Foreword

This code is developed by China Petroleum and Chemical Corporation and Sinopec Luoyang Petrochemical Engineering Corporation in cooperation with other involved organizations in accordance with the requirements of Document JIAN BIAO〔2006〕No. 136 issued by original Ministry of Construction(MOC) of the People's Republic of China-the Plan for Developing and Revising National Engineering Construction Standards(2nd Group) in 2006.

In preparing this code, the development team made extensive investigations and summarized the practices on the low temperature steel storage tanks in petrochemical engineering, made references to international standards and advanced foreign standards, solicited the comments from all involved parties, and then finalized this code.

This code comprises 10 chapters and 5 appendixes, and mainly covers General Provisions, Terms, Basic Requirements, Materials, Design of Metallic Components, Design of Concrete Structures, Insulation, Fabrication, Inspection and Acceptance of Metallic Components, Concrete Construction and Workmanship, and Tests.

Ministry of Housing and Urban-Rural Development of the People's Republic of China is in charge of administration of this code, China Petroleum and Chemical Corporation is responsible for its routine management. Sinopec Luoyang Petrochemical Engineering Corporation is tasked for explanation of specific technical contents. During implementation of this code, any comments and recommendations can be posted or passed on to Sinopec Luoyang Petrochemical Engineering Corporation (Address: No.27 Zhongzhou Xilu, Luoyang City, Henan Province, P.R, China, postcode: 471003) to provide good a reference for future revision.

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Contents

1 General Provisions

1.0.1 This code specifies the design and construction of low temperature steel storage tanks for petrochemical services.

1.0.2 This code is applicable to the design and construction of aboveground vertical cylindrical steel single containment tanks, double containment tanks and full containment tanks used to store hydrocarbons or ammonia with boiling point between 0℃ and −165℃ and at a design pressure no higher than 50kPa.

This code is not applicable to membrane tanks and primary containers that are only constructed by pre-stressing concrete.

1.0.3 The low temperature steel storage tank for petrochemical service shall include the following items in addition to the tank body and the integral parts connected to the tank body:

1 The connections between the tank and the pipe outside the tank wall shall include:

1) The first circumferential joint in welding-end pipe connections that do not have a flange located near the tank;

2) The first threaded joint on the pipe outside the tank wall in threaded pipe connections;

3) The face of the first flange in a bolted flange connection;

4) The face of the first flange in a special connector or pipe fitting.

2 The covers and fasteners of the nozzle and manhole.

3 The cold insulation of the tank bottom, tank shell, tank roof and nozzles.

4 The structural components in the tank.

5 The anchoring structure of the tank.

1.0.4 In addition to this code, the design, fabrication and erection of the low temperature steel storage tanks shall also comply with the current applicable national codes and standards.

2 Terms

2.0.1 Operating pressure

Assumed gauge pressure for the overhead vapour space under operating conditions.

2.0.2 Design pressure

Assumed maximum positive pressure(gauge)for the overhead vapour space in the tank.

2.0.3 Design negative pressure

Assumed maximum negative pressure for the overhead vapour space in the tank.

2.0.4 Test pressure

Air pressure(gauge)in the overhead space of the tank during testing.

2.0.5 Set pressure

Pressure at which the pressure relief device first opens.

2.0.6 Minimum design temperature

Assumed temperature of the medium, for which the tank is designed.

2.0.7 Design metal temperature

Minimum temperature for which the metallic component is designed.

2.0.8 Maximum design liquid level

Maximum permissible liquid level for a tank.

2.0.9 Maximum normal operating level

Maximum liquid level that will be maintained during normal operation.

2.0.10 Single containment tank

A tank consisting of only one primary liquid container with insulation or a tank consisting of a primary liquid container and a vapour container.

2.0.11 Double containment tank

A tank consisting of a primary liquid container and a secondary container that is capable of containing any leakage of the refrigerated liquid but incapable of containing any vapour resulting from this leakage.

2.0.12 Full containment tank

A tank which is defined as a tank consisting of a primary liquid container and a secondary container capable of containing both any leakage of the liquid and any vapour resulting from this leakage.

2.0.13 Primary liquid container

Part of a single, double or full containment tank that contains the low temperature refrigerated liquid during normal operation.

2.0.14 Secondary liquid container

Part of the outer container of a double or full containment tank that contains the low temperature refrigerated liquid.

2.0.15 Inner tank

Metallic self-supporting cylindrical primary container.

2.0.16 Outer tank

Self-supporting cylindrical secondary container made of steel or concrete.

2.0.17 Roof

Structure on the top of a shell or wall containing the vapour pressure and sealing off the contents from the atmosphere.

2.0.18 Shell/wall

Metal or concrete vertical cylinder.

2.0.19 Vapour container

Part of a single, double or full containment tank that contains the vapour during normal operation.

2.0.20 Supporting roof of tank

A type of tank roof for which its load is supported by beams, columns, trusses or other structures.

2.0.21 Self-supporting roof of tank

A type of tank roof for which its loads are only supported by tank shell.

2.0.22 Rollover

Uncontrolled mass movement of stored liquid, correcting an unstable state of stratified of different densities and resulting in a significant evolution of product vapour.

2.0.23 Thermal protection system

Thermally insulating and liquid tight structure in order to protect the outer tank against low temperature.

2.0.24 Vapor barrier

Barrier to prevent entry of water vapour and air into the insulation or into the outer tank.

2.0.25 Percentage of plastic elongation

The percentage of plastic elongation is the permanent percentile increase of the original gauge length corresponding to tensile strength.

3 Basic Requirements

3.1 Types of Storage Tanks

3.1.1 A low temperature steel storage tank may be a single containment tank, a double containment tank or a full containment tank.

3.1.2 A single containment tank may be a single containment tank without outer shell (Figure 3.1.2-1) or a single containment tank with outer shell (Figure 3.1.2-2).

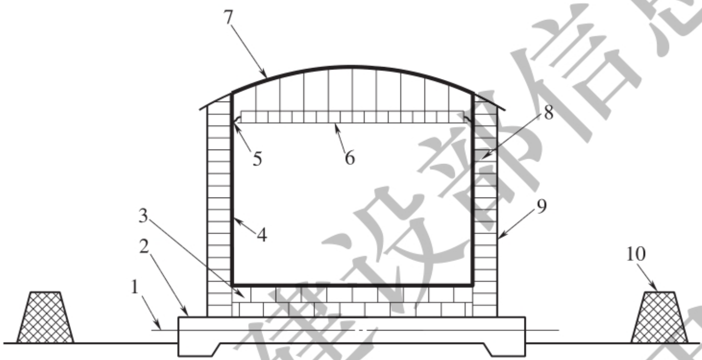


Figure 3.1.2-1 Single containment tank without outer shell

1-Foundation heating system; 2-Foundation; 3-Bottom insulation; 4-Primary container (steel); 5-Flexible insulating seal; 6-Suspended roof (insulated); 7-Roof (steel); 8-External shell insulation; 9-External water vapour barrier; 10-Bund wall

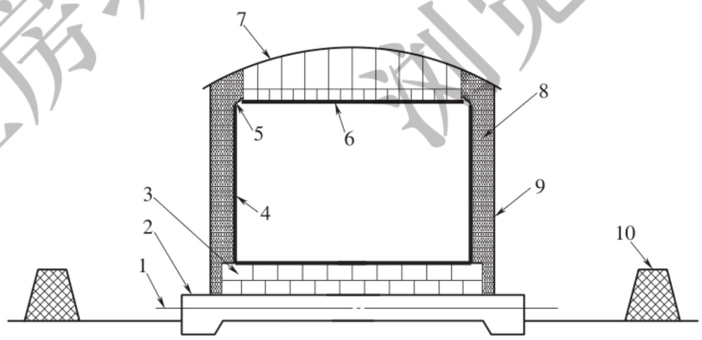


Figure 3.1.2-2 Single containment tank with outer shell

1-Foundation heating system; 2-Foundation; 3-Bottom insulation; 4-Primary container (steel); 5-Flexible insulating seal; 6-Suspended roof (insulated); 7-Roof (steel); 8-Lose fill insulation; 9-Outer shell (steel); 10-Bund wall

3.1.3 A double containment tank may consist of a primary container and a secondary steel container (Figure 3.1.3-1) or a primary container and a secondary concrete container (Figure 3.1.3-2). The annular space, between the primary and secondary containers, should not be more than 6.0m.

3.1.4 A full containment tank may consist of a primary container and a secondary steel container (Figure 3.1.4-1) or a primary container and a secondary concrete container (Figure 3.1.4-2). The annular space, between the primary and secondary containers, should not be more than 2.0m.

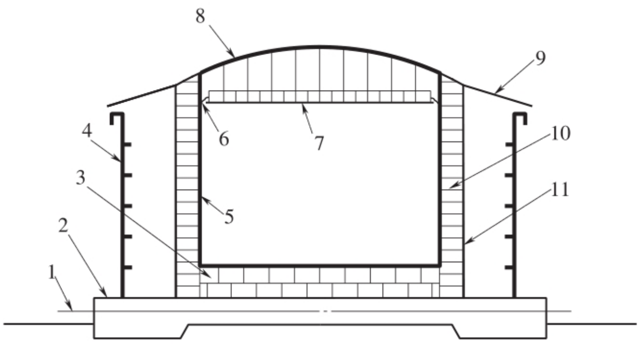


Figure 3.1.3-1 Double containment tank with secondary steel container

1–Foundation heating system; 2–Foundation; 3–Bottom insulation;
4–Secondary container(steel); 5–Primary container(steel);
6–Flexible insulating seal; 7–Suspended roof(insulated);
8–Roof(steel); 9–Cover(rain shield);
10–External insulation; 11–External water vapour barrier

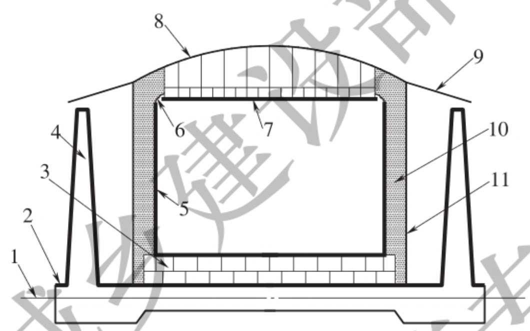


Figure 3.1.3-2 Double containment tank with secondary pre-stressed concrete container

1–Foundation heating system; 2–Foundation; 3–Bottom insulation;
4–Secondary container(concrete); 5–Primary container(steel);
6–Flexible insulating seal; 7–Suspended roof(insulated);
8–Roof(steel); 9–Cover(rain shield);
10–Lose fill insulation; 11–Outer shell(steel)

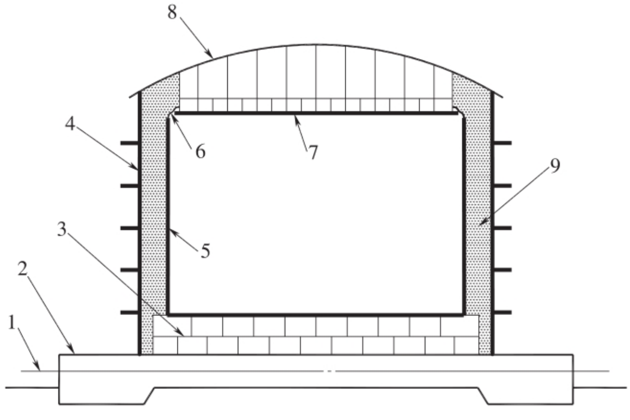


Figure 3.1.4-1 Full containment tank with secondary steel container

1–Foundation heating system; 2–Foundation; 3–Bottom insulation;
4–Secondary container(steel); 5–Primary container(steel);
6–Flexible insulating seal; 7–Suspended roof(insulated);
8–Roof(steel); 9–Loose fill insulation

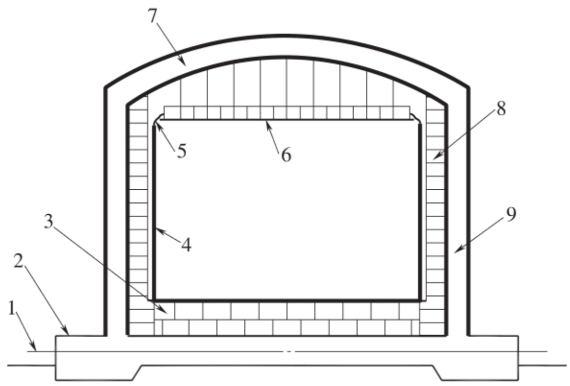


Figure 3.1.4-2 Full containment tank with secondary pre-stressed concrete container

1-Foundation heating system; 2-Foundation; 3-Bottom insulation; 4-Primary container(steel); 5-Flexible insulating seal; 6-Suspended roof(insulated); 7-Roof(concrete); 8-Insulation on inside of pre-stressed concrete outer tank; 9-Secondary container(concrete)

3.2 General Requirements

3.2.1 The main physical properties of gases stored in the low temperature steel storage tanks for petrochemical services shall be in accordance with Appendix A of this code, and the design conditions for low temperature steel storage tanks for petrochemical services shall include the information indicated in Annex B of this code.

3.2.2 The low temperature steel storage tank shall be designed to satisfy the following basic requirements:

1 The liquid and the vapour can be stored under normal operating conditions.

2 It can be filled and emptied at the specified flow rates.

3 Boil-off is controlled and in exceptional cases can be relieved to flare or vent.

4 Pressure operating range specified can be maintained.

5 Ingress of air and moisture is prevented, except in exceptional cases when the vacuum relief valves have to be opened.

6 Boil-off is as specified and condensation/frost on the external surface is minimized.

7 Damage due to specified accidental actions is limited and will not result in loss of liquid.

3.2.3 Low temperature steel storage tanks for petrochemical services should not be constructed in the areas with seismic precautionary intensity higher than 9 degrees or with design basic acceleration of ground motion greater than 0.40g.

3.2.4 Seismic design shall be made for the low temperature steel storage tanks for petrochemical services that are constructed in the areas with seismic precautionary intensity equal to or higher than 6 degrees or with design basic acceleration of ground motion no less than 0.05g. Seismic design of low temperature steel storage tanks for petrochemical service shall comply with the requirements specified in Appendix C of this code.

3.2.5 Vapour barrier may be provided for the outer pre-stressed concrete tank. The liquid tightness of the pre-stressed concrete structure, without a liquid tight liner, shall be ensured by the minimum compression zone in the concrete structure.

3.2.6 All inlets and outlets should, preferably, be made at the roof of the tank. In cases where bottom inlets and outlets are used, the external pipes should be welded to the bottom connection.

3.2.7 Fixed connections should, preferably, not be located within annular spaces between the primary and secondary containers. And if fixed connections are required, they shall comply with the specifications in Article 5.7 of this code.

