Analysis of interference caused by air blocking valves in residential water meter measurements

J Trancoso¹, M Cavaco², J Kroth³

¹ Research Scholar, Mechanical engineer department, PET-MA UFSC, Florianópolis, Brazil
² Professor, Mechanical engineering department, Labmetro UFSC, Florianópolis, Brazil
³ Research Scholar, Mechanical engineering department, PET-MA UFSC, Florianópolis, Brazil
E-mail: jp.grobberio@gmail.com, cavaco@labmetro.ufsc.br, joao.kroth@labmetro.ufsc.br

Abstract. This work consists of an experimental study to better understand the interference of air block valves in measurements performed by metrological class 'B' velocity water meters. According to ordinance 'Portaria nº 246' from the National Institute of Metrology, Quality and Technology (Inmetro), the analysis was based on three experiments required for the approval of such equipment: Errors measurement, Head loss measurement and Magnetic transmission efficiency test. In order to collect the results an automated bench was developed enabling experiments execution without human intervention. Data acquired showed non-compliance with regulation when the system operated with the device. The conclusion taken by the results indicates that the specific air block valve tested may be a harmful influence on the correct operation of water meters.

Keywords. Water meter. Air block valve. Metrology. Regulation.

1. Introduction

Air blocking valves are equipment generally installed after the water meter, with the purpose of reducing the impact of the eventual passage of air that can reach the measuring device. In general, these accessories are designed to act in "blocking" the air, not in its removal, as in valves that eliminates air. The operation of the equipment can be assimilated to the operating principle of a simple hydraulic check valve, in which the water flow is only permitted in one direction. In this sense, when the pressure of the distribution network at the location of the air blocker generates a force lower than the force exerted by the spring installed in the plug, the device prevents the passage of fluid. Otherwise, when the network pressure generates a greater force, the blockage is interrupted, and the water flow is released into the residence.

The main objective of this work is to evaluate if the addition of an air blocking valve in domestic pipes negatively interferes with measurements made by multijet water meters of metrological class B, causing larger errors than those acceptable in water measurement. The study and tests carried out will be based on 'Portaria' No. 246 of October 17, 2000 of the National Institute of Metrology, Quality and Technology (Inmetro), which regulates the use of residential and industrial water meters. This work, then, consists of performing three different tests according to the regulations: Determination of performance, Verification of magnetic transmission efficiency and Determination of head loss.

2. Experimental apparatus

The work then consisted of the construction of an automated test bench that was capable of minimally interfering and/or feedback with the measuring "water volume", object of the measurement. The bench,
as shown in Figure 1, consists of a system that draws cold water from two reservoirs (one for the lower pressure line and another for the higher-pressure line) providing water to the water meter/air blocker valve. The water passes through the piping containing the water meter, with or without the presence of the air blocker, being at the end collected in a tank with capacity of 110 L, which provides in real time the volume and flow data drained. In this way, the workbench has measurements of all the necessary quantities, and then it is possible to perform the three appropriate tests.

![Figure 1 - Representative diagram of the operation of the test bench. The manometers are represented in numbers 1 and 4; the water meter as 2; and the air blocker as 3.](image)

The operation of the workbench consists of two possible paths for the water supply. The first alternative is through a pumping system (1.1KW) and the second by gravity, through an overhead tank at 2.5m height. The path chosen will depend on the flow rate to be selected for the test (minimum, transition, nominal or maximum). Thus, being the minimum or transition flow rate, the system starts to operate by gravity. If the test flow rate is nominal or maximum, the supply will be through the pumping system. To make sure that the water flow will only have one direction, manual valves have been placed at the outlet of each supply line to avoid the return of water through the other unused supply line.

The water passes in the sequence through the manometer and water meter (represented respectively by numbers 1 and 2 in Figure 1), arriving in another subdivision of the system, where it can pass either by branching with the air blocker (represented by number 3 in Figure 1), or by an adjacent auxiliary line without the device. This is necessary to allow the evaluation not only of the water meter operation with the air blocker, but also without the interference of the accessory, which will serve as a parameter to evaluate the results with the presence of the valve.

Finally, the flow goes through the second manometer (indicated by number 4 in Figure 1) and goes to the instrumented reservoir at the end of the line, where it will be made the acquisition of the volume information elapsed in the test. To perform the volume reading the reservoir was suspended by a traction load cell. This arrangement allows the mass of the set to be known at all times, which allows the calculation of the volume knowing the density of the water. This constant measurement of the mass of the reservoir also allows the calculation of the flow of the system by the gravimetric method, by measuring the differential volume of water in known periods of time. The readings of the water meters and manometers were made with the support of cameras controlled by a program developed in LabView software and activated at each beginning and end of the test.
3. Experimental procedure

Three different types of tests were performed on the workbench and for each test performed three different samples of results were collected on each water meter. The execution was based on the regulation already described in this work, and the parameters used determine in particular the flows required for each test.

