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**Standard for seismic design of
petrochemical steel equipment**

石油化工钢制设备抗震设计标准

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Standard for seismic design of petrochemical steel equipment

1 General provisions

1.0.1 In order to implement the national laws and regulations on earthquake prevention and disaster reduction, implement a prevention-oriented policy, mitigate the seismic damage by seismic-fortifying the petrochemical equipment, reduce economic loss, this standard is hereby formulated.

1.0.2 This standard is applicable to the seismic design of the petrochemical horizontal vessel, vertical vessels supported by legs, vertical vessels supported by lugs, vertical vessels supported by skirt, spherical tanks supported by legs, vertical cylindrical storage tanks, tubular heater, other steel equipment which are used in the area where the basic seismic acceleration not exceeding 0.40 g or seismic fortification intensity of 9 degrees or less.

1.0.3 For the petrochemical equipment which is subjected to the seismic design according to this standard, when it is impacted by the fortification earthquakes equivalent to the seismic fortification intensity of the area, the body, bracing member, anchoring structure shall not be damaged.

1.0.4 The design parameters of ground motion or the seismic fortification intensity shall be determined in accordance with the relevant provisions of the current national standard "Seismic ground motion parameter zonation map of China" GB 18306. For the construction site where the seismic safety evaluation is completed, it shall carry out the seismic fortification according to the approved design parameters of ground motion or the seismic fortification intensity.

1.0.5 The seismic design of petrochemical steel equipment shall, in addition to complying with this standard, also comply with the relevant current national standards.

2 Terms and symbols

2.1 Terms

2.1.1 Seismic design

A specialized design for equipment that requires seismic fortification, including seismic calculations and seismic measures.

2.1.2 Seismic fortification intensity

The seismic intensity which is approved according to the authority as specified by the state as a basis for seismic fortification of a region.

2.1.3 Seismic action

The dynamic effects of equipment caused by ground motion, including horizontal seismic action and vertical seismic action.

2.1.4 Seismic effect

Internal forces or deformations generated by the equipment under seismic action.

2.1.5 Design parameters of ground motion

The time-history curve of acceleration of ground motion, the response spectrum of acceleration, the peak acceleration which are used for seismic design.

2.1.6 Design basic acceleration of ground motion

The design value of the acceleration of ground motion which exceeds the probability of 10% in the 50-year design base period.

2.1.7 Characteristic period of ground motion

In the seismic influence factor curve for seismic design, the period value corresponding to the starting point of the falling segment which reflects the factors such as seismic magnitude, epicentral distance, site category, and other factors.

2.1.8 Seismic influence factor

The statistical mean of the ratio of the maximum acceleration response to the gravitational acceleration of a single-mass point elastic system under seismic action.

m_{eq} - The equivalent total mass of equipment;

m_i, m_j - Respectively, the masses concentrated on the particles i, j ;

m_{eqv} - The vertical equivalent mass of equipment;

m_i - The mass concentrated at the particle i ;

m_j - The mass concentrated at the particle j ;

S_j - The effect produced by the horizontal seismic action of the vibration-mode j ;

S_h - Horizontal seismic effect;

X_{ji} - The horizontal relative displacement of the particle i of the j^{th} vibration-mode.

2.2.2 Performance and resistance of materials:

E^t - The modulus of elasticity of the material at the design temperature;

R_{el} - The yield strength of material;

σ - The stress value under the action of load combination;

$[\sigma]$ - The allowable seismic stress of the material;

$[\sigma]^t$ - The allowable stress of the material at the design temperature;

$[\sigma]_b$ - The allowable seismic tensile stress of the material;

$[\sigma]_{bc}$ - The allowable seismic compressive stress of the material;

τ - The value of the shear stress under the action of load combination;

$[\tau]$ - The allowable seismic shear stress of the material;

$[\tau]_b$ - The allowable seismic shear stress of the material.

