Wed-Po-2.6 #79

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Effect of thermal contact between gas-cooled REBCO conductors on hot-spot temperature in fusion magnets

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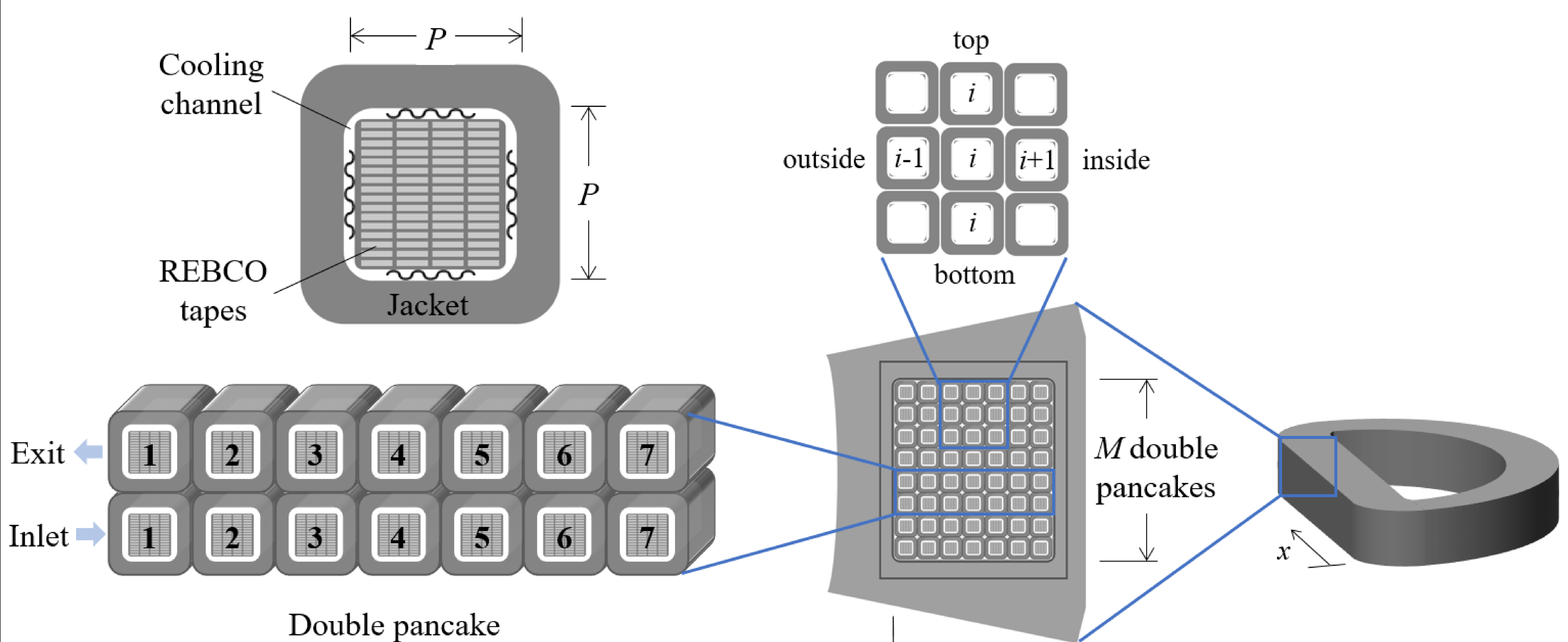
HTS MAGNETS FOR FUSION AT 20 K

- 5-year (2022-2026) Governmental Project in Korea
- Compact and Efficient High-Field (>10 T) Magnets at 20 K
- **Stacks-in-Conduit Conductors (SICC)** with REBCO Tapes
- **Forced-Flow Gas-Cooling** with Helium
- Fundamentals on Thermal Interaction between Conductors
- Recent Publication: Chang, Lee, Shin, Oh, "Improved cryogenic stability by thermal insulation between forced-flow gas-cooled REBCO conductors in fusion magnets," *Cryogenics*, 2024.

