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Technical code for low temperature steel storage tanks in petrochemical engineering

石油化工钢制低温储罐技术规范

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Foreword

This specification is, in accordance with the requirements of the requirements of the original Ministry of Construction “Notice on the issuance of 2006 construction standards development and revision plan (second batch)" (Jianbiao [2006] No.136), jointly compiled by the China Petrochemical Corporation and Sinopec Luoyang Engineering Co., Ltd.

In the compilation process, the compilation group conducted extensive investigation and study, conscientiously summed up the practical experience, consulted the foreign advanced standards, collected opinions extensively, completed the draft for approval, and finally finalized the draft.

This specification is divided into 10 chapters and 5 appendixes, AND the main technical content includes: General provisions, terms, basic requirement, materials, metal parts design, concrete components design, insulation, metallic parts construction, testing, inspection and acceptation, concrete components construction, testing, and so on.

As for this specification, the Ministry of Housing and Urban-Rural Development is responsible for its management, the China Petrochemical Corporation is responsible for daily management, AND the SINOPEC Luoyang Engineering Co., Ltd is responsible for the interpretation of the specific technical contents. Any opinions and suggestions on this specification in the implementation process please send to SINOPEC Luoyang Engineering Co., Ltd. (Address: No.27 Zhongzhou West Road, Luoyang City, Henan Province, Postal Code: 471003) for future reference during revision.

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Technical code for low temperature steel storage tanks in petrochemical engineering

1 General provisions

1.0.1 This specification is hereby established to standardize the design and construction of petrochemical steel low-temperature storage tanks.

1.0.2 This specification applies to the design and construction of the steel vertical cylindrical aboveground single containment tank, double containment tank and full containment tank which is used to store the hydrocarbons or ammonia of boiling point 0 °C ~ - 165 °C AND for which the design pressure is not more than 50 kPa.

This specification does not apply to thin-film tanks and primary tanks only using prestressed concrete.

1.0.3 The petrochemical steel low-temperature storage tank shall, in addition to the main tanks and its associated components as a whole, also be composed of the following:

1 The connection of tanks and the external pipes shall include the following:

1) The groove end surface of the first circumferential joint of the welded connection;

2) The end surface of the first threaded joint of the threaded connection;

3) The first flange sealing surface of the flanged connection;

4) The first sealing surface of the special connection or pipe connection.

2 Flat cover and its fasteners of adapter and manhole, and so on;

3 Insulation of tank bottom, wall, roof and adapter;

4 Internal structural parts of the tank;

5 Anchorage structure of the tank;

1.0.4 The design and installation of the petrochemical steel low-temperature storage tank shall, in addition to compliance with this specification, also comply with the relevant provisions of the current national standards.

2 Terms

2.0.1 Operating pressure

It refers to the gauge pressure in the gas space at the top of the tank in the operating state.

2.0.2 Design pressure

It refers to the set maximum gauge pressure in the gas space at the top of the tank.

2.0.3 Design negative pressure

It refers to the set maximum negative pressure in the gas space at the top of the tank.

2.0.4 Test pressure

It refers to the gas gauge pressure in the top of the tank during the test.

2.0.5 Set pressure

It refers to the operating pressure of the pressure relief device.

2.0.6 Minimum design temperature

It refers to the set medium temperature as designed for the tank.

2.0.7 Design metal temperature

It refers to the design temperature of metallic components.

2.0.8 Maximum design liquid level

It refers to the maximum liquid level that is allowed to be reached to of the tank.

2.0.9 Maximum normal operating level

It refers to the maximum liquid level of the tank in operating state.

2.0.10 Single containment tank

2.0.20 Supporting roof of tank

It refers to the roof the load of which is mainly supported by the beam and column, truss, or other structural members.

2.0.21 Self-supporting roof of tank

It refers to the roof the load of which is only supported by the wall periphery.

2.0.22 Rollover

It refers to the phenomenon that a large amount of medium vapor is generated due to the liquid density difference in the tank, resulting in the uncontrolled movement of the medium.

2.0.23 Thermal protection system

It refers to the insulation and liquid sealing structure installed in order to avoid the outer tank from being subjected to low temperature damage.

2.0.24 Vapor barrier

It refers to the vapor barrier structure installed in order to avoid vapor or air from entering into the insulation material.

2.0.25 Plastic elongation

It refers to the percentage between the length increment and the standard length of the standard length rebar under the ultimate tensile strength.

3 Basic requirements

3.1 Tank type

3.1.1 The petrochemical steel low-temperature tank can be in the form of single containment tank, double containment tank, and full containment tank.

3.1.2 The single containment tank can be divided into single wall single containment tank (Figure 3.1.2-1) and the double wall single containment tank (Figure 3.1.2-2) based on the vapor container structure.

Figure 3.1.4-2 Full containment tank of prestressed concrete secondary liquid container

1 - Foundation heating system; 2 - Foundation; 3 - Tank bottom insulation; 4 - Primary liquid container (steel); 5 - Flexible insulation sealing structure; 6 - Suspended ceiling (insulation); 7 - Roof (steel); 8 - Wall insulation structure; 9 - Secondary liquid container (concrete);

3.2 General requirements

3.2.1 The petrochemical steel low-temperature storage tank is applicable to store the medium with the main physical properties complying with the provisions of Appendix A of the Specification. The design conditions of the petrochemical steel low-temperature storage tanks shall include those listed in Appendix B of this Specification.

3.2.2 The petrochemical steel low-temperature storage tank shall comply with the following basic requirements:

1 Under normal operating conditions it shall be able to store liquid and vapor;

2 It shall be able to feed and discharge at the specified rate.

3 Vaporization shall be in controllable state, AND under abnormal circumstances it may be discharged to the torch or vent.

4 It shall be able to maintain the specified pressure operating range.

5 In addition to opening the negative pressure discharge valve under abnormal circumstances, it shall be able to prevent air and moisture from entering.

6 The vaporization rate shall comply with the requirements, AND avoid condensation or frost on the outer surface.

7 It shall be capable of limiting the damage caused by a specific abnormal action AND shall not result in loss of liquid storage.

3.2.3 As for the regions with the seismic fortification intensity greater than 9 degrees or design basic seismic acceleration value greater than 0.40 g, it is not preferable to build the petrochemical steel low-temperature storage tank.

3.2.4 As for the petrochemical steel low-temperature storage tank built at the regions with the seismic fortification intensity greater than or equal to 6 degrees or the designed basic seismic acceleration value greater than or equal to 0.05

g, it shall conduct seismic design. The seismic design of petrochemical steel low temperature storage tanks shall be in accordance with the provisions of Appendix C of this Specification.

3.2.5 The prestressed concrete outer tank can be installed with a vapor barrier. When the vapor barrier is not installed, the liquid tightness is ensured by the concrete compression zone.

3.2.6 It is preferable to install the tank material inlet and outlet at the roof. When they are installed at the lower part of the tank, they shall be connected with the outer pipes through welding.

3.2.7 It is not preferable to install fixed connection between the primary liquid container and the secondary liquid container. When it is required to use the fixed connection, it shall comply with the provisions of Clause 5.7 of this Specification.

3.2.8 The wall height of the primary liquid container shall be at least higher above the maximum liquid level for 300 mm.

3.2.9 During design of the petrochemical steel low-temperature storage tank, it shall provide the tank settlement observation point. AND it is preferable for the tank settlement to comply with the requirements below:

1 As for the steel storage tanks, the differential settlement value in diametrical direction (plane inclination in mm) shall not exceed 125 times the ratio of the diameter and height of the tank; the differential settlement limit of the tank periphery shall be not more than 10 mm every 10 m of arc length; the differential settlement between the tank center and the periphery (in mm) shall not exceed 1/240 of the tank radius.

