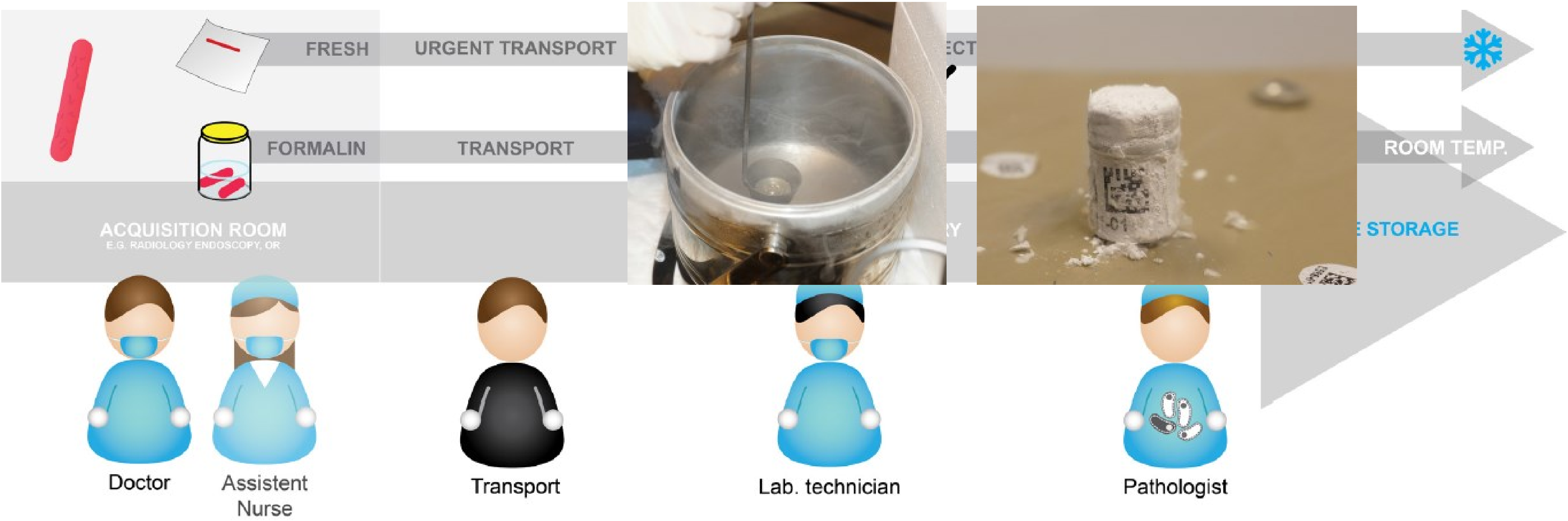
A tissue snap-freezing device without sacrificial cryogens

Michiel van Limbeek
Sahil Jagga
Harry Holland
Koen Ledeboer
Marcel ter Brake
Srinivas Vanapalli

UNIVERSITY OF TWENTE.

From patient to diagnosis: The current situation

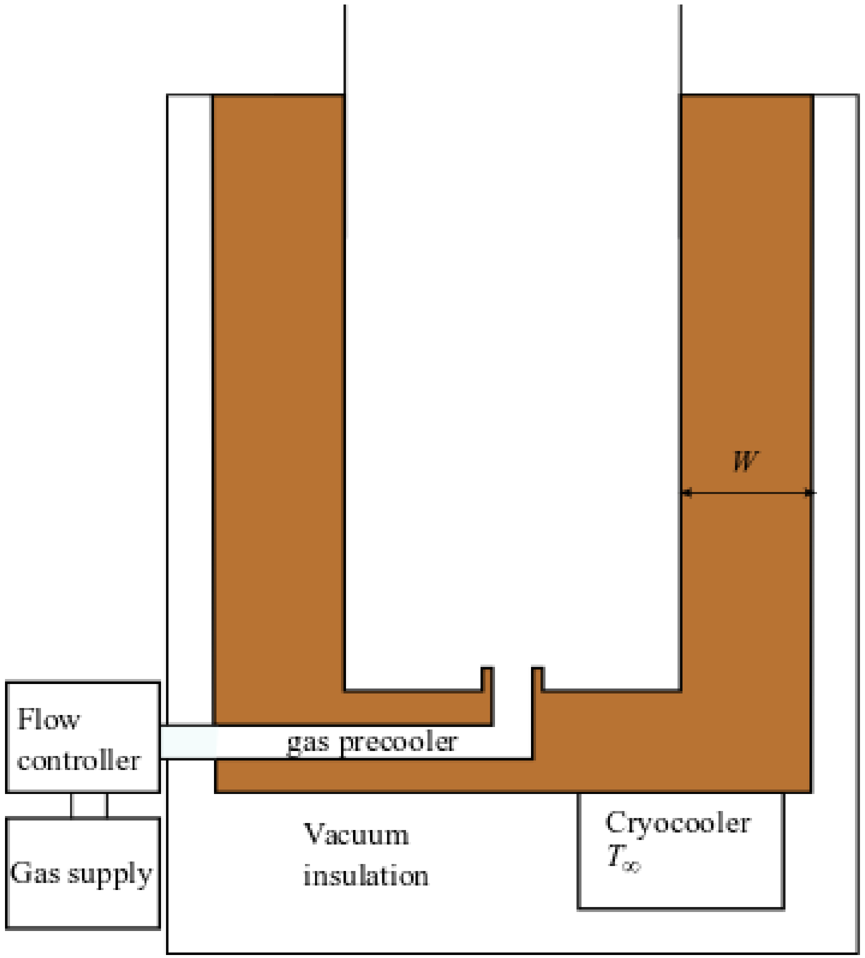


PamGene

Amsterdam UMC
University Medical Centers

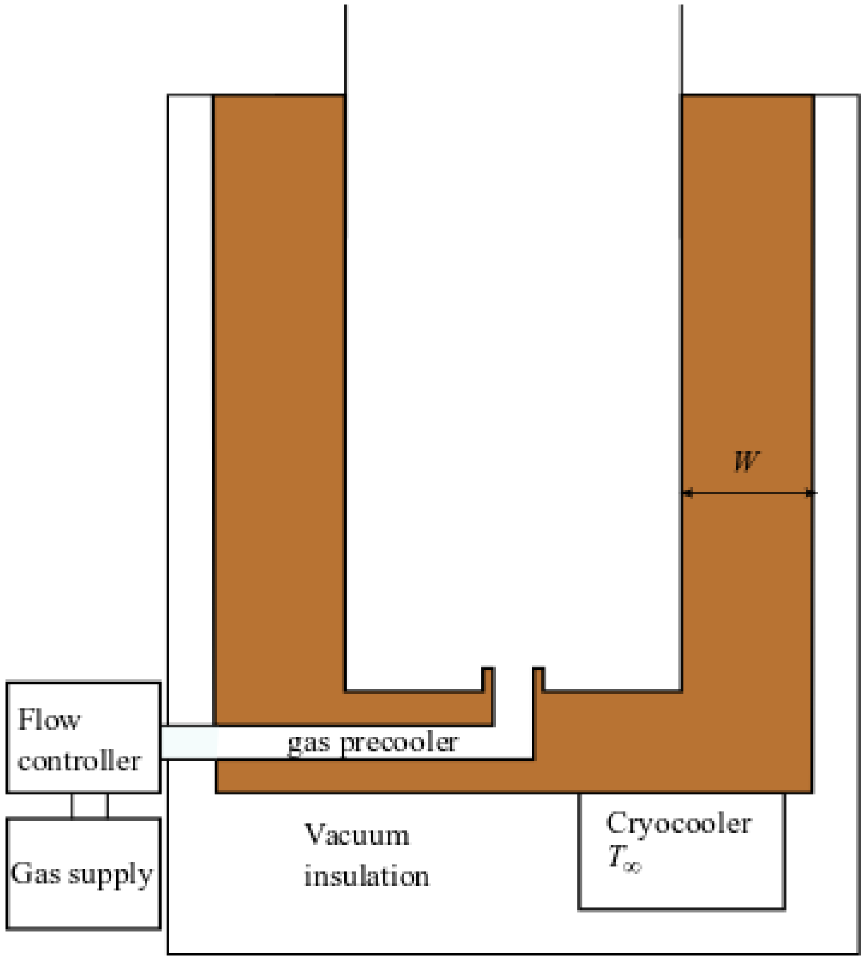
UNIVERSITY OF TWENTE.

