ILC Cryomodule piping

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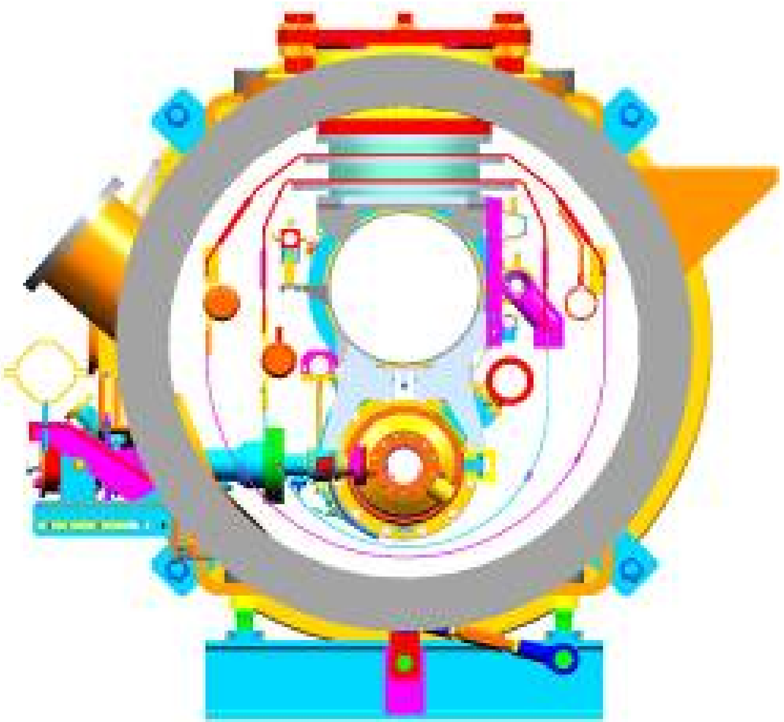
for the cryogenics global group

