Application and Uncertainty Analysis of a New Balance used in Natural Gas Primary Standard up to 60bar

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1.Introduction

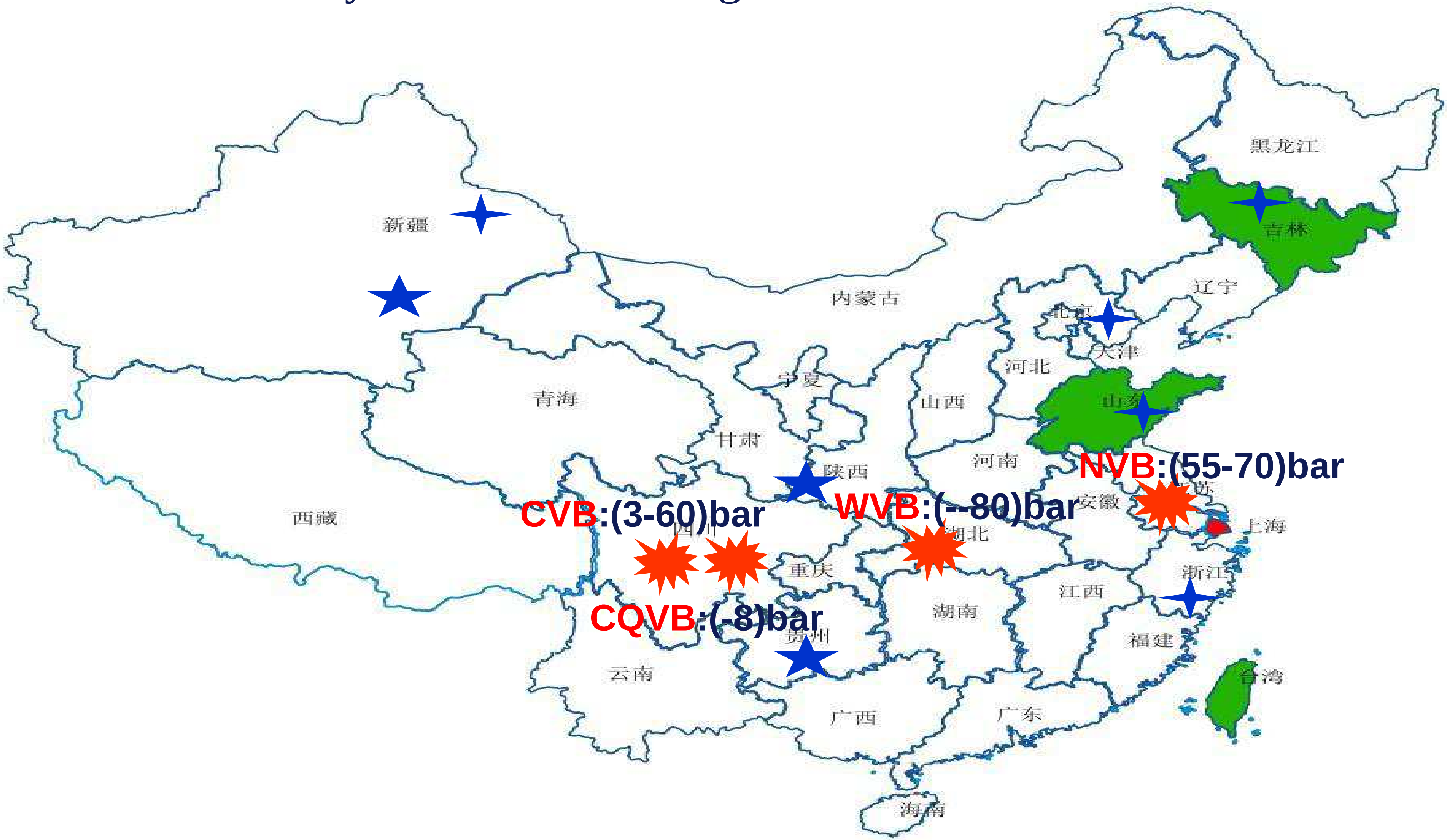
2.structure and principle

3.uncertainty evaluation

4.conclusion

1.Introduction

- traceability chain for natural gas in China

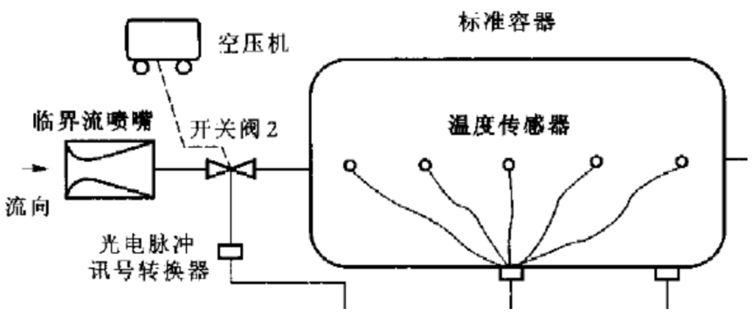


□three different primary standards for natural gas in China

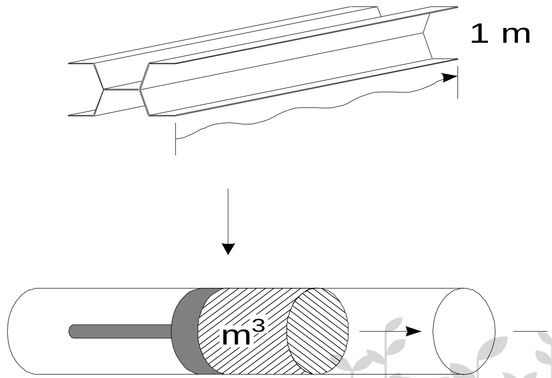
CVB:mt-electromagnetic balance

