Design of gas flow standard device for online or remote calibration of gas flow

L.Gong [1], L.S.Yang[1],C. Y.Yu[1],Y.Zhang[1]

[1]Chongqing Academy of Metrology and Quality Inspection, No. 1 Yangliu North Road of Yubei District, Chongqing, China
E-mail: gallongallon@163.com

Abstract
Online/remote calibration is the transformation and expansion of traditional measurement. Its development will play a certain role in strengthening measurement management, improving the overall strength and level of measurement, and promoting trade and economic development. In this paper, a set of on-line/remote detection standard devices with a flow range of (0.4~400) m^3/h, expanded uncertainty: $U \leqslant 0.33\%$, k=2 was designed and developed. Rely on the Internet + calibration mode, use the wireless Internet to send signals from the laboratory to the standard testing module, establish a remote service to send remote control commands, monitor the physical and electrical connections ,and control the standard testing module. The program controls the calibration process automatically complete online /remote calibration.

0. Preamble

Due to installation, process control and other reasons, it is difficult for some flowmeters to be disassembled and submitted for inspection. Liquid flowmeters can be tested online using lamp-on ultrasonic flowmeters, while most gas flowmeters cannot be tested online due to the lack of on-site testing standards [1].The traditional detection mode requires the user to send the instrument to the professional measurement institution, it has the disadvantages such as long detection cycle, difficult management, time-consuming and laborious, and low efficiency, and has fallen far behind the needs of rapidly developing instrument detection. For example, flowmeters used for process control and internal measurement in many chemical plants, natural gas extraction and deployment, cannot be disassembled for inspection, so there is a strong demand for online/remote calibration services.

In the current traceability mode, instruments passed to the superior metrology department are affected by many non-human factors such as weather and traffic during transportation, which may unexpected changes in values. In addition, the measuring instrument detection process is carried out under the specific environment and conditions of the superior metrology department, so the measurement results are relative. When returning to the user's use environment, changes in the environment and conditions will lead to additional measurement errors, resulting in difficult measurement management and low efficiency.

1. Current situation at internal and abroad

The research on remote calibration technology originated from the National Physical Laboratory (NPL) of the United Kingdom, and the concept of remote calibration was first proposed by the International Conference on Measurement and Instrumentation (IMIC) in 1999 [2]. In mid-2001, Dudley and Ridler successfully developed a remote calibration system for Automatic Network Analyzers, which enables two-way communication between the NPL server and the remote laboratory [3]. In 2002, the National Institute of Standards and Technology (NIST) launched a remote calibration service for gas flow meters, by leveraging the high-speed information infrastructure of NIST's National Advanced Manufacturing Test Platform (NAMT), by combining CEESI's volumetric calibration equipment with NIST's fluid flow group combined [4]. In 2005, Japan conducted remote calibration experiments on the time and frequency of recorders and flowmeters for Yokogawa Electric (Suzhou) Co, Ltd. for the first time abroad [5]. Yan Linbo studied the main components of the remote calibration system, and focused on the network access technology suitable for China's national conditions and the realization method of data exchange between the local and remote terminals [6]. Wang Yong et al. from Shanghai Jiao Tong University various methods of remote calibration of Internet-based test instruments, proposed the specific implementation architecture of remote calibration system, and took digital storage oscilloscope as an example to realize the construction of remote calibration system of Internet-based test instruments in two different ways [7]. Liu Lijuan of China Academy of Metrological Sciences and others used the Internet to perform remote calibration of AC energy meters, which has brought the level of electric energy testing and external service to a new level [8]. South China University of Technology cooperated and Guangdong Institute of Metrology have cooperated to study the mechanism of the reference frequency-free remote calibration system. At the same time, remote calibration was realized for the calibration of electric energy meters with frequent and large number of calibrations in the metrology institute [9]. However, there are few researches on remote detection technology of other gas flowmeters such as gas displacement meter and turbine flowmeter.

