Influence of Different Treatment Methods of Neopentane in Natural Gas Components on Measurement Accuracy

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Abstract

The main sources of domestic pipeline natural gas are central Asia, the Tarim Basin, the Sichuan Basin, and the Zhonghai Oil and Gas Field, etc. Due to the large geographical differences in gas sources, the components of natural gas are quite different. Therefore, accurate analysis of natural gas composition and calculation of the corresponding compression factor is an important part of the natural gas custody transfer process. There is a certain proportion of neopentane in current domestic natural gas, but there are no calculation parameters of neopentane in various corresponding calculation standards, including GB/T 17747/ISO 12213 and AGA 8 standards for compression factor calculation and GB/T 30491.1/ISO 20765-1 and AGA10 standards for sound velocity calculation. However, in theory, the treatment method of neopentane will directly affect the compression factor of natural gas, and then affect the measurement results. Therefore, how to deal with neopentane in natural gas and ensure the accuracy of natural gas measurement results is a problem worthy of study.

Generally, there are three ways to deal with neopentane in natural gas: (1) adding neopentane content to isopentane with similar properties; (2) adding neopentane content to n-pentane; (3) to normalize the neopentane content. In order to confirm the influence of the three different processing methods on the measurement accuracy of the flowmeter, the theoretical calculation and actual test verification are used for comparative analysis. The conclusions are as follows: The three treatment methods of neopentane have a certain influence on the calculation results of natural gas compression factor, but the overall influence is small. For the common components of domestic pipeline natural gas, the standard meter method and critical flow Venturi nozzle method standard devices are used to verify the tested flowmeter respectively. The maximum deviations of natural gas compression factor and indication error are 0.00001 and 0.00003%, 0.00001 and 0.00301%, respectively, namely, the different treatment methods of neopentane have little impact on the measurement results. Therefore, as an inherent component of natural gas, neopentane can be treated in the above three ways in trade measurement.
Keywords：natural gas；neopentane；treatment method；compression factor；indication error.

1.Introduction

Due to the low pollution, green, low carbon and cleanness nature of natural gas, it has become the leader in the field of energy development in China. With the establishment of Pipechina, natural gas pipeline business has acquired a further rapidly development. At present, the domestic sources of natural gas pipeline mainly come from Central Asia, Tarim Basin, Sichuan Basin, CNOOC Offshore Gas Field and so on. There are great differences in the components of natural gas since the difference of gas sources. Accurate analysis of natural gas components and calculation of corresponding compression factors are one of the important parts of natural gas trade handover. At present, there are a certain proportion of neopentane components in domestic natural gas. However, the corresponding standards do not have the parameters of neopentane, including the compression factor calculated by GB/T 17747/ISO 12213 and AGA8 methods, and the sound velocity calculated by GB/T 30491.1/ISO 20765-1 and AGA10 methods. How to deal with the neopentane components in natural gas and ensure the accuracy of results of natural gas measurement is a problem that needs discussion.

2. Isopentane, n-pentane and neopentane

The physical properties of n-pentane, isopentane and neopentane are not significantly different, but the structural difference could result in chemical properties differences. There are two isomers of n-pentane : isopentane and neopentane. The term 'pentane' usually refers to n-pentane, namely its straight-chain isomers. The chemical formula of n-Pentane is C5H12, which is the fifth member of alkanes. The boiling point of n-pentane is 36.1 °C. Isopentane, also known as 2-methylbutane, has the chemical formula C5H12, which is a colorless, transparent, volatile liquid with a pleasant aroma and the boiling point is 28°C. It is mainly used for organic synthesis, as well as solvent. Neopentane, which has chemical formula C_5H_{12}, also known as 2,2 - dimethylpropane and pentapentane, is a toxic chemical product with a boiling point of 10°C. Nowadays the proportion of neopentane in domestic pipeline natural gas is about one to two hundred thousandths, far less than the content of n-pentane and isopentane. And the nature of neopentane is more similar to isopentane.