NVB:mt-gyroscope

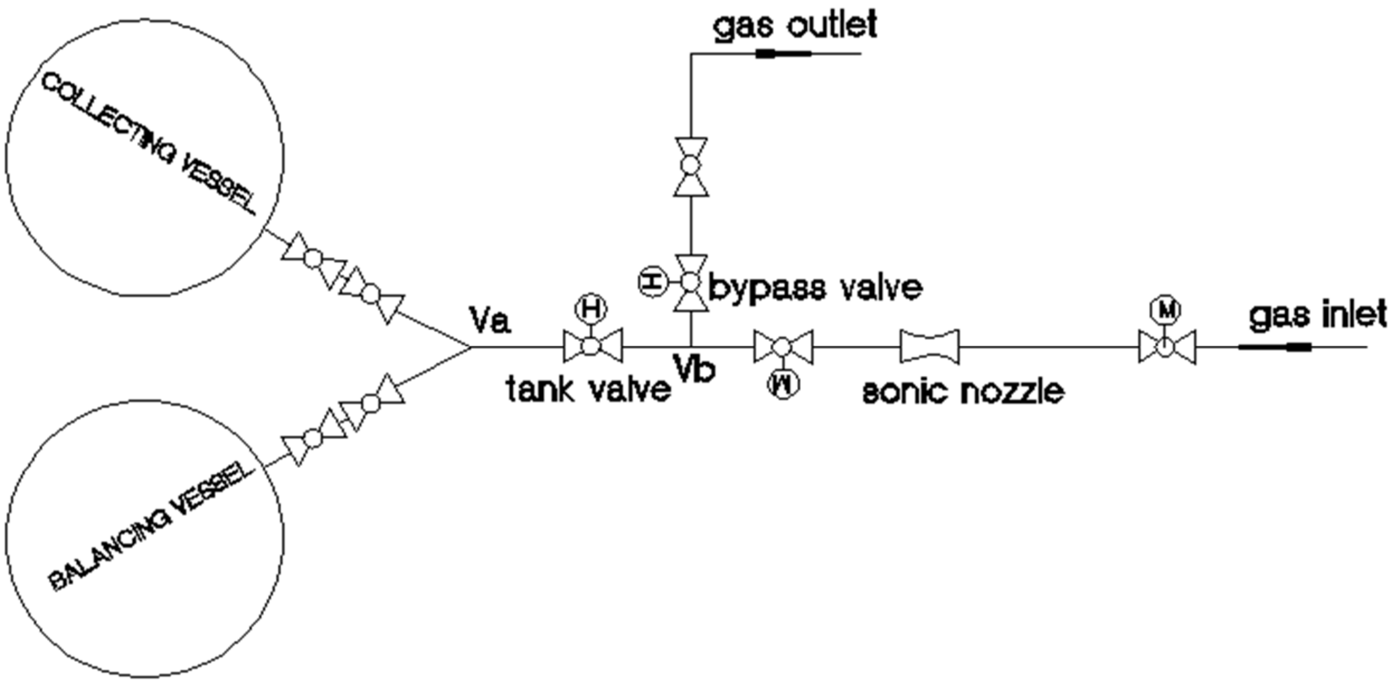
CQVB:*PVT*t



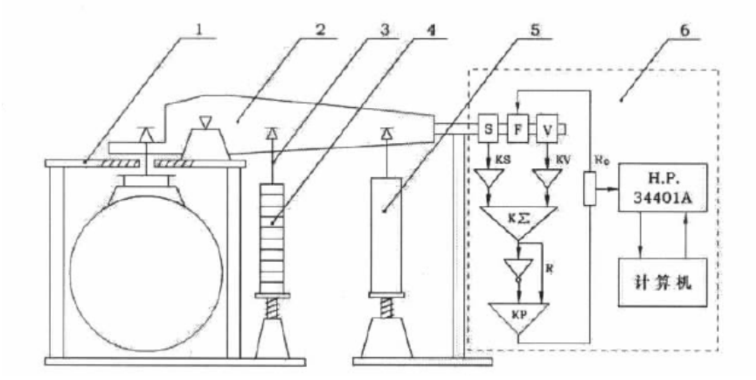
WVB:HPPP(high pressure piston prover)

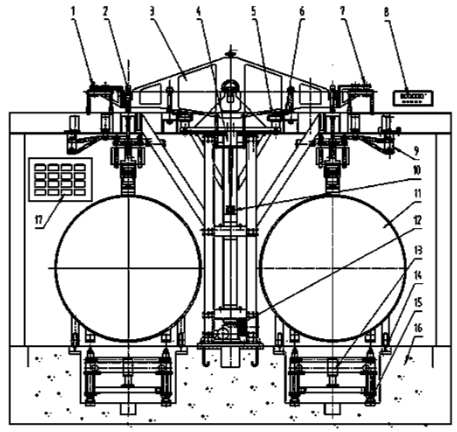


☐sketch of primary facility in CVB



□improvement of electromagnetic balance of primary standard in CVB





operation time	type	whole load	operation pressure	weighting range	actual scale interval	sensitive quantity	repeatability
1997-2015	unequal-armed	3t	(4-38)bar	(10-110)kg	0.1g	1g	2g
2017-	equal-armed	3t	(4-60)bar	(4-132.1)kg	0.1g	1g	0.5g