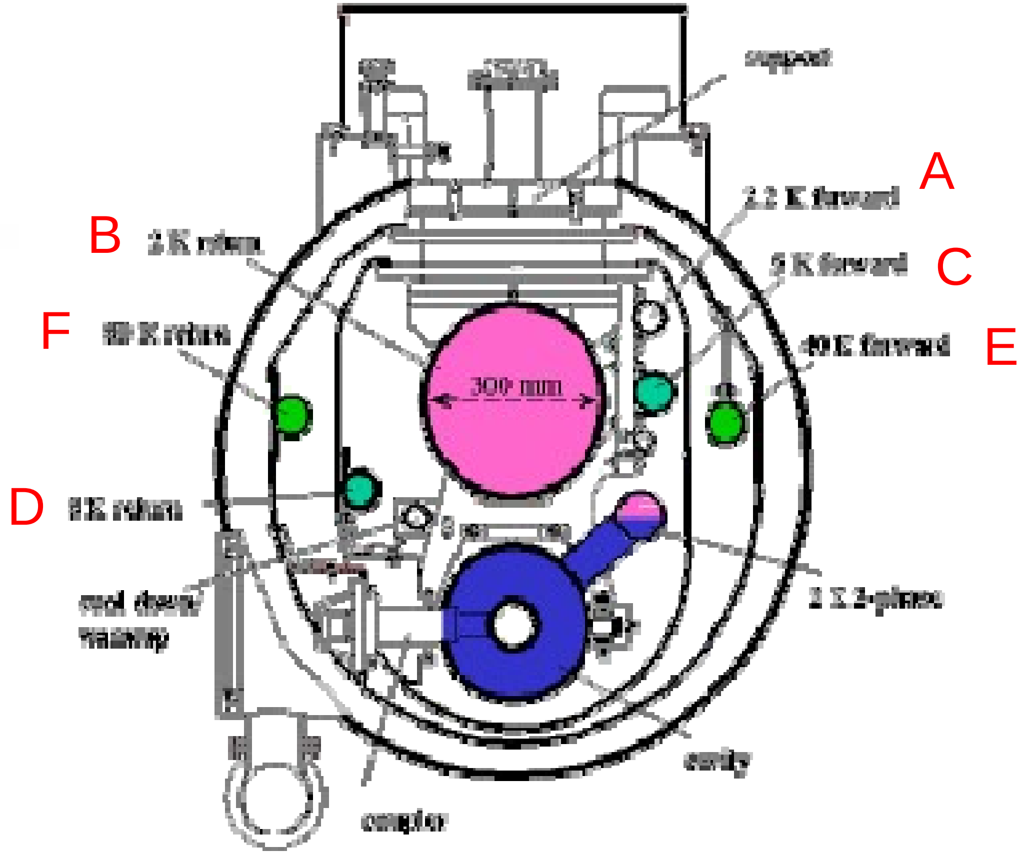
Distributed Heat Loads

Temperature level		50 - 75 K	5 - 8 K	2 K
BCD w/o contingency	[W/m]	18	1.7	1.3
BCD with contingency	[W/m]	27	3.1	1.7
RDR w/o contingency	[W/m]	13	1.3	1.0
RDR with contingency	[W/m]	19	1.9	1.5
RDR / BCD w/o contingency	[-]	0.70	0.74	0.78
RDR / BCD with contingency	[-]	0.72	0.72	0.72

RDR calculated heat load reduced by up to 30 %
w/r to BCD assessment !!!

