

# MODELISATION DES THERMOGRAMMES DSC DE LA CRISTALLISATION DES LIQUIDES PURS MACROSCOPIQUES SURFONDUS. APPLICATION A L'ETALONNAGE EN TEMPERATURE AU REFROIDISSEMENT

**Jean Pierre DUMAS, Jean Pierre BEDECARRATS,  
Erwin FRANQUET, Didier HAILLOT, Stéphane GIBOUT**

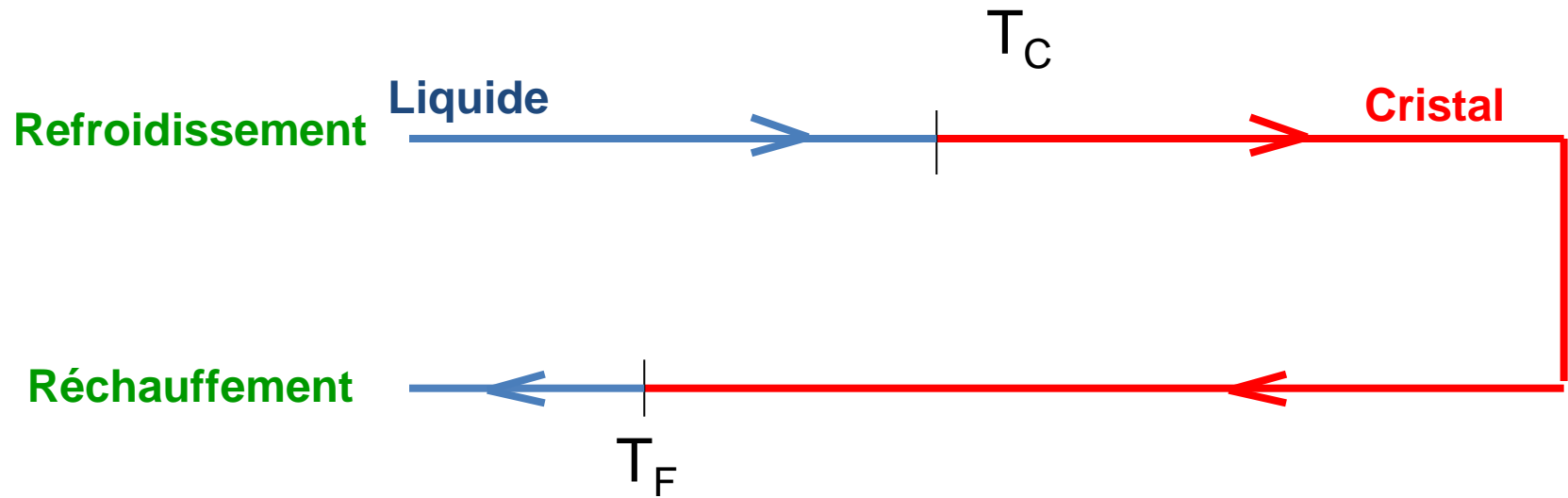
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Université de Pau et des Pays de l'Adour*

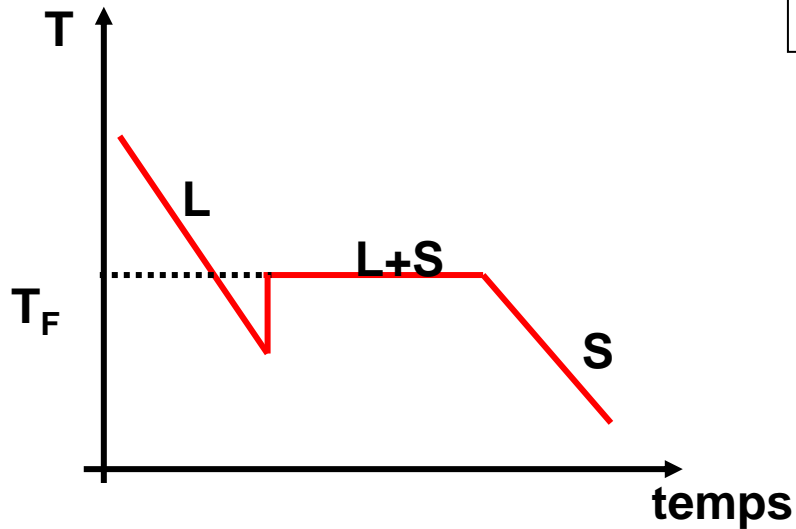
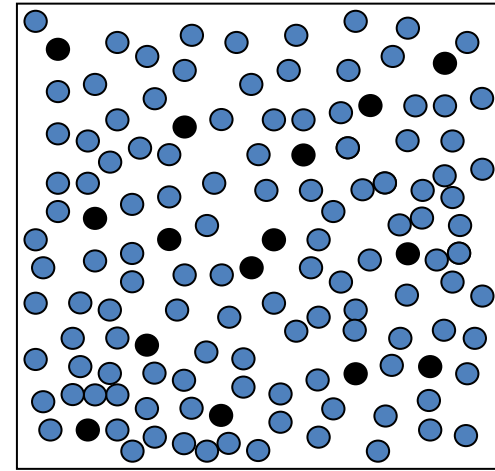


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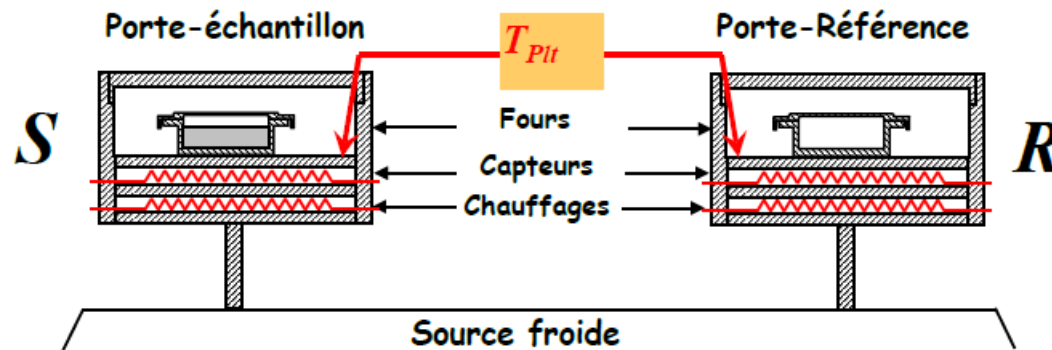
# Surfusion





Clausse D., Dumas J.P. (2016) Supercooling, crystallization and melting within emulsions and divided systems: mass, heat transfers and stability  
Bentham Publishers **DOI:** 10.2174/97816810813041160101

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$$T_{plt} = \beta t + T_{réf} \quad \beta < 0 \quad \text{refroidissement}$$

Thermogramme = courbe en fonction du TEMPS

$$T_{réf} = T_F = 0^\circ\text{C} \quad \text{eau}$$

## Hypothèse homogène

$$t_0 = \frac{T_F - T_{plt}(t_0)}{|\beta|}$$

$$0 \geq t \geq t_0$$

$$\phi = Mc_p^L \beta$$

$$t = t_0$$

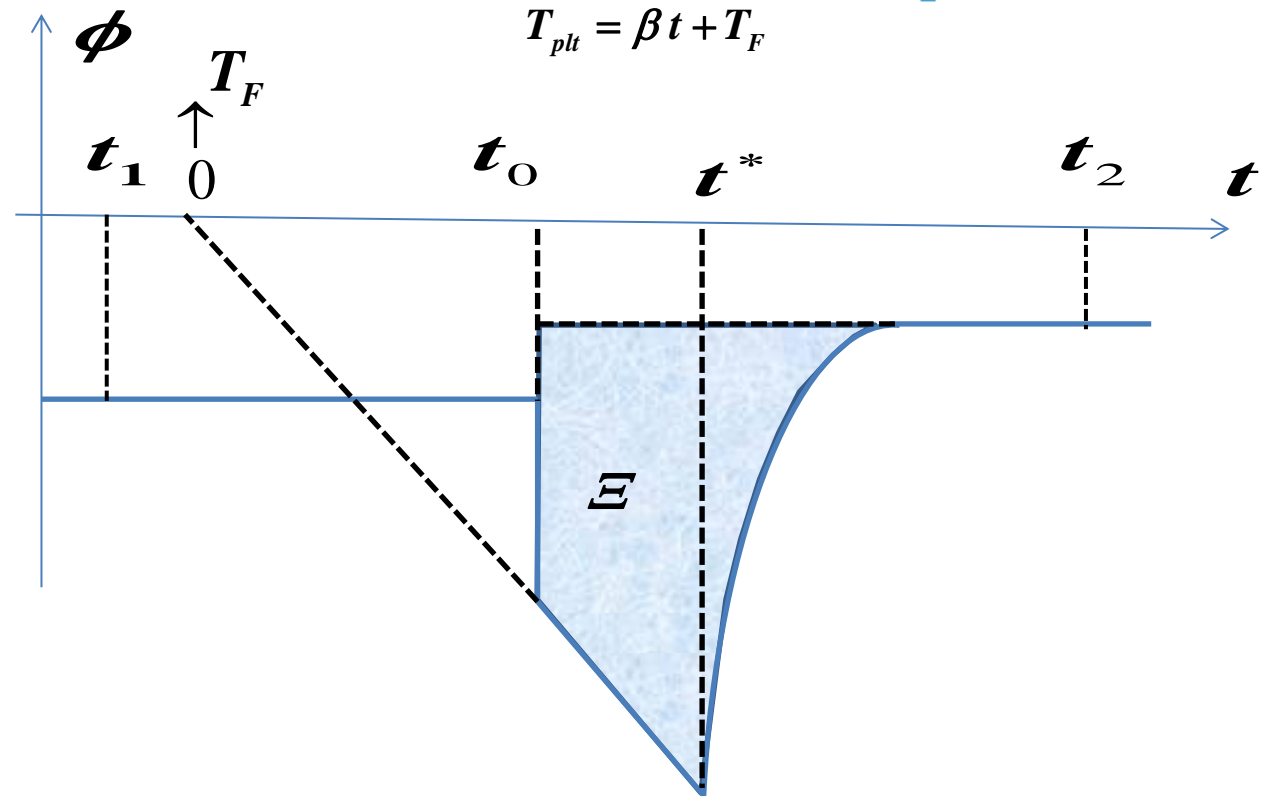
$$\chi^S(t_0) = \frac{c_P}{L_F} (T_F - T_0)$$

$$t_0 \geq t \geq t^*$$

$$\phi = \alpha S |\beta| t = \alpha S [T_F - T_{plt}]$$

$$t \geq t^*$$

$$\phi = \alpha S \left( |\beta| t^* - \frac{|\beta| Mc_p^S}{\alpha S} \right) \exp \left( -\frac{\alpha S}{Mc_p^S} (t - t^*) \right) + |\beta| Mc_p^S$$



