EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
European Laboratory for Particle Physics

Internal Note/
ALICE reference number
ALICE-INT-2007-003 v. 1.0

Date of last change

The HMPID C_6F_{14} circulation system

Authors:

A. Di Mauro[1], Y. Andres[1], A. Braem[1], K.Chileev[2], M. Davemport[1], G. De Cataldo[3], C. Dell'Olio[4], D. Dell'Olio[4], L. Dell'Olio[4] D. Di Bari[4], A. Franco[2], U. Fratino[5], A. Gallas[2], H. Hoedlmoser[1], W. Klempt[1], A. Kurepin[6], Y. Lesenechal[1], L. Liberti[4], P. Martinengo[1], A. Mastroserio[4],E. Nappi[2], C. Pastore[4], F. Piuz[1], V. Rizzi[2], I. Sgura[5], A. Tauro[1], G. Volpe[4], J. Van Beelen[1].

1 CERN CH 1211 Geneve 23
2 INFN sez. Bari, Italy
3 CERN CH 1211 Geneve 23 and INFN sez. Bari, Italy
4 Università di Bari and INFN sez. Bari, Italy
5 Politecnico di Bari and INFN sez. Bari, Italy
6 Institute for Nuclear Research, Moscow, Russia

Abstract:

This document outlines the basic principles of the system built to circulate and purify the liquid perfluorohexane to be used as Cherenkov radiator of the HMPID detector in the ALICE experiment. A closed, pressure-regulated system will continuously filter and deliver, by gravity flow, the perfluohexane to the twenty-one radiator vessels contained in the HMPID modules. In this manner, the fragile radiator vessels will be decoupled from the pumping units. Since gravity feed requires few user-serviceable parts, this system will be located next to the HMPID detector, which will not be accessible during LHC operations. Maintenance services that require regular or frequent intervention such as filter changes, addition of liquid, or transparency measurements will occur at the main liquid station, which has been located outside the experimental area.

Contact persons: C. Pastore, I. Sgura

Table of Content

1 Introduction pag. 1

2 Basic requirements and the layout of the liquid circulation system pag. 4

3 Specifications of the system pag. 7

- 3.1 Pumping station pag. 7
- 3.2 Filling and purifying station pag. 8
- 3.3 Distribution station pag. 10
  - 3.3.1 Header tube – radiator vessel pag. 13
  - 3.3.2 Radiator vessel drainage and emptying lines pag. 15
- 3.4 Principle of operation pag. 16

4 The HMPID Control System pag. 17

Appendix

Acronym

Notation

1 Introduction

The High Momentum Particle Identification (HMPID) detector is intended to perform inclusive measurements by discriminating hadrons with transverse momentum above 1 GeV/c. The anticipated low yield of such particles, in Pb-Pb collisions at LHC energy, justifies the single-arm geometry of the HMPID covering about 5% of the central barrel phase space.

HMPID will enhance the PID capability of the ALICE lay-out [1] by allowing particle identification at higher momenta than those covered by energy loss measurements (as performed by the silicon detectors of the Inner Tracking System, ITS, and the Time Projection Chamber, TPC) and the TOF. Namely, HMPID is being optimized to extend the useful range for the identification of π/K and K/p, on a track-by-track basis, up to 2.7 GeV/c and 5 GeV/c respectively [2].

It is based on Ring Imaging Cherenkov (RICH) counters and consists of seven modules, each covering a surface of about 1.5 m^2. A 1.5 cm thick layer of C_6F_{14} (perfluorohexane), liquid fluorocarbon, emits Cherenkov light when a fast charged particle is traversing it. The light is detected by a photon counter which exploits as photocathode a thin layer of CsI [3] deposited onto the pad cathode of a wire chamber (figure 1).

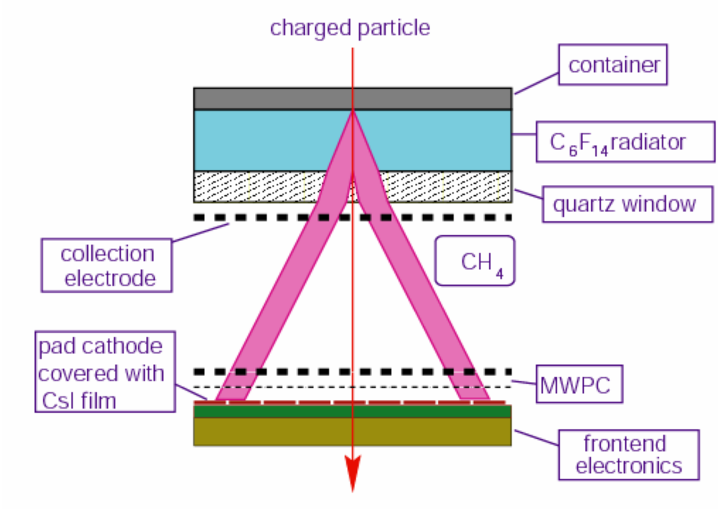


Fig. 1. Schematic cross section of the ALICE proximity focused CsI-RICH detector.

The HMPID has been mounted in an independent support cradle (figure 1 in appendix), which is fixed to the space frame, at two o'clock position (figure 2).

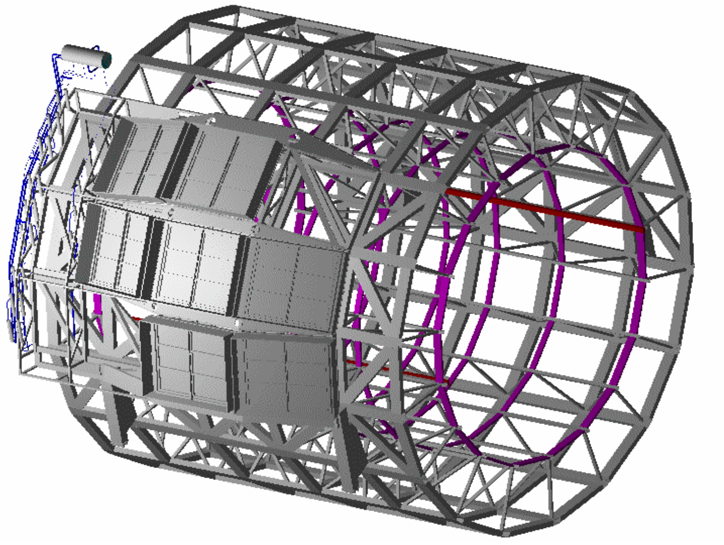


Fig.2 Axonometric view of the ALICE space frame. The seven HMPID modules and some components of the liquid radiator circulation system are shown.

Perfluorohexane, a chemically inert, non-aromatic (not derived from benzene) chlorine free saturated fluorocarbon, was chosen as RICH radiator primarily because of its optical properties. It has an index of refraction of about 1.29 at 190 nm (corresponding to a γ_{th}=1.6), a small chromatic dispersion and a good transparency to ultra-violet radiation in the operational region that matches the quantum efficiency spectrum of CsI and the fused silica transmission cut-off. However, as a consequence of its low boiling point (51 °C), perfluorohexane has an elevated vapour pressure of approximately 310 mbar at 25 °C (see Table 1 in Appendix).

Each HMPID module is equipped with three liquid radiator containers consisting of vessels of 1330x413x15 mm^3 made of a glass-ceramic material (NEOCERAM®), thermally compatible (thermal coefficient 0.5 10^{-6} °C^{-1}) with the fused silica plates used as UV-transparent windows.

Thickness and size of vessel's elements have been carefully optimized by searching the best compromise between the detector total radiation length and the perfluorohexane hydrostatic pressure: the fused silica window is 5 mm thick, while the NEOCERAM® base plate is 4 mm thick.

To withstand the hydrostatic pressure, thirty cylindrical spacers are glued to the NEOCERAM® bottom plate on one side and the quartz window on the other side. Spacers consist of fused silica rods with a diameter of 10 mm placed in three rows of ten equi-spaced elements (figure 3).

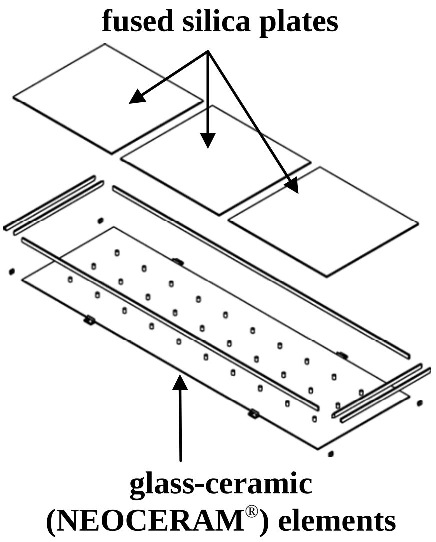


Fig.3. Design of the HMPID liquid radiator container.

The three radiator vessels are supported by a stiff composite panel made out by sandwiching a layer of Rohacell, 50 mm thick, between two 0.5 mm thin layers of aluminium.

The liquid radiator inlet and outlet are obtained by inserting stainless steel bellows (Fig. 4) on the opposite edges of the NEOCERAM® tray, the outlet always being at the highest location.