Cryomodule Piping Definition

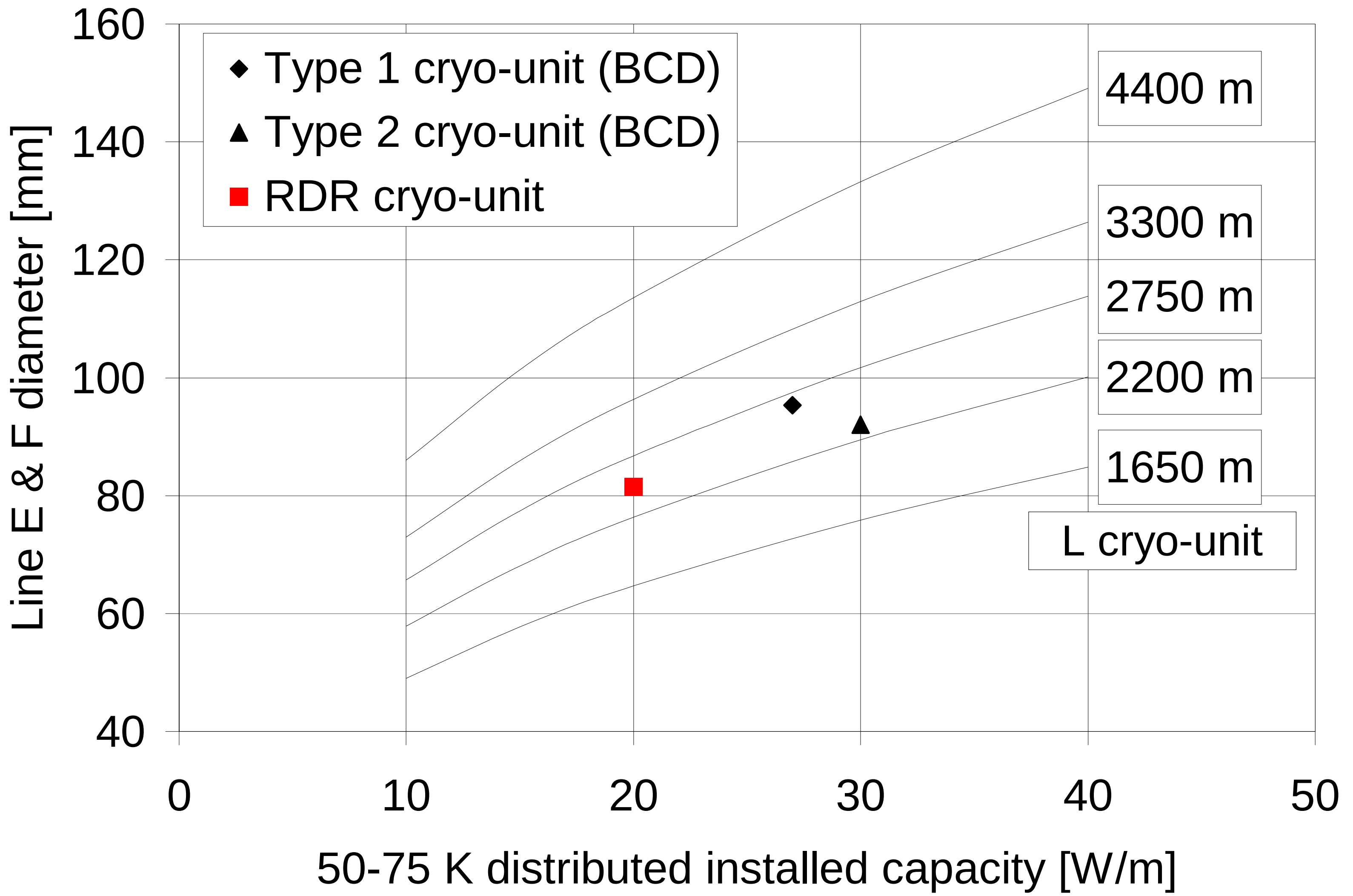




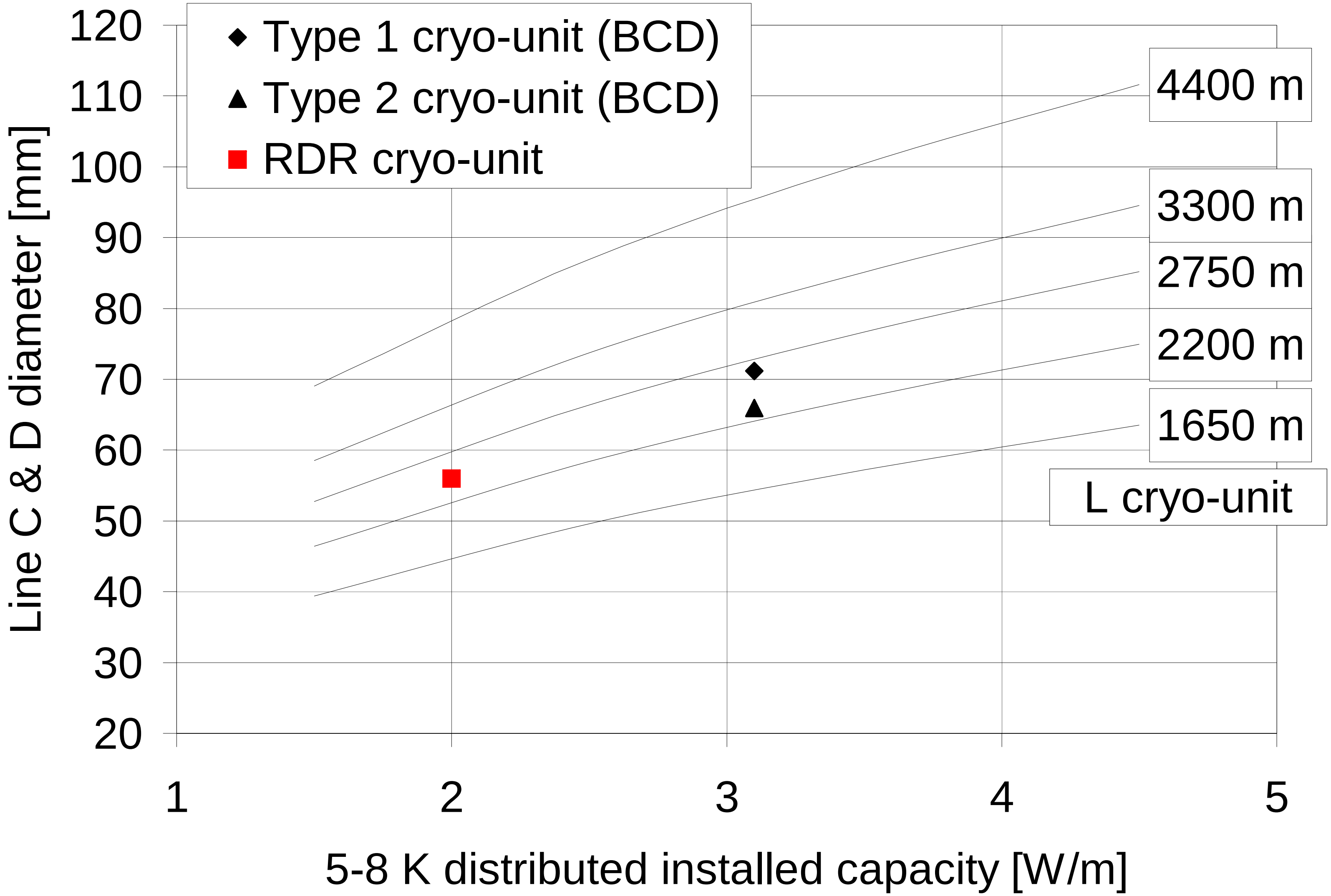