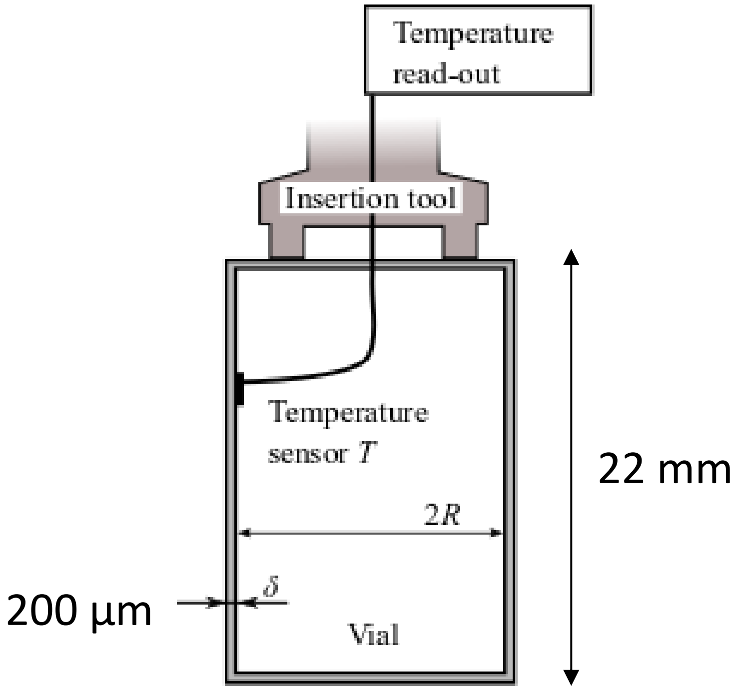
Snapfreezer skeleton



Details of functional design:
CEC 2017 proceedings, for ppt: Google

Snapfreezer skeleton





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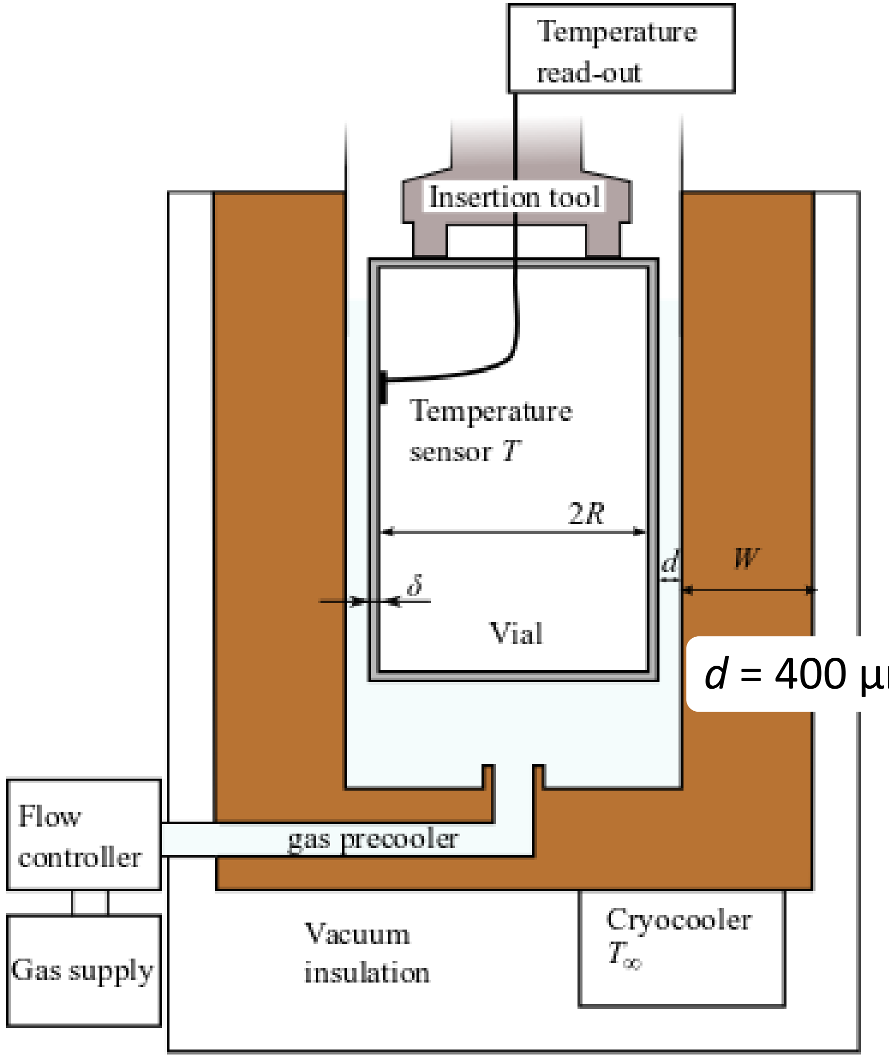

d = 400 μm

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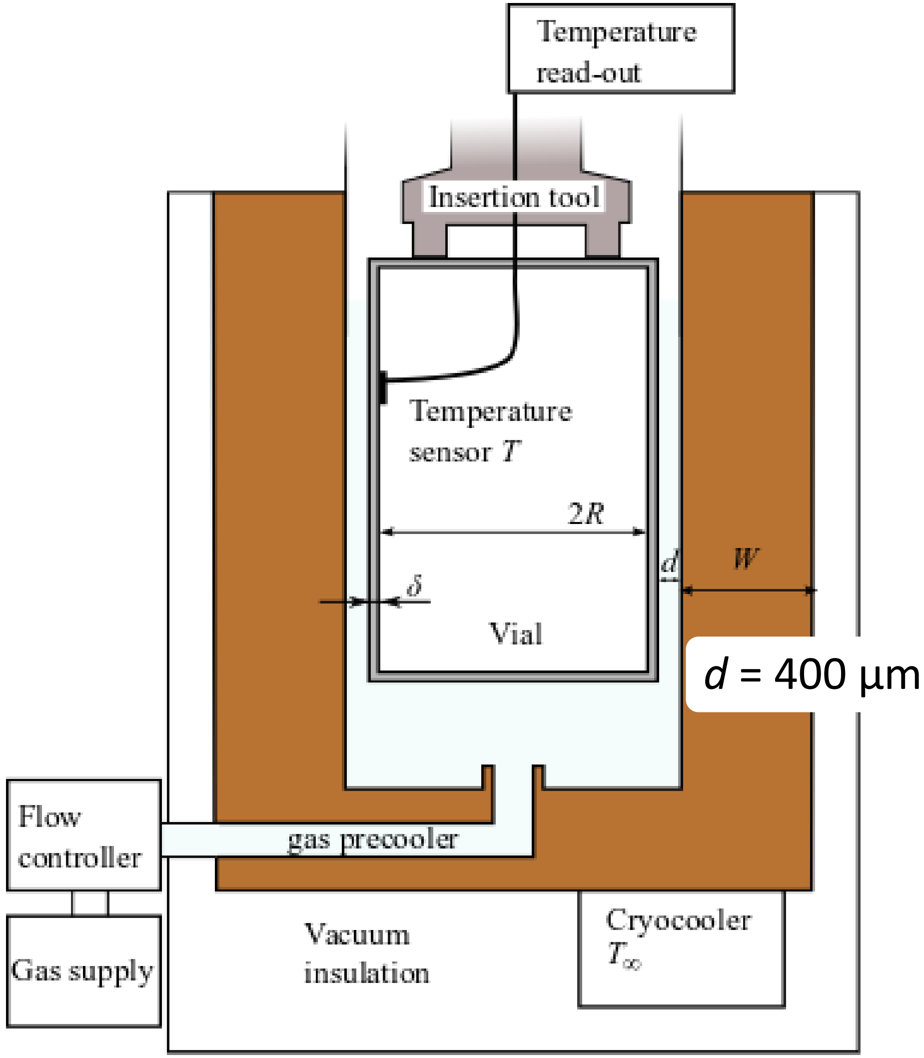
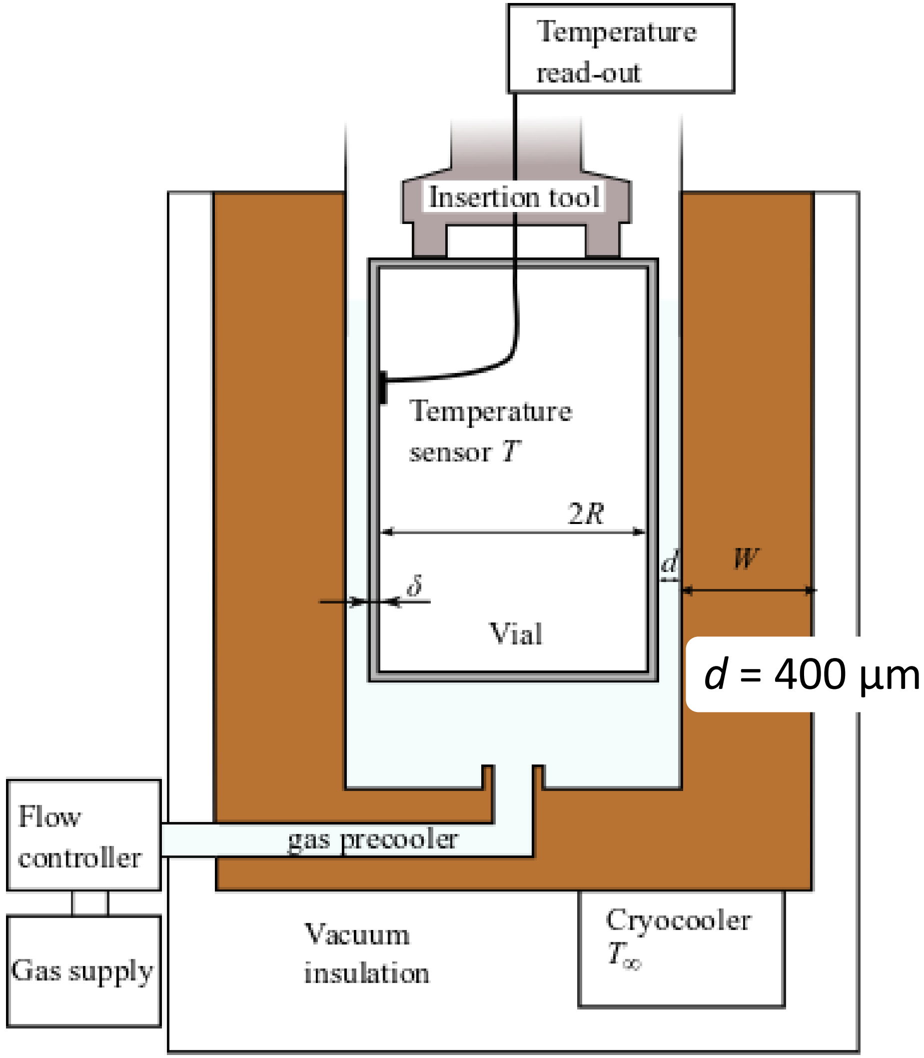