3.2.8 The primary container shall provide a minimum freeboard above the maximum liquid level equal to 300 mm.

3.2.9 Markers for monitoring tank settlement shall be designed for the low temperature steel storage tanks for petrochemical services.

Tank settlement should comply with the following requirements:

1 For steel storage tanks, their differential settlement (the plane inclination, in mm) at diameter direction shall not exceed 125times the ratio of tank diameter to height; the differential settlement at the perimeter shall not exceed 10mm each 10m of circumference, and the differential settlement (in mm) between the tank center and the perimeter shall not exceed 1/240 of the tank radius.

2 For concrete storage tanks, their plane inclination shall not exceed 1/500, and the differential settlement between the tank center and the perimeter shall not exceed 1/300 of the tank radius.

3.2.10 Provisions against frost heave in foundation shall be designed for the low temperature steel storage tank for petrochemical service. The foundation heating system, if required, shall be designed so that the temperature of the foundation shall not drop below 0 ℃ at any place.

3.2.11 Thermal protection system shall be provided for the pre-stressed concrete secondary container. The thermal protection system shall cover the whole bottom and the lower part of the wall, and shall consist of steel plates (double bottom) and insulation material.

3.2.12 The height of the vertical part of the thermal protection system shall be determined based on temperature distribution and the deformation of the rigid corner.

3.2.13 Protection against the impact of lightning shall be provided for the low temperature steel storage tanks for petrochemical services, and shall be in accordance with the current national standard *Code for design protection of structure against lightning* GB 50057, and *Code for design protection of petrochemical plant against lightning* GB 50650.

3.2.14 Firefighting facilities for low temperature steel storage tanks for petrochemical services shall be in accordance with the current national standard *Fire prevention code of petrochemical enterprise design* GB 50160 and any other applicable current national standards.

3.2.15 The design loads of low temperature steel storage tank for petrochemical service shall include:

1 Self-weights.

2 Hydrostatic load of the medium.

3 Pre-stress.

4 Imposed loads shall include:

1) Uniformly distributed load of 1.2kN/m^2 over the projected fixed roof area. If snow load exceeds 0.6kN/m^2, the excess load shall be included;

2) Uniformly distributed load of 2.4kN/m^2 acting on the platforms and walkways;

3) Concentrated load of 5kN over an area of 300mm × 300mm placed at any location on platforms or walkways.

5 Wind loads.

6 Seismic actions.

7 Snow loads.

8 The pressure exerted by the cold insulation system (including perlite powder).

9 Design pressure.

10 Design negative pressure.

11 Test loads.

12 Thermal effects.

3.2.16 The corrosion allowance of the components of low temperature steel storage tanks for petrochemical services shall be determined based on corrosive characteristics of the stored medium and environment.

4 Materials

4.1 General Requirements

4.1.1 Steels used for low temperature steel storage tanks for petrochemical service shall be provided with quality certificates supplied by the steel manufacturers.

4.1.2 The materials used to construct low temperature steel storage tanks shall be properly selected based on the tank operating conditions, the material performances and economic consideration.

4.1.3 The materials used to construct concrete components in low temperature environment shall have low temperature resistant performance.

4.1.4 The steel of the primary container and secondary steel container shall be the killed steel produced by oxygen converter or electric furnace. If the design metal temperature is lower than −20℃, secondary refining shall be also used for the low temperature steel plates, the low temperature steel forgings and low temperature steel pipes.

4.1.5 The design metal temperature for each component shall be calculated based on the most pessimistic assumption.

4.1.6 Any special requirements for steels, if any, shall be specified in the design documents.

4.2 Metallic Tank Body

Ⅰ Primary and Secondary Liquid Container

4.2.1 The delivery states of steel plates used for low temperature steel storage tanks for petrochemical services shall be in accordance with Table 4.2.1.

Table 4.2.1 Delivery states of steel plates used for low temperature steel storage tanks

S/N	Steel grade	Applicable code/standard	Delivery state	Min.design temperature(℃)	Delivery thickness (mm)
1	Q245R	GB 713	Hot rolled, controlled rolled, normalized	−20	≤12
				−10	≤16
				0	≤34
				−20	≤20
2	Q345R	GB 713	Hot rolled, controlled rolled, normalized	−10	≤25
				0	≤34
3	Q370R	GB 713	Normalized	−20	≤34
4	16MnDR	GB 3531	Normalized, normalized and tempered	−40	≤34
5	15MnNiDR	GB 3531	Normalized, normalized and tempered	−45	≤34
6	09MnNiDR	GB 3531	Normalized, normalized and tempered	−70	≤34

Table 4.2.1 (continued)

S/N	Steel grade	Applicable code/standard	Delivery state	Min.design temperature(℃)	Delivery thickness (mm)
7	9Ni490	GB 24510	Double normalized and tempered	−196	≤30
8	9Ni590A	GB 24510	Quenched and tempered or double quenched and tempered	−196	≤30
9	9Ni590B	GB 24510	Quenched and tempered or double quenched and tempered	−196	≤30
10	S30408	GB 24511	Solution heat treated	−196	≤34

Notes: 1 The compression ratio shall not be less than 3 for the steel plates made by continuous casting-direct rolling process.

2 See the List of Reference Codes/Standards for the standard names of the steel plates shown in the table above.

4.2.2 For 9Ni590A and 9Ni590B steel plates, tensile test and Charpy V-notch impact test shall be carried out per heat treatment of the material. Tensile test and impact test shall be carried out for each completed plate from which liquid containing tank plates are cut.

4.2.3 Where Q245R and Q345R steel plates of thickness greater than 25mm are used to construct the shell and bottom of the primary container or the secondary container, they shall be in normalized condition.

4.2.4 Where the following steel plates are used to construct the shell and bottom of the primary container and the secondary container, each piece of steel plate shall be ultrasonically examined, and the examination method and quality grade shall be in accordance with the current applicable national standard *Nondestructive testing of pressure equipment-part 3: ultrasonic testing* JB/T 4730.3:

1 For Q245R and Q345R steel plates of thickness greater than 30mm, their acceptance quality criterion shall not be lower than Level Ⅱ;

2 For 16MnDR, 15MnNiDR and 09MnNiDR steel plates of thickness greater than 20mm, their acceptance quality criterion shall not be lower than Level Ⅱ;

3 For Q370R steel plate of thickness greater than 25mm, its acceptance quality criterion shall not be lower than Level Ⅱ;

4 For the steel plates supplied in quenched and tempered state and of thickness greater than 16mm, their acceptance quality criterion shall not be lower than Level Ⅰ.

4.2.5 If no corresponding standards are available for the steel structures used to construct the low temperature steel storage tanks in petrochemical services, the steel plates having the same performance may be used for substitution after prefabrication.

4.2.6 Where aluminum is used to construct the suspended roof, the selected aluminum plates and aluminum profiles shall be in accordance with the current applicable 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 alloy extruded profiles for general engineering* GB/T 6892.

4.2.7 The delivery states of steel pipes used for low temperature steel storage tanks shall be in accordance with specifications in Table 4.2.7.

Table 4.2.7 Delivery states of steel pipes used for low temperature steel storage tanks

S/N	Designation	Applicable code/ standard	Delivery state	Min.design temperature(℃)	Norminal thickness (mm)
1	10	GB 9948	Normalized	−20	≤30
2	20	GB 9948	Normalized	0	≤30
3	16MnDG	GB/T 18984	Normalized	−45	≤20
4	10MnDG	GB/T 18984	Normalized	−45	≤20
5	09Mn2VDG	GB/T 18984	Normalized	−70	≤20
6	06Ni3MoDG	GB/T 18984	Normalized	−100	≤20
7	0Crl8Ni9	GB/T 14976	Solution heat treated	−196	≤28
8	0Cr19NilO	GB/T 14976	Solution heat treated	−196	≤28
9	0Cr18Nil0Ti	GB/T 14976	Solution heat treated	−196	≤28
10	06Cr19NilO	GB/T 12771	Solution heat treated	−196	≤28
11	022Cr19NilO	GB/T 12771	Solution heat treated	−196	≤28
12	06Cr18NillTi	GB/T 12771	Solution heat treated	−196	≤28

Note: See the List of Reference Codes/Standards for the standard names of the steel pipes shown in the table above.

4.2.8 The materials of forgings used for tank nozzles shall comply with the current national standard *Low-alloy steel forgings for low temperature pressure equipments* NB/T 47009 and *Stainless and heat-resisting steel forgings for pressure equipments* NB/T 47010.

4.2.9 The materials of bolts, studs and nuts used for tank nozzle flanges shall comply with the current national standard *Pressure vessels-part 2: Materials* GB 150.2.

Ⅱ Vapotur Container

4.2.10 The delivery states of steel plates used for vapour container shall be in accordance with the specifications in Table 4.2.10.

Table 4.2.10 Delivery states of steel plates used for vapour container

S/N	Designation	Applicable code/ standard	Delivery state	Min.design temperature(℃)	Nominal thickness (mm)
1	Q235B	GB/T 3274	Hot rolled	−20	≤12
				0	≤24
2	Q235C	GB/T 3274	Hot rolled	−20	≤16
				0	≤30
3	Q245R	GB 713	Hot rolled, controlled rolled, normalized	−20	≤34
4	Q345B	GB/T 1591	Hot rolled, controlled rolled, normalized	−20	≤12
				0	≤20
5	Q345C	GB/T 1591	Hot rolled, controlled rolled, normalized	−20	≤12
				0	≤24
6	Q345R	GB 713	Hot rolled, controlled rolled, normalized	−20	≤34
7	16MnDR	GB 3531	Normalized, normalized and tempered	−40	≤34

Note: See the List of Reference Codes/Standards for the standard names of the steel plates shown in the table above.

Ⅲ Welding Consumables

4.2.11 Welding consumables shall be determined based on the chemical compositions, mechanical performances and welding performances of the parent metals as well as the construction characteristics, service conditions and welding procedures of the storage tanks, and they shall be determined by testing if necessary.

4.2.12 Welding consumables shall be provided with quality certificates.

4.2.13 Welding materials used to weld carbon steel and low alloy steel of different strength classes shall ensure the anti-cracking performance and mechanical performance of the welded joints, and the tensile strength shall not be higher than the upper limit of the parent metal in higher strength and shall not be lower than the lower limit of the parent metal in lower strength.

4.2.14 Welding consumables used for joints between high alloy steel and carbon steel or low alloy steel shall ensure the crack resistant performance and mechanical performance of the weld joints, and the welding consumables with Ni-Cr content higher than that of the high alloy steel should be used.

4.2.15 Welding materials used for primary liquid container shall be re-tested.

4.3 Materials of Concrete Components

Ⅰ Concrete

4.3.1 The concrete strength classes should not be lower than the specifications in the Table 4.3.1 below.

Table 4.3.1 Concrete strength classes

Structural component	Concrete strength
Piles	C30
Pile cap, tank bottom plate	C30
Ring beam under inner tank	C30
Pre-stressed wall	C50
Tank roof	C30
Concrete screed	C20

4.3.2 Enhanced strength, that is known to exist for concrete as a material of construction at low temperature, is normally not used in determining the ultimate strength of concrete sections. However, when adequate testing data is available, the low temperature properties may be utilized.

4.3.3 Admixtures of certain ratio may be considered appropriate for concrete.

4.3.4 Where air entraining agents are used, they may be resin based to ensure the concrete mix may contain up to 5% entrained air; however, the metal-based agents should not be used.

4.3.5 Concrete material should be Portland cement with low heat of hydration, ground granulated blast furnace slag or pulverized fuel ash may be used in combination with Portland cement. However, the designer shall be aware that there may be a slower strength gain.

4.3.6 The low temperature concrete mixing proportion shall be determined by laboratory testing.

4.3.7 For corrosive environment, the concrete shall also be in accordance with the current national standard *Standard for corrosion protection design for industrial constructions* GB 50046.

Ⅱ Steels

4.3.8 Typical yield strength of reinforcing steel for concrete tank may be selected from Table 4.3.8.

Table 4.3.8 Typical yield strength of reinforcing steel for concrete tank

Structural Member	Typical yield strength(N/mm^2)
Piles	335,400
Pile cap, tank bottom plate	335,500
Ring beam under inner tank	400,500
Pre-stressed wall(including buttress)	335,400,500
Tank roof	335,500

4.3.9 $2.0\times10^5 N/mm^2$ may be taken as the modulus of elasticity of reinforcing steel.

4.3.10 The reinforcing steel shall comply with the following requirements:

1 When the service temperature is not below -20℃, the reinforcing steel shall be in accordance the current national standard *Standard of concrete structure design* GB 50010.

2 When the service temperature falls below -20℃, the connectors shall be subject to tensile tests at low temperature, and the result difference of these tests shall be within 5% of those specified at ambient temperature.

4.3.11 In addition to the requirements specified in Table 4.3.8 of this code, the low temperature resistant steel in the interior wall of the pre-stressed wall shall also comply with the ductility requirements at low temperatures specified in Attachment D of this code. If the low temperature steel fails to satisfy the ductility requirements specified in Attachment D of this code, the following alternatives may be considered:

1 Carbon-manganese steel, 9% nickel steel or austenitic stainless steel.

2 Reducing allowable tensile stress of reinforcing or pre-stressing steel.

4.3.12 Pre-stressing steel shall comply with the following requirements:

1 Pre-stressing steel should be low-relaxation steel stands and shall have proper ductility, and its physical and mechanical properties shall comply with the current national standard *Steel strand for pre-stressed concrete* GB/T 5224, the typical ultimate strength should be $1860N/mm^2$, jacking stress should not exceed 80% of typical ultimate strength of the pre-stressing steel, and the stress relaxation after jacking for 1000h shall not be higher than 2.5%.

2 The modulus of elasticity of pre-stressing steel may be taken as $1.95\times10^5 N/mm^2$.

3 Pre-stressing steel shall be less sensitive to stress corrosion.

4 Pre-stressing steel should not be welded, and only the weld joints before pre-stressing are allowed for the single stranded wires in the steel strands.

4.3.13 Anchorage, grips and couplers for pre-stressing steel shall satisfy the strength, elongation and fatigue-resistant design requirements, and their specifications shall conform to the current national standard *Anchorage, grip and coupler for pre-stressing tendons* GB/T 14370. The anchorage shall have sufficient strength to permit the stress of pre-stressing steel to be transmitted to the concrete and shall properly work in case of cracking in the anchorage zone, and the anchorage shall not be located in high stress zone.

4.3.14 When the design temperature is lower than -20℃, special testing shall be carried out for the pre-stressing steel and anchorage.

4.3.15 Steel wires may also be used as the pre-stressing steel; however, they shall comply with the current national standard *Steel wires for the pre-stressed of concrete* GB/T 5223.

5 Design of Metallic Components

5.1 General Requirements

5.1.1 The low temperature steel storage tanks for petrochemical services shall be designed based on various combinations of loads.

