EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE

CERN - ST Division

ST-Note-2003-031
24 February 2003

COOLING PROCESS OF THE LHC ENERGY EXTRACTION RESISTORS

G. Peón, K. Dahlerup-Petersen and G.J. Coelingh

Abstract

The energy stored in all the LHC dipoles, about 11 GJ, can potentially cause severe damage to the magnets, bus bars and current leads. In order to protect the superconducting elements after a resistive transition, the energy is dissipated into dump resistors switched in series with the magnet chains. This paper describes the cooling process of the resistors and explains the choice process for the main components of the cooling equipment.

Presented at the 6th ST Workshop
Thoiry, France, April 1 – April 3, 2003

1 INTRODUCTION

In the LHC, each of the eight dipole magnet chains consists of 154 units and stores 1353 MJ at a current of 13 kA. Two identical systems placed in the LHC underground are in charge of extracting the energy from each chain [1]. The energy extraction system is mainly composed of eight 4 kA d.c. breakers, a current-equalising busway, a powering and control system and a dump resistor assembly [2]. With the aim of reducing the heat dissipation to the air in the LHC underground, each dump resistor assembly has a dedicated water-cooling station. In total, there are sixteen water cooling stations: eight are placed in the main LHC tunnel and the remaining eight in the UA regions.

1.1 Dump resistor's cooling chain

The magnetic energy stored in the LHC dipole magnets passes through five different media before being rejected to the atmosphere: first, the magnetic energy of the dipole magnet chain is dissipated in the dump resistors' body that heats up to a temperature of about 300^{o}C. By forced convection, the energy is then transferred to an air closed circuit that surrounds the resistor body. The air is cool down in an air-water heat exchanger by the water in the secondary circuit of the dedicated cooling stations (see Fig. 1). In the heat exchanger of the cooling station, the energy is then transferred to the main demineralised water circuit of the LHC. In turn, this circuit is cooled in the UW caverns by the primary circuit. The primary circuit conveys the energy to the atmosphere through the cooling towers at the even points of the LHC.

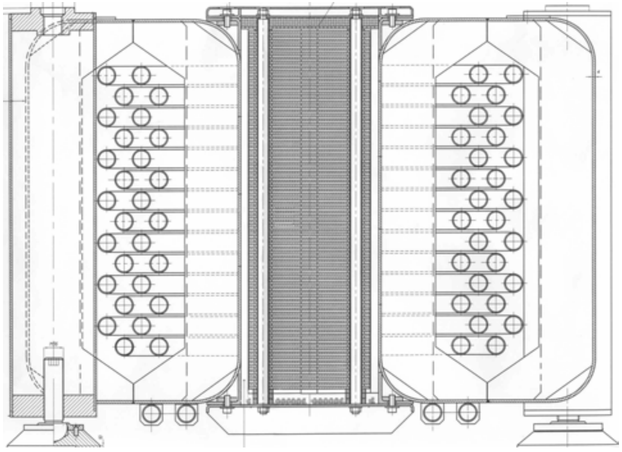

Figure 1 Cross section of a dump resistor with the air-cooling tubes and the tanks of the secondary water circuit. The resistor body in the center.

2 DESCRIPTION OF A COOLING STATION

The dedicated cooling stations for the dump resistors use demineralised water as cooling agent in both circuits. In the primary circuit (cold circuit), the quality of the demineralised water is kept to values of 0.1μS/cm by means of recirculation cartridges installed in the circuit. On the other hand, in the secondary circuit (hot circuit) the electrical conductivity of the water is not an important issue as it can rise to 300 μS/cm without any risk for the equipment. A schematic diagram of the station is shown in Fig. 2.

