ALBA Cooling System Upgrade: Thermal Hydraulic Numerical Simulations

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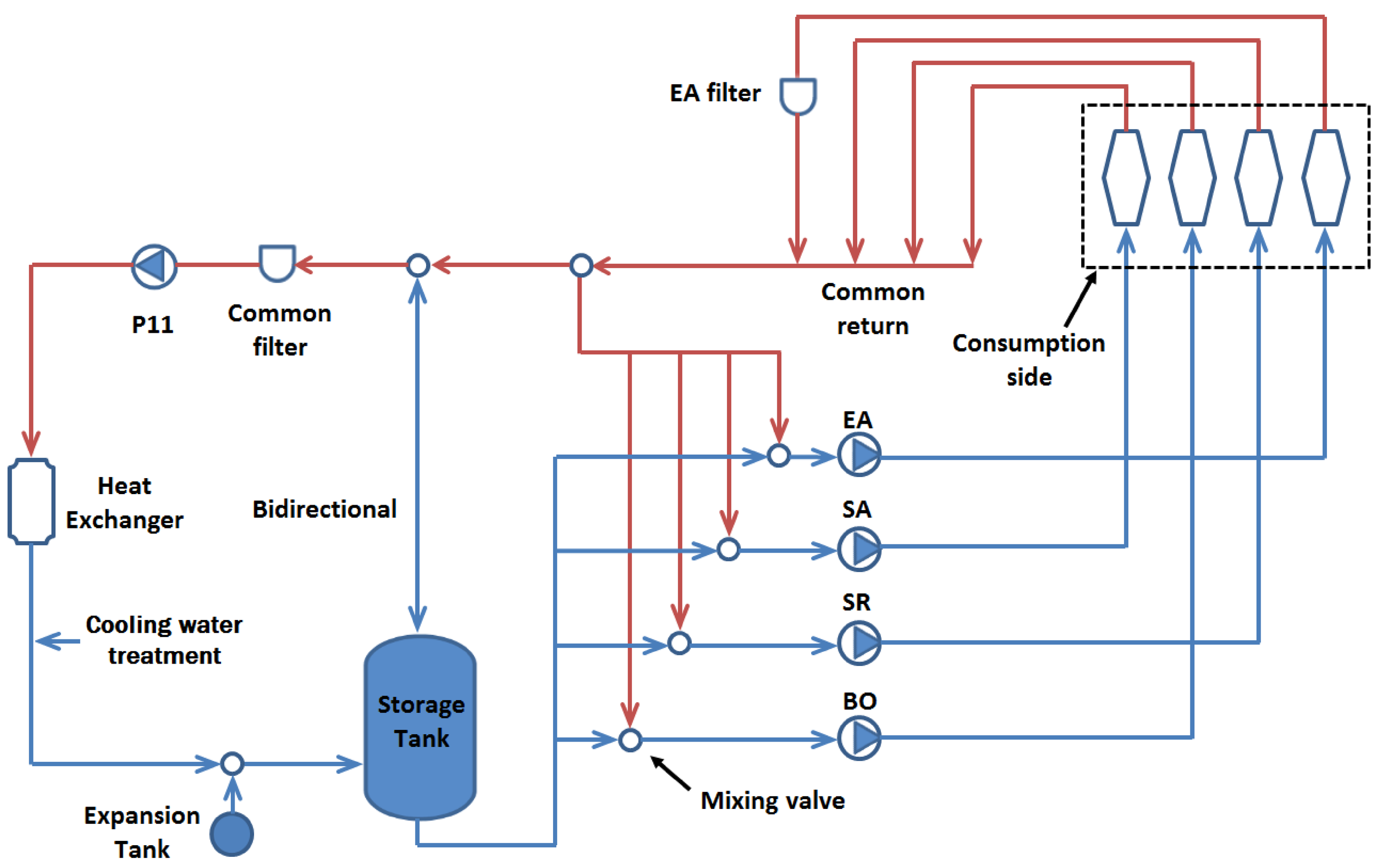
Abstract

For the period from June 2013 to October 2014 the ALBA Synchrotron has run a transversal project to accomplish an upgrade of the ALBA Cooling System, in order to increase its reliability, stability and adequacy in fail mode. All the activities have been grouped in five work packages: Fluid Dynamics and Thermal Control, Consumption Side Upgrade, Production Side Upgrade, Remote Supervision System, and Cabling and Control System. Here we present in detail the results of two numerical works: 1) 1D thermo-fluid dynamic simulation of the cooling system; 2) Two-phase flow simulation of the accumulator modification to increase de-aeration.

