FLiBe Blanket with the plasma facing Lithium stream

1. Basic assumptions and example calculations

FLiBe flows through a channel surrounding a plasma. The radial thickness D of the channel is assumed to be much smaller than the length L of the channel. Plasma side wall temperature is kept constant by a fast Lithium flow.

Stratified (first wall)/blanket layers are shown on Fig.1 together with a coordinate system n, s ($n = 0$ at the Lithium-FLiBe interface and $s = 0$ at the inlet cross-section).

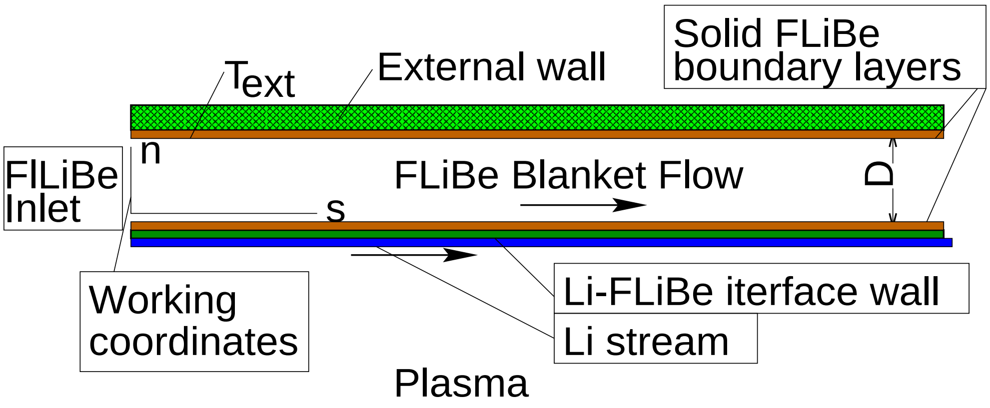


Fig. 1. Stratified (first wall)/blanket layers, consisting from a Lithium stream, guide wall (Lithium-FLiBe interface), flowing FLiBe blanket and an external wall.

The walls of the channel are kept below the melting point of FLiBe, so two solid salt layers are formed on the walls of the channel.

The stationary heat diffusion equation

$$\begin{aligned} &\rho c_p V \frac{\partial T}{\partial s} = \kappa T''_{nn} + S, \quad T > T_{melt}, \\ &0 = \kappa T''_{nn} + S, \quad T < T_{melt} \end{aligned} \tag{1.1}$$

together with the matching conditions determines the temperature distribution in the flow. Here, ρ is the mass density of FLiBe, c_p is the heat capacity, V is the velocity of the flow, κ is the thermo-conduction and S is the neutron heat source. Thickness of the solid layer is determined as an eigenvalue of the problem in a self-consistent way.

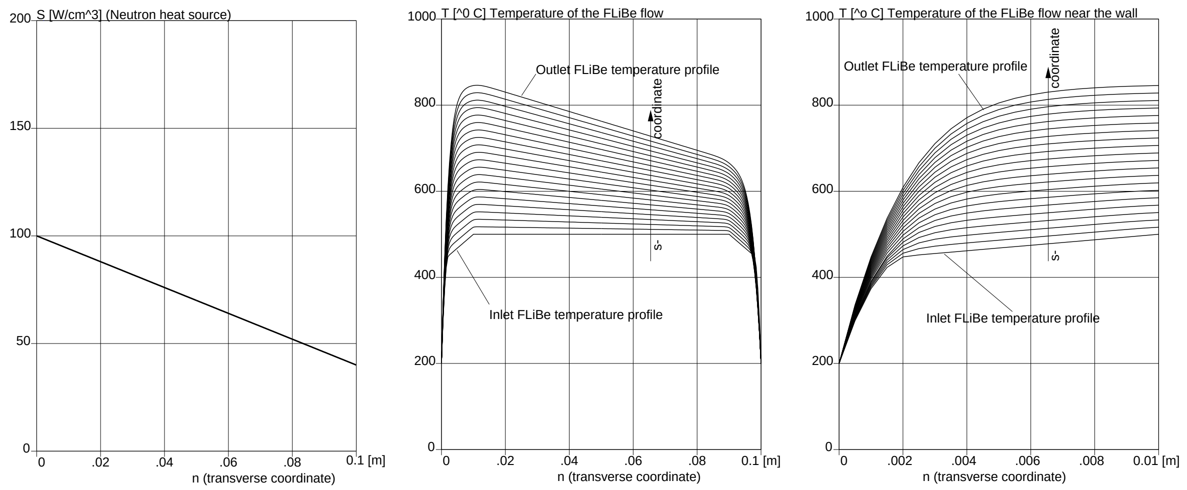
FLiBe parameters are taken according to Table 1.

