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ANALYSIS OF WATER METER ACCURACY IN PRESSURE VARIATIONS AND FLOW CONDITIONS IN GRAVIMETRY TEST EQUIPMENT

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Abstract. A water meter is a device used to measure the volume of water used by customers and is used as a basis for determining water retribution. The influence of pressure both in the position before (upstream) and after the water meter (downstream), then flow conditions that could be temporal and stable also affect on the accuracy of the water meter. Then, in this study, a prototype of a water meter test equipment was made that was able to vary the pressure in two positions and flow conditions and then determine the error of the test water meter automatically from the weighing process. Prototype scales and sensors (pressure gauge sensors, flow gauge sensors and temperature gauge sensors) have accuracy and precision in the range of 93,4%-99,9% and were connected to smartphones via an Android app that has data acquisition capabilities. The test results showed three downward error trends, namely 6,63%-4,70% (Temporal Flow, Upstream Position Pressure Regulation); 4,41%-3,66% (Temporal Flow, Downstream Position Pressure Regulation) and 3,21%-1,76% (Temporal Flow, Downstream Position Pressure Regulation). The results of the analysis showed that the pressure difference between the upstream position and the downstream position that exceeded 0,63 bar caused the test water meter error to exceed the error limit of ±4%, especially in temporal flow conditions compared to stable flow.

Keywords: water meter, weighing, pressure variation, flow conditions, pressure difference

Abstrak. *Meter air merupakan alat yang digunakan untuk mengukur volume air yang digunakan pelanggan dan digunakan sebagai dasar penentuan retribusi air. Pengaruh tekanan baik pada posisi sebelum (upstream) maupun sesudah meter air (downstream), lalu kondisi aliran yang dapat bersifat temporal maupun stabil juga memiliki efek terhadap akurasi dari meter air. Kemudian, pada penelitian ini dibuat prototipe alat uji meter air yang mampu memvariasikan tekanan pada dua posisi dan kondisi aliran lalu menentukan error meter air uji secara otomatis dari proses penimbangan. Timbangan dan sensor prototipe (sensor tekanan, sensor aliran dan sensor suhu) memiliki akurasi dan presisi pada rentang 93,4%-99,9% dan terhubung dengan smartphone melalui aplikasi Android yang memiliki kemampuan akuisisi data. Hasil pengujian menunjukkan tiga kecenderungan penurunan error yaitu 6,63%-4,70% (Aliran Temporal, Pengaturan Tekanan Posisi Upstream); 4,41%-3,66% (Aliran Temporal, Pengaturan Tekanan*

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Posisi Downstream) dan 3,21%-1,76% (Aliran Temporal, Pengaturan Tekanan Posisi Downstream). Hasil analisis menunjukkan selisih tekanan posisi upstream dan posisi downstream yang melebihi 0,63 bar menyebabkan kesalahan meter air yang diuji menjadi lebih besar dari batas kesalahan ±4% terutama pada pada kondisi aliran temporal dibandingkan pada aliran stabil.

Kata kunci*: meter air, penimbangan, variasi tekanan, kondisi aliran, selisih tekanan*

1. Introduction

One of the vital needs of mankind is clean water and currently, it is mostly supplied by Drinking Water Companies (PAM) [1]–[3]. This process is not cheap because there are costs for operating a treatment plant and distribution system so that clean water can reach customers. For this reason, the customer must pay a bill for the volume of water used [4], [5]. Therefore, the volume of water must be measured with a measuring instrument known as a water meter. In principle, a water meter is a combination of several components to calculate and state the volume of water flow that is used as the basis for water bill calculation to water customers [6]. To guarantee the correctness of the measurement, the water meter is included as a measuring instrument that is supervised by the government to ensure that there is no loss for both the PAM and the customer [7].

