Capillary cooling of superconducting coils*

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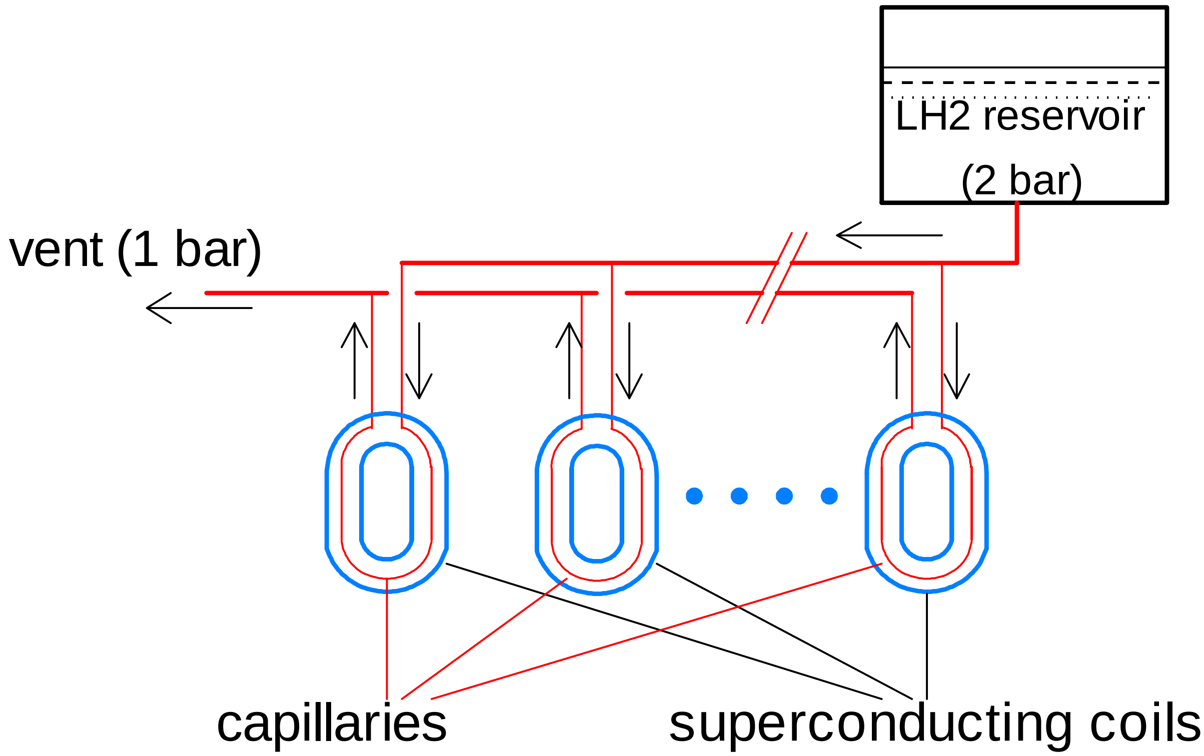
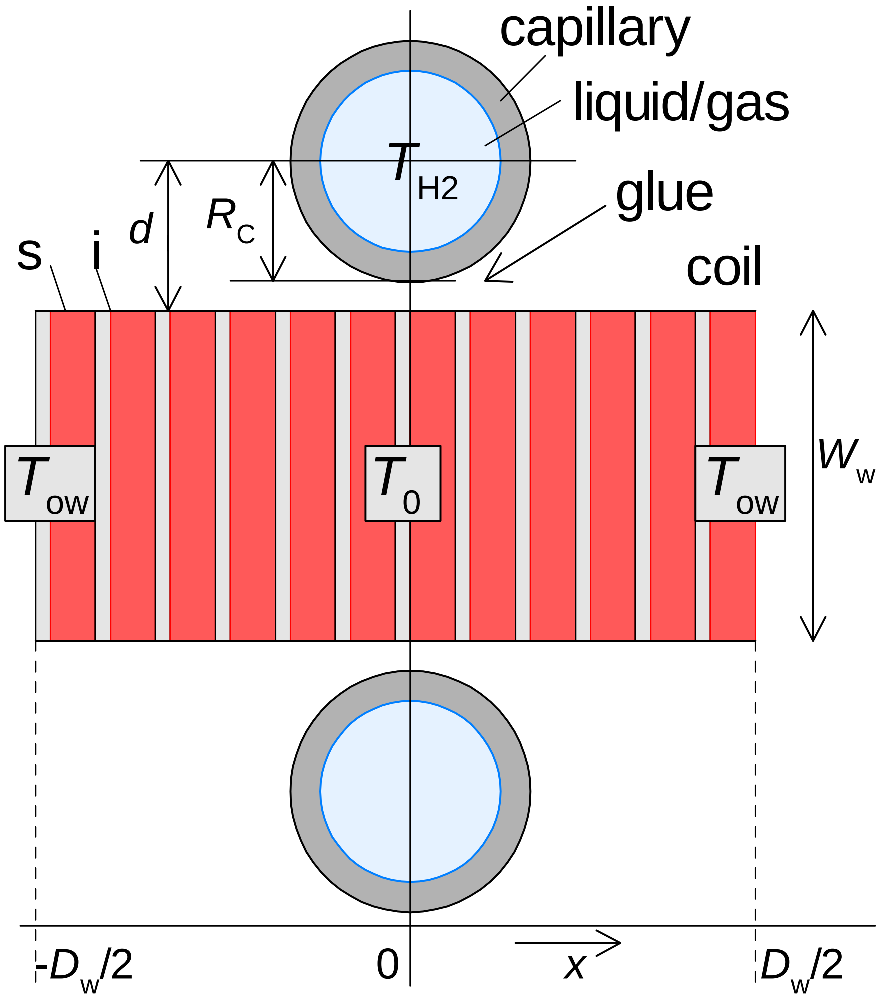
*patent pending


