Foreword

This code is prepared by China Petroleum and Chemical Engineering Survey and Design Association and Shanghai Fuchen Chemical Co., Ltd. together with other involved organizations. according to the requirements of Document JIANBIAO [2013] No.6 issued by the Ministry of Housing and Urban-Rural Development (MOHURD) "*Notice on Printing and Distributing' the Development and Revision Plan of National Engineering Construction Standards in 2013'* ".

In preparing this code, the development team carried out investigation and research, tests and verification, summarized the application experience of Chinese fibre reinforced plastics equipment and piping engineering technology, made reference to the advanced codes and standards in China and abroad, based on extensive consultation, reviewed and finalized this code.

This code consists of 11 chapters and 11 appendixes, covering: general provisions, terms, basic requirements, materials, equipment design, piping design, manufacture, quality control and inspection, marking, packing, transporting, storing, installation, project acceptance.

The provisions printed in bold type are mandatory ones and must be implemented strictly.

This code is under the jurisdiction of, and its mandatory provisions are interpreted by the Ministry of Housing and Urban-Rural Development of the People's Republic of China. The Branch of Chemical Industry, China Association for Engineering Construction Standardization is responsible for its routine management, and Shanghai Fuchen Chemical Co., Ltd. is in charge of explanation of technical specification. During the implementation of this code, any comments and advices can be posted or passed on to Shanghai Fuchen Chemical Co., Ltd. (Address: 5-21B, No. 251 Caoxi Road, Xuhui District, Shanghai; Postcode: 200235).

Chief Development Organizations, Co-Development Organizations, Participating Organizations, Chief Draffters, Chief Reviewers and Chief Translaters of this code:

Chief Development Organizations:

China Petroleum and Chemical Engineering Survey and Design Association

Shanghai Fuchen Chemical Co., Ltd.

Co-Development Organizations:

Shijiazhuang Development Zone Jiyuan Technology Co., Ltd.

Xinjiang Pengyuan New Material Co., Ltd.

East China University of Science and Technology

China Wuhuan Engineering Co., Ltd.

Sinopec Nanjing Engineering Co., Ltd.

China Enfi Engineering Technology Co., Ltd.

Jizhou Zhongyi Composite Material Co., Ltd.

Jiangxi Copper Group Company Guixi Smelting Plant

Changzhou Huake Polymer Co., Ltd.

Jinchuan Group Engineering Construction Co., Ltd.

Jilin Design Institute of CNPC Northeast Refining and Chemical Engineering Co., Ltd.

Ashland (China) Investment Co., Ltd.

China Power Engineering Consulting Group East China Power Design Institute Co., Ltd.

China Metallurgical Orient Engineering Technology Co., Ltd.

Hebei Hengxing Environmental Protection Equipment Engineering Co., Ltd.

National Chemical Construction Standardization Management Center

Participating Organizations:

Taishan Fibreglass Co., Ltd.

Chongqing International Composite Materials Co., Ltd.

Guangdong Xianli Fibre Reinforced Plastic Co., Ltd.

Deyang Shuangquan FRP Products Co., Ltd.

Chief Drafters:

LU Shiping LI Guoshu WANG Lei HOU Ruigang TANG Wenyong WANG Zhengzhu YU Qun ZHAO Aijun LAN Liqin LIU Su JIANG Xianlong LU Yuechi WANG Tiantang ZENG Shao JU Yuanqin JIANG Guoxian ZHANG Weixiu YUAN Ye LAI Xiaodong LI Dasheng NIU Chunliang GUO Quanguo LU Tian ZHAO Guiqin GAO Shangwen LI Ye

Chief Reviewers:

CHEN Bo NI Lizhong ZHU Sirong GUO Wenqiang SHA Yuan ZHANG Shiguang WANG Qianghua ZHANG Linwen LV Huimin WANG Jiandong JI Li

Chief Translaters:

ZHU Sirong LU Qi'ao LI Guoshu WANG Lei LU Shiping

Contents

1 General provisions

1.0.1 This code is prepared with a view to improve the application level of fibre reinforced plastics equipment and piping engineering, and to achieve advanced technology, safety and usability, economy and rationality, and quality assurance.

1.0.2 This code is applicable to the design, manufacture, installation and engineering quality acceptance of integral fibre reinforced plastics equipment and piping formed by winding, spraying and hand lay-up.

1.0.3 This code is not applicable to the following design of fibre reinforced plastics equipment and piping:

1 Transport tank, buried container, storage tanks and double walled tanks;

2 Irregular shape(no-gyrating) containers, tanks and towers;

3 Equipment and piping for highly toxic or radioactive chemicals;

4 Buried water supply and drainage pipes;

5 Chimneys and flues;

6 Oil and gas gathering and transportation pipes.

1.0.4 In engineering applications of fibre reinforced plastics equipment and piping, in addition to the requirements stipulated in this code, those stipulated in the current relevant standards of the nation shall be complied with.

2 Terms

2.0.1 Unit

The reciprocal of the unit area mass of fibre reinforced material (kg/m^2) and unit width (mm) of a lamina, with unit of $1/(mm \cdot kg/m^2)$; or the reciprocal of the unit width (mm) of a laminate, with unit of 1/mm.

2.0.2 Unit tensile strength

Ultimate tensile load per unit width and unit area mass of fibre reinforced material of a lamina, with unit of $N/(mm \cdot kg/m^2)$.

2.0.3 Unit tensile modulus

The ratio of the tensile load to the corresponding strain per unit width and unit area mass of fibre reinforced material of a lamina, with unit of $N/(mm \cdot kg/m^2)$.

2.0.4 Tensile load carrying capacity of a laminate

Ultimate tensile load of unit width laminate, with unit of N/mm.

2.0.5 Laminate unit tensile stiffness

Ratio of tensile load to corresponding strain of unit width laminate, with unit of N/mm.

2.0.6 Design thickness of structural layer

Thickness of structural calculation for main load in layer, which does not include the thickness of lining and outer surface.

2.0.7 Design thickness

The entire layer thickness including the thickness of the structural layer, the thickness of the lining and the outer surface.

2.0.8 Simplified failure envelope

A simplified polygonal line for the biaxial stress failure curves of anisotropic materials.

2.0.9 Air bubble

A cavity formed by air retention in a layer.

2.0.10 Chip

A small piece of damage on the edge or surface of a layer.

2.0.11 Crazing

Irregular minor crack on the surface of a layer.

2.0.12 Dry spot

Areas where fibres are not adequately saturated with resin.

2.0.13 Exposed fibre

The surface or edge fibres are exposed.

2.0.14 Pit

A crater area of a layer.

2.0.15 Scratch

Scoring or shallow mark on the surface of a layer.

2.0.16 Wrinkle

Wavy surface of the layer due to irregular shape or overlapping of the structure.

3 Basic requirements

3.1 General requirements

3.1.1 The design pressure range of fibre reinforced plastics equipment shall be in accordance with the following requirements:

1 Where the diameter is less than or equal to 4m, the design internal pressure shall not be larger than 1.0MPa, and the product of the design internal pressure and diameter shall not be larger than 2.4MPa·m, and the design external pressure shall not be larger than 0.1MPa;

2 Where the diameter is larger than 4m, the design internal pressure shall not be larger than 2.0kPa, and the design external pressure shall not be larger than 0.5kPa.

3.1.2 The design pressure range of fibre reinforced plastic piping shall be in accordance with the following requirements:

1 Where the diameter is less than or equal to 600mm, the design internal pressure shall not be larger than 1.0MPa;

2 Where the diameter is larger than 600mm and less than or equal to 1200mm, the design internal pressure shall not be larger than 0.6MPa;

3 External pressure shall not be larger than 0.1MPa.

3.1.3 When the design pressure and diameter of fibre reinforced plastics equipment and piping do not conform to the scope stipulated in Articles 3.1.1 and 3.1.2 of this code, the material properties shall be determined by testing.

3.1.4 The design temperature range of fibre reinforced plastic equipment should be −40℃ to +120℃, and the design temperature range of piping should be −30℃ to +110℃. When the temperature range is not satisfied, the performance of the material shall be determined by testing.

3.2 Functional requirements

3.2.1 Flame retardant resins or additives shall be used when flame retardant performance of fibre reinforced plastics equipment and piping is required.

3.2.2 Conductive carbon fibres or conductive fillers shall be used when fibre reinforced plastics equipment and piping are required to have anti-static properties, and the continuous surface resistivity shall not be larger than $1.0\times10^{6}\Omega$ or the volume resistivity shall not be larger than $1.0\times10^{6}\,\Omega\cdot m$. The electrostatic grounding shall meet the requirements of the relevant provisions of SH 3097 *Code for the Design of Static Electricity Grounding for Petrochemical Industry*, the current industry standard.

3.2.3 When wear resistance of fibre reinforced plastic equipment and piping are required, wear resistant fillers shall be added to the resin or other technical measures should be taken.

3.2.4 When there is food hygiene requirement for fibre reinforced plastics equipment and piping, it shall meet the requirements of the current national standards GB/T 14354 *Food Containers of Glass Fibre Reinforced Unsaturated Polyester Resin* and GB/T 5009.98 *Method for Analysis of Hygienic Standard of Unsaturated Polyester Resin and Glass Fibre Reinforced Plastics Used as Food Containers and Packaging Materials*.

3.3 Design conditions and documents

3.3.1 The design conditions of the fibre reinforced plastic equipment and piping provided by the client shall include the following contents:

1 Components and characteristics of medium;

2 Operating parameters such as working pressure, working temperature, liquid level, velocity and branch load;

3 Process description;

4 Geometric parameters, nozzle orientation and support type;

5 Natural conditions such as ambient temperature, seismic fortification intensity, wind and snow loads, etc.;

6 Other conditions.

3.3.2 Before manufacturing fibre reinforced plastics equipment and piping, the manufacturer shall have design documents such as design task sheets, calculation sheets, design drawings, design specifications, etc.

3.3.3 The following contents shall be included in the design drawing and the design specifications:

1 Name and classification of project, major regulations, specifications and product standards for design and manufacture;

2 Working pressure, working temperature, composition, characteristics, velocity, toxicity and explosion hazard of the medium;

3 Design temperature, design pressure and wind, snow and earthquake loads;

4 Types, grades and specifications of main raw materials;

5 Main characteristic parameters and deviation control range of equipment diameter, height, volume, pipe diameter, length and so on;

6 Layer sequence, number of layers, thickness and deviation control range of fibre reinforced plastics equipment and piping;

7 Accessories such as lifting lug, strut and ladder;

8 Location of nameplates for fibre reinforced plastics equipment and piping;

9 Packaging, transportation and installation requirements;

10 Testing requirements.

3.4 Overpressure protection

3.4.1 All equipment in this code shall be protected by overvoltage.

3.4.2 The overvoltage protection of the equipment connected with the atmosphere must be in accordance with the following requirements.

1 Shall be open at the top, and should be communicated directly with the air;

2 The sectional area of the vent shall not be less than the larger value between the inlet and outlet dimensions of the equipment (net circulation area);

3 Airtight vent must not be prohibited;

4 The overflow port shall be installed, and the section area of the overflow port shall not be less than the inlet dimension.

3.4.3 Overvoltage protection for equipment that does not interconnect with the atmosphere shall be in accordance with the following requirements:

1 Overpressure relief devices shall be installed for equipment with overpressure during operation;

2 The installation of overpressure relief device shall conform to the relevant provisions of GB 150.1 *Pressure Vessels-Part 1: General Requirements*.

4 Materials

4.1 General requirements

4.1.1 The material selection of fibre reinforced plastic equipment and piping shall be based on calculating, evaluating, testing and verifying of the mechanical properties, chemical resistance, physical properties and processing properties of the materials.

4.1.2 The materials used in fibre reinforced plastic equipment and piping shall have a *Material Safety Data Sheet*.

4.2 Raw materials

4.2.1 Unsaturated polyester resin, vinyl ester resin and epoxy resin should be selected for fibre reinforced plastic equipment and piping. When other types of resins are selected, their properties shall be determined by testing.

4.2.2 Resins used for fibre reinforced plastics equipment and piping shall be in accordance with the following requirements:

1 Resin shall meet the working conditions and forming process requirements;

2 Resin shall be matched with reinforcement material;

3 The same resin should be chosen for lining and structural layer;

4 Unsaturated polyester resin and vinyl ester resin shall be matched with the initiator and accelerator selected;

5 Epoxy resin shall be match with the selected curing agent.

4.2.3 The quality of the resin shall be in accordance with the following requirements:

1 The quality of unsaturated polyester resin shall meet the relevant requirements of current national standard GB/T 8237 *Liquid Unsaturated Polyester Resin for Fibre Reinforced Plastics*;

2 The quality of vinyl ester resin shall meet the relevant requirements of current national standard GB/T 50590 *Technical Code for Anticorrosion Engineering of Vinyl Ester Resins*;

3 The quality of epoxy resin shall meet the relevant requirements of current national standard GB/T 13657 *Bisphenol-A Epoxy Resin*;

4 The properties of resin casting body should be in accordance with those specified in Table 4.2.3:

Table 4.2.3 Properties of resin casting body

Mechanical property	Lining resin	Structural layer resin
Tensile strength(MPa)	≥60.0	≥60.0
Tensile modulus($\times 10^3$MPa)	≥2.5	≥3.0
Fracture elongation(%)	≥3.5	≥2.5
Heat deflection temperature(HDT,℃,1.80MPa)	≥T_d+20	

Note: T_d representing design temperature.

5 The corrosion resistance of the resin may be determined by the corrosion resistance data of the resin, existing application experience, coupon or laboratory test and verification, etc. The evaluation method shall meet the requirements of Appendix A of this code.

4.2.4 Glass fibre and its products, carbon fibre and its products, synthetic fibre and its products should be selected as reinforcement materials for fibre reinforced plastic equipment and piping. When other types of reinforcement materials are selected, their properties shall be determined by tests.

4.2.5 Reinforcement materials for fibre reinforced plastic equipment and piping shall be in accordance with the following requirements:

1 Reinforcement materials shall meet the requirements of working conditions and molding process;

2 The coupling agent used in fibre surface treatment shall be matched with resin;

3 The type of fibre reinforced material used for the connection between the equipment cylinder and pipeline shall be the same as the reinforcement materials of the equipment cylinder and pipeline.

4.2.6 Glass fibre and its products should be chosen chopped strands mat, woven roving, winding filament, gun roving, woven fabrics, surface veil, and the quality of which shall be in accordance with the following requirements:

1 The quality of chopped strand mat shall meet the requirements of the current national standard GB/T 17470 *Glass Fibre Mats-Chopped Strand and Continuous Filament Mats*;

2 The quality of woven roving shall meet the requirements of current national standard GB/T 18370 *Glass Fibre Woven Roving*;

3 The quality of winding filament and gun roving shall meet the the requirements of current national standard GB/T 18369 *Glass Fibre Roving*;

4 The quality of woven fabrics shall be in accordance with the the requirements of current national standard GB/T 25040 *Glass Fibre Stitched Fabrics*;

5 The percent moisture content of surface veil shall not be larger than 0.2%, and the mass per unit area should be (30—50) g/m^2.

4.2.7 The quality of carbon fibre and its products shall meet the relevant requirements of current national standard GB/T 26752 *PAN-Based Carbon Fibre*, and GB/T 30021 *Warp Knitting Carbon Fibre Reinforcements*.

4.2.8 Under the condition of different corrosive medium, the reinforcing materials of lining and outer surface of fibre reinforced plastics equipment and piping should be selected according to Table 4.2.8.

Table 4.2.8 Selection form of reinforced material for lining and outer surface

No.	Corrosive medium	Type of surface veil	Type of chopped strand mat
1	Alkaline inorganic substance and hydrolysable salt of alkaline inorganic substance	S	E or E-CR
2	Hydrolyzable salt of oxidizing alkaline inorganic substance	S	E or E-CR
3	Acid inorganic substance and hydrolysable salt of acid inorganic substance	C or E-CR	E-CR
4	Inorganic oxidizing acid	C or E-CR	E-CR
5	Alkaline organics	C or E	E or E-CR

Table 4.2.8(continued)

No.	Corrosive medium	Type of surface veil	Type of chopped strand mat
6	Acidic organics	C or E-CR	E-CR
7	Surface active agent	C or E or S	E or E-CR
8	Organic solvent	C or E	E or E-CR
9	Strong oxidizer	C or E or S	E or E-CR
10	Others	C or E or S	E or E-CR

Notes: 1 S stands for synthetic fibre or carbon fibre, C for chemical-resistant glass fibre, E for alkali-free glass fibre, and E-CR for acid-resistant glass fibre;

2 The classification of corrosive medium shall meet the requirements of the provisions of Appendix B of this code.

4.3 Material properties of lamina and laminate

4.3.1 The mechanical properties of fibre reinforced plastic lamina for equipment and pipes should be determined by testing. When using the layering calculation method, the mechanical properties of the glass fibre reinforced plastic lamina shall be in accordance with the following requirements:

1 The mechanical properties of the lamina shall be in accordance with Table 4.3.1-1;

2 The winding angle and the unit tensile modulus of the circumferential and axial direction of the filament wound layer should be in accordance with Table 4.3.1-2;

3 The winding angle and the poisson ratio of the filament wound layer should be in accordance with Table 4.3.1-3;

4 The glass fibre content by mass of the lamina shall be in accordance with the following requirements:

1) For chopped strand mat, it should be 25% to 35%;

2) For woven roving, it should be 45% to 55%;

3) For winding roving, it should be 60% to 75%.

Table 4.3.1-1 Mechanical properties of glass fibre reinforced plastic lamina materials

Reinforcement material types	Direction	Applicable conditions	Unit tensile strength U_i [N/(mm·kg/m²)]	Unit tensile modulus X_i [N/(mm·kg/m²)]	Interlaminar or lap shear strength τ_{lap} (MPa)
Chopped strand mat	All		200	14000	7.0
Woven roving	Warp	$\xi \geq 1/6$	$500 \times \xi$	$4000 + 24000 \times \xi$	6.0
		$\xi < 1/6$	60	4000	
	Weft	$\xi \leq 5/6$	$500 \times (1-\xi)$	$4000 + 24000 \times (1-\xi)$	
		$\xi > 5/6$	60	4000	
Filament wound	Fibre direction	$85° < \theta < 90°$	500	28000	

Notes: 1 In the table, ξ is the ratio of the warp direction of the total fibre mass of glass woven roving;

2 In the table, θ is the winding angle, representing the angle between the direction of winding and the axis x of the cylinder or pipe.

Table 4.3.1-2 Winding angle, circumferential unit and axial unit tensile modulus of the filament wound layer

The angle θ between the winding direction and the axis x of the cylinder or pipe(°)	Circumferential unit tensile modulus [N/(mm·kg/m²)]	Axial unit tensile modulus [N/(mm·kg/m²)]
0	—	28000
5	—	27400
10	—	26000

Table 4.3.1-2(continued)

The angle θ between the winding direction and the axis x of the cylinder or pipe(°)	Circumferential unit tensile modulus [N/(mm·kg/m²)]	Axial unit tensile modulus [N/(mm·kg/m²)]
15	—	23800
20	4600	19800
25	4550	16000
30	4550	12800
35	4600	9800
40	5000	7500
45	5800	5800
50	7500	5000
55	9800	4600
60	12800	4550
65	16000	4550
70	19800	4600
75	23800	—
80	26000	—
85	27400	—
90	28000	—

Table 4.3.1-3 Winding angle and Poisson's ratio of filament wound layer

Angle θ between fibre winding direction and axis x of the cylinder or pipe(°)	Poisson's ratio v_{yx}	Poisson's ratio v_{xy}
0	0.075	0.26
5	0.075	0.27
10	0.10	0.32
15	0.14	0.38
20	0.18	0.47
25	0.24	0.56
30	0.31	0.59
35	0.37	0.61
40	0.45	0.59
45	0.54	0.54
50	0.59	0.45
55	0.61	0.37
60	0.59	0.31
65	0.56	0.24
70	0.47	0.18
75	0.38	0.14
80	0.32	0.10
85	0.27	0.075
90	0.26	0.075

Notes: 1 x is the axis of the cylinder or pipe; y is the circumferential direction of the cylinder or pipe;

2 The Poisson's ratio v_{yx} is the x-direction strain caused by the stress in the y direction, and the Poisson's ratio v_{xy} is the y-direction strain caused by the stress in the x direction.

4.3.2 The mechanical properties of the fibre reinforced plastic laminates may be calculated according to the layering calculation based on the laminate theory or the testing results, and shall be in accordance with the following requirements:

1 When tested parameters or historical data are missing, the following layering calculation method shall be used:

1) The unit tensile stiffness and unit tensile strength of the laminate shall be calculated according to the following formulas:

$$X_{lam}=n_1W_1X_1+n_2W_2X_2+\cdots+n_iW_iX_i \tag{4.3.2-1}$$

$$U_{lam}=n_1W_1U_1+n_2W_2U_2+\cdots+n_iW_iU_i \tag{4.3.2-2}$$

where

X_{lam}—Unit tensile stiffness of laminate(N/mm);

U_{lam}—Unit tensile strength of laminate(N/mm);

n_i—Number of layers of the i-th lamina;

W_i—Fibre mass per unit area of the i-th lamina(kg/m^2);

X_i—Unit tensile modulus of the i-th lamina[$N/(mm\cdot kg/m^2)$]; for a filament wound layer, when the winding angle is less than 15° and the circumferential tensile modulus is calculated, the value shall be 0; when the winding angle is greater than 75° and the axial tensile modulus is calculated, the value shall be 0;

U_i—Unit tensile strength of the i-th lamina[$N/(mm\cdot kg/m^2)$].

2) The tensile modulus of the laminate shall be calculated according to the following formulas:

$$E_{lam}=X_{lam}/t_d \tag{4.3.2-3}$$

$$t_d=\sum_{i=1}^{n_i}t_i \tag{4.3.2-4}$$

$$t_i=\left[\frac{1}{\rho_g}+\frac{(100-m_g)}{m_g\times\rho_r}\right]\times W_i\times 10^3 \tag{4.3.2-5}$$

where

E_{lam}—Tensile modulus of laminate(MPa);

t_d—Calculated thickness of structural layer of laminate(mm);

t_i—Structure calculation thickness of the i-th lamina(mm);

m_g—Fibre mass percentage of the i-th lamina;

W_i—Fibre mass per unit area of the i-th lamina(kg/m^2);

ρ_r—Density of cured resin(kg/m^3);

ρ_g—Density of fibre(kg/m^3).

3) The flexural modulus of the laminate shall be calculated according to the following formulas:

$$E_b=\frac{1}{t_d^3}\sum_{i=1}^{n}W_iX_i\left[12(h_i-h_0)^2+t_i^2\right] \tag{4.3.2-6}$$

$$h_0=\frac{\sum_{i=1}^{n}W_iX_ih_i}{\sum_{i=1}^{n}W_iX_i} \tag{4.3.2-7}$$

where

E_b—Flexural modulus of laminate(MPa);

W_i—Fibre mass per unit area of the i-th lamina(kg/m^2);

X_i—Unit tensile modulus of the i-th lamina [$N/(mm \cdot kg/m^2)$];

h_i—Distance between the center of the i-th lamina and the center of the laminate(mm)(Figure 4.3.2);

h_0—Distance between the neutral plane of the laminate and the center of the laminate(mm).

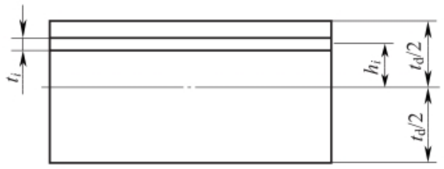


Figure 4.3.2 Schematic diagram of the distance h_i between the center of the i-th lamina and the center of the laminate

2 When testing is used to determine the performance of lamina and laminate, it shall be in accordance with the following requirements:

1)The test specimens shall be made according to the designed layers, and the number of processed specimens for each test item shall not be less than 15;

2)Lamina and laminate performance testing items shall be in accordance with those specified in Table 4.3.2-1;

Table 4.3.2-1 Lamina and laminate performance testing item

Test items		Lamina	Laminate
Tensile properties	Unit tensile strength	√	—
	Unit tensile modulus	√	—
	Unit tensile strength	—	√
	Unit tensile stiffness	—	√
Elastic modulus	Tensile modulus	—	√
	Flexural modulus	—	√
Shear strength	Interlaminar shear strength	○	○
	Lap shear strength	√	√
	Shear strength	—	√

Note: "√" means the item shall to be inspected; "○" means the item should to be inspected; "—" means no item to be inspected.

3)The confidence of the specimen data shall be calculated according to the following formulas:

$$J_{lam} = \bar{J} - t \times s \quad (4.3.2\text{-}8)$$

$$s = \sqrt{\frac{\sum (J - \bar{J})^2}{N - 1}} \quad (4.3.2\text{-}9)$$

where

J_{lam}—Typical values for preset layers performance;

$\bar{J}$—Average test results of measured performance of preset layup;

t—t-distribution threshold, which may be valued according to Table 4.3.2-2;

s—Standard deviation;

J—Actual test result;

N—Number of specimens.

Table 4.3.2-2 *t*-distribution threshold

N	*t*	*N*	*t*
15	2.160	24	2.074
16	2.145	25	2.069
17	2.131	26	2.064
18	2.120	27	2.060
19	2.110	28	2.056
20	2.101	29	2.052
21	2.093	30	2.048
22	2.086	31	2.045
23	2.080	32	2.042

Ⅰ Equipment design factor and allowable strain

4.3.3 The design factor of the mechanical properties of the equipment shall be determined in accordance with the following requirements:

1 The design factor shall be calculated according to following formulas:

$$K=2\times K_1\times K_2\times K_3\times K_4 \tag{4.3.3-1}$$

$$F=2\times K_1\times K_2\times K_3\times\sqrt{K_4} \tag{4.3.3-2}$$

where

K—Design factor, shall not less than 6.0;

F—Buckling factor, shall not less than 4.0;

K_1—Partial design factor relating to test and verification of material properties;

K_2—Partial design factor relating to chemical environment;

K_3—Partial design factor relating to the influence of the design temperature and resin HDT;

K_4—Partial design factor relating to long-term performance of laminate.

2 When the partial design factor cannot be determined, the design factor shall not be less than 10.0 and the buckling factor shall not be less than 5.0.

4.3.4 The test and verification partial design factor K_1 shall be in accordance with the following requirements:

1 When the mechanical properties of the laminate used in the design are determined by the layering calculation method and the performance values of each lamina in Table 4.3.1 of this code are adopted, K_1 shall be in accordance with the following requirements:

1) When there is a product performance of the same laminates manufactured within 18 months and there is acceptable historical test data of performance of the product, K_1 shall be taken as 2.0;

2) When there is a product performance of the same laminates manufactured within 12 months and there is acceptable historical test data of performance of the product, K_1 shall be taken as 1.5;

3) When there is a product performance of the same laminates manufactured within 12 months, and the performance of the lamina is verified by 5 data sets, get the average of 5 data and the average of 3 data excluding the maximum and minimum ones. The smaller of the two average values shall be greater than the performance value in Table 4.3.1 of this code, K_1 shall be taken as 1.3;

4) When there is a product performance of the same laminates manufactured within 12 months, and the mechanical properties of the laminates used in the design are verified by a test of 5 data sets, get the average of 5 data and the average of 3 data excluding the maximum and minimum ones. The smaller of the two average values shall be greater than the mechanical properties of the laminate used in the design, K_1 shall be taken as 1.2.

2 When the mechanical properties of the laminate used in the design are determined by the layering calculation, the performance of the lamina is determined by testing or by the original test results, and the performance of the lamina is verified by 5 data sets, get the average of 5 data and the average of 3 data excluding the maximum and minimum ones, the smaller of the two average values shall be greater than the performance value of the lamina, K_1 shall be taken as 1.1.

3 When the mechanical properties of the laminates used in the design are measured and sampled from the simulated specimens of the laboratory, the performance test data shall not be less than 15 for the test verification, K_1 shall be taken as 1.1.

4 When the mechanical properties of the laminate used in the design are measured and sampled from the equipment specimen, the performance test data shall not be less than 15 for the test verification, and K_1 shall be taken as 1.0.

4.3.5 The value K_2 of the partial design factor relating to the chemical environment shall meet the requirements of Appendix A of this code.

4.3.6 The partial design factor relating to the design temperature and the thermal deflection temperature (HDT) of the resin shall be calculated as follows, and the value K_3 shall be in the range of 1.0—1.4.

$$K_3 = 1.0 + 0.4\frac{T_d - 20}{HDT - 40} \tag{4.3.6}$$

where

T_d—Design temperature;

HDT—Heat deflection temperature of resin.

4.3.7 The partial design factor K_4 relating to the long-term performance of the laminate shall be in accordance with Table 4.3.7 and the following requirements:

1 Where combination laminates of chopped strand mat, woven roving or winding roving, the value of K_4 shall be taken for the major constituent;

2 For the calculation of the buckling factor F, only the K_4 value for flexural shall be used;

3 For the calculation of the overall design factor K, where the loading is a combination of both tension and flexural, the K_4 value for tension shall be used.

Table 4.3.7 Partial design factor K_4 relating to long-term performance of laminate

Reinforcement type	Tension		Bending
	Short-term load	Long-term load	Long-term load
Woven roving	1.00	1.30	1.90
Chopped strand mat	1.00	2.40	2.40
Filament wound(circumferential)	1.00	1.30	1.40
Filament wound(axial)	1.00	1.60	1.70

4.3.8 The allowable strain of laminates for equipment and the allowable unit load shall be in accordance with the following requirements:

1 The allowable strain value ε_{ar} of the resin shall be calculated according to the following formula, and shall not be greater than the value specified in Table 4.3.8-1;

$$\varepsilon_{ar}=0.1\times\varepsilon_{r} \quad (4.3.8\text{-}1)$$

where

ε_{ar}—Allowable strain value of resin(%);

ε_{r}—Fracture elongation of resin casting body(%).

Table 4.3.8-1 Allowable strain value of resin

Resin type	Allowable strain value(%)
Vinyl ester resin	0.27
Unsaturated polyester resin	0.23

2 The allowable strain value of the laminate shall be calculated according to the following formula:

$$\varepsilon_{lam}=\frac{U_{lam}}{K\times X_{lam}} \quad (4.3.8\text{-}2)$$

where

ε_{lam}—Allowable strain value of laminate;

X_{lam}—Unit tensile stiffness(N/mm) of the laminate, determined in accordance with Formula(4.3.2-1);

K—Design factor, determined in accordance with Formula(4.3.3-1);

U_{lam}—Unit tensile strength(N/mm) of the laminate, determined in accordance with Formula(4.3.2-2).

3 The allowable strain ε_{d} of the laminate for equipment shall be a small value in the calculated values of Formula(4.3.8-1) and Formula(4.3.8-2). When the calculated values of Formula(4.3.8-1) and Formula(4.3.8-2) cannot be determined, the allowable strain shall be 0.001.

4 The maximum strain ε_{test} in the item when tested of the equipment shall not exceed the value specified in Table 4.3.8-2.

Table 4.3.8-2 Maximum tested strain

Resin type	Maximum strain(%)
Vinyl ester resin	0.35
Unsaturated polyester resin	0.30

5 The allowable unit load of the equipment laminates shall be calculated according to the following formula:

$$[q]=\varepsilon_{d}\times X_{lam} \quad (4.3.8\text{-}3)$$

where

$[q]$—Allowable unit load for equipment laminates(N/mm).

6 The allowable shear stress of the equipment laminates shall be calculated according to the following formula:

$$[\tau]=\frac{\tau}{K} \quad (4.3.8\text{-}4)$$

where

$[\tau]$—Allowable shear stress of equipment laminates(MPa);

τ—The shear strength (MPa) of the equipment laminates, can be measured according to the current national standard GB/T 1450.2 *Fibre-Reinforced Plastic Composites-Detemination of the Punch-Type Shear Strength*; when no detected value is available, 50MPa is preferred;

K—The design factor, shall be in accordance with the requirements of Article 4.3.3 of this code.

Ⅱ Allowable stress and allowable strain of pipe

4.3.9 The allowable stress of the pipe laminates shall be the elasticity modulus multiplied by the allowable strain. The elasticity modulus shall be determined in accordance with the requirements of Article 4.3.2 of this code. The allowable strain shall be determined by specified value method or long-term performance test method. The allowable stress shall be determined in accordance with the following requirements:

1 When the allowable strain is determined by Specified Value method, and the load conditions are occasional short-term loads not including the hydrostatic test load and Sustained loads including the thermal expansion load, the allowable stress shall be taken the value calculated in this article;

2 When the allowable strain is determined by Long-term Performance Test method, and the load conditions are Sustained loads not including the thermal expansion load, the allowable stress shall be taken the value calculated in this article;

3 When the allowable strain is determined by Long-term Performance Test method, and the load conditions are Sustained loads including the thermal expansion load, the allowable stress shall be the value calculated in this article times 125%;

4 When the allowable strain is determined by Long-term Performance Test method, and the load conditions are Occasional short-term loads and Sustained loads not including the thermal expansion load, the allowable stress shall be the value calculated in this article times 133%.

4.3.10 When using Specified Value method, the allowable strain of the laminate under chemical conditions and temperature conditions shall be determined in accordance with the following requirements:

1 The classification of chemical conditions shall be determined according to the loss in flexural strength of the immersed non-stressed specimen under the set chemical environment, and shall be in accordance with the following requirements:

1) The thickness of the specimen shall be 4mm—6mm, it shall be subjected to a cure schedule simulating that to be used for the finished pipe, and shall be immersed for 6 months at the design temperature;

2) Chemical conditions Ⅰ: this condition applies when the loss in flexural strength is less than 20 % of the original value;

3) Chemical conditions Ⅱ: this condition applies when the loss in flexural strength is more than 20 % but less than 50 % of the original value;

4) If the loss of flexural strength is greater than 50 % of the original value, then the matrix fibre system shall be deemed unsuitable and not used.

2 The classification of temperature conditions shall be determined by the difference between the heat distortion temperature *HDT* of the resin and the design temperature and shall be in accordance with the following requirements:

1) Temperature condition Ⅰ, the design temperature shall be at least 40℃ below *HDT*;

2) Temperature condition Ⅱ, the design temperature shall be at least 20℃ below but not more than 40 ℃ below *HDT*.

3 When the chemical environment and temperature conditions are determined, in terms of temperature and chemical condition classifications, strain class ratings shall be selected according to those specified in Table 4.3.10-1.

Table 4.3.10-1 Temperature and chemical condition classifications corresponding strain class ratings

Chemical condition	Temperature condition	
	Ⅰ	Ⅱ
Ⅰ	Level 1	Level 2
Ⅱ	Level 3	Level 4

4 When strain class ratings are determined, allowable strain shall be selected according to those specified in Table 4.3.10-2.

Table 4.3.10-2 Strain class ratings and allowable strain

Strain class ratings	Allowable strain
Class 1	0.0018
Class 2	0.0015
Class 3	0.0012
Class 4	0.0009

5 For pipes manufactured using filament wound at any angle between ±15° and ±75°, the anisotropic elastic analysis shall be carried out to confirm that the allowable strain is not exceeded. Without such an analysis the allowable strain shall be no greater than 0.0009.

4.3.11 When using the Long-term Performance Test method, the test shall comply with the relevant requirement of the current national standard GB/T 21238 *Glass Fibre Reinforced Plastics Mortar Pipes*, the end of the specimen shall be a free end closure, and the allowable strain in circumferential direction shall be calculated according to the following formula:

$$\varepsilon_d = \frac{p_{97.5} D_i}{2K \cdot X_{lam}} \quad (4.3.11)$$

where

ε_d—Allowable strain values at design life;

D_i—Pipe specimen internal diameter for long-term performance testing(mm);

$p_{97.5}$—The 97.5 % lower confidence limit of the internal pressure to produce failure at the design life (MPa);

X_{lam}—Laminate unit tensile stiffness of the specimen. When there is no such value, the specimen can be ablated according to the current national standard GB/T 2577 *Test Method for Resin Content of Glass Fibre Reinforced Plastics*, and the fibre mass per unit area and the ply scheme of each specimen are obtained. The average value is then calculated according to the Formula (4.3.2-1) of this code;

K—Design factor, which shall not be less than 1.5.

4.3.12 When the number of cycles of fatigue load is greater than 1000 or the stress range of stress cycles is greater than 20% of the allowable stress , the allowable strain value either selected in Table 4.3.10-2 or calculated according to Formula (4.3.11) of this code shall also be divided by the fatigue correction factor K_n, K_n shall be calculated according to the following formula:

$$K_n = 1 + 0.25(A_\sigma / \sigma_n)[\mathrm{Log}_{10}(n) - 3] \quad (4.3.12)$$

where

K_n—Fatigue correction factor;

n—Number of stress cycles during design life;

A_{σ}—Stress range during a fatigue cycle;

σ_n—Maximum stress during a fatigue cycle.

4.3.13 The allowable strain of the pipe laminate shall less than 10% of the resin fracture strain.

4.3.14 When the long-term performance test method is used to determine the allowable strain value of the laminate, and then the allowable stress value is calculated, the simplified failure envelope calculation and failure determination of the pipeline and fittings shall be in accordance with the following requirements:

1 The short-term circumferential failure stress σ_{sh} and long-term regression ratio R can be obtained by the long-term performance test method , and the axial tensile strength value σ_{sa} can be obtained according to the current national standard GB/T 5349 *Fibre-Reinforced Thermosetting Plastic Composites Pipe-Determination of Longitudinal Tensile Properties*, and the biaxial stress ratio R shall be calculated according to the following formulas:

$$\sigma_{sh}=\frac{p_{6,97.5\%LCL}D_i}{2t} \tag{4.3.14-1}$$

$$R=p_{L,97.5\%LCL}/p_{6,97.5\%LCL} \tag{4.3.14-2}$$

$$r=2\sigma_{sa}/\sigma_{sh} \tag{4.3.14-3}$$

where

σ_{sh}—Short-term circumferential failure stress obtained by the long-term performance test method (MPa);

σ_{sa}—Short-term axial tensile strength value (MPa) , which can be measured according to the current national standard GB/T 5349 *Fibre-Reinforced Thermosetting Plastic Composites Pipe-Determination of Longitudinal Tensile Properties*;

t— Pipe specimen structural wall thickness for the long-term performance testing(mm);

R—Long-term regression ratio(%);

$p_{L,97.5\%LCL}$—97.5 % lower confidence limit of the internal pressure to produce failure at the design life (MPa);

$p_{6,97.5\%LCL}$—97.5 % lower confidence limit of the internal pressure to produce failure at 6min by the extrapolation curve(MPa);

r—Biaxial stress ratio, which may be calculated according to Formula(4.3.14-3). When no data, the default biaxial stress ratio of the component can be selected according to those specified in Table 4.3.14.

Table 4.3.14 The default biaxial stress ratio

Component	Default biaxial stress ratio
55° filament wound pipe	0.50
Filament wound fittings, primarily hoop winding	0.45
Laminated fittings with bidirectional reinforcement	1.90
Adhesive bonded joints	1.00
Laminated joints with bidirectional reinforcement	2.00

2 The calculation of the simplified failure envelope shall include the circumferential allowable stress and the allowable axial stress of the pure internal pressure state(2∶1), the allowable axial stress of the pure axial tensile state(0∶1), and they shall be calculated according to the following formulas:

$$\sigma_{ah(2:1)}=R\times\sigma_{sh}/K \tag{4.3.14-4}$$

$$\sigma_{al(2:1)}=\sigma_{ah(2:1)}/2 \tag{4.3.14-5}$$

$$\sigma_{al(0:1)}=r\times\sigma_{ah(2:1)}/2 \tag{4.3.14-6}$$

where

$\sigma_{ah(2:1)}$—Circumferential allowable stress of the pure internal pressure state(2∶1)(MPa);

$\sigma_{al}(2:1)$—Allowable axial stress of the pure internal pressure state(2∶1)(MPa);

$\sigma_{al}(0:1)$—Allowable axial stress of the pure axial tensile state(0∶1)(MPa);

K—Design factor, shall not be less than 1.5.

3 The three stress values calculated by the Formula(4.3.14-4) to Formula(4.3.14-6) shall be connected to the fold line which is the simplify the failure envelope(Figure 4.3.14). The safety of the pipeline shall be determined by whether the calculated values of axial and circumferential stress are within the simplified failure envelope.

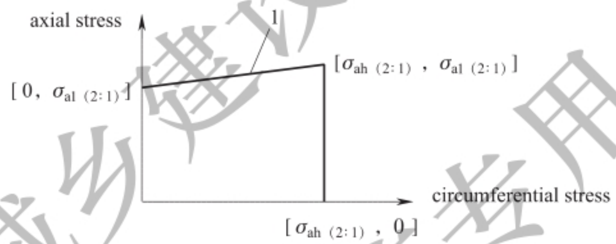


Figure 4.3.14 Simplified diagram

1—Failure envelope

5 Equipment design

5.1 General requirements

5.1.1 Design pressure of equipment shall be determined in accordance with the following requirements:

1 The design pressure of the equipment subjected to internal pressure shall be the maximum set pressure at the top of the equipment, considering corresponding design temperature, and the value shall not be lower than the working pressure;

2 The design pressure of the external pressure equipment shall be not less than the maximum internal and external pressure difference generated at any time during normal working, and shall not exceed 0.1MPa;

3 The design pressure of the vacuum equipment shall be 0.1MPa.

5.1.2 The design pressure used in the calculations for the equipment shall be the pressure used to determine the thickness of the equipment components at the corresponding design temperature and shall include additional loads such as liquid column pressure.

5.1.3 The equipment design temperature shall be the highest or lowest operating temperature of the equipment set under normal working conditions.

5.1.4 The equipment design shall include the calculation of the strength of cylinders and heads, the secondary bonding, cut-outs and compensation, the connection structure of branches and other components, bolt connection, saddle and the support structures.

5.1.5 The equipment design can adopt rule design method, analysis design method, and test verification design method. For rule design method and analytical design method, the design factor shall not be less than 6.0, and the buckling factor shall not be less than 4.0. For test verification design method, the failure pressure shall not be less than 6 times the design pressure.

5.1.6 The layering design of the equipment shall include the type of fibre and product, the resin system and mix ratio, the order, direction and number of layers, the forming and curing process, the resin or fibre content and tolerance.

5.1.7 The wall of the equipment consists of a lining, a structural layer and an outer surface, and shall be in accordance with the following requirements:

1 The lining shall be composed of the inner surface layer and the barrier layer, and the thickness shall not be less than 2.5 mm, and shall be in accordance with the following requirements:

1) The inner surface layer shall be made of surface veil, the resin content shall be greater than 85%, and the thickness shall not be less than 0.3 mm;

2) The barrier layer should be chopped strand mat, woven fabrics, and gun roving. The resin content shall not be lower than 65%.

2 The structural layer may be a combination of single or several reinforcing materials such as winding filament, chopped strand mat, woven fabrics, gun roving, woven roving, etc., which may be formed by winding, spraying and hand lay-up, and shall be in accordance with the following requirements:

1) The thickness of the structural layer shall be determined by calculation;

2) When the structural layer is made of glass fibre, its content shall meet the requirement of Article 4.3.1(4) of this code.

3 The design of the outer surface shall be in accordance with the following requirements:

1) In corrosive environment, the surface veil shall be used and the resin content shall not be lower than 85%;

2) When required to prevent UV, the resin used shall be added with UV absorbent;

3) The outermost layer of the outer surface layer shall be air-resistant resin or gelcoat resin;

4) The thickness of the outer surface layer should not be less than 0.3mm.

5.1.8 The thickness of the lining and the outer surface shall not be included in strength calculation; the total thickness shall be used in calculating the external pressure stability and the self-weight load.

5.1.9 When the steel annular support is bonded to the housing to form a rigid support, the operating temperature of the equipment should not be more than 60℃.

5.2 Load and action

5.2.1 The design load of the equipment shall include the following contents:

1 Internal pressure, external pressure or maximum pressure difference;

2 Hydrostatic pressure under working and testing conditions;

3 The weight of the internals, packing and equipment, the gravity load of the internal medium under normal working conditions or pressure test;

4 Auxiliary equipment and thermal insulation materials, linings, pipes, escalators, platform gravity loads;

5 Wind load, seismic load and snow load;

6 Eccentric load;

7 Partial load;

8 Impact load;

9 Force caused by temperature gradient or thermal expansion;

10 The load generated during the installation and operation of personnel can be calculated according to the uniformly distributed load of $1.5kN/m^2$;

11 Other short-term loads.

5.2.2 Wind loads, seismic loads and snow loads shall be in accordance with the following requirements:

1 The basic wind pressure value of each region may be determined according to the *National Basic Wind Pressure Distribution Map* or the local meteorological department data, and shall not be lower than the relevant provisions of the current national standard GB 50009 *Load Code for the Design of Building Structures*, and shall not be less than $300N/m^2$;

2 Seismic fortification intensity shall include design seismic grouping and seismic acceleration, and shall be determined according to local meteorological data, and shall not be lower than the relevant provisions of the current national standard GB 50011 *Code for Seismic Design of Buildings*;

3 The snow load shall meet the relevant requirements of the current national standard GB 50009 *Load Code for the Design of Building Structures.*

5.2.3 The local load shall include the reaction force of the support, the lugs and other accessories on the local area of the equipment housing, and the connection loads generated by the pipes, valves and other container components.

5.2.4 The impact load shall include the impact load caused by the sudden fluctuation of the pressure, the reaction force caused by the fluid impact, and the additional load generated during transportation and lifting.

5.2.5 Short-term loads shall include wind loads, snow loads, seismic loads, personnel loads, and installation loads.

5.2.6 The various loads on the equipment shall be the most unfavorable combination of installation, hydrostatic test, normal working conditions and abnormal working conditions. The combination of loads can be determined according to specified in Table 5.2.6.

Table 5.2.6 Combination of loads

Equipment status	Design load[1]
Installation	Weight of empty equipment Lifting load Accessory gravity Load generated during installation and operation
Pressure test	Weight of empty equipment Test pressure Hydrostatic pressure during testing Wind load Partial load Eccentric load Attachment gravity load
Normal work	Internal pressure, external pressure or maximum pressure difference Gravity load of the medium Equipment empty weight Snow load Eccentric load Local loads acting on supports, lugs and other accessories Impact load Load caused by temperature gradient or different amount of thermal expansion Load generated by the operator during installation and operation Attachment gravity load
	Wind load[2] Seismic load +25% wind load[2]
Abnormal work	Load during normal operation, a type of overload that may occur when work is started, stopped, or interrupted

Notes: ① According to the specific state of the equipment, the load combination in the table can be added or deleted during the design.

② Take the larger of "wind load" and "seismic load +25% wind load".

5.3 Structural calculation

5.3.1 For fibre reinforced plastic equipment, structural calculations shall be made for cylinders, conical shells, conical heads, convex heads, flat plates, flanges and ground anchor elements.