Distribution line interface conditions

Interface	Temperature [K]	Pressure [bar]
Line A inlet	2.8	1.3
Line B outlet	2.5	0.031
Line C inlet	5	5.5
Line D outlet	8	5
Line E inlet	50	20
Line F outlet	75	18

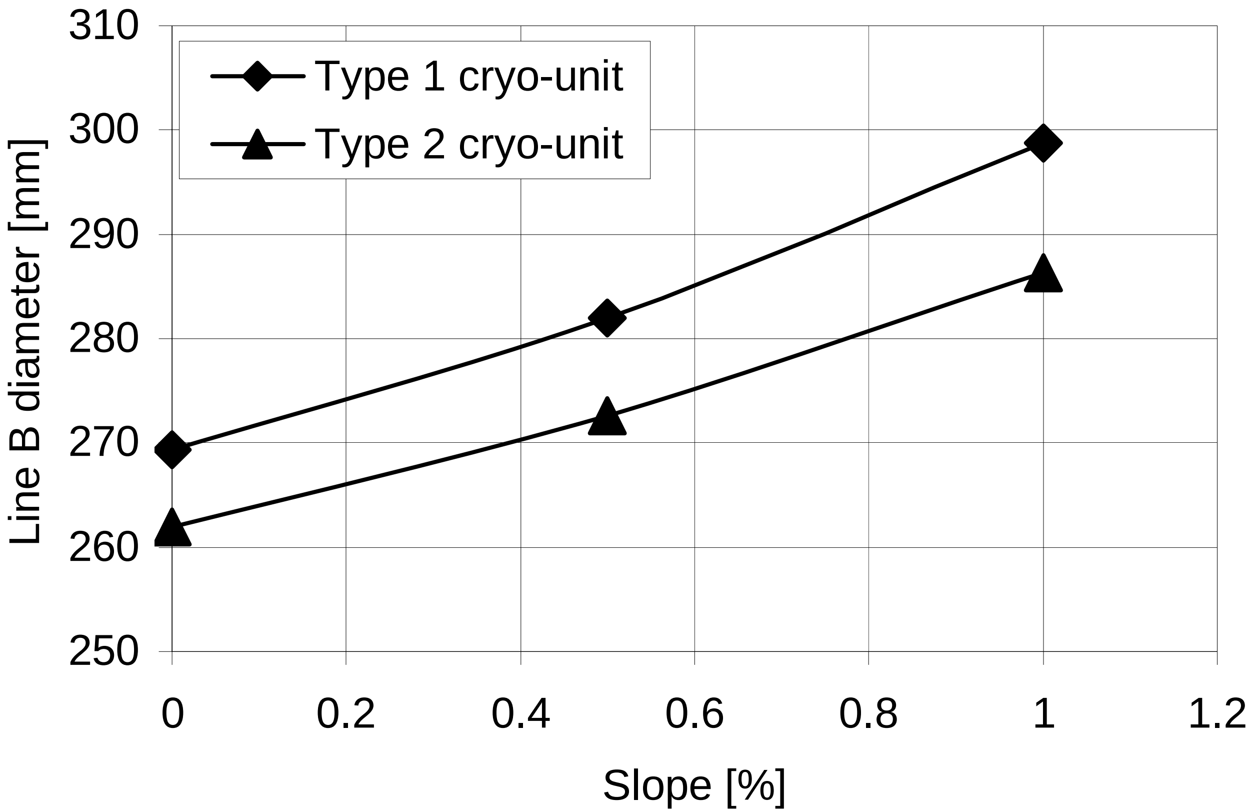
Thermal Shield Piping (E and F Lines)



