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Measurement of natural gas flow by turbine meters

用气体涡轮流量计测量天然气流量

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Foreword

This standard is non-equivalent to the European standard EN 12261:2002 "Gas flow meter - gas turbine flow meter", makes reference to AGA No.7:2004 "Measurement of fuel gas by turbine meters", ISO 9951:1993 "Measurement of gas flow in closed conduits - Turbine meters", and JJG 198-1994 "Verification regulation of velocity flow meter", AND is, combining with the actual requirements for local use, added with the standard reference conditions for the calculation of natural gas volume and calorific value, the explosion proof requirements for using turbine meter to measure the natural gas flow, the requirements for integrated intelligent flow meter, the calculation for using turbine meter to measure the natural gas flow, the calculation of compression factor, the estimation of uncertainty, real-flow calibration, and the application after calibration, and the other technical provisions.

The main differences between this standard and EN 12261:2002 are as follows:

- ADD Chapter 4 "Measurement principles", Chapter 6 "Flow meter requirements", Chapter 7 "Installation requirements, use and maintenance", and Chapter 8 "Flow calculation methods and measurement uncertainty estimation";

- ADD Appendix B "Additional performance characteristics of the flow meter", Appendix C "Field test of flow meters", and Appendix D "Example of natural gas flow calculation".

- DELETE Chapter 4 "Flow meter classification" and some contents on type tests from Chapter 5 and 6 of EN 12261;

- MODIFY some of the statements that apply to international standards into the statements applicable to Chinese standard.

Appendix A to this standard is a normative appendix.Appendix B, Appendix C and Appendix D are informative.

This standard was proposed by China National Petroleum Corporation.

This standard shall be under the jurisdiction of the Oil & Gas Measurement and Analysis Method Professional Standardization Technical Committee.

The responsible drafting organizations of this standard: National Crude Oil Flow Measurement Station Chengdu Natural Gas Flow Substation.

The participating drafting organizations of this standard: China Petroleum Southwest Oil and Gas Field Branch.

Measurement of natural gas flow by turbine meters

1 Scope

This standard specifies the measurement conditions, requirements, performance, installation, real-flow calibration and field inspection of gas turbine flow meter (hereinafter referred to as flow meter) for natural gas flow measurement.

The natural gas component measured by the flow meter shall be within the range specified in GB 17820-1999, GB/T 17747.1-1999, GB/T 17747.2-1999 and GB/T 17747.3-1999, AND the true relative density of natural gas is 0.55 ~ 0.80.

This standard specifies that the standard reference conditions for the measurement of natural gas flow and the combustion standard reference conditions for the calorific value measurement are absolute pressure P_n = 0.101325 MPa and the thermodynamic temperature T_n = 293.15 K. It may also use the contracted pressure and temperature as the reference conditions.

Unless otherwise stated, the pressure referred to in this standard is gauge pressure.

2 Normative references

The provisions in following documents become the provisions of this Standard through reference in this Standard. For the dated references, the subsequent amendments (excluding corrections) or revisions do not apply to this Standard; however, parties who reach an agreement based on this Standard are encouraged to study if the latest versions of these documents are applicable. For undated references, the latest edition of the referenced document applies.

GB 3836.1-2000 Explosive atmospheres - Part 1: Equipment - General requirements (eqv IEC 60079-0:1998)

GB 3836.2-2000 Electrical apparatus for explosive gas atmospheres - Part 2: Flameproof enclosure d (eqv IEC 60079-1:1990)

GB 3836.4-2000 Electrical apparatus for explosive gas atmospheres - Part 4: Intrinsic safety i (eqv IEC 60079-11:1999)

GB/T 4208 Degree of protection of enclosure (IP code)

GB/T 11062-1998 Natural gas - Calculation of calorific values, density, relative density and Wobbe index from composition (neq ISO 6976:1995)

GB/T 13610-2003 Analysis of natural gas by gas chromatography

GB/T 15464 General purpose specification for the packaging of instrumentation products

GB/T 17747.1-1999 Natural gas - Calculation of compression factor - Part 1: Introduction and guideline (eqv ISO 12213-1:1997)

GB/T 17747.2-1999 Natural gas - Calculation of compression factor - Part 2: Calculation using molar (eqv ISO 12213-2:1997)

GB/T 17747.3-1999 Natural gas - Calculation of compression factor - Part 3: Calculation using physical properties (eqv ISO 12213-3:1997)

GB 17820-1999 Natural gas

GB/T 18603-2001 Technical requirements for measuring systems for natural gas

GB/T 18940-2003 Measurement of gas flow in closed conduits - Turbine meters (ISO 9951:1993, IDT)

JJG 198 Verification regulation of velocity flow meter

SY/T 6143-2004 Measurement of natural gas flow with standard orifice flow meter

3 Terms, definitions and symbols

The following terms and definitions apply to this standard.

