Calculation of temperature profiles and pressure drop in concentric three-phase HTS power cables

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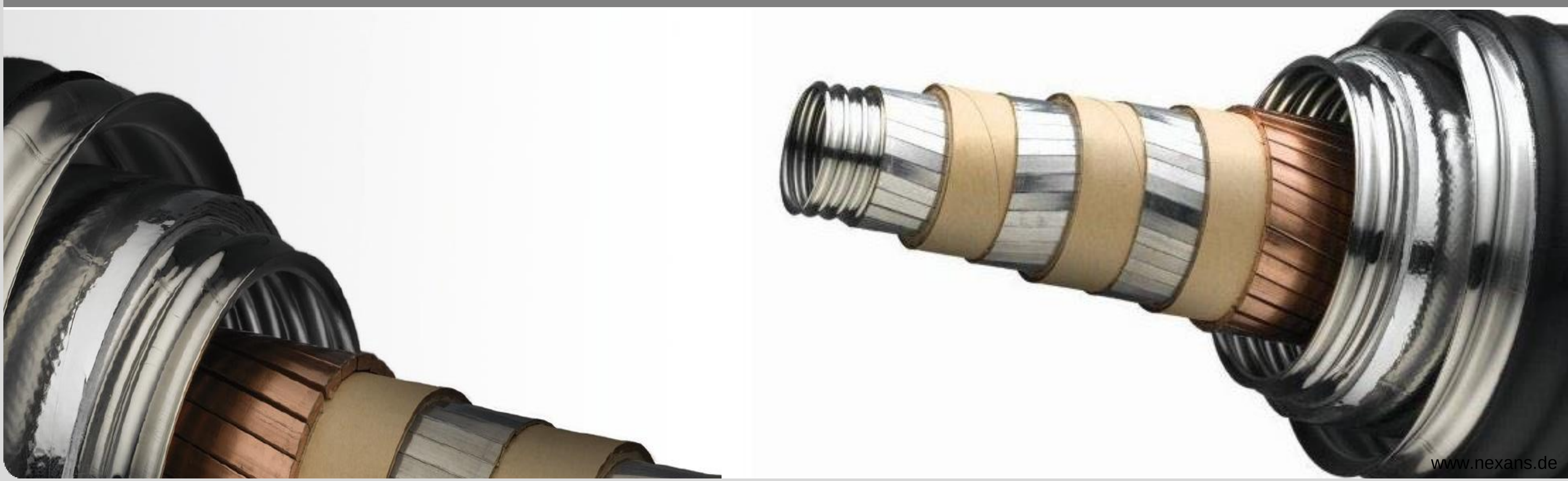
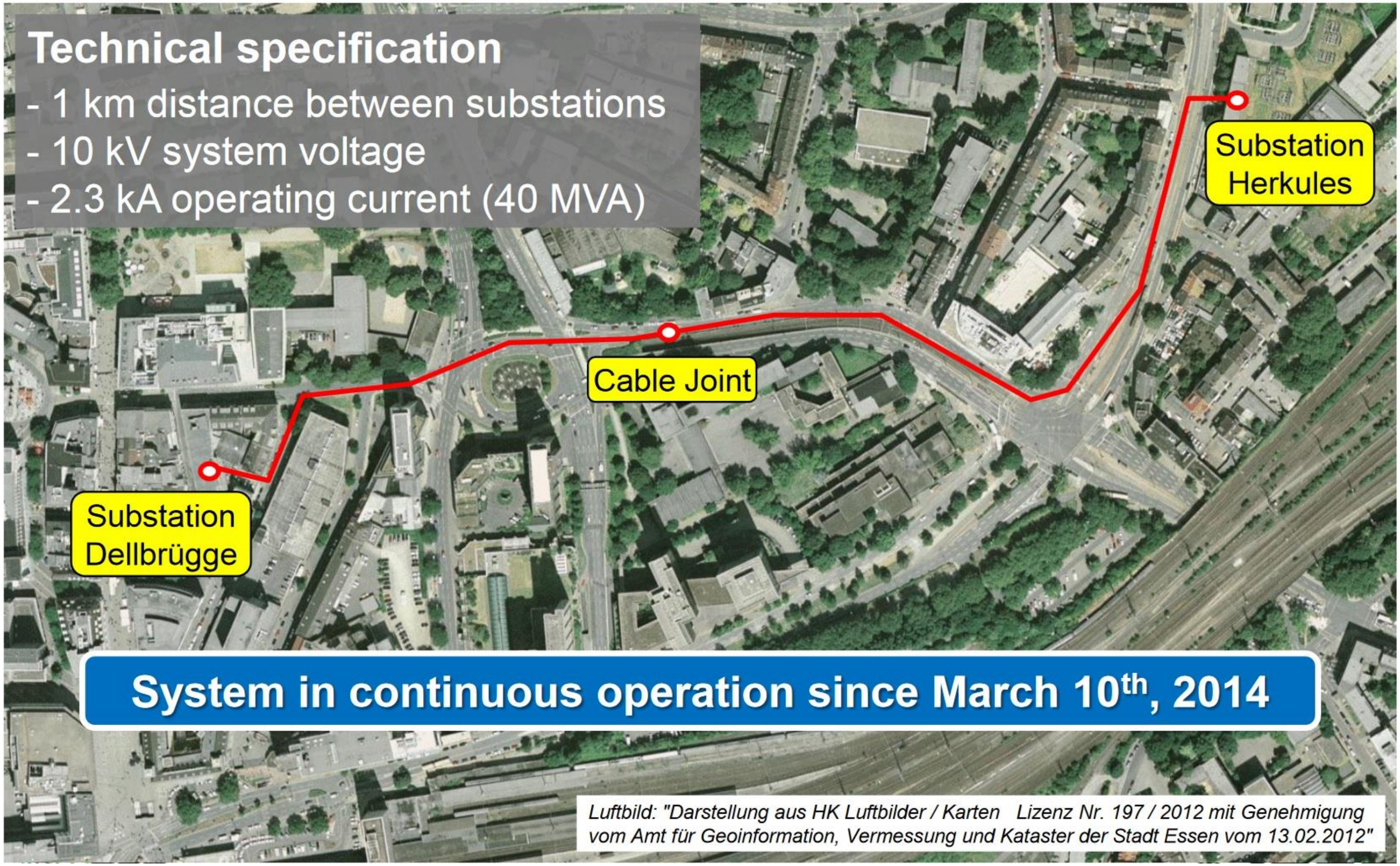
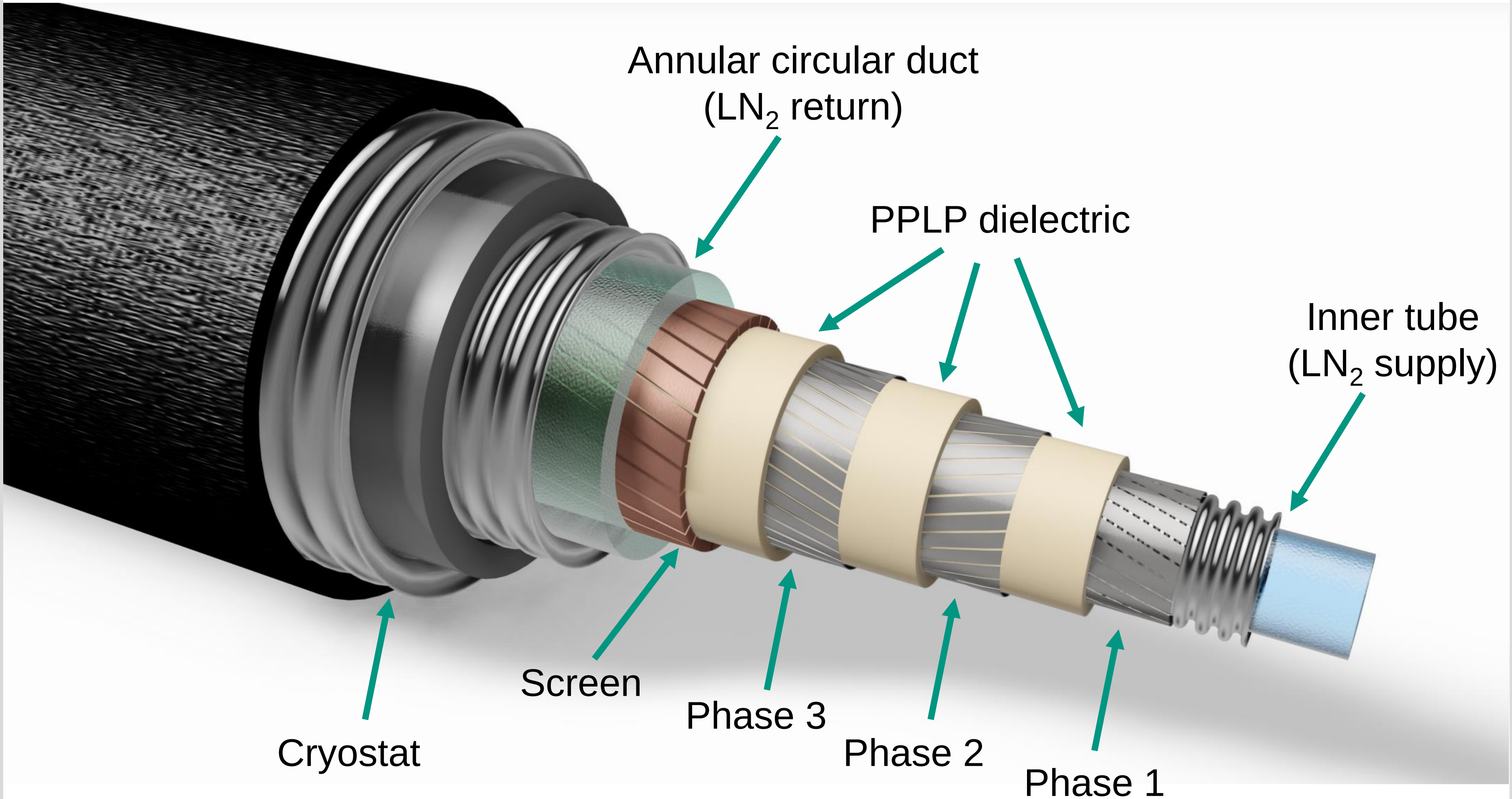


