Karlsruhe Institute of Technology

Karlsruhe Institute of Technology
Institute for Technical Physics

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Design Comparisons of Concentric Three-Phase HTS Cables

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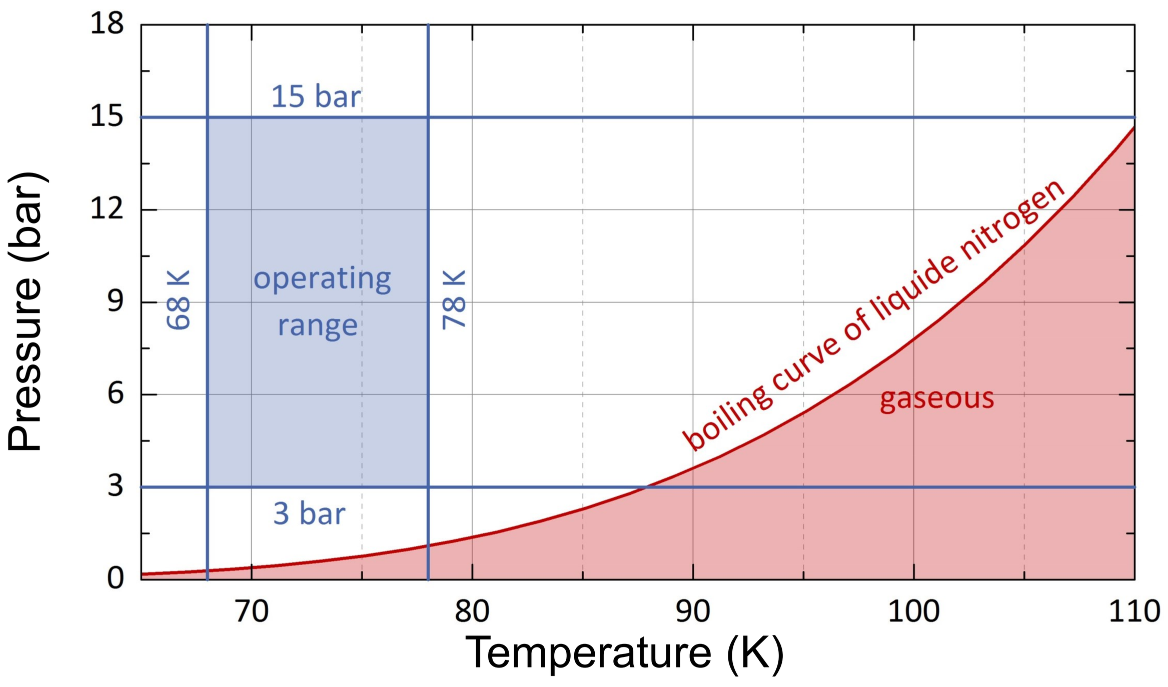
1. Design Requirements

The aim of this study is to compare different cooling concepts. This will be realized in dependency of different cable dimensions and mass flows of the liquid nitrogen. Within a defined operating range the most compact cable dimensions will be identified.

