The foundation of release system and investigation on the calculation method on energy determination of natural gas

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Abstract: To achieve the change of trade balance from volumetric determination to energy determination for natural gas in China. The smallest release system of energy determination for natural gas was built. On the base of analyses of energy determination, the uncertainty for this system was conducted taking an example of Beijing experimental station. The results showed that the uncertainty of energy determination could be lower than 1% (k=2), when the measurement process was kept in good control. On the other hand, because the influence of the flowrate and composition on energy determination was both considered for the quantity weighted averaged calorific value, which might be more suitable relative to arithmetic averaged calorific value when the value of flowrate or composition of natural gas had big change, or there were more than one natural gas sources in one consuming zone.

Keywords: Metrology, Natural gas, Energy determination, Uncertainty

1. Introduction

Nowadays, the trade balance for natural gas was mostly calculated by the volumetric flowrate in China. In fact, the consumer took care about how much the energy could be created. In China, the minimum volumetric heat was about 33.9MJ/m^3 for natural gas, while the maximum was about 45MJ/m^3, so the maximum difference could reach 31%. The balance method of energy determination might be more scientific and fair than that of volumetric determination. On the other hand, the orifice was still the most popular flowmeter as the trade balance so far. The right density was important for orifice to keep the measurement accuracy. When the component of the natural gas had some change, the measurement error might exceed 1% if the fixed density was used instead of the right density calculated from the component of the natural gas. So, there were lots of trade trouble recently due to the above problems.

The newest international standard, ISO/DIS 15112[1] was released in 2007. In practice, for the determination of the energy flow $e(t)$, the basic differential equation was given by Equ. (1),

$$e(t) = H(t)q(t) \tag{1}$$

where $H(t)$ was the calorific value, while $q(t)$ was the flowrate. The quantity of energy,

$E(t_n)$, flowing within a period of time from t_0 to t_n (for example within one day, one week or one month) was calculated by integration of Equ. (1) over the time, t, as given in Equ. (2)

$$E(t_n) = \int_{t_0}^{t_n} e(t)dt = \int_{t_0}^{t_n} H(t) \cdot q(t)dt \tag{2}$$

In practice, a small time interval, Δt was set such that the calorific value, $H(t)$, might be assumed to be a constant entity, $H_{const.}$. When the transported quantities, Q, of gas in the respective time intervals, Δt; they could be calculated by integration of the actual gas flow over the time, t. In reality, the Q, was usually directly as the results of a measurement, so the quantities of energy $E(t_n)$ finally could be expressed as,

$$E(t_n) = \sum_{m=1}^{n} E_m = (H_{const.,1} \times Q_1) + (H_{const.,2} \times Q_2) + \ldots + (H_{const.,n} \times Q_n) = \sum_{m=1}^{n} (H_{const.,m} \times Q_m) \tag{3}$$

Equ. (3) could be used for any energy-determination period, i.e. from 1 h to days or months. The monthly average for calculating thermal energy could, for example, be computed from daily values. When the calorific value was constant during the time period t_0 to t_n no special calculation was required; If the calorific value changed during this period of time, the procedures for calculation of the appropriate calorific value described in the following part should be used.

1.1 Arithmetically averaged calorific value

In practical use, the calorific value was often measured at a representative point of the pipeline grid and allocated to volume-measuring stations located at other points. Thus, the arithmetic average of the calorific value (AACV in abbreviation in the following part), H_{arith}, was derived from n single measurements, as given in Equ. (4),

$$H_{arith} = \sum_{m=1}^{n} H_m / n \tag{4}$$

Equ. (3) could be simplified, if the single factors, $H_{const.,m}$ were similar to the arithmetic average value, H_{arith} as given in Equ. (5),

$$E = H_{arith} \times Q \tag{5}$$

1.2 Quantity-weighted averaged calorific value

If the energy of the gas quantity transported from time t_0 to t_n was normalized to the gas quantity, $Q(t_n)$, that was transported in the same time period, the so-called quantity-weighted average of the calorific value (QWACV in abbreviation in the following part) was given by Equ.

(6), taking into account Equ. (3),

$$H(t_n) = E(t_n) / Q(t_n) = \sum_{m=1}^{n} H_{const.,m} \times Q_m / \sum_{m=1}^{n} Q_m \quad (6)$$

Each of the n single calorific values, $H_{const.,m}$, was weighted by the respective quantity Q_m.

