Guideline No. T-13 (202502)

T-13

Bellows Expansion Joints

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Foreword

The product inspection guideline of China Classification Society (hereinafter referred to as "CCS") specifies the applicable technical requirements and inspection and test requirements for classification products and authorized statutory products of ships to be approved/inspected by CCS.

The Guidelines allow users to adopt alternative test methods and requirements, provided they meet or exceed the standards set by the Guidelines.

The Guidelines are prepared and updated by China Classification Society (CCS) and published on http://www.ccs.org.cn. In case of any comments and suggestions, please contact CCS via service@ccs.org.cn.

Historical release version and release time: newly edited

Main modifications in this version: None

Contents

Bellows Expansion Joints

1 Scope of Application

1.1 The Guidelines are applicable to bellows expansion joints in pipeline systems used for transporting or utilizing natural gas and ammonia as fuel.

1.2 Other equivalent standards may be accepted by CCS for the technical requirements and test methods mentioned in the Guidelines.

2 Normative References

2.1 The basis for approval and inspection used in the Guidelines are as follows:

(1) Chapter 2, Part 3 of CCS *Rules for Classification of Sea-going Steel Ships*

(2) Chapter 3, Part 3 of CCS *Rules for Materials and Welding*

(3) Chapter 5, Part 3 of CCS *Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk*

(4) Resolution MSC.370(93) *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk* (IGC Code)

(5) Resolution MSC.391(95) *International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels* (IGF Code)

(6) CCS *Guidelines for Inspection of Hull Welds*

(7) ISO 10380 *Pipework - Corrugated Metal Hoses and Hose Assemblies*

(8) CCS *Guidelines for Ships Using Ammonia Fuel*

(9) GB/T 12777-2019 *General Specification for Metal Bellows Expansion Joints*

3 Terms and Definitions

3.1 Bellows expansion joint: a device composed of one or more bellows and structural members, which is used to absorb the dimensional changes in pipes and (or) equipment caused by thermal expansion and cold contraction.

3.2 Design pressure: the maximum allowable working pressure, which shall not be lower than the maximum setting pressure of safety valve or overflow valve.

3.3 Nominal pressure: a given value in technical documents of the product.

4 Drawings and Data

4.1 During product drawing approval, the following drawings and data shall be submitted for approval:

(1) List of product main performance specifications (including nominal diameter, nominal pressure, design pressure, design temperature, design fatigue life (when applicable), applicable medium of the whole series of products to be approved);

(2) Product drawings, calculation of design fatigue life of expansion joint and other relevant design calculations;

(3) List of physical and chemical properties of main parts and materials;

(4) Main process documents and product inspection procedures;

(5) Product instructions, identification and factory certificate (sample).

4.2 For type approval, in addition to the drawings and data mentioned in 4.1 above, the approved drawings/data shall at least include the following contents:

(1) Factory overview: factory name, address, production history, production capacity, technical and inspection personnel, main products, affiliation, product trademarks, etc.;

(2) Details of the product to be approved;

(3) List of main production equipment;

(4) List of main testing equipment;

(5) Brief production process of the product to be approved;

(6) Quality management documents or quality system certificates;

(7) Enterprise registration certificate;

(8) Qualification certificate and/or production license, if applicable;

(9) Product quality certificate or sample of certificate;

(10) Quality control plan, if applicable;

(11) List of qualified suppliers, if applicable;

(12) Type test program.

5 Technical Requirements

5.1 Marine environmental conditions

(1) Marine metal bellows expansion joints shall be designed and manufactured according to their design pressure, design temperature, applicable medium and application occasions, and shall comply with the relevant provisions of the normative references in the Guidelines or the standards accepted by CCS, so as to ensure their normal operation.

(2) The minimum design pressure of the product used for liquefied gas pipeline shall not be lower than 1MPa (gauge pressure).

5.2 Materials

(1) Materials for bellows shall be selected according to working conditions such as working medium, external environment, working pressure and working temperature.

(2) The manufacturer shall ensure that the selected product materials are compatible with the working medium, and provide adequate evidence that these materials comply with the requirements for use.

(3) If the factory purchases stainless steel as a raw material, the quality certificate of the raw material shall include its intergranular corrosion test information. If this information is absent from the certificate, the factory is required to conduct intergranular corrosion tests on each batch of stainless steel, following the grouping principles of recognized standards.

(4) Nickel steel containing more than 5% nickel and carbon-manganese steel that does not comply with the requirements of 3.3.1.4 and 3.3.1.5 in CCS *Guidelines for Ships Using Ammonia Fuel* shall not be used for ammonia containers and pipeline systems. If the fuel temperature comply with the requirements in 3.3.1.4(3) of CCS Guidelines for Ships Using Ammonia Fuel, nickel steels containing not more than 5% nickel may be used, such as nickel alloy steel with steel grades of 1.5Ni and 2.25Ni.