2.2.3 Calculation coefficient:

α_1 - The horizontal seismic action factor corresponding to the basic natural vibration period of the equipment or structure;

α_j - The horizontal seismic action factor corresponding to the natural vibration period of the j^{th} vibration-mode of the equipment;

$\alpha_{\max}$ - The maximum value of the horizontal seismic action factor;

4 Seismic action and seismic checking

4.1 General requirements

4.1.1 The seismic action and seismic checking of the equipment shall comply with the following provisions:

1. It shall calculate the seismic action in the horizontal direction and make seismic checking;
2. When the design basic acceleration of ground motion is $0.20\text{ g} \sim 0.40\text{ g}$, or seismic fortification intensity is 8 degrees or 9 degrees, for the horizontal vessel which has a diameter of more than 4 m and the spacing between two seats of more than 20 m, as well as the vertical vessels and the floor chimney of the tubular heater which have a height of more than 20 m, it shall calculate the vertical seismic action and make seismic checking;
3. For the on-framework equipment, it shall take into account the seismic amplification of the structure in which the equipment is located.

4.1.2 When the design basic acceleration of ground motion is equal to 0.05 g or the seismic fortification intensity is 6 degrees, the category-1 and category-2 equipment may not be subjected to the calculation of seismic action, but it shall meet the requirements for seismic measures.

4.1.3 For the seismic calculation of equipment, it should use the following methods:

1. The following equipment may use the bottom shear method:
 - 1) The vertical vessel which has a height less than or equal to 10 m;
 - 2) The vertical vessel which has an aspect ratio of less than 5 and a relatively uniform distribution of mass and stiffness along the height direction;
 - 3) Equipment that can be simplified to a single-particle system.
2. Except for the equipment in item 1 of this clause, it should use the mode decomposition response spectrum method.
3. When the design basic acceleration of ground motion is more than or equal to 0.30 g , the vertical vessel which has an aspect ratio of more than 120 m and the vertical cylindrical storage tanks which are more than $15 \times 10^4\text{ m}^3$ should be supplemented by time-history analysis.

F_{hji} - The design value of the horizontal seismic action at the particle i of the j^{th} vibration-mode (N);

α_j - The horizontal seismic influence factor corresponding to the natural vibration period of the j^{th} vibration-mode of the equipment, which is determined according to the provisions of clause 4.2 of this standard;

γ_j - The participation factor of the j^{th} vibration-mode;

X_{ji} - The horizontal relative displacement at the particle i of the j^{th} vibration-mode.

2. The horizontal seismic effect shall be determined as follows:

$$S_h = \sqrt{\sum S_j^2} \quad (4.3.2-3)$$

Where:

S_h - The horizontal seismic effect;

S_j - The effect produced by the horizontal seismic action of the j^{th} vibration-mode, taking the first 2nd ~ 3rd vibration-mode. When the basic natural vibration period is greater than 1.5 s, the number of vibration-modes is not less than 3.

4.4 Horizontal seismic action of on-framework equipment

4.4.1 When the mass ratio of the framework to the equipment is more than or equal to 2, the horizontal seismic action of the equipment should be calculated in accordance with the provisions of this clause.

4.4.2 The design value of the horizontal seismic action of on-framework equipment may be calculated as follows:

$$F_{hk} = K_m \eta R_E \alpha_1 m_{eq} g \quad (4.4.2)$$

Where:

F_{hk} - The design value of horizontal seismic action of on-framework equipment (N);

K_m - The amplification factor of seismic action of on-framework equipment, which is selected according to Table 4.4.2.

5. Design value of horizontal and vertical seismic action;
6. Snow load, considering the combination factor of 0.5, which takes 0 for high-temperature parts and for the small load-bearing surface of equipment;
7. Other loads, including the reaction force of the seat, the base ring, the lugs and other types of supports, the force of the connecting pipeline and other components, the force caused by the difference in temperature gradient or thermal expansion, etc.;
8. Live loads, including major moving loads such as people, tools, repairs, shocks, vibrations, etc.