5.1.2 The maximum allowable tensile stress of any plate or weld metal shall be in accordance with Table 5.1.2.

Table 5.1.2 Maximum allowable tensile stress of any plate or weld metal

Type of steel	Allowable stress in service	Allowable stress during hydrostatic test
Q235B、Q235C、Q245R、Q345B、Q345C、Q345R、Q370R、16MnDR、15MnNiDR、09MnNiDR	$0.43R_m$, $0.67R_{el}$, 260MPa, The lesser of: $0.43R_m$ or $0.67R_{el}$ or 260MPa	$0.60R_m$, $0.85R_{el}$, 340MPa, The lesser of: $0.60R_m$ or $0.85R_{el}$ or 340MPa
9Ni490、9Ni590A、9Ni590B	$0.43R_m$, $0.67R_{el}$, The lesser of: $0.43R_m$ or $0.67R_{el}$	
S30408	$0.40R_m$, $0.67R_{el}$, The lesser of: $0.40R_m$ or $0.67R_{el}$	

Notes: 1 R_m is specified tensile strength lower limit, in MPa, and R_{el} is specified yield strength lower limit, in MPa.

2 For 9%Ni steel, R_{el} may be 0.2% of proof stress (non-proportional) in MPa.

3 For austenitic steel, R_{el} may be 1.0% of proof stress (non-proportional) in MPa.

5.1.3 For seismic design, the allowable stress may be taken as following:

1 The allowable stress for precautionary earthquake may be 1.33times the allowable stress under operating conditions.

2 For seldom occurred earthquake, the allowable stress in tension may be $1.00R_{el}$, and the critical yield stress may be taken for allowable compression stress.

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

1 Normal operation: $0.50R_{el}$.

2 Test: $0.85R_{el}$.

3 Precautionary earthquake: $0.67R_{el}$.

4 Seldom occurred earthquake: $1.00R_{el}$.

5.1.5 Shell attachments and embedments shall be designed for a load corresponding to the full yield capacity of the uncorroded anchor bolts or anchor straps.

5.1.6 For LNG service, anchors made from 9% Ni steel or austenitic steel shall apply the anchor material yield stress at the boiling point temperature specified in the current national standard *General characteristics of liquefied natural gas* GB/T 19204 or colder .

5.1.7 The allowable compressive stress of the compression area at roof-to-shell junction shall not be greater than 120MPa.

5.1.8 For butt welds, where the load is perpendicular to the weld and in the plane of the plates, the allowable stress shall be limited to the value given in Table 5.1.2, and where the load is parallel to the weld, the allowable shear stress shall be limited to 75% of the value given in Table 5.1.2.

5.1.9 For fillet welds, where the load is perpendicular to the weld, the allowable shear stress shall be limited to 70% of the value given in Table 5.1.2, and where the load is parallel to the weld, the allowable shear stress shall be limited to 50% of the value given in Table 5.1.2.

5.2 Primary and Secondary Liquid Containers

Ⅰ Bottom

5.2.1 The annular plates of tank bottom shall have a minimum thickness (excluding corrosion allowance), t_a, but not less than 8mm:

(5.2.1)

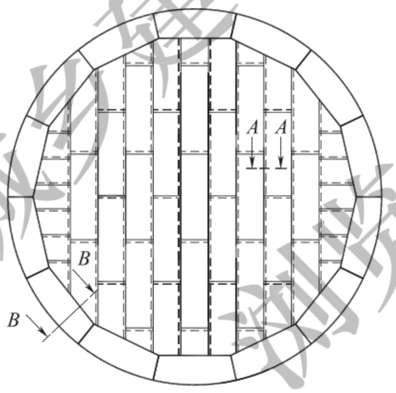
where: t_a——the minimum thickness of annular plate, in mm;

t_1——the thickness of the bottom shell course, in mm.

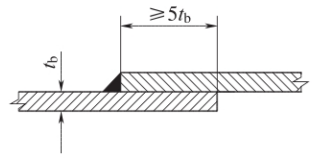
5.2.2 The joint of tank bottom and the bottom shell course shall comply with the following requirements:

1 The minimum width l_a, between the edge of the sketch plate and the inner side of the shell [see Figure 5.2.2(c)] shall be the value calculated by the following equation or 600mm, whichever is the larger:

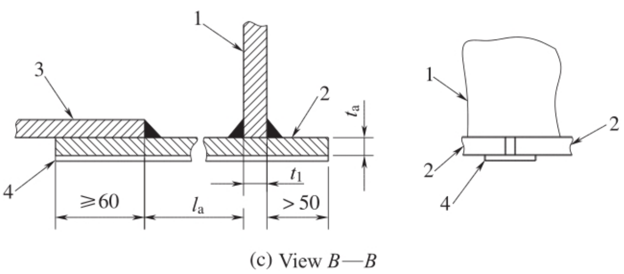
$$l_a > \frac{240}{\sqrt{H}} t_a \tag{5.2.2}$$



(a) With annular plates at the perimeter



(b) Section A—A, overlap of bottom plates



(c) View B—B

Figure 5.2.2 Typical bottom layout

1-Shell; 2-Annular plate; 3-Sketch plate; 4-Backing strip

Where: t_a——the thickness of the annular plate, in mm;

H——the maximum design liquid height, in m.

2 The radial joints between annular plates shall be butt welded.

3 Shell to annular plate attachment shall be either or:

1) Butt welded;

2) For the fillet welded at both sides, the maximum height of leg fillets is 12mm. Minimum leg size is the smaller of the shell or the annular plate thickness;

3) Groove weld plus fillet for annular plate greater than 12mm in thickness. The groove depth plus fillet leg shall equal to the annular plate thickness.

4 Annular plate radial joints shall not be located less than 300mm from any vertical shell joint.

5 Minimum distance from outside of the shell plate to the outer edge of the annular plate shall be 50mm.

6 Layouts and details for tank bottom and annular plating shall comply with the requirements in [Figure 5.2.2(a) and Figure 5.2.2(b)].

7 The annular plate width and thickness shall also meet anti-seismic requirements.

5.2.3 The minimum thickness of the bottom plates (excluding corrosion allowance) shall be 5mm, and following requirements shall apply:

1 Minimum length of straight edge of sketch plate shall be 700mm.

2 Sketch plates shall be joined by fillet or butt welding.

3 Lap joints shall have a minimum overlap of five times the thickness of the plate.

4 Fillet welds shall consist of at least two passes.

5 Bottom plates shall be lapped on top of the annular plates, and the minimum lap shall be 60mm.

6 Butt welds in bottom plates shall be welded either from both sides, or from one side using a backing strip.

7 Minimum distance between individual plate joints shall be 300mm.

8 Where reinforcing plates or backing strips are fitted to the bottom plate, continuous fillet welds shall be used.

Ⅱ Tank Shell

5.2.4 The minimum shell plate thickness shall be in accordance with specifications in Table 5.2.4.

Table 5.2.4 Minimum shell plate thickness

Tank diameter(m)	Minimum thickness(mm)
$D \leqslant 10$	5
$10 \leqslant D \leqslant 30$	6
$30 \leqslant D \leqslant 60$	8
$D > 60$	10

Note: The minimum shell plate thickness excludes the corrosion allowance.

5.2.5 The thickness of the shell plate shall be the greatest of the calculated plate thickness t_d under operating conditions, the calculated plate thickness t_t under hydrostatic test condition and the minimum tank shell thickness. The calculated plate thickness t_d under operating conditions and the calculated plate thickness t_t under hydrostatic test condition may be calculated by the following equations:

$$t_d = \frac{D}{[\sigma]_d}[4.9\rho(H-0.3)+0.5P]+C \tag{5.2.5-1}$$

$$t_t = \frac{D}{[\sigma]_t}[4.9\rho_t(H_t - 0.3) + 0.5P_t] \quad (5.2.5\text{-}2)$$

$$C = C_1 + C_2 \quad (5.2.5\text{-}3)$$

Where: C——the additional thickness, in mm;

C_1——the negative thickness deviation of steel plate, in mm;

C_2——the corrosion allowance, in mm;

D——the inside diameter of tank, in m;

t_d——the calculated wall plate thickness under operating conditions, in mm;

t_t——the calculated wall plate thickness under hydrostatic test condition, in mm;

H——the height from the bottom of the course under consideration to the maximum design liquid level, in m;

H_t——the height from the bottom of the course under consideration to the test liquid level, in m;

P——the design pressure, in kPa.0kPa for open top inner tank;

P_t——the test pressure, in kPa.0kPa for open top inner tank;

$[\sigma]_d$——the allowable design stress of steel plate or weld metal under operating conditions, in MPa;

$[\sigma]_t$——the allowable design stress of steel plate or weld metal under hydrostatic test condition, in MPa;

ρ——maximum specific gravity of liquid stored;

ρ_t——maximum specific gravity of test water.

5.2.6 No course shall be designed at a thickness less than that of the course above, except the compression area.

5.2.7 In addition to the requirements specified in Articles 5.2.4－5.2.6, the tank shell shall also comply with the following requirements:

1 All vertical and horizontal welds shall be butt welded for tank shell with full penetration and complete fusion.

2 The distance between vertical joints in adjacent courses shall not be less than 300mm.

3 Where attachments are made, Pad plates shall be used. They shall not be located within 300mm of a vertical weld or 150mm of a horizontal weld. Pad plates and reinforcing plates shall have rounded corners with a minimum radius of 50mm.

4 The inner tank shell subjected to external loading shall be able to withstand the combination of circumferential compressive and axial (longitudinal) stresses.

5.2.8 The design of intermediate ring stiffener shall comply with the following requirements:

1 The transformed shell method may be used to determine intermediate ring stiffener spacing for shells with varying shell thickness. The equivalent height (spacing) between the stiffeners may be calculated by the following equation:

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

Where: t——the as ordered thickness of each course in turn, in mm;

t_{min}——the as ordered thickness of the top course, in mm;

h——the height of each course in turn, in m;

H_e——the equivalent stable height of each course at t_{min}, in m.

2 Each intermediate horizontal ring stiffener shall be designed to take into account that portion of the shell considered to contribute to the stiffness of that ring.

3 The designs of the shell bottom corner and the top stiffener of an open top tank shall comply with the requirements for end stiffeners or bulkheads.

4 The stiffener shall be connected to the shell with a continuous fillet weld on both sides. A mouse-hole shall be used at intermediate stiffener butt welds and where the stiffener crosses a vertical weld.

5 Stiffeners shall be located at least 150mm from a horizontal weld.

5.2.9 The outer tank shell shall be designed to resist the combination of circumferential and axial (longitudinal) compressive stresses. The shell shall resist a radial pressure caused by the sum of the external wind pressure and vacuum(internal negative pressure).

5.3 Vapour Containers

Ⅰ Bottom

5.3.1 Design of tank center bottom and bottom annular plates shall be in accordance with Articles 5.2.1 to 5.2.3 of this code.

Ⅱ Shell

5.3.2 The minimum shell plate thickness shall be in accordance with Table 5.2.4.

5.3.3 For internal pressure, the shell plate thickness shall be calculated by the following equation:

$$t=\frac{PD}{2.0[\sigma]}+C \qquad (5.3.3\text{-}1)$$

$$C=C_1+C_2 \qquad (5.3.3\text{-}2)$$

Where: C——the additional thickness, in mm;

C_1——the negative thickness deviation of steel plate, in mm;

C_2——the corrosion allowance, in mm;

D——the container diameter, in m;

t——the calculated shell plate thickness, in mm;

P——the calculated internal pressure, i. e. the combination of internal gas pressure and insulation pressure, in kPa;

$[\sigma]$——the allowable design stress, in MPa.

5.3.4 Design of the outer shell with intermediate ring stiffeners shall consider vertical compression in combination with circumferential compression.

5.3.5 The shell shall be able to resist all applied loads, including but not limited to:

1 Vertical compression forces, including:

1) Dead loads;

2) Live loads(roof live, snow);

3) Pipe loads;

4) Internal vacuum pressure;

5) Wind overturning;

6) Seismic overturning.

2 Circumferential compression forces, including:

1) Wind local pressure effects;

2) Vacuum pressure.

5.3.6 The amount of design load (action) by suction on roof and overturning from wind to be considered in the calculations of the allowable biaxial stress shall depend on whether these act beneficial or adverse.

5.3.7 Stiffener splices shall be welded together with full penetration butt welds. A mouse-hole shall be used at stiffener butt welds and where the stiffener crosses a vertical weld. The overhead weld between the stiffeners and the shell shall be a continuous fillet weld, and bottom weld may be intermittent.

5.3.8 Stiffeners shall be located at least 150mm from a horizontal weld.

Ⅲ Roof

5.3.9 The minimum roof plate thickness shall be 5mm (excluding corrosion allowance).

5.3.10 For roof plates with supporting structure, the welds shall be selected in accordance with the following requirements:

1 The joint efficiency factor for single sided lap welds shall be 0.35;

2 The joint efficiency factor for double sided lap welds shall be 0.65;

3 The joint efficiency factor for butt welds with or without backing straps shall be 0.70;

4 If lap welds are used, lap welded roof plates shall have a minimum lap of 25mm.

5.3.11 The roof supporting structure should be ribbed type or ribbed type with diagonal bars. It may be designed in accordance with the current national standard *Technical specifications for space frame structures* JGJ 7.

5.3.12 Roof plates with supporting structure shall be of butt-welded or double lap welded, and the roof plate thickness shall be designed for internal pressure and to resist buckling due to external loading. The following formulas shall be used to calculate the roof plate thickness:

1 For internal pressure:

For spherical roofs:

$$t_r = \frac{PR_1}{2.0[\sigma]\varphi} \tag{5.3.12-1}$$

For conic roofs:

$$t_r = \frac{PR_1}{[\sigma]\varphi} \tag{5.3.12-2}$$

2 For buckling:

$$t_r = 40R_1\sqrt{\frac{10P_e}{E}} \tag{5.3.12-3}$$

Where: E —— the modulus, in MPa;

t_r —— the roof plate thickness (excluding corrosion allowance) in mm;

P —— the internal pressure less the weight of the corroded roof sheets, in kPa;

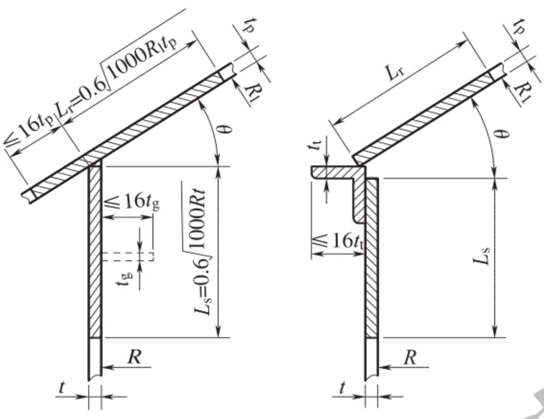
P_e —— the external loading, in kN/m^2;

R_1 —— the radius of curvature of roof, in m;

$[\sigma]$ —— the allowable design stress, in MPa;

φ —— the weld joint efficiency factor.

