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Specification for post weld heat treatment of pressure equipment

承压设备焊后热处理规程

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1 Scope

This document specifies general basic technical requirements for post weld heat treatment of steel pressure equipment.

This document applies to post weld heat treatment of boilers and pressure vessels (excluding gas cylinders).

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

GB/T 3375, *Welding terminology*

GB/T 9452, *Testing method for working zone of heat treatment furnace*

NB/T 47014, *Welding procedure qualification for pressure equipment*

3 Terms and definitions

For the purposes of this document, the terms and definitions defined in GB/T 3375, GB/T 9452 as well as the followings apply.

3.1 weldment

Welded pressure equipment or parts thereof.

3.2 post weld heat treatment

The process that, to eliminate the welding residual stress and improve the structure and performance of the welded joint, the weldment is uniformly heated to a sufficiently high temperature below the phase transition point of the metal, kept for a certain period of time, and then uniformly cooled.

3.3 soak band

During partial post weld heat treatment, the area that the volume range over which the

weldment reaches the specified temperature is on its surface. The soak band includes the weld zone, fusion zone, heat-affected zone and its adjacent base metal.

3.4 heated band

The area that during partial post weld heat treatment, heating is carried out to ensure that the weldment obtains the specified volume range of temperature uniformity.

3.5 gradient control band

The area that during partial post weld heat treatment, to prevent heat dissipation in the temperature range and heating range of the weldment, a thermal insulation material is laid on its surface.

3.6 holding temperature

To achieve the purpose of post weld heat treatment, the indicated volume range of the weldment or its partial soak band shall be maintained within the specified temperature range within the necessary time.

3.7 holding time

The time during which the indicated volume range of the weldment or its local soak band is maintained at the holding temperature. The holding time is calculated from the time when the temperature of all temperature measuring points reaches the minimum holding temperature. It ends when the temperature of any one of the temperature measuring points is lower than the minimum holding temperature.

4 Basic process

4.1 General provisions

4.1.1 In addition to complying with this Standard, the post weld heat treatment of pressure equipment shall also comply with the requirements of product standards, design documents and contracts.

4.1.2 In addition to this Standard, the effective results that have been proved through experimental research and/or practice, after they are approved by relevant parties and included in corporate standards, can also be used for post weld heat treatment of pressure equipment in this organization.

4.1.3 The thermal effects of carbon steel and low alloy steel weldments below 490°C, and the thermal effects of high alloy steel weldments below 315°C, are not treated as post weld heat treatment.

4.1.4 The constructer of pressure equipment shall have technical personnel, who have certain professional knowledge and sufficient practical experience, after they master

the following basic conditions, prepare "Process specifications for post weld heat treatment" for each (piece) weldment:

a) Welding properties of steel and welding consumables for weldments. Adaptability to post weld heat treatment;

b) Actual tempering temperature of steel. Post weld heat treatment conditions for test piece of welding material mechanical properties;

c) Weldment design document specification, service requirements and construction process;

d) Post weld heat treatment environment, post weld heat treatment methods, equipment, device characteristics and procedures.

4.1.5 The welding process evaluation items used for weldments shall include all important factors and supplementary factors that may occur during the implementation of the "Process specifications for post weld heat treatment".

4.1.6 Post weld heat treatment operators should be trained and assessed before they can take up their posts. They shall be familiar with and master the "Process specifications for post weld heat treatment" for weldments.

4.1.7 The product welding test piece shall be prepared by the actual welding process (including post weld heat treatment) that makes lower mechanical properties.

4.2 Post weld heat treatment thickness δ_{PWHT}

4.2.1 The δ_{PWHT} of equal thickness full penetration butt joint is the weld thickness (excess height is not counted). At this time, δ_{PWHT} is the same as the base metal thickness.

4.2.2 In butt weld joints, δ_{PWHT} is equal to the thickness of the butt weld. In welded joints connected by fillet welds, δ_{PWHT} is equal to the fillet weld thickness. In welded joints connected by composite welds, δ_{PWHT} is equal to the greater of the thickness of butt weld and fillet weld.