In this sense, for the error measurement tests, the flow rates used were minimum flow, nominal flow and transition flow. For the head loss determination tests, the flows were: maximum flow and nominal flow. Finally, 70% of the maximum flow rate was used to perform the tests to verify the magnetic transmission efficiency.

In addition, according to the regulation, for each type of test and water meter, the volumes drained would differ. Thus, considering that the water meter used had a nominal flow rate of 1.5 m³/h and analyzing Inmetro 'Portaria' No. 246, we have the volumes for each type of test, shown below in Table 1.

Table 1 - Volumes required for each flow and test.

| Test                      | Flow required (litres/minute) | Minimum volume drained (litres) |
|---------------------------|------------------------------|--------------------------------|
| Errors measurement        | 0.5                          | 20                             |
|                           | 2                            |                                |
|                           | 25                           |                                |
| Head loss measurement     | 50                           | 20                             |
|                           | 25                           |                                |
| Magnetic transmission efficiency | 35                      | 100                            |

In all the tests made, the flow was first determined by the line without the presence of the air blocking valve, thus, after establishing the flow of the test with the original line, the tests with the blocker were performed only by changing the path of the water, in order to pass through the valve. This was done so that the test could get as close as possible to the reality of the installation of such accessories, where consumers who already obtain the water supply at a certain flow make the insertion of the air blocker in the branches of their points of consumption.

In the error measurement test, the system was to divide the test into the pre-established flows and compare the actual volume drained, measured by the instrumented tank, with the volume computed by the water meter, according to the reading of the images captured by the water meter camera at the beginning and end of the flow.
The water meter images were read in 3 levels, manually after the test. First, the volume in cubic meters was identified in the main display and then the reading of the 1 and tenths of a litre.

The error measurement test for the water meters was first reproduced for conditions without the air blocking valve and soon after, with the accessory present in the conditions of a more rigid spring (spring 1) and less rigid spring (spring 2).

In the head loss measurement only the manometer’s camera was activated. This test was done with a similar system to the previous test, obtaining the results for the system without the air blocker first and then inserting the device with the respective springs. To try to understand if there could be variations in pressure drop at the beginning and at the end of the test, the cameras captured images of the downstream and upstream manometers of the water meter/air blocker at the beginning of the test and after the configured volume had been drained.

Like the other tests, the magnetic transmission efficiency verification test followed the same sequence of events. The particularity of the test was only presented at the beginning, in which it was necessary to use a valve with opening time less than 1 second for the water meter to start from the steady state. The cameras used in this test and the interpretation of their images were the same as the error determination test.

4. Results and Discussion

4.1. Errors measurement

Table 2 - Results of the errors measurement test.

| Water meter | Flow [L/min] | Condition       | Average error [%] |
|-------------|--------------|-----------------|-------------------|
| A168504335  | 0,5          | Air Blocker - Spring 1 | 6,45              |
|             |              | Air Blocker - Spring 2 | 1,12              |
|             |              | No air blocker     | 2,08              |
|             | 2            | Air Blocker - Spring 1 | 7,32              |
|             |              | Air Blocker - Spring 2 | 0,2               |
|             |              | No air blocker     | 0,23              |
|             | 25           | Air Blocker - Spring 1 | 0,73              |
|             |              | Air Blocker - Spring 2 | 0,64              |
|             |              | No air blocker     | 0,51              |
| A168372927  | 0,5          | Air Blocker - Spring 1 | 1,31              |
|             |              | Air Blocker - Spring 2 | 45,39             |
|             |              | No air blocker     | 3,29              |
|             | 2            | Air Blocker - Spring 1 | 0,23              |
|             |              | Air Blocker - Spring 2 | 0,41              |
|             |              | No air blocker     | 0,24              |
|             | 25           | Air Blocker - Spring 1 | 1,07              |
|             |              | Air Blocker - Spring 2 | 1,19              |
|             |              | No air blocker     | 2,09              |
| A16837282   | 0,5          | Air Blocker - Spring 1 | 2,96              |
|             |              | Air Blocker - Spring 2 | 3,47              |
|             |              | No air blocker     | 1,05              |
|             | 2            | Air Blocker - Spring 1 | 0,43              |
|             |              | Air Blocker - Spring 2 | 4,44              |
|             |              | No air blocker     | 1,3               |
|             | 25           | Air Blocker - Spring 1 | 0,5               |
|             |              | Air Blocker - Spring 2 | 0,62              |
|             |              | No air blocker     | 1,98              |
Based on the data collected, presented in Table 2, an average of the errors can be made at each flow value, seeking a better understanding of the cause and effect correlation between the type of flow and the magnitude of the error. In addition, it is necessary to define some important variables for the problem, such as Etol, the error tolerated by the standard in a given flow, and Eobt, and the average of the error values obtained in experiments with the three water meters in a given flow. Thus, for each flow we can define the distance between these two errors (Rerro) as:

\[ R_{erro} = E_{tol} - E_{obt} \] (4)

