FLOMEKO 2022

Discussion on measurement and evaluation method of natural gas flow computer

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Abstract

As an important measuring instrument and basis for the handover of natural gas measurement trade, it is necessary to formulate requirements and test standards for evaluating its structure, performance, safety and consistency. The computer evaluation and detection software of natural gas flow is developed, which realizes the functions of data acquisition and evaluation, flow calculation and verification, physical parameter evaluation and environmental impact factor evaluation. The design, software and hardware configuration of natural gas flow computer evaluation and detection system are completed, and the flow is established.The computer evaluation and detection standard device forms a natural gas flow computer evaluation and detection system, realizes the evaluation of the accuracy of the flow computer and its supporting sensors, and carries out laboratory and field application test experiments on the evaluation and detection system.

1. Introduction

Since the beginning of the 21st century, natural gas, as a clean energy, has been greatly developed in China, and a large number of flow computers have been applied to the natural gas industry. At present, the domestic natural gas trade handover has been used in more than 10,000 flow computers.With the development of domestic natural gas and the deepening of energy trade handover mode, more and more flow computers will be put into operation.Therefore, the development of natural gas flow computer test and evaluation method is very important.

At present, the evaluation and test of flow computer is mainly based on the JJG1003 "Flow Calculator" verification procedure, which is mainly used to verify the flow calculator. The technical index setting is too simple to effectively distinguish the performance of flow computer.There is no special evaluation outline for the evaluation of flow computers. At present, according to the technical standards of some electronic components and industrial computers, the evaluation methods are scattered, the evaluation methods are inconsistent, and the evaluation results cannot be unanimously recognized by all parties.

Therefore, it is necessary to develop requirements and testing standards for evaluating the structure, performance, security, and consistency of traffic computers.

2.Measurement principle and main functions

2.1 measuring principle

By performing real-time calculations using the pressure, temperature, and gas components, the volume conversion performed by the flow computer is always a function of the pressure, temperature, and deviation from the ideal gas law.

The source of volume and flow information can be specified by the manufacturer using different types of technologies (high-frequency pulse transmitter, serial link communication, etc.).

Comcompression factor shall be calculated as GB / T 17747.2 or GB / T 17747.2. Heat value shall be calculated according to GB / T 11062. The general principles of the calculation are as follows:

$$V_m = \sum_{i=\tau_1}^{T_n} V_{m,i} \tag{1}$$

In the formula, Vm is the increasing volume under the measurement condition; $V_{m,i}$ is the volume increment under the measurement condition; and τ is the sum time period (time interval).

$$V_{corr} = \sum_{i=\tau_1}^{T_n} (C_f \cdot V_{m,i}) \tag{2}$$

In the formula, V_{corr} is the correction volume increment under the measurement condition; C_f is the correction coefficient according to the flow rate or the Reynolds number, which is described as F (Q) or F (Re).

$$V_b = \sum_{i=\tau_1}^{T_n} (C \cdot V_{corr,i}) \tag{3}$$

In the equation, V_b is the increasing volume under the base condition; V_{corrt}, i is the modified volume increment under the base condition; C is the conversion coefficient given by the relationship:

$$C = \frac{p}{p_b} \frac{T_b}{T} \frac{Z_b}{Z} \tag{4}$$

In formula, p is the pressure measured; T is the temperature; Z is the compression factor; p_b is the pressure; T_b is the temperature, and Z_b is the compression factor.

To obtain a high-accuracy device, the device has a number of correction and monitoring functions.The conversion coefficient shall be recalculated at no more than 30s time intervals.

The flow computer should be able to process the input collected measurements (p, T) in no more than 5s intervals.

2.2 major function

Flow computer function description, as shown in Figure 1, functions may be located in different components by principle (e. g., calibration curves in the measuring device itself or programmed in the computer).

Sensor signal acquisition function: process the physical quantity signals provided by the sensor and the sensor as measured values.

Sensor function: the measurements are converted into corrected measurements mainly according to the calibration results and filtering procedures.

Measurement function: according to the national standards and formulas to calculate the volume, heat value, compression factor and other derived values, and supervision and monitoring, in order to achieve high accuracy and replacement value purpose.