In the beginning, one of the factors that influenced the correctness of water meter measurements was pressure [8-11]. To reach the customer, the pressure is usually kept high at the initial distribution point and must meet a minimum pressure requirement of 1 bar at the customer's endpoint. However, field data shows that the final pressure is less than the provisions and fluctuates [12-14]. This condition of course affects the water meter. A decrease in pressure is known to cause an increase in the negative error or a smaller reading of the water meter compared to the standard reading, while an increase in pressure causes an increase in the positive error of the water meter [8], [9]. Nevertheless, the study was still carried out on a separate device [8] and has not measured the pressure before and after the water meter [9]. Thus, the relationship between the pressure before and after the water meter and the correctness of the water meter measurement has not been known until now [8], [9]. Therefore, this study will develop a prototype of water meter test equipment for variations in pressure and flow conditions and automatic determination of water meter measurement errors based on Android. The prototype was made with the principle of weighing (gravimetry) because it can measure larger flow volumes according to the scales used and can produce accurate volume indications based on weighing results [15]. The effect of this pressure will be tested with two flow conditions when the water meter is used, namely temporal flow conditions and stable flow conditions by SNI 2418.3:2009 [16] because this study has never been carried out until now [8-10], [15].

2. Research Methods

The research methodology consists of making test equipment, calibrating and testing the accuracy of a water meter. This study began by making a water meter test equipment using the gravimetric method according to the standard provisions of SNI 2418.3:2009 and the Technical Requirements for Water Meters [15], [16].

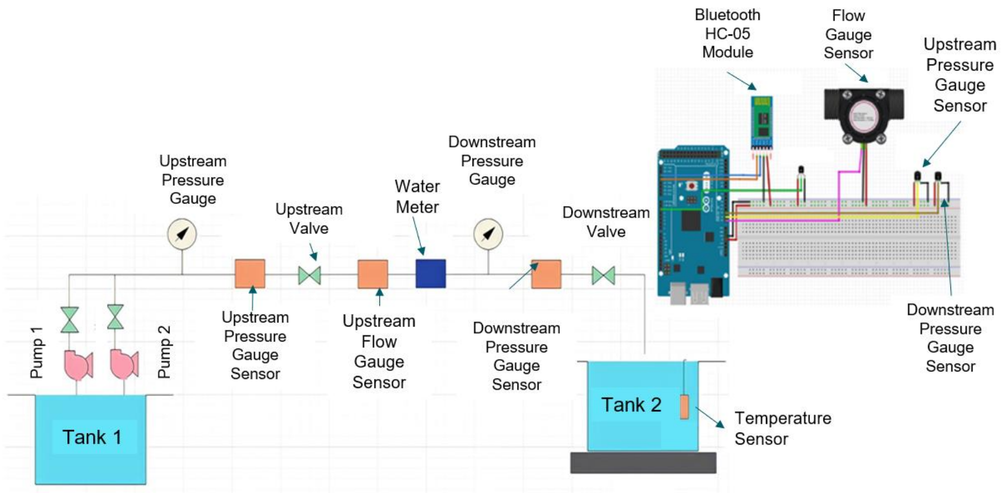

Figure 1. Prototype design

In Figure 1, the test equipment created consists of a double water pump to generate water flow and generate water pressure. The process begins with the flow of water by the water pump towards the pressure gauge sensor in the upstream position and the analog pressure gauge, then to the discharge measuring sensor, then flows towards the sample of the water meter being tested.

Then the water is supplied to the pressure gauge sensor and analog pressure gauge in the downstream position. In the final stage, the water flow will go to the tank which is located above the scale [17] to measure its mass and the water temperature will be measured with the temperature sensor [18] as the basis for calculating the density of water. Because the test is based on the gravimetric method, accuracy is determined from the difference between the standard reading (the mass of water being weighed) and the reading of the water meter being tested (the volume measured from the water meter that is being converted to mass).

There are four sensors installed, namely a pressure gauge sensor (upstream and downstream positions), a temperature gauge sensor, and a flow gauge sensor which will send the signal to the microcontroller (Arduino Mega), then the signal will be processed into several magnitude values. Then the data is sent via the HC-05 Bluetooth module to a smartphone which can be monitored using the Android application [19]. The smartphone screen will display data from each measuring sensor and other quantities used in the testing of a water meter, such as the water density calculated using the Tanaka formula [20], as well as other data that must be entered manually, such as reading scales, reading values pressure gauge, and water meter register number. Then the test conclusion will be displayed in the form of several values such as the mass readings of the standard equipment and the equipment being tested (water meter), and the percentage error value of the water meter being tested.