5.3 Welding procedure qualification

The welding procedure of stainless steel bellows expansion joints with a welded structure shall be approved by CCS. The welding procedure qualification shall be conducted in accordance with CCS *Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk* and other standards accepted by CCS.

6 Raw Materials, Parts and Components

N/A

7 Type Test

7.1 Selection of typical samples:

The typical samples selected for type approval shall cover the level of production and processing and test capabilities of the manufacturer. For each series of bellows expansion joints, at least 3 representative samples with different sizes shall be selected.

This selection can be based on parameters such as structure, purpose, design pressure and design temperature.

7.2 Test items

(1) Visual inspection;

(2) Geometric dimension inspection;

(3) NDT of welds (if applicable);

(4) Intergranular corrosion test of stainless steel welds;

(5) Pressure test;

(6) Air tightness test;

(7) Fatigue test;

(8) Type test specified in 7.3(8) for each type of bellows expansion joint intended to be used on cargo lines other than LNG liquid cargo holds, and if required by the competent authority, type test specified in 7.3(8) for bellows expansion joints in liquid cargo holds.

7.3 The test methods and technical requirements shall comply with the following requirements:

(1) Visual inspection

① The product surface shall be free from visible sharp dents, indentations, scratches, cracks or other defects that can obviously cause stress concentration and affect the strength and service life, except minor die marks.

② The appearance and shape of the product should be free from visually visible defects of uneven pitch.

③ The product surface shall be free from visible rust spots and oxide skin.

④ The product surface shall be free from visible defects such as large areas of water stains and uneven color.

⑤ The surface of welded joints between bellows and pressure cylinders shall be free from defects such as cracks, pores, slag inclusions, welding spatters, undercuts and pits. Scratches and pits that are not greater than the lower deviation of plate thickness shall be ground for a smooth transition.

(2) Geometric dimension inspection

The structural dimensions and machining accuracy of the main products shall be checked according to the design drawings of the products and the standards accepted by CCS.

(3) NDT of welds (if applicable)

100% penetrant testing shall be conducted on welds of bellows expansion joints, and the results shall comply with the standards accepted by CCS.

(4) Intergranular corrosion test of stainless steel welds

This test can be carried out according to the requirements in Section 7, Chapter 2, Part 1 of CCS *Rules for Materials and Welding*, or in the standards accepted by CCS.

(5) Pressure test

① In principle, a hydrostatic test should be conducted. However, if a hydrostatic test is unsuitable, an air pressure test may be conducted instead. During the air pressure test, effective safety measures shall be implemented.

② During the test, the test device shall ensure that both ends of the expansion joint are fixed and effectively sealed, and the bellows is in a straight alignment.

③ After the hydrostatic test, water stains shall be thoroughly removed. If impossible, the chloride ion content in test water shall be controlled not above 25 mg/L. The air pressure test medium shall be dry and clean compressed air or inert gas.

④ For the hydrostatic test of internal pressure expansion joint, use the following formula for calculation, whichever is smaller:

$$Pt=1.5pd(\sigma)b/(\sigma)bt \quad \text{——①}$$

$$Pt=1.5psc(E)b/(E)bt \quad \text{——②}$$

For the air pressure test of internal pressure expansion joint, use the following formula for calculation, whichever is smaller:

$$Pt=1.1pd(\sigma)b/(\sigma)bt \quad \text{——③}$$

$$Pt=1.1psc(E)b/(E)bt \quad \text{——④}$$

Where: Pt - test pressure (MPa)

Pd - design pressure (MPa)

(σ)b - allowable stress of bellows material at test temperature (MPa)

(σ)bt - allowable stress of bellows material at design temperature (MPa)

psc - ultimate design pressure for column instability when both ends of the bellows are fixed (MPa)

(E)b - elastic modulus of bellows materials at test temperature according to the Guidelines (MPa)

(E)bt - elastic modulus of bellows materials at design temperature (MPa)

⑤ For external pressure expansion joints, use Formula ① for hydrostatic test and Formula ② for air pressure test.

⑥ Two qualified pressure gauges with the same measuring range shall

be used in the pressure test. The measuring range of pressure gauges should be about twice the test pressure. However, it must not be less than 1.5 times or exceed 3 times the test pressure. The accuracy grade of pressure gauges shall not be lower than 1.6. During the test, the pressure shall be increased slowly to the specified test pressure and then maintained for at least 10 minutes. There shall be no leakage from expansion joint, no noticeable deformation of any structural parts, and no instability at the bellows. A product is considered to have lost stability if the maximum change rate of the wave pitch under test pressure exceeds 15% compared with that before pressurization for non-reinforced U-shaped bellows or if it exceeds 20% for reinforced U-shaped bellows and Ω-shaped bellows.

⑦ When the nominal diameter of bellows is not less than 1500mm and the nominal pressure is not higher than 0.25MPa, the air-soap bubble test or kerosene leakage test may be used as an alternative to the pressure test. The jet test pressure shall not be lower than 0.8MPa. The kerosene immersion time shall not be less than 30min.