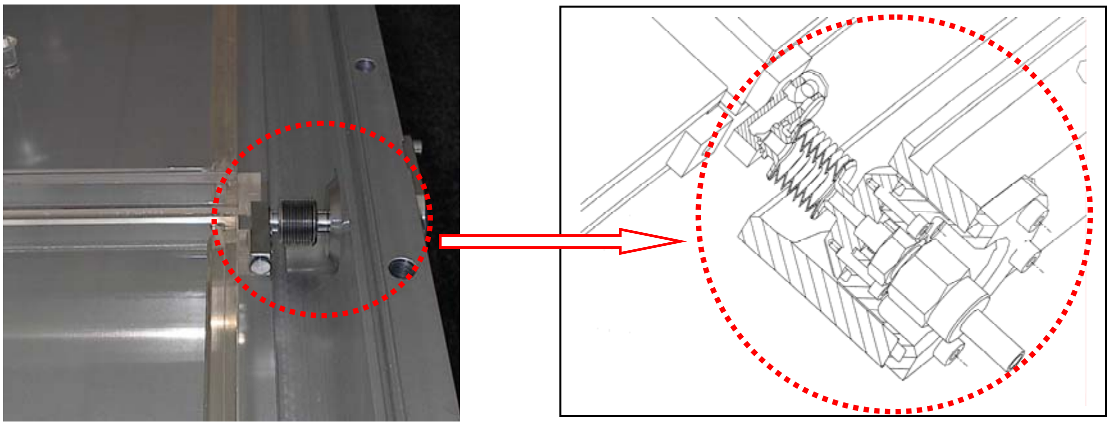


Fig. 4. Detail of a radiator vessel showing the stainless steel bellow used as feedthrough

Since C_6F_{14} has a high affinity for oxygen and water, which is detrimental to keeping it transparent in the UV region, and it is not available in a high-purity grade form, a dedicated liquid circulation system equipped with appropriate filters has been designed in order to remove contaminants and achieve the best transparency in the region where the RICH detector operates. The liquid circulation system is required not only to purify C_6F_{14}, but also to fill and drain the radiator vessels remotely and safely, at a constant flow of 4 l/h , and empty them independently.

In view of the inaccessibility of the HMPID array during the LHC running period and the considerable hydrostatic load exerted by the high density of the C_6F_{14} on the fragile fused silica windows of the radiator vessels, a system based on a gravity flow principle has been chosen owing to its intrinsic safe nature. Passive security elements and interlocks generated by PLC units together with a transparency monitor have been anyhow implemented to allow rapid remedial actions to avoid any detector performance degradation.

A gravity feed has been successfully implemented in the liquid system of the CRID detector at SLD [4]. Moreover, an extended prototyping study was performed by the ALICE-HMPID group that built and operated for two years in STAR at RHIC a large size RICH detector equipped with a liquid circulation system designed with the same technical solutions of the final one [5]. The running experience at BNL represented a unique opportunity to verify in practice the effectiveness of the methods to filter the liquid, the behaviour from stagnant tests, and the correctness of choices made on the construction materials used in the system. These issues are relevant since a long-term degradation of certain material in contact with C_6F_{14} has been observed [6].

2 Basic requirements and the layout of the liquid circulation system

The system has been designed according to the following criteria:

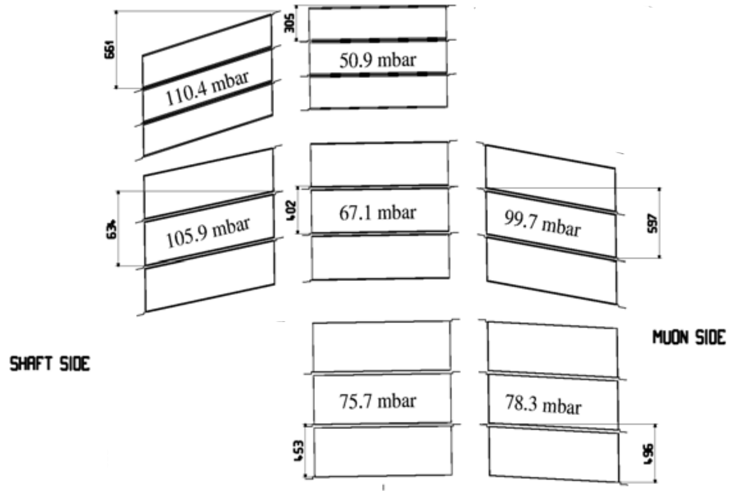
- use of the minimum number of active components, especially in those zones which will not be accessible during the LHC operations;

- implementation of a safety passive control by means of an overflow system to avoid any type of over-pressure on the optical windows of the radiator vessels. The maximum working pressure of the radiator containers, evaluated to be 140 mbar [3] above atmospheric pressure, assuming a safety coefficient equal to seven, must not be exceeded at all times in any of the various geometrical positions of the seven modules. Figure 5 illustrates how the hydrostatic load, merely produced by the weight of the liquid contained in the radiator vessels, varies with the module location in the cradle;

- ensuring laminar flow through the radiator vessels (figure 2 in Appendix);

- absence of siphons in the outlet pipes;

- implementation of a gas reference line in which anhydrous argon is continuously flushed in the volumes above the liquid. This gas is maintained, by means of an oil bubbler, at a constant positive pressure value of some mbar thus creating a buffer from the atmosphere. To minimize the release of perfluorohexane to the atmosphere, argon is exhausted through a cold trap which serves to condense liquid vapors from the gas stream.



The liquid circulation system consists of three distinct units as shown in figure 6:

1. the pumping station located in UX25, outside the ALICE solenoid magnet. At the time of LHC operations it will be accessible only during the short access periods;
2. the filling and purifying station located in CR5, on the radiation shielding plug. It will be accessible at all times during LHC operation;
3. the distribution station located on the HMPID cradle, inside the ALICE solenoid magnet. Although this station will never be accessible during LHC operation, a maintenance of the most relevant components, located in the forefront patch panels, will be possible during the short shut down periods whenever the magnet will be unpowered.

The liquid is continuously pumped from the pumping station to the filling and purifying station from where the liquid flows, by gravity, into the distribution station. The distribution station has been designed to control the flow rate into the radiator vessels as well as the hydrostatic pressure that can be applied to each vessel. After having filled the radiator vessels, the liquid falls into a collector line and eventually returns into the main storage tank of the pumping station from where the cycle restarts.

The three stations are connected by the liquid C_6F_{14} pipes and the aerial gas line where argon flows thus allowing pressure equilibration between the various elements of the circulation system.

The recirculation system does not introduce any specific new type of hazards in the ALICE layout. Stainless steel has been used for all pipes, valves and fittings within the system in order to reduce the occurrence of contamination and leaks. For this reason only metal-metal seals and welded joints have been used. Where it is necessary to dismount components for maintenance, compression fittings have been used. The only exceptions are represented by the pump’s gear (made in PEEK), the O-rings (made in BUNA) of the relief valve and pump, and the O-rings (made in Viton) of the molecular sieve cartridge interfaces and the mechanical filters.

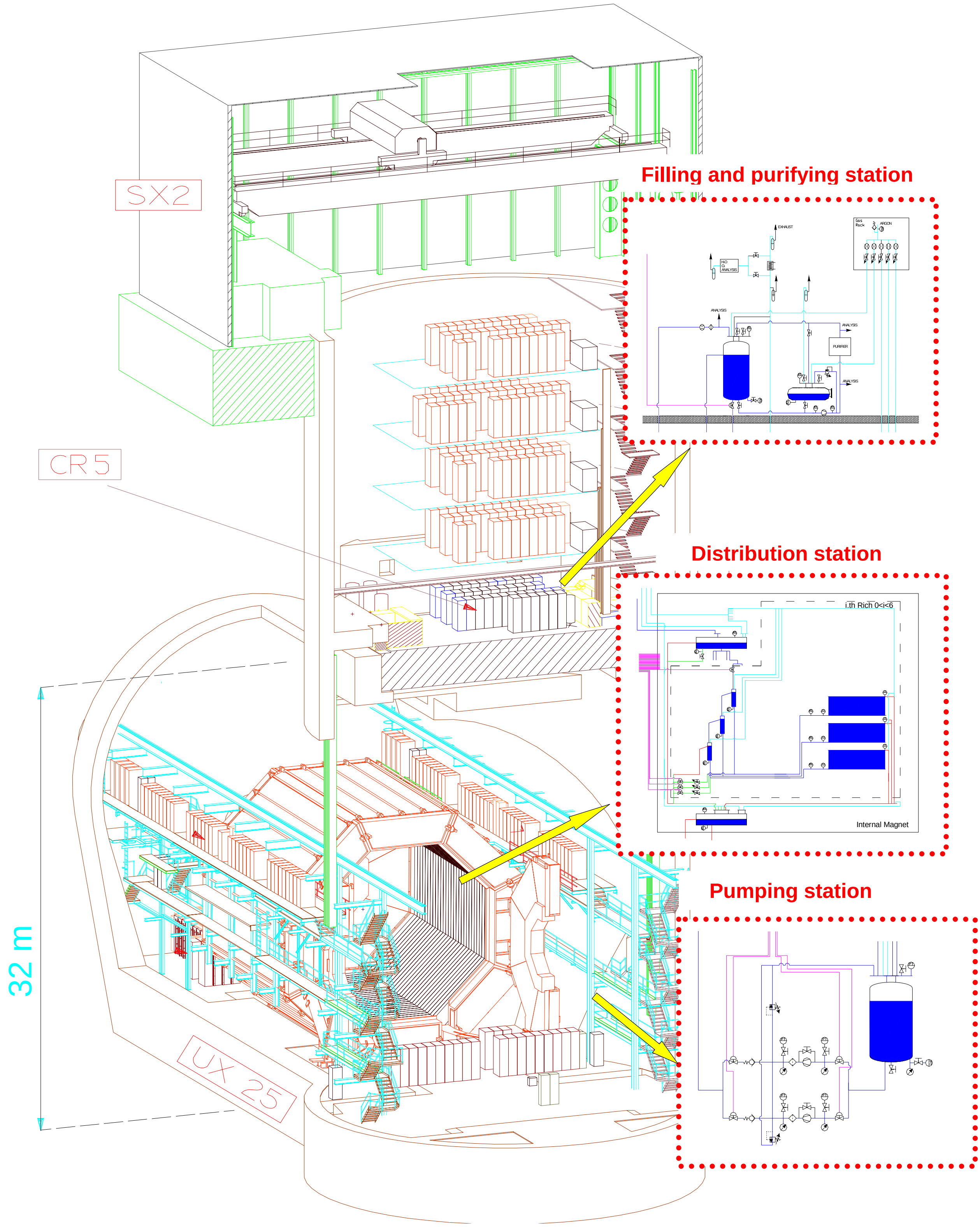


Fig. 6 Location of the three units of the HMPID liquid system in the experimental cavern.