		Table 1
ρ	$\frac{kg}{m^3}$	2240
c_p	$\frac{J}{kg \cdot C^o}$	2380
κ	$\frac{W}{m \cdot C^o}$	1
T_{melt}	C^o	450

Parameters of the flow are given in Table 2. It is assumed that the flow is homogeneous ($V(n,s) \equiv const$) and the heat source does not depend on the s-coordinate ($S(n,s) \equiv S(n)$).

			Table 2
d	m	0.1	
L	m	10	
V	$\frac{m}{sec}$	0.5	(same over all cross-section)
$S(n)$	$\frac{W}{cm^3}$	100-40	(see Fig. 2)
$T_{plasmasidewall}$	C^o	200	
$T_{TFCsidewall}$	C^o	200	

Fig.2 shows an example of calculations, corresponding approximately to 10 MW/M^2 of the neutron wall loading.



a) b) c)

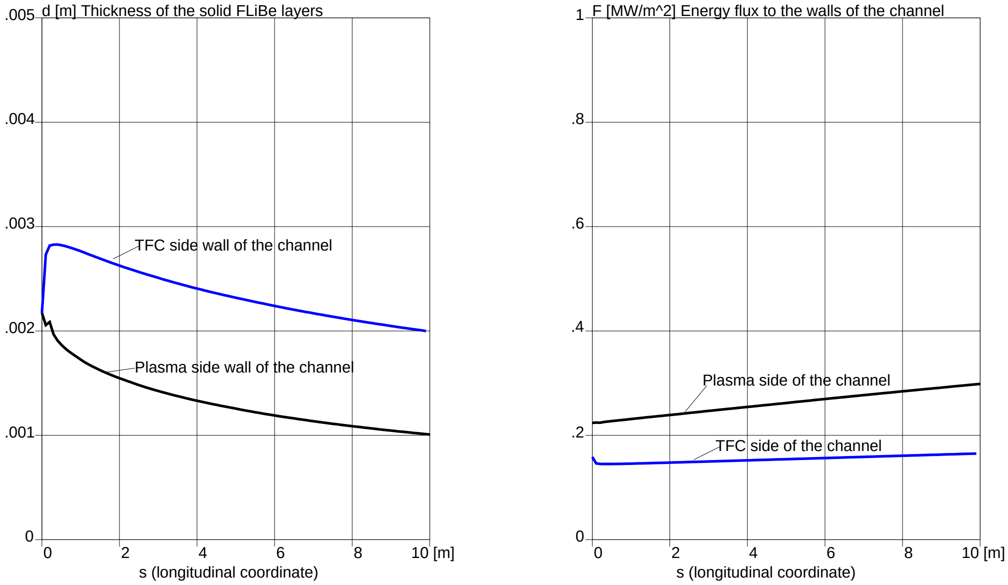
Fig. 2. a) Heat source profile as a function of a transverse coordinate n. b) FLiBe temperature profiles in consecutive channel cross-sections, starting from an inlet. c) Expanded temperature profiles near the plasma side wall.

FLiBe thermo-conduction is so small that the temperature (Fig. 2b) inside body of the flow is determined only by the heat source power

$$\rho c_p V \frac{\partial T}{\partial s} \simeq S, \quad T > T_{melt}, \tag{1.2}$$

not by thermo-conduction losses. Two boundary layers of the order of 1-3 mm (Fig. 2c) are formed near walls of the channel. Inside, each of them contains a sublayer of solid FLiBe.

Fig. 3 shows thickness of these layers and the heat flux (losses) to the walls of the channel.



a)

b)

Fig. 3. a) Thickness of the solid FLiBe layers as a function of a longitudinal coordinate s. b) Energy losses to the side walls from the FLiBe flow.

In this example the averaged energy losses are 0.26 MW/m^2 trough the which plasma side wall and 0.16 MW/m^2 through the Toroidal Field Coil (TFC) side of the wall, which constitute approximately 4 % of the incoming neutron flux energy.

The energy flux to the Lithium guide wall surface is approximately 2.5 % of the neutron flux which is about 10 % of the plasma energy flux. This number suggests that the guide wall surface of the Lithium flow experiences only a 10 % increase in temperature compared to the plasma facing surface of the Lithium.