5 K Heat Intercept & Screen (C and D Lines)



2 K Cooling Loop (A and B Lines)



Line B designed for cavity temperature spread of 50 mK:
300 mm acceptable for slope up to 1 %
Line A: 60 mm required for cavity cool-down

Cryomodule Diameter Summary

Line	Minimum Inner Diameter [mm] (BCD value)
Line A	60 (60)
Line B	300 (300)
Line C	60 (70)
Line D	60 (70)
Line E	85 (100)
Line F	85 (100)

Piping and Vacuum failure

- **Limit external pressure on the cavities to 2 bar warm, 4 bar cold.**
- **Limit the length of the vacuum loss**
  - Insulating vacuum breaks every 150 m
  - Cold beam valves every 600 m
  - Helium releases from cavity into 2.5 km of 300 mm header.
  - 300 mm header volume is over 800 liters per module; the liquid helium vessel volume is 200 liters per module
- **300 mm header then acts as a huge buffer volume over the full cryogenic unit length (2.5 km).**
- **12” collection header for various other flows (shield gas relief valves)**
- **Large external pipes not required under reasonable failure conditions**

Vacuum failure: Worst Case Scenario

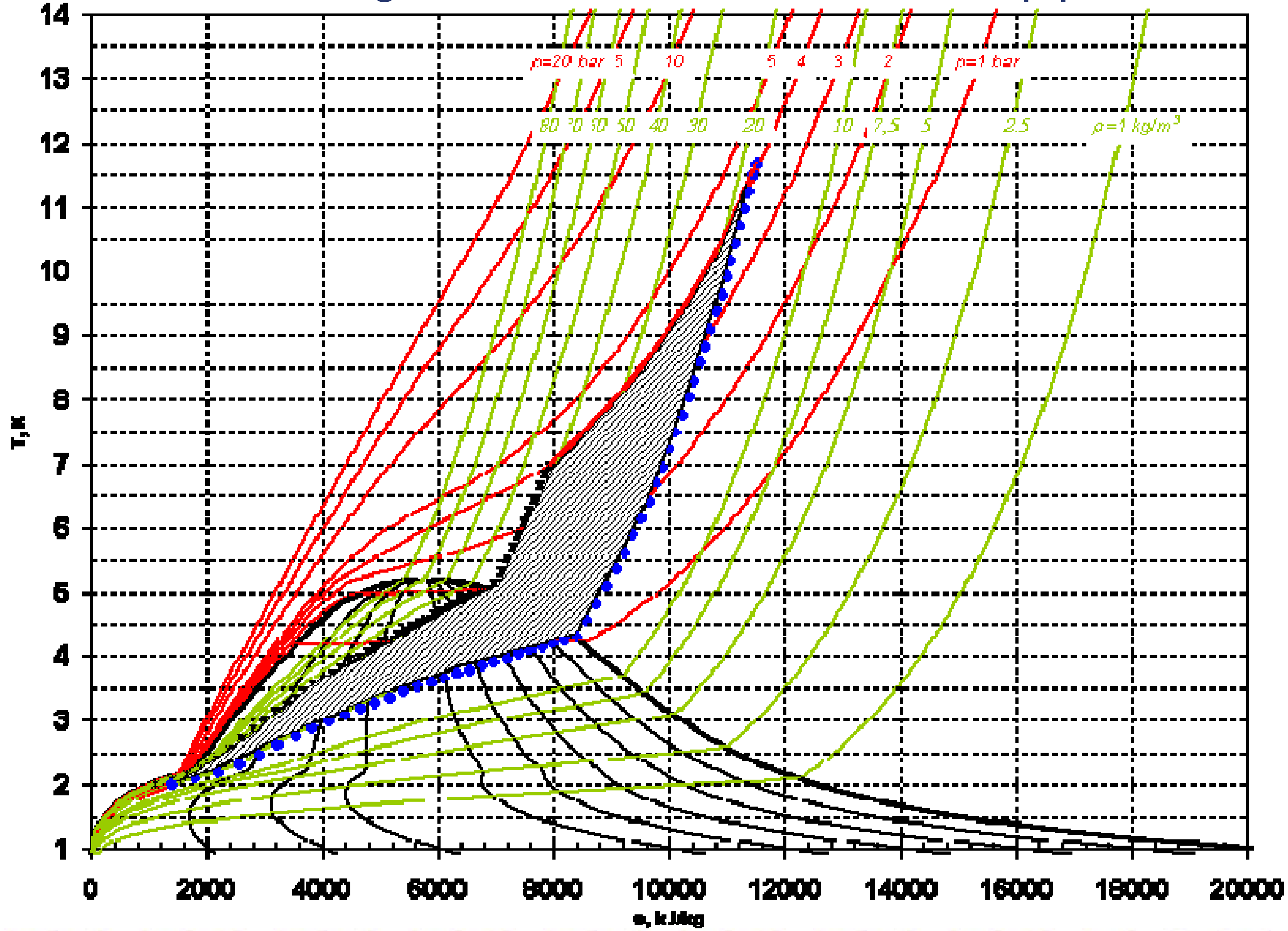
- Worst case scenario corresponds to the break of the beam vacuum with air:
  - Air condensation on a bare cold surface
  - production of heat fluxes up to 50 kW/m2
  - A large quantity of liquid helium will be vaporized and discharged in the cold pumping return pipe (line B).
- During the discharge, the cold mass structure and line B will pressurize:
  - Safety relief valves must be installed to limit the pressure build-up.
  - The spacing of the safety relief valves needed to protect the circuit depends strongly on the design pressure of the cavity cold mass structure..

Vacuum failure: Worst Case Scenario

- A sonic flow of air at atmospheric conditions in an 80 mm orifice (beam pipe diameter) gives a mass-flow rate of 1.2 kg/s.
- Taking into account the specific heat and the latent heat of liquefaction and solidification of air, the cool-down of this air flow will produce a power of about 600 kW:
  - 12 m2 of bare cold surface sufficient to exchange this power.
- The corresponding mass-flow generated by this power in a helium boiling saturated bath at 2 K is about 26 kg/s and corresponds to the flow produced at the beginning of the process.

