LIQUID COOLLING SYSTEMS (LCS2) FOR LHC DETECTORS.

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Abstract

This paper describes a number of projects involving the liquid cooling of electronics, undertaken by the SF section of the CERN/EST/SM group. These facilities have been specially designed to cool LHC-type detectors, in collaboration with users and services of the ST/CV group.

The liquid circuit operating conditions in large physics detectors can be summarised as follows:

- as the facilities are generally located in temporarily inaccessible areas, the filling, bleeding and draining operations must be automatic;
- the number of active components installed in these areas must be reduced to a minimum and be able to cope with the special conditions prevailing there – magnetic fields, radiation, restricted access;
- the risk of leaks must be reduced as far as possible. If the fluid used is water the consequences of leaks are obvious, while if fluorocarbons are used, the cost of leaks can quickly become prohibitive;
- all parameters must be controllable from the control rooms;
- the equipment, preferably tried-and-tested industrial plant, must be selected in collaboration with the future maintenance and operations services, for certain CERN facilities, for instance, with the ST/CV group.

1. LCS2 OPERATING PRINCIPLE

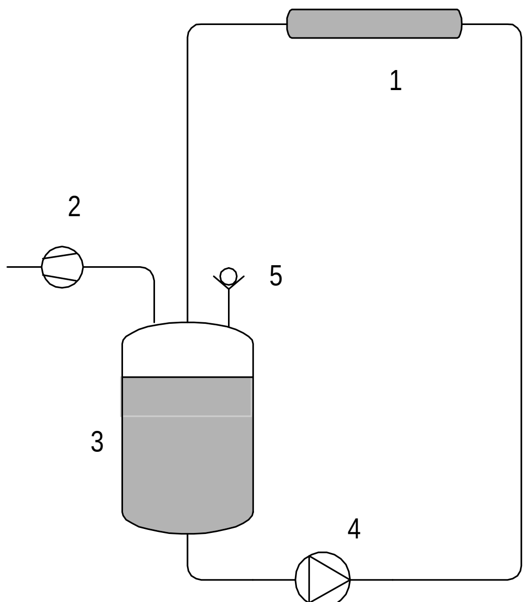


Fig.1

The liquid is held in a storage tank (3) maintained below atmospheric pressure by a vacuum pump (2). A check valve discharges any excess air in the event of drainage and prevents the pressure in the storage tank from rising above atmospheric pressure. The liquid is moved into the exchangers (1) incorporated through the electronic system by a circulator (4).

The pressure at the various points of the circuit depends on the head losses and hydrostatic pressures. The detailed operating principle can be found on the Web [1].

At start-up, if the pressure in the storage tank is not low enough the vacuum pump is activated. While the latter is in operation, in the event of an air intake for instance, the circulator cannot function. The pressure throughout the circuit still equals the pressure in the storage tank.

2. THE COOLING OF THE CERES TPC

2.1 Aims

TPC detectors require a precise operating temperature, 20°C for CERES, with +/- 0.2 °C stability.

The sources of temperature variation in CERES are:

- its proximity to the RICH detector, which can heat up to 50°C,
- the magnet,
- the detectors' read-out electronics,
- the hall environment.

Three types of cooling system have been installed:

- an insulating screen between the magnet and the TPC,
- cold screens against the electronic cards,
- various CO_2 circuits.

2.2 Isolating screen

The screen consists of an aluminium cylinder attached by heat-transfer cement to copper pipes in which water circulates. The pipes are connected to two adjustable-temperature manifold assemblies. The aim is to set a constant temperature outside the TPC, by removing the heat deriving from the environment.

2.3 Cold screens

Attached to each electronic card is a copper plate with welded-on pipe. The plates are water-cooled. The temperature is maintained above dew-point and is the same on all the plates. The aim here is to remove the heat deriving from the electronics.

2.4 CO_2 circuits

A closed CO_2 circuit is used both to prevent air intake by diffusion into the TPC active drift gas and to maintain a uniform temperature. The circuit is divided into 6 sub-circuits, each with adjustable flow-rate and temperature.

