NOVEL MODIFICATION OF LARGE WATER CALIBRATION FACILITY

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Abstract: Traditionally, the method used to determine measurement errors of water meters is the so-called "collection" method, in which the quantity of water passed through the water meter is collected in a vessel. Then the quantity is determined volumetrically or by weighing. Other methods with permitted accuracy levels are also accepted by international standards. Now some types of flow meters have relatively high accuracy and can be used to substitute volume tanks as flow standards for error tests of water meters. A flow laboratory which has the water meter test facility has the largest flow capacity in Taiwan. It adopts "collection" method and "delivering" method for error tests of water meters with nominal size (DN) equal to or less than 300 mm and DN from 400 mm to 2000 mm respectively. Nevertheless, test facilities which introduced volume tanks and "delivering" method were normally processed of an unstable flow rate because of the reducing of water level in the volume tank during the measurement and then affected the measurement accuracy of tests. This paper describes the modification of the test facility. The "master meter" method was substituted for "collection" method and will had a maximum test meter size up to 800 mm. The maximum test flow rate could be to 4200 m^3/h and the measurement uncertainty was estimated to be 0.2 %. A novel design of a multi-channel flow adaptive control device was provided for improving the flow stability of "delivering" method. It used a number of drains with control valves to adjust the flow during the measurement. The maximum test flow rate could be up to 10000 m^3/h and the maximum test meter size could reach to 1500 mm.

Keywords: water meter test facility, "collection" method, "delivering" method, "master meter" method, flow rate

1. Introduction

Before 2005, the only water meter permitted by ISO standard for cold potable water is the mechanical water meter. However, with the performance enhancement of electronic water meter, and the increased demand for large diameter water meter, the latest ISO standard [1,2] has no longer imposed any restriction on the type of water meter that can be used for cold potable water. Those cold potable water pipelines constructed in Taiwan with diameters above 600 mm which cannot be measured originally due to the size limitation of mechanical water meter are now going to start being measured by electronic water meter. Therefore, the establishment of measurement error inspection facility meeting ISO standard for water meter with diameter above 600 mm has become a necessary challenge.

The flow calibration facility with the largest water meter test capability in Taiwan adopts "collection" method and "delivering" method for performance tests of water meters with large diameters, and it is capable of calibrating pipelines with maximum diameter up to 2000 mm. However, during calibration process the test facilities adopting volumetric tanks and "delivering" method normally had to face an unstable flow rate leading to measurement error with respect to water meter that cannot be assessed. This kind of test facility cannot obtain the ISO 17025 accreditation of calibration laboratory and the credibility of its measurement results will be questioned.

To meet the flow verification requirements for C class mechanical water mete of existing verification and inspection regulation, and the requirement of water meter diameter from 25 mm to 1500 mm for performing calibration, the working range of flow test equipment improved by this study must cover from 0.1 m^3/h to 10000 m^3/h with maximum diameter nominal up to 1500 mm.

Traditionally, the method used to determine measurement errors of water meters is the so-called “collection” method, in which the quantity of water passed through the water meter is collected in a vessel. Then the quantity is determined volumetrically or by weighing. However, other methods with permitted accuracy levels are also accepted by international standards. Now some types of flow meters have relatively high accuracy and can be used to substitute volume tanks as flow standards for error tests of water meters. For the test facility adopting volumetric tanks and “delivering” method, flow control must be conducted during flow test in order to eliminate the issue of unstable flow resulted from the dropped water level in the volumetric tank and ensure the accuracy of water meter measurement.

This study is about improving the design of water meter test facility under space constraints based on the ISO 5167-1[4] internal fluid flow distribution for the installation of flow meter, the flow rate suitable for flow meter, the pipeline configurations and the calculation of pressure loss. We will describe in detail how to replace “collection” method with “master meter” method and to increase the test range of water meter to diameter nominal of 800 mm. In addition, a novel design of a multi-channel flow adaptive control device was provided for improving the flow stability of “delivering” method. With a number of effluent pipes and flow control valves to adjust the flow during the measurement, the stability of flow can be improved.