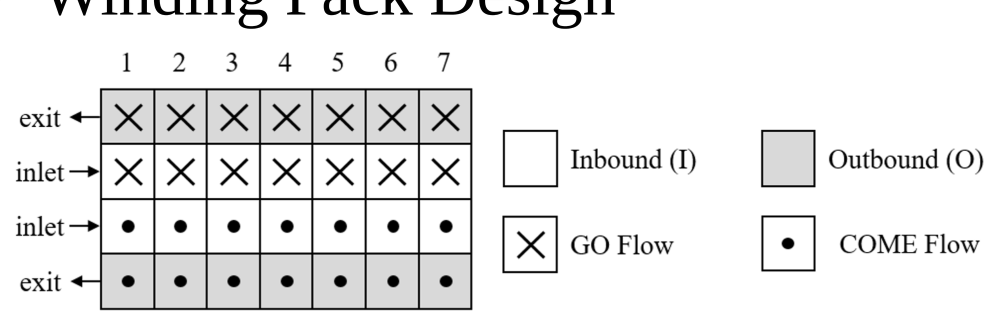
FORCED-FLOW GAS-COOLED TF MAGNET (KFE)



A Pair of Windings (Double Pancake) with Single Cooling Loop

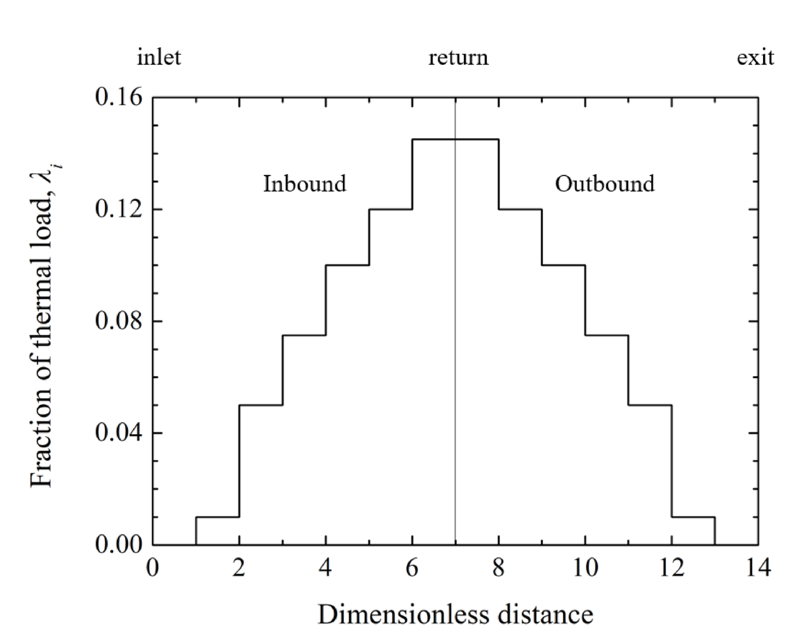
N × 2M Windings

- Winding Pack Design



Double Pancake A (Outbound) + B (Inbound)
Symmetric Array . . A + B + B + A . .
Counter Flow . . GO + GO + COME + COME . .

- Thermal Load

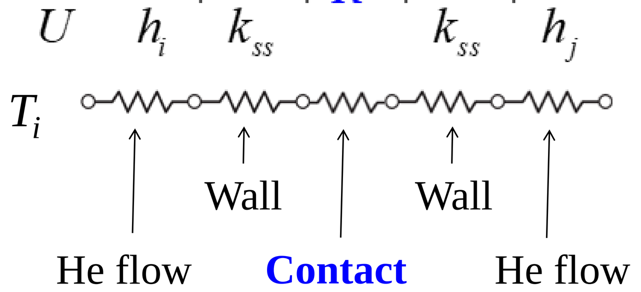


Normalized by Layer

$$\lambda_i = \frac{q_i'}{q'} \qquad \left(\sum_{i=1}^{N} \lambda_i = 1\right)$$

- Thermal Resistance Model

$$\frac{1}{U} = \frac{1}{h_i} + \frac{\delta_i}{k_{ss}} + R'' + \frac{\delta_j}{k_{ss}} + \frac{1}{h_j}$$



Approximated by Infinite Slab Model (Oh et al. *IEEE TAS*, 2023)

FORMULATION AND ANALYSIS

(Chang et al. *Cryogenics*, 2024)