4.7 Seismic checking

4.7.1 When using the limit state design, it shall carry out seismic checking according to the relevant provisions of the current national standard “Code for seismic design of buildings” GB 50011.

4.7.2 When using the allowable stress design, it shall carry out seismic checking according to the following provisions:

1. When the equipment is subjected to seismic checking, the stress value of the checked part under the action of load combination shall meet the requirements of the following formula:

$$\sigma \leq \phi[\sigma] \quad (4.7.2-1)$$

$$\tau \leq [\tau] \quad (4.7.2-2)$$

Where:

σ - The stress value under the combination of loads (MPa);

Φ - Welded joint factor, which takes 1.0 when compressed;

$[\sigma]$ - Seismic allowable stress of the material (MPa);

τ - Shear stress value under combination of loads (MPa);

$[\tau]$ - Seismic allowable shear stress of the material (MPa).

2. The allowable stress for seismic checking of equipment shall be determined in accordance with the following provisions:

- 1) The body and bearing member may be calculated as follows:

5 Horizontal vessels

5.1 General requirements

5.1.1 The seismic design of horizontal vessel shall comply with the provisions of this clause.

5.1.2 The basic natural vibration period of horizontal vessel may be taken as 0.10 s; when multiple vessels overlap, the basic natural vibration period may be 0.15 s.

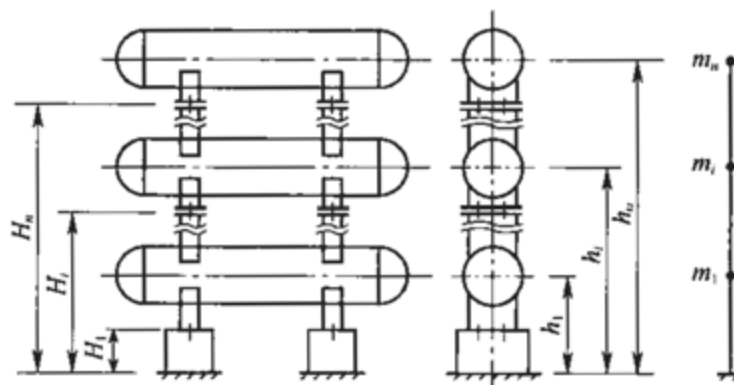
5.2 Seismic action and seismic checking

5.2.1 For the calculation of horizontal seismic action of horizontal vessel, the seismic influence factor may be taken as the maximum value according to the provisions of clause 4.2.1 of this standard.

5.2.2 For the horizontal vessels installed above-ground, it shall follow the requirements of clause 4.3 of this standard to respectively calculate its axial and lateral seismic actions. For the on-framework horizontal vessels, it may follow the requirements of clause 4.4 of this standard to respectively calculate its axial and lateral seismic action.

5.2.3 The damping ratio of horizontal vessel may be 0.05.

5.2.4 For overlapping horizontal vessels, both axial and lateral directions can be regarded as a multi-degree-of-freedom system (Figure 5.2.4). The seismic action of overlapping horizontal vessels installed above-ground may be calculated according to the clause 4.3 of this standard. The seismic influence factor may be taken as the maximum value of the horizontal seismic influence factor; the total seismic action of the overlapping on-framework horizontal vessels and the horizontal seismic action of each particle may be calculated according to clause 4.4 of this standard.



h - The height from the foundation's top surface to the centroid of the equipment (mm).

6.3 Seismic action and seismic checking

6.3.1 For the calculation of horizontal seismic action of vertical vessels supported by legs, the seismic influence factor shall comply with the provisions of clause 4.2 of this standard for the fortified earthquakes.

6.3.2 The seismic action of the vertical vessels supported by legs installed above-ground shall be calculated in accordance with clause 4.3.1 of this standard; the seismic action of the vertical vessels supported by legs installed on-framework shall be calculated in accordance with clause 4.4 of this standard.