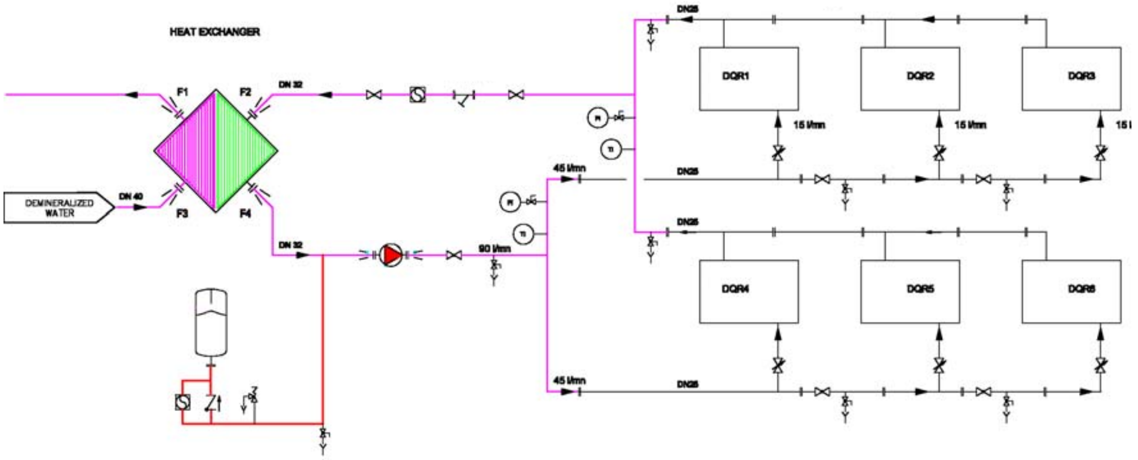

Figure 2 Schematic diagram of a cooling station for the dump resistors

The main compoments of the cooling station are the heat exchanger, the expansion vessel and the pump (see Fig. 3). There are two flow switches, one to indicate the availability of enough water flow in the secondary circuit and a second one to indicate a major water leak in the secondary circuit. A pressure switch avoids the circuit to reach a gauge pressure higher than 1 bar.

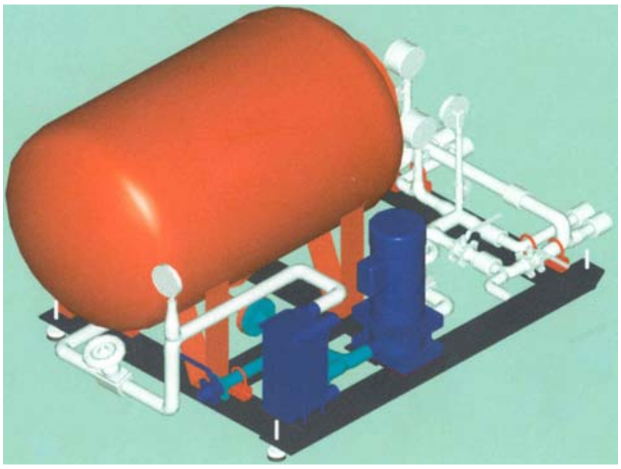

Figure 3 3D model of a prototype cooling station for the dump resistors

3 PARTICULAR REQUIREMENTS FOR THE COOLING STATION

3.1 Able to work with no cooling in the primary side

One of the main requirements comes from the fact that the energy stored in the LHC dipoles must be removed even if, for any reason, the cooling in the primary side does not work at all. In that case, it is assumed that all the energy stored in the dipole magnets passes to the water in the cooling station's secondary circuit. In the 5 m^3 water volume that each secondary circuit contains, the increase in temperature is 33.5 K and the volume change is about 70 liters. This is the main input for the dimensioning of the expansion vessel.

3.2 Temperature recovery time in the resistor

The will of the LHC group is to be able to re-power the LHC two hours after the occurrence of an energy extraction. Calculations were done and presented in [2], see Fig. 4. The simulation considers the inlet water temperature always constant and equal to 25^{o}C. In the real case, the supply cold water in the primary circuit is 27 ^{o}C and the highest supply temperature in the secondary circuit will be about 30 ^{o}C. In the graph, it can be observed that the maximum water temperature is about 41 ^{o}C and it occurs one hour after the beginning of the extraction process. Therefore, the maximum power needed in the heat exchanger is 100 kW. This determines the dimensioning of the heat exchanger and the needed water flow in the cooling station's primary circuit.

