ISBN: 978-3-95450-188-5 doi:10.18429/JACoW-MEDSI2016-MOPE43

HYDRAULIC FAILURE CAUSED BY AIR IN PIPELINES OF THE EXPERIMENTAL AREA RING OF ALBA SYNCHROTRON LIGHT SOURCE: RESEARCH, SIMULATIONS AND SOLUTIONS

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Abstract

After five years in operation of the ALBA Synchrotron Light Source a hydraulic failure caused a maximum decreasing of water flow about 40% of its nominal value, hampering the refrigeration of the local components. The problem was mainly caused by the air accumulated in pipes due to very low velocities of water flow. A literature review was conducted about the minimum water flow velocity for removing air in pipelines as design criteria. The aim of this work is to develop hydraulic solutions in order to achieve the minimum flow rate in pipelines of the Experimental Area (EA) ring. In the short term it is proposed to install a controlled bypass in the EA. A numerical simulation using the software Pipe Flow Expert has been implemented in order to determine the requirements of the bypass that works under different conditions to assure a minimum flow rate all along the ring. The velocity map in EA ring is simulated for different scenarios: 180 and 360 degrees distribution for both clockwise and anticlockwise rotation. For the long term a design of pipes with variable cross section is proposed which optimizes the flow velocity magnitude in EA ring in agreement with the design criteria.

BACKGROUND

The ALBA cooling system consists of four main rings which feed the local consumption of the Service Area (SA), Booster (BO), Storage Ring (SR) and Experimental Area (EA) (see Fig. 1). The water is heated through all the rings and it is collected in a common return. The pump P11 takes the heated water from the return and feeds a couple of heat exchangers HE that cool it. The cooled water is brought to a storage tank 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. Finally, a pipe line connecting the tank 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.

In 2013 a hydraulic failure in the ALBA cooling system caused a maximum decreasing of water flow about 40% of its nominal value, hampering the refrigeration of the local components. The problem was mainly caused by the air accumulated in the four rings due to very low velocities of water flow [1].

This paper analyses the problem and proposes new solutions. The Experimental Area has been selected for this study. The conclusions will be extrapolated to the other rings.

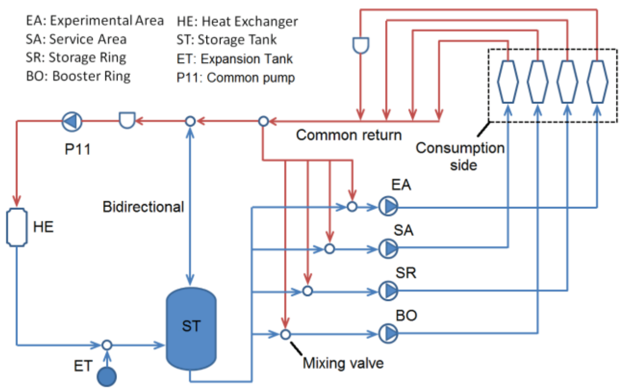

Figure 1: ALBA cooling system scheme.

THE MINIMUM WATER FLOW VELOCITY AS DESIGN CRITERIA

Research studies have shown that a minimum flow velocity is always required to move air pockets in pipelines [2, 3]. Air pockets decrease flow capacity, they induce significant head losses and energy losses, they prompt serious corrosion, and they can trigger and/or enhance pressure surges. Other problems include false flowmeter readings, increased biological activity, vibration and structural damage.

The minimum flow velocity for transporting air pockets depends on the size, shape, and concentration of the bubbles and on the down-slope and diameter of the pipe. The minimum velocity usually increases with increase in bubble size, in down-slope and in pipe diameter. In conditions of low velocity, below the minimum velocity, entrained air bubbles combine to form air pockets at peaks, at the crown of the pipe, at in-line and online fittings and accessories, and at other locations along the pipeline. These entrained air pockets often grow to sizes that even fast-flowing water cannot carry downstream.

Escarameia [3] has studied exhaustibly this issue and analyzes the problem in terms of three variables: diameter of the pipe, angle of inclination and the Froude non-dimensional number. The Froude number, which is proportional to the critical velocity and is inverse proportional to square root diameter, has a range from 0.3 to 0.8 in horizontal pipelines, which is the case of the present paper.