Mathematical model

Experimental

Mathematical model

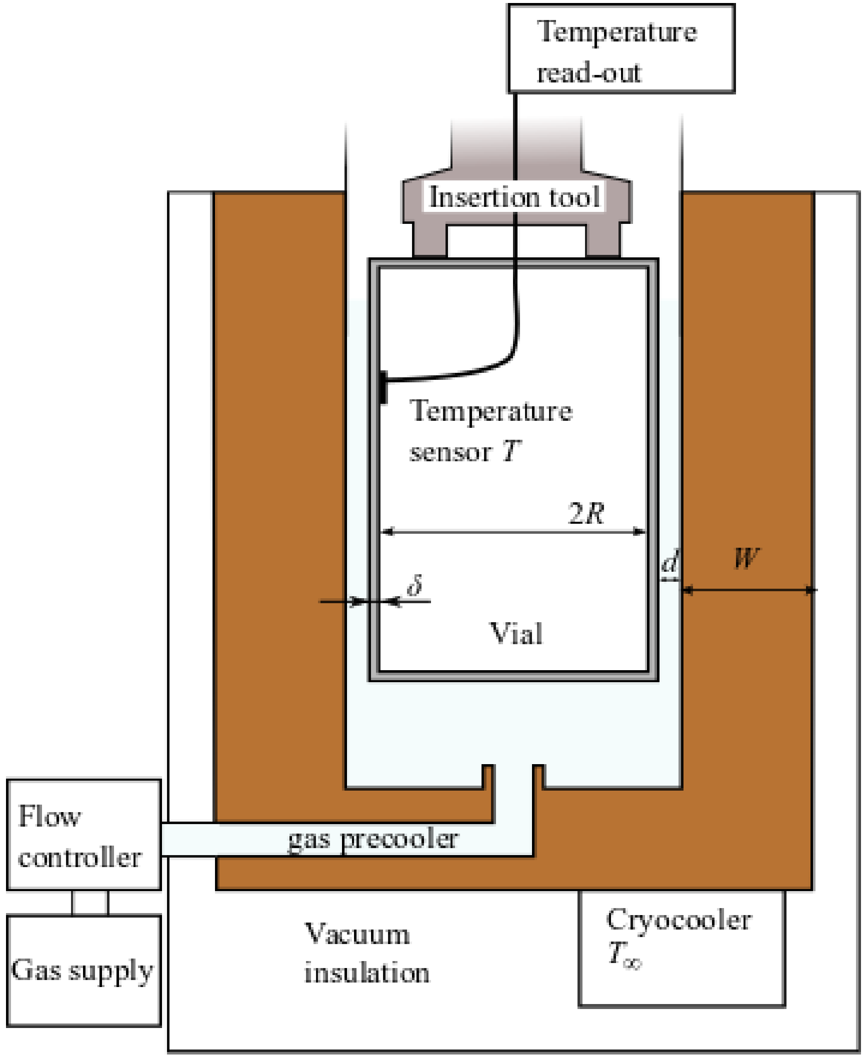


Thermal time scales

Cooling of the vial:

$$t \sim RC \sim (\rho c_p \delta A_v \Delta T)/(A_v k_g/d) \sim \mathcal{O}(1) \text{ second}$$

Mathematical model



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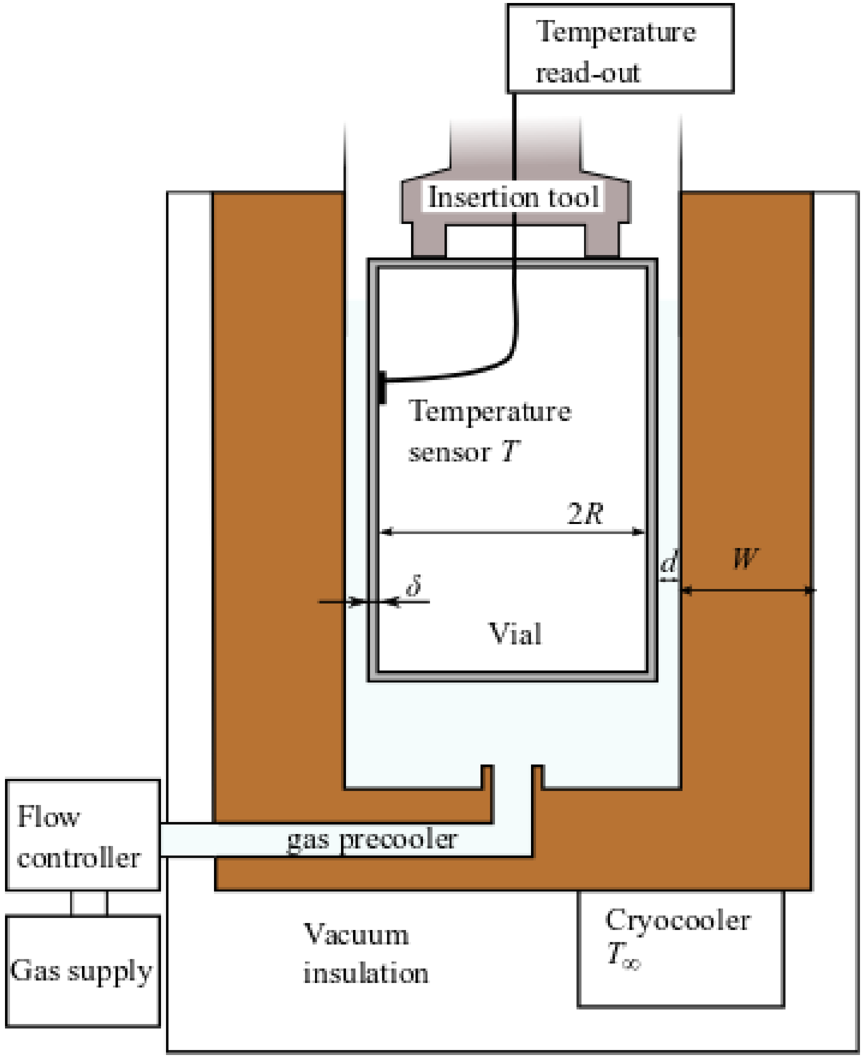
In various domains:

	ℓ [m]	α [m^2 s^{-1}]	τ [s]
vial wall δ	2×10^{-4}	1×10^{-4}	4×10^{-4}

Mathematical model



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In various domains:

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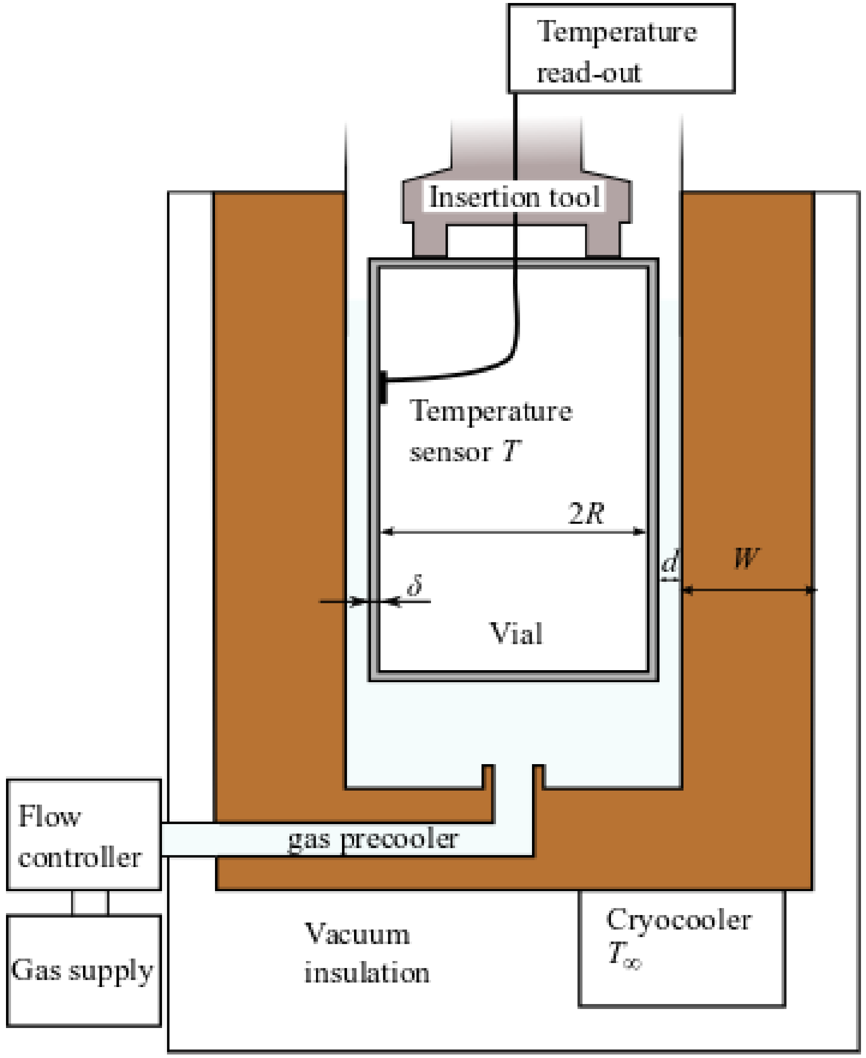
gap d	4×10^{-4}	2×10^{-5}	8×10^{-3}

Mathematical model



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In various domains:

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vial wall δ	2×10^{-4}	1×10^{-4}	4×10^{-4}
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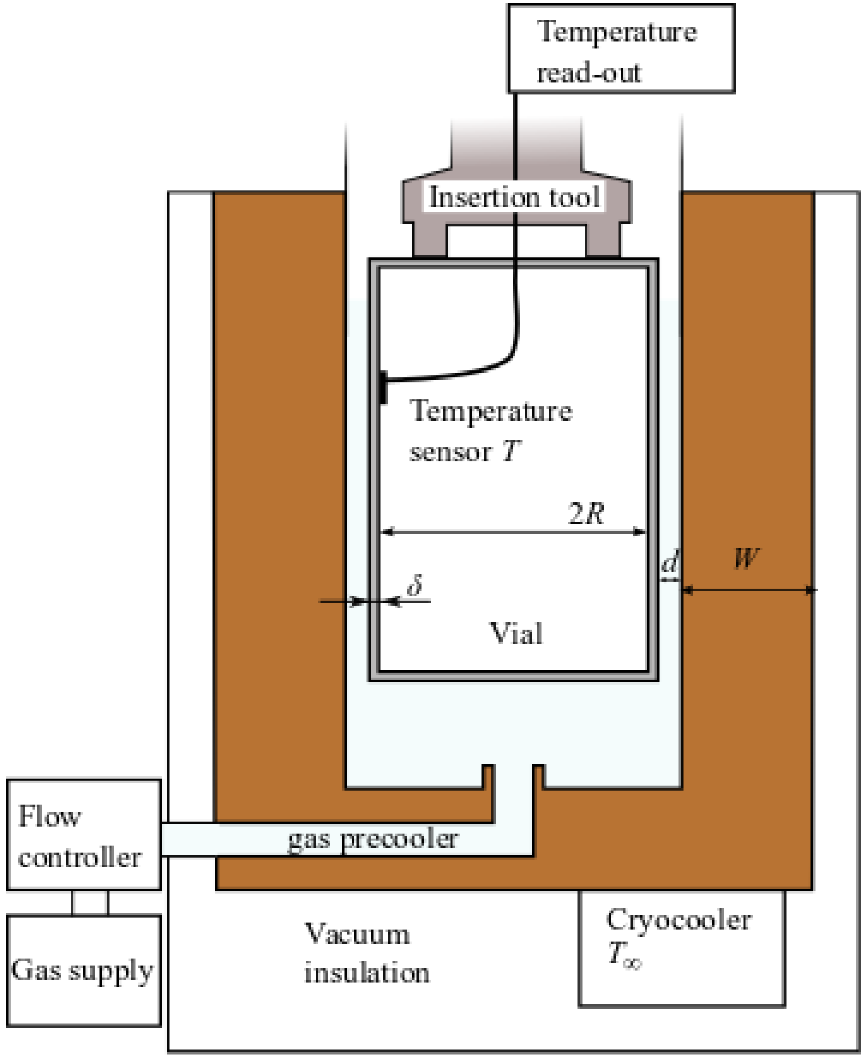
TESU wall W	1×10^{-2}	1.5×10^{-4}	6×10^{-1}

