Study on Data Collection Methods of Natural Gas Flow Verification

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Abstract

Based on the different ways of data collection which adopted by the current domestic natural gas flow metering station, this paper first analyzes the theoretically applicability and limitations for two kinds of data collection methods: instantaneous flow and cumulative flow, and obtains the relation and distinction between these two ways. Then, the flow-meters with different diameters are actual tested in two data acquisition ways, instantaneous flow and cumulative flow, which performed by the work level standard device of substation in Guangzhou. The results show that the different methods of data collection have no evident impact on indication error but high effect on the repeatability of indication error.

1. Introduction

With the rapid development of the oil and gas industry and frequent trade in the world, China has also ushered in a period of vigorous development of this industry, a large number of natural gas pipelines have been built, and natural gas as a clean energy has been widely used in many fields. Undoubtedly, the popularization of natural gas also requires the continuous development of its metering technology. Therefore, high-pressure and large-caliber natural gas flow meters have been promoted and applied in many fields, e.g. the flow meters have been used as the settlement basis of international natural gas trade [1]. In addition, the natural gas metering is an important part of energy measurement and environmental protection, as well as an important guarantee for industrial production quality. Therefore, the accuracy of the standard device used to verify the natural gas flow meter involves the economic interests of both trading parties and is closely related to people's livelihood .

Now, for the small flow verification, multiple data collection is required to meet the requirement of repeatability due to large fluid fluctuations, which leads to low verification efficiency and fails to meet the requirements of the rapid development of domestic natural gas pipeline business for the verification of flow meters. Besides, the data collection methods of different national metrological sub-stations are different, which also need to further verify whether the collection method affects the flow meter verification result.

Therefore, this paper focuses on the influence of data collection method on the verification result of flow meters, and then explores the more effective method of data collection and processing. Finally, the accuracy and reliability of metrological verification are guaranteed while improving the verification efficiency.

2. Theoretical analysis

2.1 Instantaneous flow test

When the instantaneous flow is used for verification of the natural gas flow meter, and the sampling method is frequency collection. The instantaneous flow of the working standard flow meter (q) and the detected flow meter (qf) are shown in formula (1) and (2) respectively:

$$q = \frac{f_n}{K_n} \times 3600 \tag{1}$$

$$q_f = \frac{f_f}{K_f} \times 3600 \tag{2}$$

Where ff and Kf are the output frequency and metering coefficient of the detected flow meter, which are measured in 1/s and 1/m3, respectively; fn and Kn are the output frequency and metering coefficient of the standard flow mete.

The standard volume flow rate (qs) of the detected flow meter under the operating condition is:

$$q_s = q\left(\frac{P_f}{P_n}\right)\left(\frac{T_n}{T_n}\right)\left(\frac{Z_n}{Z_f}\right) \tag{3}$$

Where Pf, Tf and Zf are the environment pressure, temperature and compression factor of the detected flow meter, respectively; Pn, Tn and Zn are the pressure, temperature and compression factor under the standard state.

The indication error (Eij) of the detected flow meter is:

$$E_{ij} = \frac{q_{ij}-(q_s)_{ij}}{(q_s)_{ij}} \times 100\% \tag{4}$$

When each flow point is repeatedly verified n times, the repeatability (Er)i of the flow point is:

$$(E_r)_i = \left[\frac{1}{(n-1)}\sum_{j=1}^{n}(E_{ij} - E_i)^2\right]^{\frac{1}{2}} \tag{5}$$

For instance, if the system collects one frequency every 500 ms, 2t instantaneous frequency values will be acquired within a sampling period (t (s)), and the average value will be calculated to obtain the instantaneous frequency of the flow meter. The evolution of sampling frequency with collection time is shown in Figure 1.

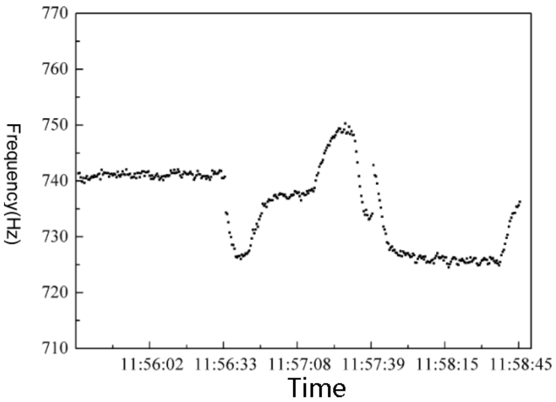

Figure 1 Evolution of sampling frequency with collection time

2.2 Cumulative flow test

When using the cumulative flow to verify the natural gas flow meter, the selected sampling method is pulse acquisition. The cumulative flow of the working standard flow meter (Q) and the detected flow meter (Qf) are shown in formula (5) and (6) respectively:

$$Q = \frac{N_n}{K_n}\frac{3600}{t} \tag{6}$$

$$Q_f = \frac{N_f}{K_f}\frac{3600}{t} \tag{7}$$

Where Nf and Nn are the corrected pulse counts of the detected flow meter and the standard flow meter, t is the collection time.