2. Overview

The specifications of existing fundamental facilities and site to be improved by this study such as power source, water storage tank and volumetric tank are shown in Table 1. The improved pipelines must meet the ISO 5167-1 flow field distribution of the installation of flow meter in order to prevent vortex and asymmetric flow field distribution. If ideal pipeline installation condition cannot be provided, appropriate flow conditioner can be installed on the upstream of flow meter to reduce the space requirement.

The installation of continuous water pump is necessary for water meter test facilities adopting either “collection” method or “master meter” method. Therefore, the electricity configuration and operating costs of necessary pump installation cannot be avoided. For the test facility using volumetric tank and “delivering” method, the pump for water supply does not have to be operated continuously due to fewer required pump actions such that the costs for electricity configuration and operation can be effectively reduced.

The design of the procedure for flow calibration facility can be divided into two parts: master meter method is used for water meter with diameter smaller than 800 mm, and volumetric tank delivering method is used for water meter with diameter from 900 mm to 1500 mm. The parameter specifications to be achieved after system improvement are shown in Table 2, while the planning of power requirement for system operation is shown in Table 3. In consideration of the power for operation, minimum test flow requirement, and standard part usage, the test region adopting master meter method will be partitioned into large flow region of 800 mm to 200 mm and small flow region of 150 mm to 25 mm. The working standard flow meters used here can be sent to National Standard Laboratory for calibration and trace standard.

Table1 Specifications of site and fundamental facilities

Power source	175 HP/1100 CMH pump x 1 80 HP/500 CMH pump x 2 40 HP/250 CMH pump x 1
Underground storage tank	Volume 300 m^3
Volumetric tank	Maximum volume 200 m^3 (This study uses 80 m^3 of water)
Site area	20 m x 11 m (length x width)

Table 2 Design parameters of water meter test facility

Parameters of water meter teat facility				
methods of measurement	Calibration methods	flow range	meter size	U_{95}
Flying-start-and-finish mode	master meter	4200 to 0.1 m^3/h	25 to 800 mm	0.2 %
	Volumetric (delivering)	10000to 4200 m^3/h	900 to 1500mm	0.4 %

Table 3 Overview of power requirements for system operation

Horse power (HP)	40	80	80	100	175	215
Flow (m^3/h)	250	500	500	600 (INV)	1100	1400 (INV)
Diameter (mm)						
25~80	●					
100~250				●		
300~350	●			●		
400~450	●	●		●		
500				●	●	
600		●	●	●	●	
700	●			●	●	●
800	●	●	●	●	●	●
900~1500					●	

Description：1. INV indicates installation of frequency convertor
2. Master meter method is used for water meter with diameter under 800 mm.
3. Volumetric tank delivering method is used for water meter with diameter from (900 to 1500) mm
4. ● indicates the need for pump

The process flow diagram of flow calibration facility is as shown in figure 1. For the large flow region of 800 mm to 200 mm with master meter method, 300 mm electromagnetic flow meter is used as the standard for work and check, and the flow rate is increased to 4200 m^3/h by parallel approach. For meeting the minimum requirement of flow verification for C class water meter, the calibration facility is supplemented by the electromagnetic flow meters of 80 mm and 25 mm as the standards for work and check such that the minimum flow rate can be as low as 1.5m^3/h. For the small flow region of 150 mm to 25 mm with master meter method, the electromagnetic flow meter of 100 mm, 25 mm, 15 mm are utilized in parallel as the standards of work and check such that the range of flow can be from 600 m^3/h to 0.1 m^3/h. Volumetric tank delivering method is used for the test of water meter with diameter from 900 mm to 1500 mm and the maximum flow can be as high as 10000 m^3/h. The flow stability during test period can be maintained by the design combining buffer tank and multi-channel pressure adjustment.