5.3.2 The load calculation of the cylinder under internal pressure shall be in accordance with the following requirements:

1 The maximum circumferential unit load shall be calculated according to the following formulas:

$$q_{\Phi}=p_{D}\times\frac{D}{2} \tag{5.3.2-1}$$

$$p_{D}=PS+PH \tag{5.3.2-2}$$

where

q_{Φ}—Maximum circumferential unit load(N/mm);

p_{D}—Design pressure used in the calculations(MPa);

D—Inside diameter of equipment(mm);

PS—Maximum allowable pressure(MPa);

PH—Static pressure of the liquid column(MPa).

The circumferential load bearing capacity of cylindrical laminates shall satisfy the following formula:

$$q_{\Phi}\leqslant[q_{\Phi}] \tag{5.3.2-3}$$

where

$[q_{\Phi}]$—Circumferential allowable unit load of laminates of the cylinder under internal pressure (N/mm).

2 Combined axial loads shall be calculated in accordance with the following requirements:

1) The axial unit load caused by internal pressure shall be calculated according to the following formulas:

$$q_{x,p}=p_{D}\times\frac{D}{4} \tag{5.3.2-4}$$

$$p_{D}=PS+\frac{P_{e}}{\sqrt{K_{4}}} \tag{5.3.2-5}$$

$$p_{D}=PS+\frac{P_{e}}{K_{4}} \tag{5.3.2-6}$$

where

$q_{x,p}$—Axial unit load caused by internal pressure(N/mm);

p_{D}—Design pressure used in the calculations(MPa); when the cylinder is under compression, it shall be calculated according to Formula(5.3.2-5); when the cylinder is under tension, it shall be calculated according to Formula(5.3.2-6);

P_{e}—Short-term pressure load(MPa);

K_{4}—The partial design factor relating to the long-term performance of laminates shall be in accordance with Table 4.3.7.

2) The axial unit load resulting from the bending moment caused by wind, snow or seismic load shall be calculated according to the following formulas:

$$q_{x,m}=\frac{4M_{D}}{\pi\times D^{2}} \tag{5.3.2-7}$$

$$M_{D}=M+\frac{M_{e}}{\sqrt{K_{4}}} \tag{5.3.2-8}$$

$$M_D = M + \frac{M_e}{K_4} \tag{5.3.2-9}$$

where

$q_{x,m}$—Axial unit load due to bending moments caused by wind, snow loads or seismic loads(N/mm);

M_D—Bending moment in calculation(N·mm); when the cylinder is under compression, it shall be calculated according to Formula(5.3.2-5); when the cylinder is under tension, it shall be calculated according to Formula(5.3.2-6);

M—Bending moment(N·mm);

M_e—Short-term moment load(N·mm).

3) Axial unit load caused by dead weight of equipment, medium weight and additional load generated by maintenance should be calculated according to the following formulas:

$$q_{x,w} = \frac{W_D}{\pi \times D} \tag{5.3.2-10}$$

$$W_D = W + \frac{W_e}{\sqrt{K_4}} \tag{5.3.2-11}$$

$$W_D = W + \frac{W_e}{K_4} \tag{5.3.2-12}$$

where

$q_{x,w}$—Axial unit load caused by dead weight of equipment, medium weight and additional load generated by maintenance(N/mm);

W_D—Weight used in calculations (N): when the cylinder is under compression, it shall be calculated according to the Formula(5.3.2-11); when the cylinder is under tension, it shall be calculated according to the Formula(5.3.2-12);

W—Weight(N);

W_e—Short-term weight(N).

The combined axial unit load shall be the sum of the values of Formula(5.3.2-4), Formula(5.3.2-7) and Formula(5.3.2-10), considering direction of load.

4) The axial load of the shell shall be calculated according to the following formula:

$$q_{x,c} = q_{x,M} + q_{x,w} - q_{x,p} \tag{5.3.2-13}$$

where

$q_{x,c}$—Axial unit load of cylinder under compression(N/mm);

$q_{x,M}$—Axial unit load due to bending moment(N/mm);

$q_{x,p}$—Axial unit load due to pressure(N/mm);

$q_{x,w}$—Axial unit load above the point caused by the weight of the equipment and medium, and additional load of maintenance(N/mm).

5) Axial unit load (N/mm) of cylinder under tension shall be calculated according to the following formula:

$$q_x = q_{x,p} + q_{x,M} + q_{x,w} \tag{5.3.2-14}$$

where

q_x—Axial unit load of cylinder under tension(N/mm);

$q_{x,w}$—Axial unit load below the point caused by the weight of the equipment and medium, and additional load of maintenance(N/mm);

6) The axial compressive load $q_{x,c}$ of laminates of the cylinde shall satisfy the requirements of Article 5.3.3 of this code, and the axial tensile load bearing capacity of the laminate shall satisfy the following formula:

$$[q_x] \leqslant [q_x] \tag{5.3.2-15}$$

where

$[q_x]$—The axial tensile allowable unit load of the laminate of the cylinder under internal pressure (N/mm).

5.3.3 The load calculation for the cylinder under external pressure shall be in accordance with the following requirements:

1 The axial compression critical buckling load of the cylinder shall be calculated according to the following formulas:

$$u_c = k \times \sqrt{E_{\phi b} \times E_x} \times \frac{t^2}{D} \tag{5.3.3-1}$$

$$k = \frac{0.84}{\sqrt{1 + \frac{D}{200 \times t}}} \tag{5.3.3-2}$$

$$\frac{d_{co}}{\sqrt{\frac{D \times t}{2}}} \leqslant 3.5 \tag{5.3.3-3}$$

$$k = \frac{0.78}{\sqrt{1 + \frac{D}{200 \times t}}} \tag{5.3.3-4}$$

$$\frac{d_{co}}{\sqrt{\frac{D \times t}{2}}} > 3.5 \tag{5.3.3-5}$$

$$k = \frac{0.54}{\sqrt{1 + \frac{D}{200 \times t}}} \tag{5.3.3-6}$$

where

u_c—Axial compressive buckling unit load for the cylindrical shell (N/mm);

$E_{\phi b}$—Flexural modulus in circumferential direction (MPa);

E_x—Flexural modulus in axial direction (MPa);

t—Shell thickness (mm);

D—Inner diameter of the equipment (mm);

k—Factor in calculations: for shells without cut-outs, k is calculated according to Formula (5.3.3-2); for shells with with cut-outs or skirt supports, when the Formula (5.3.3-3) is satisfied, k is calculated according to Formula (5.3.3-4); when the Formula (5.3.3-5) is satisfied, k shall be calculated according to Formula (5.3.3-6);

d_{co}—Diameter of the cut-out (mm).

The axial bearing capacity of the laminate of the cylinder should meet the following formula:

$$\frac{u_c}{q_{x,c}} \geqslant F \tag{5.3.3-7}$$

where

F—Buckling safety factor;

$q_{x,c}$—Axial compression unit load of the cylinder(N/mm).

2 The critical circumferential buckling pressure of cylinder subject to external pressure shall be calculated according to the following formulas:

1)When using the short cylinder with $L_s \leqslant 6D$, it shall be calculated according to the following formula:

$$p_c = 2.4 \times (E_{\phi b}^3 \times E_x)^{0.25} \times \frac{D}{L_s} \times \left(\frac{t}{D}\right)^{2.5} \tag{5.3.3-8}$$

2)When using the long cylinder with $L_s > 6D$, it shall be calculated according to the following formula:

$$p_c = 2.1 \times E_{\phi b} \times (t/D)^3 \tag{5.3.3-9}$$

where

p_c—Critical circumferential buckling pressure of cylinder subject to external pressure(MPa);

L_s—Calculated length(mm), which shall be the distance between two adjacent support lines on the cylinder. When there is no stiffening ring on the cylinder, the total length of the cylinder shall be taken plus 1/3 of the depth of each convex head surface(Figure 5.3.3-1); when there is a stiffening ring on the cylinder, the maximum distance between the center lines of two adjacent stiffening rings shall be taken(Figure 5.3.3-2); when there is a stiffening ring on the cylinder, take the center of the first stiffening ring of the cylinder. The distance between the line and the tangent of the convex head is 1/3 of the convex surface of the convex head(Figure 5.3.3-2); when the cylinder is connected to the cone shell and the joint can be used as the support line, the maximum distance between the joint and the adjacent support line is the calculated length of the cone section(Figure 5.3.3-3).

The circumferential compression bearing capacity of laminate of the cylinder should meet the following formula:

$$\frac{p_c}{p_D} \geqslant F \tag{5.3.3-10}$$

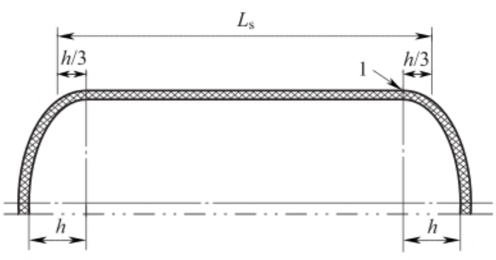


Figure 5.3.3-1 The calculated length of the cylinder without stiffening ring

1—Tangent point

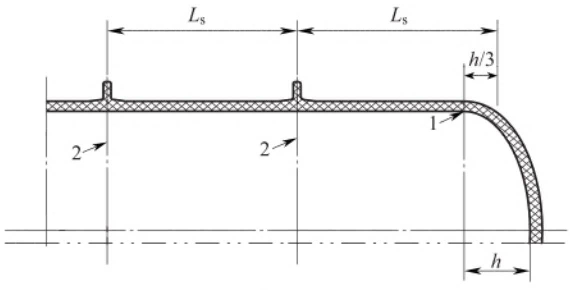


Figure 5.3.3-2 The calculated length of the cylinder with stiffening ring

1—Tangent point; 2—Center line of stiffening ring

3 The combined axial and radial loads shall satisfy the following formula:

$$\left(\frac{q_{x,c} \times F}{u_c}\right)^{1.25} + \left(\frac{p_D \times F}{p_c}\right)^{1.25} \leqslant 1 \tag{5.3.3-11}$$

where

$q_{x,c}$—The axial unit load(N/mm) of the cylinder under compression shall be calculated according to the Formula(5.3.2-13);

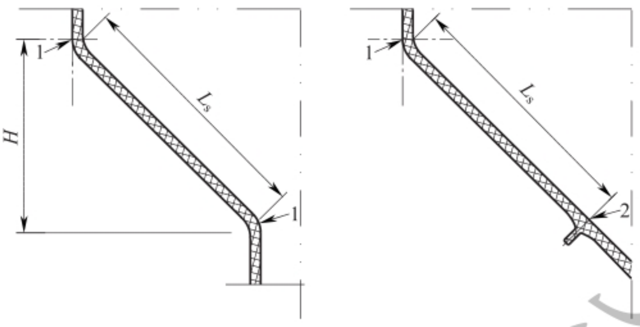


Figure 5.3.3-3 Calculated length of the cone shell when the cylinder is connected to the cone

1—Tangent point; 2—Center line of stiffening ring

u_c—The buckling load (N/mm) of the axial compression unit of the cylinder shall be calculated according to the Formula (5.3.3-1);

p_c—Critical circumferential buckling pressure of cylinders subject to external pressure (MPa).

4 When using a method with internal or external stiffening rings to shorten the calculated length of the cylinder to a thinner cylinder thickness than that of the second paragraph of this article, the calculation of the critical buckling pressure shall be in accordance with the following requirements:

1) The total critical buckling pressure shall be calculated according to the following formulas:

$$p_c=\left(E_{\phi b}^3\times E_x\right)^{0.25}\times\frac{2\times t_c}{D}\times\frac{\lambda^4}{\left(m^2-1+\frac{\lambda^2}{2}\right)\times\left(m^2+\lambda^2\right)^2}+\frac{8\times\left(m^2-1\right)\times E_s\times I_s}{L_s\times D_s^3}\quad(5.3.3\text{-}12)$$

$$\lambda=\frac{\pi\times D}{2\times\left(L_s+\frac{2}{3}h\right)}\quad(5.3.3\text{-}13)$$

where

p_c—Total critical buckling pressure (MPa), the minimum value shall be found after the trial calculation with $m=2,3$, etc.;

$E_{\phi b}$—Circumferential flexural modulus of cylinder (MPa);

E_x—Axial flexural modulus of cylinder (MPa);

m—Circumferential buckling wave number;

E_s—Circumferential bending modulus of the stiffening ring (MPa);

I_s—Moment of inertia of the stiffening ring (mm^4);

L_s—Distance between the two stiffening rings (mm); when the distance between the stiffening rings is not equidistant, the average value of the stiffening ring spacing shall be taken;

t_c—Minimum shell thickness t_{c1} (Figure 5.4.3-4) or t_{c2} (Figure 5.3.3-5) of the cylinder in area of the stiffening ring;

λ—Parameter of the shell.

The circumferential bearing capacity of a cylindrical shell with internal or external stiffening rings shall satisfy the following formula:

$$\frac{p_c}{p_D}\geqslant F\quad(5.3.3\text{-}14)$$

2) When L_s is greater than $20D$ or the contribution from the shell is ignored, the stiffening ring stiffness shall meet the following formula:

$$E_s \times I_s \geqslant \frac{p_D \times L_s \times D_s^3 \times F}{24} \tag{5.3.3-15}$$

where

D_s—Neutral axis diameter of stiffening ring(mm).

3)The size of the solid stiffening ring may be determined according to those specified in Figure 5.3.3-4. The effective width L of the cylinder used in the calculation shall satisfy the following formulas:

$$L = b_s + 1.15 \times \sqrt{D \times t_c} \tag{5.3.3-16}$$

$$5t_c \leqslant b_s \leqslant 20t_s \tag{5.3.3-17}$$

$$1.5t_c \leqslant t_s \leqslant 4b_s \tag{5.3.3-18}$$

$$b_s \leqslant 300\text{mm} \tag{5.3.3-19}$$

where

b_s—Stiffening ring outer edge width (mm), the value shall meet the requirements of Formula (5.3.3-17), Formula (5.3.3-18), and Formula (5.3.3-19).

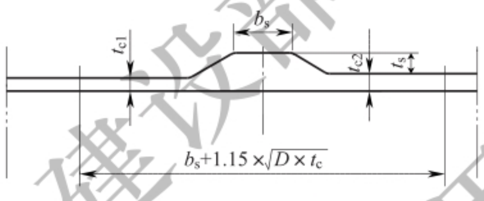


Figure 5.3.3-4 Solid stiffening ring

4)Hollow or covered stiffening ring configuration, when calculated according to Formula (5.3.3-12), its basic size shall be determined according to Figure 5.3.3-5:

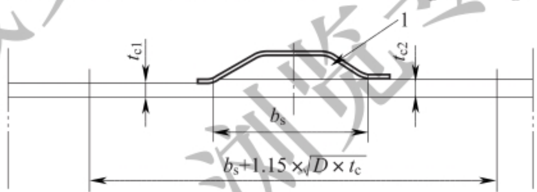


Figure 5.3.3-5 Hollow or covered stiffening ring

1— Filler(foam) or open; t_c— Average thickness

5 The stiffening ring shall be circled around the circumference of the cylinder and should be tightly bonded.

5.3.4 The design of the conical shell and conical head (Figure 5.3.4-1, Figure 5.3.4-2) shall be in accordance with the following requirements:

1 The knuckle radius shall not be less than 0.06 times the diameter of the cylinder at the joint;

2 When the pressure is −600Pa—+6500Pa, the non-folding structure may be adopted;

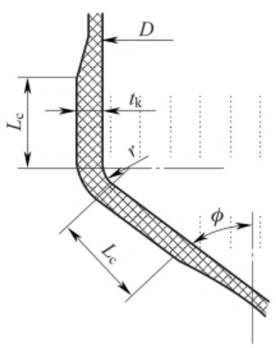


Figure 5.3.4-1 Conical shell with knuckle

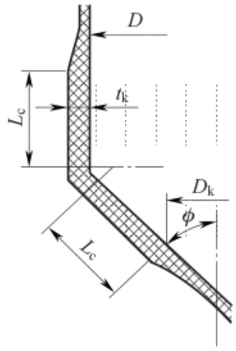


Figure 5.3.4-2 Conical shell without knuckle

3 When the pressure is greater than +6500Pa or less than or equal to − 600Pa, the flanged structure shall be adopted, and the cone apex angle shall not be greater than 150°;

4 Conical heads with a cone angle greater than 150° shall be designed in accordance with the flat cover and shall be calculated in accordance with the provisions of Article 5.3.20 and Article 5.3.22 to Article 5.3.24 of this code;

5 The length of stress concentration attenuation on the cylindrical and conical shells in the knuckle area shall be calculated as follows:

$$L_c = \sqrt{\frac{D \times t_k}{\cos\phi}} \tag{5.3.4}$$

where

L_c—Length of stress concentration attenuation (mm);

t_k—Thickness on the conical shell (mm);

ϕ—Half cone angle.

5.3.5 The conical shell load design subject to internal pressure shall be in accordance with the following requirements:

1 The circumferential unit load of cone subject to internal pressure shall be calculated according to the following formula:

$$q^{\phi} = \frac{p_D \times D_k}{2\cos\phi} \tag{5.3.5-1}$$

where

q^{ϕ}—Maximum circumferential unit loads (N/mm);

ϕ—Half the angle at the apex of the cone;

D_k—Calculate the diameter of the circle (mm).

The circumferential load bearing capacity of the cone subjected to internal pressure shall satisfy the following formula:

$$q^{\phi} \leqslant [q^{\phi}] \tag{5.3.5-2}$$

where

$[q^{\phi}]$—Circumferential allowable unit load of the cone (N/mm).

2 At the knucke area, the axial unit load of the cone subject to internal pressure shall be calculated according to the following formulas:

1) Axial unit load of a conical shell with knuckle (Figure 5.3.4-1) under internal pressure shall be calculated according to the following formula:

$$q_{x1} = \frac{p_D \times D_k \times K_{c1}}{2} \tag{5.3.5-3}$$

where

q_{x1}—Axial unit load of conical shell with knuckle (N/mm);

K_{c1}—The stress concentration factor for conical shell with knuckle shall be according to those specified in Table 5.3.5-1.

The axial unit load of the conical shell with knuckle shall satisfy the following formula:

$$q_{x1} \leqslant [q_x] \tag{5.3.5-4}$$

Table 5.3.5-1 Stress concentration factor K_{c1} of conical shell with knuckle

$\frac{r}{D}$	Angle ϕ					
	10°	20°	30°	45°	60°	75°
0.06	1.57	2.18	2.55	3.22	4.1	6.28
0.08	1.52	2.02	2.34	2.74	3.51	5.53
0.10	1.46	1.86	2.13	2.26	2.93	4.79
0.15	1.33	1.46	1.46	1.53	1.93	3.59
0.20	1.06	1.20	1.20	1.26	1.53	2.79
0.30	1.00	1.06	1.13	1.20	1.33	1.86

where

$[q_x]$—Axial allowable unit load of the laminate forming the wall thickness of the conical shell with knuckle(N/mm).

2)The axial unit load of the conical shell wall thickness subject to internal pressure without knuckle(Figure 5.3.4-2) shall be calculated according to the following formula:

$$q_{x2}=\frac{p_D\times D_k\times K_{c2}}{2} \tag{5.3.5-5}$$

where

q_{x2}—Axial unit load of conical shell without knuckle(N/mm);

K_{c2}—Stress concentration factor of conical shells without knuckle shall be taken as specified in Table 5.3.5-2.

Table 5.3.5-2 Stress concentration factor K_{c2} of cone shell without knuckle

$\frac{t_k}{D}$	Angle ϕ			
	15°	30°	45°	60°
0.002	2.94	5.62	8.90	13.6
0.005	2.05	3.70	5.80	8.70
0.010	1.60	2.75	4.12	6.30
0.020	1.24	2.00	3.00	4.40
0.040	1.00	1.55	2.20	3.20
0.050	1.00	1.45	2.00	2.75

The axial element load of the wall thickness of the conical shell without knuckle shall satisfy the following formula:

$$q_{x2}\leqslant[q_x] \tag{5.3.5-6}$$

where

$[q_x]$—Axial unit load of a conical shell without knuckle(N/mm).

5.3.6 The conical shell load design subject to external pressure shall be in accordance with the following requirements:

1 The strength of the cone subject to external pressure shall meet the circumferential unit load bearing capacity required by Formula(5.3.5-2).

2 The radial stability of the cone subject to external pressure shall be calculated according to the following formulas:

1)When $L\leqslant6D_m$, the critical radial buckling pressure shall be calculated according to the following formula:

$$p_c = 2.40 \times \sqrt[4]{E_{\phi b}^3 \times E_x} \times \frac{D_m}{L_s \times \cos\phi} \times \left(\frac{t \times \cos\phi}{D_m}\right)^{2.5} \tag{5.3.6-1}$$

$$L_s = \frac{H}{\cos\phi} \tag{5.3.6-2}$$

$$D_m = \frac{D_1 + D_2}{2} \tag{5.3.6-3}$$

2) When $L > 6D_m$, the critical radial buckling pressure shall be calculated according to the following formula:

$$p_c = 2.1E_{\phi b} \times \left(\frac{t \times \cos\phi}{D_m}\right)^3 \tag{5.3.6-4}$$

where

p_c—Critical radial buckling pressure (MPa);

L_s—Effective length of conical shell or distance between ribs (mm) (Figure 5.3.3-3);

D_m—Average diameter of the taper (mm).

The radial stability of the conical shell subject to external pressure shall satisfy the following formula:

$$\frac{p_c}{p_D} \geqslant F \tag{5.3.6-5}$$

3 The axial critical compressive load of the conical subject to external pressure (Figure 5.3.6) shall be calculated according to the following formulas:

$$u_c = k \times \sqrt{E_{\phi b} \times E_x} \times \frac{t^2 \times \cos\phi}{D_m} \tag{5.3.6-6}$$

$$k = \frac{0.84}{\sqrt{1 + \dfrac{D_m}{200 \times t \times \cos\phi}}} \tag{5.3.6-7}$$

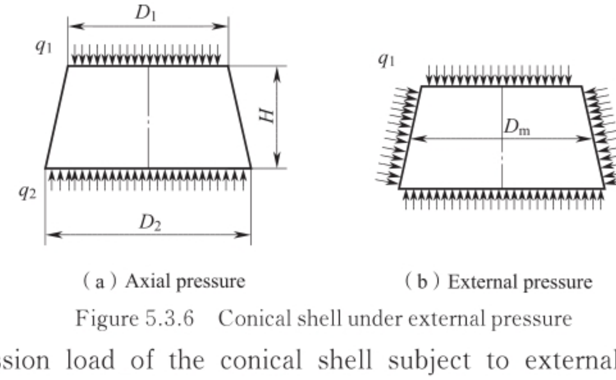
$$q_1 = \frac{N_{x1}}{\pi \times D_1} \qquad q_2 = \frac{N_{x2}}{\pi \times D_2} \tag{5.3.6-8}$$

where

u_c—Critical axial unit compression load (N/mm);

k—Coefficient;

q_1, q_2—The geometrical change of the conical shell under external pressure (Figure 5.3.6) and the axial pressure of the element under the action of axial force N_{x1} and N_{x2} (N/mm).



(a) Axial pressure (b) External pressure

Figure 5.3.6 Conical shell under external pressure

The axial compression load of the conical shell subject to external pressure shall satisfy the following formula:

$$\frac{u_c}{q_x} \geqslant F \tag{5.3.6-9}$$

where

q_x—Axial unit compression load of cone shell subject to external pressure(N/mm).

4 The combined axial and radial unit compressive loads shall satisfy the following formula:

$$\left(\frac{q_x \times F}{u_c}\right)^{1.25} + \left(\frac{p_D \times F}{p_c}\right)^{1.25} \leqslant 1 \tag{5.3.6-10}$$

where

p_c—Critical radial unit buckling pressure(N/mm);

u_c—Axial unit compression load(N/mm).

5.3.7 The axial unit load calculation subject to internal pressure conical head(Figure 5.3.7) shall be in accordance with the following requirements:

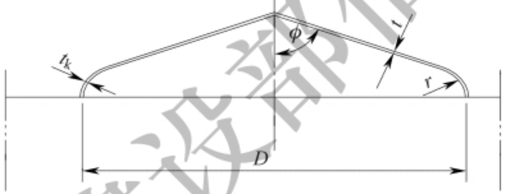


Figure 5.3.7 Conical head

1 When the apex angle of the half cone is 60°—75°, and $0 \leqslant \frac{r}{D} \leqslant 0.1$, the axial element load of the laminate at the corner shall be calculated according to the following formulas:

$$q_x = \alpha_b \times p_D \times \frac{1}{\sin\phi \times \cos\phi} \times \left(\frac{D}{t_k}\right)^{1+\beta_b} \times t_k \tag{5.3.7-1}$$

$$\alpha_b = -64 \times \left(\frac{r}{D}\right)^2 + 7.6 \times \left(\frac{r}{D}\right) + 0.13 \tag{5.3.7-2}$$

$$\beta_b = 51.6 \times \left(\frac{r}{D}\right)^2 - 8.18 \times \left(\frac{r}{D}\right) + 0.52 \tag{5.3.7-3}$$

where

q_x—Axial unit load of laminate at corner(N/mm);

α_b—Structural feature coefficient;

β_b—Structural feature coefficient.

The axial unit load of the laminate subject to internal pressure conical head at the corner shall meet the following formula:

$$q_x \leqslant [q_x] \tag{5.3.7-4}$$

where

$[q_x]$—Forming an axially permitted unit load of the laminate at the corner subject to internal pressure conical head(N/mm).

2 When the half cone angle is not in the range of 60°—75°, and shall be in the range of $0 \leqslant \frac{r}{D} \leqslant 0.1$, it shall be designed according to the flat cover.

5.3.8 The critical radial buckling pressure of the conical head subject to external pressure shall be calculated according to the following formula:

$$p_c = 13.58 \times E_b \times \sin\phi \times (\cos\phi)^{1.5} \times \left(\frac{t}{D}\right)^{2.5} \qquad (5.3.8\text{-}1)$$

where

p_c—Critical radial buckling pressure(MPa);

E_b—Flexural modulus of conical head structure(MPa).

The stability check subject to external pressure conical head shall meet the following formula:

$$\frac{p_c}{p_D} \geqslant F \qquad (5.3.8\text{-}2)$$

5.3.9 The convex head shall include a hemispherical head(Figure 5.3.9-1) and an elliptical or dished head(Figure 5.3.9-2). When an elliptical or dish-shaped head is used, the inner radius of the spherical portion of the head shall be $0.8D \leqslant R < D$, and the inner radius of the corner of the head shall be $0.1D \leqslant r < 0.25D$.

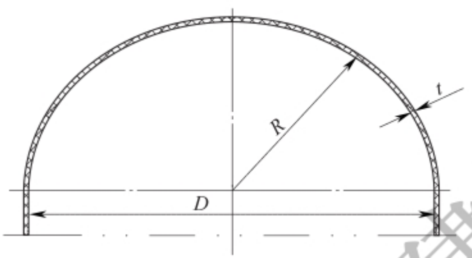


Figure 5.3.9-1 Hemispherical head

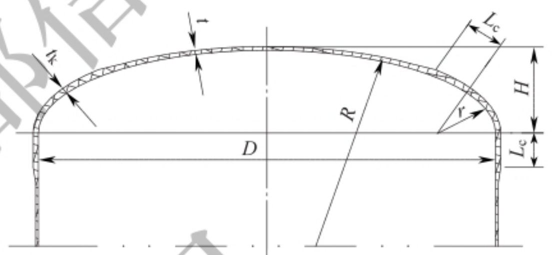


Figure 5.3.9-2 Oval head and dish-shaped head

5.3.10 The unit load calculation of the convex head subject to internal pressure shall be in accordance with the following requirements:

1 The unit load of the oval head and the corner of the dish head shall be calculated according to the following formula:

$$q_{k,p} = \frac{p_D \times D \times K_d}{2} \qquad (5.3.10\text{-}1)$$

where

$q_{k,p}$—Unit load in the corner area of the oval head and the dish head(N/mm);

K_d—Concentration factor at the corners of the elliptical head and the butterfly head shall be checked in accordance with Table 5.3.10.

2 The spherical area unit load of the torispherical head and the hemispherical head shall be calculated according to the following formula:

$$q_p = 0.6 \times p_D \times R \qquad (5.3.10\text{-}2)$$

where

q_p—Spherical area unit load of dish head and hemispherical head(N/mm);

R—Spherical area radius(mm).

3 When the thickness of the laminate in the corner area of the dish head is greater than the thickness of the laminate in the spherical area, the upper corner area of the head and the length of the reinforcing section on the casing shall be calculated according to the following formula:

$$L_c = \sqrt{D \times t_k} \qquad (5.3.10\text{-}3)$$

where

L_c—Length of local thickening on the head knuckle area or on the shell(mm);

t_k—Thickness of cylinder knuckle area(mm).

4 The load bearing capacity of the convex head subject to internal pressure shall meet the following formula:

$$q_{k,p} \leqslant [q_p] \tag{5.3.10-4}$$

where

$[q_p]$—Allowable unit loads for elliptic head and torispherical head(N/mm).

Table 5.3.10 The concentration factor of the knuckle area of elliptic head and torispherical head K_d

$\frac{h_i}{D}$	$\frac{t}{D}$	K_d	
		$R=D$	$R<D$
		$0.1 \leqslant \frac{r}{D} \leqslant 0.15$	$0.15 \leqslant \frac{r}{D} \leqslant 0.25$
0.20	0.005	2.95	Not allowed
	0.010	2.85	
	0.020	2.65	
	0.040	2.35	
	0.050	2.25	
0.25	0.005	2.35	1.90
	0.010	2.25	1.80
	0.020	2.10	1.75
	0.040	1.85	1.70
	0.050	1.75	1.70
0.30	0.005	1.95	1.45
	0.010	1.85	1.45
	0.020	1.60	1.40
	0.040	1.40	1.35
	0.050	1.30	1.30

5.3.11 The stability of the convex head subject to external pressure shall be checked, and the critical buckling pressure shall be calculated according to the following formula:

$$p_c = 0.242 \times E_b \times \left(\frac{t}{R}\right)^2 \tag{5.3.11-1}$$

The stability of the convex head subject to external pressure shall meet the following formula:

$$\frac{p_c}{p_D} \geqslant F \tag{5.3.11-2}$$

5.3.12 When designing flat-bottom equipment, the foundation shall be flat, and the allowable support clearance of the attachment on the bottom plate should meet the requirements of setting the support plate.

5.3.13 When the knuckle radius $r > 30$mm or $r/D > 0.05$ of the knuckle region (Figure 5.3.13) of the flat bottom equipment, the calculation of the maximum axial unit load of knuckle region shall be in accordance with the following requirement:

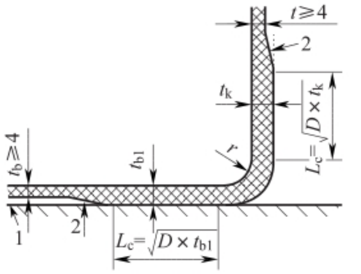


Figure 5.3.13 Flat bottom equipment knuckle area

1—Filled area; 2—Slope

1 The unit load in the knuckle region from internal pressure (hydrostatic plus overpressure) shall be calculated according to the following formulas:

$$q_{xk,1}=3\times k_p\times p_D\times D \quad (5.3.13\text{-}1)$$

$$k_p=0.22+\left(0.6+0.0566\times\frac{D}{t_k}\right)\times\left[\frac{2\times r}{D}-4.44\times\left(\frac{t_k}{D}\right)^{1.15}-0.04\right] \quad (5.3.13\text{-}2)$$

where

$q_{xk,1}$—Maximum axial unit load in the knuckle region from internal pressure (hydrostatic plus overpressure)(N/mm);

k_p—Structural characteristic coefficient shall not be less than 0.22.

2 The axial unit load of the cylinder shall be calculated according to the following formulas:

$$q_{xk,2}=6\times k_n\times\sum q_{x,i} \quad (5.3.13\text{-}3)$$

$$k_n=\left|1.38+0.41\times\frac{r}{D}\times\left(\frac{D}{t_k}\right)^{1.15}-0.077\times\left(\frac{r}{t_k}\right)^2\right| \quad (5.3.13\text{-}4)$$

where

$q_{xk,2}$—Axial unit load of the cylinder(N / mm);

$\sum q_{x,i}$—Axial unit load combination(N/mm) caused by static load, wind load, gravity load, etc.;

k_n—Structural feature coefficient, taking the absolute value.

3 The combination q_{xk} between loads shall be calculated according to the following formulas and shall take a larger value.

$$q_{xk}=q_{xk,1}+0.3\times q_{xk,2} \quad (5.3.13\text{-}5)$$

$$q_{xk}=q_{xk,2}+0.3\times q_{xk,1} \quad (5.3.13\text{-}6)$$

4 The laminate in the knuckle region of the flat bottom equipment fully supported shall be calculated according to the following formulas and shall also comply with the requirements of this code (5.3.2-3):

$$q_{xkmax}=-\frac{W_D}{\pi\times D}\pm\frac{4\times M_D}{\pi\times D^2}\pm q_{xk} \quad (5.3.13\text{-}7)$$

$$q_{xkmax}\leqslant[q_{xk}] \quad (5.3.13\text{-}8)$$

where

q_{xkmax}—The maximum axial unit load(N/mm) in the knuckle region;

$[q_{xk}]$—Axial allowable unit load in the knuckle region(N/mm).

5.3.14 When the knuckle radius $r\leqslant30$mm or $r/D\leqslant0.05$ in the knuckle region of the flat-bottom equipment(Figure 5.3.13), the calculation of the maximum axial unit load of the knuckle region shall be in accordance with the following requirement.

1 The maximum axial unit load in the knuckle region from internal pressure (hydrostatic plus overpressure) shall be calculated according to the following formulas:

$$q_{xk,1}=0.72\times p_D\times D \quad (5.3.14\text{-}1)$$

$$q_{xk,1}=0.90\times p_D\times D \quad (5.3.14\text{-}2)$$

$$q_{xkmax}=-\frac{W_D}{\pi\times D}\pm\frac{4\times M_D}{\pi\times D^2}\pm q_{xk,1} \quad (5.3.14\text{-}3)$$

where

$q_{xk,1}$—Axial unit load (N/mm) in the knuckle region from internal pressure (hydrostatic plus overpressure), when $t_{b1}\leqslant t_k$, shall be calculated according to Formula(5.3.14-1); when $t_{b1}>$

t_k, it shall be calculated according to Formula(5.3.14-2);

q_{xkmax}—Maximum axial unit load in the knuckle region(N/mm).

2 The bearing capacity of the laminate in the knuckle region shall meet the requirements of this code(5.3.2-3) in addition to the following formula:

$$q_{xkmax} \leqslant [q_{xk}] \tag{5.3.14-4}$$

where

$[q_{xk}]$—Axial allowable unit load(N/mm) in the knuckle region.

3 The length L_c of local thickening at the bottom of the shell(Figure 5.3.13) shall be calculated according to the following formula:

$$L_c = \sqrt{D \times t_k} \tag{5.3.14-5}$$

The length L_c of local thickening at the bottom of the flat bottom(Figure 5.3.13) shall be calculated according to the following formula:

$$L_c = \sqrt{D \times t_{b1}} \tag{5.3.14-6}$$

5.3.15 The cut-out of equipments shall be compensated, and a disc-shaped compensation plate should be placed around the cut-out. The calculation of branches and cut-out compensation shall be in accordance with the following requirements:

1 Branch structure for compensation at the cut-outs of the equipment shall be flush branch(Figure 5.3.15-1) or through branch(Figure 5.3.15-2).

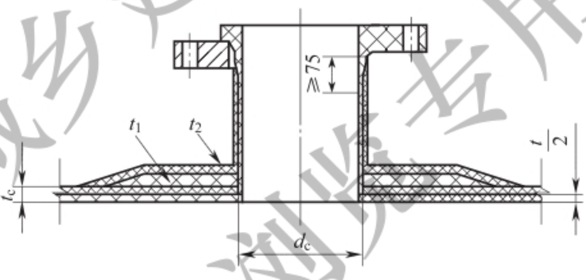


Figure 5.3.15-1 Flush branch

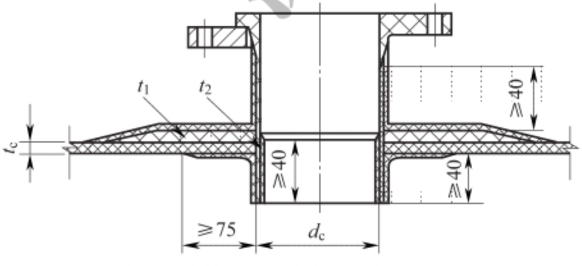


Figure 5.3.15-2 Through branch

2 The maximum unit load in the region of the cut-out shall be calculated according to the following formulas:

$$q_{max} = q \times \nu_A \tag{5.3.15-1}$$

$$\nu_A = 1.5 \times \left(1 + \frac{d_c}{2 \times \sqrt{D \times t_c}}\right) \tag{5.3.15-2}$$

where

q_{max}—Maximum unit load(N / mm) in the region of the cut-out;

q—Maximum unit load(N/mm) of the shell without cut-out;

ν_A—Load concentration factor;

d_c—Diameter (mm) of the cut-out on the shell/head;

t_c—Thickness of the shell at the branch(mm).

3 The maximum unit load in the region of the cut-out shall satisfy the following formula:

$$q_{max} \leqslant [q]_{lam} + [q]_c \quad (5.3.15\text{-}3)$$

where

$[q]_{lam}$—Allowable unit load(N / mm) of the shell laminate;

$[q]_c$—Allowable unit load(N/mm) for compensation laminate.

4 The width of the compensation laminate can be calculated as follows and shall be greater than 100mm:

$$l_a = \sqrt{D \times t_a} \quad (5.3.15\text{-}4)$$

where

l_a—Width of the compensation laminate(mm);

t_a—Total compensation thickness required at the branch.

5 The minimum inner compensation shall be in accordance with the following requirement:

1) When the diameter of the cut-out is less than or equal to 50mm, the inner compensation shall be a lining and no less than a layer of 300g/m^2 chopped strand mat;

2) When the diameter of cut-out is greater than 50mm and less than or equal to 150mm, the inner compensation shall be a lining and two layers of 450g/m^2 chopped strand mat;

3) When the diameter of the cut-out is greater than 150mm, the inner compensation shall be a lining and at least 3 layers of 450g/m^2 chopped strand mat.

6 The minimum reinforcement overlay at branch position (Figure 5.3.15-3) shall be 3 layers of 450g/m^2 chopped strand mat, and the length shall not be less than 75mm.

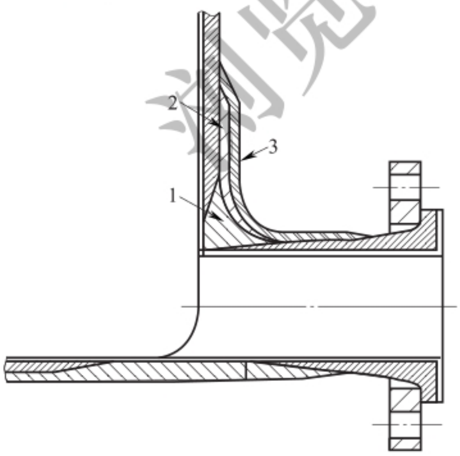


Figure 5.3.15-3 The reinforcement overlay at branch position

1—Filled area; 2—Compensation layer; 3—Reinforcement overlay

5.3.16 The tensile and shear loads of the compensation layer shall be verified according to the following formulas.

$$q_b = \frac{p_D \times d_c}{4} \quad (5.3.16\text{-}1)$$

$$\tau'_{lap} = \frac{q_b}{20 \times t_{over}} \leqslant \frac{\tau_{lap}}{K} \quad (5.3.16\text{-}2)$$

where

q_b—Tensile unit load of the compensation layer(N/mm);

τ'_{lap}—Shear stress of the compensation layer(MPa);

τ_{lap}—The lap shear strength of the laminate compensation layer (MPa), when using glass fibre reinforced materials, may be measured according to the provisions of Table 4.3.1 of this code or according to the provisions of Appendix L of this code;

K—Design factor, which can be valued in accordance with the provisions of Article 4.3.3 of this code;

t_{over}—Compensation thickness(mm).

5.3.17 The joint between the equipment head and the cylinder and the cylinder(Figure 5.3.17) shall be in accordance with the following requirement:

1 The bearing capacity of the joint overlay shall not be less than the load of the connected cylinder in both the circumferential direction and the axial direction;

2 The slope of the joint zone of the joint overlay shall not be greater than 1∶6;

3 The length of the joint overlay L_j shall be calculated as follows:

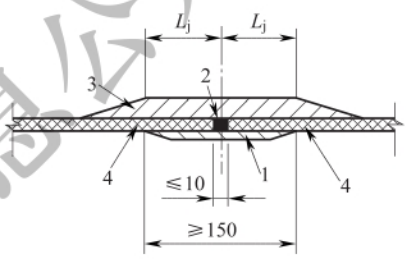


Figure 5.3.17 Seam joint diagram
1—Inner overlay; 2—Resin putty filler; 3—Outer overlay; 4—Main laminate

$$L_j = \frac{K \times q}{\tau_{lap}} \tag{5.3.17}$$

where

L_j—Joint overlay length(mm);

K—Design factor, according to the provisions of Article 4.3.3 of this code;

q—Maximum unit load in the circumferential or axial direction in the enclosure(N/mm);

τ_{lap}—Lap shear strength (MPa) of the secondary bonded laminate overlay. When glass fibre reinforced materials are used, the values may be specified in Table 4.3.1 of this code.

4 The length of the overlay shall be in accordance with the following requirement;

1)When the thickness of the overlay is less than or equal to 6mm, the minimum length shall be 100mm;

2)When the thickness of the overlay is greater than 6mm, the minimum length shall be 150mm;

3)The length of the overlay should not be less than 20 times the thickness of the overlay.

5.3.18 The plates of the equipment components shall be rectangular, circular, sector, and triangular. The boundary classification of rectangular plates shall be in accordance with the following requirements:

1 Four edges simply supported shall be Class A;

2 Four edges fixed shall be Class B;

3 One long edge simply supported, the other three edges fixed should be Class C;

4 One short edge simply supported, the other three edges fixed should be Class D.

5.3.19 The bending moment calculation of rectangular flat plates shall be in accordance with the following requirements.

1 Bending moment of rectangular plates under uniformly distributed load shall be calculated according to the following formula:

$$M_p = \beta_1 \times p \times b^2 \tag{5.3.19-1}$$

where

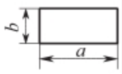
M_p—Bending moment of rectangular plate under uniformly distributed load(N·mm/mm);

β_1—Constants of rectangular flat plates subjected to uniformly distributed loads are found in Table 5.3.19-1;

p—Uniformly distributed load on a rectangular plate(MPa);

b—Length of the short side of a rectangular plate(mm).

Table 5.3.19-1 Constants of rectangular flat plates subjected to uniformly distributed loads

Boundary type	Boundary classification	Constant	Aspect ratio(a/b)									
			1.00	1.25	1.50	1.75	2.00	2.50	3.00	4.00	5.00	>5.00
	A	β_1	0.048	0.067	0.081	0.093	0.102	0.113	0.119	0.125	0.125	0.125
		α_1	0.044	0.060	0.084	0.099	0.111	0.126	0.134	0.140	0.142	0.142
	B	β_1	0.051	0.067	0.075	0.080	0.083	0.083	0.083	0.083	0.083	0.083
		α_1	0.014	0.020	0.024	0.026	0.028	0.0281	0.0282	0.0284	0.0284	0.0284
	C	β_1	0.060	0.077	0.094	0.107	0.114	0.121	0.124	0.124	0.124	0.124
		α_1	0.017	0.028	0.037	0.044	0.049	0.055	0.057	0.058	0.058	0.058
	D	β_1	0.060	0.073	0.079	0.082	0.083	0.083	0.083	0.083	0.083	0.083
		α_1	0.017	0.022	0.025	0.027	0.028	0.0284	0.0284	0.0284	0.0284	0.0284

Note: ——— Indicates that the boundary is simply supported; ////// Indicates that the boundary is a fixed.

2 The bending moment of the rectangular plate subjected to the hydrostatic load varying linearly from 0 to p_1 should be calculated according to the following formula:

$$M_p = \beta_1 \times p_1 \times b^2 \tag{5.3.19-2}$$

where

M_p—Moment of rectangular plate subjected to hydrostatic load(N·mm/mm);

β_1—Constants for rectangular plates subjected to hydrostatic load, which can be found in Table 5.3.19-2;

p_1—Maximum value of linearly varying load on a rectangular plate(MPa);

b—Length of the short side of a rectangular plate(mm).

Table 5.3.19-2 Constants of a rectangular flat plate with hydrostatic load varying linearly from 0 to p_1

Boundary classification	Constant	Aspect ratio(a/b)								
		1/2	1/1.75	1/1.5	1/1.25	1.00	1.25	1.50	1.75	≥2.00
A、C、D	β_1	0.0115	0.0145	0.0187	0.0245	0.0334	0.0393	0.0462	0.0481	0.0500
	α_1	0.0009	0.0015	0.0024	0.0041	0.0069	0.0094	0.0120	0.0131	0.0142
B	β_1	0.0348	0.0339	0.0324	0.0298	0.0264	0.0355	0.0429	0.0486	0.0529
	α_1	0.0553	0.0495	0.0422	0.0329	0.0222	0.0329	0.0422	0.0495	0.0553

3 The bending moment of a A-class rectangular plate with a concentrated load at its center shall be calculated according to the following formula:

$$M_p = \frac{W}{4 \times \pi} \times \left(1.3 \times \ln \frac{2b}{\pi \times r_1} + \beta_2\right) \tag{5.3.19-3}$$

where

M_p—Bending moment of a A-class rectangular plate with a concentrated load at its center (N·mm/mm);

β_2—Constants of rectangular flat plates subjected to central local load are found in Table 5.3.19-3;

r_1—Radius of the area of the local load on a rectangular plate(mm);

b—Length of the short side of a rectangular plate(mm);

W—Local load on a rectangular plate(N).

4 The bending moment of a B-class rectangular plate with central local load shall be calculated according to the following formula:

$$M_p = \beta_3 \times W \tag{5.3.19-4}$$

where

M_p—Bending moment of a B-class rectangular plate with central local load(N·mm/mm);

β_3—Constants of rectangular flat plates subjected to central local load are found in table 5.3.19-3;

W—Local load on a rectangular plate(N).

