COOLING STUDIES

Internal Technical Note

Barrel EM Calorimeter

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Definition of the chiller of the cooling plant

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This document is for the supplier and PANDA engineers.
This is a preliminary version to be completed after iterations with suppliers and users.

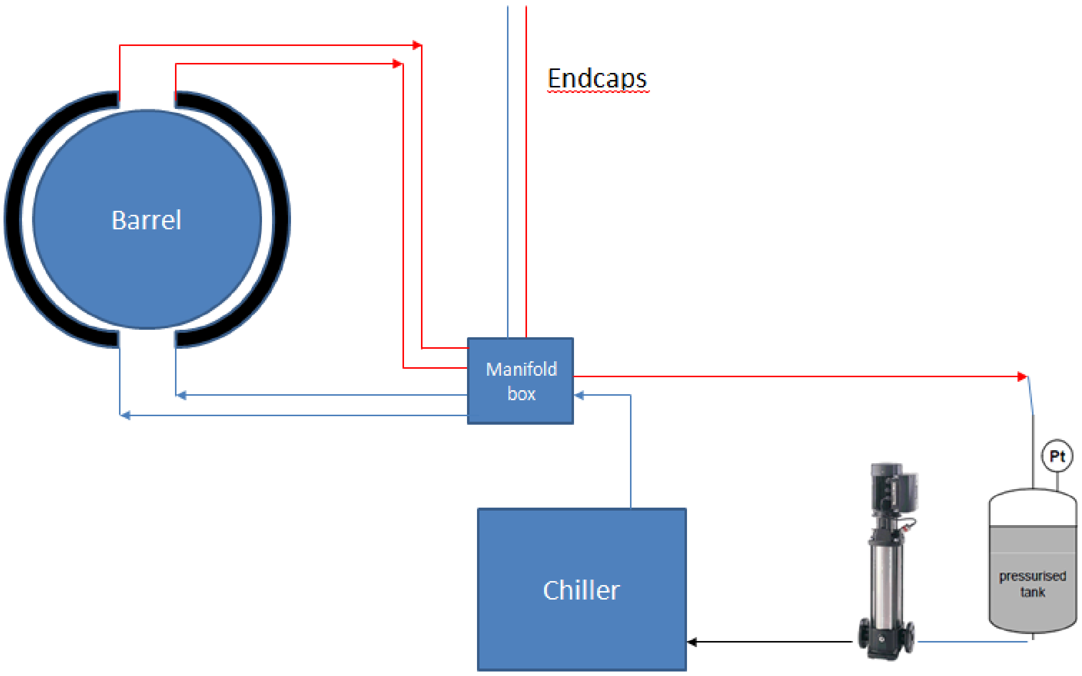
1. Introduction

For the cooling of the electromagnetic calorimeter (EMC) @ -25°C, a special cooling plant must be designed. The concept is based on the leakless machine developed by the CERN for the LHC experiments.

This report gives an estimate of the device necessary to cool down the whole EMC detector, composed of 11360, 3600 and 592 crystals, respectively in the Barrel, the forward Endcap and the Backward Endcap. The analysis is based on the Barrel and an extrapolation is used for the two Endcaps.

As illustrated in the figure n°1, the circuit is composed of:

- A pump + vacuum tank,
- A chiller composed of compressors, condensers, heat exchangers, regulation,
- A cooling circuit through the detectors splitted with a manifold box. This is designed in order to minimize the pressure drops. In particular the Barrel is composed of 16 slices whose the circuit is split in parallel lines. The circuit can be made of stainless steel and LD-PE tubes. These tubes are in shape of serpentines on the thermal screens covering the EMC.
- Manometers, valves, flow meters and temperature sensors helps the control & command of the EMC.