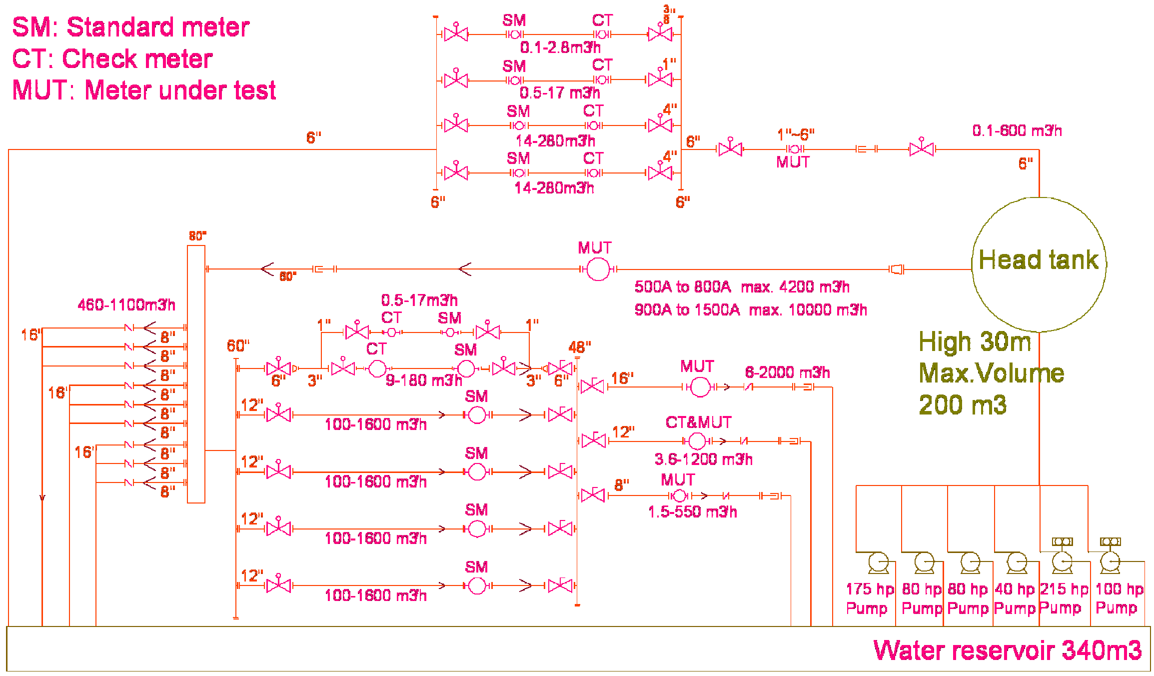

Fig. 1 Process flow chart

3. Detail of Calibration facility

In this study, the on-site configurations of pipelines and equipments are organized according to process flow planning and available space, and the velocity fields of pipelines of calibration system with the addition of flow conditioner are simulated with computational fluid dynamics (CFD) as the reference for the device effect of flow meter based on which the feasibility of pipeline configuration and details of test operation can be confirmed. Master meter pipeline region must be equipped with master meter and its installation pipelines and valves, and it must meet the flow field distribution of ISO 5167-1.

Due to the space limit, for the flow test facility to be improved by this study, the maximum length of straight pipeline which can be provided for the upstream of 300 mm master meter is only 10 times the diameter of pipeline, and with poor flow field distribution confirmed by computer flow field simulation. Therefore, flow conditioner must be installed to improve this situation. During the course of system design in this study, various types of flow conditioners such as Tube bundle, New Zanker, and NEL FC have been tried with different locations in the pipelines to eliminate vortex and asymmetric fluid flow distribution. For example, the New Zanker flow conditioner was installed at the location of 8 times the pipeline diameter in the upstream of 300 mm master meter and connected with pipelines with short pipes of 2 times the diameter. The simulation result of this design with the flow rate of 4200 m^3/h is shown in Figure 2. Under this circumstance, the axial velocity of fluid inside the pipeline of flow meter is within ±5 % of the distribution of fully developed velocity, and the swirl angle at any position of the cross section of pipeline is smaller than 2°, therefore the flow field distribution of ISO 5167-1 is met.