2 As for concrete tanks, the plane inclination shall not exceed 1/500; the differential settlement between the tank center and the periphery shall not exceed 1/300 of the tank radius.

3.2.10 During design of the petrochemical steel low-temperature storage tank, it shall take measures to avoid the frozen swelling of the foundation. When the foundation heating system is installed, it shall ensure that the temperature of any part of the foundation is not less than 0 °C.

3.2.11 Prestressed concrete secondary liquid container shall be equipped with thermal protection system. The thermal protection system shall cover the entire bottom and the lower part of the wall, AND shall consist of a double bottom slab and a cold insulation material.

12 Thermal effects;

3.2.16 The corrosion allowance of the petrochemical steel low-temperature storage tank components shall be determined based on the corrosive nature of the medium and the environment.

4 Material

4.1 General requirements

4.1.1 The steel materials used in the petrochemical steel low-temperature storage tanks shall be with the quality certificate issued from the steel manufacturing unit.

4.1.2 When selecting the materials for the petrochemical steel low-temperature storage tanks, it shall make selection based on the tank utilization conditions, material performance, and economic rationality.

4.1.3 Materials for concrete structures in low temperature environments shall have low temperature resistance.

4.1.4 The steels used for the primary liquid container and the steel secondary liquid container shall select the killed steel as smelted from the oxygen converter or electric furnace. When the design metal temperature is lower than -20 °C, the low temperature steel plate, low temperature steel forgings and low temperature steel pipe shall also be subjected to the external refining process.

4.1.5 The design metal temperature of each part shall be determined based on the most unfavorable conditions.

4.1.6 When there are special technical requirements for steels, they shall be specified in the design documents.

4.2 Metal tanks

I Primary liquid container and secondary liquid container

4.2.1 The conditions of use of steel plates for petrochemical steel low-temperature storage tanks shall be in accordance with Table 4.2.1 of this Specification.

4.2.4 When the following steel plates are used for the wall and bottom plate for the primary liquid container and the secondary liquid container, it shall be subjected to the ultrasonic test one by one, AND the test methods and quality classification shall follow the provisions of the current national standard "Nondestructive testing of pressure equipment - Part 3: Ultrasonic testing" JB/T 4730.3:

1 As for the Q245R and Q345R steel plate with thickness greater than 30 mm, the quality level shall not be lower than level II.

2 As for the 16MnDR, 15MnNiDR and 09MnNiDR steel plate with thickness greater than 20 mm, the quality level shall not be less than level II.

3 As for the Q370R steel plate with thickness greater than 25 mm, the quality level shall not be less than level II.

4 As for the steel plate with the thickness greater than 16 mm AND supplied after being quenched and tempered, the quality level shall not be less than level I.

4.2.5 When the profiles used in the petrochemical steel low-temperature storage tanks have no corresponding standard, it may use the steel plate of equivalent performance after being processed.

4.2.6 When the aluminum material is selected as the ceiling material, the aluminum plate and the aluminum profile used shall comply with the requirements of the current national standard "Wrought aluminum and aluminum alloy plates, sheets and strips for general engineering" GB/T 3880.1 ~ GB/T 3880.3 and "Wrought aluminum and aluminum alloys extruded profiles for general engineering" GB/T 6892.

4.2.7 The conditions for use of the steel pipes in petrochemicals steel low-temperature storage tanks shall be in accordance with the provisions of Table 4.2.7.

Table 4.2.7 Conditions for the use of steel pipes for petrochemical steel low-temperature storage tanks

mechanical properties of the welding joints, AND it is preferable to use the welding materials of chromium nickel content higher than the high alloy steel base metal.

4.2.15 Various welding materials for the primary liquid container shall be subjected to retest.

4.3 Concrete

I Concrete

4.3.1 The strength grade of concrete shall not be less than that specified in Table 4.3.1 of this Specification.

Table 4.3.1 Strength grades of concrete

Component types	Concrete strength grade
Pile	C30
Pile cap, tank bottom plate	C30
Inner tank lower ring beam	C30
Prestressed wall	C50
Roof	C30
Levelling layer	C20

4.3.2 The strength of concrete as increased in low temperature state shall not be taken as the ultimate strength of the cross-section of concrete components; however, if there is sufficient test data, it may use the increased strength.

4.3.3 The concrete can be mixed with a certain percentage of admixtures.

4.3.4 When using the air entrainment agent, it may use the resin-based air entrainment agent to increase the air content in the concrete mixture up to 5%, BUT it is not preferable to use the metal-based air entrainment agent.

4.3.5 As for the concrete materials, it is preferable to select the cement of low hydration heat such as Portland cement; the Portland cement can be used together with the blast furnace slag or fly ash and other materials, BUT it shall be selected during design based on its retardation effect onto the increase of the concrete strength.

4.3.6 The mixing ratio of low-temperature concrete shall be determined through test.

4.3.7 In the corrosive environment, the concrete shall also comply with the relevant provisions of the current national standard “Code for anticorrosion design of industrial construction” GB 50046.

	0.43R_m and 0.67R_{el}	
S30408	The smaller value between 0.43R_m and 0.67R_{el}	

Note:

1 R_m is the lower limit of the standard tensile strength (MPa) AND R_{el} is the standard lower yield strength (MPa) of the material.

2 As for 9% Ni steels, R_{el} may be taken as 0.2% non-proportional extension strength (MPa) as specified in the material standards.

3 As for austenitic stainless steels, R_{el} may be 1.0% non-proportional elongation strength (MPa) as specified in the material standard.

5.1.3 The allowable stress of seismic verification may be selected in accordance with the following provisions:

1 Under the fortification intensity seismic conditions, it may take 1.33 times of the allowable stress under the operating conditions;

2 Under rare earthquakes, the allowable tensile stress may be taken as 1.00 R_{el} AND the allowable compressive stress may be taken as the critical yield stress.

5.1.4 The allowable tensile stress of anchorage shall comply with the following requirements:

1 Under normal operating conditions, it shall be 0.50R_{el}.

2 Under test conditions, it shall be 0.85R_{el}.

3 Under fortification intensity seismic conditions, it shall be 0.67R_{el}.

4 Under rare earthquakes, it shall be 1.00R_{el}.

5.1.5 The connection pieces and inserts of the wall shall be capable of withstanding the load when the non-corrosive anchor bolt or anchor zone reaches to the full section yield.

5.1.6 When the tank storing the liquefied natural gas (LNG) uses 9% Ni steel and austenitic stainless steel as the anchorage, it shall determine the material yield strength in accordance with the boiling temperature or lower temperature as specified in the current national standard “General characteristics of liquefied natural gas” GB/T 19204.

5.1.7 The compressive stress at the joint between roof and wall shall not exceed 120 MPa.

5.1.8 Where the butt joint is used, the load is applied to within the steel plate plane AND perpendicular to the weld, the allowable stress value shall be selected in accordance with the provisions of Table 5.1.2 in this Specification; when the load is applied parallel with the weld, the allowable shear stress shall be taken as 75% of the specified value in Table 5.1.2 of this Specification.

5.1.9 Where the corner joint is used AND the load is perpendicular to the weld, the allowable shear stress shall be taken as 70% of the value as specified in Table 5.1.2 of this Specification; when the load is parallel with the weld, the allowable shear stress shall be taken as 50% of the specified value in Table 5.1.2 of this Specification.

