EXPERIMENTAL AND NUMERICAL STUDY OF THE ALBA LINAC COOLING SYSTEM

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Abstract

This work investigates experimentally and numerically the performance of the ALBA LINAC cooling system. The main objective is to enhance the hydraulic system in order to significantly improve its thermal and water flow stability. In normal operation some problems have been identified that affect the performance of the LINAC: flowrate below the nominal values and water flow decreasing in time. The cooling subsystems have been experimentally characterized in terms of the pressure drop and flowrate. The measurements were taken using a portable hydraulic unit made at ALBA as well as a set of ultrasonic flowmeters. For the numerical studies the cooling network has been simulated using the software Pipe Flow Expert. The experimental results have shown that a number of components are too restrictive. In some cases the possibility to increase the flowrate is limited. The numerical results show that the velocity magnitude is inadequate in some places, producing air bubble entrapment, high pressure drop at pipes and insufficient flow. Based on this study several modifications are presented in order to raise the nominal flow and to adequate the water flow velocities between 0.5 and 3 m/s.

BACKGROUND

The ALBA facility is composed of a 100 MeV LINAC (see Fig. 1), a Booster that accelerates the beam up to the full energy of 3 GeV, the Storage Ring (SR), and the corresponding transfer lines (LINAC To Booster – LTB, and Booster To Storage – BTS).

Figure 1: The ALBA LINAC.

The LINAC consists of a 90 kV DC thermoionic gun, followed by a bunching system designed to reduce the energy spread and the electron losses. This one comprises a sub-harmonic pre-buncher (500 MHz), a pre-buncher (3 GHz) and 22-cells SW buncher (3 GHz). Two travelling wave constant gradient accelerating sections increase the energy up to 100 MeV. Beam focusing is ensured by shielded solenoids up to the bunching system exit and a triplet of quadrupoles between the two accelerating structures [1, 2].

The LINAC is running reliably since started its operation in 2010. At the early stages of the operation it was experienced that the beam charge is sensitive to variations of more than 0.1 ºC in cooling water temperature of the LINAC bunker and Service Area.

THE LINAC WATER COOLING SYSTEM

Description

The LINAC cooling water system has two different functions. From one side it cools the elements with strong dissipation of power: klystrons, RF cavities, RF loads, RF ceramic windows and magnets. And from the other side the system regulates the water temperature of the RF cavities in order to tune them for working at the nominal RF frequency.

The hydraulic scheme of the cooling water system is illustrated in Fig. 2. The main inlet pipe is connected to the supply ring at the Service Area. The total nominal flowrate is estimated at 100 l/min for a mean increase of temperature of 5.8 ºC. The total power transmitted by the LINAC to the cooling water is 61 kW according with the technical specifications. The inlet pressure of the supply ring is 10.2 bar. However a pressure reducer installed in the supply line set to 8.8 bar protects the downstream piping and components from over–pressurization. The inlet water temperature is 23 +/- 0.1 ºC in nominal conditions.

The main cooling circuit is divided in two subsystems, one for inside and the other for outside the bunker. The resistor load (RL1) and klystron amplifiers (KA1 and KA2) are outside the bunker. Both klystrons dissipate 45 kW.

Inside the bunker the RF cavities are made of copper whose dimensions change with temperature. As the resonant frequency is directly related to the dimensions, any change of temperature will lead to a lower electric field. Calculations of beam dynamics show that a temperature stability of ± 0.2 °C is necessary. The nominal regulation for temperature is around 30 °C.

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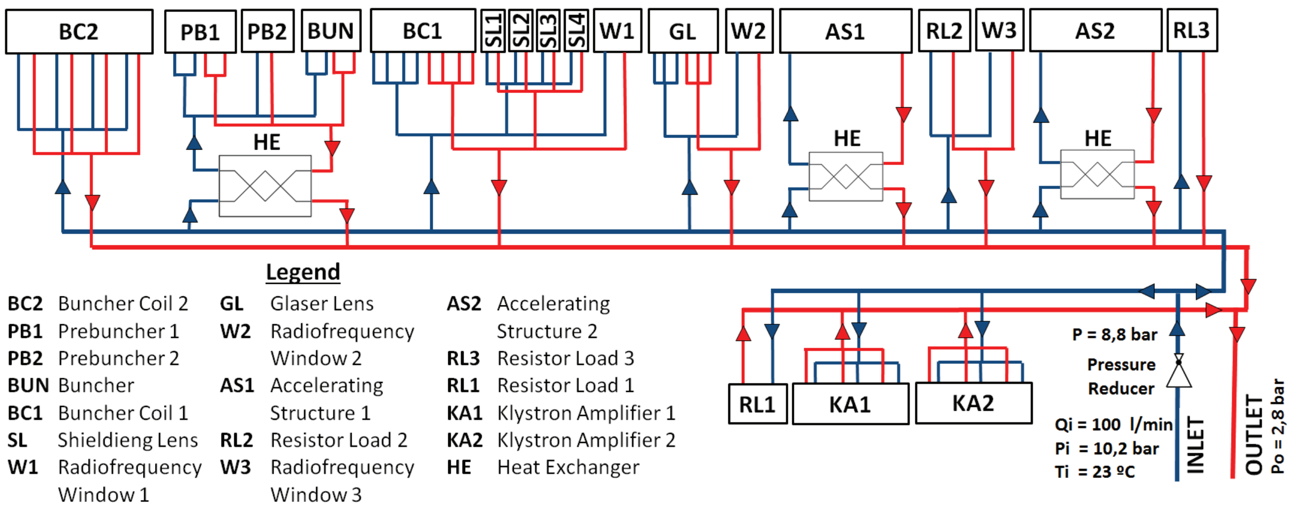