6.3.3 The damping ratio of the vertical vessels supported by legs may be 0.05.

6.3.4 The seismic checking of the casings, legs, connecting weld between legs and cylinder, anchor bolts, etc. of vertical vessels supported by legs shall comply with the provisions of clause 4.7 of this standard.

6.3.5 The seismic checking method for vertical vessels supported by legs can be carried out in accordance with the provisions of Appendix B of this standard.

6.4 Details of seismic design

6.4.1 The number of legs shall not be less than 3, the fortification intensity shall be 8 degrees or 9 degrees. When the diameter of the equipment is more than 800 mm, the number of legs should not be less than 4.

6.4.2 Each leg shall be provided with anchor bolts. The diameter of the bolts should not be less than M16. The nuts shall be provided with anti-loose measures.

8 Vertical vessels supported by skirt

8.1 General requirements

8.1.1 The seismic design of the vertical vessels supported by skirt shall comply with the provisions of this clause.

8.1.2 When the height is greater than 20 m and the design basic acceleration of ground motion is greater than or equal to 0.20 g or the seismic fortification intensity is 8 degrees and 9 degrees, it shall take into account of the influence of the vertical seismic action.

8.2 Natural vibration period

8.2.1 The vertical vessels supported by skirt can be simplified to a multi-particle system to calculate the natural vibration period.

8.2.2 For the equal-diameter & equal-thickness vertical vessels supported by skirt installed on the ground foundation, the basic natural vibration period may be calculated as follows:

$$T_1 = 90.33H \sqrt{\frac{m_0 H}{E^t D_i^3 \delta_e}} \times 10^{-3} \quad (8.2.2)$$

Where:

T_1 - The basic natural vibration period of the equipment (s);

H - The height from the foundation's top surface to the equipment's top (mm);

m_0 - The total mass of the equipment (kg);

E^t - The modulus of elasticity of the material (MPa);

D_i - The inner diameter of the cylinder of the equipment (mm);

δ_e - The effective thickness of the cylinder of the equipment (mm).

8.2.3 For the unequal-diameter or unequal-thickness floor-standing vertical vessel, it may consider the equipment whose diameter, thickness, material changes along height into a multi-particle system (Figure 8.2.3). The basic natural vibration period may be calculated according to the following formula.

influence factor may take the maximum value of the horizontal seismic influence factor of the fortified earthquake.

8.3.4 For the vertical vessel supported by skirt which has a height of more than 10 m and an aspect ratio of more than 5, it may use the vibration-mode decomposition method for calculation.

8.3.5 The damping ratio of the vertical vessel supported by skirt may be determined as follows:

1. When the basic natural vibration period of the equipment is less than or equal to 1.5 s, it may take 0.035.
2. When the basic natural vibration period of the equipment is more than 1.5 s and less than or equal to 2.0 s, it may be calculated as follows:

$$\zeta = 0.11 - 0.05T_1 \quad (8.3.5)$$

3. When the basic natural vibration period of the equipment is more than 2.0 s, it may take 0.01.

8.3.6 The vertical seismic action of the vertical vessel supported by skirt shall be calculated in accordance with the provisions of clause 4.5 of this standard.

8.3.7 The casing, the skirt cylinder, the foundation ring, the anchor bolt seat, the connecting weld of skirt and casing, the connecting weld of bolt seat and skirt cylinder, the anchor bolts of the vertical vessel supported by skirt shall be subjected to seismic checking, meanwhile it shall comply with the provisions of clause 4.7 of this standard.

8.4 Details of seismic design

8.4.1 The platform of the equipment should not be directly connected to other equipment or structures.

8.4.2 The heavier auxiliary equipment outside the equipment should be provided with a separate bracing structure, which should not be directly braced by the equipment.