Table 5.3.19-3 Constants of rectangular flat plates subjected to central local load

Boundary classification	Constant	Aspect ratio(a/b)									
		1.00	1.25	1.50	1.75	2.00	2.50	3.00	4.00	5.00	>5.00
A	α_2	0.1267	0.1518	0.1671	0.1763	0.1805	0.1821	0.1831	0.1842	0.1849	0.1851
	β_2	0.435	0.691	0.838	0.917	0.958	0.976	0.986	0.997	1.000	1.000
B	α_2	0.0611	0.0720	0.0768	0.0785	0.0788	0.0790	0.0791	0.0791	0.0791	0.0791
	β_2	−0.238	−0.052	0.036	0.067	0.067	0.067	0.067	0.067	0.067	0.067
	β_3	0.1257	0.1530	0.1632	0.1665	0.1674	0.1677	0.1679	0.1680	0.1680	0.1680

5.3.20 The bending moment calculation of the circular plate shall be in accordance with the following requirement.

1 The bending moment of a circular plate with peripheral simply supports under a uniformly distributed load shall be calculated according to the following formula:

$$M_p = 0.0516 \times p_D \times d_p^2 \tag{5.3.20-1}$$

where

M_p—Moment of a circular flat plate subjected to uniformly distributed load(N·mm/mm);

p_D—Uniformly distributed load on a circular plate(MPa);

d_p—Calculated diameter of a circular plate(mm).

2 The bending moment of a circular plate with peripheral fixed supports under a uniformly distributed load shall be calculated according to the following formula:

$$M_p = 0.03125 \times p_D \times d_p^2 \tag{5.3.20-2}$$

where

M_p—Moment of a circular flat plate subjected to uniformly distributed load(N·mm/mm);

p_D—Uniformly distributed load on a circular plate(MPa);

d_p—Calculated diameter of a circular plate(mm).

3 The bending moment of a circular plate with peripheral simply supports under central local load shall be calculated according to the following formula:

$$M_p = \frac{W}{4 \times \pi}\left[1.3 \times \ln \frac{d_p}{2 \times r_1} + 1\right] \tag{5.3.20-3}$$

where

M_p—Bending moment of a peripheral simply supported circular plate under central local load

(N·mm/mm);

W—Local load on a circular plate(MPa);

r_1—Radius of the area of local load on a circular plate(mm);

d_p—Calculated diameter of a circular plate(mm).

4 The bending moment of a circular plate with peripheral fixed supports under concentrated load at center shall be calculated according to the following formulas, and should be taken to a large value:

$$M_p = 0.325 \times \frac{W}{\pi} \times \ln \frac{d_p}{2 \times r_1} + 1 \quad (5.3.20\text{-}4)$$

$$M_p = \frac{W}{4 \times \pi} \quad (5.3.20\text{-}5)$$

where

M_p—The bending moment of a circular plate with fixed supports under concentrated load at center (N·mm/mm);

W—Concentrated load on a circular plate(MPa);

r_1—Radius of the area of concentrated load on a circular plate(mm);

d_p—Calculated diameter of a circular plate(mm).

5.3.21 The bending moment of a sector or triangular plate subjected to a uniformly distributed load shall be calculated according to the following formula:

$$M_p = \beta \times p_D \times r_p^2 \quad (5.3.21)$$

where

M_p—Moment of a sector or triangular plate subjected to a uniformly distributed load(N·mm/mm);

β—Constants of sector or triangular flat plates subjected to uniformly distributed loads are found in Table 5.3.21;

p_D—Uniformly distributed load on a sector or triangular plate(MPa);

r_p—Radius of the sector plate or the length of the side of the triangular plate(mm).

Table 5.3.21 Constants of sector or triangle plate calculation subjected to uniformly distributed load

Angle	π	π/2	π/3	π/4
Peripheral simply supports				
α	0.0368	0.0144	0.0062	0.0031
β	0.0756	0.0488	0.0340	0.0250
Peripheral fixed supports				
α	0.0886	0.0246	0.0100	0.0054
β	0.0868	0.0381	0.0255	0.0183

5.3.22 When the plate is subjected to bending moment loads including internal pressure, vacuum, liquid column static pressure, wind load, snow load, locally concentrated load and the most severe combination of various loads, the design bending moment of the plate should be calculated according to the following formula:

$$M_D = M_p + M_l + \frac{M_s + M_w}{K_4} \quad (5.3.22)$$

where

M_D—Design bending moment of the plate(N·mm/mm);

M_p—According to the Formula (5.3.19-1), Formula (5.3.19-4), Formula (5.3.20-1), Formula (5.3.20-5) and Formula (5.3.21), bending moment caused by uniform or concentrated load (N·mm/mm);

M_l—Partial bending moment acting on the plate(N·mm/mm);

M_s—Snow load acting on the plate(N·mm/mm);

M_w—Wind load acting on the plate(N·mm/mm);

K_4—Partial design factor relating to long-term performance of laminate shall be in accordance with Table 4.3.7 of this code.

5.3.23 The mass calculation of the unit area reinforcing material of the plate under load shall be in accordance with the following requirements:

1 When chopped strand mat is used as the reinforcing material for the flat plate, the mass of the chopped strand mat per unit area shall be calculated according to the following formula:

$$m_{\mathrm{CSM}}=\left(\frac{6M_{\mathrm{D}}}{u_{\mathrm{CSM}}\times t_{\mathrm{g}}}\right)^{0.5} \tag{5.3.23-1}$$

where

m_{CSM}—Mass of chopped str and mat per unit area when chopped strand mat is used as a reinforcing material for the flat plate(kg/m²);

M_{D}—Flat design bending moment(N·mm/mm);

U_{CSM}—Unit design load for chopped strand mat lamina [N/mm·(kg/m²)];

t_{g}—Lamina thickness of chopped strand mat per unit area[mm/(kg/m²)].

2 When using a bolted flange cover(Figure 5.3.23-1), the mass of reinforcement material per unit area shall be calculated according to the following formula:

$$m_{\mathrm{CSM}}=\left(\frac{p_{\mathrm{D}}\times d_{\mathrm{m}}^{2}}{3.23\times u_{\mathrm{CSM}}\times t_{\mathrm{g}}}\right)^{0.5} \tag{5.3.23-2}$$

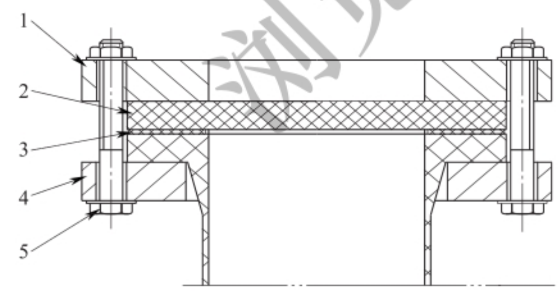


Figure 5.3.23-1 Bolted flange cover

1—Steel flange; 2—Laminate flange cover; 3—Gasket; 4—Steel flange; 5—Bolt

where

m_{CSM}—Mass of chopped strand mat per unit area when chopped strand mat is used as a reinforcing material for the flat plate(kg/m²);

p_{D}—Design uniformly distributed load for the flange cover(MPa);

U_{CSM}—Design unit load for chopped strand mat lamina [N/mm·(kg/m²)];

d_{m}—Center circle diameter of the bolt hole of the flange cover(mm);

t_{g}—Thickness of the chopped strand mat lamina per unit area[mm/(kg/m²)].

3 When using a bolted flange cover (Figure 5.3.23-2), the unit area reinforcement shall be calculated according to the following formula:

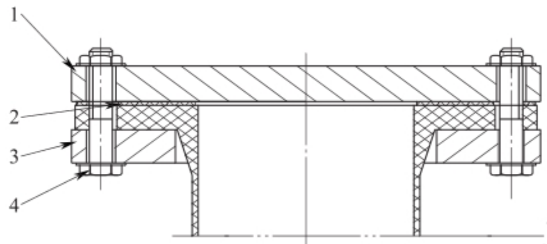


Figure 5.3.23-2　Bolted flange cover

1—Laminate flange cover; 2—Gasket; 3—Steel flange; 4—Bolt

$$m_{CSM}=\left(\frac{p_D\times d_b^2}{5.33\times u_{CSM}\times t_g}\right)^{0.5} \tag{5.3.23-3}$$

where

m_{CSM}—Mass of chopped strand mat per unit area when chopped strand mat is used as a reinforcing material for the flat plate(kg/m^2);

p_D—Flange cover design uniformly distributed load(MPa);

u_{CSM}—Unit design load for chopped strand mat lamina [$N/mm\cdot(kg/m^2)$];

d_b—Bolt hole center circle diameter of flange cover(mm);

t_g—Lamina thickness of chopped strand mat per unit area mass[$mm/(kg/m^2)$].

5.3.24 The calculation for the thickness of the flat plate shall be in accordance with the following requirements:

1 The minimum thickness of a rectangular plate under load shall be calculated according to the following formula:

$$t_{min}=\left(\frac{\alpha_1\times p\times b^4}{1.5\times E_b}+\frac{\alpha_1\times p_1\times b^4}{1.5\times E_b}+\frac{\alpha_2\times W\times b^2}{1.5\times E_b}\right)^{0.25} \tag{5.3.24-1}$$

where

t_{min}—Minimum thickness of rectangular plate(mm);

α_1—Constant, refer to Table 5.3.19-1 or Table 5.3.19-2;

α_2—Constant, refer to Table 5.3.19-3;

p_1—Maximum linearly varying loads on the rectangular plate(MPa);

p—Uniformly distributed load on the rectangular plate(MPa);

E_b—Flexural modulus of a rectangular plate(MPa);

W—Local load on the rectangular plates(MPa);

b—Short side length on the rectangular plate(mm).

2 The minimum thickness of a simply supported circular plate under load shall be calculated according to the following formula:

$$t_{min}=\left(\frac{0.04347\times p_D\times d_p^4}{1.5\times E_b}+\frac{0.013787\times W\times d_p^2}{1.5\times E_b}\right)^{0.25} \tag{5.3.24-2}$$

where

t_{min}—Minimum thickness of the circular plate(mm);

E_b—Flexural modulus of the circular plate(MPa);

W—Local load on the circular plate(MPa);

p_D—Design pressure on a circular plate(MPa);

d_p—Diameter of a round plate(mm).

3 The minimum thickness of the surrounding fixed circular plate under load shall be calculated according to the following formula:

$$t_{min}=\left(\frac{0.01066\times p_D\times d_p^4}{1.5\times E_b}+\frac{0.05431\times W\times d_p^2}{1.5\times E_b}\right)^{0.25} \qquad (5.3.24\text{-}3)$$

where

t_{min}—Minimum thickness of the circular plate(mm);

E_b—Flexural modulus of a circular plate(MPa);

W—Concentrated load on a circular plate(MPa);

d_p—Diameter on a round plate(mm);

p_D—Design pressure on a circular plate(MPa).

4 The minimum thickness of a sector or triangular plate subjected to a uniformly distributed load shall be calculated according to the following formula:

$$t_{min}=r_p\times\left(\frac{\alpha\times p_D}{1.5\times E_b}\right)^{0.25} \qquad (5.3.24\text{-}4)$$

where

t_{min}—Minimum thickness of a sector or triangular plate subject to uniformly distributed load(mm);

E_b—Flexural modulus of a sector or triangular plate(MPa);

p_D—Design pressure on a sector or triangular plate(MPa);

α—Constant, taken from Table 5.3.21.

5.3.25 Horizontal container design shall meet the requirements of Appendix C.

5.3.26 Flange design shall meet the requirements of Appendix D.

5.3.27 The design of ground anchors shall meet the requirements of Appendix E.

5.4 Structural design

5.4.1 Flat-bottom equipment design shall be in accordance with the following requirements:

1 It may be classified according to the overall tank bottom(Figure 5.4.1-1)and the socket bottom (Figure 5.4.1-2);

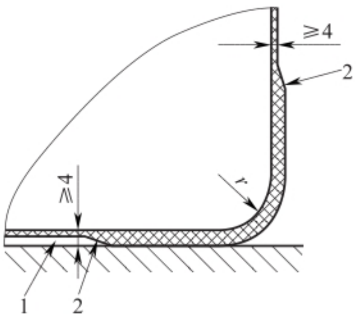


Figure 5.4.1-1 Overall tank bottom

1—Filler; 2—Slope

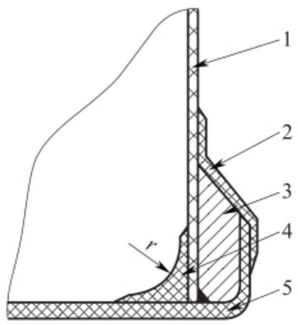


Figure 5.4.1-2 Socket type bottom

1—Shell; 2—Outside overlay; 3—Resin paste infill; 4—Inner coating; 5—Flat head

2 The equipment foundation shall be complete except for the cut-outs at the bottom of the equipment;

3 Flat-bottomed equipment installed outdoors and subjected to loads such as wind loads and shock loads shall be anchored (Figure 5.4.1-3) and designed in anchorage form;

4 For equipment with a diameter less than or equal to 1200mm, the bottom knuckle radius of the equipment shall not be less than 25mm, and the equipment with a diameter greater than 1200mm shall have a bottom knuckle radius of not less than 38mm;

5 The slope of the overall tank bottom (Figure 5.4.1-1) shall not larger than 1:6.

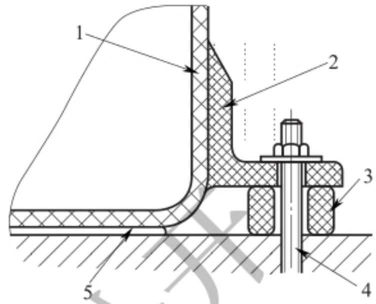


Figure 5.4.1-3 Schematic diagram of anchoring structure of flat bottom equipment

1—Tank wall; 2—Fixed support; 3—Gesket; 4—Anchor bolt; 5—Base bedding material

5.4.2 The leg supports may be divided into fixed type (Figure 5.4.2-1) and split type (Figure 5.4.2-2). The structural design shall be in accordance with the following requirements:

1 When the diameter of the equipment is less than or equal to 1500mm, the height of the cylinder is less than or equal to 2000mm, and the specific gravity of the medium is less than or equal to 1.2, leg supports can be used;

2 Legs shall not be directly attached to the convex bottom of the equipment;

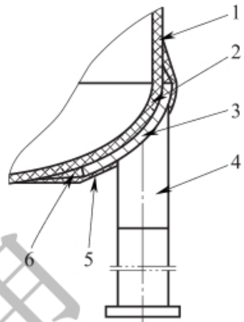


Figure 5.4.2-1 Fixed leg support

1—Cylinder; 2—Head; 3—Steel pad; 4—Support leg; 5—Overlay; 6— Resin putty filler

3 Separate leg supports and the equipment joint surfaces shall be laid with corrosion-resistant rubber gesket (Figure 5.4.2-2).

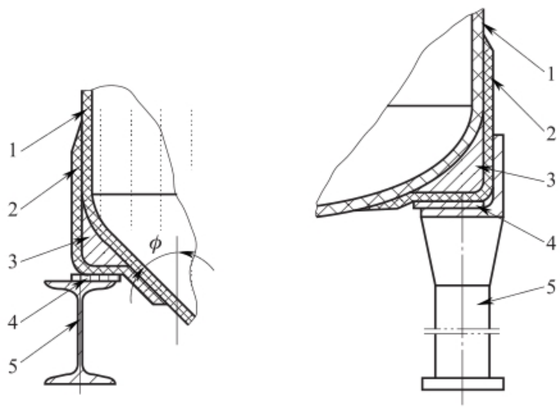


Figure 5.4.2-2 Split leg support

1—Shell; 2—Overlay; 3—Resin putty filler; 4—Corrosion resistant rubber gasket; 5—Support leg

5.4.3 The ring supports (Figure 5.4.3-1, Figure 5.4.3-2) shall be in accordance with the following requirements.

1 The wall jointed with the ring support shall be strengthened;

2 The ring support shall be tightly integrated with the equipment.

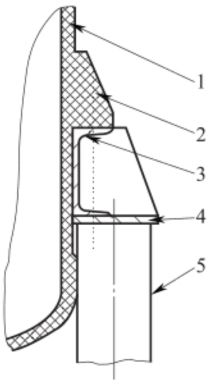


Figure 5.4.3-1 Ring support 1

1—Shell;2—Flange;3—Steel ring;

4—Steel plate;5—Column

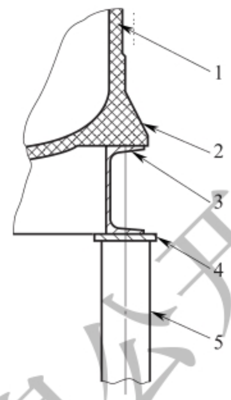


Figure 5.4.3-2 Ring support 2

1—Shell;2—Flange;3—Steel ring;

4—Steel plate;5—Column

5.4.4 Suspended bearing structure shall be in accordance with the following requirements:

1 When the container, storage tank and other equipments are supported by the floor of the building or by having an annular bracket or a cow leg structure, the hanging support should be used (Figure 5.4.4-1,Figure 5.4.4-2);

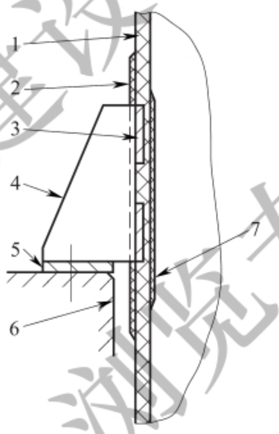


Figure 5.4.4-1 Hanging support 1

1—Shell;2—Overlay with a taper no steeper than 1∶6;3—Circumferential steel plate;

4—Vertical plate of lug;5—Base plate of lug;6—Floor or support ring;7—Internal cover

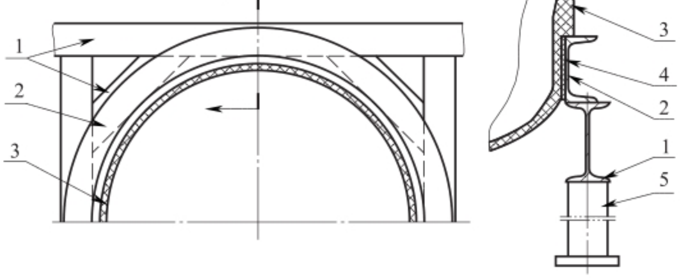


Figure 5.4.4-2 Hanging support 2

1—Structural parts;2—Ring grider;3—Tank wall;4—Rubber gasket;5—Column

2 Strengthen shall be taken at the support site.

5.4.5 The skirt support design shall be in accordance with the following requirements:

1 The skirt support and the shell shall be bonded to an integral rigid support;

2 Skirt supports can be divided into fibre reinforced plastic skirt supports(Figure 5.4.5-1) and steel skirt supports(Figure 5.4.5-2).

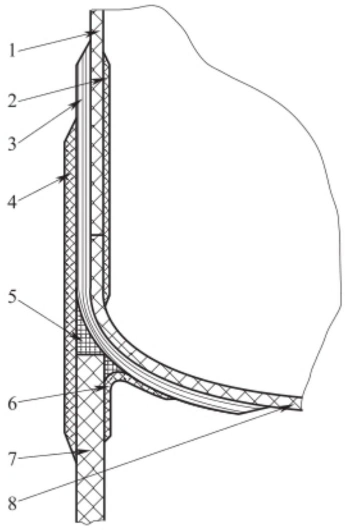


Figure 5.4.5-1 Fibre reinforced plastic skirt support

1—Shell; 2—Inner overlay; 3—Knuckle reinforcement; 4—Outer overlay; 5—Resin putty filler; 6—Outer overlay; 7—Skirt support; 8—Convex head

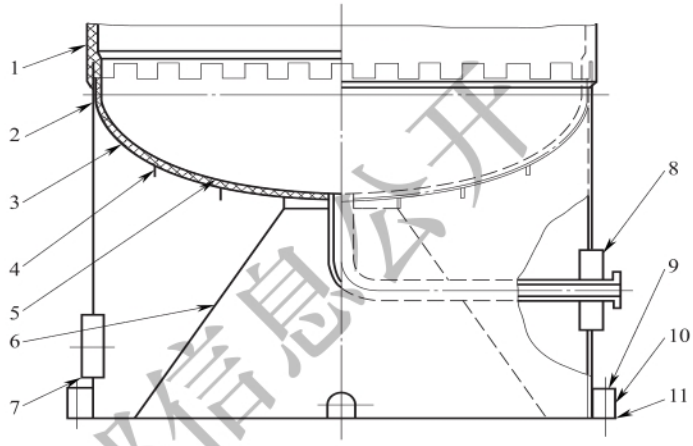


Figure 5.4.5-2 Steel skirt support

1—Shell; 2—Zigzag steel cylinder; 3—Radial steel strip; 4—Hoop steel strip; 5—Convex head; 6—Reinforcing steel plate; 7—Steel pipe; 8—Steel pipe; 9—Steel plate; 10—Rib; 11—Bottom

5.4.6 The saddle support design shall meet the relevant requirements of Appendix C.

5.4.7 The connection between the head of the equipment and the cylinder, and the connection between cylinders shall be in accordance with the following requirements:

1 The seam may be fixed or detachable;

2 The fixed connection shall be a butt joint (Figure 5.4.7-1) or spigot and socket joint (Figure 5.4.7-2);

3 The detachable connection should be a flange joint with corrosion resistant gaskets and fasteners (Figure 5.4.7-3);

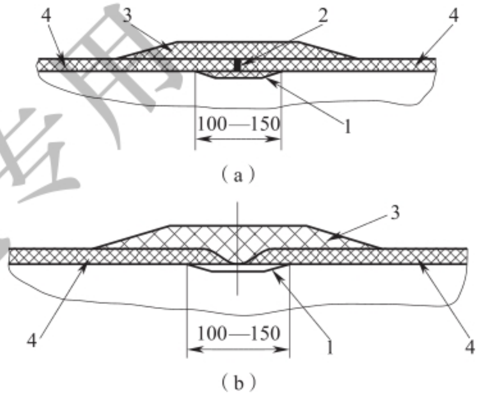


Figure 5.4.7-1 Butt joint

1—Inner overlay; 2—Resin putty filler; 3—Outer overlay; 4—Laminate

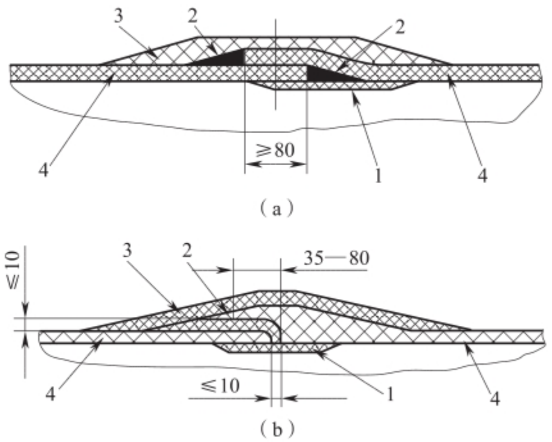


Figure 5.4.7-2 Spigot and socket joint

1—Inner overlay; 2—Resin putty filler; 3—Outer overlay; 4—Laminate

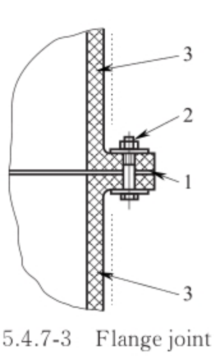


Figure 5.4.7-3 Flange joint

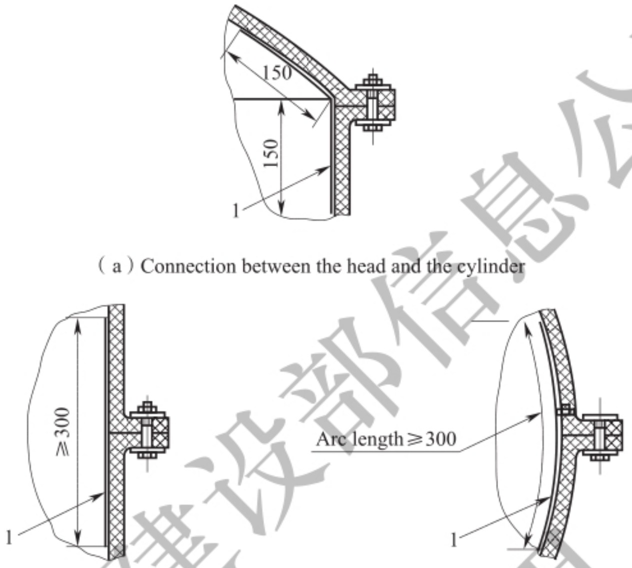
1—Gasket; 2—Fastener; 3—Shell

4 Flange joint can be covered by inner overlay(Figure 5.4.7-4);

5 The head and shell or shell and shell can be connected by butt joint(Figure 5.4.7-5);

6 A butt joint between the conical head and the barrel can be used(Figure 5.4.7-6);

7 A butt joint between the Disc, semicircle, oval and other convex heads and the cylinder can be used(Figure 5.4.7-7).



(a) Connection between the head and the cylinder

(b) Circumferential overlay (c) Segmented arc piece longitudinal joint

Figure 5.4.7-4 Flange joint with inner overlay

1—Inner overlay

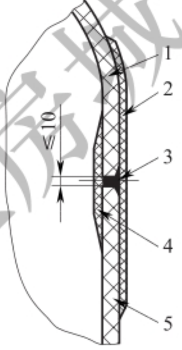


Figure 5.4.7-5 Dutt joint between the head and the shell or between shells

1—Head; 2—Outer overlay; 3—Resin putty filler; 4—Inner overlay; 5—Cylinder

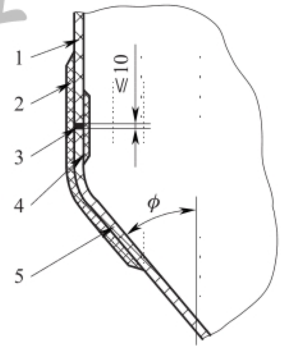


Figure 5.4.7-6 Butt joint between the conical head and the cylinder

1—Cylinder; 2—Knuckle reinforcement; 3—Resin putty filler; 4—Internal sealing layer; 5—Conical head

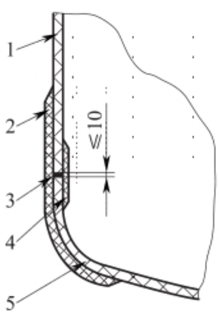


Figure 5.4.7-7 Butt joint between convex head connected and the cylinder

1—Shell; 2—Knuckle reinforcement; 3—Resin putty filler; 4—Internal bonding layer; 5—Convex head

5.4.8 The design of the compensation for cut-outs of equipment shall be in accordance with the following requirements:

1 The cut-outs and branches of equipment under external pressure shall be designed according to the requirements under internal pressure. The pressure value shall be the larger one of the internal pressure or the external pressure;

2 The maximum cut-out size on the cylindrical shell should not be larger than 0.3 times the diameter of the cylinder;

3 The cut-out position of the convex head shall be within the range of 40% of the diameter of the cylinder, and the maximum opening size should not be larger than 50% of the diameter of the cylinder;

4 Branches should not be placed in the knuckle area of the convex head.

5.4.9 Branches and compensation of cut-outs shall be in accordance with the following requirements:

1 When the inner diameter of the branch db is larger than 100mm, the following joints can be adopted, wherein all the fillet radius of the stiffener shall not be less than 6mm.

1) Flush branch (Figure 5.4.9-1);

2) Stretch branch (Figure 5.4.9-2);

3) Bottom branch (Figure 5.4.9-3);

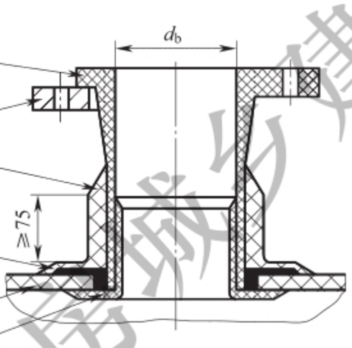


Figure 5.4.9-1 Flush branch

1—Flange or ledge; 2—Steel loose flange; 3—Outer overlay; 4—Fibre/resin filler; 5—Shell; 6—Inner overlay

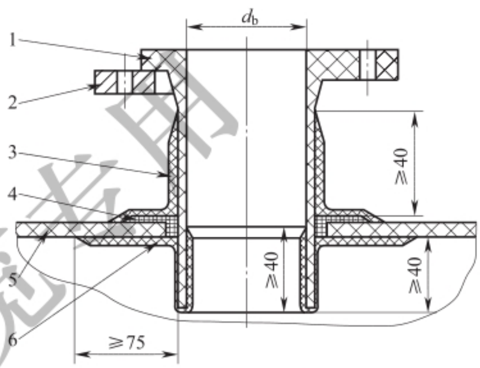


Figure 5.4.9-2 Stretch branch

1—Flange or ledge; 2—Steel loose flange; 3—Outer overlay; 4—Fibre/resin filler; 5—Shell; 6—Inner overlay

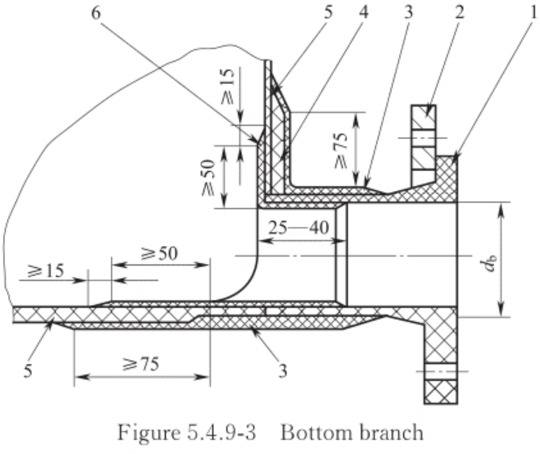


Figure 5.4.9-3 Bottom branch

1—Flange or ledge; 2—Steel loose flange; 3—Outer overlay; 4—Fibre/resin filler; 5—Shell; 6—Inner overlay

4) Vent branch (Figure 5.4.9-4);

5) Branch stiffener plate (Figure 5.4.9-5).

2 When the inner diameter of the branch d_b is less than or equal to 100mm, a backpanel can be set at the nozzle, and the following connection type can be adopted:

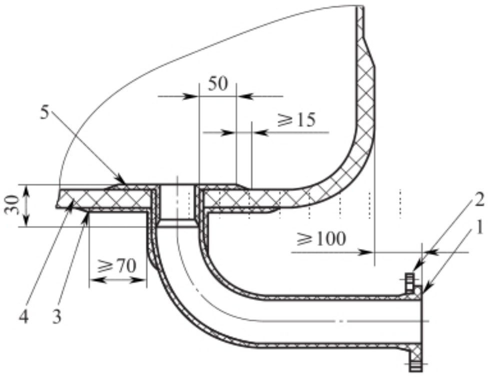


Figure 5.4.9-4 Vent branch

1—Flange or ledge; 2—Steel loose flange; 3—Outer overlay; 4—Shell; 5—Inner overlay

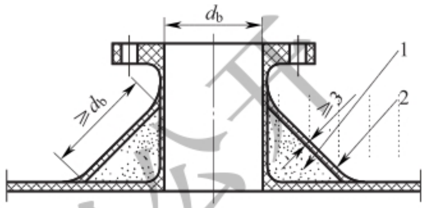


Figure 5.4.9-5 Branch stiffener plate

1—Filler; 2—Overlay

1) Branch support plate (Figure 5.4.9-6);

2) Branch cone support plate (Figure 5.4.9-7).

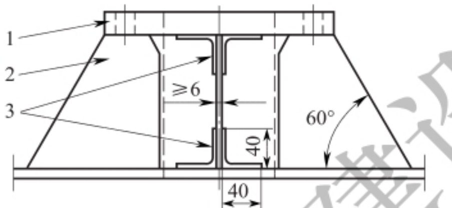


Figure 5.4.9-6 Branch support plate

1—Flange and branch; 2—Four uniformly distributed fibre reinforced panels; 3—Overlay

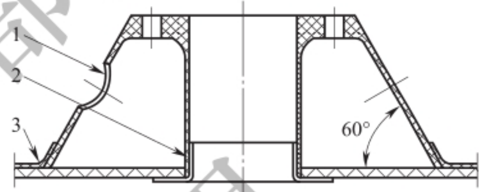


Figure 5.4.9-7 Branch conical support plate

1—Inspection hole; 2—Inner overlay; 3—Outer overlay

5.4.10 Stiffening rings shall be in accordance with the following requirement:

1 Stiffening rings shall be a complete circle, which shall be completely connected to the shell and tightly bonded together;

2 Stiffening rings shall meet the stiffness required of the design;

3 The section of the stiffening ring can be rectangular, circular, semi-circular or triangular;

4 The stiffeningr ring can be placed inside or outside the shell.

5.4.11 The inlet and outlet tubes shall be in accordance with the following requirements:

1 The liquid inlet tube which is easy to be corroded, worn and easily blocked by liquids can be classified according to the stretch inlet tube (Figure 5.4.11-1) and the easily replaceable inlet tube (Figure 5.4.11-2);

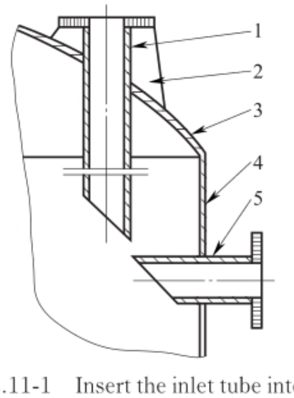


Figure 5.4.11-1 Insert the inlet tube into the tank

1—Top inlet pipe; 2—Reinforced rib plate; 3—Head; 4—Shell wall; 5—Horizontal inlet tube

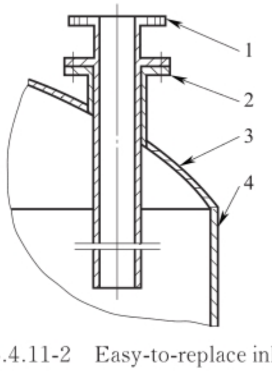


Figure 5.4.11-2 Easy-to-replace inlet tube

1—Inlet insertion tube; 2—Support tube; 3—Head; 4—Shell wall

2 The inlet tube of flammable and non-conductive liquid shall be inserted into the liquid. The depth should be 2/3 of the height of the cylinder. The angle θ of the nozzel should be 45°—60°(Figure 5.4.11-3). The upper part of the inlet tube shall be opened in the cylinder(Figure 5.4.11-4);

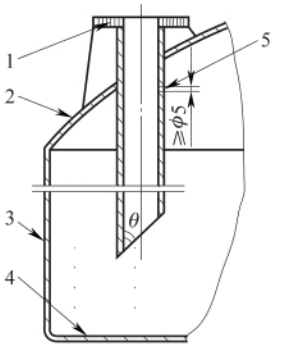


Figure 5.4.11-3 Anti-siphon inlet tube

1—Top inlet pipe;2—Head;3—Shell wall;
4—Tank bottom;5—Hole

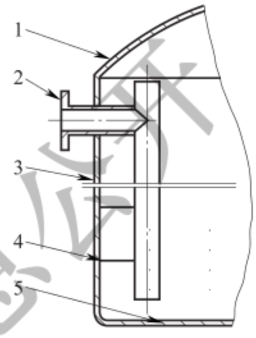


Figure 5.4.11-4 Upper open inlet tube

1—Head;2—Inlet tube;3—Shell wall;
4—Support plate;5—Tank bottom

3 The inlet tube of the easy fuel liquid shall be placed along the tank wall and inserted into the liquid(Figure 5.4.11-5);

4 The cutting edges of the inlet and outlet tubes(Figure 5.4.11-6,Figure 5.4.11-7) shall be sealed with corrosion-resistant resin.

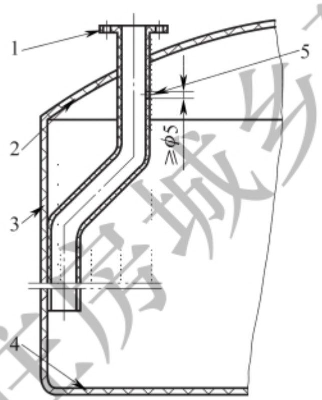


Figure 5.4.11-5 The liquid inlet tube laid along the tank wall

1—Inlet pipe;2—Head;3—Shell wall;
4—Tank bottom;5—Hole

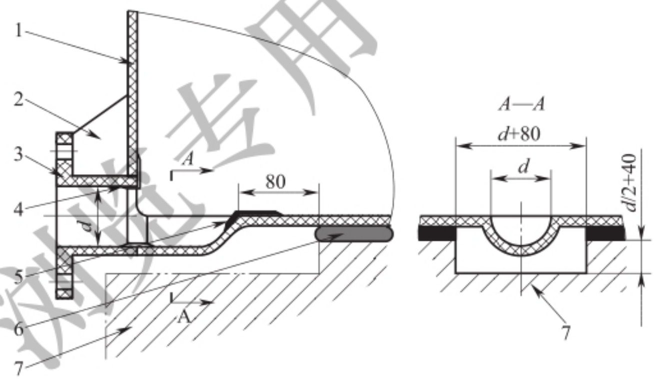
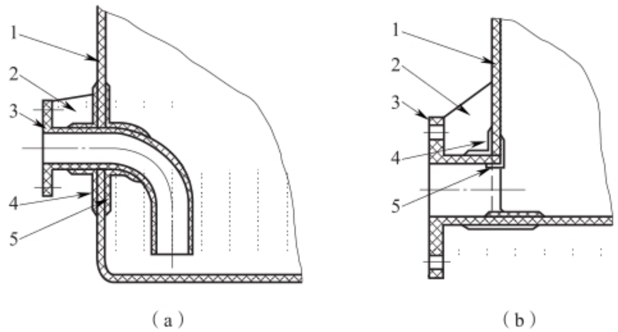


Figure 5.4.11-6 Outlet tube 1

1—Shell wall;2—Reinforced plate;3—Outlet pipe;4—Branch inner overlay;
5—Knuckle inner overlay;6—Base layer;7—Base



(a) (b)

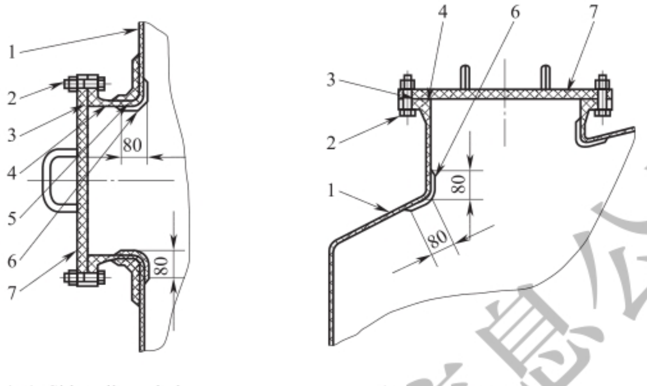
Figure 5.4.11-7 Outlet tube 2

1—Shell wall;2—Support plate;3—Branch;4—Outer overlay;5—Inner overlay

5.4.12 The setting of the equipment manhole shall be in accordance with the following requirements:

1 Manholes should be installed for equipment with diameter larger than 900mm;

2 If the height of equipment exceeds 1800mm, manholes should be arranged on the side wall and the top respectively(Figure 5.4.12);



(a) Sidewall manhole (b) Top manhole

Figure 5.4.12 Manhole structure type

1—Shell wall; 2—Fastener; 3—Gasket; 4—Branch; 5—Outer overlay; 6—Inner overly; 7—Manhole cover

3 When the manhole is pressed more than 0.07 MPa, the manhole cover should be arc shape;

4 The inner side of the joint between the equipment wall and the manhole shall be laminated with not less than 4 layers of chopped strand mat and 1 layer of surface veil.

5.4.13 The bolted flange cover can be either an integral flange type (Figure 5.4.13-1) or a loose flange type (Figure 5.4.13-2).

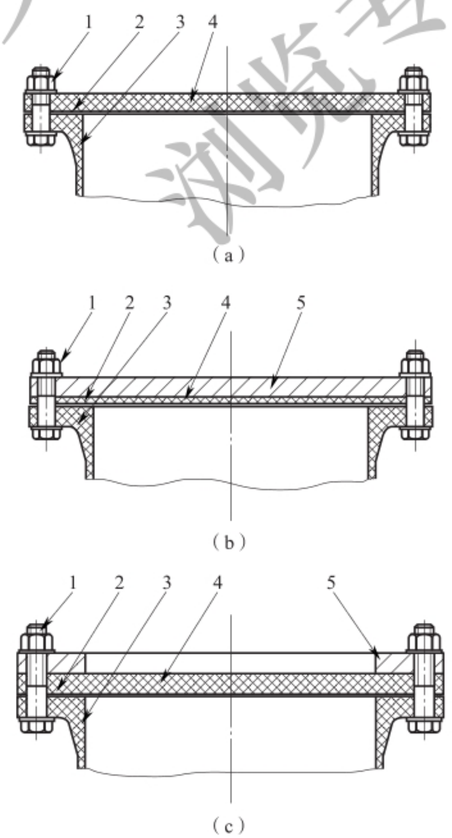


Figure 5.4.13-1 Flange cover type of integral flange

1—Fastener; 2—Sealing gasket; 3—Flange; 4—Fibre reinforced plastic sheet; 5—Steel pressure plate(ring)

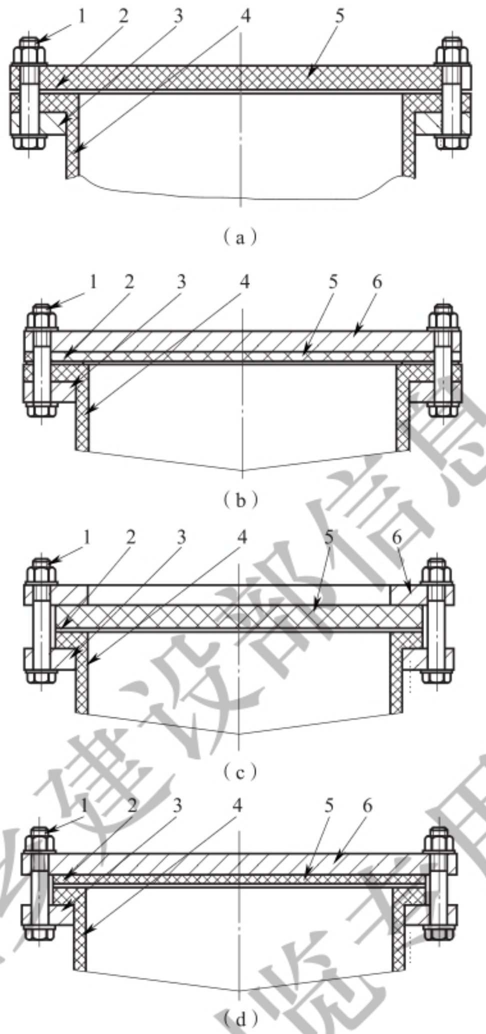


Figure 5.4.13-2 Flange cover type of loose flange

1—Fastener; 2—Sealing gasket; 3—Loose flange; 4—Branch and flange; 5—Fibre reinforced plastic sheet; 6—Steel plate (ring)

5.4.14 Equipment accessories design shall meet the following requirements:

1 The local strain of all equipment accessories shall not be larger than the allowable strain;

2 The material characteristics of the internal accessories shall meet the conditions of usage, and the lining resin shall be used where contacting with the medium;

3 Equipment shall be provided with lifting lugs or other accessories for safe loading and field installation;

4 Independent supports shall be provided when there is a stirrer or other external drive.

5.4.15 The specifications of the reinforced flange on the top of equipment for vertical open top storage tanks shall comply with the relevant provisions of Appendix F of this code.

6 Piping design

6.1 General requirements

6.1.1 The pipeline design pressure shall be determined in accordance with the following requirements:

1 The design pressure of each component in a piping system shall not be less than the pressure at the most severe condition of coincident internal or external pressure and temperature (minimum or maximum) expected during service.

2 The most severe condition shall be that results in the greatest required component thickness and the highest component rating according to strength analysis.

3 The piping design pressure for the following special conditions shall be compared with Item 1 of this Article and shall take the larger of them:

1) The design pressure of the fluid piping with low gasification temperature, such as conveying refrigerant and liquefied hydrocarbons, shall not be less than the highest pressure that can be achieved by gasification at the highest ambient temperature when the valve is closed or the fluid is not flowing;

2) The design pressure of the outlet pipe of the centrifugal pump shall not be less than the sum of the suction pressure and the corresponding pressure of the pump head;

3) For piping not protected by a pressure relieving device, or isolated from a pressure relieving device, design pressure shall not be lower than the maximum pressure that can be reached by the fluid.

4 Vacuum piping shall be designed according to external pressure. When equipped with a safety control device, the design pressure shall be the lower value of 1.25 times the maximum difference between internal and external pressure or 0.1MPa; when there is no safety control device, the design pressure shall be 0.1MPa.

5 The piping design pressure with the pressure relief device shall not be less than the pressure at which the pressure relief device is opened.

6.1.2 The determination of piping design temperature shall be in accordance with the following requirements:

1 The piping design temperature shall be the temperature of the piping under the most severe conditions in which the pressure and temperature are coupled during operation;

2 When the design temperature is determined, the parameters such as fluid temperature, ambient temperature, solar radiation, heating or cooling fluid temperature shall be considered;

3 The minimum design temperature shall be the minimum operating temperature of the pipe components and shall not be less than the temperature lower limit of the used material;

4 When the pipeline is heated by heat tracing pipe or jacket, the higher temperature of the external heating temperature and the temperature of the pipe fluid shall be used as the design temperature;

5 When no solar radiation or other heat source causes higher temperatures, the pipe design temperature without insulation shall be the fluid temperature;

6 The design temperature of the external insulation pipe shall be determined in accordance with items 1,2,3 and 4 of this article. Other temperatures may be used when the results of calculations, tests or measurements are otherwise available;

7 The design temperature of the internal insulation pipe shall be determined according to heat transfer calculations or tests.

6.1.3 The design provisions adopted for ambient effects shall comply with the relevant requirements of the current national standard GB 50316 *Design Code for Industrial Metallic Piping*.

6.1.4 The Sustained loads on the pipeline shall include design pressure, gravity of the transport fluid, ice and snow in cold areas, gravity of pipes and insulation materials, thermal expansion loads and other permanent loads supported by the pipeline.

6.1.5 The Occasional loads on the pipeline shall include hydrotest loads, wind, earthquake, reaction force generated when the fluid is depressurized or discharged, and shall be in accordance with the following requirements:

1 When designing a pipeline, occasional loads may be not considered applying simultaneously;

2 When the seismic intensity is 9 degrees or above, the earthquake check shall be performed.

6.1.6 The piping design shall calculate the forces and moments generated by the thermal expansion or contraction of the constrained piping.

6.1.7 Pipeline design shall adopt provisions to prevent fatigue damage caused by pressure cyclic loading, temperature cyclic loading and other cyclic alternating loads.

6.1.8 The piping design shall take the displacement of the pipe support and the connecting equipment as the calculation conditions, the displacement of the equipment or the support generated by thermal expansion, foundation sinking, tidal flow, and wind load.

6.1.9 The properties, allowable stresses and strains of fibre reinforced plastics used in piping design shall be valued in accordance with the relevant provisions of Section 4.3 of this code.