4.2.3 The δ_{PWHT} for stud welding is equal to the nominal diameter of the stud.

4.2.4 The values of δ_{PWHT} when welding pressure components with different thicknesses are as follows (see Annex A):

a) Among the two adjacent pairs of pressure-receiving elements, take the thickness of the base metal on the thinner side;

b) For the head structure inside the cylinder, take the larger of the thickness of the cylinder wall and the thickness of the fillet weld;

c) When the tube sheets, flat heads, covers, flanges or flanges are welded to the barrel, except for the case that the flange thickness δ_f is taken when $\delta_f > \delta_o$ shown in Figure A.3 in Annex A, take the cylinder wall thickness for the rest;

d) When connecting parts such as nozzles and manholes are welded to the cylinder body and head, take the larger of the thickness of the neck weld of the connecting piece, the thickness of the barrel weld, the thickness of the head weld, or the thickness of the fillet weld of the connecting piece such as the reinforcing plate;

e) When the nozzle is welded to the flange, take the thickness of the weld at the joint of the nozzle;

f) When the non-pressure components are welded with the pressure parts, take the thickness of the weld at the welding point;

g) When the pipe and the tube sheet are welded, take the thickness of the weld;

h) When welding and repairing, take the thickness of the weld metal filled.

4.2.5 Thickness of post weld heat treatment calculation holding time:

a) When the overall post weld heat treatment is carried out, the maximum δ_{PWHT} of the part without post weld heat treatment shall be used;

b) When multiple (pieces) pressure equipment or parts are installed in the same furnace, the maximum δ_{PWHT} on the weldment without post weld heat treatment shall be used.

4.3 Post weld heat treatment methods

4.3.1 Overall post weld heat treatment

The overall post weld heat treatment has the following two forms. When conditions permit, the overall heating method in the furnace shall be used:

a) Load the weldment into a closed furnace for overall heating;

b) Conduct overall heating inside or outside the weldment.

4.3.2 Segmental post weld heat treatment

When the overall weldment is heated in segments, the length of the overlapping portion of each heated segment is at least 1500mm. Heat insulation measures shall be taken for weldments (including their pipe joints) of non-heating parts. Prevent harmful temperature gradients.

4.3.3 Partial post weld heat treatment

4.3.3.1 Figure 1 shows the average temperature, heating and thermal insulation range

shall not exceed $\frac{5\ 500}{\delta}$ ℃/h (δ is the maximum thickness of the weldment shell, in mm). It shall not exceed 220°C/h;

c) During the heating period of the weldment, the temperature difference within the range of any length of 4600mm within the heating range shall not be greater than 140°C;

d) During the heat holding period of the weldment, the difference between the highest and lowest temperature within the heating range shall not be greater than 80°C;

e) During the heating and holding period, the atmosphere within the heating range shall be controlled. Prevent excessive oxidation of the weldment surface;

f) When the temperature of the weldment is higher than 400°C, the cooling rate within the heating range shall not exceed $\frac{7\ 000}{\delta}$ ℃/h (δ is the maximum thickness of the weldment shell, in mm). It shall not exceed 280°C/h;

g) During the heating and cooling process of the weldment above 400°C, the heating and cooling rate shall not be less than 55°C/h. If there is no harmful effect, the heating and cooling speed can be reduced;

h) When the weldment is released, the weldment shall not be higher than 400°C. Once out of the oven it shall be cooled in still air.

4.4.10 General limits for out-of-furnace post weld heat treatment process parameters:

a) The post weld heat treatment process outside the furnace is the same as the post weld heat treatment process in the furnace;

b) When the heating area is cooled, the temperature in the range shown in the soak band is lower than 400°C. And then it can be cooled in still air.