The results of the real flow tests of selected 300 mm master meter with and without the installation of the New Zanker flow conditioner was at the location of 8 times the pipeline diameter in the upstream master meter are shown in Figure 3. The results show that with the installation of the New Zanker flow conditioner, the coefficient of flow meter can be regarded as constant within the range of test flow rate. However, the coefficient of flow meter would vary according to the test flow rate without the installation of the New Zanker flow conditioner. This indicates that the installation of the New Zanker flow conditioner indeed could effectively improve the measurement performance of flow meter, which corresponds to the computer simulation result.

The test for water meter with diameter 900 mm to 1500 mm is conducted by using flow calibration facility with volumetric tank delivering method in order to reduce the costs of electricity configuration and operation. For effectively maintaining the flow stability during test period, the design of flow adaptive control device integrating buffer tank and multiple channels is introduced in this study. By adjusting flow area in the channel, the resistance force at the outlet of test pipeline can be varied in response to the pressure drop in the upstream pipeline due to lowered liquid level in the volumetric tank such that the flow stability of volumetric tank effluent during flow test can be under control and the requirements for testing water meter with large diameter can be met. In this study 7 butterfly valves are used as switches and 2 butterfly valves are used as flow control such that simultaneous control and adjustment of flow area can be achieved. Meanwhile, in conjunction with the pressure detection of test pipeline and the liquid level detection of volumetric tank, the real time adjustment can be achieved to effectively stabilize the water flow during test period. The buffer tank and multi-channel control valves are shown in Figure 4, where valve 1 and valve 2 work as adjustment valves with maximum controllable flow rate around 1400 m^3/h, and valve 3 to 9 work as switches with maximum controllable flow rate around 1750 m^3/h. Figure 5 is the block diagram of the control enabled by buffer tank and multi-channel interactive adjustment.

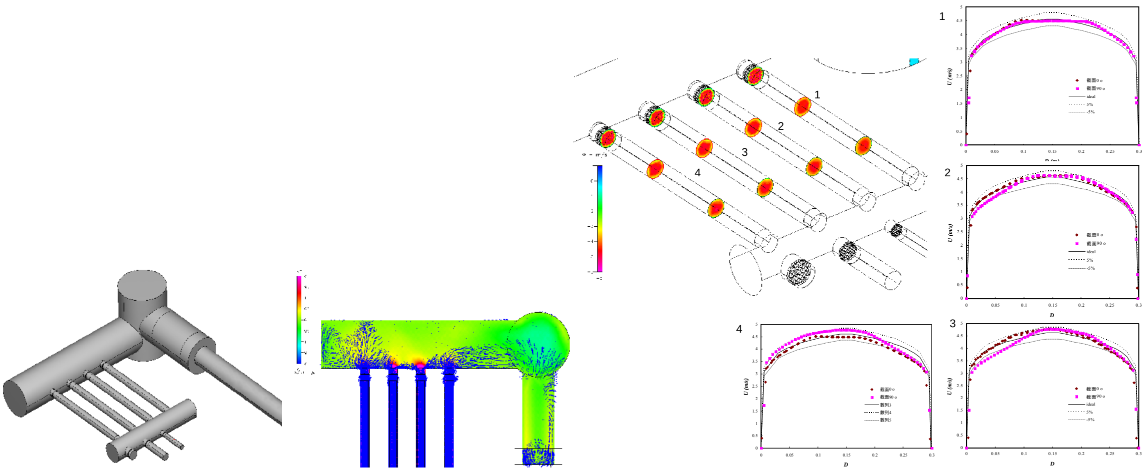

Fig. 2 The elimination of vortex and asymmetric flow field distribution of 300 mm standard device region by using the New Zanker flow straightener