6.1.10 When using the long-term performance test method value specified in Article 4.3.14 of this code, in addition to calculating the maximum combined stress, the simplified failure envelope calculation and failure determination of the filament wound pipe and fittings shall also be performed.

6.1.11 The types of construction for the laminate of pipes may be classified as follows:

1 Type Ⅰ shall be a lining, all chopped strand mat construction and an outer protective layer;

2 Type Ⅱ shall be a lining, chopped strand mat/filament wound construction and an outer protective layer;

3 Type Ⅲ shall be a lining, chopped strand mat/filament roving construction and outer protective layer.

6.1.12 The safety requirements for piping design shall meet with the relevant requirements of the current national standard GB 50316 *Design Code for Industrial Metallic Piping*.

6.1.13 The calculation procedure of mechanical design of pipeline may be carried out in accordance with Appendix G of this code.

6.2 Configuration design

6.2.1 Pipe supports shall include anchor, support and guide, and shall be in accordance with the following requirements, in addition to meet the relevant requirements of the current national standard GB 50316 *Design Code for Industrial Metallic Piping*;

1 A fibre reinforced plastic, thermoplastic or rubber material shall be used between supports and pipe. The thickness of the pad shall be included in the determination of the inner diameter of supports.

2 Pipe anchors shall be in accordance with the following requirements:

1) The anchors shall be located at where the pipe changes directions, or the main pipe near the major branch connections, or the connection between glass fibre reinforced piping and metal piping, or where pipe could be moved caused by the water hammer in the pipeline, or the sensitive in-line equipment or the stable position of the long-distance straight pipe;

2) The anchors shall be firmly attached to a sub-structure, and shall be capable of supporting the applied forces;

3) The anchors on the straight pipe (Figure 6.2.1-1) may be composed of pipe clamps and pipe sleeves, and may also be bolted to flange connection (Figure 6.2.1-2 and Figure 6.2.1-3);

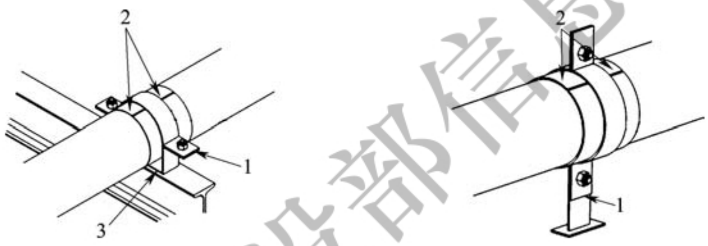


Figure 6.2.1-1 Pipe clamps and pipe sleeves of anchors

1—Pipe clamps; 2—Pipe sleeves; 3—Welded or bolted

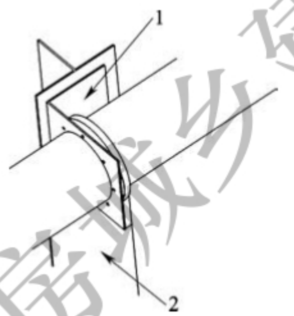


Figure 6.2.1-2 Anchors bolted to flange connection 1

1—Steel anchor bolted to flange connection; 2—Column

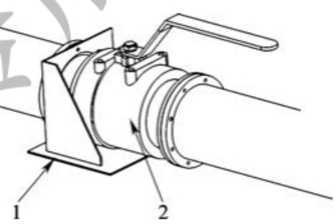


Figure 6.2.1-3 Anchors bolted to flange connection 2

1—Steel anchor bolted to flange connection; 2—Valve

4) The minimum width of supports and clamps shall be in accordance with those specified in Table 6.2.1-1.

Table 6.2.1-1 The minimum width of supports and clamps (mm)

Pipe nominal diameters (*DN*)	Minimum width
25	25
40	25
50	25
80	40
100	40
150	40
200	50
250	70
300	80
350	100

Note: The minimum width of the supports and clamps with a *DN* greater than 350 shall not be less than $\sqrt{30DN}$.

3 The pipe support(Figure 6.2.1-4)shall be in accordance with the following requirements:

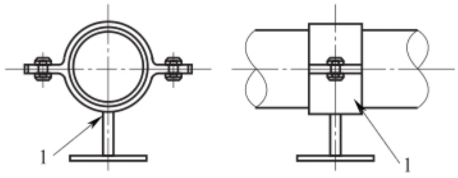


Figure 6.2.1-4 Support

1—Support

1)The support should be made of two pieces of steel material, and the pipe should be surrounded by 360°; the contact angle between clamp and pipe should be 180°. When the contact angle is less than 180° or supporting large diameter pipe, support saddle shall be installed at the contact position. Support saddle should be bonded to the pipe.

2)The minimum width of the supports shall not be less than that specified in Table 6.2.1-1.

3)The minimum width of the support saddle shall not be less than that specified in Table 6.2.1-2.

4)The contact material of the support and the sub-structure shall be made of hard materials.

Table 6.2.1-2 Minimum width of the support saddle(mm)

Pipe nominal diameters(*DN*)	Minimum width
25	50
40	50
50	100
80	100
100	100
150	150
200	200
250	250
300	300
350	350

Note: The minimum width of support pad with a *DN* greater than 350 pipe may be extrapolated proportionally.

4 The pipe guide(Figure 6.2.1-5)shall be in accordance with the following requirements:

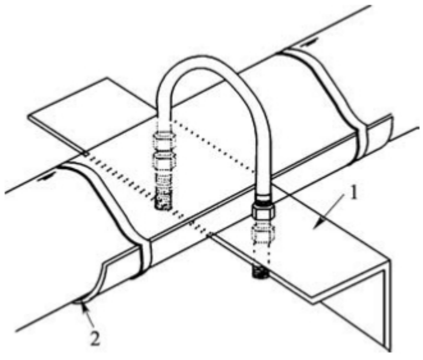


Figure 6.2.1-5 Guide

1—Support; 2—Support saddle

1)Guide should be placed between anchors, near entry points of expansion joints and loops;

2)The design and installation of the guide shall prevent the pipe from sliding off support beams and allow the pipe to freely move in the axial direction;

3) The guide shall be bonded to the pipe bottom with a 180° support saddle;

4) The guide shall be fixed with U-bolt with a diameter of less than 20mm or U-shaped steel strip. There shall be a gap between the fixing member and the outside diameter of pipe. The guide shall not be made of soft materials.

6.2.2 The construction and mechanical calculation of the pipe joint shall be in accordance with the following requirements:

1 A joint may be classified as flexible joint and rigid joint.

2 Flexible joints may be classified as bell-and-spigot elastomeric sealed joints (without locks) (Figure 6.2.2-1) and bell-and-spigot elastomeric sealed joints with locks (Figure 6.2.2-2). Bell-and-spigot elastomeric sealed joints (without locks) may not resist end loads, bell-and-spigot elastomeric sealed joints with locks may resist end loads.

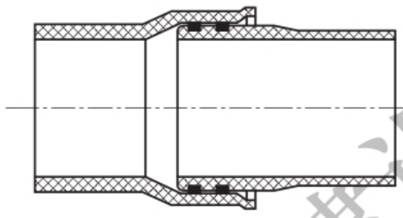


Figure 6.2.2-1 Bell-and-spigot elastomeric sealed joints (without locks)

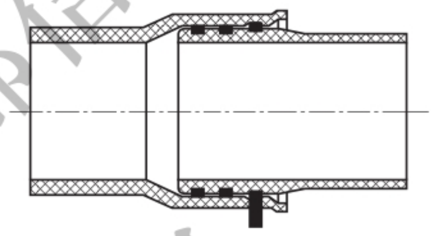


Figure 6.2.2-2 Bell-and-spigot elastomeric sealed joints with locks

3 Rigid joints may be classified as flange joints and bonded joints. Rigid joints may resist end loads.

4 The mechanical properties of the joint shall be in accordance with the following requirements.

1) The circumferential load bearing capacity of the joint shall not be less than that of the fibre reinforced plastic straight pipe with the same pressure and stiffness class.

2) The end-loaded joint has a circumferential, axial, bending and torsional load bearing capacity that shall not be less than the bonded fibre reinforced plastic straight pipe.

3) The lap shear strength of the rigid joint using double overlapped joint test pieces shall not be less than 7.0MPa.

4) The hand lay-up butt joint (Figure 6.2.2-3) have an overlay length, which shall not be less than the calculated value of the following formula and half of the joint inner diameter, and shall not be less than 150mm:

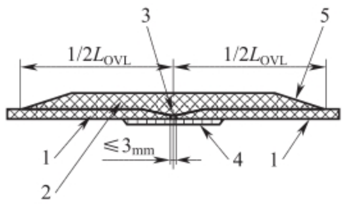


Figure 6.2.2-3 Hand lay-up butt joints

1—Main pipe; 2—Overlay; 3—Resin putty filler; 4—Inner sealing strip if required; 5—Tapers not steeper than 1:6

$$L_{OVL}=\frac{2F_S\varepsilon_d X_{lam}}{\tau_{lap}} \tag{6.2.2-1}$$

where

L_{OVL}—Calculated overlay length (mm);

ε_d—Allowable strains, which may be valued in accordance with the requirements of Articles

4.3.10 to 4.3.13 of this code;

τ_{lap}—Lap shear strength(MPa), when using glass fibre reinforced materials, it may be determined according to those specified in Table 4.3.1 of this code or be tested according to the requirements of Appendix L of this code;

F_S—Safety factor, which may be related to the strain class ratings of pipe, may be determined according to those specified in Table 6.2.2.

Table 6.2.2 Strain class ratings of pipe and safety factor

Strain class ratings	Safety factor F_S
Class1	8
Class2	10
Class3	12
Class4	16

5)Hand lay-up butt joints should be fabricated in the shop. The design quantity of reinforcement used in the overlay shall be such as to produce a design unit tensile modulus of at least that of the pipe wall; and for the overlay made on site, the requirements above shall not be less than 1.25 times that of the pipe wall.

6)When jointing pipes of different wall thickness or load carrying capacity, the requirements for overlay length and laminate shall correspond to those of the thinner wall pipe or lower load carrying capacity pipe.

7)When hand lay-up butt joints are used, the pipe manufacturer shall provide a process document for the pipe joint made on site, the contents of which shall include the number of layers, the sequence and the type of reinforcement material, auxiliary tools and the secondary bonding process evaluation report.

8)The interior of butt joints, where accessible, shall be sealed with a minimum of 1.2kg/m^2 of CSM and surface veil. The reinforcement of this internal layer shall not be counted in the calculation of the unit tensile modulus of the joint.

9)The spigot and socket joint(Figure 6.2.2-4)shall be a straight or tapered joint, and the socket depth shall not be less than the calculated value according to the following formulas and shall not be less than 25mm.

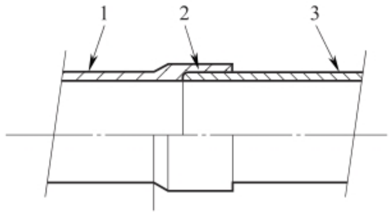


Figure 6.2.2-4 Spigot and socket joint

1—Pipe with integral socket end; 2—Adhesive; 3—Pipe with spigot end

$$L_s = \frac{F_S \varepsilon_d X_{lam}}{\tau_{lap}} \qquad (6.2.2\text{-}2)$$

where

L_s—Calculated socket depth(mm).

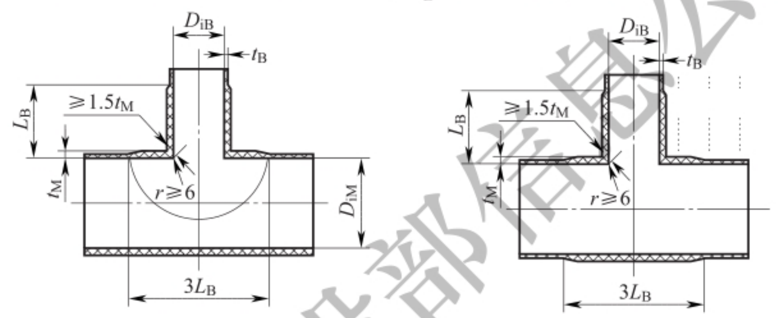
10)When spigot and socket joints are used, the pipe manufacturer shall provide proof of the suitability of the adhesive to the pipe application environment, and shall specify the temperature and humidity requirements for the curing of the adhesive, the bonding process, the assembly method, etc.

11) If practicable the interior of the joints shall be sealed with a laminate containing a minimum of 900g/m^2 CSM which shall be covered by a surface veil and sealing coat.

12) The calculation of the flanged joint shall meet the requirements of Appendix D of this code.

6.2.3 The construction and dimensions of tee shall be in accordance with the following requirements:

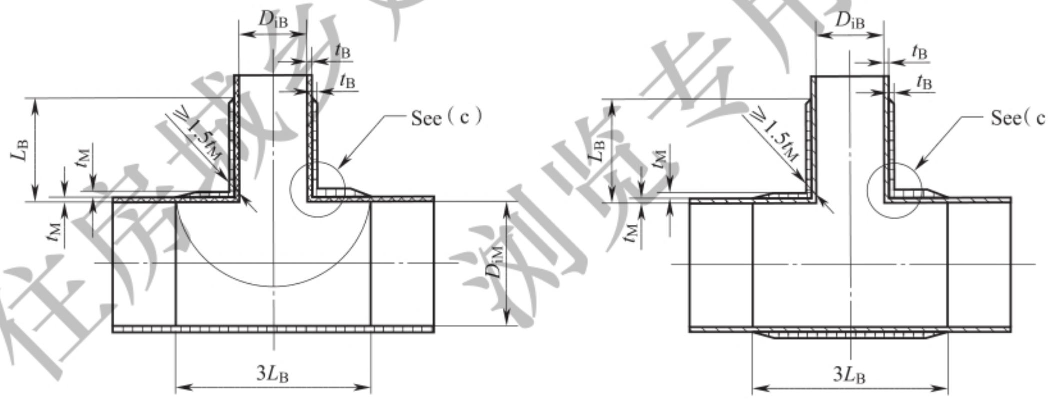
1 The tees shall be classified as moulded tees (Figure 6.2.3-1) and fabricated tees (Figure 6.2.3-2);



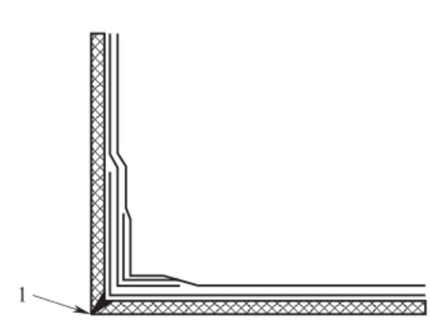
(a) $D_{iB} \leqslant 0.25D_{iM}$ (b) $D_{iB} > 0.25D_{iM}$

Figure 6.2.3-1 Moulded tees

t_M—Thickness of the reference laminates of the main of the tee; D_{iM}—Internal diameter of main of tee; D_{iB}—Internal diameter of the branch; t_B—Wall thickness of the branch adjacent to the junction; L_B—Length of overlay along a branch, not less D_{iB}



(a) $D_{iB} \leqslant 0.25D_{iM}$ (b) $D_{iB} > 0.25D_{iM}$



(c)

Figure 6.2.3-2 Fabricated tees

1—Resin putty filler; L_B—Length of overlay along a branch, not less D_{iB}

2 The dimensions of butt joint fittings (Figure 6.2.3-3) shall be in accordance with those specified in Table 6.2.3-1; the dimensions of flanged joint fittings (Figure 6.2.3-4) shall be in accordance with those specified in Table 6.2.3-2.

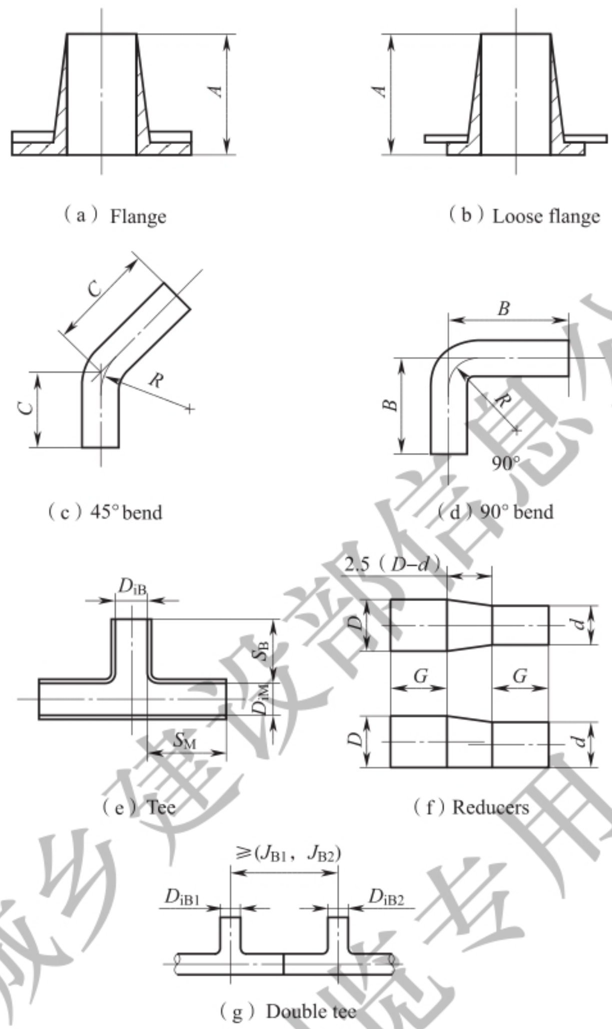


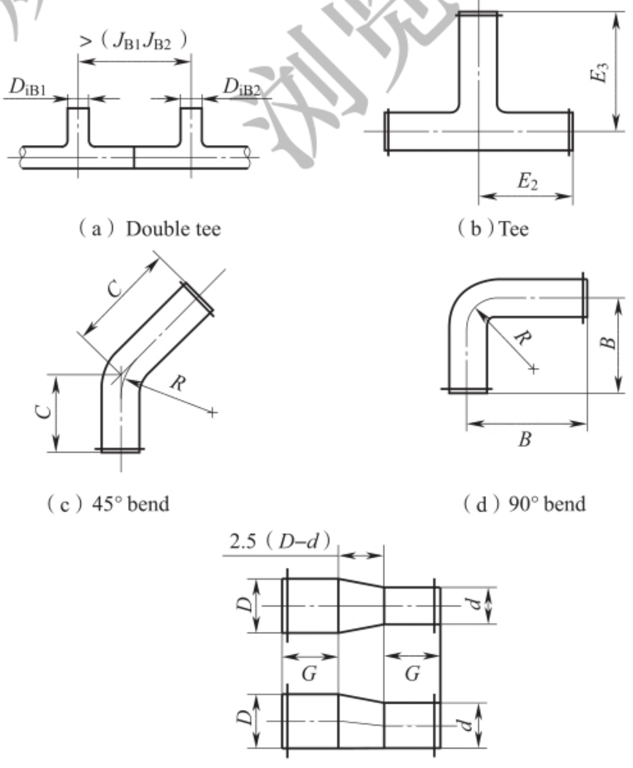
Figure 6.2.3-3 Butt joint fittings

Table 6.2.3-1 Dimensions of butt joint fittings(mm)

Nominal diameter	Dimension							
	D_{iM}, D_{iB}, D or d	A	R	B	C	S_B or S_M	J_{B1} or J_{B2}	G
40	40	150	115	165	100	75	100	50
50	50	150	150	200	125	75	125	50
80	80	175	225	275	150	75	125	50
100	100	200	300	350	175	100	150	50
150	150	225	225	300	175	150	200	75
200	200	275	300	375	200	200	225	75
250	250	300	250	325	175	225	250	75
300	300	350	300	375	200	275	275	75
350	350	400	350	450	250	325	325	100
400	400	450	400	500	275	325	350	100
450	450	475	450	550	275	425	375	100

Table 6.2.3-1（continued）

Nominal diameter	Dimension							
	D_{iM}, D_{iB}, D or d	A	R	B	C	S_B or S_M	J_{B1} or J_{B2}	G
500	500	500	500	600	300	425	400	100
550	550	550	550	650	325	525	425	100
600	600	600	600	700	325	525	450	100
650	650	475	650	750	350	500	475	100
700	700	500	700	800	375	525	500	100
750	750	525	750	850	400	575	525	100
800	800	550	800	900	425	600	575	100
850	850	575	850	950	425	650	600	100
900	900	600	900	1000	450	675	625	100
950	950	625	950	1050	475	725	650	100
1000	1000	650	1000	1100	500	750	675	100
1050	1050	675	1050	1150	525	800	700	100
1100	1100	700	1100	1200	525	825	750	100
1150	1150	725	1150	1250	550	875	775	100
1200	1200	750	1200	1300	575	900	800	100



(e) Reducer

Figure 6.2.3-4 Flanged joint fittings

Table 6.2.3-2 Dimensions of flanged joint fittings(mm)

Nominal diameter	Dimension							
	G	E_3	E_2	R	B	C	D_{iB1} or D_{iB2}	J_{B1} or J_{B2}
40	100	150	175	115	225	150	40	100
50	125	175	200	150	275	200	50	125
80	150	200	250	225	375	250	80	125
100	150	200	250	300	450	275	100	150
150	175	225	300	225	400	275	150	200
200	175	250	350	300	475	300	200	225
250	200	275	400	250	450	300	250	250
300	200	275	425	300	500	325	300	275
350	200	275	450	350	550	350	350	325
400	250	325	525	400	650	4254	400	350
450	250	325	550	450	700	425	450	375
500	300	400	650	500	800	500	500	400
550	300	400	650	550	850	525	550	425
600	300	400	700	600	900	550	600	450
650	300	400	750	650	950	575	650	475
700	300	400	750	700	1000	575	700	500
750	300	400	800	750	1050	600	750	525
800	300	400	800	800	1100	625	800	575
850	400	500	900	850	1250	750	850	600
900	400	500	950	900	1300	750	900	625
950	400	500	950	950	1350	800	950	650
1000	400	500	1000	1000	1400	800	1000	675
1050	400	500	1050	1050	1450	850	1050	700
1100	500	600	1100	1100	1600	950	1100	750
1150	500	600	1100	1150	1650	975	1150	775
1200	500	600	1150	1200	1700	1000	1200	800

6.2.4 When the pipe is thermally expanded and a semi-restrained pipe system is used, the expansion may be controlled with L-shaped pipe joint, ∏-shaped pipe joint and expansion joint .

6.2.5 The flexible pipe leg and in-plane bending moment of L-shaped pipe joint(Figure 6.2.5) shall be calculated according to the following formulas:

$$L_{leg}=\sqrt{\frac{m\Delta l E_{lamx} D_e}{\sigma_i}} \tag{6.2.5-1}$$

$$D_e = D_i + 2t_t \tag{6.2.5-2}$$

$$\sigma_i = \sigma_{dx} - \sigma_{xp} \tag{6.2.5-3}$$

$$M_i = \frac{6E_{lamx} \cdot I \cdot \Delta l}{L_{leg}^2} \tag{6.2.5-4}$$

where

L_{leg}—Flexible pipe leg of L-shaped pipe joint(mm);

m—Constant, may be 3.0;

Δl—Thermal expansion absorbed with L-shaped pipe joint(mm);

E_{lamx}—Axial tensile modulus(MPa);

D_e—Outside diameter of a pipe(mm);

D_i—Internal diameter of a pipe(mm);

t_t—Total pipe thickness(mm);

σ_i—Allowable axial bending stress(MPa);

σ_{dx}—Allowable axial stress(MPa), may be calculated in accordance with the provisions of Article 4.3.9 of this code;

σ_{xp}—Axial stress by design pressure(MPa), may be calculated according to Formula(6.4.6-2) and Formula(6.4.6-3);

M_i—In-plane bending moment of L-shaped pipe joint(N·mm);

I—Axial moment of inertia of pipeline(mm^4).

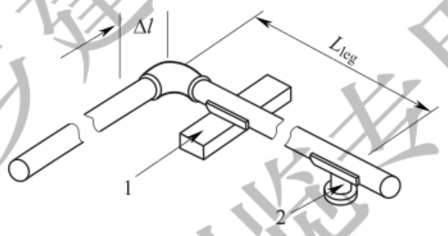


Figure 6.2.5 L-shaped pipe joint

1—Guide or anchor; 2—Support

6.2.6 The length and in-plane bending moment of ∏ -shaped pipe joint (Figure 6.2.6) shall be calculated according to the following formulas:

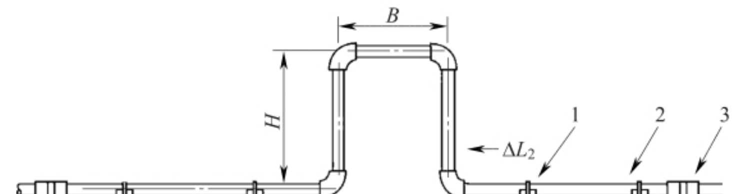


Figure 6.2.6 ∏-shaped pipe joint

1—First guide; 2—Second guide; 3—Anchor; A—4 nominal pipe diameter; C—14 nominal pipe diameter

$$H = \sqrt{\frac{m \Delta l E_{lamx} D_e}{\sigma_i}} \tag{6.2.6-1}$$

$$B = H/2 \tag{6.2.6-2}$$

$$M_i = \frac{3E_{lamx} \cdot I \cdot \Delta l}{H^2} \tag{6.2.6-3}$$

where

H—Cantilever length of ∏-shaped pipe joint(mm);

m—Coefficient, which may be evaluated by 1.5;

Δl—Sum of the thermal expansion changes(Δl_1, Δl_2) of the pipelines on both sides of ∏-shaped pipe joint;

B—Parallel leg length of ∏-shaped pipe joint(mm);

M_i—In-plane bending moment of L-shaped pipe joint(N·mm);

I—Axial moment of inertia of pipeline(mm^4).

6.2.7 The expansion joint (Figure 6.2.7) shall be calculated in accordance with the following requirements:

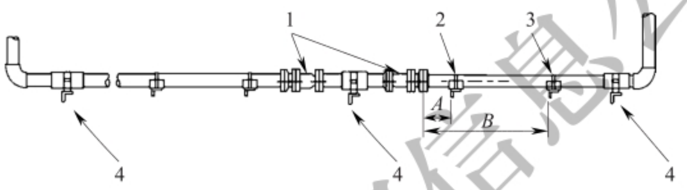


Figure 6.2.7 Expansion joint

1—Expansion joint; 2—First guide; 3—Second guide; 4—Fixed support;

A—4 nominal pipe diameters; B—14 nominal pipe diameters

1 The maximum expansion and contraction of expansion joint shall not be less than 1.5 times the calculated thermal expansion of the pipe between the two anchors. The activation force of expansion joint shall be less than 0.25 times the axial load of anchor calculated by Formula(6.2.8-1) and shall be less than the critical compressive load calculated by Formula(6.2.7-1).

$$P \leqslant \frac{\pi^2 E_{lamx} I}{4L_{max}^2} \tag{6.2.7-1}$$

where

P—Critical compressive load(N);

I—Axial moment of inertia of the pipeline(mm^4);

L_{max}—Maximum distance between the guide and the adjacent guide or anchor(mm).

2 The initial installed position of expansion joint shall be set according to the maximum expansion and contraction of expansion joint and shall be calculated according to the following formulas:

$$S = \xi \times L_J \tag{6.2.7-2}$$

$$\xi = \frac{T_i - T_{min}}{T_{max} - T_{min}} \tag{6.2.7-3}$$

where

S—Distance from the full compression position of the expansion joint(m);

L_J—Maximum expansion and contraction of expansion joint(m);

ξ—Coefficient, shall be calculated according to Formula(6.2.7-3);

T_i—Installation tie-in temperature of pipes between two anchors where the expansion joint is located (℃);

T_{max}—Maximum design temperature of the pipeline(℃);

T_{min}—Minimum design temperature of the pipeline(℃).

6.2.8 When the pipe is thermally expanded and a full-restrained pipe system is used, pipeline calculations shall include the following:

1 The axial load F_r on anchors and the maximum length L of the compressive straight pipe shall be calculated according to the following formulas:

$$F_r = \alpha_1 \Delta T E_{lamx} \pi \left(D_i + t_t\right) t_t \qquad (6.2.8\text{-}1)$$

$$L \leqslant \pi \sqrt{\frac{E_{lamx} I}{F_r}} \qquad (6.2.8\text{-}2)$$

$$I = \frac{\left(D_i + 2t_d\right)^4 - D_i^4}{64} \qquad (6.2.8\text{-}3)$$

where

F_r—restraining load or compressive load of the pipe end(N);

α_1—axial linear thermal expansion coefficient(mm/mm/℃);

I—Axial moment of inertia of the pipeline(mm^4).

2 The sum of the circumferential strain caused by the axial compressive stress of the pipe and the internal pressure shall not exceed the following allowable strain:

1)When using type Ⅰ and type Ⅱ laminates, the following formula shall be met:

$$\frac{\sigma_\Phi - \nu \cdot \sigma_x}{E_{lam\Phi}} \leqslant \varepsilon_d \qquad (6.2.8\text{-}4)$$

2)When using type Ⅲ laminates, the following formula shall be met:

$$\frac{\sigma_\Phi - \nu_{yx} \cdot \sigma_x}{E_{lam\Phi}} \leqslant \varepsilon_d \qquad (6.2.8\text{-}5)$$

3 The maximum axial compression strain shall meet the following formula:

$$\alpha \Delta T + \frac{\sigma_{ab}}{E_{lamx}} \leqslant 1.25\varepsilon_d \qquad (6.2.8\text{-}6)$$

6.3 Structure calculation

6.3.1 According to the design pressure, the straight pipe parameters shall be in accordance with the following requirements:

1 Laminate unit tensile stiffness of straight pipe shall be calculated according to the following formula:

$$X_{lam} = \frac{D_i \times p_d}{2\phi_d} \qquad (6.3.1\text{-}1)$$

where

X_{lam}—Laminate unit tensile stiffness of straight pipe(N/mm);

p_d—Design pressure(MPa).

2 The X_{lam} obtained by the laminate design according to the relevant provisions of Section 4.3 of this code shall not be less than the X_{lam} calculated according to Formula(6.3.1-1);

3 The reference laminates may be selected according to Table 6.3.1-1. The reference laminates with the allowable strain value of 0.0018, 0.0015, 0.0012, 0.0009 may be selected according to Table 6.3.1-2 to Table 6.3.1-5;

4 According to the data provided by the pipe manufacturer, laminate unit tensile stiffness X_{lam} calculated by the following formula shall not be less than the X_{lam} calculated according to Formula(6.3.1-1).

$$X_{lam} = Et \qquad (6.3.1\text{-}2)$$

where

E—Circumferential tensile modulus provided by the pipe manufacturer(MPa);

t—Pipe calculation wall thickness provided by the pipe manufacturer(mm).

Table 6.3.1-1 Reference laminates

Reference laminates code	Laminate unit tensile stiffness X_{lam} (N/mm)	Design thickness t_d(mm)			Reference laminates code	Laminate unit tensile stiffness X_{lam} (N/mm)	Design thickness t_d(mm)		
		Type Ⅰ	Type Ⅱ	Type Ⅲ			Type Ⅰ	Type Ⅱ	Type Ⅲ
L25	25000	4.4	4.0	1.9	L160	160000	28.3	17.9	12.3
L30	33000	6.0	5.0	2.8	L180	180000	31.6	21.1	14.2
L40	42000	7.6	5.7	3.8	L200	200000	34.9	23.2	15.1
L50	50000	8.7	6.4	3.8	L225	225000	39.2	25.2	17.0
L60	58800	10.4	7.4	4.7	L250	250000	43.6	27.3	18.9
L80	80000	14.2	9.5	6.6	L275	275000	48.0	30.5	20.8
L100	100000	17.4	11.6	7.5	L300	300000	52.3	33.7	22.6
L120	120000	21.8	13.7	9.4	L350	350000	61.1	38.9	26.4
L140	140000	25.1	15.8	11.3	L400	400000	69.8	45.2	30.2

Notes: 1 Type Ⅰ: All chopped strand mat construction (CSM) with an internal surface veil;

2 Type Ⅱ: Chopped strand mat/woven roving construction (CSM/WR) with an internal surface veil. There shall be a minimum of 1.2kg/m^2 of CSM before the first layer of WR is applied;

3 Type Ⅲ: Chopped strand mat/filament roving construction (winding angle of ±55°) with an internal surface veil. The CSM is on the internal wall after the surface tissue reinforced layer and shall be a minimum of 1.2kg/m^2 of glass.

Table 6.3.1-2 Reference laminates table for allowable strain of 0.0018

DN(mm)	*PN*(MPa)						
	0.10	0.25	0.40	0.50	0.60	0.80	1.00
40	L25	L25	L25	L25	L25	L25	L25
50	L25	L25	L25	L25	L25	L25	L25
80	L25	L25	L25	L25	L25	L25	L25
100	L25	L25	L25	L25	L25	L25	L30
150	L25	L25	L25	L25	L30	L40	L40
200	L25	L25	L25	L30	L40	L50	L60
250	L30	L30	L30	L40	L40	L60	L80
300	L30	L30	L40	L40	L60	L80	L100
350	L30	L30	L40	L50	L60	L80	L100
400	L30	L30	L50	L60	L80	L100	L120
450	L30	L30	L60	L80	L80	L120	L140
500	L30	L40	L60	L80	L100	L120	L140
550	L30	L40	L80	L80	L100	L140	L160
600	L30	L40	L80	L100	L120	L140	L180
650	L30	L50	L80	L100	L120	—	—
700	L30	L50	L80	L100	L120	—	—
750	L30	L60	L100	L120	L140	—	—
800	L30	L60	L100	L120	L140	—	—

Table 6.3.1-2 (continued)

DN(mm)	*PN*(MPa)						
	0.10	0.25	0.40	0.50	0.60	0.80	1.00
850	L30	L80	L100	L120	L160	—	—
900	L30	L80	L120	L140	L160	—	—
950	L30	L80	L120	L140	L160	—	—
1000	L30	L80	L120	L140	L180	—	—
1050	L30	L80	L120	L160	L180	—	—
1100	L30	L80	L140	L160	L200	—	—
1150	L30	L80	L140	L160	L200	—	—
1200	L40	L100	L140	L180	L225	—	—

Table 6.3.1-3 Reference laminates table for allowable strain of 0.0015

DN(mm)	*PN*(MPa)						
	0.10	0.25	0.40	0.50	0.60	0.80	1.00
40	L25	L25	L25	L25	L25	L25	L25
50	L25	L25	L25	L25	L25	L25	L25
80	L25	L25	L25	L25	L25	L25	L30
100	L25	L25	L25	L25	L25	L30	L40
150	L25	L25	L25	L30	L30	L40	L60
200	L25	L25	L30	L40	L40	L60	L80
250	L30	L30	L40	L40	L60	L80	L100
300	L30	L30	L40	L60	L80	L100	L120
350	L30	L30	L50	L60	L80	L100	L120
400	L30	L40	L60	L80	L100	L120	L140
450	L30	L40	L80	L80	L100	L140	L160
500	L30	L40	L80	L100	L120	L140	L180
550	L30	L50	L80	L100	L120	L160	L200
600	L30	L60	L100	L120	L140	L180	L225
650	L30	L60	L100	L120	L140	—	—
700	L30	L60	L100	L120	L160	—	—
750	L30	L80	L120	L140	L160	—	—
800	L30	L80	L120	L140	L180	—	—
850	L30	L80	L120	L160	L180	—	—
900	L30	L80	L140	L160	L200	—	—
950	L30	L80	L140	L160	L200	—	—
1000	L40	L100	L140	L180	L225	—	—
1050	L40	L100	L160	L180	L225	—	—
1100	L40	L100	L160	L200	L225	—	—
1150	L40	L100	L160	L200	L250	—	—
1200	L40	L120	L180	L225	L250	—	—

Table 6.3.1-4 Reference laminates table for allowable strain of 0.0012

DN(mm)	*PN*(MPa)						
	0.10	0.25	0.40	0.50	0.60	0.80	1.00
40	L25	L25	L25	L25	L25	L25	L25
50	L25	L25	L25	L25	L25	L25	L25
80	L25	L25	L25	L25	L25	L30	L40
100	L25	L25	L25	L25	L30	L40	L40
150	L25	L25	L30	L30	L40	L60	L80
200	L25	L25	L40	L40	L60	L80	L100
250	L30	L30	L40	L60	L80	L100	L120
300	L30	L30	L60	L80	L80	L120	L140
350	L30	L40	L60	L80	L100	L120	L160
400	L30	L40	L80	L100	L120	L140	L180
450	L30	L50	L80	L100	L120	L160	L200
500	L30	L60	L100	L120	L140	L180	L225
550	L30	L60	L100	L120	L140	L200	L250
600	L30	L80	L120	L140	L160	L225	L275
650	L30	L80	L120	L140	L180	—	—
700	L30	L80	L120	L160	L180	—	—
750	L30	L80	L140	L160	L200	—	—
800	L40	L100	L140	L180	L225	—	—
850	L40	L100	L160	L180	L225	—	—
900	L40	L100	L160	L200	L250	—	—
950	L40	L100	L160	L200	L250	—	—
1000	L40	L120	L180	L225	L275	—	—
1050	L50	L120	L180	L225	L275	—	—
1100	L50	L120	L200	L250	L300	—	—
1150	L50	L120	L200	L250	L300	—	—
1200	L60	L140	L225	L275	L350	—	—

Table 6.3.1-5 Reference laminates table for allowable strain of 0.0009

DN(mm)	*PN*(MPa)						
	0.10	0.25	0.40	0.50	0.60	0.80	1.00
40	L25	L25	L25	L25	L25	L25	L25
50	L25	L25	L25	L25	L25	L25	L30
80	L25	L25	L25	L25	L30	L40	L50
100	L25	L25	L25	L30	L40	L50	L60
150	L25	L25	L40	L40	L60	L80	L100

Table 6.3.1-5(continued)

DN(mm)	PN(MPa)						
	0.10	0.25	0.40	0.50	0.60	0.80	1.00
200	L25	L30	L50	L60	L80	L100	L120
250	L30	L40	L60	L80	L100	L120	L140
300	L30	L40	L80	L100	L120	L140	L180
350	L30	L50	L80	L100	L120	L160	L200
400	L30	L60	L100	L120	L140	L180	L225
450	L30	L80	L120	L140	L160	L225	L275
500	L30	L80	L120	L140	L180	L225	L300
550	L30	L80	L140	L160	L200	L250	L350
600	L40	L100	L140	L180	L225	L275	L350
650	L40	L100	L160	L200	L225	—	—
700	L40	L100	L160	L200	L250	—	—
750	L40	L120	L180	L225	L275	—	—
800	L50	L120	L180	L225	L275	—	—
850	L50	L120	L200	L250	L300	—	—
900	L60	L140	L225	L275	L350	—	—
950	L60	L140	L225	L275	L350	—	—
1000	L60	L140	L225	L300	L350	—	—
1050	L60	L160	L250	L300	L350	—	—
1100	L80	L160	L250	L350	L400	—	—
1150	L80	L160	L275	L350	L400	—	—
1200	L80	L180	L275	L350	L400	—	—

6.3.2 The allowable external pressure calculation of the straight pipe shall be in accordance with the following requirements:

1 The allowable external pressure of the straight pipe shall be calculated according to the following formula:

$$P_e = \frac{2.0X_{lam\Phi}}{t_d \times F_S} \cdot \left(\frac{t_d}{D_i + t_d}\right)^3 \tag{6.3.2-1}$$

where

P_e—Allowable external pressure(MPa);

$X_{lam\Phi}$—Circumferential unit tensile stiffness(N/mm);

F_S—External pressure safety factor, the value shall not be less than 4.

2 When the allowable external pressure calculated according to Formula(6.3.2-1) is less than the design external pressure, the following method shall be used to correct the design:

1)Choose a larger X_{lam}, and shall recalculate the allowable external pressure according to Formula(6.3.2-1);

2) Use stiffening rings, the distance between stiffening rings and the minimum moment of inertia of the stiffening ring shall be calculated according to the following formulas:

$$J = \frac{2.5X_{\text{lam}\Phi}}{p_e \times F_S} \cdot \left(\frac{t_d}{D_i + 2t_d}\right)^{1.5} \tag{6.3.2-2}$$

$$I_J = \frac{0.018(D_i + 2t_d)JD_{na}^2 p_e t_d}{X_{\text{lam}\Phi}} \tag{6.3.2-3}$$

where

J—Maximum distance between stiffening rings(mm);

I_J—Second axial moment of area of the stiffening ring section about its neutral axis(mm^4);

D_{na}—Diameter of the neutral axis of the stiffening ring(mm);

3) When using a stiffening ring and calculating the moment of inertia of the stiffening ring, J_S shall be calculated as follows, and is not taken to be greater than J:

$$J_S = 0.75\left[(D_i + 2t_d)t_d\right]^{0.5} \tag{6.3.2-4}$$

where

J_S—Length of shell, which shall be regarded as effectively contributing to the amount of the stiffening ring section(mm).

6.3.3 The calculation of piping pressure loss shall meet the requirements of Appendix H of this code.

6.3.4 The bending stress, deflection and support span L of the horizontal pipe shall be in accordance with the following requirements:

1 The bending stress caused by the self-weight of the pipeline shall not be greater than the allowable axial stress;

2 The bending deflection caused by the self-weight of the pipeline shall be in accordance with the following requirements:

1) The design deflection of the pipeline shall not be greater than 12.5mm and shall be compared with $L/300$, and shall be smaller;

2) The deflection of the pipe outside the plant shall not exceed 38mm;

3) When laying a steam pipe without slope, the deflection should not exceed 10mm;

4) When there are special requirements, the pipe deflection shall meet the design requirements.

3 For pipelines subjected to axial compression loads, the span or support spacing L shall meet the requirements of Formula (6.2.8-2) of this code.

6.3.5 The calculation of axial bending caused by the supporting pipe shall be in accordance with the following requirements:

1 Type Ⅰ and Type Ⅱ laminates shall be valued as the following requirements:

1) The bending stress for supporting pipe should be 25% of the allowable axial stress;

2) The axial stress caused by internal pressure should be 50% of the allowable axial stress;

3) The stress caused by the thermal expansion effect should be 25% of the allowable axial stress.

2 Type Ⅲ laminates shall be valued as the following requirements:

1) When expansion joints or flexible joints are used, the bending stress for supporting pipe should be 50% of the allowable axial stress;

2) When the pipe wall is subjected to the axial force generated by the design internal pressure, the bending stress for supporting pipe should be 25% of the allowable axial stress.

6.3.6 When there is no fluid requirement between the supports for the pipeline with slope, the spacing of the pipe supports shall comply with the requirements of Article 6.3.4 of this code, and the deflection and slope shall also meet the following formula:

$$L \leqslant \frac{2\Delta i}{\sqrt{1+i^2-1}} \tag{6.3.6}$$

where

L—Spacing of the pipe supports(mm);

Δi —Bending deflection caused by the self-weight of the pipeline(mm);

i—Pipeline slope.

6.3.7 For pipelines with pressure fluctuations, the natural frequency of the pipeline shall be calculated when determining the support spacing.