Cable design requirements

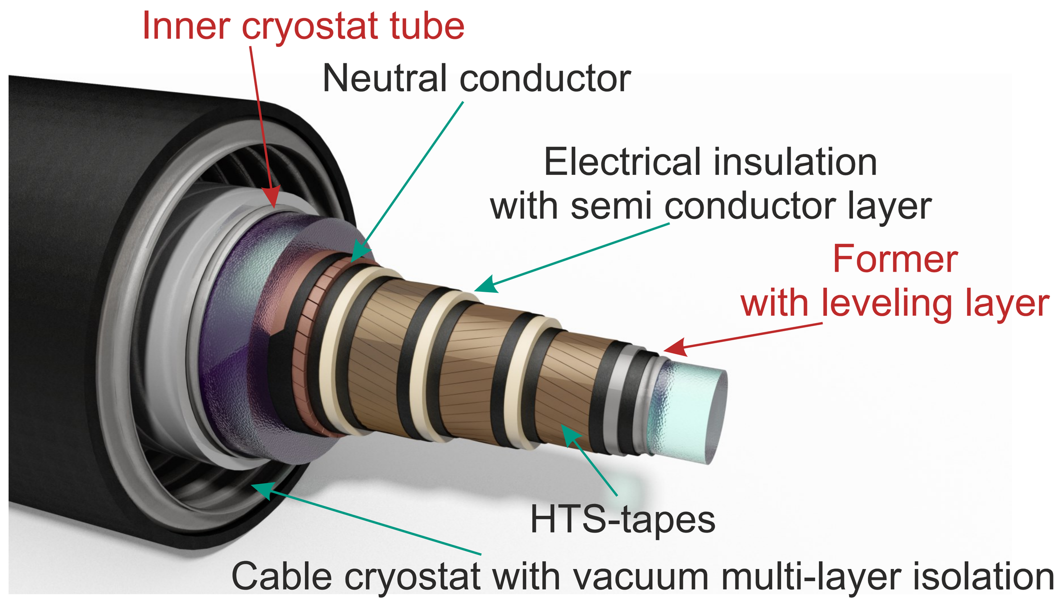
Requirements	Values
Rated voltage	12 kV
Rated power	30 MVA (1,75 kA)
Overcurrents	20 kA for 1 s 50 kA for 30 ms
Utility load factor	0,7 continuous load
Maximum outer diameter	105 mm
Cable length	2,6 km
Mass flow range	0,25 kg/s – 1 kg/s