3. Effect of Natural Gas Composition on Value Transfer

According to JJG 2064-2017 'Measuring Instruments of Gas Flow', the domestic measurement system value transfer follows the order of measurement reference instruments to measurement standard instruments, measurement standard instruments to measurement working instruments, carrying out value transfer step by step. This work discusses the influence of different calculation methods of natural gas components on the results of final value transfer in the process of value transfer with critical flow Venturi nozzle device and standard meter gas flow standard device.

3.1 Working principle of critical flow Venturi nozzle gas flow standard device

According to the characteristics of critical flow for the sonic nozzle, when the gas passes through the critical flow nozzle, if the pressure ratio between upstream and downstream airflow reaches a certain value, the throat of the nozzle will form a critical state, the airflow will reach the maximum speed (local sound speed) and the gas mass flow qm through the nozzle will reach the maximum. qm is only related to the nozzle inlet stagnation pressure and stagnation temperature, and is not affected by its downstream state. Mass flow qm through a critical flow nozzle can be calculated as follows.:

$$q_m = \frac{\pi d^2}{4} C C_R \sqrt{p_0 \rho_0} = \frac{\pi d^2 C C_* p_0}{4\sqrt{\frac{RT_0}{M}}} \quad (1)$$

where: d—Nozzle throat diameter, m;

C—nozzle flow coefficient ; C_R—critical flow coefficient;

p_0—stagnation pressure, Pa;

T_0—stagnation temperature, K;

ρ_0—Density under stagnation condition, kg/m^3;

R—molar gas constant, J · mol^{-1} · K^{-1};

M—Molar mass of natural gas, kg /mol.

Volumetric flow rate of critical flow nozzle under stagnation condition can be calculated according to the following formula

$$q_v = 900\pi d^2 C C_R \sqrt{p_0/\rho_0} \quad (2)$$

where: q_v—Volumetric flow rate under nozzle stagnation condition, m3/h。

In the use of standard devices, multiple critical flow Venturi nozzles are used, and the standard flow is the sum of the flow of each combined nozzle, namely

$$q = \sum_{i=1}^{12} q_i \quad (3)$$

where: q—Total mass flow of combined nozzles or volumetric flow under stagnation condition, kg/s or m3/h;

q_i—Mass flow or volumetric flow under stagnation condition of the i-th combined nozzle, kg/s or m3/h.

3.2 Working principle of standard meter gas flow standard device

The formula of volume indicating flow for standard and measured flowmeters under working conditions are as follows:

$$q_i = 3600\frac{N}{Kt} \quad (4)$$

where: q_i—Indicating flow measured by flowmeter, m3/h;

N—Pulse Number Measured by Flowmeter;

K—Instrument coefficient of flowmeter, 1/m3;

t—Flow measurement time, s。

The formula of volume standard flow of standard flow meter under working conditions is as follows:

$$q_s = q_{s,i} M_f \quad (5)$$

where: q_s—Volumetric standard flow of standard flowmeter under working conditions, m3/h;

$q_{s,i}$—The volumetric indicating standard flow of standard flowmeter under working conditions, m3/h;

M_f—Flowmeter coefficient of standard flow-meter using data Interpolation in calibration certificate.

The formula of standard volumetric flow of the mea-sured flowmeter under the working conditions is as follows:

$$q_{s,m} = \frac{P_s Z_m T_m}{P_m Z_s T_s} q_s \quad (6)$$

Where: $q_{s,m}$—Volumetric standard flow of measured standard flowmeter under working conditions, m3/h;

p_s—Absolute pressure of standard flowmeter, MPa;

Z_m—Compression factor of measured flowmeter;

T_m—Temperature of measured flowmeter, K;

p_m—Absolute pressure of measured flowmeter, MPa;

Z_s—Compression factor of standard flowmeter;

T_s—Temperature at standard flowmeter，K.

3.3 Indicating error and repeatability calculation method

The formula of indicating error for flowmeter verification is as follows:

$$E = \frac{q_{m,i} - q_{s,m}}{q_{s,m}} \times 100\% \tag{7}$$

where：E—Indicating error of flowmeter verification;

$q_{m,i}$—Volumetric indicating flow of measured flowmeter under working conditions，m^3/h.