5.3.13 Without consideration of corrosion allowance, the minimum compression area, shall be determined by the following equation. The effective compression area shall be made up of plates and/or sections, where the maximum width shall meet the requirement (Figure 5.3.13).



(a) Without corner ring　　(b) With corner ring

Figure 5.3.13　Typical shell-roof compression areas

t-the thickness of shell, in mm (excluding corrosion allowance);

t_t-the thickness of top corner ring, in mm; t_g-the thickness of the horizontal girder, in mm;

t_p-the thickness of roof plate at compression ring, in mm (excluding corrosion allowance);

L_r-the effective roof length, in mm; L_s-the effective shell length, in mm;

R-the radius of tank shell, in m; R_1-the radius of curvature of roof, in m

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

Where: A——the minimum compression area required, in mm^2;

P——the internal pressure less the weight of the corroded roof sheets, in kPa;

R——the radius of the shell, in m;

$[\sigma]_c$——the allowable compressive stress, in MPa (see 5.1.7);

θ——the slope of the roof meridian at roof-shell connection, in degrees.

5.3.14　Where a top corner ring is used, the minimum size shall be in accordance with the specifications in Table 5.3.14.

Table 5.3.14　Minimum size of top corner ring

Shell diameter D (m)	Size of corner ring (mm×mm)
$D\leqslant 10$	∠63×6
$10<D\leqslant 20$	∠63×8
$20<D\leqslant 36$	∠80×10
$36<D\leqslant 48$	∠100×12
$D>48$	∠160×10

5.3.15　Single lap welded roof plates shall not be included in the compression area. Double lap welded roof plates may be included in the compression area.

5.3.16　The compression area shall meet the following requirements:

1　The horizontal projection of the effective compression area has a radial width of no less than 1.5% of the horizontal radius of the tank.

2　The compression area shall be arranged such that the centroid of the compression area falls within a vertical distance equal to 1.5times the average thickness of the two members intersecting at the corner, above or below the horizontal plane through the corner.

3 The compression area shall be checked for tension loading due to external loads (including internal negative pressure).

4 Care should be taken to avoid excessive bending in the compression area at the connection between the roof supporting member and the compression area.

5.4 Suspended Roofs

5.4.1 A suspended roof and its supporting structure shall be designed for the minimum design temperature.

5.4.2 The design load of suspended roof shall at least include the self-weight of suspended roof, the weight of insulation and live load, etc.

5.4.3 The structure's design shall be safe when any hanger becomes ineffective.

5.4.4 The design of ventilation openings of the suspended roof shall be such that the pressure difference between the space below and above the suspended roof is not greater than the weight of the suspended roof so that uplift cannot occur.

5.5 Nozzles

5.5.1 Pipe connections to the primary or secondary liquid container shall be in accordance with the specifications of Article 3.2.7 of this code.

5.5.2 Nozzles shall be designed to withstand the loads resulting from the connected piping and attachments.

5.5.3 When the nominal diameter of shell nozzle is larger than or equal to 80mm, reinforcement shall be required, and the nozzle connection and the minimum thickness of the nozzle shall be in accordance with the specifications of the current national standard *Code for design of vertical cylindrical welded steel oil tanks* GB 50341 and Table 5.5.3 of this code.

Table 5.5.3 Minimum shell nozzle body thickness (mm)

Nominal diameter	Minimum shell nozzle body thickness	
	Carbon steel and low alloy steel	Stainless steel
80≤*DJV*≤100	7.5	6.0
100<*DN*≤150	8.5	7.0
150<*DN*≤200	10.5	8.0
DN>200	12.5	9.0

5.5.4 When the nominal diameter of shell nozzle is less than 80mm, no additional reinforcement may be required, and the nozzle connection and the minimum thickness of the nozzle shall be in accordance with the specifications of current national standard *Code for design of vertical cylindrical welded steel oil tanks* GB 50341 and Table 5.5.4 of this code.

Table 5.5.4 Minimum shell nozzle body thickness (mm)

Nominal diameter	Minimum shell nozzle body thickness	
	Carbon steel and low alloy steel	Stainless steel
DN≤50	5.0	3.5
50<*DN*<80	5.5	5.0

5.5.5 Where nozzles are used as manholes they shall have a minimum internal diameter of 600mm.

5.5.6 The shell nozzle welding details shall be in accordance with the specifications of the current national standard *Code for design of vertical cylindrical welded steel oil tanks* GB 50341.

5.5.7 For design pressures equal to or lower than 6kPa, penetrations through the roof shall be reinforced and welded in accordance with the specifications of the current national standard *Code for design of vertical cylindrical welded steel oil tanks* GB 50341.

5.5.8 When design pressures are greater than 6kPa, penetrations through the roof shall be reinforced and welded as specified for shell nozzles in Articles 5.5.3-5.5.6 of this code.

5.5.9 Where the opening in the roof is elliptical, the required reinforcement shall be based on the long dimension of the elliptical opening.

5.5.10 Roof nozzles for cold liquid or cold vapour shall be provided with thermal distance pieces (see Figure 5.5.10).

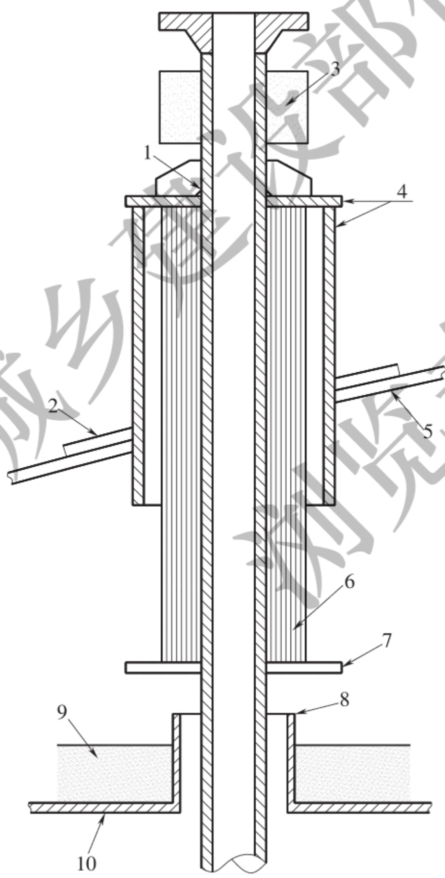


Figure 5.5.10 Typical roof nozzle with thermal distance piece

1-Nozzle pipe (cold temperature); 2-Nozzle reinforcing plate (ambient); 3-External pipe insulation; 4-Thermal distance piece (low temperature); 5-Dome roof (ambient); 6-Internal pipe cold insulation; 7-Support ring for cold insulation; 8-Suspended roof sleeve; 9-Suspended roof insulation; 10-Suspended roof

5.5.11 The flanges of all mountings, except shell and roof manholes, shall be made to have a pressure rating no less than 2.0MPa as a minimum.

5.6 Bottom Connections of Primary and Secondary Containers

5.6.1 The differential settlement of the tank foundation shall be in accordance with the specifications of Article 3.2.9 of this code.

5.6.2 The tank construction shall be designed to accommodate the differential contraction of the inner tank relative to the outer tank.

5.6.3 Nozzle opening shall be reinforced with doubled plate, thickened annular or sketch plate.

5.6.4 The space surrounding the nozzle and pipe shall be filled with suitable insulating material, and sufficient local anti-freezing measure base shall be provided.

5.7 Connections Between Primary and Secondary Containers

5.7.1 The connections between containers shall accommodate the thermal and hydrostatic forces caused by relative movement between the inner and outer tanks.

5.7.2 A heat insulation shall be considered for the connections between the inner and outer tanks.

5.7.3 Flanged joints shall not be located in the inaccessible annular spaces between the inner and outer shells.

5.7.4 The connections between openings in the inner and outer tank roofs shall be designed to accommodate the differential movement between the roofs. The connections passing through the suspended roof shall be able to move freely through the suspended roof, thus eliminating additional loads on either the outer roof or the suspended roof.

5.8 Other Requirements

5.8.1 The following subjects shall be considered for tank anchorage design:

1 Both the inner and the outer tanks shall be designed independently for all combinations of loads.

2 Attention shall be paid to the design of the inner tank anchorage where it penetrates the outer tank bottom plate to ensure the liquid tightness.

3 Anchorage points shall be equally spaced over the circumference of the tank with a maximum spacing of 3m.

4 No initial tension shall be applied to the anchorage.

5 Anchorage design shall allow for adjustment due to settlement prior to commissioning.

6 Anchorage shall be designed to take account of bending due to thermal movement.

7 Anchorage shall be attached to shells with pads or brackets. Any anchor bar, bolt or strap shall have a minimum cross-sectional area of $500mm^2$.

8 A corrosion allowance of at least 3mm shall be applied to all surfaces of anchorage bars, bolts or straps for anchors directly exposed to the atmosphere.

9 Cold protection measures shall be provided to prevent failure of the anchorage or tank from ice formation.

5.8.2 A name-plate shall be installed on each tank.

6 Design of Concrete Structures

6.1 General Requirements

6.1.1 The loads applied on the concrete tank and the design conditions shall be in accordance with Article 3.2.15 of this Code and Appendix B of this Code.

6.1.2 For concrete tanks, the limit state method based on probability theory should be used, the reliability index is used to measure the reliability of the structural components, and partial factor design equations are used for structure design for ultimate limit state and serviceability limit state.

6.1.3 When ultimate limit state method is used to design the concrete tanks, fundamental combinations of loads or seismic combinations of loads should be used for calculation, and when serviceability limit state method is used to design the concrete tanks, quasi-permanent combinations of loads and long-term effects or characteristic combinations of loads and long-term effects should be used for calculation.

6.1.4 In addition to satisfying the requirements for ultimate limit state and service ability limit state, the minimum wall thickness of the concrete tank shall also comply with the following requirements:

1 The spacing shall be sufficient for the reinforcement and pre-stressing tendons.

2 A homogeneous, liquid tight concrete structure shall be ensured, and the spacing between the reinforcement and pre-stressing tendons shall be sufficient.

6.1.5 Concrete cover shall comply with the following requirements:

1 The concrete cover selection of reinforcement shall take into account the exposure classification, soil conditions and emergency design conditions e.g. fire protection.

2 The minimum thickness of the concrete cover of reinforcement shall be in accordance with the current national standard *Code for design of concrete structures* GB 50010.

6.1.6 The position of pre-stressing system shall comply with the following requirements:

1 For internal pre-stressing systems using buttresses and grouted tendons, due account of the emergency conditions, e.g. fire scenarios, shall be taken to determine the position of the pre-stressing system.

2 The tendons shall be well protected from corrosion during the life of the tank.

3 Grouting procedures shall be properly designed.

6.1.7 Attention shall be paid to the design and execution of the construction joints. For the areas where liquid tightness is to be assured, the contractor shall carry out tests to demonstrate that the construction joint is liquid tight prior to construction.

6.1.8 The height of the wall section shall be at least 500mm above any temporary construction opening.

6.2 Liquid Tightness

6.2.1 For liquid tightness, the following shall be considered for the concrete tank:

1 For concrete outer containers without a liquid tight liner or coating, the liquid tightness of the concrete shall be ensured by means of the minimum compression zone of 100mm.

2 Where a liquid tight liner or coating is applied for the concrete container, the cracking of the concrete section shall be permitted within the limits specified by the current national standard *Code for design of concrete structures* GB 50010.

6.2.2 The cracking width of the concrete section shall be determined in accordance with the current national standard *Code for design of concrete structures* GB 50010.

6.2.3 Coating shall have sufficient flexibility to be capable of bridging crack widths. A bridging capability value of 120% of the calculated design crack width at normal operating temperatures shall be used.

6.3 Concrete Tanks

Ⅰ Tank Wall

6.3.1 Tank wall should be pre-stressed concrete structure.

6.3.2 Horizontal pre-stressing shall be applied for pre-stressed concrete wall. The vertical pre-stressing shall be determined based upon the calculations of tank design pressure, tank diameter and roof thickness.

6.3.3 Buttress columns shall be symmetrically provided around the outer face of the concrete wall, horizontal pre-stressing shall be made at the buttress columns, and the horizontal pre-stressing tendons shall be anchored.

6.3.4 Post tensioning method shall be used for pre-stressing. The design shall consider the pre-stressing loss due to anchor distortion, pre-stressing steel retraction, friction between the pre-stressing steel and conduits and at the steering devices, stress relaxation of the pre-stressing steel and concrete shrinkage and creep, etc.

Ⅱ Base Slab

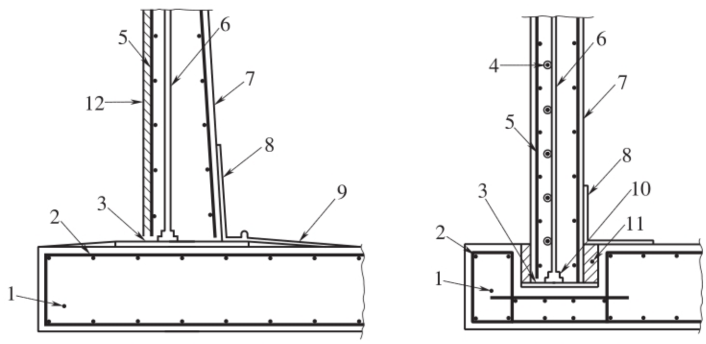
6.3.5 The tank base slab may be made of either pre-stressed or reinforced concrete.

6.3.6 When base slab is made in sections with construction joints, full attention shall be paid to the integrity of the construction joints so that a monolithic structure is ensured.

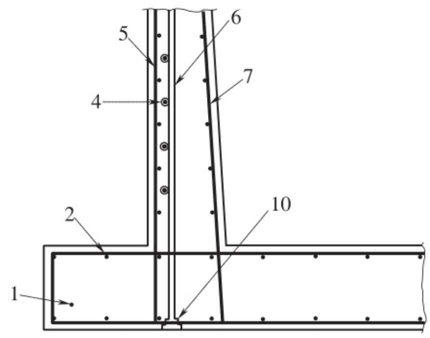
Ⅲ Wall to Base Junction

6.3.7 The wall to base connection may include sliding joint, pinned joint and fixed joint (see Figure 6.3.7).

6.3.8 For large and midsize tanks, fixed joint should be used.



(a) Sliding joint (b) Pinned joint



(c) Fixed joint

Figure 6.3.7 Typical joints of wall to base junction

1–Tank base; 2–Base reinforcement; 3–Bearing plate; 4–Circumferential pre-stress steel; 5–Wall reinforcement; 6–Vertical pre-stress steel; 7–Pre-stressed wall; 8–Stainless/nickel steel seal; 9–Radial strap; 10–Pre-stressing anchorage; 11–Grout; 12–Wire wound circumferential pre-stress of shotcrete layer

Ⅳ Tank Roof

6.3.9 When the design pressure is higher than 14kPa, reinforced concrete roof should be used, and roof structure shall comply with the following requirements:

1 An internal steel liner should be provided inside of the roof.

2 The steel liner may be used as formwork and may work as a composite structure.

3 When steel liner is used as a composite structure, the liner shall be anchored to the concrete by studs.

6.3.10 Roof may be also designed based on the construction methods used.

6.3.11 During the concreting, an air pressure inside the tank might be necessary to support the fresh concrete weight until sufficient resistance is reached.