$$E = M L(T_0) = L(T_F) - (T_F - T_0)(c_P^L - c_P^S)$$

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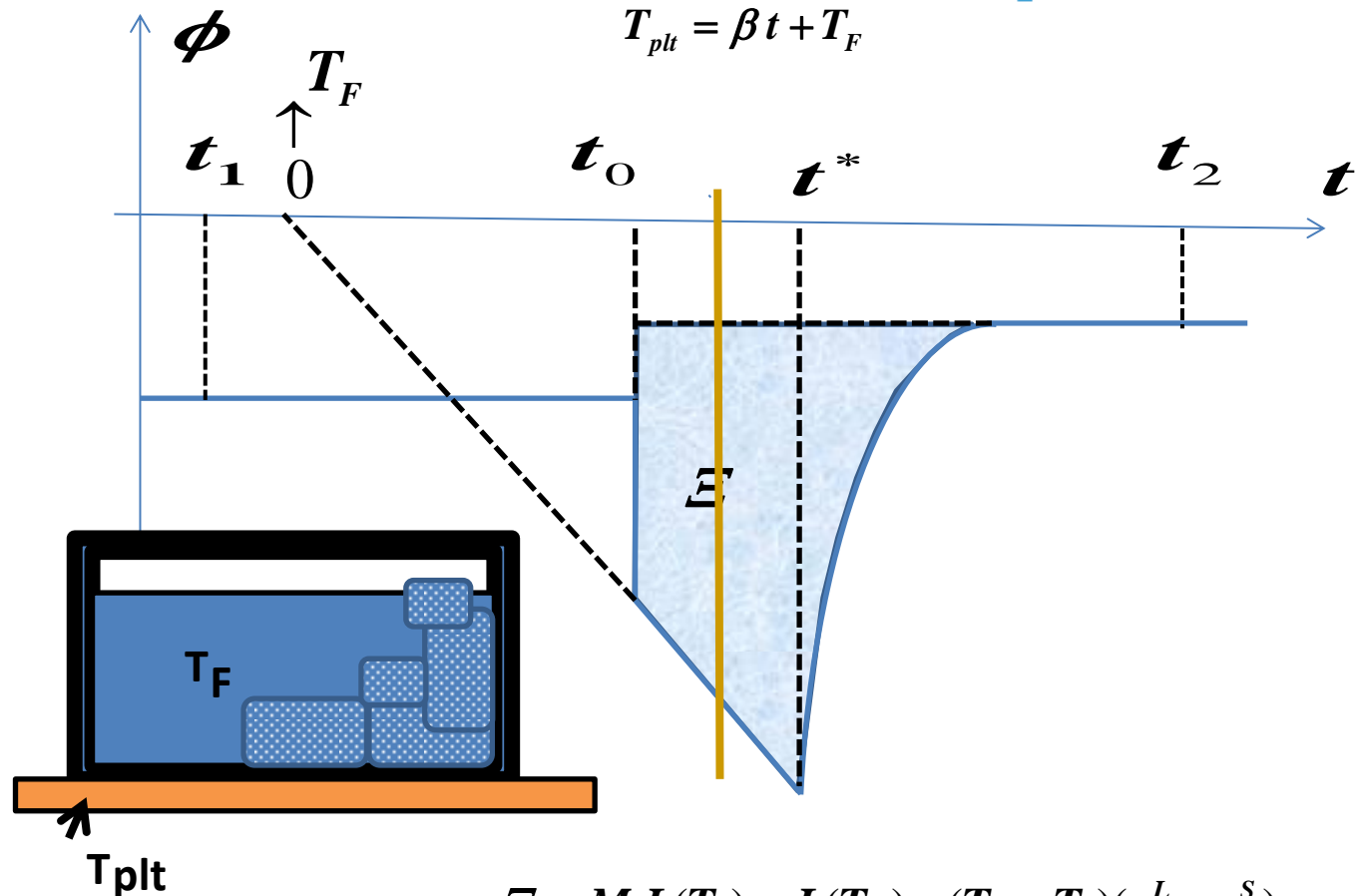
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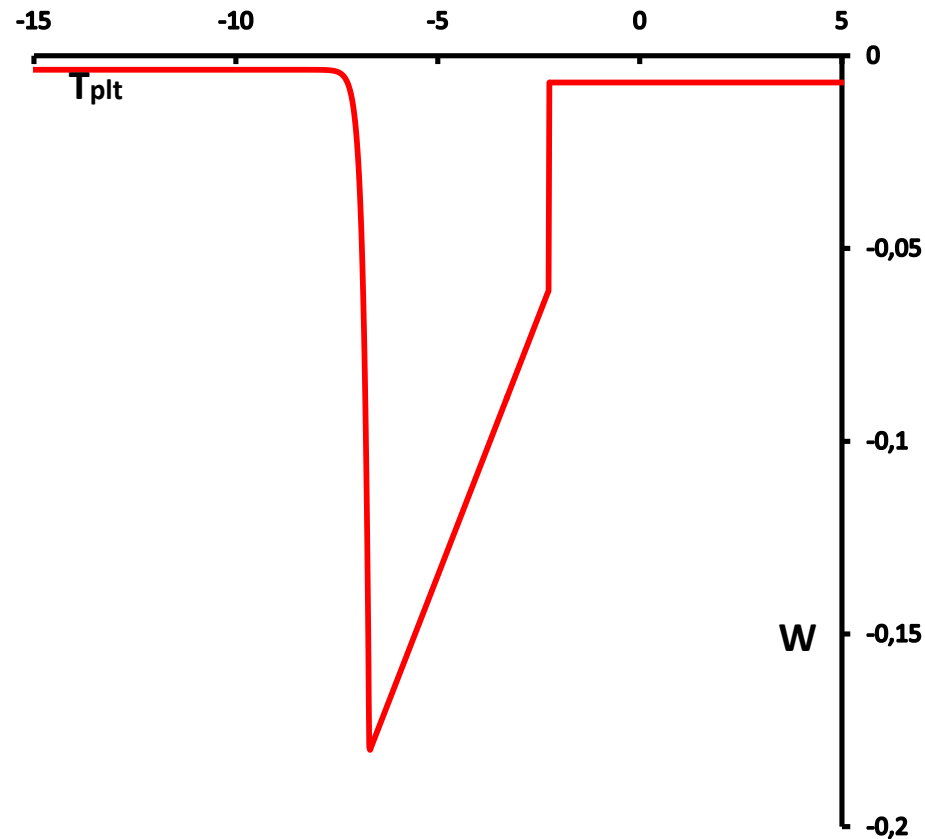
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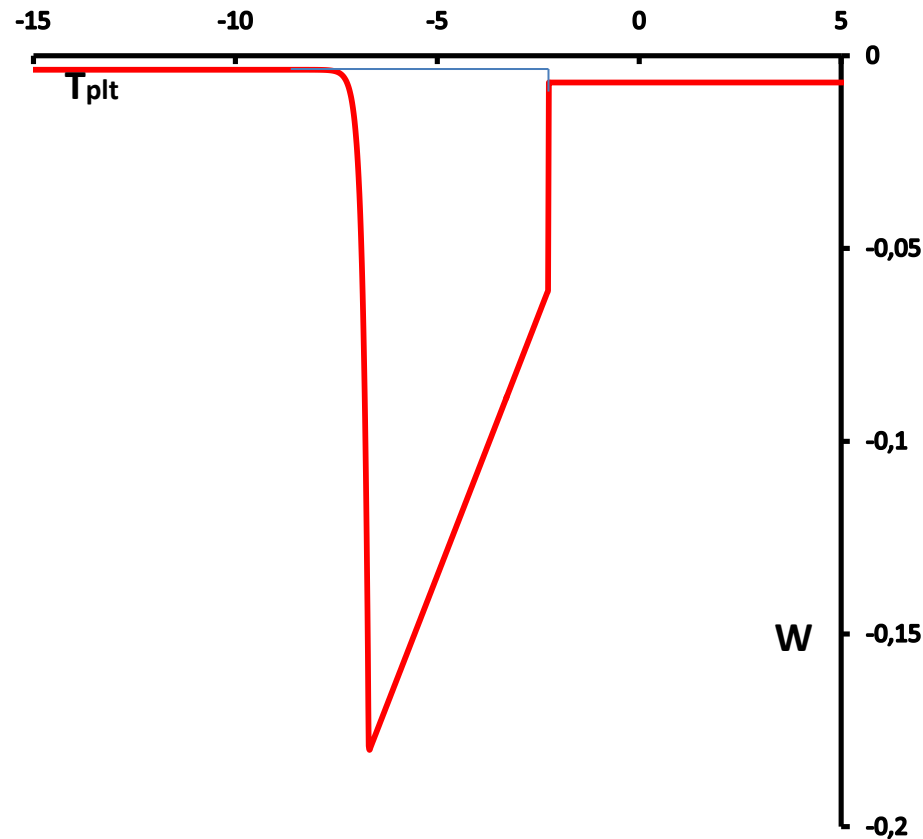
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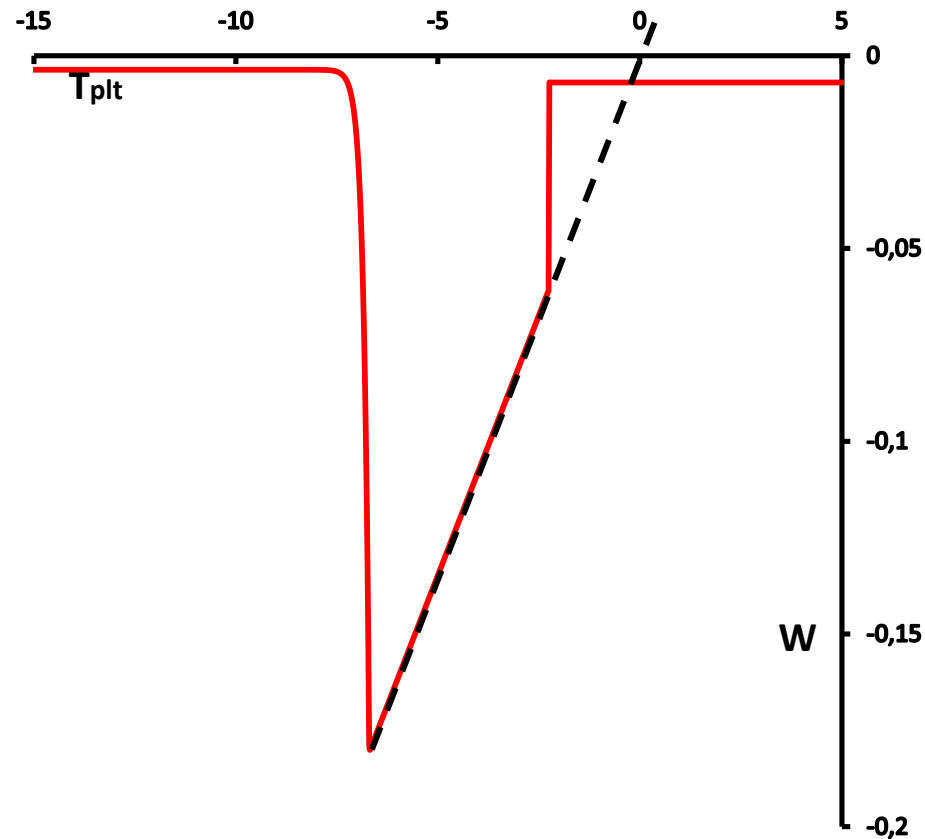
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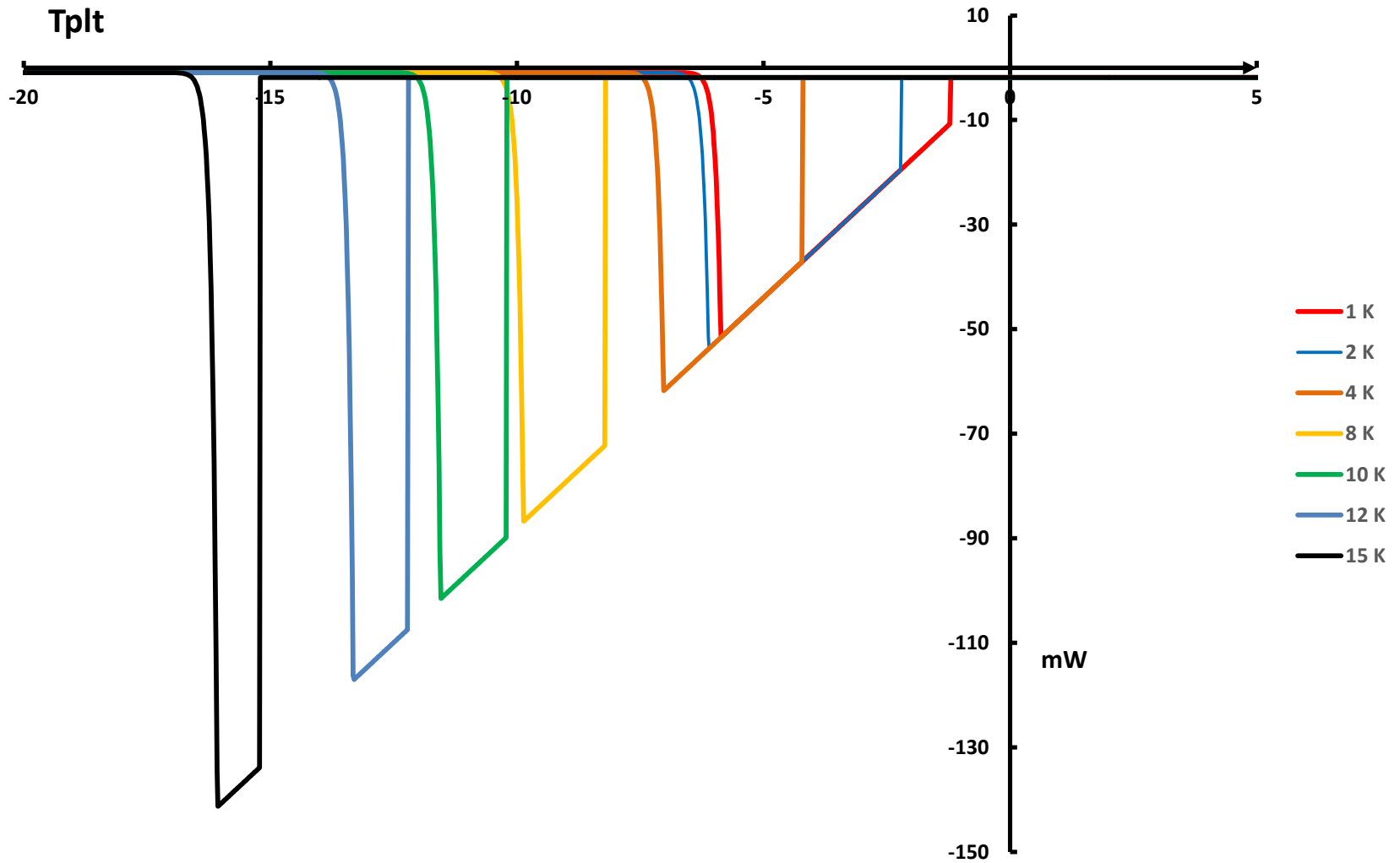
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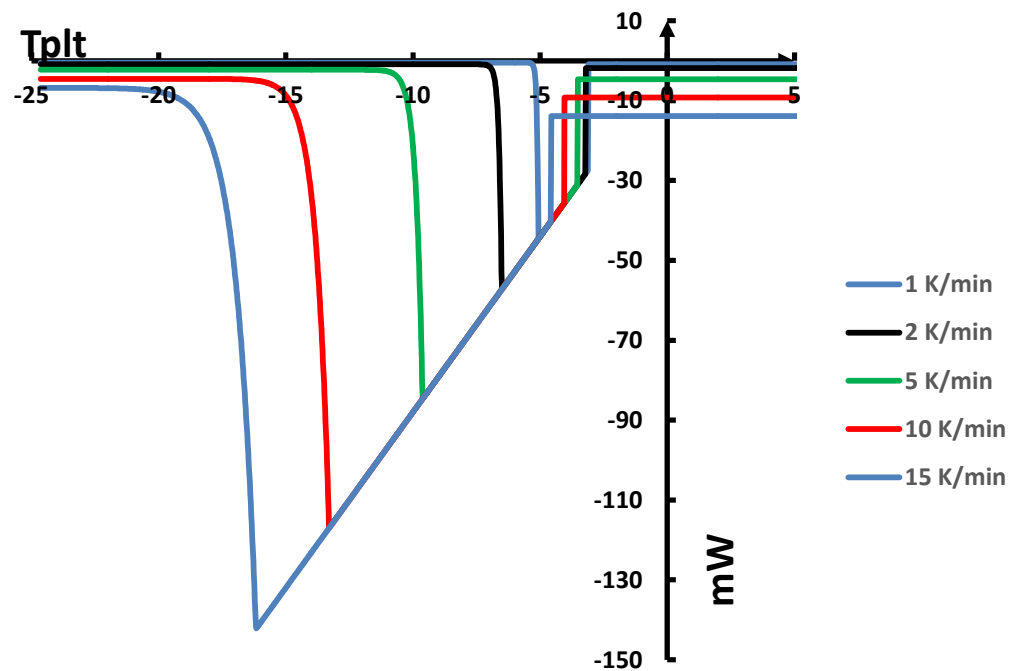