Figure 3 - Relation between errors obtained and errors tolerated, according to the standard, in each arrangement

Figure 3, through Rerro, facilitates the interpretation of how far or close the mean errors in each flow are to the limit error, which is accepted by the standard in each flow. When Rerro is presented with negative values, the errors obtained are greater than the tolerable ones, otherwise, the errors obtained are within normality. This analysis shows that, in general, the errors measured in the water meters when placed together with the air blocker are above the accepted limits in situations with lower flow rate, while the errors for the water meter without the device (air blocker), on average, are adequate in the tested flows.

This situation where the errors are greater at lower flows, when the air blocker valve is operating, can be explained by the drop in flow rate (lower than 0.5 L/min) where the water meter is not designed to operate. As previously mentioned, the water meter presented has a minimum flow rate of 0.5 L/min, i.e., the lowest flow rate in which it provides indications that do not have errors higher than the maximum allowable errors. Also, considering that the operation of the air blocker acts similarly to a check valve, its presence in the line causes an increase in the pressure drop, thus reducing the flow rate that flows into the pipeline.

Thus, when the test is at the tolerated flow rate threshold, in this case 0.5 L/min or even 2L/min, the effect caused by the device to further reduce the operating flow can cause an increase in errors recorded between the collected volume and the actual flow, as seen. In this same analysis we can see that in one of the cases - flow rate of 0.5 L/min with spring 2 device - the error is much higher than the orders of magnitude of the others. This value could be interpreted as an outlier, however, in situations in which the operating flow is lower than the minimum flow, the device may present errors well above the tolerated limits for not having the necessary sensitivity to measure the elapsed volume.

Based on the data obtained for this type of test, the non-conformity of some operations according to the average of the test results in the different water meters induces the affirmation that the air blocking device is shown as a negative influence on the operation of the measuring instruments.
4.2. Head loss measurement

The data collected in the pressure drop verification tests, demonstrated as an average of the samples for each flow rate at each water meter in the different situations, can be seen in the Table below.

| Water meter | Flow [L/min] | Condition      | Average pressure variation [Mpa] |
|-------------|--------------|----------------|----------------------------------|
| A16S372927  | 50           | Air Blocker - Spring 1 | 0.1504                          |
|             |              | Air Blocker - Spring 2 | 0.1226                          |
|             |              | No air blocker       | 0.0785                          |
| A16S37282   | 25           | Air Blocker - Spring 1 | 0.0981                          |
|             |              | Air Blocker - Spring 2 | 0.0572                          |
|             |              | No air blocker       | 0.0212                          |
| A16S37282   | 50           | Air Blocker - Spring 1 | 0.1487                          |
|             |              | Air Blocker - Spring 2 | 0.1177                          |
|             |              | No air blocker       | 0.0785                          |
| A16S372927  | 25           | Air Blocker - Spring 1 | 0.0981                          |
|             |              | Air Blocker - Spring 2 | 0.0572                          |
|             |              | No air blocker       | 0.0294                          |
| A16S37282   | 50           | Air Blocker - Spring 1 | 0.1471                          |
|             |              | Air Blocker - Spring 2 | 0.1275                          |
|             |              | No air blocker       | 0.0801                          |
| A16S37282   | 25           | Air Blocker - Spring 1 | 0.1079                          |
|             |              | Air Blocker - Spring 2 | 0.0654                          |
|             |              | No air blocker       | 0.0294                          |

Table 3 - Average pressure variation in each arrangement.

This test was performed with a greater purpose of ascertaining how much the air blocker could interfere with the pressure drop of the system. In this sense, it can be seen from the data in Table 3 that, in general, all the tests that used the device were significantly out of the standards (red colored) accepted by the regulation. It is also valid to observe that in some results obtained for the system without the air blocker, specifically in the flow rate of 25 L/min, the results subtly exceed the tolerated limit. This can be explained by a slight increase in the pressure loss due to the bench structure between the two gauges (elbows 90°, valves, straight pipe distances, etc.).