LH2 reservoir
(2 bar)
vent (1 bar)
capillaries
superconducting coils

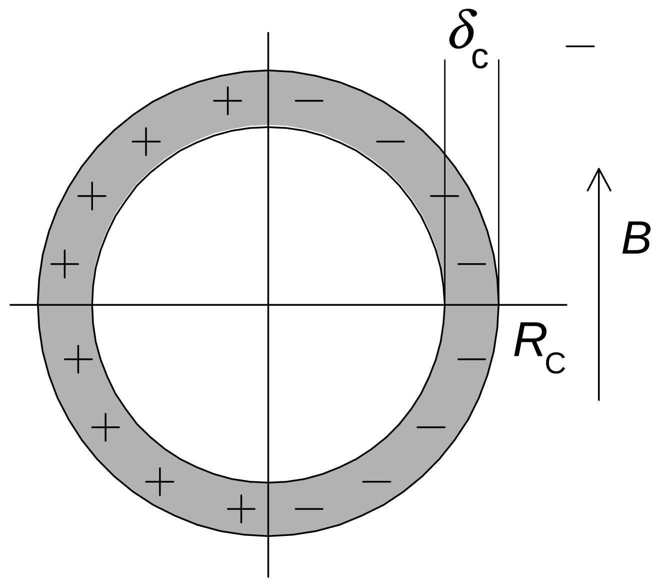
cross section of a coil with capillaries glued on top



assumed values of the various parameters.

description	**symbol**	**assumed value**
exit pressure	p_1	1 bar
capillary inner diameter	D_C	1.6 mm
capillary wall thickness	δ_c	0.2 mm
distance capillary to coil	d	1.1 mm
length one coil winding	L_w	0.5
length capillary	L_C	2×0.5 m
frequency	ν	10 Hz
field amplitude	B_0	1 T
electrical resistivity	ρ_c	34×10^{-8} Ωm
AC loss	$\dot{Q}_\mathsf{C}$	10 W
thermal cond. insulation	κ_i	0.1 W/Km
conductor/insulator ratio	$t_\mathsf{s}/t_\mathsf{i}$	5
coil thickness	D_w	10 mm
tape width	W_w	3 mm
friction factor	f_r	0.02