5.2 Primary and secondary container

I Tank bottom

5.2.1 The minimum thickness of the edge of the tank bottom (excluding corrosion allowance) shall be calculated using the equation below AND shall not be less than 8 mm:

$$t_a = 3.0 + t_1/3 \qquad (5.2.1)$$

Where:

t_a - The minimum thickness of tank bottom edge (mm);

t_1 - The bottom ring wall plate thickness (mm);

5.2.2 The connections between tank bottom plate and bottom ring wall plate shall comply with the following requirements:

1 The minimum distance l_a between the edge of the center plate and the inside of the bottom ring wall plate [SEE Figure 5.2.2 (c)] shall be taken as the value calculated from the equation below and 600 mm, whichever is larger:

$$l_a > \frac{240}{\sqrt{H}} t_a \qquad (5.2.2)$$

Where:

t_a - Edge plate thickness (mm);

H - Maximum design level (m).

2 The radial welded joints between edge plates shall use butt welds.

3 The connection between the bottom ring wall plate and the edge plate shall be in one of the following ways:

1) Butt corner joint;

2) Double-sided fillet weld, the maximum weld foot height is 12 mm AND the minimum weld foot height is taken as the wall thickness and the edge plate thickness, whichever is smaller;

3) When the edge plate thickness is greater than 12 mm, the wall plate adopts the form of open groove, AND the total of the groove depth and the weld foot weld height shall be equivalent to the edge plate thickness.

4 The distance between the radial joint of the edge plate and any longitudinal weld of the wall shall not be less than 300 mm.

5 The distance between the outer surface of the wall and the outer edge of the edge plate shall not be less than 50 mm.

6 The layout and connection details of the center plate and edge plates at the tank bottom shall comply with the requirements [Figure 5.2.2 (a) and Figure 5.2.2 (b)].

7 The width and thickness of the edge plates shall also comply with the requirements for seismic fortification.

5.2.3 The minimum thickness of the center plate at the bottom of the tank (excluding corrosion allowance) shall be taken as 5 mm AND it shall comply with the following requirements:

1 The minimum length of the straight side of the center plate shall not be less than 700 mm;

2 Between the center plates it shall use the overlap weld or butt weld;

3 The minimum overlap width of the overlap joint shall be taken as 5 times of the center plate thickness;

4 Overlap joints shall consist of at least two weld passages.

5.2.7 In addition to comply with the requirements of Clauses 5.2.4 to 5.2.6 of this Specification, the wall shall also comply with the following requirements:

1 The girth welds and longitudinal welds of walls shall adopt butt joints AND it shall ensure the full penetration and full fusion.

2 The distance between longitudinal welds of two adjacent layers of walls shall not be less than 300 mm.

3 All attachments connected with the wall shall use the backing plate, its distance to the wall longitudinal weld shall be greater than 300 mm, AND its distance to the wall circumferential weld shall be greater than 150 mm. The periphery of the backing plate and the reinforcing plate shall be rounded, with the fillet radius not less than 50 mm.

4 The inner wall subjected to external loads shall be capable of withstanding the combined stresses in the circumferential and axial directions.

5.2.8 The design of the reinforcement ring shall comply with the following provisions:

1 When the wall thickness changes with height, it may use the wall conversion method to determine the spacing between reinforcement rings; AND the equivalent height between reinforcement rings may be calculated using the equation below:

$$H_e = h\sqrt{\left(\frac{t_{min}}{t}\right)^5} \qquad (5.2.8)$$

Where:

t - Nominal thickness of the ring wall where calculation is conducted (mm);

t_{min} - Nominal thickness of the topmost ring wall (mm);

h - Actual height of the ring wall where calculation is conducted (m);

H_e - Equivalent height of the ring wall where calculation is conducted (m);

2 When designing each reinforcement ring, it shall include the wall portion within the effective range of this reinforcement ring.

3 The design of the joint between the wall and the tank bottom as well as the top of the open-type tank shall be in accordance with the requirements for the end reinforcement ring.

P - Calculated pressure, that is, the sum of the design internal pressure and the side pressure from the insulation structure (kPa);

[σ] - Design allowable tensile stress (MPa).

5.3.4 The outer wall with intermediate reinforcement ring shall be designed based on the combination of longitudinal compression and circumferential compression.

5.3.5 The wall shall be capable of withstanding all applied loads which include, but not be limited to, the following loads:

1 The longitudinal compressive forces shall include the following loads:

1) Static load;

2) Live load (roof live load, snow load);

3) Pipeline load;

4) Internal negative pressure;

5) Overturning caused by wind pressure;

6) Overturning caused by earthquake.

2 The circumferential compressive forces shall include the following loads:

1) Local wind pressure;

2) Negative pressure.

5.3.6 The roof suction force as caused by wind and the allowable biaxial stresses of the wall caused by overturning shall be calculated based on the combinations of the most unfavorable conditions.

5.3.7 The reinforcement ring weld shall be fully welded butt-connection. Where the reinforcement ring intersects with the longitudinal weld, it shall open a semi-circular hole at the corresponding location on the reinforcement ring. The top connection weld between the reinforcement ring and the wall shall be continuous fillet weld, AND the bottom weld may be interrupted type.

5.3.8 The distance between the reinforcement ring and the circumferential weld of the wall shall not be less than 150 mm.

III Roof

Where:

E - Elastic modulus (MPa);

t_r - Roof thickness (not including corrosion allowance) (mm);

P - Weight per unit area of roof plate after deducting the corrosion from internal pressure (kPa);

P_e - External load (kN/m^2);

R_1 - Roof curvature radius (m);

[σ] - Design allowable tensile stress (MPa);

φ - Weld joint coefficient.

5.3.13 The minimum area of the pressure-bearing area shall be determined using the equation below irrespective of the corrosion allowance. The effective pressure bearing area shall consist of steel plates and (or) combined cross-sections, AND the maximum width shall comply with the requirements (Figure 5.3.13):

$$A=\frac{5PR^2}{[\sigma]_c\tan\theta} \qquad (5.3.13)$$

Where:

A - Minimum area of the required pressure bearing area (mm^2);

P - Weight of the roof plate after deducting the occurred corrosion from the internal pressure (kPa);

R - Wall radius (m);

$[\sigma]_c$ - Allowable compressive stress (MPa), which can be determined in accordance with Clause 5.1.7 of this Specification;

θ - The slope of the roof at the connection between roof and wall (°);

5.3.16 Pressure bearing areas shall comply with the following requirements:

1 The radial width of the horizontal projection of the effective pressure bearing area shall not be less than 1.5% of the horizontal radius of the storage tank.

2 The center of mass of the pressure bearing area shall be located on the upper or lower side of the horizontal plane through the corner, AND the distance to the horizontal plane shall be within 1.5 times the average thickness of the two components.

3 It shall verify the extension as caused by the loads beyond the pressure bearing area (including internal negative pressure).

4 It is preferable to avoid the transitional deformation at the connection between the roof supporting component within the pressure bearing area and the pressure bearing area.

5.4 Suspend roof

5.4.1 The suspend roof and supporting structure shall be designed in accordance with the minimum design temperature.

5.4.2 The design load of the suspend roof shall include at least the weight of the suspend roof, the weight of the insulation material and the live load, etc.

5.4.3 When any one of the boom fails, it shall still be able to ensure the safety of the suspend roof structure.

5.4.4 The suspend roof ventilation holes shall be designed to ensure that the pressure difference between the spaces above and below the suspend roof is not more than the weight of the suspend roof; AND the suspend roof uplifting shall not occur.

5.5 Pipe

5.5.1 The connection pipe to the primary liquid container or the secondary liquid container shall comply with the provisions of Clause 3.2.7 of this Specification.