Figure 2: Hydraulic scheme of the LINAC cooling water system.

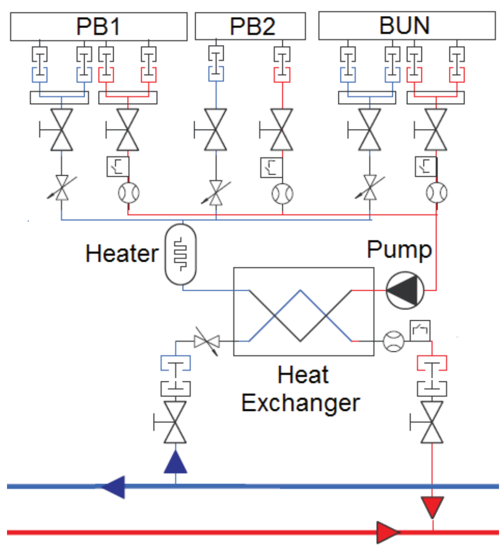

Figure 3: Hydraulic circuit of cooling loop 1 (CL1).

The RF cavities are regulated by three closed circuits, named cooling loops, grouped as follows: CL1 (PB1, PB2 and BUN), CL2 (AS1) and CL3 (AS2). Figure 3 shows the hydraulic scheme of CL1. The main components are a pump, a heat exchanger between the primary and secondary circuits and a heater. The loop operates with 5.5 bar as maximum pressure and 35 l/min. The thermal load is removed from the RF cavities to a secondary circuit across the heat exchanger. The electric heater of 500 W has the function of heating the circuit water and maintain it stable around 30 ºC with an stability of +/-0.1°C. For that, the power drive of the heater is adjusted by a PID.

Hydraulic Problems

In normal operation some problems have been identified that affect the performance of the LINAC:

Flowrate below the nominal values. This problem is affecting some components; as a consequence some points with overheating have been detected in the cooling system.

Flowrate decreasing in time. This phenomenon may be induced for the entrapment of air bubbles inside the system pipes. The problem was solved with an expansion tank installed at the impulsion of pump.

Instrument`s failure. Some flowmeters are not working properly. This fact complicates the study of the cooling system.

Water flow instability in the Service Area return. This problem is associated with an overall instability in the ALBA cooling system [3]. Measurements in the common return confirm that the pressure oscillates with +/- 0.2 bar deviation.

EXPERIMENTAL MEASUREMENTS

All the LINAC sub components have been characterized in terms of the pressure drop versus flowrate. The measurements were taken using a portable hydraulic unit made at ALBA (Fig. 4) as well as a set of ultrasonic flowmeters.

The hydraulic unit consists of a water pump that moves water from a tank to the device to be characterized. The difference of pressure is measured between the inlet and the outlet of the device. The setup is provided with two flowmeters. The readings of differential pressure and water flow are recorded in a central register.

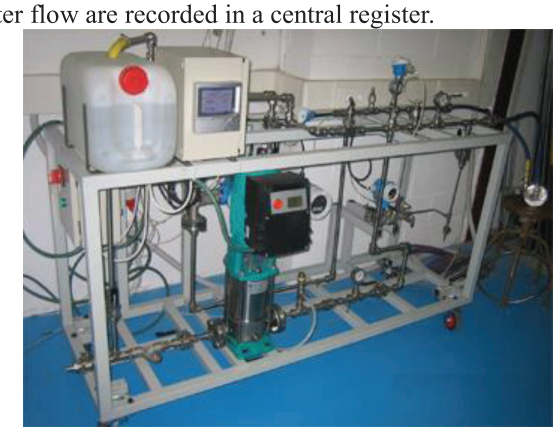

Figure 4: The ALBA experimental hydraulic unit to characterized pressure drop versus flowrate.