3.1

Turbine gas meter

It refers to the metering equipment for which the rotation speed and gas volume flow are in functional relationship when the impeller rotates under the effect of gas flow. The gas volume flow passing through the flow meter is obtained based on the number of impeller rotations.

3.2

Rangeability

5.2.2 Error requirements for integrated intelligent flow meter

As for the integrated intelligent flow meter, within its designated flow range, its error shall not be more than ± 1.5%.

5.3 Repeatability

The repeatability of the flow rate of each flow meter at each flow point under operating condition shall not exceed 1/3 of the maximum allowable error of the flow meter. The repeatability of an integrated intelligent flow meter shall not exceed 1/2 of the maximum allowable error of the flow meter.

5.4 Calibration

It shall, based on the working pressure as specified by the user, calibrate the flow meter under one or more pressures. If the flow meter is calibrated under the calibration pressure p_{test}, the suitable pressure range of this flow meter is 0.5 p_{test} ~ 2.0 p_{test}. The choice of flow meter p_{test} is given in Appendix A.

5.5 Short-term overload

The flow meter shall be capable of operating at a flow rate of 1.2 q_{max} for 30 minutes without damage, AND its performance is not affected.

5.6 Working temperature range

The temperature range of the gas flow that complies with the performance requirements of the flow meter shall be at least -10 °C ~ 40 °C.

5.7 Installation conditions

The influence of the installation conditions on the flow meter shall not exceed 1/3 of the maximum allowable error as specified in Table 2. The test of influence of the installation conditions on the flow meter is described in Appendix E of GB/T 18940-2003.

5.8 Maximum allowable pressure loss

The manufacturer shall provide pressure loss data for the flow meter or flow meter components of various types and caliber. For more details, SEE Appendix B.

6 Flow meter requirements

6.1 General

Normally on the flow meter shall be provided with at least one pressure taps for measurement, in order to measure the static pressure at the turbine impeller under measurement conditions. This pressure tap is marked with "p_m"; if there are more than one "p_m" pressure taps, when using the air under normal pressure (± 10 kPa) is used for test, the difference between the pressure readings at each pressure tap shall not exceed 50 Pa.

6.4.2 Other pressure taps

The other pressure taps on the flow meter are marked with "p".

6.4.3 Size

The diameter of the circular pressure tap shall be between 3 mm and 12 mm, AND its length shall be equal to the aperture. In addition, the others shall comply with the provisions of SY/T 6143-2004.

The size of the grooved pressure tap in the direction of flow shall be at least 2 mm, the maximum size of 10 mm, cross-sectional area not exceed 80 mm^2, and the minimum cross-sectional area of 10 mm^2.

6.5 Removable flow meter movement

6.5.1 Integrity

As for the flow meter with a removable movement, its disassembly and replacement shall not affect the structure and integrity of the flow meter, AND meanwhile comply with the tightness requirements of 6.2.2.

6.5.2 Performance

The performance of the removable movement of the flow meter shall be guaranteed after repeated replacement or disassembly on the flow meter of same type and same caliber.

The removable movement of the flow meter shall have a unique number AND be clearly marked on the outside surface of the flow meter.

The removable movement of each flow meter shall be able to be sealed AND shall not be removed without permission.

6.6 Lubrication

In order for the flow meter to operate well, it shall be so constructed that any lubricating device required for sealing is not leaking AND may be in the form of a permanent maintenance-free or external filling pump.

d) Nominal diameter;

e) Flow range under operating conditions;

f) Explosion-proof grade and explosion-proof certificate marking.

6.9.3 Flow direction

The direction of the gas flow shall be indicated with a permanent marking.

6.9.4 Installation method

It shall indicate the installation method of the flow meter.