The standard volume flow rate (Qs) of the detected flow meter under the operating condition is:

$$Q_s = Q\left(\frac{P_f}{P_n}\right)\left(\frac{T_n}{T_n}\right)\left(\frac{Z_n}{Z_f}\right) \tag{8}$$

The indication error (Eij) of the detected flow meter is:

$$E_{ij} = \frac{Q_{ij}-(Q_s)_{ij}}{(Q_s)_{ij}} \times 100\% \tag{9}$$

For the cumulative flow test, the relationship between the collection time and the cumulative of pulse count is shown in Figure 2. In the whole collection process, the cumulative flow is calculated by cumulating the pulse count collected during this period.

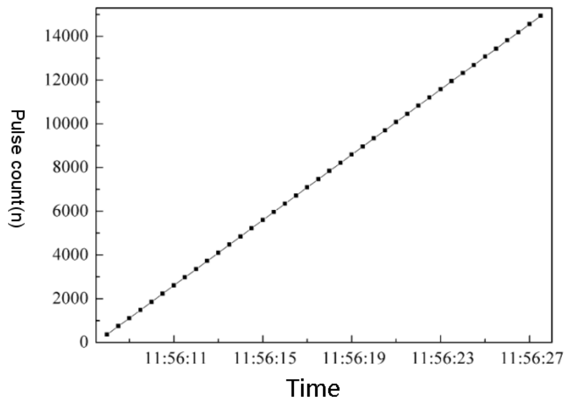

Figure 2 Relationship between the collection time and the cumulative of pulse count

2.3 Comparative analysis

Due to the following relation between pulse, frequency and sampling time,

$$f = \frac{N}{t} \tag{10}$$

the instantaneous flow test and cumulative flow test have the same essence and can be derived from each other. But according to Figure 1 and 2, it can be seen that the data collected by the two methods are still different to some extent. For the cumulative flow test, its collection is the cumulative of pulse count over a period of time, which is a cumulative process and unable to collect the fluctuation of the flow state, so its anti-interference ability is poor, and it is unable to identify and eliminate abnormal data, corresponding to the lower configuration of hardware devices and low cost. On the contrary, the instantaneous flow test can obtain the fluctuation of the flow, which is convenient for timely detection and elimination of abnormal values, thus improving the effectiveness of data. However, the collection time of this method is short, the requirements for hardware equipment are high, and the corresponding data processing algorithm is more complex.

3. Analysis of experimental results

The standard turbine flow meter of National oil and natural gas flow metering station substation in Guangzhou was used to test the flow meters with different diameters by two verification methods: instantaneous flow and cumulative flow. The test flow points were Qmin, Qt, 0.25Qmax, 0.4Qmax, 0.7Qmax and Qmax, and the sampling time were 60 s, 100 s, 120 s and 200 s, respectively.

3.1 Influence of collection method on verification results

In order to compare the influence of instantaneous flow collection and cumulative flow collection on verification results, the curves of operating flow and indication error under different collection methods and sampling times were compared and analyzed. The relationship between operating flow and indication error of DN80 and DN250 flow meters are shown in Figure 3 and Figure 4, respectively.

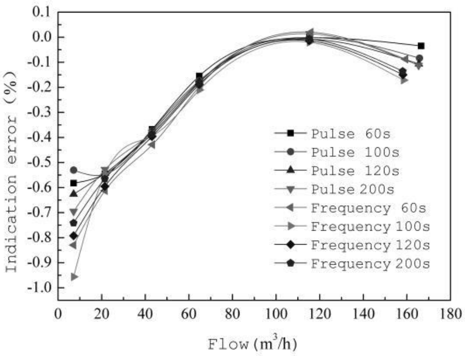

Figure 3 Relationship between operating flow and indication error of DN80 flow meter

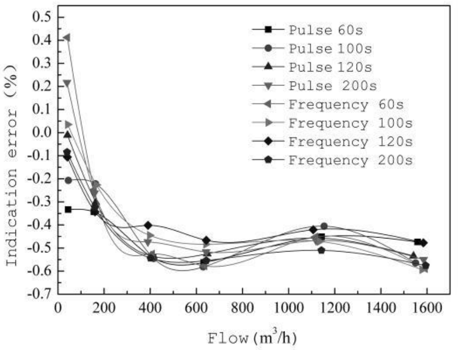

Figure 4 Relationship between operating flow and indication error of DN250 flow meter

Based on the Figure 3 and Figure 4, under the different collection ways, the overall trend of operating flow and indication error is basically consistent, except for the small flow point. The main reason is that there are many factors affecting the indication error of the small flow point, such as the performance of the flow meter, the collection time, and the poor stability of flow. In general, it can be concluded that different collection methods have little influence on the indication error of each flow point.