- Governing Equations and Boundary Conditions

$$\dot{m}C_p \frac{dT_i}{dx} = q_i' + \sum_j UP\left(T_j - T_i\right)$$

Inbound : $T_1(0) = T_{inlet}$ $T_i(0) = T_{i-1}(L)$ $[i = 2, 3, \ldots, N]$ $[T_N(L) = T_{return}]$

outbound : $T_N(0) = T_{return}$ $T_{i-1}(0) = T_i(L)$ $[i = N, N-1, \ldots, 2]$ $[T_1(L) = T_{exit}]$

- Dimensionless Form

$$\frac{d\theta_i}{d\xi} = \lambda_i + \sum_j NTU\left(\theta_j - \theta_i\right)$$

Inbound : $\theta_1(0) = 0$ $\theta_i(0) = \theta_{i-1}(1)$ $[i = 2, 3, \ldots, N]$ $[\theta_N(0) = \theta_{return}]$

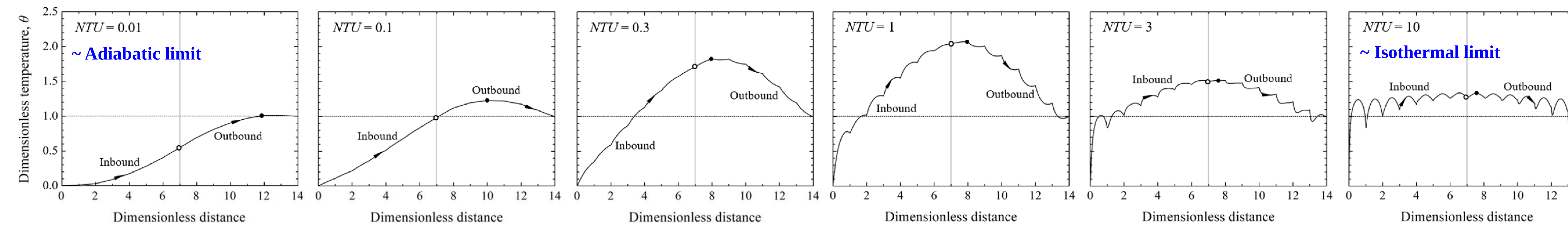
Outbound : $\theta_N(0) = \theta_{return}$ $\theta_{i-1}(0) = \theta_i(1)$ $[i = N, N-1, \ldots, 2]$ $[\theta_1(1) = 1]$

$$\xi \equiv \frac{x}{L} \qquad \theta(\xi) \equiv \frac{T(x) - T_{inlet}}{T_{exit} - T_{inlet}}$$

$$q' = \sum_{i=1}^{N} q_i' \qquad \lambda_i \equiv \frac{q_i'}{q'} \qquad NTU \equiv \frac{UPL}{\dot{m}C_p}$$

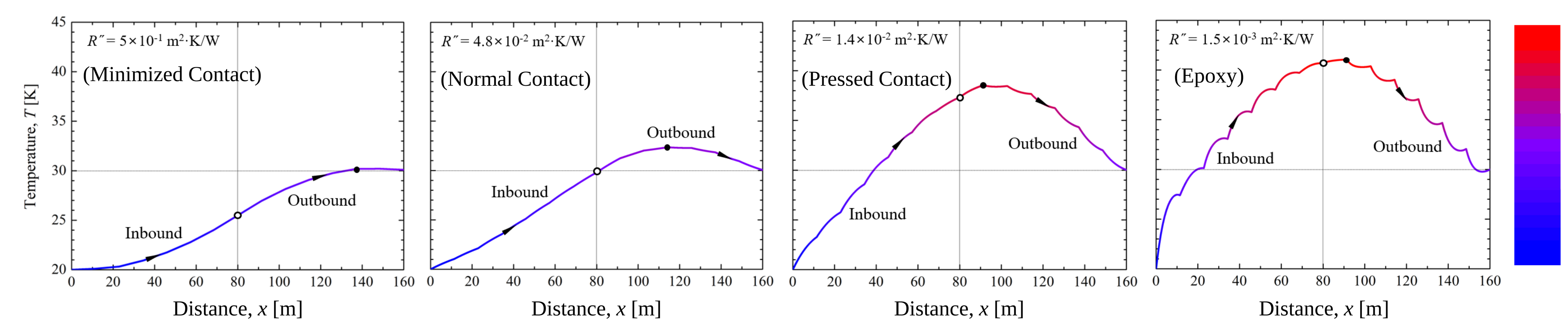
$$\dot{m}C_p\left(T_{exit} - T_{inlet}\right) = 2q'L$$