5.5.2 The pipe shall be capable of withstanding the loads from the connected pipelines and accessories.

5.5.3 When the nominal diameter of the wall pipe is greater than or equal to 80 mm, it shall install reinforcement. The pipe connection structure and the pipe

5.6.2 The tank structure shall be adapted to the non-uniform shrinkage of the primary liquid container and the secondary liquid container.

5.6.3 The pipe openings shall be reinforced through using the reinforcement plate or the thick-walled pipe.

5.6.4 The surrounding space of the pipe and pipeline shall be filled with appropriate insulation materials AND take local antifreeze measures.

5.7 Primary and secondary container connection

5.7.1 The connections type between tanks shall be such as to accommodate the effects of thermal expansion and contraction between the primary liquid container and the secondary liquid container as well as the hydrostatic pressure.

5.7.2 The connection between the primary liquid container and the secondary liquid container shall adopt thermal insulation measures.

5.7.3 It shall not install flange connection in the annular space between the primary liquid container and the secondary liquid container wall.

5.7.4 The connection between the roof opening of the primary liquid container and the secondary liquid container shall be adapted to the relative displacement between the inner and outer roofs. The openings through the suspend roof shall be free to move AND shall avoid generating additional loads onto the outer roof or the suspend roof.

5.8 Other requirements

5.8.1 Tank anchors shall comply with the following conditions:

1 The inner tank and outer tank shall be separately calculated based on different load combination conditions;

2 When the inner tank anchor passes through the outer tank bottom plate, it shall ensure the liquid tightness of the outer tank bottom plate;

3 The anchorages shall be distributed along the circumference of the storage tank, AND the maximum spacing shall not be greater than 3 m;

4 It is not allowed to apply the pre-tensioning to the anchors;

5 When settlement occurs before putting into operation, it shall be allowed to adjust the anchors;

6 The anchoring structure of the storage tank shall be adapted to the bending due to temperature difference.

7 The anchors shall be connected to the wall by means of backing plate or anchor bolt; AND the minimum cross-sectional area of a single anchor bolt or anchor belt shall not be less than 500 mm^2.

8 The corrosion allowance for anchor bolts or anchor belts exposed to the atmosphere shall be greater than or equal to 3 mm.

9 It shall take the insulation measures to avoid the damage of the anchor or storage tank due to freezing.

5.8.2 The nameplate shall be installed on the storage tank.

6 Concrete components design

6.1 General requirements

6.1.1 The loads and design conditions acting onto the concrete tanks shall be determined in accordance with Paragraph 3.2.15 of this Specification and the Appendix B of this Specification.

6.1.2 It is preferable for the concrete storage tank to use the limit state design method based on the probability theory, using the reliability indicator to measure the reliability of the structural components; it shall use the design expression with sub-coefficient AND conduct design based on the bearing capacity ultimate state and the normal utilization limit state.

6.1.3 When designing the concrete storage tank based on the bearing capacity ultimate state, it is preferable to conduct calculation based on the basic combination of loads or earthquake combinations; when designing the concrete storage tank based on the normal utilization limit state, it is preferable to be based on the effects of the quasi-permanent load combination and long-term effects OR the effects of the standard combination and long-term effect.

6.1.4 The minimum thickness of the concrete wall shall comply with the following requirements in addition to the requirements for the bearing capacity ultimate state and normal utilization limit state:

1 There shall be sufficient space to accommodate all rebar and prestressing tendons.

current national standard “Code for design of concrete structures” GB 50010.

6.2.2 The crack width of concrete shall be determined in accordance with the relevant provisions of the current national standard “Code for design of concrete structures” GB 50010.

6.2.3 The elongation of the liquid-tight inner lining or coating shall comply with the requirement of 1.2 times the crack width of the base concrete.

6.3 Concrete tanks

I Wall

6.3.1 It is preferable for the wall to be in prestressed concrete structure.

6.3.2 The wall shall be configured with horizontal prestressed tendons. The vertical prestressed tendons shall be determined through calculation of tank design pressure, tank diameter, and roof thickness.

6.3.3 It is preferable to install symmetrically buttress columns outside the wall, conduct horizontal prestressing tension at the buttress, AND anchor the horizontal prestressed tendons after tensioning.

6.3.4 The application of prestress shall be through post-tensioning method. During design, it shall count the prestress loss due to anchor deformation and rebar shrinkage, friction between the prestressed rebar and the rebar holes as well as the direction turning device, the stress relaxation of prestressed rebar, and the shrinkage and creep of concrete, etc.

II Foundation plate

6.3.5 The foundation plate of the storage tank may use reinforced concrete or prestressed concrete structure.

6.3.6 When the building the construction joint along the tank foundation plate, the design shall take technical measures to ensure the integrity of the foundation plate.

III Connection of wall to foundation

6.3.7 The connection of walls to foundations can be divided into sliding connection, pin connection, and fixed connections (Figure 6.3.7).

3 When it is used as a composite structure, the lining shall be anchored to the concrete through shear studs.

6.3.10 Roofs shall also be designed in accordance with different construction methods.

6.3.11 Before the roof concrete reaches to the design strength, it may use pressure air in the tank to balance the weight of the freshly-poured concrete.

6.3.12 It is preferable for the connection between the roof and wall to use rigid connection.

V Foundation

6.3.13 Tank foundation can be of natural foundation; however, when the natural foundation fails to comply with the requirements, it may also use pile foundation.

6.3.14 As for the foundation form of natural foundation, it is preferable to use the raft foundation; as for the regions on the tank and wall where it is required to bear high loads, it is preferable to increase the concrete plate thickness.

6.3.15 The pile foundation design shall comply with the following requirements:

1 The pile foundation design shall be determined based on economic rationality; AND it shall optimize the pile type, pile diameter, and pile length;

2 The pile forming method and single pile bearing capacity shall be determined through on-site test pile.

3 When the single pile fails, the pile foundation design shall be able to re-distribute the load.

4 As for the connection between the pile and the concrete plate, it is preferable to use rigid connection.

5 When there is an explosive load, it shall calculate the horizontal force due to the explosive load.

6 When using the elevated foundation plate, it shall be based on the earthquake effect to determine whether it is required to use the “removable” type vibration isolator.

7 When using the elevated foundation plate, the overhead height shall be determined based on temperature through calculation.

8 The wall shall be sloped outwards to the foundation plate edge.

2) The possible structural damage effects of the thermal resistance reduction, water or freezing process (freeze/thaw cycles) due to the water and water vapor infiltration onto the insulating materials;

5 The effects of stored products onto the insulating materials shall include the following:

1) The closed porosity of the insulating material;

2) The product vapor absorption rate and its impact onto other properties of insulating materials;

3) The absorption to liquid products and the permeability from liquid products;

4) The effects of long-term absorption of liquid onto the other properties of insulating materials;

5) Desorption effect: time/percentage.

6 The compatibility and possible chemical reactions between the insulation system, the environment and the tank material and/or coating in contact with the insulation system;

7 During construction process OR an external fire occurs, it shall also assess the following characteristics of the insulating materials:

1) Combustion performance: it main assess the flammability, flame retardant and toxic gas generation;

2) The maximum temperature limit of insulating materials: it mainly includes melting temperature, decomposition temperature, and ignition temperature.

7.1.3 The performance of insulating materials shall be verified by laboratory tests, simulation tests or testing of the installed tank structures.