1-Scheme of the cooling installation

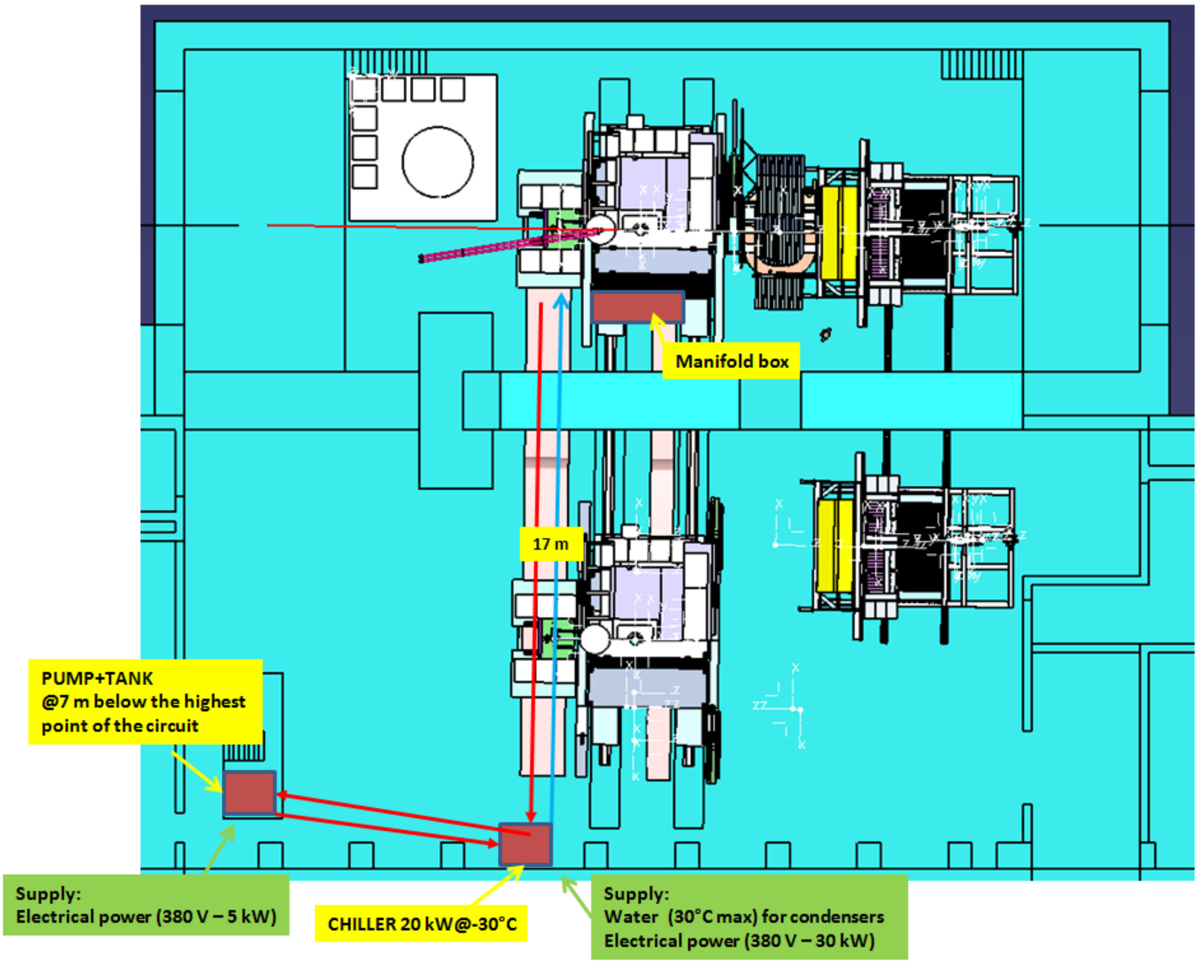
2. Location in the PANDA hall

The location of this installation is illustrated in the figure n°2 representing the PANDA Hall.

The pump is placed in a pit below the ground level in order to get a height difference of 7 m with the highest point of the cooling circuit. This is mandatory to recover hydrostatic pressure for the depressive return flow in the leakless mode.

The chiller is placed on the upstream part of the netwok in a fixed position as closest as possible of the PANDA experiment. The detector is going to move by around 11m, during maintenance, so the chiller is placed closed to this last position. Special flexible cooling lines will be defined between the detector and the chiller.

A manifold box sits on the PANDA moving floor in order to get rigid cooling lines close to the EMC detector.



2-GSI PANDA Hall implementation

3. Heat sources

a-Constant heat sources:

There are several heat sources to take in account inside a slice (which represent 1/16 of the Barrel):

- Internal source coming from the read-out electronics around crystals:
  - Front-End: APFEL asic = 150 mW / crystal => 106 W/slice
  - Drivers in the back PCB: 1 mW / crystal => 0.7 W/slice
- External source coming from the insulation, cabling, fixing points and environment:
  - Front Insulation through VIP: 10W/slice

- Back Insulation (25 mm foam): 53W/slice
- Support feet (42 of 25x10mm² 50mm long) = 2 W/slice
- Cables (10cm, shield flex, 10°C delta) = 33 W/slice
- Hot environment from the ambient beam cooling = 15W/slice
- Total 263W/slice

From the barrel through the target spectrometer until the manifold box, the cooling lines (length 10m) get heat from the ambient (insulation 40 mm thickness or vacuum VIP):

- Target spectro. lines: 240 W

Between the manifold box and the chiller and along the whole path of the cooling circuit in the hall (length 2x30 m):

- General lines : 15 W / m => 900 W
- General manifold box: 2000 W (conservative estimate, to be defined)
- Circulator pump + tank: 2000 W (conservative estimate, to be defined)

3b-Transient heat source:

The cooling of the crystal mass will require an extra power evaluated around 3445 W. It is necessary to succeed to cool down all the Barrel crystals (structure not taken into account) within 12 hours.

