INVESTIGATION OF THERMAL INSTABILITIES IN THE ALBA COOLING SYSTEM, BASED ON NUMERICAL SIMULATIONS AND EXPERIMENTAL MEASUREMENTS

F. Hernández†, M. Quispe*, E. Ayas, J.J. Casas, M.Ll. Fuentes, J. Iglesias, C. Colldelram

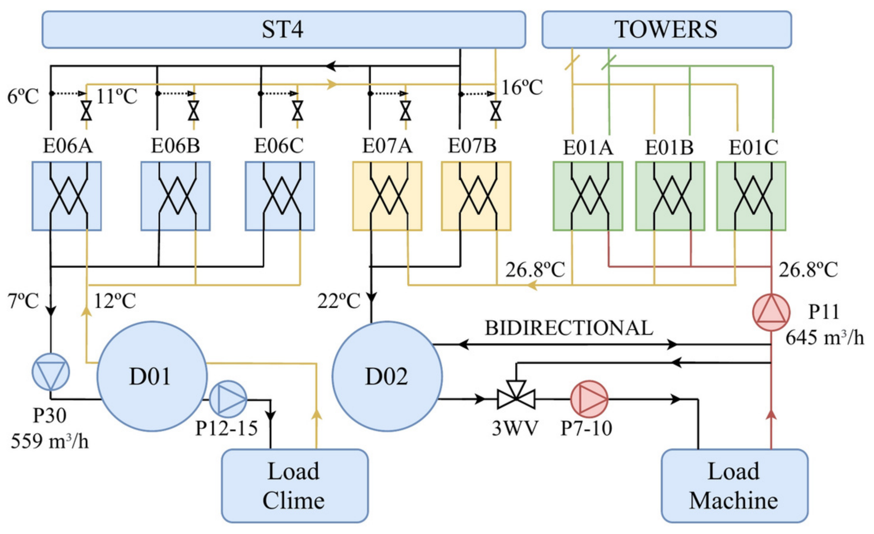
ALBA-CELLS Synchrotron, 08290 Cerdanyola del Vallès, Spain

ABSTRACT

This paper presents an investigation into the thermal instability problems that currently affect the ALBA Cooling System. During these periods of instabilities, which occur for a few hours every week of operation, there are deviations up to +1.5 ºC, concerning the nominal temperature of 23 ± 0.2 ºC in the four rings of ALBA: Service Area, Booster, Storage and Experimental Hall. This problem has a direct impact on the quality of the beam of the Accelerator. Previous studies have preliminarily concluded that the causes of this problem are due to (1) thermohydraulic anomalies in the operation of the external cogeneration plant, which supplies cold water to ALBA, and (2) cavitation problems in the pumping system (the water mass flow has been reduced to 67% of its nominal value to temporarily mitigate the cavitation). In order to confirm these hypotheses and propose solutions to the problem, an investigation has been developed making use of one-dimensional thermohydraulic simulations, performing Computational Fluid Dynamic (CFD) studies, statistical evaluations of data taken from our control system, and systematic flow measurements in critical areas, with ultrasonic flowmeters. As a result of this research, a set of solutions and recommendations are finally proposed to solve this problem.

THERMOHYDRALIC CIRCUIT

The inlet temperature in E07 heat exchangers is unstable, as the cogeneration plant ST4 has an irregular behaviour, altering the tank temperature as consequence. It is important to understand the temperature evolution in the thermohydraulic circuit to determine which behaviour should ALBA have at these moments of instabilities. These anomalies are affecting the heat exchanging in E06 & E07.