7.1.4 The commonly used insulating materials can be selected in accordance with Appendix E of this Specification.

7.2 Outer tank and protection of insulation

7.2.1 When the outer tank is used as the protection and support structure of the insulating materials, the outer tank shall comply with the following requirements:

1 It shall have sufficient sealing performance.

2 When the outer tank is constructed from concrete, it shall use metal lining or polymer vapor barrier.

7.2.2 The outer protective layer of insulating material shall comply with the following requirements:

1 The insulating materials installed on the tank external surface shall be configured with the external protective layer. The installation of the external protective layer shall be able to adapt to the climate and atmospheric environment impacts of water vapor, rain, snow, hail, wind, storm, sunlight radiation, ultraviolet radiation, etc., AND to prevent the mechanical damage or fire damage due to human beings and birds;

2 It is preferable for the insulating layer to be installed with vapor barrier. Under the average water vapor pressure difference at the region wherein the petrochemical steel low-temperature storage tank is located, the maximum permeability of the vapor barrier layer shall be 24h: 0.5g/m^2.

3 The outer protective layer and vapor barrier layer can adopt metallic, non-metallic or the combination of metallic and non-metallic materials.

7.3 Insulation design

I Thermal design

7.3.1 The thermal design for the tank insulation system shall be designed based on the tank structure, temperature, installation method, startup and shutdown requirements, etc.

7.3.2 The thermal design shall comply with the following requirements:

1 The daily evaporation rate shall not be greater than the maximum allowable value.

2 It shall prevent the outer surface of the tank from frost or condensation, AND the minimum design temperature of the outer tank components shall be higher than the dew point temperature.

3 It shall prevent soil from frozen swelling

7.3.3 The thickness of insulation layer shall be determined in accordance with the amount of cold loss and minimum condensation or frosting requirements.

II Structure design

3 The allowable load factor (PLDF) shall be determined by repeated creep tests.

4 The safety factor shall be taken as follows:

1) Under the normal operating condition: 1.25;

2) Under the hydrostatic test condition: 1.00, with the duration less than or equal to 1 month;

3) Under fortification intensity conditions, polyurethane foam (PUF) and polyvinyl chloride (PVC) can be taken as 0.5;

4) Under rare earthquake conditions, polyurethane fishing foam (PUF) and polyethylene (PVC) can be taken as 0.33.

7.3.8 As for other loads, it shall be based on the specific conditions to determine the safety factor of the allowable stress theoretical method.

III Insulation design of the various parts of tank

7.3.9 The insulation thickness of each part shall be determined based on the maximum allowable cold loss AND the minimum condensation or frosting requirements.

7.3.10 The ring beam insulation design shall comply with the following requirements:

1 The structure shall be able to withstand the horizontal force as caused by storage tank contraction and earthquake, as well as the possible wall displacement effects as caused by wind load, material feed/discharge, and earthquake.

2 It shall have waterproof and vapor barrier function.

3 The thermal design of ring beam shall be combined with the foundation plate heating system design, AND avoid the frozen swelling phenomenon under the ring beam.

4 As for the raft foundations, the temperature under the foundation plate shall be not less than 0 °C.

5 As for the vertical anchor belt passing through the ring beam, it is preferable to reduce the cold bridge effects, AND it shall avoid water/vapor intrusion; the anchor belt shall be sufficiently flexible.

5 When filling the loose insulating material, it shall vibrate to compact it; AND it shall provide nozzle to supplement expansion perlite.

6 Under normal operating or leakage conditions, the insulating material shall not produce absorption/desorption effects against the stored medium, AND shall be able to adapt to the possible purging of the stored medium against the insulating materials.

7.3.14 The roof outer insulation design shall comply with the following requirements:

1 It shall provide the weather shields and vapor barriers.

2 It shall be able to adapt to the external climate and atmospheric environment of the tank installation area.

3 It shall comply with the thermal-mechanical stress onto the insulating materials due to the tank size variation.

4 It shall provide overhauling access.

5 The roof external insulation system shall be fireproof.

7.3.15 The roof insulation design shall comply with the following requirements:

1 It shall provide such temporary access as pedestrian access channel.

2 The cold loss of the entire tank shall be included in the cold loss due to the thermal conductivity and convection of the insulating materials of the suspend roof AND the cold bridge of the suspender.

3 The initial installation thickness of the suspend roof insulation layer shall be able to compensate for settlement in use.

4 The suspend roof insulation layer design shall prevent the adverse effects of the possible product condensation in the storage tank dome space.

7.4 Installation

7.4.1 The insulation construction shall comply with the relevant provisions of the design document, this Specification and the current national standard “Code for construction of industrial equipment and pipeline insulation engineering” GB 50126.

7.4.2 Before insulation construction, it shall compile detailed insulation construction program. When establishing the storage tank construction

characteristic data shall comply with the relevant standards and the requirements of the design documents.

8.2.2 The quality certification documents of low-temperature steel, low-temperature welding material and low-temperature accessories shall indicate the steel designation, specification, chemical composition, mechanical property, low-temperature impact toughness value, supply condition and material manufacturing standard.

8.2.3 The steel plates used for petrochemical steel low-temperature storage tanks shall be subjected to appearance quality inspection one by one, which shall comply with the following requirements:

1 The steel plate surface shall not have cracks, bubbles, folding, inclusions, scarring or insertion of iron oxide, AND the steel plate shall not be stratified.

2 The low-temperature steel plate surface shall not have mechanical scratches.

3 The manufacturer's mark on the surface of the steel plate shall be legible and correspond to the quality certificate.

8.2.4 The sum of the local thinning of the steel plate surface and the actual negative deviation of the steel plate shall not be greater than the negative deviation of the steel plate as allowed by the design.

8.2.5 The chemical compositions and physical properties of low-temperature steel and low-temperature welding materials shall be re-inspected in accordance with the relevant provisions.

II Storage and transportation

8.2.6 In the processing, storage and transportation of petrochemical steel low-temperature storage tank, it shall take measures to prevent confusion.

8.2.7 In the processing, storage and transportation of stainless steel materials, it shall prevent surface contamination.

8.2.8 The 9% Ni steel shall be avoided from magnetization, AND the remanence shall not exceed 50Gs.

8.2.9 The custody and storage of the welding materials shall be in accordance with the relevant welding material standards OR the requirements stated by the welding material supplier.

III Identification and transplantation

8.3.3 When the steel plate is rolled, the direction of the steel plate shall be perpendicular to the axis of the roller. After the steel plate is rolled, it shall be vertically placed on the platform; along the horizontal direction, it shall use the inner arc template of chord length not less than 2000 mm for inspection, and the gap shall be not more than 4 mm; along the vertical direction, it shall use the straight line template of length not less than 1000 mm for inspection, and the gap shall be not more than 2 mm.

8.3.4 When the pipe of the primary liquid container and the secondary liquid container is rolled from steel plate, it shall conduct 100% ray or ultrasonic testing against the pipe longitudinal weld.

8.3.5 When the wall pipe is made from the carbon steel plate of thickness more than or equal to 25 mm, the pipe, wall and reinforcement ring welding region shall be subjected to ultrasonic testing, AND it shall be free from delamination.

8.3.6 Flat welding flanges shall be double-side welded. Butt-welded flange with neck shall adopt the fully penetrated butt joint.

8.3.7 Reinforcement plates shall be subjected to rolling-arc machining, AND each reinforcement plate shall have at least one signal hole.