The experience on the energy determination for natural gas was limited in China. Some researches on this field was began from 2005 in NIM. The foundation of release system for energy determination of natural gas, the uncertainty of the system and the influence of different calorific calculation methods would be presented in this paper.

2. The foundation of the release system for energy determination

At present, the GC (gas chromatogram) was usually installed in the main station in China. Due to the expensive investment of this kind of machine, it was impossible and unnecessary to install it in each trade balance position. When the natural gas source was fixed in one cosuming area, the component of the natural gas was almost the same. So, it was reasonable to measure the component of natural gas in the main pipeline, and the information was used in other place with the same source of natural gas. Besides the component, superior caloric heat, density and so on, the complete information of natural gas should be instantly transferred and easily searched for the history value. So, there was possible scheme to achieve the management of natural gas if all the information of natural gas and the running condition, alarming recording, and the accident recording of the meter was summarized together. Then, the management platform of natural gas information was built to provide the information of natural gas with justice, accuracy, fast, convenience and low cost for the natural gas company and society of city. This system would take positive action on the macro adjustment and control, the information sharing, decreasing the trade trouble for the natural gas.

2.1 The function and requirement of the system

To achieve the object of our research, the following functions and requirements were needed,

1) The information of the natural gas was collected in one consuming area, and the information by AACV and QWACV per hour or day, week, month was calculated. Then, all the information with the universal format was sent to the flowmeter on line mounted in the same consuming area to make the component modification and energy calculation;
2) The information of the natural gas in the central service database could be automatically released by the Web service to the management website platform. So the component modification and energy calculation could be made for the other flowmeters not on line;
3) All the information on the running condition, alarming recording, accident recording and so on of the meters might be collected with the universal data format and be saved in the database of central service;
4) The manager of the metrological administration could get and manage all the information of natural gas and the running condition, alarming recording, accident recording of the meter. So, they could watch and manage the data, running, accident, man malfunction and so on for the metrological meters;

5) The technique requirement: there must be some protection function on the all data transferred by the internet or saved in the service. And, it must have the good stability to satisfy lots of customs' visit;
6) It must be consistent with the international standard for the treatment, AACV and QWACV per hour or day, week, month, year, the standard mathematic model of modification for the flowmeter.

