SiPM Fiber Tracker Cooling System Solutions

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Workshop on SiPM cooling for Fiber Tracker
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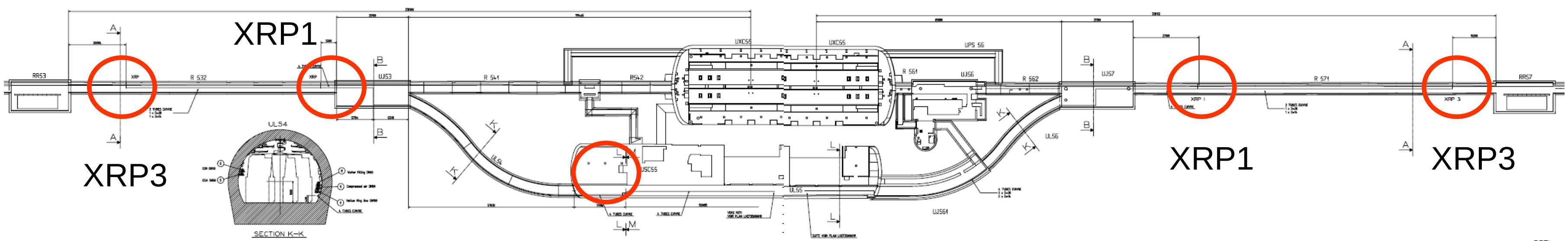
AGENDA

- Perfluorocarbon or not perfluorocarbon??
    - evaporative solution
    - mono-phase solution
- Details on the pre-study for SiPM cooling

TOTEM Roman Pots
C_3F_8 Evaporative Cooling System

Eng Spec EDMS 778214 v1

POTS STATIONS LOCATION

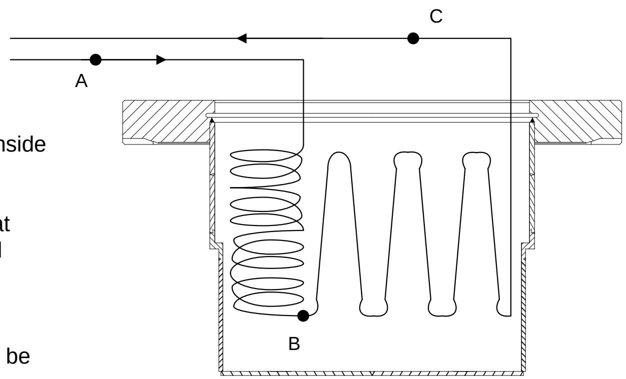


DESIGN PARAMETERS

Coolant	C_3F_8
Expected heat load per single Pot	25 W
Design individual dissipation	50 W
Total design cooling capacity	1200 W
Maximum ΔT between sensors and fluid	10 °C
Silicon sensor operation temperature	-15 °C
Fluid evaporation temperature	-30 °C
Total design mass flow	40 g/s

Roman Pot cooling
Evaporative system @ C_3F_8

Lamination phase between points A and B

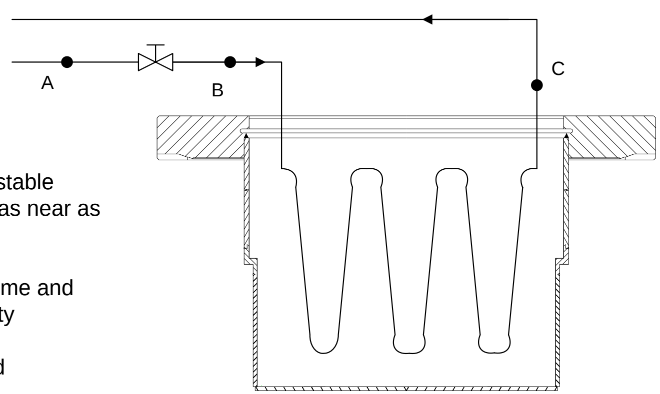


OPTION 1 - Capillary

lamination into a capillary located inside the Pot

\+ no need of insulation and heat intake on the supply line, horizontal flexibility

\- to be individually tested, time consuming, behaviour off design to be studied



OPTION 2 - Manual valve

lamination into a manually adjustable valve located outside the Pots, as near as possible

\+ commercial component, time and cost effective, reliability, flexibility

\- need of insulation to avoid condensation, heat intake from environment

Compressor design

[data from HAUG, supplier of dry compressors succesfully tested for SR1 and Atlas evaporative machine]