6.3.12 Roof to wall junction should be rigid junction.

Ⅴ Foundation

6.3.13 Tank foundation may be shallow foundation, and when shallow foundation does not satisfy the requirements, piled foundation may be used.

6.3.14 Shallow foundation should be raft foundation. The thickness of slab should be increased for highly loaded areas e.g. under the tank shell and walls.

6.3.15 The design piled foundation shall satisfy the following requirements:

1 The use of piles is based on economic justification, and pile types, diameters and lengths shall be optimized in the foundation design.

2 The installation method and pile capacity shall be verified through a pre-production and production-testing program.

3 Consideration shall be given to designing the base and pile system to accommodate a redistribution of load in the event of failure of an individual pile.

4 Piles should be rigidly connected to the base.

5 The horizontal force caused by blast loading shall be calculated when there is explosion load.

6 When elevated slab is used, earthquake load shall be used to determine if "removable" vibration isolators are required.

7 When elevated slab is used, the elevated height shall be determined by temperature calculation.

8 The paving under the tank shall slope to the edge of the tank.

7 Insulation

7.1 Selection, Performance and Testing of Insulation Materials

7.1.1 The following factors shall be considered in the selection of the appropriate insulation materials:

1 The factor contributing to heat in-leak through the insulation system during normal operation of the tank.

2 The design thermal resistance for each component of insulation and the actual thermal resistance offered by the insulation under accidental conditions as well as the designed duration of the accidental condition.

3 The static and dynamic loads-applied to the insulation materials in all directions.

4 Tank insulation design inherent with the selected specific insulation system, installation method and type of containment.

7.1.2 Assessment of the performances of the insulation materials and their products shall include:

1 Thermal resistance: it shall include thermal conductivity and the possible heat in-leak through radiation, convection and cold bridges.

2 Mechanical properties: it shall include short-term and long-term compressive properties, tensile and shear properties, and the adhesive strength for insulation systems.

3 Temperature resistance: it shall include the impacts of maximum and minimum service temperatures and possible temperature changes, expansion coefficient, tensile strength and tensile modulus on the shrinkage, expansion and possible cracking in the design temperatures.

4 Resistance to water and water vapour: it shall include:

1) Closed cell content, permeability for water vapour and water absorption of the insulation;

2) Reduction of thermal resistance due to water and water vapour penetration, and the possible structural damage to the insulation by liquid water or by the process of freezing (possibly freeze/thaw cycles).

5 Influences of stored products on the insulation shall include:

1) Closed cell content of the insulation;

2) Absorption of product vapours and effect on other material properties;

3) Absorption of/and permeability for liquid product;

4) Effects of long—term liquid absorption on other material properties;

5) Desorption behavior: time/percentage.

6 An assessment shall be made of the compatibility between and/or possible chemical reactions of insulation system, its environment and tank material and/or its coating in contact with the insulation system.

7 For fire risk during construction or in case of an external fire, the following properties of insulation shall be assessed:

1) For combustion performance, the flammability, fire retarding properties and toxic gas generation are the main aspects for assessment;

2) For the maximum temperature limits of the material, melting temperature, decomposition temperature and ignition temperature are the main aspects for assessment.

7.1.3 The performances of the insulation materials shall be demonstrated by laboratory testing, simulation testing or testing of complete installed tank insulation system.

7.1.4 Commonly used insulation materials are selected based upon Annex E.

7.2 Protection of Insulation

7.2.1 The outer tank shall comply with the following requirements if it provides the protection and the support for the insulation:

1 The outer tank shall have sufficient tightness;

2 If the outer tank is made of concrete, a metallic liner or a polymer vapour barrier (PVB) shall be provided.

7.2.2 Protective cover for external insulation shall comply with the following requirements:

1 Where the insulation is placed externally, an appropriate cover shall be provided. This cover shall give protection against weather factors such as water vapour, rain, snow, hail, wind, storm, solar radiation and UV, other atmospheric factors such as pollution and corrosion, mechanical damages by humans and birds, and fire damage.

2 A water vapour barrier (WVB) shall be installed on the outside of the insulation. The maximum WVB permeability shall be $0.5g/m^2$ 24h under the average water vapour pressure differential of the area where low temperature steel storage tanks for petrochemical services are installed.

3 The protective cover and water vapour barrier of external tank insulation may be metallic or non-metallic and a combination of both.

7.3 Design of Insulation System

Ⅰ Thermal Design

7.3.1 The design of the tank insulation system shall be based on structural and thermal requirements, the installation method and the commissioning and decommissioning requirements.

7.3.2 Thermal design shall comply with the following requirements:

1 The boil-off per day shall not be higher than the maximum allowable boil off.

2 Icing/condensation on external surfaces of the tank shall be prevented, and the minimum design temperature of outer tank components shall be higher than the dew point temperature.

3 Soil freezing shall be prevented.

7.3.3 The insulation thickness shall be determined based on heat in-leak and the minimum condensation or icing requirements.

Ⅱ Structural Design

7.3.4 The structural design of the insulation system shall be based on the allowable stress theory.

7.3.5 The tank bottom insulation and thermal protection system shall be able to withstand the compressive loads.

7.3.6 When brittle materials are subject to compression, its allowable compressive strength shall be nominal compressive strength σ_n divided by the safety factors. And the nominal compressive strength σ_n and safety factors shall be determined in accordance with the following requirements:

1 The compressive strength shall be tested in accordance with the current national standard *Test methods for inorganic rigid thermal insulation* GB/T 5486, and the results are expressed as maximum compressive strength σ_m.

2 The average value of maximum compressive strength σ_m is taken as the nominal compressive strength σ_n of this material; however, if the lower specification limit (average value, less two times the standard deviation) is lower than 67% of σ_n, then the σ_n shall be adjusted as 1.5 times the lower specification limit.

3 The safety factors shall be taken as follows:

1) Normal operation: 3.00;

2) Hydraulic test: 2.25;

3) Precautionary earthquake: 2.00;

4) Seldom occurred earthquake: 1.50.

7.3.7 For material susceptible to creep, its permissible compressive strength shall be the permissible load (PLD) divided by the safety factor. PLD and the safety factor shall be calculated in accordance with the following requirements:

1 The permissible load (PLD) shall be the product of nominal compressive strength σ_n multiplying permissible load factor (PLDF).

2 The nominal compressive strength σ_n of the material shall be calculated as the average value of a statistically sufficient number of short term compressive tests; however, if the lower specification limit (average value less two times the standard deviation) is lower than 67% of σ_n then the σ_n shall be adjusted as 1.5 times the lower specification limit.

3 The PLDF for a specific material shall be determined with repeated creep tests.

4 The safety factors shall be taken as follows:

1) Normal operation: 1.25;

2) Hydraulic test: 1.00 (duration: less than or equal to 1 month);

3) Precautionary earthquake: for PUF and PVC material, 0.5 may be used;

4) Seldom occurred earthquake: for PUF and PVC material, 0.33 may be used.

7.3.8 The safety factors of other loads for allowable stress theory shall be determined on a case-by-case basis.

Ⅲ Insulation for Each Tank Component

7.3.9 The thickness of insulation for each tank component shall be determined based on the total maximum heat in-leak and the minimum condensation or icing formation.

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

1 The structural design shall take into account of the lateral forces due to tank shrinkage and earthquake, and the possible movement of the tank shell due to wind load, filling/emptying and earthquake.

2 Waterproofing and water vapour barrier shall be provided for the ring-beam.

3 The thermal design of the ring-beam shall be carried out in conjunction with base slab heating system, and the design shall be such that a "cold spot" under the supporting ring is minimized/prevented.

4 For a base slab supported by a raft foundation, the temperature under the foundation shall not drop below 0℃.

5 For the vertical anchors passing through the ring-beam, cold bridge effects should be reduced, water/water vapour ingress shall be prevented, and the anchors shall have sufficient flexibility.

7.3.11 The structural design of tank bottom insulation shall take into account the flatness of base plate, flatness of individual insulation layers, prevention of cold spot in foundation and the load bearing of materials. Purging facilities and thermal protection system shall be provided when necessary.

7.3.12 The structural design for shell external shell insulation shall comply with the following requirements:

1 The insulation structural design shall take into account of the thermo-mechanical stresses imposed on the insulation by dimensional changes of the tank and its anchors, and the method of fixing the insulation around the tank shell may be determined based on the conditions of insulation and vapour barrier.

2 Fire resistance of the external shell insulation shall be designed based on the local adjacent facilities, piping etc. of the tank.

3 The selected insulation system shall withstand the external weather and atmospheric conditions in the designated location for the specified design lifetime of the insulation.

4 Anticipated weather conditions during insulation works shall be considered in the selection process of the insulation materials and system.

7.3.13 The design for shell/wall insulation shall comply with the following requirements:

1 The thickness of the shell insulation layer shall be determined based on the thermal engineering design.

2 The strength of insulation fixed against the inner surface of the outer tank shall withstand its dead load and thermal stresses, and the fixing method shall be determined based on the insulation, shrinkage/expansion of the outer tank wall, vapour tightness and liquid tightness of the insulation system, and chemical resistance of the insulation in the annular space conditions.

3 The strength of insulation fixed against the outer surface of the inner tank shall withstand its dead load and thermal stresses, and the fixing method shall be determined based on the insulation, shrinkage/expansion of the inner tank wall, and water vapour tightness of the insulation system.

4 When loose fill insulation is used in annular space, it shall withstand the thermo-mechanical stresses imposed on the insulation by possible dimensional changes of the inner tank and possibly the outer tank, and in this case, a resilient blanket shall be used on the outer surface of the inner tank.

5 The settlement of the loose fill materials can be reduced by the use of vibration during installation, and the use of perlite refill nozzles shall be considered.

6 During normal operation or in case of leakage, the insulation shall not result in absorption/desorption of the product stored, and shall be suitable for the possible purging of insulation.

7.3.14 The design for roof external insulation system shall comply with the following requirements:

1 Weather protective cover and water vapour barrier shall be provided.

2 The insulation system shall be suitable to withstand the external weather and atmospheric conditions in the tank site.

3 The insulation system shall withstand the thermo-mechanical stresses on the insulation from the dimensional changes of the tank.

4 Access for maintenance shall be provided.

5 The insulation system shall be fire resistant.

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

1 Temporary access, such as walkways etc. shall be provided.

2 For the thermal design, not only the thermal conductivity of the selected insulation material shall be taken into account but also the possible heat leak through convection, cold bridges (suspended roof hangers) etc.

3 The initial thickness of the roof insulation shall compensate for the possible settling of the insulation.

4 Special attention shall be paid to the design of tanks where internal product condensation may occur in the dome roof space.

7.4 Insulation Installation

7.4.1 Insulation installation shall be in accordance with the relative specifications of the design documents, this Code and the current national standard *Code for construction of industrial equipment and pipeline insulation engineering* GB 50126.

7.4.2 Detailed installation procedures shall be developed prior to the start of insulation installation works. In the development of construction procedures of storage tanks and during the installation of insulation system, measures shall be taken to prevent the insulation materials from being damaged.

7.4.3 Insulation materials and their products shall be provided with product quality inspection reports and ex-factory certificates, and their technical indicators such as sizes and performance shall comply with the applicable technical standards and design documents.

7.4.4 Transport and storage shall be in such conditions that no degradation (physical or chemical or any other) can occur between the stage of manufacturing and the stage of installation.

7.4.5 Anti-corrosion protection of all tank surfaces that require the treatment shall be completed prior to start of installation of insulation works.

7.4.6 Insulation installation and repair shall be carried out with such methods so as not to damage the anti-corrosion protection.

7.4.7 After insulation installation is completed, it shall be inspected and accepted in accordance with the applicable technical documents.

8 Fabrication, Inspection and Acceptance of Metallic Components

8.1 General Requirements

8.1.1 The fabrication of metallic components of low temperature storage tanks for petrochemical service shall comply with the requirements specified in design documents and this code, and the construction of associated steel structures shall comply with the specifications in current national standard *Code for acceptance of construction quality of steel structures* GB 50205.

8.1.2 The changes of the design documents and materials shall be approved by the original designers in written form.

8.2 Material Management

Ⅰ Inspection and Acceptance of Materials

8.2.1 Steels, attachments and welding consumables for low temperature steel storage tanks for petrochemical service shall be provided with quality certificates, and their performance data shall comply with the applicable codes and standards, and shall satisfy the requirements specified in the design documents.

8.2.2 Material quality certificates for low temperature steels, low temperature welding consumables and low temperature attachments used to construct low temperature steel storage tanks shall clearly indicate the steel grades, specifications, chemical compositions, mechanical properties, low temperature impact toughness, delivery state and applicable material fabrication standards.

8.2.3 Steel plates used to construct the low temperature steel storage tanks for petrochemical service shall be visually inspected piece by piece, and shall comply with the following requirements:

1 Steel plate surfaces shall be free of cracks, pores, shrinkage, sand inclusion, heat tears, scale or lamination;

2 Steel plate surfaces shall be free of any mechanical scratches.

3 Markings shall be clearly stamped or engraved on the steel surface, and consistent with material quality certificates.

8.2.4 The sum of local thinning plus actual negative deviation of steel plates shall not be greater than the specified allowable negative deviation in the applicable codes and standards.

8.2.5 Chemical compositions and mechanical properties of low temperature steels and low temperature welding consumables shall be re-checked based on the applicable specifications.

Ⅱ Storage and Handling

8.2.6 All plates used for low temperature steel storage tanks shall be fabricated, handled and stored separately to prevent materials from intermixing.

8.2.7 Surface of Stainless steel shall be prevented from contamination during fabrication, storage and handling.

8.2.8 Magnetism of 9% nickel steel shall be avoided, and the residual magnetism shall not exceed 50 Gauss.

8.2.9 Welding consumables shall be protected and stored in accordance with the conditions specified by the welding consumables standards and/or the supplier's recommendations.