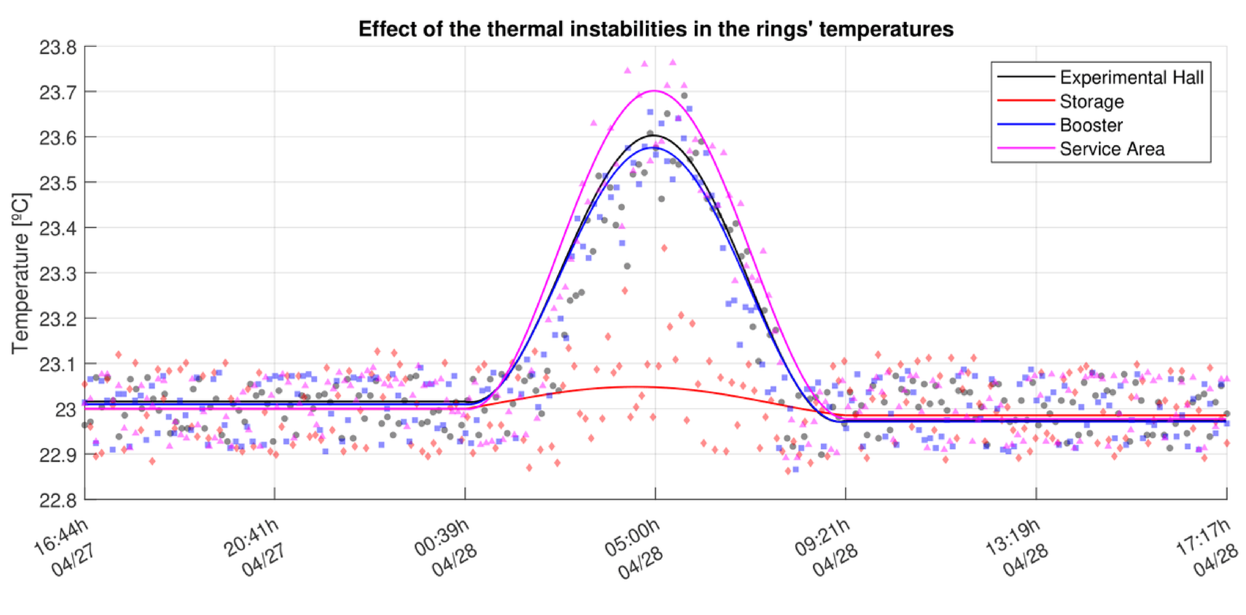
Scheme of the thermohydraulic circuit

Picture of the P11 pump

The ST4 anomalies appear during changes in its operating modes, which last 10 hours per week as an average, decreasing the external mass flow and/or increasing its temperature. Otherwise, the mass flow circulating through ALBA's circuit is reduced to 67% of the design specified value of 650 m^3/h due to a cavitation phenomenon that appeared in the P11 pump. This second anomaly, in addition to the ST4 unstable behaviour, is strongly affecting the D02 tank thermal stability.

THERMAL INSTABILITIES

The temperature peaks caused by the thermal instabilities appear in the first hours of the morning. These have a mean duration of almost 9 hours and have reached a maximum value of 1.5ºC. In this example, the mean amplitudes of the temperature oscillations for the Experimental Hall, Storage, Booster and Service Area rings are 0.59ºC, 0.05ºC, 0.57ºC and 0.70ºC, respectively.



Inlet temperature of the rings. Date 28th of April of 2021.

