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UCRL -73993-Addendum
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**MAGNETIC FIELD EFFECTS ON THE HEAT TRANSFER
OF POTENTIAL FUSION REACTOR COOLANTS**

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Fig

1. Flibe Heat Transfer in Strong Transverse Magnetic Fields

In the discussions of the effects of transverse magnetic fields on lithium and flibe heat transfer, a basic assumption was made throughout UCRL-73993 that the field component transverse to the flow velocity, $B_{\perp}$, never exceeded about 1 tesla. This condition can probably be met with reasonable blanket coolant flow channel geometry in open machines. However, in closed machines such as tokamaks and stellarators, it appears to be very difficult to reduce the $B_{\perp}$ component to 1 tesla, particularly for the segmented blanket conceptual designs.

As $B_{\perp}$ increases the right-hand boundaries of the flow regimes for lithium and flibe shown on Figure 1 of UCRL-73993 move to the right. For example, for the case where $B_{\perp} \approx 10$ tesla, the Hartmann number, $H_{\perp}$, for flibe in a 1 cm radius tube is roughly 36 (using the flibe property data of Reference 6 for 1200° K). The corresponding magnetic interaction parameter $I_{\perp}$, is about 2 for low Reynolds numbers around 3000. For these conditions, the Reynolds number below which the flow is fully magnetically laminarized is given approximately by:

$$Re_{tr} \approx 500 H \approx 2 \times 10^4$$

Consequently, it is clear that, in spite of its low electrical conductivity, flibe can be fully laminarized under certain flow conditions if $B_{\perp}$ is large enough.

The effect of full magnetic laminarization on the heat transfer coefficient for flibe is extremely detrimental; it is far worse than for liquid metals due to the relatively high Prandtl number (i.e. low thermal

*This work was performed under the auspices of the United States Atomic Energy Commission.

conductivity) of flibe. The laminar heat transfer coefficient for flibe for the limiting case of slug-like Hartmann flow is:

$$hD = Nu \times k \approx 8.0 \times 0.01 \approx 0.08 \text{ watts/cm}^2 \text{ K}$$

This should be compared to the other heat transfer coefficients shown in Figure 9. The above laminar value is about an order of magnitude less than the turbulent heat transfer coefficient for flibe at a Reynolds number of 10^4 . Furthermore, the laminar flibe heat transfer coefficient is a factor of about 65 lower than that for laminar lithium flows (i.e. simply the ratio of the thermal conductivities).*

It should be noted that when comparing the heat transfer capabilities of various coolants on a plot such as Figure 9, they should not be compared at the same Reynolds number, in general. The choice of the best Reynolds number to operate at must be determined from a study of the entire energy conversion system, and will normally be different for each coolant.

2. Estimation of the Temperature Drop Across the First Wall

In UCRL-73993 the temperature drop across the first wall was estimated assuming that the entire first-wall-energy flux into the lithium, q_{w1} , passed through the entire wall thickness. This is, of course, only an approximation and yields an upper limit to the temperature drop across the wall.

For more accurate results, one must take account of the neutron

*Although the flibe heat transfer coefficient is strongly affected by strong transverse B fields, the magnetic (Hartmann) pressure drops are still very much less than those in lithium.

TABLE 3 (Modified)

TYPICAL WALL TEMPERATURES FOR A PARALLEL PLATE FLOW CHANNEL

Example Number	$t_{w1}=t_{w2}$ (cm)	q_{n1} (watts/cm ²)	q_{a1} (watts/cm ²)	q_{r1} (watts/cm ²)	$q_{w1}(\text{eff})$ (watts/cm ²)	Symmetric Case (q_{w1} to both walls)		q_{w2} (watts/cm ²)	Asymmetric Case First wall temperatures		
						$(T_{w1}-T_B)$ °K	$(T_{w2}-T_{w1})$ °K		$(T_{w1}-T_B)_1$ °K	$(T_{w2}-T_{w1})_1$ °K	$(T_{w2}-T_B)_1$ °K
1	0.03	7.5	25	60	88.8	48	4.4	7.1	91	4.4	95
	0.1	25.	25	60	97.5	57	16.	23.	102	16.	118
	0.3	75.	25	60	123.	82	62.	66.	130	62.	192
	1.0	250.	25	60	210.	172	350.	175.	254	350.	604
2	0.03	7.5	250	60	314.	163	15.	7.1	322	16.	338
	0.1	25.	250	60	323.	172	54.	23.	332	54.	386
	0.3	75.	250	60	348.	198	174.	66.	362	174.	536
	1.0	250.	250	60	435.	287	725.	175.	484	725.	1209

Common Values for all Cases: Lithium flows for $H_1 \gg 10$ (Slug Flow Limit)Parallel-plate half-height, $a = 1$ cm.

volumetric energy deposition throughout the wall and the subsequent absorption of the gamma rays released in many of the neutron collisions with the wall material. If it is assumed that the neutron (and gamma) energy deposition is uniformly distributed across the wall, then the first wall temperature drop is given by:

$$\begin{aligned} (T_{wo} - T_{wi})_1 &= \left(\frac{S_{n1} t_w}{2} + q_{\alpha 1} + q_{r1} \right) \frac{t_w}{k_w} \\ &= \left(\frac{q_{n1}}{2} + q_{\alpha 1} + q_{r1} \right) \frac{t_w}{k_w} \\ &\equiv q_{w1(\text{eff})} \frac{t_w}{k_w} \end{aligned}$$

where S_{n1} is the uniform energy source strength per unit volume of wall material. (It has been assumed that none of the internal heat generated flows toward the plasma side of the first wall).

If this effective value to the heat flux, $q_{w1(\text{eff})}$, is used, the new values of the temperature drops are those given in the modified Table 3.

It can be seen that the values change very little for very thin walls of 0.1 cm thickness or less. For the thicker walls, the temperature drops are less than the original estimates, but the basic conclusion remains unchanged; namely, that thin first walls are mandatory to keep the wall temperature excess and thermal stresses reasonably small.

3. Typographical Errors in UCRL-73993

On page 21, q_{w2} should be written:

$$q_{w2} \approx \left\{ 1 - \left[\frac{q_{n1} + \langle PD \rangle_n \langle Li \rangle \langle 2a \rangle}{q_{NWL}} \right] \right\} q_{n1}$$

In Table 1, the density of Helium should be 2.5 kg/m^3 .