The second stage was the calibration of the measuring sensor in the prototype. Calibration is an activity of determining the correctness of the value of a measuring instrument that is tested against the value of a standard measuring instrument that is traceable to national and international standards [21]. Therefore, calibration was carried out on the scales and the prototype sensors such as the temperature gauge sensor, flow gauge sensor, and pressure gauge sensor. Scale calibration was carried out using the CSIRO Calibration

Method [22] in the form of testing the correctness of the scale, testing the repetition of readings, and testing the influence of weighing positions. Furthermore, the calibration of the temperature gauge sensor is carried out according to the ASTM E-77:1998 method [23]. Then, calibration of the flow gauge sensor was conducted using a Standard Measuring Vessel as a standard volume measuring instrument [24] and a stopwatch [21]. Finally, calibration of the pressure gauge sensor was carried out by comparing the indication of the pressure gauge sensor with an indication of an analog pressure gauge which has higher accuracy [25].

The third stage is testing the water meter using a prototype test tool. This stage is carried out by following the provisions and procedures in the Technical Requirements for Water Meters [15] and SNI 2418.3:2009 [16]. The test begins with operating the pump (pump 1 then pump 2) to circulate water and increase the pressure, then the pump valve is opened. The upstream valve and downstream valve are set to determine the pressure under test. The first test condition is the Temporal Flow Condition (Method A SNI 2418.3:2009) [16], the initial water meter register is entered into the application and the scales is being tared, then when the water flowing through the test water meter has already flowed to the tank 2, therefore the gauge sensor reading on the application is taken (by operating the 'Hold' button), then the analog scale reading on the pressure gauge is entered on the application. After one minute the water flows, the test is stopped, then the final register of the water meter is entered into the application system then the 'calculate' button in the application is operated to convert the water volume data of the tested measuring equipment (water meter) into the test mass and determining its percentage error from the difference with the mass standard. The collection of data is then taken from operating the sequence numbering of data in the application system. Testing with the second condition is Stable Flow Condition (Method B SNI 2418.3:2009) [16] where the difference to the first method is that the time of test procedure is started when the prototype test equipment is already operated with a steady flow state.

3. Results and Discussion

The prototype of the water meter test equipment using the gravimetric method is shown in Figure 2.

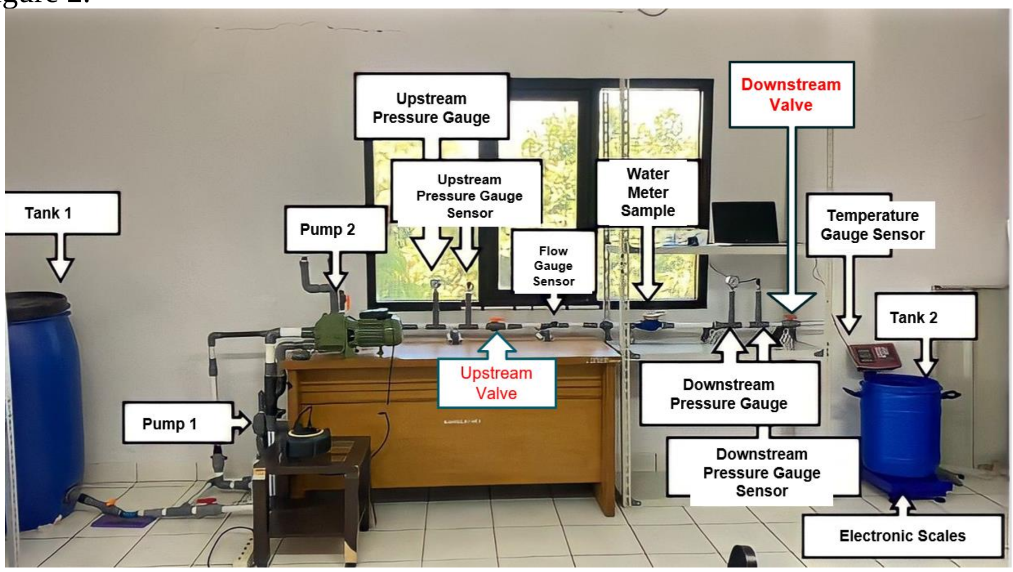

Figure 2. Manufacturing result of Water Meter Test Equipment Prototype

The prototype test equipment was made according to the plan in Figure 1. Based on this design, the prototype test equipment can test household-type water meters in several upstream and downstream pressure conditions (with pumps, upstream valves, downstream valves, pressure gauge sensors and pressure gauges) by gravimetric method (integrated with scales, temperature gauge sensors, and flow gauge sensors) both in stopped-flow conditions and steady flow conditions.