ALBA cooling system description

The ALBA cooling system is comprised by two main parts: the production and consumption sides. For the refrigeration four groups of pumps feed the rings Experimental Area (EA), Service Area (SA), Storage Ring (SR) and Booster (BO) (see attached Figure). The deionized water is heated thorough all the rings and it is collected in a common return line. Another pump (P11) takes the heated water from the return and feeds a couple of heat exchangers that cool it. The cooled water is brought to a large volume accumulator from which a suction line takes water again to the rings' pumps. In order to regulate the water temperature, a series of controlled mixing valves permit to combine the cooled water with the heated water prior to being pumped to the rings. Moreover, a pressure maintenance system with a compressor is mounted at the exit line of the heat exchangers before the accumulator. Finally, a pipe line connecting the accumulator with the common return line permits to compensate the lack/excess of flow to the cooling loop when the total flow rate changes in the rings' loops.



1D model simulation

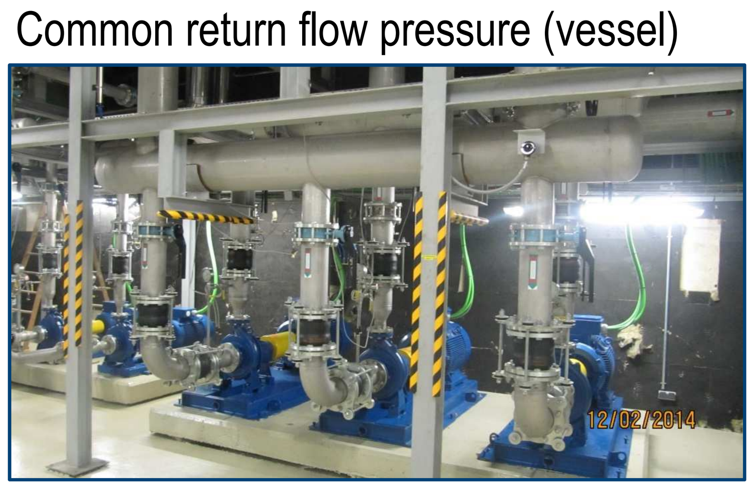
➢ More than 1027 components modeled

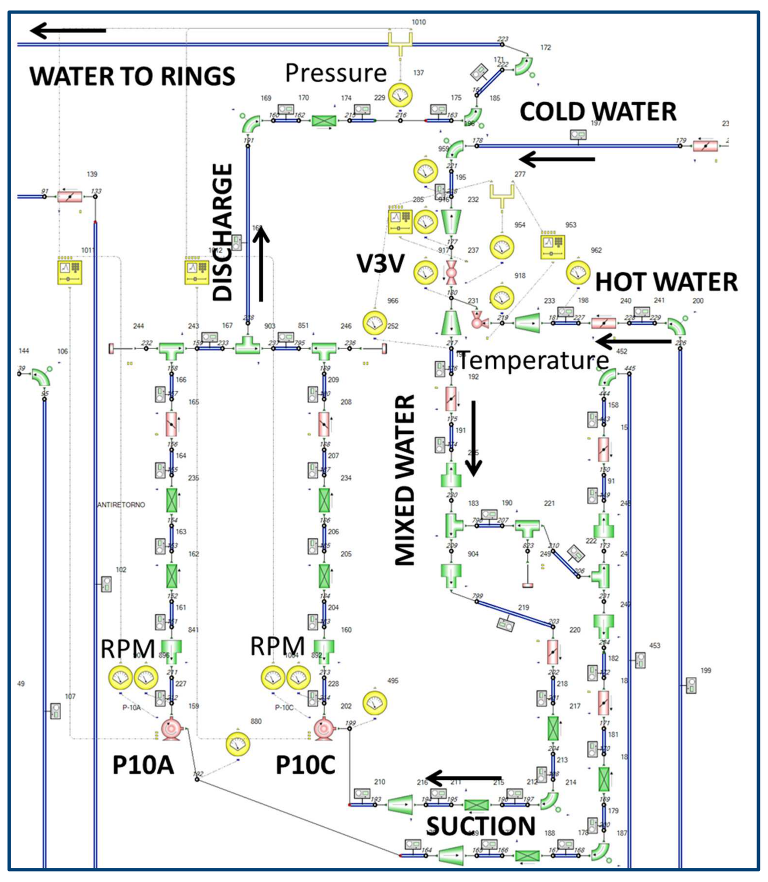
- System regulation

➢ Ring delivery pressures (pump rpm's)

➢ Flow temperatures (mixing valves)

➢ Common return flow pressure (vessel)





- Accuracy

➢ Model goodness confirmed by maximum deviations around:

