	$4.41x10^{20}$	$3.67x10^{20}$	$2.88x10^{20}$

The condensation correction at 550 C for a 0.5 m distance from the liquid to the edge plasma is a 30% reduction in the rate of molecules impinging on the edge plasma. At 500 C the correction is only 6 % but at 600 C the correction is 67%.

For case one the average evaporation at best might be $\sim 7\times10^{19}/m^3s$ and for case / option 2 it might be $\sim 4.\times10^{19}/m^3s$.

Surface temperature

For a 500 C inlet temperature the evaporation increases almost linearly with temperature so that there is little error in assuming the average evaporation rate is the same as if the liquid had its average temperature. That is

Tav = (Tin + Tout) / 2.

For example with a 600 C outlet temperature the average temperature would be 550 C where as the evaporation corresponds to an average temperature of about 555 C. See discussion later and the graph.

The question is what is the surface temperature. There are two options as discussed in a prior memo.
1-Assume little mixing and inject a cool thin layer (few cm) at 500 C, for example. The bulk can be closer to 555 C but does not mix as assumed.
2-Assume lots of mixing in which case the surface temperature is close to the bulk mixed mean of 550 C.

In case one at best we might have an average temperature only a little over 500 C and in case two at best we have an average temperature only a little over 550 C.

1. The molecular size for use in estimating the elastic collision cross section was estimated by Art Molvik, 12 / 99 for BeF_2.
2. Bird, Stewart and Lightfoot, Transport Phenomena, John Wiley & Sons, New York (1960),p666.