The formula of flow meter verification repeatability is as follows:

$$E_{r,i} = \sqrt{\frac{\sum_{j=1}^{n}(E_{i,j} - E_i)^2}{n-1}} \tag{8}$$

where：$E_{r,i}$—The repeatability of the i-th flow point verification，%;

$E_{i,j}$—The j-th verification indicating error of the i-th flow point，%;

E_i—Mean verification indicating error of i-th flow point，%;

n—Number of verification for i-th flow point.

According to the working principle of the standard device and formula above, in the process of value transfer of the critical flow Venturi nozzle standard device, the results of value transfer will be affected by the natural gas density ρ_0 under the stagnation condition, the compression factor Z_m of the measured flowmeter and the compression factor Z_s of the standard device. In the process of value transfer for the standard meter gas flow standard device, the measurements are affected by the compression factor Z_m of the measured flowmeter and the compression factor Z_s at the standard device. Since the density and compression factor of natural gas are related to the gas composition, theoretically there will be certain impact on the final results of value transfer if different methods of treatments for neopentane components are used.

4. Validation of treatments for neopentane

As the neopentane content is low, there are following treatment

1、Adding neopentane to isopentane which has similar properties

2、Adding neopentane to n-pentane

3、to normalize the neopentane content

In order to confirm the influence of different treatments on the results of flowmeter, we adopt the above three methods to calculate and verify.

4.1 Verification of Standard Device for Critical Flow Venturi Nozzle

The verification is as follows

1、In the calibration data of DN100 turbine standard flowmeter in Wuhan Metrology Verification Room through secondary nozzle device at Nanjing Branch of National Petroleum and Natural Gas Large Flow Measurement Station, a test data with the smallest, median and largest temperature difference between the standard flowmeter and the measured flowmeter is selected.

2、The compression factor and natural gas density under stagnation conditions were calculated by using the data adding to isopentane, adding to pentane and without consideration of neopentane after normalization, as well as the temperature and pressure at the nozzle and the measured flowmeter.

3、Using formula (2) to calculate volumetric flow rate for nozzle under stagnation

4、Using formula (6) to calculate the three standard flow rates of the measured flowmeter

5、Calculation of three indicating errors by formula (7)

6、Comparison of three indication errors.

4.2 Verification of standard meter gas flow standard device

The verification method is as follows

1、In the 1st, 2nd and 3rd standard test data of Wuhan Metrology Laboratory during the standard test period, one test data with the smallest, median and largest temperature difference between the standard flowmeter and the measured flowmeter is selected.

2、Using data adding to isopentane, adding to pentane and without consideration of neopentane, and temperature and pressure of standard and measured flowmeters, respectively, to calculate compression factors

3、Using formula (6) to calculate the three standard flow rates of the measured flowmeter

4、Calculation of three indicating errors by formula (7)

5、Comparison of three indication errors

The test data is as follows :

Table 1. Verification of critical flow Venturi nozzle testing turbine standard flowmeter

flow ratem ^{3}/h	flowmeter	Verification												deviation			
		Adding neopentane to isopentane				Adding neopentane to n-pentane				to normalize the neopentane content							
		q_f（m³/h）	Z	ρ_0(kg/m³)	E（%）	q_f（m³/h）	Z	ρ_0(kg/m³)	E（%）	q_f（m³/h）	Z	ρ_0(kg/m³)	E（%）	q_f（m³/h）	Z	ρ_0(kg/m³)	E（%）
394.57	MUT	394.57	0.8827	49.8651	-0.37	394.57	0.8827	49.8652	-0.37	394.57	0.8827	49.8626	-0.36	0.0000	0.00001	0.00262	0.00301
	PZ6501	244.15	0.8827	49.8258		244.15	0.8827	49.8258		244.14	0.8827	49.8232		0.0072	0.00001	0.00264	
	PZ6601	121.72	0.8827	49.8366		121.72	0.8827	49.8365		121.72	0.8827	49.8339		0.0039	0.00001	0.00264	
	PZ6801	30.16	0.8826	49.8615		30.16	0.8826	49.8615		30.16	0.8826	49.8589		0.0009	0.00001	0.00264	
157.49	MUT	157.49	0.8819	50.2637	-0.13	157.49	0.8819	50.2637	-0.13	157.49	0.8819	50.2610	-0.13	0.0028	0.00001	0.00265	0.00280
	PZ6601	120.24	0.8824	49.6871		120.24	0.8824	49.6870		120.24	0.8824	49.6844		0.0027	0.00001	0.00266	
	PZ6801	29.90	0.8819	49.9107		29.90	0.8819	49.9107		29.90	0.8819	49.9081		0.0026	0.00001	0.00266	
	PZ6902	7.56	0.8822	49.8606		7.56	0.8822	49.8606		7.56	0.8822	49.8580		0.0026	0.00001	0.00267	
37.77	MUT	37.77	0.8807	51.1342	-0.10	37.77	0.8807	51.1342	-0.10	37.77	0.8808	51.1315	-0.10	0.0028	0.00001	0.00265	0.00265
	PZ6801	30.18	0.8800	51.2251		30.18	0.8800	51.2250		30.18	0.8800	51.2223		0.0027	0.00001	0.00266	
	PZ6902	7.63	0.8803	51.1741		7.63	0.8803	51.1741		7.63	0.8803	51.1714		0.0026	0.00001	0.00266	