AmpaCity Project - Germany



Source: Nexans Deutschland GmbH

Cable design



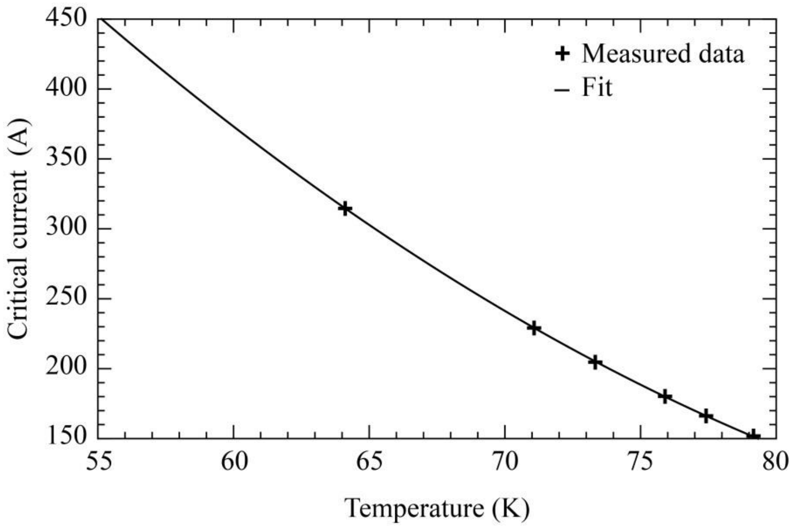
Electrical design

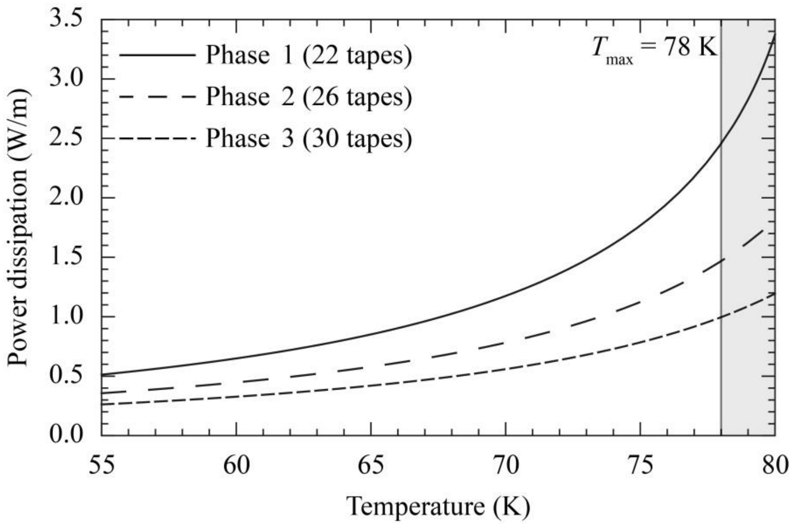
- Transmission power 40 MVA at an electric potential of 10 kV
- BISCCO Tapes (Bi 2223)
  - $I_C(T = 78\text{ K}) = 163\text{ A}$
  - Power dissipation @ 78 K
    - Phase 1 (22 tapes) = 2.5 W/m
    - Phase 2 (26 tapes) = 1.5 W/m
    - Phase 3 (30 tapes) = 1.0 W/m