⑧ The pressure test for an expansion joint used in vacuum conditions can be replaced by internal pressure test. The test pressure should be 1.5 times the design differential pressure (differential pressure is calculated by subtracting the vacuum degree from the atmospheric pressure). Alternatively, the expansion joint can be assessed through vacuum pumping tests.

(6) Air tightness test

① The air tightness test shall be carried out after the expansion joint passes the pressure test. During the test, ensure that the test device securely fixes and seals both ends of the expansion joint. Additionally, the bellows must be in a straight line with its free length.

② The air tightness test can be carried out simultaneously with the air pressure test.

③ The test medium should be dry and clean compressed air or inert gas.

④ The air tightness test pressure is equal to the design pressure.

⑤ During the test, the pressure shall be increased slowly to the specified test pressure and then maintained for at least 10 minutes. There shall be no leakage from expansion joint.

⑥ Soap bubbles and a water tank can be used for leakage test.

(7) Fatigue test

Fatigue test method for bellows with design temperature lower than the creep temperature of material:

① The test shall be carried out using a special fatigue test device which shall able to constrain pressure thrust and displacement counter-force of bellows and ensure that applied axial cyclic displacement is coaxial with the bellow axis. The initial state of the bellows is in a straight line with its free length.

② The test bellows shall be qualified for all other type test items, with a minimum of three waves. The structure of other components in the test sample can be designed according to the test device so as to comply with the test requirements.

③ The test medium can be tap water, compressed air, inert gas or oil.

④ The test temperature should be ambient temperature, and the pressure gauge used for test shall comply with the requirements in (5)②(f) above.

⑤ The test pressure is equal to the design pressure, and the pressure fluctuation value during the test shall not be greater than ±10% of the test pressure.

⑥ The test cyclic displacement shall be axial displacement, and the range of the test cyclic displacement shall be equal to design axial displacement or designed equivalent axial displacement. The test

cyclic displacement should be the symmetrical axial displacement. The test cycle rate should be determined based on the time needed for the displacement to evenly distribute among the waves, and shall be less than 25mm/s.

⑦ Number of test cycles: The number of cycles of circular bellows shall be more than twice the design fatigue life. The number of cycles of rectangular bellows shall be greater than the design fatigue life. Bellows shall be free from leakage within the specified number of test cycles. If the test medium is water, bellows shall be free from water leakage. If the test medium is gas, the surface of bellows shall be free from gas leakage through soap bubble test.

Fatigue test method for bellows with design temperature within the creep temperature range of materials:

① The test shall be carried out according to the standards accepted by CCS.

② Number of test cycles: The number of cycles of circular bellows shall be greater than the calculated average number of failure cycles. Bellows shall be free from leakage within the specified number of test cycles.

(8) The following type tests shall be carried out for each type of bellows expansion joint intended to be used on cargo lines other than liquid cargo holds, and if required by the competent authority, the following type tests shall also be carried out for bellows expansion joints in liquid cargo holds:

① Bellows elements without pre-compression shall undergo a pressure test of not less than 5 times the design pressure without rupture. The test duration shall not be less than 5 min.;

② Prototype expansion joints with all accessories such as flanges, tie rods and hinged parts, shall be subjected to a pressure test of 2 times the design pressure without permanent deformation under the

minimum design temperature and the maximum displacement recommended by the manufacturer;

③ The complete expansion joint shall be subject to cyclic test (thermal movement). Under the conditions of pressure, temperature, axial movement, rotational movement and transverse movement, the complete expansion joint shall be able to withstand at least the same number of cycles it will encounter in actual use. Testing at room temperature is permitted if these tests are as rigorous as those conducted at service temperature; and

④ The complete expansion joint must undergo a cyclic fatigue test under no internal pressure (hull deformation). This means simulating the movement of the bellows equivalent to the compensating pipe segment, and conducting at least 2,000,000 cycles at a frequency not exceeding 5 Hz (cycles per second). However, this test is required only if the pipeline will be exposed to hull deformation loads due to its arrangement.

8 Unit/Batch Inspection

8.1 The inspection for issuing the marine product certificate shall be conducted after the manufacturer has completed the required inspections/tests and the product has passed inspections/tests, reaching a deliverable state.

8.2 Unit/batch inspection of products from manufacturers that have obtained CCS type approval

(1) The inspection shall be conducted following the approved inspection plan outlined in the quality control plan at the time of type approval. The test items include:

① Visual and dimension inspection;

② Pressure test;

③ Air tightness test.

(2) The above tests shall be independently completed by the manufacturer in accordance with the factory's inspection procedures (internal control standards). A complete test report shall be issued and submitted to the surveyor for review.

(3) The surveyor should randomly select and re-inspect 1-3% of each batch/specification of products, with a minimum of 1 item, for the aforementioned inspections and tests. The surveyor should be present for tests conducted at the manufacturer's site.

(4) Each time the unit/batch inspection application is submitted, the Quality Certificate for Raw Materials of Main Parts and Components for that batch of products must be provided to CCS surveyors for approval.