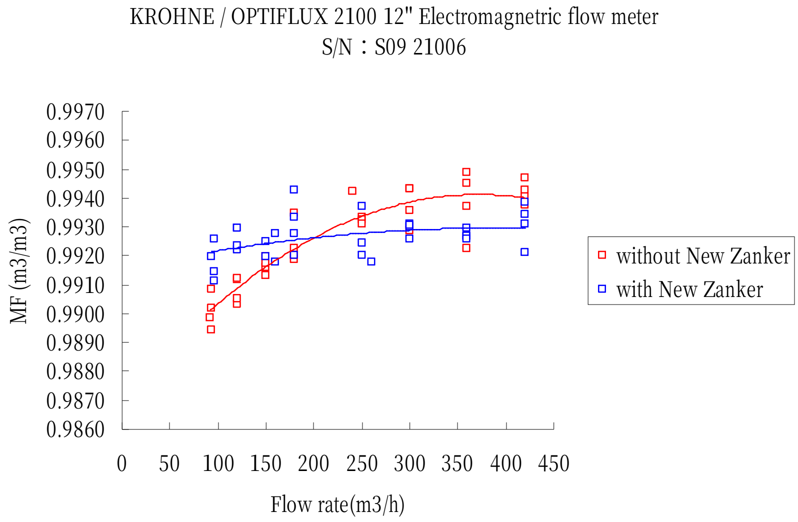

Fig. 3 The comparison between the test results of 300 standard devices with and without the New Zanker flow straightener