$$P_{AC}(T) = P_{AC,tape}(T) \cdot N_{tape} \cdot f_N$$

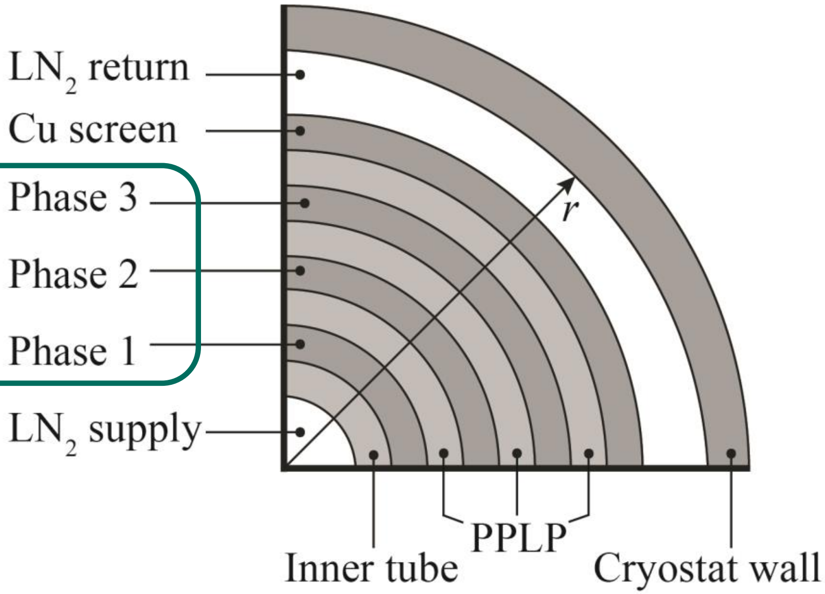
Elliptic Norris Equation

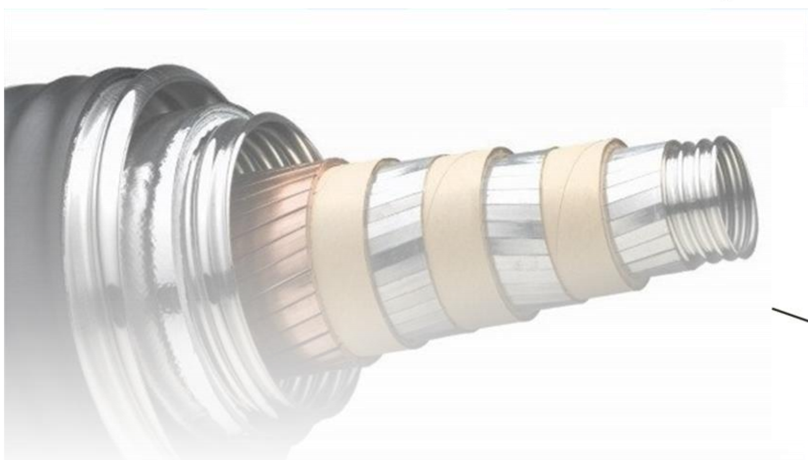
Source: Norris WT. Calculation of hysteresis losses in hard superconductors carrying ac: isolated conductors and edges of thin sheets. J Phys D:Appl Phys 1970;3 (4):489. http://dx.doi.org/10.1088/0022-3727/3/4/308.