Nominal flow rate — 2 g/s per circuit, 48 g/s total, 20.3 Nm3/h

Option 1

WTEGX 80/60
3 cylinders
2 stages

0.8-10 bara @ 13 Nm3/h
1.0-10 bara @ 18 Nm3/h

~30 kCHF

Option 2

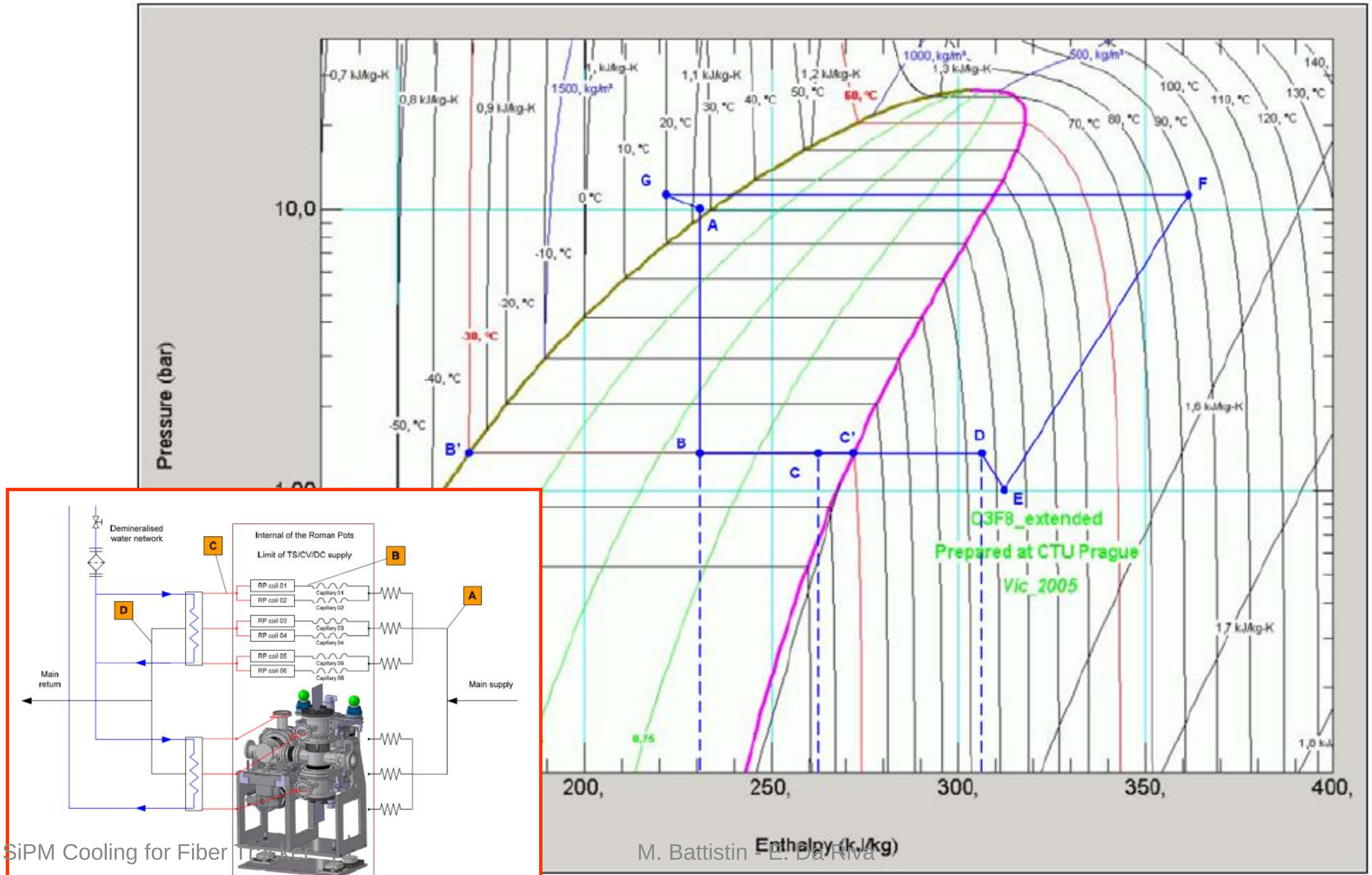
VTOGX 120/60
2 cylinders
2 stages

0.8-10 bara @ 20 Nm3/h
1.0-10 bara @ 30 Nm3/h

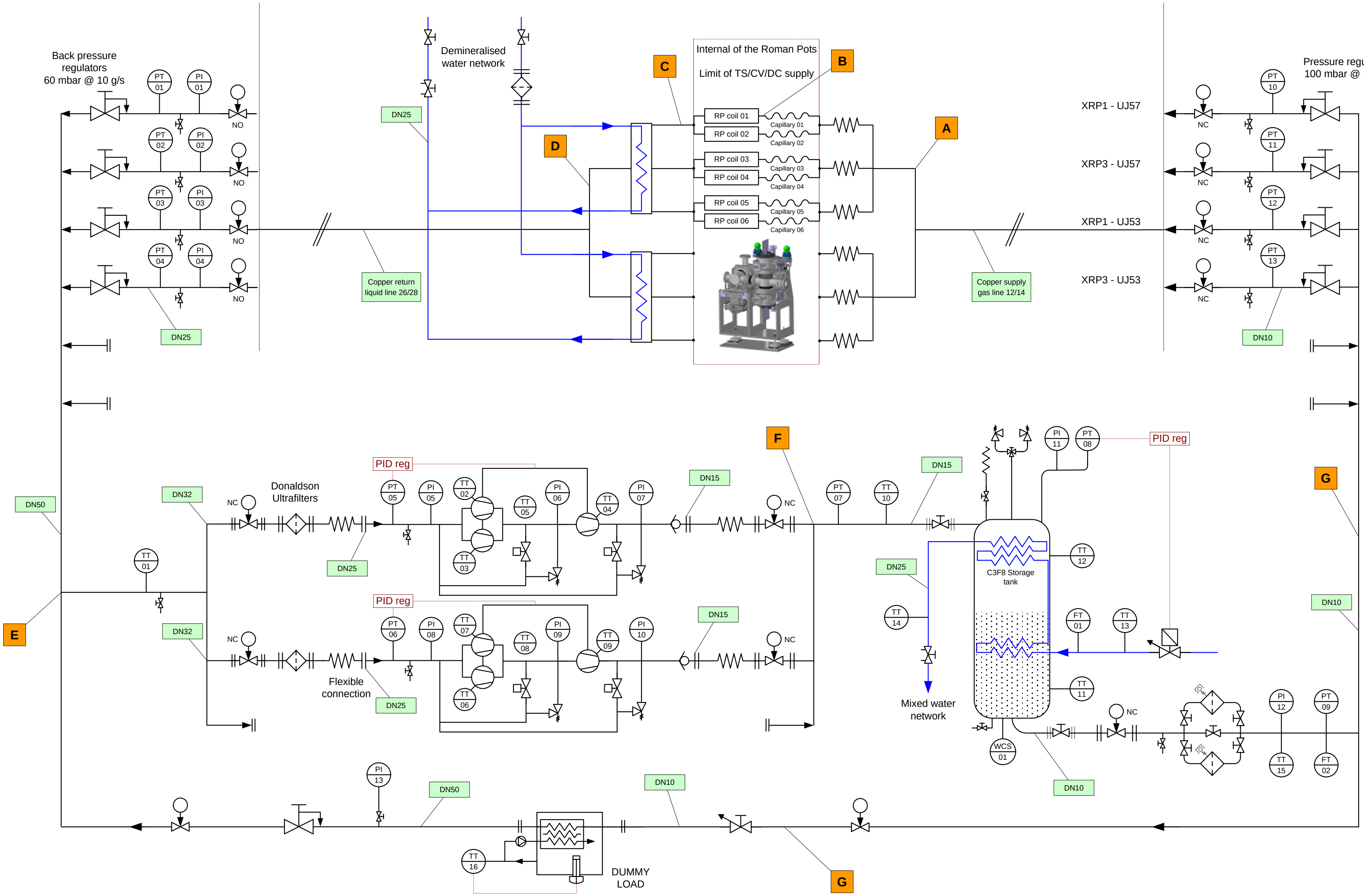
~50 kCHF

2006 costs

TOTEM RP cooling
C_3F_8 main working points



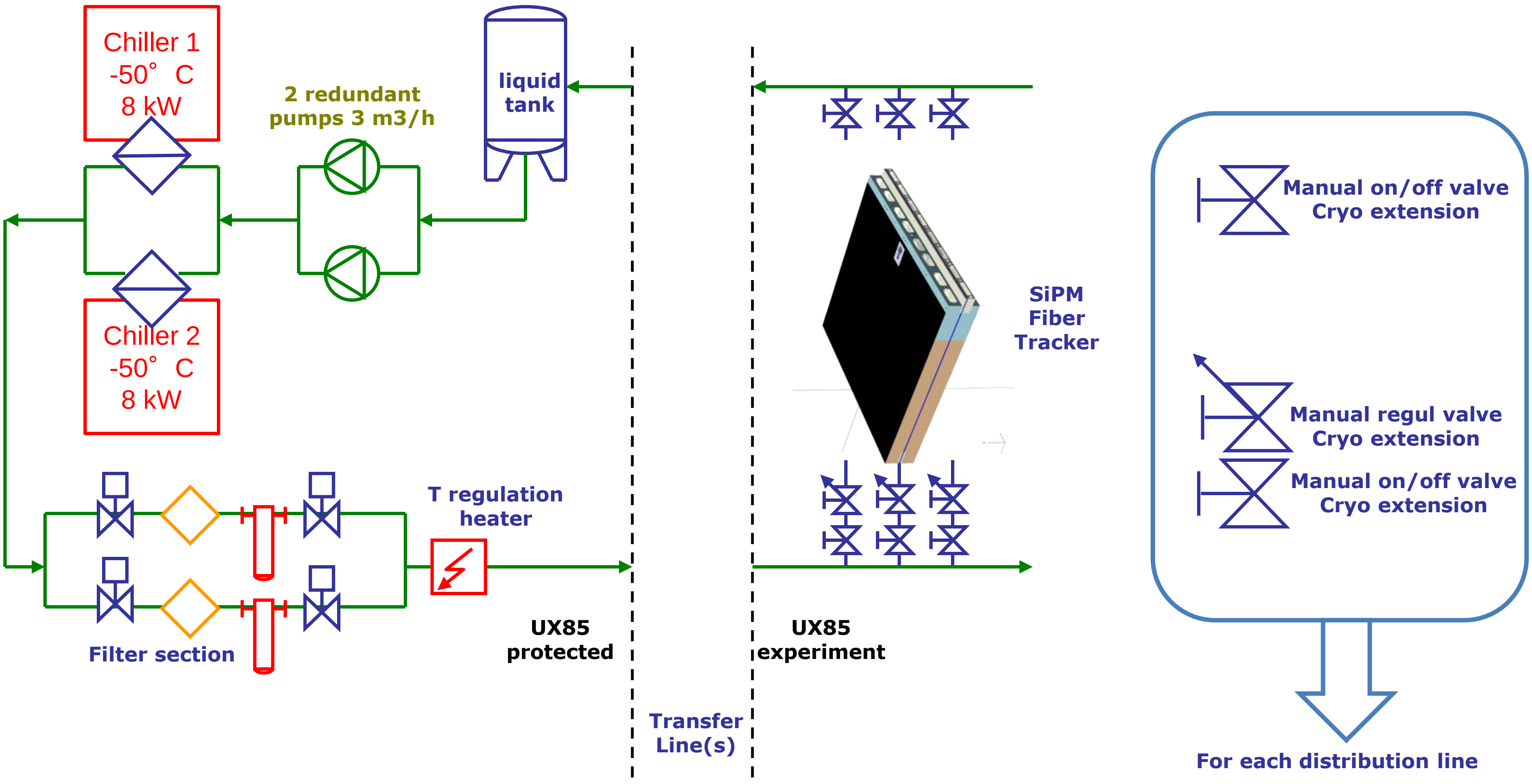
TOTEM RP Cooling System Schematic



Could C_3F_8 or C_2F_6 Evaporative System Be the Solution for SiPM Fiber Tracker?

- The solution has already been used for TOTEM Roman Pots and ATLAS Blends
  - Low operation temperature easily achivable (-43° C during Totem tests with C_3F_8 – lower with C_2F_6);
  - Low opeartion pressure on the detector (0.8 - 1 bara);
  - Temperature stability and uniformity is granted by the evaporation pressure;
  - Tranfer lines operates at ambient temperature: can be very long (300 m for Totem). The cooling station can be in an accessible area (no operation in the protected zone);
- Known technology both on detector structure than on the cooling system
  - The system is running since 2007 with high reliability;
- Cost estimate (based on TOTEM and ATLAS-Blends cooling):
  - Cooling station 250 kCHF @ 2007 (EN-CV-DC mechanical and electr. construction);
  - Copper not insulated transfer lines 30-50 kCHF;
  - Manifolding ??
- Do we need to use C_3F_8? **NO**
  - No radiation -> other industrial refrigerants (more green) could be studied (R23; R125;…)

A mono-phase system ??