6.9.5 Other connections

Drive rod, electric pulse generator, and pressure and temperature sampling port shall have a clear marking hard to wear.

6.10 Appearance quality

The appearance of the flow meter shall be clean, beautiful, the surface shall be well handled, AND there shall be no burrs, marks, cracks, rust, mildew or coating peeling phenomenon.

All words, symbols and signs shall be clear and difficult to fall off.

6.11 Adaptability to environment

The flow meter enclosure, indicating equipment, nameplate and external components shall be able to withstand the effects of climate effects (sunlight, humidity and temperature variations) and conventional cleaning agents in the process of use.

Flow meter enclosure protection requirements shall comply with the provisions of GB/T 4208, at least reaching to the IP 65 requirements.

6.12 Transport and storage

The connection face of the flow meter shall be properly protected against other impurities entering the flow meter or damaging the connection face during transport and storage.

The flow meter packaging shall comply with the requirements of GB/T 15464. For flow meters with connectors of DN100 or above, it shall ensure that the flow meter is fixed in the package box during transport.

The temperature sensor shall be installed at the downstream end of the flow meter impeller, at distance from the impeller of less than 5D, extending into the pipe at about 1/3 of nominal diameter, BUT the length not exceeding 150 mm.

6.14.4 Output

It shall be able to display the pressure, temperature, the instantaneous volumetric flow under the standard reference conditions, and the cumulative volume flow under the standard reference conditions. If it has the remote communication function, it shall provide the communication protocol and the interface form. The flow meter shall be able to store at least the cumulative flow per month of a year and the latest 300 times of instantaneous flow data (typically including time, pressure, temperature, volume flow under instantaneous standard reference conditions and volume cumulative flow under standard reference conditions).

6.14.5 Power supply

It can be supplied by the internal power supply or external power supply. If using the internal power supply, the battery shall be able to continuously work for over one year. It is preferable for the external power supply to adopt direct current, at a voltage not exceeding 24 V.

6.14.6 Other requirements

The metering performance shall comply with the requirements of Chapter 5. The others shall comply with the other provisions of Chapter 6.

7 Installation requirements, use and maintenance

7.1 Installation environment

7.1.1 Temperature

The ambient temperature in which the follow meter is used shall be between -25 °C ~ 55 °C; if beyond the above temperature range, it shall make special requirements to the manufacturer. Meanwhile, it shall, based on the actual environment and operating conditions of the place of installation, take necessary thermal insulation, antifreeze and other protective measures (such as rain shielding, sunscreen, etc.).

7.1.2 Vibration and pulsation

The flow meter shall be installed in the measurement environment as far away as possible from the vibrating and pulsating flow.

If the flow meter body does not have a temperature tap, it is recommended to measure the temperature along the straight pipe section downstream of the flow meter, the distance from the impeller shall be 5D and as close as possible to the flow meter, AND located upstream of any outlet valve or flow limiter.

7.2.5 Installation method

Flow meter shall be installed horizontally with correct installation of inlet and outlet; AND it shall consult the manufacturer for the other installation methods.

7.2.6 Filter or filter screen

In the case of dirty gas, it shall install a gas filter or filter screen of good effect upstream of the flow meter. The structure and size of the filter shall be able to minimize the pressure loss under the maximum flow, AND minimize the flow distortion as much as possible.

7.2.7 Bypass

For important metering circuits, it may provide alternate metering bypasses, AND the bypass device can be subjected to leakage test.

7.2.8 Vent valve

If vent valve is installed downstream of the flow meter, its size shall not exceed 1/6 of the nominal diameter of the flow meter, in order to avoid over-speed of the impeller during exhaust, damaging the flow meter.

7.2.9 Flow limiter

In the field, when sufficient pressure is available, it is advisable to install a critical orifice or a critical flow venturi nozzle downstream of the flow meter pipeline AND limit its size, so that the actual flow rate is close to 1.2 times the maximum rated speed of the flow meter, in order to avoid the flow meter from impacting by the ultra-high-speed natural gas flow.

7.2.10 Online real-flow calibration interface

On important measurement occasions or, if agreed by the supplier and the purchaser, the online real-flow calibration interface may be reserved for the purposes of online calibration. The online calibration standard gauge shall be installed downstream of the calibrated gauge, with appropriate space.