☐improvement of primary standard in CVB

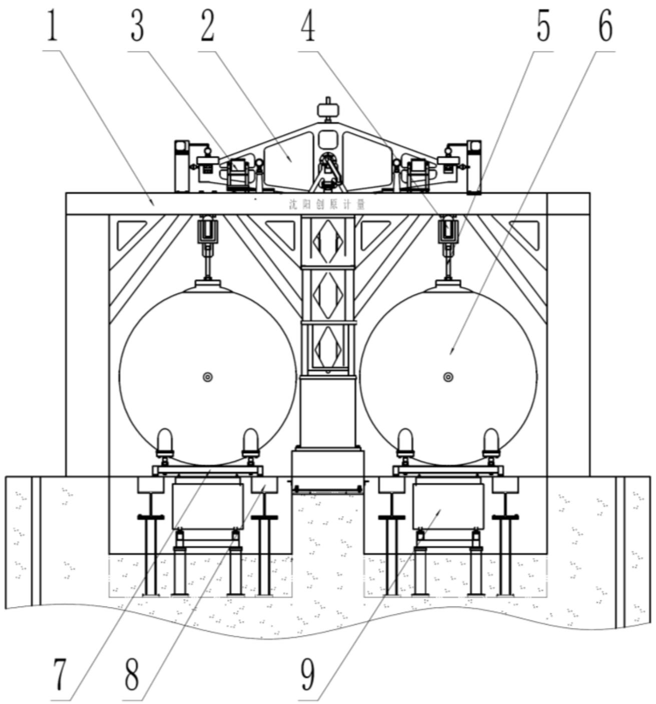
operation time	actural mass flowrate	operation pressure	CFV calibration uncertainty
1997-2015	2.63kg/s	(4-38)bar	0.20%(*k*=2)
2017-	5.4kg/s	(4-60)bar	0.10%-0.12%(*k*=2)

2.Structure and principle of the balance

□theory: lever equilibrium and electromagnetic force equilibrium

➢So the mass of the thick-walled collecting vessel can be balanced by the beam system which can bear heavy loads and balance the main weights.