Mathematical model



Thermal time scales

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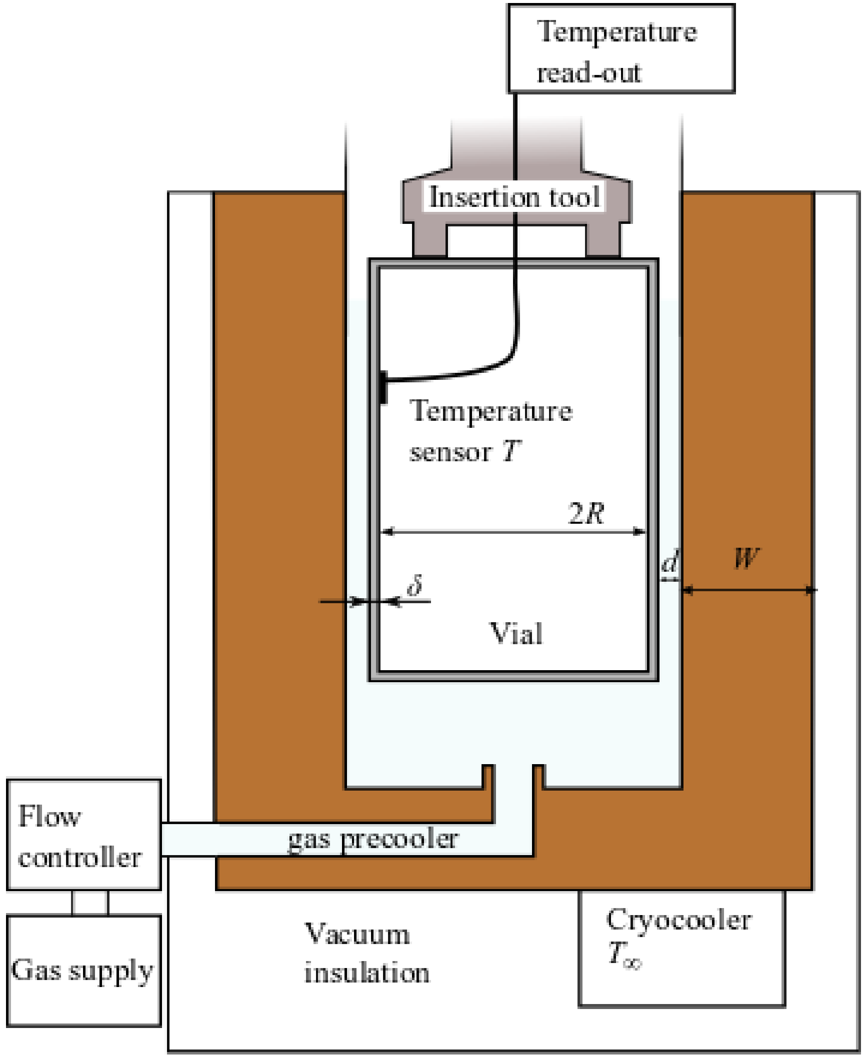
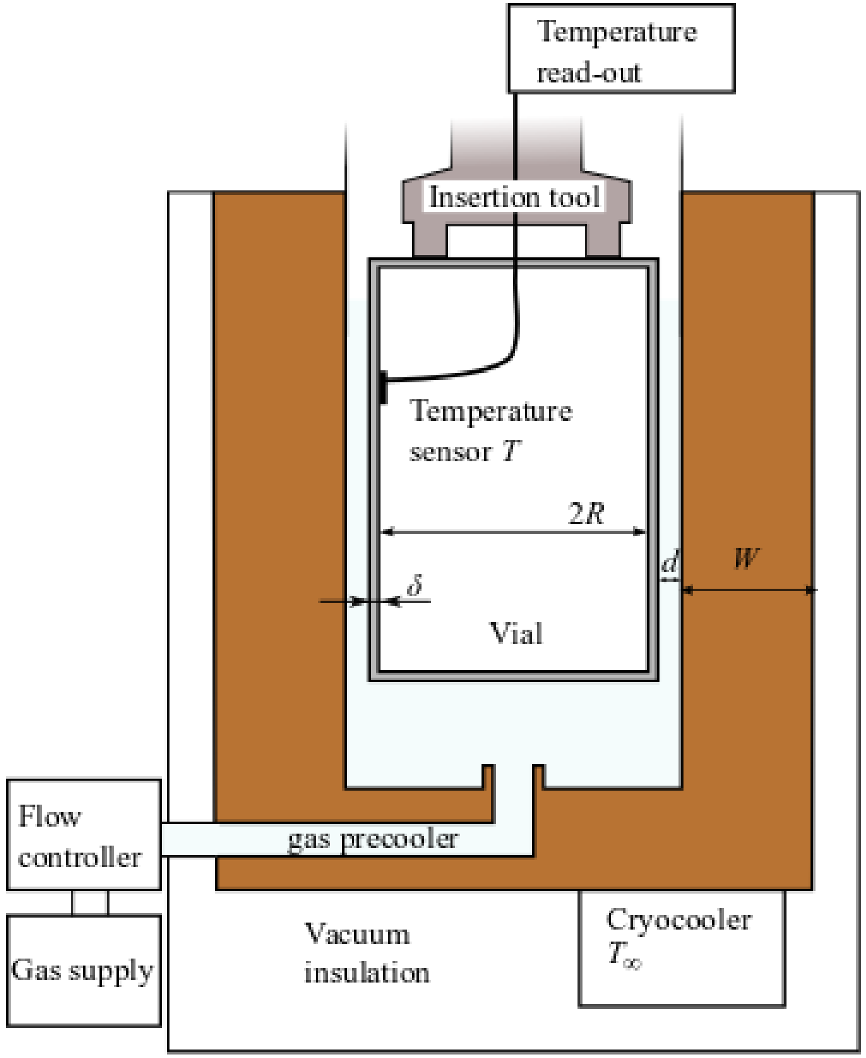
<u>Quasi-static problem!</u>

Mathematical model



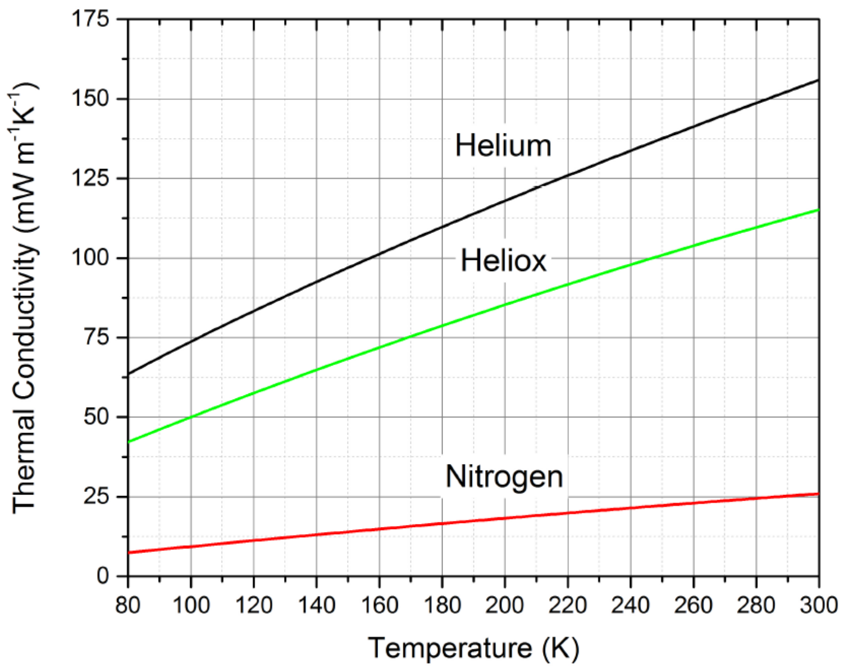
$$C(T)\partial_t T = -\epsilon \frac{\bar{k}_{\mathrm{g}}(T) A_{\mathrm{v}}}{d}(T - T_\infty)$$

