THE DAΦNE WATER COOLING SYSTEM

L. Pellegrino, LNF-INFN, Frascati, Italy

Abstract

A water cooling system for the DAΦNE complex has been constructed and operated successfully. Special care has been taken to improve system reliability and temperature accuracy during the design, the realization and the commissioning; specific solutions have been adopted to meet accelerator requirements. Here the design, specifications and results of performance tests are revised.

1 INTRODUCTION

The DAΦNE complex cooling system is divided in three subsystems (LINAC, Damping Ring, Main Rings) and is the heart of the fluid auxiliary system of the whole installation.

More than 1200 meters of piping ranging from 12" to 1" convey treated and cooled water from pumping stations to end users in the accelerator buildings. All pipes are made of stainless steel jointed in situ with high quality TIG welding.

Table 1: DAΦNE complex cooling system data

Cooling Power	9 MW
Users Supply Mean Temperature	32°C
Water (Demineralized)	65000 liters
Water (Towers)	14000 liters
Flow (Demineralized)	133 liters/s
Flow (Towers)	382 liters/s
Tower Makeup Water	4 liters/s
Supply Pressure Range	800-500 kPa
# Towers	6
# Pumps	40
# Distribution Manifolds	147
# Hose Couplings	1780
# Control Loops	26
# Measure Points	384

The cooling system has to fulfill three main requirements: reliability and safety, low level of mechanical vibration and temperature stability and accuracy.

Stable functioning rely on high degree of modularity: each pump or tower has a spare on line, and both work alternatively; moreover each control valve or heater is driven by a stand alone DDC controller put in a network with the main PLC. Therefore a central fault will not affect peripheral units, and greater flexibility is achieved.

Tower water treatment has been employed to minimize makeup and time consuming maintenance operations.

Safety is ensured by automatic section of main branches in case of leakage, high sensitivity flow switch on each distribution manifold, absence of gaskets or sealing due to fittings to prevent leakage for material aging and inert gas tank pressurization to minimize O_2 corrosion. Water conductivity control has been adopted (< 0.5 μS/cm) by on-line mixed bed deionizers and continuous monitoring. Reverse osmosis demineralizer can quickly refill water leakage (e.g. during maintenance work).

In order to reduce vibrations, water velocity in piping has been kept low (less than 1 m/s) and evaporative cooling has been preferred to chillers; as a matter of fact, optical instruments used in surveying magnets (sensitivity 0.02 mm) has shown no appreciable movement.

Here emphasis will be put on preliminary results on temperature control in the Main Rings subsystem.

2 GENERAL DESCRIPTION

The components of Main Rings (magnets, synchrotron light absorbers, power supplies and RF apparatus, divided in three subsystems by pressure level and localization) are cooled by demineralized water. The heat removed is rejected in the secondary side of a rank of heat exchangers. Finally the heat is dissipated in evaporative towers which cool the primary side of the exchangers.

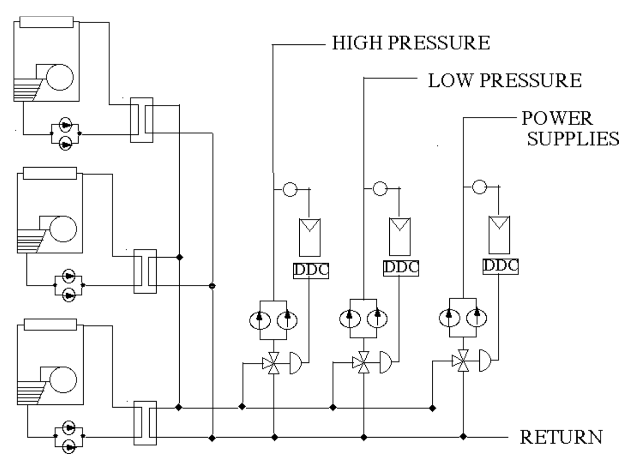

Figure 1: Main rings cooling system schematic

2.1 Temperature regulation system

The temperature regulation is accomplished in three stages: first, cooling towers have a coarse, three steps regulation by progressive fans insertion.

Second, a line of three-way valves on each sub-circuit of the secondary side makes a finer stabilization by mixing fresh and hot (return) water. This stage is sufficient for most accelerator components.

Third and last stage, two kind of different devices arrangements keeps temperature stable up to RF components requirement.

1. A cascade of two electric heaters refines and limits at the lower end the temperature of each RF circulator and coaxial load.