7.2.11 Other installation requirements

The flow meter and measurement pipeline shall be so installed as to minimize the stresses generated during pipeline installation.

$$q_f = \frac{f}{K} \qquad \cdots\cdots(1)$$

Where:

q_f - Volume flow in operating conditions, in cubic meters per second (m^3/s);

f - Output working frequency, in hertz (Hz), collected by the frequency meter;

K - K factor, in per cubic meter (m^{-3}), which may be from the value provided on the flow meter nameplate, the flow meter parameter setting, or the values specified in the verification certificate or calibration certificate.

8.1.2 Practical equation for the volume flow calculation under standard reference conditions [SEE equation (2)]

$$q_n = q_f\left(\frac{p_f}{p_n}\right)\left(\frac{T_n}{T_f}\right)\left(\frac{Z_n}{Z_f}\right) = q_f F_Z^2\left(\frac{p_f}{p_n}\right)\left(\frac{T_n}{T_f}\right) \qquad \cdots\cdots(2)$$

Where:

q_n - The volume flow under the standard reference condition, in cubic meters per second (m^3/s);

p_f - Absolute static pressure under operating conditions, in megapascal (MPa);

Z_f - Gas compression factor under operating conditions;

T_f - Absolute gas temperature under operating conditions, in Kelvin (K);

p_n - Absolute static pressure under standard reference conditions, in megapascal (MPa);

Z_n - Gas compression factor under standard reference conditions;

T_n - Thermodynamic temperature of the gas under standard reference conditions, in Kelvin (K);

F_Z - Over compression factor of natural gas.

The over compression factor F_Z of natural gas is the correction factor derived from the natural gas deviation from the ideal gas law. Its definition is as shown in equation (3):

$$F_Z = \sqrt{\frac{Z_n}{Z_f}} \qquad \cdots\cdots(3)$$

U_{qn} - Flow measurement extended uncertainty under standard reference conditions;

u_{qn} - Flow measurement uncertainty under standard reference conditions;

u_{qf} - Flow measurement uncertainty under operating conditions, determined by the precision level of the flow meter;

u_{pf} - Absolute static pressure measurement uncertainty under operating conditions, estimated based on the performance of the static pressure measurement instrument used in accordance with the equation (12);

u_{Tf} - Thermodynamic temperature measurement uncertainty under the operating conditions, estimated based on the performance of the temperature measurement instrument used in accordance with the equation (12);

u_{Zf} - Compression factor measurement uncertainty under the operating conditions; if the compression factor calculation method uses GB/T 17747.2-1999 or GB/T 17747.3-1999, it will be taken as 0.1%; if uses AGA.3 NX-19, it will be taken as 0.5%;

u_{Zn} - Compression factor measurement uncertainty under the standard reference conditions, which is related to the natural gas component analysis method and the standard gas. When the component analysis is carried out in accordance with the provisions of GB/T 13610-2003 AND the level II standard gas is used, it may be taken as 0.3%;

u_{an} - Additional flow measurement uncertainty due to installation, which is taken as 1/3 of the maximum allowable error of the flow meter.

8.4.2 Mass flow measurement uncertainty estimation

In accordance with the equation (8), it may use the equation (10) to estimate the mass flow measurement comprehensive uncertainty under the standard reference conditions:

$$u_{q_m} = \sqrt{u_{q_{Vn}}^2 + u_{\rho_n}^2} \quad \cdots\cdots\cdots\cdots (10)$$

The extended uncertainty is calculated by reference to the equation (9).

$u_{\rho n}$ - The concentration calculation uncertainty under standard reference conditions, which may be taken as 0.3% if calculated in accordance with GB/T 11062-1998.

Appendix A

(Normative)

Real-flow calibration

A.1 Overview

The flow meter for the trade measurement of natural gas shall, before use, after repair, and during use, be tested in accordance with JJG 198 when reaching to the verification period. After the flow meter passes the verification, the flow meter used to measure the natural gas flow under different pressures can be subjected to the real-flow calibration in accordance with this Appendix as required by the user, in order to minimize the measurement error of the flow meter. If condition permits, it may conduct online real-flow calibration.

A.2 Calibration conditions

A.2.1 Technical requirements for standard device

The real-flow calibration standard device and its auxiliary measurement instruments shall have an effective verification certificate.