3.2 Influence of sampling time on verification results

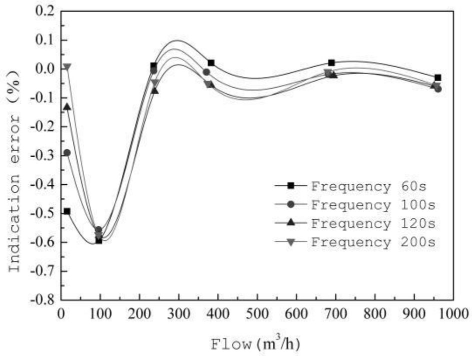

Figure 5 Curves of the operating flow vs. indication error for the DN100 flow meter

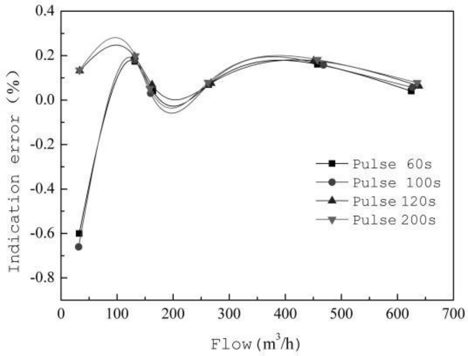

Figure 6 Curves of the operating flow vs. indication error for the DN150 flow meter

Figure 5 and Figure 6 show the curves of the operating flow vs. indication error for the DN100 and DN150 flow meters under the same collection method and different sampling times, respectively. Under different sampling times, the difference of each flow point is mainly reflected in the small flow point, while the difference of other flow points is small. In order to display the repeatability and indication error of each flow point at different calibration stations more directly, the variation of the indication error repeatability of DN100, DN200 and DN300 flow points with pulse or frequency are shown in Figure 7, Figure 8 and Figure 9.

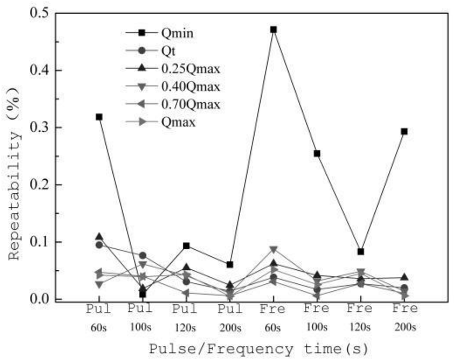

Figure 7 Indication error repeatability of each flow point for the DN100 flow meter

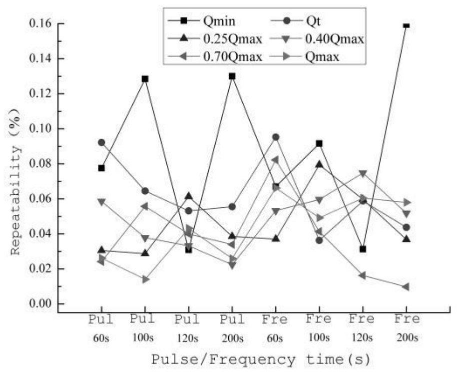

Figure 8 Indication error repeatability of each flow point for the DN200 flow meter

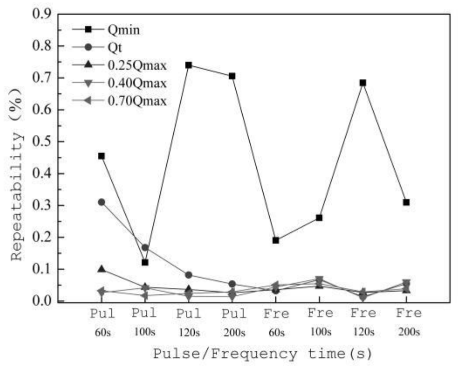

Figure 9 Indication error repeatability of each flow point for the DN300 flow meter

As can be seen from Figure 7 to Figure 9, the sampling time has a significant influence on repeatability, especially on small flow points. At the minimum flow point, for cumulative flow collection, the indication error repeatability is small when the sampling time is 200 s, while for instantaneous flow collection, it is 120 s. In Qt point, the minimum indication error repeatability can be obtained at the 120 s and 200 s during the cumulative flow collection, but for the instantaneous flow collection, it can be gained is at the 100 s and 120 s. From the 0.25Qmax to Qmax points, for the flow meters with small caliber calibration station, such as DN100, the sampling times corresponding to the minimum indication error repeatability are mainly at 120 s and 200 s during the cumulative flow collection, and they are at 100 s and 120 s for the instantaneous flow collection. But For the flow meters with large caliber calibration station, such as DN200 and DN300, they are mainly at 60 s and 100 s during the cumulative flow collection, and they are at 100 s and 200 s for the instantaneous flow collection.

Therefore, in order to improve the verification efficiency of the flow meter, it is necessary to select the appropriate method and sampling time according to different calibration stations.

4. Conclusions

(1) Theoretically, the instantaneous flow test and cumulative flow test have the same essence and can be derived from each other.
(2) Experimentally, the indication error trends of the each detected flow meter verified by instantaneous flow and cumulative flow tests are basically consistent with the result of theoretical analysis.
(3) The sampling time has a certain influence on the indication error repeatability. In order to improve the verification efficiency, it is suggested to give priority to the instantaneous flow test for the small-caliber flow meter and the cumulative flow test for the large-caliber one.

References

[1] Guang Zheng Jia, Jin Cai Geng, Yong Ling Fu. Development of High-Pressure Gas Test System[J].Applied Mechanics andMaterials，2013, 278-280: 873-877.