2.2 The achievement of the release system

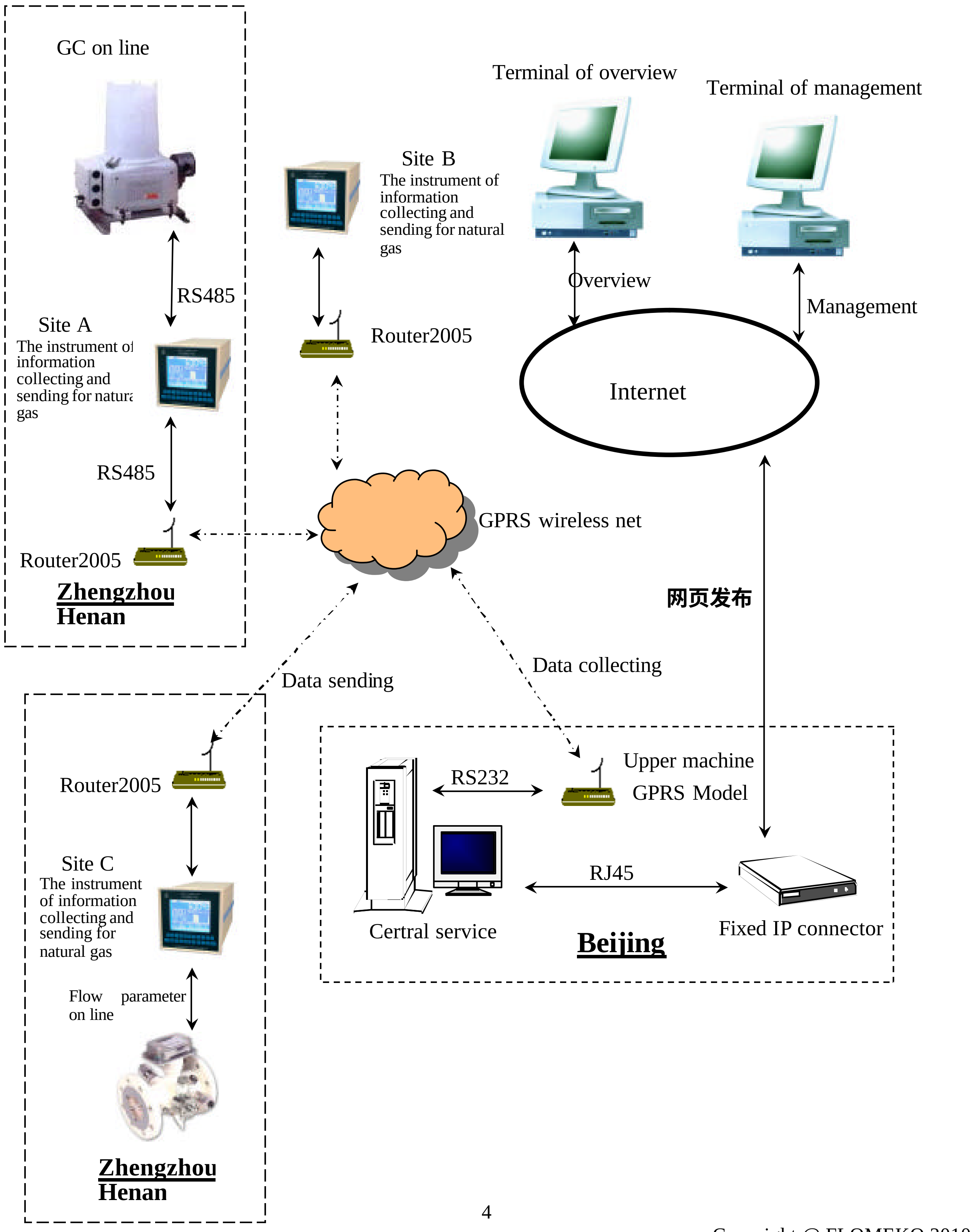

Fig.1 the systemic diagraph of the system

The systematic diagraph of the release and management system was shown in Fig.1, in which the management system achieved by internet was clearly shown. The main experimental place was located in Zhengyhou, Henan province, shown as Site A and Site C, while part of experiment was conducted in Beijing, shown as Site B in Fig.1.

In the website for the information of natural gas, all the data in the central service was released to the website by WEB method. So, all the data could be overviewed by any terminal through internet, and which could also be sent by short message through the GPRS wireless net.

In the system, all the calculation models were on the base of international standard to achieve the modification for the volumetric flowrate according to the component of natural gas, which was satisfied with the requirement for the general types of flowmeters. The software could be used in the flowmeters to receive the information of natural gas and conduct the calculation for volumetric flowrate and energy determination. All the calculation results and the running condition, alarming recording, accident recording and so on could be sent to the central service. All the data were classified into different database with the similar format and saved in the central service. On the base of the database, the metrological management was developed, which could be satisfied with the requirement for natural gas company of city to achieve the macro management for the each trade balance point. All the data of running history data, alarm recording, accident recording and so no of the meters saved in the database could be transferred the consumer and the manager of metrological administration. So, the corresponding person could watch and manage the data, running condition, accident, person malfunction of the meters.

3. The uncertainty analyses

According to the function of the energy determination system, the uncertainty of the system was analyzed on the base of the Beijing experimental station. The experiments in Beijing were conducted from at the beginning of Jan. to the end of March in 2008. The GC on line of ABB BTU/CV 8000 and the double rotatory volumetric flowmeter of Actaris were utilized.

3.1 The basic component of uncertainty

The basic component of uncertainty was consisted of the following items,

1) The uncertainty of component measurement and the component change with time of natural gas was estimated 0,3% (*k*=2). So, the standard uncertainty, $u_Z = 0.15\%$;
2) The uncertainty was ± 0.3°C for temperature measurement, and the uncertainty of uneven distribution for temperature was estimated ± 0.2°C. When the temperature was assumed 293,15K in situ and the distribution was rectangle, $k = \sqrt{3}$, so, the standard uncertainty, $u_T = 0.1\%$;
3) The uncertainty was 0,1% for pressure measurement, and the distribution was assumed rectangle, $k = \sqrt{3}$, so, the standard uncertainty $u_p = 0.058\%$;
4) The uncertainty of flowmeter was 0,5%, and the distribution was assumed rectangle, $k = \sqrt{3}$, so, the standard uncertainty $u_L = 0.29\%$;