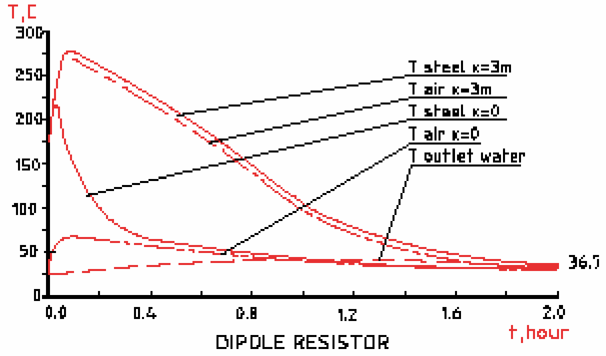

Figure 4 Temperature evolution in a dump resistor during the energy extraction process [2]

3.3 Low pressure in the resistor’s tanks

For design requirements, the resistor’s tanks require a gauge pressure lower than 1 bar. The expansion vessel must be pressurised at 0.25 bar in order to avoid a pressure below the atmospheric when the pump is off for the dump resistor vertical configuration. This implies that the nominal pressure in the pump must be lower than 0.65 bar (a pressure relief valve will avoid a higher pressure if the pump works at zero flow). Being the pressure loss in the tank 0.15 bar, it remains only 0.5 bar for the rest of the circuit. This requirement is extremely demanding for what concerns the filter, the heat exchanger and the flow switch.

3.4 Dump resistors configuration

There are two types of configuration depending on the position in the LHC underground: the 3 DQR tanks housing the resistors are one on top of the other when placed in the UA galleries and are in a row when installed in the main ring tunnel, just below the beam tubes (see Fig. 5). The position in the tunnel limits the height of the equipment in the cooling station whereas the position in the UA gallery reduces the available pressure drop in 0.25 bar.

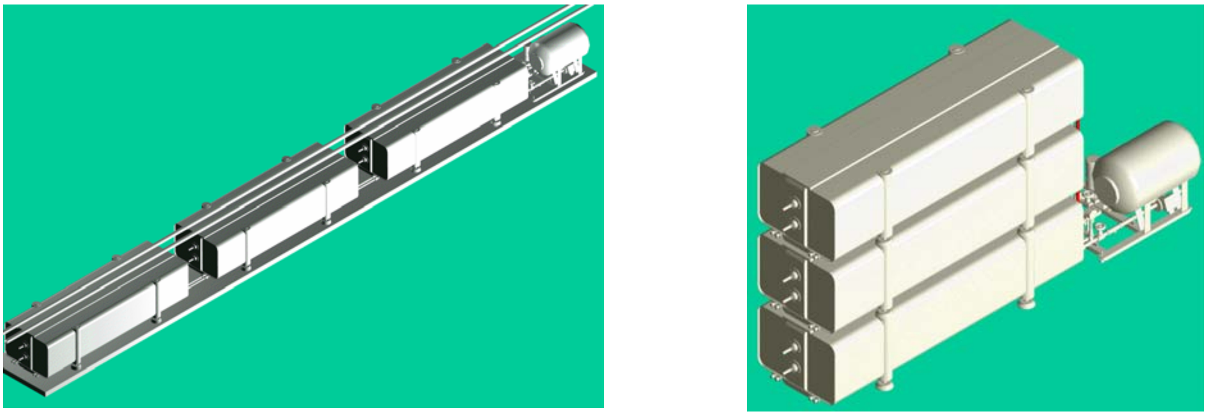

Figure 5 Dump resistors and cooling station in the ring tunnel (left) and in the UA galleries (right)

3.5 Radiation constraints

The expected radiation dose for the dump resistor’s cooling stations below the beam screen is about 20 Gray/year. For a 20-year operation, the total radiation load accounts for about 400 Gray. According to literature [3] materials such as EPDM, Nitrile rubber (NBR), PVDF, Viton, PEEK, PUR, PP, PE and Nylon can withstand such a dose.

4 CONCLUSIONS

ST/CV participates in the design and construction of dedicated cooling stations for the dump resistors in the 16 energy extraction systems of the LHC dipoles. The dump resistors have very particular features. The consequences for the different components in the cooling station are drawn and are presented in this paper. The delivery to CERN of the first of the 16 cooling station is foreseen for January 2004.

5 REFERENCES

[1] K. Dahlerup-Petersen et al., “Energy extraction for the LHC superconducting circuits”, PAC’2001, Chicago, USA

[2] K. Dahlerup-Petersen et al., “Energy extraction resistors for the main dipole and quadrupole circuits of the LHC”, EPAC’2000, Vienna, Austria

[3] Report CERN 82-10, “Compilation of radiation damage test data, pt 3: materials used around high-energy accelerators”