FLOMEKO 2022

Exploration of Natural Gas Remote Metrology Technology

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Abstract

With the development of Metrology, the new definition of SI is based on quantum physics, and will lead metrology into a new era of quantum metrology. There are many problems in current metrology mode, and it is urgent to find a remote metrology mode. The remote measurement will be better integrated with advanced technologies such as Big Data and The Internet of Things.It can be easier to analyze the causes of problems, which is conducive to energy conservation and emission reduction.The paper explores the application of remote metrology in the field of natural gas metering. First it analyzes the development of remote metrology in domestic and international status, and summarizes the difficulties in the application of remote metrology. Second it explores various ways and methods of remote metrology. Finally,the paper provides a valuable reference for the development of remote measurement technology in the future.

1. Introduction

The traditional calibration method of natural gas flowmeter needs to remove the flowmeter installed on the site, and packaged to the upper level of measurement calibration unit for calibration. Or the calibration personnel carry the standard instrument to the installation site for the calibration . There are many difficulties in this calibration method. First, The disassembly and installation of flowmeter are very complex. It's may cause flowmeter damage . Second, One-time calibration takes too long time, and users need to shutdown related equipment, which is not conducive to the development of production. Third, when calibration in the field, due to the complex environment, the accuracy of the standard instrument is difficult to ensure. Finally, calibration will not be possible in exceptional circumstances such as epidemics.

In order to solve the difficulties in the calibration of traditional natural gas flowmeters, many scholars and institutions have proposed remote calibration methods. By using advanced technologies such as information communication technology, quantum technology, Internet, 5G and GPS system, the calibration personnel can complete the calibration of the flowmeter without coming to the scene. At present, there are many applications of remote calibration in China and abroad, which started earlier in the developed manufacturing countries such as the United States, Germany and Japan. Especially, Japan carried out remote calibration experiments on the time and frequency of recorders and flowmeters in the early years[1] . In China, the paper [2]proposed to establish a general model of 'Internet +' remote calibration method by using the Internet.The paper[3] proposed the design and implementation of remote calibration system based on LabVIEW software.The paper[4] proposed the design of remote calibration system by using software component technology.

This paper summarizes the application of remote calibration technology at home and abroad, analyzes and discusses several main remote calibration methods and principles, and puts forward several ways to realize remote calibration technology of natural gas flowmeter in the future.

2. Remote Calibration of Natural Gas Flowmeter Based on Network Control

The remote calibration of natural gas flowmeter based on network control needs to send the measurement standard equipment to the customer site. Using the network communication platform, data exchange technology and video multimedia means, the superior measurement laboratory can directly participate in the whole process of calibration, control the calibration process, and complete the remote calibration of the flowmeter[5]. Before calibration, it is necessary to establish an experimental environment that meets the calibration requirements at calibration site, including the temperature and humidity environment. Second, real-time network multimedia communication is established between the at calibration site and the superior measurement laboratory by means of network communication, network database and high-definition camera. Third, the measurement standard equipment should be sent to the at calibration site. Fourthly,

standardized calibration training for field operators is needed.

During the calibration, the field calibration personnel carry out the calibration work according to the standard steps. The superior measurement laboratory personnel remotely supervise, control or guide the field calibration through the network communication platform. The relevant data of the field calibration are uploaded to the data server in the superior measurement laboratory. After verification, the certificate is issued to the user site to complete the equipment calibration. The whole calibration process is shown in Figure 1[6].

This remote calibration method can realize the remote participation of the personnel in the superior measurement laboratory and control the standardization of the whole calibration process. However, the main problem is that the measurement standard equipment needs to be sent to the calibration site in advance. After the calibration is completed, it will be sent back to the superior measurement laboratory.

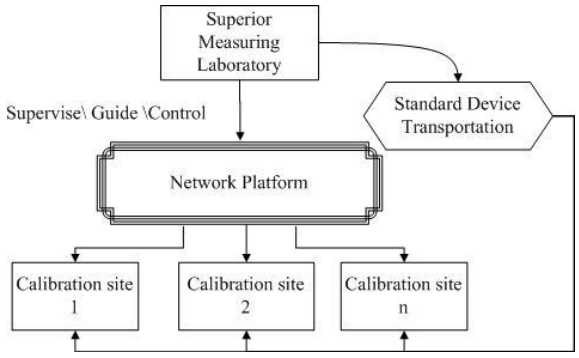

Figure 1: Remote Calibration of Natural Gas Flowmeter Based on Network Control.

3. Remote Calibration of Natural Gas Flowmeter Based on Calculation Standard Value

At present, ultrasonic flowmeter is widely used in natural gas flow measurement and can be calibrated by sound velocity comparison method. The compression factor of natural gas is calculated according to the AGA8-92DC calculation method proposed by 'AGA8 compression factor of natural gas and gas hydrocarbon', and then the propagation velocity of ultrasonic wave in natural gas is calculated through the natural gas sound velocity equation proposed by 'AGA10 sound velocity of natural gas and other gas hydrocarbon'. The calculated sound velocity is compared with the measured sound velocity of ultrasonic flowmeter to realize the calibration of flowmeter. The compression factor and sound velocity calculation are shown in Formula (1) and Formula (2)[7].

$$Z = 1 + B\rho_m - \rho_r \sum_{n=13}^{18} C_n^* + \sum_{n=13}^{58} C_n^* (b_n - c_n k_n \rho_r^{kn}) \rho_r^{kn} \exp(-c_n \rho_r^{kn}) \quad (1)$$

Which Z is compression factor , B is the second virial coefficient, ρ_m is the molar density of natural gas, ρ_r is the relative density of natural gas, b_n c_n k_{n} are constant, C_n^* is the correlation function of temperature and composition.

$$c = [\frac{c_p}{c_v}(\frac{RT}{M_r})(Z + \rho_m(\frac{\partial Z}{\partial \rho_m})_T)]^{0.5} \quad (2)$$

Which c is the sound speed, c_p is the constant pressure specific heat capacity of natural gas in actual state , c_v is the constant specific heat capacity of natural gas in actual condition, R is the gas constant, T is the pipeline temperature, M_r is the mole mass of natural gas.