Mathematical model

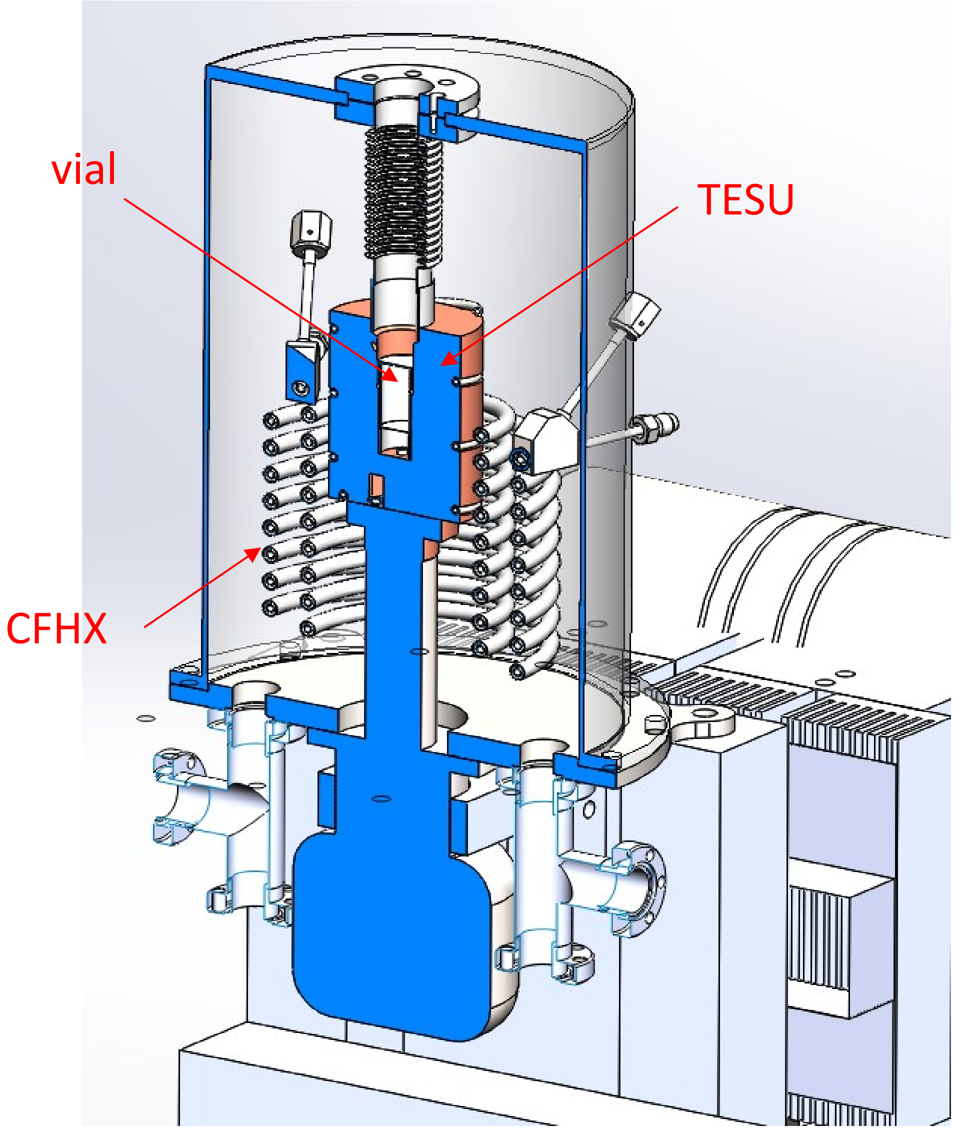


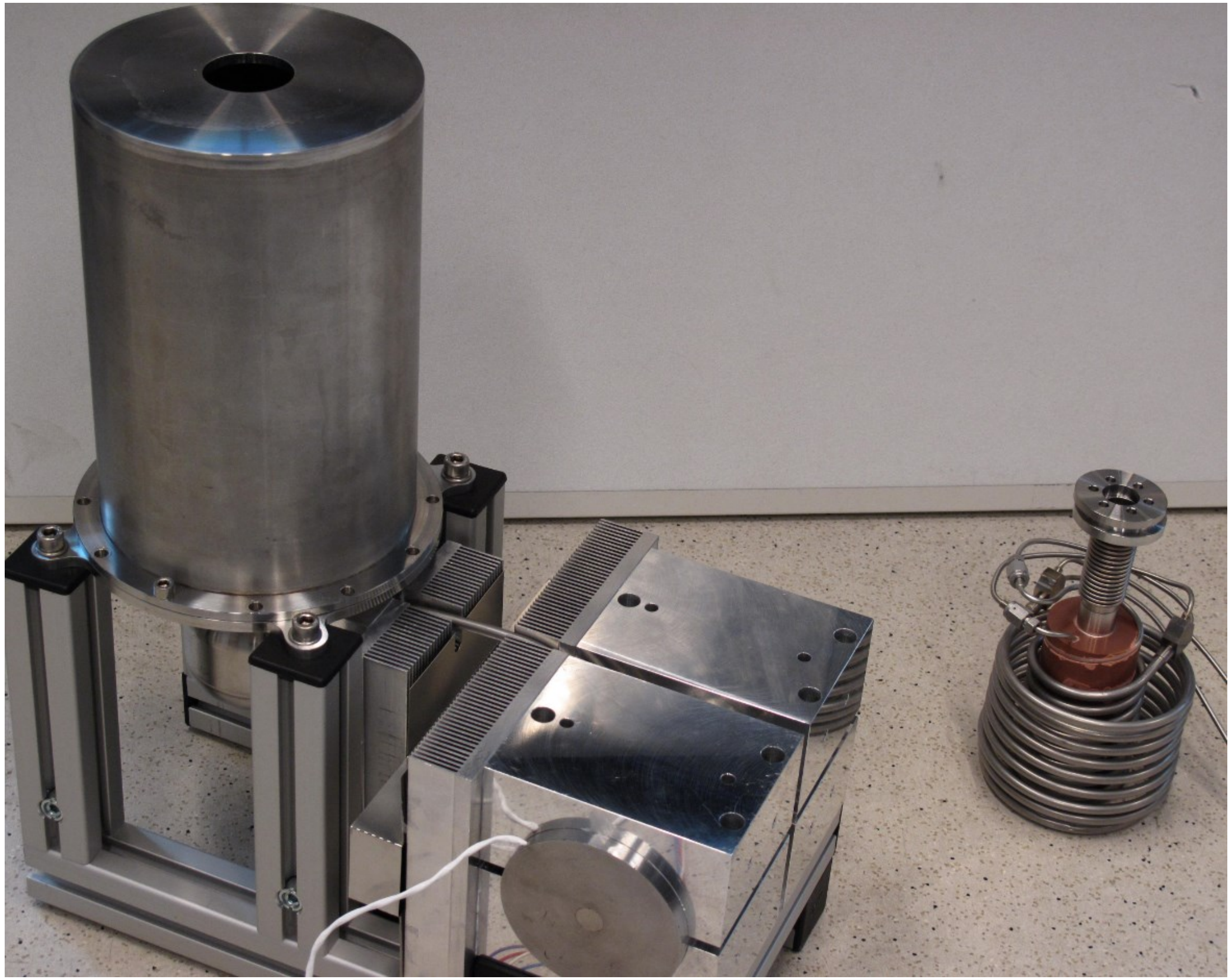
$$C(T)\partial_t T = -\epsilon \frac{\bar{k}_{\mathrm{g}}(T)A_{\mathrm{v}}}{d}(T - T_\infty)$$

$$\bar{k}_{\mathrm{g}} = 1/\Delta T \int k(T)\mathrm{d}T$$



Hardware





THALES Cryogenics

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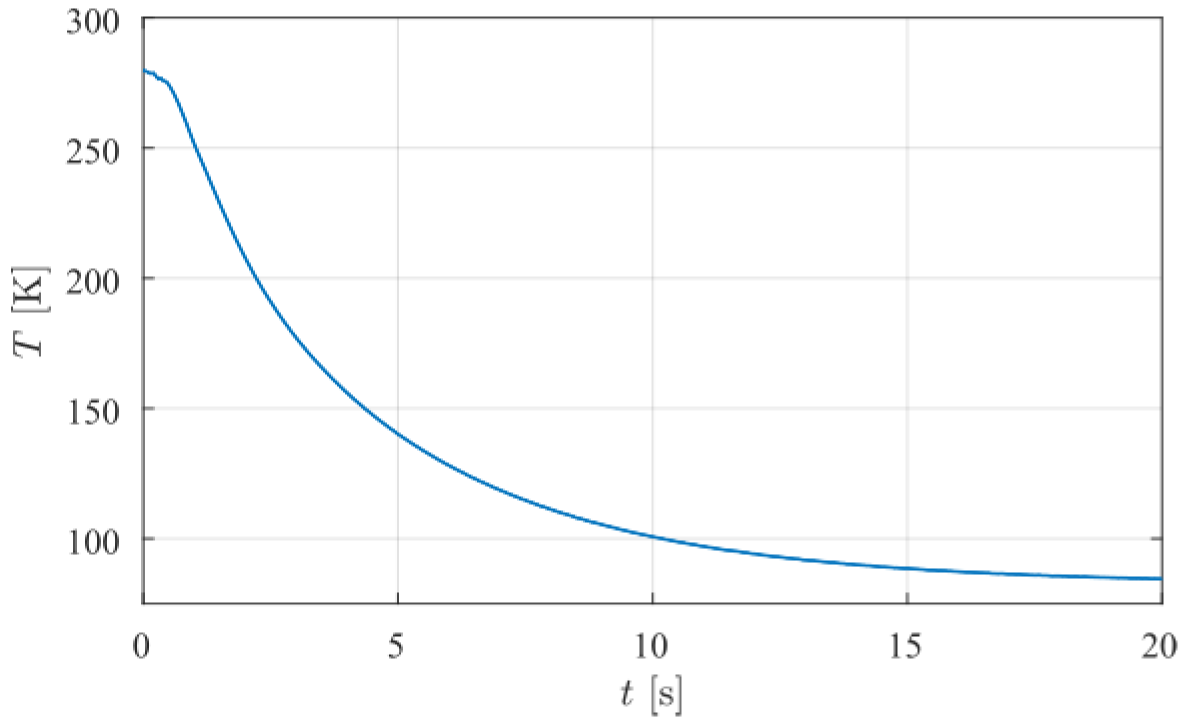
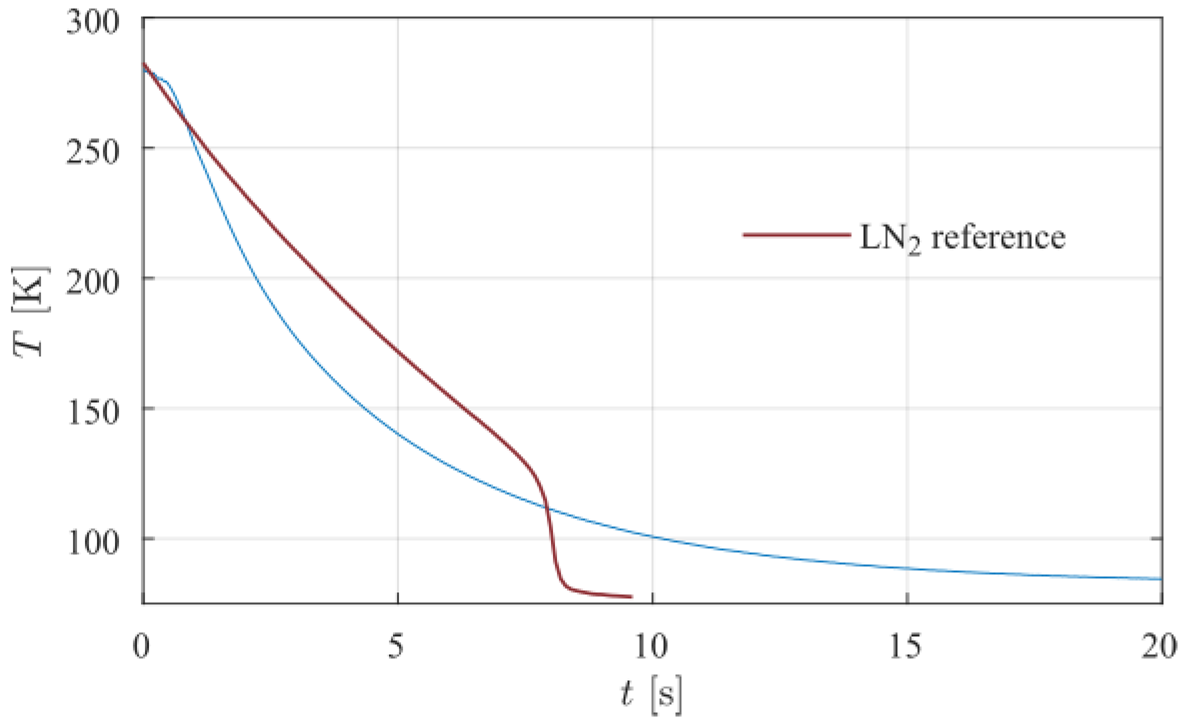
Results: no flow of contact gas



