Compact water meter calibration bench

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Abstract A calibration bench was developed and constructed to calibrate domestic water meters, especially for the needs of the water distribution companies. The bench could calibrate up to 6 water meters at the same time in the present version. It was designed to work with water and in normal operation with two reservoirs and a battery of working standards, electromagnetic flowmeters of special grade. The mag meters assure an uncertainty of less than 0,3%, because they are calibrated on the spot: there is an electronic scale in the circuit of the bench that can be used at any time to calibrate the secondary standards or the meters under test. With this, this bench is almost a "primary" laboratory. A centrifugal pump feeds the constant head level tank and the water in excess turns back to the lower reservoir, assuring that there is no influence of the level of water, or of its oscillation due to the pump movement, in the calibration of the meter. For the highest flow rates, the pump is used in direct connection to the meters under test, with no passage through the upper reservoir. The range of operation is from 2 L/h up to 7500 L/h. The control is totally automated using a PLC and data is stored in an electronic data sheet.

Keywords: water flowmeters, calibration, bench, laboratory

1. Introduction

Water in Brazil presently is an issue of great concern regarding measurement. There are new rules and an agency that is preparing to monitor water consumption on large companies, establishing payment of royalties for the water drawn from reservoirs and rivers, and is taking care of the unaccounted for water index of the water companies. Only in São Paulo City the water company supplies 65 m³/s, of which up to 45% is not accounted for in the consumer's meters. This high loss index can result in higher interest rates when the company needs financing from funding institutions. There are about 2,6 million consumers with residential water meters in the city and its surroundings. There is a difficulty in closing the water mass balances between the supplied amount of water and the water actually measured by the residential water meters, due either to the level of uncertainty measured in large pipelines and to the difficult to assure the desired level of uncertainty in domestic water meters.

The intent of developing this kind of bench is therefore to improve the level of uncertainty in the metering of residential water consumption.

The most common calibration benches nowadays utilize the principle of calculating the flow using the pressure drop metered with many tiny orifices, which besides needing a long time to perform the calibration, have an uncertainty level to be determined.

This way, there was a need of building a compact bench, with a small uncertainty level, easy to operate, automated and movable.

2. Lab in a bench – developing the idea.

The proposed rig reproduces a classic laboratory for calibration of water flow meters, with two circuits: a gravimetric system and a system of comparison with master meters.

The gravimetric system allows the calibration of the master meter and also the calibration of tested meters. The advantage of calibrating the master meters in the same local they are installed is the improvement in the calibration uncertainty, because the electromagnetic meters are influenced by the velocity profile, caused by the compact pipework of the arrangement upstream and downstream the standard meters.

With this gravimetric calibration "in situ", the uncertainty level can reach 0,3%.

In normal conditions, in order to accelerate the calibration process, always warranting the flowing stability in relationship with pressure and flow, the tested meters are calibrated against the master meters. In cases when there are doubts, the meters can be calibrated using the gravimetric system.

3. Circuit Description

The intention of building a "Lab in a Bench" was to improve the level of uncertainties, reduce the time of calibration, and offer a complete lab easily transportable.

Thus, meters to be calibrated can have diameters up to 1 inch, which is the normal size of residential meters and the project maximum flow of the bench is 10 m³/h.

The bench can be used to calibrate up to 6 residential meters at the same time, arranged in series.

The Brazilian standard NBR 8193 demands that, if the meter under test has an analog indicator, when calibrating the minimum flow of the meter, the amount of collected water should be at least 100 times the minimum scale division. The minimum flowrate this kind of meter can operate with is 0,006 m³/h. So that stability is achieved for these low flowrates, there is a reservoir whose level is maintained constant by means of a double propeller centrifugal pump. This regulation also demands that the minimum flow is measured, which demands a long time for the calibration in the present calibration processes. For instance, for a minimum flow of 6 liters/hour, in a meter with a resolution of 0,1 liter, the minimum amount of water required for the calibration is 10 liters, which would demand 1h40min of calibration, only for that flowrate. Since it is necessary to measure three times the same flowrate, the time needed for one flowrate would be about 5 hours. To overcome this time consumption, an electronic system was installed in the bench, using an optical sensor to generate pulses to every passage of a gear-like device in the axis of the meter display. The total water volume required is therefore smaller, and the time of calibration can be reduced. The electronic resources provide a very distinctive difference between the developed bench and the regular benches, which are totally mechanical. The automated bench can totalize volumes and acquire standard volume and tested volume at the same time.