3 Specifications of the system

3.1 The pumping station

The schematic of the pumping station and its connections to the filling and purifying station and to the distribution station are shown in figure 7.

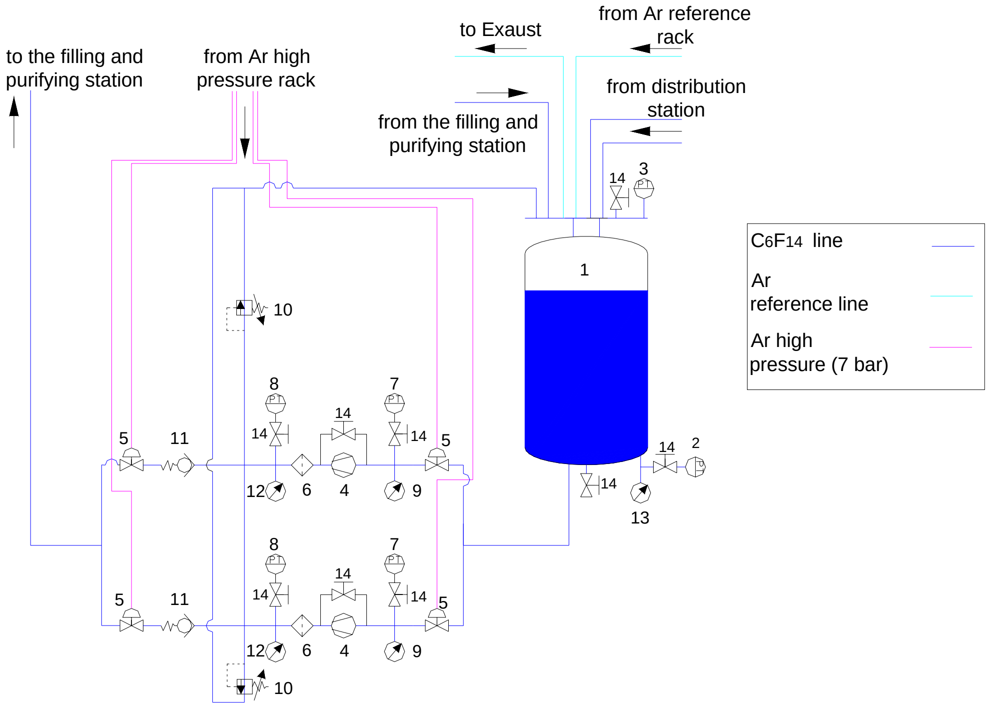


Fig.7. *Schematic of the pumping station*.

The pumping station is designed to supply and receive the liquid of the whole system in order to realize a closed circuit.

A volumetric pump (4) moves the C_6F_{14} from the tank (1), which can contain all the liquid needed for the detector operation, to the filling and purifying station.

The fluid level inside (1) is monitored by combining the two pressure measurements by (2) and (3), manometer (13) as redundant back up. The first one provides the hydrostatic pressure, the second one provides the gas pressure on the top part of (1) which is connected to the gas reference line.

The system is equipped with pneumatic valves (5) to switch ON-OFF the system, filters of protection (6), pressure transducers to control the upstream (7) and downstream (8) pump pressure, manometers as redundant back up (9) and (12), a safety valve (10) to protect the pump unit from any overpressure (7 bar) and a check valve (11) to avoid the flow reversal. Since the pumping station will not be accessible during LHC running period two identical lines, one normally in operation and the other one in stand-by for redundancy, have been designed.

The constraints for designing the pumping station, the pump performance curves and the main characteristics of the components are shown in appendix, respectively in table 1 figure 3 and in table 2.

3.2 The filling and purifying station

The schematic of the filling and purifying station and Ar racks [7] are shown in Figure 8.

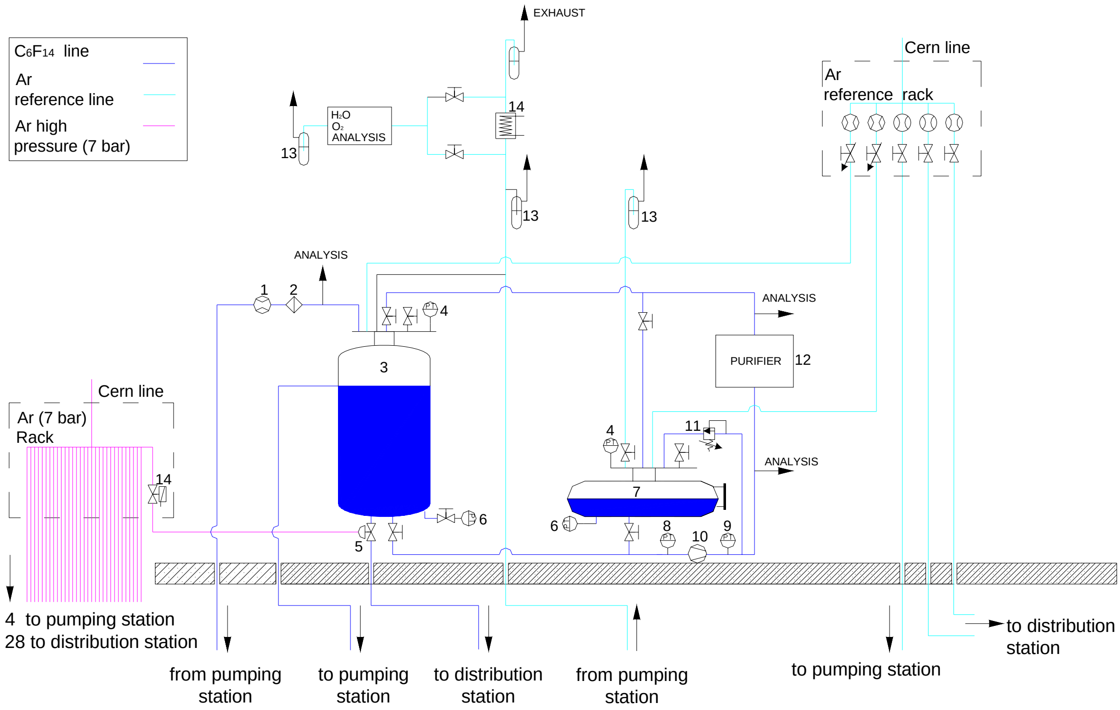


Fig. 8 Schematic of the filling and purifying station.

From the pumping station the liquid goes to the tank (3) from which a fraction of the C_6F_{14} flows to the distribution station, the other one, drawn by means of the pump (10), goes through the purifying system (12) and then back into (3).

In order to avoid the pollution of the purified liquid, a service tank (7) is used for adding unpurified C_6F_{14}.

The system is equipped with a flow meter (1) to check the flow rate, a mechanical filter (2), a pneumatic valve (5) to switch ON-OFF the distribution station's supply line, pressure transducers to control the upstream (8) and downstream (9) pump pressure, a pump safety valve (11), and pressure transducers (6) and (4) to measure, respectively, the hydrostatic pressure and Ar pressure in (3) and (7).

The maximum liquid height in (3) is fixed by means of a large-diameter unimpeded overflow pipe. The main characteristic of the components are listed in table 3.

On-line purification (figure 9) is carried out via two purifier columns installed in parallel such that in the event of one becoming saturated or blocked, the flow of the liquid will be diverted through the second column. Precautions are required when changing columns since an exothermic reaction takes place when replacing the nitrogen purge gas with the process liquid, resulting in formation of important quantities of gas.

Only when there is a steady flow of liquid leaving the column and the temperature has dropped to the ambient one can the empty liquid be shut off and the column isolated. Safety relief valves are installed to protect the system against overpressure. The liquid quality will be continuously monitored on-line via UV-transparency and refractive index measurements.

Among the several manufacturers of perfluorohexane, according to the findings made by the DELPHI and SLD teams, the Company 3M delivers a type of high interest for RICH applications. Labeled Performance Fluid PF 5060 DL, it can be purchased at a reasonable cost and can be cleaned with conventional filters. Following procedures extensively tested by the HMPID group for several years at CERN and in the long endurance experience at STAR, water is actively removed by continuously pumping the liquid through a 13X molecular sieve, while oxygen is simply removed by out-gassing the liquid in a nitrogen atmosphere. A mechanical filter is installed to remove any dust generated by the molecular sieve material.

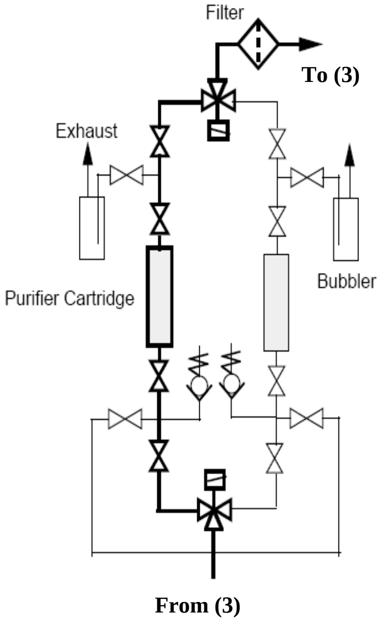


Fig. 9 Schematic of the purifier.

As experienced at STAR, the usual way to reduce the vapor content is to install a cold trap (14) in the escaping argon pipe using Propylene Glycol as cooling liquid.