Furthermore, to guarantee the correctness of the results of testing the water meter by the prototype, it is necessary to calibrate the prototype scales and sensors to determine the characteristics of precision and accuracy. Accuracy shows the percentage of closeness between the value of the test measuring instrument and the value of the standard measuring instrument, while precision is the closeness of the measurement results when the system measures the same object repeatedly [26].

Because the test was carried out using the gravimetric or weighing method, the first part of the prototype to be calibrated was an electronic scale (having a load cell sensor) with a weighing capacity of 150 kg with 3 (three) tests, namely reading repetition testing, testing the correctness of the scale, and testing the effect of weighing position [22]. Repeated reading testing with 10 (ten) consecutive weighing at half full load capacity (70 kg) and full load capacity (150 kg) resulted in a standard deviation of 0,021 kg and 0 kg, a bias of 0,01 kg and 0,05 kg; precision 99,9% and 100%; and 99,89% and 99,96% accuracy. With such high values of precision and accuracy, the scales have good results in the reading repetition test [22]. Furthermore, the results of testing the correctness of the scale at a load of 150 kg showed a correction of 0,00 kg which was much smaller than the 3 × standard deviation value which also showed that the scales were still working properly [22]. Finally, the results of testing the effect of weighing position with a load of 50 kg (half the maximum capacity) show the same weighing result of 50,00 kg in all positions on the loading scale floor (center, right, left, front and rear). All of these calibration results show that the scales do not need to be reset [22].

The calibration results of the upstream and downstream position pressure gauge sensors are summarized in Table 1 and Table 2.

Table 1. Calibration result of upstream position of pressure gauge sensor

No.	Standard (bar)	Test (bar)	Bias (bar)	Deviation Standard (bar)	Accuracy (%)	Precision (%)
1	0,4	0,4	0,0	0,0	100,0	100,0
2	0,6	0,6	0,0	0,0	100,0	100,0
3	1,0	1,0	0,0	0,0	100,0	100,0
4	1,2	1,2	0,0	0,0	100,0	100,0
5	1,5	1,5	0,0	0,0	100,0	100,0
6	1,8	1,8	0,0	0,0	100,0	100,0
7	2,0	2,0	0,0	0,0	100,0	100,0
8	2,2	2,2	0,0	0,0	100,0	100,0
9	2,5	2,5	0,0	0,0	95,1	94,4
10	2,8	2,8	0,0	0,0	100,0	100,0
11	3,0	3,0	0,0	0,0	100,0	100,0
12	3,5	3,5	0,0	0,0	96,5	96,0
13	4,0	4,0	0,0	0,0	100,0	100,0
14	4,5	4,5	0,0	0,0	97,3	96,9

Table 2. Calibration result of downstream position of pressure gauge sensor

No.	Standard (bar)	Test (bar)	Bias (bar)	Deviation Standard (bar)	Accuracy (%)	Precision (%)
1	0,5	0,5	0,0	0,0	100,0	100,0
2	1	1,0	0,0	0,0	100,0	100,0
3	1,5	1,5	0,0	0,0	100,0	100,0
4	2	2,0	0,0	0,0	100,0	100,0
5	2,5	2,5	-0,7	0,0	95,1	94,4
6	3	3	0,0	0,0	100,0	100,0
7	3,5	3,5	0,0	0,0	100,0	100,0
8	4	4,0	0,0	0,0	100,0	100,0
9	4,5	4,5	0,0	0,0	100,0	100,0

The calibration of the upstream position pressure gauge sensor was measured at 14 (fourteen) test points (Table 1) and each test point was measured 3 (three) times for up and down measurement conditions. In the same way, the downstream pressure gauge sensor is calibrated at 9 (nine) measuring points (Table 2). As shown in both tables, the two pressure gauge sensor units of the prototype show very good average accuracy and precision of 99,2% and 99,1% (upstream pressure gauge sensor) and 99,5% and 99,3% respectively (downstream position pressure gauge sensor). The high accuracy and precision of both pressure gauge sensors indicate that these sensors can be used for pressure measurement on prototypes. All accuracy and precision values are determined from standard values (as true values), bias and standard deviation [26].

The temperature gauge sensor from the prototype is calibrated with the results as shown in Table 3. This table shows the Micro-bath temperature values (as the temperature test medium), standard temperature and sensor temperature. From the six data displayed, the results of the temperature gauge sensor (test measuring instrument) indications are close to their respective of the standard measuring instrument at every test point, with an accuracy percentage of 98,1% and a precision percentage of 99,8% which indicates that the temperature gauge sensor is working properly in the prototype.