8.4.3 The internal load-bearing members of the equipment shall be securely connected to the casing.

8.4.4 When the aspect ratio of the equipment is more than 5 and the seismic fortification intensity is greater than 7 degrees, the equipment's cylinder should not be overlapped with the skirt seat.

9 Spherical tanks supported by legs

9.1 General requirements

9.1.1 The seismic design of spherical tanks supported by legs of the adjustable and fixed tie-bar structure (hereinafter referred to as spherical tanks) which are braced by tangential or inter-cross column around equator shall comply with the provisions of this clause.

9.1.2 The seismic action of the spherical tanks supported by legs shall be calculated taking into account of the impact of the stored liquid.

9.2 Natural vibration period

9.2.1 The equivalent mass of the spherical tank supported by legs under operating conditions shall be calculated according to the following formula:

$$m_{eq} = m_1 + m_2 + m_5 + 0.5m_6 + m_7 \quad (9.2.1-1)$$

$$m_2 = m_L \varphi \quad (9.2.1-2)$$

Where:

m_{eq} - The equivalent mass of the spherical tank under operating conditions (kg);

m_1 - The mass of spherical shell (kg);

m_2 - The effective mass of the stored solution (kg);

m_5 - The mass of the spherical tank's thermal-insulation layer (kg);

m_6 - The mass of the brace and tie-bar (kg);

m_7 - The mass of accessories (kg), including manholes, adaptors, level gauges, internal components, sprinklers, safety valves, ladder platforms, etc.;

m_L - The mass of the stored solution in spherical tank supported by legs (kg);

φ - The effective mass factor of the stored solution, which is selected based on the fullness of the solution in spherical tank according to Figure 9.2.1.

9.3.2 The horizontal seismic action of spherical tanks supported by legs may be calculated in accordance with clause 4.3.1 of this standard.

9.3.3 The damping ratio of the spherical tank supported by legs may be 0.035.

9.3.4 The total bending moment generated by the horizontal seismic action on the upper segment of bracing shall be calculated as follows:

$$M = F_{EK} L \quad (9.3.4)$$

Where:

M - The total bending moment produced by the horizontal seismic action on the upper segment of bracing (N • mm);

F_{EK} - The design value of the horizontal seismic action on the spherical tank supported by legs (N);

L - The distance from the equatorial plane of the spherical shell to the center of the upper lug pin (mm).

9.3.5 The seismic verification of the braces, the connecting welds between bracing and spherical shell, the tie-bar, the accessories of tie-bar, the baseplate of brace, the anchor bolts, etc. shall comply with the requirements of clause 4.7 of this standard.

9.4 Details of seismic design

9.4.1 The diameter of the anchor bolt of the spherical tank's braces shall not be less than M24, the nut shall be provided with anti-loose measures.

9.4.2 The connecting welds between the spherical tank's shell and the braces, the braces and the lug plates, the tie-bar and the wing plates, the braces and baseplates shall be the equal-strength welds of the thinner parts. The weld shall be full and free from surface defects.

9.4.3 The tension of the tie-bar be moderate, the tension of each tie-bar shall be substantially the same, the intersection of the tie-bars shall not be welded.

10 Vertical cylindrical storage tanks

10.1 General requirements

10.1.1 The seismic design of vertical cylindrical steel-welded flat-bottom storage tanks (hereinafter referred to as storage tanks) which has an aspect ratio of tank wall of not more than 1.6 and a nominal volume of more than or equal to 100 m³ shall comply with the provisions of this clause.

10.1.2 The space between the upper surface of the stored solution of the fixed-top storage tank and the top cover shall be less than 4% of the nominal volume of the storage tank.

10.1.3 The calculation of the seismic action of the storage tank shall take into account of the impact of the stored solution.