The uncertainty of the standard device shall not be greater than 1/2 of the maximum allowable error limit of the calibrated flow meter.

A.2.2 Tightness

Before calibration, the calibrated flow meter shall be installed on the calibration device together for tightness test. The test medium is air, natural gas and other gases, with the test pressure at least the maximum calibration pressure AND less than the maximum working pressure of the calibrated flow meter. It shall be stabilized under the test pressure at least for 15 min, AND deemed as qualified if there is no leakage through inspection.

A.2.3 Installation conditions

The installation for calibration purpose shall be in accordance with 7.2.

The pressure tap and thermometer port of the flow meter shall comply with the requirements of 6.4 and 7.2.4.

A.2.4 Real-flow calibration fluid

If the working pressure as specified by the user is 0.5 MPa, the flow meter is calibrated at p_{test} = 0.5 MPa, AND the calibration results apply to the working pressure range of 0.25 MPa ~ 1.0 MPa.

Example 2: (only need to be calibrated under one pressure)

If the working pressure range as specified by the user is 1.5 MPa ~ 3.5 MPa, the flow meter is calibrated at p_{test} = 2.0 MPa, AND the calibration results apply to the working pressure range of 1.0 MPa ~ 4.0 MPa.

If the upper limit of the working pressure range as specified by the user is greater than 4 times the lower limit, it is needed to calibrate the flow meter at the pressure of $p_{test\ min}$ and the pressure of $p_{test\ max}$, respectively. The calibration results apply to the operating pressure range of 0.5 $p_{test\ min}$ ~ 2.0 $p_{test\ max}$.

Where: $p_{test\ min}$ and $p_{test\ max}$ respectively indicate the minimum and maximum calibration pressure (gauge pressure) of the flow meter.

Example 3: (need to be calibrated under two pressures)

If the working pressure range as specified by the user is 0.3 MPa ~ 1.5 MPa, it is needed to calibrate the flow meter under two pressures. However, not only one method can meet these conditions. If the flow meter is calibrated at $p_{test\ min}$ = 0.4 MPa and $p_{test\ max}$ = 0.8 MPa, the calibration results apply to the working pressure range of 0.2 MPa ~ 1.6 MPa. If the working pressure range as specified by the user is 0.3 MPa ~ 1.5 MPa BUT it is recommended that the flow meter usually work at 1.0 MPa, then it shall calibrate the flow meter at $p_{test\ min}$ = 0.4 MPa and $p_{test\ max}$ = 1.0 MPa, respectively, AND the working pressure range to which this calibration results apply is 0.2 MPa ~ 2.0 MPa. If the user has a special requirement, the flow meter shall be further calibrated.

Note: p_{test} can be selected in accordance with the actual situation of the calibration device and the user's requirements, as long as the working pressure (or pressure range) specified by the user is within the range of 0.5 p_{test} ~ 2.0 p_{test} OR 0.5 $p_{test\ min}$ ~ 2.0 $p_{test\ max}$, it will comply with the requirements.

A.3.4 Numbers and time of test

In the calibration, each flow point shall be tested at least 3 times; if condition allows, it shall be tested 6 times, AND the arithmetic mean of each test value is taken as the measurement result of this test point. Each data collection time shall be not less than 60 s.

A.3.5 Pre-run

A.4.3 Calculation of flow meter factor

After calibration, it may also provide the flow meter factor to correct the output of the mechanical device or electronic pulse generator of the flow meter. As for the calculation of the flow meter factor, SEE equation (A.10).

$$(M_f)_i = \frac{q_i}{(q_s)_i} \quad \cdots\cdots\cdots\cdots (A.10)$$

Where:

$(M_f)_i$ - The factor of flow meter at the i^{th} calibration point.

It may use the arithmetic mean method, flow weighted mean method and polynomial fitting method to process the factor of the flow meter at each flow point, in order to obtain the final flow meter factor M_f.

A.4.4 Flow weighted mean error correction method

Depending on the actual situation, there are several ways to determine the calibration factor. If the flow output of the flow meter is linear within its working flow range, the flow weighted mean error method can effectively reduce the measurement uncertainty of the flow meter. If the output of the flow meter is non-linear, more complex error correction techniques can be used. The following describes the flow weighted mean error method to calculate the single calibration coefficient, in order to correct the measurement error of the flow meter.