5 Equipment, instruments, temperature measuring supplies and thermal insulation materials

5.1 The post weld heat treatment furnace shall meet the following requirements:

a) Do not use coal or coke as fuel;

b) Use automatic methods such as program controller or computer to control the post weld heat treatment process. The temperature in the furnace and the temperature rise (fall) speed range can be adjusted;

c) The medium used to heat the weldment in the furnace can flow sufficiently;

d) During the heat treatment process, the furnace shall maintain positive pressure in a timely manner;

e) The atmosphere in the heating area of the furnace can be controlled. Prevent excessive oxidation of the weldment surface;

f) It shall be equipped with temperature measurement, temperature control and alarm system. The temperature can be automatically recorded;

g) At least the following technical requirements shall be specified:

1) Rated load capacity;

2) Size of the loading space in the furnace;

3) Loading regulations into the furnace;

4) Maximum heating rate at rated load;

5) Maximum cooling rate at rated load;

6) Accuracy level of temperature control instrument;

7) Accuracy level of temperature measuring instrument;

h) There shall be product manuals and operation manuals.

5.2 The effective heating area of the post weld heat treatment furnace shall be determined according to the provisions of Annex C. The schematic diagram of the effective heating area shall be placed in a prominent position of the heat treatment furnace. The furnace temperature uniformity of the effective heating area of the post weld heat treatment furnace is generally ±10℃, ±15℃, ±20℃.

5.3 Insulation materials, temperature control instruments and temperature measuring instruments shall meet corresponding standards. The product shall have quality certificate and instruction manual.

5.4 Manufacturers of thermocouples and compensation wires shall have corresponding qualifications. The used thermocouple and compensation wire shall have quality certificate.

5.5 All kinds of measuring instruments shall pass the measurement inspection according to the standard. Before use, calibrate as specified.

5.6 The post weld heat treatment heating, temperature control, temperature measurement device and the whole system outside the furnace shall be inspected and

treatment.

6.2 For the specification for post weld heat treatment process of the overall post weld heat treatment outside the furnace (including the overall post weld heat treatment outside the furnace), an expert review shall be organized if necessary. The main contents of the specification for post weld heat treatment process include:

a) Requirements specified in the standards, contracts and design documents on which they are based;

b) Basic condition of weldment: name, number, designation, structure, size, material, thickness and quality;

c) Thermal calculation of post weld heat treatment of weldment as a whole and each part;

d) Weldment thermal deformation prevention and control measures;

e) Post weld heat treatment heating method, heater name, model, specification, quantity and placement;

f) Auxiliary devices (such as diversion umbrellas) and installation for post weld heat treatment;

g) Post weld heat treatment parameters: post weld heat treatment thickness δ_{PWHT}, heating rate, holding temperature, holding time, cooling method and cooling rate;

h) Types, specifications and laying methods of thermal insulation materials;

i) Name, model and quantity of temperature control device and temperature measuring instrument;

j) Type and quantity of thermocouple and compensation wire;

k) Arrangement and quantity of temperature measuring points, connection method of temperature measuring instrument and weldment;

l) Post weld heat treatment process procedures and technical requirements, temperature uniformity and temperature control requirements, cooling methods;

m) Quality inspection requirements (such as performance, dimensions, defects);

n) Environmental conditions, wind, rain and snow protection measures;

o) Quality assurance system implementation;

p) List of various machines, equipment, facilities, auxiliary devices, instruments, meters, tools and consumables used for post weld heat treatment;

q) Agency name, personnel, institution and organization that implements the post weld heat treatment;

r) Fire and explosion-proof measures;

s) Personnel and equipment safety measures;

t) Emergency plan.

6.3 Remove the non-permanent connections on weldments not related to post weld heat treatment.

6.4 Effective measures shall be taken for finishing surfaces such as sealing surfaces and screw holes of weldments, so as to prevent high temperature oxidation.

6.5 When performing post weld heat treatment outside the furnace, the heating equipment shall have sufficient power reserve.

6.6 The weldment shall be inspected and tested as qualified according to the requirements of the manufacturing (installation) process. Carry out post weld heat treatment before the pressure proof test.