8.3.8 All bolt holes at site shall be mechanically drilled and shall not be flame cut.

8.3.9 The shop fabricated components shall be marked with the component number in time.

8.3.10 The storage and transportation of shop fabricated components shall take anti-deformation measures.

8.4 Site installation

8.4.1 When the foundation adopts ring beam, the ring beam top shall be leveled; when measured from the design elevation, the levelness shall comply with the following requirements:

1 Within the range of any 10 m arc length, the allowable levelness deviation shall not exceed ± 3 mm.

2 Along the entire circumference, the allowable levelness deviation shall not exceed ± 6 mm.

8.4.2 When using the whole concrete slab foundation, the range 300 mm inwards and outwards of the wall position shall comply with the ring beam

levelness requirements; the rest portion shall be measured by 3 m length template, AND the levelness shall not exceed ± 15 mm.

8.4.3 Bottom assembly welding shall adopt a reasonable procedure, AND it may install the temporary work clamp to control the bottom plate welding deformation. After finishing the bottom welding, the depth of the local concave and convex deformation shall neither exceed 2% of the deformation length nor exceed 50 mm.

8.4.4 The amount of misalignment of the wall assembly shall comply with the following requirements:

1 The amount of maximum misalignment shall comply with the provisions of Table 8.4.4;

Table 8.4.4 Maximum misalignment amount of longitudinal joint (mm)

Plate thickness δ	Maximum misalignment amount
δ ≤ 10	1
δ > 10	≤ 0.1δ AND not more than 1.5
	≤ 1 when using automatic welding

2 The maximum misalignment amount of the circumferential joint shall comply with the following requirements:

1) When using the welding electrode arc welding AND the upper ring wall plate thickness is less than or equal to 8 mm, the misalignment of any point shall be not more than 1.5 mm; when the upper wall plate thickness is more than 8 mm, the misalignment of any point shall be neither more than 0.2 times of the plate thickness nor more than 2 mm;

2) When using automatic welding, the misalignment of any point shall not be greater than 1.5 mm.

8.4.5 After welding the bottom wall plate and the tank bottom, it shall measure the radius at each center point location on each wall plate 300 mm height above the wall plate bottom, AND the allowable deviation of the bottom ring radius shall comply with the provisions of Table 8.4.5.

Table 8.4.5 Allowable deviation of bottom ring radius

flange nor more than 3 mm; AND the flange bolt hole shall be installed across the middle.

8.4.14 Temporary accessories shall be welded in the same welding procedure as the material to which they are attached AND shall comply with the following requirements:

1 Temporary accessories shall be removed by means of thermal cutting, planing or grinding.

2 When using the thermal cutting or planning method to remove the temporary accessories, it shall retain 2 mm temporary accessory which shall be ground.

3 After removal of the temporary accessories, it shall conduct magnetic powder or penetration testing.

8.5 Welding

I Welding procedure assessment

8.5.1 The welding procedure assessment shall comply with the following requirements:

1 All welds, including repair welds and tack welds, shall be subjected to a welding procedure assessment AND a welding procedure shall be established.

2 The welding procedure assessment of petrochemical steel low-temperature storage tank shall follow the provisions of the current national standard “Welding procedure qualification for pressure equipment” NB/T 47014 AND the provisions of this Specification.

3 The steels used for the welding procedure assessment of the primary liquid container and the secondary liquid container shall be manufactured by the same steel mills with same manufacturing process of the steel used by the product; when any changes occur, it shall re-conduct the welding procedure assessment.

4 When the product needs to be welded under the conditions of not cleaning the groove protective coating, the test specimen subjected to the welding procedure assessment shall also be welded under the conditions with protective coating.

3 The test temperature and impact energy of the V-notch impact test for welds and heat affected zones shall comply with the design documentation requirements.

4 When using 9% Ni steel to manufacture tanks to store ethylene or ethane, the impact test temperature may be -140 °C.

8.5.4 The tensile strength of 9% Ni steel tensile test shall not be less than 80% of the design value of vertical weld design value of wall OR the design value of circumferential weld of wall.

II Welder qualification

8.5.5 Welders and welding machine operators shall pass the examinations stipulated for the national special equipment welding operators.

III Product test plates

8.5.6 The product test plates for single containment tank, double containment tank, and full containment tank shall comply with the following requirements:

1 As for the vertical welds of the thickest wall plate and the thinnest wall plate of the primary liquid container and the secondary liquid container, it shall respectively make one product test plate. AND each welding procedure shall be provided with one test plate.

2 When the difference between the thickness of the bottom ring wall and the top ring wall is greater than 20 mm, it shall make an additional test plate, the thickness of which shall be taken as the approximate average of the bottom wall plate thickness and the top wall plate thickness.

3 Product test plate shall be the same heat number with the wall plate.

4 The product test plate shall use the welding materials same as that used for the corresponding product weld.

5 The width at both sides of the product test plate weld shall not be less than 200 mm.

6 When the site conditions permit, it is preferable to conduct the welding and testing of the product test plate as soon as possible.

7 If the product test plate cannot be placed on the upper end of the vertical weld of the wall due to the limitation of the installation method, the weld of the product test plate shall adopt the welding procedure same as that for the wall vertical weld AND be conducted in the vicinity of the storage tank.

8 The inspection and test requirements for the product test plate shall be same as that of the welding procedure assessment. It shall allow for the V-notch impact tests only for the weld metal and heat affected zone.

IV Welding

8.5.7 Positioning welding and temporary welding shall comply with the following provisions:

1 Positioning and temporary welds shall be completed by qualified welders.

2 When the positioning weld is fully fused with the subsequent weld AND not affect the weld quality, it may not be removed.

8.5.8 Welding environmental conditions shall comply with the following requirements:

1 The welding unit shall take measures to prevent moisture, rain or wind;

2 When the base metal temperature is lower than 5 °C, it shall pre-heat the base metals at both sides of the weld, with the preheating temperature more than or equal to 5 °C.

8.5.9 When preheating is required, it shall be conducted before welding begins. The preheating range shall be not less than 4 times the weldment thickness on both sides of the weld AND shall not be less than 75 mm. The preheating time shall be such as to ensure the uniform temperature along the base metal thickness direction.

8.5.10 Post-weld heat treatment shall comply with the following requirements:

1 After the pipe and manhole of the carbon-manganese steel tank are welded to the wall and inserted reinforcement plate, it shall, before installing the tank, conduct the post-weld heat treatment against this group of welded pieces. Before the heat treatment, it shall establish the heat treatment plan. The post-weld heat treatment can be exempted if complying with the following requirements:

1) The group weldment of thickness less than 16 mm;

2) The group weldment of thickness less than 30 mm AND the pipe nominal diameter less than 300 mm;

3) Pipe or manhole on the outer tank wall which only stores gas;

Penetrant testing" JB/T 4730.5. The test shall be conducted with permeable material which will not contaminate the test sample and stored products.

8.6.7 Magnetic powder testing shall be conducted in accordance with the current standard of "Non-destructive testing of pressure equipment - Part 4: Magnetic particle testing" JB/T 4730.4. The 9% Ni steel shall not be subjected to magnetic powder testing.

8.6.8 Vacuum leakage test shall comply with the following requirements:

1 The steel plate shall be clean.

2 The weld shall be removed of oil stain and any welding slag which may affect the quality of the testing.

3 It shall ensure that the vacuum degree the pumping system is not less than 30kPa.

4 The soap water used shall be with high wetting, low degree of viscosity, small surface tension, and high foaming capacity.

8.6.9 The testing of soap bubbles shall comply with the provisions of item 1, 2 and 4 of Clause 8.6.8 of this Specification, as well as the following provisions:

1 When the double-sided fillet weld is adopted between the wall of the tank bottom, MAKE the pressure air of not less than 50kPa pass through the dedicated test screw hole and inject into the fillet weld, and MAINTAIN this pressure in the entire test process; BRUSH or SPRAY soap water over the weld, AND it shall be deemed as qualified if there is no leakage. During testing, it shall ensure that the test pressure of the fillet welds at both sides of the wall is continuously distributed along the periphery of the wall; after the test, it shall close the screw holes.

