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Simple pressure vessels

简单压力容器

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Simple pressure vessels

1 Scope

1.1 This standard specifies the construction requirements for the type and materials, design, manufacturing, inspection and acceptance of simple pressure vessels (hereinafter referred to as "vessels").

1.2 This standard applies to mass-produced vessels, that meet the following conditions:

- a) The design pressure is less than or equal to 1.6 MPa;
- b) The design temperature is greater than or equal to -20 °C; the maximum operating temperature is less than or equal to 150 °C;
- c) The volume is less than or equal to 1.0 m³;
- d) The product of working pressure and volume is less than or equal to 1.0 MPa·m³;
- e) The medium is air, nitrogen, carbon dioxide, inert gas, water vapor evaporated from medical distilled water, or a mixture of the above gases (vapors); the medium is allowed to contain other components such as oil that are not enough to change the characteristics of the medium, but its flash point or ignition point shall be 30 °C higher than the maximum working temperature of the vessel, without affecting the compatibility with the material;
- f) The structure meets the requirements of 4.1.1.

1.3 The following products do not fall within the scope of this standard:

- a) Vessels used in military equipment, nuclear facilities, aerospace vehicles, offshore facilities, ships;
- b) Non-independent pressure-bearing parts on the machine (such as compressor cylinder, etc.);
- c) Fire extinguisher;
- d) Quick opening vessel;
- e) Mobile vessels;
- f) Vessels that require fatigue analysis and design;

c) The design organization shall keep the following design documents of the vessel for reference, meanwhile the retention period shall not be less than the design service life of the vessel:

- 1) Design drawing;
- 2) Design calculations, including at least volume calculations, strength calculations or explosion test reports (including quality certification documents for test sample materials, manufacturing process documents, inspection records, test records, etc.), design service life, safe discharge volume calculation, calculation of safety valve displacement, etc.;
- 3) Design instructions, including at least the basis for selecting design parameters, selection of materials, selection of accessories, manufacturing technical conditions, inspection requirements, etc.;
- 4) Installation, use, maintenance instructions, including at least the maximum working pressure, maximum working temperature, designated use, installation requirements, design service life, safety maintenance points, etc.

5.2.2.3 Responsibilities of the manufacturer:

- a) The manufacturer shall manufacture according to the design drawings; if the original design needs to be modified, a written document agreeing to the modification shall be obtained from the original design organization, meanwhile the modified parts shall be recorded in detail.
- b) The manufacturer shall formulate a complete quality plan before batch manufacturing of vessels, which at least includes manufacturing process control points, inspection items, qualification indicators.
- c) During the manufacturing process, the manufacturer shall ensure the stability of the manufacturing process; conduct specific inspections and tests on the vessel in accordance with this standard and drawings; issue an inspection report; be responsible for the accuracy and completeness of the report; issue a product certificate after passing the inspection.
- d) The manufacturer shall keep the type test report and certificate of the vessel for long-term reference; each batch of vessels it produces shall have at least the following relevant technical documents for reference. The retention period of the technical documents shall not be less than the design service life of the vessel, and no less than five years:
 - 1) Material quality certificate for pressure components;
 - 2) General manufacturing process documents;

- 3) Welding process documents;
- 4) Inspection and test records during the manufacturing process and after completion of the vessel;
- 5) Original design drawings and as-built drawings of the vessel.

5.2.2.4 Responsibilities of inspection agencies

The institutions and their supervisory inspectors that conduct supervisory inspections of vessels, within the jurisdiction of TSG 21, shall perform corresponding work responsibilities, in accordance with the provisions of the specifications during supervisory inspections; they shall be responsible for the completeness and accuracy of the inspection reports issued.

5.3 General provisions for design

5.3.1 Design methods are divided into calculation methods and test methods. The wall thickness of the pressure components of the vessel is calculated according to the rules of the corresponding chapter of GB 150.3. The wall thickness of the main pressure components, such as the cylinder, convex head, flat cover, etc. of the vessel, is determined by the bursting test using the physical vessel sample, as the test method. Austenitic stainless steel vessels are not allowed to be designed using test methods.

