

Hydro-Electrical-Mechanical characterization of air valves

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Abstract

As water flows through pipelines, it's essential to remove the air that is entrapped. This is due to the fact that the air in water pipelines can cause damage to the water supply system, even causing the interruption of supply. Besides that, significant overpressure might be generated during the filling of pipelines. Other problems, such as, additional losses, transients, decrease of efficiency in pumps, vibration, corrosion, wear and even breaking, reading errors can occur, reducing the efficiency of the system and increase of costs. To mitigate these problems, air valves are used in the pipelines. These valves allow the air to scape to the atmosphere. However, the study of the air flow and it's elimination through the air valves is complex. For that, we performed mathematical characterization of the air flow in an air valve, based on experimental characterization.

Key words:

Air valves, mathematic characterization, experimental characterization

Introduction

Since ancient years, Romans noticed that the presence of air in pipes could interrupt the flow of water. To solve that, they isolated a portion of the water pipeline and, in a high point, the pipe was opened and filled with water manually, draining the air into stages. Such procedure was adopted until late 19th century, when it became impracticable. In the beginning of the 20th century, in countries that adopted the fire emergency system with hydrants, it was believed that the manual opening of these hydrants was sufficient to remove the entrapped air. Other methods, such as opening valves in the high point of pipelines or the use of vertical pipes were also adopted. However, it was not possible to predict when the opening should be done, and this process proved not to be effective. Therefore, air valves that could, automatically, expel or admit the air were developed. According to Tullis (1989), there are 3 types of automatized air valves (figure 1).

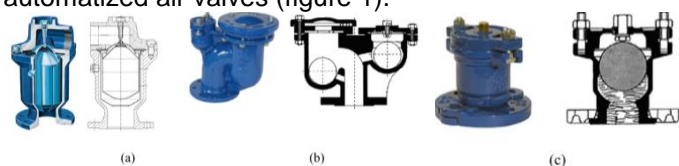


Image 1. a) simple air valve with large orifice, b) simple air valve with small orifice and c) triple function air valve.

This study characterized the flow of air through an air valve, based on experimental data extracted from a laboratory facility.

Results and Discussion

It's necessary to correctly design an air valve geometry to control velocity (and pressure) in a pipe. The valve diameter can't be so small to cause a long time filling, neither can be so large to cause the water velocity to become so high that could cause a water hammer (Bianchi et al., 2007). A practical formula has been developed by Bianchi et al. (2007) considering the Allievi-Joukowski equation relating pressure and mass discharge (equation 1).

$$\dot{m} = \frac{\Delta p \cdot A_{pipe} \cdot \rho_{fill}}{c \cdot \rho_{water}} \quad (1)$$

The authors assumed that the flow on air valves is polytropic and sonic. However, if the flow is sonic it would generate excessive noise as the air is expelled. So, another equation to design an air valve properly should be derived. Taking the massic flow equation of air expulsion (equation 2)

$$\dot{m} = C_{exp} \cdot A_{valve} \cdot \sqrt{\frac{7}{R \cdot T} \cdot \left[\left(\frac{P_{atm}}{P_{fill}} \right)^{1,429} - \left(\frac{P_{atm}}{P_{fill}} \right)^{1,714} \right]} \quad (2)$$

And after mathematical arrangement, equation 3 can be derived.

$$A_{valve} = \frac{\Delta p \cdot A_{pipe} \cdot \rho_{fill}}{c \cdot \rho_{water} \cdot C_{exp} \cdot \sqrt{\frac{7}{R \cdot T} \cdot \left[\left(\frac{P_{atm}}{P_{fill}} \right)^{1,429} - \left(\frac{P_{atm}}{P_{fill}} \right)^{1,714} \right]}}$$

Being A_{valve} =area of air valve's cross section, Δp =maximum water hammer pressure, A_{pipe} =area of the pipe section, P_{fill} =maximum pressure value in pipe minus maximum water hammer pressure, C =water hammer wave velocity, ρ_{water} =water density, C_d =coefficient of discharge, R =universal gas constant, T =temperature, P_{atm} =atmospheric pressure, P_{fill} =pressure inside the pipe.

Conclusions

A mathematical characterization is necessary to optimize air valve's use in water supply systems. The practical formula developed must be experimentally tested. It's also important to assure that the assumptions made are correct in real functioning air valves. Many assumptions made in the literature haven't been tested yet, making it difficult to have a reliable equation to dimension air valves and to control if its functioning is correct after installation.

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