2 As for the testing of the weld of the reinforcement plate, it shall use soap water to wet it, AND then make the pressure air of not less than 50kPa pass through the screw hole and inject into the reinforcement plate weld for at least 30 s; AND it shall be deemed as qualified if there is no leakage; after the test, it shall close the screw holes.

3 The roof outer fillet weld testing shall be conducted after the roof pneumatic test; under the design pressure, USE soap water to wet the outside of the fillet weld. During the test process, it shall maintain the design pressure.

8.6.10 Radiographic testing shall be conducted in accordance with the current national standard "Nondestructive testing of pressure equipment - Part 2: Radiographic testing" JB/T 4730.2.

8.6.11 Ultrasonic testing shall be conducted in accordance with the current national standard “Nondestructive testing of pressure equipment - Part 3: Ultrasonic Testing” JB/T 4730.3 AND shall comply with the following requirements:

1 It shall be a recordable, pulsed-reflective method of ultrasonic testing and it is only used as a supplementary method for radiographic testing;

2 When using ultrasonic testing, it shall use the radiographic testing for review, with the review rate of 20%.

8.6.12 The use of time of flight diffraction (TOFD) testing method shall follow the provisions of the current national standard "Non-destructive testing of pressure equipment Part 10: Ultrasonic testing of time difference of diffraction" NB/T 47013.10.

8.6.13 Excessive defects in the weld shall be removed and repaired, and the test shall be expanded. Expanded testing shall comply with the following requirements:

1 At both ends of the original testing region, it shall respectively add one film of radiographic testing OR 1 m of ultrasonic testing.

2 When the radiographic testing or ultrasonic testing results are still not qualified, as for the automatic welding, it shall test all the welds produced by the welding machine of the day which produces this defect; as for the electrode arc weld, it shall test all the welds produced by the welder of the day who produces this defect.

8.6.14 The surface defects as found through inspection shall be removed as a whole through grinding, and the surface shall be checked again. The allowable amount of the local thickness reduction after removing the defects by grinding shall comply with the following requirements:

1 In the range of not less than 6t × 6t (t is the steel plate thickness), the final thickness of the steel plate shall not be less than 95% of the nominal thickness of the steel plate.

2 The distance between any two thickness reduction zones of steel plates shall be greater than or equal to the diameter of the circumscribed circle in which the area is to be largely reduced.

the provisions of the current industrial standard “Technical specification for post-installed fastenings in concrete structures” JGJ 145.

3 The permanently buried piece materials in the low-temperature work area (embedded parts and structural adhesive) shall comply with the low-temperature resistance performance requirements.

4 The embedded parts for construction shall be buried after approval by design.

9.0.6 Concrete curing measures shall be determined based on site climatic conditions as well as concrete mixing and other factors.

9.0.7 When the outdoor daily average temperature is lower than 5 °C for consecutive 5 days OR the minimum temperature is below 0 °C, it shall take winter construction measures. Winter construction measures shall comply with the provisions of the current industry standard “Specification for winter construction of building engineering” JGJ 104.

9.0.8 Concrete coating shall be applied directly on the surface. Before spraying, it shall polish the concrete surface; when the residual release agent and curing agent affect the cohesion of the coating, it shall remove them and conduct vacuuming treatment.

9.0.9 Prestressing tendons construction for wall shall comply with the following requirements:

1 The prestressed tendons shall be set in the central or outside the concrete wall.

2 Prestressing sequence shall be determined in accordance with the design, which may use circumferential direction after vertical direction AND the overall symmetrical method.

3 It is preferable for the wall horizontal circumferential tendons to be tensioned from bottom up; AND it is preferable for the steel strands of each layer to be done symmetrically from both ends.

4 The vertical tendons shall adopt vertical spacing symmetrical tensioning method along the wall column, AND it is preferable to use one end tensioning; the lower end may be fixed on the ground tensioning gallery AND the upper end may be fixed onto the ring beam of the dome.

9.0.10 It is not preferable for the construction joints of the foundation slab structure to be set on the bottom plate.

1 FH means full height hydraulic test, AND the water filling in the tank during test shall reach to the maximum design level;

2 PH indicates a partial height hydraulic test; during the test, the test water level in the inner tank shall be equivalent to 1.25 times of the maximum design level multiplied by the density of the specified stored liquid.

10.1.2 After all accessories on the wall and bottom of the tank are welded and passed inspection, it shall be subjected to the hydraulic test. After the hydraulic test, it shall not conduct welding again. The hydraulic test shall be conducted before the insulation construction of the inner tank and the outer tank.

10.1.3 It is preferable to use clean water to conduct tests which shall not damage the steel components. When the water quality fails to reach to requirements, it shall add appropriate inhibitor OR take other test methods.

10.1.4 When seawater is used as the test medium, it is preferable to provide cathodic protection. It is not allowed to use the seawater as the test medium for the stainless steel petrochemical steel low-temperature storage tanks.

10.1.5 It shall be cleaned after the test.

10.1.6 The hydrostatic test shall comply with the following requirements:

1 Before hydraulic test, it shall remove all the welding slag AND all materials, components or temporary installation pieces in the construction process, AND clean the storage tank.

2 When the outer tank is subjected to hydraulic test, it shall take measures to avoid the test water from entering into the bottom insulation layer.

3 In the test process it shall use permanent or temporary pressure release system which has a certain discharge capacity.

4 The water filling rate for the hydraulic test shall be determined based on the water source, equipment capacity, and the foundation soil conditions.

5 Before the test, it shall install the settlement observation points on the outer surface of the storage tank; AND the installation of the observation points shall comply with the following requirements:

1) When the tank diameter is less than or equal to 10 m, it shall install 4 observation points;

2) When the tank diameter is greater than 10 m, it shall install 8 observation points;

10.2.3 During the pressure test, it shall maintain the pressure at test pressure for 30 min, then reduce the pressure to the design pressure, AND conduct the soap liquid leakage test against all the welds; if there is no leakage, it is deemed as qualified. If the weld joint was subjected to vacuum leakage test, it may use visual inspection to substitute the soap liquid to conduct leakage test.

10.2.4 After passing the pneumatic pressure test, it shall set the set pressure of the pressure relief valve as the design pressure. The set pressure of the pressure relief valve shall be verified by pumping the air to the gaseous space.

10.2.5 The repair of the leakage shall be conducted after the finishing of the test, AND the repaired portion shall pass the vacuum leakage test.

10.2.6 The test pressure of the negative pressure test shall be equivalent to the design negative pressure of the storage tank. After reaching to the design negative pressure, it shall be deemed as qualified if there is no abnormal condition through inspection.

10.2.7 It is preferable for the negative pressure test to be conducted under the state when the tank has the hydrostatic pressure.

10.2.8 During the negative pressure test, the negative pressure shall be able to automatically release; it may install and adjust the negative pressure relief valve; AND it may also install a set of temporary pressure release system. When the negative pressure exceeds the test negative pressure, the negative pressure release valve and the temporary pressure release system shall be discharged automatically in time.

10.2.9 Before the negative pressure test, it shall close all the openings except for the negative pressure relief valve. The negative pressure test pressure can be ensured by lowering the water level OR using the air extractor.

10.2.10 After passing the negative pressure test, it shall set the set pressure of the negative pressure relief valve as the design negative pressure. The set pressure of the vacuum relief valve shall be verified by means of a reduced water level or by means of an air extractor.