10.2 Natural vibration period

10.2.1 The basic natural vibration period of the couple vibration of the stored solution of the storage tank may be calculated as follows:

$$T_1 = K_c H_w \sqrt{\frac{R}{\delta_{1/3}}} \times 10^{-3} \quad (10.2.1)$$

Where:

T_1 - The basic natural vibration period of the couple vibration of the stored solution of the storage tank (s);

K_c - The factor of couple vibration period of the stored solution, which can be found from Table 10.2.1, where the intermediate value may be calculated by the interpolation method;

H_w - The designed maximum liquid level of the storage tank (mm);

R - The inner radius of the storage tank (mm);

$\delta_{1/3}$ - The nominal thickness of the tank wall at a position of 1/3 height to the baseplate, after deducted by the negative deviation of the thickness of the steel plate or the actual thickness (mm).

$$F_t = \frac{4M_g}{\pi D_1^2} \quad (10.5.1)$$

Where:

F_t - The lifting force per unit length in the circumferential direction of the bottom of the tank wall (N/mm).

10.5.2 The anti-lifting force per unit length in the circumferential direction of the bottom of the tank wall shall be calculated according to the following formula:

$$F_L = F_{L0} + \frac{N_1}{\pi D_1} \quad (10.5.2-1)$$

$$F_{L0} = 99\delta_{eb}\sqrt{R_{eL}H_w\rho_s} \times 10^{-6} \quad (10.5.2-2)$$

Where:

F_L - The anti-lifting force per unit length in the circumferential direction of the bottom of the tank wall (N/mm);

F_{L0} - The maximum anti-lifting force of the stored solution and tank's bottom (N/mm), which takes $0.02 H_w D_1 \rho_s g \times 10^{-9}$ where it is more than $0.02 H_w D_1 \rho_s g \times 10^{-9}$, meanwhile the width of the inner edge plate of the tank takes $0.035D$;

N_1 - The gravity as undertaken at the bottom of the first ring of tank wall (N);

δ_{eb} - The effective thickness of the bottom edge plate of the tank (mm);

R_{eL} - The yield strength of the material of the bottom edge of the tank (MPa);

ρ_s - The density of the stored solution (kg/m³).

10.5.3 When the lifting force (F_t) per unit length in the circumferential direction of the bottom of the tank wall is more than 2 times the anti-lifting force ($2F_L$), the storage tank shall be anchored to the foundation.

10.5.4 The anchorage of storage tanks shall comply with the following requirements:

1. The vertical compressive stress at the bottom of the storage tank wall shall be calculated according to the following formula:

$$\sigma_c = C_v \frac{N_1}{A_1} + \frac{M_g}{Z_1} \quad (10.5.4-1)$$

$$\sigma_c \leq [\sigma_{cr}] \quad (10.5.4-2)$$

bottom of the tank wall (F_t) is more than the anti-lifting force (F_L) and less than or equal to 2 times the anti-lifting force ($2F_L$), it shall be calculated according to the following formula:

$$\sigma_c = C_v \frac{N_1}{A_1} + C_L \frac{M_g}{Z_1} \quad (10.5.5-2)$$

$$C_L = 0.4 \left(\frac{F_t}{F_L} \right)^2 - 0.7 \left(\frac{F_t}{F_L} \right) + 1.3 \quad (10.5.5-3)$$

Where:

C_L - The bottom lifting influence factor.

3. The vertical compressive stress at the bottom of the tank wall shall meet the requirements of the following formula:

$$\sigma_c \leq [\sigma_{cr}] \quad (10.5.5-4)$$

4. When the vertical compressive stress (σ_c) at the bottom of the tank wall is more than the allowable critical stress of stability ($[\sigma_{cr}]$), it may use one or more of the following measures, meanwhile it shall repeat the calculations of item 1 and item 2 of this clause, until it meets the requirements:

- 1) Reduce the aspect ratio of the storage tank;
- 2) Increase the thickness of the first ring of tank wall;
- 3) Increase the thickness of the bottom edge of the tank;
- 4) Anchor the storage tank to the foundation.