The electronics of the bench consists of a PC, a supervisory system, a data acquisition system and a PLC. The PLC gets all the information from the bench: number of pulses, water temperature, water pressure and actual flow rate, corrected to the standard conditions. It also controls the frequency inverter, which regulates the flowrate, and maneuvers proportional and on-off valves. All the information acquired by the supervisory system is exported to an Excel sheet.

The bench provides three options for flowrate regulating: a frequency inverter, a proportional valve or, for very low flowrates, the regulation is done manually, using the water in the reservoir. The frequency inverter and the proportional valve can be used together.

The master meters of the bench are electromagnetic meters, which present an uncertainty of 0,3%. The flowrates of these meters superimpose each other. The minimum flowrate measured by the electromagnetic meters is 7 liters/hour. This way, the electromagnetic meter with the lowest flowrate can be substituted by a positive displacement meter, which can achieve even lower flow rates, since it has been calibrated for a range between 2 and 100 liters/hour.

4. Bench Construction

The following figures show some details of the bench.
Figure 1 shows a picture of the bench.
Figure 2 shows a general scheme of the bench.
Figure 3 shows the gravimetric system, which is used to calibrate the master meters as well as some of the meters under test.
Figure 4 shows the bench being used in a calibration of four residential meters. In the back, it is possible to see the master meters. The indicators shown in the picture belong to the master meters.

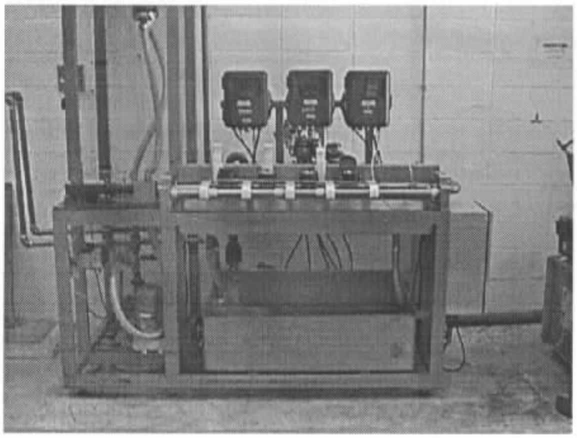

Figure 1: Compact water meter calibration bench

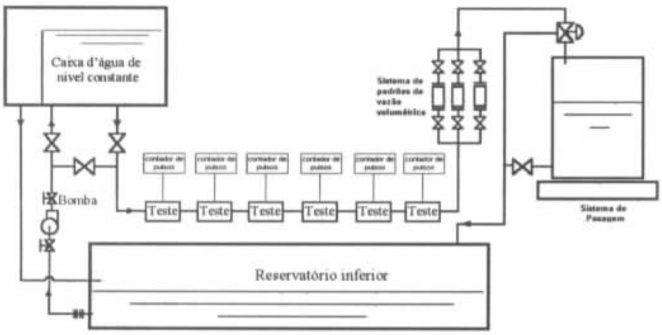

Figure 2: Scheme of the bench

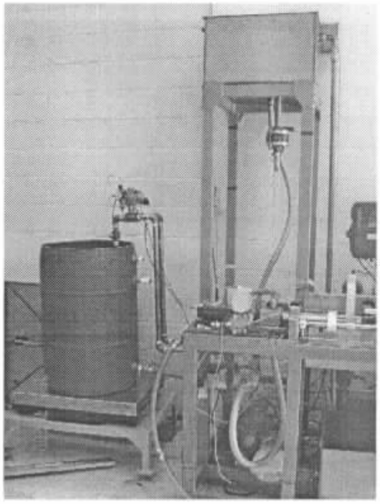

Figure 3: Weighing tank and reservoir

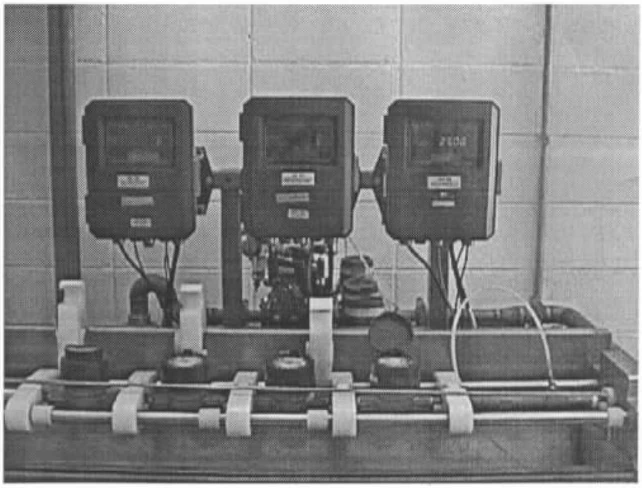

Figure 4: Meters being tested

5. Software and Supervisory System

The system uses a graphic interface to control the bench. With the supervisory system, which works with a software specially developed for this bench, the controller is able to specify which valves they want to open or close or how much the proportional valves must be opened. They can also verify the flowrates in the meters and the water temperature and pressure as well as control the pump rotation speed through the frequency inverter.
Figure 5 shows the working screen of the supervisory.