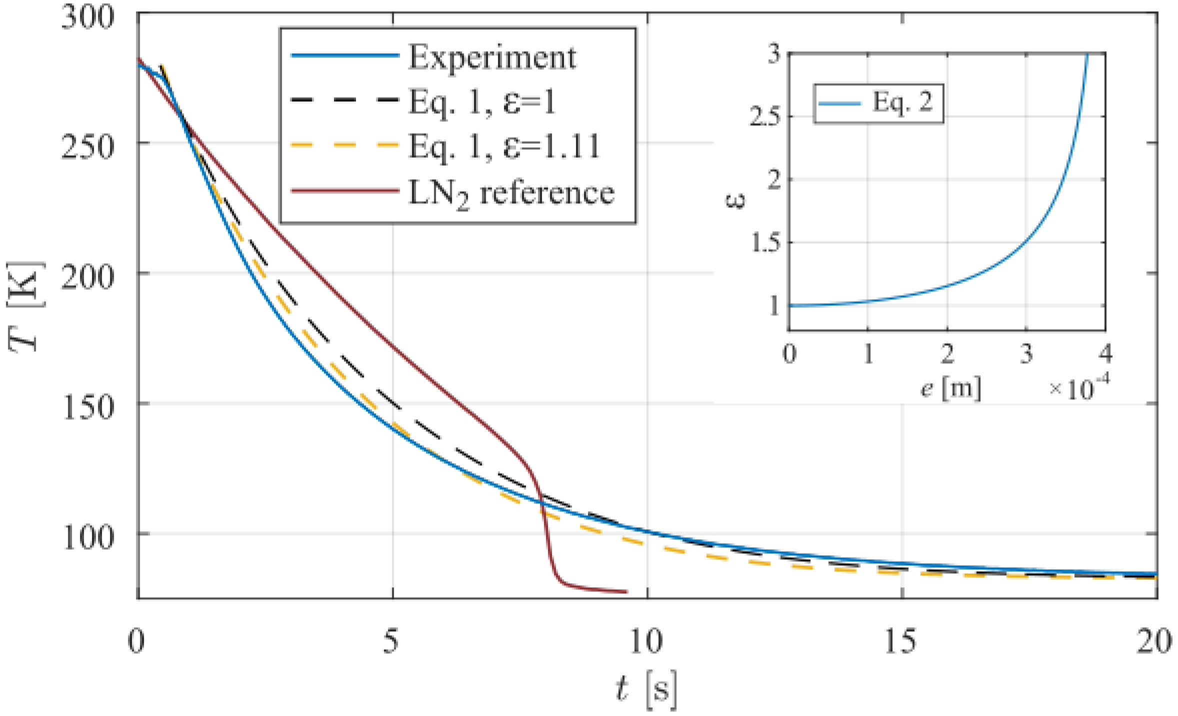
MSc thesis (2018)
Koen Ledeboer

Results: no flow of contact gas



Next presentation:
Sahil Jagga

Results: no flow of contact gas

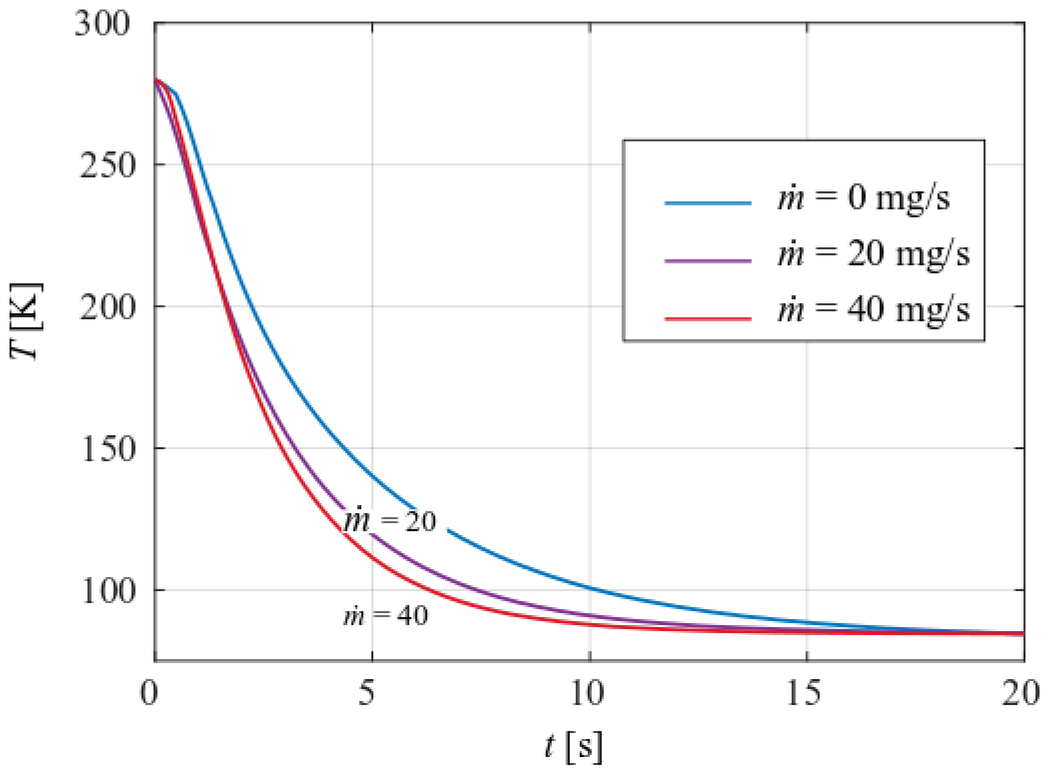


$$\epsilon = \frac{S(e)}{S(0)} = \frac{\cosh^{-1}\left(\frac{R^2+(R+d)^2}{2R(R+d)}\right)}{\cosh^{-1}\left(\frac{R^2+(R+d)^2-e^2}{2R(R+d)}\right)}$$