10.5.6 When the thickness of the first ring of tank wall as obtained by seismic checking according to this clause is more than the thickness as calculated based on the hydrostatic pressure (excluding the corrosion allowance), the thickness of the other rings of tank wall shall also be calculated based on the thickness as calculated according to the hydrostatic pressure, through seismic checking ring by ring.

10.6 Liquid sloshing height

10.6.1 The liquid sloshing wave height of the liquid level in the storage tank under horizontal seismic action shall be calculated according to the following formula:

11 Tubular heater

11.1 General requirements

11.1.1 Except for the ethylene cracking furnace, the seismic design of the collection flue duct and chimney of the tubular heater, the auxiliary combustion chamber, the sulfur tubular heater, the waste heat recovery system shall comply with the provisions of this clause.

11.1.2 The calculation of the seismic action of the tubular heater structure shall comply with the following provisions:

1. For the frame structure of the box-type tubular heater and the cylindrical furnace's convection chamber, it shall calculate the horizontal seismic action in the two main axial directions on the horizontal plane, respectively, meanwhile perform the seismic checking. The horizontal seismic action in each direction shall be undertaken by the lateral force-resisting member in this direction;
2. For the horizontal tubular heater, it may only calculate the horizontal seismic action of the body along lateral direction, and carry out seismic checking;
3. For the floor-standing chimney, when the design basic acceleration of ground motion is $0.20\text{ g} \sim 0.40\text{ g}$ or the seismic fortification intensity is 8 degrees and 9 degrees, it shall calculate the vertical seismic action and follow the relevant provisions of the current national standard "Code for seismic design of buildings" GB 50011 to combine with the horizontal seismic action, and carry out seismic checking;
4. For the tubular heater which has a height of more than 30 m (including the height of the heater-top-chimney, when the design basic acceleration of ground motion is 0.4 g or the seismic fortification intensity is 9 degrees, it shall calculate the vertical seismic action and follow the relevant provisions of the current national standard "Code for seismic design of buildings" GB 50011 to combine with the horizontal seismic action, and carry out seismic checking;

11.2 Natural vibration period

11.2.1 The tubular heater may be simplified into a multi-particle structure system. When using the matrix iterative method to calculate the natural vibration period, the flexibility matrix elements may be calculated according to the provisions of Appendix D of this standard.

11.4 Details of seismic design

11.4.1 The box-type tubular heater shall comply with the following requirements:

1. The top and bottom beams of the side wall of the tubular heater's frame as well as the beam of the variable cross-sectional parts of the frame column of the tubular heater should use the hot-rolled H-profile steel. When the seismic fortification intensity is 7 degrees, it should not be less than H250 x 125. When the seismic fortification intensity is 8 degrees, it should not be less than H300 x 150. When the seismic fortification intensity is 9 degrees, it should not be less than H350 x 175;
2. The top plane of the tubular heater shall be provided with a structural diagonal bracing. When using the single-limb steel-angle and the seismic fortification intensity is 7 degrees, it should not be less than the steel-angle 75 x 6. When it is 8 degrees, it should not be less than the steel-angle 90 x 8. When it is 9 degrees, it should not be less than the steel-angle 110 x 10. When using the double-limb steel-angle and the seismic fortification intensity is 7 degrees, it should not be less than the steel-angle 63 x 6. When it is 8 degrees, it should not be less than the steel-angle 75 x 6. When it is 9 degrees, it should not be less than the steel-angle 90 x 8;
3. When there is a chimney on the top of the tubular heater, it shall provide a diagonal bracing between the two columns which brace the chimney. The angle between the diagonal bracing and the column should be 30° ~ 60°;
4. The frame column of the tubular heater and the column which braces the convection chamber shall be rigidly connected;
5. The both ends of the seat beam which braces the chimney at the top of the tubular heater shall be rigidly connected;
6. There shall be a gentle transition segment at the joint of the frame columns of tubular heaters of different cross-sections;
7. It should provide the below-knee braces between the bottom columns of the side wall of the tubular heater's frame see Figure 11.2.3-2 of this standard).