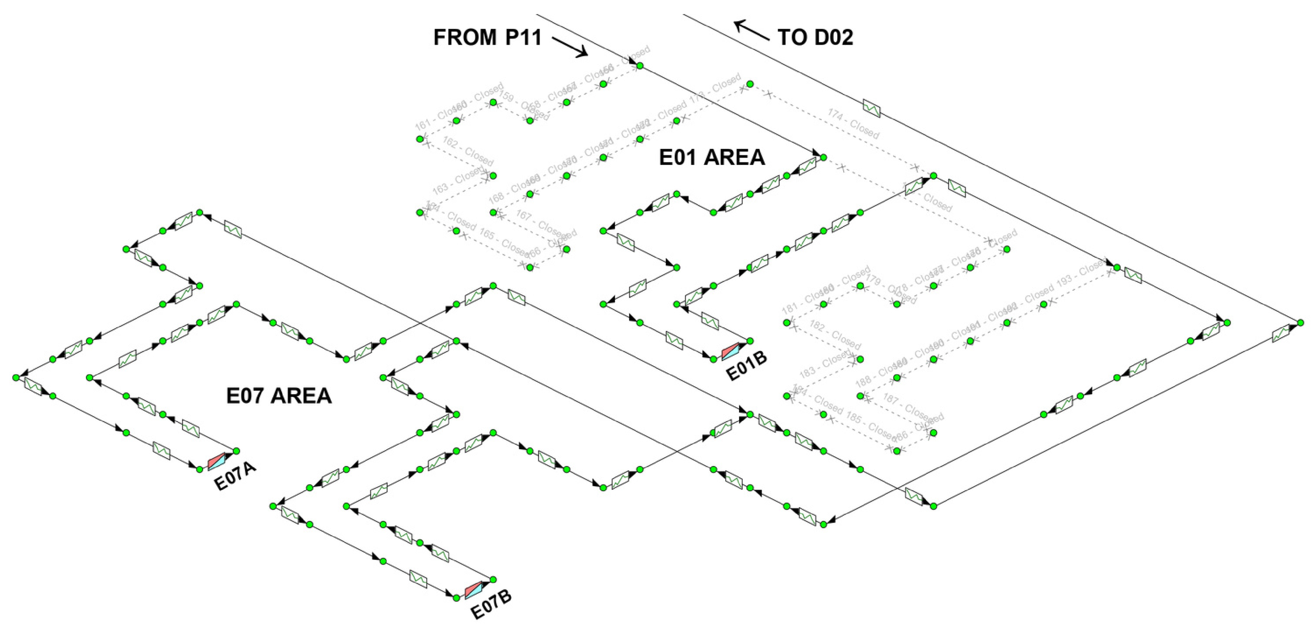
CONCLUSIONS

- The setpoint of the differential pressure valves needs to be increased to permit a reduction of the two-way mixing valves opening point, which is now at its maximum.
- The one-dimensional model detected an irregular distribution of the flow in the suction zone of the P11 pump, which has been confirmed by the use of ultrasonic equipment measurements.
- Lack of instrumentation for the pressure and mass flow measurements has been evidenced in the E06 & E07 zones.
- An increase of cold water in the heat exchangers is needed to improve the temperature conditions of the tank. This hypothesis has been confirmed with experimental tests.
- To achieve a desired in-tank temperature of 21ºC, 25 m^3/ h of additional cold water are needed in each E07 for the current regime, and 65 m^3/h for the nominal regime.
- The external air temperature does not produce a significant variation in the tank temperature between summer and winter.
- By recovering the nominal mass flow rate of the P11 pump, temperature deviations in the rings due to the thermal instabilities, currently up to 1.50 ºC, would be mitigated to 0.75 ºC.

PIPE FLOW EXPERT SIMULATIONS

The thermohydraulic system has been modelled in the Pipe Flow Expert software to obtain:

- Pressure distribution along the circuit.
- Pressure drop at each singularity.
- Mass flow distribution in the pipes of the circuit.
- Discretized model of the circuit geometry.