3.2 The distribution station

The schematic of the distribution station, for one HMPID module is shown in figure 10. The system consists of:

- seven groups of header tubes, each one formed by three columns (5, 6, 7) which supply, by independent lines, three radiator vessels (13, 14, 15) according to a one to one correspondence with modules (figure 11).
  Each header tube (figure 3 in appendix) has a large-diameter unimpeded overflow pipe to control the liquid height, measured indirectly by means of a pressure transducer (8). In this manner, the pressure on the radiator vessels will never exceed 140 mbar. Each header is connected to the gas reference system;

- the tank (2) which supplies the header tubes. The hydrostatic pressure and thus indirectly the height of the liquid, is measured by means of (3), whereas the maximum liquid level is fixed by a large diameter overflow pipe. The top of the (2) is connected to the gas reference line equipped with a pressure gauge (1);

- seven pneumatic valves (4), feed or seal-off the corresponding i-th group (i = 0…6). The pneumatic valves are controlled by electro valves located outside the ALICE solenoid magnet (figure 8). The presence of the two valves system is necessary to avoid gas pockets formed by perfluorohexane, as a result of its high vapor pressure [8], coming in contact with the heated housing of a continuously powered electro-valve. Moreover electro-valves cannot be utilized in a magnetic field;

- twenty-one pneumatic valves (10) allow to empty independently each radiator vessel when required;

- twenty-one precision metering valves (9) on the emptying line of the radiator vessels;

- the tank (17), which receives liquid from the overflow pipes of (2) and of the header tubes, in addition to the drainage and emptying lines. A sensor (19) measures the hydrostatic pressure and thus indirectly the height of the liquid whose maximum value is fixed by large diameter overflow pipe. The top part of (17) is also connected to the gas reference line equipped with a pressure gauge (18).

The main characteristics of the components are listed in table IV (Appendix).

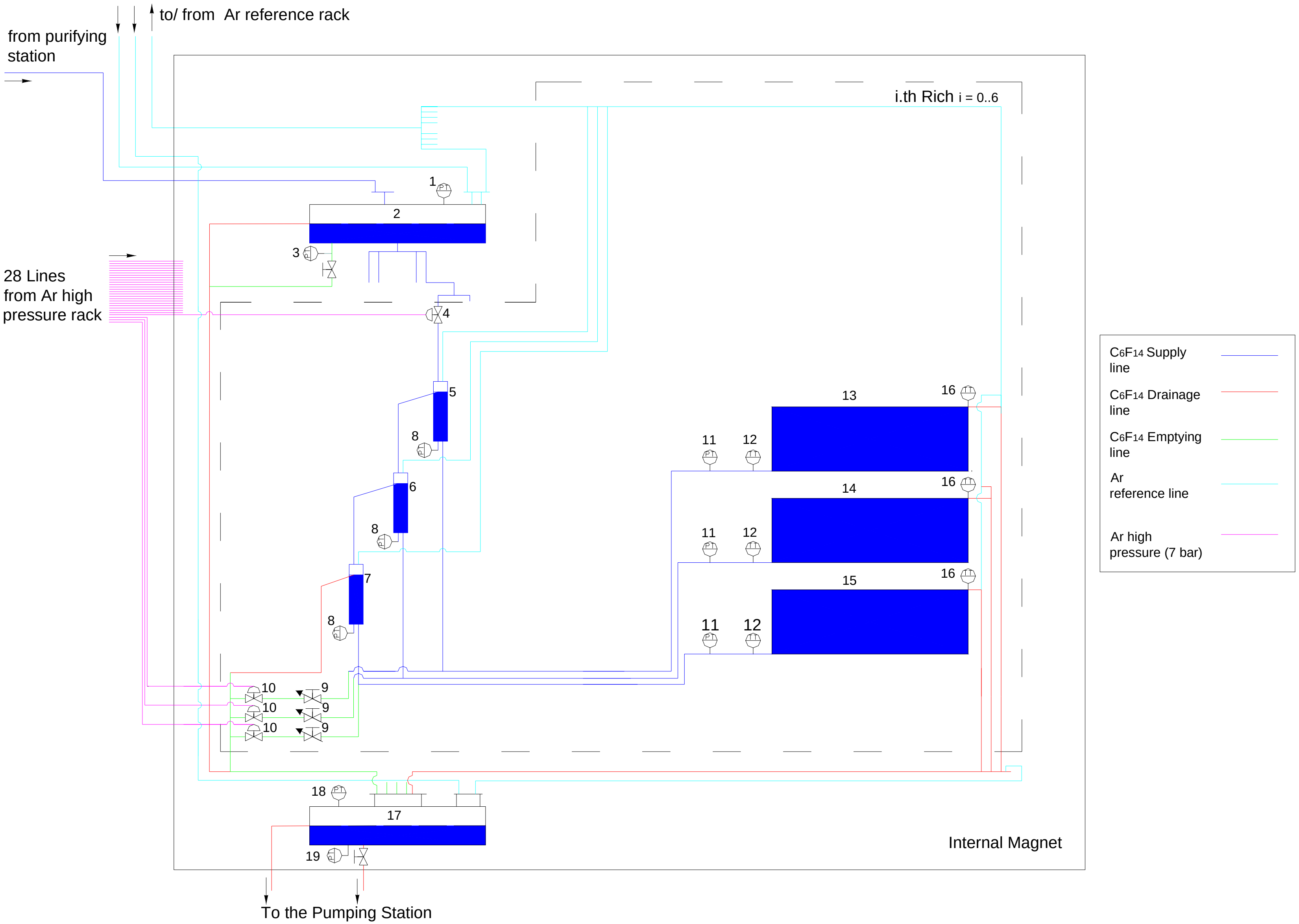


Fig 10 Schematic of the distribution station for one module.

The design of the distribution station between the (2) and the header tubes was based on the following requirements:

- supply twenty-one header tubes at the minimum flow rate of 4 l/h;
- dissipate the excess of potential energy ranging between 0.6 m (for the upper header tubes' group) and 3 m (for the lower group), in correspondence to the point from where the liquid falls into the overflow line (figure 11);
- possibility to isolate the C_6F_{14} supply line of each group and thus the respective module by means of a pneumatic valve.

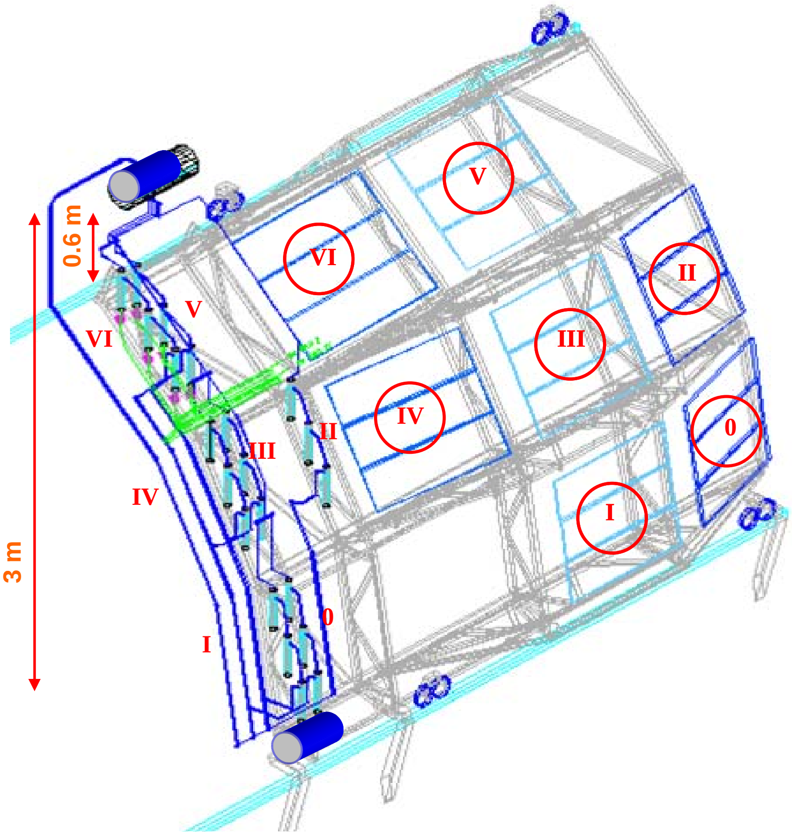


Fig . 11 Schematic view of groups and modules

In order to comply with the above requirements, the fluid flows from (2) to the upper header tube (5) of each group at a flow rate equal to about 16 l/h, by means of four independent lines (figure 10): the first three lines in common with the groups 0-I, III-IV V-VI, subsequently split in six helical lines [9] for each group, while the fourth line goes directly to the group III. The design flow rate has been achieved by properly choosing diameter, length and geometry of each pipe (see table V and figure 4 in appendix).

The feeding scheme to the header tubes (figure 10 and 12) could be named 'cascade'. From (5) a fraction of the liquid flows to the respective radiator vessel (13) at 4 l/h, while the liquid in excess flows to (6) via the overflow line. Analogously, (6) feeds the second radiator vessel (14) and the lower header tube (7) of the group, which is directly connected to the third radiator vessel (15) and, indirectly, to (17) by means of the overflow line. A large diameter collector pipe receives the liquid from the overflows of (7), and conveys it into (17).

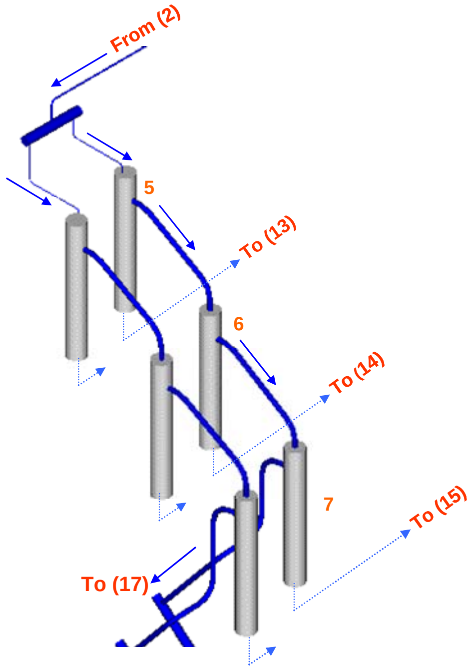


Fig. 12 Axonometric view of the "cascade" scheme.

3.2.1 Header tube – radiator vessel

The basic requirements of the design of the header tube–radiator vessel lines are:

- feed twenty-one radiator vessels at a constant flow rate of 4 l/h. This flow rate must be almost the same (within 10%) regardless the variations with respect to the nominal positions (figure 13) that eventually occurred during the implementation of the various header tube and radiator vessel in the ALICE experimental lay-out;
- ensure a laminar flow into the radiator vessels to avoid turbulences, pressure fluctuations and flow separation;
- fill the radiator vessels from the bottom to displace the argon purge gas through the outlet situated in the upper part of each vessel.

