Research of Improving Accuracy of the 3-ton Electric Balance for Gas Flow Measurement

Duan Jinqin, Liu Chunyan,Chen Huiyu,
Chengdu Verification Branch for Natural Gas Flow of Nation Crude Oil Large Flow Rare Measurement Sation
Zhao Baorui,
Beijing Air Flight Industry 102 Facility

Abstract: There is a professional 3-ton electric balance for gas mass flow measurement in Chengdu Verification Branch for Natural Gas Flow of National Crude Oil Large Flow Rate Measurement Station. The weighting range of this balance is 0kg to 110kg ,the minimum sensible mass is :1g ,and the shift of indication value is no more than 2g (P=95%) .It has been proved stable and reliable during its 8-year usage.This article brieves the method of improving the original circuit control system by applying advanced electrc technology .Using this method, the shift of indication value can been reduced to less than 2g and the balance can work even more stable. In addition, the author introduces an indirect weighting method to reduce the negative effect caused by the balance crossbeams and the hanging weights used after many years.Thus the accuracy of the electronic balance can be improved.

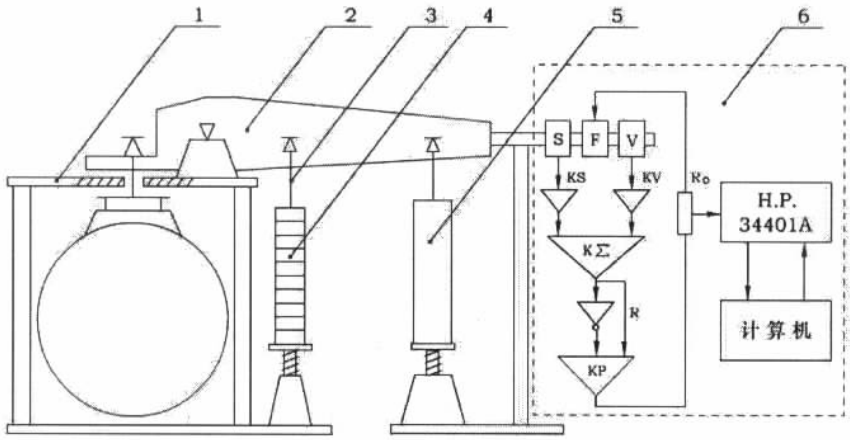
Keyword: special 3-ton electric balance, accuracy, electronic technology, indirect weighting

1. Foreword

In Chengdu Verification Branch for Natural Gas Flow of National Crude Oil Large Flow Rate Measurement Station, the gas flowrate primary standard facility of national by means of “mass-time” method was established in 1996. It consists professional 3-ton electronic balance weighing system and time –counting system, and the uncertainty of it is 0.1%. The system has run 8 years. The author reseachs on the methods of improving systematic accuracy of its mass weighing control system, Thus, its corresponding time-counting system is not involved.

2. Structural Characteristic and Principle

The weighing range of this balance is 0-10 kg , the minimum sensible mass value is 1g ,and the shift of indication value is no more than 2g. The whole system is composed of supporting system, beam system, hanging system (including weighing container)、balance weight、normal weight ,and measuring system. The measuring system is made up of torque detector, speed detector, displacement detector, combination amplifier and computer. (Fig.1).



1 – supporting system　2 – beam system　3 – hanging system
4 – normal weight　5 – balance weight　6 – measuring system

There are three characteristics of this system: the balance beam is an inequality lever of four blades, which has one more blade than the common equal beam double-disc balance and two more blades than the unequal beam single-disc balance. The supporting system is a frame structure system made up of the up base, the bottom base and the four stainless steel posts between them. By using the loop-locked electromagnetic balance control system, the measuring data can be transferred and processed automatically.

3. The Improvement of the Amplifier Advanced by Electronic Technology

3.1 the loop-locked electromagnetic balance control system

Electronic measurement part utilizesal electromagnetic balance sensor on electronic balance with high accuracy the sensor applies loop-locked electromagnetic balance principle, i.e. electromagnetic force(F) balances with the load weight(W) applied to balance disk, If F equals to W in a opposite direction, the beam is balanceable. At this moment the equation of the mass of the weighing object and the electric current can be listed.