2. Disconnected circuits (sub-sub-systems) for cavities are realized by interposition of a rank of heat exchangers for each cavity. The primary side of these exchangers is cooled by magnet circuit water with a variable flow, three way valve arrangement for first temperature adjustment; at the secondary side, water cools the cavity, keeping temperature under finer control with a cascade of two electric heaters.

A system of pressure driven valves keeps water pressure stable when difference between end users pressure drops could lead to flow disuniformity.

3 MAGNETS SUBSYSTEM WATER TEMPERATURE

3.1 Temperature stability

Thanks to the two stage regulation system, the temperature stability of subsystems is fully satisfactory.

Preliminary data taken in June 1998 at sunset time is shown in Fig. 2. The effect of the two first stages of regulation is clear. The bottom line shows the temperature regulated by the tower fans insertion only; the upper line shows the temperature stabilized by the 3-way valve.

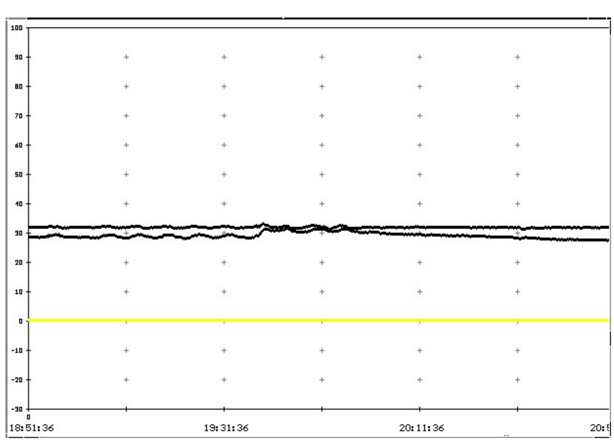

Figure 2: Secondary system temperature stabilization

3.2 Indirect measure of temperature stability

Figure 3 shows the temperature measured on splitter magnets power supply by load resistivity change. The plot obtained is useful an index of the actual temperature stability of cooled coils, taking into account the effect of the thermal capacity of the distribution system and of the magnet itself. The range of temperature is kept very narrow in spite of the large dead time between the control valve and end users.

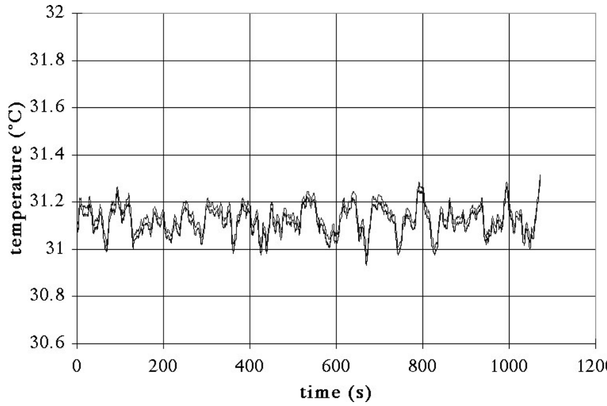

Figure 3: Temperature reading at splitters coils

4 CAVITIES SUB-SUBSYSTEM WATER TEMPERATURE

4.1 Cavity cooling design

The two DAΦNE normal conductive RF cavities are made of copper, with cooling tubes brazed in caves machined on their surface.

The cooling of the cavity body has been designed to keep its temperature uniform within 3°C, to allow homothetic volume changes with coolant temperature (see Tab. 2).

Table 2: Cavity cooling data

Total flow	18	m^3/h
# of circuits	44	
Tubes inner ø	8	mm
Pressure drop	13	kPa
Water velocity	0.6	m/s

A very accurate 3-D simulation and measurements on the first cavity have been done to verify tubes spacing and coolant flow distribution. The difference in flow among the 44 circuits is below ± 8%.

A transient analysis has been performed taking into account the actual fluid flow and heat exchange with the body. The results of simulation of the cavity body response vs. time to a step change of the coolant temperature at the inlet of the tubes are shown in Fig. 4.

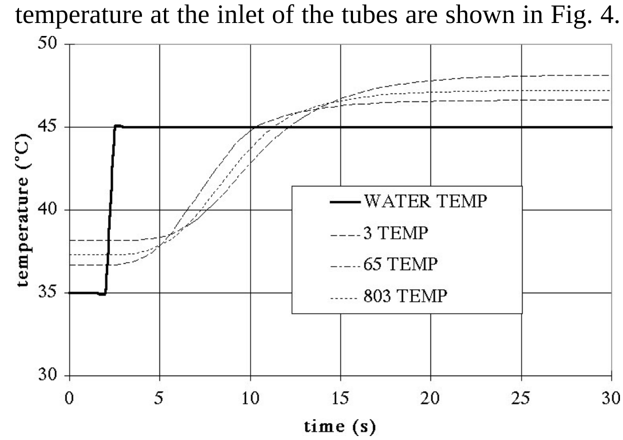

Figure 4: Calculated cavity temperature response

The analysis highlights the really fast thermal reaction of the massive copper body.