The error as obtained from the equation (A.4) is used to calculate E_{FWM}, AND it shall calculate a single E_{FWM} and a single calibration factor at each p_{test} (as for the calculation example of the flow weighted mean error method, SEE A.4.9).

E_{FWM} is calculated using the equation (A.11):

$$E_{FWM} = \frac{\sum_{i=1}^{n} (q_i/q_{max}) E_i}{\sum_{i=1}^{n} (q_i/q_{max})} \quad \cdots\cdots\cdots\cdots (A.11)$$

Where:

E_i - The relative indication error of the flow meter at the i^{th} calibration point; %;

q_i - The flow indication of the flow meter at the i^{th} calibration point; in cubic meters per hour (m^3/h);

A.5 Estimation of uncertainty in flow measurement under standard reference conditions after real-flow calibration

The real-flow can be in the form of either offline calibration or online calibration. For different calibration method, the estimation method for the flow measurement uncertainty is also different.

A.5.1 Offline real-time calibration

The flow measurement uncertainty u_{qn} under standard reference conditions are estimated in accordance with the equation (A.16):

$$u_{q_n} = \sqrt{u_{q_{f,x}}^2 + u_{p_f}^2 + u_{T_f}^2 + u_{Z_f}^2 + u_{Z_n}^2 + u_{a_n}^2} \quad \cdots\cdots(A.16)$$

Where:

U_{qfx} - Flow measurement uncertainty after flow meter calibration under calibration conditions, estimated in accordance with equation (A.18).

The remaining symbols are the same as those in equation (8). The extended uncertainty is calculated with reference to the equation (9).

A.5.2 Estimation of uncertainty in flow measurement after online real-flow calibration

As for the online real-flow calibration, the calibration conditions are almost same or similar with the operating conditions. The flow measurement uncertainty under the standard reference conditions is estimated in accordance with the equation (A.17):

$$u_{q_n} = \sqrt{u_{q_{f,x}}^2 + u_{p_f}^2 + u_{T_f}^2 + u_{Z_f}^2 + u_{Z_n}^2} \quad \cdots\cdots(A.17)$$

The extended uncertainty is calculated with reference to the equation (9).

A.5.3 Estimation of flow measurement uncertainty under calibration conditions

The flow measurement uncertainty under calibration conditions is calculated using the equation (A.18):

$$u_{q_{f,x}} = \sqrt{u_r^2 + u_s^2} \quad \cdots\cdots(A.18)$$

Where:

Appendix B

(Informative)

Other performance characteristics of flow meter

B.1 Pressure loss

B.1.1 Overview

The pressure loss of the flow meter is determined by the energy required to drive the flow meter AND the internal channel friction loss caused by the variation of the flow area and direction. The pressure loss shall be measured between the upstream pipe 1D and the downstream pipe 1D of the flow meter, AND the sizes of the upstream and downstream pipes shall be same as that of the flow meter. When selecting and processing the measurement point, it shall avoid the distortion of the flow profile from affecting the pressure reading.

The pressure loss is estimated in accordance with the equation (B.1) (except for small flows):

$$\Delta p_f = c\rho_f q_f^2 \qquad \text{……………………………(B. 1)}$$

Where:

Δp_f - Pressure loss in operating conditions, in megapascal (MPa);

c - Pressure loss depending on the flow meter types, in per biquadrate millimeters (mm^{-4});

ρ_f - Gas concentration under operating conditions, in kilograms per cubic meter (kg/m^3);

q_f - Volume flow rate of gas under operating conditions, in cubic meters per cubic meter (kg/m^3);

Taking into account the pressure loss under the specified conditions AND the ideal gas state equation, the pressure loss is calculated in accordance with the equation (B.2) or (B.3)

$$\Delta p_f = \Delta p_n \left[\frac{\rho_f}{\rho_n}\right]\left[\frac{q_f}{q_n}\right]^2 \qquad \text{……………………………(B. 2)}$$

Unless otherwise stated, this maximum flow rate of the flow meter is the same for all operating conditions, including the specified maximum allowable working pressure. In accordance with the minimum flow rate, pressure, temperature and gas components as specified by the manufacturer, the minimum flow rate under operating conditions can be calculated approximately using the equation (B.4):

$$q_{\mathrm{f\,min}} = q_{\mathrm{s\,min}} \sqrt{\frac{\rho_{\mathrm{s}}}{\rho_{\mathrm{f}}}} \quad \text{(B.4)}$$

Where:

ρ_s - Gas concentration under specified conditions, in kilograms per cubic meter (kg/m^3);

ρ_f - Natural gas concentration under operating conditions, in kilograms per cubic meter (kg/m^3);

$q_{f\,min}$ - Minimum flow rate under operating conditions, in cubic meters per hour (m^3/h);

$q_{s\,min}$ - Minimum flow rate under specified conditions, in cubic meters per hour (m^3/h).