$$T_{plt} = \beta t + T_F$$

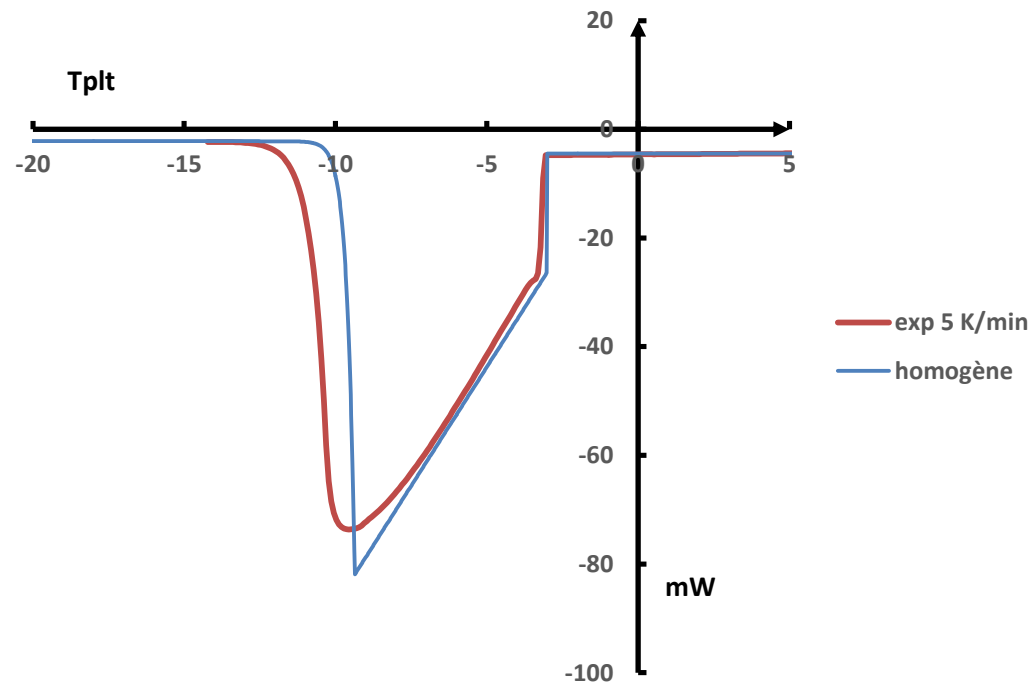
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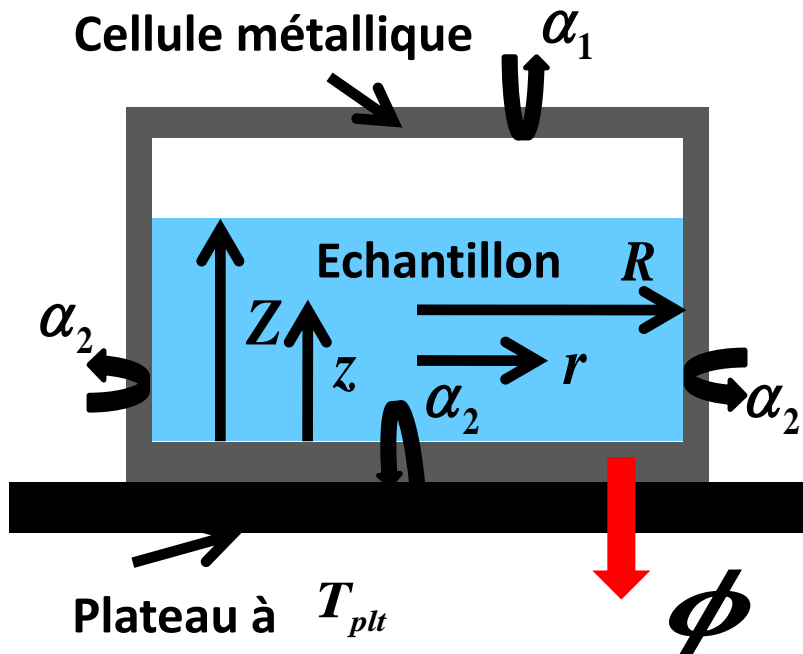


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## Modèle avec transferts



$$\frac{\partial \rho h}{\partial t} = \vec{\nabla} \cdot (\lambda \vec{\nabla} T)$$

$$T_{plt} = \beta t + T_{réf}$$

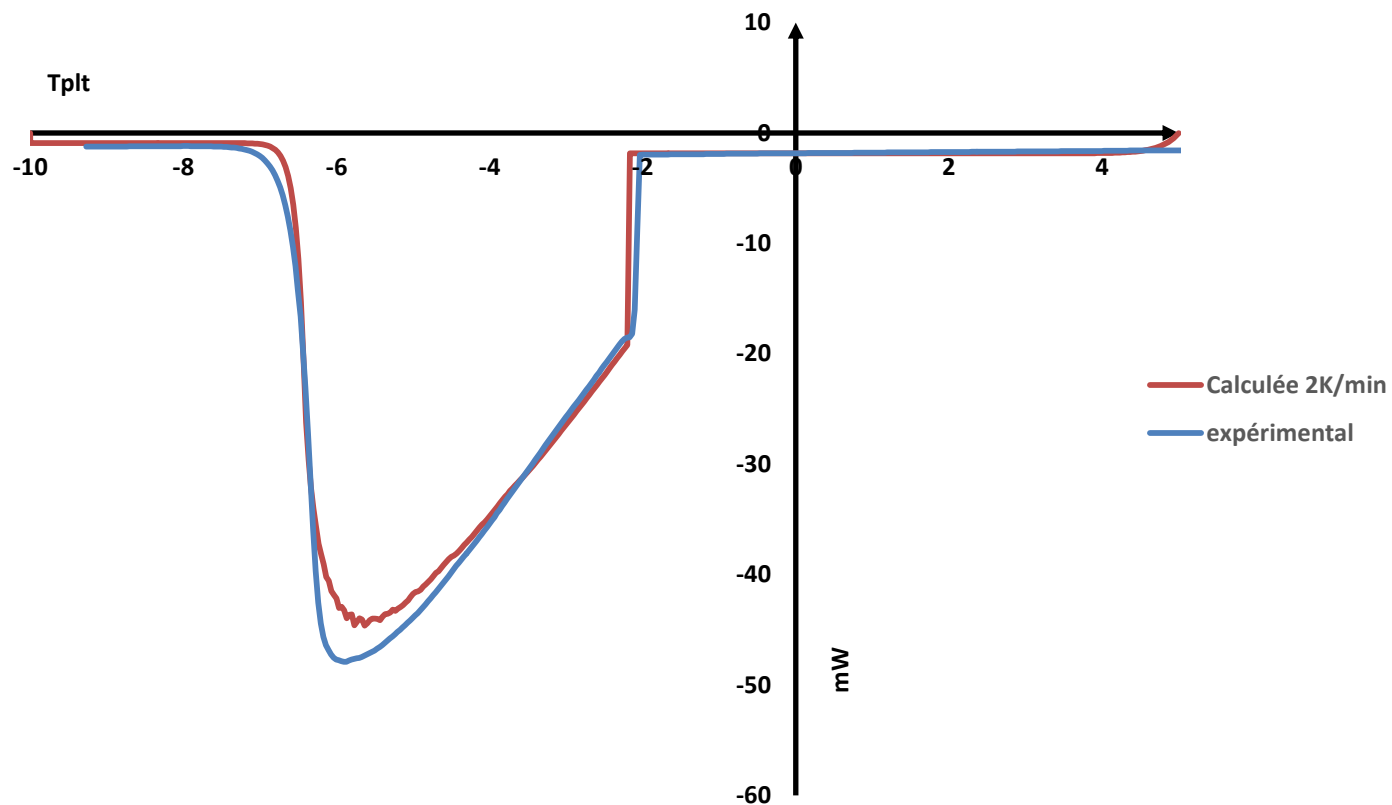
$$-k \vec{\nabla} T \cdot \vec{n} = \alpha_i (T_i - T_{plt}) \quad \forall S_i$$

## Thermogramme

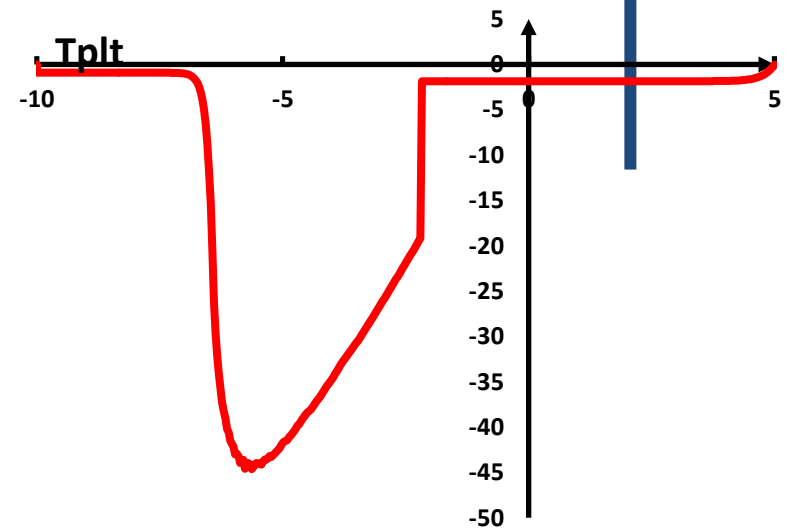
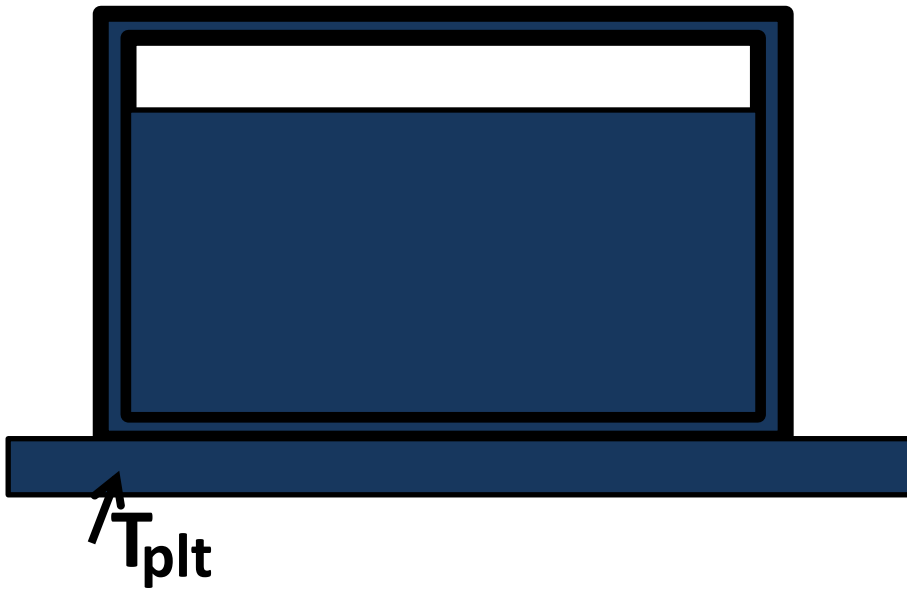
$$\phi = \sum_i \alpha_i S_i (T_{plt} - T_i)$$

