

# STUDY OF WATER FLOW CALIBRATION FACILITIES WITH MULTI-FUNCTION AND HIGH ACCURACY

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## Abstract

The paper describes a water flow calibration facility combined weighing method and master meter method. The flowmeter calibration system aims at obtaining a very high level of accuracy and assurance of product reliability. Moreover, a new method, synchronous pulse counting method, to improve the calibration accuracy and efficiency of master meter method is proposed. Experimental results show that the computer control system is reliable and the accuracy using weight method and master meter method is up to 0.066% and 0.076%, respectively.

## Introduction

Flowmeters perform important fluid measurement tasks for a broad range of industries, including power and energy, oil and gas, water and waste-water treatment, and many others. Whether the measurement is for custody transfer, process control, or trend monitoring, the accuracy, repeatability, and reliability if these measurements depends on the selection of the best flowmeter technology for the application, followed by the proper calibration of the flowmeter optimum performance within its operating environment.

The purpose of this paper is to describe a water calibration system designed to encompass both weighing method and master method that provide a high degree of confidence in flow metering accuracy. This system is used to calibrate vortex flowmeter, turbine flowmeter, float flowmeter, Electromagnetic flowmeter, and so on. All processes conform to corresponding national criterion. Further more, hardware and software designs provide the calibrate method about facility.

## Design of the flow rig

Static weighing method is the primal criterion of flow calibration, and also is transfer standard. Since the static test mode, the effect of fluid flow can be avoid, therefore, it offers the highest accuracy. Equation (1) shows the calculating manner of actual mass of liquid in tank.

$$MS = (M - M_0)(1 + e) \tag{1}$$

where

$$e = \rho_a \left( \frac{1}{\rho_w} - \frac{1}{\rho_p} \right)$$

—the air buoyancy coefficient;

$\rho_a$ —the air density /m<sup>3</sup>

$\rho_w$ —the water density /m<sup>3</sup>

$\rho_p$ —the weights density /m<sup>3</sup>

The volume shows in equation (2)

$$VS = \frac{MS}{\rho_w} = \frac{M - M_0}{\rho_w}(1 + e) \tag{2}$$

So, the coefficient of the test meter is KM<sup>1</sup>/m<sup>3</sup>):  $KM = NM/VS$  (3)

Where NM--- the pile-up pulse of the test meter

The weighing method, which is the core of this system, could be used to test all kinds of water flowmeter. But if calibrating low velocity liquid, the use of weighing method is limited by the weighing accuracy. Because calibrating time must be long enough, this leads to low efficiency.

Master meter method is a new mode relatively. The calibration principle is comparing the master meter and the test meter when the similar liquid flows for the same time-interval, then confirming the accuracy of the test meter. Therefore, the way overcomes time limitation. In order to assuring precise, the key is selecting exact master flowmeter.

Master method possesses another predominance, namely paralleling several master meters to calibrating large capacity meter. The measuring range of every master meter is lower than that of the test meter, but after paralleling, they can complete the test process. The volume flow is showed by equation (4).

$$VS = \sum_{i=1}^n q_{Ei} = \sum_{i=1}^n (NS_i / KS_i) \quad ??$$

where  $NS_i$ —the pile-up pulse of the  $i_{th}$  master meter

$KS_i$ —the coefficient of the  $i_{th}$  master meter

The coefficient of the test meter  $KS$  could be calculated by equation (3).

There are different advantages and disadvantage between two ways. To bring them together could overcome some shortages. So, a calibration facility combining two methods is designed. Synchronously, the calibration processes are controlled by computer system. Thus, the whole rig possesses significant predominance.

Firstly, Using master meter method could avoid to operating weighing system frequently. As the primal criterion, weighing method is the center of the system and the basis of the master meter method. For master meters are calibrated by weighing method periodically, they have the coordinative accuracy like as that of the weighing method. Generally, this manner can instead of the weighing method to calibrate the water flowmeters and curtail calibration time, accordingly, improve efficiency. For example, calibrating a turbine flowmeter which pipe diameter is  $f 100$  and flow range is  $10.0\text{m}^3/\text{h} \sim 110.0\text{m}^3/\text{h}$ , comparing results are shown in sheet 1. The timesaving is obvious.