6.7 Master the weather conditions. Prepare for wind, rain and snow.

7 Heating, temperature control

7.1 Technical requirements

7.1.1 When performing post weld heat treatment in the furnace, according to the technical requirements of the weldment, the corresponding type of heat treatment furnace shall be selected in accordance with the provisions of GB/T 9452. Weldments shall be placed within the effective heating area.

7.1.2 When the internal heating method is used for post weld heat treatment, the high-temperature gas in the weldment must flow sufficiently. Positive pressure shall be maintained in a timely manner during the post weld heat treatment process. The pressure within the weldment shall not exceed 50% of the design pressure at the highest metal wall temperature expected during heat treatment.

7.1.3 The heating medium shall avoid spraying the weldment directly.

7.1.4 The heating medium shall not cause oxidation, decarburization, carburization and corrosion on the surface of the weldment that exceeds the depth specified in the technical documents.

7.2 Regulations for post weld heat treatment furnaces and instruments

8.3.1 During the post weld heat treatment and heat holding period, the temperature of any point on the weldment of the overall post weld heat treatment and the temperature of any point within the volume range shown in the soak band of the weldment of the partial post weld heat treatment shall be within the specified range.

8.3.2 The post weld heat treatment temperature is subject to direct measurement on the weldment.

8.3.3 During the post weld heat treatment process, when the temperature of the weldment is above 400℃, it shall be continuously and automatically displayed, recorded, stored and printed. The temperature and time of each temperature measurement point on the record chart (table) shall be distinguished.

8.3.4 The recording paper installed in the continuous automatic recorder shall match the graduation number scale of the recorder.

8.3.5 The display temperature of the computer temperature control system shall be adjusted according to the temperature display of the automatic recorder. For the heat treatment records recorded and displayed by the computer system, the systematic error shall be less than 0.5%.

9 Heat insulation

9.1 The thermal insulation material shall be able to maintain the original performance at the post weld heat treatment temperature and holding time without reducing the thermal insulation effect.

9.2 The thermal insulation material shall be close to the surface of the weldment during the entire post weld heat treatment process. Prevent loosening and falling off. When the thermal insulation material is laid on the weldment, it shall be divided into at least two layers. The seams between each two layers shall be staggered. The overlapping width of two adjacent thermal insulation materials on the same layer shall be greater than 100mm.

9.3 When the internal heating method is used for post weld heat treatment, the outer side of the weldment shall take thermal insulation measures according to the wall thickness, accessories, and dimensions of the nozzle. For struts or skirts connected to the weldment, the thermal insulation range extends at least 1000mm from the connection.

9.4 The temperature of the outer surface of the thermal insulation layer shall not be higher than 60℃.

10 Post weld heat treatment report

10.1 The main contents of the post weld heat treatment report are as follows:

a) Post weld heat treatment sequence number;

b) Weldment name, drawing number, serial number, part code and tag number, and number of post weld heat treatment process specification;

c) Post weld heat treatment contract number or power of attorney number;

d) Types of post weld heat treatment, heating ways, heating methods and auxiliary devices;

e) Weldment structure drawing, size, steel designation, thickness;

f) Name, number and location of the post weld heat treatment furnace;

g) Heater name, model and number; Name, model and serial number of temperature control instrument and temperature measuring instrument (including thermocouple and compensation wire); Name and thickness of thermal insulation material;

h) Number and layout of temperature measurement points;

i) Post weld heat treatment process: Post weld heat treatment thickness δ_{PWHT}, furnace entry temperature, heating rate, holding time (statistics based on each temperature measurement point), release temperature, cooling method and cooling rate;

j) Post weld heat treatment time-temperature continuous automatic record. When the record chart (table) cannot distinguish the value of each temperature measurement point, the inspection time-temperature record of each temperature measurement point shall also be provided;

k) Post weld heat treatment time, location and weather conditions;

l) Signature of the post weld heat treatment operator and the responsible person.

10.2 See Annex D for an example of the record of the overall post weld heat treatment outside the furnace (including the overall segmental post weld heat treatment outside the furnace).

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