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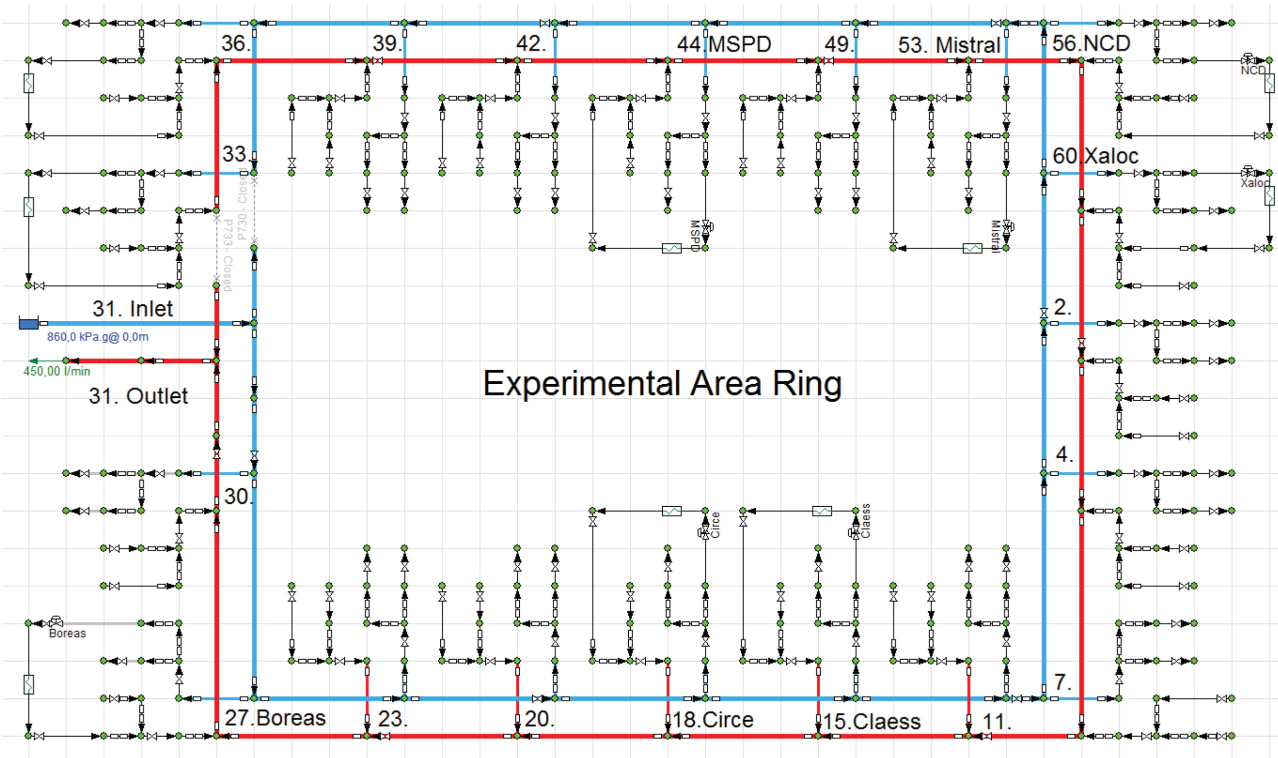

Figure 2: Hydraulic model based on Pipe Flow Expert to simulate the Experimental Area Ring.

EXPERIMENTAL AREA RING

The Experimental Area Ring has been designed to operate with 32 beamlines. In that condition the nominal flowrate capacity is 85 m^3/h. But in the current situation the ring feeds only seven beamlines: BOREAS, CIRCE, CLAESS, XALOC, NCD, MISTRAL and MSPD, which operate with a total consumption of around 27 m^3/h and 8.5 bar at the inlet pressure.

The pipes in Experimental Area (inlet and outlet) have the same cross section along the ring: the type pipe DN100 SCH10S with an internal diameter of 108.20 mm. According to the design criteria [3] the range of minimum velocities in the ring must be in between 0.31 m/s and 0.82 m/s, as gathered in the Table 1.

Table 1: Froude Number, Velocity and Flow per Pipe Ring

Froude number	Internal diameter [mm]	DN	Minimum velocity [m/s]	Flow [m^3/h]
0.3	108.20	DN100 SCH10S	0.31	10.23
0.8	108.20	DN100 SCH10S	0.82	27.28

In the current configuration the water is circulating along the EA ring with 360° rotation, which means the main flow is forced to circulate only in counter clockwise direction at the inlet ring and in the opposite direction at the outlet ring. For this condition the velocity is below 0.3 m/s in around 26 percent of the ring length. Therefore, there is a high risk of air accumulation in this zone.

1D SIMULATION OF THE EXPERIMENTAL AREA RINGS

The experimental area ring has been simulated using the unidimensional software Pipe Flow Expert [4].

To achieve a proper simulation model previously many experimental data have been obtained using non-invasive ultrasonic flowmeters and electronic pressures gauges at three different points.

In this model about 1200 elements have been characterized, not only pipes but singularities, such as dilators, elbows, gate valves, section reducers and pressure reducer valves. Figure 2 shows the simulation model of the Experimental Area Ring.

A good agreement with real measurements has been found with deviations of the main variables below 10%.

As a result the model allows checking the distribution of the flow in the ring in the current conditions and to study all possible configurations for the circulations of the flow in pipes.

PROPOSAL FOR IMPROVEMENTS

The problem of low velocities in the ring is partially solved forcing the flow circulation in the opposite direction periodically. This preventive protocol needs a lot of people and there are many risks [1]. Two solutions are described in order to solve this problem. Both proposals are based on the numerical model described before.