Then, thermal-structural analysis has given 0.01-0.02 mm/°C displacements in the range of 35-45°C.

Applying the field distribution calculated in [1], the ensuing resonant frequency shift has been evaluated as 10 kHz/°C in the same range.

4.2 Temperature control loop

The three elements placed in cascade act on the coolant before entering the cavity (see Fig. 5). Two independent loops with the same set point control the 3way valve and the two heaters (50 and 12 kW). The three actions are simultaneous but with different gains and integral effects.

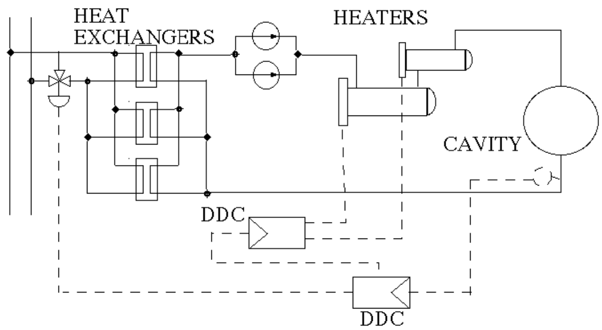

Figure 5: Cavity cooling circuit

4.3 Sensitivity analysis

A first setup of the control loop has allowed a sufficient stable operation of the cavities at fixed temperature (32 ± 0.5°C) during DAΦNE commissioning.

An NI-DAQ board SCXI 1120 and LabView have been employed to remote monitoring four points of the cavity surface during operation.

A data acquisition is reported in Fig. 6, showing the response of the cavity system to a set point step change of 5°C.

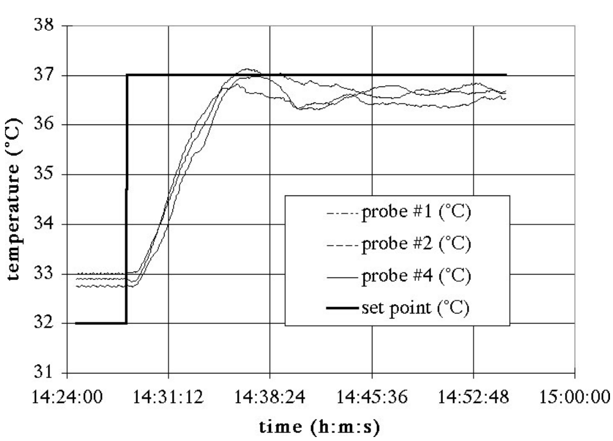

Figure 6: Cavity temperature response to step change

4.4 Cavity response to temperature variation

Recently a check on the effect on cavity geometry and resonant frequency has been performed.

First the tuner position at several temperature set points has been recorded (Table 3, 2nd row). The temperature accuracy available has been enough to ensure stable readings because variations are below the lower limit of the tuner feedback sensitivity.

Then frequency spectra have been recorded with tuner position locked (Figure 7 and Table 3, 3rd row).

Table 3: Effect of temperature variation on RF system

Temperature (°C)	tuner position (mm)	frequency shift (MHz) (tuner off)
32	16.520	368.2326
37	17.071	368.2253
42	17.735	368.1962
47	18.403	368.1668

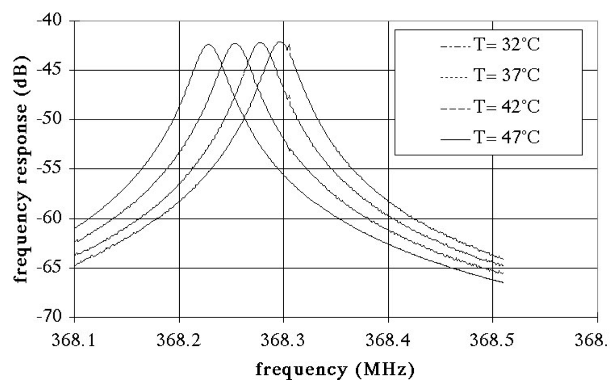

Figure 7: Cavity frequency change with temperature

10 CONCLUSIONS

First operation of cooling system has shown a good adequacy to the required tasks, and permitted successful achievement of DAΦNE Project important milestones.

For cavity circuits, the next goal is to keep the temperature stability within 0.1°C, while having a response to set point changes as fast as possible, should it be needed for RF tuning.

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