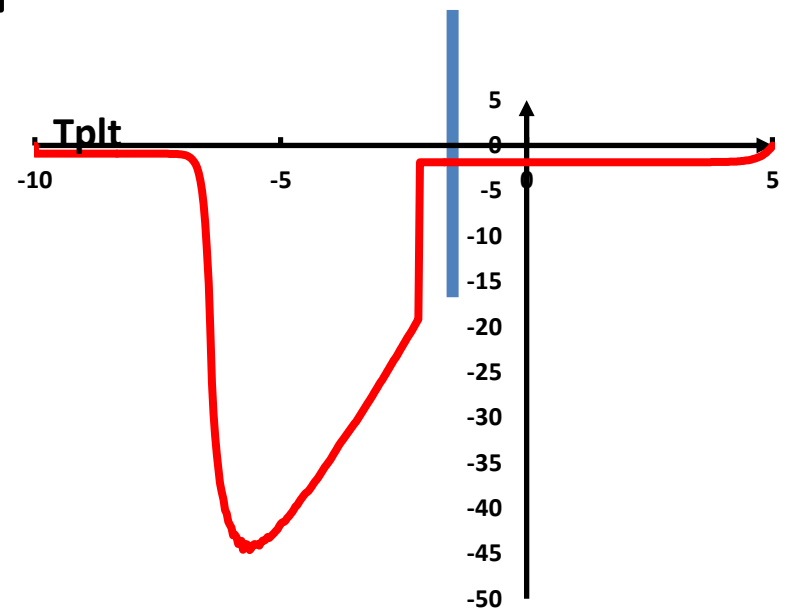
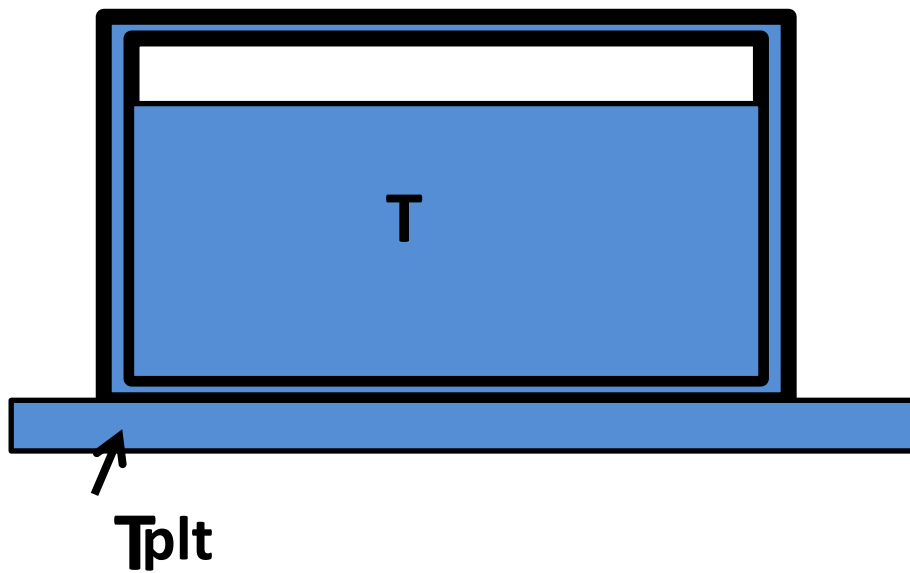
$$\phi(t) \quad \phi(T_{plt})$$

## Méthode enthalpique

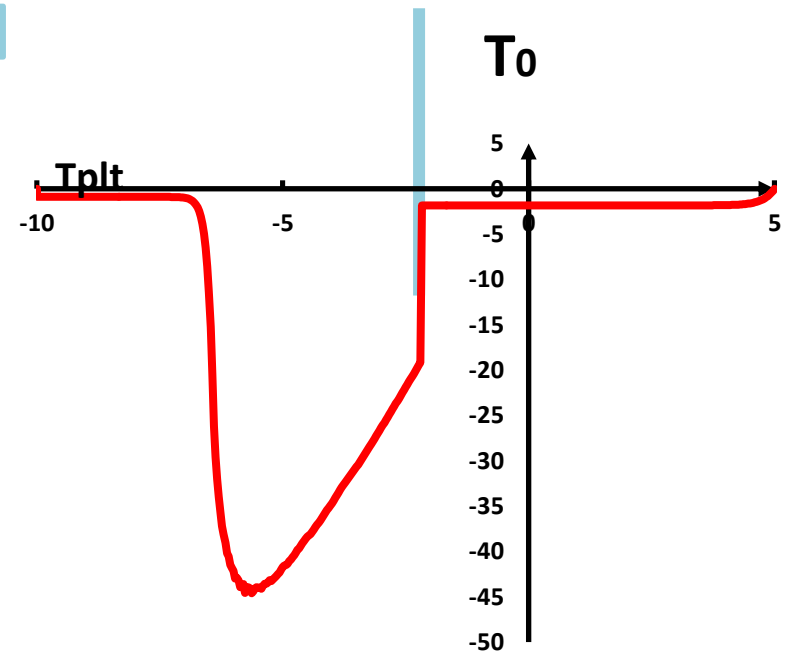
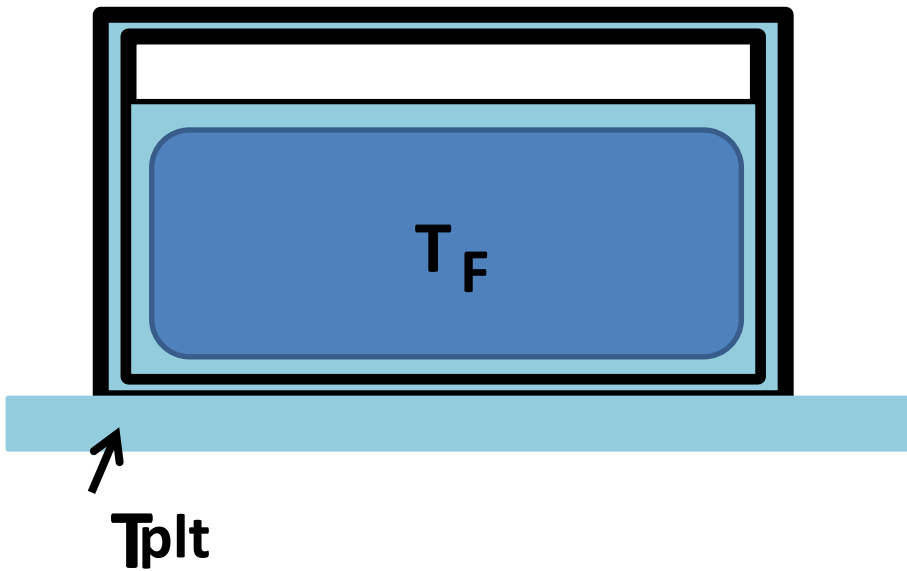


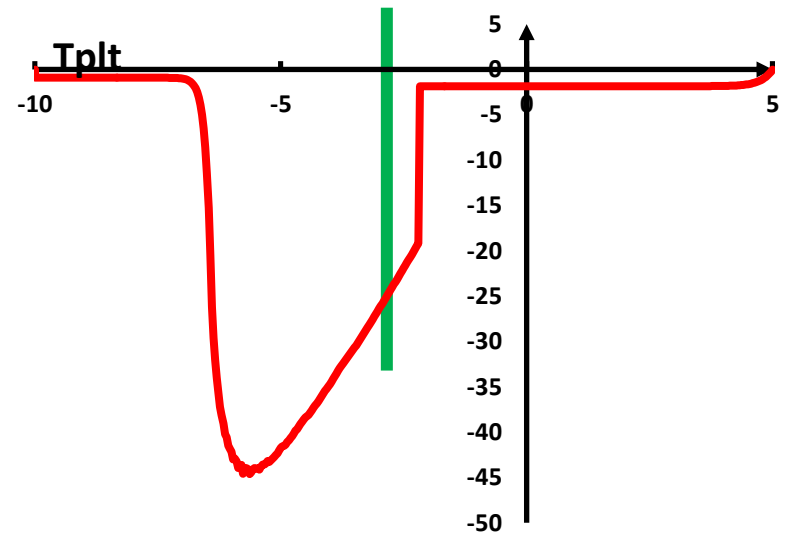
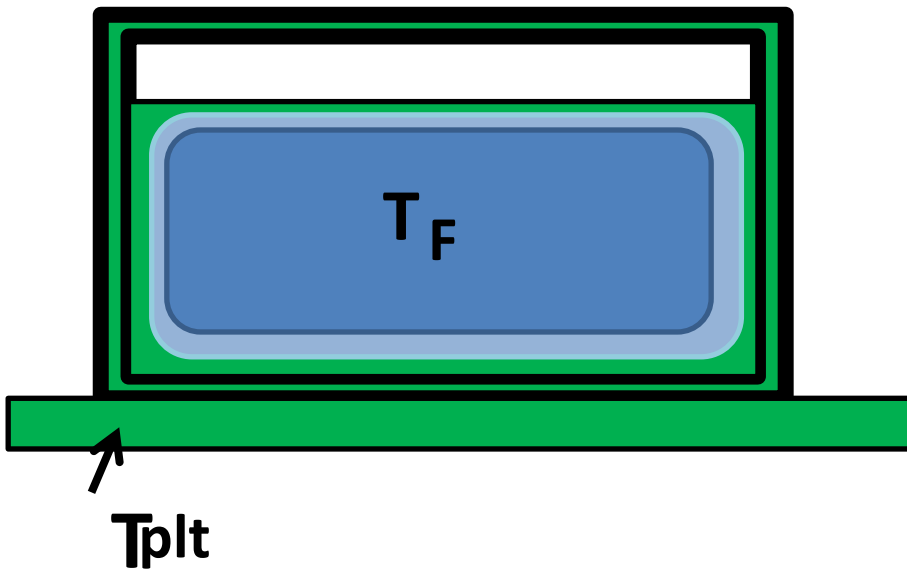
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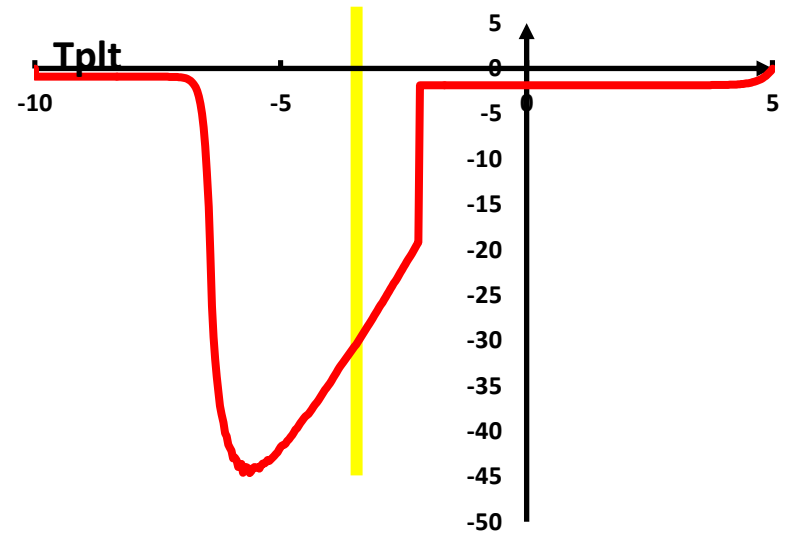
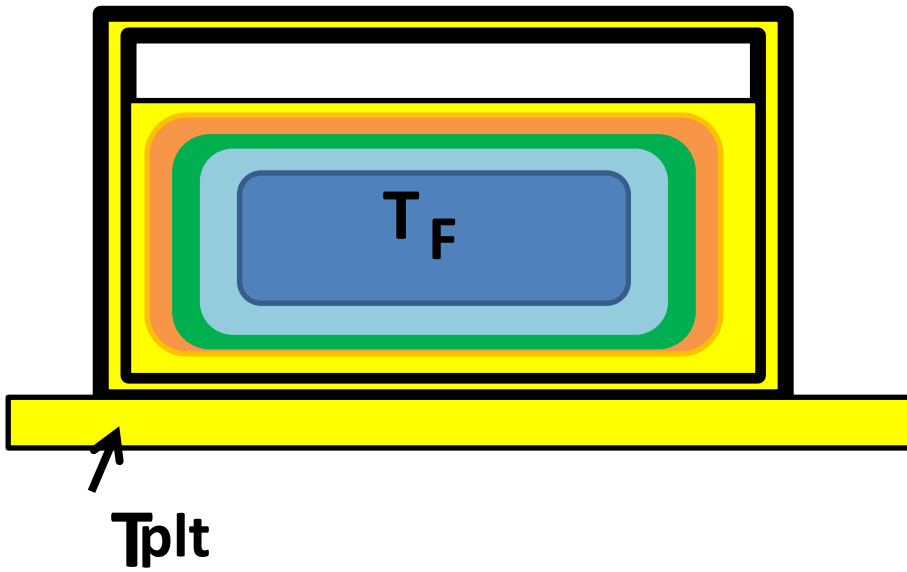