To deliver the required flow rate of 4 l/h, each header tube has been located at a fixed height determined by the orientation and height of its respective radiator vessel and of the pressure losses in the inlet pipes. In order to adjust, during the calibration phase, the height of the header tubes in accordance with the respective radiator vessels location each header tube is equipped with a micrometric screw and with the inlet and outlet pipes having a small flexible part.

The selected internal pipe diameter guarantees a variation of maximum ±10% in the flow rate, when the difference in height between the header tube overflow line and the respective radiator vessel outlet positions varies of ± 1 cm (figure 13).

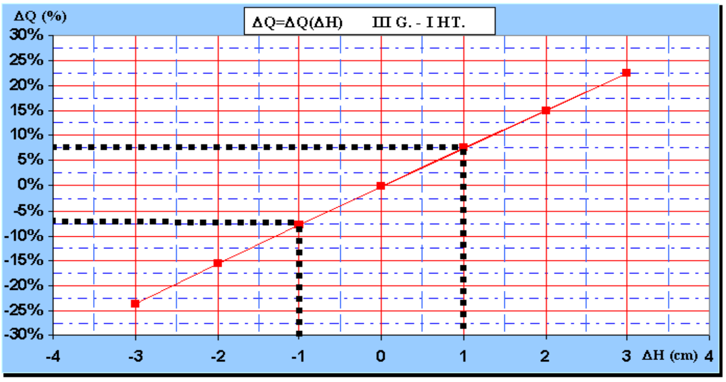


Fig.13 Variation in the flow rate (ΔQ) as a function of the difference in height ΔH between the header tube overflow line and the radiator vessel outlet.

Two pressure gauges on the supply line, respectively located at the bottom of each header tube and at the inlet of each radiator vessel (figure14), provide an indirect way to measure the flow rate by using the following formula:

$$\Delta Q_P = \frac{\pi \times D_{1-2}^4}{128 \times \mu \times L_{1-2}} \times \left(\left|\Delta p_1\right| + \left|\Delta p_2\right|\right) \qquad (1)$$

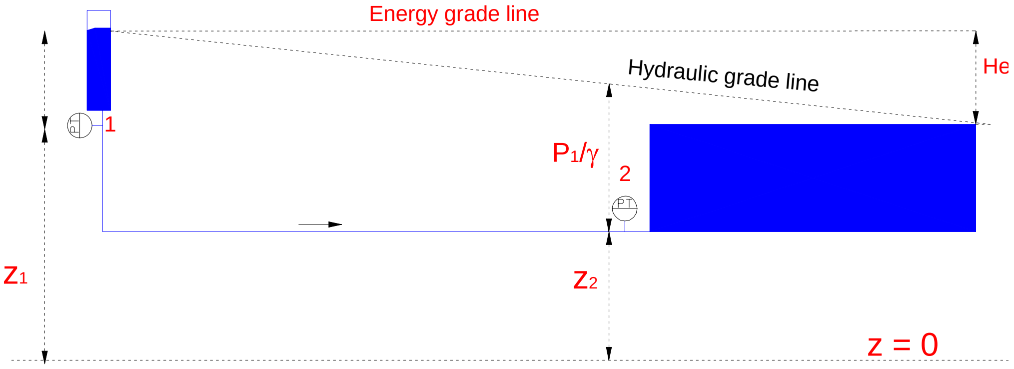


Fig. 14 Schematic of the supply line equipped with two pressure sensors to measure the flow rate.

3.3.2 Radiator vessel drainage and emptying lines

The requirements for designing the drainage lines are:

- drain independently the twenty-one radiator vessels;
- guarantee a supercritical flow.

In order to comply with these requirements, each radiator vessel has an independent large-diameter outlet tube which is connected upward to the gas reference line and downwards to a collector line connected to the (17), which receives the liquid from the twenty-one drainage lines (figure 10).

The requirements for the design of the emptying lines are:

- empty independently the twenty-one radiator vessels;
- ensure the emptying of the radiator vessels at fixed flow rate in order to avoid pressure values below the reference pressure.

Each emptying line is directly connected upward to the correspondent supply line and indirectly downwards to (17) by means of a collector pipe that receives liquid from the other lines (figure 10).
The pneumatic valve (10), located on the line, allows to empty the radiator vessel at a fixed flow rate by means of the precision metering valve (9).

3.3 Principle of operation

From (1), the perfluorohexane is pumped to (2) at a constant flow rate of 180 l/h, against a pressure head of 7 bar. A part of fluid flows from (2) to purifier (3), the other one flows from (2) to (3) at a constant flow rate of 150 l/h; the excess flow, of about 30 l/h, leaves (2) via the overflow pipe and reaches again (1). From (3), the fluid flows to the header tubes (5), according to the 'cascade scheme', with a total flow rate of about 125 l/h; liquid height in the radiator vessels (6) increases until the perfluorohexane starts to overflow from the unimpeded outlet line. The gravity feed produces, at this point, a constant flow rate of about 4 l/h through the radiator vessels. The excess liquid from (4) and from the header tubes flows through the overflow line. The circulation cycle ends soon as the liquid falls from (7) to (1) where the cycle restarts.

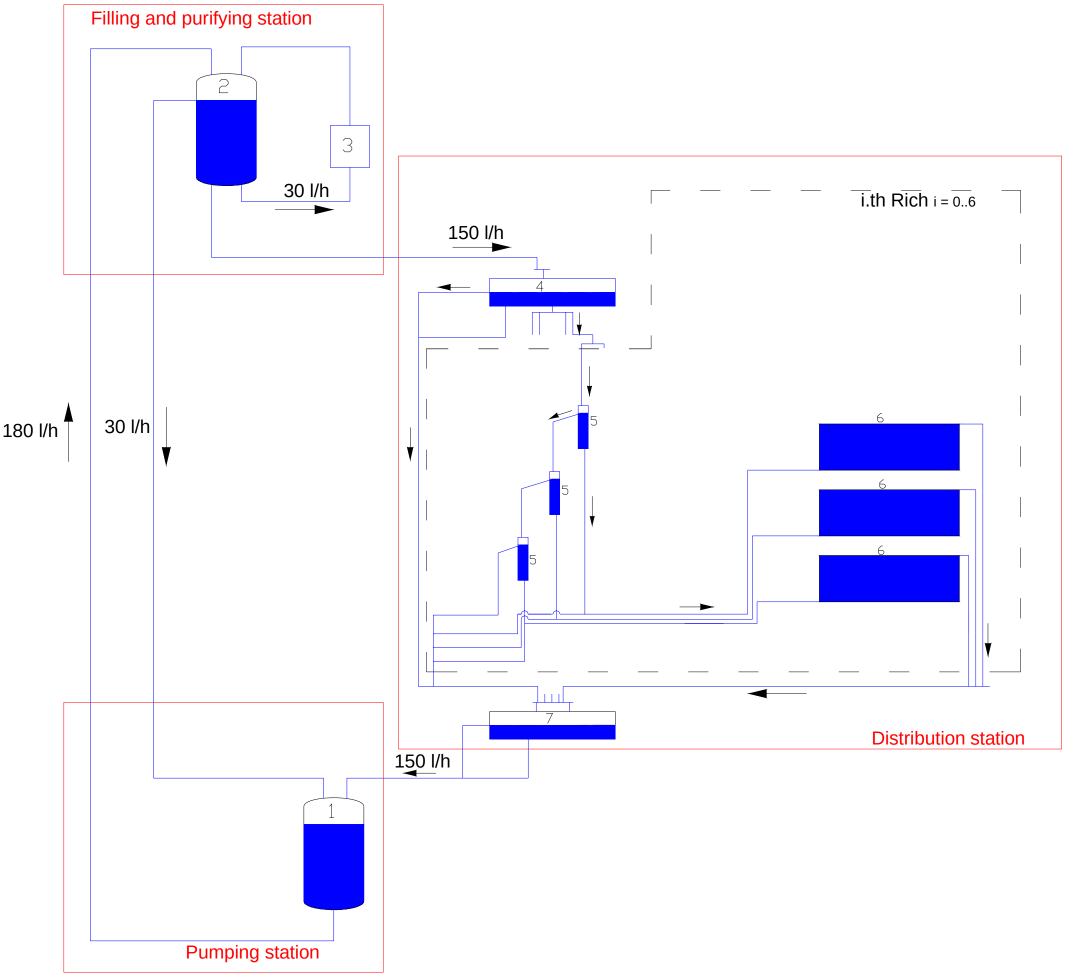


Fig. 15 Schematic of HMPID liquid circulation system

4 The HMPID Control System

The HMPID Detector Control System (DCS), developed in the PVSS SCADA environment [10], is intended to ensure a safe and synchronized operation of the following sub-systems:

- low voltage supplies (LV),
- MWPC high voltage supplies (HV),
- C_6 F_{14} liquid circulation system (LCS),
- gas,
- cooling.

The DCS and the sub-system controls have been modeled as Finite State Machine (FSM) using the SMI++ software tool developed at CERN [11] and embedded in the JCOP Framework. The FSM approach provides the DCS automation, its partitioning and various modes of operation that will make easy the integration or the exclusion of any sub-system control from the main HMPID DCS, and if needed the exclusion of the HMPID DCS itself from the Experiment Control System (ECS). This feature allows the user to operate either the entire detector or the single sub-system in any of the following conditions: debugging, calibration, automatic or manual operation. The HMPID DCS, either at the highest hierarchical level or at the single sub-system control, contains a certain level of automation. When the user issues a command, the control executes a series of operations according to a predefined sequence that prevents or reduce the possibility of operator errors.

The control program for the C_6F_{14} circulation system, based on FSM, has been developed and tested on a prototype of reduced size of the LCS. Resulting performance is reported in [12].