5.3.2 The overall design drawing of the vessel shall indicate at least the following:

- a) Name of the specification and standard based on;
- b) Vessel name;
- c) Design methods;
- d) Material designation and material requirements of pressure components;
- e) Design conditions, including design temperature, design pressure, working pressure, design service life, medium, corrosion allowance, etc.;
- f) Main characteristic parameters, including volume, weight, etc.;
- g) Welding methods and requirements; the degree of mechanization of the welding method of longitudinal butt joints of pressure components and the degree of mechanization of the welding method of non-full-section penetration pipe seats when designing the calculation method;
- h) Anti-corrosion requirements (if necessary);
- i) Pressure test requirements, including test pressure, medium, etc.;

6.3 The negative deviation of steel plate and steel pipe materials shall comply with the provisions of the corresponding material standards.

6.4 The materials, usage conditions, allowable stress of non-welded parts such as studs and nuts shall be in accordance with the provisions of the corresponding chapters of GB 150.

6.5 The material of the permanent backing plate shall be the same or similar to the steel designation of the weldment.

6.6 The welding materials used shall ensure that the performance of the welded joint meets the design requirements.

7 Design

7.1 Design of wall thickness

7.1.1 Design of calculation method

7.1.1.1 The design pressure of the vessel shall not be lower than its working pressure.

7.1.1.2 For vessels equipped with safety valves, the design pressure shall be determined according to the following steps:

- a) Determine the safety valve's setting pressure p_z , according to the working pressure p_w of the vessel, take $p_z = (1.05 \sim 1.1) p_w$;
- b) Take the design pressure p of the vessel to be equal to or slightly greater than the setting pressure p_z .

7.1.1.3 The calculated thickness δ of the pressure component shall be calculated, according to the relevant formulas of GB 150.3; the allowable stress shall be as specified in Table 1.

7.1.1.4 If the longitudinal butt welded joint of a pressure component is manually welded, the calculated thickness of the component shall be increased by 15%.

7.1.1.5 Take the design thickness of the pressure component of the vessel, which is designed using the calculation method $\delta_d = \delta + C_2$.

7.1.1.6 Flanges, flange covers and other pressure components can be designed or selected, with reference to other relevant standards.

7.1.2 Design of test method

7.1.2.1 The design organization shall conduct bursting tests on the physical samples of vessels, which are trial-produced by the client; it shall proceed according to the steps

7.1.2.4 Determine the design thickness δ_d , based on the actual measured wall thickness of each main pressure component, as measured on the sample that passed the bursting test.

7.1.2.5 The design organization shall fully consider the repeatability of bursting test results, as well as the differences in mechanical properties between different batches of materials of the same steel designation.

7.1.3 Marking of thickness

7.1.3.1 Calculation method for designed vessels:

- a) The minimum forming thickness of the convex head shall be marked on the design drawing. Whether the nominal thickness of the convex head is marked on the design drawing is decided by the design organization;
- b) The nominal thickness and minimum formed thickness of other pressure components shall generally be marked on the design drawing; for some small vessels, as long as the minimum formed thickness meets 5.3.4, the strength requirements can be guaranteed. For the main pressure components such as cylinders, flat covers, it may only mark the minimum forming thickness.

7.1.3.2 Vessels designed by test method

The minimum forming thickness of the main pressure components of the vessel designed by the test method shall be marked on the design drawing; whether the nominal thickness of the main pressure component is marked on the design drawing is decided by the design organization.

7.2 Opening and opening reinforcement

7.2.1 In addition to the necessary process nozzle openings, the vessel can be equipped with inspection holes such as observation holes and hand holes, as needed. A drain outlet shall be provided at the lowest point at the bottom of the vessel.

7.2.2 The maximum allowable diameter of the opening on the vessel shell is $d_{op} \leq D_i/2$. Except for 7.2.3, all other provisions for openings and reinforcements shall comply with the corresponding chapters of GB 150.3.

7.2.3 All openings shall avoid butt welding joints. The distance -- between the edge of the weld at the opening and the edge of other welds -- shall not be less than 4 times the actual measured wall thickness of the opening and not less than 20 mm.

7.3 Welded structure

7.3.1 All main body welding joints must adopt full penetration type.

7.3.2 See Appendix C for commonly used welded joint structures.

- b) The reinforcement ring complies with the requirements of JB/T 4736;
- c) The pipe flange complies with the requirements of HG/T 20592 ~ 20635.

8.1.2 Type test

Vessels shall be type tested by a type testing agency, which has corresponding qualifications; type testing shall be in accordance with the provisions of 8.4.

8.1.3 Material substitution

The manufacturer shall obtain written approval, in advance from the original design organization when substituting materials for pressure components. Substitution of materials must be recorded in detail on the as-built drawings.