2. Structure of Facility

The standard meter group, acquisition system, monitoring module, and industrial computer are integrated into a standard detection module by compact process, and the fan and frequency converter are composed of drive source module by compact process to form a set of standard meter method online/remote detection standard device. The laboratory-side program uses the mobile Internet to send signals to the standard detection module server-side program to send remote control commands to complete online/remote detection. The structure diagram is shown in Figure 1.

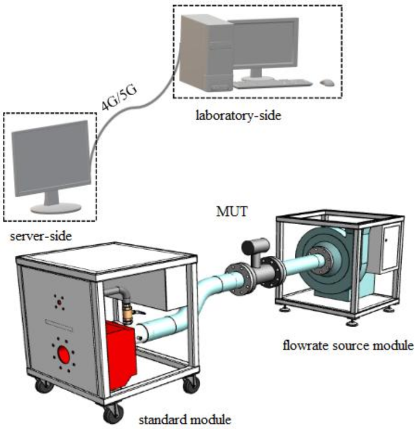

Figure 1:on-line/remote calibration standard devices structure diagram

In order to realize the modularization of detection standards and facilitate transportation, the device should be small and light, so the roots flowmeter for gas is used as the main standard device. According to statistics, more than 75% of the gas flow meters used by industrial and commercial users are below DN100mm, the rate of flow is below 400m3/h, and the level of accuracy level is 1.0 and below. The number of roots flowmeter for gas should not be too large to reduce the supporting pipelines and valves and improve the mobility and transportability of the device. Therefore, two gas roots flowmeters which the level of accuracy is 0.2 are used, one of flowmeter is DN25 with a flow range of (0.4-25) m^3/h; the other is DN100, with a flow range of (5~400) m^3/h. Electric on-off butterfly valves are installed in front of the flow meter, and flow control valves are installed in front of the manifold.

The control and acquisition system of the standard detection module is developed based on virtual instruments, using industrial control wide-angle camera for real-time monitoring of installation and detection process, using DAQ system to automatically collect temperature, pressure and flow, using PLC for logical control of detection process, using portable computer and group State software for visual programming to complete human-computer interaction.

Some gas flowmeters may not have a gas supply source in the field, so the drive source module is designed, and the fan and the inverter are composed of the module through a compact process. The rated flow of the fan is 400 m^3/h, and 220V voltage needs to be provided on site. The inverter is controlled by the standard detection module, and the RS485 communication command is used to control the fan speed to adjust the flow to the corresponding detection point. The flow connection port of the drive source module and the standard detection module is connected by a common standard flange through a hose, and the electrical interface is connected by an anti-interference aviation plug.

3. Uncertainty analysis of the facility

The calibration of facility flowmeter error of indication E is

$$E=\frac{V_m-V_{ms}}{V_{ms}},\quad V_{ms}=V_s\frac{P_sT_m}{P_mT_s} \qquad (1)$$

The measurement uncertainty mainly comes from the indicated value of the standard flowmeter V_{ms} and the indicated value of the tested flowmeter V_m, the temperature at the standard flowmeter T_s and the temperature at the tested flowmeter T_m, the pressure at the standard flowmeter P_s and the pressure at the inspected tested flowmeter P_m and atmospheric pressure P_a.

3.1. The standard uncertainty of standard flowmeters u_{Vs}

Two standard flowmeters are calibrate, the measurement uncertainty result is 0.20%(k=2). The relative standard uncertainty component of the absolute pressure of the standard facility is:

$$u_{V_s}=\frac{0.20\%}{2}=0.1\% \qquad (2)$$

3.2 The pressure standard uncertainty of standard flowmeters u_{Ps} and tested flowmeter u_{Pm}

the measurement uncertainty result of the pressure sensor is 0.1%(k=2),so

$$u_{P_s}=u_{P_m}=\frac{0.1\%}{2}=0.05\% \qquad (3)$$

3.3 The temperature standard uncertainty of standard flowmeters u_{Ts} and tested flowmeter u_{Tm}

The measurement uncertainty of the temperature sensor measurement is U=0.18 ℃(k=2), the temperature of the facility is 20℃, so the standard uncertainty introduced by the medium temperature of the standard flowmeter and tested flowmeter is

$$u_{T_S} = u_{T_m} = \frac{0.18}{2\times 293.15}\times 100\% = 0.031\% \qquad (4)$$