In the following months the overall performance of the hydraulic circuit will be tested in the final experimental location, so far the LCS control has been endowed with a reduced set of automatic behaviors. According to his expertise the operator is anytime asked to acknowledge the control status changing during the system operation (filling, empting …..). A higher level of the control automation will be introduced as soon as precise pressure and temperature trends, recorded during the LCS operation in its final location, will be available.

The system is anyway equipped with a preliminary alarm handling system. If severe alarm conditions occurs (corresponding to the FATAL FSM state) the control automatically move the LCS in a safe state, which triggers the HV and LV ramp down reducing any additional harmful conditions.

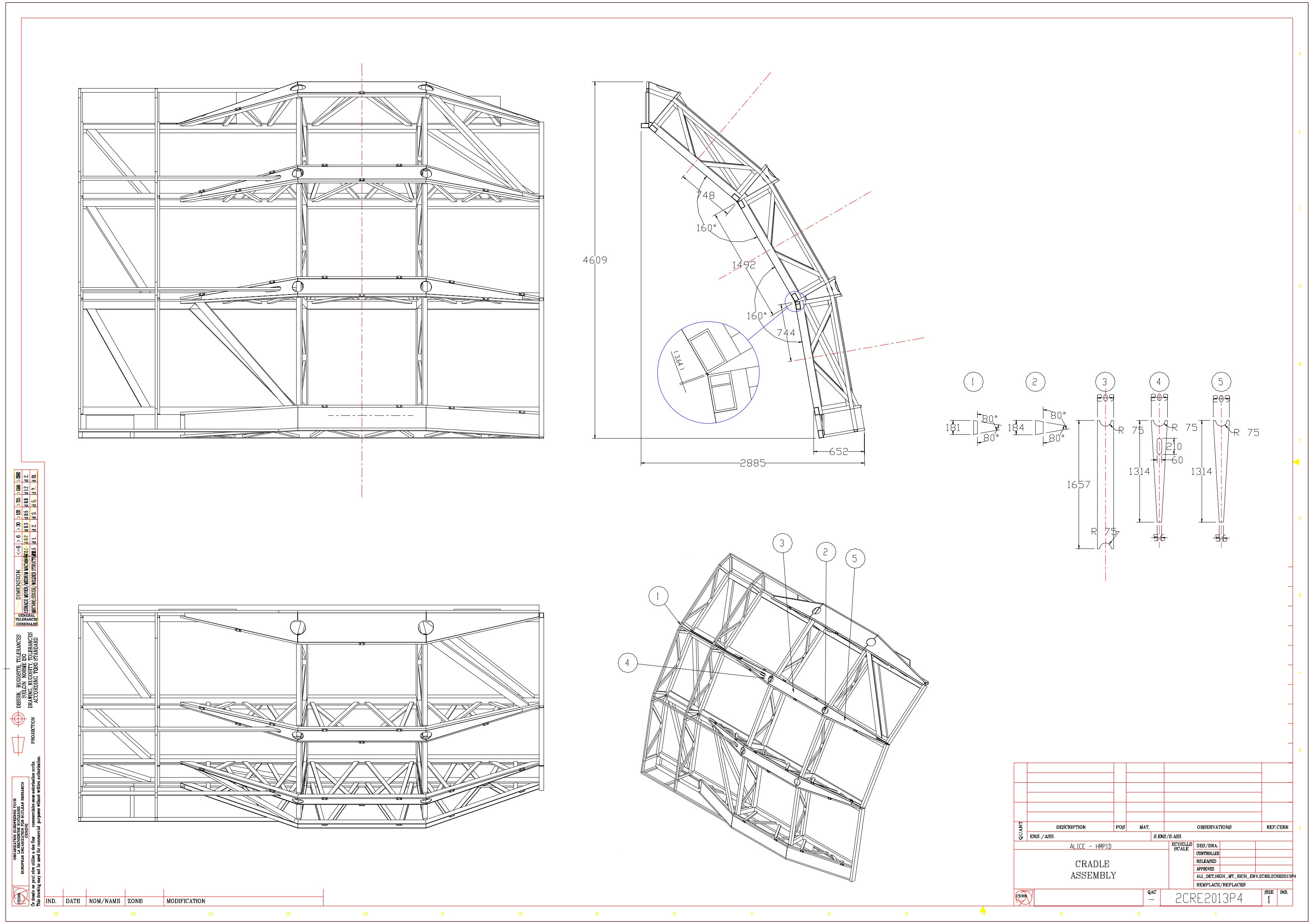
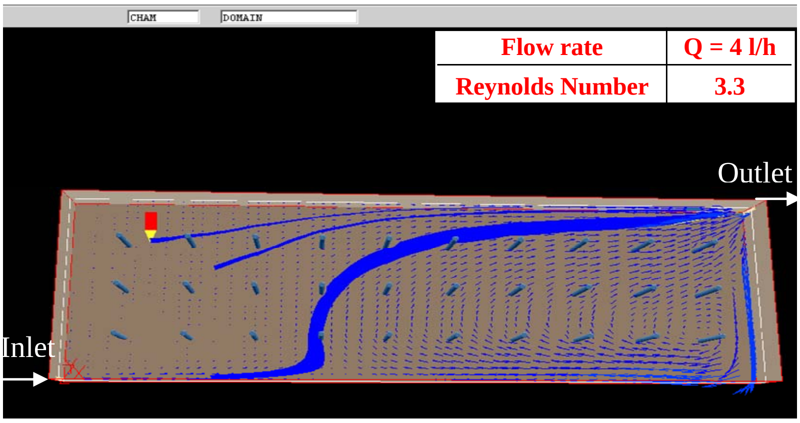


Fig. 1 Cradle assembly layout.



Flow rate	Q = 4 l/h
Reynolds Number	3.3

Fig. 2 Streamlines inside the radiator vessel as evaluated by means of the software PHOENICS

Table 1

C_6F_{14} characteristics (@ 20°C)	
ρ(kg/m^3)	1687.8
μ (Pa*s)	0.00069
ν (mm^2*s)	0.40881
γ (N/m^3)	16475
Constrains	
Hgeo(m)	32
L (m)	50
ID (mm)	19
ε (mm)	0.05
Q (l/h)	200
Pressure operating point of the system	
Hman [bar]	7

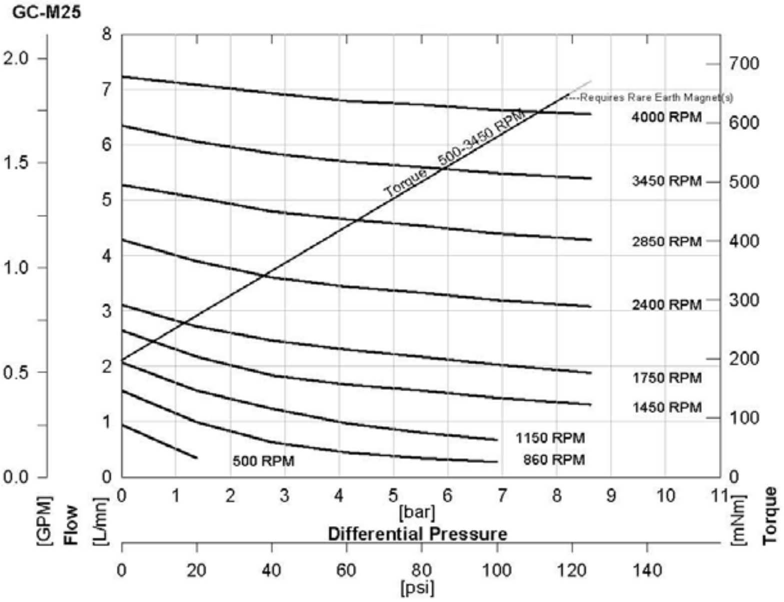
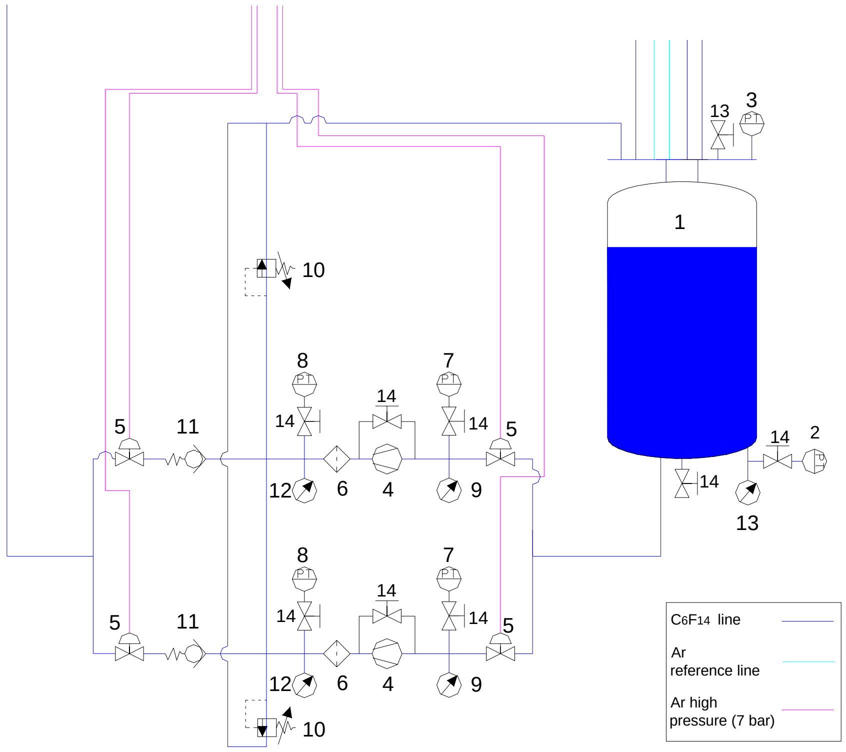
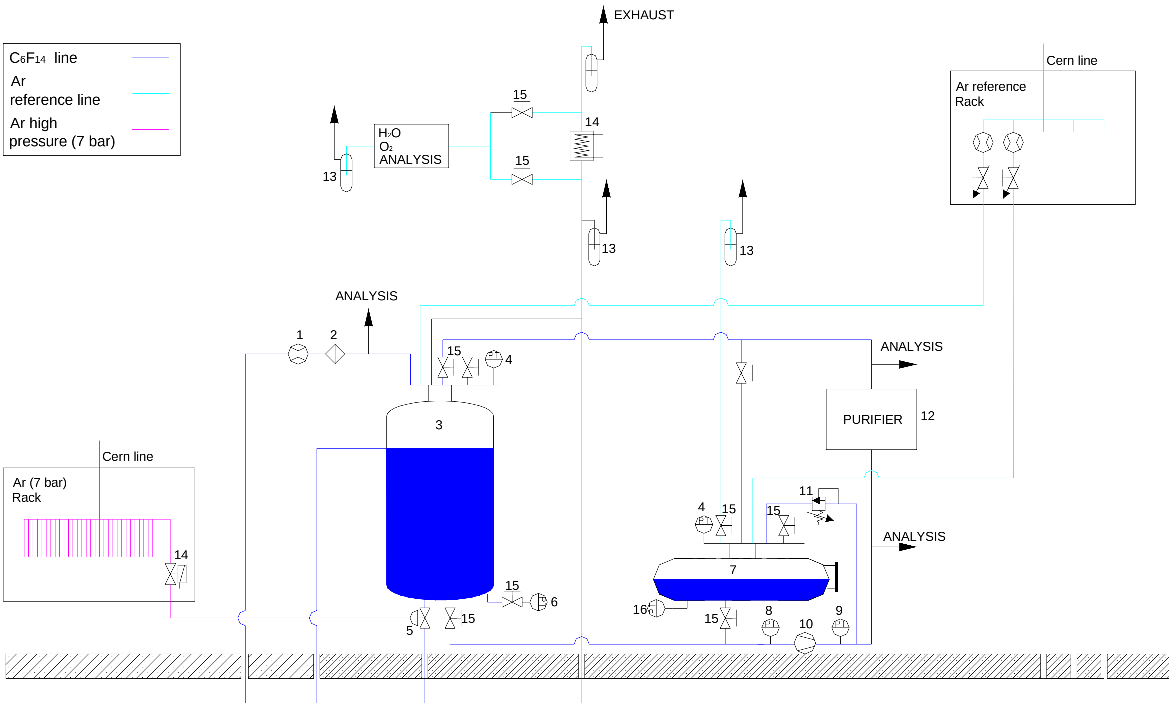