Because:

$$W=mg \qquad (1)$$

$$F=ILB\sin\alpha=I\pi dNB\sin\alpha \qquad (2)$$

According to the balanceable condition, the two equation above should be equal, thus(3):

$$mg= I\pi dNB\sin\alpha \qquad (3)$$

Whileα=90, $\sin\alpha$=1 so

$$mg = I\pi dNB$$

- L-- the length of the wire in the electromagnetic field
- B--- magnetic induction intensity
- α- the angle of the magnetic-curve and the electrified wire
- d is average coil diameter
- n is the turn number of the coil
- g is gravitational acceleration

As we know form the equation (3), when the balance is settled, the gravitational acceleration g is decided. Thus, except for the electric current I, the right part of the equation are all constants, and can be regarded as K. So if the current which generates the balancing magnetic force can be measured, the mass of the weighing object can be calculated accurately i.e. current is correspondent to mass, mass can be measured by electrical measurement method.

3.2 Considerable improvement is made on the circuit of the amplifier :

(1) The new amplifier uses the high input resistant and high common mode inhibit circuit, improve the stability of it.

(2) The displacement signal transfer circuit and the speed signal transfer circuit in the old amplifier are not independent. The new amplifier is a compound amplifier. The independent displacement and speed signal transfer circuit is used in the new amplifier, so the interference is reduced.

(3) The more stable new-style follower is used in the new amplifier, instead of the old one which is not stable.

(4) In the new amplifier, the reverse feedback circuit and the The power accumulates circuit, make NO.1 class power output, which generates a higher antiinerference ability, and the damping factor can be more easily adjuste

(5) The over-load protection function is strengthened in the new amplifier. There is a anti-short-pass output circuit in the displacement sensor, which can active automatically when the output of the displacement is over-ranged..

As stated above: after the modification of the amplifier, great improvement has been made on it, the signal output becomes more stable, and the self-protection function is strengthened. (See the table 1 and the table 2)

Table 1: test records of the shift of indication value of a special 3-ton electric balance for gas mass flow measurement

Test number of times	Test timeand date	times of average data and result (g)			Total average data (g)
		1	2	3	L
1	1996.7.3.14: 00	-7.3	-7.2	-7.2	-7.2
2	1996.7.3.14: 04	-7.0	-7.0	-7.0	-7.0
3	1996.7.3.14: 10	-6.7	-6.7	-6.7	-6.7
4	1996.7.3.14: 20	-5.8	-5.9	-6.0	-5.9
5	1996.7.3.14: 25	-5.7	-5.6	-5.6	-5.6
6	1996.7.3.14: 32	-5.4	-5.3	-5.3	-5.3

Table 2: test records of the shift of indication value of a special 3-ton electric balance for gas mass flow measurement

Test number of times	Test time and date	times of average data and result (g)			Total average data (g)
		1	2	3	L
1	2003.4.22.9: 15	1.517	1.596	1.574	1.560
2	2003.4.22.9:20	1.607	1.683	1.559	1.616
3	2003.4.22.9:26	1.612	1.618	1.619	1.616
4	2003.4.22.9:33	1.686	1.520	1.603	1.601
5	2003.4.22.9:47	1.523	1.554	1.732	1.603
6	2003.4.22.10:02	1.699	1.696	1.626	1.673

From the table 1 and the table 2: before reform , the shift of indication value of a special 3-ton electric balance for gas mass flow measurement is 1.9 g, and now the shift of indication value is 0.13 g, accurate of 3-ton electric balance for gas mass flow measurement is improved.

4. Indirect measurement can improve accuracy

The balance weighting system has been stable and reliable during 8 years. See Table 3.