2.5 Liquid supply

All the circuits are supplied with water via an LCS2 system. In all the CERES circuits, the pressure always remains below atmospheric pressure.

2.6 Controls

All the circuits are remote-controlled by a PLC. The temperatures are adjusted by individual PID controllers. This facility has been operating continuously for two years, with the only maintenance operation being the replacement of the filters once a year.

3. ATLAS LIQUIS ARGON CALORIMETER COOLING

3.1 Aims

The electronics of this detector gives off a total maximum power of 200 kW. The facility will be 25 m high.

3.2 Description of the facility (Fig. 2)

A 20 kW cooling facility for the calorimeter tests is currently in service at CERN. The chosen technique is to place a liquid-cooled screen between each card; the liquid currently used is demineralised water, circulating partially below atmospheric pressure, although tests with C_6F_{14} were recently successfully carried out.
The water is held in a storage tank (1) maintained below atmospheric pressure by a vacuum pump. A variable-speed circulator (2) injects the water into the riser pipes via a chilled-water heat exchanger (3). Equal pressure is maintained in all the sub-circuits by an expansion valve (4).
The pressure may be adjusted according to the head loss in the circuits, and in the case of the ATLAS calorimeter it will be set at 50 mbars below atmospheric pressure.
The water then flows into the screens and is returned by gravity to the storage tank. The pressure in the riser depends on the hydrostatic pressure and the head loss, and the pressure in the screens is equal to that of the storage tank plus their own head loss.
The facility can operate using other liquids, such as C_8F_{18} or similar. The temperature gradients and flow-rates depend on the properties of the liquids used. We have built a similar system, operating with liquid C_6F_{14}, for the joint tests on the CMS micro-strip gas-chambers and the ATLAS transition radiation tracker. This system has also been used for tests on the ATLAS Tile Calorimeter and the ALICE tracker.

4. COOLING OF THE STAR FTPC

4.1 Aims

TPC-type detectors require extremely precise temperature with +/- 0.2°C stability.
For this facility the temperature stability is also required when the detector is shut down.
The electronics dissipates 600 W.

4.2 Description of the facility (Fig. 3)

The cooling liquid used is demineralised water, which is held in a storage tank (1) and maintained at 0.5 bar below atmospheric pressure by a vacuum pump (2). The water is moved by a circulator (3) into a plate heat exchanger (4), cooled by chilled water from the CERN network.
The temperature is adjusted by a proportional thermal valve controlled by a PID controller according to the exchanger output temperature. This controller has two set temperatures, according to whether the detector power is on or off, and can be modified remotely. The liquid flow is spread over the two circuits by two rotameters.
The system is controlled by a small PLC.

5. CMS PIXEL COOLING

5.1 Aims

This detector, containing silicon pixel detectors, must be kept below 0°C. Its electronics dissipates 16 kW (4). The small diameters of the pipes permissible in the detector impose high pressure drop.

5.2 Description of the system (Fig. 3)

A 7 kW facility capable of operating at –20°C has been built and tested for testing the SI prototypes for CMS.
The liquid used is C_6F_{14}.
As with the facilities mentioned previously, the liquid is held in a storage tank maintained below atmospheric pressure. To avoid losses of C_6F_{14} vapours via the vacuum pump, a molecular sieve trap (28) is installed at the vacuum pump outlet. The liquid is moved into the circuits at an adjustable pressure of up to 10 bars by a variable-speed pump. The liquid then passes through two exchangers – an electric re-heater (10) and an evaporator (11) connected to a refrigerator unit using R404 refrigerant.
The cold liquid is then passed through a distribution manifold to supply the various circuits.
The pressure at the pump outlet can reach 8 bars.