5) The high stability 16 digital Analog/Digit converter, the sum for resolution, stability and permitted uncertainty was 0,05%. When the distribution was assumed rectangle, $k = \sqrt{3}$, the standard uncertainty, $u_h = 0.029\%$;

6) The uncertainty of calculation model was about 0.015% (*k*=2), so, the standard uncertainty, $u_m = 0.008\%$;

7) Due to digital transferring, the uncertainty coming from the sending and receiving, and the releasing to the website was lower than 0,001%, which could be neglected.

3.2 The component of uncertainty on energy determination

The uncertainty of the energy determination was generally consisted of three parts: the uncertainty of flowrate, the uncertainty of calorific value and the uncertainty of density.

3.2.1 The volumetric flowrate under standard condition

The uncertainty of flowrate under standard condition, u_1, was mainly consisted of,

1) The uncertainty of flowmeter;
2) The uncertainty of temperature;
3) The uncertainty of pressure;
4) The uncertainty of Analog/Digit converter for pressure and flowrate measurement

$$u_1 = (u_L{}^2 + u_T{}^2 + u_p{}^2 + 2u_h{}^2)^{0.5} = 0.31\% \tag{7}$$

3.2.2 The quantity-weighted averaged calorific value

The uncertainty of QWACV, u_2, was mainly consisted of,

1) The uncertainty of calculation model;
2) The uncertainty of component measurement;
3) The uncertainty of flowmeter;
4) The uncertainty coming from the change of component and flowrate, which was assumed 20% of the measurement uncertainty.

$$u_2 = (u_m{}^2 + 1.04u_Z{}^2 + 1.04u_L{}^2)^{0.5} = 0.33\% \tag{8}$$

3.2.3 The density of natural gas

The uncertainty of density, u_3, was mainly consisted of the following items,

1) The uncertainty of component measurement;
2) The uncertainty of temperature
3) The uncertainty of pressure measurement;
4) The uncertainty of calculation model;
5) The uncertainty of Analog/Digit converter for pressure measurement.

$$u_3 = (u_Z{}^2 + u_T{}^2 + u_p{}^2 + u_m{}^2 + u_h{}^2)^{0.5} = 0.19\% \tag{9}$$

3.3 The uncertainty of energy determination

When the density modification was not needed by the volumetric flowrate, the standard uncertainty of the energy determination, $u_{ef,1}$, could be expressed as,

$$u_{ef,1} = (u_1^{\ 2} + u_2^{\ 2})^{0.5} = 0.46\% \tag{10}$$

When the density modification was needed by the volumetric flowrate, the uncertainty of the energy determination, $u_{ef,2}$ was related the relationship between the volumetric folwrate and density modification model. When the flowmeter was differential type, the standard uncertainty of the energy determination, $u_{ef,2}$, could be expressed as,

$$u_{ef,2} = (u_1^{\ 2} + u_2^{\ 2} + 0{,}25u_3^{\ 2})^{0.5} = 0.47\% \tag{11}$$

So, the expanded uncertainty of the energy determination, U_{ef}, could be expressed as

$$U_{ef} = ku_{ef} \quad (k = 2) \tag{12}$$

From above analyses, the expanded uncertainty could be kept under 1%, when the process measurement was kept good condition.

4. The difference between AACV and QWACV

The flowrate, component and energy determination results in 11th and 13th, Feb., 2008, Beijing station was taken as the example to indicate the difference between AACV and QWACV.

The flowrate was shown in Fig.2 and 3

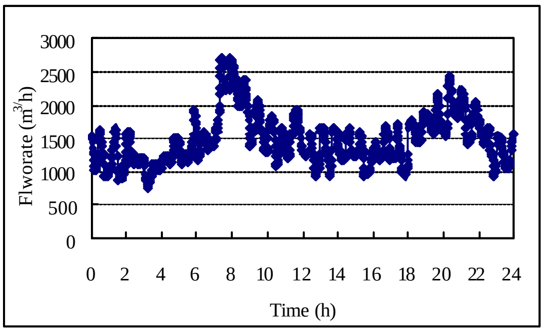

Fig. 2 the flowrate data in 11th Feb.