Table 2. Standard Meter Method DN200 Turbine Standard Flowmeter Verification Results

Test sequence	flow rate m ^{3}/h	flowmeter	Verification									deviation		
			Adding neopentane to isopentane			Adding neopentane to n-pentane			to normalize the neopentane content					
			$q_{s,m}$（m³/h）	Z	E（%）	q_f（m³/h）	Z	E（%）	q_f（m³/h）	Z	E	q_f（m³/h）	Z	E（%）
1	1592.97	MUT	1586.14	0.9112	-0.43	1586.14	0.9112	-0.43	1586.14	0.9112	-0.43	0.0000	0.00001	0.00001
		STM	1579.79	0.9105		1579.79	0.9105		1579.79	0.9105		0.0000	0.00001	
	643.93	MUT	640.51	0.9116	-0.53	640.51	0.9116	-0.53	640.51	0.9116	-0.53	0.0000	0.00001	0.00001
		STM	640.41	0.9107		640.41	0.9107		640.41	0.9107		0.0000	0.00001	

	82.79	MUT	82.38	0.9116	-0.49	82.38	0.9160	-0.49	82.38	0.9160	-0.49	0.0000	0.00440	0.00004
		STM	81.73	0.9107		81.73	0.9130		81.73	0.9130		0.0000	0.00232	
2	1560.99	MUT	1555.27	0.9146	-0.37	1555.27	0.9146	-0.37	1555.27	0.9146	-0.37	0.0000	0.00001	0.00001
		STM	1547.77	0.9138		1547.77	0.9138		1547.77	0.9138		0.0000	0.00001	
	657.68	MUT	653.76	0.9146	-0.60	653.76	0.9146	-0.60	653.76	0.9146	-0.60	0.0000	0.00001	0.00001
		STM	654.59	0.9140		654.59	0.9140		654.59	0.9140		0.0000	0.00001	
	82.69	MUT	82.32	0.9160	-0.45	82.32	0.9160	-0.45	82.32	0.9160	-0.45	0.0000	0.00001	0.00001
		STM	82.27	0.9149		82.27	0.9149		82.27	0.9149		0.0000	0.00001	
3	1555.68	MUT	1550.95	0.9180	-0.30	1550.95	0.9180	-0.30	1550.95	0.9180	-0.30	0.0000	0.00001	0.00001
		STM	1538.33	0.9169		1538.33	0.9169		1538.33	0.9169		0.0000	0.00001	
	651.30	MUT	647.43	0.9175	-0.59	647.43	0.9175	-0.59	647.43	0.9175	-0.59	0.0000	0.00001	0.00001
		STM	647.76	0.9167		647.76	0.9167		647.76	0.9167		0.0000	0.00001	
	81.89	MUT	81.41	0.9209	-0.59	81.41	0.9209	-0.59	81.41	0.9209	-0.59	0.0000	0.00001	0.00003
		STM	80.99	0.9184		80.99	0.9184		80.99	0.9184		0.0000	0.00001	

Table 3. Standard Meter Method DN300 Turbine Standard Flowmeter Verification Results