➢The imbalance value can be measured accurately by electromagnetic force system which includes speed detector,displacement detector and torque detector.



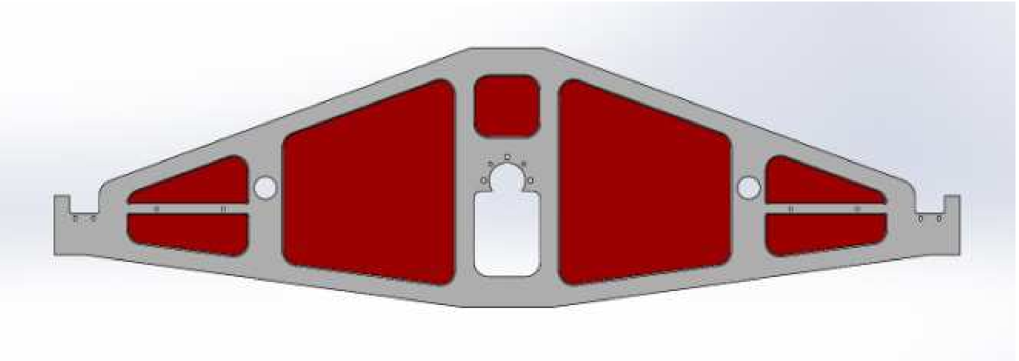
1-supporting system
2-beam system
3-measuring system
4-automatic weighting system
5-hanging system
6-weighting tank
7-movable platform
8-roller rail
9-precision positioning platform

2.Structure and principle of the balance

□equal-armed beam system and special treatments

➢The beam system is made of high speed tool steel.
➢The high and low temperature aging and natural aging are applied to eliminate the inner stress.
➢The supporting points of the beam system are quenched to ensure a good toughness as well as high hardness. So the supporting points can be very sharp lines.

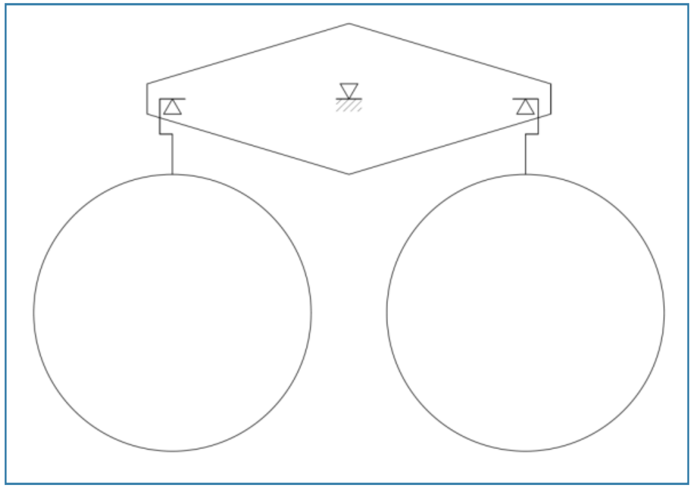
Then the deformation of the beam system under heavy loads can be minimized.The left and right part of the beam would keep in equal when the environmental temperature and humidity change because of the totally symmetrical structure which could avoid the inaccuracy measurement caused by uneven change of two sides.



2.Structure and principle of the balance

□two symmetrical vessels

➢two equal vessels are located in each side of the balance. One is for gas collection and another is for balance weight. The difference of air buoyancy of two vessels, which cause by the change of environmental temperature and humidity, can be minimized to achieve high accurate mass measurement.