For each distribution line
-
Large cost reduction possible reducing loops number

Could C_6F_{14} Mono-phase System Be the Solution for SiPM Fiber Tracker?

- The solution has already been used for 13 cooling systems for LHC Exp. detectors
  - LHCb Inner Tracker, Trigget Traker, Rich1&2;
  - Low operation temperature easily achivable (-50° C or less) depending on chiller selection;
  - Low opeartion pressure on the detector (3-5 bar);
  - Temperature stability and uniformity is granted by a fast T regulation heater;
  - Tranfer lines shall be insulated (0.5 K temperature rise – see: E. Da Riva);
- Known technology both on detector structure than on the cooling system
  - Refers to E. da Riva presentation this morning for the on-detector solution;
- Cost estimate (based on LHCb IT-TT-Rich cooling systems)
  - Cooling station: 140-180 kCHF @ 2013 (tendered);
  - Insulated transfer lines 80-100 kCHF;
  - Manifolding: about 1500 CHF/cooling loop (based on 48 loops of 6 modules – see E. Da Riva presentation);
- Do we need to use C_6F_{14}? **NO**
  - No radiation -> other industrial (more green) fluids are available (NOVEC646 – see: E. Da Riva).

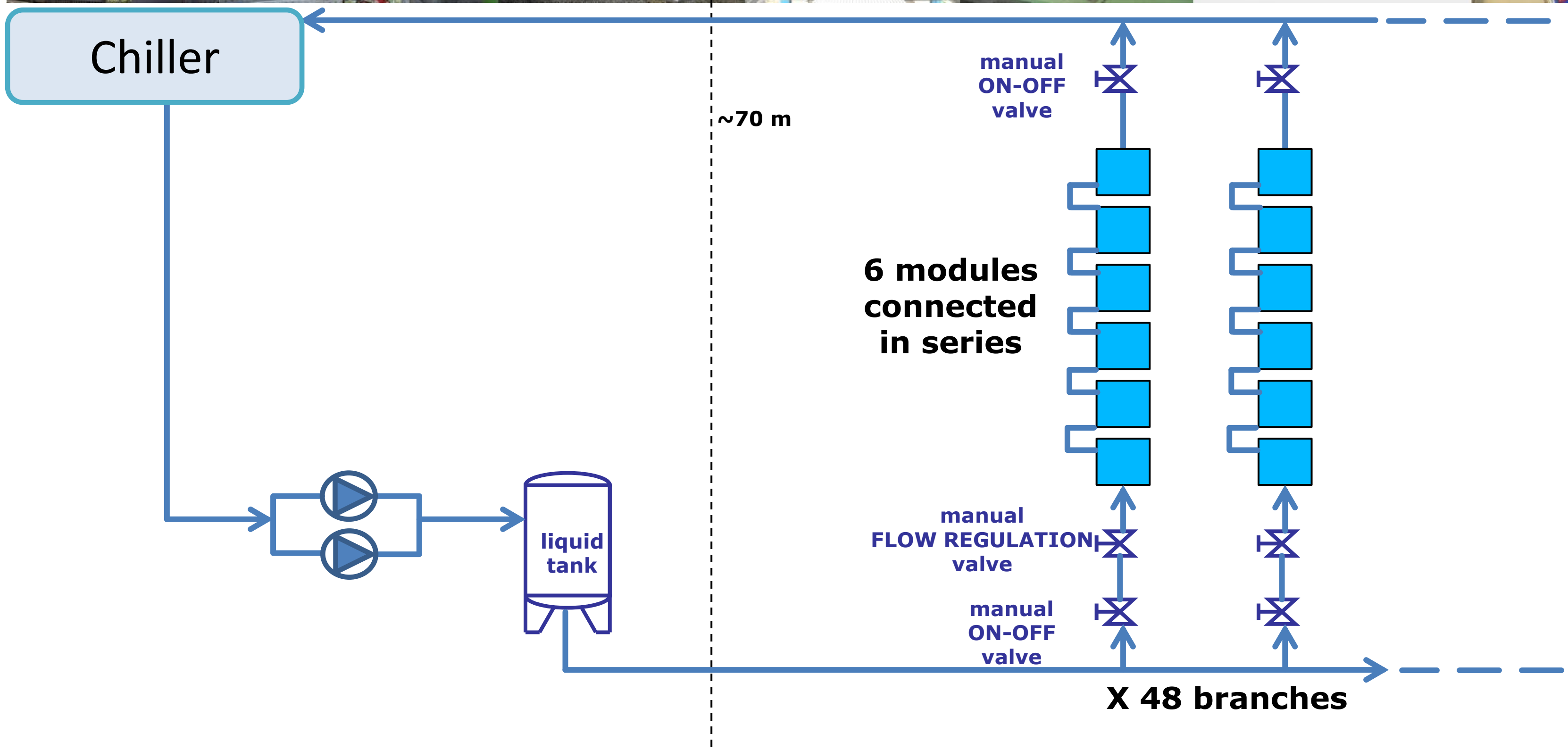
Conclusions

- Perfluorocarbons have no advantages: alternative fluids can be used in the same process installation.
- Liquid mono-phase cooling appears more appealing for
  - cooling system simplicity (installation & maintenance cost)
  - cooling efficiency (operation cost)
- Two-phases allows warm small pipe distribution up to the protected “enclave” (integration issues)

Thanks for your attention

You can find as back-up the details of the C_6F_{14} single-phase cooling system preliminary design done by Enrico Da Riva

"Order of magnitude estimate for open discussion"



- Very simple design, as compared to traditional two-phase systems, which would require 288 capillaries, automatic pressure regulation valve(s), (two-stage) compressor, lubricant-free compressor or dealing with oil return issues, higher system pressure …;