Long-term data storage capabilities: Keep all the relevant information needed to construct or reconstruct the calculated values for later legal and relevant purposes (e. g., completion of commercial transactions) and to back up the relevant data.

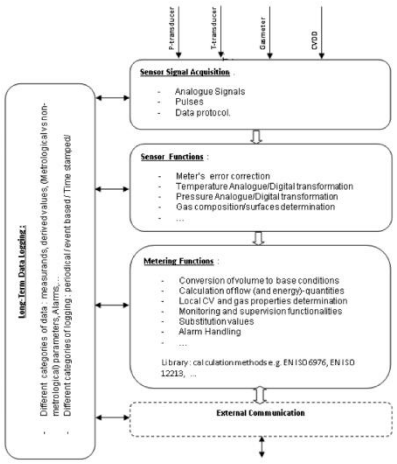

Figure 1: Description of the functionalities of the flow computer calculator.

2.3 test method

In modular methods, flow computers are independently validated combinations of measuring instruments and computers.Each instrument is validated according to its test procedures, using instructions from the computer or the relevant measuring instrument itself.In such case, the instructions should be consistent with the instructions of the measuring instrument.Functional verification includes verification of the calculation of each gas feature quantity and (or) volume conversion.

In the case of external communication, ensure adequate resolution of the data required during data transfer.To ensure the associated interoperability, the relevant measurement instruments have been validated against, or together with, the same type of computer.In the holistic approach, the flow computer is tested as a software package, including the computer and its associated measuring instruments and functions.

3.Measurement performance requirements

For the flow computer, the maximum allowable error (MPE) is expressed as a relative value, which is applicable to all kinds of indicators or various separation components, without considering the error of the flowmeter, as shown in Table 1.

Table 1: Maximum permissible error (MPE) of a flow computer.

Instructions or parts	reference ndition	Nominal working conditions
Primary value of volume conversion (e_c)	±0.3%	±0.5%
computer (e_f)	±0.1%	±0.1%
temperature (e_t)	±0.1%	±0.1%
pressure (e_p)	±0.1%	±0.1%

According to the current provisions, the metering control may involve: 1) In the modular method, the errors of the components (computers, temperature sensors and pressure sensors) and the errors based on their respective output at e_f, e_t and e_p shall be compared with the MPE shown in Table 2; 2) in the overall method, the main value error shall be compared to the MPE shown in Table 1.Computer-related MPE is only considered when the computer is controlled alone.

3.1 Overall method (main sample value error)

The percentage error ec of the principal value is defined by the following formula:

$$e_C = \frac{C - C_{CT}}{C_{CT}} \tag{5}$$

In the formula, e_c is the main sample value error of the volume conversion; C is the sample value of the conversion factor; and CCT is the convention true value of the conversion factor.

The allowable errors are given by the following equation:

$$e_C \le \mathrm{MPE} \tag{6}$$

3.2 Modularity method (the specific error of the flow computer)

Each component of a flow computer (e.g.,a computer, pressure sensor, and temperature sensor) has specific errors.These errors are defined by the following relationships:

$$e_f = \frac{C - C_{CT}}{C_{CT}} \tag{7}$$

$$e_p = \frac{p - p_{CT}}{p_{CT}} \tag{8}$$

$$e_t = \frac{T - T_{CT}}{T_{CT}} \tag{9}$$

In the formula, e_f is the flow computer value error; e_p is the value error of the pressure sensor; p is the value of the pressure sensor; p_{CT} is the agreed true value of the pressure sensor; e_t is the value error of the temperature sensor; T is the value of the temperature sensor; TCT is the agreed true value of the temperature sensor.

The allowable combined errors are:

$$|e_c| = |e_f| + |e_p| + |e_t| \le MPE \tag{10}$$

4.Main tests carried out

4.1 Computer verification and testing device for natural gas flow rate

4.1.1 How the device works

The flow computer can receive the electrical signal of the reaction temperature, pressure and flow rate in real time, and correct the temperature and pressure of the flow measurement value to realize the accurate measurement of the flow rate.The detection of the flow computer is to determine the quantity value of the flow computer by verifying each individual parameter, and then evaluating each parameter.