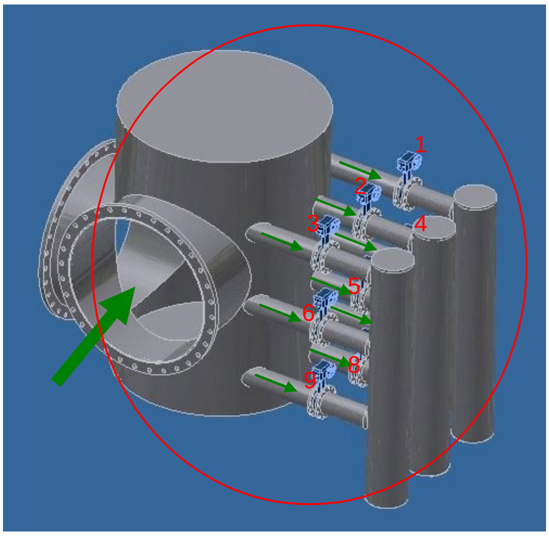

Fig. 4 Buffer tank and multi-channel control valve device

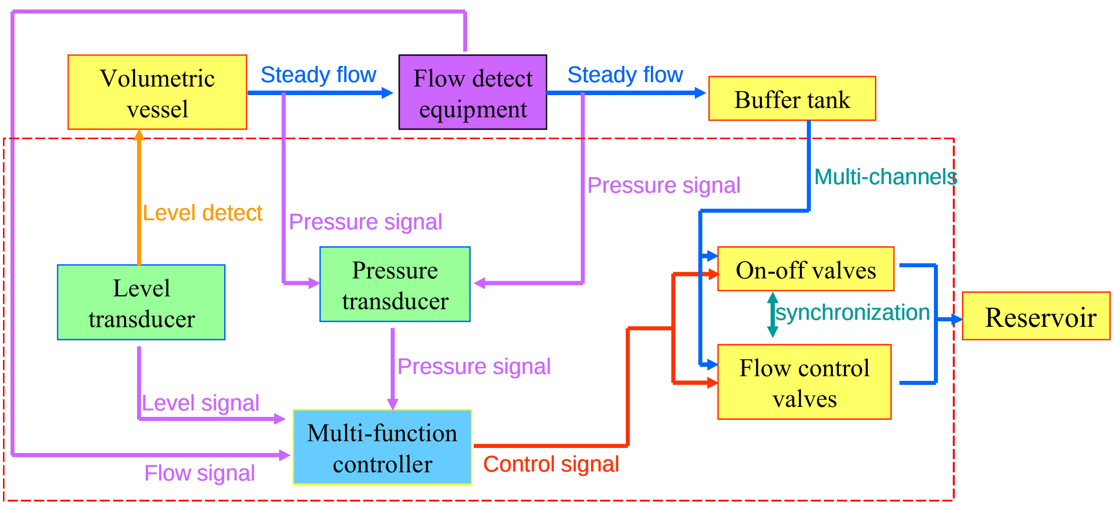

Fig. 5 Buffer tank and multi-channel interactive adjustment method

4. Discussion

For the use of flow calibration facility in the large flow region of 800 mm to 200 mm master meter method, water flow must go through buffer tank and the 1500 mm horizontal connecting pipe and be redirected such that severe vortex and asymmetric flow field distribution will be generated. The most straight forward approach to eliminate this phenomenon is to increase the length of upstream straight pipe of flow meter. However, this option is not available for our study due to insufficient space. Therefore, during the course of system design, various types of flow conditioners have been tried to eliminate vortex and asymmetric flow field distribution and to reduce the length of upstream straight pipe of the flow meter in light of the space constraint. However, in this study we found that for all kinds of configurations, the length of upstream straight pipe of the flow meter must be at least 10 times the diameter for the vortex and asymmetric flow field distribution to be effectively eliminated. With the installation of flow conditioner, the length of upstream straight pipe of the flow meter must still be at least 8 times the diameter. From this we know that for the flow meter affected by installation effect to be applied to the work site, its measurement performance can be compromised if the installation conditions do not meet the requirements. This effect must be evaluated.

In this study we use volumetric delivering method together with buffer tank and multi-channel interactive adjustment for the calibration of flow meter with diameter from 900 mm to 1500 mm. The initial test results show that the unstable water flow due to the dropped water level resulted from volumetric tank effluent can be effectively resolved. Figure 6 is the evaluation of the application of buffer tank and multi-channel interactive adjustment approach by effluent test using the 80 m^3 volumetric tank. After immediate activation of switch valve number 5 without using adjustment valve, the variation rate of displayed flow rate is around 7.2%. If the real time adjustment by adjustment valve number 1 is involved, then the variation rate of displayed flow rate is around 1%. In Figure 7 it is shown that the variation rates under different flow rates can be maintained around 1% with the approach of using buffer tank and multi-channel interactive adjustment. Thus it is proved that this innovative control method can indeed effectively stabilize flow rate during calibration period.