Table 3

July third, 1 9 9 6 examination record.			July third, 1 9 9 6 examination record.		
Data of standard weight (kg)	Total average (kg)	indication value of subtract the zero (kg)	Data of standard weight (g)	Total average (g)	indication value of subtract the zero (g)
0	0.001	--------	0	-0.6	-------
1	1.002	1.001	100	99.5	100.1
2	2.002	2.001	300	299.5	300.1
3	3.000	2.999	500	499.2	499.8
4	3.999	3.998	700	699.5	700.1
5	4.999	4.998	1000	999.0	999.6

As time goes by, slight change may happen to the structure of balance beam, and slight charge may also happen to the weight, which can not be taken down to calibrate and adjust easily. To eliminate the negative effect caused by balance arm and changed weight, we suggest use indirect measuring method to enhance the accuracy.

First, we estimate mass of the natural gas filled in the container .According to the pressure, temperature ,natural gas density and capacity of weighting container. Lay the stándard weight of the estimated mass on the weighing container, and match the corresponding hanging weight. Retaining balance, you can measure for the first time. Then, take off the standard weight, connect the pipeline system, and fill the container, providing the flow rate unstability less than 0.5% by regulating the flow rate, temperature and pressure of natural gas in pipe, and record the filling time. Measure the mass of the container for the second time in order to get the gas mass in it under the corresponding pressure, temperature, and time. According to moment balanced equation:

$$a(m_G - v_G \rho_k)g + a(m_B - v_B \rho_K)g = b_1(m_T - v_T \rho_k)g + b_2(m_p - v_p \rho_k)g + I_0 \quad (4)$$

$$a(m_G - v_G \rho_k)g + am_A g = b_1(m_t - v_T \rho_k)g + b_2(m_p - v_p \rho_k)g + I \quad (5)$$

m_G expresses the mass of weighing container,

v_G expresses the volume of weighing container

m_B expresses standard weight mass,

v_B expresses the volume of weight

m_A expresses the mass of natural gas

m_T expresses normal weight mass,

v_T expresses the corresponding volume

m_p expresses balance weight mass,

v_p expresses the corresponding volume

A expresses the left beam length of left beam,

b_1 and b_2 express the two right beam length of righ arm has two arm lengthes respectively

ρ_k express the air density,

g expresses the gravity acceleration

(2) minus (3), we get:

$$m_A = m_B - v_B * \rho_K + (I - I_0) \quad (6)$$

In equation (4): ($I-I_0$) is the difference between the two readings of balance output system, equivalent to direct measuring deduct tare.

In equation (4),obviously , there is no beam length, so there is no error caused by the beam length. There is no error caused by normal weight mass as well.

5. The error of weighing quality is evaluated

According to the equation: $m_A = m_B - v_B \rho_K + (I - I_0)$, error margin source contain three aspects:

For the convenience for evaluation, take measuring 20 kg natural gas, for example

The first error is arised by standard weight (parameter m_B). According to the weight rules, the mass error limits of the F2 level 20 kg weight is 0.3 g .

The second error is arised by V_B, known as the remained error after air buoyancy correction. According to the long-turn actual measurement result for air density of Chengdu area, statistical average is1.14 kg/m^3 · After air buoyancy correction, its remained error is 0.1 g.

The third error is arised by weighing error(I-I0) ,which is determined by the uncertainty of indicated value on the balance. The uncertainty of this balance is 1g according to many repeated tests made under the relevant stipulation of balance calibrating rules .

As estimated above, relative combined standard uncertainty of measured flow-rate of the device is kess than 1×10^{-4} (P=99%) while the sum of absolute value is still less than 2 g

6. Results and conclusion

After modification of the mechanical and electronic measuring parts of this balance, every measure performance index this balance reaches the international advanced level according to the actual measurement and error assessment (the weighting range of this balance is 0kg to 110kg ,the smallest sensible mass value is 1g ,and the shift of indication value is less than 2g). It establishes the foundation for the primary standard facilities and guarantees the reliable accuracy for the natural gas measurement of our country.

References:

[1] *Huan Jincai , "mass measure ", Beijing: China measure publisher, 1990*