11.4.2 Cylindrical tubular heaters shall comply with the following requirements:

1. The height of the convection chamber should not be more than the height of the radiation chamber;
2. The structural members of the convection chamber shall be arranged

11.4.3 Horizontal tubular heaters shall comply with the following requirements:

1. The thickness of the cylinder should not be less than 10 mm;
2. The thickness of the saddle's baseplate which braces the cylinder body shall not be less than 12 mm, the width shall not be less than 200 mm, the thickness of the saddle's vertical plate shall not be less than 12 mm, the thickness of the rib plate shall not be less than 10 mm;
3. The number of anchor bolts for the fixed seat shall not be less than 2, the nut shall be provided with anti-loose measures;
4. The sliding seats shall be provided with measures to limit the lateral displacement of the horizontal tubular heater.

11.4.4 The anchor bolts of the tubular heater shall not be less than M24. The nuts shall be provided with anti-loose measures. The thickness of the baseplate of the column leg shall not be less than 14 mm.

11.4.5 When the chimney's base at the top of tubular heater is flange-connected, the connecting bolts shall not be less than M16, the bolt's spacing shall not be more than 250 mm. When connected by the high platform base, the connecting bolts shall not be less than M24, the number of bolts shall not be less than 8. The nut shall be protected against loosening.

11.4.6 The welded joints of the tubular heater's frame members shall not be located in the maximum stress area where plastic hinge may be produced.

11.4.7 The overhead flue shall comply with the following requirements:

1. The wall thickness of the flue shall not be less than 6 mm;
2. When using the socket-type flue for temperature compensation, the setting of expansion joint shall be determined by calculation, meanwhile it shall reserve the expansion gap;
3. At the compensation part of the socket-type flue, it shall provide a bearing structure;
4. At both sides of the flue at the seat, it shall provide the position-limit device. The position-limit plate shall be parallel to the flue, at a distance to the outer wall of the flue of 30 mm ~ 50 mm.

11.4.8 The thickness of the ring plate of the floor-standing chimney's seat shall not be less than 14 mm, it shall provide the high platform seat base at the bottom. The anchor bolts shall not be less than M24, the number shall not be less than 8. The nuts shall be protected against loosening.

Where:

F_1 - The vertical reaction force of the lug (N);

M_1 - The overturning moment generated by the design value of horizontal seismic action (N • mm);

M_2 - The overturning moment (N • mm), the moment generated by horizontal loads other than horizontal seismic actions, the moment generated by eccentric mass, the moment generated by the pipeline, other bending moments;

D_b - The diameter of the center circle of the equipment's anchor bolt (mm);

W - Vertical load (N), including equipment weight, pipeline and other vertical loads.

C.0.3 The stress of the lugs may be calculated as follows:

$$\sigma = \frac{F_1 l}{Z_1} + \frac{F_t l}{Z_t} + \frac{F_r}{A_1} \quad (\text{C. 0. 3})$$

Where:

σ - The stress of the lugs (MPa);

F_1 - The vertical reaction force of the lug (N), which is calculated according to the formula (C.0.2) of this standard;

F_t - The circumferential reaction force at the equipment's lug as caused by horizontal load (N), which is calculated according to the formula (C.0.1) of this standard;

F_r - The radial reaction force at the equipment's lug as caused by horizontal load (N), which is calculated according to the formula (C.0.1) of this standard;

l - The distance from the outer wall of the body to the point of reaction (mm);

Z_1 - The axial bending modulus of the lug to the equipment (mm³);

Z_t - The bending resistance of the lug to the equipment (mm³);

A_1 - The cross-sectional area of the lugs (mm²).

C.0.4 The stress of the weld at the joint of the lugs shall comply with the following requirements:

1. The tensile stress may be calculated according to the following formula:

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