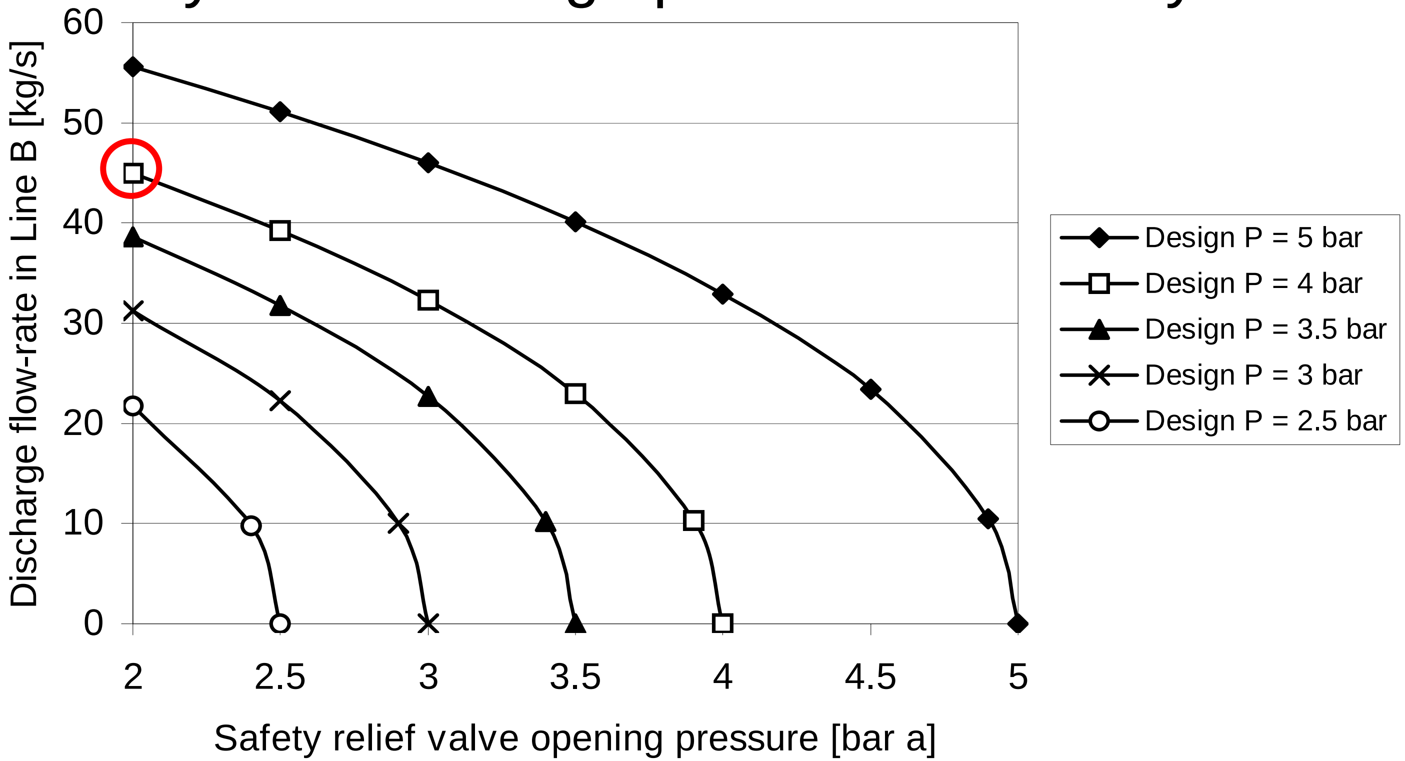
Thermodynamic evolution of helium in line B

following an in-rush of air in the beam pipe



Maximum discharge flow-rate in line B

With only one discharge point at the one cryounit end



A design pressure of 4 bar at cold allows a discharge flow of 45 kg/s with a SV opening pressure of 2 bar -> i.e. a factor of about of 2 w/r to the worst case scenario

At warm, the flow is limited (max. compressor flow ~2 kg/s) -> the DP in line B will be small and compatible with a SV opening pressure of 2 bar