B.3 Rangeability

Since the maximum flow rate usually does not change AND the minimum flow rate may change, the rangeability of the gas turbine flow meter generally varies with the square root of the gas concentration, as shown in equation (B.5):

$$\psi_{\mathrm{f}} = \psi_{\mathrm{s}} \sqrt{\frac{\rho_{\mathrm{f}}}{\rho_{\mathrm{s}}}} \quad \text{(B.5)}$$

Where:

Ψ_f - Working range under operating conditions;

Ψ_s - Working range under specified conditions.

B.4 Effects of temperature and pressure

When the working temperature and working pressure of the flow meter are very different from the calibration conditions, its performance may change. The reason for these changes may be dimensional changes, changes in bearing resistance or physical phenomena.

Appendix C

(Informative)

Field test of flow meter

C.1 Overview

The most commonly used field test of turbine flow meters is the visual inspection and the rotation time test. As for the flow meter in operation, it may obtain the working conditions of the flow meter through observation of its noise or vibration.

The violent vibration of the flow meter usually indicates that the turbine impeller is unbalanced damaged, which can cause the flow meter to fail completely. At lower flow rates, the friction sound of the turbine impeller and the poor working sound of the bearing are often heard, which will not be covered by the normal flowing noise.

C.2 Visual inspection

During visual inspection, it shall check whether the turbine impeller is missing leaves, accumulating solid matter or corrosion, and whether it has other damages that may affect the turbine impeller balance and impeller configuration. It shall also inspect the inside of the flow meter, in order to avoid the accumulation of debris inside.

It shall also inspect the flow channels, drain holes, vent holes, and the lubricating system, in order to avoid the accumulation of debris.

C.3 Rotation time test

The rotation time test is used to determine the relative change in the mechanical resistance of the flow meter now as compared with the past. In the case where the flow meter area is clean and its interior is not damaged, the flow meter precision shall not change if there is no significant change in mechanical resistance. If the mechanical resistance is greatly increased, it indicates that the flow meter precision characteristics have been degraded at the small flow rate. In accordance with user requirements, the manufacturer can provide a typical rotation time of the flow meter.

The rotation time test must be carried out in the area without gas flow, AND the measurement mechanism shall be in its normal working position. The turbine impeller rotates at an appropriate speed, for example, the minimum speed is

Appendix D

(Informative)

Example of natural gas flow calculation

D.1 Known conditions

a) Turbine flow meter K factor: $K = 2548\ m^{-3}$;

b) Commonly used gas flow temperature: $t_1 = 21\ °C$;

c) Commonly used static gauge pressure: $p_1 = 1.28$ MPa;

d) Local atmospheric pressure: $p_a = 0.0965$ MPa;

e) The measured frequency is 50 Hz;

f) Natural gas components are shown in Table D.1.

Table D.1 Natural gas components

Component	Methane	Ethane	Propane	Butane	2-methyl propane (iso-butane)	Helium	Nitrogen	Carbon dioxide
Molar fraction	0.96630	0.01466	0.00188	0.00024	0.00034	0.00014	0.00530	0.01114

D.2 Calculation

D.2.1 Calculation of volume flow of turbine meter under operating conditions

The volume flow under the operating conditions can be obtained through calculation in accordance with the equation (1):

$$q_f = \frac{f}{K} = 50/254\ 8\ m^3/s = 0.019\ 62\ m^3/s$$

D.2.2 Determination of the natural gas compression factor Z or the over compression factor F_Z

D.2.2.1 When the natural gas metering system complies with the precision level A and B requirements in Table A.1 of GB/T 18603-2001:

D.2.2.1.1 Calculation of the compression factor Z_n of the natural gas under the standard reference conditions:

------ The End ------