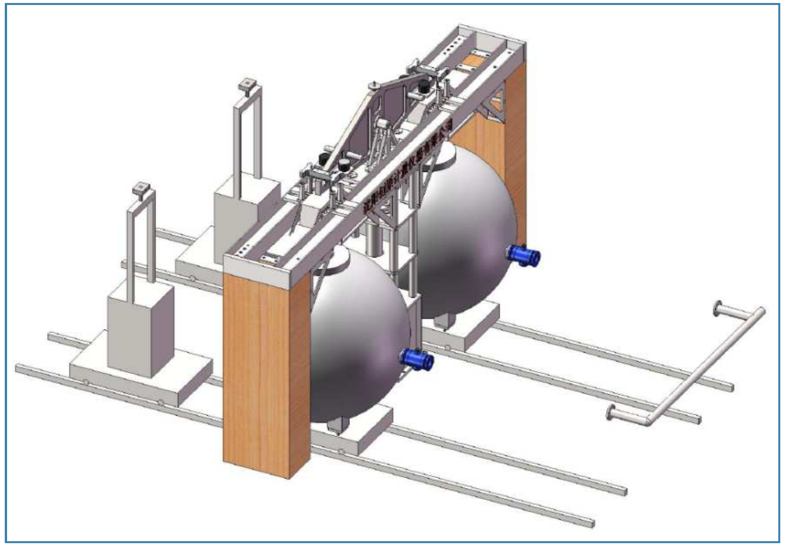


2.Structure and principle of the balance

□aotumatic moving and positioning of collecting vessel

➢The connection between collecting vessel and test pipeline is done outside of the weighting room to avoid the change of environmental temperature and air turbulence in the room.

➢The collecting vessel is movable to minimize the “line-pack” volume between the collecting vessel and under test meter.



2.Structure and principle of the balance

☐aotumatic moving and positioning of collecting vessel

There are several accurate locating devices to minimize the swing while the collecting vessel is hanging on the beam system of balance after gas filling.

- ➢mechanical positionings between the collecting vessel and the movable platform.
- ➢electrical positioning between the movable platform, the roller rail system and the docking system.
- ➢a precision positioning platform combined with the roller guide and located under the balance..
- ➢the docking system is specially designed to be adjusted on 6 different directions.

2.Structure and principle of the balance

☐aotumatic weighting and mass calculation

➢load all reference weights automatically on two sides of balance while the natural gas has been vented properly.

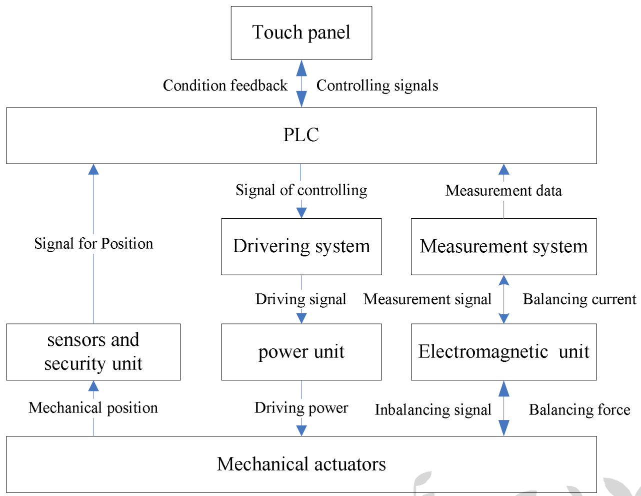
➢Turn on the balance and get I_0 as the initial measurement result without gas filing.

➢Fill the collecting vessel with expectant quantity of natural gas and unload the relevant reference weights as $m_{weights}$ on the same side.

➢Turn on the balance and get I_p as the final measurement result.

➢The mass of natural gas m_{gas} in the vessel can be calculated by following equation.

$$m_{gas} = m_{weights} - (I_0 - I_p)$$



3.Uncertainty evaluation

$$m_{gas} = m_{weights} - (I_0 - I_p)$$

$$u^2(m_{gas}) = u^2(m_{weights}) + u^2(I_0) + u^2(I_p) \qquad u^2(m_{gas}) = 2\times u^2(m_{balance}) + u^2(F_{buoyancy})$$

$$u(m_{balance}) = \sqrt{u^2(m_{weights}) + u^2(E_r) + u^2(I) + u^2(EM)}$$

$$u_r(m_{gas}) = \frac{u(m_{gas})}{m_{gas}}$$

name	quantities	Sensitive coefficient	Standard uncertainty component
$u(m_{weights})$	0.06g	1	0.06g
$u(E_r)$	0.288g	1	0.288g
$u(I)$	0.029g	1	0.029g
$u(EM)$	0.005g	1	0.005g
$u(F_{buoyancy})$	0.2g	1	0.2g
$u(m_{gas})$			0.591g
$u_r(m_{gas})$			0.018%

4.Conclusion

- Application of proper structure, substitution weighting method, precision positioning system achieve high accuracy.
- The mass measurement of natural gas is no more than 0.6g and the relative uncertainty is less than 0.02%.
- Repeatability of balance and air buoyancy effect after gas filling are the main uncertainty components for mass measurement
- CVB is doing further research on minimizing temperature change around the collecting vessel during gas filling procedure.

Thanks for your kind attention!