Table 3. Calibration result of temperature gauge sensor

No.	*Micro-bath* (°C)	Standard (°C)	Test (°C)	Deviation Standard (°C)	Accuracy (%)	Precision (%)
1	20	20,4	20,2	0,0	98,2	99,3
2	22	22,5	22,3	0,0	98,1	99,3
3	25	24,3	24,5	0,0	99,2	100,0
4	28	28,3	27,6	0,0	97,6	100,0
5	30	30,4	29,6	0,0	97,4	100,0

The results of the flow sensor calibration are shown in Table 4.

Table 4. Calibration result of flow gauge sensor

No.	Test Point (LPM)	Test (LPM)	Standard (LPM)	Deviation Standard (LPM)	Accuracy (%)	Precision (%)
1	5	5,18	5,211	0,188	89,1	88,6
2	10	9,47	9,519	0,052	98,4	97,9
3	15	14,75	14,802	0,273	94,4	94,1
4	20	19,55	20,029	0,416	93,6	91,4

This calibration is carried out by comparing the results of the readings of the flow gauge sensor (test gauge) with the standard measure of flow determined from the division of the water volume (as measured by the Standard Measuring Vessel) by the flow time (as measured by a stopwatch). Before calibration is carried out, initial measurements are carried out to determine the value of the sensor coefficient on programming in the microcontroller and a linear regression equation is obtained with a slope coefficient value of m = -0,85 and a constant c = 1,12. Then, these two equation numbers are entered into the programming so that the flow sensor measurement values can approach the actual values in LPM units (Liters Per Minute) as shown in Table 4. The average calculation results for flow sensor accuracy and precision from Table 4 data are 93,9% and 92,9% so it can be stated that this flow sensor can be used in the prototype for measuring the flow.

With the calibration results of all prototype components as shown in Table 1 to Table 4, the scales and all measuring sensors on the prototype have shown a good level of accuracy and precision. However, the calculation results of the prototype application need to be validated before being used. The application is shown on the Smartphone screen and connected to the prototype sensor by Bluetooth. The process of the application begins with the display of temperature, flow, upstream position pressure, downstream position pressure and density data (Figure 4). By entering T = 24,8°C in Tanaka's Formula [20], namely $\rho = \alpha_0\{1 - [(T+\alpha_1)^2(T+\alpha_2)]/[(\alpha_3(T+\alpha_4)]$, where α_0 = 0,99997495 kg/l; α_1 is -3,983035 °C; α_2 is 301,797 °C; α_3 is 522528,9 °C^2; and α_4 is 69,34881 °C, then the density of water at the testing time is obtained as 0,997098 kg/l which is consistent with the designation of the density in the application of 0,9970 kg/l in Figure 3.