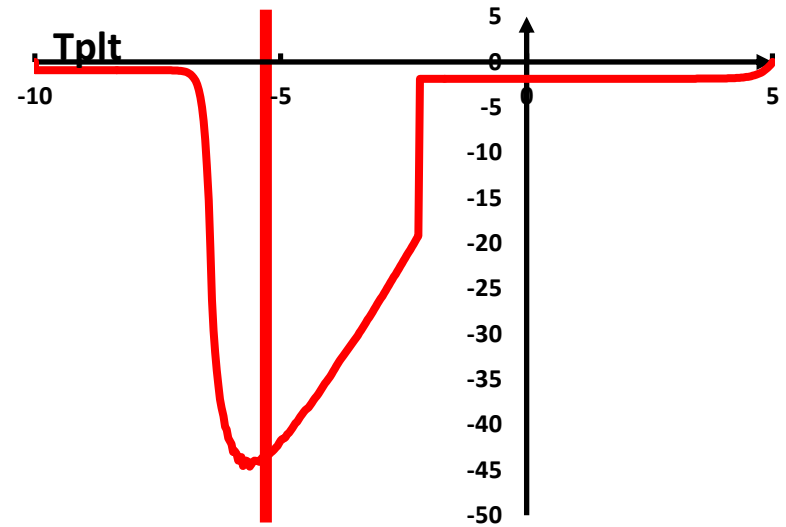
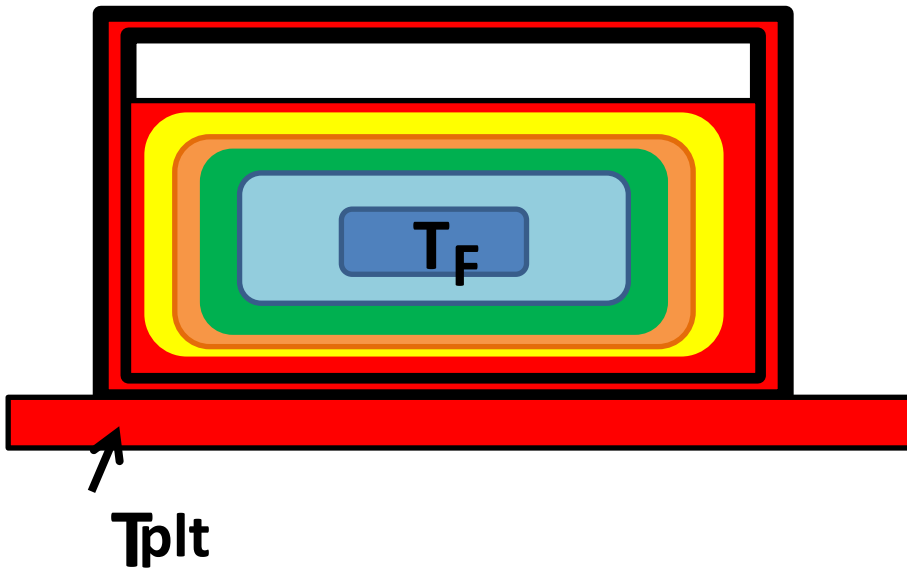


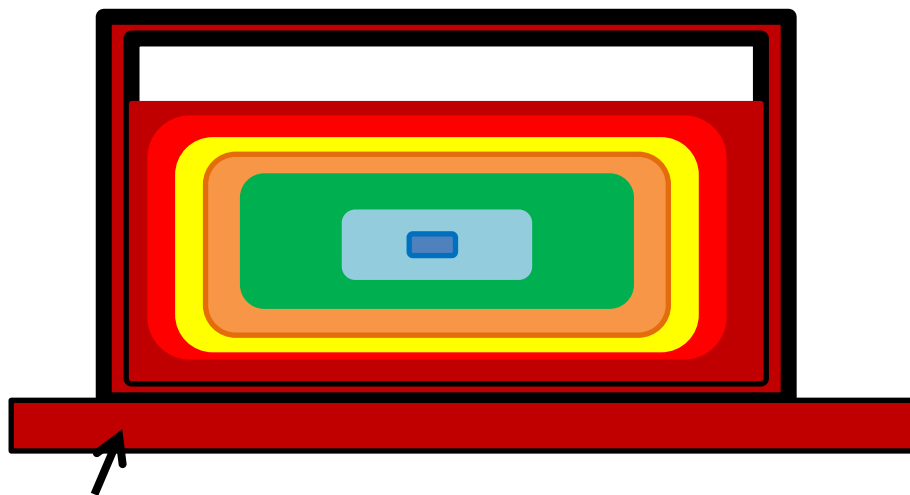




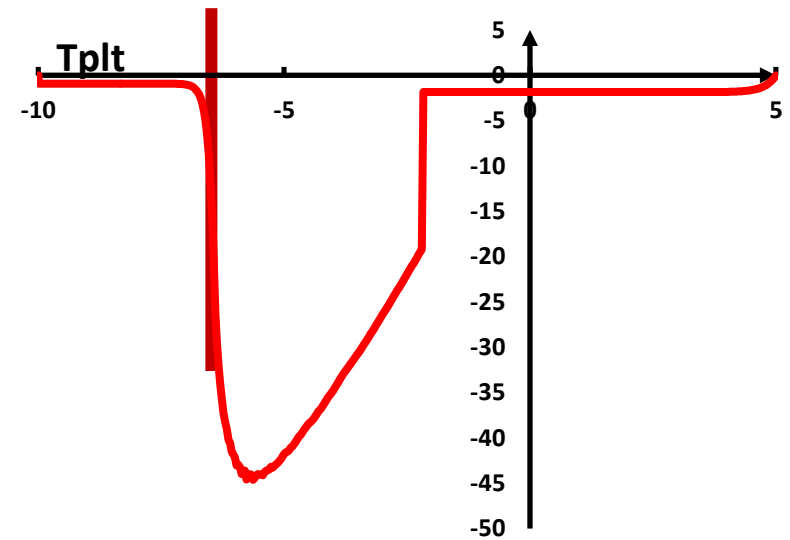


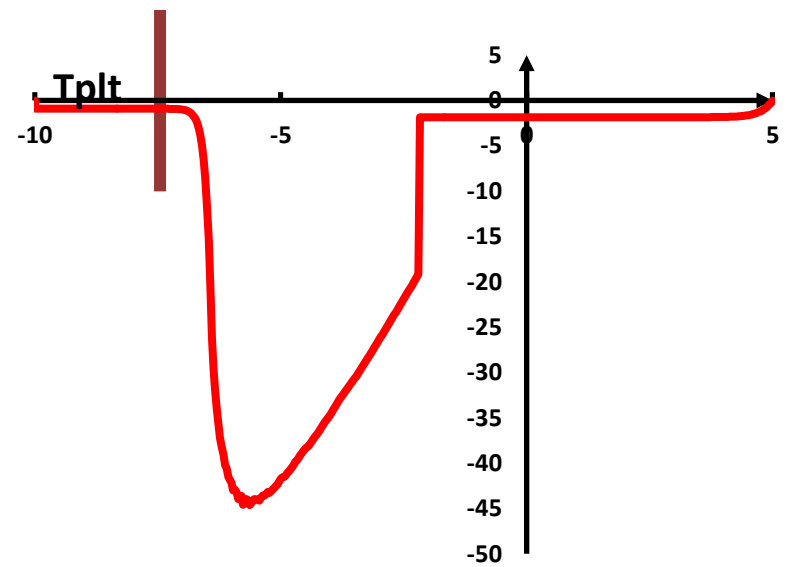




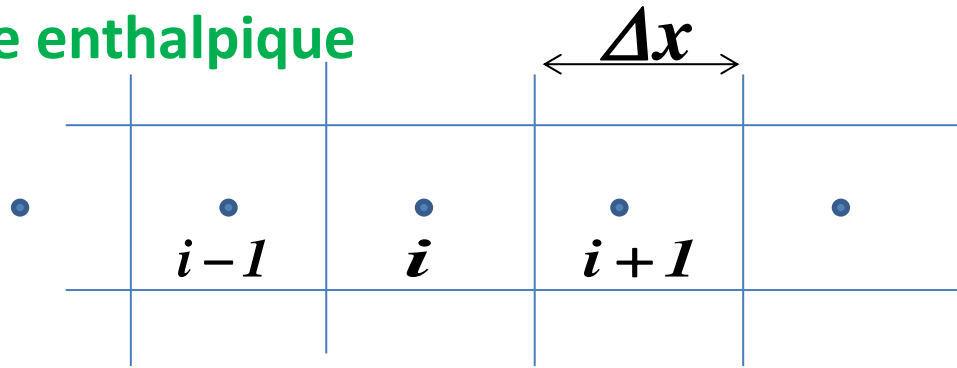


$T_{plt}$





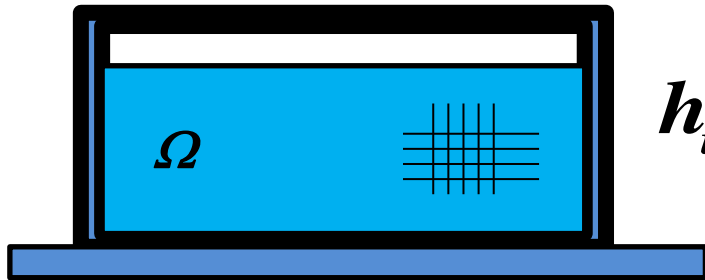
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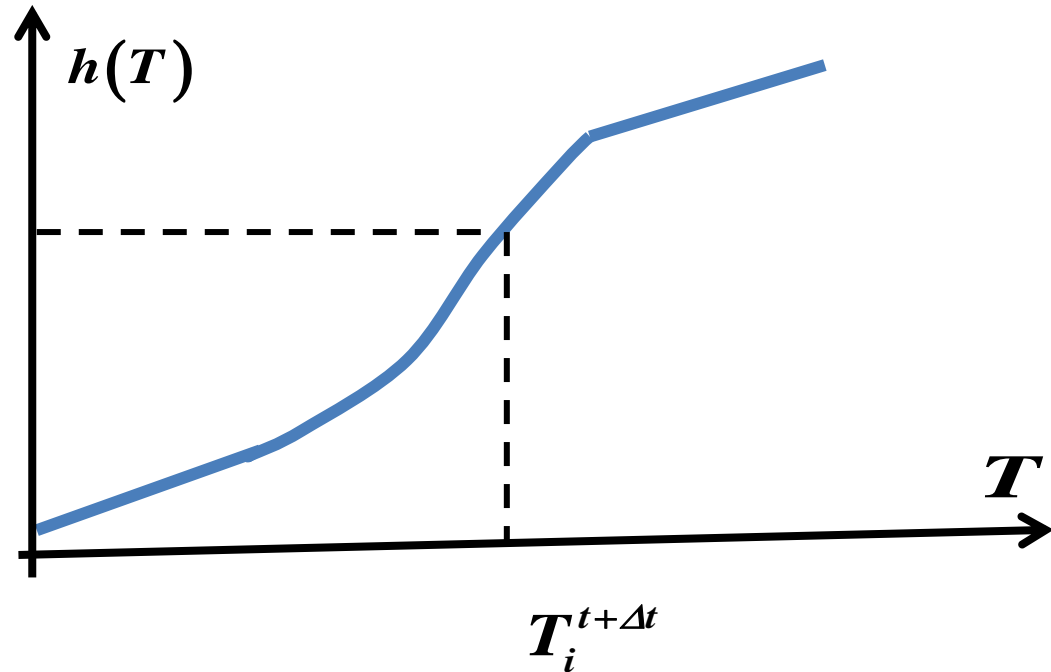
$T_{plt}(t)$

$$\rho \frac{h_i^{t+\Delta t} - h_i^t}{\Delta t} = \lambda \frac{(T_{i-1}^t - T_i^t)}{\Delta x} + \lambda \frac{(T_{i+1}^t - T_i^t)}{\Delta x}$$

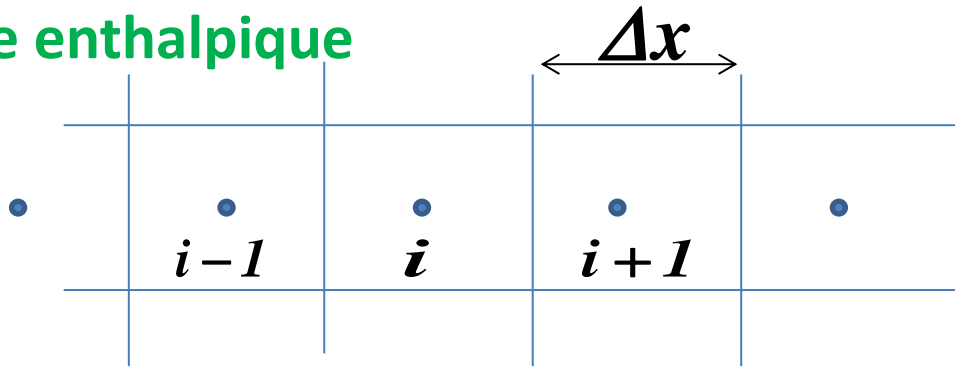
$$\frac{\partial \rho h}{\partial t} = \nabla \cdot (\lambda \nabla T)$$