Ⅲ Markings and Transplant

8.2.10 Low temperature steel plates shall be marked. Markings shall remain visible after erection of the low temperature steel storage tanks for petrochemical services. In case the markings become obliterated during fabrication, at least one marking shall be moved to a location that will be visible after completion of the tank.

8.3 Fabrication

8.3.1 The layout of shell plates and bottom plates of low temperature steel storage tank for petrochemical services shall comply with the following requirements:

1 The minimum length of straight edge of sketch plate shall be 700mm.

2 The minimum distance between any neighboring welds of bottom plates shall be 300mm.

3 The minimum distance between annular plate radial joints and vertical shell joint shall be 300mm.

4 The distance between vertical joints in adjacent courses shall be no less than 300mm.

5 Shell stiffener radial joints shall not be located within 150mm from any vertical shell joint.

8.3.2 Plate edge fabrication shall comply with the following requirements:

1 Flame cut edges shall be ground to bright metal and shall be free from oxides and scale.

2 Tolerances shall be determined based on the steel making process, shop fabrication procedures and proposed erection method. The maximum difference in width of a shell ring shall be within 4mm of the value used in the design.

3 The grooves of low temperature steel plates should be machined.

4 All annular plates shall have the outer edge and both short edges ultrasonically examined for a width of 150mm after fabrication for laminations in accordance with the current national standard *Nondestructive testing of pressure equipment-part 3: ultrasonic testing* JB/T 4730.3.

8.3.3 When the shell plates are rolled, the rolling direction of the steel plates shall be perpendicular with the roller axis. After the steel plates are rolled, they shall be positioned perpendicular with the platform, an inner arc gauge in a cord length no less than 2000mm shall be used to check the horizontal direction and the gap shall not be larger than 4mm, and a straight gauge in a length no less than 1000mm shall be used to check the vertical direction and the gap shall not be larger than 2mm.

8.3.4 Where nozzle necks in primary or secondary liquid container are made from rolled plate, the longitudinal weld in the nozzle neck shall be 100% radio graphically or ultra-sonically tested.

8.3.5 When shell nozzle necks are manufactured from carbon steel plate of thickness $\geqslant$ 25mm, an ultrasonic examination for laminations shall be made in the area where the shell and reinforcing plate are welded to the nozzle.

8.3.6 Slip-on flanges shall be welded from both sides. All weld-neck flanges shall have full penetration butt welds.

8.3.7 The reinforcement plates shall be arc machined, and each reinforcement plate shall have at least one signal hole.

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

8.3.9 Prefabricated components shall be marked with numbers in a timely manner.

8.3.10 Provisions against deformation shall be provided for storage and handling of prefabricated components.

8.4 Field Installation

8.4.1 Where a concrete ring beam is provided under the shell, the top of the ring beam shall be level in accordance with the following requirements as measured from the average elevation:

1 The top of the ring beam shall be level to ±3mm in any 10m of circumference.

2 The top of the ring beam shall be level to ±6mm in the total circumference.

8.4.2 Where a concrete base slab is provided, the area 300mm inside and 300mm outside the shell shall comply with the concrete ring beam level tolerances. Any deviation for other foundation surfaces, measured with a 3m long template, shall not exceed ±15mm.

8.4.3 Local distortions of the bottom plates shall be minimized by controlling the welding sequences, installation of temporary stiffeners etc. After the bottom plates are welded, the depth of local distortion shall not be larger than 2% of the distortion length and shall not be larger than 50mm.

8.4.4 The misalignment of shell plate assembly shall comply with the following requirements:

1 The maximum misalignment of shell plates at vertical joints shall be in accordance with Table 8.4.4.

Table 8.4.4 Maximum misalignment at vertical joints (mm)

Shell plate thickness (δ)	Maximum misalignment
$\delta \leqslant 10$	1
$\delta > 10$	$\leqslant 0.1\delta$, $\leqslant 1\%0.1\delta$, and not larger than 1.5
	$\leqslant 1$ for automatic welding

2 The misalignment of shell plates at horizontal joints shall comply with the following requirements:

1) When manual welding by the welders is used and the thickness of the upper plate is less than or equal to 8mm, the misalignment at any point shall not be greater than 1.5mm; if the thickness of the upper plate is larger than 8mm, the misalignment at any point shall not be greater than 0.2 times the thickness of the plate and shall not be larger than 2mm.

2) When automatic welding is used, the misalignment at any point shall not be greater than 1.5mm.

8.4.5 After assembly and welding of the bottom shell course to the bottom, the inside radius measured horizontally at a height of 300mm above the bottom of the shell shall be within the limits given in Table 8.4.5. Measurements shall be made at the center of each shell plate.

Table 8.4.5 Radius tolerance

Tank diameter D (m)	Radius tolerance (mm)
$D \leqslant 12$	±12
$12 < D \leqslant 46$	±19
$46 < D \leqslant 76$	±25
$D > 76$	±30

8.4.6 The difference between the maximum and minimum diameter at any elevation shall not exceed 1% of the diameter, or 300mm, whichever is the lesser.

8.4.7 After assembly and welding, the local deformation in the shell plates shall be smooth. Local deformation in shell plates shall be examined with a 1m straight edge in the vertical direction and with a 1m long template in the horizontal direction (see Figure 8.4.7). The maximum difference between the design profile and the as built profile shall be as given in Table 8.4.7.

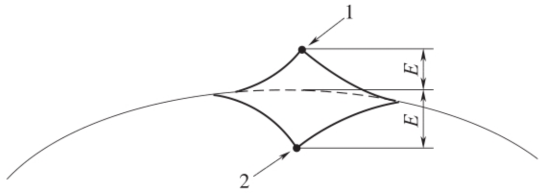


Figure 8.4.7 Outward and inward peaking

1–Outward peaking; 2–Inward peaking

Table 8.4.7 Maximum differences between the design and the as built profile(mm)

Pate thickness(δ)	Permissible local deformation in shell plates, E
$\delta \leqslant 12.5$	15
$12.5 < \delta \leqslant 25$	13
$\delta > 25$	10

8.4.8 The allowable local deformation at welds, peaking, (see Figure 8.4.8) shall be in accordance with Table 8.4.8.

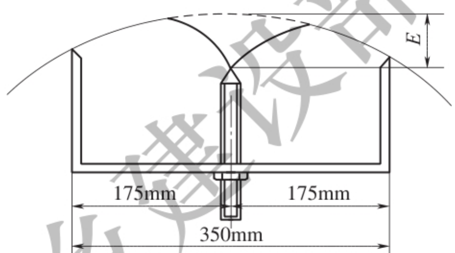


Figure 8.4.8 Gauge for measuring peaking

Table 8.4.8 Allowable local deformation at welds(mm)

Pate thickness(δ)	Allowable local deformation at welds, E
$\delta \leqslant 12.5$	12
$12.5 < \delta \leqslant 25$	9
$\delta > 25$	6

8.4.9 The maximum out-of-plumpness of the top of the shell relative to the bottom of the shell shall not exceed 0.4/100 of the total height or 50mm whichever is less. The same tolerance shall apply to individual shell courses.

8.4.10 The method of construction shall be such that stability of the roof shall be ensured throughout the erection process. Where a temporary supporting structure is used, the contractor shall take all necessary precautions to avoid the twisting of the support frame and rotation of the structure as a whole.

8.4.11 The maximum out-of-plumpness of liners shall not exceed 100mm.

8.4.12 The tolerance of the center of the nozzle openings shall not be larger than 10mm, and the tolerance of the extended length of the nozzles shall be +100mm.

8.4.13 The nozzle flange face shall be well protected without any radial scratches, the out-of-plumpness of the flange face and the nozzle axial line shall not be larger than 1% of the outer diameter of the flange and shall not be greater than 3mm, and the flange blots shall saddle the centerline.

8.4.14 Temporary attachments shall be welded by the same procedures used for the material to which they are attached, and shall comply with the following requirements:

1 The temporary attachment shall be removed by thermal cutting, gouging or grinding.

2 After removal of temporary attachment by thermal cutting or gouging, 2mm material shall be left and ground off to a smooth surface.

3 Magnetic powder examination or penetration examination shall be performed after removal of temporary attachment.

8.5 Welding Procedures

Ⅰ Welding Procedure Approval Record(WPAR)

8.5.1 WPAR shall comply with the following requirements:

1 All weldings, including repair and tack weldings, shall have a Welding Procedure Approval Record(WPAR)and a Welding Procedure Specification(WPS).

2 WPAR for low temperature steel storage tanks in petrochemical service shall be in accordance with the current national standard *Welding procedure qualification for pressure equipment* NB/T 47014 and this Code.

3 For primary and secondary containers, the steel used for WPAR shall be made by the same mill using the same steel manufacturing process, and WPAR shall be approved for any variations, irrespective of previous approvals.

4 In the case of pre-painted protection of the plates, which may remain in place during the welding operation, the approval of the welding procedures shall be carried out on plates with this paint.

8.5.2 The weld position and thickness of test plate shall comply with the following requirements:

1 The thickness ranges approved in the testing conditions shall meet the requirements as specified in the current national standard *Welding procedure qualification for pressure equipment* NB/T 47014.

2 The following requirements shall be met for each WPAR of weld circumferential seams in the primary and secondary container shell:

1)In the horizontal position;

2)Application of the plate with a thickness equal to or less than the minimum tank shell thickness;

3)Application of the plate with a thickness equal to or greater than maximum tank shell thickness.

3 The following requirements shall be met for each WPAR of vertical welds in the primary and secondary container shells:

1)In the vertical position;

2)Application of plate with a thickness equal to or less than the minimum tank shell thickness;

3)Application of plate with a thickness equal to or greater than maximum tank shell thickness.

8.5.3 Impact testing shall comply with the following requirements:

1 When specified, impact testing of the weld metal and HAZ shall be performed for each WPS or WPAR. Each set of specimens shall be comprised of three test specimens. One set of specimens shall be required for the weld metal and one set is required in the HAZ.

2 If impact testing is specified, the test plates for impact testing shall be marked with the plate rolling direction. The plate rolling direction of the test plates for impact testing shall be parallel with the weld joints except for the test plates for vertical joints which can be orientated with the rolling direction transverse to joint.

3 The test temperature and impact power of Charpy V-notch impact test for the weld metal and heat affected zone(HAZ)shall be in accordance with the design documents.

4 When 9%Ni steel is used to fabricate tank to store propylene and ethane, its impact test temperature may be−140℃.

8.5.4 The value of 9% nickel steel tensile test specimens shall not be less than the value used in design for vertical welds or 80% of the value for horizontal welds.

Ⅱ Welder Qualification

8.5.5 Each welder and welding operator shall be qualified and approved in accordance with the national provisions on welding operators for special equipment.

Ⅲ Product Test Plates

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

1 For a primary and secondary liquid containers, as a minimum, one product test plate shall be made from the vertical weld of the thickest and the thinnest course and for each welding process used to weld these courses.

2 If the difference in thickness between the bottom and top shell courses is equal to or exceeds 20mm, an additional product test plate shall be required for each welding process used in the vertical position on a plate thickness approximately in the middle of the thickness range between the bottom and top shell ring thicknesses.

3 The test plate material used for the product test plates shall be from steel used to build the tank shell.

4 The welding consumables used to weld the product test plates shall be of the same manufacturer and type used to weld the respective product weld.

5 The product test plates shall have a minimum width of 200mm each side of the weld joint.

6 If site conditions permit, the welding and testing of the product test plates shall be performed as early as possible.

7 When the test plate cannot be placed at the end of a vertical weld due to the limitations of erection method, then it shall be welded at the site at an appropriate location using the WPS's used to weld the represented production seam.

8 The inspection and test requirements for the product test plates shall be the same as those for the WPAR.However, only Charpy V-notch impact tests of the weld metal and HAZ shall be performed.

Ⅳ Welding

8.5.7 Tack and temporary welds shall comply with the following requirements:

1 Tack and temporary welds shall be made by qualified welders.

2 Tack and temporary welds need not be removed provided that they are sound and the subsequent weld passes are thoroughly fused into the tack welds.

8.5.8 Environmental conditions shall comply with the following requirements:

1 The welding contractor shall take measures to ensure that the welds are protected against moisture, rain and t wind.

2 When the parent metal temperature is below 5℃, the material on both sides of the weld joints shall be preheated.The preheating temperature is equal to or higher than 5℃.

8.5.9 When preheating is required, it shall be made before welding begins.Preheating shall encompass the whole thickness of the parts to be welded for a distance of four times the plate thickness or 75mm, whichever is the greater. Preheating time shall ensure uniform temperature at the parent metal thickness direction.

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

1 After welding of carbon manganese steel shell nozzles and manholes into the shell plate or thickened insert plate, and the welded assembly shall be post-weld heat treated. Heat treatment scheme shall be prepared before the treatment. No post weld heat treatment is necessary under any of the following conditions.

1) Part of the weld assembly with a thickness of less than 16mm;

2) Part of the weld assembly with a thickness of less than 30mm or the nozzle is smaller than 300mm in nominal diameter;

3) Nozzles or manholes installed on the shell of an outer tank designed for storage of gas only.

2 Cold-formed 9% Ni plates shall be post-weld heat treated when the extreme fiber strain from cold forming exceeds 3%. The extreme fiber strain from cold forming may be determined by the following equation:

$$S=50\frac{t}{R_{\mathrm{f}}}\left(1-\frac{R_{\mathrm{f}}}{R_{0}}\right) \tag{8.5.10}$$

Where: R_0——the original radius (infinity for flat plate), in mm;

R_{f}——the final middle radius, in mm;

S——the extreme fiber strain, in %;

t——the plate thickness, in mm.

8.6 Inspection

8.6.1 NDE personnel in petrochemical industry shall be qualified to special equipment NDT certification rules.

8.6.2 Weld inspections of primary and secondary liquid containers of low temperature steel storage tank in petrochemical industry shall be performed in accordance with specifications in Table 8.6.2-1 and Table 8.6.2-2.