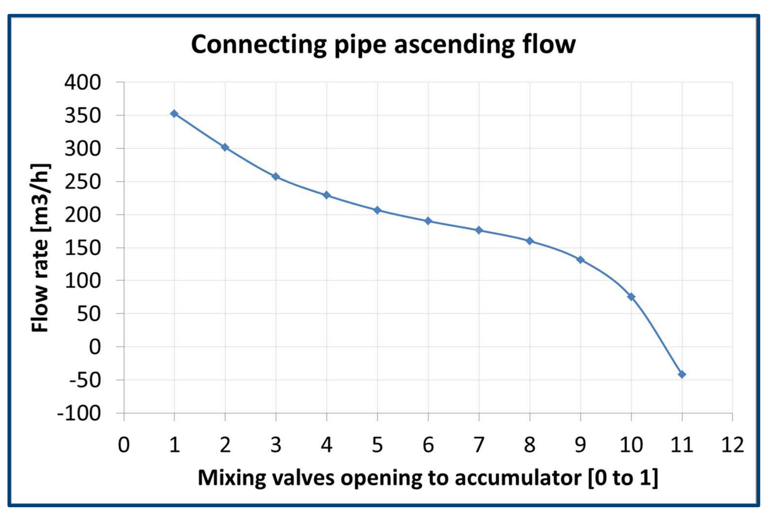
❑ 6 % for the hydraulic variables

❑ 10% for thermal variables

- Stability

➢ Under extreme operation of the mixing valves the flow rate on the connecting pipe is close to zero condition

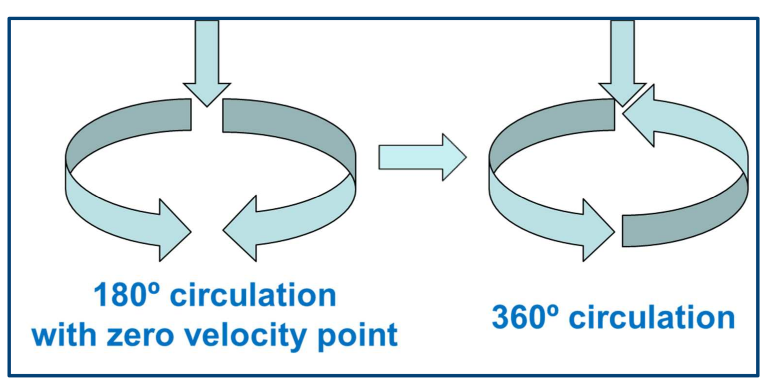
➢ If flow reverses and becomes negative, the thermal control can not be achieved



- Mean pipe velocity

➢ To avoid air problems, minimum flow velocities above 0.5 m/s are required

➢ Forcing a 360° circulation in the rings permits a significant velocity increase

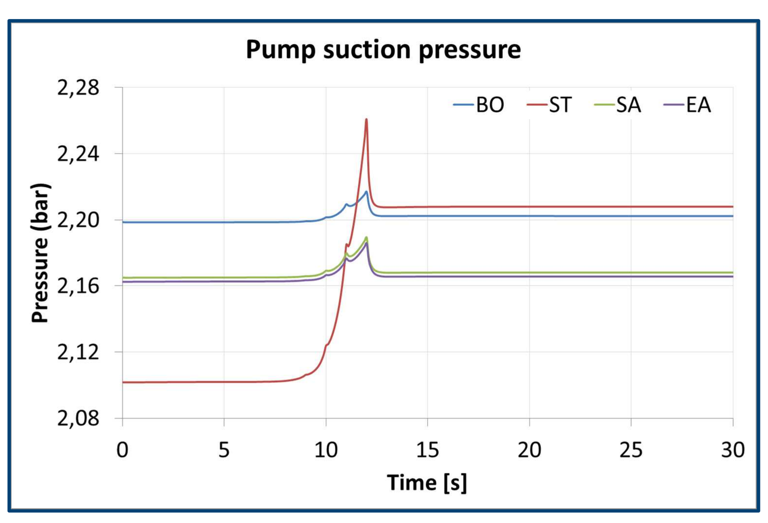


- Common return effect

➢ The flow through the rings is not fully independent due to the parallel piping configuration with a common return

➢ The resulting interdependent behavior needs to be understood

➢ For example, a flow reduction in a ring provokes the increase of all pump suction pressures