$h_i^{t+\Delta t}$



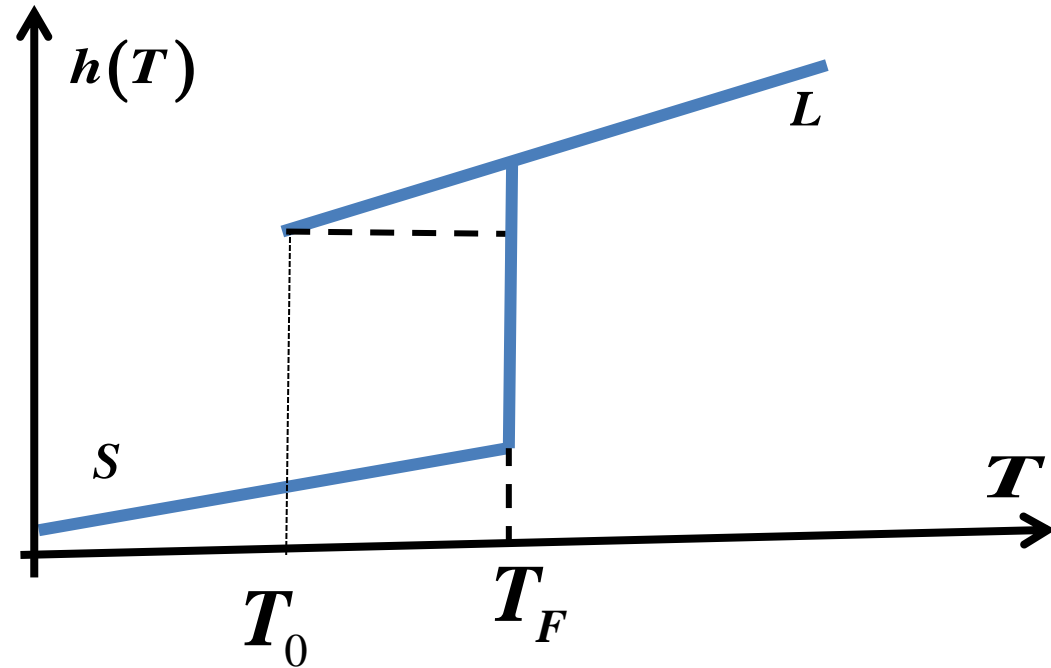
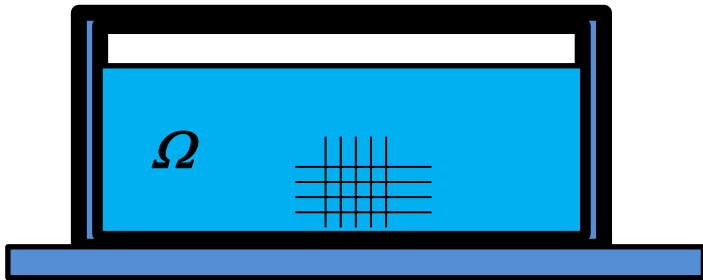
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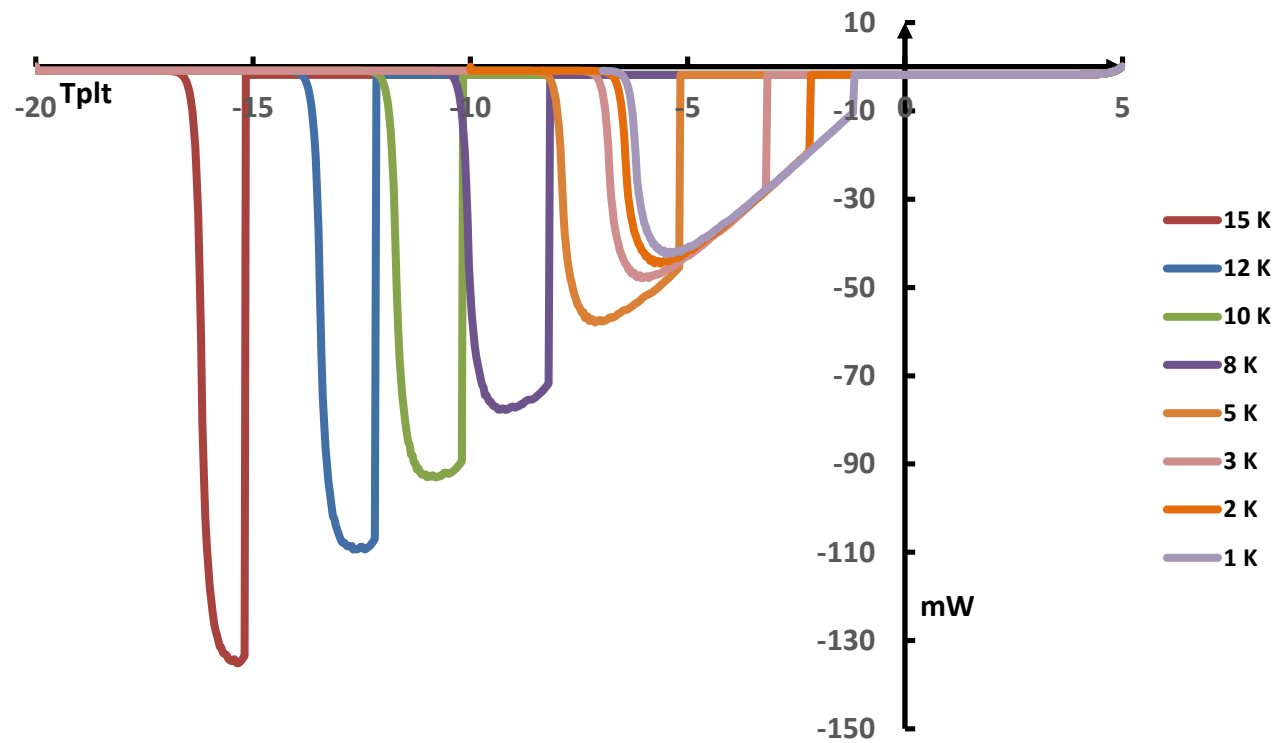
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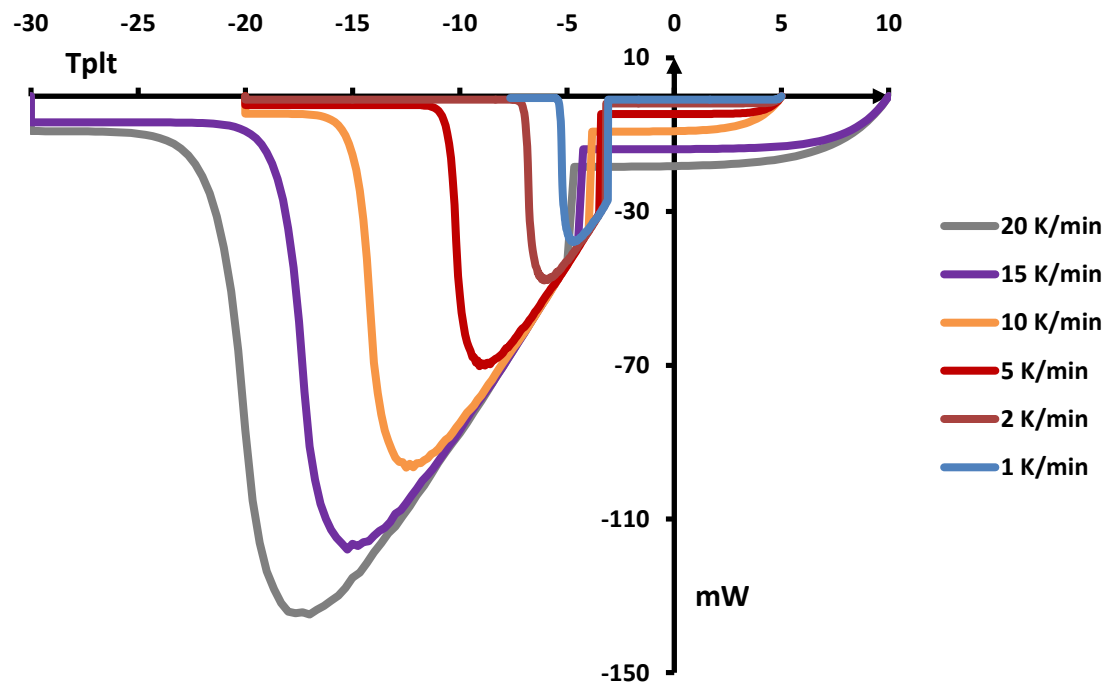
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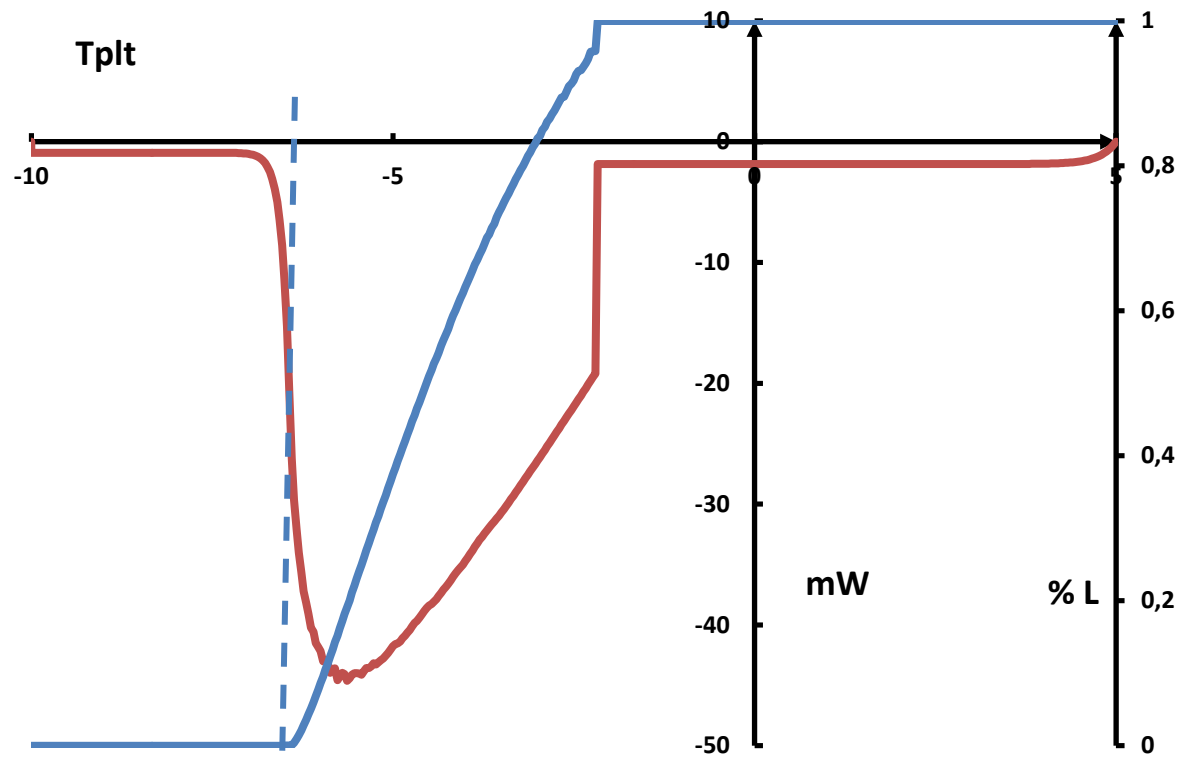