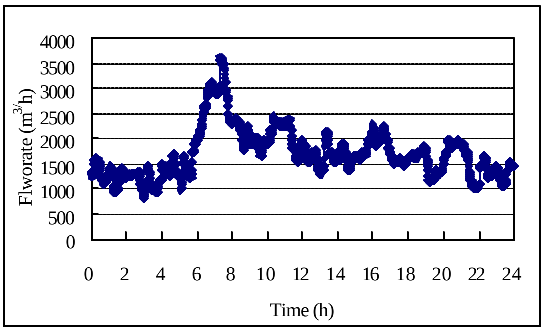

Fig. 3 the flowrate data in 13th Feb.

With combination of the component and the flowrate in each day, and the calorific value for different component, the superior calorific value was shown in Fig. 4 and 5, when the reference condition was kept at 20°C, 101325Pa. In Fig. 4 and 5, SCV expressed the superior calorific value.

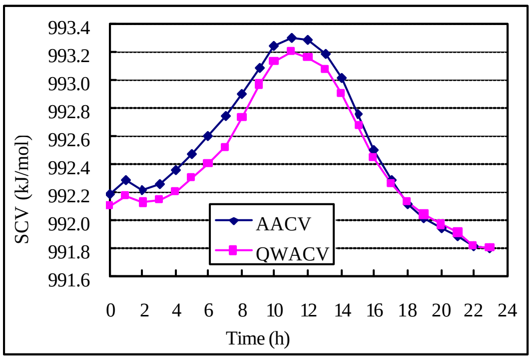

Fig. 4 the calorific value in 11th Feb.

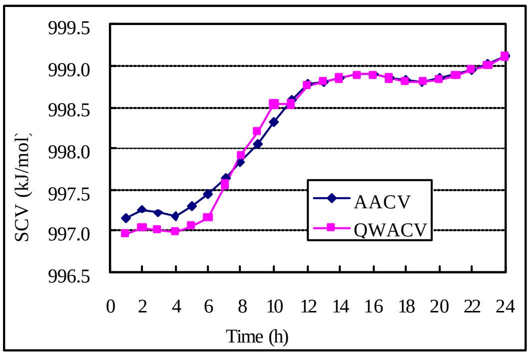

Fig. 5 the calorific value in 13th Feb.

The calorific value for each day was shown in Table. 1,

Table 1 the calorific value for each day (unit:MJ/kmol)

Day	AACV	QWACV
11th Feb.	992.19	992.10
13th Feb.	997.15	996.97

Because there was some change for flowrate and component of natural gas in different time, which made the daily difference was within 0.50% for the same energy calculation method, the maximum difference between the AACV and QWACV was only 0.02%. This difference could be neglected relative to 1% (k=2) uncertainty for this system. When there were more than one source of natural gas, the difference between AACV and QWACV might be enlarged dramatically due to the different flowrate with different component, so, the difference could not be neglected at that condition. Because the effect of flowrate was considered in the calculation of QWACV, this value was recommended to be used to calculate the calorific value.

6. Conclusions and outlook

The release system was built to achieve the energy determination and management for natural gas. In this system, much information, such as component, flowrate, temperature, pressure and so, was collected, calculated, sent and released in the website. All the calculations were conducted on the base of international standard. From this website, it was easy for customer and metrological administration to watch and manage the data, running condition, accident, person malfunction of the meters. When the process measurement was kept in good control, the uncertainty of the energy determination could be better 1% (k=2).

There were two methods to calculate the calorific value, AACV and QWACV. According to the experimental data, it was clearly that the difference between the two methods was neglected when there was only one source of natural gas, otherwise, QWACV was recommended when there was more than one source of natural gas.

The smallest system to release the information of nature gas was built in last a few years. In the system, the information of natural gas, including the component, AACV, QWACV, and so on, and all the data could be sent to the central website and be transferred to the meter with authority. In the future, many experimental places will be contained in this system. On the other hand, the system will be kept renewed capability with the new international standard releasing.

References

[1] ISO/DIS 15112. Natural gas energy determination, 2007
[2] OIML R 75. Heat meters, 2000

[3] GB/T 13609. Natural gas-sampling guidelines, 1999
[4] GB/T11062. Natural gas-calculation of calorific values, density, relative density and Wobbe index from composition, 1998