5.3 Controls

The whole facility is monitored by an Ethernet-connected PLC.
The liquid loss protection operates as follows:
- the entire system is first maintained at 0.5 bar below atmospheric pressure for a certain period. If this pressure level remains stable, the circulator pump (9) is switched on and the circuits are filled. After bleeding, the level in the storage tank stabilises; this level is monitored by a controller (3). If suddenly the level in the storage tank falls sharply during operation, the pump is stopped and start-up recommences. Then the faulty circuit has to be identified by isolating the circuits in sequence.

All the drawings and photos of these various systems can be found on the Web [1]

6. CONCLUSIONS

The LCS2 liquid cooling system at controlled low pressure has now been used on most of the facilities for the LHC projects. Users have not encountered any problems and the friendly use is highly appreciated.
For the final facilities in the LHC experiments we propose using 20 to 50 kW capacity modules, spread across the experiments.
These modules would include the liquid storage in the experimental area, together with the circulator pump, the chilled water exchanger and pneumatic regulating valve. All the other equipment would be installed in areas accessible while the detectors are in operation.
The use of similar modules in all the experiments will result in cost savings and will simplify the maintenance.

[1] http://nicewww.cern.ch/~pbonneau/CWGWeb/SFHomePage.htm

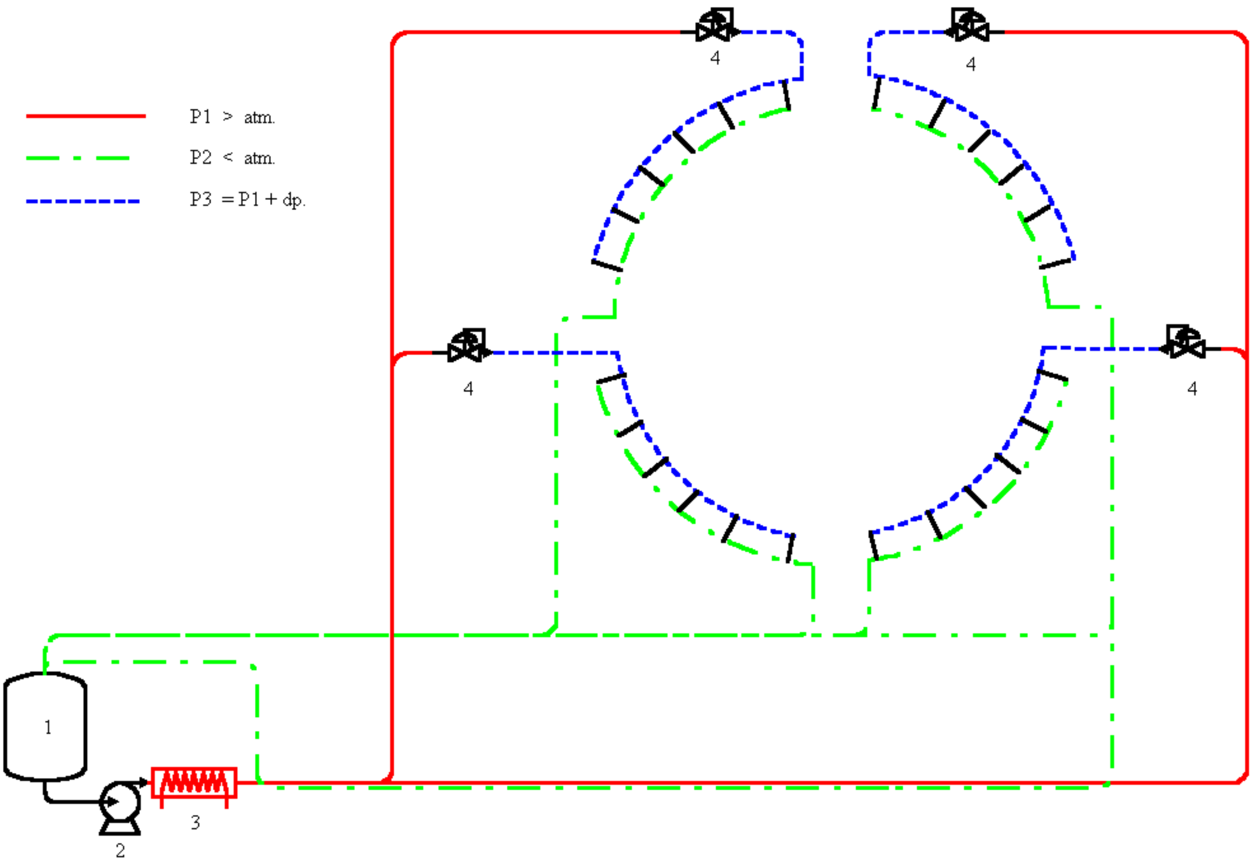
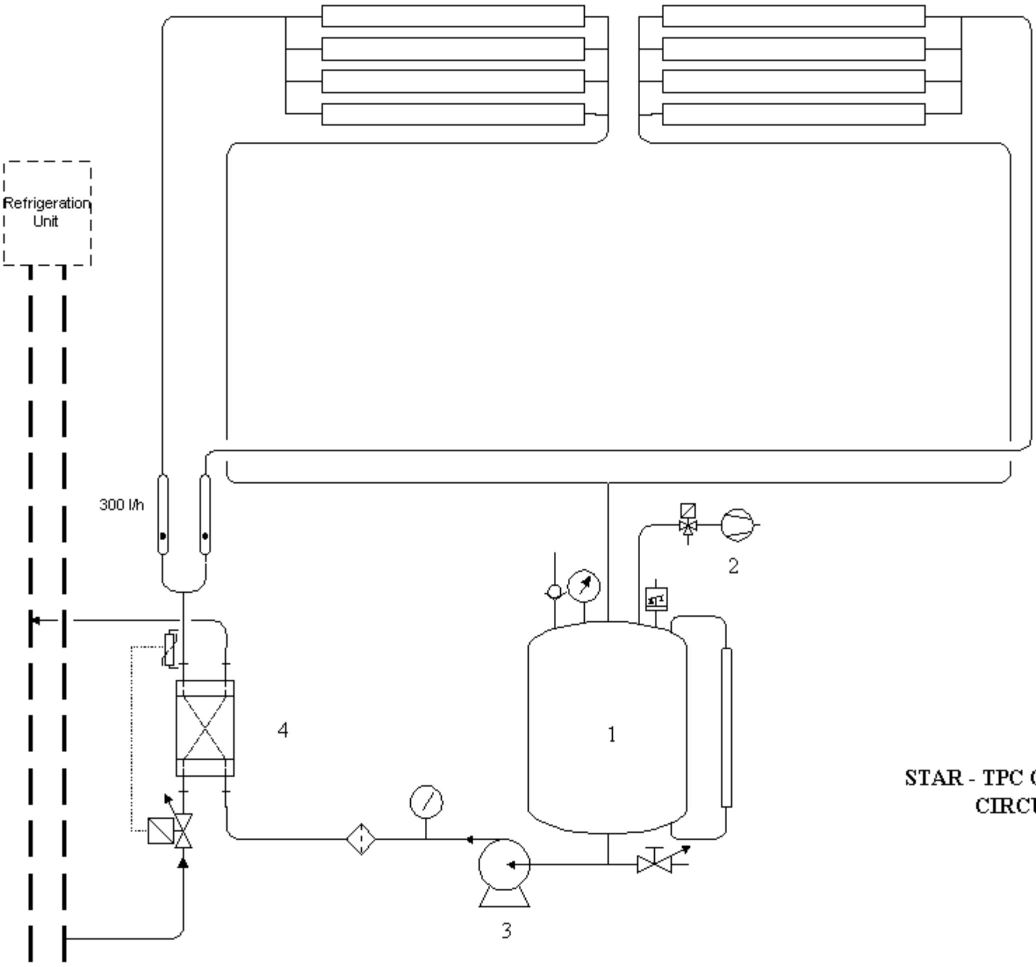
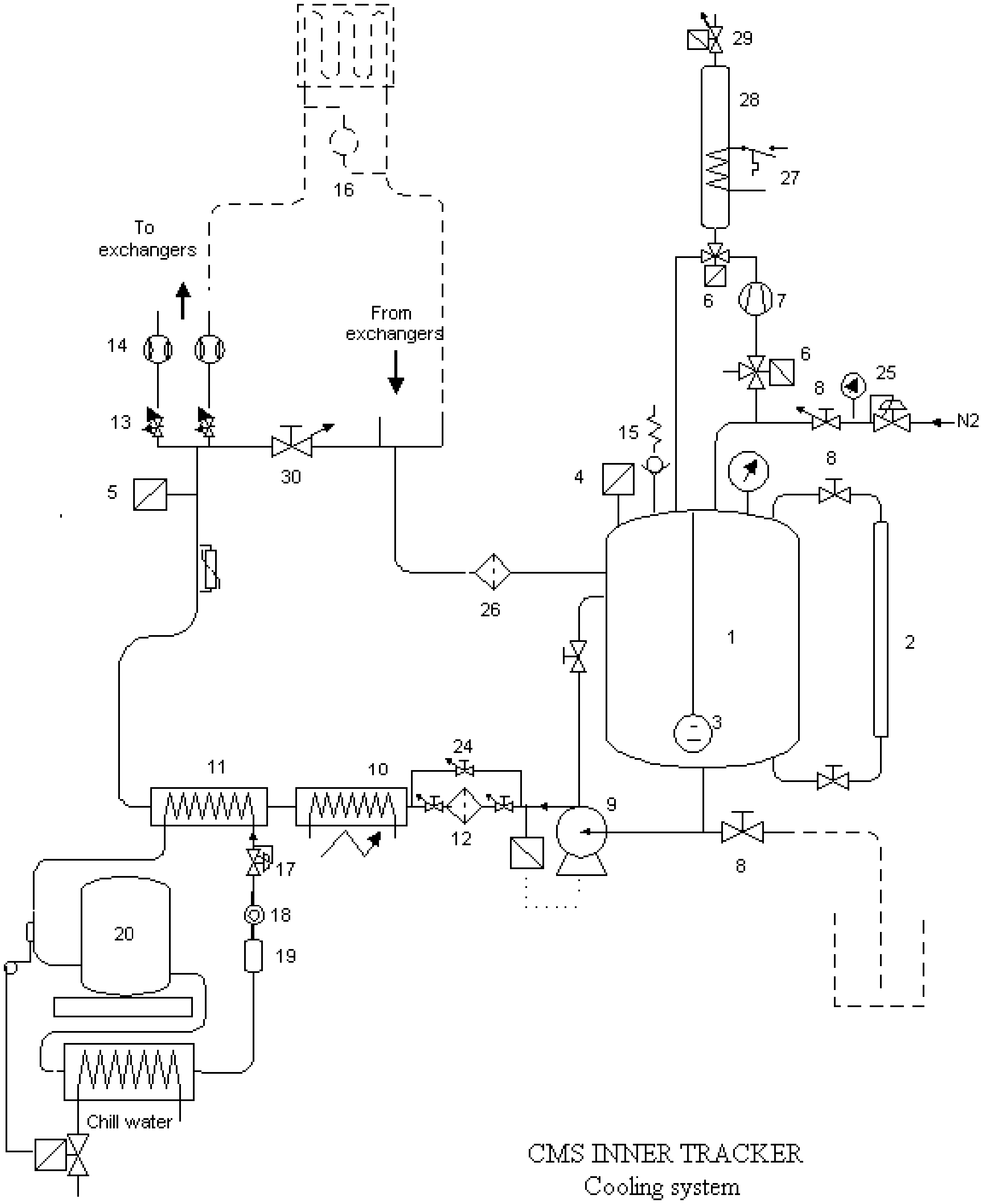


Fig. 2



STAR - TPC COOLING CIRCUIT

Fig.3



CMS INNER TRACKER
Cooling system

Fig. 4