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Variable Cross Section

Variable cross section is the proper solution for avoiding high or low velocities. For the criteria of minimum flow velocity a range of velocities is suggested based on the Froude number. But this criteria is not practical from the pipe sizing point of view. Based on the 1D simulation model a systematic study has been conducted in order to determine a unique minimum velocity as design criteria. Assuming different future scenarios, considering more beam lines in operation, the present paper proposes 0.6 m/s as the appropriate minimum flow velocity where most scenarios run into the same solution of variable cross section. As result it is proposed to do a modification of the pipes from DN100 to DN40 only in sectors 1, 2, and 3 (see Fig. 3).

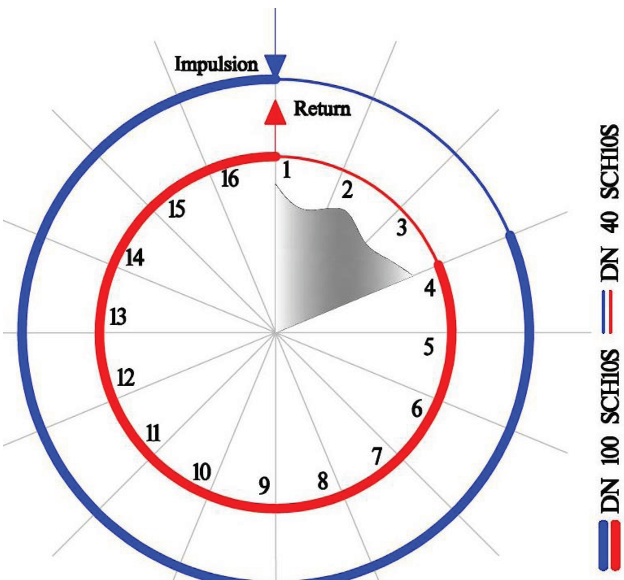

Figure 3: Description of the modification in the pipe ring of EA. Sectors 1, 2 and 3 made of type pipe DN40 SCH10S.

Controlled Bypass

The purpose of a controlled bypass is to regulate the total flowrate in the ring at the last point, in sector 1 (see Fig. 3). This is a practical solution with a minimal intervention in the installation. This solution implies to have a controlled flow that accomplishes the following requirements: (i) increase of the velocity map above of 0.6 m/s for the entire ring, (ii) avoid velocities above of 3 m/s and (iii) working in the range of pump possibilities. This solution has the next advantages: (i) it is not necessary switch off the pumps, (ii) reduced intervention time and (iii) only one person is involved in this operation.

The controlled bypass can operate with the current pipe geometry (all ring at a constant cross section) and also with the previous solution of a variable cross section.

Figure 4 shows a simplified hydraulic scheme with main components and the PID loop to control the flowrate. The controlled bypass has a modulating valve in order to maintain the flow required in the ring that meets the criteria of the minimum velocity. The flowrate in the bypass has been calculated to be 10 m^3/h.

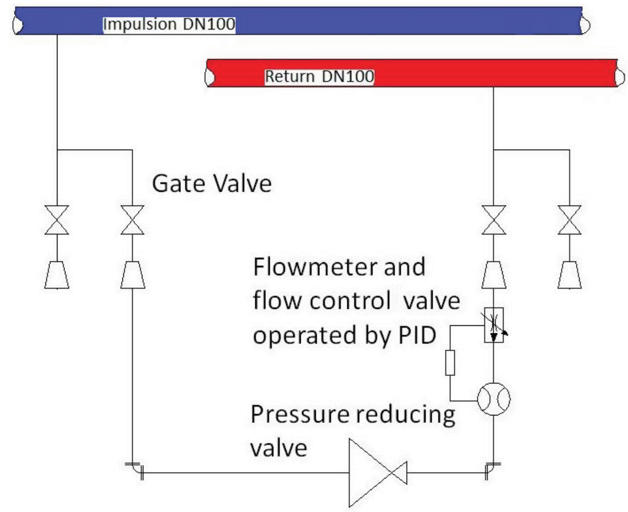

Figure 4: Schematic of the proposed Controlled Bypass.

CONCLUSION

According to the literature review a minimum flow velocity is always required to move air pockets in pipelines.

Based on the software Pipe Flow Expert an accurate 1D model of the Experimental Area Ring has been built that permits to evaluate the hydraulic behaviour of the ring and the response when it is subject to possible modifications.

The two improvements proposed, variable cross section and controlled bypass, solve the problem but have a different scope: the first is dedicated for a final stage of developing of ALBA and causes a great impact on its implementation. The second one is capable to work in the short and middle stage of development. By controlling the flow crossing the bypass it is possible to guarantee the minimum flow that removes the air. In addition, the impact of its implementation is lighter compared to the former one.

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