6.3.8 Pipe support span may be selected according to Table 6.3.8-1 to Table 6.3.8-8.

Table 6.3.8-1 Pipe support span selection table

PN(MPa)	Allowable strain	Pipe support span(mm)					
0.6	0.0018	Air medium			Water medium		
DN (mm)	Reference laminates code	Type Ⅰ	Type Ⅱ	Type Ⅲ	Type Ⅰ	Type Ⅱ	Type Ⅲ
40	L25	4000	4200	4100	2800	2900	2800
50	L25	4500	4600	4500	2900	3000	3000
80	L25	5600	5800	5700	3200	3200	3300
100	L25	6300	6400	6400	3200	3300	3400
150	L30	7500	7900	7600	3800	3800	3900
200	L40	8700	9400	8600	4300	4400	4400
250	L40	9800	10400	9600	4400	4500	4400
300	L60	10800	11800	10900	5100	5300	5200
400	L80	12000	12000	12000	5900	6100	6100
500	L100	12000	12000	12000	6700	6900	6800
600	L120	12000	12000	12000	7300	7500	7500
700	L120	12000	12000	12000	7400	7400	7400
800	L140	12000	12000	12000	7400	7400	7400
900	L160	12000	12000	12000	7400	7400	7400
1000	L180	12000	12000	12000	7400	7400	7400
1200	L225	12000	12000	12000	7400	7400	7400

Table 6.3.8-2　Pipe support span selection table

PN(MPa)	Allowable strain	Pipe support span(mm)					
0.6	0.0018	Air medium			Water medium		
DN(mm)	Reference laminates code	Type Ⅰ	Type Ⅱ	Type Ⅲ	Type Ⅰ	Type Ⅱ	Type Ⅲ
40	L25	3600	3800	4100	2600	2600	2800
50	L25	4100	4300	4500	2700	2700	2900
80	L25	5100	5400	5700	2900	2900	3000
100	L25	5700	6000	6400	3000	3000	3100
150	L30	6900	7500	7600	3400	3500	3500
200	L40	8000	9000	9000	3900	4000	4000
250	L60	9000	10700	9000	4600	4700	4700
300	L80	9900	12000	10800	5300	5500	5500
400	L100	11500	12000	12000	5900	6200	6200
500	L120	12000	12000	12000	6500	6800	6800
600	L140	12000	12000	12000	7100	7400	7300
700	L160	12000	12000	12000	7400	7400	7400
800	L180	12000	12000	12000	7400	7400	7400
900	L200	12000	12000	12000	7400	7400	7400
1000	L225	12000	12000	12000	7400	7400	7400
1200	L250	12000	12000	12000	7400	7400	7400

Table 6.3.8-3　Pipe support span selection table

PN(MPa)	Allowable strain	Pipe support span(mm)					
0.6	0.0018	Air medium			Water medium		
DN(mm)	Reference laminates code	Type Ⅰ	Type Ⅱ	Type Ⅲ	Type Ⅰ	Type Ⅱ	Type Ⅲ
40	L25	3300	3400	4100	2300	2300	2500
50	L25	3600	3800	4500	2400	2400	2600
80	L25	4600	4800	5700	2600	2600	2700
100	L30	5000	5500	6200	2900	3000	3100
150	L40	6200	7000	7500	3400	3500	3500
200	L60	7200	8500	8900	4000	4100	4200
250	L80	8100	9800	9900	4600	4800	4800
300	L80	8800	10800	10800	4700	4900	4900

Table 6.3.8-3 (continued)

PN(MPa)	Allowable strain	Pipe support span(mm)					
0.6	0.0018	Air medium			Water medium		
DN(mm)	Reference laminates code	Type Ⅰ	Type Ⅱ	Type Ⅲ	Type Ⅰ	Type Ⅱ	Type Ⅲ
400	L120	10100	12000	12000	5700	6000	6000
500	L140	11300	12000	12000	6200	6500	6500
600	L160	12000	12000	12000	6700	7000	6900
700	L180	12000	12000	12000	7100	7400	7400
800	L225	12000	12000	12000	7400	7400	7400
900	L250	12000	12000	12000	7400	7400	7400
1000	L275	12000	12000	12000	7400	7400	7400
1200	L350	12000	12000	12000	7400	7400	7400

Table 6.3.8-4 Pipe support span selection table

PN(MPa)	Allowable strain	Pipe support span(mm)					
0.6	0.0018	Air medium			Water medium		
DN(mm)	Reference laminates code	Type Ⅰ	Type Ⅱ	Type Ⅲ	Type Ⅰ	Type Ⅱ	Type Ⅲ
40	L25	2800	3000	4100	2000	2000	2200
50	L25	3100	3300	4500	2100	2100	2300
80	L30	3900	4200	5500	2400	2500	2600
100	L40	4400	5000	6000	2800	2900	2900
150	L60	5400	6400	7700	3300	3500	3500
200	L80	6300	7600	8900	3800	4100	4100
250	L100	7100	8600	10100	4300	4600	4600
300	L120	7600	9500	11000	4700	5000	5000
400	L140	8800	11000	12000	5200	5500	5500
500	L180	9900	12000	12000	5900	6200	6200
600	L225	10900	12000	12000	6500	6900	7000
700	L250	11800	12000	12000	6900	7400	7400
800	L275	12000	12000	12000	7300	7400	7400
900	L350	12000	12000	12000	7400	7400	7400
1000	L350	12000	12000	12000	7400	7400	7400
1200	L400	12000	12000	12000	7400	7400	7400

Table 6.3.8-5 Pipe support span selection table

PN(MPa)	Allowable strain	Pipe support span(mm)					
0.6	0.0018	Air medium			Water medium		
DN(mm)	Reference laminates code	Type Ⅰ	Type Ⅱ	Type Ⅲ	Type Ⅰ	Type Ⅱ	Type Ⅲ
40	L25	4000	4200	4100	2800	2900	2800
50	L25	4500	4600	4500	2900	3000	3000
80	L25	5600	5800	5700	3200	3200	3300
100	L30	6200	6500	6200	3600	3700	3800
150	L40	7600	8200	7500	4100	4300	4300
200	L60	8800	9700	8900	4900	5100	5100
250	L80	9900	11000	9900	5600	5900	5900
300	L100	10900	12100	11100	6300	6600	6600
400	L120	12000	12000	12000	6900	7300	7300
500	L140	12000	12000	12000	7600	7900	7900
600	L180	12000	12000	12000	8500	8900	8900

Table 6.3.8-6 Pipe support span selection table

PN(MPa)	Allowable strain	Pipe support span(mm)					
0.6	0.0018	Air medium			Water medium		
DN(mm)	Reference laminates code	Type Ⅰ	Type Ⅱ	Type Ⅲ	Type Ⅰ	Type Ⅱ	Type Ⅲ
40	L25	3600	3800	4100	2600	2600	2800
50	L25	4100	4300	4500	2700	2700	2900
80	L30	5000	5500	5600	3200	3200	3400
100	L40	5700	6400	6100	3600	3700	3800
150	L60	7000	8300	7700	4300	4500	4600
200	L80	8100	9800	8900	5000	5300	5300
250	L100	9100	11100	10100	5600	5900	6000
300	L120	9800	12000	11000	6100	6500	6500
400	L140	11400	12000	12000	6700	7100	7100
500	L180	12000	12000	12000	7600	8000	8000
600	L225	12000	12000	12000	8400	8900	9000

Table 6.3.8-7 Pipe support span selection table

PN(MPa)	Allowable strain	Pipe support span(mm)					
0.6	0.0018	Air medium			Water medium		
DN(mm)	Reference laminates code	Type Ⅰ	Type Ⅱ	Type Ⅲ	Type Ⅰ	Type Ⅱ	Type Ⅲ
40	L25	3300	3400	4100	2300	2300	2500
50	L25	3600	3900	4500	2400	2400	2600
80	L40	4500	5100	5500	3100	3200	3300
100	L40	5100	5700	6100	3200	3300	3400
150	L80	6300	7600	7700	4200	4500	4600
200	L100	7300	8900	9100	4800	5100	5200
250	L120	8000	10000	10100	5300	5600	5700
300	L140	8800	11000	11000	5700	6100	6200
400	L180	10300	12000	12000	6500	7000	7100
500	L225	11500	12000	12000	7300	7800	7900
600	L275	12000	12000	12000	8100	8600	8700

Table 6.3.8-8 Pipe support span selection table

PN(MPa)	Allowable strain	Pipe support span(mm)					
0.6	0.0018	Air medium			Water medium		
DN(mm)	Reference laminates code	Type Ⅰ	Type Ⅱ	Type Ⅲ	Type Ⅰ	Type Ⅱ	Type Ⅲ
40	L25	2800	3000	4100	2000	2000	2200
50	L30	3100	3400	4400	2200	2300	2500
80	L50	4000	4700	5800	2800	3000	3100
100	L60	4400	5300	6400	3100	3300	3400
150	L100	5500	6700	7900	3900	4200	4400
200	L120	6200	7800	9100	4400	4700	4800
250	L140	7000	8700	10000	4800	5200	5200
300	L180	7700	9400	11100	5400	5800	5900
400	L225	9000	11100	12000	6100	6600	6700
500	L300	10000	12000	12000	6900	7500	7700
600	L350	11000	12000	12000	7500	8200	8300

Notes: 1 Table 6.3.8-1 to Table 6.3.8-8 are the values of mid-span of continuous beam calculated according to Formula (6.4.6-5) and Formula (6.4.6-6) of this code. The value of side span may be taken as 0.816 times the data in the table;

2 The uniformly distributed load in the table is calculated using a density of $1.0\times10^3 kg/m^3$ for the liquid;

3 The data in the table is the recommended value, and the corresponding deflection and stress calculation shall be carried out for the specific project; stability calculation shall also be carried out when having thermal expansion.

6.4 Piping stress calculation and flexibility analysis

6.4.1 Pipe stress calculation may be classified as simple stress calculation and detailed stress calculation, and shall be in accordance with the following requirements:

1 Simple stress calculation may be used when replacing pipeline without significant change and which operating with a successful service record;

2 Simple stress calculation may be used when the pipeline could be judged adequate by comparison with previously analyzed systems;

3 Simple stress calculation may be used for the pipeline with thermal expansion absorption facility as specified in Article 6.2.5 to Article 6.2.7 of this code;

4 For other pipelines, detailed stress calculation should be carried out.

6.4.2 The simple stress calculation shall include the following calculations:

1 Circumferential stress due to design internal pressure;

2 Axial stress due to design internal pressure;

3 Bending stress due to self-weight of pipeline;

4 Deflection due to uniformly distributed loads and concentrated loads;

5 Bending stresses due to in-plane bending moment and out-plane bending moment of L-shaped pipe joint and ∏-shaped pipe joint;

6 Stresses due to any other sustained or occasional loads;

7 Axial compression stability and external pressure stability;

8 Stresses at the pipe support when the diameter is greater than 600mm;

9 Other stresses that need to be calculated.

6.4.3 The detailed stress calculation should use computer-aided stress analysis and shall include the following calculations:

1 Circumferential stress due to design internal pressure;

2 Axial stress due to design internal pressure;

3 Axial compressive stress due to thermal expansion;

4 Bending stress due to self-weight of pipeline;

5 Bending stress due to thermal and pressure expansion;

6 Stresses due to any other sustained, thermal or occasional loads;

7 Deflection due to uniformly distributed loads and concentrated loads;

8 Stresses at the pipe support when the diameter is greater than 600mm;

9 Other stresses that need to be calculated.

6.4.4 The design temperature change ΔT used to calculate thermal expansion and thermal load shall be calculated according to the following formulas:

1 When the pipeline is heated, the larger of the calculated values of Formula (6.4.4-1) and Formula(6.4.4-2)shall be taken.

$$\Delta T_d = c\left(T_p - T_a\right) \tag{6.4.4-1}$$

$$\Delta T_d = \left(T_a - T_{as}\right) \tag{6.4.4-2}$$

2 When the pipeline is cooled, the larger of the calculated values of(6.4.4-3)and(6.4.4-4)shall be taken:

$$\Delta T_d = c\left(T_a - T_p\right) \tag{6.4.4-3}$$

$$\Delta T_d = \left(T_{as} - T_a\right) \tag{6.4.4-4}$$

where

ΔT_d—Design temperature change(℃);

T_p—Process temperature(℃);

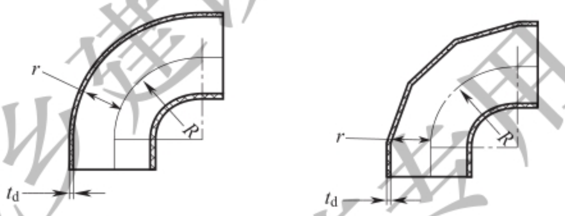
T_a—Ambient temperature (℃), When calculating according to Formula (6.4.4-1) and Formula (6.4.4-4), the lowest encountered ambient temperature may apply; when calculating according to Formula (6.4.4-2) and Formula (6.4.4-3), the highest encountered ambient temperature may apply;

c—Coefficient, is to be taken as 0.85 for liquids and 0.8 for gases;

T_{as}—Estimated installation temperature(℃).

6.4.5 Flexibility factors, stress intensification factors and pressure stress multiplier for bends and tees shall be determined in accordance with the following requirements:

1 The bends (Figure 6.4.5-1) may be classified as smooth bends [Figure 6.4.5-1(a)] and mitred bends [Figure 6.4.5-1(b)], The calculation of flexibility factors and stress intensification factors for bends shall be in accordance with those specified in Table 6.4.5-1.



(a) Smooth bends (b) Mitred bends

Figure 6.4.5-1 Bends

R—Mean pipe bend radius; r—Pipe bore radius; t_d—Design thickness of bends

Table 6.4.5-1 Flexibility factors and stress intensification factors for bends

Bends type			Smooth bends			Mitred bends		
Pipe factor			$\lambda_b = \frac{t_d R}{r^2}$					
Flexibility factor			$f = \gamma a_1 \lambda_b^{-1}$			$f = \gamma a_1 \lambda_b^{-0.83}$		
Laminate type			Type Ⅰ	Type Ⅱ	Type Ⅲ	Type Ⅰ	Type Ⅱ	Tyep Ⅲ
α_1	In-plane		1.0	1.0	0.7	0.9	0.9	0.64
	Out-of-plane		1.0	1.0	0.7	0.9	0.9	0.64
Correction factor			$\gamma = (1 + 2.53\varepsilon_d R^{1/3} r t_d^{-4/3})^{-1}$					
Stress intensification factor			$SIF = \delta_x a_2 \lambda_b^{-2/3}$			$SIF = \delta_\phi a_2 \lambda_b^{-2/3}$		
Laminate type			Type Ⅰ	Type Ⅱ	Type Ⅲ	Type Ⅰ	Type Ⅱ	Tyep Ⅲ
α_2	In-plane	Axial	0.96	0.96	0.76	0.65	0.69	0.5
		Circ.	1.84	1.6	1.6	1.47	1.37	1.2

Table 6.4.5-1(continued)

Bends type			Smooth bends			Mitred bends		
Laminate type			Type Ⅰ	Type Ⅱ	Type Ⅲ	Type Ⅰ	Type Ⅱ	Tyep Ⅲ
α_2	Out-of-plane	Axial	1.1	1.03	0.56	0.86	0.86	0.51
		Circ.	1.8	1.42	1.58	1.72	1.4	1.53
Correction factor		Axial	$\delta_x = (1 + 2.53\varepsilon_d R^{1/3} r t_d^{-4/3})^{-1}$					
		Circ.	$\delta_\phi = (1 + 1.1\varepsilon_d R^{2/3} r^{5/6} t_d^{-3/2})^{-1}$					
Pressure stress multiplier m			1.0 or $0.83(1 - r/2R)/(1 - r/R)$ whichever is the greater			1.3		

Note: In the table, f is the flexibility factor; SIF is the stress intensification factor; m is the pressure stress multiplier.

2 The tees (Figure 6.4.5-2) may be classified as moulded equal tees [Figure 6.4.5-2(a)], moulded unequal tees [Figure 6.4.5-2(b)], fabricated equal tees [Figure 6.4.5-2(c)], and fabricated unequal tees [Figure 6.4.5-2(d)]. The calculation of flexibility factors and stress intensification factors for tees shall be in accordance with those specified in Table 6.4.5-2:

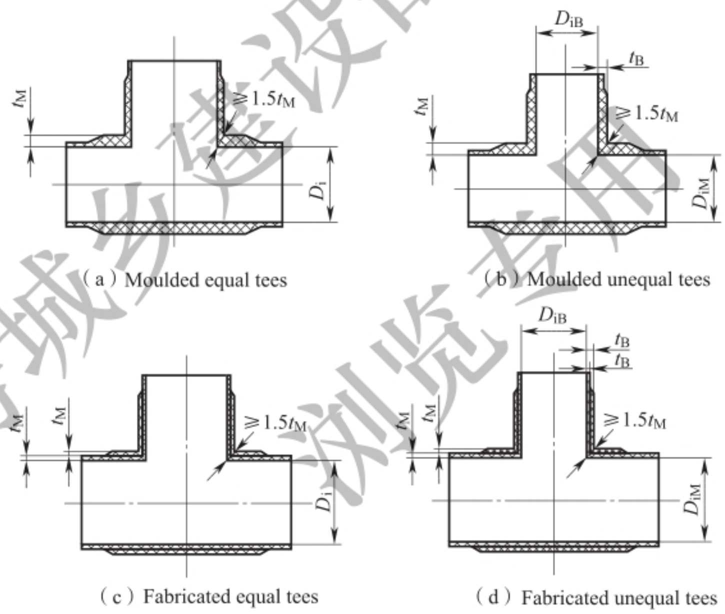


Figure 6.4.5-2 tees

D_i—Internal diameter of pipe; t_M—thickness of the main of the tee; t_B— Wall thickness of the branch adjacent to the junction; D_{iM}— Internal diameter of main of tee; D_{iB}— Internal diameter of the branch

Table 6.4.5-2 Flexibility factors and stress intensification factors for tees

Tees type	Moulded equal or unequal tees	Fabricated equal or unequal tees
Flexibility factors	1.0	
Stress intensification factors	$SIF_T = 0.66\lambda_T^{-0.5}$	
Pipe factor	$\lambda_T = \frac{2t_M}{D_i}$	
Pressure stress multiplier	$m = 1.4\lambda_z^{0.25}$	
Pipe factor	$\lambda_z = \frac{D_i}{2t_M}$	$\lambda_z = \left(\frac{D_{iB}}{2t_B}\right)^2 \times \left(\frac{2t_M}{D_{iM}}\right)$

Note: t_M is the thickness of the main of the tee; t_B is the wall thickness of the branch adjacent to the junction; D_{iM} is the internal diameter of main of tee; D_{iB} is the internal diameter of the branch.

6.4.6 Straight pipe stress calculation shall be in accordance with the following requirements:

1 The circumferential stress due to design internal pressure shall be calculated according to the following formula:

$$\sigma_{\Phi p}=\frac{p_d\left(D_i+t_d\right)}{2t_d} \tag{6.4.6-1}$$

2 The axial stress due to design internal pressure shall be calculated according to the following formulas.

1) When the pipe end is free, it shall be calculated according to the following formula:

$$\sigma_{xp}=\frac{p_d\left(D_i+t_d\right)}{4t_d} \tag{6.4.6-2}$$

2) When the pipe end is constrained, it shall be calculated according to the following formula:

$$\sigma_{xp}=v_{yx}\frac{p_d\left(D_i+t_d\right)}{2t_d} \tag{6.4.6-3}$$

3 When the pipe end is constrained, axial compressive stress due to thermal expansion shall be calculated according to the following formula:

$$\sigma_{ac}=\alpha_1 \Delta T E_t \tag{6.4.6-4}$$

4 Bending stress due to self-weight of pipeline shall be calculated according to the following formula:

$$\sigma_{ab}=\frac{M\left(D_i+2t_d\right)}{2I} \tag{6.4.6-5}$$

1) When the two ends are supports or guids, the bending moment caused by uniformly distributed loads at the mid-span of pipeline (Figure 6.4.6-1) shall be calculated according to the following formula:

$$M=\frac{WL^2}{12} \tag{6.4.6-6}$$

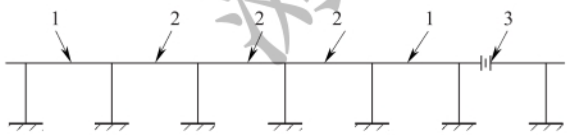


Figure 6.4.6-1 Schematic diagram of mid-span and side span of pipeline

1—Side span; 2—Mid-span; 3—Equipment

2) When the two ends are supports or guids, the bending moment caused by uniformly distributed loads at the side span of pipeline (Figure 6.4.6-1) shall be calculated according to the following formula:

$$M=\frac{WL^2}{8} \tag{6.4.6-7}$$

3) When the two ends are supports or guids, the bending moment caused by concentrated loads shall be calculated according to the following formula:

$$M=\frac{PL}{4} \tag{6.4.6-8}$$

4) When the two ends are anchors, the bending moment caused by uniformly distributed loads shall be calculated according to the following formula:

$$M=\frac{WL^2}{24} \tag{6.4.6-9}$$

5) When the two ends are anchors, the bending moment caused by concentrated loads shall be calculated according to the following formula:

$$M=\frac{PL}{8} \tag{6.4.6-10}$$

where

W—Uniformly distributed loads(N/mm);

P—Concentrated loads(N).

5 Bending stress induced by expansion or contraction for straight pipe shall be calculated according to the following formula:

$$\sigma_{xb}=[(D_i+2t_d)/2I][M_i^2+M_o^2]^{0.5} \tag{6.4.6-11}$$

where

M_i—In-plane(Figure 6.4.6-2)bending moment(N·mm);

M_o—Out-plane(Figure6.4.6-2)bending moment(N·mm).

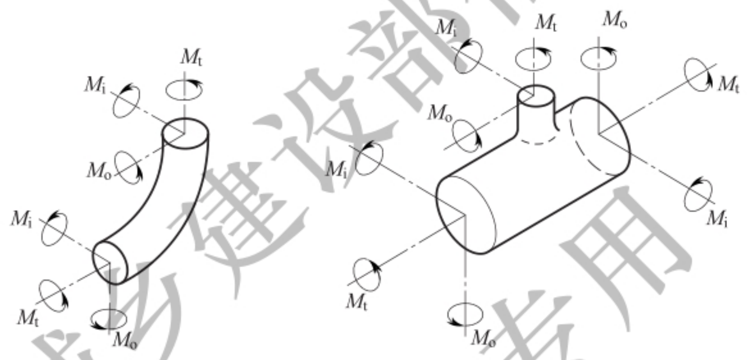


Figure 6.4.6-2 Schematic diagram of in-plane bending moment M_i, out-plane bending moment M_o

M_t—torque

6 Circumferential bending stress induced by expansion or contraction for straight pipe shall be calculated according to the following formula:

$$\sigma_{\Phi b}=0 \tag{6.4.6-12}$$

7 The torsional stress for straight pipe and bends shall be calculated according to the following formula:

$$\sigma_s=M_S(D_i+2t_d)/4I \tag{6.4.6-13}$$

where

M_S—Maximum torque(N·mm).

6.4.7 The calculation of axial stress, circumferential stress and shear stress in the pipe at supports for liquid-filled pipes of diameter more than 600mm shall be in accordance with the following requirements:

1 Axial bending stresses in the pipe at the support shall be calculated according to the following formulas:

1) Axial bending stresses at the point of greatest point of the cross-section shall be calculated according to the following formula:

$$\sigma_{ab}=\frac{0.125}{t_d}\left[\rho_L\times 9.81\times D_i^{\,2}+\frac{\rho_L\times 9.81}{\gamma_1}\left(L^2-0.5D_i^{\,2}\right)\right]\times 10^{-6} \tag{6.4.7-1}$$

2) Axial bending stresses at the lowest point of the cross-section shall be calculated according to the following formula:

$$\sigma_{ab}=\frac{0.125}{t_d}\left[\rho_L\times 9.81\times D_i{}^2-\frac{\rho_L\times 9.81}{\gamma_2}\left(L^2-0.5D_i{}^2\right)\right]\times 10^{-6} \quad (6.4.7\text{-}2)$$

where

ρ_L—Liquid density in pipeline(kg/m^3);

L —Span(m);

D_i—Internal diameter of pipe(m);

t_d—Pipe design thickness(m);

γ_1,γ_2—Coefficient for a range of total saddle angles θ shall be selected according to Table 6.4.7-1;

θ—Saddle angles(Figure 6.4.7).

Table 6.4.7-1 Values of coefficients γ_1, γ_2

Saddle angle θ	γ_1	γ_2
120	0.107	0.192
135	0.132	0.234
150	0.161	0.279
165	0.193	0.328
180	0.229	0.380

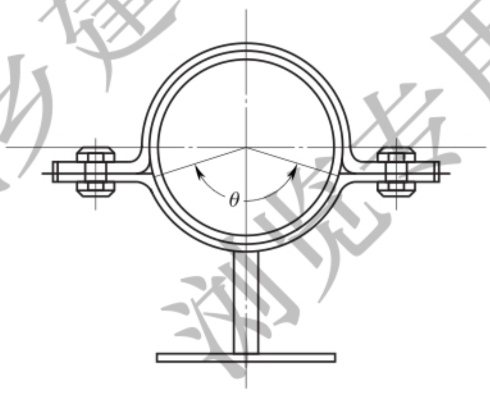


Figure 6.4.7 Saddle angle

2 Maximum shear stress in the pipe at the support shall be calculated according to Formula(6.4.7-3) and shall meet the requirements of Formula(6.4.7-4).

$$\tau_{max}=\gamma_3\times\left(\rho_L+\frac{4t_t}{D_i}\right)\times 9.81\times\left[\frac{\pi D_i}{4t_d}\right]\times L/10^6 \quad (6.4.7\text{-}3)$$

$$\tau_{max}\leqslant[\tau] \quad (6.4.7\text{-}4)$$

where

γ_3—coefficient for a range of total saddle angles θ shall be selected according to Table 6.4.7-2;

ρ_L—Liquid density in pipeline(kg/m^3);

t_t—Pipe total thickness(m);

$[\tau]$—Allowable shear stress(MPa)of laminates, calculated according to Formula(4.3.8-4).

Table 6.4.7-2 Values of coefficient γ_3

Saddle angle θ	120	135	150	165	180
γ_3	1.171	0.958	0.799	0.675	0.577

3 Circumferential bending stresses in the pipe at the support shall be calculated according to the following formulas:

1) The hoop bending stresses at the point of lowest point of the cross-section shall be calculated according to the following formula:

$$\sigma_h = -\gamma_4 \times \frac{L \times W}{t_d \times (b_1 + 10t_d)} / 10^6 \tag{6.4.7-5}$$

where

b_1—Width of the saddle support(m);

W—Uniformly distributed loads(N/m);

γ_4—Coefficient for a range of total saddle angles θ. If the pipe is not fixed to the support, γ_4 shall be selected according to Table 6.4.7-3. If the pipe and support are fixed together, γ_4 shall be 1/10th the value given in Table 6.4.7-3.

Table 6.4.7-3 Values of coefficient γ_4

Saddle angle θ	120	135	150	165	180
γ_4	0.750	0.711	0.673	0.645	0.624

2) The hoop bending stresses at the uppermost point of the support (the saddle horn) shall be calculated according to the following formula:

$$\sigma_{\Phi b} = \left[\frac{L \times W}{4t_d(b_1 + 10t_d)} + \frac{3}{2}\gamma_5\left(\frac{L \times W}{t_d^2}\right)\right] / 10^6 \tag{6.4.7-6}$$

where

γ_5—Coefficient for a range of total saddle angles θ shall be selected according to Table 6.4.7-4.

Table 6.4.7-4 Values of coefficient γ_5

Saddle angle θ	120	135	150	165	180
γ_5	0.0528	0.0413	0.0316	0.0238	0.0174

6.4.8 Straight pipe deformation calculation shall be in accordance with the following requirements:

1 Thermal expansion shall be calculated according to the following formula:

$$l_{TE} = \alpha_1 \Delta T l \tag{6.4.8-1}$$

2 Pressure expansion shall be calculated as follows:

1) When the pipe end is constrained, pressure expansion shall be calculated according to the following formula:

$$l_{PE} = \frac{p(D_i + t_d)}{2}\left(\frac{1}{2X_{lamx}} - \frac{\nu_{yx}}{X_{lam\Phi}}\right) \tag{6.4.8-2}$$

2) When the pipe end is free, pressure expansion shall be calculated according to the following formula:

$$l_{PE} = -\frac{p(D_i + t_d)}{2} \times \frac{\nu_{yx}}{X_{lam\Phi}} \tag{6.4.8-3}$$

3) When the pipe wall is type Ⅰ and type Ⅱ laminates, the axial unit tensile stiffness X_{lamx} in Formulas (6.4.8-2) and Formulas (6.4.8-3) shall be equal to the circumferential unit tensile stiffness $X_{lam\Phi}$, Poisson Ratio ν_{yx} and Poisson ratio ν_{xy} shall be 0.3;

3 When the two ends are supports or guids, deflection shall be calculated according to the following formulas;

1) Deflection caused by uniformly distributed loads at the mid-span of pipeline shall be calculated according to the following formula:

$$\Delta S=\frac{1.2WL_4}{384EI} \tag{6.4.8-4}$$

2) Deflection caused by uniformly distributed loads at the side span of pipeline shall be calculated according to the following formula:

$$\Delta S=\frac{5WL^4}{384EI} \tag{6.4.8-5}$$

3) Deflection caused by concentrated loads at the midpoint of span shall be calculated according to the following formula:

$$\Delta S=\frac{PL^3}{48EI} \tag{6.4.8-6}$$

4 When the two ends are anchors, deflection shall be calculated according to the following formulas.

1) Deflection caused by uniformly distributed loads at the mid-span of pipeline shall be calculated according to the following formula:

$$\Delta S=\frac{WL^4}{384EI} \tag{6.4.8-7}$$

2) Deflection caused by concentrated loads at the midpoint of span shall be calculated according to the following formula:

$$\Delta S=\frac{PL^3}{192EI} \tag{6.4.8-8}$$

6.4.9 Stress calculation for bends shall be in accordance with the following requirements:

1 The circumferential stress due to design internal pressure shall be calculated according to the following formula:

$$\sigma_{\Phi p}=\frac{mp_d(D_i+t_d)}{2t_d} \tag{6.4.9-1}$$

2 Circumferential bending stress induced by expansion or contraction for bends shall be calculated according to the following formula:

$$\sigma_{\Phi b}=[(D_i+2t_d)/2I][(M_i SIF_{\Phi i})^2+(M_o SIF_{\Phi o})^2]^{0.5} \tag{6.4.9-2}$$

where

M_i—In-plane bending moment(N·mm);

$SIF_{\Phi i}$—Circumferential stress intensification factor under in-plane bending moment;

M_o—Out-plane bending moment(N·mm);

$SIF_{\Phi o}$—Circumferential stress intensification factor under out-plane bending moment M_o.

3 The axial stress due to design internal pressure shall be calculated according to the following formula:

$$\sigma_{xp}=\frac{mp_d(D_i+t_d)}{2t_d} \tag{6.4.9-3}$$

4 The axial bending stress induced by expansion or contraction for bends shall be calculated according to the following formula:

$$\sigma_{xb}=\frac{D_i+2t_d}{2I}\times\left[\left(M_i SIF_{xi}\right)^2+\left(M_o SIF_{xo}\right)^2\right]^{0.5} \tag{6.4.9-4}$$

where

SIF_{xi}—Axial stress intensification factor under in-plane bending moment M_i;

SIF_{xo}—Aaxial stress intensification factor under out-plane bending moment M_o.

6.4.10 Stress calculation for tees shall be in accordance with the following requirements:

1 The circumferential stress of the main of the tee due to design internal pressure shall be calculated as follows:

$$\sigma_{\Phi pB} = \frac{mp_d(D_i + t_M)}{2t_M} \tag{6.4.10-1}$$

where

D_i—Internal diameter of the main of the tee(mm);

t_M—Minimum thickness of the main at the branch connection(mm).

2 The non-directional bending stress induced by thermal expansion or other loads at branch junctions shall be the greatest value applicable to the three connections, and shall be calculated according to the following formulas.

1) The bending stress at branch from connection on main shall be calculated according to the following formula:

$$\sigma_{bB} = [(D_i + 2t_d)/2I] \times SIF_T \times [(M_i)^2 + (M_o)^2]^{0.5} \tag{6.4.10-2}$$

2) The bending stress at the branch junction from the branch connection shall be calculated according to the following formulas:

$$\sigma_{bB} = [(D_{iB} + 2t_s)/2I_B] \times SIF_T [(M_i)^2 + (M_o)^2]^{0.5} \tag{6.4.10-3}$$

$$I_B = \frac{(D_{iB} + 2t_s)^4 - D_{iB}^4}{64} \tag{6.4.10-4}$$

where

D_{iB}—Internal diameter of the branch of the tee(mm);

SIF_T—Stress intensification factors for tees;

t_s—t_M and $SIF_T \times t_B$, whichever is the smaller;

t_B—Wall thickness of the branch(mm);

I_B—Second moment of area at the branch junction(mm^4).

3 Torsional stress at the branch junction shall be calculated according to the following formula:

$$\sigma_s = M_s(D_{iB} + 2t_d)/4I \tag{6.4.10-5}$$

6.4.11 The deflection of the straight pipe shall meet the requirements of Article 6.3.4 of this code. The following load combinations shall be included in the deflection calculation:

1 Uniformly distributed loads shall include piping weight, contents of pipeline weight and insulation weight, etc.

2 Concentrated loads shall include permanent point loads.

6.4.12 The maximum combined stress at any part of the pipeline shall include the stress induced by the maximum operating internal pressure, bending stress induced by expansion or contraction over the total design temperature range, bending stresses caused by the weight of pipe, insulation and pipe contents, bending stresses caused by external loadings, bending stresses arising from movement of supports.

6.4.13 The axial and circumferential stress at any part of the pipeline shall be within the simplified failure envelope or the maximum combined stress shall not exceed the maximum design stress for the laminate at any location. The maximum combined stress shall be in accordance with the following requirements:

1 The combined stress in straights and bends shall be the maximum value, and shall be calculated according to the following formulas:

$$\sigma_c = (\sigma_\Phi^2 + 4\sigma_s^2)^{0.5} \tag{6.4.13-1}$$

$$\sigma_c = (\sigma_x^2 + 4\sigma_s^2)^{0.5} \tag{6.4.13-2}$$

$$\sigma_\Phi = \sigma_{\Phi p} + \sigma_{\Phi b} \tag{6.4.13-3}$$

$$\sigma_x = \sigma_{xp} + \sigma_{xb} + \sigma_{ac} + \sigma_{ab} \tag{6.4.13-4}$$

where

σ_c —Maximum axial or circumferential combined stress, the maximum hoop combined stress shall be calculated according to Formula (6.4.13-1), the maximum axial combined stress shall be calculated according to Formula (6.4.13-2).

σ_Φ —Maximum circumferential stress;

σ_x —Maximum axial stress;

σ_s —Torsional shear stress;

$\sigma_{\Phi p}$ —Circumferential stress due to design internal pressure;

$\sigma_{\Phi b}$ —Circumferential bending stress induced by expansion or contraction over the total design temperature range;

σ_{xp} —Aixal stress due to design internal pressure;

σ_{xb} —Axial bending stress induced by expansion or contraction over the total design temperature range;

σ_{ab} —Axial bending stresses caused by self-weight;

σ_{ac} —Axial stress due to expansion or contraction in full-restrained pipe system.

2 The combined stress at a branch junction shall be calculated according to the following formula:

$$\sigma_{cB} = [(\sigma_{\Phi pB} + \sigma_{bB})^2 + 4\sigma_{sB}^2]^{0.5} \tag{6.4.13-5}$$

3 The calculation of axial compressive stress of straight pipe shall be in accordance with the following requirements:

1) When the entire pipe wall cross-section is compressed, it shall be calculated according to the following formula:

$$\sigma_x \leqslant \frac{\pi^2 (D_i + 2t_t - t_d)^2 E_{lamx}}{8 \times F_s \times L^2} \tag{6.4.13-6}$$

where

F_s—Compression stability safety factor, the value shall not be less than 4;

L—Compressed straight pipe length in full-restrained pipe system, vertical pipe length with end compressive loads, the length of unsupported pipe which wall full cross-section is compressed (m).

2) When the pipe wall cross-section is partially compressed, it shall be calculated according to the following formula:

$$\sigma_x \leqslant \frac{0.58 \times \sqrt{E_{lamx\Phi} \times E_{lamx}} \times t_d}{F_s \times (D_i + 2t_t - t_d)} \tag{6.4.13-7}$$

3) When the pipe wall is type Ⅰ and type Ⅱ laminates, the axial unit tensile modulus E_{lamx} in Formula (6.4.13-6) and Formula (6.4.13-7) shall tbe equal to the circumferential unit tensile modulus $E_{lam\Phi}$.

6.4.14 When using the failure envelope analysis, the axial and circumferential stress values of each dangerous point of the pipeline shall be calculated for different load conditions which are Sustained loads including the thermal expansion load, Sustained loads not including the thermal expansion load and Occasional short-term loads. The stress of the dangerous point shall be within the simplified failure envelope.

7 Manufacture

7.1 General requirements

7.1.1 The manufacturing environment of equipments and pipings shall be in accordance with the following requirements:

1 Manufacturing sites shall be located in factory workshops or on sites with temporary enclosures, and should be divided into storage area, production area or assembly area.

2 Ventilation shall be taken in the manufacturing site.

3 The ambient temperature should be 15℃—30℃ and the relative humidity shall not be larger than 80%. When the ambient temperature is less than 10℃, heating and insulation measures shall be taken, and direct heating by open fire or by steam shall not be used. When the ambient temperature is above 35℃, cooling measures shall be taken.

4 The temperature of raw materials should not be less than the ambient temperature.

7.1.2 The manufacturing machines and molds of the equipment and pipes shall be in accordance with the following requirements:

1 The yarn guide system of winding machine shall meet the requirements of uniform, continuous and repeatable conveying. Gap or structural damage shall not occur during winding.

2 The deviation of the diameter of the mould used in manufacturing the lining shall conform to the product design requirements. The stiffness, strength and dimensional stability of the mould shall be determined by calculation.

3 Mould surface shall be dry, clean, smooth and defect-free. Shall be coated with polyester film or smeared with release agent before use.

4 Resin mixing equipment shall be accurately measured. The accelerator shall be proportionally added to the resin and shall be mixed evenly. Before conveying to the fibre dipping tank, the initiator shall be proportionally added and shall be evenly mixed.

7.1.3 The storage and use of raw materials shall be in accordance with the following requirements:

1 Documents for raw material such as resin, fibre, additives, etc. Shall be kept, and they shall include test reports, certificates, grades, batches, production dates and storage periods.

2 Resins and assistants shall be stored in cool and ventilated places.

3 The accelerant of unsaturated polyester resin and vinyl ester resin must be prohibited from contacting with initiator directly and joining in the resin at the same time. Initiator must be stored separately and leakage must be prohibited.

4 The resin gel time test shall be carried out before use and the mixture ratio of accelerant and initiator shall be determined.

5 Gelated resin shall not be used.

6 Fibre materials shall be kept dry before use, and their percentage of moisture shall meet the requirements with the provisions of Article 4.2.6 and Article 4.2.7, and shall not be damaged or polluted.

7.2 Manufacture for equipment and piping

7.2.1 The lining of the equipment and piping shall include the inner surface layer and the barrier layer, and the manufacturing shall be in accordance with the following requirements:

1 The inner surface layer should be uniformly coated with the prepared resin glue on the mould, and then the surface veil shall be wound on the mould, and shall be completely soaked, and shall not have any wrinkles and gaps.

2 The barrier layer should adopt chopped strand mat, woven fabrics and gun roving, and shall adopt hand lay-up, winding and spray processes, and its thickness shall meet the design requirements:

1) The thickness shall be uniform and the surface shall be smooth;

2) When using hand lay-up, the same layer of fibres shall be continuous, the interlayer seam shall be staggered, the staggered width shall not be less than 60mm, and the lap width shall not be less than 30mm;

3) When using spray forming, there shall be no fibre erection on the spray surface.

3 There shall not be air bubble on the surface when the lining is finished.

7.2.2 The manufacturing interval between the structural layer and the lining of the equipment and piping shall be in accordance with the following requirements:

1 After curing the lining, acetone sensitivity test should be done on the surface. When the surface is sticky, structural layer may be made.

2 When the lining surface for acetone sensitivity test is not sticky or contaminated, the following steps shall be taken:

1) The surface of the lining shall be polished and cleaned;

2) The surface shall be brushed with resin glue and then the structural layer can be made.

7.2.3 The structural layer of equipment and piping shall be in accordance with the following requirements:

1 The cylinder of the equipment and pipeline should be formed by winding. The yarn arrangement and tension shall be uniform and continuous. The appearance shall be smooth and the fibres shall be completely soaked. When the axial load bearing capacity needs to be strengthened, reinforcing materials such as chopped strand mat, gun roving, woven roving or woven fabrics may be used.

2 The head and bottom of the equipment should be hand lay-up by chopped strand mat and woven roving alternately. Gun roving may also be used for spray forming. The production requirements shall meet the requirements of Article 7.2.1.

3 When the designed thickness of the structural layer cannot be reached at one time, the interval time and surface treatment shall meet the requirements of Article 7.2.2.

7.2.4 The outer surface of equipment and piping shall be manufactured in accordance with the following requirements:

1 When the equipment and piping are exposed to corrosive environment, the outer surface shall be wound with surface veil or hand lay-up;

2 When exposed to ultraviolet radiation, the resin for outer surface shall be added with ultraviolet absorbent;

3 The outermost layer of the outer surface layer shall be made of air-resistant resin, and gel coat resin or polyester film;

4 The manufacturing interval and surface treatment of the outer surface and the structural layer shall meet the requirements of Article 7.2.2.

7.2.5 The ends and sections of pipes shall be sealed.

7.2.6 The site manufacture of the equipment shall be in accordance with the following requirements:

1 Environmental conditions, equipment, moulds and raw materials for on-site manufacturing should meet the requirements of the relevant provisions of Section 7.1.

2 The manufacturing method shall meet the requirements of Articles 7.2.1 to 7.2.4.

3 The bottom of the equipment should be completed at the equipment installation site, and split prefabrication shall not be used.

4 Spigot and socket joint should be used at the bottom of cylinder and equipment(Figure 5.4.1-2). Hand lay-up shall be used for strengthening and assembling the inner and outer joints:

1)The knuckle radius and reinforcement width of internal hand lay-up shall meet the requirements of Article 5.3.13 of this code, and the corner radius should not be less than 50mm and the reinforcement width should not be less than 200mm;

2)The knuckles shall be smooth and shall be tangent to the bottom and side walls of the equipment.

7.2.7 Equipment and piping shall be cured according to resin technology requirements. When heat curing is applied, the surface shall be heated evenly.

7.3 Quality control of manufacture process

7.3.1 The manufacturing process of equipment and piping shall be in accordance with the following requirements:

1 Layer materials and specifications, number of layers, sequence, moulding and curing process, resin or fibre content shall meet the design requirements;

2 When winding is used, the winding angle shall meet the design requirements;

3 Resin, initiator and accelerant shall be measured accurately and mixed evenly before use.

7.3.2 The quality inspection of equipment and pipeline manufacturing process shall be in accordance with the following requirements:

1 The dimension, thickness and appearance quality of the lining shall be tested after production;

2 Thickness, ply scheme and appearance quality shall be inspected after the structural layer is made.

7.3.3 After the equipment and pipeline are manufactured, the appearance, dimension, curing degree, resin content, mechanical properties and impermeability shall be inspected, and shall be in accordance with the following requirements:

1 The inner and outer surfaces shall be smooth and even in color.

2 Dimensions, mechanical properties and impermeability shall conform to design requirements.

3 Resin content and allowable deviation shall meet the requirements of Article 5.1.6 and Article 5.1.7 of this code. When the design is not specified, the allowable deviation of resin content shall be ±3% of the design value.

4 After curing at room temperature, the Barcol hardness shall not be lower than 80% of the Barcol hardness of the resin casting body used; after heating, the Barcol hardness shall not be lower than

85% of the Barcol hardness of the resin casting body used.

7.4 Fault and repair

7.4.1 Permissible defects in equipment and piping shall be in accordance with those specified in Table 7.4.1.

Table 7.4.1 Permissible defects in equipment and piping

Defect		Lining	Structural layer	Outer surface
Air bubble	Equipment	The diameter of air bubbles shall not be greater than 4mm. No more than five bubbles with a maximum diameter of 4mm in an area of 300mm × 300mm are allowed; The area of air bubbles should not exceed 10% of the total area	Diameter shall not be greater than 10mm, or width should not be greater than 6mm	—
	Piping	Diameter shall not be greater than 1.5mm; within the range of 10mm × 10mm, shall not be more than 2 (acceptable if beyond the stipulation, without affecting the chemical and mechanical properties of the lining)	The diameter shall not be greater than 3mm, and the total area of air bubbles should not exceed 3% of the corresponding inspection area	The diameter shall not be greater than 3mm, and the total area of bubbles should not exceed 3% of the corresponding inspection area
Chip		Not allowed	—	Should not be larger than 6mm and shall not penetrate the structural layer
Crazing		Not allowed	—	Should not larger than 6.5mm
Dry spot		Not allowed	The diameter should not be greater than 10mm, and the number of dry spots shall not exceed 10 in the range of $1m^2$	The diameter shall not be greater than 10mm, and the number of dry spots shall not exceed 10 in the range of $1m^2$
Impurity		Not allowed	—	Not allowed
Exposed fibre		Not allowed	—	Not allowed
Pit		The diameter shall not be greater than 3mm, and the depth shall not be greater than 0.5mm. Within the range of 100mm × 100mm, the number of pits shall not exceed 1	—	The diameter shall not be greater than 3mm and the depth shall not be greater than 1.5mm
Scratch		Depth shall not be greater than 0.2mm	—	Depth shall not be greater than 0.5mm
Wrinkle		The maximum deviation shall be 20% of the wall thickness and shall not be greater than 3mm	Minimum wall thickness shall be within the allowable deviation range of design	The minimum wall thickness shall be within the allowable deviation range of design, and within the range of $1m^2$, wrinkles shall not exceed 10 places
Layered		Not allowed	Not allowed	Not allowed

Note: "—" indicates not applicable.

7.4.2 When the allowable defects exceed the requirements of Article 7.4.1 of this code, the equipment and pipelines shall be repaired, and the repairs shall be in accordance with the following requirements:

1 The surface of the defective area shall be polished. After polishing, the surface shall be even, rough and clean up;

2 The surface of the defective area shall be coated with the same resin glue as the repaired layer, and shall be lined with chopped strand mat to the design thickness;

3 The outermost layer of lining repair shall be lined with surface veil, and the same resin cover as the lining shall be used;

4 After repairing the structural layer, the surface treatment shall meet the requirements of the provisions of Article 7.2.2 of this code;

5 After repairing the outer surface, when there are burrs on the surface, it shall be polished, and air-resistant resin shall be painted.

7.5 Secondary bonding

7.5.1 Materials and facilities for secondary bonding shall be in accordance with the following requirements:

1 Resin shall be the same resin as the bonded equipment and pipe;

2 Reinforcement materials shall be surface veil, chopped strand mat and woven roving;

3 Filling materials may be made of fibre reinforced materials and resin putty;

4 Fixtures or other equivalent tools shall be used for positioning facilities.

7.5.2 In preparation for secondary bonding process, environmental requirements such as temperature and humidity shall meet the requirements of Article 7.1.1 of this code and shall include the following contents:

1 Preparation of tool and fixture;

2 Preparation of bonded end;

3 Determination of bonding material;

4 Determination of the sequence and number of layers;

5 Determination of gelation time and curing time.

7.5.3 Secondary bonding shall be in accordance with the following requirements:

1 Secondary bonding process shall be verified by test. Only after qualified evaluation may bonding be carried out.

2 The evaluation method of secondary bonding process shall meet the relevant requirements of Appendix J of this code.

3 The surface ends of the bonded parts shall be polished or cut diagonally into groove, and the surface shall be roughened to expose fibres within a range of at least 25mm beyond the bonding area; the polishing area shall be clean and dry.

4 The surface of the polishing area shall be coated with the same resin as the lining layer, and the filling material shall be used to form a smooth surface at the joint.

5 When the secondary bonding can not be completed at one time, the interval between the stages shall be in accordance with the requirements of Article 7.2.2 of this code, and the first layer of each stage operation shall be chopped strand mat.

6 The internal bonding of the bonded parts shall be in accordance with the following requirements:

1) The barrier layer shall consist of two or more layers of chopped strand mat;

2) Surface veil shall be used at the interface with medium;

3) The width of the first layer should not be less than 50mm, and the subsequent width shall be increased evenly layer by layer. It should not be less than 12mm for each side of each layer to exceed the previous layer.

7 The external bonding of the bonded parts shall be in accordance with the following requirements:

1) Surface veil shall be used at the interface with the medium; barrier layer shall consist of two or more layers of chopped strand mat.

2) All structural layers shall be made of chopped precursor felt or chopped strand mat with woven roving alternately. The first and last layers shall be chopped strand mat.

3) The width of the first layer should not be less than 50mm, and the subsequent width shall be increased evenly layer by layer. It should not be less than 12mm for each side of each layer to exceed the previous layer.

8 After the exterior bonding is completely cured, the outer surface shall be made in accordance with the requirements of Article 7.2.4 of this code.

8 Quality control and inspection

8.1 General requirements

8.1.1 The quality control documents for fibre reinforced plastics equipment and piping shall include the following contents:

1 Procedure documents for materials, manufacturing, inspection, testing and delivery;

2 The original record of procedure documents implementation.

8.1.2 Employees shall be trained and assessed to be qualified.

8.1.3 Testing instruments and testing equipment shall be verified or calibrated by legal units of measurement.

8.1.4 Measurements and instruments shall be in accordance with the following requirements:

1 The division value shall not be greater than the minimum dimension deviation of the corresponding measured part;

2 The measured data shall be within the valid range;

3 The measurement environment should be standard temperature and standard relative humidity.

8.1.5 Selection of test specimens shall be carried out in accordance with this code. When there is no specific stipulation, it may comply with the requirements of the current national standard GB/T 2828 *Sampling Procedures for Inspection by Attributes*.

8.1.6 Test records shall be archived.

8.1.7 Formula symbol b is the initial average width (mm) of the standard distance length of the specimen. The width of the hoop filament-wound pipe rings may be the width at the notch of semi-elliptical groove in the middle part of the specimen according to Article 8.6.2.1 B method and Appendix A of the current national standard GB/T 21238–2007 *Glass Fibre Reinforced Plastics Mortar Pipes*.