In addition, with the data from the three water meters, a comparative analysis can also be made here between the average head loss for the system in the lines without the air blocking accessory and the increase caused by it. This is possible because both lines (with or without the device) are symmetrical in structure, i.e. they have the same construction elements.

With this analysis we can understand exactly what was stated in the interpretation of the previous test: the presence of the device adds a considerable load loss in the system (in some cases above 3.7 times the pressure loss of the water meter), which can interfere in the operating flows of the line.

4.3. Magnetic transmission efficiency test

As a group, the tests performed for the magnetic transmission efficiency verification test showed results in accordance with the standard. Having errors around 1%, the results are quite distant from the limit condition, which is imposed as 10%.

In Table 4 we can see an average of the errors obtained from the three samples for each arrangement of the system, in each water meter. As it was detailed previously, this test is made for larger flows, about 70% of the maximum flow accepted for the water meter, and thus, even with the
impediment caused by the air blocker, the operating flow still remains in the appropriate measuring range for the water meter.

Table 4 - Average errors for the magnetic transmission efficiency check test for each arrangement.

| Water meter | Flow [L/min] | Condition          | Average pressure variation [Mpa] |
|-------------|--------------|-------------------|----------------------------------|
| A16S504335  | 35           | Air Blocker - Spring 1 | 0.91                             |
|             |              | Air Blocker - Spring 2 | 0.80                             |
|             |              | No air blocker        | 0.37                             |
| A16S372927  | 35           | Air Blocker - Spring 1 | 0.29                             |
|             |              | Air Blocker - Spring 2 | 1.83                             |
|             |              | No air blocker        | 0.71                             |
| A16S37282   | 35           | Air Blocker - Spring 1 | 0.98                             |
|             |              | Air Blocker - Spring 2 | 1.47                             |
|             |              | No air blocker        | 0.77                             |

5. Conclusion

The development of this work was based on the survey of more information regarding the influence that the air blocking valve added to the domestic or commercial piping to mitigate the problem on the measurement of water meters. Throughout this study, it was also possible to briefly analyze how the device performs its function, understanding more deeply the elements behind this accessory that has its structure similar to that of a check valve. This provided the basis for a more substantiated analysis of the results achieved in the tests with the device.

Three different tests based on Inmetro 'Portaria' No. 246 of October 17, 2000, which regulates the use of residential and industrial water meters, were performed to understand how the air blocking valve could interfere with the measurement of commonly used metrological class B water meters. The tests aimed at verifying the measurement error of volumes flowed for different flows and arrangements, as well as the pressure drop that the equipment could insert in the line.

The results of the tests indicated a possible negative influence that the investigated air blocker could have on the adequacy of the water meters. This could be verified through the error pointed out both by the pressure loss test, in which the pressure differential of the arrangements is measured, and by the error determination test, where the volumes recorded by the water meter are compared, working together with the air blocker, with the actual volume drained.

Some errors obtained in volume measurements were especially high when smaller water flows were operated, presenting average errors of 16.69% and 2.63% in some arrangements, which exceeds the limits of acceptance of the regulation. The explanation of these results is obtained by further investigation of the effects of the device on the pressure drop of the system.

As the device operates as a check valve, the pressure drop it inserts into the hydraulic system can cause a flow drop that enables the water meter to operate below the design minimum flow rate. Under these flow rates, the velocimetric meters used in this study are not able to make a correct measurement of passing volumes, resulting the indication of smaller recorded volumes.

Increased pressure drop was obtained in the tests for measuring the manometric pressure downstream and upstream of the water meter/air blocker assembly. It was generally seen that the pressure reduction caused by the insertion of the accessory goes beyond the limit determined in all cases,
and may reach about 0.075 MPa with the most rigid spring, which is three times the limit accepted in the flow rate tested (according to Inmetro ‘Portaria’ No. 246).

For the tests with higher flow rate, on average, the measurement errors recorded by the water meters, both by the errors measurement tests and by the magnetic transmission efficiency tests, were adequate. This once again indicates that greater care should be taken with the air blocking device in situations where operating flows are lower, as is the case for some supply zones in the distribution network.

Finally, according to the research carried out, it is understood that the problems of air occurrence in the distribution pipes can be caused by a series of factors related to the operation of the water treatment and supply systems, such as filling and emptying of pipelines or low levels in the reservoirs. The need to mitigate the problem should be seen as an objective to ensure that end consumers are better served, increasing their satisfaction and confidence in supply. In this sense, it is seen that the modifications and improvements in the entire system should be the responsibility of the service providers, through investments, maintenance and proper operation in their systems.

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