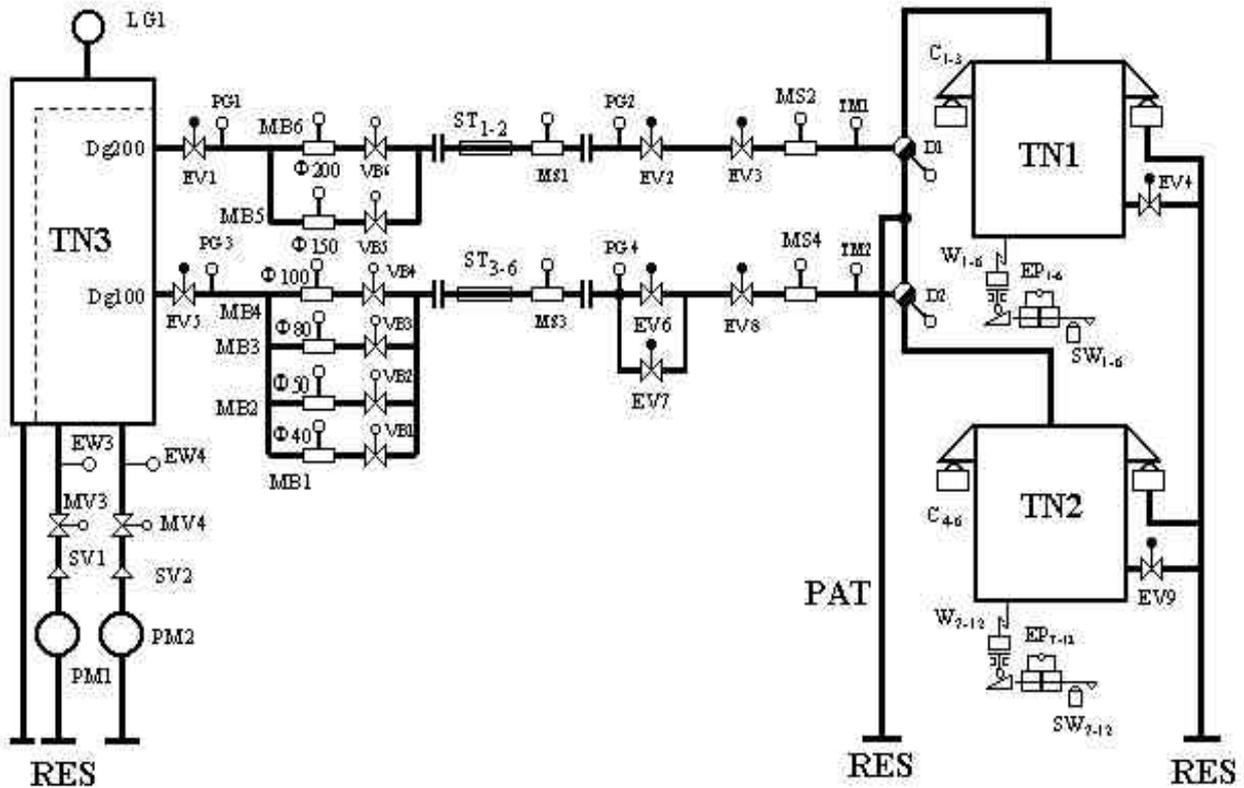
	The coefficient ( $1/\text{m}^3$ )	The error (%)	The repeatability (%)	Calibration time (s)
Weighing	4478.000	$\pm 0.395$	0.0349	1544
Master meter	4497.805	$\pm 0.439$	0.0669	180

Secondly, master meters calibrate others and are calibrated on the same pipelines, keep away from error causing by the different of rig and timer. Consequently, the error of replacing facilities could not be considered in the program about calculation of the error. Apparently the precise of the system is improved.

In addition, the application of the computer system provides the intelligent compromises which based on the actual capabilities of the laboratory, as well as on lab operator's thorough knowledge of the flowmeter and its intended application.