8.2 Quality inspection documents

8.2.1 The quality inspection documents shall include the following contents:

1 Raw material quality inspection documents;

2 Manufacturing process quality inspection documents;

3 Manufactured goods quality inspection documents;

4 List of documents.

8.2.2 The raw materials quality inspection documents shall include the following contents:

1 Material safety technical specifications, quality technical indicators and test methods, quality inspection reports and certificates;

2 Material mix ratio and preparation process;

3 Specimen inspection or re-inspection report.

8.2.3 The manufacturing process quality inspection documents shall include the following contents:

1 Training and assessment records;

2 Operation process record;

3 Inspection records in manufacturing process.

8.2.4 The manufactured goods quality inspection documents shall include the following contents:

1 Factory inspection record;

2 Type inspection record.

8.3 Raw material testing and inspection

8.3.1 Sampling of resin raw materials shall be separated from the original packaging barrel into test specimens and reference specimens.

8.3.2 The performance testing of liquid unsaturated polyester resin and its castings shall meet the relevant requirements of the current national standard GB/T 8237 *Liquid Unsaturated Polyester Resin for Fibre Reinforced Plastics*.

8.3.3 The performance testing of vinyl ester resin and its castings shall meet the relevant requirements of the current national standard GB/T 50590 *Technical Code for Anticorrosion Engineering of Vinyl Ester Resins*.

8.3.4 The performance test of epoxy resin shall meet the relevant requirements of the current national standard GB/T 13657 *Bisphenol-A Epoxy Resin*.

8.3.5 When designing equipment and pipelines with internal pressure greater than 0.1MPa or negative pressure, the thermal deformation temperature of resin shall be checked again. The measurement of thermal deformation temperature shall meet the relevant requirements of the current national standard GB/T 1634.2 *Plastics-Determination of Temperature of Deflection Under Load*.

8.3.6 Sampling of fibre raw materials shall be taken from the original packaging, divided into inspection specimens and reference specimens.

8.3.7 The performance test of glass fibre chopped strand mat shall meet the relevant requirements of the current national standard GB/T 17470 *Glass Fibre Mats-Chopped Strand and Continuous Filament Mats.*

8.3.8 The performance testing of woven roving shall meet the relevant requirements of the current national standard GB/T 18370 *Glass Fibre Woven Roving*.

8.3.9 The performance testing of glass winding roving and gun roving shall meet the relevant requirements of the current national standard GB/T 18369 *Glass Fibre Roving*.

8.3.10 The performance testing of glass fibre woven fabrics shall meet the relevant requirements of the current national standard GB/T 25040 *Glass Fibre Stitched Fabrics*.

8.3.11 The measurement of unit area quality and moisture content of glass fibre surface veil shall meet the relevant requirements of the current national standard GB/T 9914 *Test Method for Reinforcement Products*.

8.3.12 The performance testing of carbon fibres and their products shall meet the relevant requirements of the current national standards GB/T 26752 *PAN-Based Carbon Fibre* and GB/T 30021 *Warp Knitting Carbon Fibre Reinforcements*.

8.3.13 The testing of unit tensile strength and modulus of fibre reinforced plastics and the testing of unit tensile strength and unit tensile stiffness of laminates shall be in accordance with the following requirements:

1 The shape, dimension and testing procedure of the plane-ply specimen shall meet the requirements of the relevant provisions of the current national standard GB/T 1447 *Fibre-Reinforced Plastics Composites-Determination of Tensile Properties*. The shape, dimension and testing procedure of winding layers such as pipe rings shall meet the relevant requirements of Article 8.6.2—Article 8.6.3 of the current national standard GB/T 21238-2007 *Glass Fibre Reinforced Plastics Mortar Pipes*.

2 The number of test specimens shall be in accordance with the following requirements:

1) When testing is adopted, each group of specimens shall not be less than 15, and the confidence of the test data shall be calculated according to this code Formula(4.3.2-8) and Formula(4.3.2-9).

2) When the layering calculation method is used to verify the properties of single or laminated plates, no fewer than 5 specimens are required for each group.

3 The unit tensile strength U_i of fibre reinforced plastics single layer shall be calculated according to the following formulas. When T_S value is known, it may be calculated according to Formula(8.3.13-2):

$$U_i = \frac{P}{b \times W} \tag{8.3.13-1}$$

$$U_i = \frac{T_S \times H}{W} \tag{8.3.13-2}$$

where

U_i—Unit tensile strength of single layer[N/(mm·kg/m²)], the calculation result is taken as an integer;

P—Maximum tensile load(N);

b—Initial average width of gauge length of specimen(mm);

H—Initial average thickness of gauge length of specimen(mm);

W—Fibre unit area quality of single layer board(kg/m²);

T_S—Tensile strength of single layer board(MPa).

4 Tensile modulus X_i of fibre reinforced plastics single layer board shall be calculated according to the following formulas. When T_M value is known, it may be calculated according to Formula(8.3.13-4):

$$X_i = \frac{P_2 - P_1}{Z_2 - Z_1} \times \frac{L_0}{b \times W} \tag{8.3.13-3}$$

$$X_i = \frac{T_M \times H}{W} \tag{8.3.13-4}$$

where

X_i—Unit tensile modulus of single layer board [N/(mm·kg/m²)], the calculation result is taken as an integer;

(P_2-P_1) —Tensile load change value(N) corresponding to tensile elongation change value(Figure 8.3.13);

(Z_2-Z_1) —Variation of elongation in tension(mm);

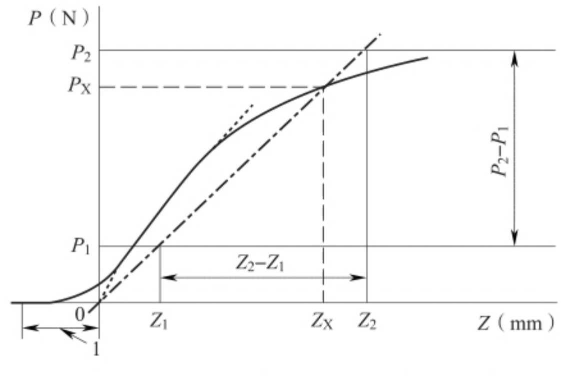


Figure 8.3.13 Relation between tensile load P and tensile elongation Z

1—Final adjustment of starting position

L_0—Gauge length of specimen(mm), the value for plane-ply specimen is 50;

b—Initial average width of gauge length of specimen(mm);

H—Initial average thickness of gauge length of specimen(mm);

W—Fibre unit area quality of single layer board(kg/m^2);

T_M—Tensile modulus of single layer board(MPa).

5 Unit tensile strength U_{lam} of fibre reinforced plastic laminates shall be calculated according to the following formula:

$$U_{lam}=\frac{P}{b} \tag{8.3.13-5}$$

where

U_{lam}—Unit tensile strength of laminates(N/mm), the calculation result is taken as an integer;

P—Maximum tensile load(N);

b—Initial average width of gauge length of specimen(mm).

6 The unit tensile stiffness X_{lam} of fibre reinforced plastic laminates shall be calculated according to the following formula:

$$X_{lam}=\frac{P_2-P_1}{Z_2-Z_1}\times\frac{L_0}{b}=\frac{P_2-P_1}{\varepsilon_2-\varepsilon_1} \tag{8.3.13-6}$$

where

X_{lam}—Unit tensile stiffness of laminates(N/mm), the calculation result is taken as an integer;

(P_2-P_1)—Tensile load change value (N) corresponding to tensile elongation change value (Figure 8.3.13);

(Z_2-Z_1)—Variation of tensile elongation(mm);

L_0—Gauge length of specimen(mm), the value for plane-ply specimen is 50;

b—Initial average width of gauge length of specimen(mm);

ε_2—Strain value of corresponding tensile load P_2;

ε_1—Strain value of corresponding tensile load P_1.

8.3.14 Tensile modulus of fibre reinforced plastic laminates shall be obtained by dividing the calculated value of the Formula(8.3.13-6)of this code by the thickness of the laminates.

8.3.15 The flexural modulus test of fibre reinforced plastic laminates shall be in accordance with the following requirements:

1 The shape, dimension, testing procedure and calculation of flexural modulus of plane-ply specimens shall meet the requirements of the relevant provisions of the current national standard GB/T 1449 *Fibre-Reinforced Plastic Composites-Determination of Flexural Properties*;

2 The shape, dimension and testing procedure of the hoop filament-wound pipe rings shall meet the relevant requirements of Article 8.6.7 of the current national standard GB/T 21238-2007 *Glass Fibre Reinforced Plastics Mortar Pipes*;

3 The calculation of flexural modulus of hoop filament-wound pipe rings shall meet the relevant requirements of Article 6.6.7 of the current national standard GB/T 21238-2007 *Glass Fibre Reinforced Plastics Mortar Pipes*.

8.3.16 The shear strength of fibre reinforced plastic laminates shall meet the relevant requirements of the current national standard GB/T 1450.2 *Fibre-Reinforced Plastic Composites-Determination of the Punch-Type Shear Strength*.

8.3.17 The testing of interlaminar shear strength of fibre reinforced plastics single layer and laminate shall meet the requirements of Appendix K of this code.

8.3.18 Testing of lap shear strength of fibre reinforced plastics single layer and laminate shall meet the requirements of Appendix L of this code.

8.4 Product measurement, inspection and determination

Ⅰ Fibre reinforced plastics equipment

8.4.1 Equipment quality shall be in accordance with the following requirements:

1 The inner and outer surfaces of the equipment shall be smooth, uniform in colour and lustre, and shall be free from damage, delamination, impurities and fibre exposure. The allowable defects shall be in accordance with those specified in Table 7.4.1 of this code.

2 Dimensions shall conform to design requirements, and shall be in accordance with the following requirements in case of no design requirement:

1) The allowable deviation of inner diameter shall be ±1% of nominal diameter, and the maximum deviation shall not exceed 50mm;

2) The conical degree of inner wall should not be greater than 1°;

3) The allowable deviation of total length (high) shall be ±0.5% of the design value, and the maximum deviation shall not exceed 13mm;

4) The error range of thickness shall not be greater than 10% of the design thickness, and the average thickness shall not be less than the design thickness;

5) The measurement value of lining thickness should not be less than 2.5mm;

6) The allowable deviation of inner surface ellipticity shall be ±1% of inner diameter of cylinder and the tolerance of long and short axes of elliptical products shall be ±1%;

7) Straightness, verticality, flange and surface smoothness shall be within the tolerance range of design dimensions;

8) The allowable deviation of the axis of flange branch to the position of the radial or axial datum line of the equipment should be ±6mm;

9) Installation angle deviation of flange branch at shall not be greater than those specified in Table 8.4.1-1;

Table 8.4.1-1 Installation angle deviation of flange branch

Nominal diameter of flange branch *DN* (mm)	Angular deviation (°)
<250	1
≥250	0.5

10) The deviation of verticality between flange branch end face and nozzle axis shall not be greater than those specified in Table 8.4.1-2.

Table 8.4.1-2 Verticality deviation between flange branch end face and the axis

Nominal diameter of flange branch *DN* (mm)	*DN*≤100	100<*DN*≤250	250<*DN*≤500	500<*DN*≤1000
Verticality deviation (mm)	1.5	2.5	3.5	4.5
Nominal diameter of flange branch *DN* (mm)	1000<*DN*≤1800	1800<*DN*≤2500	2500<*DN*≤3500	3500<*DN*≤4000
Verticality deviation (mm)	6.0	8.0	10.0	13.0

3 Surface barcol hardness shall meet the requirements of the provisions of Article 7.3.3(4) of this code.

4 The insoluble matter content of resin shall be in accordance with the following requirements:

1) When unsaturated polyester resin is used, it shall not be less than 85%;

2) When vinyl ester resin or epoxy resin is used, it shall not be less than 90%.

5 Resin content shall meet the design requirements. When the design is not specified, the resin content of the lining and outer surface shall meet the requirements of the provisions of Article 5.1.7 of this code. The deviation value of resin content in each layer shall meet the relevant requirements of Article 7.3.3(3).

6 Pressure and leakage resistance tests of equipment shall be in accordance with the following requirements:

1) Equipment shall be leak-free;

2) When static resistance strain gauge is used, the maximum circumferential strain of the equipment shall not be greater than the allowable design strain.

7 Mechanical properties shall be in accordance with the following requirements:

1) When the design is carried out by layering calculation method, the test strain values shall meet the relevant requirements of Article 4.3.8 of this code;

2) When the design is based on test results, the unit tensile stiffness and unit tensile strength of the specimen shall meet the relevant requirements of Article 4.3.2 of this code;

3) Deformation or breakage shall not be allowed during the testing for the head;

4) When the flange diameter is less than or equal to 50mm, it shall be able to withstand the moment load of 1360N·m, and the flange and joint shall be undamaged; When the flange diameter is greater than 50mm, it shall bear 2700N·m moment load, and the flange and joint shall be undamaged. Flanges and connections of straight pipes shall be undamaged under torsional moment loads.

8 Equipment used for food hygiene shall meet the relevant requirements of the current national standard GB/T 14354 *Food Containers of Glass Fibre Reinforced Unsaturated Polyester Resin*.

9 Testing and evaluation of corrosion resistance of equipment shall meet the relevant requirements of Appendix A of this code.

8.4.2 Test methods for equipment quality testing shall be in accordance with the following requirements:

1 Visual inspection, touch and tapping may be used to detect appearance quality.

2 Dimensions shall be measured in accordance with the following requirements:

1) The inner diameter of the equipment may be measured by a tape measure with a graduation value of 1mm. The maximum inner diameter of 4 points in the equipment can be measured with an average value.

2) The conical degree of the inner wall may be measured by a steel tape with the indexing value of 1mm. The difference of inner diameter between the two ends of the measuring equipment and its corresponding length (height) shall be calculated according to the following formula:

$$C=\arctan\frac{D-2}{2H} \qquad (8.4.2)$$

where

C—Conical degree of inner wall of equipment (°), calculating by the arctangent function of $(D-d)/2H$ value;

H—Length(height)difference of measuring points at both ends of inner wall of equipment(mm);

D—Diameter of inner wall of equipment at both ends of measurement (mm), take the larger number;

d—Diameter of inner wall of equipment at both ends of measurement (mm), take the smaller number.

3) Total length (high) may be measured using a tape measure with division value of 1mm to measure the distance between the top and bottom head of the equipment.

4) Head and cylinder wall thickness may be measured by vernier caliper with division value of 0.02mm. The thickness of flange cut-out or any place shall be measured three times and the arithmetic average value shall be obtained.

5) The thickness of the lining may be measured by a vernier caliper with a division value of 0.02mm. The measuring points shall be evenly distributed and shall not less than four, and the arithmetic average value shall be taken.

6) The ellipticity of the inner surface may be measured by a tape scale with division value of 1mm. The ratio of the difference of the inner diameter of different positions of the measuring equipment to the inner diameter can be measured.

7) Straightness may be measured by ruler method or gravity method.

8) Verticality may be measured by verticality measuring instrument.

9) Evenness may be tested by dialgauge.

10) Angle deviation may be measured by protractor or square combination.

3 Surface Babbitt hardness testing shall meet the relevant requirements of the current national standard GB/T 3854 *Test Method for Hardness of Reinforced Plastics by Means of A Barcol Impresser*, and at least 10 sites shall be selected in different parts, each of which must not be less than 3 measuring points.

4 The determination of insoluble matter content of resin shall meet the requirements of the relevant provisions of the current national standard GB/T 2576 *Test Method for Insoluble Matter Content of Resin Used in Fibre Reinforced Plastics*.

5 Resin content detection shall meet the relevant requirements of the current national standard GB/T 2577 *Test Method for Resin Content of Glass Fibre Reinforced Plastics*.

6 Pressure and leakage test methods shall be in accordance with the following requirements:

1) Before water filling test of open equipment, the opening shall be sealed and the water filling shall meet the highest level requirement.

2) The static pressure test of closed equipment shall be carried out in the manufacturer's factory at first, and shall be kept for 48 hours under normal working condition and full of water. After installation and delivery, it shall be filled with actual filling materials, and the static pressure shall be kept for 48 hours.

3) Hydraulic test of closed equipment shall be carried out in normal working condition. The test pressure shall not be less than 1.1 times of the design internal pressure, and the external pressure shall not be less than 1 times of the design pressure. At the same time, acoustic emission test shall be carried out.

4) When acoustic emission test cannot be used, the internal pressure of pressure and leakage resistance test shall not be less than 1.5 times the design pressure, and the external pressure shall not be less than 1.1 times the design external pressure but must not more than 0.1 MPa.

5) When testing pressure leakage resistance of closed equipment, the pressure shall be kept for 3 minutes and then reduced to the design pressure. The total pressure holding time shall not be less than 20 minutes.

6) When water pressure test is not suitable for closed equipment, air tightness test may be used and circumferential strain value shall be measured.

7 The testing methods for mechanical properties shall be in accordance with the following requirements:

1) When designing with layering calculation method, the strain value should be tested under the design load. The test method shall meet the relevant requirements of Article 8.4.2(6) of this code.

2) When the design is based on test results, the specimens shall be obtained from the equipment itself, or may be from the laminates manufactured in the same process as the equipment when they are not available. The test of unit tensile stiffness and unit tensile strength of the laminates shall meet the relevant requirements of Article 8.3.13 of this code.

3) Head inspection shall apply 1110N load on the surface of the equipment head with an area of 100mm × 100mm, and shall observe the deformation and fracture of the head.

4) When testing flange moment load, the moment load shall be added to the flange step by step by connecting a tube 1m long on the flange. The increment of load shall be 20% of the specified load until the required moment load is loaded.

5) When testing the torsional moment load of flange, the torsional moment load shall be added to the flange step by step through a tube 1m long connected to the flange. The increment of load shall be 20% of the specified load until it is loaded to the torsional moment load specified in Table 8.4.2.

Table 8.4.2 Torsional moment load of flanges

Branch diameter(mm)	Torsional moment load(N·m)	Branch diameter(mm)	Torsional moment load(N·m)
20	230	65	400
25	270	100	430
40	370	150	470
50	390	200	520

8 Inspection of equipment used in food hygiene shall meet the relevant requirements of the current national standard GB/T 5009.98 *Method for Analysis of Hygienic Standard of on Saturated Polyester Resin and Glass Fibre Reinforced Plastics Used as Food Containers and Packaging Materials*.

9 Corrosion resistance test shall meet the relevant requirements of the current national standard GB/T 3857 *Test Method for Chemical Resistance of Glass Fibre Reinforced Thermosetting Plastics*, and shall comply with the methods specified in Appendix A of this code.

8.4.3 Equipment inspection and judgement shall include factory inspection and judgement, type inspection and judgement.

8.4.4 The equipment factory inspection and assessment shall be in accordance with the following requirements:

1 The factory inspection items of each equipment shall include appearance quality, thickness, diameter, height, Barcol hardness and leakage. The inspection methods shall meet the relevant requirements of Article 8.4.2 of this code, and the judgement shall meet the relevant requirements of Article 8.4.1 of this code.

2 If all the inspection items are qualified, the product shall be judged to be qualified.

3 One of the items of raw materials, manufacturing process, thickness, height and diameter does not meet the requirements and the product shall be judged as unqualified.

4 If there is leakage in the main structure of the cylinder and head of the equipment, it shall be judged as unqualified; if there is leakage in the overlapping parts of the equipment, such as branches and flanges, it may be repaired three times, and if it is qualified after re-examination, it shall be judged as qualified.

5 Only when the appearance and Barcol hardness do not meet the requirements, it may be treated twice. After re-examination, it shall be judged to be qualified.

8.4.5 Type inspection shall be carried out when the equipment has one of the following conditions:

1 Transfer, trial-manufacture and finalization of new or old products;

2 When the structure, material or process are changed after putting into production formally;

3 After normal production, every 12 months when inspection;

4 Equipment shutdown for more than 6 months and pipeline shutdown for more than 3 months, when production resumes;

5 When the results of ex-factory inspection are different from those of the previous type inspection;

6 When a quality supervision body makes a request.

8.4.6 Type inspection and determination of equipment shall be in accordance with the following requirements:

1 Specimens of equipment type inspection shall be randomly sampled at 5% from qualified products manufactured for inspection, and shall not less than 1 unit.

2 Equipment type inspection items shall meet the requirements of the provisions of Article 8.4.1 of this code.

3 The judgment of equipment type inspection shall be in accordance with the following requirements:

1) When all the indexes of the type inspection are qualified, the product in the type inspection shall be judged to be qualified.

2) If any of the raw materials, manufacturing process and dimensions do not meet the requirements, the product shall be judged to be unqualified.

3) If the main structure of the cylinder and head of the equipment has leakage, it shall be judged to be unqualified; if the overlap parts of the equipment such as nozzles or flanges have leakage, it may be repaired three times, and if they are qualified after re-examination, it may be judged to be qualified.

4) If the appearance and Barcol hardness do not meet the requirements, it may be treated twice. After re-examination, it may be judged to be qualified.

5) If there are unqualified items in the mechanical properties test, the second sampling test may be carried out. If the product is still unqualified. It shall be judged to be unqualified.

4 When the equipment type inspection determines that it is not qualified, the production shall be stopped for inspection, and the production may be resumed only after the type inspection is qualified again.

Ⅱ Fibre reinforced plastic pipeline

8.4.7 Pipeline quality shall be in accordance with the following requirements:

1 The end face of the pipeline shall be level, the edges shall be without burrs, the surface shall be even and smooth, and the allowable defects shall be in accordance with those specified in Table 7.4.1 of this code.

2 Dimensions shall conform to design requirements, and when there is no design requirement, it shall be in accordance with the following requirements:

1) The nominal diameter and allowable deviation of the pipeline shall be in accordance with those specified in Table 8.4.7-1;

Table 8.4.7-1 Nominal diameter and allowable deviation of pipeline (mm)

Nominal diameter DN	Allowable deviation
$DN \leqslant 150$	±1.5
$150 < DN \leqslant 600$	±3.0
$DN > 600$	$\pm 0.5\% \times DN$

2) The effective length and allowable deviation of the pipeline shall be in accordance with those specified in Table 8.4.7-2;

Table 8.4.7-2 Effective length and allowable deviation of pipeline (mm)

Effective length	Allowable deviation
≤4000	±20
>4000	$\pm 0.5\% \times L$

3) The average thickness of the pipeline wall shall not be less than the design value, the minimum thickness of the pipeline wall shall not be less than 90% of the design thickness; the thickness of the lining shall not be less than 1.2mm;

4) The control value of pipeline end verticality shall be in accordance with those specified in Table 8.4.7-3.

Table 8.4.7-3 Control value of pipeline end verticality (mm)

Nominal diameter DN	Control value of pipeline end verticality
$DN < 600$	4.0
$600 \leqslant DN < 1000$	6.0
$DN \geqslant 1000$	$0.6\% \times DN$

3 Surface Barcol hardness shall meet the requirements of Article 7.3.3(4) of this code.

4 The insoluble matter content of resin in pipeline wall shall not be less than 90%.

5 The resin content of straight pipeline wall shall conform to the design requirements, and the allowable deviation value of resin content shall meet the requirements of the provisions of Article 7.3.3 (3) of this code.

6 When conducting hydraulic leakage test on pipelines, there shall be no leakage, and there shall be no damage, craze or cracks on the outside of pipelines and fittings.

7 Mechanical properties shall be in accordance with the following requirements:

1) When the allowable strain value is determined by the specified value method, the strain value of the pipeline shall meet the relevant requirements of Article 4.3.10 of this code;

2) When the allowable strain is measured by the long-term performance test method, the ultimate strength of the specimen shall not be lower than that calculated by Formula 4.3.14-1 of this code.

8 Pipelines used for food hygiene shall meet the requirements of Article 8.4.1(8) of this code.

9 Pipelines used in corrosive environments shall meet the requirements of the design, and the evaluation of corrosion resistance shall meet the relevant requirements of Article 4.3.10 of this code.

8.4.8 The test method for pipeline quality inspection shall be in accordance with the following requirements:

1 Appearance quality may be achieved by visual inspection, touch or tapping, etc.

2 Measurement method of dimensions shall be in accordance with the following requirements:

1) For pipelines with $DN \geqslant 600$mm, the outer diameter may be measured by a circumferential diameter ruler or steel tape ruler with a graduation value of 1mm. The measuring points shall not be less than 5, and the arithmetic average value shall be taken.

2) For pipe with $DN < 600$mm, the external diameter may be measured directly by vernier calipers with the indexing value of 0.02mm, and the average value of the two vertical directions of the pipe section shall be taken; the test shall not be less than 5 places, the measuring points shall be distributed evenly, and the arithmetic average value shall be obtained.

3) The inner diameter may be measured with an internal diameter measuring ruler with a grading value of 0.1mm. The values of the inner diameter in the vertical and horizontal directions of the same section shall be measured twice and the arithmetic average value shall be taken.

4) The length of the pipe may be measured by a steel tape with a graduation value of 1mm along the generatrix of the pipe, and the arithmetic average of the length of the four generatrixs can be obtained.

5) The thickness of the pipe wall shall be measured along the circumference with a vernier caliper of 0.02mm. There must be no less than 7 measuring points per pipe. The measuring points shall be evenly arranged and the maximum, minimum and average wall thickness shall be recorded.

6) The lining thickness shall be measured by a vernier caliper with a graduation value of 0.02mm. The measuring points shall not be less than four, and the measuring points shall be evenly distributed. The measuring results shall be taken as the arithmetic average value.

7) The perpendicularity of the end face of the pipeline may be measured by a square ruler and a steel plate ruler with a grading value of 1mm.

3 Surface Barcol hardness test shall meet the relevant requirements of the current national standard GB/T 3854 *Test Method for Hardness of Reinforced Plastics by Means of A Barcol Impresser*, and each pipe shall not be less than 10 inspection points.

4 The determination of insoluble matter content of resin shall meet the relevant requirements of the current national standard GB/T 2576 *Test Method for Insoluble Matter Content of Resin Used in Fibre Reinforced Plastics*.

5 Detection of resin content in straight pipe wall shall meet the relevant requirements of current national standard GB/T 2577 *Test Method for Resin Content of Glass Fibre Reinforced Plastics*.

6 The test method of pipeline hydraulic leakage shall meet the relevant requirements of the current national standard GB/T 5351 *Fibre-Reinforced Thermosetting Plastic Composites Pipe-Determination of Short-Time Hydraulic Failure Pressure*, and shall be in accordance with the following requirements:

1)When the pipeline in service does not withstand the axial force generated by the internal pressure, its sealing type shall adopt the restrained end seal; when withstanding the axial force generated by the internal pressure, the sealing type shall adopt the free end seal;

2)When the test pressure reaches 1.5 times of the design pressure, the pressure shall be kept for 2 minutes; the test shall be carried out at the prescribed water temperature, and safety precautions shall be taken.

7 The test methods of mechanical properties shall be in accordance with the following requirements:

1)When the allowable strain is measured by specified value method, the strain value verification test should be carried out under the design load. The test method shall meet the requirements of Article 8.4.7(6) of this code.

2)When the allowable strain is measured by long-term performance test, the verification of unit tensile stiffness and unit tensile strength of the specimen shall meet the requirements of Article 8.3.13 of this code.

8 Food hygiene test shall meet the relevant requirements of the current national standard GB/T 5009.98 *Method for Analysis of Hygienic Standard of Unsaturated Polyester Resin and Glass Fibre Reinforced Plastics Used as Food Containers and Packaging Materials*.

9 Corrosion resistance test shall meet the relevant requirements of the current national standard GB/T 3857 *Test Method for Chemical Resistance of Glass Fibre Reinforced Thermosetting Plastics*.

8.4.9 Pipeline inspection and judgment shall include factory inspection and judgment, type inspection and judgment.

8.4.10 Pipeline ex-factory inspection and judgment shall be in accordance with the following requirements:

1 Factory inspection items and quantity shall be in accordance with the following requirements.

1)Each pipe shall be inspected for appearance quality, dimension and Barcol hardness.

2)One hundred pipes of the same material, process and specifications shall be used as a batch, and when less than 100 pipes, they shall be used as a batch. The thickness, insoluble matter content of resin and mechanical properties of a random specimen pipe shall be examined.

3)The inspection quantity of hydraulic leakage may be agreed by both the supplier and the demander, but it shall not be less than 1% of the specimen number.

4)Testing items, quality requirements and testing methods shall meet the relevant requirements of Article 8.4.7 and Article 8.4.8 of this code.

2 The factory inspection judgment shall be in accordance with the following requirements:

1)Appearance quality, dimension, pasteurization hardness, insoluble matter content of resin, hydraulic leakage and mechanical properties all meet the requirements, and the batch of products shall be judged to be qualified.

2)When the water pressure leakage test is not qualified, the water pressure leakage test shall be carried out one by one in this batch of pipelines. If the test is qualified, the pipe shall be judged to be qualified.

3)When there are more than two unqualified items in the thickness, insoluble matter content of resin and mechanical properties test, the product shall be judged to be unqualified; when the unqualified items are not more than two, the unqualified items may be checked in double the quantity, and the products shall be judged to be qualified when all the items are qualified.

8.4.11 Conditions for type inspection of pipelines shall meet the requirements of Article 8.4.5 of this code.

8.4.12 Pipeline type inspection and judgement shall be in accordance with the following requirements:

1 100 pipes of the same material, process and specifications shall be taken as a batch, and when less than 100 pipes are used, they shall also be treated as a batch.

2 Six of them shall be randomly selected from each batch for inspection of appearance quality, dimension and Barcol hardness; one of them shall be selected for inspection of hydraulic leakage, mechanical properties and insoluble matter content of resin.

3 Items and quality of type inspection shall meet the requirements of the provisions of Article 8.4.7 of this code.

4 The judgement of type inspection shall be in accordance with the following requirements:

1)When the appearance quality, dimension, Barcol hardness, hydraulic leakage, mechanical properties and insoluble matter content of resin meet the requirements, the type inspection shall be judged to be qualified.

2)When there are no more than 2 unqualified items in appearance quality, dimension and Barcol hardness test, the second sampling test may be carried out for unqualified items. The second sampling test is still unqualified, and the type inspection shall be judged to be unqualified.

3)When water pressure leakage, mechanical properties and insoluble matter content of resin are not qualified, double sampling inspection shall be done. When sampling inspection is not qualified, type inspection shall be judged to be unqualified.

9 Marking, packing, transporting, storing

9.1 Equipment

9.1.1 Equipment logo shall be clear and firm, including equipment name, specification type, design temperature, design pressure, working medium, manufacturer name, manufacturing date and so on.

9.1.2 Equipment packaging shall be in accordance with the following requirements:

1 When using bracket and cushion to fix, the cushion shall be wrapped in the place of easy collision or friction;

2 There shall be in-box information such as product qualification certificate, instructions for use and list of spare accessories. The instructions for use shall include the following contents:

1) Main performance and parameters of the equipment;

2) Matters needing attention in transportation, storage and use;

3) Installation and maintenance requirements.

9.1.3 Equipment transportation shall be in accordance with the following requirements:

1 The equipment shall be fixed reliably with the means of transport and shall not move in any direction in the course of transportation;

2 Transportation vehicles shall keep smooth running and shall not be subject to severe vibration.

9.1.4 Equipment handling shall be in accordance with the following requirements:

1 Lifting shall be forced from the hoisting ring of the equipment.

2 The lifting of equipment without hoisting rings shall be in accordance with the following requirements:

1) The gravity center shall be calculated before the bundling hoisting is adopted;

2) The load-carrying capacity of the sling shall be confirmed to meet the requirements before using the synthetic fabric sling;

3) Before hoisting, the guide rope shall be attached to the equipment; when the equipment is hoisted and moved, it shallt not impact other objects;

4) When hoisting with hoisting rings, the distance between hoisting hooks and equipment shall not be less than that between hoisting rings.

3 On the ground, the equipment shall not roll or slide, and it is forbidden to pry the body of the equipment directly, or collide with parts.

4 When using forklift truck to adjust the position of equipment, the fork shall have cushion.

9.1.5 The storage site of equipment shall be level, the direction of placement shall be the same as the design orientation. When the direction of placement needs to be adjusted, support shall be set and fixed. Equipment shall not be placed on the ground with hard protrusions.

9.1.6 In the transportation and storage of equipment, the heat source and fire source shall be kept away.

9.1.7 During the transportation and storage of equipment, objects other than design requirements shall not be stacked.

9.2 Piping

9.2.1 The markings of each pipe shall be clear. The markings shall include nominal size, design pressure, design temperature, working medium, name of the manufacturer, batch number and date of manufacture, etc.

9.2.2 Pipeline packaging shall be in accordance with the following requirements:

1 Flexible material shall be used to pack the end face and outer connection face of the pipe at both ends.

2 Pipes with nominal diameter not exceeding 150mm may be bundled together. Pipes with nominal diameter exceeding 150mm should be packed in a single package.

3 Single packaged pipes with different diameters may be packed, and the pipes after packed shall not slide.

4 There shall be product certificate, instructions and other information in the box.

9.2.3 Pipeline handling or handling shall be in accordance with the following requirements:

1 Flexible sling or rope shall be used for hoisting, and wire rope or chain shall not be used for direct binding and hoisting.

2 Pipeline shall be hoisted at two points symmetrical to the midpoint of pipe length. The hoisting point shall be located at the minimum bending moment of pipeline, and the control direction and landing point of guide rope shall be set during hoisting.

3 Lifting rope shall not be lifted after passing through the pipe.

9.2.4 Pipeline shall be supported and fixed during transportation.

9.2.5 Pipeline storage shall be in accordance with the following requirements:

1 The stacking site shall be level and the bottom of the pipeline should be provided with support;

2 The original packing should be used for storage, and the stacking height shall not exceed 2m;

3 Pipelines should not be stored in the open for long;

4 Stack away from heat source, fire source, pollution and chemical erosion environment.

9.2.6 Small pipe fittings should be classified and stored, and may be transported in box packing without collision.

10 Installation

10.1 General requirements

10.1.1 Installation personnel shall be qualified through technical and safety training.

10.1.2 The information provided for the equipment and pipelines entering the installation site shall meet the requirements of of Article 9.1.2(2)and Article 9.2.2(4)of this code.

10.1.3 The bearing structures or foundations related to the installation of equipment and pipes shall be checked and accepted.

10.1.4 Hoisting, unloading and secondary handling of equipment and pipelines shall be in accordance with the following requirements in addition to the requirements of Article 9.1.4 and Article 9.2.3 of this code:

1 Lifting methods for binding manholes, branches and other accessories must not be adopted;

2 Shall not load when hoisting.

10.1.5 Before installation, the inner and outer surfaces of equipment and pipelines shall be inspected. When there are scratches and other defects, they shall be repaired in accordance with the requirements of Article 7.4.2 of this code.

10.1.6 Installation and inspection documents for equipment and pipelines shall be complete.

10.2 Equipment installation

10.2.1 The equipment foundation shall go through the procedures of handover and acceptance. The allowable deviation of flatness per meter shall be ±2mm and the allowable deviation of flatness of the whole plane foundation shall be ±5mm.

10.2.2 Vertical flat bottom equipment shall be installed on the foundation of continuous leveling and shall be in accordance with the following requirements:

1 When installing equipment with bottom drainage port, grooves shall be left on the foundation, and the branch flange of drainage port shall not contact the foundation;

2 The vertical deviation of equipment installation shall not be greater than 0.5 degree;

3 When installing flat-bottomed equipment manufactured off-site, the equipment foundation shall be paved with corrosion-resistant soft materials, and the paving thickness shall meet the requirements of full contact with the bottom of the equipment.

10.2.3 Horizontal circular equipment shall be installed in accordance with the following requirements:

1 The saddle support shall be adopted. The saddle support shall meet the design requirements. The support shall coincide with the outer wall of the equipment. The gap between the support and the bottom of the equipment shall be less than 5mm.

2 The support installed on the foundation shall be straightened, leveled and fixed firmly.

3 The cushion between the support and the cylinder body shall be made of corrosion-resistant soft material.

10.2.4 Installation of suspended vertical equipment shall be in accordance with the following requirements:

1 The support shall meet the design requirements;

2 The vertical deviation of equipment installation shall not be greater than 0.5 degree;

3 Support gaskets shall be made of load-bearing and corrosion-resistant materials.

10.2.5 Installation of vertical equipment with supporting legs and skirts shall be in accordance with the following requirements:

1 The supporting legs and skirts shall meet the design requirements;

2 The equipment shall be installed vertically, and the deviation of verticality shall not be greater than 0.5 degrees;

3 The gaskets of supporting legs and skirts shall be made of load-bearing and corrosion-resistant materials.

10.2.6 The connection and installation of accessories or external equipment shall be in accordance with the following requirements:

1 Pipeline connecting equipment shall be supported, and equipment body shall not be used as support, and the local load of the pipe connection shall not exceed the design value;

2 Valves installed horizontally on equipment and other heavier accessories shall be supported separately;

3 Installation of appendices such as mixing port, mixer, cooling (heating) snake pipe, etc. shall be designed separately;

4 When connecting with vibration equipment, flexible connection shall be adopted.

10.2.7 When the equipment is installed, the pressure and leakage resistance tests shall be carried out in accordance with the design requirements and shall meet the requirements of Article 8.4.2(6) of this code.

10.3 Piping installation

10.3.1 Pipeline assembly and connection shall be in accordance with the following requirements:

1 The equipment connected with the pipeline shall be installed in place and passed the quality inspection;

2 Pipeline joints shall be set in places convenient for maintenance and observation;

3 When installing overhead pipeline, the operation platform shall be set at the joint of pipeline;

4 Pipeline and equipment must not be strongly docked.

10.3.2 The slope direction and gradient of the pipeline shall meet the design requirements.

10.3.3 When installing pipes, the appearance, specifications and models of pipes, fittings, valves and expansion joints shall be inspected. The inner and outer surfaces shall be clean, and there must be no scratches, cracks and other defects.

10.3.4 Setting and installation of pipeline support or suspension shall meet the requirements of Article 6.2.1 of this code.

10.3.5 Pipeline should be connected by rigid joints, including socket bonded joints (Figure 10.3.5-1), hand lay-up butt joints (Figure 10.3.5-2) and flange joints (Figure 10.3.5-3).

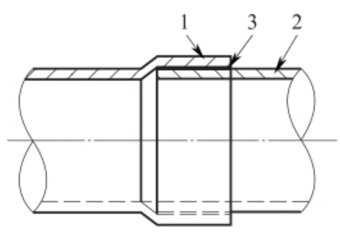


Figure 10.3.5-1 Socket bonded joints

1—Pipeline socket end; 2—Pipeline spigot end; 3—Resin putty filler

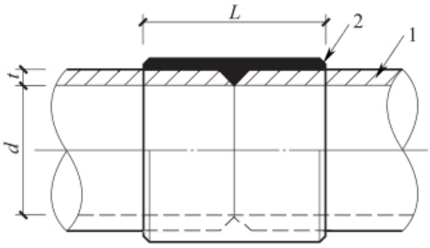


Figure 10.3.5-2 Hand lay-up butt joint

1—Pipeline; 2—Coated fibre reinforced plastics

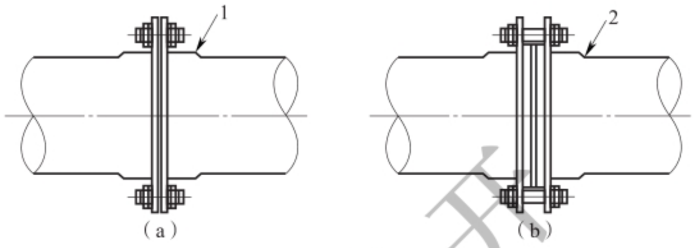


Figure 10.3.5-3 Flanged joints

1—Flat end flange; 2—Loose flange

10.3.6 When connecting pipes with socket-bonded joints, it shall be in accordance with the following requirements:

1 The surfaces of the mouthing and socket shall be polished and cleaned. The inner surface of the mouthing and the outer surface of the socket shall have uniform roughness.

2 The dust on the polishing surface shall be cleaned up.

3 Insertion length and bonding process shall meet the requirements of Article 6.2.2 of this code.

10.3.7 When using hand lay-up butt joints to connect pipes, the bonding process shall meet the relevant requirements of Section 7.5 of this code, and the coating width and laying process shall meet the requirements of Article 6.2.2 of this code.

10.3.8 When flanged joints are used to connect pipes, it shall be in accordance with the following requirements:

1 The flange sealing surface and the sealing gasket surface shall not have defects affecting the sealing performance.

2 Flange connection shall be parallel, deviation shall not be greater than 1‰ of flange outer diameter, and shall not be greater than 1mm. Flange deflection shall not be eliminated by tightening bolts.

3 The flange connection shall be coaxial and the connecting bolt shall penetrate freely. Flat gaskets shall be used at the tightness of bolts and nuts to flanges.

4 When bolts are tightened, the applied force shall be symmetrical and even, and shall be gradually tightened. The bolts shall be tightened symmetrically in turn according to the clockwise order of the upper and lower centerlines and the left and right centerlines(Figure 10.3.8).

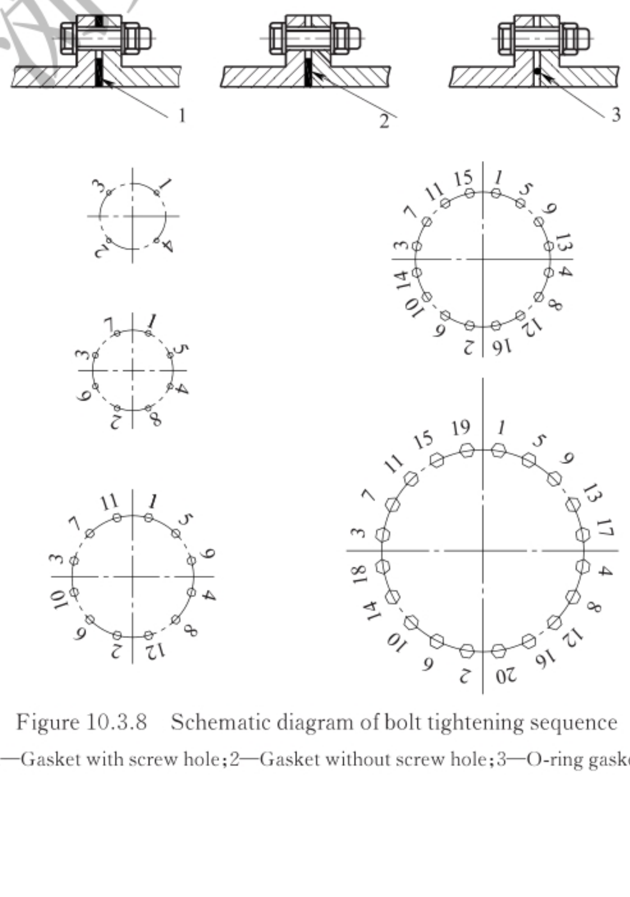


Figure 10.3.8 Schematic diagram of bolt tightening sequence

1—Gasket with screw hole; 2—Gasket without screw hole; 3—O-ring gasket

10.3.9 Flexible connectors shall be installed when connecting pipes to vibration-producing equipment.

10.3.10 Valves and other equipment

connected to the pipeline should be supported separately in horizontal and vertical directions (Figure 10.3.10). The vertical direction of the pipeline shall not be overloaded.

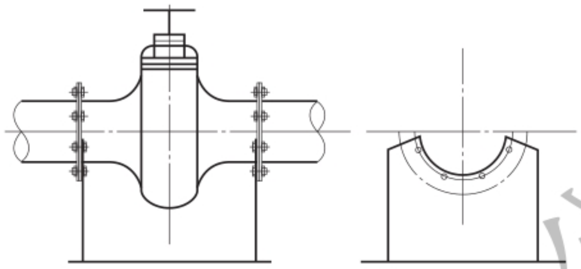


Figure 10.3.10 Individual support for valves

10.3.11 Pipelines passing through walls and floors shall be sleeved, and pipe joints shall not be set in the sleeve. The length of sleeve through wall and floor shall exceed 50mm of wall and floor. The gap between pipe and sleeve shall be filled with asbestos or other non-combustible materials.

10.3.12 When the installation of pipelines is interrupted, the nozzle shall be closed.

10.3.13 Pipeline installation allowable deviation shall be in accordance with those specified in Table 10.3.13.

Table 10.3.13 Pipeline installation allowable deviation (mm)

Item			Allowable deviation	
Coordinates and elevation	Outdoor	Overhead	±15	
		Trench	±15	
	Indoors	Overhead	±10	
		Trench	±15	
Horizontal tube flatness	$\leq DN100$		1/1000	Max 40
	$> DN100$		1.5/1000	
Verticality of riser			2/1000	Max 15
Rows of pipes	Spacing on the same plane		7.5	
	Spacing not on the same plane		±7.5	
Overlapping	Pipe outer wall or insulation layer spacing		±10	

10.3.14 The pressure test and leakage test of the pipes installed and connected shall be in accordance with the following requirements:

1 Clear water should be used in pressure test medium, and anti-freezing measures shall be adopted in winter pressure test.

2 In the process of pressure test, one shall not stand at the plugs at both ends of the pipeline and on the pipeline. Knocking or repairing defects on the pipeline or the interface shall not be carried out. In case of defects, marks shall be made and repaired after pressure relief.

3 The rigid connection pipeline with length greater than 1000m shall be subdivided into sections and then tested, and the length of pressure test should be 500m to 800m. The whole section of pressure test shall be carried out after the section pressure test is qualified.

4 The whole pipeline of flexible socket connection pipeline may carry out pressure test.

5 The test pressure shall be 1.5 times the design pressure and shall be in accordance with the following requirements:

1) When testing pressure, the test pressure shall be slowly boosted, and each boost shall not exceed 0.5 MPa. After stabilizing without abnormality, the test pressure should be boosted in turn until the test pressure is reached.

2) Pressure shall be stabilized for 10 minutes after each boost, and shall be stabilized for more than 30 minutes after reaching the test pressure. Check the pipeline and its connections and accessories, there shall be no cracks and leakage. Pressure drop of the pressure gauge should not exceed 1% of the test pressure, and pressure test shall be stopped when the pressure drop exceeds 1%.

3) After drainage, the defect shall be repaired and the pressure test shall be carried out again.

6 When vacuum pressure test is carried out on pipelines, the test pressure shall be 1.3 times the design pressure or 0.1 MPa, which ever the lesser. Pressure stabilization shall be less than 30 minutes after reaching test pressure. No damage shall be found in the inspection pipelines and their joints and accessories.