Operating range of liquid nitrogen in cable

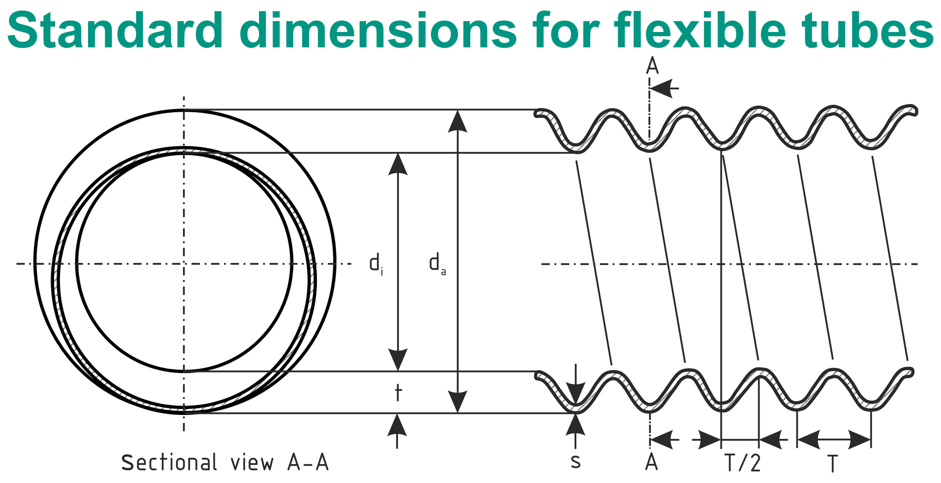


2. HTS Cable Design Parameters

Concentric three-phase design of a medium-voltage cable



Standard dimensions for flexible tubes

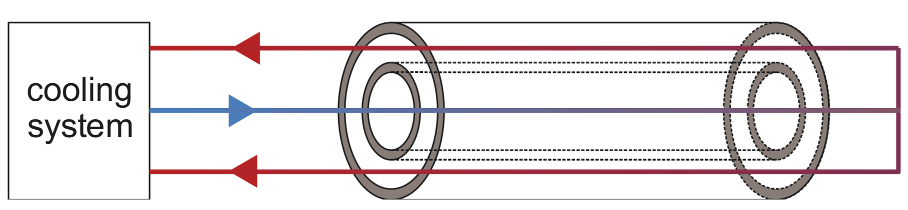


DIN EN 10380

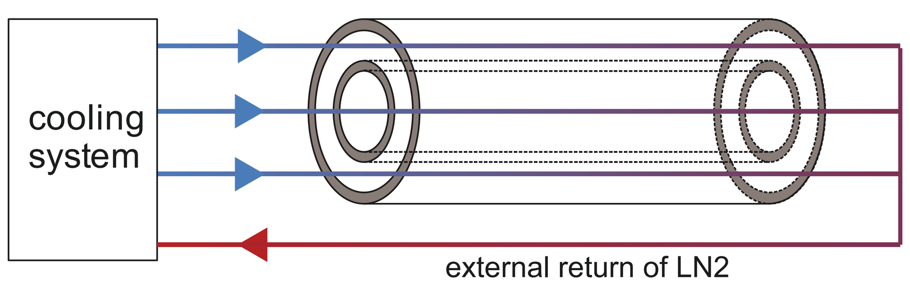
	d_i	d_a
	mm	mm
20	20,2	22,2
25	25,2	27,4
32	33,7	35,9
40	40,0	42,8
50	50,0	52,8
65	65,0	68,4
80	79,8	83,8
100	99,8	104,4
125	125,6	130,8
150	151,9	157,9