#### Hardware and Software

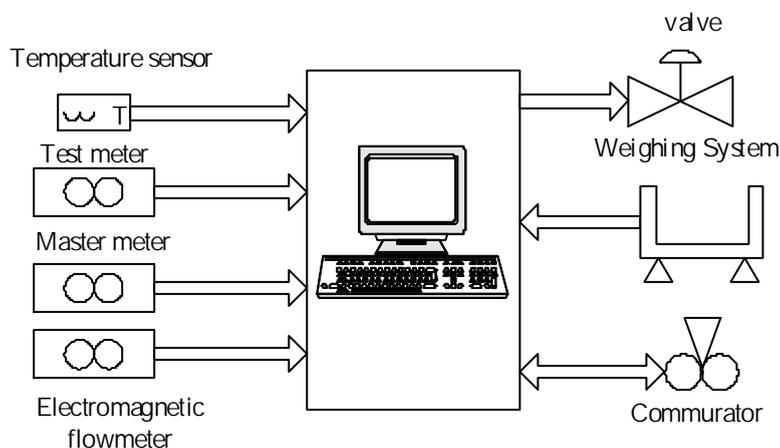
Basing on above depiction, the design of hardware system is shown Fig.1.



TN1, TN2, C1-6, W1-12—the Weigh System    TN3—the Water Tower    PM1-2—Pump    PG1-4 — the Pressure Sensor    MB1-6—the Master Meters  $\varnothing 40, \varnothing 50, \varnothing 80, \varnothing 100, \varnothing 150, \varnothing 200$     MS1, MS3—the Test Meters  
 MS2, MS4—the Electromagnetic Flowmeter    TM1, TM2—the Temperature Sensors    D1, D2—the Commutator  
 RES—the Reservoir

**Fig. 1 Calibration Facilities Diagram**

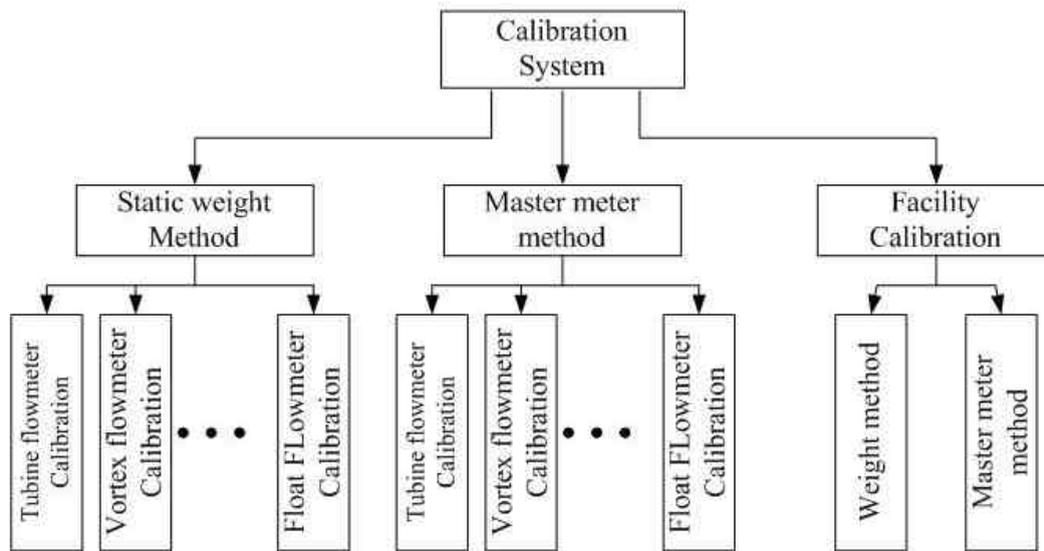
The two similar facilities are shown in diagram, and can be used to calibrate velocity type flowmeters and mass type flowmeters, such as vortex shedding flowmeter, turbine flowmeter, float flowmeter et al. There are six species of pipe diameter of the test meters,  $\varnothing 40, \varnothing 50, \varnothing 80, \varnothing 100, \varnothing 150, \varnothing 200$ . The calibration range of one of rig is from  $75.6\text{m}^3/\text{h}$  to  $442.8\text{m}^3/\text{h}$ , another is from  $9.94\text{m}^3/\text{h}$  to  $115.92\text{m}^3/\text{h}$ .



**Fig. 2 The Control System**

The computer system (Fig.2) controls the processes of the flowmeters and facilities calibrations. Instruments signals input computer and the measurement results are displayed and printed. After selecting the correct parameters, all actions are completed automatically according to the national criterions. The computer could control the opening angle of the valves to change the flow of the pipeline.

