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Behavior of flow measurements on a straight pipe

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Abstract. Accurate measurement is of paramount importance when dealing with precious liquids, as is the case of water. In irrigation, for example, where concessions are granted, accurate measurement is essential for balancing money paid by users with the necessary care that water needs. Manufacturers of meters recommend straight pipe sections before and after the meter for good measurement. However, sometimes there is not enough space for those sections. As a result, measurements are not accurate. In this paper, by statistically analyzing lab data, we get a general view of the errors that may occur.

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1. Introduction

Taking care of such a vital liquid as water, including maintaining of the infrastructure for its handling and distribution, is currently crucial. In Mexico, irrigation for farming areas is usually performed under the form of concessions. Water laws in many countries have strict regulations. The National Water Law and Regulations in Mexico states that every farmer has the right to extract a maximum amount of water and, for the right to be granted, the user must comply with a number of rules. Even though this Law has not been strictly enforced, measurement has been further regulated by the Constitution of the United Mexican States. In summary, the rules for measuring, distributing the water and paying, have also implied benefits, such as saving power, prevent aquifer depletion, and control of overexploitation of aquifers, among others.

2. Background review

The main problems regarding measurement exist in the system itself. It is essential, that the water in the pipe flows in a uniform and constant manner, under one-phase conditions, since the presence of air or other particles severely affects measurement [1]. Measurement can be performed with different meters. In general, for precision, a meter needs to be mounted with a certain length of straight pipe upstream and downstream. Manufacturers recommendations are not uniform, and the ISO norm proposes a relation of 5-8 (diameters of pipe upstream and downstream). However, the most common problem in water extraction is the lack of space and the existence of complex structure configurations, which disables the installation of the necessary pipe sections so as to reduce the measurement error to a reasonable lower level.

3. Experimental design

For accurate measurement, we started with the hypothesis of having enough straight length of pipe, for better reading. A 2PT868 ultrasonic meter was used because it allows displacement to perform the measurement at any straight pipe point. For a properly meter function, characteristics, from both fluid and pipe, must be considered such as, density, viscosity, temperature, material, thickness. This data gave the distance separation for the meter sensors. The pipeline was 12 inches diameter, PVC material. Measurements were made for flows close to 12, 23 and 37 liters per second, with a meter and a pouring spout at the same time, for data comparison [2]. The pouring spout was calibrated, its adjusted formula being

$$Qv = 1.054h^{1.478}, \tag{1}$$

where Qv is the pouring spout´s flow measured, and h, is the measured height in the pouring spout, as read directly by means of a liminimeter.

4. Physical design

The physical model was built in the Hydraulic's Laboratory of the Universidad Michoacana de San Nicolás de Hidalgo, Mexico. Water is supplied from an elevated tank, which is controlled with a valve, and then goes into two 45° elbows, which change direction and introduce turbulence in the pipe, following by 100 diameters of straight pipe, two more 45° elbows to enforce uniform, constant flow, and a stilling tank to mitigate the water force and direct it into a drainage channel where the pouring spout is located. We draw lines each diameter distance; this way we were allowed to know the position of the meter. Boundaries were on the lines 0, 50 and 100. Given a distance in pipe diameters of straight pipe upstream the meter, the complement to 100 gives the distance downstream the meter.

5. Experiments

Seven to ten measurements were made in each line marked on the pipe and at the same time an equal number of measurements in the pouring spout for comparison, obtaining approximately 2000 measurement data from the experiment. The experiment being time-consuming, we stopped sometimes to restart the next day, getting some variation in the flow but without affecting the experiment. Three experiments were made for different flows [2].

6. Results

The resulting information consists of the length of straight pipe after and before the ultrasonic meter, the data obtained by the electromagnetic flow meter, and the the flow measured in the pouring spout. As the pouring spout was calibrated, the flow measured with it was considered as the benchmark. For the presentation and analysis, flows were treated with the simple formula

$$E = (Qv - Qm)/Qv * 100, \tag{2}$$

where E is the error between flows expressed as a percentage, Qv is obtained with the pouring spout (1) and Qm is obtained with the ultrasonic meter. If E is positive then, the flow will be greater in the pouring spout; if is negative, the flow in the ultrasonic meter is higher [1].

7. Analysis of results

For flows close to 8 l/s the results were not satisfactory. From markings 0 to 40, the difference could not be established because the errors were very hight; from markings 40 to 70 errors reached values around 60 percent and from markings 70 to 100 error values were around 10 percent. In this case the first evidence relating the measurement was that the pouring spout was not able to measure less than 8 l/s. For flows close to 22 l/s, for markings 0 to 10 the errors were around 7 percent, for markings 10 to 50, the error was reduced to around 2-3 percent, while for the last length, for markings 50 to 100, the errors behaved randomly with values between -1 to 8 percent. For flow close to 33 l/s, in general, the experiment had better repeatability, and more stable behavior; for markings 0 to 20, the error was negative between 2 and 5 percent, for markings 20 to 100 the errors were between -1 to 3, mostly positive, and, finally for markings 30 to 40 there was a very favorable trend of errors between 2 and 3 percent, the minimal amount of error ocurring between the two meters [2].

8. Conclusions and recommendations

Apparently, the length of the straight pipe before and after meter sections were decisive factors in the quality of the measurement, but the great dispersion of results, and the poor repeatability of the measurements data obtained by the ultrasonic meter, said the opposite. We have to be careful in measurement with ultrasonic meters because of the low reliability due to uncertainty and bias under the experimental conditions shown in this work, according to the obtained results.

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