cross section of a capillary with AC magnetic field

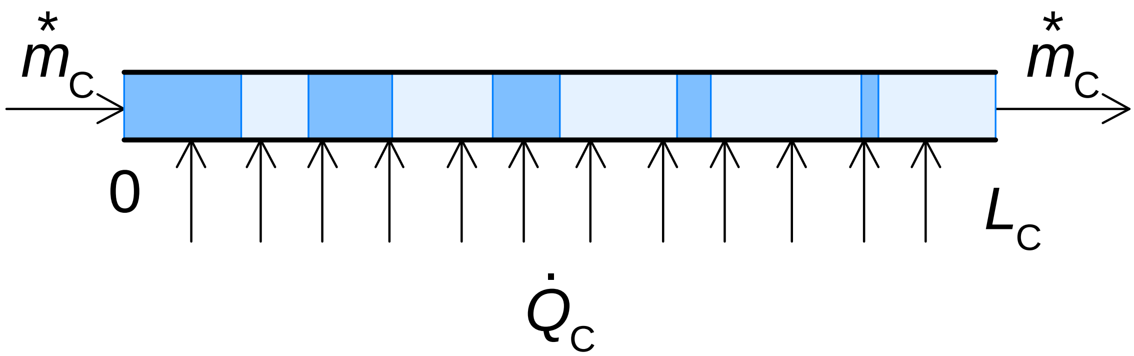


eddy-current heating

$$\dot{Q}_e = \frac{\pi\left(2\pi\nu B_0\right)^2}{2\rho_c}\delta_c R_C^3 L_C = 1.8\ \mathrm{mW}$$

flow resistance

flow per coil 1.1 liter LH2 per hour

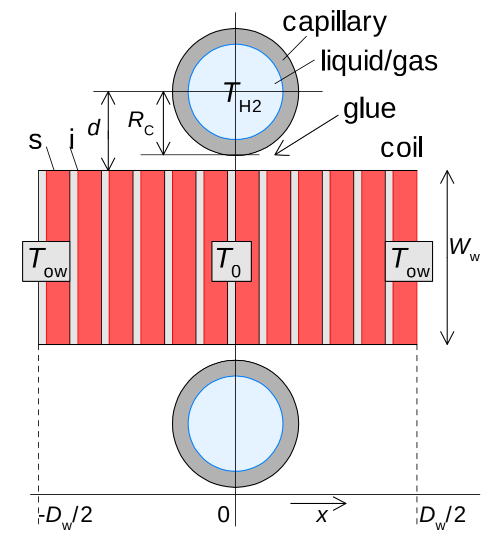


assume:

- plug flow
- constant friction factor
- pressure drop below 1 bar

pressure drop (rough estimation!)

$$p_0 - p_1 \approx \frac{0.3}{D_C^5}\left(\frac{\dot{Q}_C}{\rho_V L_1}\right)^2 L_C f_r = 160 \text{ Pa}$$



ΔT between the LH2 and the center of the coil (borrow expression from electrical capacitor)

$$\Delta T = \frac{\dot{Q}_\mathsf{c}}{2\pi\kappa_\mathsf{i} L_\mathsf{C}} \ln\left(\frac{d}{R_\mathsf{C}} + \sqrt{\left(\frac{d}{R_\mathsf{C}}\right)^2 - 1}\right) = 7 \text{ K}$$

ΔT between the center of the coil and the outer windings

$$\Delta T = \frac{t_\mathsf{i}}{t_\mathsf{i} + t_\mathsf{s}} \frac{\dot{Q}_\mathsf{c}}{\kappa_\mathsf{i} L_\mathsf{w} W_\mathsf{w}} \frac{D_\mathsf{w}}{8} = 14 \text{ K}$$

T of the outer layers $20 + 7 + 14 = 41$ K

Conclusion

- capillary cooling is a promising technique for cooling superconducting AC coils
- the thermal resistance between the outer windings of the coil and the LH2 needs attention