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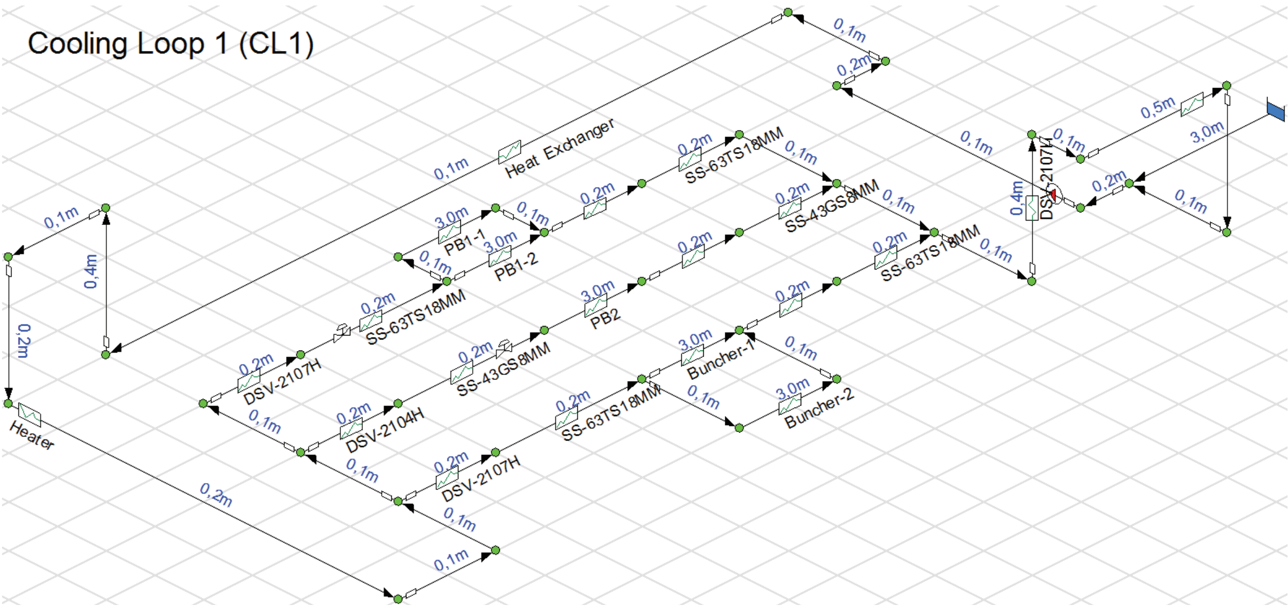

Figure 5: Software Pipe Flow Expert: piping network of the Cooling Loop 1 (CL1).

1D SIMULATION OF THE LINAC COOLING SYSTEM

Based on the software Pipe Flow Expert [4] an accurate 1D model of the LINAC cooling system has been built that permits to evaluate the response of the hydraulic system for the current situation and when it is subjected to possible modifications. The model includes all the net pipes, bends, pipe entrance, changes of section, branding of current, valves (open/close type, regulators), pressure reducer, flowmeters, pumps and local components. A total of 199 pipes and 57 components have been used for the simulation model. The numerical predictions have been compared with experimental data. A good agreement has been found with deviations of the main variables below 11%. Figure 5 shows the model Pipe Flow Expert for CL1.

RESULTS

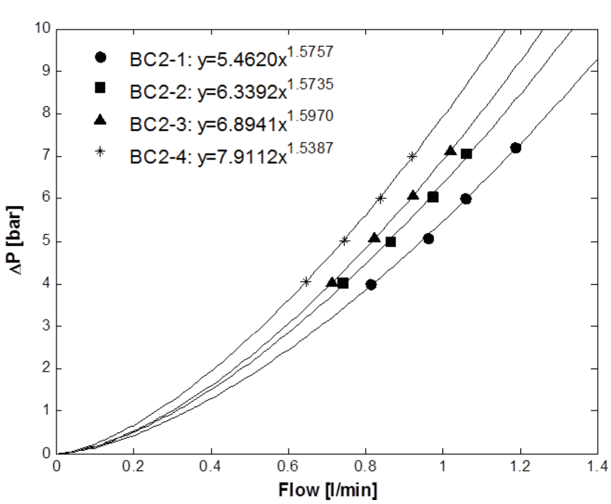

Figure 6: Experimental correlations for BC2.

The 31 subcomponents of the LINAC have been characterized. For each case a mathematical correlation has been developed to describe the pressure drop as a function of the flowrate.

Figure 6 shows the results for BC2 which is the most restrictive case. If the flow had to be increased it would be necessary to increase significantly the gap pressure (which it is limited).

The numerical results show that the velocity magnitude is out of optimum range in some places, producing air bubble entrapment, high pressure drop at pipes and insufficient flow.

Based on the experimental and numerical results a complete modification of the interface of CL1 is proposed. Currently this intervention is in progress.

CONCLUSIONS

The hydraulic characteristics of the LINAC sub components were investigated both experimentally and numerically. By applying mathematical correlations of pressure drop versus flow rate, it has been found that a number of sub components are too restrictive. On the other hand, a detailed description of the velocity magnitude at the interfaces has been obtained. Based on these results, modifications have been implemented in the LINAC cooling system with the aim to improve its performance.

REFERENCES

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[4] Pipe Flow Expert, `http://www.pipeflow.co.uk/`

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