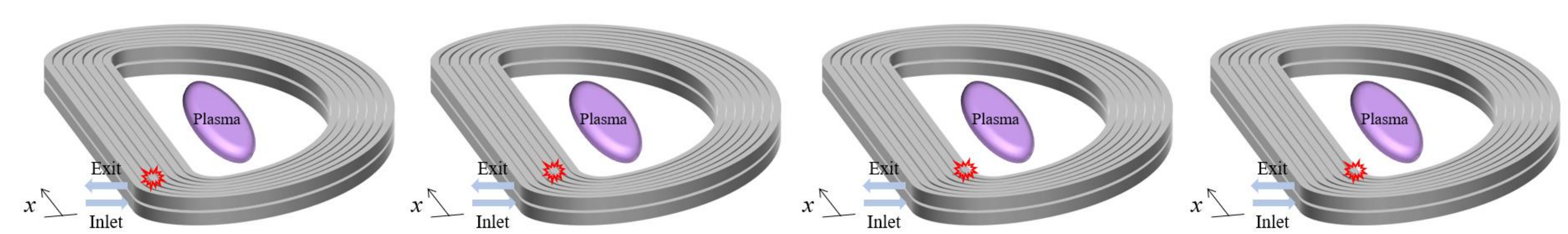
- Effect of Dimensionless *NTU* (Number of Transfer Unit)

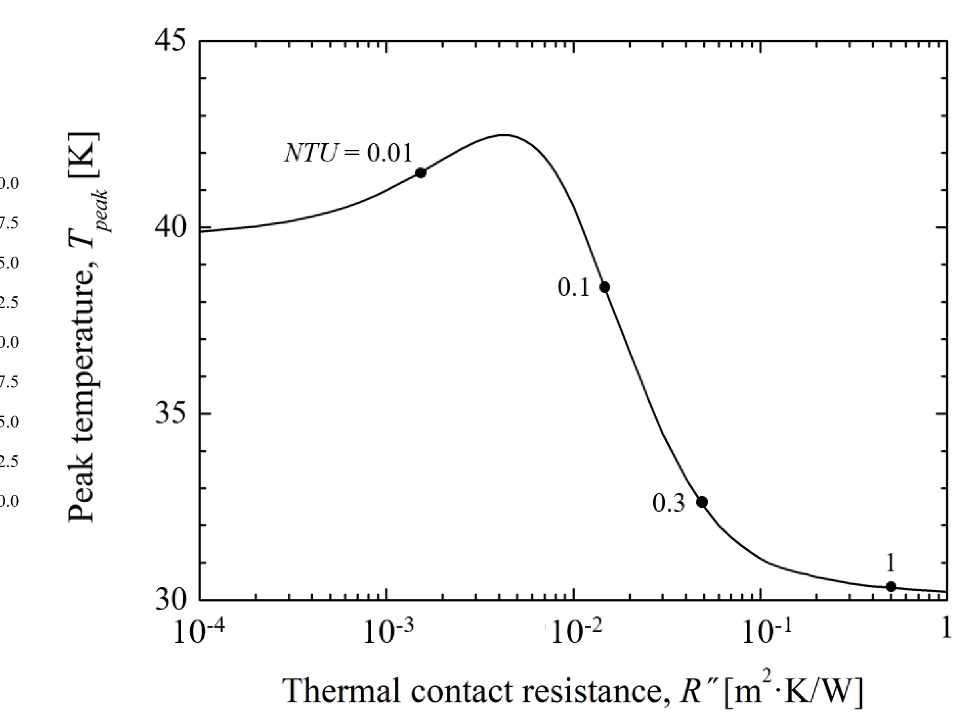


EFFECT OF THERMAL CONTACT

- Temperature Profile and Location of Internal Hot Spot (T_{inlet} = 20 K, T_{exit} = 30 K)