CFD flow simulation

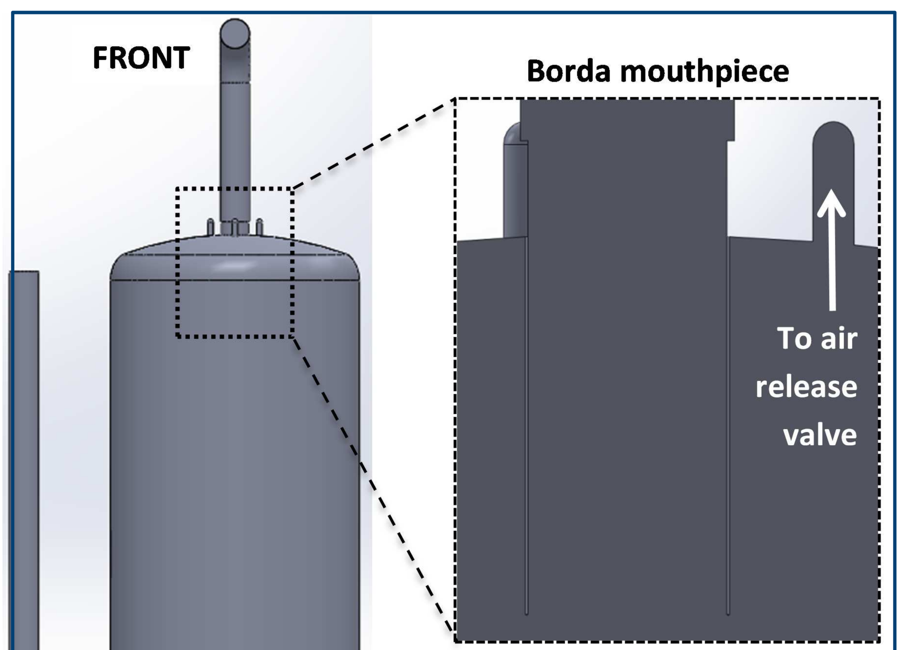
- Model set-up

➢ Steady state isothermal two-phase flow

➢ Around 1 million of tetrahedral elements

➢ Lagrangian Particle Tracking model with the Ishii-Zuber correlation

➢ Eulerian-Eulerian multiphase model



The Borda mouthpiece consists of a pipe extension from the top exit towards the inner part of the accumulator. Three holes connect with the air release valves through vertical tubes.

- Results

➢ Accumulator flow rates:

❑ 370 m^3/h at inlet

❑ 33 m^3/h at top outlet

❑ 337 m^3/h at bottom outlet

➢ Accumulator pressure:

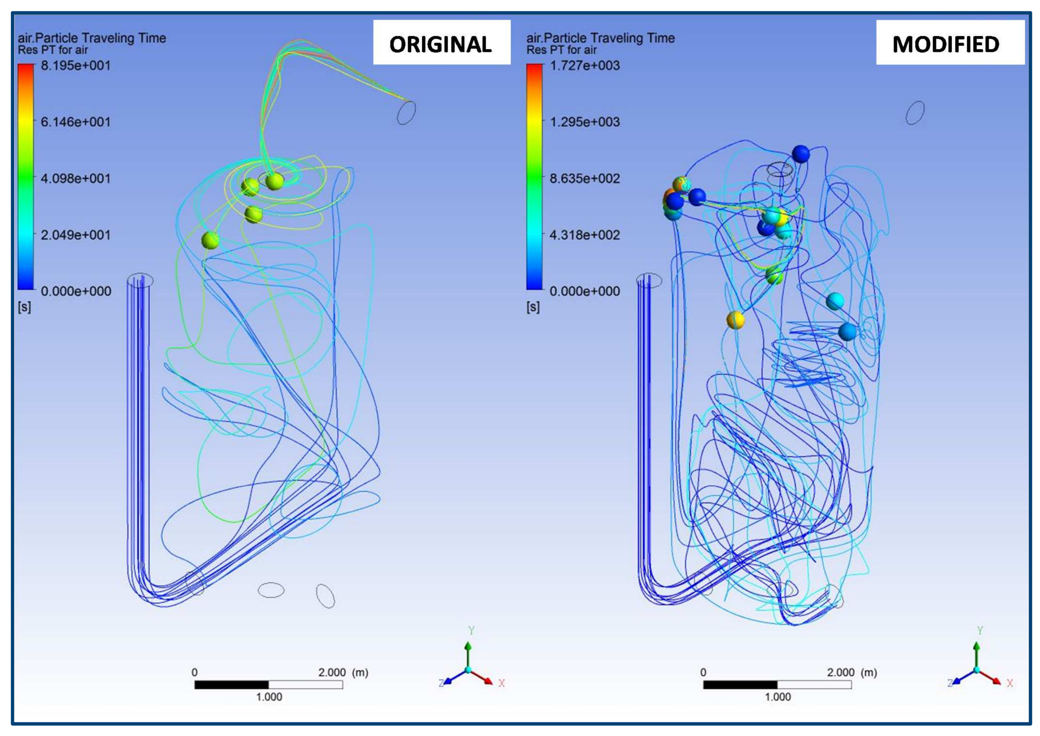
❑ Around 1.98 bar

➢ Simulated oxygen content:

❑ About 4000 ppb

❑ Diameters: 0.1 to 2.0 mm

❑ Equal mass of particles



- De-aeration efficiency

➢ Around a 51 % of air bubbles are retained in the accumulator

➢ For the particles that exit the domain, around a 2% is through the upper outlet and the rest (96%) is through the bottom outlet

➢ Air bubbles tend to fill the vertical tubes connecting with the air release valves