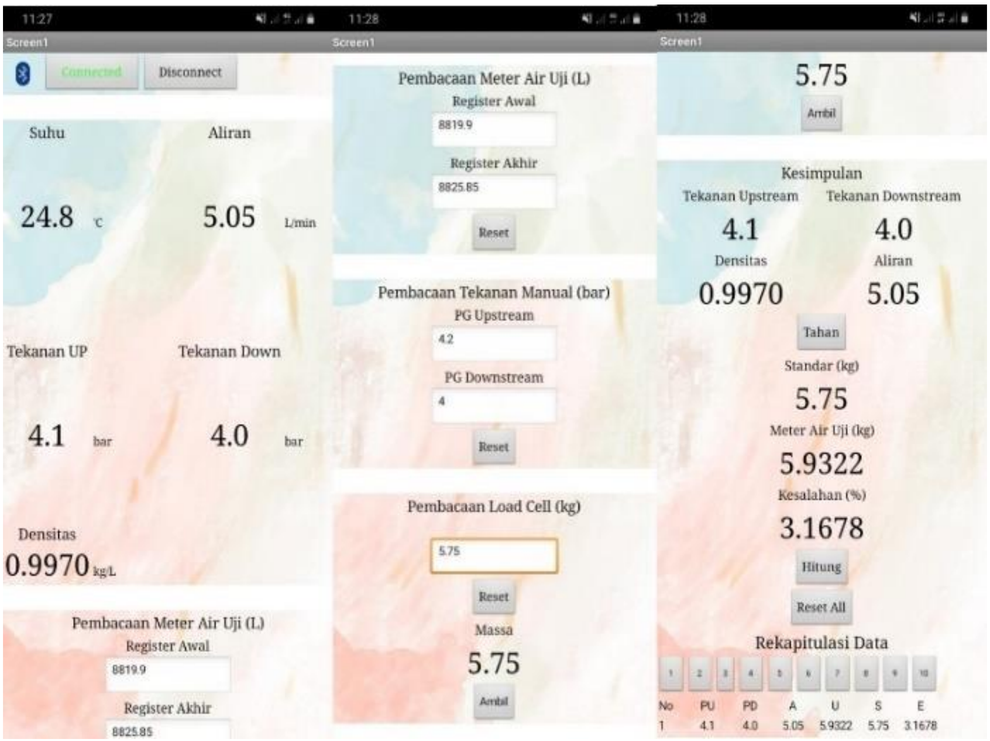

Figure 3. Result of smartphone screen on displaying the water meter testing condition

Furthermore, from the difference between the reading of the final register and the initial register of the test water meter, the volume of the test water meter will be obtained

(8825,85 l – 8819,9 l = 5,95 L), then with the density value obtained, the test mass is calculated from multiplying the density by the test volume (test mass = 0,9970 kg/L × 5,95 L = 5,93215 kg) which is consistent to the test water mass of 5,9322 kg in the application. Furthermore, the difference between the test and standard indications [27] [28] is processed into error = 100 ×[(test mass-standard mass)/standard mass], where the standard mass is obtained from the reading of the scales, so the error is calculated as error = 100 [(5,93-5,75)/5,75], and an error of 3,17% is obtained which is consistent with the calculation results in the application of 3,1678%. Values of upstream pressure (PU), downstream pressure (PD), flow (A), test mass (U), standard mass (S), and error (E) are recorded in the Data Summary. Because the application has been validated on the results of its calculations, the prototype is ready to be used for testing water meters under various conditions of pressure and flow.

By the water meter specifications and water flow requirements in the Technical Requirements for Water Meters [15], [29], there are 4 (four) test flows namely Q1 of 0,5 LPM; Q2 of 2,1 LPM; Q3 of 26,7 LPM and Q4 of 33,4 LPM. To be used for determining the PDAM water bill, the test water meter has at least an error value not exceeding ± 4% and ± 10% for low flow areas (Q1≤Q≤Q2) at the time of re-calibration because the test water meter has been calibrated previously.

Table 5 shows the results of testing the accuracy of the water meter using the stop flow condition (Method A) by modifying the upstream pressure setting by 30 repetitions at each test point. When the pressure in the upstream position (PU) is increased from 0,6 bar to 4 bar while the downstream position pressure (PD) is kept constant at 0,2 bar, the indication of the mass of the test meter (MT) from the test water meter approaches the mass of the weighing results of the standard measuring instrument (MS) with a test water meter measurement error ranging from 6,63% to 4,70%. In this pressure range, the observed discharge is 4,46 LPM to 18,48 LPM which is close to the test flow ranges Q2 and Q3 of the water meters tested or in high flow areas, so the error in the test results tends to exceed the error limit.

Table 5. Water meter accuracy test result on Method A (upstream pressure regulation)

No.	Flow Rate (LPM)	PU (bar)	PD (bar)	ΔP (bar)	MT (kg)	MS (kg)	*Error* (%)
1	4,46	0,6	0,2	0,4	5,14	4,82	6,63
2	8,77	1,1	0,2	0,9	9,03	8,51	6,22
3	6,68	1,5	0,2	1,3	7,38	6,99	5,58
4	7,24	2,0	0,2	1,9	8,37	7,97	4,96
5	14,92	2,5	0,2	2,3	15,30	14,64	4,50
6	18,48	3,0	0,2	2,8	18,93	18,07	4,78
7	17,14	3,5	0,2	3,3	18,55	17,69	4,91
8	8,49	4,0	0,2	3,8	8,17	7,81	4,70

Furthermore, the water meter test conditions will be changed by adjusting the downstream position pressure to see possible changes in errors from Method A and the results are shown in Table 6. In the table, the downstream position pressure is increased from 0,6 bar gradually to 4 bar while the upstream position pressure is measured in the range of 3,0 bar to 4,2 bar producing a discharge between 4,99 LPM to 18,10 LPM and a decrease in the test water meter error from 4,41% to 3,66% which is smaller than the error range 6,63% - 4,70% at upstream pressure setting conditions. Thus, the results of the condition test in Table 6 begin to produce an error below the allowable error limit of ±4%, which is observed when the pressure in the downstream position is above 3 bar.