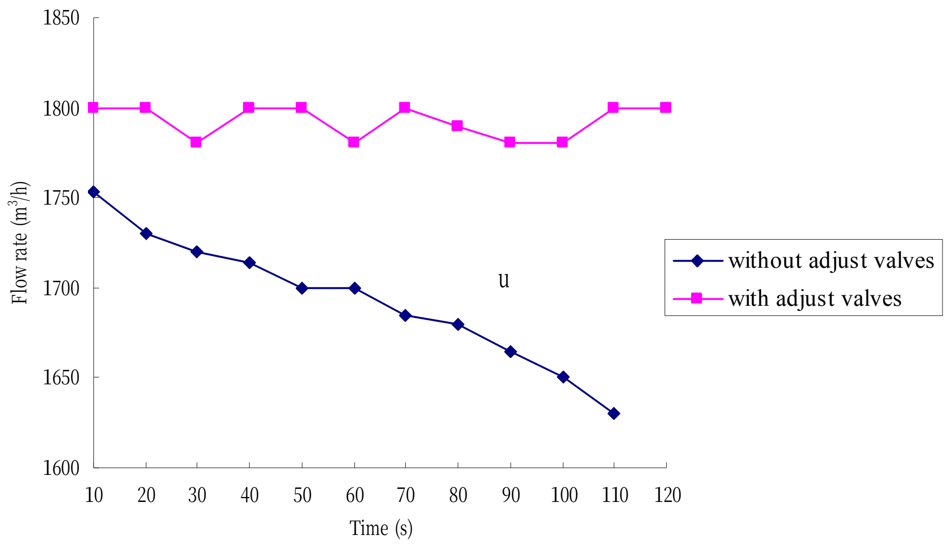

Fig. 6 The flow rate variations during effluent period before and after the use of buffer tank and multi-channel interactive adjustment approach

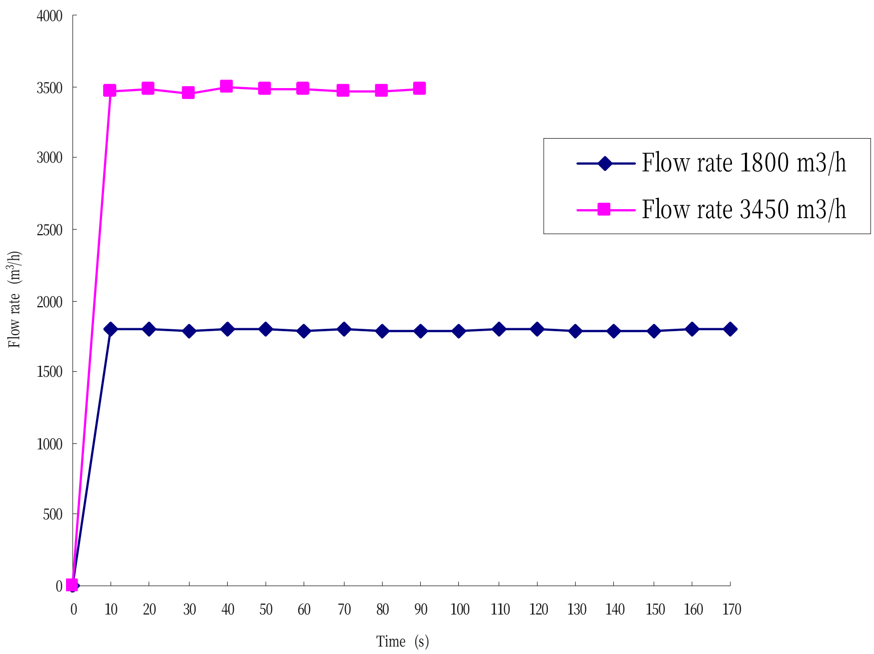

Fig. 7 The flow rate variations under different flow rates with the use of buffer tank and multi-channel interactive adjustment approach

5. Conclusion

The test facility improved by this study is developed by the integrated applications of master meter and volumetric tank delivering method suitable for water meters with the diameters from 1500 mm to 25 mm and with the flow rate range from 10000m^3/h to 0.1m^3/h. Other than meeting the existing flow verification regulations for C class mechanical water meter in Taiwan, water meters equipped with electronic devices are also included in its scope of application in response to international trends.

The innovative approach using buffer tank and multi-channel interactive adjustment is introduced in this study to solve the issue of test accuracy of water meter affected by unstable flow of volumetric tank effluent method caused by dropped water level in the tank. This control mode is capable of effectively reducing the construction cost without the need for additional purchase and maintenance of expensive equipments, and the initial test results have shown that this design can indeed achieve the goal of flow stabilization.

The follow-up system assessment of measurement uncertainty must be conducted for the test facility improved by this study. It is estimated that the measurement uncertainty of test facility using "master meter" method will reach 0.2%, while the number for the test facility using volumetric tank delivering method will reach 0.4%.

Acknowledgment

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