Thermal design – Radial heat conduction

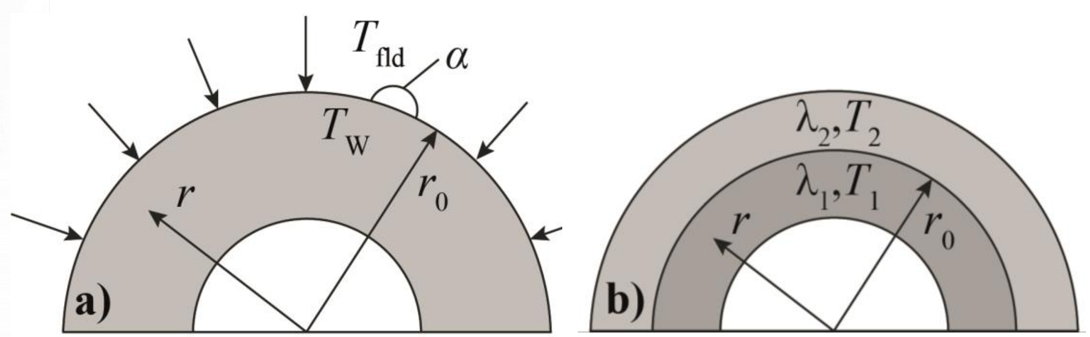




- Steady state heat equation in cylindrical coordinates

$$\frac{d^2T}{dr^2} + \frac{1}{r} \cdot \frac{dT}{dr} + \frac{P_{AC}(T)}{\lambda \cdot A} = 0$$

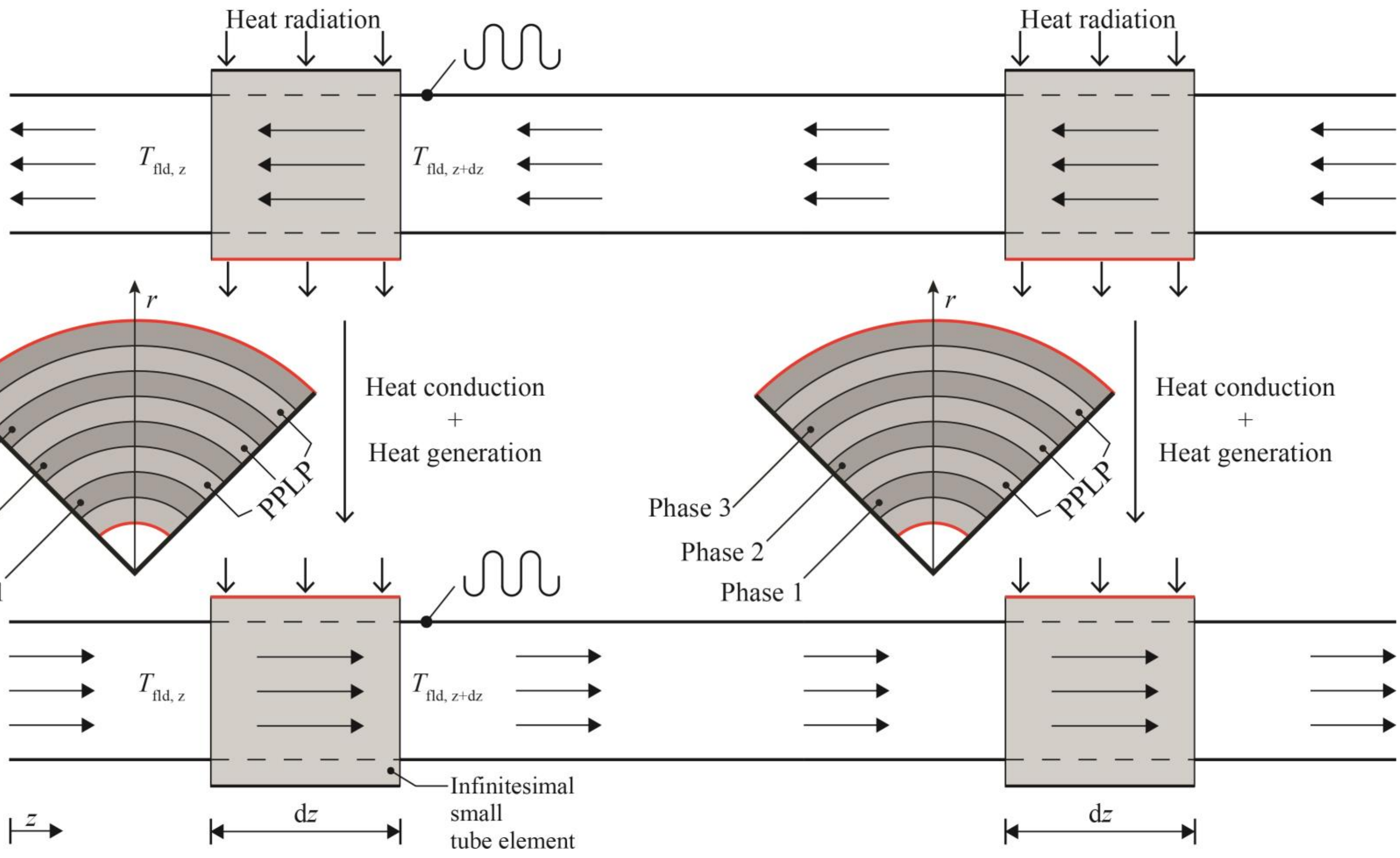
- 8 Differential equations
- 16 Boundary Conditions
  - a) Convection BC → $T_{fld}(z)$
  - b) Interface BC