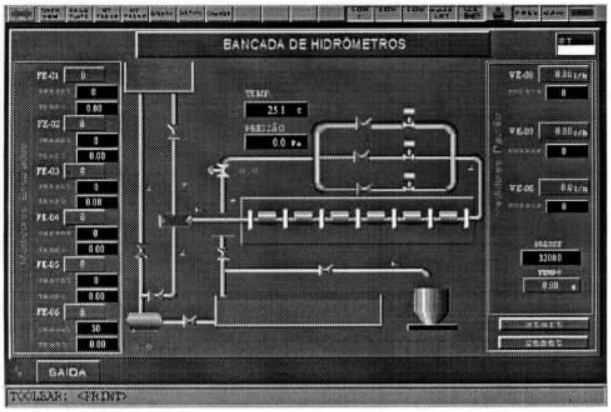

Figure 5: Screen of the supervisory

6. Results

The electromagnetic master meters have been calibrated "in situ", and the results of this calibration are shown in tables 1, 2 and 3. All the meters have a polynomial estimative of the error, which is given by the following equation:

$$\text{Error (\%)} = c_{-2}(Q)^{-2} + c_{-1}(Q)^{-1} + c_0 + c_1(Q) + c_2(Q)^2$$

The equations used to calculate the true volume are:

$$\text{Indicated volume} = \frac{\text{Number of pulses}}{\text{Nominal K factor}}$$

$$\text{Indicated flow (Q)} = \frac{\text{Indicated volume}}{\text{Metering interval}}$$

$$\text{Error (\%)} = \frac{\text{Indicated volume} - \text{True Volume}}{\text{True Volume}}$$

Table 1: Calibration results of the electromagnetic master meter in the range between 70 and 700 L/h.

Indicated Flowrate L/h	True K Factor Pulses/L	Error %
71,27	1006,6	0,66
178,9	1005,0	0,50
315,4	1005,0	0,50
526,9	1003,8	0,38
706,2	1003,0	0,30
Factors for the polynomial estimative	c_{-2} = 1,9215E+04 c_{-1} = -2,50288E-02 c_0 = 2,05389E+00	c_1 = -3,32142E-03 c_2 = 1,84559E-06
Polynomial expanded uncertainty		0,12%
Coverage factor		2,03
Confidence level		95%

Table 2: Calibration results of the electromagnetic master meter in the range between 260 and 2500 L/h.

Indicated Flowrate L/h	True K Factor Pulses/L	Error %
261	1006,0	0,60
393	1003,7	0,37
260	1001,4	0,14
698	1000,9	0,09
1237	1000,3	0,03
1858	998,8	-0,12
2475	998,5	-0,15
Factors for the polynomial estimative	c_{-2} = -5,59788E+04 c_{-1} = 5,67803E+02 c_0 = -8,87796E-01	c_1 = 5,14527E-04 c_2 = -1,26050E-07
Polynomial expanded uncertainty		0,12%
Coverage factor		2,02
Confidence level		95%

Table 3: Calibration results of the electromagnetic master meter in the range between 1500 and 7400 L/h.

Indicated Flowrate L/h	True K Factor Pulses/L	Error %
1515	101,5	1,54
3002	101,6	1,65
5006	100,4	0,45
6435	100,9	0,87
7420	100,2	0,17
Factors for the polynomial estimative	c_{-2} = -1,65455E+08 c_{-1} = 2,12720E+05 c_0 = -8,66667E+01	c_1 = 1,44047E-02 c_2 = -8,29235E-07
Polynomial expanded uncertainty		0,45%
Coverage factor		2,25
Confidence level		95%

Acknowledgment

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Reference

[1] ABNT – Associação Brasileira de Normas Técnicas. *NBR NM 212 - Medidores velocimétricos de água fria até 15 m³/h.* Rio de Janeiro, Brazil. 1999.

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