10.4 Usage and maintenance

10.4.1 Equipment shall be used in accordance with the following requirements:

1 The equipment manufacturer shall provide technical information on the use, maintenance and repair of the equipment;

2 Overvoltage protection in use shall meet the requirements of the provisions of Article 3.4.2 and Article 3.4.3 of this code;

3 The type, concentration and temperature of storage medium shall meet the design requirements;

4 Fire and high temperature heat sources shall be kept away.

10.4.2 Pipeline shall be used in accordance with the following requirements:

1 The service pressure of the pipeline shall not exceed the design pressure;

2 The type, concentration and temperature of pipeline medium shall meet the design requirements. When there is a change, it shall be determined by design;

3 Pipeline pressurization and decompression shall be slow and uniform;

4 When using the pipeline, it shall avoid the impact of hard and sharp objects and external extrusion. It shall not add load other than design. It shall be far away from fire source and high temperature heat source.

10.4.3 During the use of the equipment, when the lining damage, local bump or leakage are found, the equipment shall be repaired, and shall be in accordance with the following requirements:

1 Before repairing the equipment, the storage medium of the equipment shall be emptied and the inner surface of the equipment shall be cleaned and dried;

2 When entering the equipment for cleaning and overhaul, the operator shall wear soft soled shoes in addition to the relevant regulations for the operation in restricted space; the tools, scaffolding and other hard objects used shall not impact the wall of the equipment, and the contact points with the equipment shall be covered with soft cushions;

3 The raw materials and processes for repairing shall meet the requirements of the Article 7.4.2 of this code;

4 The repaired parts of the equipment shall not be put into use until they have reached the required strength.

10.4.4 Pipeline shall be repaired or replaced when lining damage, local bruising, leakage and other phenomena are found during service, and shall be in accordance with the following requirements:

1 Before repairing the pipeline, the medium in the pipeline shall be emptied and the pipeline shall be cleaned and dried;

2 The raw materials and processes for repairing shall meet the requirements of Article 7.4.2 of this code;

3 Pipeline repair parts must not be put into use until they have reached the required strength;

4 When the pipeline can not be repaired after inspection, it shall be replaced.

11 Project acceptance

11.0.1 The division of construction quality acceptance of fibre reinforced plastics equipment and pipeline shall be in accordance with the following requirements:

1 The quality acceptance of the construction may be divided into inspection batches, sub-item projects and subsection projects;

2 For the division of inspection batches, the equipment should be divided into one inspection batch by a single unit, and the pipeline should be divided into one inspection batch according to the system, or the same medium, the same pressure grade and the same batch;

3 The division of sub-item projects may consist of one or more inspection batches;

4 The division of subsection projects may be made up of one subsection project or several subsection projects with the same manufacturing material.

11.0.2 The construction quality inspection of fibre reinforced plastics equipment shall be in accordance with the following requirements:

1 Pressure and leakage resistance tests shall be the main control items. Quality requirements and testing methods shall meet the relevant requirements of Article 8.4.1 and Article 8.4.2 of this code.

2 The inspection of appearance quality, equipment installation verticality, flange branch installation angle deviation, end face and axis verticality deviation should be general items. The quality requirements and inspection methods shall meet the requirements of the relevant provisions of Article 8.4.1 and Article 8.4.2 of this code.

11.0.3 The construction quality inspection of fibre reinforced plastic pipes shall be in accordance with the following requirements:

1 Hydraulic leakage test shall be the main control item, and the quality requirements and testing methods shall meet the relevant requirements of Article 8.4.7 and Article 8.4.8 of this code.

2 The inspections of appearance quality and allowable deviation of installation dimension should be general items. The appearance quality shall meet the relevant requirements of Article 8.4.7(1) and Article 8.4.8(1) of this code. The allowable deviation of installation dimension shall be in accordance with those specified in Table 10.3.13 of this code.

11.0.4 The construction quality acceptance of fibre reinforced plastics equipment and pipeline shall include intermediate handover and construction acceptance. Projects that have not been submitted for acceptance shall not be put into production and use.

11.0.5 Fibre reinforced plastics equipment and pipeline construction quality acceptance qualification shall be in accordance with the following requirements:

1 The main control items shall be qualified for inspection;

2 The qualified rate of general items shall not be less than 80%, and the unqualified points shall not affect the use;

3 Documents such as product quality inspection documents, handover and installation documents, pressure and anti-leakage inspection of equipment and pipelines shall be complete.

11.0.6 When there is non-conforming items in the construction quality acceptance of fibre reinforced plastics equipment and pipeline, it shall be handled according to the following requirements:

1 If it has been reworked or repaired, it shall be re-examined;

2 If the design requirements are met by inspection and appraisal, they shall be checked and accepted;

3 If the test and appraisal fail to meet the design requirements, it shall not be accepted.

11.0.7 Construction of fibre reinforced plastics equipment and pipeline which can not meet the requirements of safe use after repairing or repairing shall not be accepted.

11.0.8 The following documents shall be submitted for construction quality acceptance of fibre reinforced plastics equipment and pipeline:

1 Computation books, design drawings and design instructions;

2 End-product quality inspection documents;

3 Installation and inspection documents;

4 Operating instruction;

5 Intermediate handover or concealed construction records;

6 Repair or rework records;

7 Record drawings;

8 Completion or acceptance report.

Appendix A Sub-item design factor K_2's determination for corrosion-resistant inner liner layer of fibre reinforced plastics equipment

A.1 General requirements

A.1.1 The sub-item design factor K_2 of corrosion-resistant lining of fibre reinforced plastics equipment shall be determined in the following ways:

1 Resin corrosion resistance data supplied by manufacturers;

2 Application experience;

3 Laboratory test or coupon test.

A.1.2 The lowest value shall be chosen in the design when the partial design factor K_2 is obtained by different methods.

A.2 Determination of resin corrosion resistance data and partial design factor K_2

A.2.1 The contents of chemical corrosion data of resin shall be in accordance with the following requirements:

1 The phase states of corrosive medium shall include liquid, gaseous, solid and mixed phase states;

2 The action of corrosive medium shall include mass percentage concentration or pH value;

3 The recommended material data for corrosive media conditions shall include the maximum resin service temperature T_{max} and heat deflection temperature (HDT), reinforced fibres and curing systems matched with the resin;

4 Recommended curing conditions for resins shall include curing time and temperature, post curing time and temperature.

A.2.2 The partial design factor K_2 shall be selected according to the provisions of Table A.2.2, and shall be in accordance with the following requirements:

1 The heat deflection temperature (HDT) of the recommended resin shall be 20°C higher than the design temperature (T_d);

Table A.2.2 Partial design factor K_2

Designed temperature T_d (°C)	K_2
$T_d = T_{max}$	1.4
$T_d = T_{max} - 10$	1.4
$T_d = T_{max} - 20$	1.3
$T_d = T_{max} - 30$	1.3
$T_d = T_{max} - 40$	1.2
$T_d = T_{max} - 50$	1.2
$T_d = T_{max} - 60$	1.1
$T_d = T_{max} - 70$	1.1

Note: T_{max}—Maximum temperature; T_d—Designed temperature.

2 The post-curing temperature of the resin shall be maintained for at least 4 hours at the heat deflection temperature of the resin or at the temperature recommended by the resin manufacturer;

3 The conditions for using maximum temperature T_{max} shall meet the requirements of Article A.2.1 of Appendix A of this code.

A.3 Determination of application experience and partial design factor K_2

A.3.1 The determination of partial design factor K_2 under application experience shall be in accordance with the following requirements:

1 In the same or similar application conditions, with more than three years of use records, the original design of the partial design factor K_2 may be used;

2 If, under the same or similar operating conditions, a service record of more than three years is maintained and the lining surface of the equipment has passed the inspection and evaluation according to the method in Section A.4 of Appendix to this code, the value of the partial design factor K_2 shall be in accordance with the following requirements:

1) The K_2 value of the original design may be reduced, but the reduction rate shall not be larger than 0.1;

2) The value of K_2 shall not be less than 1.1;

3) Under the same or similar application conditions, the original design K_2 value may be used if the service record is more than 6 months but less than 3 years, and the equipment lining surface has been tested and evaluated according to the method in Section A.4 of Appendix A to this code.

A.3.2 When the partial design factor K_2 is determined, the lining structure consisting of the same resin and fibre, the curing system, the curing and post-curing conditions as the original design shall be adopted.

A.4 Laboratory test or coupon verification and determination of partial design factor K_2

A.4.1 The corrosion resistant lining structure shall be adopted for the test and verification specimens, and the composition of the corrosion resistant lining and the resin content shall meet the requirements of Article 5.1.7 of this code.

A.4.2 The specimen preparation for test and verification and test method shall meet the relevant requirements of the current national standards GB/T 27797.2 *Fibre-Reinforced Plastics-Methods of Producting Test Plates-Part 2: Contact and Spray-up Moulding* and GB/T 3857 *Test Method for Chemical Resistance of Glass Fibre Reinforced Thermosetting Plastics*.

A.4.3 Laboratory tests shall be in accordance with the following requirements:

1 The test temperature shall be the design temperature, and the temperature fluctuation shall not be larger than 2°C;

2 The test period may be determined through consultation, and the immersion time shall not be less than 16 weeks;

3 Liquid media for the test shall be replaced periodically;

4 The following immersion methods shall be used for the test template:

1) One side of one test specimen shall be immersed in liquid medium, and one side of the other test specimen shall be exposed to gas phase of liquid medium;

2) The test template shall be immersed in liquid medium.

A.4.4 Coupon verification shall be in accordance with the following requirements:

1 Under operation condition, the coupon may be immersed in the equipment or pipe on one side or both sides. Short fittings may also be immersed or exposed to the operating environment in the form of adjacent pipes, but the dimensions of the fittings shall meet the requirements of specimen preparation and testing.

2 The test period shall not be less than 3 months.

A.4.5 The items and indicators for evaluating the corrosion resistance of test and verification specimens shall be selected according to the provisions of Table A.4.5 and shall be in accordance with the following requirements:

1 The performance grading of appearance indicators shall be in accordance with the following requirements:

1) The color shall be graded from the unchanged translucent initial color (grade 0), to the gradual change of the color after immersion in the medium, to the color is completely discolored and darkened (grade 5).

2) The gloss retention shall be graded from keeping the original gloss after immersion (grade 0) to the matte surface (grade 5).

3) Opacity shall be graded from unchanged after immersion (grade 0) to completely opaque and fibre whitening (grade 5).

4) Tackiness shall be graded from the imperceptible tackiness after immersion (grade 0), to the surface tackiness and removable tackiness during contact (grade 5). When grade 5 is reached, the use of this material shall be rejected by this criterion alone.

5) Fibre exposure shall be graded from never exposed (grade 0). They shall be divided into 1 to 5 grades when the fibres are swelling and when the fibres are exposed to small blisters at the overlap of fibres.

6) Surface resin loss shall begin with no defect (grade 0) and proceed to surface resin loss (grade 5). When resin and fibre are both missing, the use of this material shall be rejected by this criterion alone.

7) Blister formation, the size and distribution of blisters on the surface shall be graded, starting with the same with original (grade 0), to some of the diameter of 1mm to 2mm blisters (grade 1) gradually to the diameter of more than 5mm in the medium blisters (grade 5). When a large number of blisters larger than 5mm in diameter or occasionally larger than 20mm in diameter occur, the use of the material shall be rejected according to this criterion alone.

8) Crazing shall start with no crazing (grade 0) and be graded to no more than 50% surface has crazed (grade 5). When there is crazing on the surface of more than 50% of the material, the use of the material shall be rejected according to this criterion alone.

9) Crack formation grading shall start with no crack (grade 0) to multi crack (grade 5). When multiple cracks lead to deep cracks and "break-up" of the material, the use of the material shall be rejected according to this criterion alone.

10) Delamination grading shall start with no delamination (level 0), to delamination up to 25mm (5 level).

Table A.4.5 Corrosion resistance evaluation items and indicators

Item	Indicator	Weighting factor (single side immersion)	Weighting factor (double-sided immersion)	Performance grade
Appearance	Color	2	2	0—5
	Gloss retention	3	3	0—5
	Opacity	3	3	0—5
	Tackiness	4	4	0—5
	Fibre exposure	4	4	0—5
	Surface resin loss	5	5	0—5
	Blister formation	5	5	0—5
	Crazing	5	5	0—5
	Crack formation	5	5	0—5
	Delamination	5	5	0—5
Dimensional stability	Swelling	8	4	0—5
	Weight change	10	5	0—5
	Change in barcol hardness	5	5	0—5
Mechanical properties	Retention of flexural strength	20	10	0—10
	Retention of flexural modulus	20	10	0—10

2 The performance grading of the dimensional stability index shall be in accordance with the following requirements:

1) Swelling shall be graded from thickness unchanged (grade 0) to 20% increase in thickness (grade 5);

2) Weight change shall be graded from no weight change (grade 0) to 5% weight change (grade 5);

3) Change in Barcol hardness shall be graded from no change (grade 0) to a 50% reduction in Barcol hardness (grade 5).

3 The semi logarithmic diagram of flexural strength and flexural modulus shall be used in the evaluation of mechanical properties and shall be in accordance with the following requirements:

1) The retention of flexural strength and flexural modulus shall correspond to the logarithm of time and shall be determined by progressive approximation of the retention of less than 50% or by linear extrapolation to the retention of 50%;

2) The test shall be graded from no change in the retention rate (grade 0), to 50% retention rate after 10 years (grade 10);

3) When the relative time of flexural strength or flexural modulus at the 50% retention point is less than 10 years, the use of the material shall be rejected according to this criterion alone.

4 Corrosion resistance evaluation shall be in accordance with the following requirements:

1) The same immersion test method and corrosion resistance evaluation scale shall be used;

2) There must be no lack of evaluation index of mechanical performance;

3) Within the scope of the evaluation index, the final corrosion resistance evaluation score shall be obtained by multiplying the performance rating scores of each index by the weighting factors of the corresponding indexes and adding them together;

4) Within the scope of the selected evaluation index, the maximum (worst) score of the performance rating of each index shall be multiplied by the weighting factor of the corresponding index, and the maximum total score shall then be obtained;

5) When the final assessment score is less than 50% of the maximum total score, the material shall be used.

A.4.6 The partial design factor K_2 shall be set according to the provisions of Table A.4.6.

Table A.4.6 Partial design factor K_2

Percentage of grade score in total score (%)	K_2
≤20	1.1
30	1.2
40	1.3
50	1.4
>50	Unsuitable for purpose

Appendix B Corrosion medium classification

Table B Corrosion medium classification

Medium	Medium
1 Alkaline inorganic matter/Alkaline inorganic hydrolyzing salts	6 Acid organic matter
Ammonium Hydroxide, aq	Acetic Acid
Calcium Hydroxide, aq	Formic Acid
Hydrazine Hydrate, aq	Oxalic Acid
Potassium Hydroxide, aq	Toluene Sulphonic Acid
Sodium Aluminate, aq	7 Surfactants
Sodium Hydroxide, aq	Alkyl Amino Polyglycolether
2 Oxidizing alkaline inorganic hydrolyzing salts	Alkyl Aryl Sulfonates
Calcium Hypochlorite, aq (17% active Chlorine)	Alkyl Aryl Ammonium Salts (Na, K)
Chlorinated lime, aq	Alkyl Naphthol Polyglycolether
Sodium Hypochlorite, aq (16% active Chlorine)	Alkylol Ether Sulphates
3 Acid inorganic matter/Acid inorganic hydrolyzing salts	Alkylol Ether Phosphates
Hydrochloric Acid	Alkyl-/Aryl Phosphates
Aluminium Sulphate	Amides of Fatty Acids
Ferrous Chloride, aq	Ethylene Diamine Polyglycolether
Ferric Chloride, aq	Na-, K-salts (EDTA salts from Ethylenediamine Tetraacetic Acid)
Ferrous Sulphate, aq	Na-, K-salts (NTA salts) from Nitrilo Triacetic Acid
Ferric Sulphate, aq	8 Organic solvent
Sulphuric Acid	Cyclohexanol
4 Inorganic oxidizing acid	Cyclohexanone
Chromic Acid	Ethanol, aq
Nitric Acid	9 Oxidizing agents
Perchloric Acid	Hydrogen Peroxide
5 Alkaline organic matter	Potassium Permanganate
N, *N*-Dimethyl Aniline	10 Others
N, *N*-Diethyl Aniline	Caprolactam, aq

Note: When using media of classes 1, 2, 7 and oxalic acid, the corrosion resistant layer shall be synthetic fibre or carbon fibre.

Appendix C　Horizontal vessel design

C.1　General requirements

C.1.1　Horizontal vessel design shall include calculation of cylinder, number of saddles, structural form, saddle arrangement and selection of saddle support angle.

C.1.2　Horizontal vessel saddles (Figure C.1.2) shall be designed in accordance with the following requirements:

1　The support angle of saddles should be 180°, and shall not less than 120°.

2　The distance between the center line of saddle and the tangent line of head should not be greater than 0.5 times of the cylinder radius and 0.2 times of the tangent distance of head. The distance between any two saddles shall not be greater than 1.5 times of the cylinder diameter.

3　The shape of saddles shall be consistent with the shape of horizontal vessel.

4　The vessel shall be able to move freely in the horizontal direction.

5　The buffer layer between saddle and cylinder shall be made of rubber sheet or other low elastic modulus materials with minimum thickness of 6 mm.

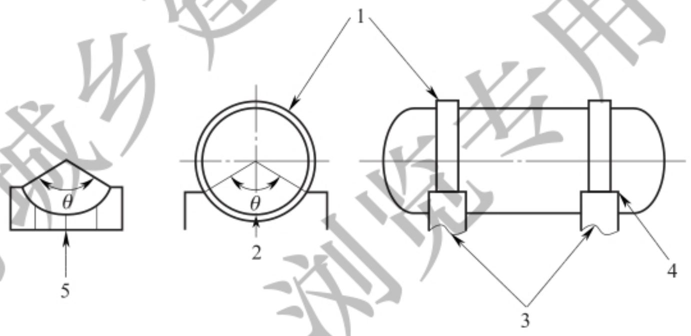


Figure C.1.2　Horizontal vessel saddle

1—Stiffening ring; 2—Saddle angle; 3—Concrete rigid saddle; 4—Saddle side angle; 5—Steel rigid saddle

C.2　Calculation of horizontal vessels

C.2.1　The calculation of the longitudinal bending moment of the cylinder shall be in accordance with the following requirements:

1　The vessel supported on the saddle may be simplified as a straight beam. When the vessel is subjected to dead weight, material weight, additional load and liquid column pressure, the bending moment generated on the vessel head shall be calculated.

2　The flexural moment M_1 at the support of horizontal vessels supported by double saddles (Figure C.2.1-1) and M_2 at mid span (Figure C.2.1-2) shall be calculated according to the following formulas respectively:

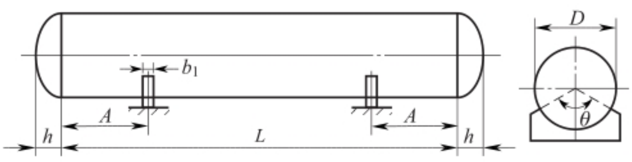
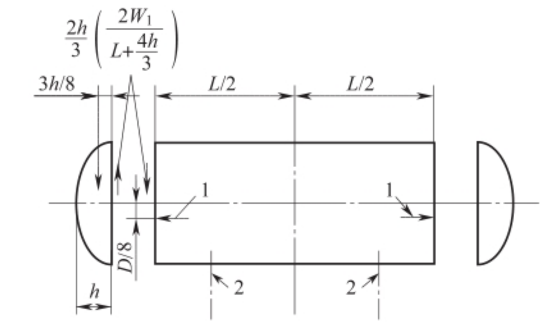
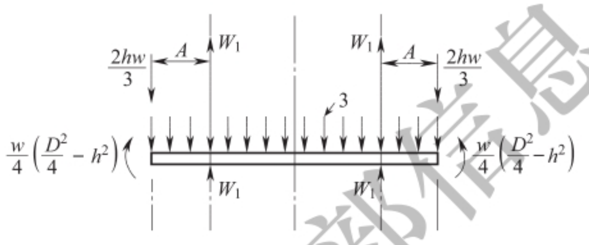


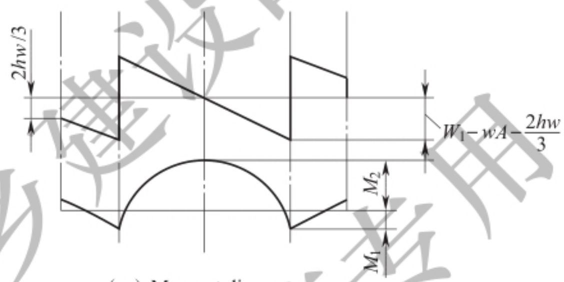
Figure C.2.1-1　Horizontal vessel supported by double saddles



(a) Load and saddle reaction of horizontal vessels



(b) Shear force diagram



(c) Moment diagram

Figure C.2.1-2 Diagram of stress distribution of double saddle cylindrical vessels

1—Hydrostatic load acting on vessel head ($wD/2$); 2—Saddle center line;

3—Uniformly distributed load per unit length w

$$M_1 = \frac{w}{4} \times \left(\frac{D^2}{4} - h^2 - 2A^2 - \frac{8hA}{3}\right) \tag{C.2.1-1}$$

$$M_2 = \frac{w}{8} \times \left(L^2 + \frac{D^2}{2} - 2h^2 - 4LA - \frac{16hA}{3}\right) \tag{C.2.1-2}$$

$$w = \frac{2W_1}{L + \frac{4h}{3}} \tag{C.2.1-3}$$

where

M_1—Flexural moment at the support of horizontal vessels (N·mm); the value shall be in accordance with those specified in Table C.2.1;

M_2—Flexural moment (N·mm) at mid span;

w—Uniformly distributed load per unit length (N/mm);

D—Average diameter of vessel (mm);

h—Curved surface depth of head (mm);

A—Distance from the center line of saddle bottom to the tangent line of head (mm);

L—Distance between tangent lines of two heads (mm);

W_1—Reaction (N) of each saddle.

Table C.2.1 Axial bending moment M_1 of cylinder at saddle

Head type	Value of M_1
Flat head, when $2A/D<0.707$	>0
Dished head with 10% head diameter in transition angle, when $2A/D<0.44$	>0
Standard elliptical head (length to short half-axis ratio 2 : 1), when $2A/D<0.363$	>0
Hemispherical head	<0

Note: The distance from the section to the center of gravity of the convex head may be approximated to $3h/8$. The weight of the head itself and the material in the head may be calculated together approximately as acting on the center of gravity of the head.

C.2.2 Cylinder axial element load calculation shall be in accordance with the following requirements:

1 The axial unit loads on the mid section of the cylinder shall be calculated according to the following formulas:

1) At the highest point, the axial unit load shall be calculated according to the following formula:

$$q_{x1}=\frac{p_D\times D}{4}-\frac{4M_2}{\pi\times D^2} \quad \text{(C.2.2-1)}$$

2) At the lowest point, the axial unit load shall be calculated according to the following formula:

$$q_{x2}=\frac{p_D\times D}{4}+\frac{4M_2}{\pi\times D^2} \quad \text{(C.2.2-2)}$$

where

q_{x1}—Axial unit load (N/mm) at the highest point of the mid section of the cylinder;

q_{x2}—Axial unit load (N/mm) at the lowest point of the mid section of the cylinder;

p_D—Pressure of internal pressure plus additional pressure in calculations (MPa).

3) When the mid section of the cylinder is subjected to compressive load, the maximum axial unit compressive load shall be calculated according to the relevant requirements of Article 5.3.3 of this code.

2 The axial unit load at the saddle section shall be calculated according to the following formulas:

1) The axial unit load at the highest point of the section shall be calculated according to the following formula:

$$q_{x3}=\frac{p_D\times D}{4}+\frac{4M_1}{K_1\times\pi\times D^2} \quad \text{(C.2.2-3)}$$

2) The axial unit load at the lowest point of the section shall be calculated according to the following formula:

$$q_{x4}=\frac{p_D\times D}{4}+\frac{4M_1}{K_2\times\pi\times D^2} \quad \text{(C.2.2-4)}$$

where

q_{x3}—Axial unit load at the highest point of saddle (N/mm);

q_{x4}—Axial unit load at the lowest point of saddle (N/mm);

K_1, K_2—Coefficient, values shall be taken in accordance with Table C.2.2.

3 Load checking of cylindrical axial unit shall be in accordance with the following requirements:

1) At the mid section of the cylinder, the calculation shall be made according to Formula (C.2.2-1) and Formula (C.2.2-2), and the following formula shall be satisfied:

$$\max\{q_{x1}, q_{x2}\}\leqslant[q_x] \quad \text{(C.2.2-5a)}$$

Table C.2.2 Coefficient K_1, K_2

Condition	Saddle wrap angle θ(°)	K_1	K_2
1 A cylinder reinforced by a head or stiffening ring, i.e. $A \leqslant D/4$, or a cylinder with reinforcement rings on the saddle plane	$120 \leqslant \theta \leqslant 180$	1	1
2 Cylinders not reinforced by heads or stiffening rings, i.e. $A \leqslant D/4$, and without reinforcement rings on the saddle plane	120	0.107	0.192
	135	0.132	0.234
	150	0.161	0.279
	165	0.193	0.328
	180	0.229	0.380

2)The saddle plane shall be calculated by Formula (C. 2.2-3), Formula (C. 2.2-4) and the following formula shall be satisfied:

$$\max\{q_{x3}, q_{x4}\} \leqslant [q_x] \tag{C.2.2-5b}$$

3)The axial instability check of the mid section of the cylinder shall satisfy the following formula:

$$\frac{u_c}{q_{xc}} \geqslant F \tag{C.2.2-5c}$$

where

$[q_x]$—The allowable axial unit load (N/mm) of the laminates;

q_{xc}—The maximum axial unit compression load of cylinder (N/mm);

F—The buckling factor, value selection in accordance with Article 4.3.3 of this code;

u_c—The compressive buckling load (N/mm) of the axial unit of the cylinder.

C.2.3 The calculation and verification of cylinder stability shall be in accordance with the following requirements:

1 The stability of cylinders shall be checked in accordance with the relevant provisions of Article 5.3.3 of this code and shall be in accordance with the following requirements:

1)When the pressure load is zero or negative, the maximum compression unit load of the middle section of the cylinder shall be calculated according to Formula (C.2.2-1).

2)When the pressure load is zero or negative, the maximum compression unit load on the saddle plane shall be calculated according to Formula (C.2.2-3).

3)The maximum axial unit compression load u_c of the container shall be calculated in accordance with the relevant provisions of Article 5.3.3 of this code.

4)The criterion shall satisfy the following formula:

$$\frac{u_c}{q_x} \geqslant F \tag{C.2.3-1}$$

where

q_x—Cylinder axial unit load (N/mm), the larger value in the calculation results of Formula (C.2.2-1) and Formula (C.2.2-3) shall be taken.

5)When subjected to negative pressure, the following formula shall be satisfied under the combined action of axial load and radial load:

$$\left(\frac{q_x \times F}{u_c}\right)^{1.25} + \left(\frac{p_u \times F}{p_c}\right)^{1.25} \leqslant 1 \tag{C.2.3-2}$$

where

p_c—Critical buckling pressure of cylinder (MPa), shall be determined in accordance with Article 5.3.3 of this code;

p_u—Negative pressure (MPa).

2 When the thickness of the vesse can not meet the requirements of Formula (C.2.3-1) and Formula (C.2.3-2), stiffening rings shall be set near the saddle, and larger values of K_1 and K_2 shall be selected according to Table C.2.2, then calculation and check shall be carried out again.

3 When two longitudinal stiffeners parallel to the full length of the container are used, the stiffeners shall be located at the top of the container, and the spacing should be 0.4 times the diameter of the cylinder. The stiffeners shall form a whole with the container and shall not fail under external loads.

C.2.4 The tangential shear force distribution of the cylinder supported by double saddles may be determined according to Figure C.2.1-2 of this code, and the shear force of the cylinder supported by multiple saddles may be calculated according to the method of continuous beam analysis. The calculation of the tangential shear force of a cylinder shall be in accordance with the following requirements:

1 The maximum shear force of the double saddle structure at the saddle section (Figure C.2.1-2) shall be calculated according to the following formula:

$$Q=\frac{W_1(L-2A)}{L+\frac{4h}{3}} \tag{C.2.4-1}$$

where

Q—Shear force (N) at the calculated point of cylinder.

2 The shear stress in the saddle area shall be calculated according to the following formula:

$$\tau_{max}=\frac{2K_3W_1}{t\times D}\times\frac{L-2A}{L+\frac{4h}{3}} \tag{C.2.4-2}$$

where

τ_{max}—Maximum tangential shear stress (MPa) of cylinder;

t—Thickness of cylinder (mm);

K_3—Coefficient, values shall be taken in accordance with Table C.2.4.

Table C.2.4 Coefficient K_3

Condition	Saddle wrap angle θ(°)	K_3	
		$A>D/4$	$A\leqslant D/4$
1 Cylinder without stiffening ring or with stiffening ring near saddle	120	1.171	0.880
	135	0.958	0.654
	150	0.799	0.485
	165	0.675	0.357
	180	0.577	0.260
2 Cylinders with stiffening rings on the saddle plane	$120\leqslant\theta\leqslant180$	0.319	0.319

C.2.5 Checking the maximum tangential shear stress of cylindrical laminates shall satisfy the following formula:

$$\tau_{max} \leqslant [\tau] \qquad (C.2.5\text{-}1)$$

where

$[\tau]$—Allowable shear stress (MPa) of cylindrical laminates, may be calculated according to Formula (4.3.8-4) of this code.

C.2.6 The shear stability check of the cylinder shall satisfy the following formulas:

$$\frac{\tau_c}{\tau} \geqslant F \qquad (C.2.6\text{-}1)$$

$$\tau_c = 1.31 \times \left(E_x^3 \times E_{\Phi,b}^5\right)^{0.125} \times \left(\frac{t}{D}\right)^{1.25} \times \left(\frac{D}{L_S}\right) \qquad (C.2.6\text{-}2)$$

$$\tau = k_q \times \frac{2Q}{\pi \times D \times t} \qquad (C.2.6\text{-}3)$$

where

τ_c—Critical instability shear stress (MPa) of cylinder at saddle;

τ—Maximum shear stress (MPa) at the cross section of cylindrical saddle;

$E_{\Phi,b}$—Circumferential bending modulus (MPa) of laminates;

E_x—Axial tensile modulus (MPa) of laminates;

L_S—The distance between saddle or stiffening rings (mm);

k_q—The function of cylinder load; when the load is tensile load, k_q takes 1.5; when the load is compressive load, k_q takes 1.0.

C.2.7 When $A > D/4$ and there is no stiffening ring on the saddle section, the calculation and verification of the circumferential unit load shall be in accordance with the following requirements:

1 The maximum circumferential unit load of a circular cylinder may occur at the lowest point of the cylinder at the corner of the saddle and the cross-section of the saddle. The maximum unit load of the lowest point of the cylinder at the cross-section of the saddle shall be calculated according to the following formula:

$$q_{\Phi 5} = \frac{K_5 \times W_1}{b_1 + 10t} \qquad (C.2.7\text{-}1)$$

where

$q_{\Phi 5}$—The maximum circumferential unit load (N/mm) at the lowest point of the cylinder at the saddle cross section;

b_1—Axial width of saddle (mm);

K_5—Coefficient, values shall be taken in accordance with Table C.2.7. When the saddle and container are rigidly fixed, K_5 may be selected according to $\frac{1}{10}K_5$; when the saddle and container can slide horizontally, K_5 may be selected according to $3K_5$ or test data.

Table C.2.7 Coefficient K_5

Saddle wrap angle θ (°)	120	135	150	165	180
K_5	0.76	0.711	0.673	0.645	0.624

2 The maximum value $q_{\Phi 5}$ of the circumferential unit load calculated by Formula (C.2.7-1) for a cylinder without stiffening rings shall be in accordance with the compression stability stipulated in Article 5.3.3 of this code and shall satisfy the following formula:

$$\max\{q_{\Phi 5}\} \leqslant [q_{\Phi}] \qquad (C.2.7\text{-}2)$$

where

$[q_\Phi]$—Allowable circumferential unit load (N/mm) for laminated plates.

C.2.8 The calculation of the load at the saddle horn of the cylinder without stiffening ring or the cylinder strengthened by the head shall be in accordance with the following requirements:

1 The maximum bending moment M_H at the saddle horn shall be calculated according to the following formula:

$$M_H = K_6 \times W_1 \times \frac{D}{2} \tag{C.2.8-1}$$

where

M_H—The maximum bending moment (N·mm) at the saddle horn of the cylinder without stiffening ring or the cylinder strengthened by the head;

K_6—Coefficient, values shall be taken in accordance with Table C.2.8.

Table C.2.8 Coefficient K_6

$\frac{2A}{D}$	Saddle support angle θ (°)				
	120	135	150	165	180
≤0.5	0.0132	0.0103	0.0079	0.0059	0.0041
≥1.0	0.0528	0.0413	0.0316	0.0238	0.0165

Note: When $0.5 < \frac{2A}{D} < 1.0$, the K_6 value may be obtained by linear interpolation of the values in the table.

2 The bending component of circumferential unit load shall be calculated according to the following formulas:

1) When $L \geqslant 4D$ and the effective width (Figure C.2.8) $L_r = 2D$, it shall be calculated according to the following formula:

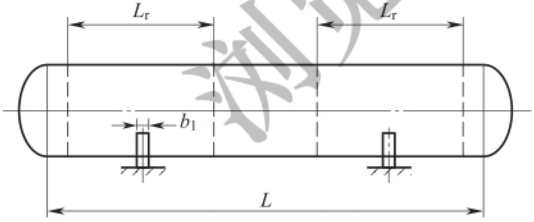


Figure C.2.8 Effective width L_r of vessel subjected to bending moment M_H

$$q_{\Phi b} = \frac{3K_6 W_1}{2t} \tag{C.2.8-2}$$

2) When $L < 4D$ and effective width $L_r = L/2$, it shall be calculated according to the following formula:

$$q_{\Phi b} = \frac{6K_6 W_1 D}{Lt} \tag{C.2.8-3}$$

3 Compressive loads at the saddle horn shall be calculated according to the following formula:

$$q_{\Phi m} = \frac{W_1}{4 \times (b_1 + 10t)} \tag{C.2.8-4}$$

4 The maximum circumferential compressional unit load at the saddle horn shall be calculated according to the following formulas:

1) When $\frac{L}{D} \geqslant 4$, it shall be calculated according to the following formula:

$$q_6 = -\frac{W_1}{4\times(b_1+10t)} - \frac{3}{2}\times K_6 \times \frac{W_1}{t} \qquad \text{(C.2.8-5)}$$

2)When $\frac{L}{D} < 4$, it shall be calculated according to the following formula:

$$q_6 = -\frac{W_1}{4\times\left(b_1+10t\right)} - \frac{6K_6W_1D}{L\times t} \qquad \text{(C.2.8-6)}$$

where

q_6—Maximum circumferential unit compressional load (N/mm)at the saddle horn of the cylinder without stiffening ring or the cylinder strengthened by the head.

3) q_6 at the saddle horn calculated by Formula (C.2.8-5) and Formula (C.2.8-6) shall satisfy the following formula:

$$\max\{q_6\} \leqslant [q_\Phi] \qquad \text{(C.2.8-7)}$$

Appendix D Flange design

D.1 General requirements

D.1.1 The safety factor K of fibre reinforced plastics flange shall be 8.

D.1.2 The steel bolt material used for fibre reinforced plastic flange shall meet the relevant requirements of the current national standard GB 150.2 *Pressure Vessels-Part 2*:*Materials*.

D.1.3 The steel material in loose flanges shall meet the relevant requirements of the current national standard GB 150.2 *Pressure Vessels-Part 2*:*Materials*.

D.2 Flange type and requirements

D.2.1 Fibre reinforced plastics flanges may be divided into integral flanges and loose flanges (Figure D.2.1). The design shall be in accordance with the following requirements:

1 Flange compensation height (Figure D.2.1) (position a) shall not be less than 4 times the flange thickness (δ_f);

2 Tapered structure (Figure D.2.1) (position b) should be adopted from flange to branch;

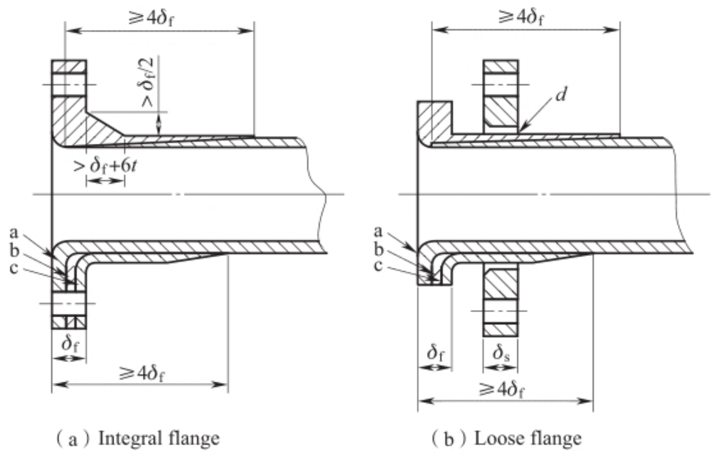
3 The fibre chopped strand mat with a mass of 1.2kg/m^2 per unit area should be used for the overlay (Figure D.2.1) (position c);

4 The flange thickness shall be greater than ($\delta_f/2$) mm along ($\delta_f + 6t$) mm the length direction of the cylinder or branch;

5 Steel gasket ring with minimum thickness of 6mm or steel washer should be designed on the back of integral flange;

6 All radii shall not be less than 3mm;

7 The clearance between the outer diameter of the loose flange and the inner diameter of the steel flange (Figure D.2.1) (position d) shall not be greater than 3mm.



(a) Integral flange　　(b) Loose flange

Figure D.2.1 Fibre reinforced plastic flanges

t—Cylinder or branch thickness(mm)

D.2.2 The load position distribution of the integral flange may be determined by Figure D.2.2-1, and that of the loose flange may be determined by Figure D.2.2-2.

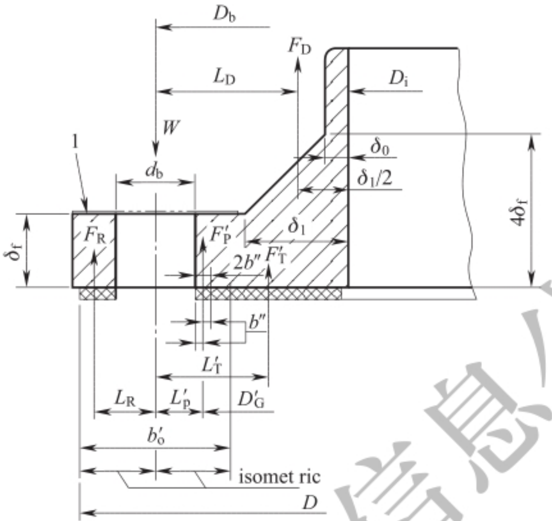


Figure D.2.2-1 Distribution of loading position of integral flange

1—Steel gasket ring or steel washer

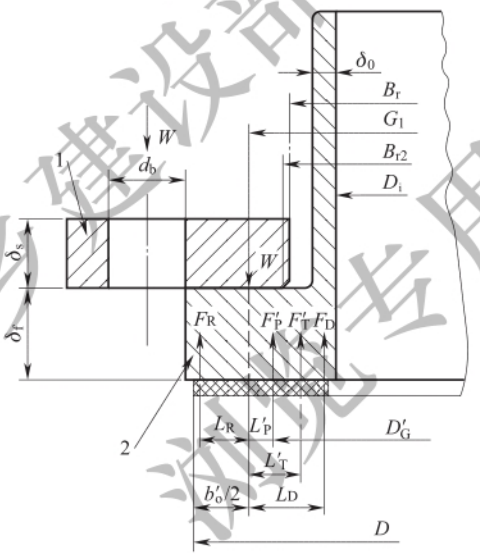


Figure D.2.2-2 Loose flange load location distribution

1—Steel flange; 2—Flange

D.3 Integral flange design

D.3.1 The design and calculation of integral flange under load (Figure D.2.2-1) may be carried out in accordance with the relevant requirements of the current national standard GB 150.3 *Pressure Vessels-Part 3: Design*.

D.3.2 Flange thickness shall be calculated according to the following formulas:

$$\delta_f = \sqrt{\frac{6 \times F_R \times L_R \times K}{\sigma_{CSM} \times (\pi \times D - n \times d_b)}} \quad \text{(D.3.2-1)}$$

$$\sigma_{CSM} = \frac{U}{t_g} \quad \text{(D.3.2-2)}$$

where

δ_f—Effective thickness of flange (mm);

F_R—Axial force (N) required to balance the moment produced by F_D and F'_P on the outer side of the central circle of bolt loads on flanges;

L_R—Radial distance (mm) from the diameter of the center circle of the bolt load acting on the flange to the action position of F_R;

K—Design factor, shall take 8;

σ_{CSM}—Ultimate tensile strength (MPa) of single layer of fibre chopped strand mat;

U—Unit tensile strength of single layer of fibre short-cut raw fibre felt [N/(mm·kg/m^2)];

t_g—Thickness of the single layer of fibre short-cut raw fibre felt per unit area mass [mm/(kg/m^2)];

D—Outer diameter of gasket or flange, whoever the smaller value shall be taken (mm);

n—Number of bolts;

d_b—Bolt hole diameter (mm).

D.3.3 The basic parameters of integral flanges may be selected in accordance with Table D.3.3 and shall be in accordance with the following requirements:

1 The allowable strain of single layer of fibre chopped strand mat shall not be less than 0.25%;

2 Non-woven rubber pads or high content fibre rubber synthetic pads with Shaw hardness of 50—65 shall be used for gaskets;

3 Gasket characteristic coefficient m shall be 1.0, and y shall be 1.4.

Table D.3.3 Basic parameters of integral flanges

Branch diameter *DN* (mm)	Flange thickness (mm)	Connection size (Class 150)					Connection size (*PN*10)				
		Flange outer diameter (mm)	Bolt center circle diameter (mm)	Bolt hole diameter (mm)	Number of bolt holes	Bolt specification	Flange outer diameter (mm)	Bolt center circle diameter (mm)	Bolt hole diameter (mm)	Number of bolt holes	Bolt specifica-tion
1.0MPa											
25	23	115	79.4	16	4	M14	115	85	14	4	M14
32	24	125	88.9	16	4	M14	140	100	18	4	M14
40	25	134	98.4	16	4	M14	150	110	18	4	M14
50	28	152	120.7	18	4	M16	165	125	18	4	M16
65	30	178	139.7	18	4	M16	185	145	18	8	M16
80	32	190	152.4	18	4	M16	200	160	18	8	M16
100	32	230	190.5	18	8	M16	220	180	18	8	M16
125	32	255	215.9	22	8	M20	250	210	18	8	M20
150	32	280	241.3	22	8	M20	285	240	22	8	M20
200	38	345	298.5	22	8	M20	340	295	22	8	M20
250	45	406	362	26	12	M24	395	350	22	12	M24
300	50	485	431.8	26	12	M24	445	400	22	12	M24
350	55	535	476.2	30	12	M24	505	460	22	16	M24
0.60MPa											
400	55	595	539.8	30	16	M27	565	515	26	16	M27
450	60	635	577.8	33	16	M30	615	565	26	20	M30
500	60	700	635	33	20	M30	670	620	26	20	M30
600	65	815	749.3	36	20	M33	780	725	30	20	M33

Table D.3.3(continued)

Branch diameter DN (mm)	Flange thickness (mm)	Connection size(Class 150)					Connection size(PN10)				
		Flange outer diameter (mm)	Bolt center circle diameter (mm)	Bolt hole diameter (mm)	Number of bolt holes	Bolt specification	Flange outer diameter (mm)	Bolt center circle diameter (mm)	Bolt hole diameter (mm)	Number of bolt holes	Bolt specification
0.25MPa											
700	55	925	863.6	36	28	M33	895	840	30	24	M33
800	60	1060	977.9	42	28	M39	1015	950	33	24	M39
900	65	1170	1085.8	42	32	M39	1115	1050	33	32	M39
1000	70	1290	1200.2	42	36	M39	1230	1160	36	36	M39

D.3.4 The design and calculation of integral flanges shall comply with the requirements of Article D.3.3 and Article D.3.2 of this code when they do not meet the requirements of Article D.3.3 or exceed the basic parameters of flanges specified in Article D.3.3 of this code.

D.4 Design of loose flange

D.4.1 The design and calculation of gaskets shall be in accordance with the following requirements:

1 The characteristic parameters (m, y) of the commonly used gaskets shall meet the relevant requirements of GB 150.3 *Pressure Vessels-Part 3*: *Design* of the current national standard GB 150.3 *Pressure Vessels-Part 3*: *Design*.

2 The effective sealing width of gaskets shall be calculated according to the following formulas:

1)In the case of pre-tightness, it shall be calculated according to the following formulas:

$$G_1 = \frac{D + B_{r2}}{2} \quad \text{(D.4.1-1)}$$

$$b'_o = D - G_1 \quad \text{(D.4.1-2)}$$

$$b' = 4\sqrt{b'_o} \quad \text{(D.4.1-3)}$$

2)When operating, it shall be calculated according to the following formula:

$$2b'' = 5 \quad \text{(D.4.1-4)}$$

where

G_1—Diameter of the center circle (mm) of the load acting on the flange;

B_{r2}—Inner diameter (mm) of the loose flange at the contact point with the flange;

b'_o—Basic sealing width (mm) of the pre-tightened gasket;

b'—Effective sealing width (mm) of the pre-tightened gasket;

$2b''$—Effective sealing width (mm) of gasket in operation state, value shall be 5.

3 The diameter of the center circle of the gasket compression load shall be calculated according to the following formula:

$$D'_G = G_1 - 2b'' \quad \text{(D.4.1-5)}$$

where

D'_G—Diameter of the center circle of action (mm) of the gasket compression load F'_P.

4 The minimum compression load required for gaskets shall be calculated according to the following formulas:

1)In the case of pre-tightness, it shall be calculated according to the following formula:

$$F_a' = 3.14 \times G_1 \times b' \times y \tag{D.4.1-6}$$

2)When operating, it shall be calculated according to the following formula:

$$F_P' = 6.28 \times D_G' \times m \times p \times b'' \tag{D.4.1-7}$$

where

F_a'—Minimum gasket compression load (N) required in pre-tightening state;

y—Gasket specific pressure (MPa), shall be calculated according to the relevant requirements of the current national standard GB 150.3 *Pressure Vessels-Part 3: Design*;

F_P'—Minimum gasket compression load (N) required for operation state;

m—Gasket coefficients, shall be in accordance with the relevant requirements of the current national standard GB150.3 *Pressure Vessels-Part 3: Design*;

p—Flange design pressure (MPa).

D.4.2 The design and calculation of bolts shall be in accordance with the following requirements:

1 The arrangement of the bolts shall meet the requirements of the relevant requirements of the current national standard GB 150.3 *Pressure Vessels-Part 3: Design*.