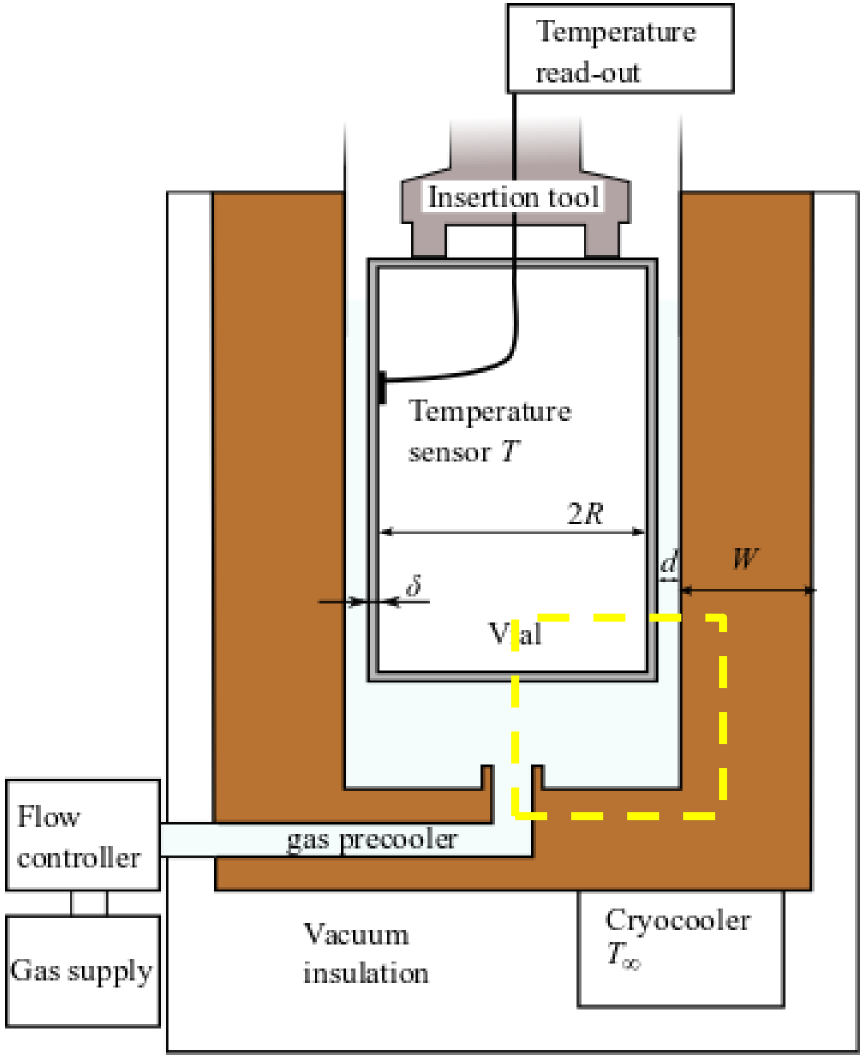
BSc thesis (2018)
Marijn Kalter

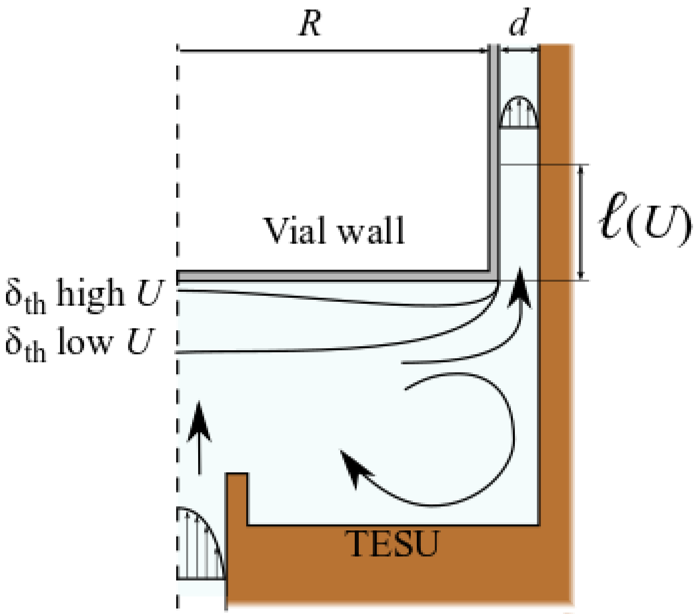
Results: Flow

Results: Flow

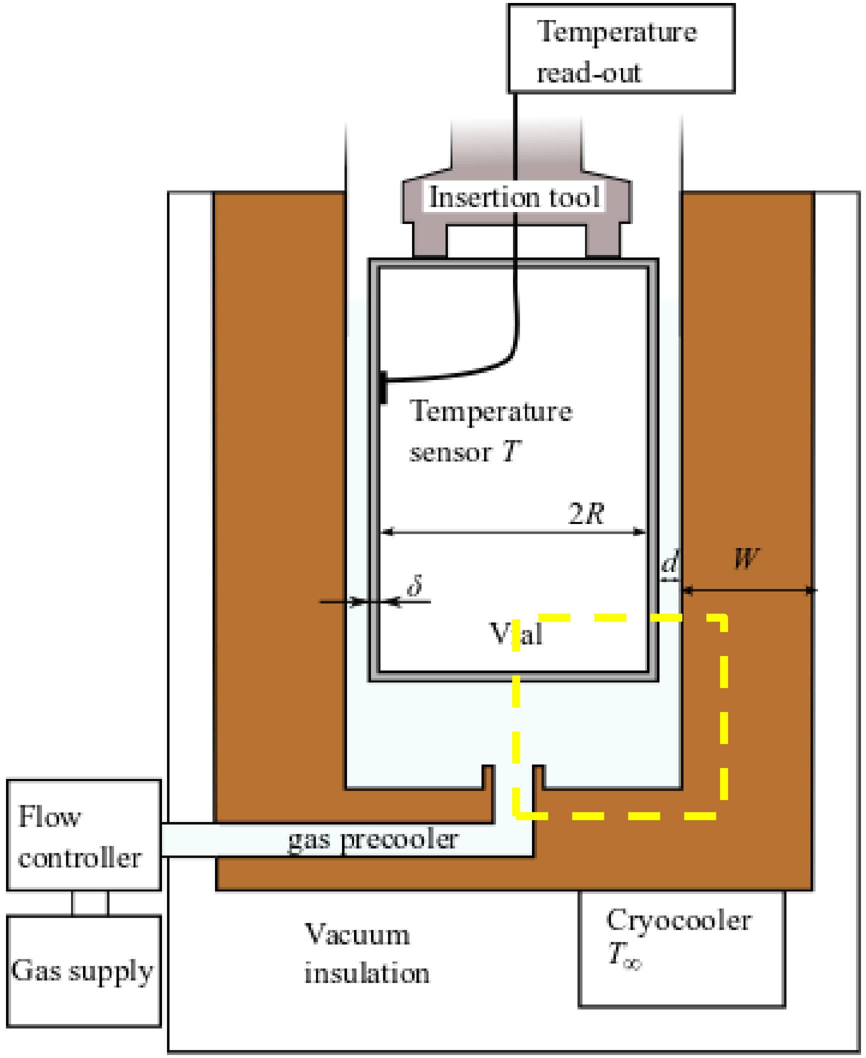


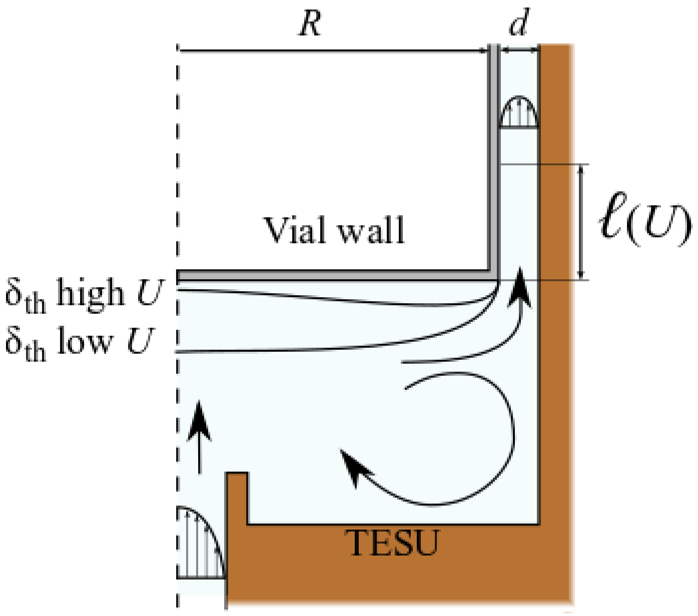
Results: Flow





Results: Flow



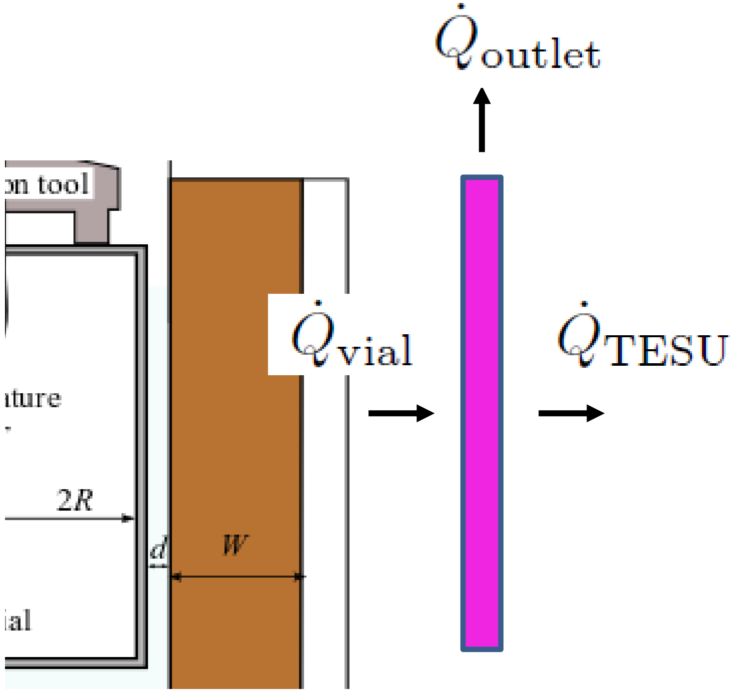


$$\ell \sim \frac{d^2 U \alpha}{2 \cdot \mathcal{N}u}$$

$$\ell \sim 1\text{mm}$$

$$\text{height of vial} = 22 \text{ mm}$$

Results: Flow

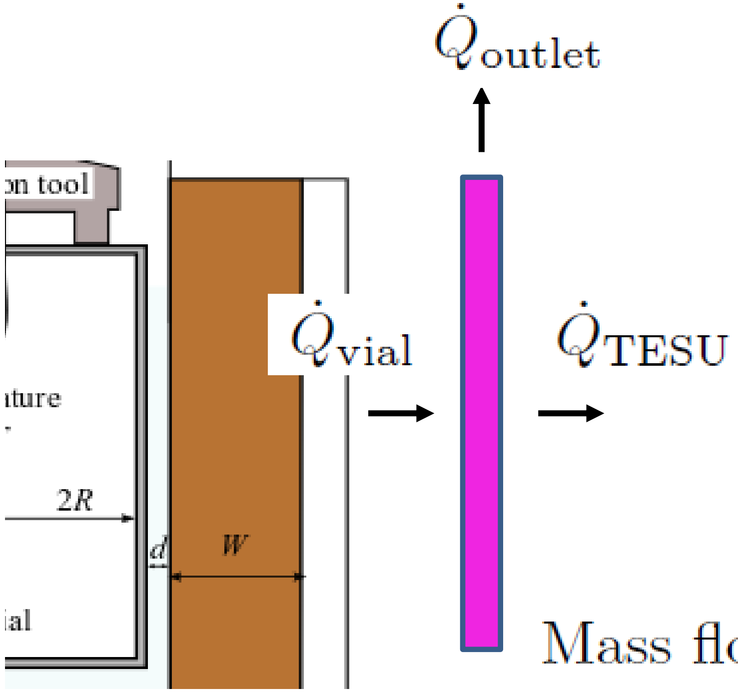


$$\nabla \cdot (\rho \vec{u}) = 0$$

$$\rho \left(\vec{u} \cdot \nabla (\rho \vec{u}) \right) = -\nabla p + \nabla \cdot \left(\mu (\nabla \vec{u} + (\nabla \vec{u})^T) - \frac{2}{3} \mu (\nabla \cdot \vec{u}) \mathbf{I} \right)$$

$$\nabla \cdot (k \nabla T) = 0,$$

Results: Flow



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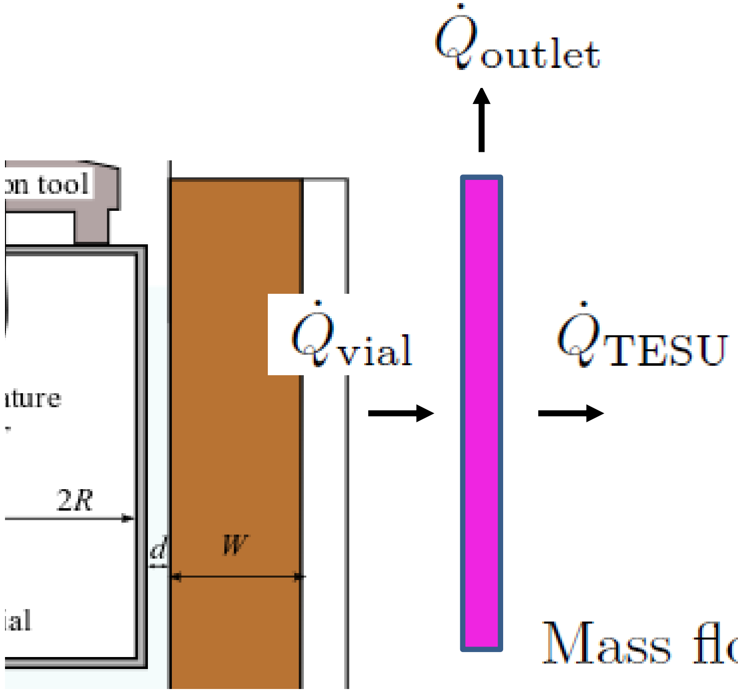
Mass flow $\dot{m}$ [$\mathrm{mg\,s^{-1}}$]	$\dot{Q}_{\text{vial}}$ [W]	$\dot{Q}_{\text{TESU}}$ [W]	$\dot{Q}_{\text{outlet}}$ [W]	$\frac{\dot{Q}_{\text{vial}}(\dot{m})}{\dot{Q}_{\text{vial}}(\dot{m}=0)}$	$\frac{\dot{Q}_{\text{outlet}}}{\dot{Q}_{\text{vial}}}$
0	-68.2	68.0	0	-	-