Thermal design – Fluid flow energy balance

Annular circular duct

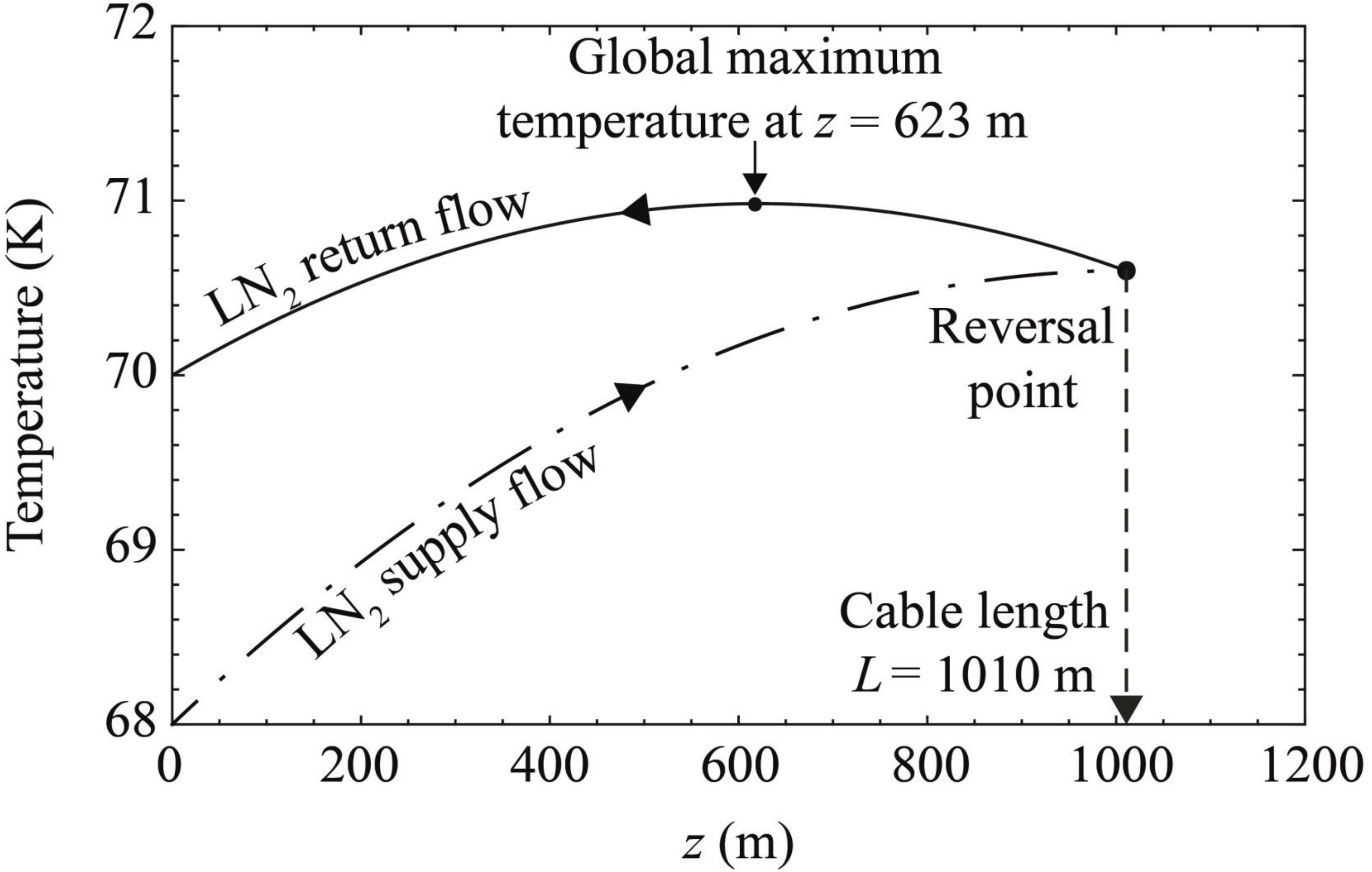
Inner tube



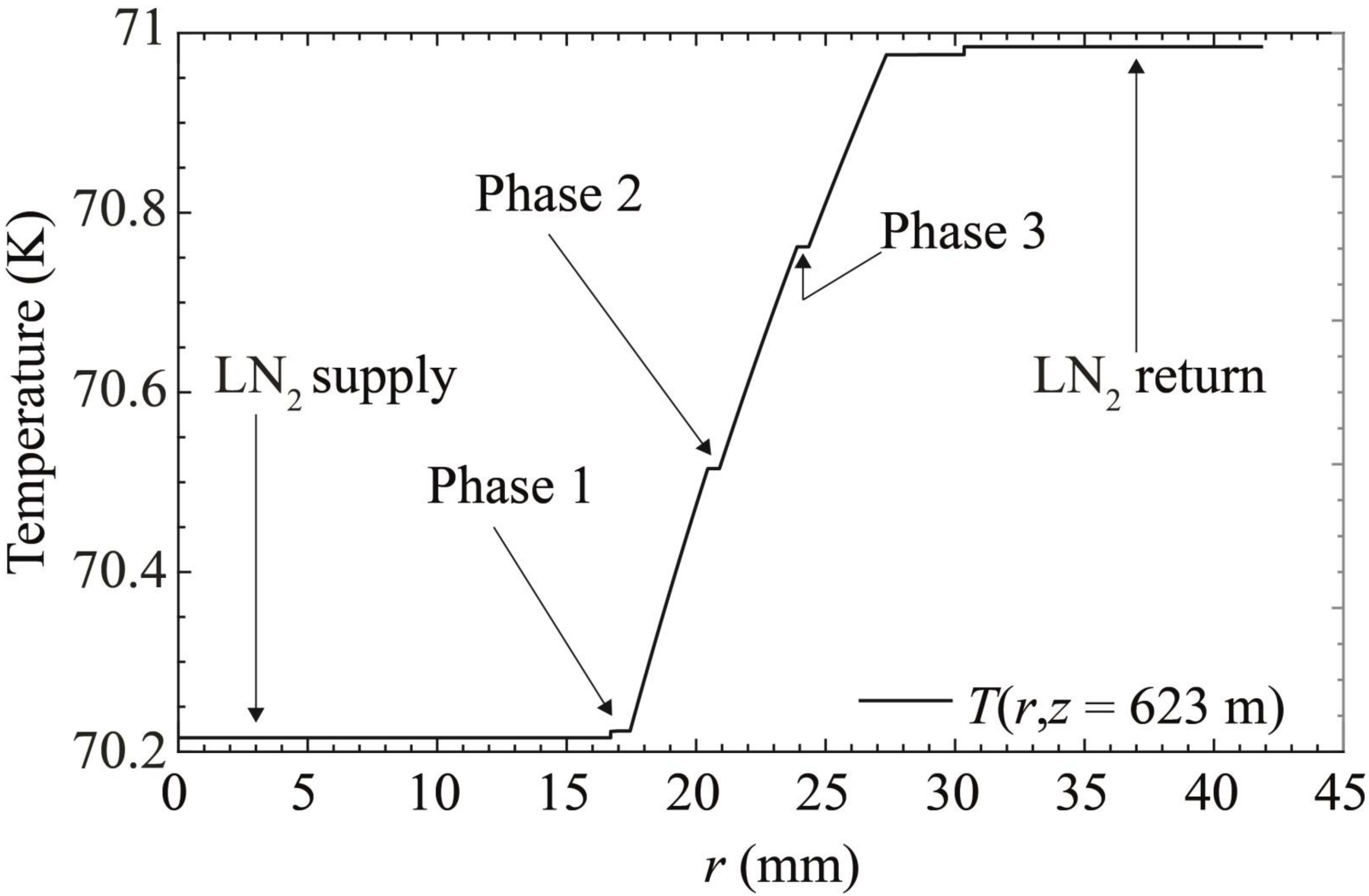
Model verification

	AmpaCity - Project	Model
Inlet temperature (K)	68	68
Outlet temperature (K)	70	70
Mass flow (kg/s)	0.425	0.425
Inlet pressure (bar)	8.4	8.4
Heat radiation (W/m)	1.7	1.7
Nominal current (A)	200	200
Outlet pressure (bar)	6.4	6.6
Cable length (m)	1000	1010