The remote calibration method of natural gas ultrasonic flowmeter based on the calculation of standard value. Firstly, the temperature, pressure and composition of natural gas are collected, and the collected data are sent to the calibration server in the superior measurement laboratory through the network. The server calculates the standard sound velocity under the current working condition, and then sends the standard value to the calibration site through the network. The field calibration personnel complete the calibration work by comparing the measured sound velocity and the standard sound velocity of the ultrasonic flowmeter. Finally, the comparison results are fed back to the superior measurement laboratory, and the certificate is issued after verification. The whole calibration process is shown in Figure 2.

This remote calibration method does not need to carry out the transportation of measurement standard equipment in the superior measurement laboratory and calibration site, and the standard value is obtained through the theoretical calculation of mathematical model for calibration. However, there are problems of field temperature, pressure and component acquisition accuracy, which will directly affect the accuracy of calibration.

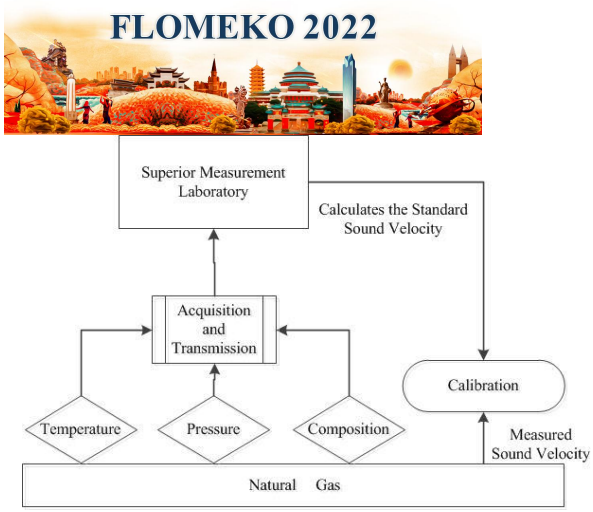

Figure 2:.Remote Calibration of Natural Gas Flowmeter Based on Calculation Standard Value

4. Remote Calibration of Natural Gas Flowmeter Based on Quantum Technology

In 2019, the new International System of Units was redefined by using the invariable physical constants, so that the transfer of quantities was completely free from the physical substances. The measurement benchmark could be arbitrarily and unlimitedly reproduced anywhere, which provided a solid foundation for the remote calibration of measurement equipment. Seven International Basic Units, corresponding definition constants and implementation methods are shown in Table 1[8].

Table 1: Basic Units relevant constants and implementation methods

Unit Name	Sign	Relevant Constants	Implementation Method
Second	s	$\Delta\upsilon_{Cs}$	Hot cesium Beam Clock, Laser Cooling, Cesium Fountain Clock
Meter	m	$c,\Delta\upsilon_{Cs}$	Measuring the Distance of Light Passing
Kilogram	kg	$h,c,\Delta\upsilon_{Cs}$	Kiebull Balance, XRCD Experiment
Ampere	A	$e,\Delta\upsilon_{Cs}$	Josephson Effect, Quantum Hall Effect
Kelvin	K	$k,h,\Delta\upsilon_{Cs}$	DCGT,AGT,RT, Doppler Broadening Temperature Measurement
Mole	mol	N_A	Gravimetric Method, Isotope Dilution Mass Spectrometry
Candela	cd	$K_{cd},h,\Delta\upsilon_{Cs}$	No Difference from Previous SI Definitions

At present, there are many application cases in this regard. In terms of time calibration, GPS common-view method is used to achieve remote calibration. In terms of voltage, the standard voltage is reproduced by Josephson voltage. In terms of length, the length remote calibration is realized through the interference of light[9]. In the remote calibration of natural gas flowmeter, there are many parameters to be calibrated, which are different according to the flowmeters with different measurement principles, mainly including temperature, pressure, frequency, length etc.. According to the characteristics of the new international unit system that is independent of physical objects, with the progress of technology and the development of science, the relevant calibration parameters of flowmeter will be realized in any situation.

5. Conclusion

In this paper, the various implementation methods of remote calibration of natural gas flowmeter are analyzed and summarized. There are mainly three types, including Remote Calibration of Natural Gas Flowmeter based on Network Control, Remote Calibration of Natural Gas Flowmeter based on Calculation Standard Value and Remote Calibration of Natural Gas Flowmeter based on Quantum Technology. The first method needs to establish a network communication platform and the transport of standard devices. Compared with the traditional calibration method, it only changes the way in which the calibration personnel participate. The second method needs accurate mathematical model, and the suitable application scenarios are less. The third method is a new model, which is the real sense of remote calibration. Based on the new international unit system of quantization, it completely gets rid of the dependence of standard traceability on objects. Any institution that needs calibration can be calibrated only by selecting the appropriate standard value implementation.

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