Test sequence	flow rate m^3/h	flowmeter	Verification									deviation		
			Adding neopentane to isopentane			Adding neopentane to n-pentane			to normalize the neopentane content					
			q_f（m^3/h）	Z	E（%）	q_f（m^3/h）	Z	E（%）	q_f（m^3/h）	Z	E	q_f（m^3/h）	Z	E（%）
1	3477.42	MUT	3479.77	0.9157	0.07	3479.77	0.9157	0.07	3479.77	0.9157	0.07	0.0000	0.00001	0.00001
		STM	3443.28	0.9150		3443.28	0.9150		3443.28	0.9150		0.0000	0.00001	
	1600.26	MUT	1600.72	0.9113	0.03	1600.72	0.9113	0.03	1600.72	0.9113	0.03	0.0000	0.00001	0.00001
		STM	1594.42	0.9107		1594.42	0.9107		1594.42	0.9107		0.0000	0.00001	
	402.56	MUT	401.89	0.9113	-0.17	401.89	0.9124	-0.17	401.89	0.9124	-0.17	0.0000	0.00109	0.00001
		STM	400.82	0.9107		400.82	0.9113		400.82	0.9113		0.0000	0.00058	
2	3356.22	MUT	3361.86	0.9165	0.17	3361.86	0.9165	0.17	3361.86	0.9166	0.17	0.0000	0.00001	0.00033
		STM	3322.99	0.9156		3322.99	0.9156		3322.99	0.9156		0.0000	0.00001	

	1594.13	MUT	1596.11	0.9167	0.12	1596.11	0.9167	0.12	1596.11	0.9167	0.12	0.0000	0.00001	0.00000
		STM	1589.32	0.9163		1589.32	0.9163		1589.32	0.9163		0.0000	0.00001	
	406.22	MUT	405.38	0.9153	-0.21	405.38	0.9153	-0.21	405.38	0.9153	-0.21	0.0000	0.00001	0.00001
		STM	405.22	0.9148		405.22	0.9148		405.22	0.9148		0.0000	0.00001	
3	3706.68	MUT	3712.02	0.9186	0.14	3712.02	0.9186	0.14	3712.02	0.9186	0.14	0.0000	0.00001	0.00001
		STM	3668.08	0.9181		3668.08	0.9181		3668.08	0.9181		0.0000	0.00001	
	1595.76	MUT	1597.36	0.9195	0.10	1597.36	0.9195	0.10	1597.36	0.9195	0.10	0.0000	0.00001	0.00000
		STM	1591.73	0.9192		1591.73	0.9192		1591.73	0.9192		0.0000	0.00001	
	410.34	MUT	409.20	0.9191	-0.28	409.20	0.9191	-0.28	409.20	0.9191	-0.28	0.0000	0.00001	0.00000
		STM	409.55	0.9187		409.55	0.9187		409.55	0.9187		0.0000	0.00001	

4.3 Verification results

Through the verification of three treatments of neopentane, it can be seen from table 1 to table 3 that the three treatments of neopentane have small influences on compression factor and indicating error of natural gas. Compared to the standard meter gas flow standard device, the critical venturi nozzle is relatively more affected. For the standard meter gas flow standard device, the maximum deviation of natural gas compression factor is 0.00001, and the maximum deviation of indicating error is 0.0003 %. For the critical venturi nozzle, the maximum deviation of natural gas compression factor is 0.00001, and the maximum deviation of indicating error is 0.00301 %. In summary, for the neopentane components in natural gas metering during the actual trade metering, adding the content of neopentane to isopentane which has similar properties, adding the content of neopentane to n-pentane, to normalize the neopentane content, will not have a great impact on the final metering results.

5. Conclusion

In this paper, based on the working principle of critical flow Venturi nozzle standard device and standard meter gas flow standard device, the parameters related to natural gas components in the process of natural gas value transfer are analyzed. By changing the treatment of neopentane and combining with the existing relevant test data, the influence of different treatments of neopentane on the indicating error of measurement is quantitatively analyzed. According to the verification results, it can be inferred that different treatments of neopentane have small influences on measurement results. Therefore, as an inherent component of natural gas, it is feasible to add neopentane content to isopentane which shares similar properties in trade metering as a common method.

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