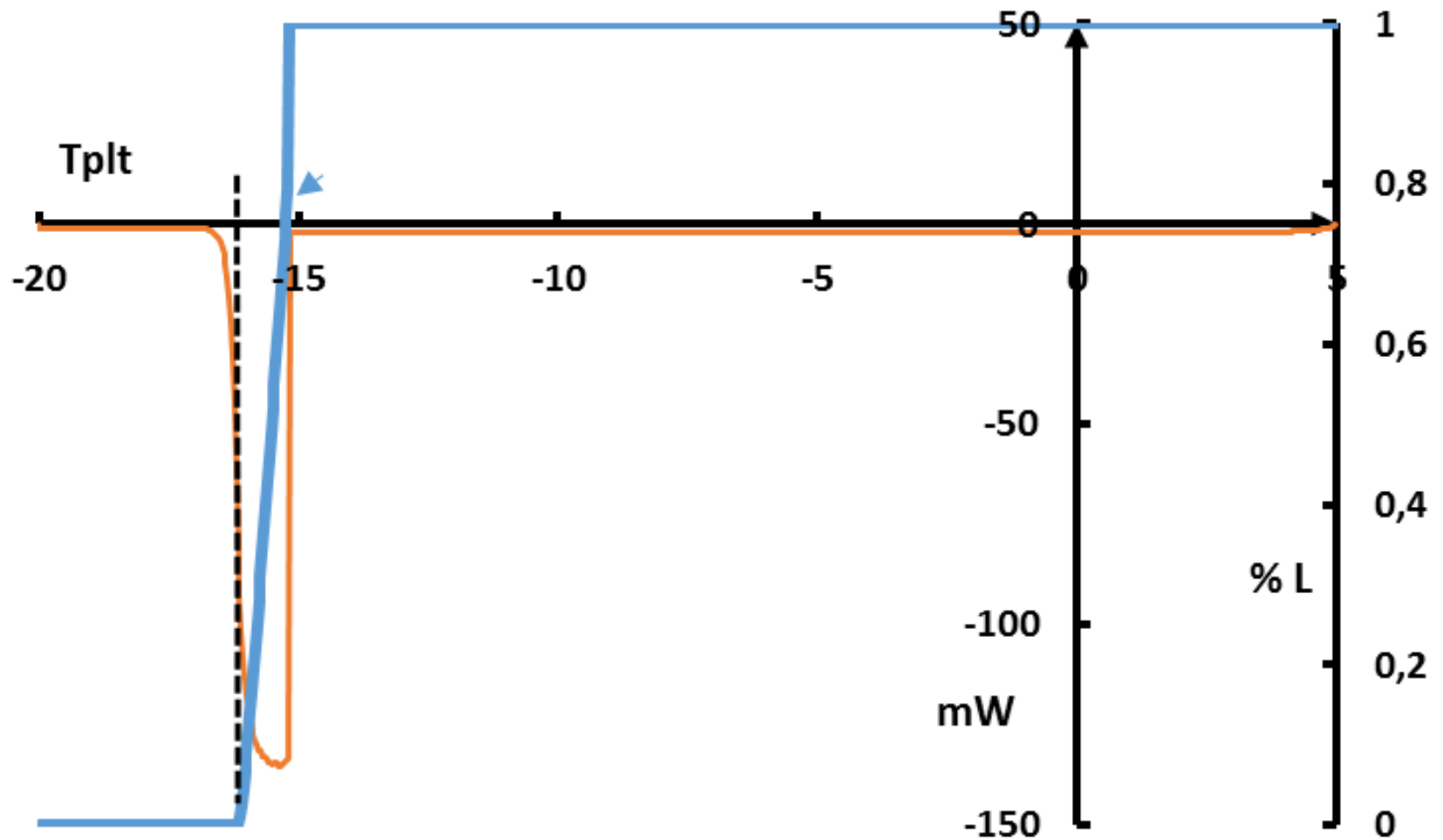
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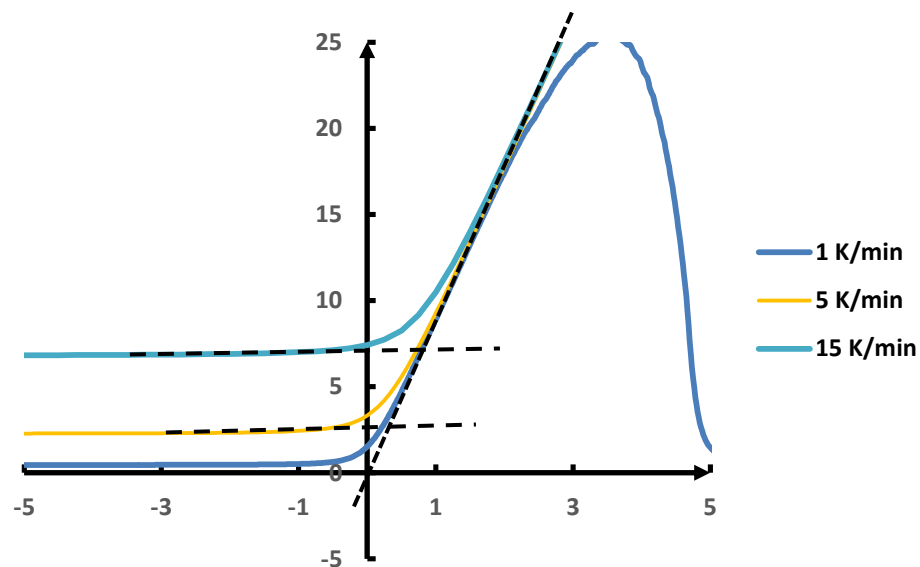
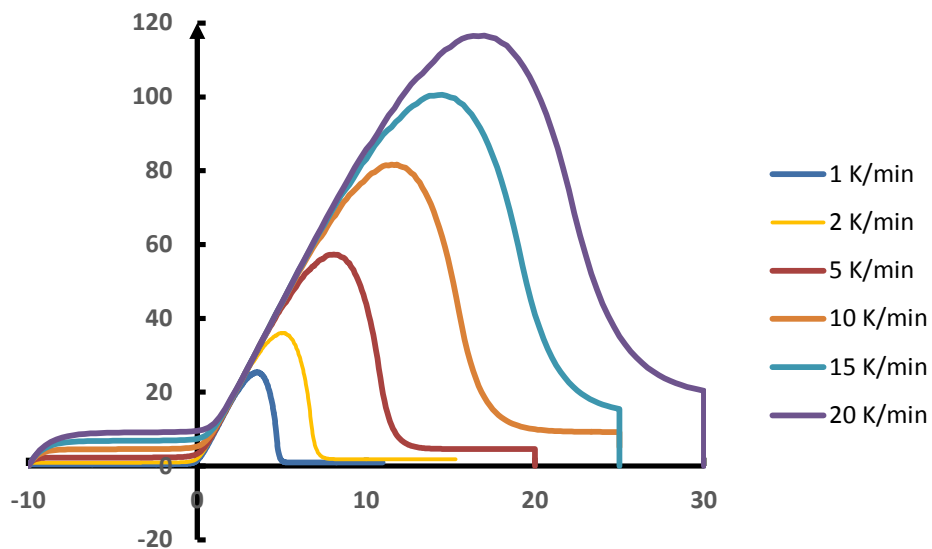


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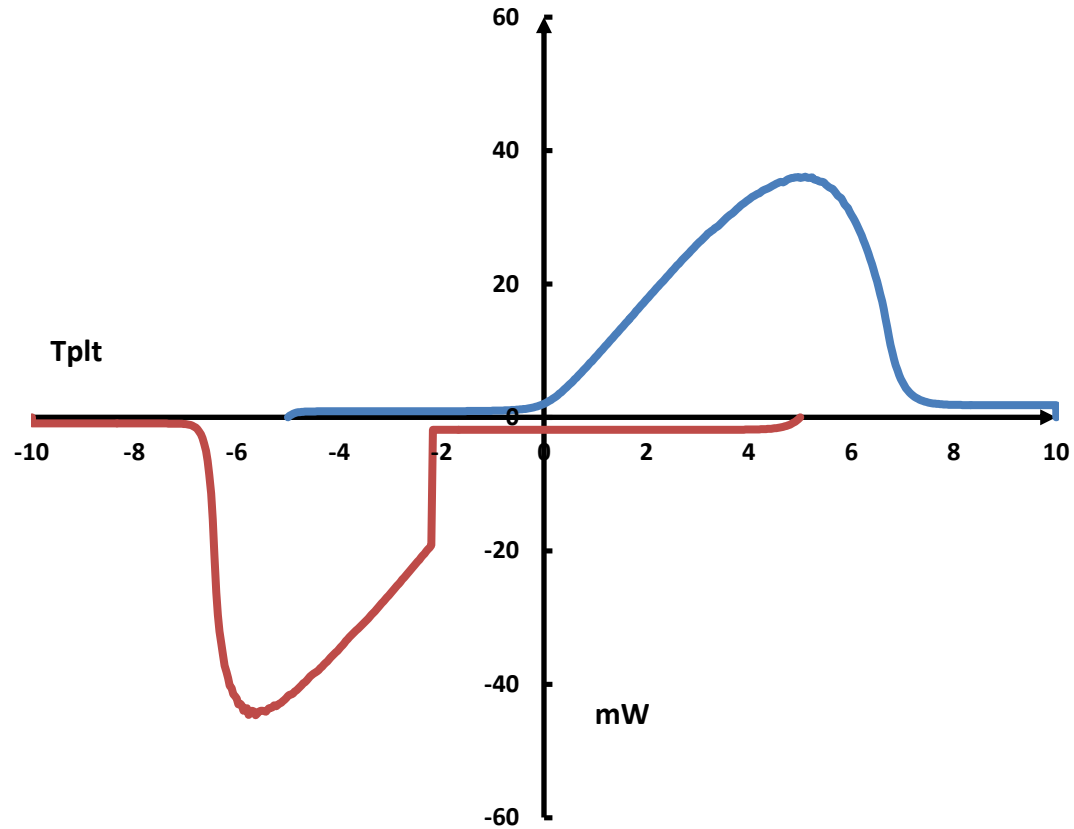


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# ETALONNAGE EN TEMPERATURE

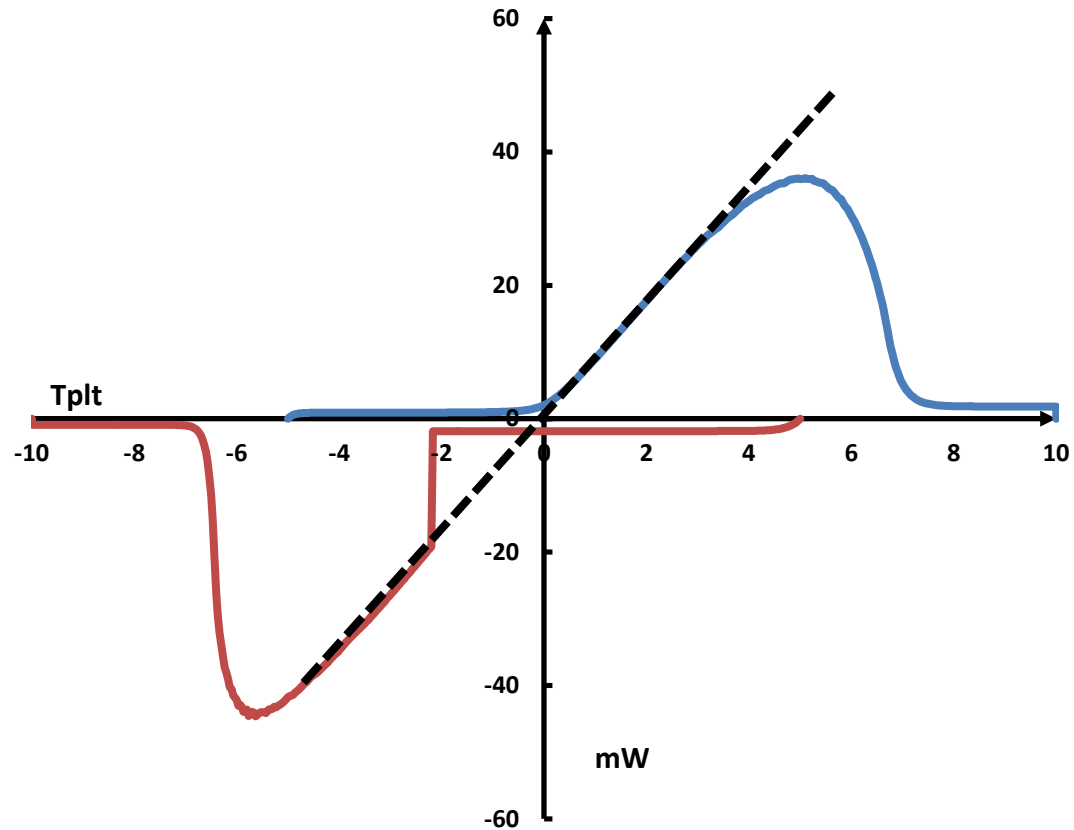


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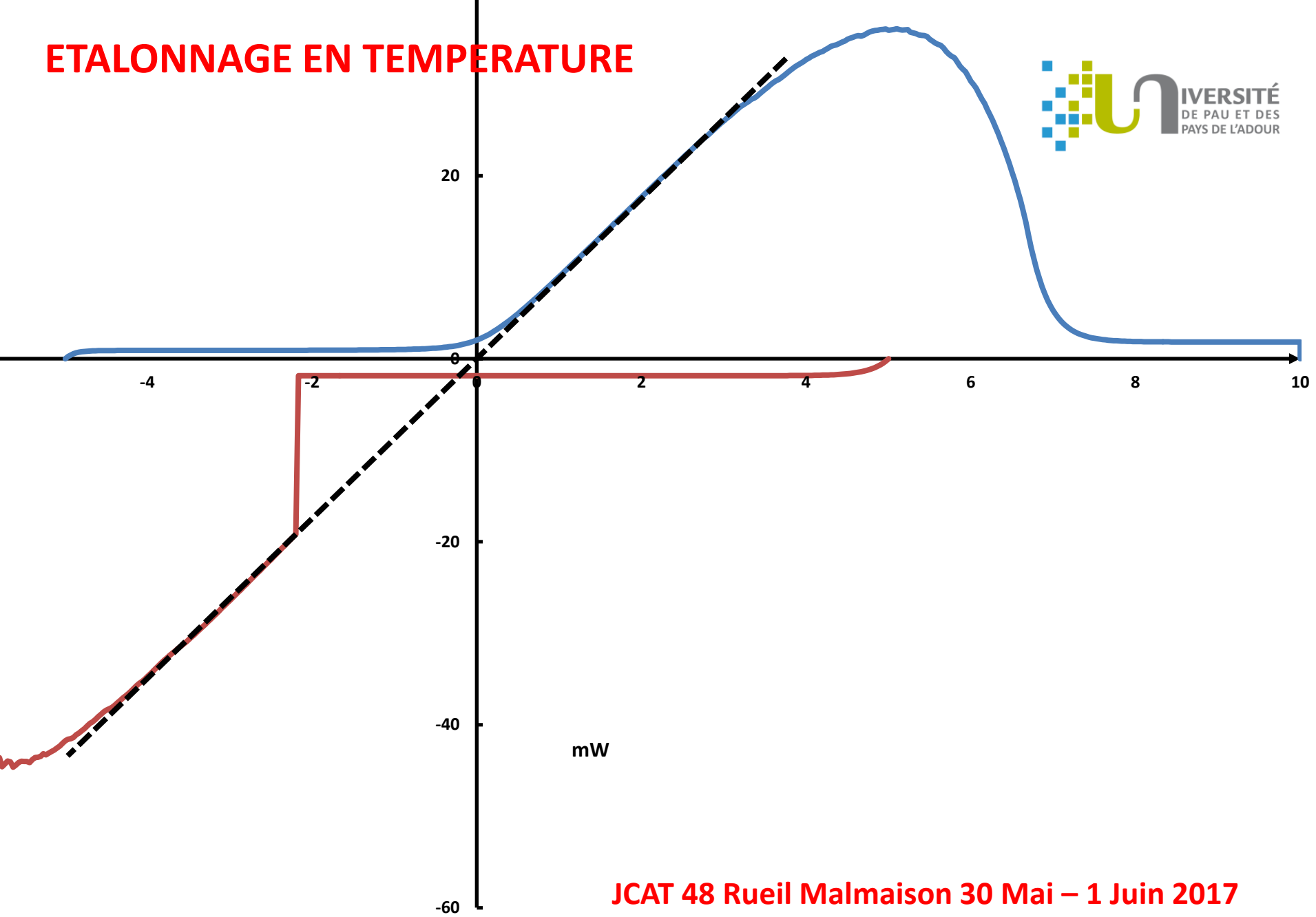
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# ETALONNAGE EN TEMPERATURE