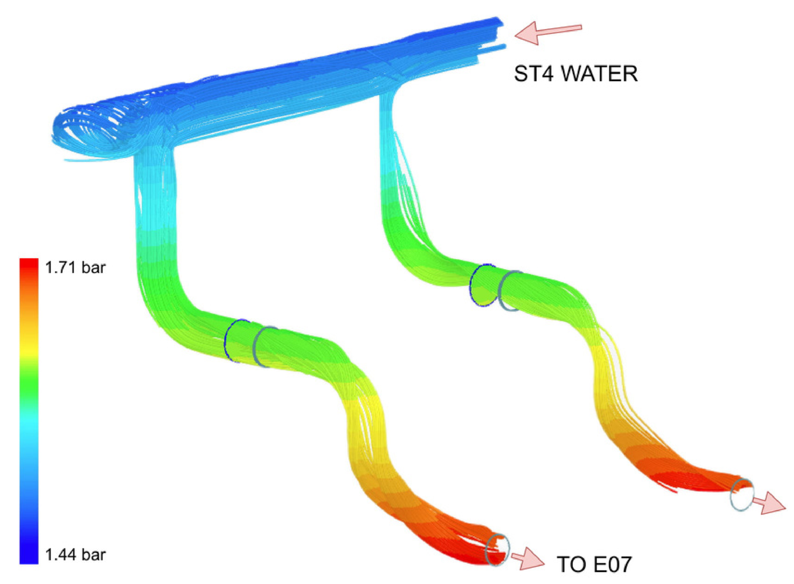


Pipe Flow Expert model of the thermohydraulic circuit

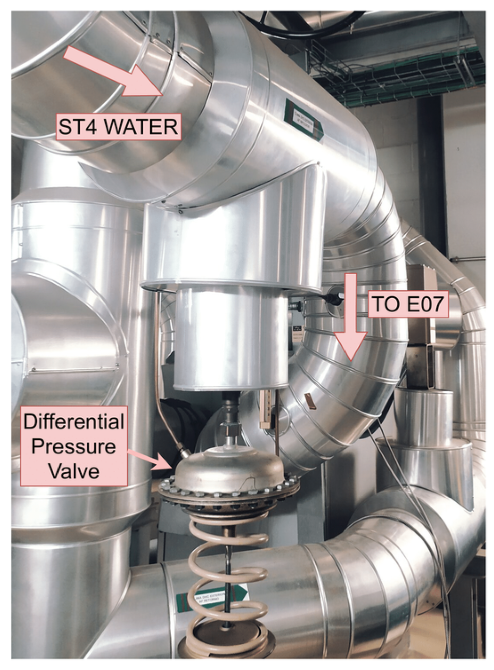
CFD SIMULATIONS

High precision CFD three-dimensional simulations permitted to obtain:

- Accurate description of the thermophysical variables at the exchanger inlets.
- Pressure drop in the involved pipes close to E07.
- Mass flow rate in each exchanger.



CFD simulation of the ST4 water in the E07 heat exchanger inlet

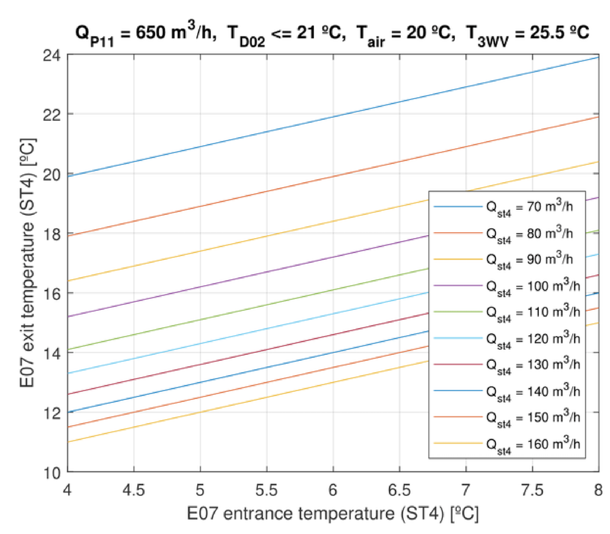


Picture of the ST4 circuit in the E07 heat exchanger inlet

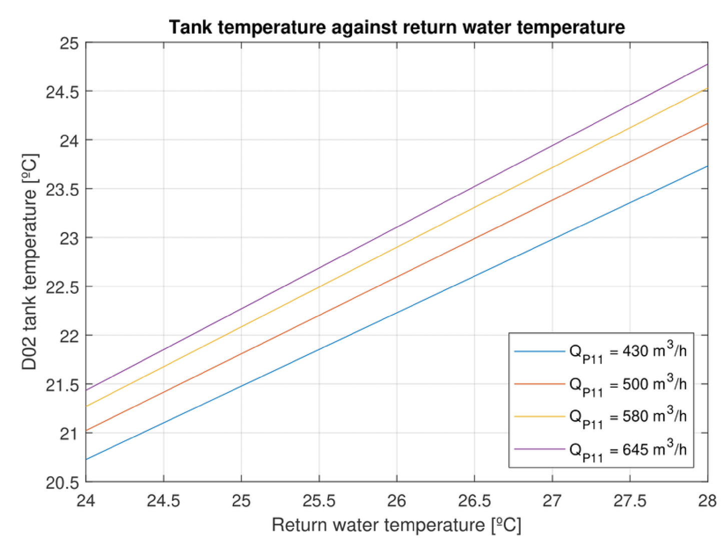
MATLAB CALCULATIONS

A self-made Matlab script based on one-dimensional heat transfer equations gives:

- Temperature distribution along the Pipe Flow Expert discretized model of the circuit.
- Effect of the external air temperature.
- Minimum ST4 working conditions to ensure a good performance of the circuit.
- D02 tank temperature dependency with P11 operating mass flow.
- Statistical model of the E07 power as a function of the ST4 working conditions.



ST4 minimum working conditions



D02 temperature against return water temperature at ST4 nominal conditions.

ACKNOWLEDGEMENT

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† fran.14hg@gmail.com | * mquispe@cells.es