8.2 Manufacturing

8.2.1 Material re-inspection and sign transplantation

8.2.1.1 Reinspection of materials

8.2.1.1.1 The following materials shall be re-inspected:

- a) The authenticity of the quality certificate cannot be determined or the performance and chemical composition of the main pressure component materials are doubtful;
- b) S30408 open plate for manufacturing main pressure components
- c) When the design requires.

8.2.1.1.2 The mechanical properties of the S30408 open flat plates shall be retested according to the batch number (for use of whole coil, it shall cut a set of retesting specimens from the corresponding open flat plates at the head, middle, tail of the coil for after the flat opening operation; for use of non-whole coil, it shall cut a set of retesting specimens from the end of the open flat plate). For situations where retesting is required in items a) and c) in 8.2.1.1.1, the chemical ingredients shall be retested according to the heat number; the mechanical properties are rechecked by batch.

8.2.1.1.3 The results of material retesting shall comply with the provisions of the corresponding material standards or the requirements of the design documents.

8.2.1.2 Material sign transplantation

Materials used to manufacture pressure components shall be marked traceable by batch.

8.2.2 Group batching

Vessels of the same model, drawing number, welding joint using the same welding

process can be produced in batches. The requirements for group batching are as follows:

- a) Group batching time: Continuous production time shall not exceed 15 days:
- b) Batch quantity: For vessels with an inner diameter of the shell $D_i \leq 400$ mm, a batch shall not exceed 1000 units according to the production sequence; for vessels with an inner diameter $D_i > 400$ mm, a batch shall not exceed 500 units according to the production sequence.

8.2.3 Forming and assembly

8.2.3.1 Forming

8.2.3.1.1 The manufacturer shall determine the processing allowance based on process conditions and the actual thickness of the steel, to ensure that the measured minimum forming thickness of the pressure components of the vessel is not less than the design thickness.

8.2.3.1.2 When the selected nominal thickness cannot guarantee the minimum forming thickness, the manufacturer shall consider selecting an appropriate steel thickness.

8.2.3.2 Groove

The groove shall meet the following requirements:

- a) The groove surface must not have defects such as cracks, delamination, inclusions, etc.;
- b) Before welding, oxide scale, oil stain, melting slag, and other hazardous impurities shall be removed, within a range of at least 20 mm (measured from the edge of the groove) on the groove and the surface of the base metal on both sides.

8.2.3.3 Sealing head

8.2.3.3.1 Use a full-size inner template, which has a gap, to check the shape deviation of the inner surface of the sealing head. The indent size is $3\%D_i \sim 5\%D_i$. For the maximum shape deviation, the convex shall not be greater than $1.25\%D_i$ and concave shall not be greater than $0.625\%D_i$. During inspection, the template shall be perpendicular to the surface to be tested.

8.2.3.3.2 There shall be no longitudinal wrinkles on the straight edge of the sealing head.

8.2.3.4 Assembly of cylinder and shell

8.2.3.4.1 The offset of the mating edges of category A and category B welded joints shall not be greater than $1/4$ of the steel thickness δ_s at the mating joint and 0.5 mm, whichever is larger.

8.2.4.2.2 The welders performing the welds mentioned in 8.2.4.2.1 shall have corresponding qualifications and be within the validity period.

8.2.4.2.3 The welder code shall be recorded in the welding record containing the weld layout diagram. If necessary, the welder code stamp can be stamped on the designated location, near the welded joint of the pressure component.

8.2.4.3 Welds

The surface quality of welds shall meet the following requirements:

- a) The weld and heat-affected zone shall be free of cracks, blisters, arc craters, unfilled, non-fusion, slag inclusions, spatter. It shall have a smooth transition between the weld and base metal; the shape of the fillet weld shall be concave and have a smooth transition;
- b) The reinforcement of butt welds is 0 mm ~ 2 mm; the width difference of the same weld shall not be greater than 4 mm;
- c) The welding leg dimensions of categories C and D joints shall be as specified in the design drawings;
- d) The depth of the undercut shall not be greater than 0.5 mm; the continuous length of the undercut shall not be greater than 100 mm; the total length of the undercut on both sides of the weld shall not exceed 10% of the length of the weld; austenitic stainless steel vessels are not allowed to have undercuts.

8.2.4.4 Repair of welds

Defects in welds shall be completely removed; only one repair is allowed on the same part; repairs shall be recorded.