When the signal channel detection, with the DC resistance box, multi-function calibration instrument, function signal generator, give the temperature corresponding resistance value or analog signal (4~20 mA), pressure corresponding analog signal (4~20 mA), flow pulse signal, using the above standard signal source to detect the flow computer measurement channel (temperature, pressure, flow), read the output value of each channel of the flow computer, calculate the measurement error of each channel of the flow computer.The flow computer detection device and its main equipment are shown in Fig. 2 and Figure 3, respectively.

Figure 2: Test system for flow computers

Figure 3: Main equipment of the test system

4.1.2 How the device works

The main equipment of the device is shown in Table 2.

Table 2: List of the main equipment of the test system

Iname	model	measuring range	Uncertainty or accuracy level or maximum allowable error (MPE)
Function signal generator	SPF05A	1 μHz～5 MHz	U_f=0.005 Hz，k=2，f=1 Hz
multi-functional counter	SG3310	1 Hz～1.5 GHz	U=2×10-7，k=2
DC resistance box	ZX74	0.1～1111.21 Ω	Level 0.01
	ZX75	0.01～11111.11 Ω	Level 0.01
Multi-function checksum	MC6	0～22 mA	U=0.0008 mA，k=2
		0～5 MHz	U=0.3 Hz，k=2
	744	0～20 mA	U=0.0010 mA，k=2
insulation resistance meter	3001B	500 V,1000 V	Level 2.0
Voltage-resistant tester	CC2670A	0～5 kV	Level 5

4.1.3 How the device works

Main technical indicators of the device.

Frequency output range: 1μHz~ 5 MHz, uncertainty: U=0.010 Hz, k=2;Resistance output range: 0.01~11111.11 Ω, accuracy level: 0.01; DC current output range: （4~20）mA, uncertainty: U= 0.0010 mA, k=2.

4.2 Natural Gas flow computer evaluation and test software

The software of traffic computer evaluation system is divided into five parts: flow calculation evaluation, compression factor evaluation, material parameter evaluation, communication ability evaluation, and environmental security impact.

As an important part of flow computer, flow calculation is tested on two scales: working flow calculation and standard flow calculation.As an important part of the flow computer, the compression factor calculation mainly uses three mainstream calculation methods: GB / T 17747.2 with mole composition, GB / T 17747.3 with physical property value, and GB / T 21446-2008 with the standard hole plate flow meter.As an important part of the flow computer, the physical parameter evaluation is tested by the calculation of the calorific value, density, relative density and Volper index of natural gas.As an important part of the traffic computer, the data acquisition test uses the RS232 / RS485 serial port as the physical communication port and the Modbus protocol.Since the traffic computer manufacturer only provides the communication manual between traffic computer and upper computer, only the communication ability evaluation between traffic computer and traffic computer is supported.Traffic computer acquisition flow meter data communication ability test requires the traffic computer manufacturer to provide the corresponding protocol can be fully used.Environmental security is an objective indicator affecting the performance of the traffic computer.

4.3 Field measurement accuracy test

The flow channel and temperature and pressure channel of 19 flow computers were tested on the site. The experimental point selected 0.2 times, 0.4 times, 0.6 times, 0.8 times and 1 times around the input signal of the maximum flow rate of the flow computer.The temperature and pressure parameters were manually set and kept unchanged.FIG. 4 shows the relative error of each point of each flow computer, in which the flow computer numbering 16,18, and 19 far exceeds the provisions of the error limit specified in Table 1.Table 3 and Table 4 show the specific data of 16 of the computer flow channel, temperature channel and pressure channel. It can be seen from the data that the maximum error of the temperature channel is 0.11%, and the maximum error of the pressure channel is 0.09%. Because the flow meter has been verified by the superior verification institution, the components and related parameters are set manually.Thus, the error of this measurement system mainly comes from the flow computer itself.