2 Bolt load shall be calculated according to the following formulas:

1)In case of pre-tighteness, it shall be calculated according to the following formula:

$$W_a = F_a' \tag{D.4.2-1}$$

2)When operating, it shall be calculated according to the following formulas:

$$F' = 0.785 \times G_1^2 \times p \tag{D.4.2-2}$$

$$F_D = 0.785 \times D_i^2 \times p \tag{D.4.2-3}$$

$$F_T' = F' - F_D \tag{D.4.2-4}$$

$$F_R = \frac{F_D \times L_D + F_P' \times L_P' + F_T' \times L_T'}{L_R} \tag{D.4.2-5}$$

$$L_D = \frac{G_1 - D_i - \delta_o}{2} \tag{D.4.2-6}$$

$$L_P' = b'' \tag{D.4.2-7}$$

$$L_T' = \frac{G_1 + 2b'' - D_i}{4} \tag{D.4.2-8}$$

$$L_R = \frac{D - G_1}{4} \tag{D.4.2-9}$$

$$W_P = F_P' + F' + F_R \tag{D.4.2-10}$$

where

F'—Total axial force (N) caused by internal pressure;

F_T'—Difference between the total axial force F' caused by the internal pressure and the axial force F_D caused by the internal pressure acting on the inner diameter section of the flange (N);

F_D—Axial force (N) acting on the inner diameter section of the flange caused by the internal pressure;

D_i—Inner flange diameter (mm);

δ_o—Effective thickness of the hub (mm);

L_D—Radial distance (mm) acting on the center circle diameter of the bolt load on the flange to the F_D action point (Figure D.2.2-2);

L_P'—Radial distance (mm) acting on the center circle diameter of the bolt load on the flange to the F_P' action point (Figure D.2.2-2);

L'_T—The radial distance (mm) acting on the center circle diameter of the bolt load on the flange to the F'_T action point (Figure D.2.2-2).

3 Bolt area calculation shall be in accordance with the following requirements:

1) In case of pre-tighteness, it shall be calculated according to the following formula:

$$A_a = \frac{W_a}{[\sigma]_b} \tag{D.4.2-11}$$

2) When operating, it shall be calculated according to the following formula:

$$A_P = \frac{W_P}{[\sigma]_b^t} \tag{D.4.2-12}$$

where

A_a—Minimum total bolt cross-sectional area (mm^2) required in the pre-tightening state;

A_P—Minimum total bolt cross-sectional area (mm^2) required in the operating state;

A_b—Total cross-sectional area of the bolt actually used (mm^2);

A_m—Total cross-sectional area of the bolt required (mm^2);

W_a—Minimum bolt load (N) required in the pre-tightening state;

W_P—Minimum bolt load (N) required during operation;

$[\sigma]_b$—Allowable stress (MPa) of the bolt material at room temperature, value shall meet the requirements of the current national standard GB150.2 *Pressure Vessels-Part 2: Materials*;

$[\sigma]_b^t$—Allowable stress (MPa) of the bolt material at the design temperature, value shall meet the requirements of the current national standard GB150.2 *Pressure Vessels-Part 2: Materials*.

3) The required bolt area A_m shall take a large value in A_a and A_P.

4) The actual bolt area A_b shall not be less than the required bolt area A_m.

5) The minimum bolt section shall be calculated separately for thread diameter and minimum diameter of unthreaded part, and shall take the smaller value.

D.4.3 The design and calculation of flanges shall be in accordance with the following requirements:

1 Flange design torque shall be calculated according to the following formula:

$$M_o = F_R \times L_R \tag{D.4.3-1}$$

where

M_o—Flange design torque (N·mm).

2 The flange thickness shall be calculated according to the following formula:

$$\delta_f = \sqrt{\frac{6 \times F_R \times L_R \times K}{\sigma_{CSM} \times \pi \times G_1}} \tag{D.4.3-2}$$

3 The shear stress calculation of the stub flange shall be in accordance with the following requirements:

1) The shear load in the pre-tightening state shall be calculated according to the following formula:

$$W = \frac{A_m + A_b}{2} [\sigma]_b \tag{D.4.3-3}$$

where

W— Steel loose flange shear load (N).

2) The shear load under operating state shall be calculated according to the following formula:

$$W = W_P \tag{D.4.3-4}$$

3)The shear area shall be calculated according to the following formula:

$$A_{\tau}=3.14\times B_{r2}\times \delta_{f} \quad \text{(D.4.3-5)}$$

where

A_{τ}—Shear area of the flange disc (mm^2).

4)The shear stress in the pre-tightening state and the operating state shall be calculated according to the following formula:

$$\tau=\frac{W}{A_{\tau}} \quad \text{(D.4.3-6)}$$

where

τ—Shear stress (MPa)of the laminate.

5)At the design temperature, the shear stress in the pre-tightening state and the operating state shall satisfy the following formula:

$$\tau\leqslant[\tau] \quad \text{(D.4.3-7)}$$

where

$[\tau]$—Allowable shear stress (MPa)of the laminate, may be calculated according to the Formula (4.3.8-4) of this code.

D.4.4 The design and calculation of steel loose flanges shall be in accordance with the following requirements:

1 When the steel loose flange is a whole ring, its thickness δ_R shall be in accordance with the relevant provisions of the current national standard GB 150.3 *Pressure Vessels-Part 3*:*Design*.

2 When the ring is split, the loose flange thickness shall be calculated according to the following formula:

$$\delta_S=1.41\times \delta_R \quad \text{(D.4.4)}$$

where

δ_R—Thickness of steel loose flange (mm);

δ_S—Split steel loose flange thickness (mm).

D.4.5 The basic parameters of loose flanges may be selected in accordance with Table D.4.5 and shall meet the following requirements:

1 The allowable strain of the fibre chopped strand mat lamina shall not be less than 0.25%;

2 The gasket shall be a non-woven rubber mat or a fibre synthetic rubber mat with a Shore hardness of 50—65;

3 The gasket characteristic coefficient m shall be 1.0 and y shall be 1.4.

Table D.4.5 Basic parameters of loose flanges (mm)

Branch diameter	Loose flange		
DN	Outer diameter Class 150	Outer diameter *PN* 10	Thickness
1.0MPa			
25	—	—	—
32	—	—	—
40	—	—	—
50	102	107	10
65	121	127	11

Table D.4.5 (continued)

Branch diameter	Loose flange		
DN	Outer diameter Class 150	Outer diameter *PN*10	Thickness
80	133	142	12
100	172	165	14
125	193	192	15
150	219	218	17
200	276	273	20
250	335	328	23
300	405	378	26
350	446	438	27
400	509	489	29
450	544	539	30
500	601	594	31
600	713	695	35
0.6MPa			
700	829	810	36
800	937	917	39
900	1045	1017	43
1000	1159	1124	46

D.4.6 The design and calculation of the loose flange shall meet the requirements of Article D.4.1 to Article D.4.5 of this code when it does not meet the requirements of the requirements of Article D.4.5 of this code or exceeds the basic flange parameters specified in Table D.4.5 of the Appendix of this code.

Appendix E　Ground anchor design

E.1　General requirements

E.1.1　The connection between fibre reinforced plastic equipment and ground anchors shall be formed by hoop winding or secondary bonding.

E.1.2　Equipment and foundation shall be anchored (Figure 5.4.1-3).

E.1.3　The safety factor K of the fibre reinforced plastic ground anchor shall not be less than 10.

E.2　Wound lug design

E.2.1　The calculation of the reaction force of wound lug (Figure E.2.1-1) shall be in accordance with the following requirements:

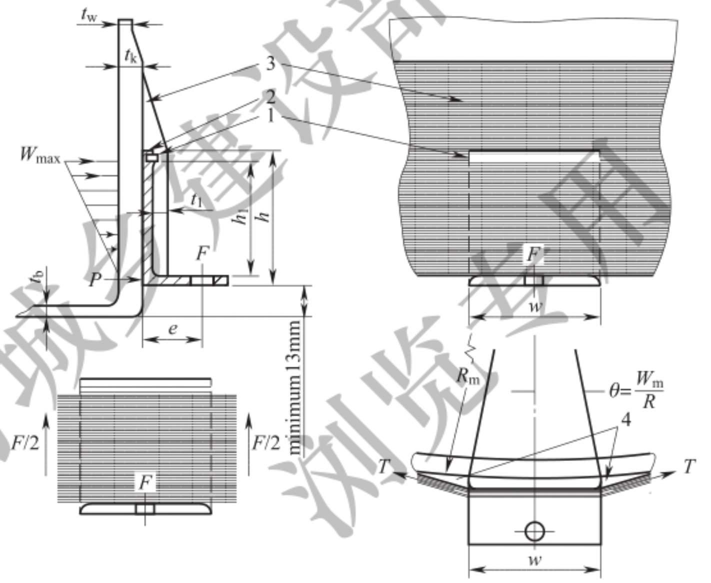


Figure E.2.1-1　Wound lug

1—Reinforced rod; 2—Shear flange; 3—Wound layer; 4—Resin putty filler

1　The wind load lifting force at the top of the equipment shall be calculated according to the following formulas:

$$U = A_t \times (P_G \times G) \tag{E.2.1-1}$$

$$A_t = \frac{\pi \times D_o^2}{4} \tag{E.2.1-2}$$

where

U—Wind load lifting force (N) at the top of the equipment;

P_G—Wind load uplift coefficient, dimensionless, may be valued according to Table E.2.1;

G—Wind pressure (MPa);

A_t—Top plane area (mm^2);

D_o—Outer diameter of equipment (mm).

2　The wind load acts on the center of gravity of the equipment, and its overturning moment may be calculated according to the following formula:

Table E.2.1 Wind load uplift coefficient P_G

Head type		D/H							
		0.8	1.0	1.5	2.0	2.5	3.0	3.5	4.0
P_G	Convex shape	0.88	0.81	0.75	0.71	0.68	0.65	0.62	0.60
	Tapered or flat	0.53	0.50	0.45	0.43	0.40	0.38	0.36	0.35

Notes: 1 D is the nominal diameter of the equipment (mm); H is the height of the straight section of the equipment (mm);

2 When $0.4 < D/H < 4.0$, P_G values may be obtained by linear interpolation according to the values in the table.

$$M_Q = 0.5GS_f DH^2 + 0.25GDH_D\left(H + \frac{H_D}{3}\right) \quad \text{(E.2.1-3)}$$

where

M_Q—The bending moment caused by wind load (N·mm);

S_f—Wind shape influence coefficient, dimensionless, take 0.7 for cylindrical equipment;

D—The mid-diameter (mm) of the equipment (mm);

H—The height of the straight section of the equipment (mm);

H_D—Top head surface depth (mm).

3 Taking into account factors such as weight, the lifting force of the equipment shall be calculated according to the following formula:

$$U_{net} = U - W + \frac{4M_Q}{D_C} \quad \text{(E.2.1-4)}$$

where

U_{net}—Equipment lifting force (N);

W—Total equipment load (N);

D_C—Bolt hole center circle diameter (mm).

4 The force acting on a single ground anchor shall be calculated according to the following formula:

$$F = \frac{U_{net}}{N} \quad \text{(E.2.1-5)}$$

where

F—Ground anchor reaction force (N);

N—Number of ground anchors, shall be an integer multiple of 4, and its spacing along the arc shall not exceed 1500 mm.

5 The calculation of anchor bolts shall be in accordance with the following requirements:

1) The maximum tensile stress of a single anchor bolt shall be calculated according to the following formulas:

$$\sigma_a = \frac{F}{f} \quad \text{(E.2.1-6)}$$

$$f = \frac{\pi \times d_1^2}{4} \quad \text{(E.2.1-7)}$$

where

σ_a—Calculated stress of the bolt (MPa);

f—Cross-sectional area of each bolt (mm^2);

d_1—Root diameter (mm) of the bolt.

2)The criterion shall satisfy the following formula:

$$\sigma_a \leqslant [\sigma_a] \quad \text{(E.2.1-8)}$$

where

$[\sigma_a]$—The allowable stress(MPa) of the bolt material, shall be in accordance with the current national standard GB 150.2 *Pressure Vessels-Part 2:Materials*.

6 The bending moment of the ground anchor shall be calculated according to the following formula:

$$M = F \times e \quad \text{(E.2.1-9)}$$

where

M—Bending moment of the ground anchor (N·mm);

F—Ground anchor reaction force (N);

e—Ground anchor reaction force F to the force arm (mm) of the housing.

7 The flexural modulus of the ground anchor may be calculated according to the following formula:

$$Z = \frac{w t_a^2}{6} \quad \text{(E.2.1-10)}$$

where

Z—Bending modulus of the ground anchor (mm^3);

t_a—Ground anchor thickness (mm);

w—Ground anchor width (mm).

8 When the allowable bending stress S of the ground anchor is known, the minimum flexural modulus required for the ground anchor shall be calculated according to the following formula:

$$Z_{min} = \frac{M}{S} \quad \text{(E.2.1-11)}$$

where

S—Allowable bending stress (MPa) of the ground anchor;

Z_{min}—Minimum flexural modulus (mm^3) required for the ground anchor.

9 The minimum thickness t_a' required for ground anchors shall be calculated according to the following formula:

$$t_a' = \sqrt{\frac{6Z_{min}}{w}} \quad \text{(E.2.1-12)}$$

where

t_a'—Minimum thickness (mm) required for the ground anchor.

E.2.2 The calculation of the radial load of the wound layer shall be in accordance with the following requirements:

1 The radial unit load in the ground anchor area shall be distributed along the ground anchor height according to the linear law. The bottom load shall be 0, and the radial unit load at the top of the ground anchor shall be W_{max} (Figure E.2.1-1).

2 The radial unit load of the wound layer for the equipment at the ground anchor shall be calculated according to the following formula:

$$W_{max}=\frac{3\times F\times e}{h^2} \tag{E.2.2-1}$$

where

W_{max}—Radial unit load of the wound layer (N/mm);

h—Ground anchor height (mm).

3 The total radial load caused by bending moments shall be calculated according to the following formula:

$$P=\frac{W_{max}\times h}{2} \tag{E.2.2-2}$$

where

P—Total radial load (N) caused by the bending moment.

4 The circumferential tension of the wound layer caused by the total radial load of the ground anchor area shall be calculated according to the following formulas:

$$T=\frac{PR_m}{w} \tag{E.2.2-3}$$

$$R_m=\frac{D_i+2t_k}{2} \tag{E.2.2-4}$$

where

T—Wound layer circumferential tension (N);

R_m—The outer radius of the wound layer (mm);

D_i—Device inner diameter (mm);

t_k—Thickness of equipment anchorage (mm).

E.2.3 The calculation and verification of the circumferential tensile unit load of the wound layer caused by the radial load of the ground anchor area shall be in accordance with the following requirements:

1 The wound layer tensile unit load shall be calculated according to the following formula:

$$q_1=\frac{T}{h_1} \tag{E.2.3-1}$$

where

q_1—Circumferential tensile unit load (N/mm);

h_1—The height of the wound layer (mm).

2 The criterion shall satisfy the following formula:

$$q_1\leqslant[q_\Phi] \tag{E.2.3-2}$$

where

$[q_\Phi]$— Allowable circumferential tensile unit load of wound layer (N/mm).

E.2.4 The calculation and verification of the lateral shear stress of the equipment wall shall be in accordance with the following requirements:

1 The lateral shear stress of the equipment wall shall be calculated according to the following formula:

$$\tau_w=\frac{P}{t_k\times w} \tag{E.2.4-1}$$

where

τ_w—Equipment wall shear stress (MPa).

2 The criterion shall satisfy the following formula:

$$\tau_W \leqslant [\tau] \quad (E.2.4\text{-}2)$$

where

$[\tau]$—Allowable shear stress (MPa) of the laminate of the equipment wall, may be calculated according to the Formula (4.3.8-4) of this code.

E.2.5 The bending coefficient of the equipment wall shall be calculated according to the following formula:

$$\beta = \left[\frac{3(1-\nu^2)}{R_m^2 \times t_k^2}\right]^{\frac{1}{4}} \quad (E.2.5\text{-}1)$$

When the Poisson's ratio ν is 0.3, it shall be calculated according to the following formula:

$$\beta = \frac{1.28}{\sqrt{R_m \times t_k}} \quad (E.2.5\text{-}2)$$

where

β—Bending coefficient (mm^{-1});

ν—Poisson's ratio, dimensionless.

E.2.6 The unit radial load of the wound layer at the ground anchor shall be calculated according to the following formula:

$$P^* = \frac{P}{w} \quad (E.2.6)$$

where

P^*— Unit radial load (N/mm).

E.2.7 The bending moment caused by ground anchors shall be calculated according to the following formulas:

The axial bending moment shall be calculated according to the following formula:

$$M_x = \frac{P^*}{4\beta} \quad (E.2.7\text{-}1)$$

The hoop moment shall be calculated according to the following formula:

$$M_\Phi \approx \nu M_x \quad (E.2.7\text{-}2)$$

where

M_x—Axial bending moment (N·mm/mm);

M_Φ—Hoop bending moment (N·mm/mm).

E.2.8 The axial and circumferential unit loads of the equipment at the ground anchor caused by the pressure p shall be calculated according to the following formulas:

$$N_x = \frac{pR_m}{2} \quad (E.2.8\text{-}1)$$

$$N_\Phi = p \times R_m \quad (E.2.8\text{-}2)$$

where

N_x—Axial unit load (N/mm);

N_Φ—Circumferential unit load (N/mm);

p—Pressure used in the calculations for equipment (MPa).

E.2.9 The axial unit load and the circumferential unit load of the equipment at the ground anchor shall be calculated according to the following formulas:

$$q_x = N_x \pm \frac{6M_x}{t_k} \tag{E.2.9-1}$$

$$q_\Phi = N_\Phi \pm \frac{6M_\Phi}{t_k} \tag{E.2.9-2}$$

where

q_x—Axial unit load (N/mm);

q_Φ—Circumferential unit load (N/mm).

E. 2.10 The axial and circumferential carrying capacity of the equipment laminates shall meet the following formulas:

$$q_x \leqslant [q_x] \tag{E.2.10-1}$$

$$q_\Phi \leqslant [q_\Phi] \tag{E.2.10-2}$$

where

$[q_x]$—Allowable axial tensile unit load (N/mm) of the equipment laminate at the ground anchor;

$[q_\Phi]$—Allowable circumferential tensile unit load (N/mm) of the equipment laminates at the ground anchor.

E.3 Secondary bonded lug design

E.3.1 The design of the second bonded lug shall be in accordance with the following requirements:

1 The secondary bonded lug shall not withstand the direct tensile load and shall not be lifted vertically;

2 When the type A lug (Figure E. 3.1-1) is used, the radial tensile load on the unit perimeter length caused by the eccentric moment load shall not exceed 8.8N/mm; when it is greater than 8.8N/mm, type B lug shall be used (Figure E.3.1-2);

3 The anchoring block of the lug (Figure E.3.1-3) shall be greater than or equal to the width of the lug, and the axis shall be in the middle; the thickness of the compact shall not be less than 1.5 times the thickness of the anchor plate of the equipment.

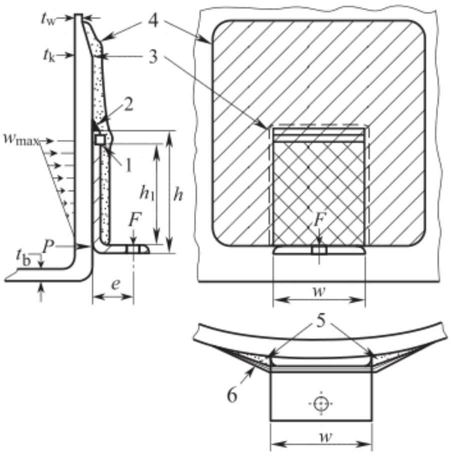


Figure E.3.1-1 Type A ground anchor

1—Reinforced rod; 2—Resin putty filler; 3—Tension boundary; 4—Overlay; 5—Resin putty filler; 6—Overlay

Note: The tension boundary shall be $(2h_1 + w)$.

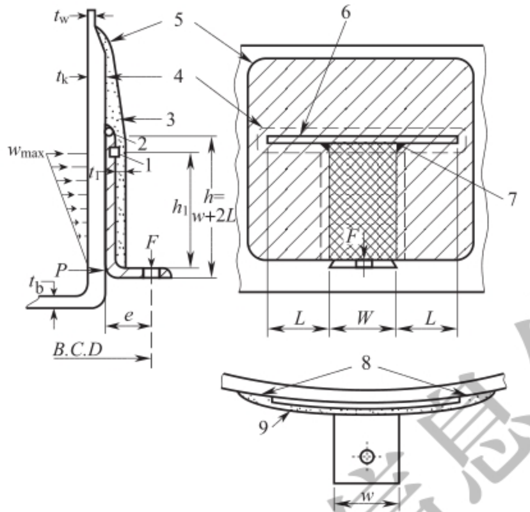


Figure E.3.1-2 Type B ground anchor

1—Reinforcing rod; 2—Welding; 3—Resin putty filler; 4—Tensile perimeter; 5—Overlay; 6—Bent to radius of tank; 7—Welding; 8—Resin putty filler; 9—Overlay; L—The outer elongation of the rod (mm); $B.C.D.$—Bolt center circle (mm)

Note: The tension boundary shall be $(2h_1+w+4L)$.

Figure E.3.1-3 Pressing block of ground anchor

1—Press block

E.3.2 The minimum height of ground anchors shall be calculated according to the following formulas:

$$h_{\min}=\sqrt{\frac{6\times D_o\times W\times e\times M_L}{N\times[q_x]\times t_k}} \tag{E.3.2-1}$$

$$M_L=\frac{1}{2}\times\left[\frac{N}{2}\left(\frac{\cos\theta+\theta\sin\theta}{\pi}\right)-\left(\frac{\sin\theta}{2}\right)-\left(\frac{1}{2}\cot\frac{\pi}{N}\right)\right] \tag{E.3.2-2}$$

$$\theta=\frac{w}{D_o} \tag{E.3.2-3}$$

The thickness of the transition zone of the type A ground anchor shall be calculated according to the following formula:

$$t_k=t_b+t_w \tag{E.3.2-4}$$

where

$h_{\min}$—Minimum height of the ground anchor (mm);

D_o—Outer diameter of equipment (mm);

M_L—Moment coefficient, dimensionless;

θ—Corresponding angle (rad) when the hoop anchor width is w;

t_k—Thickness of the transition zone of the type A ground anchor (mm);

t_b—Thickness of the bottom of the device (mm);

t_w—Wall thickness (mm);

$[q_x]$—Allowable axial tensile unit load of overlay (N/mm).

E.3.3 The minimum thickness (t_a') required for ground anchors shall be calculated according to the Formula (E.2.1-1) to Formula (E.2.1-12) of Appendix E in this code.

E.3.4 The calculation of the radial unit tensile force of the overlay shall be in accordance with the following requirements:

1 The radial unit load in the ground anchor area shall be distributed along the ground anchor height according to the linear law. The bottom load shall be 0, and the radial unit load at the top of the ground anchor shall be W_{max} (Figure E.3.1-1 and Figure E.3.1-2).

2 The radial unit length load of the overlay at the ground anchor site shall be calculated according to the following formula:

$$W_{max}=\frac{3F\times e}{h^2} \tag{E.3.4-1}$$

3 After forming, the total radial load caused by bending moments shall be calculated according to the following formula:

$$P=\frac{W_{max}\times h}{2} \tag{E.3.4-2}$$

E.3.5 The edge unit tensile load of the ground anchor shall be calculated according to the following formula:

$$w_b=\frac{P}{2h_1+w} \tag{E.3.5-1}$$

where

w_b—Unit tensile load (N/mm) at the edge of the ground anchor.

When w_b>8.8N/mm, a type B ground anchor may be used and shall be calculated according to the following formula:

$$w_{b1}=\frac{P}{2h_1+w+4L} \tag{E.3.5-2}$$

where

w_{b1}—Tensile unit load (N/mm) at the edge of the B-type ground anchor, shall not exceed 8.8N/mm.

E.3.6 The minimum area required for the secondary bonding of the overlay on the wall of the equipment shall be calculated according to the following formula:

$$A_r=\frac{U_{net}}{[\tau]\times N} \tag{E.3.6}$$

where

A_r—Minimum area (mm^2) required for the secondary bonded overlay of each ground anchor bonded to the outer wall of the equipment;

$[\tau]$—Allowable shear stress (MPa), shall not exceed 13.8.

E.3.7 The circumferential load of the overlay caused by the total radial load of the ground anchor area shall be calculated according to the following formulas:

$$T=\frac{PR_{m}}{w} \tag{E.3.7-1}$$

$$R_{m}=\frac{D_{i}+2t_{k}}{2} \tag{E.3.7-2}$$

E.3.8 The calculation and verification of the circumferential tensile unit load of the overlay caused by the total radial load of the ground anchor area shall be in accordance with the following requirements:

1 The circumferential tensile unit load of the overlay shall be calculated according to the following formula:

$$q_{1}=\frac{T}{h_{1}} \tag{E.3.8-1}$$

2 The criterion shall satisfy the following formula:

$$q_{1}\leqslant[q_{\Phi}] \tag{E.3.8-2}$$

E.3.9 The calculation and verification of the transverse shear stress of the equipment wall shall be in accordance with the following requirements:

1 The transverse shear stress of the equipment wall shall be calculated according to the following formula:

$$\tau_{w}=\frac{P}{t_{k}\times w} \tag{E.3.9-1}$$

2 The criterion shall satisfy the following formula:

$$\tau_{w}\leqslant[\tau] \tag{E.3.9-2}$$

E.3.10 The bending coefficient of the equipment wall shall be calculated according to the following formulas:

$$\beta=\left[\frac{3\left(1-\nu^{2}\right)}{R_{m}^{2}\times t_{k}^{2}}\right]^{\frac{1}{4}} \tag{E.3.10-1}$$

When Poisson's ratio $\nu=0.3$, it shall be calculated according to the following formula:

$$\beta=\frac{1.28}{\sqrt{R_{m}\times t_{k}}} \tag{E.3.10-2}$$

E.3.11 The radial load per unit length of the overlay at the ground anchor shall be calculated according to the following formula:

$$P^{*}=\frac{P}{w} \tag{E.3.11}$$

E.3.12 The moment load of the overlay at the ground anchor shall be calculated according to the following formulas:

The axial bending moment shall be calculated according to the following formula:

$$M_{x}=\frac{P^{*}}{4\beta} \tag{E.3.12-1}$$

The circumferential bending moment shall be calculated according to the following formula:

$$M_{\Phi}\approx\nu M_{x} \tag{E.3.12-2}$$

E.3.13 The axial and circumferential unit loads of the overlay at the ground anchor caused by pressure p shall be calculated according to the following formulas:

$$N_{x}=\frac{pR_{m}}{2} \tag{E.3.13-1}$$

$$N_{\Phi}=p\times R_{m} \tag{E.3.13-2}$$

E.3.14 The axial unit load and the circumferential unit load of the overlay at the ground anchor shall be calculated according to the following formulas:

$$q_{x}=\frac{6M_{x}}{t_{k}} \tag{E.3.14-1}$$

$$q_{\Phi}=\frac{6M_{\Phi}}{t_{k}} \tag{E.3.14-2}$$

E.3.15 The axial and circumferential bearing capacity of the overlay at the ground anchor shall satisfy the following formulas:

$$q_{x}\leqslant[q_{x}] \tag{E.3.15-1}$$

$$q_{\Phi}\leqslant[q_{\Phi}] \tag{E.3.15-2}$$

where

$[q_{x}]$—Allowable axial tensile unit load (N/mm) of the overlay;

$[q_{\Phi}]$—Allowable circumferential tensile unit load (N/mm) of theoverlay.

When $q_{x}>[q_{x}]$ or $q_{\Phi}>[q_{\Phi}]$,the thickness of the overlay shall be increased and shall be recalculated.

Appendix F Reinforced flange′s specification for opening hole tank top

Table F Specification of reinforcing flange at top for open tank

L (m)	Tank diameter D_t (m)										Flange type	Flange size (mm)	
	0.6	1.2	1.6	2.4	2.8	3.0	3.4	3.6	3.8	4.0		Width	Thickness
0.6	A	A	A	C	D	E	F	G	H	J	A	51	5
1.2	A	A	A	C	D	E	F	G	H	J	B	51	10
1.8	A	A	A	C	D	E	F	G	H	J	C	51	13
2.4	A	A	A	C	D	E	F	G	H	J	D	64	10
3.0	A	A	B	C	D	E	F	G	H	J	E	64	13
3.6	A	A	B	D	D	E	F	G	H	J	F	76	10
4.2	A	A	B	D	E	F	F	G	H	J	G	76	13
4.8	A	A	C	E	E	G	G	H	H	J	H	76	16
5.4	A	A	C	E	F	G	G	H	J	K	J	76	19
6.0	A	A	D	E	F	G	H	J	K	K	K	76	25
7.0	A	B	D	F	G	H	J	K	K				
9.0	A	B	E	G	H	H	K	K					
11	A	B	E	H	J	K	K						
12	A	B	E	H	J	K							

Notes: 1 This table does not calculate the effects of wind loads and seismic loads;

2 In addition to the flange structure, other structure may also be used to provide the same or higher stiffness at the opening;

3 L shall be the distance from the reinforced flange to the top of the tank or to the uppermost stiffening ring of the tank;

4 The thickness of the reinforcing flange shall not be less than the wall thickness of the adjacent tank;

5 A, B, …, K is the flange type code, corresponding to the tank top flange size.

Appendix G Calculating process for pipeline structure design

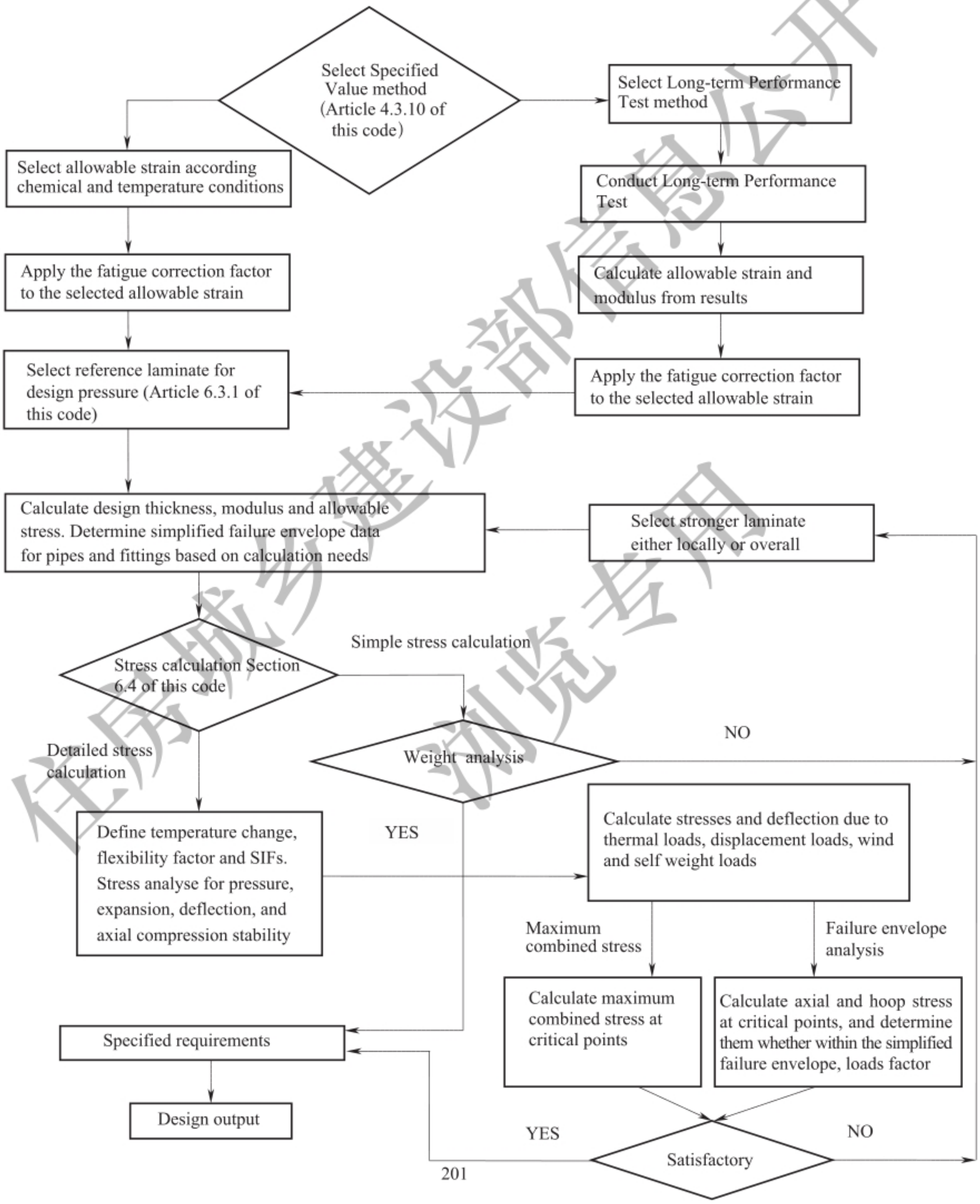


Figure G Flowchart of mechanical design of pipeline

Appendix H　Calculating of piping pressure loss

H.0.1　The head loss in the pipeline shall be calculated according to the following formulas:

$$h_f = \lambda \frac{L}{d} \times \frac{V^2}{2g} \tag{H.0.1-1}$$

$$\lambda = \frac{64}{Re} \tag{H.0.1-2}$$

$$\frac{1}{\sqrt{\lambda}} = -2 \times \log\left(\frac{e}{3.7d} + \frac{2.51}{Re\sqrt{\lambda}}\right) \tag{H.0.1-3}$$

$$Re = \frac{Vd}{\nu} \tag{H.0.1-4}$$

where

h_f—Head loss in the pipeline (m).

L—Pipeline length (m).

d—Internal diameter of pipe (m).

V—Fluid velocity (m/s).

g—Gravitational acceleration (9.81m/s^2).

λ—Darcy-Weisbach friction factor, dimensionless, related to the type of flow, the pipe diameter and surface roughness of the pipe. When the Reynolds number $Re < 2000$, it shall be calculated according to Formula (H. 0.1-2), and the reynolds number $Re > 4000$, it shall be calculated according to Formula (H.0.1-3).

e—Surface roughness factor, can be valued at 0.00518mm.

Re—Reynolds Number, should be calculated according to Formula (H.0.1-4).

ν—Fluid kinematic viscosity (m^2/s).

H.0.2　When the fluid is water, the flow rate and head loss in the pipeline can be calculated according to the following formulas:

1　For gravity flow or partially full flow, it can be calculated according to the following formulas:

$$Q = \frac{1}{n} \cdot A \cdot R^{\frac{2}{3}}{}_{h} \cdot S^{\frac{1}{2}} \tag{H.0.2-1}$$

$$R_h = \frac{A}{\chi} \tag{H.0.2-2}$$

$$S = \frac{h_f}{L} \tag{H.0.2-3}$$

where

Q—Flow rate (m^3/s);

A—Flow cross sectional area (m^2);

n—Manning's constant, can be valued at 0.009;

R_h—Hydraulic radius (m), can be calculated according to Formula (H.0.2-2), $d/4$ for full flow round pipe;

χ—Wetted perimeter of pipe (mm), contact length of water and pipe on the water flow section;

perimeter of pipe for full flow;

S —Hydraulic slope, can be calculated according to Formula (H.0.2-3).

2 For pressure full flow, it can be calculated by the following formula:

$$h_f = 10.5 \cdot \left(\frac{Q}{C}\right)^{1.85} \cdot \frac{L}{d^{4.87}} \quad \text{(H.0.2-4)}$$

where

C—Hazen William's coefficient, can be valued at 150.

H.0.3 The local head loss in fittings shall be the product of flow head and the coefficient ξ, and shall be calculated according to the following formula:

$$h_i = \xi \cdot \frac{V^2}{2g} \quad \text{(H.0.3)}$$

where

h_i—The local head loss in fittings;

ξ—Local head loss coefficient, shall be selected according to Table H.0.3.

Table H.0.3 Local head loss coefficient ξ

Type of fitting	Loss coefficient ξ
90° elbow, standard	0.5
90° elbow, single miter	1.4
90° elbow, double miter	0.8
90° elbow, triple miter	0.6
Tee, straight flow	0.4
Tee, flow to branch	1.4
Tee, flow from branch	1.7
Reducer	0.7

Appendix J Secondary bonding fabrication evaluation

J.1 General requirements

J.1.1 Secondary bonding fabrication evaluation shall include the following contents:

1 Prepare a bonding process guide book;

2 Make specimens;

3 Test specimen performance;

4 Evaluate specimen performance;

5 Evaluate the proposed bonding process instruction.

J.1.2 The bonding process guide book shall include the following contents:

1 Environmental condition such as temperature and humidity;

2 Material type and specification;

3 Layer sequence and layer number;

4 Curing time;

5 Equipment and tools;

6 The operation process shall be carried out in accordance with the relevant provisions of Section 7.5 of this code.

J.1.3 When the main raw material and molding process change, the secondary bonding fabrication process shall be re-evaluated.

J.2 Specimen making

J.2.1 The process of specimen making shall be recorded and archived.

J.2.2 The dimension of the specimen made shall be in accordance with the following requirements:

1 When making specimen 1, two pieces of lay-up flat plate shall be made synchronously. Each piece shall be 500mm×500mm in dimension. Four layers of chopped strand mat and three layers of woven roving may be used. The order of laying may be mat-cloth-mat-cloth-mat-cloth-mat;

2 When making specimen 2, a cladding shall be hand lay-up to bond and coat the joint of flat plates, and the dimension shall be 500 mm×500mm. It may be made in the following ways:

1) The hand lay-up plate of specimen 1 may be cut into two pieces, and on the joint, the hand lay-up overlay can be made according to the secondary bonding fabrication technology;

2) The overlay may be made up of 4 layers of chopped strand mat and 3 layers of woven roving, and the sequence of laying may be mat-cloth-mat-cloth-mat-cloth-mat.

J.2.3 The material used for the secondary bonding joints shall be the same as that of the motherboard.

J.3 Test requirements and result evaluation

J.3.1 The environmental conditions for specimen inspection shall be in accordance with the requirements of the bonding process guide book.

J.3.2 The items of specimen inspection and test methods shall shall be in accordance with the following requirements:

1 Exterior inspection may be done by visual inspection, touch and percussion;

2 Unit tensile strength inspection shall meet the requirements of Article 8.3.13 of this code;

3 The interlaminar shear strength inspection shall meet the relevant requirements of Appendix K to this code;

4 The lap shear strength inspection shall meet the relevant requirements of Appendix L to this code;

5 Surface Barcol hardness test shall meet the requirements of the relevant provisions of the current national standard GB/T 3854 *Test Method for Hardness of Reinforced Plastics by Means of A Barcol Impresser*, and the measuring points shall not be less than 10;

6 Insoluble matter content of resin detection shall meet the relevant requirements of existing national standards GB/T 2576 *Test Method for Insoluble Matter Content of Resin Used in Fibre Reinforced Plastics*;

7 The detection of resin content shall meet the requirements of the relevant regulations of current national standard GB/T 2577 *Test Method for Resin Content of Glass Fibre Reinforced Plastics*;

8 Specimen 1 shall be tested for item 1, 2, 3, 5, 6 and 7, and specimen 2 shall be tested for item 1, 4, 5, 6 and 7.

J.3.3 When the test results of the specimens meet the following requirements, the procedure qualification shall be qualified:

1 Exterior inspection shall meet the requirements of Article 8.4.1 of this code;

2 Unit tensile strength shall not be less than the calculated value of this code 4.3.2-2;

3 The interlaminar shear strength and lap shear strength of specimens reinforced with glass fibres shall not be less than those specified in Table 4.3.1-1 of this code;

4 Surface Barcol hardness, insoluble matter content of resin and resin content shall meet the requirements of Article 8.4.1 of this code;

5 The order, specification and type of fibre layer after ablation shall meet the requirements of adhesive bonding process instruction.

Appendix K　Measurement and test for inter laminar shear strength of laminates

K.0.1　Fibre reinforced plastic laminates interlaminar shear strength test and specimen dimensions (Figure K.0.1) shall be in accordance with the following requirements:

1　The edges of specimens shall be smooth;

2　The width b of the specimen shall be (25.0 ± 1.0)mm, the thickness shall not be less than 3.0mm, and the length L should be 200mm;

3　Parallel cutting shall be adopted and shall be in accordance with the following requirements:

1) The distance a between the sides of the cutting place shall be (12.0 ± 0.5)mm;

2) The width of the cutting edge shall be less than 0.8mm;

3) The depth of the single side cut shall be half the thickness of the laminate plus (0—0.1)mm.

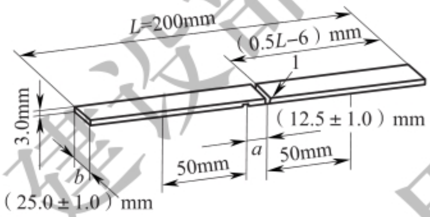


Figure K.0.1　Interlaminar shear strength test specimen and dimensions

1—Thin saw cut

K.0.2　The number of specimens in each group shall not be less than 15.

K.0.3　The state and treatment of the specimens shall meet the relevant requirements of the current national standard GB/T 2918 *Plastics-Standard Atmospheres for Conditioning and Testing*.

K.0.4　The specimen shall be placed on the jig of the tensile tester, and the relative speed of loading shall be 5.0mm/min.

K.0.5　The interlaminar shear strength τ_{lap} shall be calculated according to the following formula:

$$\tau_{lap} = \frac{P}{a \times b} \tag{K.0.5}$$

where

τ_{lap}—Interlaminar shear strength (MPa), the calculation result shall retain 1 valid digit after the decimal point;

P—Maximum tensile load (N);

a—The distance between two parallel cuts (mm);

b—Specimen width (mm).

Appendix L Measurement and test for lap shear strength of bond between laminates

L.0.1 The edges of the specimens shall be smooth and the specimens and dimensions (Figure L.0.1) shall be in accordance with the following requirements when cutting and sampling from two overlapped fibre reinforced plastic laminates:

1 The width b of the specimen shall be (20.0 ± 1.0)mm, and the length L should be 200mm, which may also be changed according to the requirements of testing instruments;

2 The cutting edges shall be perpendicular to the length direction. The distance a between the two cutting edges shall be (10.0 ± 0.5)mm, and the width of the cutting edge shall be less than 0.8 mm;

3 The depth of one-sided cutting shall be the thickness of overlapped laminates plus the thickness of a layer of fibre reinforced plastics, or the thickness of all laminates plus (0—0.1)mm.

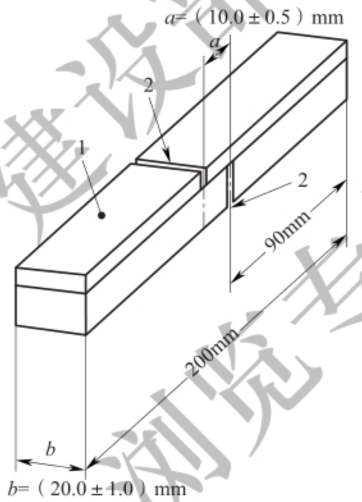


Figure L.0.1 Lap shear strength test specimens and dimensions

1—Laminate material; 2—Thin saw cut

L.0.2 The number of specimens in each group shall not be less than 15.

L.0.3 The state and treatment of the specimens shall meet the relevant requirements of the current national standard GB/T 2918 *Plastics-Standard Atmospheres for Conditioning and Testing*.

L.0.4 When the specimen is clamped on the tensile testing machine, it is stretched along the axial direction of the specimen, and the sawing section is perpendicular to the tensile direction. The relative speed of loading shall be 5.0mm/min.

L.0.5 The interlaminar shear strength τ_{lap} shall be calculated according to the following formula:

$$\tau_{lap} = \frac{P}{a \times b} \tag{L.0.5}$$

where

τ_{lap}—Lap shear strength (MPa), the calculation result shall keep one significant digit to the decimal point;

P—Maximum tensile load (N);

a—Distance between two parallel cuts (mm);

b—Specimen width (mm).

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 the implementation of 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 quoted standards

GB 50009　Load Code for the Design of Building Structures

GB 50011　Code for Seismic Design of Buildings

GB 50316　Design Code for Industrial Metallic Piping

GB/T 50590　Technical Code for Anticorrosion Engineering of Vinyl Ester Resins

GB 150.1　Pressure Vessels-Part 1:General Requirements

GB 150.2　Pressure Vessels-Part 2:Materials

GB 150.3　Pressure Vessels-Part 3:Design

GB/T 1447　Fibre-Reinforced Plastics Composites-Determination of Tensile Properties

GB/T 1449　Fibre-Reinforced Plastic Composites-Determination of Flexural Properties

GB/T 1450.2　Fibre-Reinforced Plastic Composites-Determination of the Punch-Type Shear Strength

GB/T 1634.2　Plastics-Determination of Temperature of Deflection Under Load

GB/T 2576　Test Method for Insoluble Matter Content of Resin Used in Fibre Reinforced Plastics

GB/T 2577　Test Method for Resin Content of Glass Fibre Reinforced Plastics

GB/T 2828　Sampling Procedures for Inspection by Attributes

GB/T 2918　Plastics-Standard Atmospheres for Conditioning and Testing

GB/T 3854　Test Method for Hardness of Reinforced Plastics by Means of A Barcol Impresser

GB/T 3857　Test Method for Chemical Resistance of Glass Fibre Reinforced Thermosetting Plastics

GB/T 5009.98　Method for Analysis of Hygienic Standard of Unsaturated Polyester Resin and Glass Fibre Reinforced Plastics Used as Food Containers and Packaging Materials

GB/T 5349　Fibre-Reinforced Thermosetting Plastic Composites Pipe-Determination of Longitudinal Tensile Properties

GB/T 5351　Fibre-Reinforced Thermosetting Plastic Composites Pipe–Determination of Short-Time Hydraulic Failure Pressure

GB/T 8237　Liquid Unsaturated Polyester Resin for Fibre Reinforced Plastics

GB/T 9914　Test Method for Reinforcement Products

GB/T 13657　Bisphenol-A Epoxy Resin

GB/T 14354　Food Containers of Glass Fibre Reinforced Unsaturated Polyester Resin

GB/T 17470　Glass Fibre Mats-Chopped Strand and Continuous Filament Mats

GB/T 18369　Glass Fibre Roving

GB/T 18370　Glass Fibre Woven Roving

GB/T 21238　Glass Fibre Reinforced Plastics Mortar Pipes

GB/T 25040　Glass Fibre Stitched Fabrics

GB/T 26752　PAN-Based Carbon Fibre

GB/T 27797.2 Fibre-Reinforced Plastics-Methods of Producting Test Plates-Part 2: Contact and Spray-up Moulding

GB/T 30021 Warp Knitting Carbon Fibre Reinforcements

SH 3097 Code for the Design of Static Electricity Grounding for Petrochemical Industry