Model verification – Axial temperature profile



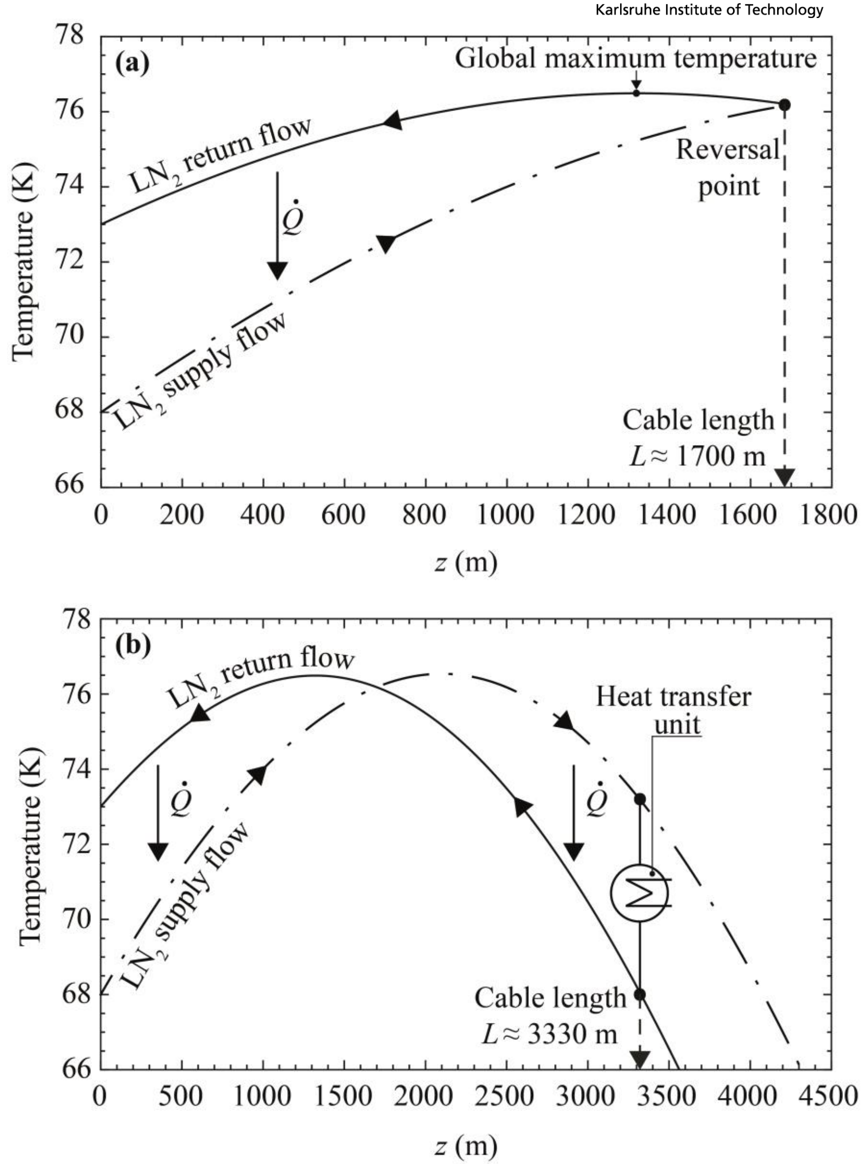
Model verification – Radial temperature profile