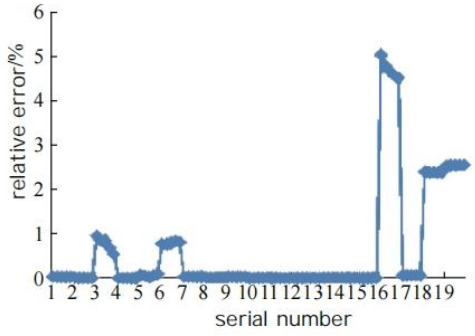

Figure 4: Relative error chart of 19 flow computers

Table 3: Test results of the flow channel of #16 flow

computer

Standard value (m^3 / h)	Measurement value (m^3 / h)	Error (m^3 / h)	fractional error (%)
5771.31	5481.54	289.77	5.0
11542.6	10990.6	552.04	4.8
17313.9	16508.2	805.72	4.7
23085.3	22031.1	1054.12	4.6
28856.6	27557.8	1298.76	4.5

For the above flow computer out of tolerance, figure 5 and Figure 6 give the curve of the absolute error of the flow computer. Among them: Figure 5 selects the maximum error point of each flow computer for statistics; Figure 6 select four flow computers with large deviation to count 0.2 times, 0.4 times The error near 0.6 times, 0.8 times and 1 times the measurement limit.

Table 4: Test results of the temperature and the pressure channels of #16 flow computer

The temperature channel				Pressure channel			
standard value (℃)	measured value (℃)	error (℃)	fiducial error (%)	standard value (MPa)	measured value (MPa)	error (MPa)	fiducial error (%)
-30.000	-29.976	0.024	0.02	0.000	0.002	0.002	0.02
-2.500	-2.457	0.043	0.04	3.000	3.005	0.005	0.04
25.000	25.07	0.070	0.06	6.000	6.007	0.007	0.06
52.500	52.598	0.098	0.09	9.000	9.009	0.009	0.08
80.000	80.125	0.125	0.11	12.000	12.011	0.011	0.09

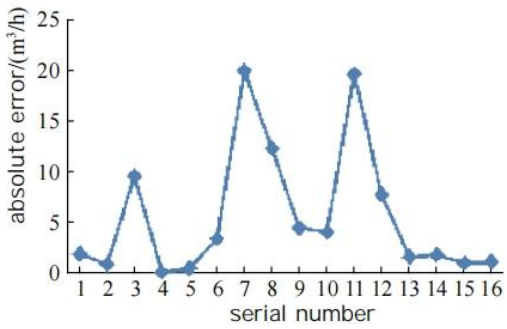

Figure 5: Absolute error chart of the flow computers

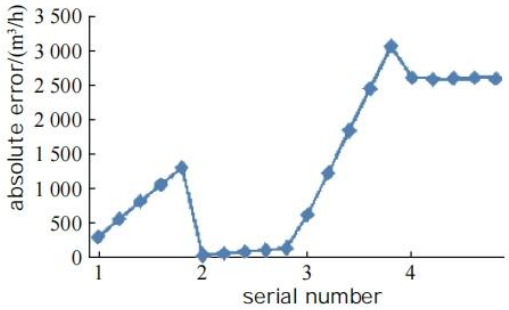

Figure 6: Absolute error chart of 4 flow computers with great errors

5.conclusion

This paper introduces the research work on the development of natural gas flow computer performance evaluation method, forms a perfect flow computer evaluation and test method, and provides a complete flow computer function realization and test and evaluation basis for the flow computer manufacturers and users.The current work mainly focuses on the measurement performance, and the relevant research on the data collection function, monitoring function and data storage function of the traffic computer has not been carried out yet, which is the main research direction and goal of the next work.At present, a complete test theory and test method have not yet been formed for the evaluation and test of natural gas flow computer in China. As an important measurement equipment related to the accurate and reliable measurement of natural gas flow computer, it is urgent to formulate relevant evaluation methods.Metering performance is the most important part of the computer performance of natural gas flow performance. In order to meet the measurement needs and ensure the accurate and reliable trade handover, it is also a feasible way to formulate the evaluation method of the computer measurement performance of natural gas flow performance alone.

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