3c-Summary:

The estimate in §a and §b is done for the barrel. In the following board, an extrapolation to the 2 endcaps is done by multiplying by the number of respective crystals in each.

Constant heat source (W)					
	Slice	**Barrel EMC**	**FWEMC**	**BWEMC**	**EMC**
FE ASIC	106	1696	537	88	2322
Driver	0.7	11.2	4	1	15
Front VIP	10	160	51	8	219
Back Insulat.	53	848	269	44	1161
Cables	33	528	167	28	723
Support feet	2	32	10	2	44
Beam	15	240	76	13	329
Target lines		240	76	13	329
Total	220	3755	1190	196	5141
Transient heat source (only crystals mass) (W)					
12 hours	215	3440	1090	179	4709
Circulator pump + tank					2000
General manifold box					2000
General lines					900
Total Cooling power	434 W				**14750 W**

The EMC needs a minimum cooling power of 14.75 kW to run at -25°C.

Therefore the requested cooling power is conservatively set at **20 kW@-30°C**. This does not take into account the power for the chiller itself which must be evaluated and add by the supplier.

Remarks: The radiative heat transfer is not taken into account anywhere.

4. Temperature stability

The EMC crystals must work at -25°C to get improved performance. This temperature must be stable within +/- 0.1°C in time after calibration.

In order to get this temperature, the chiller must provide a -30°C coolant to take into account the rise along the circuit and the heat transfer through the barrel circuit (see §6).

The regulation of the temperature is a critical point. Nevertheless, 2 points helps this precision stability:

- The important inertia of the crystal mass
- No fast process exists in the EMC that could create any perturbation.

The chiller must have a PID regulation in order to optimize the regulation following the crystal monitoring temperature.

5. Choice of the coolant

The choice of the detector coolant is done following several criteria:

- Minimizing the pressure drop (low viscosity)
- Maximizing the heat exchange behaviour
- Avoid silicon or petrol pollution in case of leak or maintenance
- Reducing the flammability risk
- Minimizing corrosion with aluminium
- Compatibility with plastic materials
- Low vapour pressure

The candidates are mixture water/ethanol or water/methanol (40/60).

Nature	Cp	ρ	μ	λ	Vapor Pressure max
Water/methanol@-30°C	3151	930	7.7e-3	0.341	160 mbar (20°C) (to confirm)

6. Nominal flow and temperature homogeneity

The following board gives the temperature rise along the circuit, the temperature difference through the wall exchange and the flow to extract the heat.

Flow and temperature					
	Slice	**Barrel EMC**	**FWEMC**	**BWEMC**	**EMC**
dT_rise (°C)	0.9	0.96	0.9	0.9	0.9
dT_exchange (°C)	1.8	1.8	0.8	0.8	1.8
Flow (L/mn)	4.8	84	26.6	4.4	115
Flow (m3/h)	0.28	5			7

In conclusion it shows that in the barrel in particular, we need to set a temperature of -27.7 °C minimum at the inlet of the Barrel in order to obtain 25°C in the thermal screens.

The heat exchanger is defined in order to work with a flow minimum of 7 m3/h. A flow of 10 m3/h is conservatively chosen.

7. Cooling tube sizes of the network, pressure drop in the heat exchanger

The chiller is on the upstream part of the circuit regards to the barrel, so placed between the pump and the barrel, in the "pressurized" part of the cooling line. The size of the cooling tube is 22 mm in diameter.

The pressure drop through the heat exchanger must be minimized, **not higher than 1 bar at a flow of 10 m3/h for our coolant@-30°C**. It must sustain an exceptional pressure of 5 bars in case of leak test and filling line process.

8. The supply of the chiller and particular equipment

The supply of the chiller is listed here :

- Connection to the water cooling network (30°C to confirm) for the condensers.
- The electrical connection (380 V ? – power ?)

Some of the chiller characteristics are listed here :

- Ground footprint around 4 m².
- It is placed closed to the hall wall as illustrated in the figure n°2.
- Ground underbath in case of leakage
- data transmission to the computing room (alarm, control, regulation read-out)
- Insulation

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