- Only evident drawback: lines must be insulated, while two-phase system can have warm lines up to the capillaries and heater or water heat exchanger at the modules outlet;
- Temperature stability demanded to the chiller only, no other regulation needed (constant heat load);
- C_6F_{14} is not binding, “green” fluids such (e.g. its substitute NOVEC649) can be used, but tests needed.

MAIN COMPONENTS

- Chiller power: 5~8 kW @ -50° C (~5 kW from modules in the very worst case scenario assuming 20 W per module, ~3 kW due to heat pick-up along lines);
- Pump: 3.3 m^3/h, Δp ≤ 3 bar;
- Mass of C_6F_{14}: ~300 kg;
- 96 on/off valves (2 per branch);
- 48 manual flow regulation valves (1 per branch);
- Liquid tank / expansion vessel (~200 L);
- 336 connectors between modules;

MAIN DISTRIBUTION LINE

- DN32 (o.d. 42 mm), 1 m/s, 70 m + 70 m (a/r);
- 5 cm armaflex insulation, $T_{surface}$ ~ 17° C, heat pick-up ~12 W/m;
- Temperature rise along 70 m: ~ 0.5 K;
- Δp along 70 m + 70 m ≤ 1 bar

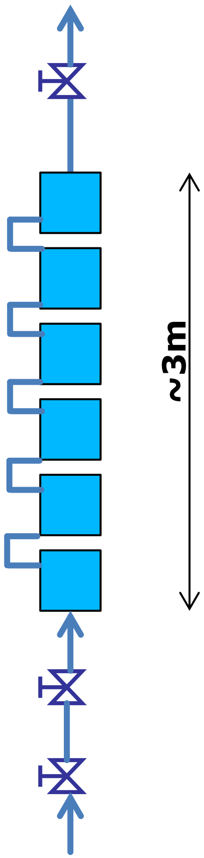
MODULES LINES

- 48 branches, 6 modules fed in series;
- i.d. 4 mm, o.d. 6 mm, 1.5 m/s;
- 3 cm armaflex insulation, $T_{surface}$ ~ 17° C, heat pick-up ~ 6 W/m;
- Refrigerant temperature rise along 5 m of insulated line: <1 K;
- Refrigerant temperature rise through 6 modules: 3.6 K [assuming 20 W per module];
- HTC: 1200 $Wm^{-2}K^{-1}$, refrigerant-to-wall ΔT: 2.6K [assuming 20 W per module];
- Δp through 6 modules (3 m + 24 bends) ≤ 1 bar.

EXPECTED SILICON DIE TEMPERATURE (worst case scenario)

- Assumption, ΔT through ceramic stiffener, flex-cable, teflon substrate < 3K;
- Silicon die at the beginning of the first module fed: -43.9° C;
- Silicon die at the end of the last module fed: -40.3° C.

Serial vs parallel module connection



Serial connection is to be preferred to parallel connection:

- ➢ Much lower length to insulate → easier to install, lower heat load;
- ➢ Optimal flow rate in every module (good for HTC inside the pipes and heat pick up);
- ➢ Connectors can be installed between each module: in case of problems the two on/off valves can be closed, only 6 modules over 288 will be off, the faulty module alone can be removed.