§28. Design Chart of High Temperature Superconducting Current Leads Cooled with Laminar Flow Gas

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General design equations[1)] derived from one dimensional energy balance equations of current leads made of high temperature superconducting (HTSC) material for the cooling by the laminar flow gas were solved to evaluate generalized characteristics such as the heat flow from the cold ends Q_c [mW/A], the geometrical dimension of the conductor D [A/m] and the pressure drop of the cooling gas $\Delta P/C_f$ [PaAsm^2/kg]. A general cooling parameter γ_{lam} was introduced to evaluate generalized characteristics for the laminar flow cooling. The parameter γ_{lam} indicates the relationship between the geometrical dimension of the conductor and cooling channel of the leads. Gas-cooled HTSC leads are assumed to be operated in the temperature range from 4.2K to 77K under the condition of the self-sustained cooling. The use of larger geometrical dimension allows further reduction of the heat flow from the cold ends, while such geometrical dimension accelerates the temperature rise of the conductor in the case of an accidental thermal runaway. Therefore, the generalized temperature rise time τ in the case of stoppage of the cooling gas was obtained by solving the time dependent heat balance equation with the consideration of the quench propagation. In this work, the maximum permissible temperature of the conductor is assumed to be 300K to prevent leads from any damage.

Generalized characteristics of HTSC leads cooled with laminar flow gas were arranged in Figure 1 by means of the generalized temperature rise time τ. The effect of the gas cooling appears explicitly in the range of $\gamma_{lam} > 1.0 \times 10^{-7}$ m^2/A^2. Symbols plotted in Figure 1 shows generalized characteristics of conduction-cooled HTSC leads. As an example, values of Q_c and l is taken to be 2.1×10^{-4} W/A and 0.20m, respectively for both HTSC leads. Figure 1 indicates values of γ_{lam} and τ are 1.0×10^{-8} m^2/A^2, 2.0×10^4 s/m^2 for gas-cooled HTSC leads, whereas value of τ for conduction cooled leads is 4.0×10^2 s/m^2. Temperature rise time of gas-cooled and conduction-cooled HTSC leads is estimated to be 800 s and 16 s, respectively. Values of τ indicate the difference of the safety sense between gas-cooled HTSC leads and conduction-cooled HTSC leads.

Various high performance gas-cooled HTSC leads can be designed simply by the use of the design chart in consideration of the thermal runaway.

Nomenclature

d	Hydraulic diameter [m]
I	Current [A]
l	Conductor length [m]
m	Mass flow rate of helium gas [kgs^{-1}]
ΔP	Pressure drop of cooling gas [Pa]
Q_c	Heat flow from cold end normalized by the current [W/A]
r	Ratio of length along channel to l
s	Cross-sectional area of conductor [m^2]
s_g	Cross-sectional area of cooling channel [m^2]
ts	temperature rise time [s]

$\gamma_{lam} = S S_g / d^2$, $S = s/I$, $S_g = s_g/I$, $D = I/S$

$G = m/s_g$, $C_f = r S G / d^2$, $\tau = ts/l^2$

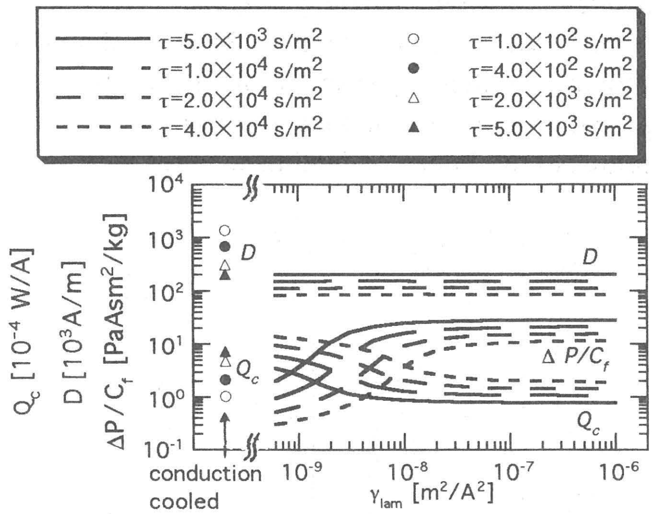

Fig.1. Design chart of HTSC leads with laminar flow gas

Reference

1) Nishioka, T. et al. : Advances in Superconductivity VII (Proceedings of the ISS'94) vol. 2, p. 1231.