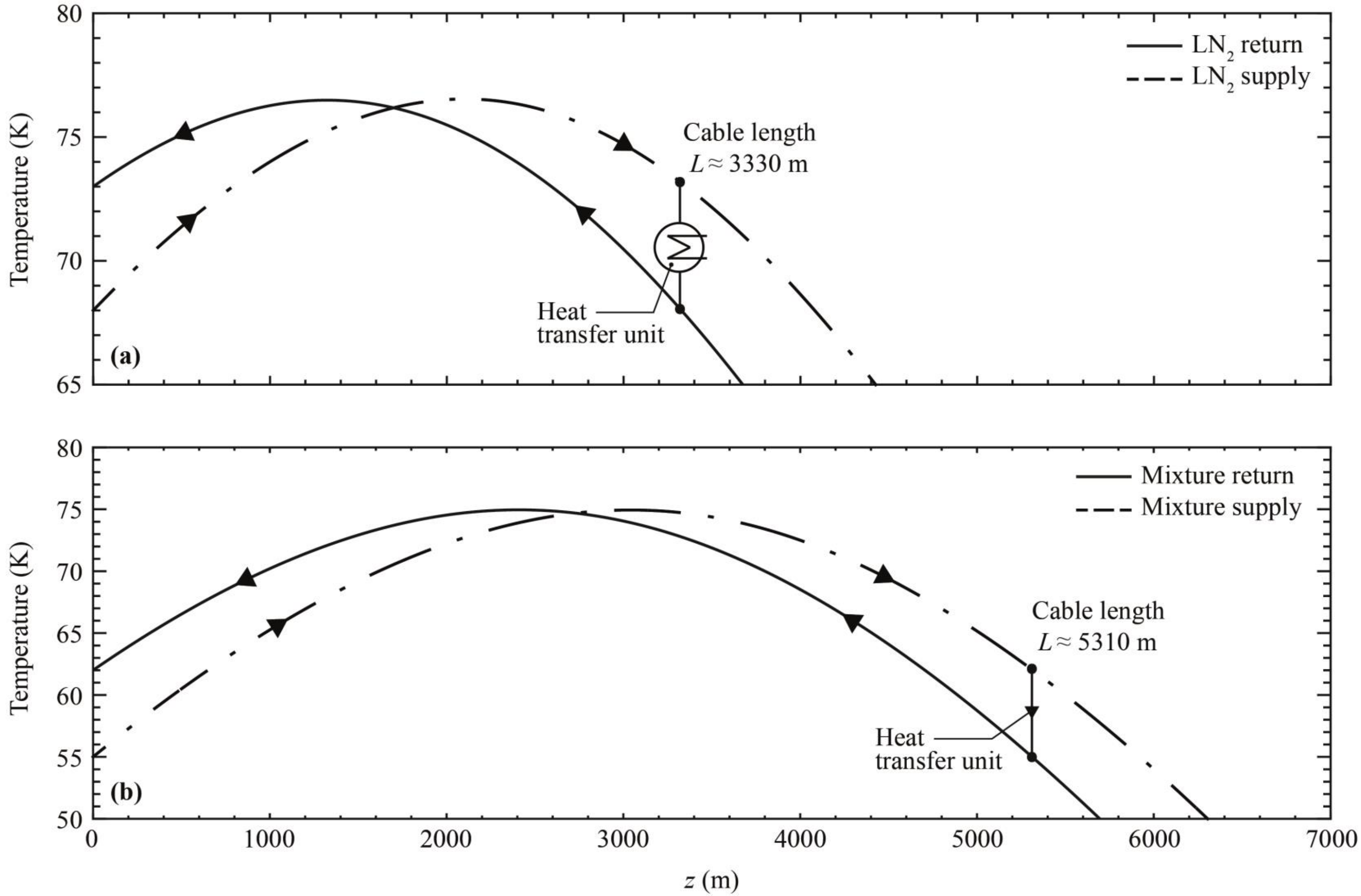
Cable operating range

- Longer cable and a higher nominal current are possible by increasing the mass flow of the coolant

	Model
Nominal current	2150 A
Mass flow	0.85 kg/s
Cable length	1700 m
Pressure drop	10.6 bar
Additional cooling unit	
Cable length	3330 m

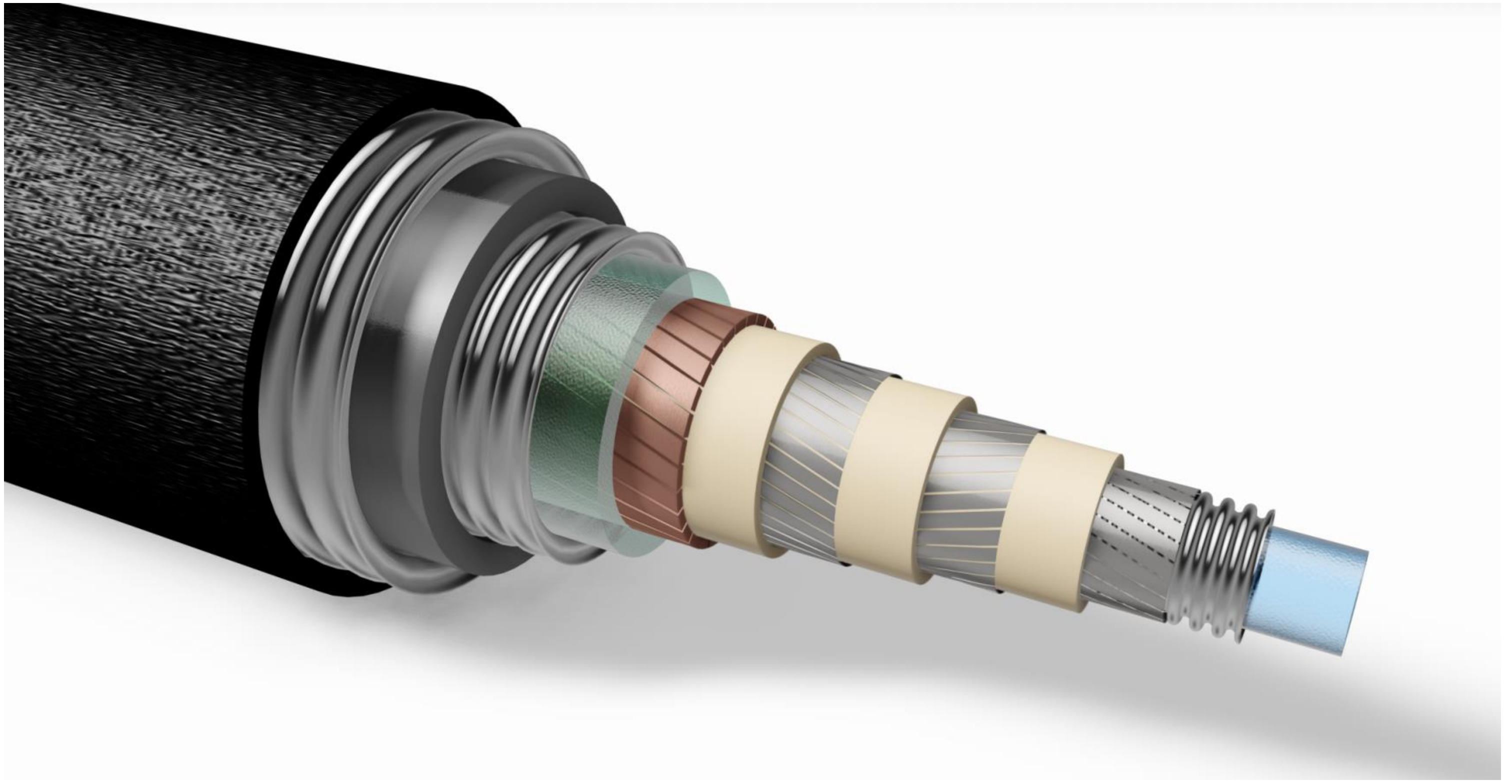


Mixed refrigerant cooling



Outlook

- Calculation of transient temperature profiles during a short circuit current in superconducting cables



Thank you for your attention