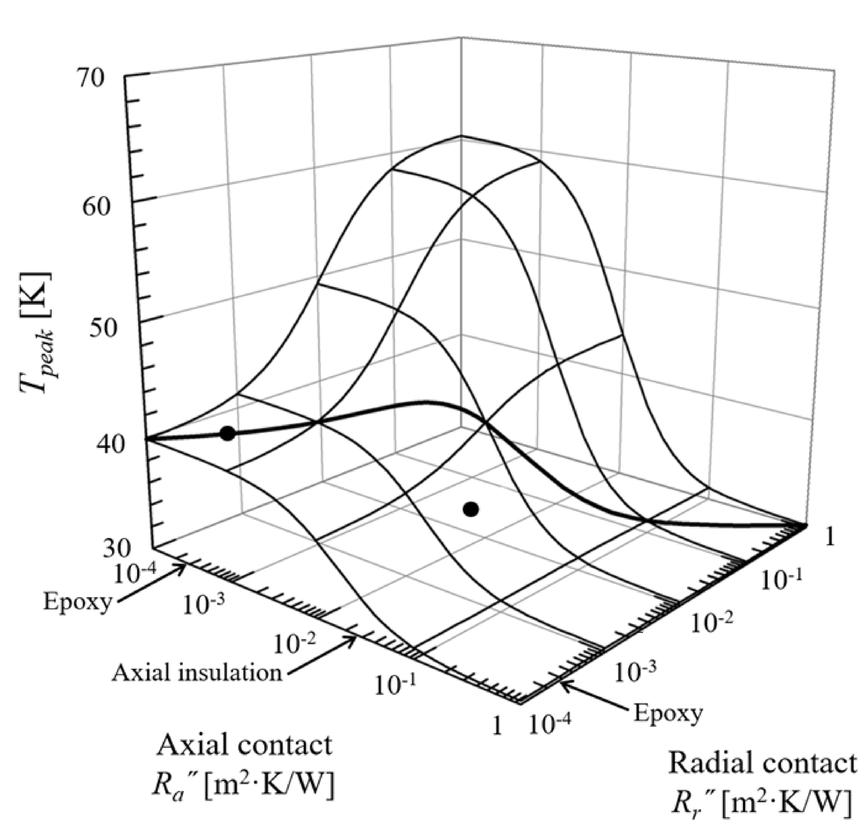


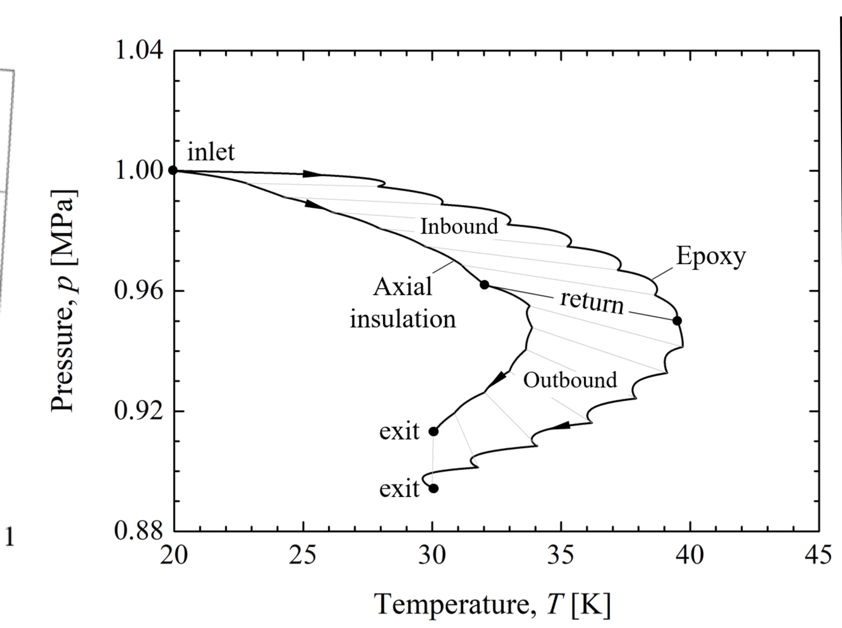
$R'' \to 0$, $T_{peak} \to 30.1$ K

$R'' \to \infty$, $T_{peak} \to 39.7$ K

T_{max} = 42.5 K

- Effect of Axial and Radial Insulation





The peak temperature and press drop can be significantly reduced by **the axial insulation.**

SUMMARY AND CONCLUSIONS

- The temperature distribution is rigorously calculated with thermal interaction between conductors.
- There exists an internal hot spot, and the thermal contact resistance affects the peak level.
- Thermal insulation in axial contact is proposed to improve the cryogenic stability.

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