3.4The value standard uncertainty of texted flowmeters u_{m}

Calibrating the flow meters of class A, the instrument pulse input N≥1000 pulses, and the pulse measurement error ΔN=±1, take the uniform distribution, then

$$u_{\mathrm{m}} = \frac{1}{1000\times\sqrt{3}} = 0.058\% \qquad (5)$$

Calibrating the flow meters of class B, the main u_{Vs} is come from repeatability. The repeatability measurement is carried out on the standard device with a 1.0 level the roots flowmeter for gas, and the standard deviation of a single measurement is 0.18%, so the measurement uncertainty caused by the repeatability is (generally 3 times of calibration measurement)

$$u_s = \frac{0.18\%}{\sqrt{3}} = 0.10\% \qquad (6)$$

Take the maximum value of the two as the uncertainty of the tested value, that is u_{m}=0.10%.

the combined standard uncertainty $u_{V\mathrm{ms}}$

$$u_{V\mathrm{ms}}=0.167\% \qquad (7)$$

Taking the coverage factor k=2, the expanded uncertainty $U_{Vms}$is

$$U_{Vms}=2u_{V\mathrm{m}}\text{-}0.33\%(k=2) \qquad (8)$$

4. Remote calibration implementation

To realize remote calibration, the standard module needs to establish a connection with the laboratory computer and realize wireless data transmission. Zigbee, WiFi and 433MHz wireless technologies are commonly used wireless communication technologies for short distances, while mobile Internet is used for long distance transmission, such as 4G/5G base stations. The standard module of the device integrates the mobile Internet receiving module, and uses remote control software for communication. In the remote calibration communication mode, the laboratory terminal (Server)-industrial control terminal (Client) mode is adopted, the standard module is used as the industrial control terminal, the laboratory computer is used as the server terminal, and the on-site standard module sends link instructions to the laboratory. After the connection is successful, check whether the pipeline connection is normal, whether the electrical connection is normal, and start the detection work if everything is all set. The test is carried out according to the requirements of the relevant flowmeter verification regulations. Through the flow rate, calculate the error between the standard meter and the inspected meter. The schematic diagram of the device detection structure is shown in Figure 2.

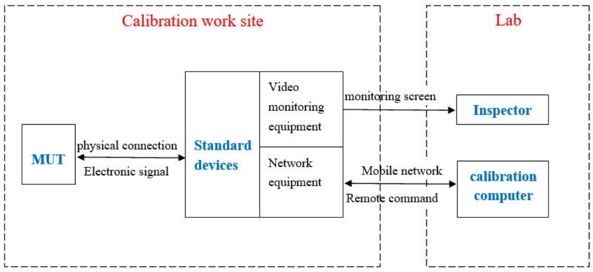

Figure 2: On-line/remote calibration process flow diagram

5. Conclusion

The Internet + calibration mode is adopted to enable laboratory calibrator to "attend" the calibration site via the network, and monitor and control the detection process, complete remote calibration. It can greatly improve the problems faced by traditional detection methods. The customer's tested flowmeters can be directly traced to the national main benchmark or standards of other technical institutions without transportation. It will greatly shorten the time required for calibration and reduce the costs; the flowmeter is calibrated under normal working conditions, which not only shortens the downtime, but also avoids resulting uncertainty changes through inspection process. The whole process has higher degree of freedom and higher completion efficiency.

Acknowledgments

The authors gratefully acknowledge the financial support provided to this study by the ChongQing Municipal Bureau of Science and Technology of China (Cstc2020jxjll 20013).

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