Table 8.6.2-1 Weld inspections of primary and secondary liquid containers (%)

Part of tank	Type of welds	Visual examination	Dye penetration examination or magnetic particle examination	Vacuum box test	Soap bubble examination	Radiographic or ultrasonic examination
Bottom plate	Butt weld	100[a]	—	100[a]	—	—
	Fillet weld	100[a]	—	100[a]	—	—
Bottom annular plates	Radial butt weld	100	—	100	—	100
Part of tank	Type of weld	Visual examination	Dye penetration examination or magnetic particle examination	Vacuum box test	Soap bubble examination	Radiographic or ultrasonic examination
Bottom to shell	Butt weld	100[b]	—	100	—	—
	Fillet weld	100[b]	—	—	100[b]	—

Table 8.6.2-1 (continued)

Part of tank	Type of welds		Visual examination	Dye penetration examination or magnetic particle examination	Vacuum box test	Soap bubble examination	Radiographic or ultrasonic examination
Shell	Butt weld		100[b]	—	—	—	See Table 8.6.2-2
Nozzles in shell or bottom	Longitudinal weld		100[c]	—	—		100
	Weld neck flange to pipe	$d_n \geq$ 100mm	100[c]	100	—	—	10
		$d_n <$ 100mm	100[c,d]	100	—	—	—
	Fillet weld of slip on flange to pipe		100[c]	100	—	—	—
Nozzle to shell (insert and nozzle with reinforcing plate)	Nozzle to shell or insert weld		100[c]	100	—	—	—
	Nozzle to reinforcing plate weld		100[c]	100	—	—	—
	Reinforcing plate to shell weld		100[c]	—	—	100	—
	Insert plate to shell weld		100	—	—	—	100
Permanent bracket and pad plates	Fillet weld		100	100	—	—	—
Stiffening rings	Main butt welds in stiffening rings		100	—	—	—	100
	Fillet welds to shell		100	100	—	—	—

Notes: [a]–Before and after hydrostatic testing;

[b]–At both sides;

[c]–After post weld heat treatment, if required;

[d]–One side.

Table 8.6.2-2 Extent of radiographic/ultrasonic examination of shell welds of primary and secondary liquid container

Type of examination	Welds		
	Vertical	Tee [a]	Horizontal
Radiographic or ultrasonic	100	100	5

Note: [a]–400mm film to be positioned horizontally.

8.6.3 When 9% Ni steel is used as the material of the primary container or secondary steel container, the butt welds shall be examined dye penetration testing.

8.6.4 Inspections of welds of vapour container or liner of single, double and full containment tanks shall be in accordance with Table 8.6.4-1 and Table 8.6.4-2.

Table 8.6.4-1 Weld inspections of vapour container or liner(%)

Part of tank	Type of assembly	Visual examination	Dye penetration examination or magnetic particle examination	Vacuum box test	Soap bubble examination	Radiographic or ultrasonic examination
Bottom plate	Butt weld	100	—	100	—	—
	Fillet weld	100	—	100	—	—
Bottom annular plates	Radial butt weld	100	—	100	—	—
Bottom to shell	Fillet weld	100	—	100	—	—
Shell	Butt weld	100	—	100	—	See Table 8.6.4-2
Compression area	Vertical and radial butt welds	100	100	—	—	25
	Circumferential butt or fillet welds	100	100	—	100	—
Roof	Fillet weld	100	—	—	100	—
	Butt weld	100	—	—	100	—
Nozzles in shell, bottom or roof	Longitudinal nozzle weld	100	—	—	100	—
	Flange to nozzle body	100	—	—	100	—
Nozzle to shell or insert and Nozzle with reinforcing plate	Nozzle to shell or insert weld	100	100	—	100	—
	Nozzle to reinforcing plate	100	100	—	100	—
	Reinforcing plate to shell	100	—	—	100	—
	Insert plate to shell	100	—	—	—	100
Temporary bracket	After removal of the bracket	100	100	—	—	—
Permanent bracket and pad plates	Fillet weld	100	100	—	—	—
Stiffening rings	Main butt welds in stiffening rings	100	100	—	—	—
	Fillet welds to shell	100	—	—	—	—

Table 8.6.4-2 Extent of radiographic and ultrasonic examination of shell plate welds of vapour containers

Type of examination	Welds		
	Longitudinal weld	Tee [a]	Horizontal
Radiographic or ultrasonic	5	25	1

Note: [a]–50% of the radiographs shall be taken with a 400mm film positioned horizontally and 50% with a film positioned vertically.

8.6.5 A visual examination shall be conducted in accordance with the current national standard *Technical code for construction of vertical cylindrical low temperature storage tanks* SH/T 3537 to check weld beads, shapes and dimensions, and to detect surface imperfections both on welds and on the plates, nozzles and all accessories on the tank during its fabrication and erection.

8.6.6 Dye penetration examination shall be conducted in accordance with the current national standard *Nondestructive testing of pressure equipment-part 5: penetration testing* JB/T 4730.5, and contractor shall ensure that there is no risk of the products contaminating the items being examined and products which are to be stored.

8.6.7 The magnetic particle examination shall be conducted in accordance with the current national standard *Nondestructive testing of pressure equipment-part 4: magnetic particle testing* JB/T 4730.4. Magnetic particle inspection shall not be used for 9% nickel steel.

8.6.8 Vacuum box examination shall comply with the following requirements:

1 The steel plates shall be clean.

2 The welds shall be degreased and free of any welding slag or scale that might affect the quality of the examination.

3 The pumping system used shall guarantee a minimum vacuum of 30kPa.

4 The soapy water used shall have high wetting power, low viscosity, low surface tension and high foaming power.

8.6.9 In addition to Items 1, 2 and 4 in Article 8.6.8, soap bubble examination shall also comply with the following requirements:

1 For shell plates welded to the bottom with double fillet welds, air at a minimum pressure of 50kPa shall be introduced through a threaded hole provided for this purpose into the space between the fillet welds, and shall be maintained at this pressure during the examination. Soapy water shall be applied by brush or spray to the welds without leaking. In the test, testing pressure of fillet welds at both sides of tank shell shall be continuously distributed along the tank shell. After the test, the threaded hole shall be sealed.

2 For testing of welds of reinforcement plates and after suitable wetting of the reinforcement plate welds with soapy water, the air at a minimum pressure of 50kPa shall be introduced through the threaded hole and maintained for at least 30s. The test is accepted when there is no leaking. After the test, the threaded hole shall be sealed.

3 Following the pneumatic test of the steel roof, the external fillet welds shall be tested with soapy water. The design pressure shall be maintained during this examination.

8.6.10 The radiographic examination 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 The ultrasonic examination 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 ultrasonic pulse-echo examination, and shall be only used as a supplementary examination process.

2 Where UT examination is used, RT examination shall be used for re-check purpose and re-check rate is 20%.

8.6.12 If ultrasonic time of flight diffraction (TOFD) technique is used, the examination shall be in accordance with the current national standard: *Nondestructive testing of pressure equipment-part 10: ultrasonic time of flight diffraction technique* NB/T 47013.10.

8.6.13 When unacceptable defects are found, defects shall be removed, weld repairs shall be made and additional inspections shall be performed. Additional inspections shall meet the following requirements:

1 One further film shall be taken or 1m of ultrasonic examination shall be carried out at each side of the original film.

2 If one of these additional films or ultrasonic examinations is off specification, then there shall be a total examination of that t day's welds by that welding machine for automatic welding; there shall be a total examination of that day's welds by the welder in question for manual welding.

8.6.14 If surface defects have been detected, the defects shall be removed entirely by grinding and the surface shall be checked by a further examination. The allowable local thinning relative to the thickness after the surface defects are removed by grinding shall comply with the following requirements:

1 Final thickness of the plate shall not be less than 95% of the ordered plate thickness over an area of 6t by 6t(*t* is the thickness of the plate);

2 Distance between any two areas affected by thinning shall be at least equal to the diameter of the circle circumscribing the largest area.

9 Concrete Construction and Workmanship

9.0.1 Concrete construction shall comply with the following requirements:

1 The concrete construction process shall be determined based on the design requirements and the construction conditions at site.

2 The concrete ratio, production, quality, placement, and curing etc. of the concrete shall be properly controlled.

3 The ratio of the concrete, the cement type and construction method shall be determined based on the heat of hydration and the effects of drying and thermal shrinkage in the concrete structure.

9.0.2 Temperature differences between new and old constructions and the environment shall be considered in the construction plan.

9.0.3 In addition to the requirements specified in the current national standard *Technical specification for large-area formwork building construction* JGJ 74 and *Technical code for safety of construction forms* JGJ 162, the formwork and tie-rods shall also comply with the following requirements:

1 The formwork shall be tightly sealed at all joints.

2 Calculations of the formwork shall be made to ensure sufficient strength and stiffness.

3 Special arrangements shall be applied at the tie-rods.

4 All cone openings shall be sealed so that liquid tightness is ensured.

9.0.4 Spacers shall be located at accurate positions, correct cover shall be provided for the reinforcement, and liquid tightness shall not be affected.

9.0.5 The embedments shall comply with the following requirements:

1 The embedments shall be located at accurate positions based on the design requirements, and their elevations and tolerances shall comply with the current national standard *Code for acceptance of constructional quality of concrete structures* GB 50204.

2 Construction of post-embedments shall satisfy the post-anchorage technical requirements for concrete structures, and shall conform to the current industrial standard *Technical specifications for post-installed fasteners in concrete structures* JGJ 145.

3 The permanent embedment materials (embedments and structural adhesives) located in low temperature working zones shall satisfy the requirements low temperature resistant performance.

4 Embedments for construction shall be approved by the designer before installation.

9.0.6 Concrete curing measures shall be determined based on many factors, including site climate conditions and concrete mixes.

9.0.7 When the outdoor daily average temperature is lower than 5℃ for 5 successive days or when the minimum outdoor temperature is lower than 0℃, winterization provisions shall be provided. Winterization provisions shall conform to the current industrial standard *Specifications for winter construction of building engineering* JGJ 104.

9.0.8 The coatings shall be applied directly to the concrete surface. Prior to application, the concrete surfaces shall be grit blasted and subsequently vacuum cleaned. All remains of release agents and curing compounds shall be removed if they affect the binding performance of the coatings.

9.0.9 Construction of pre-stressing tendons shall comply with the following requirements:

1 Tendons shall be placed in the center of the concrete wall or slightly outwards from the center of the concrete wall.

2 The tensioning sequence for pre-stressing shall be determined based on the design. It may be performed first vertically then circumferentially or integratedly symmetrically.

3 The horizontal circumferential tendons in the tank wall should be tensioned from the bottom to the top, and the tendons in each course should also be tensioned at two ends at the same time.

4 The vertical tendons shall be vertically and symmetrically tensioned along the wall columns, and they should be tensioned at one end, the lower end may be fixed to tensioning corridor on the ground, and the upper end may be fixed to ring beam of dome roof.

9.0.10 The horizontal construction joint of base slab structure should not be provided in the base slab.

9.0.11 The roof may be casted continuously or may be divided into a number of sections. The roof may also be cast in several layers, depending on its thickness; however, the construction method adopted shall ensure the flatness of the roof after construction.

9.0.12 The foundation construction of tanks shall also be in accordance with the current national standard *Specifications for construction and acceptance of steel storage tank subgrade and foundation in petrochemical industry* SH/T 3528 and *Technical code for construction of vertical cylindrical low temperature storage tanks* SH/T 3537.

9.0.13 In addition to the design requirements, the construction quality and acceptance of concrete structures shall also be in accordance with the current national standard *Code for acceptance of constructional quality of concrete structures* GB 50204 and *Technical code for construction of vertical cylindrical low temperature storage tanks* SH/T 3537.

10 Tests

10.1 Hydrostatic Test

10.1.1 For various types of low temperature steel storage tanks used for petrochemical services, the hydrostatic test items and water fill height shall be in accordance with Table 10.1.1.

Table 10.1.1 Hydrostatic test items and water fill height for various types of low temperature steel storage tanks for petrochemical services

Contents	Single containment		Double containment		Full containment	
	Test item	Water fill height	Test location	Water fill height	Test location	Water fill height
Ammonia, butane, propane and propylene	Tank	FH	Inner tank	FH	Inner tank	FH
			Outer steel tank	FH	Outer steel tank	FH
			Outer pre-stressed concrete tank	—	Outer pre-stressed concrete tank	—
LNG ethane, ethylene and LNG	Tank	PH	Inner tank	PH	Inner tank	PH
			Outer steel tank	PH	Outer steel tank	PH
			Outer pre-stressed concrete tank	—	Outer pre-stressed concrete tank	—

Notes: 1 FH means full height hydrostatic test, the inner tank shall be filled to the maximum design level.

2 PH means partial height hydrostatic test, the test level in the inner tank shall be equal to 1.25 times the maximum design liquid level multiplying the specified density of the specified product to be stored.

10.1.2 Hydrostatic test shall not be carried out until all welded accessories to the shell and bottom of the tank are in place, tested and accepted. Welding shall not be allowed after completion of hydrostatic test. Hydrostatic test shall be carried out before installation of insulation for inner tanks and outer tanks.

10.1.3 Fresh water should be used for the test, which shall not damage the steel components. If the required water quality cannot meet the requirement, the alternative test methods utilizing suitable inhibitors shall be considered.

10.1.4 When seawater is used for the test, cathodic protection should be provided. Seawater shall not be used to hydrostatically test the low temperature stainless steel storage tanks for petrochemical services.

10.1.5 Tanks shall be all cleaned after the test.

10.1.6 Hydrostatic test shall comply with the following requirements:

1 Before the start of hydrostatic test, any spatter and slag shall be removed from the welds, and all materials, objects or temporary installations used during its construction shall be removed, and the tank shall be cleaned.

2 When outer tanks are hydrostatically tested, measures shall be taken to prevent that test water from entering into the bottom insulation.

3 A permanent or temporary pressure relief system shall be used during the test, and the pressure relief system shall have sufficient capacity.

4 The rate of filling shall be determined based on water availability, equipment capacity and subsoil conditions.

5 Before testing, the markers shall be installed on the outer surface of the tank which shall comply with the following requirements:

1) Four markers shall be installed for the tanks with a diameter less than or equal to10m;

2) Eight markers shall be installed for the tanks with a diameter larger than 10m;

3) Markers shall be installed on the inner tank in double and full containment tank systems;

4) The markers shall be of such a type that they remain usable or visible after the tank is painted.

10.1.7 Settlement of the tank shall be monitored during hydrostatic test, and shall comply with the following requirements:

1 The settlement of the tank shall be monitored during the filling and emptying operations of the tank, and as a minimum, this shall be done when the tank is half full, three-quarters full and full.

2 For the tanks, where bottom differential settlements of more than 30mm are predicted, measuresshall be provided to monitor the settlements in the center of the tank.

3 During the test, the observed settlements shall be compared with the predicated values. If differences occur, the supervision engineers, the designer and the owner shall be informed.

10.1.8 Control and inspection during test shall comply with the following requirements:

1 Water shall be filled to the test liquid level and maintained for 24h. The welds shall be inspected for any possible leakages.

2 The anchors, if installed, shall be adjusted when water is filled to 70% of the design liquid level.

10.1.9 Water discharge shall not impose any adverse impact on the surrounding environment.

10.2 Pneumatic Test

10.2.1 A positive pressure test shall be carried out at a test pressure equal to 1.25 times the design pressure of the tank. The positive test pressure shall be applied to the vapour space above the test water.

10.2.2 The test pressure shall be automatically relieved. Positive pressure relief valves may be installed, or a temporary pressure relief system may be provided. When the pressure exceeds the test pressure, the vacuum relief valves and the temporary vacuum relief system shall automatically open immediately to relief.