8.2.5 Heat treatment

8.2.5.1 When hot forming or warm forming changes the supply heat treatment state of the material, heat treatment shall be performed again, to restore the supply heat treatment state of the material.

8.2.5.2 When the manufacturer ensures that after cold forming of the convex head, if the material properties meet the design and usage requirements, heat treatment is not required.

8.2.5.3 Other situations where the vessel requires heat treatment shall comply with the provisions of the design document.

8.3 Inspection and test

8.3.1 Appearance inspection

The appearance of each finished vessel shall comply with the following requirements:

- a) The outer dimensions, wall thickness, etc. of the vessel shall be tested, using appropriate measuring tools; it shall comply with the requirements of the design drawing;
- b) The surface of the vessel shall be smooth, without cracks, double skin, slag inclusions, pits with a depth exceeding 0.5 mm, scratches and corrosions with a depth exceeding 0.3 mm;
- c) The appearance and reinforcement of the weld, the width difference of the same weld, the height of the weld leg, undercut, etc. shall comply with the provisions of 8.2.4.3.

8.3.2 Sampling inspection and test

For vessels designed according to the test method, the manufacturer shall conduct bursting tests, on a batch basis during manufacturing; for vessels designed according to a calculation method, the manufacturer shall conduct radiographic testing on a batch basis.

8.3.2.1 Sampling

The inspection personnel of the manufacturer shall select test samples from the same batch of finished products, that have been assembled. The number of samples shall be as specified in 8.3.2.2 and 8.3.2.3. Sampling must ensure randomness and representativeness of the sample.

8.3.2.2 Bursting test

8.3.2.2.1 The bursting test of the vessel shall be carried out, in accordance with the following requirements:

- a) For vessels whose main body welding joints are mechanized welding, one sample will be selected in batches for bursting test;
- b) If the main welding joint is manually welded, at least one sample must be taken from the vessel welded by each welder every day, for bursting test;
- c) The bursting test shall be carried out according to the steps specified in 7.1.2.2.

8.3.2.2.2 Only when the following requirements are met can the product be deemed to have passed the bursting test:

- a) The circumferential permanent deformation rate does not exceed 1%;
- b) The burst pressure P_b is not lower than the specified value in formula (5);

8.3.2.3.3 When the radiographic detection fails, 2 more samples are allowed to be taken from the batch of products for radiographic detection and re-inspection. After both samples are qualified, the batch of products is qualified. If the categories A and B butt joints are welded manually, among the products welded by the welder that day, 2 more samples will be taken for radiographic detection. If both products are qualified, the products welded by the welder that day will be qualified.

8.3.2.3.4 If the product is still unqualified after re-inspection, the batch of products shall be deemed unqualified. However, the batch of products or the products welded by the welder on that day are allowed to be judged to be qualified after radiographic detection one by one. The position of radiographic detection shall be in accordance with the requirements of 8.3.2.3.1 d); the qualification requirements shall be in accordance with the provisions of 8.3.2.3.2.

8.3.2.3.5 Vessels that fail the radiographic detection are allowed to be repaired, but supplementary radiographic detection shall be carried out before repair. The detection location is the undetected area extending from both ends of the excessive defect. The length of the supplementary detection is not less than the 10% of the length of the welded joint (except those that have been fully tested). Radiographic detection shall be carried out again after repair; the qualification requirements are in accordance with 8.3.2.3.2.

8.3.2.3.6 After sampling and partial detection, the manufacturer is still responsible for the quality of the uninspected parts.

8.3.3 Pressure resistance test

8.3.3.1 Each finished vessel shall be subject to a pressure resistance test in accordance with the drawings.

8.3.3.2 During the pressure resistance test, two pressure gauges with the same range and within the verification period shall be installed on the top of the tested vessel or test device. The range of the pressure gauge shall be 1.5 ~ 3 times the test pressure. The accuracy of the pressure gauge shall not be lower than level 1.6; the dial diameter shall not be less than 100 mm.

8.3.3.3 Before the pressure test, compressed air of 0.4 MPa ~ 0.5 MPa shall be passed into the opening reinforcement ring, to check the quality of the welded joint.

8.3.3.4 The pressure of the pressure resistance test shall not be lower than that specified in 5.5.2.

8.3.3.5 Before the pressure resistance test, the fasteners at each connection part of the vessel shall be fully assembled and tightened properly; for temporary pressure components assembled for the pressure resistance test, appropriate measures shall be taken to ensure safety.

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