Fig. 2 The performance curves of the adopted pump.



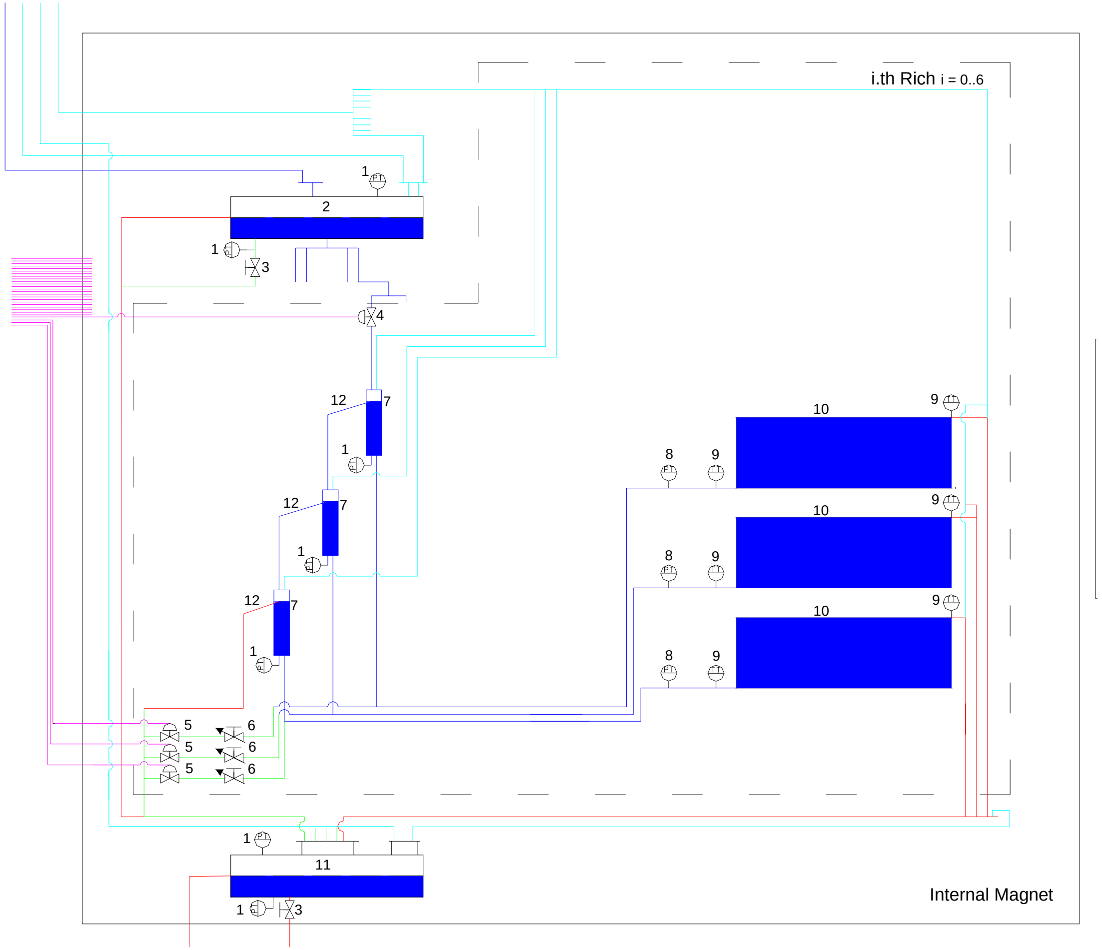
Item	QTY.	Manufacturer	Model	Description
1	1	Cern		Tank 500 l
2	1	Sensor Technics	CTEM9350GN4	**PT** [0:350] mbar
3	1	Sensor Technics	CTEM9350GN4	**PT** [-10:190] mbar
4	2	Micropump	GCM25JBS6	
5	4	Rotarex	K312PM90NFI/RDB12	**PV** On-Off
6	2	Parker Balston	200-35-AAQ	**MF** [0.3 μ]
7	2	Sensor Technics	CTEM9N01GN4	**PT** [-1:1]bar
8	2	Sensor Technics	CTEM9010GN4	**PT**[0:10] bar
9	2	Blondelle		**M**[-1:1] bar
10	2	Swagelok	SS-RL4S12MM-BU	**RV**
11	2	Swagelok	SS-58S12MM	**CV**
12	2	Blondelle	SCEM code 22.41.21.310.7	**M**[-1:10] bar
13	1	Blondelle		**M**[0:1] bar
14	9	Swagelok		**MV** Bellow Valve

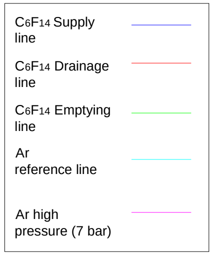
Table 2 Main characteristics of the pumping station ‘s components



Item	QTY.	Manufacturer	Model	Description
1	1	Bronkhorst	M55AGB330	FM [0:500] Kg/h
2	1	Parker Balston	200-35-AAQ	**MF** [0.3 µ]
3	1	Cern		Tank 500 l
4	2	Sensor Technics	CTEM9350GN4	**PT** [-10:190] mbar
5	1	Rotarex	K312PM90NFI/RDB12	**PV** On-Off
6	1	Sensor Technics	CTEM9350GN4	**PT** [0:350] mbar
7	1	Cern		Tank 100 l
8	1	Sensor Technics	CTEM9N01GN4	**PT** [-1:1]bar
9	1	Sensor Technics	CTEM9005GN4	**PT** [0:5]bar
10	1	Liquiflo	45S6PPB100	Pump
11	1	Swagelok	SS-RL4S12MM-BU	**RV**
12		Cern		Purifier
13	4	Cern		**OB** Oil Bubbler
14	33	Cern	SCEM code 18.60.80.905.3	**EV** Electro Valve
15	10	Swagelok		**MV** Bellow Valve
16	1	Sensor Technics	CTEM9350GN4	**PT** [-10:160] mbar

Table 3 Main characteristics of the filling and purifying station ‘s components





Item	QTY.	Manufacturer	Model	Description
1	25	Sensor Technics	CTEM9350GN4	**PT** [-10:90] mbar
2	1	Cern		Tank 23 l
3	2	Swagelok		**MV** Bellow Valve
4	7	Rotarex	M4.1SHPNFI/MA B:RDB6	**PV** On-Off
5	21	Rotarex	M4.1SHPNOI/M AB:RDB1/4	**PV** On-Off
6	21	Swagelok	SS-4BMW	**NV** Needle Valve
7	21	Cern		Column 1.3 l
8	21	Sensor Technics	CTEM9350GN4	**PT** [-10:160] mbar
9	42	Bourdon Haenni	Conical sensor	**TT** Pt100
10	21	INFN Bari		**RV** Radiator Vessel