3. Overview of Cooling Concepts

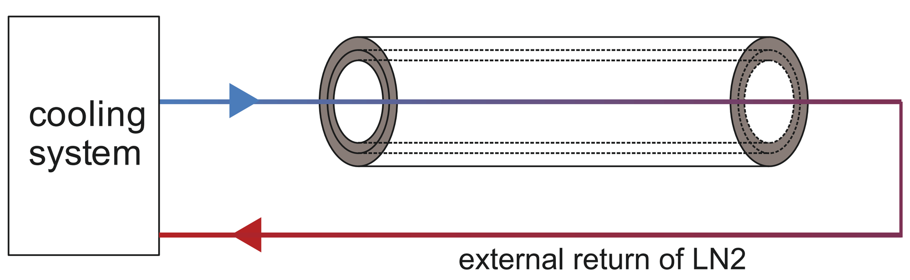
Option 1:
+ No external return



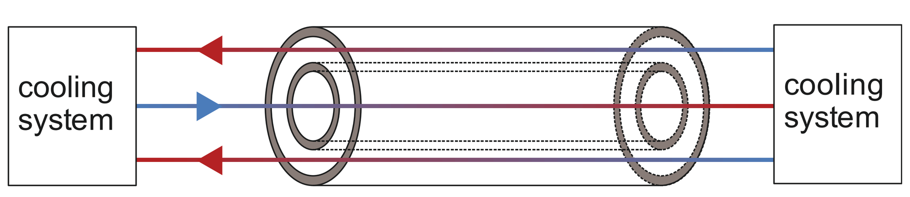
Option 2:
+ Compact cable diameter



Option 3:
+ Smallest cable diameter



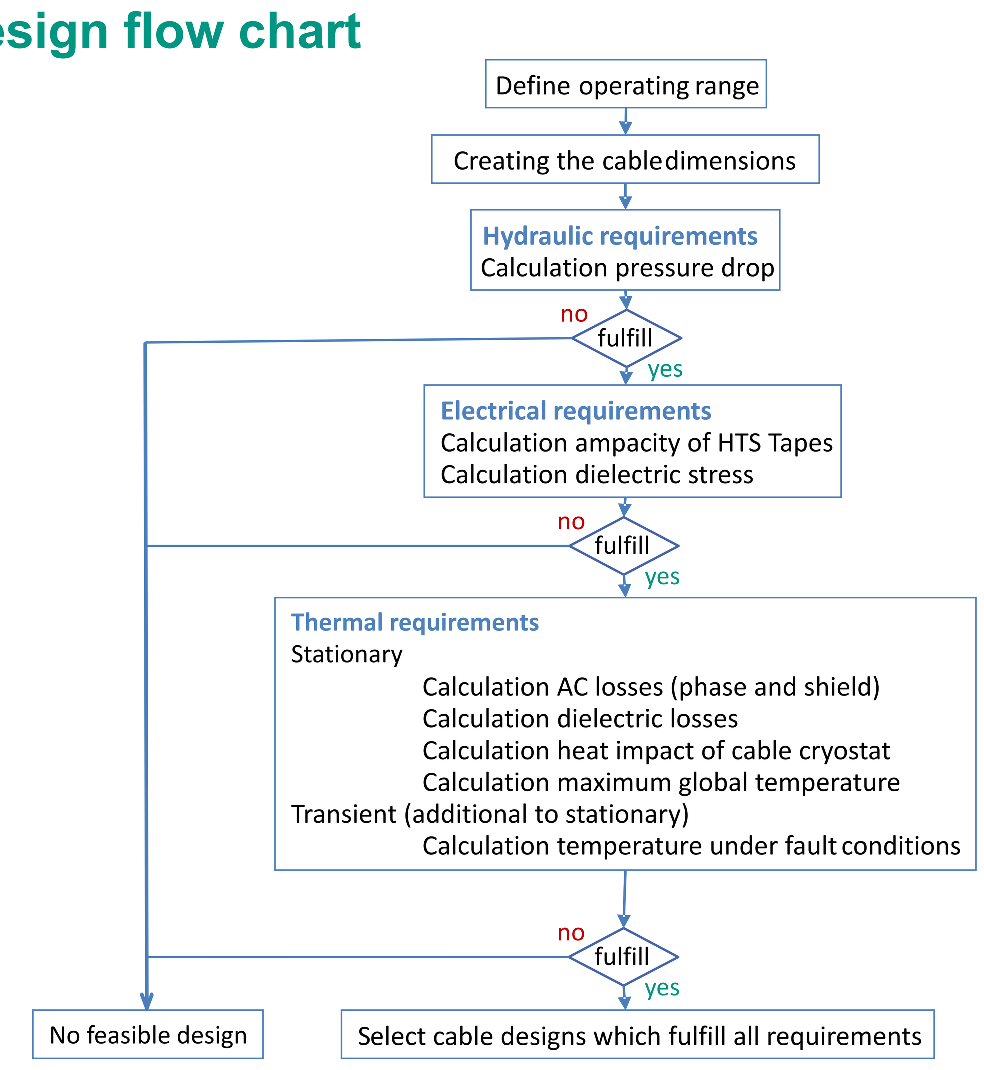
Option 4:
+ Longer cable length
+ No external return



cold (68 K) warm (< 78 K) inlet (< 15 bar) outlet (> 3 bar)

4. Electrical, Hydraulic and Thermal Design

Cable design flow chart



Results of the cooling "option 3"

Maximum cable length

Nominal diameter – inner cryostat tube	Mass flow	Nominal diameter - **former** 20	25	32	40	50
65	$\dot{M} = 0{,}25$ kg/s					
	$\dot{M} = 0{,}5$ kg/s		3420			
	$\dot{M} = 0{,}75$ kg/s					
	$\dot{M} = 1$ kg/s					
80	$\dot{M} = 0{,}25$ kg/s					
	$\dot{M} = 0{,}5$ kg/s		3920	4210		
	$\dot{M} = 0{,}75$ kg/s			6310		
	$\dot{M} = 1$ kg/s					
100	$\dot{M} = 0{,}25$ kg/s					
	$\dot{M} = 0{,}5$ kg/s		4290	4670	4460	
	$\dot{M} = 0{,}75$ kg/s			6990	6690	
	$\dot{M} = 1$ kg/s				8910	

The feasibly of a cable design is proved if all given boundary conditions (pressure drop < 12 bar; temperature limit < 78 K; ampacity < 1750 A) are fulfilled. Cable designs which not fulfilled the requirements are colored red.

5. Conclusion

Comparison of the different cooling concepts

	Option 1	Option 2	Option 3	Option 4
Min. outer cable diameter	150,5 mm	126,6 mm	104,6 mm	150,5 mm
Max. cable length	2611 m	3840 m	3420 m	4185 m

The "option 3" is the only design which fulfill the outer diameter requirements.

6. Publications

- E. Shabagin, C. Heidt, S. Strauß, S. Grohmann, Modelling of 3D temperature profiles and pressure drop in concentric three-phase HTS power cables, Cryogenics 81, 2017, 24-32