Results: Flow



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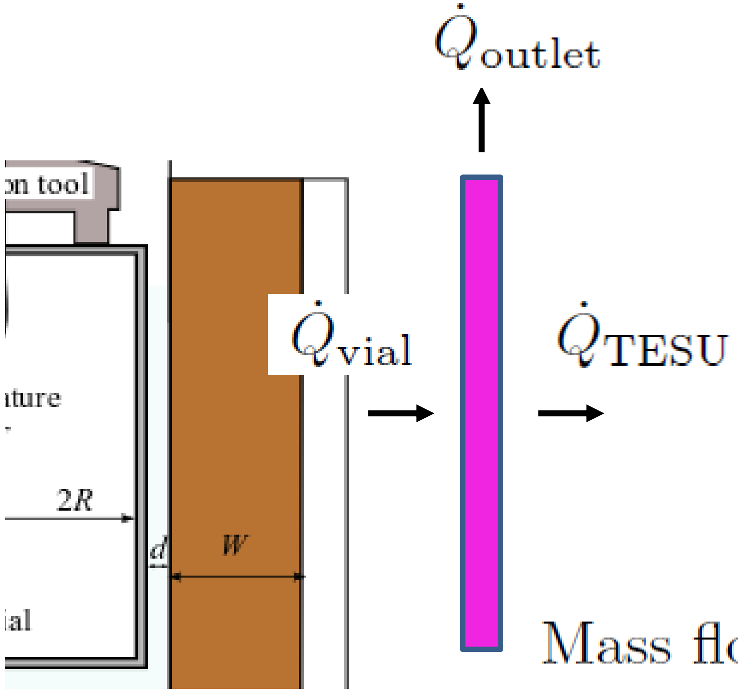
0	-68.2	68.0	0	-	-
4	-71.1	69.1	1.8	1.04	0.03
20	-80.0	70.1	9.0	1.17	0.11
40	-88.7	69.0	18.0	1.30	0.20

Results: Flow



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Mass flow $\dot{m}$ [$\mathrm{mg\,s^{-1}}$]	$\dot{Q}_{\text{vial}}$ [W]	$\dot{Q}_{\text{TESU}}$ [W]	$\dot{Q}_{\text{outlet}}$ [W]	$\Delta \dot{H}_{\text{est}}$ [W]	$\frac{\dot{Q}_{\text{vial}}(\dot{m})}{\dot{Q}_{\text{vial}}(\dot{m}=0)}$	$\frac{\dot{Q}_{\text{outlet}}}{\dot{Q}_{\text{vial}}}$
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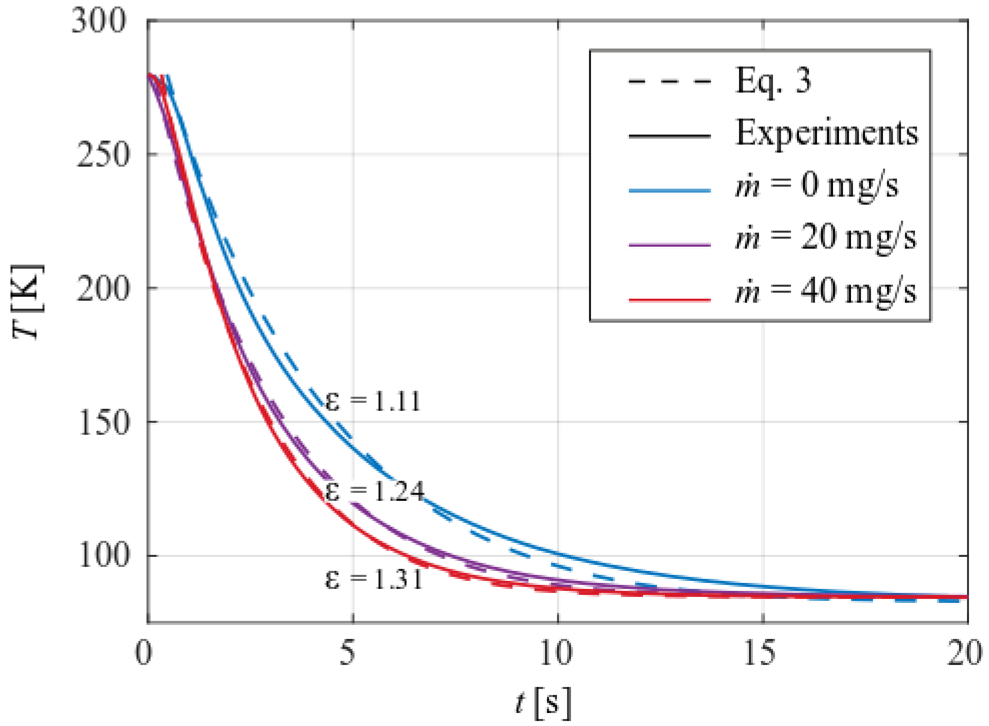
40	-88.7	69.0	18.0	20.8	1.30	0.20

Results: Flow

$$\partial_t T = -\epsilon \frac{\bar{k}_g(T) A_v}{m_v c_p(T)} \frac{T - T_\infty}{d} - \frac{1}{2} \dot{m} \bar{c}_g (T - T_\infty)$$



End remarks

Funding Acknowledgement:
CryoON- Cryogenics meets Oncology

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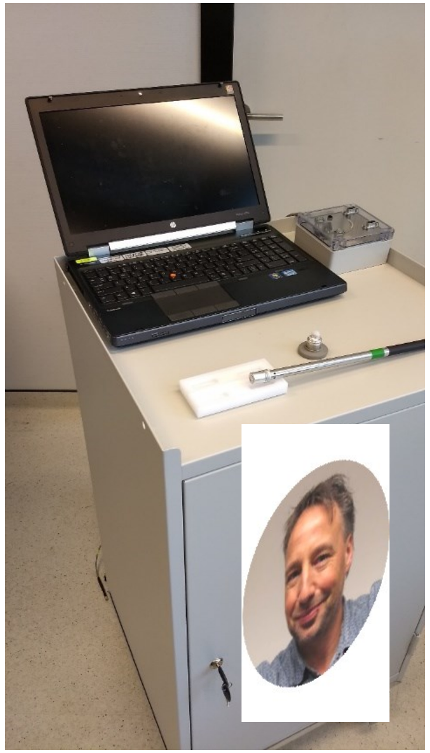

Discussion

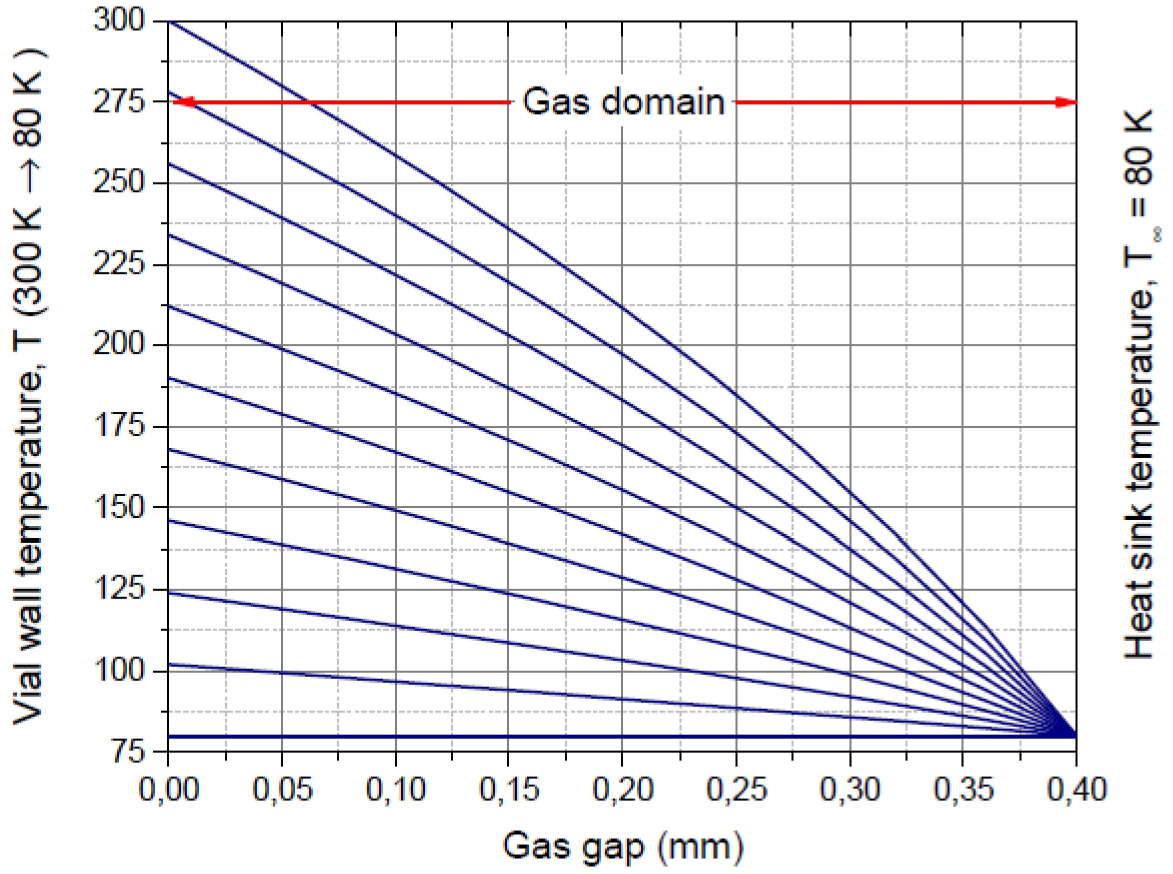

FIGURE 5.7: The calculated helium gas temperature in a gas-gap formed by two parallel plates of gap 0.4 mm with one plate fixed at 80 K and the temperature of the second plate is varied.