Table 4 Main characteristics of the distribution station's components

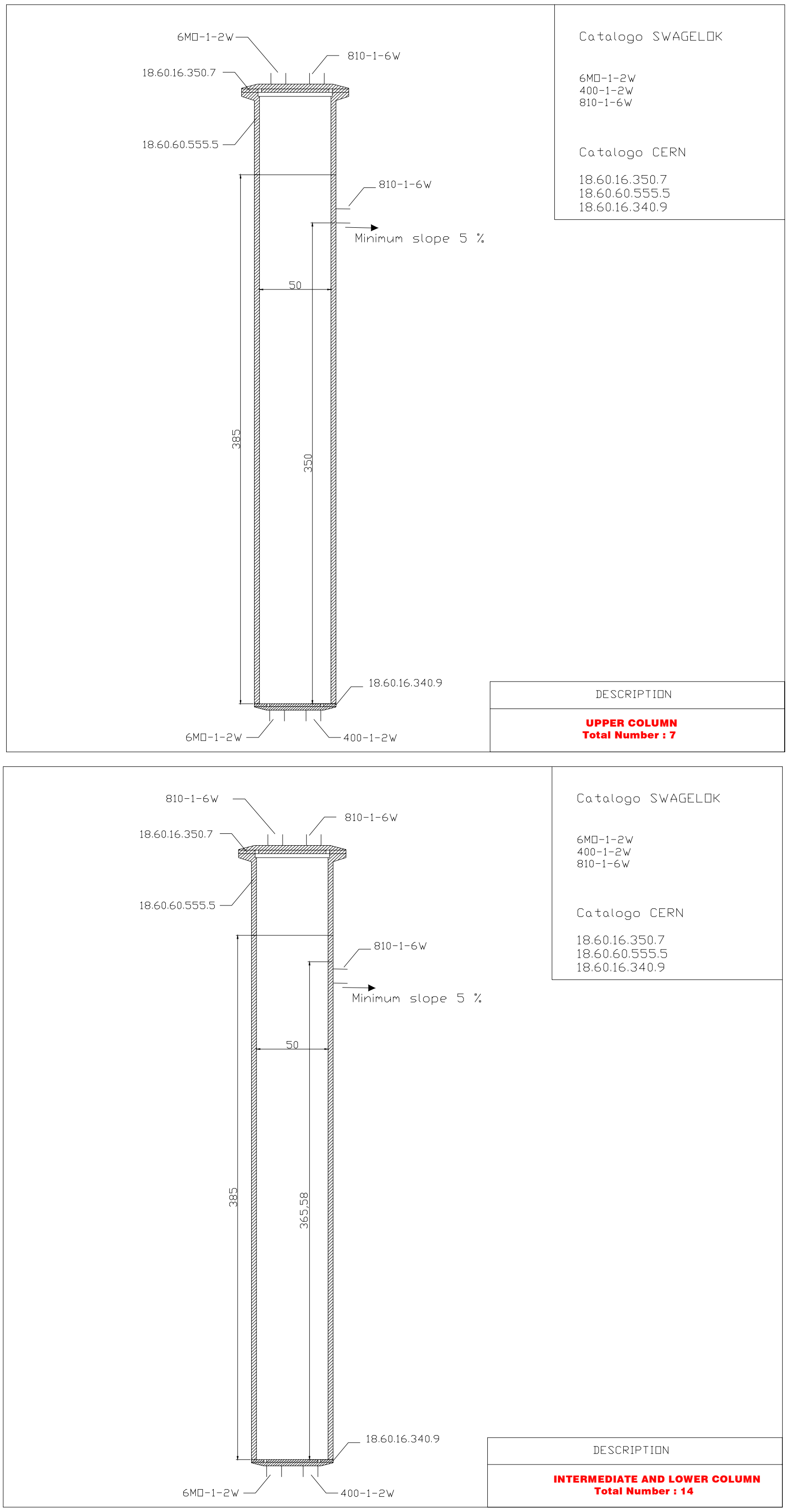


Fig. 3 Drawing of the header tubes.

Group	L_1 [mm]	D_1 [mm]
0	3730	4.0
I	3730	4.0
II	2150	4.0
III	2450	4.0
V	2450	4.0
VI	330	4.0
VII	330	4.0

Table 5 Length and diameter of the lines between the tank and the helical pipes

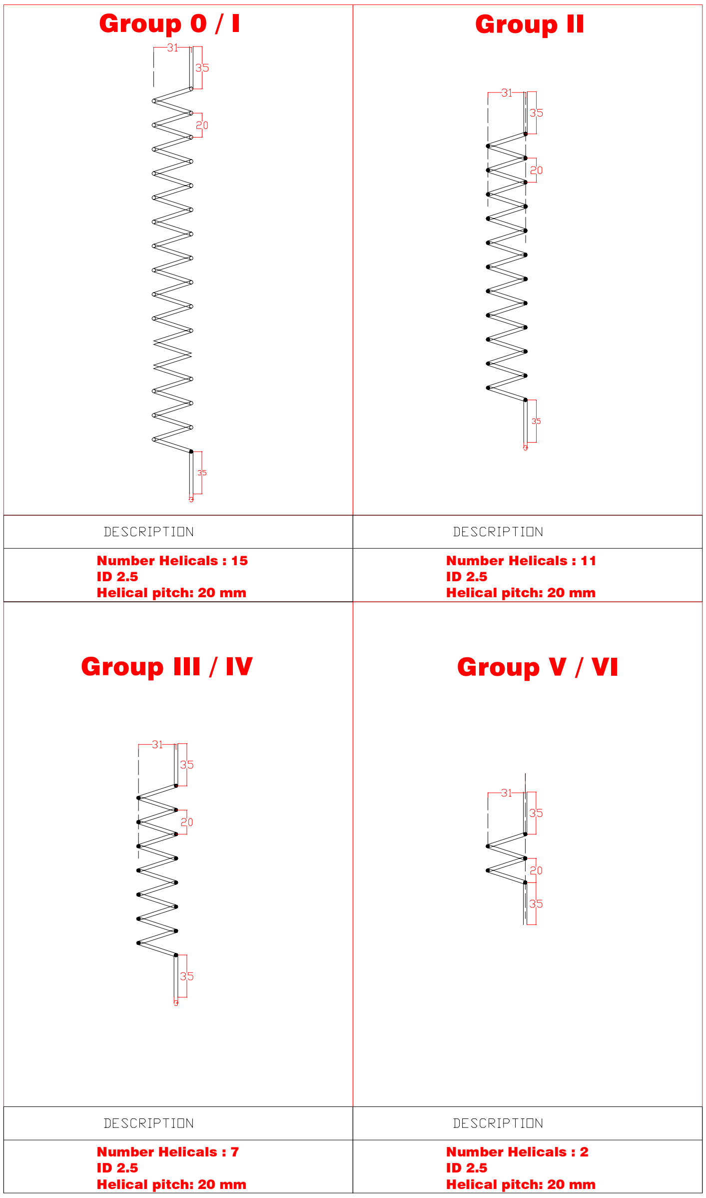


Fig.4 Drawing of the helical pipes

References

[1] ALICE Collaboration, Technical Proposal, CERN/LHCC 95-71.

[2] ALICE Collaboration, PPR Vol.1, CERN/LHCC 2003-049.

[3] ALICE Collaboration, HMPID TDR, CERN/LHCC 98-19.

[4] K. Abe et al., IEEE Trans. Nucl. Sci. 40 4, 1993; SLAC-PUB-5888, 1992.

[5] Y. Andres et al., Nucl. Instr. and Meth. A 486 (2002) 590.

[6] E. Albrecht et al., *Perfluorocarbon effects on composite and polymeric materials used within RICH detectors*, DELPHI note 95-21;
J. Va'vra, Nucl. Instr. Methods A367 (1995) 353.

[7] ALICE Collaboration, *ALICE_InstallationWP_CR5_Cavern.*

[8] *3M™ Performance Fluid PF-5060DL*
http://multimedia.mmm.com/mws/mediawebserver.dyn?6666660Zjcf6lVs6EVs666xWiCOrrrrQ-

[9] Huaiming JU et al., *Hydraulic Performance of Small Bending Radius Helical Cil Pipe*

[10] http://itco.web.cern.ch/itco/Projects-Services/JCOP/welcome.html

[11] http://itco.web.cern.ch/itco/Projects-Services/JCOP/ProjectTeam/Minutes/1999/23-06-99/smi_jcop/index.htm

[12] G. De Cataldo et al, *The integrated HV,LV, and Liquid radiator Control system for the HMPID in the ALICE Experiment at LHC,proceedings* , ICALEPCS 2001

Acronyms

CT	**Vapor recovery refrigerator**
DCS	**Detector Control System**
EV	**Electro Valve**
FM	**Flow meter**
HV	**High voltage**
OB	
LCS	**Liquid Control System**
LV	**Low Voltage**
M	**Manometer**
MF	**Mechanical Filter**
MV	**Manual Valve**
NV	**Needle Valve**
PT	**Pressure Transmitter**
PLC	**Programmable logic controller**
PV	**Pneumatic Valve**
RV	**Relief Valve**
SV	**Safety Valve**
T	**Tank**

Notation

Fluid characteristics

Density	(Kg*m^{-3})	ρ
Specific weight	(N*m^{-3})	$\gamma = \rho * g$
Dynamic viscosity	(Pa*s)	μ
Kinematic viscosity	(m^{2}*s^{-1})	$\upsilon = \frac{\rho}{\mu}$

Geometrical data

Inner diameter	(m)	ID
Pipe Radius	(m)	R
Pipe length	(m)	L
Pipe wall roughness	(m)	ε
Potential energy	(m)	H_{geo}

Hvdraulic factors

Volumetric flow rate	(m^{3} /s)	Q
Cross-section area	(m^{2})	$A = \frac{\pi D^2}{4}$
Flow velocity	(m/s)	$V = \frac{Q}{A}$
Reynolds number		$Re = \frac{\rho V D}{\mu}$
Friction coefficient λ		$\lambda = \frac{1}{4} * \frac{1}{[\ \mathrm{Log}(\frac{5.8}{Re^{0.9}} + \frac{\varepsilon}{3.71D})\ ]^2}$
Hydraulic grade-line		$J = \lambda * \frac{V^2}{2g} * \frac{1}{D}$
Local head loss	(m)	$\Delta h = \alpha \frac{V^2}{2g}$ (α local resistance coefficient)
Total head loss	(m)	$H_{tot} = J * L_{con} + \Delta h_{tot}$
Manometric head	(m)	$H_{man} = H_{tot} + H_{geo}$
Delivery pressure	(Pa)	$P_{man} = H_{ma\ n} * \gamma$
NPSHr	(mbar)	Net Positive Suction Head required
NPSHa	(mbar)	Net Positive Suction Head available