10.2.11 After passing the air pressure test, it shall conduct the following work:

1 When anchor piece is installed, it shall re-check the anchorage tightness of the anchor seat, AND feed air into the empty tank and make the pressure reach to design pressure, AND the foundation shall not be uplifted during inspection.

2 It shall check whether the tank bottom has abnormality AND conduct vacuum leakage test against all welds of the tank bottom.

Appendix B Design information

B.0.1 Tank design conditions shall include, but not be limited to, the following:

1 Various working conditions;

2 Tank type;

3 Working pressure, design pressure and design negative pressure;

4 Set pressure;

5 Liquid inlet and outlet flow rate;

6 Confirmed action of earthquake, wind, pipeline or pipe load;

7 Abnormal effects of overflow, fire, explosion and other factors;

8 Design life;

9 Plan layout of storage tanks;

10 Tank capacity (net capacity or nominal capacity).

11 Environmental data (including ambient temperature, minimum temperature, or maximum temperature);

12 Process flow diagram (PFD), process and instrumentation flowchart (P & ID);

13 Metal design temperature of primary liquid container;

14 Relevant parameters of stored liquid (including specific gravity, temperature, toxicity, flammability);

15 Measures to prevent rollover (installing the density meter, making the product into a continuous cycle);

16 Allowable evaporation rate and environmental conditions;

17 Maximum normal operating fluid level;

18 Design parameters (flow rate) for pressure relief valve and negative pressure relief valves;

19 High-precision level gauge;

Appendix C Seismic design

C.0.1 As for the primary liquid containers, it shall conduct design based on the seismic impact of the fortified earthquake under the maximum operating level state. When using the secondary liquid container, it shall conduct design based on the seismic impact of the fortified earthquake under the maximum operating liquid level state of the secondary liquid container; meanwhile, it shall also conduct design based on the seismic impact of the rare earthquakes under the empty state of the secondary liquid container.

C.0.2 Earthquake action shall be determined in accordance with the seismic fortification intensity or the design ground motion parameters approved by the competent national authority.

C.0.3 When the secondary liquid container adopts reinforced concrete structure, its seismic fortification category shall be in accordance with category B, AND shall comply with the relevant requirements of the current national standard “Standard for classification of seismic protection of buildings and special structures in petrochemical engineering” GB 50453.

C.0.4 When the seismic fortification intensity is greater than 8 degrees OR the design basic seismic acceleration value is greater than 0.30g, it is preferable to use the time history analysis method for calculation.

C.0.5 When using the time history analysis method, it shall comply with the relevant provisions of the current national standard “Code for seismic design of buildings” GB 50011 and “Code for seismic design of structures” GB 50191.

C.0.6 The damping ratio of the primary liquid container is 4% at the fortified seismic level; the damping ratio of the reinforced concrete secondary liquid container is 5% at the fortified seismic level; the damping ratio at rare earthquake conditions is 10%; AND the damping ratio of the stored liquid is 0.5%.

C.0.7 When adopting the seismic isolation and energy dissipation design, it shall comply with the relevant provisions of the current national standard “Code for seismic design of buildings” GB 50011 and “Code for seismic design of structures” GB 50191.

Appendix D Testing for reinforced steel

D.1 Sampling

D.1.1 The rebar subjected to test shall be sampled from the ordered products of the same designation, same heat number, same rolling technology or same heat treatment system of each specification, AND it shall take samples from all the proposed strength classes.

D.1.2 The test records provided by the supplier shall not be used as the final basis.

D.2 Test

D.2.1 The tensile test shall be conducted at the design metal temperature, AND the design metal temperature shall be the minimum temperature may be exposed by the rebar under abnormal load conditions.

D.2.2 During the test, the temperature difference between any two points on the test specimen and the difference between the temperature at any point on the test specimen and the design temperature shall not exceed 5 °C.

D.2.3 The tensile test shall be conducted respectively on rebar specimens with notch and the rebar specimens without notch, AND it shall comply with the following requirements:

1 When the Notch Sensitivity Coefficient (NSR) is greater than or equal to 1, the toughness of the product can be judged as qualified. Notch sensitivity coefficient (NSR) can be determined in accordance with the following equation:

$$NSR = \frac{\text{Tensile strength of rebar with notch}}{\text{0.2\% ultimate elastic stress of rebar without notch}} \qquad (D.2.3\text{-}1)$$

OR

$$NSR = \frac{\text{Tensile strength of rebar with notch}}{\text{Lower yield stress of rebar without notch}} \qquad (D.2.3\text{-}2)$$

2 The notch on the rebar test specimen shall be located at the center of the mechanical clamps at both ends of the test bench, the notch shall be in V-shape, the internal included angle shall be 45°, AND the bottom radius

List of quoted standards

Code for design of concrete structures GB 50010

Code for seismic design of buildings GB 50011

Code for anticorrosion design of industrial construction GB 50046

Design code for lightning protection of buildings GB 50057

Code for construction of industrial equipment and pipeline insulation engineering GB 50126

Fire prevention code of petro chemical enterprise design GB 50160

Code for seismic design of structures GB 50191

Code for acceptance of constructional quality of concrete structures GB 50204

Code construction and acceptance of steel structure engineering GB 50205

Code for design of vertical cylindrical welded steel oil tanks GB 50341

Standard for classification of seismic protection of buildings and special structures in petrochemical engineering GB 50453

Code for design protection of petrochemical plant against lightning GB 50650

Pressure vessel - Part 2: materials GB 150.2

Steel plates for boilers and pressure vessels GB 713

High strength low alloy structural steel GB/T 1591

Hot rolled plates and strips of carbon structural steels and high strength low alloy structural steels GB/T 3274

Low alloy steel plates for low temperature pressure vessels GB 3531

Wrought aluminum and aluminum alloy plates, sheets and strips for general engineering GB/T 3880.1 ~ GB/T 3880.3

Steel wires for prestressed concrete GB/T 5223

Steel strand for prestressed concrete GB/T 5224

Test methods of inorganic rigid thermal insulation GB/T 5486

Wrought aluminum and aluminum alloys extruded profiles for general engineering GB/T 6892

Seamless steel tubes for petroleum cracking GB 9948

Welded stainless steel pipes for liquid delivery GB/T 12771

Anchorage, grip and coupler for prestressing tendons GB/T 14370

Seamless stainless steel pipes for fluid transport GB/T 14976

Seamless steel tubes for low-temperature-service piping GB/T 18984

General characteristics of liquefied natural gas GB/T 19204

9% Nickel steel plates for pressure vessels with specified low temperature properties GB 24510

Stainless steel plate, sheet and strip for pressure equipment GB 24511

Nondestructive testing of pressure equipment - Part 2: Radiographic testing JB/T 4730.2

Nondestructive testing of pressure equipment - Part 3: Ultrasonic Testing JB/T 4730.3

Nondestructive testing of pressure equipment - Part 4: Magnetic particle testing JB/T 4730.4

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Technical specification for spatial lattice structure JGJ 7

Technical specification for large-area formwork building construction JGJ 74

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Technical specification for post-installed fastenings in concrete structures JGJ 145

Technical code for safety of forms in construction JGJ 162

Low-alloy steel forgings for low-temperature pressure equipment NB/T 47009

Stainless and heat resisting steel forgings for pressure equipment NB/T 47010

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Welding procedure qualification for pressure equipment NB/T 47014

Specification for construction and acceptance of steel storage tank subgrade & foundation in petrochemical industry SH/T 3528

Technical code for construction of vertical cylindrical low temperature storage tank SH/T 3537

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