The next stage is testing the water meter with Method B with downstream pressure setting conditions and the results are shown in Table 7 obtained from 10 repetitions at 8 pressure test points. On increasing the pressure in the downstream position from 0,6 bar to 3,6 bar, the error decreased from 3,21% to 1,76%. These results indicate that the downstream pressure setting in Method B resulted in a lower error reduction compared to the Method A results and the tolerance or allowable error limit of ± 4% over the observed downstream pressure range.

Table 6. Water meter accuracy test result on Method A (downstream pressure regulation)

No.	Flow Rate (LPM)	PU (bar)	PD (bar)	ΔP (bar)	MT (kg)	MS (kg)	*Error* (%)
1	18,10	3,0	0,6	2,4	19,05	18,25	4,41
2	17,41	3,1	1,0	2,1	18,08	17,31	4,49
3	16,18	3,3	1,5	1,8	16,68	15,95	4,60
4	12,83	3,6	2,0	1,6	13,75	13,15	4,61
5	10,63	3,8	2,5	1,3	11,54	11,09	4,08
6	9,40	4,0	3,0	1,0	9,96	9,60	3,83
7	7,38	4,2	3,5	0,7	7,97	7,69	3,68
8	4,99	4,2	4,0	0,2	6,04	5,83	3,66

Table 7. Water meter accuracy test result on Method B (downstream pressure regulation)

No.	Flow rate (LPM)	PU (bar)	PD (bar)	ΔP (bar)	MT (kg)	MS (kg)	*Error* (%)
1	4,47	0,7	0,6	0,1	4,45	4,32	3,21
2	7,47	1,1	0,9	0,2	7,69	7,46	3,08
3	6,95	1,5	1,1	0,4	7,05	6,87	2,63
4	6,38	2,1	1,7	0,4	6,94	6,77	2,60
5	7,24	2,5	2,0	0,5	7,18	7,00	2,59
6	7,54	3,0	2,6	0,4	7,67	7,49	2,37
7	4,85	3,4	3,2	0,2	4,99	4,91	1,74
8	7,23	4,0	3,6	0,4	7,38	7,26	1,76

To investigate the trend of results, the test water meter errors in pressure variations of the upstream and downstream pressure setting positions of Method A and Method B are shown in Figure 4. Thus, this study becomes the first study on the accuracy of water meters under two pressure settings [8], [9], [30]. In studying the influence of the distribution network pressure on the measurement of water meters, the pressure is set only at the upstream position pressure of 0,5 bar to 2,0 bar [9]. Furthermore, in the reliability study of water meters, the regulated pressure is the upstream pressure resulting in a pressure loss of 0,05 bar to 0,08 bar [30]. Then in the study of the accuracy of water meters in housing, the pressure measured only comes from the upstream pressure which comes from tap water [8].

Three trends of decreasing errors due to adjustments are shown in Figure 4, namely 6,63% to 4,70% (A – Upstream method, pressure setting in the upstream position) 4,41% to 3,66% (A–Downstream method, adjusting the downstream position pressure); and 3,21% to 1,76% (Method B –Downstream, downstream pressure regulation).