The software of the system includes three part programs, facility calibration, weighing method calibration and master meter method calibration. Every program block is independent.



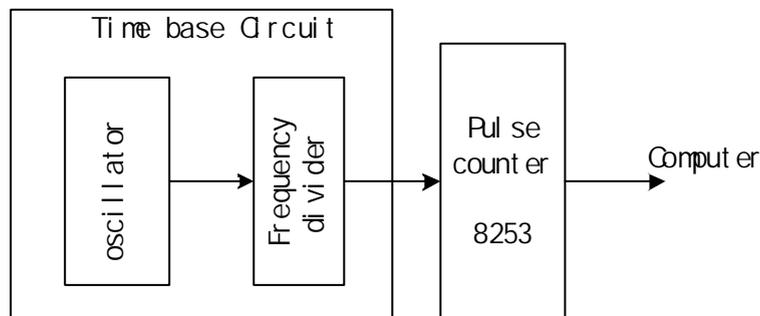
**Fig.3 The Flow Chart of The Program**

Analyses of high accuracy

In order to assuring the precise of the system, precision timing and correct coefficient calculation are keys. The improving means are adopted on the design, including hardware and software.

1) Precision timing

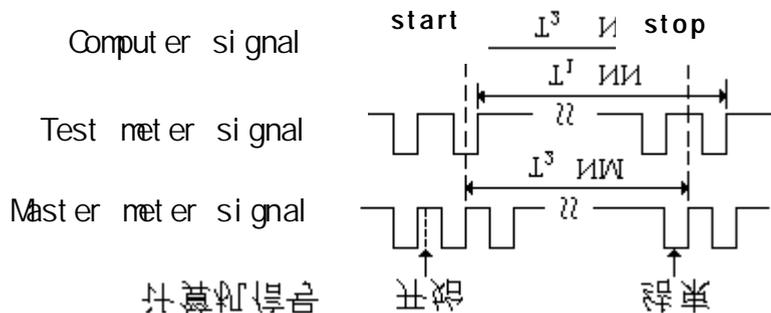
The timer of computer could not suffice the timing requirement of the system, because of low frequency of crystal oscillator. Therefore, a new time base circuit (Fig. 4) is designed, additional oscillator is divided frequency, then input to chip 8253 to be counting, the value of the counting is read by computer. Using this manner, the timer distinguishability is up to 0.000512s.



**Fig. 4 The theory of precision timing**

The aim of precision timing is to counting. There are some questions for counting, such as losing pulse when the computer sends out start/stop signal, especially to low frequency status. Because counter samples the rising edge or trailing edge of pulse, a sampling flag start or stop maybe appears after or

before an edge, when the next edge arrives, the real counting value will lose one. This paper provides the synchronous pulse counting method to conquer the trouble. The method is shown (Fig.5). Between the start and stop signals, the number of pulse and times should be recorded, then using the equation (6) calculates the exact value. The experimental result indicates that the means is effective. The error equates 0.00512%.



**Fig. 5 Synchronous pulse counting method**

$$f = \frac{NS}{T_2} = \frac{NN}{T_1} \tag{5}$$

Namely  $NS = NN \frac{T_2}{T_1} \tag{6}$

Where NS, NN---the number of the pulses

2) Curve fitting method

The calibration data are often nonlinear. Another way of improving precise is applying software to compensate. The Least square method is in used to fit coefficient curve. The consequence is better than that of the mean method.

Conclusion

Experiments (Sheet2,3) indicate the design of facility is successful. The facility possesses not only multi-function, but also high accuracy.

Sheet 2 The accuracy of the static weighing method

	Timer dt	Weight dm	Commutator d <sub>d</sub> ?t	Error d1
System 1	0.00172	0.0125	0.0649	0.066
System 2		0.0225	0.0560	0.060

Sheet 3 The accuracy of the whole facility

	Diameter	Curve error EC(%)	Timer error (%)	Accuracy of W. Method d1(%)	Accuracy of M. method d2(%)
system1	f 200	0.0249	0.00483	0.066	0.071
	f 150	0.0144			0.068
system2	f 100	-0.00971	0.00483	0.060	0.061
	f 80	0.0001			0.060

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f 50	-0.0466	0.076
f 40	-0.0431	0.074

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