10.2.3 The test pressure, when reached, shall be held for at least 30min, thereafter, the test pressure shall be reduced to the design pressure, and soap solution test shall be performed for all welded joints, and welds without any leakage are acceptable. If the joint has previously been vacuum box tested, the soap solution test may be substituted by visual inspection.

10.2.4 After the positive pressure test is accepted, the pressure relief valves shall be adjusted to open at the design pressure. The set pressure of the pressure relief valve shall be verified by purging air into the vapour space.

10.2.5 Repairs leaking shall be made after the test, and shall be individually vacuum box tested.

10.2.6 A negative pressure test shall be performed at a pressure equal to the design internal negative pressure of the tank. When the design negative pressure of the tank is reached, all welded joints shall be checked, and then the test is considered as accepted if there are no abnormalities.

10.2.7 The negative pressure test should be carried out while there is water pressure in the tank.

10.2.8 Negative pressure shall be automatically relieved during negative pressure test. Vacuum relief valves shall be installed and adjusted to open at the negative test pressure, or a temporary vacuum relief system shall be installed. When the negative pressure exceeds negative test pressure, the vacuum relief valves and the temporary vacuum relief system shall automatically open immediately to relief.

10.2.9 All openings shall be closed except those of vacuum relief valves prior to negative pressure test. The required negative pressure may be obtained by lowering the water level or by the use of an air-ejector.

10.2.10 After the negative pressure test is accepted, the vacuum relief valves shall be adjusted to open at the design negative pressure. The set pressure of the vacuum relief valve shall be verified by lowering the water level or using the air-ejector.

10.2.11 After the pneumatic test is accepted, the following actions shall be considered:

1 Anchorage, if provided, shall be re-checked for tightness against the hold-down brackets, and air is introduced into the empty tank until the pressure equal to the design pressure to check the foundation for uplift.

2 Bottom shall be checked for abnormalities, and all bottom welds shall be vacuum box tested again.

3 When bottom connections are fitted, all welds shall be inspected by 100% visual inspection and 100% dye penetration or magnetic powder examinations.

4 Liners shall be visually inspected.

Appendix A Main Physical Properties of Gases

Table A Physical properties of gases

Description	Chemical formula	Mol. mass (g/mol)	Boiling point(℃)	Latent heat of vapour at boiling point(kJ/kg)	Liquid density at boiling point (kg/m³)	Gas density at boiling point [(kg/m³)·10^{-2}]	Vol.of gas liberated by 1m³ of liquid(m³)
N-butane	C_4H_{10}	58123	−0.5	385	601	270	239
Butadiene	C_4H_6	54091	−4.5	417	650	255	279
Iso-butane	C_4H_{10}	58123	−11.7	366	593	282	236
Ammonia	NH_3	17030	−33.3	1367	682	905	910
Propane	C_3 Hs	44096	−42	425	582	242	311
Propylene	C_3H_6	42080	−47.7	437	613	236	388
Ethane	C_2H_6	30069	−88.6	487	546	205	432
Ethylene	C_2H_4	28054	−103.7	482	567	208	482
Methane	CH_4	16043	−161.5	509	422	181	630

Note: The volume of gas liberated by 1m³ of liquid refers to the gas volume at a state of 0.1MPa and 15℃.

Appendix B Design Conditions of Tanks

B.0.1 The design conditions of the tanks shall include but not limited to the following:

1 The conditions in various cases;

2 Tank type;

3 Operating pressure, design pressure and design negative pressure;

4 Set pressure;

5 Filing/emptying flowrates;

6 Certain actions like earthquake, wind, connection piping/nozzle loading;

7 Accidental actions such as spillage, fires and explosions;

8 Design life;

9 Tank plot plan;

10 Tank capacity(net or gross);

11 Environmental data(including ambient, minimum/maximum temperatures);

12 Process Flow Diagrams(PFD's), Process and Instrumentation Diagrams(P and ID's);

13 Design metal temperature of primary container;

14 Relevant properties of the contained fluid, including relative density, temperature, toxicity, flammability;

15 Provisions to prevent rollover (installing density meter, applying continuous circulation of product);

16 Permissible boil-off rate and ambient conditions;

17 Maximum normal operating liquid level;

18 Design data for pressure and vacuum relief valves(flow rates);

19 High precision level gauges;

20 Ultra high and ultra low pressure gauges;

21 Temperature gauges;

22 Piping and instrumentation requirements;

23 Predicted settlements and future inspections of the tank;

24 Requirements for cooling piping system for tanks;

25 Selection of leakage detection system for primary container: temperature drop, vapor detection and DP measurement.

Appendix C Seismic Design Requirements

C.0.1 The primary container shall be designed at the maximum operation level per the seismic impact of precautionary earthquake conditions. If secondary container is used, it shall be designed per seismic impact of earthquake conditions. At the same time, the secondary container shall be also designed at no liquid level in the secondary container for seldom occurred earthquake conditions.

C.0.2 The seismic action shall be calculated and determined based on the seismic precautionary intensity or design parameters of ground motion approved by the national authorities.

C.0.3 If the secondary container is built by reinforced concrete, it shall be designed per seismic precautionary Category B, and shall satisfy the requirements specified in *Standard for classification of seismic protection of buildings and special structures in petrochemical engineering* GB 50453.

C.0.4 Time history analysis should be used for the cases where the seismic precautionary intensity is higher than 8 degrees or design basic acceleration of ground motion is larger than 0.30g.

C.0.5 When time history analysis is used, it shall comply with the current national standard *Code for seismic design of buildings* GB 50011 and *Code for seismic design of special structures* GB 50191.

C.0.6 For primary container, the damping value for seismic precautionary intensity earthquake conditions may be taken as 4%. For the secondary container constructed with reinforced concrete, the damping value for the seismic precautionary intensity earthquake conditions may be taken as 5%, and the damping value for seldom occurred earthquake conditions may be taken as 10%. For the liquid stored in the tank, the damping value may be taken as 0.5%.

C.0.7 If seismic isolation and energy dissipation are designed, they shall comply with the requirements specified in *Code for seismic design of buildings* GB 50011 and *Code for seismic design of special structures* GB 50191.

Appendix D Reinforcement Bar Testing

D.1 Sampling

D.1.1 For testing of the bars, fully finished bars shall be sampled from the bars of same grades, the same heating, the same rolling process or the same heat treatment process, and each size of product of the order, and shall be sampled from all strength classes to be used.

D.1.2 The test records provided by the manufacturer shall not serve as the final basis.

D.2 Testing

D.2.1 Tensile tests shall be carried out at the design metal temperature. The design metal temperature should be the lowest temperature that the reinforcement bar would be subjected to under abnormal loading conditions.

D.2.2 During the test, the temperature difference at any two points of the specimen or difference between the temperature at any point and the design temperature shall not exceed 5℃.

D.2.3 Tensile tests shall be conducted on notched and un-notched bar specimens, and shall comply with the following requirements:

1 A NSR (Notch Sensitivity Ratio) value of 1 or greater is required to achieve acceptable toughness. NSR value may be calculated by the following equation:

$$NSR = \frac{\text{Tensile strength of notched bar}}{0.2\%\ \text{proof stress of un-notched bar}} \tag{D.2.3-1}$$

or

$$NSR = \frac{\text{Tensile strength of notched bar}}{\text{Lower yield stress of un-notched bar}} \tag{D.2.3-2}$$

2 The test specimen for notched bar tests should be notched at the half-length position between the machine grips, a V-notch shall be used that has an internal angle of 45° and a radius at the root of 0.25mm. The notch position shall comply with the following requirements:

1) For longitudinal ribbed bars, the notch shall be placed across the rib and penetrate 1mm into the underlying bar.

2) For transverse ribbed bars, the notch shall be placed on the crown (see Figure D.2.3).

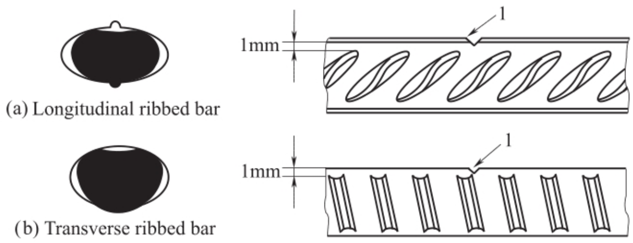


Figure D.2.3 Notch on reinforcement bar

1–V-notch

3 Each un-notched specimen shall demonstrate a percentage plastic elongation of at least 3%.

4 The yield strength of the un-notched specimen found during testing shall be at least 1.15 times the design minimum yield strength.

Appendix E　Common Insulation Materials and Application

E.0.1　Usage of insulation materials for single and double containment tanks are given in Table E.0.1.

Table E.0.1　Usage of common insulation materials for single and double containment tanks

Material		Supporting ring	Bottom insulation	Roof insulation		Shell insulation	
				External	Internal (with suspended roof)	External of single steel tank	Tanks with double steel shell
Hard wood		√	—	—	—	—	—
Perlite concrete blocks/beam		√	—	—	—	—	—
Lightweight concrete blocks/beam		√	—	—	—	—	—
Reinforced concrete		√[a]	—	—	—	—	—
Cellular glass		√[b]	√	√	—	√	√
Expanded perlite		—	—	—	√	—	√
Mineral wool blankets		—	—	—	√	—	√[c]
PVC foam	MD	—	√	—	—	—	—
	HD	√	√	—	—	—	—
PUF/PIR	ND BL-SPR-FIP	—	—	√	—	√	—
	MD BL-SPR	—	—	√	—	√	—
	HD BL-SPR	√[b]	√	—	—	—	—
	GR BL	√[b]	√	—	—	—	—
Phenolic foam plastic		—	—	—	—	√	—
Polystyrene-expanded		—	—	—	—	√[d]	—
Polystyrene-extruded	ND	—	—	—	—	√[d]	—
	HD	—	√	—	—	—	—

Notes: 1　a-is used as load distribution plate placed under the thermal insulation material; b-may require a load distribution plate; c-is placed between perlite insulation and inner tank shell, mineral wool blanket can be used as resilient blanket; d-is only used for double containment tank (limited temperature resistance).

2　BL: block-type, HD: high density, FIP: foam on site, ND: normal density, GR: glass fibre reinforced, MD: medium density, SPR: spray-type, √: optional.

E.0.2　Application of insulation materials for full containment tanks is given in Table E.0.2.

Table E.0.2　Application of insulation materials for full containment tanks

Materials	Supporting ring	Bottom insulation	Roof insulation		Shell insulation		Thermal protection system	
			On suspended roof	On inner tank dome roof	Internal space	On inside of wall	Without metalplate	With metal plate
Hard wood	√	—	—	—	—	—	—	—
Perlite concrete blocks/beam	√	—	—	—	—	—	—	—
Lightweight concrete blocks/beam	√	—	—	—	—	—	—	—

Table E.0.2(continued)

Materials		Supporting ring	Bottom insulation	Roof insulation: On suspended roof	Roof insulation: On inner tank dome roof	Shell insulation: Internal space	Shell insulation: On inside of wall	Thermal protection system: Without metalplate	Thermal protection system: With metal plate
Reinforced concrete		√[a]	—	—	—	—	—	—	—
Cellular glass		√[b]	√	—	—	—	—	—	√
Expanded perlite		—	—	√	√	√	—	—	—
Mineral wool blankets		—	—	√	√	√[c]	—	—	—
PVC foam	MD	—	√	—	—	—	—	—	√
	HD	√[b]	√	—	—	—	—	—	√
(PIR) PUF/ PIR	ND BL-SPR-FIP	—	—	—	—	—	—	—	—
	MD BL-SPR	—	—	—	—	—	√[d]	√[d]	√
	HD BL-SPR	√[b]	√	—	—	—	√[d]	√[d]	√
	GR BL	√[b]	√	—	—	—	—	√[d]	√

Notes: 1 a-To be used as load distribution plate under thermal insulation material, b-To be used underneath a load distribution plate, c-Mineral wool blanket which can be used as resilient blanket between perlite insulation and GR=glass fiber reinforced inner tank shell, d-Only applicable to special grades of spray-applied, jointless, vapour tight, liquid tight systems.

2 BL: block-type, HD: high density, FIP: foam in place, ND: normal density, GR: glass fibre reinforced, MD: medium density, SPR: spray-type, √: optional.

Explanation of Wording in This Code

1 Words used for different degrees of strictness are explained as follows in order to mark the differences in executing the requirements in this code:

1)Words denoting a very strict or mandatory requirement:

"Must" is used for affirmation, "must not" for negation.

2)Words denoting a strict requirement under normal conditions:

"Shall" is used for affirmation, "shall not" for negation.

3)Words denoting a permission of a slight choice or an indication of the most suitable choice when conditions permit:

"Should" is used for affirmation, "should not" for negation.

4)"May" is used to express the option available, sometimes with the conditional permit.

2 "Shall comply with..." or "Shall meet the requirements of..." is used in this code to indicate that it is necessary to comply with the requirements stipulated in other relative standards and codes.

List of Reference Codes/Standards

GB 50010 *Code for design of concrete structures*

GB 50011 *Code for seismic design of buildings*

GB 50046 *Standard for anticorrosion design of industrial constructions*

GB 50057 *Code for design protection of structures against lightning*

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

GB 50160 *Fire prevention code of petrochemical enterprise design*

GB 50191 *Code for seismic design of special structures*

GB 50204 *Code for acceptance of constructional quality of concrete structures*

GB 50205 *Code for acceptance of construction quality of steel structures*

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

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

GB 50650 *Code for design protection of petrochemical plants against lightning*

GB 150.2 *Pressure vessels-part 2: materials*

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

GB/T 5223 *Steel wires for the pre-stressed of concrete*

GB/T 5224 *Steel strand for pre-stressed concrete*

GB/T 5486 *Test methods for inorganic rigid thermal insulation*

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

GB/T 14370 *Anchorage, grip and coupler for pre-stressing tendons*

GB/T 19204 *General characteristics of liquefied natural gas*

JB/T 4730.2 *Nondestructive testing of pressure equipment-part 2: radiographic testing*

JB/T 4730.3 *Nondestructive testing of pressure equipment-part 3: ultrasonic testing*

JB/T 4730.4 *Nondestructive testing of pressure equipment-part 4: magnetic particle testing*

JB/T 4730.5 *Nondestructive testing of pressure equipment-part 5: penetrant testing*

JGJ 7 *Technical specifications for space frame structures*

JGJ 74 *Technical specification for large-area formwork building construction*

JGJ 104 *Specification for winter construction of building engineering*

JGJ 145 *Technical specification for post-installed fasteners in concrete structures*

JGJ 162 *Technical code for safety of construction forms*

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

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

NB/T 47013.10 *Nondestructive testing of pressure equipment-part 10: ultrasonic time of flight diffraction technique*

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

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

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