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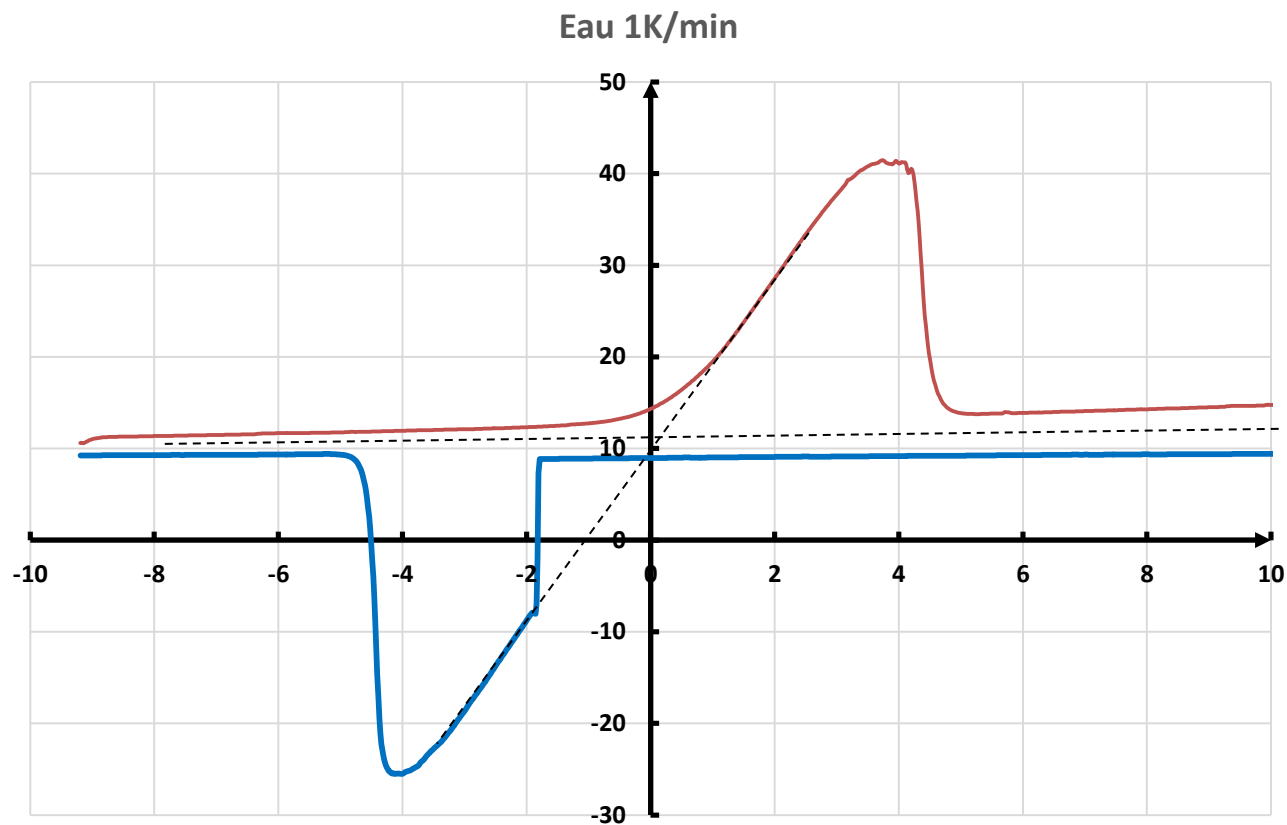
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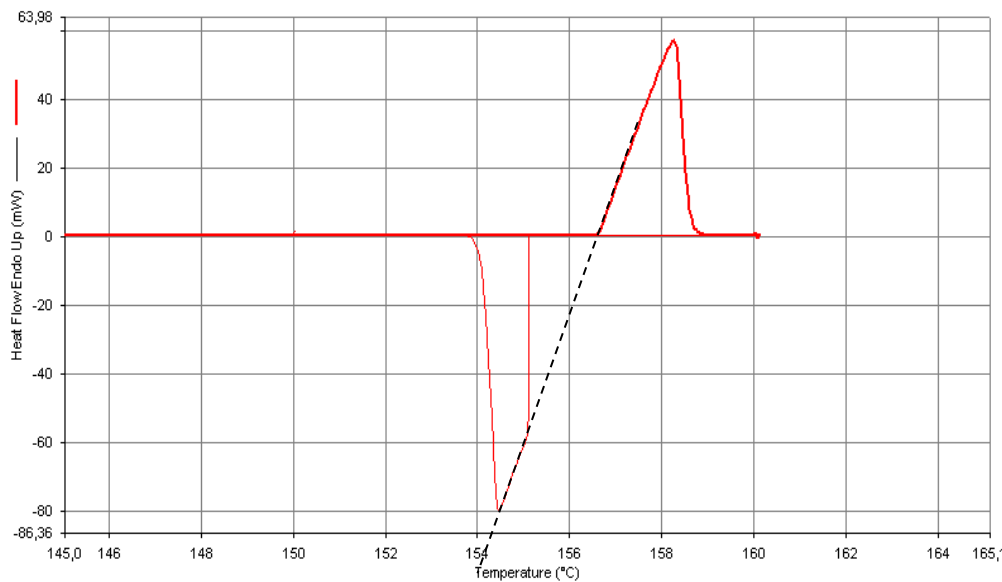
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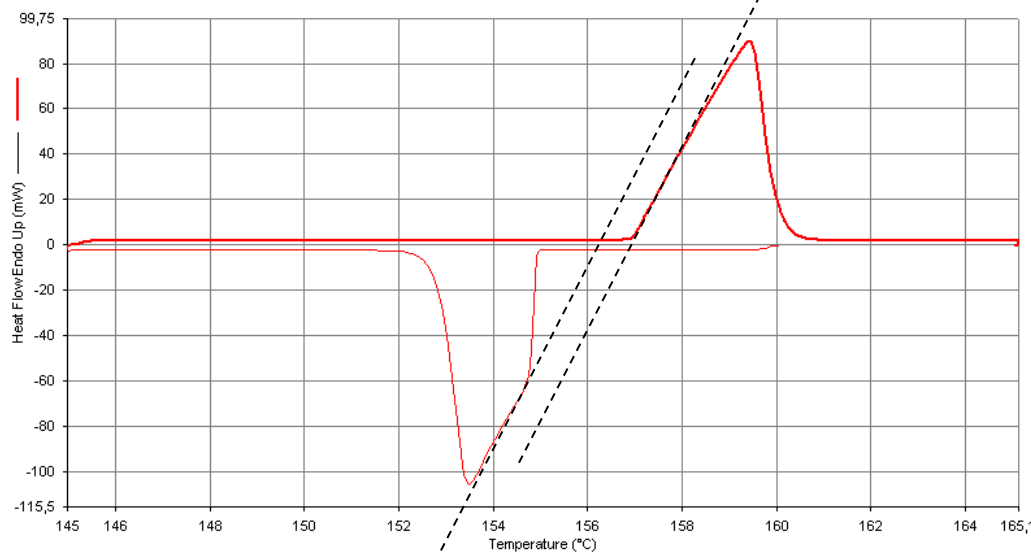
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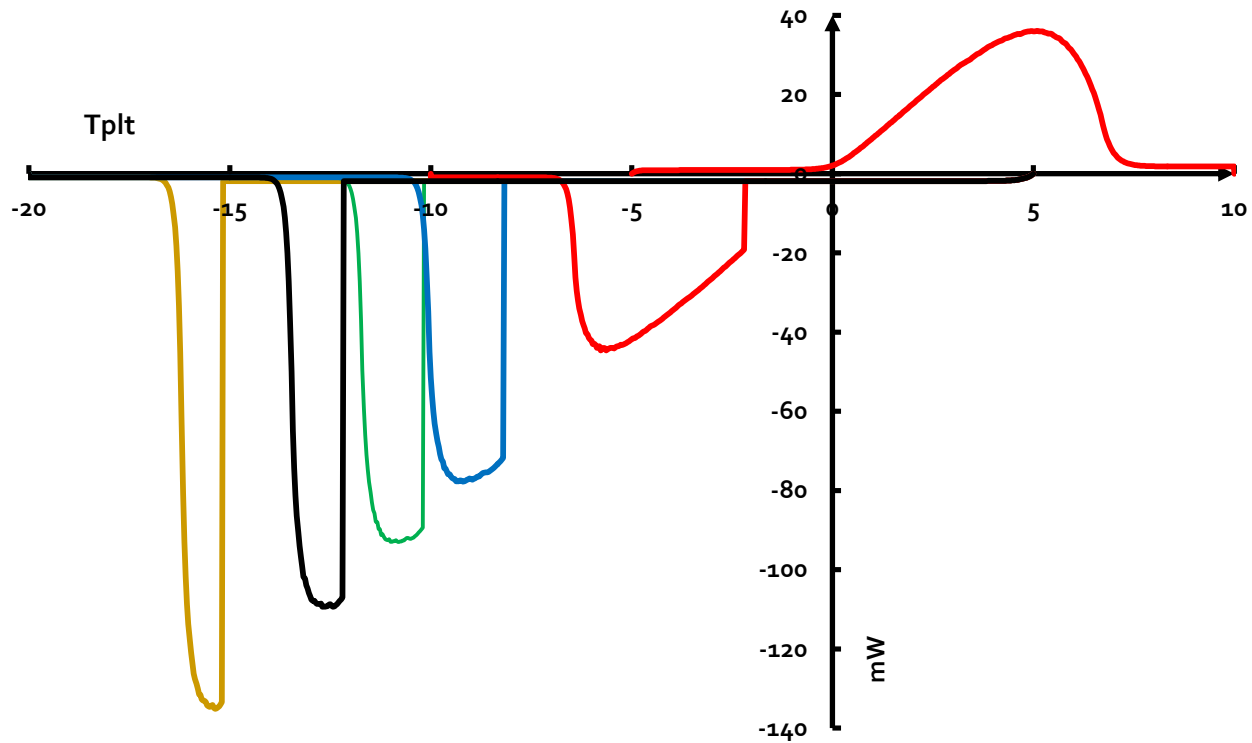
## Indium 2 K/min



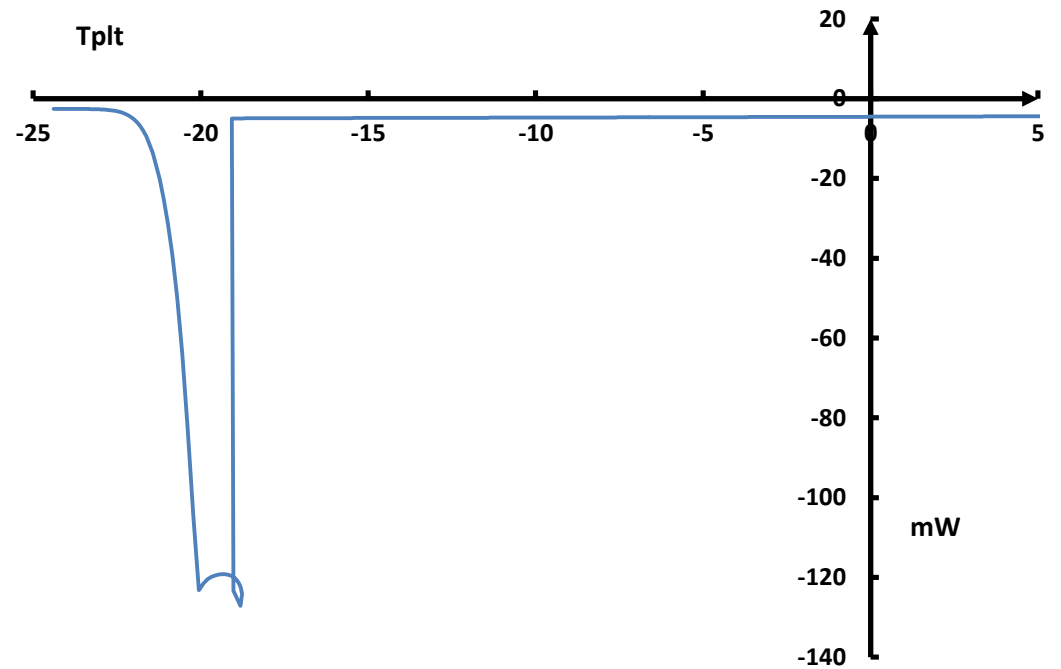
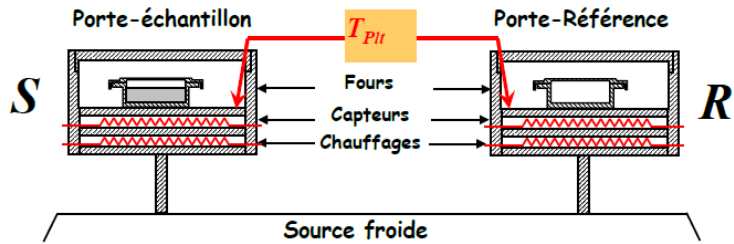
## Indium 5 K/min



# ETALONNAGE EN TEMPERATURE



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## Conclusions Perspectives

- Au cours de la cristallisation du liquide surfondu macroscopique la température de la partie liquide restante remonte à la température de fusion.
- Il est nécessaire de tenir compte de la conduction thermique dans le solide
- On déduit des modèles une stratégie pour l'étalonnage en température au cours du refroidissement

**Merci de votre attention**



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