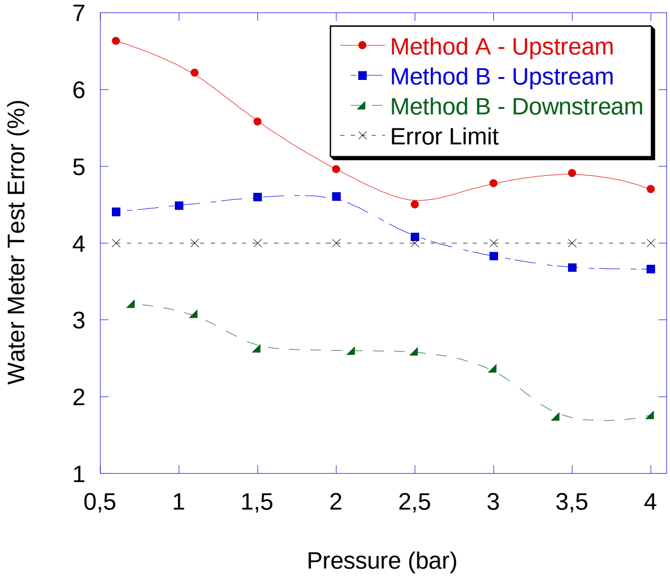

Figure 4. Testing results of test water meters under various conditions

These trends are consistent with observations of a decrease in the value of the water meter error when the pressure is increased which can be caused by one of the following factors such as a decrease in the initial flow [9], [31], an increase in the ability to read the water meter [8], and pressure differences [16], [30]. Among these three factors, the easiest to observe in this study is the difference in pressure because pressure measurements are available in the upstream and downstream positions, the results of which are shown in Figure 5.

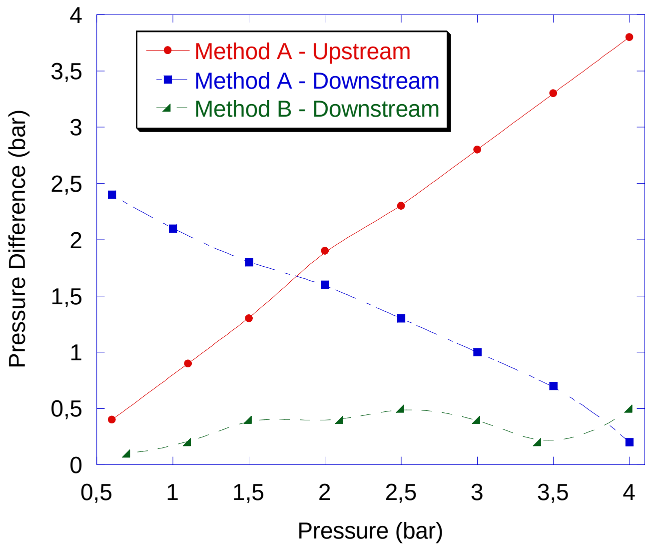

Figure 5. Difference in upstream pressure and downstream pressure under various test conditions of water meters

In the test conditions with Method A – Upstream, the pressure difference increased from 0,4 bar to 3,8 bar because the pressure in the downstream position was maintained at 0,2 bar while the pressure in the upstream position was increased to 4,0 bar. Under these conditions, the resulting error was above the margin of error (±4%) at all test pressures (Fig. 4). The high error value can be attributed to the high-pressure difference which exceeds the provisions, namely 0,5 bar based on SNI 24318.2:2009 [29] and 0,63 bar on the Technical Requirements for Water Meters [15]. In the conditions of Method A - Downstream data, error is below 4% at the pressure difference value below 0,63 bar such as 3,66% and all errors are below 4% due to testing on the B-Downstream Method due to the pressure difference of around 0,1 bar to 0,5 bar which is less than 0,63 bar. Thus, the reduction in error in this study can be attributed to the difference in pressure in the upstream position and the pressure in the downstream position.

4. Conclusions

A prototype of gravimetric test equipment for testing the accuracy of water meters under temporal flow conditions (Method A) and steady flow (Method B) which can be adjusted at upstream and downstream pressures has been successfully created. The prototype can produce a pressure of 0,6 bar to 4,0 bar and can automatically calculate the error of the test water meter from the difference in the mass of water that results from weighing the water flow reservoir from the water meter and the mass of water converted from the indication of the test water meter. The calibration results on the prototype show a very high level of accuracy and precision, such as scales (99,9 and 100%), upstream position pressure gauge sensor (99,2% and 99,1%), downstream position pressure gauge sensor (99,5%) and 99,3%), temperature gauge sensors (98,1% and 99,8%), and flow gauge sensors (92,9% and 93,9%). The results of testing the water meter at increased water pressure produced three tendencies for decreasing the error, namely 6,63% - 4,70% (Method A, upstream); 4,41% - 3,66% (Method A, downstream) and 3,21% - 1,76% (Method B, downstream). The results of the analysis of the pressure difference between the upstream position pressure and the downstream pressure position show that the pressure difference of more than 0,63 bar causes the error of the water meter being tested to be higher than the tolerance or allowable error limit of ± 4%, especially in the temporal flow condition (Method A) compared to the steady flow state (Method B).

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